

**The Complete Larval Development of *Hemigrapsus sinensis* Rathbun
(Brachyura, Grapsidae) Reared in the Laboratory**

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털보꼬마풀게 (*Hemigrapsus sinensis* Rathbun)의 幼生發生

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要 約

털보꼬마풀게 (*Hemigrapsus sinensis* Rathbun) (바위게과, 참게亞科)의 幼生을 孵化에서부터 첫번째 期까지 水溫 20.2°C에서 24.1°C, 鹽分濃度 32.9%에서 33.2%에서 飼育하고, 各 幼生期의 形態的인 特徵을 記述 및 圖示하여, 같은 屬內에 報告된 다른 7種의 幼生들과 比較하였다.

이 種은 5期의 Zoea와 1期의 Megalopa 幼生을 거쳐 첫번째 期로 變態하였다.

제 1 Zoea期의 제 1 觸角과 尾節이 Aikawa의 基準에 依한 B型이며 甲側棘은 있고 제 2 小顎內肢의 剛毛式이 2.2인 點에서는 같은 屬의 다른 7種과 一致하나, 제 1 顎脚의 基節 및 內肢와 제 2 顎脚의 內肢의 剛毛式에 若干의 差異가 있다.

INTRODUCTION

The shore crab, *Hemigrapsus sinensis* Rathbun (Grapsidae, Varuninae), inhabits under stones on the mud-flat between high and low tidal marks (Sakai, 1976) and in the cracked rocks of tidal regions (Kim, 1973). It is found in the coastal area of islands in front of Incheon beach in Korea, the Bay of Ariake in Japan, the north of Fukien, and the peninsula of Shantung in China (Kim, 1973). Knowledge of larval development in this genus is sparse, restricted to the thorough descriptions of *H. nudus* (Hart, 1935) and *H. penicillatus* (Kim, 1979); and the short and incomplete descriptions of *H. oregonensis* (Hart, 1935) and *H. sanguineus* (Kurata, 1968); and the pre-zoea, the first zoeal descriptions of *H.*

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crenulatus and *H. edwardsi* (Wear, 1970); and the first zoeal description of *H. longitarsis* (Aikawa, 1929).

The purpose of the present paper is to describe the complete larval development of *Hemigrapsus sinensis* Rathbun. Also we hope to discuss their distinctive characters in relation to the larvae already described for the other species of the same genus. This species is only the third of the genus *Hemigrapsus* for which the complete larval development is known.

MATERIALS AND METHODS

Ovigerous females of *Hemigrapsus sinensis* Rathbun were collected from the breakwater of beach in Sorae, Kyeong-Gi-Do, Korea on April 10, 1983. The captured females were held individually in a jar filled with sea water at temperatures ranging from 20.2°C to 24.1°C and in salinities from 32.9‰ to 33.2‰ in order to obtain larvae.

Part of the larvae was fixed immediately after hatching. While hatching, the first zoeae were separated into groups of 10 larvae per glass bowl, fed *Artemia salina* nauplii and *Brachionus plicatilis*, and maintained under the same conditions of temperature and salinity as above. The zoeae were removed in new bowls with clean sea water and fed daily, and when the zoeae reached megalopa stage, they were transferred to individual compartments to prevent mortality due to fighting and cannibalism.

The larvae were preserved in 7% neutral formalin and exuviae were kept in 70% alcohol to check setation of the appendages. Drawings of the exuviae and of entire larvae were made with the aid of a compound microscope and camera lucida. All scales on figures are in mm. Five individuals were examined at each stage. All setal counts are sequenced from proximal to distal. Carapace length was measured from the orbit to the posterior carapace border. The chromatophore patterns were determined from the observation of living larvae.

RESULTS

There are five zoeal stages and one megalopa stage in the complete larval development of *Hemigrapsus sinensis*. The major morphological characteristics of each developmental stage are as follows:

First Zoea (Fig. 1)

Size.-Carapace length 0.43-0.48 mm; mean 0.46 mm. Tip of dorsal to tip of rostral spine 0.81-0.89 mm; mean 0.85 mm.

Carapace(Fig. 1A): With rostral, dorsal and lateral spines. Rostral spine straight about three times length of antennules. Dorsal spine, short and curved caudally. Lateral spines short, curved downwards and inclined posteriorly. Posterolateral margin with 6 small den-

ticles. Eyes sessile.

Abdomen(Fig. 1B): With 5 somites plus telson; pair of short setae projecting from posterodorsal surface of somites 2 to 5. Mediolateral projection of second somite with horn-like tip directed anteriorly; mediolateral spine on somites 3 to 4 with short pointed tip posteriorly. Telson B type, with two forks bearing two rows of tiny spinules; widely forked with long slender rami; lateral cornua curved slightly inwards, strongly curved dorsally, median notch in posterior margin of telson. Inner telson margin with 3 pairs of setae: inner pair of posterior setae with 3 pairs of stronger hairs centrally.

Antennule(Fig. 1C): Conical with 2 long, 2 shorter aesthetascs plus small simple seta.

Antenna(Fig. 1D): B₃ type, spinous process with protopodite bearing two rows of spinules on distal portion. Exopodite, about half length of protopodite, with one simple seta and one shorter hair on the middle surface.

Mandibles (Fig. 1E): Asymmetrical; incisor ridge with denticles; molar surface with grinding nodules. On junction of molar and incisor, 3 teeth on right mandible and no teeth on left. This difference essential in all zoeal stages.

Maxillule(Fig. 1F): With 2-segmented endopodite; proximal segment short with lateral seta, distal segment longer bearing 4 terminal and 1 subterminal setae; endopodite setation unchanged until fifth stage. Basal endite with 5 setae, coxal endite with 4 terminal and 1 subterminal setae.

Maxilla(Fig. 1G): Scaphognathite bearing 4 plumose setae and 1 plumose process on apical tip; endopodite unsegmented, hairy, slightly bifurcated, with 2 terminal and 2 subterminal setae; endopodite setal arrangement unchanged through all zoeal stages. Proximal and distal lobes of basal and coxal endites each with 5, 5 and 4, 3 setae respectively.

First maxilliped(Figs. 1A, H): Basipodite with 10 ventral setae, progressing distally 2, 2, 3, 3. Endopodite 5-segmented; ventral setal formula progressing distally 2, 2, 1, 2, 4+1 dorsal seta; an outer tuft of fine hairs on the carpus. Exopodite incompletely 2-segmented, 4 plumose natatory setae.

Second maxilliped(Figs. 1A, I): Basipodite with 4 ventral setae progressing distally 1, 1, 1, 1. Endopodite 3-segmented with 1 ventral seta on middle segment; 1 short and 5 longer setae on distal segment. Exopodite incompletely 2-segmented, 4 plumose natatory setae.

Chromatophores(Fig. 1A): The majority of the chromatophores are brown-black and occur between the eyes; at the base of antennule; on the posterior of carapace; ventral margin to lateral carapace spines; on labrum and mandible; at the distal end of basis of first maxilliped; along the abdominal somites 1-5 and telson; posterior at the base of the dorsal carapace spine. Most of red-orange coexist as spot and line with the brown-black. This pattern is consistent during all zoeal stages.

Second Zoea (Fig. 2)

Size.—Carapace length 0.48-0.55 mm; mean 0.51 mm. Tip of dorsal to tip of rostral spine

0.93-1.01 mm; mean 0.99 mm.

Carapace (Fig. 2A): Similar in form to stage 1, with 2 dorsal simple setae above eye. Posterolateral border bearing 2 plumose setae and 9 small denticles. Eyes stalked.

Abdomen (Fig. 2B): First somite bearing 1 seta mid-dorsally; mediolateral spine on fourth somite disappeared. Telson similar in form and setation to stage 1.

Antennule (Fig. 2C): With 6 unequal aesthetascs plus minute simple seta.

Antenna (Fig. 2D): Similar in form and setation to stage 1.

Mandibles (Fig. 2E): Similar to stage 1.

Maxillule (Fig. 2F): Distolateral margin bearing 1 single, feathery dorsal seta. Basal endite with 7 setae, coxal endite unchanged.

Maxilla (Fig. 2G): Scaphognathite bearing 5 marginal and 3 terminal plumose setae, basal and coxal endites with 9, 7 setae, respectively.

First maxilliped (Figs. 2A, H): Unchanged except coxopodite with 1 seta; exopodite bearing 6 plumose natatory setae.

Second maxilliped (Figs. 2A, I): Unchanged except exopodite bearing 6 plumose natatory setae.

Third Zoea (Fig. 3)

Size.-Carapace length 0.64-0.70 mm; mean 0.67 mm. Tip of dorsal to tip of rostral spine 1.24-1.36 mm, mean 1.30 mm.

Carapace (Fig. 3A): Now bearing small single seta on dorsal spine. Posterolateral border with 5 plumose setae, 8 small denticles; postero-dorso-lateral border bearing one seta.

Abdomen (Fig. 3B): With 6 somites. Inner telson margin with 4 pairs of setae.

Antennule (Fig. 3C): With 4 unequal aesthetascs plus minute simple seta.

Antenna (Fig. 3D): With endopodite bud; one short hair on exopodite disappeared. B₂ type.

Mandibles (Fig. 3E): Similar in form to previous stage.

Maxillule (Fig. 3F): Similar in setation to stage 2.

Maxilla (Fig. 3G): Scaphognathite bearing 12 plumose setae; basal and coxal endites unchanged.

First maxilliped (Figs. 3A, H): Coxopodite and basipodite unchanged. Endopodite setation now 2, 2, 2, 2, 4+1, exopodite with 8 plumose natatory setae.

Second maxilliped (Figs. 3A, I): Similar to stage 2; exopodite now with 8 plumose natatory setae.

Fourth Zoea (Fig. 4)

Size.-Carapace length 0.75-0.89 mm; mean 0.82 mm. Tip of dorsal to tip of rostral spine 1.51-1.68 mm; mean 1.60 mm.

Carapace (Fig. 4A): More inflated, with 2 simple setae on dorsal spine. Posterolateral border with 6 plumose setae, 9 small denticles; postero-dorso-lateral border bearing 4 simple

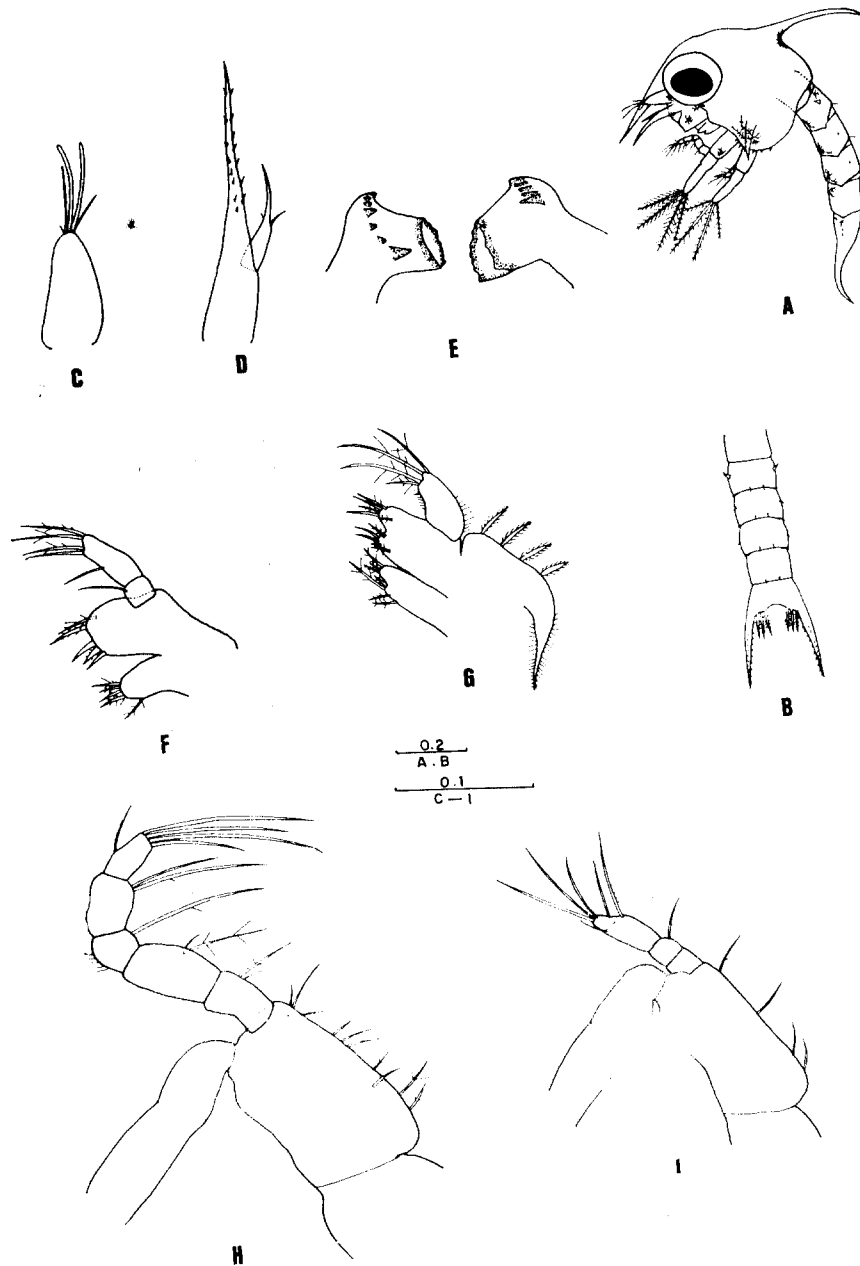


Fig. 1. *Hemigrapsus sinensis* Rathbun, first zoeal stage. A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

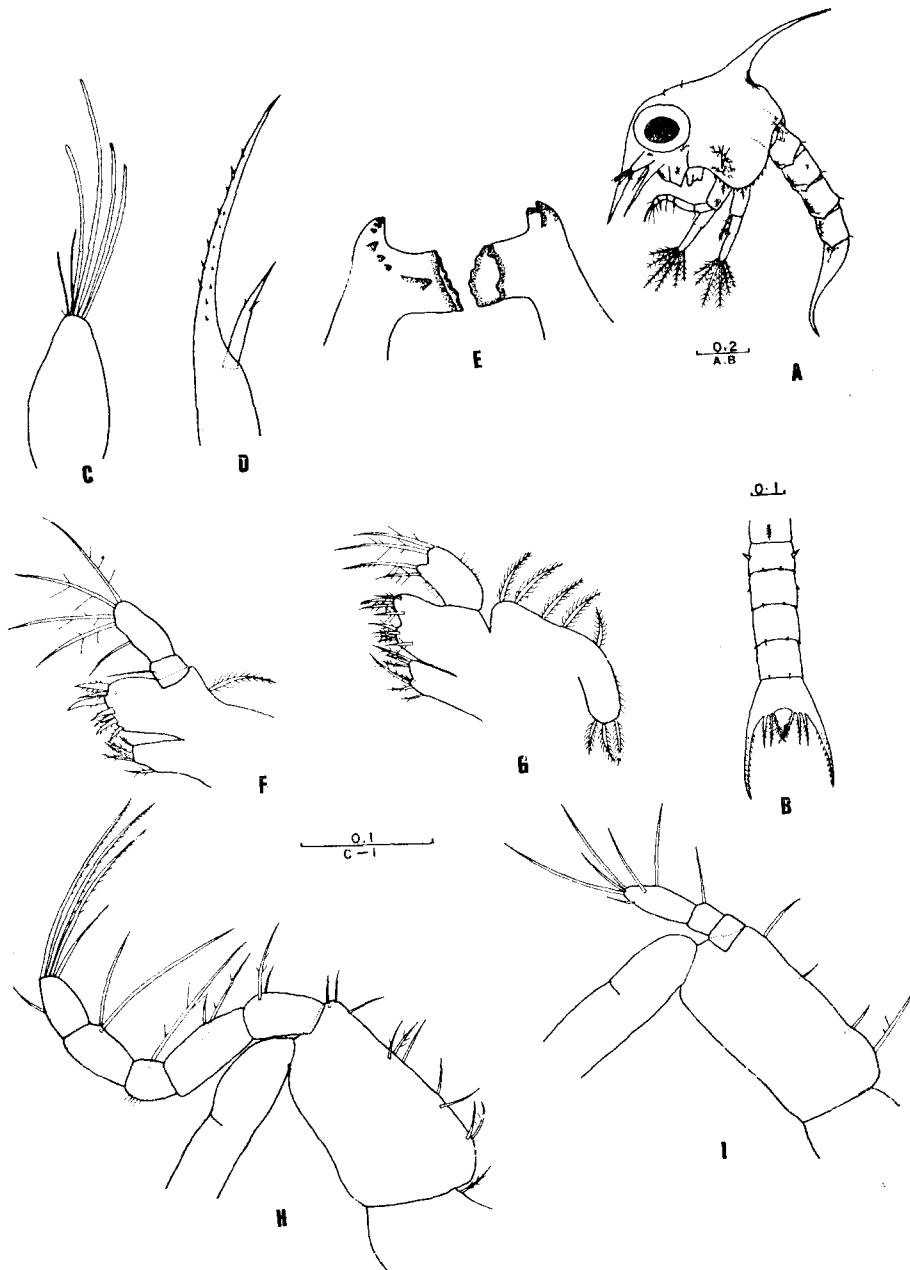


Fig. 2. *Hemigrapsus sinensis* Rathbun, second zoeal stage. A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

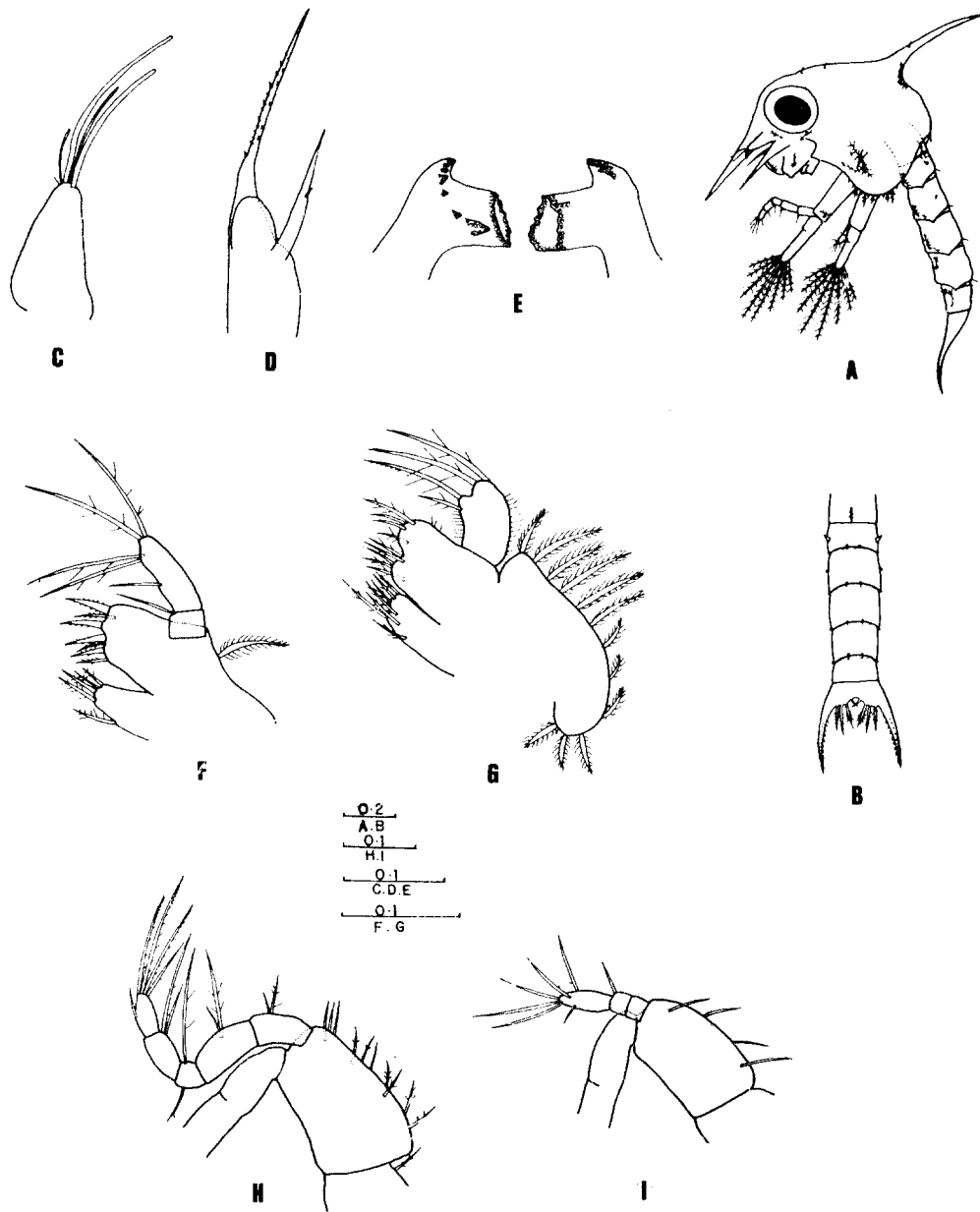


Fig. 3. *Hemigrapsus sinensis* Rathbun, third zoeal stage. A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

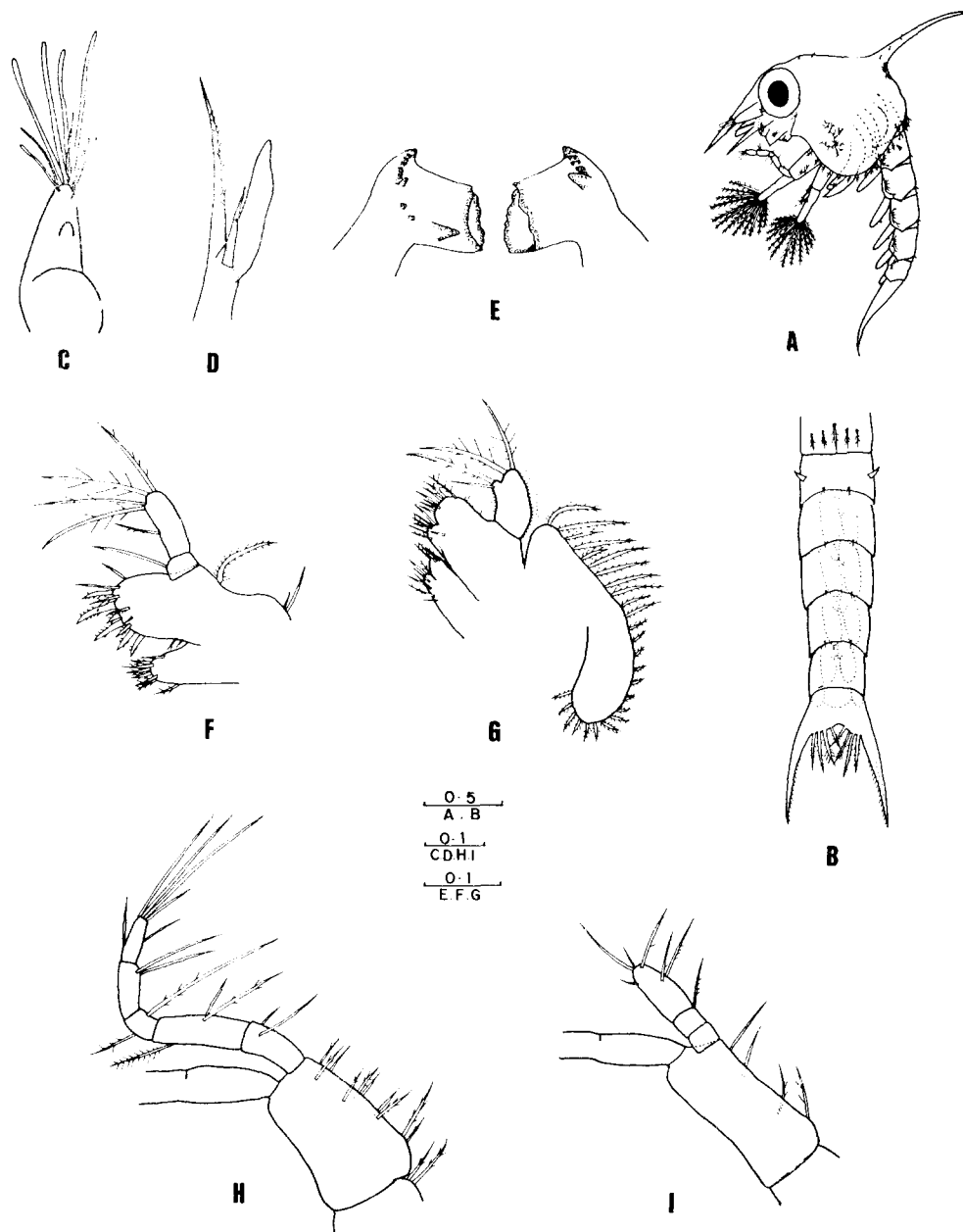


Fig. 4. *Hemigrapsus sinensis* Rathbun, fourth zoeal stage. A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandible; F, maxillules; G, maxilla; H, first maxilliped; I, second maxilliped.

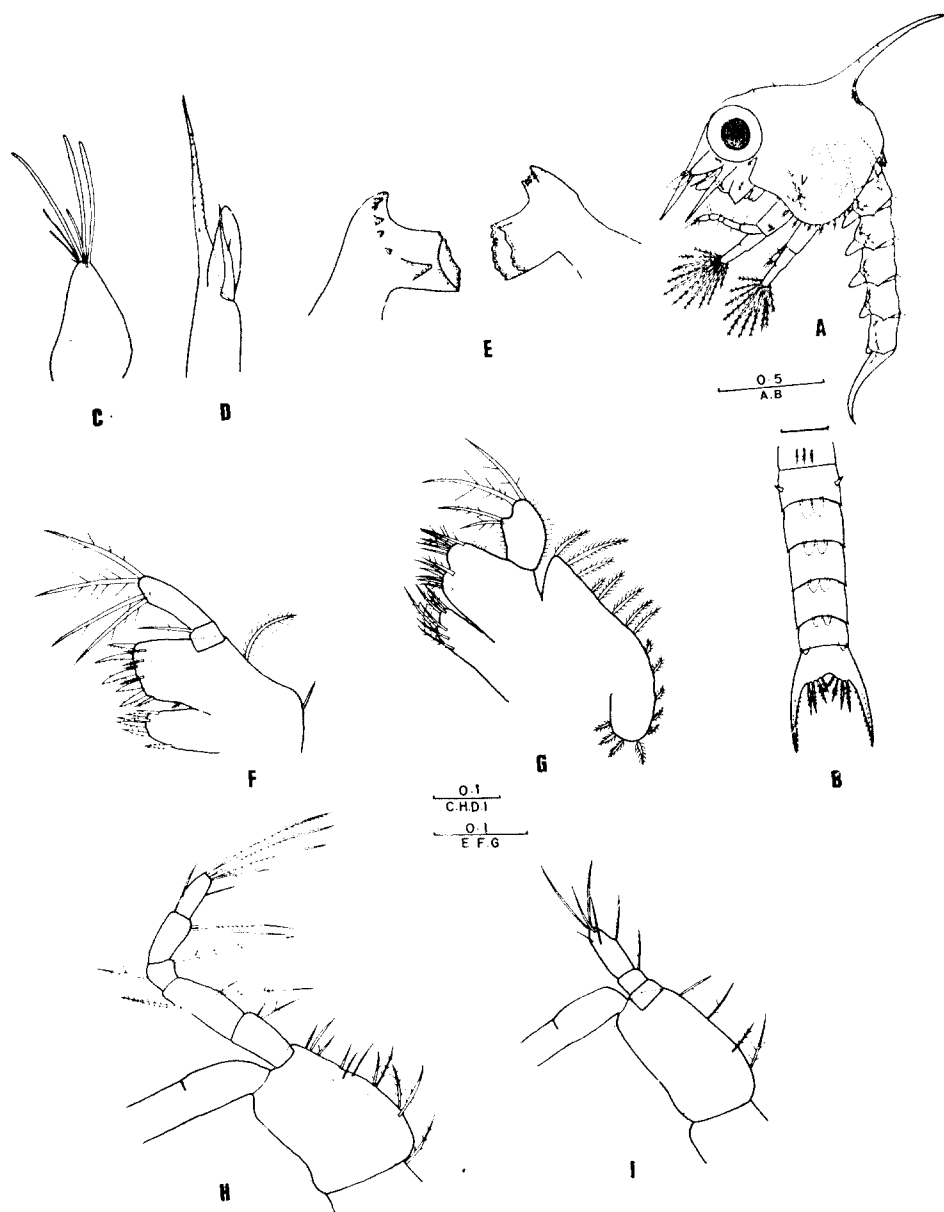


Fig. 5. *Hemigrapsus sinensis* Rathbun, fifth zoeal stage. A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

setae. Developing buds of third maxilliped and thoracic appendages being under carapace.

Abdomen(Fig. 4B): First somite with 3 setae mid-dorsally; mediolateral spine on third somite disappeared. Pleopod primordia present on somite two through six. Telson unchanged.

Antennule(Fig. 4C): With 3 long and 3 shorter aesthetascs plus minute simple seta.

Antenna(Fig. 4D): Endopodite as long as exopodite with small seta only. B₂ type.

Mandibles(Fig. 4E): No changed.

Maxillule(Fig. 4F): With 1 feathery dorsal seta on distolateral margin, and 1 simple seta proximolaterally. Basal and coxal endites with 11, 6 setae, respectively.

Maxilla(Fig. 4G): Scaphognathite bearing 17-20 setae. Basal and coxal endites with 11, 7 setae, respectively.

First maxilliped(Figs. 4A, H): Basipodite as in previous stage. Endopodite setal formula progressing distally, 2, 3, 2, 2, 5+1. Exopodite with 9 or 10 plumose natatory setae.

Second maxilliped (Figs. 4A, I): Basipodite and endopodite as in stage 3. Exopodite with 10 plumose natatory setae.

Fifth Zoea (Fig. 5)

Size.-Carapace length 0.97-1.06 mm, mean 1.03 mm. Tip of dorsal to tip of rostral spine 1.86-2.10 mm; mean 1.94 mm.

Carapace (Fig. 5A): 3 setae on dorsal spine. Posterolateral and postero-dorso-lateral border bearing 13-15 and 6 setae, respectively. Thoracic appendages unsegmented, but developing through the stage, extending slightly below the posterolateral margin of carapace.

Abdomen(Fig. 5B): First somite with 3-5 setae mid-dorsally. Pleopod buds biramous, well-developed on somites 2-5; uniramous, rudimentary buds on somite 6. Telson similar to previous stage.

Antennule(Fig. 5C): With small endopodite bud; basal region swollen; 5 short, 4 longer, terminal aesthetascs plus minute simple seta.

Antenna (Fig. 5D): Endopodite two thirds length of protopodite.

Mandibles(Fig. 5E): Without palp. The number of tooth on incisor margin increased.

Maxillule(Fig. 5F): With 1 feathery dorsal seta on distolateral margin, and 2 unequal simple setae proximolaterally. Basal and coxal endites with 14, 8 setae, respectively.

Maxilla(Fig. 5G): Scaphognathite bearing 24-26 plumose setae. Basal and coxal endites with 14, 11 setae, respectively.

First maxilliped(Figs. 5A, H): Coxopodite now with 2 setae. Exopodite bearing 11 or 12 plumose natatory setae.

Second maxilliped (Figs. 5A, I): Basipodite and endopodite unchanged. Exopodite bearing 12 plumose natatory setae.

Megalopa (Figs. 6, 7)

Size.-Carapace length 1.04-1.20 mm; mean 1.14 mm. Carapace width 0.88-0.98 mm; mean 0.92 mm.

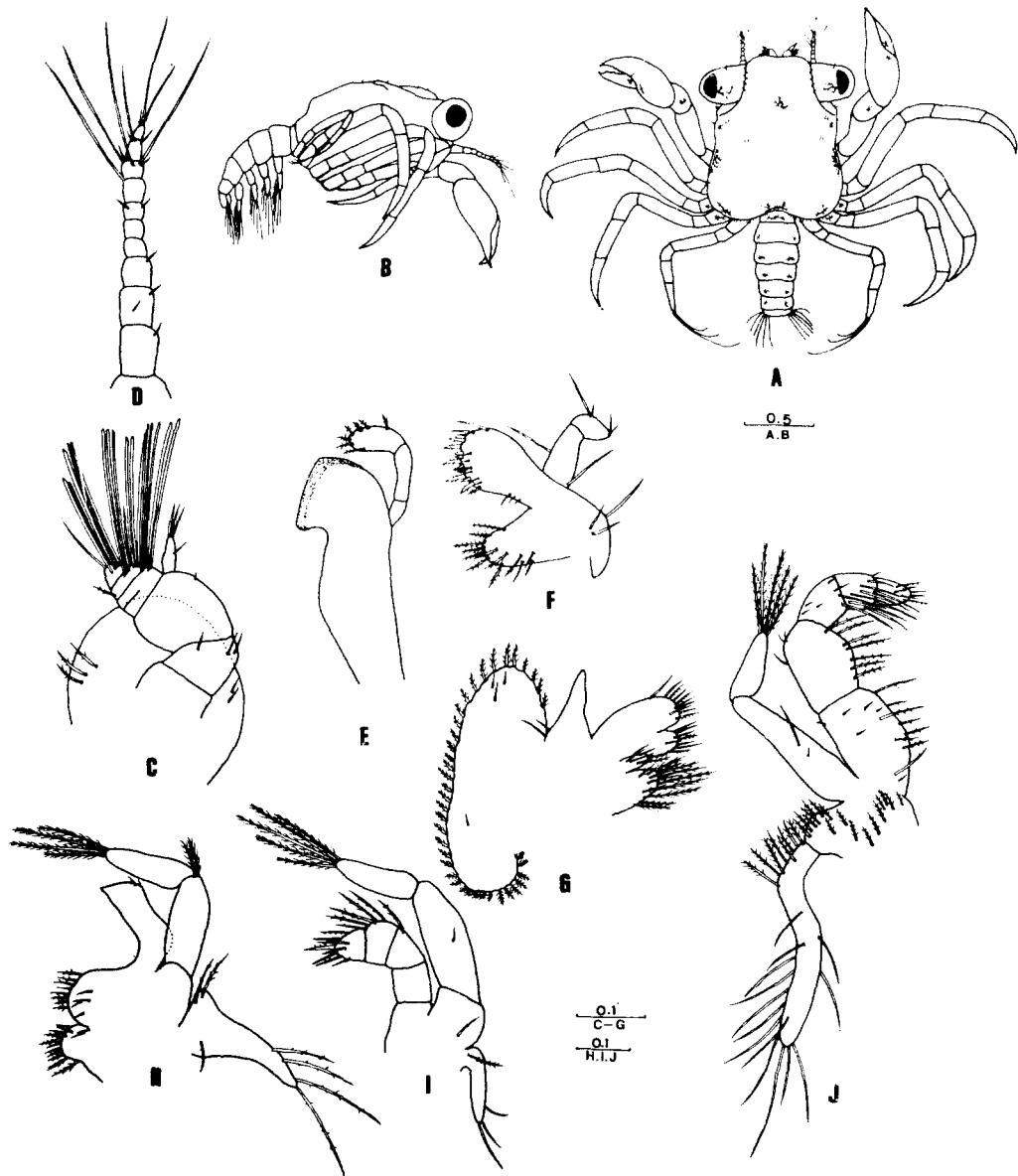


Fig. 6. *Hemigrapsus sinensis* Rathbun, megalopa stage. A, dorsal view; B, lateral view; C, antennule; D, antenna; E, mandible; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped.

Carapace (Figs. 6A, B): Subquadrate with frontal region rectangular. Short hairs on carapace and on anterior margin of eyestalks. Carapace smooth, undulating, with a wide front, the center of which is depressed where the downward-pointing rostrum has not occurred.

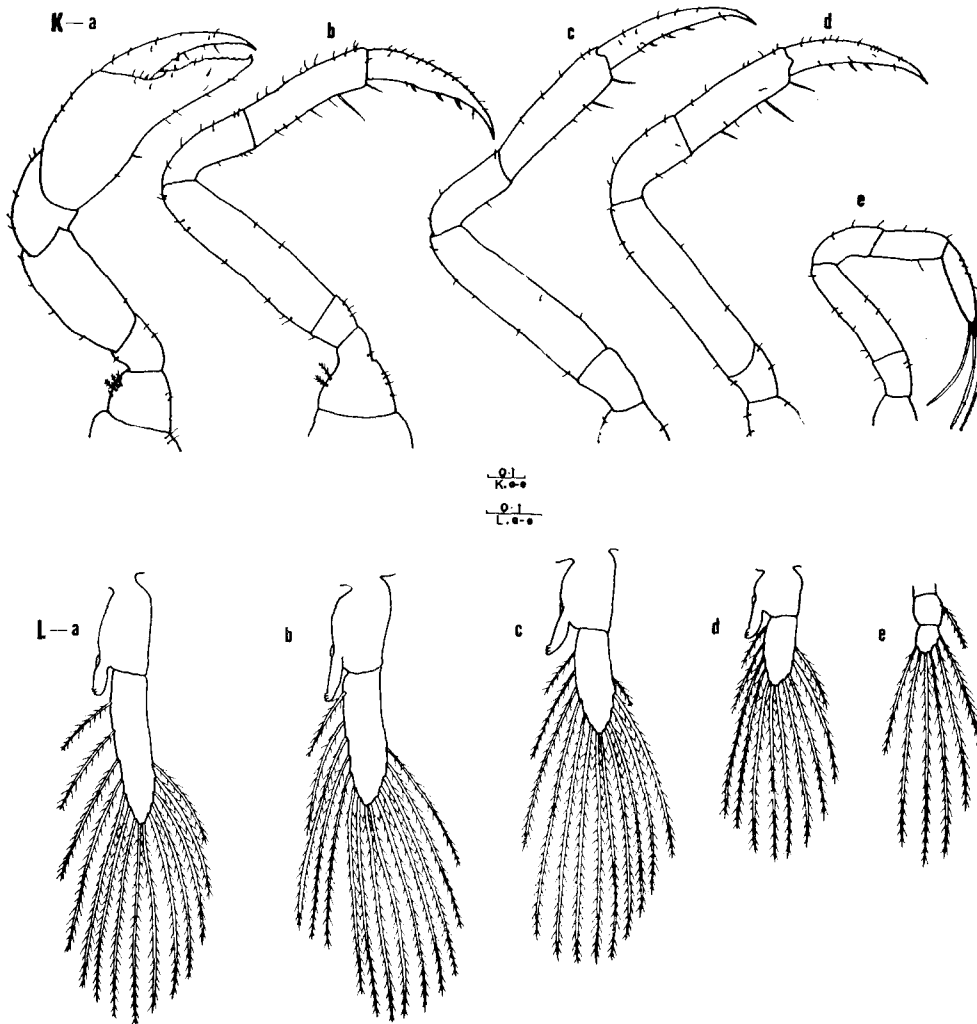


Fig. 7. *Hemigrapsus sinensis* Rathbun, megalopa stage. K-a, chela; b, second pereiopod; c, third pereiopod; d, fourth pereiopod; e, fifth pereiopod; L-a, first pleopod; b, second pleopod; c, third pleopod; d, fourth pleopod; e, fifth pleopod.

Abdomen(Figs. 6A, B): With 6 somites plus telson. Pleopods(Fig. 7L) progressively decreasing in size on somites 2-6, with 14, 14, 13, 11-12, 7 plumose setae on each exopodite, respectively. Endopodites present on pleopods 1-4 all with appendix interna.

Antennule(Fig. 6C): Peduncle 3-segmented; basal segment with 5 setae, second with 3, third with 1. Lower ramus with 4 setae. Upper ramus 3-or incompletely 4-segmented; second segment with 6 setae, third with 7, terminal with 6.

Antenna(Fig. 6D): Flagellum 10-segmented with setation proceeding distally; 1-3, 1-2,

1-2, 0, 0, 0-3, 1, 3+2, 1+2, 2+1.

Mandible(Fig. 6E): With curved, heavily chitinized incisor. Palp 2-segmented, terminal segment with 7 setae.

Maxillule(Fig. 6F): With 3 setae below endopodite. Endopodite 2-segmented with setation progressing distally 2, 4. Basal and coxal endites with 20-23, 13-16 setae respectively.

Maxilla(Fig. 6G): Scaphognathite with 31-41 plumose setae and 4~5 simple setae on surface; endopodite with 2 simple setae on proximal region; setation on proximal and distal lobes of basal and coxal endites 8-9, 10-11 and 12-14, 6 respectively.

First maxilliped(Fig. 6H): Endopodite unsegmented with 2 setae. Exopodite 2-segmented; proximal segment with 2 plumose setae, distal with 4 plumose natatory setae. Basal endite with 11-12, coxal endite with 11-13 setae. Epipodite with 7 setae.

Second maxilliped(Fig. 6I): Endopodite 4-segmented with setation 0, 1, 4-5, 8 progressing distally. Exopodite 2-segmented; proximal segment with 1 short seta, distal segment with 5 plumose natatory setae. Protopodite with 1 seta. Epipodite with 1 proximal seta, 3 distal setae.

Third maxilliped(Fig. 6J): Endopodite 5-segmented with setation progressing distally 14, 10, 7, 9-11, 7-8. Exopodite 2-segmented; proximal segment with 2 simple setae, distal segment with 5 plumose natatory setae. Epipodite with 8 plumose setae, 14 simple setae. Protopodite bearing 14-19 setae.

Chela(Fig. 7Ka): Propodus and dactylus with small teeth on cutting edge, tip slightly hooked, crossing when dactylus closed. Pleopods(Fig. 7L) and Pereiopods 2-5(Figs. 7Kb-e) setation as illustrated. Pereiopod 5 with 3 long curved brachyuran feelers.

Chromatophores(Fig. 6A): Most of brown-black chromatophores are distributed on mesogastric region, midlateral and posterolateral portions of carapace, cardiac region, bases of pereiopods 3-4, and on each abdominal segment. Several red-orange and brown-black chromatophores as spots are occurring in cheliped.

DISCUSSION

The identification of *Hemigrapsus sinensis* larvae in the plankton should not be difficult. Their small size, small lateral carapace spines during all zoeal stages and lateral spine on third somite in the zoeal stage 1 are easily observed characteristics which make these zoeae quite striking in comparison with those of many other known *Hemigrapsus* larvae. Other salient features include an antennule with 2 long, 2 shorter aesthetascs plus small simple seta (2 aesthetascs plus simple seta in other known *Hemigrapsus* larvae) in the zoeal stage 1, 3 teeth with right mandible and no teeth with left on junction of molar and incisor in all zoeal stages, and mandible with strong cutting edge, a two-jointed palp, the second segment of which bears 7 stiff setae in megalopa stage. Such characteristics presently serve to distinguish *H. sinensis* not only from other members of its subfamily Varuninae, but from

Table 1. First zoeal features known in the genus *Hemigrapsus*

	Tel- son Type	An- tenna Type	Lat- eral Spines	Mouthpart Setation				Stages	Authors
				Maxilla endop- odite	Maxil- liped 1 basi- podite	Maxilliped 1 endopodite	Maxil- liped 2 endop- odite		
VARUNINAE									
<i>Hemigrapsus crenulatus</i>	B	B	+	2, 2	3, 3, 3, 3	1, 1, 1, 2, 4+1	1, 1, 6	N.D.**	Wear, 1970
<i>Hemigrapsus edwardsi</i>	B	B	+	2, 2	3, 3, 3, 3	2, 2, 2, 2, 4+1	1, 1, 6	N.D.**	Wear, 1970
<i>Hemigrapsus longitarsis</i>	B	B	+	4	2, 2, 3, 3	2, 2, 1, 2, 4+1	N.D.**	N.D.**	Ailawa, 1929
<i>Hemigrapsus nudus</i>	B	B	+	2, 2	2, 1, 3, 3	2, 2, 1, 2, 4+1	0, 1, 6	5	Hart, 1935
<i>Hemigrapsus oregonensis</i>	B	B	+	2, 2	"9"	2, 2, 1, 2, 4+1	0, 1, 6	5	Hart, 1935
<i>Hemigrapsus penicillatus</i>	B	B	+	2, 2	2, 2, 3, 3	2, 2, 1, 2, 4+1	0, 1, 6	5	Kim, 1979
<i>Hemigrapsus sanguineus</i>	B	B	+	2, 2	2, 2, 3, 3*	3, 2, 1, 2, 4+1	0, 1, 6	5	Kurata, 1968
<i>Hemigrapsus sinensis</i>	B	B	+	2, 2	2, 2, 3, 3	2, 2, 1, 2, 4+1	0, 1, 6	5	This study

* Data from Aikawa, 1929. **N.D. : No data.

other species in the Grapsidae as well.

The genus *Hemigrapsus* is completely typified by a Type B telson, Type B antenna, possession of lateral spines on the carapace, maxilla endopodal setation being 2. 2. However, it is difficult to find such a uniformity in the setations of basipodite and endopodite of maxilliped 1, and endopodite of maxilliped 2. For example, basipodites of maxilliped 1 show three types of setal formula—2. 2. 3. 3, 3. 3. 3. 3 and 2. 1. 3. 3 (Table 1).

Natatory setae on tips of exopodites of first maxillipedes of *H. sinensis* are 9 or 10 in fourth stage, eleven or twelve in fifth stage while those of *H. nudus* (Hart, 1935) have ten in fourth stage, twelve in fifth respectively and setation of the other appendages of these two species of *Hemigrapsus* appears to be consistently different and, as has been shown for larvae of many other species of Brachyura, increases progressively throughout larval development.

The megalops of the two species of *H. sinensis* and *H. nudus* are similar in many minute respects but may easily be separated by the difference in the rostrum. The megalops of *H. nudus* (Hart, 1935) has a rostral spine while that of *H. sinensis* does not. Apparently the megalops of *H. sinensis* differs in this respect from the other species of Grapsidae described to date from rearing studies. In spite of the differences in the rostrum of the megalops of *H. sinensis* and *H. nudus*, a similarity exists which may conveniently allow separation of the megalops of this genus from the other Grapsidae.

However, confirmation of this supposition and its implications for the genus status of *H. sinensis* must await the laboratory culture and descriptions of other species in the genus *Hemigrapsus*.

Recent publications on rearing larvae in the laboratory should contribute to our knowledge of larval development and to our ability to identify planktonic forms. If complete descriptions of appendages and setation are omitted, the value is considerably reduced. Without accurate descriptions of possible diagnostic features, comparative studies on planktonic material and the positive identification of larval decapoda will not be possible.

SUMMARY

The larvae of Korean grapsid crab, *Hemigrapsus sinensis* Rathbun (Grapsidae, Varuninae), were cultured in laboratory from hatching to the first crab at temperatures ranging from 20.2°C to 24.1°C and in salinities from 32.9‰ to 33.2‰, were completely described and illustrated, and compared to the larvae of the other seven species belonging to the same genus described to date.

The complete larval development consists of five zoeal and one megalopal stage. The morphological characteristics of *H. sinensis* larvae are consistent with the other seven species of the same genus in that the antenna and the telson of the first stage zoea are type B, possession of lateral spines on the carapace, and the setal formula of the maxillary endopodite is 2.2, whereas differ in the point that basipodite and endopodite of the first maxilliped and endopodite of the second maxilliped are subject to a few variations in setation.

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