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The Complete Larval Development of *Acmaeopleura parvula* Stimpson (Brachyura, Grapsidae) Reared in the Laboratory

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The complete larval development of the Korean grapsid crab, *Acmaeopleura parvula* Stimpson, from hatching to first crab was described and illustrated. Larvae were reared in 12 different combinations of temperature and salinity, and passed through five (uncommonly six) zoeal and a megalopal stage. Best survival to first crab stage occurred in 20°C-31.4‰. Development to first crab was 22-23 days (at 25°C), 34-37 days (at 20°C) and 50-51 days (at 15°C). Additional sixth zoeae were obtained only at 15°C. Larvae of *A. parvula* were distinguished from the larvae of other Varuninae in the absence of lateral carapace spines and were morphologically similar to *Gaetice depressus* (De Haan). Other characters of appendages were compared with those of the known larvae of the subfamily Varuninae.

Introduction

Acmaeopleura parvula Stimpson is a small varunine crab which inhabits the coasts of high tidal mark. It is known to occur in from the south coast of the East Sea, the Korean Strait to Cheju-do in Korea, and from Sagami Bay to Kyushu in Japan (Kim, 1973; Sakai, 1976).

Informations on larval development of genus *Acmaeopleura* are sparse. Gamo(1960) described only the megalopa of *Acmaeopleura parvula* and Kurata's (1968a) description of *A. parvula* is very brief. In the subfamily Varuninae, larval informations are available only in other genera, including *Gaetice depressus* (De Haan) (Kim and Lee, 1983) *Eriocheir japonicus* De Haan (Morita, 1974), *E. sinensis* H. Milne Edwards (Kim and Lee, 1982) and *Euchirograpsus americanus* A. Milne Edwards (Wilson, 1980). In the genus *Hemigrapsus*, there have been relatively extensive works; the complete larval stages are known for *Hemigrapsus nudus* (Dana) and *H. oregonensis* (Dana) (Hart, 1935), *H. sanguineus*(De Haan) (Kurata, 1968b), *H. penicillatus* (De Haan)(Kim, 1979) and *H. sinensis* Rathbun (Kim and Moon, 1987), and first zoeal stages for *H. longitarsis* (Miers) (Aikawa, 1929), *H. crenulatus* (*H. Milne* Edwards) and *H. edwardsi* (Hilgendorf) (Wear, 1970).

The purpose of the present study is to describe the complete larval development of *A. parvula* Stimpson, to determine the effects of different temperature-salinity combinations on development and survival of the larvae and to compare larval characters of *A. parvula* with those known from other members of Varuninae.

Material and Methods

On June 16, 1985, ovigerous females of *Acmaeopleura parvula* were collected under pebbles near high tidal mark in Songnam beach, Namhae-gun, Kyongsangnam-do, Korea. The crabs were placed individually in glass bowls (1000 *ml*) filled with seawater with a salinity of 34.4‰ until hatching occurred. Larvae were reared in three salinities (26.9‰, 31.4‰ and 34.4‰) and maintained four temperatures (15°C, 20°C, 25°C and room temperature).

For each of the 12 different salinity-temperature

combinations, 50 individuals of first zoeae were placed in five glass bowls (80 *ml*) with filtered seawater and fed *Artemia* nauplii and *Brachionus plicatilis*. The cultures were kept in controlled-temperature cabinets with a light regime of 14 hours light and 10 hours darkness. The room temperature ranged from 23.5°*C* to 28.5°*C* (mean 25.2°*C*) during the period of 28 days. To obtain the different salinities, seawater was diluted with distilled water. For the detailed description of the larvae, mass culture was separately carried out under 25°*C* and 34.4‰. The larvae were moved daily into clean glass bowls with filtered seawater. At each developmental stage, dead and some living larvae and exuviae were preserved in 7% neutral formaline. Drawings were made with the aid of a camera lucida. The chromatophore patterns were determined from the observation of living or freshly killed larvae. Carapace length was measured from the base of rostrum between the eyes to the most posterior margin, and for the megalopa, carapace width was measured across the widest part of the carapace. Measurements were based on the mean of at least 10 specimens in each stage except the intercalated fifth and the sixth zoeal stage. All scales in figures represent 0.1mm.

Results of Rearing Experiment

The influence of salinity and temperature on the survival and duration of development of *Acmaeopleura parvula* larvae is shown in Table 1. Although survival and developmental rate varied considerably in different temperature-salinity combinations, megalopae and the first crabs were obtained from all the combinations. Salinities of 31.4‰ and 34.4‰ were favorable for complete larval development at all four temperatures. Survival to the first crab was highest in 31.4‰ at all four temperatures, with the highest survival at 20°*C*. At this temperature, 66% of the first zoeae molted to the megalopal stage and 58% to the first crab stage. In 26.9‰, the survival was relatively higher at 15°*C* than at 20°*C*, 25°*C* and room temperature. While 24% molted to the megalopal stage and 22% to the first crab stage at 15°*C*, only 4% molted to the megalopal stage and 2% to the first crab stage at 25°*C*.

Atypical fifth and additional sixth stage zoeae occurred at 15°*C* only and successfully molted to megalopal stage.

Fig. 1 and Table 1 show the time required to reach each zoeal, megalopal and the first crab

Table 1. *Acmaeopleura parvula*. Survival and duration of the larval development from hatching to megalopa and first crab. Room temperature (R.T.), 23.5°*C*–28.5°*C* (mean, 25.2°*C*).

Temperature (°*C*)	Salinity (‰)	Percentage of Survival		Days of Development			
		Hatch to Megalopa	Hatch to Crab	Hatch to Megalopa		Hatch to Crab	
				Mean	Range	Mean	Range
15	26.9	24	22	41.1	34-40	64.4	51-75
15	31.4	48	38	40.6	34-49	59.1	50-73
15	34.4	46	38	35.9	34-44	53.6	50-65
20	26.9	12	12	24.0	23-25	39.8	37-42
20	31.4	66	58	23.2	22-27	37.6	35-44
20	34.4	58	48	24.3	22-30	37.0	34-42
25	26.9	4	2	15.5	15-16	23.0	23
25	31.4	50	42	16.5	15-20	25.1	23-28
25	34.4	46	32	17.2	16-20	24.7	23-27
R.T.	26.9	10	10	16.9	16-20	24.2	23-25
R.T.	31.4	52	42	16.9	15-21	24.0	22-27
R.T.	34.4	42	38	17.0	15-19	24.4	23-27

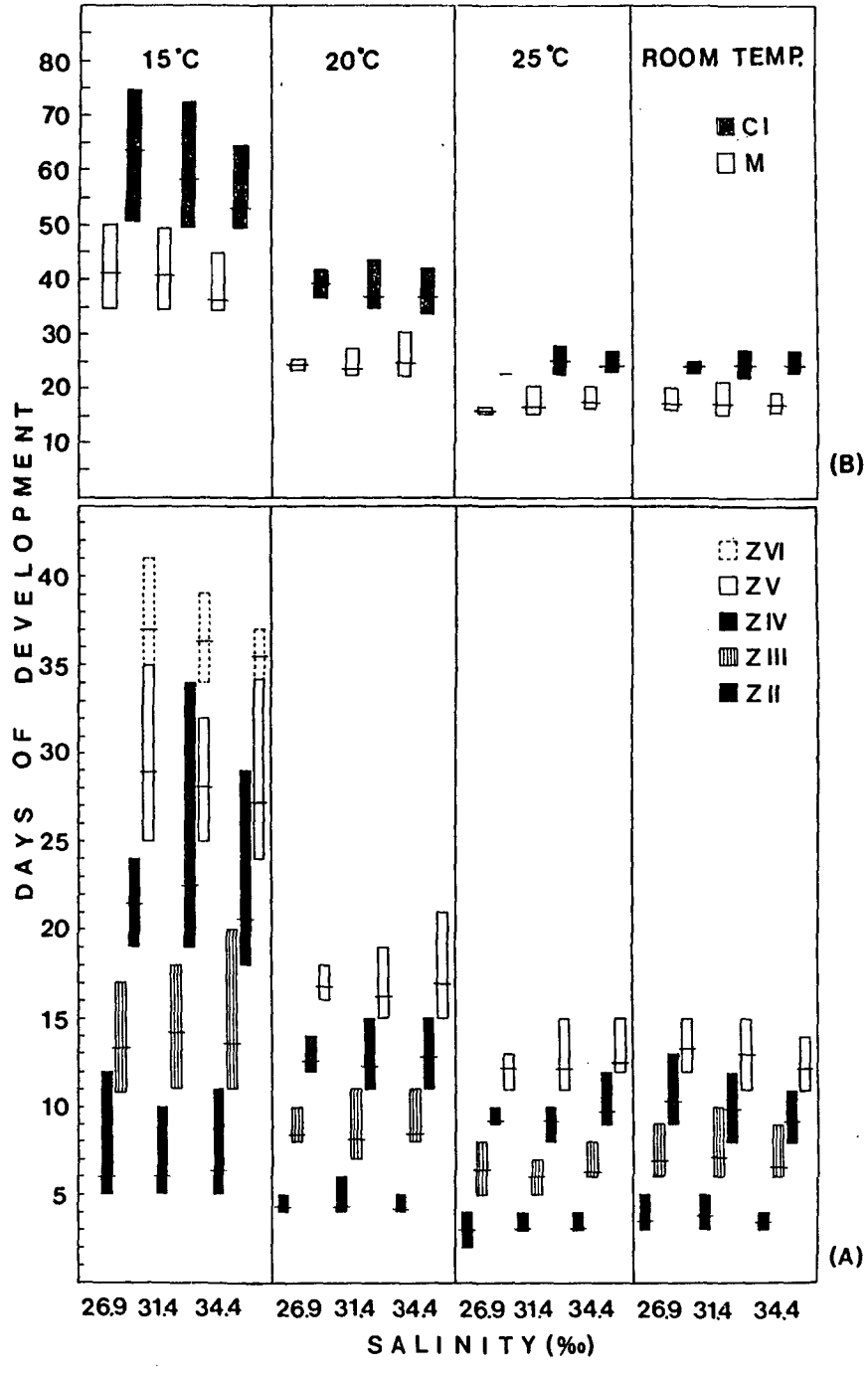

Fig. 1. *Acmaeopleura parvula*. Comparison of time required for molting to (A) each zoeal and (B) megalopal and first crab stages of the larvae reared in 12 different temperature-salinity combinations. Blocks represent total range of time, and horizontal lines represent mean values. ZI-ZVI, first to sixth stage zoeae; M, megalopa; CI, first crab; room temperature, 23.5°C-28.5°C (mean, 25.2°C).

stages in 12 combinations of salinities and temperatures. Developmental time was affected by temperature. At 15°C, the zoeae did not initiate the first molt until those at 25°C had completed the first molt. For example, the first molt at 15°C in 34.4‰ occurred from 5 to 11 days whereas at 25°C in 34.4‰, the first zoeae completed first molting between 3 and 4 days. The longer span of larval stages at the lower temperature was also observed in the subsequent stages. Comparing with 15°C combinations, duration of the whole larval stages at 20°C and 25°C were approximately 1.5 and 2 times shorter respectively. At given four temperatures, there were not remarkable differences of the minimum developmental times with different salinities.

Description of the Larvae

Acmaeopleura parvula Stimpson passed through five (unommonly six) zoeal stages followed by a megalopal stage. The typical fifth stage zoeae directly molted to megalopae, but the atypical fifth stage zoeae molted to the sixth stage. The additional sixth stage zoeae successfully molted to megalopae and could be distinguished from the typical fifth stage zoeae by its size and morphological difference. The major characteristics of the

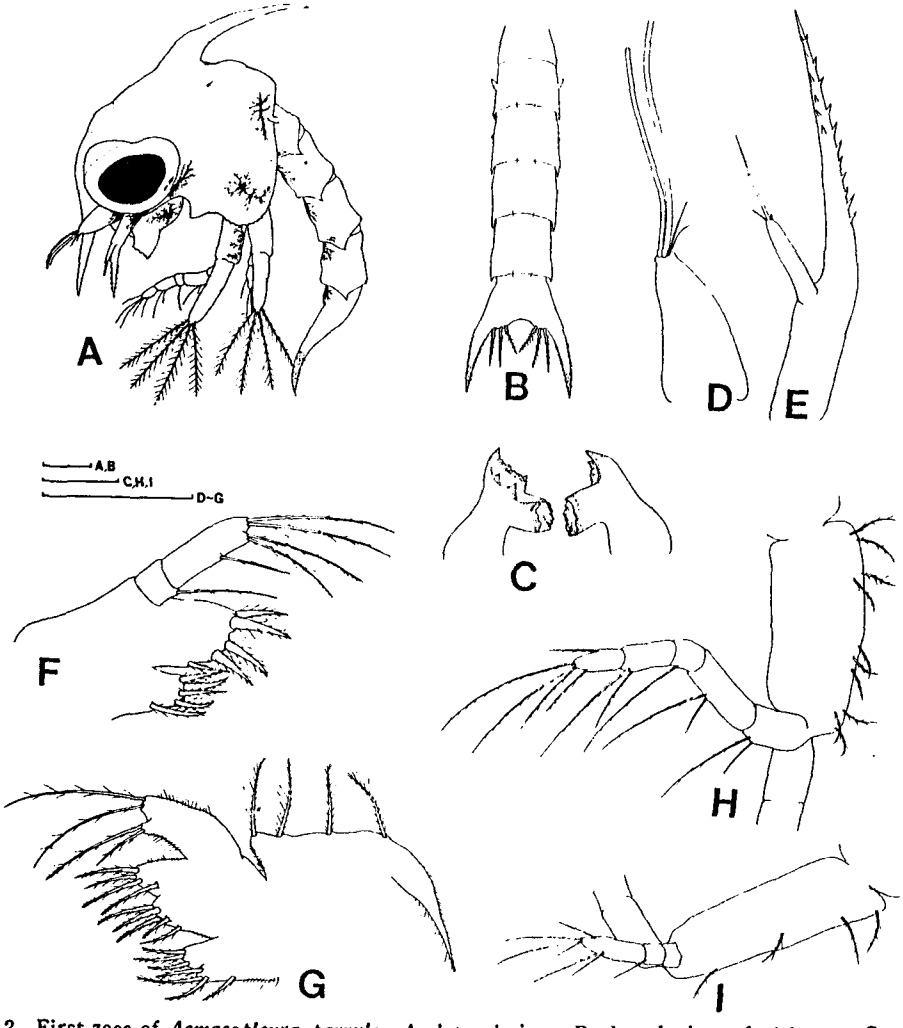

Fig. 2. First zoea of *Acmaeopleura parvula*. A, lateral view; B, dorsal view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped

individual larval stage are as follows:

First Zoea (Fig. 2)

Carapace length: 0.54–0.58 (mean 0.56) mm.

Carapace (Fig. 2 A)-Rostral and dorsal spine present; lateral spines absent in all zoeal stages. Rostral spine stright downwards and approximately equal in length to antenna. Dorsal spine strongly curved posteriorly. Simple seta at lateral base of dorsal spine. Several minute denticles along postero-lateral carapace margin. Eyes sessile.

Abdomen (Fig. 2 B)-Five somites and a telson: somites 2-5 each having a pair of simple setae on postero-dorsal margin and terminating in acute postero-lateral spines. Somite 2 with a pair of lateral processes projecting anteriorly and somite 3 with a pair of smaller processes projecting posteriorly: both pairs remaining unchanged in all zoeal stages.

Telson(Fig. 2 B)-Bifurcated. Each fork covered with rows of fine spinules distally. Three (rarely four) pairs of denticulate setae on telson inner margin.

Mandibles (Fig. 2 C)-Asymmetrical, boot-like in shape. Left incisor margin with 5 sharp-edged teeth and small denticles, right with 5 larger teeth. Molar region circular, irregularly dentate.

Antennule (Fig. 2 D)-Smooth and conical, with 2 long aesthetascs plus 1 or 2 simple setae.

Antenna (Fig. 2 E)-Protopodite tapered, bearing 2 rows of spinules distally. Exopodite about 1/3 length of protopodite, with 2 unequal setae and 1 long terminal spine.

Maxillule (Fig. 2 F)-Endopodite two-segmented; proximal segment with 1 long plumose seta, distal segment with 4 terminal and 1 subterminal plumodenticulate setae in all zoeal stages. Basal endite with 4 terminal and 1 subterminal plumodenticulate setae; coxal endite with 4 terminal and 1 subterminal plumodenticulate setae.

Maxilla (Fig. 2 G)-Endopodite unsegmented, weakly bilobed; each lobe with 2 plumose setae. Distal and proximal lobes of basal endite with 4, 5 plumodenticulate setae; distal and proximal lobes of coxal endite with 3, 4 plumodenticulate setae respectively. Scaphognathite bearing 4 plumose setae along outer margin, terminating in setose apical tip.

First maxilliped (Fig. 2 H)-Basipodite with 10 plumose setae in all zoeal stages, progressing distally 2, 2, 3, 3. Endopodite five-segmented; setal formula progressing distally 2, 2, 1, 2, 5. Exopodite incompletely two-segmented, with 4 terminal natatory setae.

Second maxilliped (Fig. 2 I)-Coxopodite naked throughout all zoeal stages. Basipodite with 4 long ventral plumose setae, as 1, 1, 1, 1. Endopodite three-segmented, setal formula progressing distally 0, 1, 6. Setal formulae of basipodite and endopodite remaining unchanged in all zoeal stages. Exopodite incompletely two-segmented, with 4 terminal natatory setae.

Chromatophores-Blackish brown chromatophores were placed as follows: in the ventral region of basipodite of first maxilliped; on the postero-lateral and postero-dorso-lateral carapace margin; at the posterior base of dorsal carapace spine; on the ventral surface of abdominal somites 2-5 (at first and second stage), somites 2-6 (at third and subsequent zoeal stages) and telson. Reddish orange chromatophores also occurred at the base of antenna, on the basipodite of first maxilliped, on the postero-dorso-lateral carapace margin and along the abdominal somites. This pattern was consistent throughout all zoeal stages.

Secoond Zoea (Fig. 3)

Carapace length: 0.62–0.70 (mean 0.66) mm.

Carapace (Fig. 3 A)-Similar in form to first stage, but dorsal spine more or less straight. Postero-lateral carapace margin with 3-5 plumose setae, postero-dorsal arch with 2 plumose setae. Eyes stalked.

Abdomen (Fig. 3 B)-Somite 1 with 1 long plumose seta mid-dorsally. Somites 2-5 and telson same as in first stage.

Mandibles (Fig. 3 C)-Similar in form and armature to first stage.

Antennule (Fig. 3 D)-Three aesthetascs plus 2 unequal simple setae.

Antenna(Fig. 3 E)-Showing no substantial change in form, but 1 seta on exopodite disappeared in this

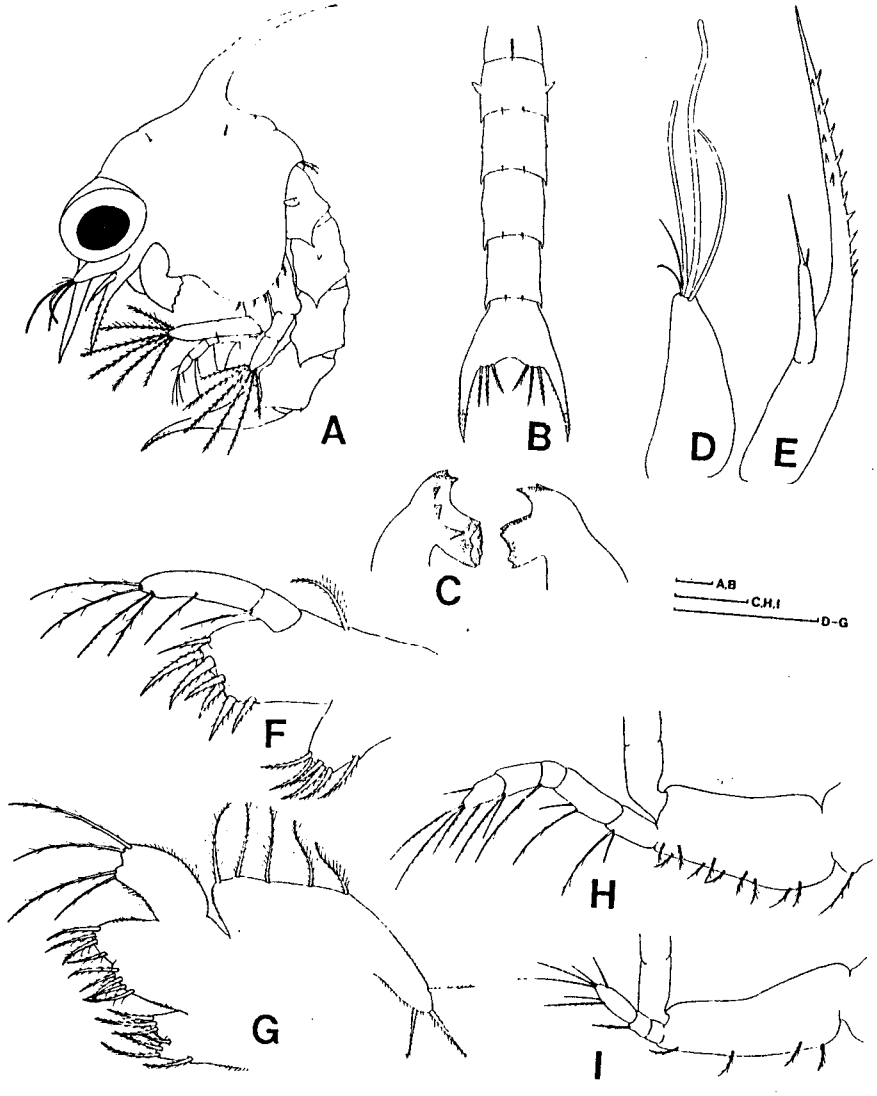

Fig. 3. Second zoea of *Acmaeopleura parvula*. A, lateral view; B, dorsal view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

and subsequent stages.

Maxillule (Fig. 3 F)-Basal endite with 7 plumodenticulate setae terminally and 1 long dorsal feathery seta on disto-lateral margin. Coxal endite with 5 or 6 plumodenticulate setae.

Maxilla (Fig. 3 G)-Setation on basal and coxal endites as in first stage. Scaphognathite bearing 5 marginal plus 3 terminal plumose setae.

First maxilliped (Fig. 3 H)-Coxopodite bearing 1 plumose seta in this and next two stages. Exopodite with 6 natatory terminal setae.

Second maxilliped (Fig. 3 I)-Unchanged except exopodite having 6 natatory setae.

Third Zoea (Fig. 4)

Carapace length: 0.76–0.84 (mean 0.80) mm.

Carapace (Fig. 4 A)-Similar in form and armature to second stage. Postero-lateral carapace

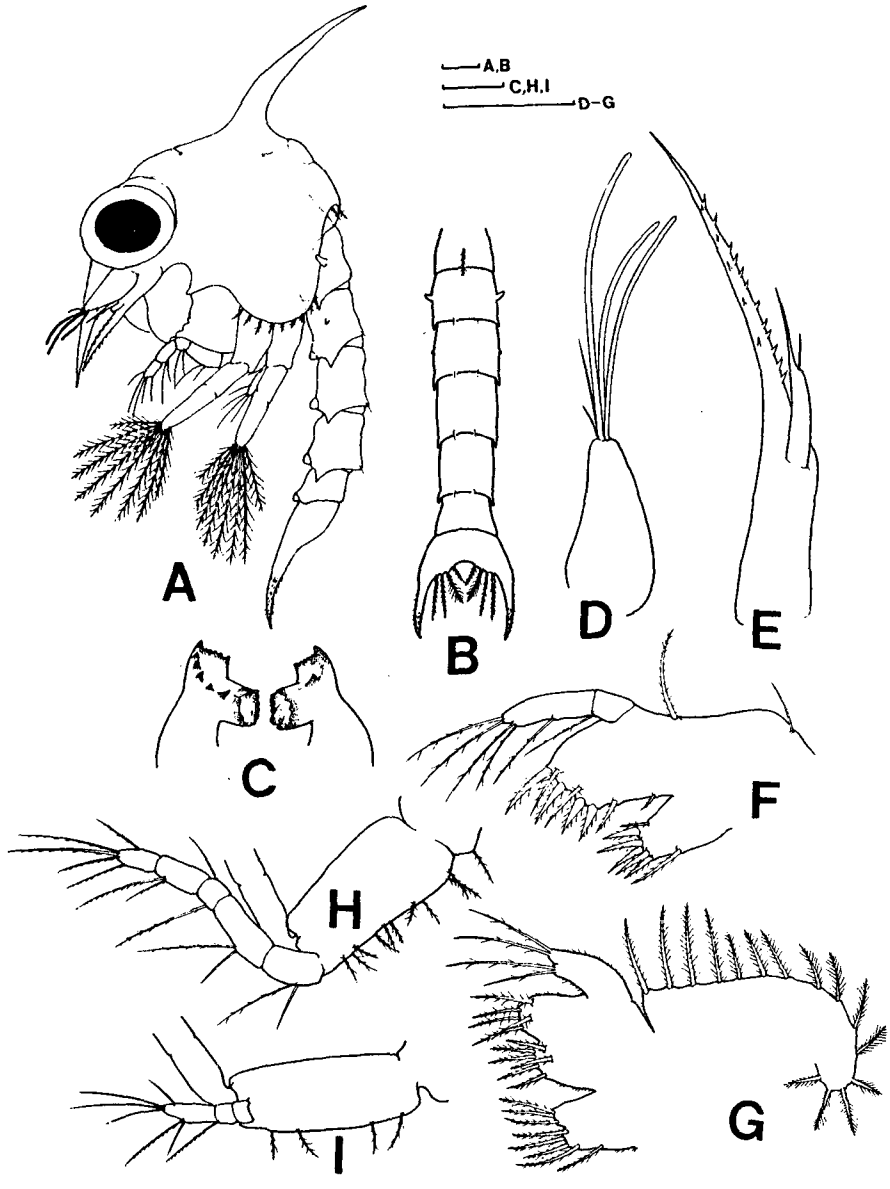

Fig. 4. Third zoea of *Acmaeopleura parvula*. A, lateral view; B, dorsal view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

margin bearing 8 plumose setae.

Abdomen(Fig. 4 B)-Six somites; somite 6 without postero-dorsal setae, terminating in rounded postero-lateral spines. Inner margin of telson with 4 pairs of setae.

Mandibles (Fig. 4 C)-Both molar processes similar in form to second stage, but 1 and 2 additional teeth on right and left incisor respectively.

Antennule (Fig. 4 D)-Similar to the previous stage.

Antenna (Fig. 4 E)-Small endopodite bud.

Maxillule(Fig. 4 F)-One dorsal simple seta added on proximo-lateral margin. Coxal endite with 7 setae terminally.

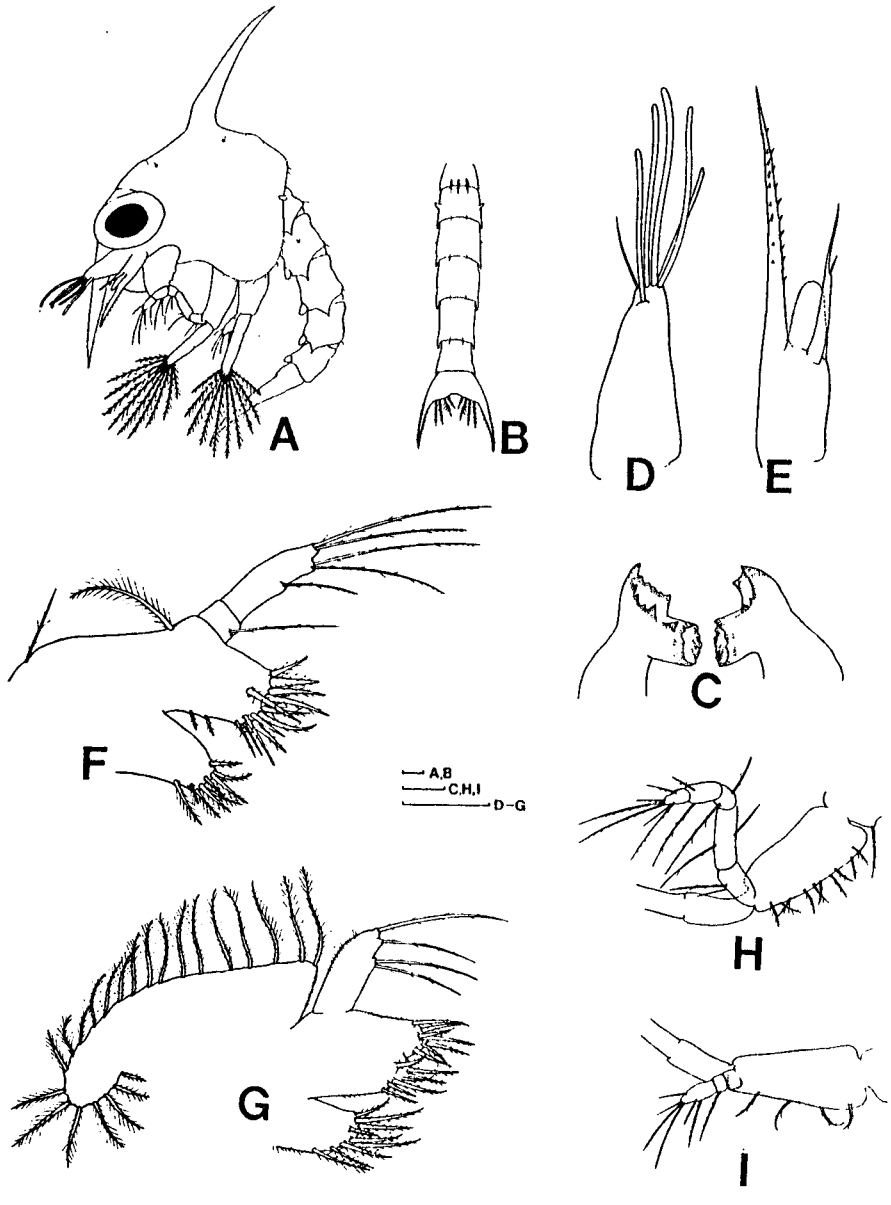

Fig. 5. Fourth zoea of *Acmaeopleura parvula*. A, lateral view; B, dorsal view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

Maxilla (Fig. 4 G)-Distal and proximal lobes of basal and coxal endites each with 5, 6 and 3, 5 setae respectively. Scaphognathite with 15 plumose setae.

First maxilliped (Fig. 4 H)-Endopodite with 1 additional seta on third segment: setal formula progressing distally 2, 2, 2, 2, 5. Exopodite with 8 natatory setae.

Second maxilliped (Fig. 4 I)-Natatory setae on exopodite increased to 8.

Fourth Znea (Fig. 5)

Carapace length: 0.86–0.92 (mean 0.91) mm.

Carapace(Fig. 5 A)-With 9 plumose setae along postero-lateral margin. Postero-dorsal arch with 4 plumose setae. Third maxilliped and pereiopod buds visible under carapace.

Abdomen (Fig. 5 B)-Somite 1 with 3 plumose setae mid-dorsally. Pleopod buds on somites 2-6. Telson same as in third stage.

Mandibles (Fig. 5 C)-Teeth on both molar regions enlarged.

Antennule (Fig. 5 D)-Simple setae decreased to 1; aesthetascs increased to 5.

Antenna (Fig. 5 E)-Endopodite elongated, now about 1/4 length of protopodite process.

Maxillule (Fig. 5 F)-Basal endite with 14 plumodenticulate setae: 12 setae terminally, 2 small setae laterally. Coxal endite with 9 plumodenticulate setae.

Maxilla (Fig. 5 G)-Distal and proximal lobes of basal and coxal endites with 7, 7 setae and 3, 6 plumodenticulate setae respectively. Scaphognathite bearing 23 plumose setae.

First maxilliped (Fig. 5 H)-An additional seta on distal segment of endopodite: setal formula 2,2,2, 2,6 in this and the subsequent stages. Exopodite with 10 natatory setae.

Second maxilliped (Fig. 5 I)-Exopodite with 10 natatory setae.

Fifth Zoea (Fig. 6)

Carapace length: 0.96－1.12 (mean 1.05) mm.

Carapace (Fig. 6 A)-With 16 plumose setae along postero-lateral margin and 6 pulmose setae along postero-dorsal arch. Third maxilliped and pereiopod buds much more elongated than previous stage, but not protruded beyond margin of carapace.

Abdomen (Fig. 6 B)-Somite 1 with 5 plumose setae mid-dorsally. Pleopod buds on somites 2-5 bearing rudimentary endopods. Inner telson margin with 4 or 5 pairs of setae.

Mandibles (Fig. 6 C)-Mandibular palp bud present.

Antennule (Fig. 6 D)-Small, rounded endopodite bud present. Basal region swollen. Nine aesthetascs arranged in two tiers: 4 aesthetascs plus 1 simple seta terminally, and 5 subterminally.

Antenna (Fig. 6 E)-Endopodite incompletely two-segmented, approximately 3/5 length of protopodite process.

Maxillule (Fig. 6 F)-Setae on basal endite increased to 16, including 3 lateral small setae. Coxal endite with 11-12 setae.

Maxilla (Fig. 6 G)-Proximal and distal lobes of basal and coxal endites with 9, 10 and 4, 8 setae respectively. Scaphognathite bearing 31-34 plumose setae.

First maxilliped (Fig. 6 H)-Coxopodite with 2 plumose and 1 simple setae. Exopodite with 12 natatory setae.

Second maxilliped (Fig. 6 I)-Exopodite with 12 natatory setae.

Intercalated Fifth Zoea (Fig. 7)

This stage zoeae molted to an atypical sixth stage before molting to megalopae.

Carapace length not measured.

Abdomen (Fig. 7 A, B)-Somite 1 with 3 mid-dorsal setae. Pleopods without endopodite buds and similar in form to fourth stage. Telson as in fourth stage.

Mandibles (Fig. 7 C)-No mandibular palp buds.

Antennule (Fig. 7 D)-Endopodite bud absent. Aesthetascs arranged in two tiers: 4 aesthetascs plus 1 simple seta terminally, and 4 aesthetascs subterminally.

Antenna (Fig. 7 E)-Endopodite slightly shorter than that of typical fifth stage, approximately 2/5 length of protopodite process.

Maxillule (Fig. 7 F)-Setation on both endites same as in fourth stage.

Maxilla (Fig. 7 G)-Proximal and distal lobes of basal and coxal endites with 9, 8 and 3, 7 plumose setae respectively. Scaphognathite with 26-28 setae marginally.

First maxilliped (Fig. 7 H)-Setations on coxopodite and endopodite as in fourth stage. Exopodite with 11-12 natatory setae.

Second maxilliped (Fig. 7 I)-Exopodite with 11-12 natatory setae.

Sixth Zoea (Fig. 8)

The additional sixth stage zoeae successfully molted to megalopae, and could be distinguished

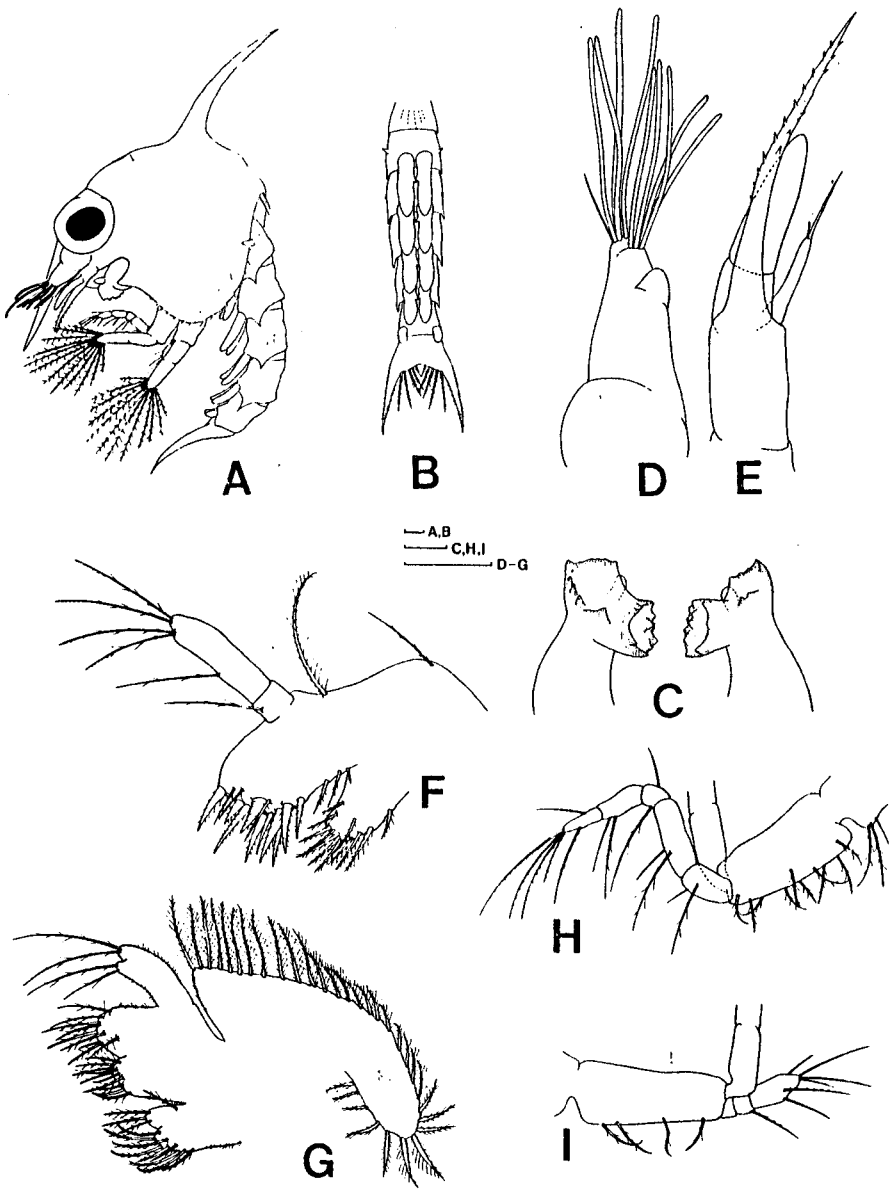

Fig. 6. Fifth zoea of *Acmaeopleura parvula*. A, lateral view; B, ventral view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

from the typical fifth stage zoeae by size and morphological characters.

Carapace length: 1.26-1.28 (mean 1.27) mm.

Carapace (Fig. 8 A)-Noticeably larger than previous stages; 4 simple setae above eye.

Abdomen (Fig. 8 B)-Somite 1 with 5 mid-dorsal setae. Pleopods longer than in typical fifth stage. Distal margin of pleopods more or less serrated, bearing 1 or 2 simple setae. Telson inner margin with 5 pairs of setae.

Mandibles (Fig. 8 C)-Mandibular palp bud present.

Antennule (Fig. 8 D)-Endopodite bud present.

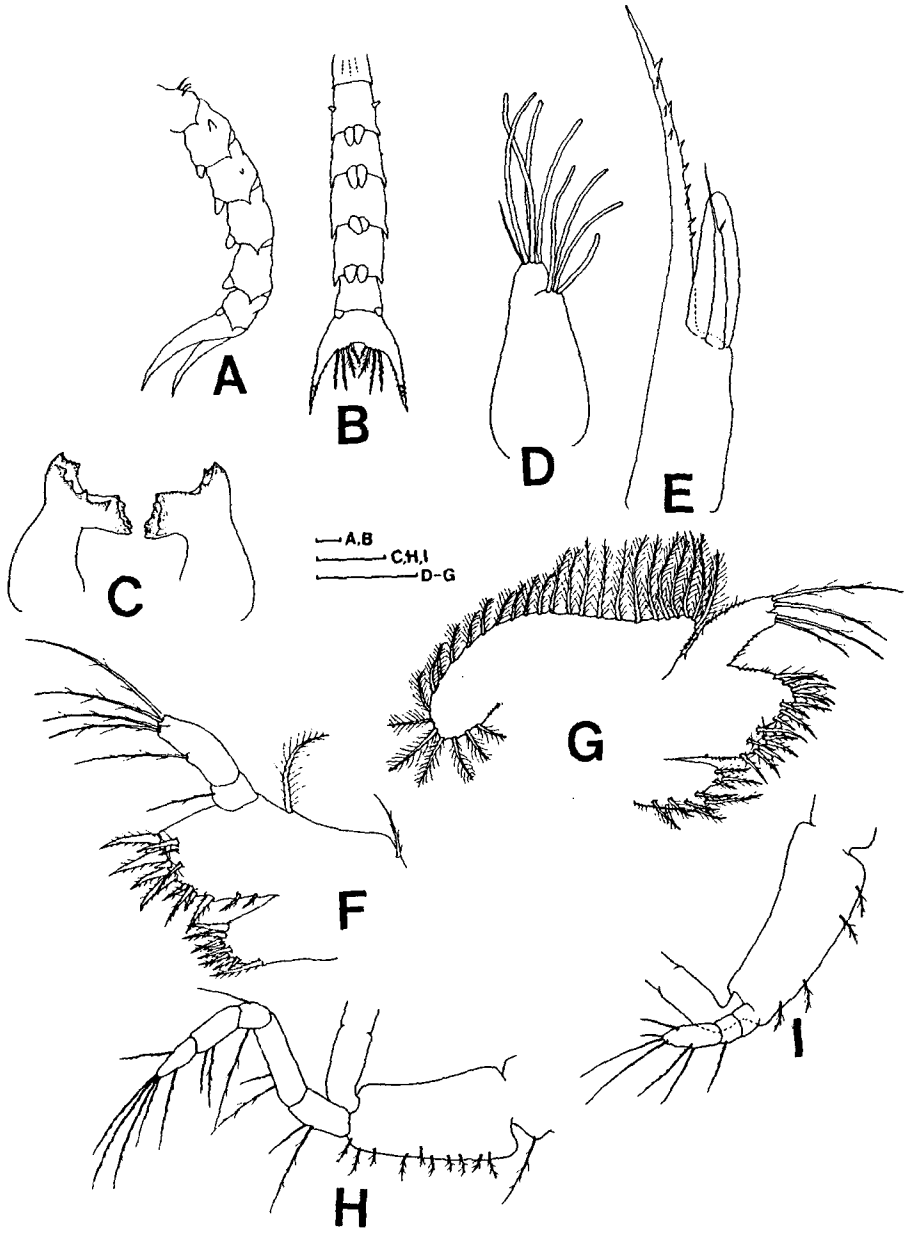

Fig.7. Intercalated fifth zoea of *Acmaeopleura parvula*. A, lateral view of abdomen; B, ventral view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

Basal region swollen, but no evidence of segmentation. Aesthetascs arranged in three tiers: progressng distally 3, 4, 4+1(simple seta) or 4, 5, 5+1.

Antenna(Fig. 8 E)-Endopodite incompletely three-segmented, approximately 2/3 length of protopodite process.

Maxillule(Fig. 8 F)-Basal endite with 17-18 setae, including 3 lateral setae; coxal endite with 13 setae.

Maxilla (Fig. 8 G)-Distal and proximal lobes of basal and coxal endites with 10, 11 and 4, 13 setae

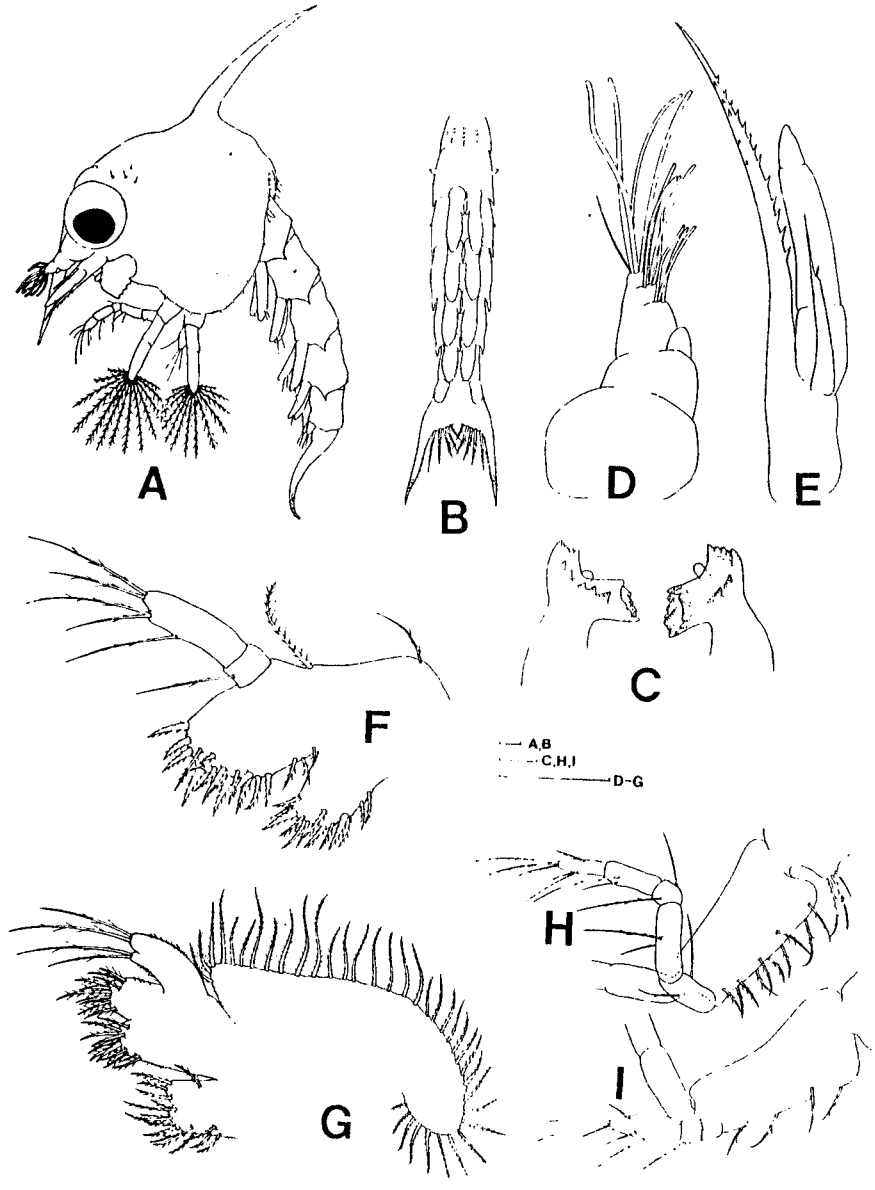

Fig. 8. Sixth zoea of *Acmaeopleura parvula*. A, lateral view; B, ventral view of abdomen; C, mandibles; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped.

respectively. Scaphognathite bearing 35-39 plumose setae along margin.

First and second maxilliped (Fig. 8H, I)-Exopodite each with 13 natatory setae. Other setations same as in typical fifth stage.

Megalopa (Fig. 9)

Carapace length: 1.36-1.64 (mean 1.51) *mm*.

Carapace width: 1.08-1.20 (mean 1.11) *mm*.

Carapace (Fig. 9 A, B)-Subovate in dorsal view; carapace length slightly longer than width; rostrum

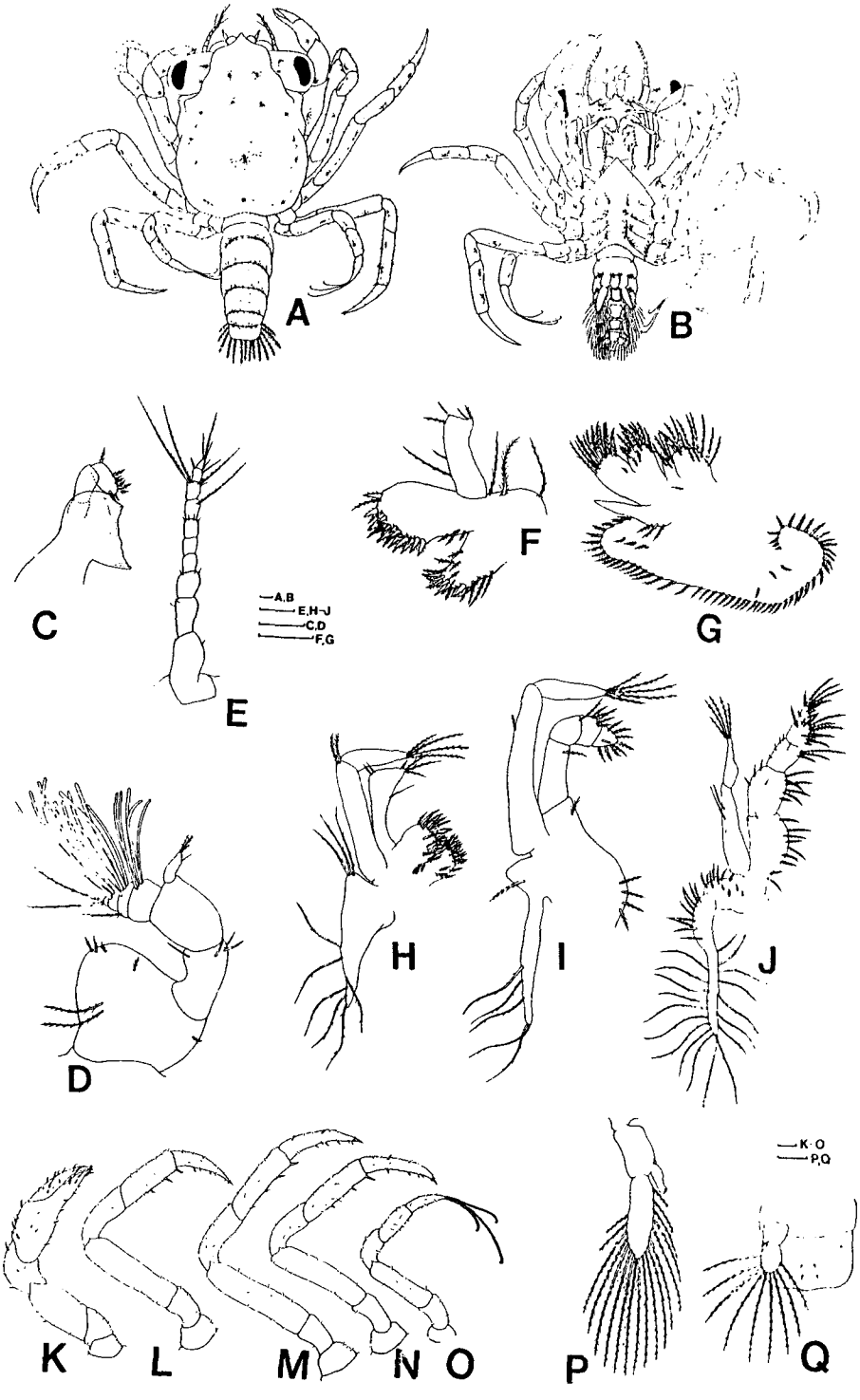

Fig. 9. Megalopa of *Acmaeopleura parvula*. A, dorsal view; B, ventral view; C, mandible; D, antennule; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, cheliped; L-O, pereiopods 2-5; P, pleopod 1; Q, pleopod 5 and telson.

bent obliquely downwards, ending in pointed tip; two undulations in antero-lateral region; postero-lateral margin smooth and rounded. Row of fine setae along lateral and posterior carapace margin; numerous hairs scattered in dorsal surface.

Abdomen(Fig. 9 A, B, Q)-Six somites and a telson; somites 2-6 each with 10-14 fine setae dorsally. Telson subquadrate, bearing 2 pairs of setae on mid-dorsal region and 1 pair on anterior angles.

Mandible(Fig. 9 C)-Right and left mandibles similar in form to each other; palp three-segmented, with 9 plumodenticulate setae on distal segment.

Antennule (Fig. 9 D)-Biramous. Peduncle three-segmented; proximal segment globular, with 5 short and 2 long plumose setae; second segment with 4 terminal simple seta; third segment naked. Lower ramus with 3 terminal denticulate and 1 subterminal simple seta. Upper ramus incompletely four-segmented; 1 and 2 denticulate setae on second and terminal segment respectively; first three segments provided with 16 aesthetases, progressing distally 5, 6, 5.

Antenna (Fig. 9 E)-Composed of 10 segments; setal formula progressing distally 2, 2, 3, 0, 0, 4, 1, 2 +(3), 3, 2+(1)(long serrate setae in parentheses).

Maxillule (Fig. 9 F)-Endopodite segmented, with 2 simple, 3 plumose setae. Basal endite with 21 setae terminally and 4 setae proximally. Disto-lateral and coxo-lateral margin with 1 feathery and 2 plumose setae. Coxal endite with 20 setae.

Maxilla (Fig. 9 G)-Endopodite with 3 plumose setae on proximal margin. Setal formula on distal and proximal lobes of basal and coxal endites 15, 12 and 5, 14 respectively. Scaphognathite bearing 56-57 plumose setae along margin and 6 plumose setae on blade.

First maxilliped (Fig. 9 H)-Coxal and basal endites each with 20 setae respectively. Endopodite unsegmented, with 3 plumose, 3 simple setae and 1 stout spine. Exopodite two-segmented, with 4 plumose setae on distal segment and 2 plumose setae on proximal segment. Epipodite triangular in shape, with 9-10 plumose setae along margin.

Second maxilliped (Fig. 9 I)-Basipodite with at least 5 plumose setae. Endopodite four-segmented, setal formula 1, 1, 5, 8 progressing distally. Exopodite two-segmented, with 1 lateral plumose seta on proximal segment, 5 terminal plumose setae on distal segment. Epipodite bearing 1 proximal, 5 distal plumose setae.

Third maxilliped (Fig. 9 J)-Protopodtie with approximately 11 setae. Epipodite bearing 9 setae proximally and 18 long setae along distal region. Endopodite five-segmented, denticulate setation progressing distally 9+(5), 6+(4), 3+(5), 10, 9 (simple setae in parentheses).

Cheliped (Fig. 9 K)-Bearing irregular teeth on cutting margin of dactyl and propod. Pereiopods 2-4 (Fig. 9 L-N) similar in form to each other; propod with 3-4 stout spines along inner margin, dactyl with 1 spine on distal end. Pereiopod 5(Fig. 9 O) with 3 unequal "brachyuran feelers" terminally.

Pleopods(Fig. 9 P, Q)-Progressively decreasing in size on somites 2-6, with 18, 18, 17, 16, 9+1 (or 10+1 on proximal segment) natatory setae on each exopodite respectively. Endopodites present on pleopods 1-4, all with 2 hooked appendix internae.

Chromatophores-The location of blackish brown chomatophores on cephalothorax was as follows: one pair on anterior, one on dorso-median, 5 pairs around dorso-median, one on dorso-posterior and one pair at base of antennules. Other chromatophores were found on mouth parts and abdominal somites 2-6. Yellow and reddish orange chromatophores appeared in all pereiopods.

Discussion

Rearing Experiment

Larvae of *Acmaeopleura parvula* showed 42% or higher survival to the megalopal stage at all salinity-temperature combinations tested, except all four temperatures with a salinity of 26.9‰ (Table 1). The highest survival to megalopa(66%) was seen at a temperature of 20°C and a salinity of 31.4‰. This range of temperature and salinity corresponds to that of mean temperature and sali-

nity (19.7°C and 33.1‰) of the sampling area of the females in June for the ten years (1972-1981) (Fisheries Research and Development Agency, 1983). The spawning period of *A. parvula* has not been known in detail, but we found that almost all of the females were ovigerous in the end of May. Therefore, it may be suggested that the larvae of *A. parvula* hatched in June survive better than any time of all the year round.

As expected, duration of larval development was highly dependent on temperature(Fig. 1). At given four temperatures, however, we observed no remarkable differences of the minimum developmental times to megalopal stage under different salinities.

Kurata(1968a) reared the larvae of *A. parvula* between temperatures of 14.9°C and 18.6°C, but did not report extra larval stages. In the present study, *A. parvula* had an extra sixth stage at a temperature of 15°C only, but not at any other higher temperatures(20°C, 25°C and room temperature). And, therefore, the variability in the number of larval stages of *A. parvula* seems to be temperature-dependent(Table 1). Although similar results were obtained by Scotto(1979), a difference in temperatures tested can be noted; in his study on larval development of *Mennipe nodifrons*(Xanthidae), five zoeal stages were attained at 30°C, while an atypical sixth stage was infrequently obtained at both room temperature(mean 24.5°C) and 20°C.

Description of the Larvae

The description of first zoea of *Acmacopleura parvula* given by Kurata(1968a) agrees with that of the present study. But his description of the subsequent stage zoeae and megaloap is too brief to be compared with the present study. Kurata's illustration of the second antennae shows B3-type (Aikawa, 1933) in all zoeal stages, whereas we found B2-type in the first zoea and B3-type in the following stages. His description of megalopal antenna shows total 11 segments compared with "10" we found; he also found the setation on proximal and distal segment of fifth pleopod of megalopa to be 0-1 and 10-11, while our material shows setation of 1 and 9-10 respectively.

In the following discussion on Varuninae larvae, we will exclude *Euchirograpsus americanus*, because Wilson(1980) suggested that *E. americanus* zoeae were much more closely related with both Plagusiinae and Grapsinae zoeae than other members of the Varuninae on the basis of its A-type antenna, C-type telson and endopodal setation on the maxilla being 2, 2 respectively.

The first zoea of *A. parvula* exhibits the typical features of varunine larvae in B-type telson, B-type antenna and endopodal setation on maxillule and maxilla being 1, 5 and 2, 2. The zoea of this species also has basipodal and endopodal setations on first maxilliped of 2, 2, 3, 3 and 2, 2, 1, 2, 5 with many other varunine members (Table 2).

Aikawa(1929, 1933) classified the second antennae of the zoeae into four main types and then further divided each type into several subtypes; for example, B1, B2,···B7 subtypes. From this point of view, almost all the varunine zoeae possess B2 or B3-type antennae. *A. parvula* zoeae have B3-type antennae at the first stage, but acquire B2-type antenna in the subsequent zoeal stages. Similar transformations of the second antennal types are shown in *Gaetice depressus*, *Eriocheir sinensis* and *Hemigrapsus sinensis* zoeae. (Kim and Lee, 1982, 1983; Kim and Moon, 1987).

On the other hand, larvae of *A. parvula* closely resemble those of *Gaetice depressus* previously described by Kim and Lee(1983). Above all, these two species lack lateral carapace spines in all zoeal stages, while in the subfamily Varuninae the other known species always acquire those. And also, *A. parvula* differs from *G. depressus* only in the setation of the maxillary coxal endite in the first zoeal stage (Table 2). In the subsequent stages, there are significant similarities in the setations of their appendages between two species: for examples, setation of the first maxillipedal endopodite (2, 2, 1, 2, 5 in the first two stages, 2, 2, 2, 2, 5 in the third stage and 2, 2, 2, 2, 6 in the last two zoeal stages) and the numbers of setae on telson inner margin (6, 6, 8, 8 and 10) and antennule (3, 5, 5, 6 and 10) in the first through fifth stages.

Table 2. Comparison of the first stage zoeae of 13 species of the subfamily Varuninae

	Acmaeopleura parvula (present study)	*Gaetice depressus* (Kim & Lee, 1983)	*Eriocheir japonicus* (Morita, 1974)	*E. sinensis* (Kim & Lee, unpubl.)	*Hemigrapsus sinensis* (Kim & Moon, 1987)	*H. penicillatus* (Kim, 1979)	*H. crenulatus* (Wear, 1970)	*H. edwardsi* (Wear, 1970)	*H. sanguineus* (Kurata, 1968b)	*H. nudus* (Hart, 1935)	*H. oregonensis* (Hart, 1935)	*H. longitarsis* (Aikawa, 1929)	*Euchirograpsus americanus* (Wilson, 1980)
Lateral carapace spines	—	—	+	+	+	+	+	+	+	+	+	+	+
Antennal type	B	B	B	B	B	B	B	B	B	B	B	B	C
Telson type	B	B	B(A)	B	B	B	B	B	B	B	B	B	A
Abd. segments with lateral processes	2-3	2-3	2-4	2-4	2-4	2-3	2	2	2-3	2-3	2	2-3	2-5
Antennule; aesthetascs +setae	2+2 or 2+1	2+1 (2+2)	2+1	2+1	4+1	2+2	2+1	2+1	(4)	2+1	—	2+1	3+1
Maxillule													
Endopodite	1,5	1.5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	—	1,5	1,5
Basal endite	5	5	4	5	5	5	5	6	(5)	6	—	5	5
Coxal endite	5	5	4	5	5	5	4	4	(5)	5	—	5	5 or 6
Maxilla													
Endopodite	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	—	4	2,3
Basal endite	4,5	4,5	3,3	4,5	4,5	5,4	3,3	4,4	(9)	7	—	8	4,5
Coxal endte	3,4	3,3	3,1	2,4	3,4	2,4	2,4	2,4	(6)	6	—	6	3,5
Scaphognathite	4	4	3	4	4	4	3	5	(4)	4	—	4	3 or 4
1st maxilliped													
Basipodite	2·2·3·3	2·2·3·3	(2·1·3·3)	2·2·3·3	2·2·3·3	(2·2·3·3)	3·3·3·3	—	(2·2·3·3)	2·1·3·3	—	2·2·3·3	2·2·2·2
Endopodite	2·2·1·2·5	2·2·1·2·5	1·1·1·2·5	1·1·1·2·4	2·2·1·2·5	2·2·1·2·5	1·1·1·2·5	2·2·2·2·6	3·2·1·2·5	2·2·1·2·5	—	2·2·1·2·5	2·2·1·2·5
2nd maxilliped													
Endopodite	0·1·6	0·1·6	0·1·5	0·1·6	0·1·6	0·1·5	1·1·6	1·1·6	0·1·6	0·1·5	—	—	1·1·6
Zoeal stages	5 or 6	5	5	5	5	5	—	—	5	5	5	—	5 or 6

( ) : data from Aikawa (1929).

In spite of very close resemblance of the present larvae to that of *G. depressus*, identification of them in the plankton may not be impossible. *A. parvula* larvae has a small tubercle on the anterior and the posterior region to dorsal spine throughout all zoeal stages, but *G. depressus* larvae do not have. In the first zoeal stage only, the dorsal spine of *A. parvula* is much more posteriorly curved than that of *G. depressus*.

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애기비단게(*Acmaeopleura parvula* Stimpson)의 幼生發生

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애기비단게(*Acmaeopleura parvula* Stimpson)의 幼生을 孵化에서부터 제1蟹期까지 12가지의 溫度一鹽度條件에서 飼育하고 各 幼生期의 形態的 特徵을 記述·圖示하였다.

이 種은 5期(가끔 6期가 出現함)의 zoea와 1期의 megalopa 幼生을 거쳐 제1蟹期로 變態하였다. 제1蟹期까지의 發生期間은 25°C에서 22-23日, 20°C에서 34-37日, 15°C에서는 50-51日이 所要되었으며, 間期인 6期 zoea는 15°C에서만 出現하였다.

애기비단게의 幼生은 全 zoea期에 걸쳐 甲殼의 側棘을 缺如하고 있는 點에서 참게亞科내의 다른 種의 幼生들과 區分될 수 있었으며, 남작게 幼生과는 形態的으로 매우 密接한 類緣關係를 보여주었다. 그 밖의 附屬肢의 特徵들이 같은 亞科내에 報告된 12種의 幼生들과 比較되었다.