

# Larval development of *Galathea inflata* Potts, 1915 (Decapoda: Anomura: Galatheidae) described from laboratory-reared material

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**Abstract.**—The complete larval development of *Galathea inflata* Potts, 1915, a symbiont of comatulid crinoids, is described and illustrated from laboratory-reared material. The zoeas of *G. inflata* are easily distinguished from those of *G. rostrata* and *G. intermedia* by an abdomen, including a telson, that is covered with very minute spines in all zoeal stages, a rostrum that bears lateral teeth in the second to fifth zoeal stages, and by the setations of the maxillule and first and second maxillipeds. This species had five zoeal stages and one megalopal stage. However, the fifth zoeal stage may be abnormal because it possesses a mixture of zoeal and megalopal characters. It is suggested that the fourth stage zoeas possibly molt directly to the megalopa under favorable conditions.

## Introduction

*Galathea inflata* Potts, 1915 is a small galatheid crab that lives symbiotically with comatulid crinoids. It has been recorded from the Torres Strait, Moluccas, Ryukyu Islands and Hachijo Island, Japan (Potts, 1915; Baba, 1979; Fujita & Baba, 1999; Kato & Okuno, 2001). Fujita & Baba (1999) recently reported that the megalopa larvae of *G. inflata* settled on their host crinoids. However, the complete larval development of the species remained unknown.

Studies of *Galathea* larvae have been mostly on Atlantic species: *G. dispersa* Bate, 1859 (Lebour, 1930; Webb, 1921; Bourdillon-Casanova, 1960; Pike &

Williamson, 1972; Martin, 2000), *G. intermedia* Lilljeborg, 1851 (Sars, 1889; Webb, 1921; Lebour, 1931; Bourdillon-Casanova, 1960; Pike & Williamson, 1972; Christiansen & Anger, 1990; Martin, 2000, as *G. intermedia intermedia*), *G. nexa* Embleton, 1834 (Sars, 1889; Bourdillon-Casanova, 1960; Pike & Williamson, 1972), *G. rostrata* (A. Milne Edwards, 1880) (Gore, 1979), *G. strigosa* (Linnaeus, 1767) (Webb, 1921; Lebour, 1930; Bourdillon-Casanova, 1960; Pike & Williamson, 1972; Martin, 2000), and *G. squamifera* Leach, 1814 (Sars, 1889; Webb, 1921; Lebour, 1930; 1931; Bourdillon-Casanova, 1960; Pike & Williamson, 1972; Martin, 2000). Of these, the complete larval development was described for *G. rostrata* and *G. intermedia*, based on laboratory-reared materials (Gore, 1979; Christiansen & Anger, 1990). With regard to the Indo-West Pacific species, Gurney (1938) and Al-Kholy (1959) described the larvae of *G. longimana* Paulson, 1878 and *Galathea* sp., respectively, from the Red Sea. Gurney (1942: fig. 103, H) also illustrated a *Galathea* sp. from Melbourne Harbour, Australia, suggesting that it probably belonged to a genus other than *Galathea* and *Munida*.

This paper provides a description of the complete larval development of *G. inflata* and the zoeal characters of the species are compared with the two known Atlantic species, *G. rostrata* and *G. intermedia*. The variability in number of larval stages of the *Galathea* species is also discussed.

### Materials and Methods

Two ovigerous specimens of *G. inflata* were collected from the host crinoid, *Comaster schlegelii* (Carpenter), at Mizugama coast of Okinawa, Ryukyu Islands, on 26 August 2000. The animals were transported to the Marine Science Laboratory of the University of the Ryukyus and kept in a 1.4-liter plastic aquarium until the zoeas hatched. The hatched zoeas were mainly mass-cultured in circular plastic tanks (30 cm in diameter) containing 8-liter of filtered, UV treated seawater. However, in order to recognize the normal number of their larval stages, ten fourth-stage zoeas were cultured individually in 50 ml glass beakers. These rearing experiments were conducted in water that had not been in contact with crinoids. The salinity and water temperatures of the sea water were 34.5–35.0‰ and 25.5–27.0°C, respectively. Newly hatched nauplii of *Artemia* enriched by "SUPER ARTEMIA" (Higashimaru Co., Ltd) were fed to the larvae.

Larvae were fixed and preserved in 50% ethylene glycol. Six specimens of each stage were examined. The appendages were dissected with fine entomological needles and mounted, using strands of human hair between glass slide and cover slip to prevent crushing. Drawings and measurements were made with a drawing tube attached to a NIKON OPTIPHOT-2 microscope. Body somites are described from anterior to posterior, appendages from endopod to exopod, and their segments and setae from proximal to distal. Long plumose setae are drawn truncated. Setal terminology generally follows that of Ingle (1992) and Gore (1979). Carapace length (CL) was measured from the tip of the rostrum to the posterior midpoint of the carapace; total length (TL) from the rostral tip to the posterior end of the telson, excluding telsonal processes. The postorbital carapace length (PCL) was

also measured in megalopas.

Larvae and spent females are deposited in the National Science Museum, Tokyo, Japan under the catalogue numbers NSMT-Cr 14231–14235 for zoeas 1–5, NSMT-Cr 14236 for megalopas, and NSMT-Cr 14237 for spent females. The dissected larvae were not preserved.

### Results

*Galathea inflata* passed through five zoeal stages and one megalopal stage before attaining the first juvenile stage. The megalopal larvae appeared in 13–17 days after hatching, and the first juvenile stages in 25–28 days. Minimum durations of the first to fifth zoeal stages were 2, 2, 3, 3, 3 days, respectively.

Five of the 10 fourth stage zoeas that were reared solitarily molted to the fifth zoeal stage. The remaining five died, three of which, however, were molting to the megalopa, and the other two of which stayed in the fifth stage.

#### *Galathea inflata* Potts, 1915

Figs. 1–12

##### First zoea

Size: CL 0.98–1.18 mm (mean 1.09 mm), TL 2.30–2.48 mm (mean 2.42 mm).

Carapace (Fig. 1A, B, F): Carapace of typical galatheid larval form, posteriorly produced into acute spine on each side; anterodorsal carapace setae absent; posterodorsal and posteroventral margins of carapace with 12–15 and 17–21 small teeth, respectively; rostrum elongated and spine-like, without lateral teeth, extending as far forward to level of tip of antennal scaphocerite; eyes sessile.

Antennule (Fig. 2A): Uniramous, elongated and rod-like, terminally with 3 aesthetascs plus 2 simple setae and 1 plumose seta, subterminally with 1 long plumose seta.

Antenna (Fig. 2B): Biramous. Protopod with 1 serrated spine at

distoventral end, equally long as endopod; endopod fused to protopod, with a long plumose seta terminally; scaphocerite (exopod) ending in long and robust process at distolateral margin, mesial margin with 10 plumose setae, ventral surface with minute denticles.

Mandible (Fig. 2C): Left and right mandibles asymmetrically dentate, incisor processes each with some strong and a few very small teeth, molar processes strongly serrate or spinose; palp absent.

Maxillule (Fig. 2D): Coxal endite with 7 plumodenticulate setae; basal endite with 2 cuspidate and 3 plumodenticulate setae; endopod 2-segmented, proximal segment with 1 small seta at distomesial margin, distal segment with 5 setae (1 subterminal and 4 terminal).

Maxilla (Fig. 2E): Coxal endite bilobed, with 8+4 plumodenticulate setae, basal endite bilobed with 5+4 plumodenticulate setae; endopod unsegmented, bilobed, with 3+6 (2+4) simple/plumodenticulate setae; scaphognathite (exopod) with 4 marginal plumose setae, posteriorly ending in elongate plumose process.

First maxilliped (Fig. 2F): Coxa with 2 distal setae; basis with 12 setae (3+3+3+3) on ventral margin; endopod 5-segmented, with 3, 2, 1, 2, 5 (1 subterminal + 4 terminal); setae; exopod 2-segmented, distally bearing 4 long plumose natatory setae.

Second maxilliped (Fig. 2G): Coxa without setae; basis with 3 setae on distoventral margin; endopod 4-segmented, with 2, 2, 2, 5 (1 subterminal + 4 terminal) setae; exopod as in first maxilliped.

Third maxilliped (Fig. 2H): Usually uniramous small bud, but often small endopodal bud present.

Pereopods: Not observed.

Abdomen (Fig. 1A, B, C): Five-segmented, each segment covered with numerous very small spines; posterodorsal margins of segments 2–5 with distinct

teeth, bearing a pair of short plumose setae; segments 4 and 5 with a pair of posterolateral spines; pleopods absent.

Telson (Fig. 1C, D): Trigonal in dorsal view, slightly concave on posteromesial margin; dorsal surface covered with numerous very small spines; posterior margin with 7+7 processes (telsonal formula; I+ii+3–7), lateralmost unarticulated spine, second short plumose seta (= anomuran hair), third to seventh articulated, long and stout plumose processes with very small spinules (Fig. 1E).

Color: Carapace, abdomen including telson and appendages essentially transparent; median gastric region and anterolateral gastric region behind and lateral to eyes bright orange; red chromatophores present on mandibles, basis and endopod of first and second maxillipeds.

#### Second zoea

Size: CL 1.19–1.38 mm (mean 1.31 mm), TL 2.87–3.07 mm (mean 2.99 mm).

Carapace (Fig. 3A, B, D): Three pairs of antero-dorsal carapace setae. Rostrum broad, with 17–22 lateral teeth; posterodorsal and posteroventral margins of carapace with 6–14 teeth (sometimes naked) and 13–24 teeth (usually more than 20), respectively; eyes now stalked.

Antennule (Fig. 4A): Biramous. Protopod with 4 short plumose setae at distal one-fourth and 3–5 (usually 4) aesthetascs plus 4 setae terminally; endopodal bud developed, bearing 1 long plumose terminal seta.

Antenna (Fig. 4B): One serrated spine appeared at ventrodorsal end of protopod; endopodal plumose seta now disappeared; scaphocerite with 10–11 (usually 10) marginal plumose setae, distolateral spine somewhat reduced.

Mandible (Fig. 4C): Unchanged.

Maxillule (Fig. 4D): Basal endite with 4 cuspidate and 3 plumodenticulate setae; otherwise unchanged.

Maxilla (Fig. 4E): Basal endite now with 5+6 setae; scaphognathite with 6

plumose marginal setae, posterior plumose process slightly reduced; otherwise unchanged.

First maxilliped (Fig. 4F): Exopod with 7 natatory setae, otherwise unchanged.

Second maxilliped (Fig. 4G): Exopod with 7 natatory setae, otherwise unchanged.

Third maxilliped (Fig. 4H): Biramous; endopod naked or with 1 or 2 terminal setae; exopod developed, with 6 natatory setae.

Pereopods (Fig. 4I): Uniramous buds appeared.

Abdomen (Fig. 3A, B): Unchanged.

Telson (Fig. 3C): Posterior margin with 8+8 processes (telsonal formula; I+ii+3-8); 1 pair of small setae present at posterodorsal surface; otherwise unchanged.

Color: Similar to first zoea, but tip of rostrum and posterodorsal regions of carapace (including posterior spines) pale orange.

#### Third zoea

Size: CL 1.49–1.58 mm (mean 1.52 mm), TL 3.50–3.80 mm (mean 3.62 mm).

Carapace (Fig. 5A, B): Rostrum now with 18–23 lateral teeth; posterodorsal and posteroventral margins of carapace now with 0–11 and 13–21 small teeth, respectively; otherwise unchanged.

Antennule (Fig. 6A): Protopod with 1 plumose seta at proximal part, 1 plumose seta about at midlength of lateral margin, 4 plumose setae at junction with exopod, and 1 long plumose seta directly proximal to endopod; endopod slightly more elongate, terminating in long plumose seta; exopod now articulated, bearing 1–3 rows of marginal aesthetascs numbering 1–2 (if present), 1–3 (if present), 2 from proximal to distal, distal end with 3–5 aesthetascs and 3–4 setae.

Antenna (Fig. 6B): Endopod well developed, bearing 1 subterminal plumose seta; scaphocerite with 12–13 (usually 12)

plumose setae, distolateral spine more reduced than in previous stages; otherwise unchanged.

Mandible (Fig. 6C): Small, unsegmented bud of palp present.

Maxillule (Fig. 6D): Coxal endite with 8 simple/plumodenticulate setae; basal endite with 5 cuspidate and 3 plumodenticulate setae; otherwise unchanged.

Maxilla (Fig. 6E): Basal endite with 6+7 setae; scaphognathite with 10–11 marginal plumose setae, posteriorly ending in plumose process; otherwise unchanged.

First maxilliped (Fig. 6F): Unchanged.

Second maxilliped (Fig. 6G): Unchanged.

Third maxilliped (Fig. 6H): Endopod developed, with 0–2 terminal setae; exopod with 7 natatory setae.

Pereopods (Fig. 6I): More developed than in previous stage, first pereopod bifid.

Abdomen (Fig. 5A–C): Six-segmented; segment 6 longest; posterodorsal teeth now reduced or absent on segments 1–3; pleopods still not differentiated; biramous uropods newly appeared, endopods small, naked, exopods well developed, with 10–11 marginal plumose setae.

Telson (Fig. 5C): Posterior processes still 8+8, but fourth pair of processes elongate robust spines fused to telson (telsonal formula I+ii+3+IV+5-8); 2 pair of small setae present on posterodorsal surface.

Color: Almost as in previous stage.

#### Fourth zoea

Size: CL 1.50–1.80 mm (mean 1.71 mm), TL 3.50–4.25 mm (mean 4.05 mm).

Carapace (Fig. 7A, B): Rostrum with 19–23 lateral teeth; posterodorsal margin of carapace with 0–8 small teeth, posteroventral margin with 10–18 small teeth; otherwise unchanged.

Antennule (Fig. 8A): Protopod swollen

basally, with 2 plumose setae at proximal part, 2 lateral plumose seta on middle part, 1 long plumose seta directly proximal to endopod, and 4 dorsodistal plumose seta at junction of exopod; endopod more developed than in previous stage, terminal plumose seta now disappeared; exopod with 4 rows of marginal aesthetascs numbering 3–6 on proximal first row, 3–4 on second, 2–3 on third, 2 on distal row, distal end with 3–4 aesthetascs plus 3–4 setae.

Antenna (Fig. 8B): Endopod well developed, extending to tip of scaphocerite lateral spine; scaphocerite with 13–14 (usually 13) marginal plumose setae; otherwise unchanged.

Mandible (Fig. 8C): Palp more developed than in third zoea.

Maxillule (Fig. 8D): Coxal endite with 9–10 plumodenticulate setae; basal endite with 7 cuspidate and 3 plumodenticulate setae; otherwise unchanged.

Maxilla (Fig. 8E): Coxal endite with 11–13+4–6 setae; basal endite with 8–9+9–10 setae; scaphognathite with 18–20 plumose setae on lateral margin, 1–2 plumose setae on mesial margin, and 1 posterior plumose process; otherwise unchanged.

First maxilliped (Fig. 8F): Exopod with 7 or 8 natatory setae; otherwise unchanged.

Second maxilliped (Fig. 8G): Exopod with 7 or 8 natatory setae; otherwise unchanged.

Third maxilliped (Fig. 8H): Endopod well developed and incompletely 2-segmented, bearing 2–6 setae; exopod with 7 or 8 natatory setae.

Pereopods (Fig. 8I): More developed than in previous stage, fifth pereopod bifid.

Abdomen (Fig. 7A–D): Biramous pleopods on segments 2–5; endopod of uropod with 6–8 marginal plumose setae, exopod with lateral spine and 11–14 marginal

plumose setae; otherwise unchanged.

Telson (Fig. 7C): Telsonal formula I+ii+3+IV+5–8; 3 pairs of small setae present on dorsal surface; otherwise unchanged.

Color: Similar to third zoea.

#### Fifth zoea

The characters of appendages in this stage may be unusual (see Discussion). Some appendages have megalopa-like features, and setal arrangements are also highly variable. However, these appendages are described below as the first case of abnormality in galatheid larvae.

Size: CL 1.95–2.15 mm (mean 2.04 mm), TL 4.35–4.80 mm (mean 4.65 mm).

Carapace (Fig. 9A, B): A pair of extra lateral setae appeared on middle part of rostrum; rostrum with 16–22 lateral teeth; posterodorsal and posteroventral margins of carapace with 1–9 and 8–20 small teeth, respectively.

Antennule (Fig. 10A): Peduncle incompletely 3-segmented, sparsely setose; endopod with 1 proximal and 2 terminal setae; exopod with 4 rows of lateral aesthetascs numbering 6–9, 3–5, 3, 2–4 from proximal to distal, distal end with 3–5 aesthetascs and 4–5 setae.

Antenna (Fig. 10B): Endopod well developed, flagellum-like, with sparse setae; scaphocerite with 14–15 marginal plumose setae.

Mandible (Fig. 10C): Palp developed, incompletely 3-segmented; distal segment with terminal seta.

Maxillule (Fig. 10D): Coxal endite with 14–18 simple/plumodenticulate setae; basal endite with 10–12 cuspidate and 6 plumodenticulate setae; otherwise unchanged.

Maxilla (Fig. 10E): Coxal endite with 20–29+6–8 setae; basal endite with 10–13+12–17 setae; scaphognathite with 21–29 plumose setae on lateral margin, 2–4 plumose setae on mesial margin, and 1 posterior plumose process; otherwise un-

changed.

First maxilliped (Fig. 10F): Coxa with 3–4 setae; basis with 14–19 setae on ventral margin; otherwise unchanged.

Second maxilliped (Fig. 10G): Coxa and basis unchanged; third and fourth segments of endopod with 2–5, 4–8 (including dorsal seta) setae, respectively; exopod with 7–9 natatory setae.

Third maxilliped (Fig. 10H): Endopod much like that of megalopa (see below), 5-segmented; proximal segment with 3–7 crista dentata and 1 distal seta; second segment with 0–3 setae; third, fourth and fifth segments with 2–6, 6–15, 14–21 setae (including stout serrate setae), respectively; exopod with 8 natatory setae.

Pereopods (Fig. 10I): Well developed and completely segmented (occasionally incompletely segmented), sparsely setose.

Abdomen (Fig. 9A, B): Similar to that of fourth zoea, but 1 pair of extra setae on anterior part of segments 2–6; pleopods well developed (Fig. 9D), setal formulae of exopods progressing posteriorly with 5–10, 6–10, 6–10, 6–9; endopod naked or with 1–3 small hooks; uropod having endopod with 9–12 marginal plumose setae, exopod with 14–16 marginal plumose setae.

Telson (Fig. 9C): Telsonal formula still I+ii+3+IV+5–8; otherwise unchanged.

Color: Body transparent brown overall; no other distinct change from previous stage.

#### Megalopa (Decapodid)

Size: PCL 0.95–1.16 mm (mean 1.06 mm), CL 1.62–1.95 mm (mean 1.83 mm), TL 3.35–3.85 mm (mean 3.61 mm).

Carapace (Fig. 11A, B): Carapace longer than broad, numerous setae scattered on dorsal surface as illustrated, 6 small spines along lateral margins; rostrum triangular, with 4 lateral spines.

Antennule (Fig. 12A): Biramous, peduncle 3-segmented; endopod 2-segmented, proximal segment with 2–3 se-

tae, distal segment with 4–5 subterminal and 4 terminal setae; exopod 4-segmented, proximal segment naked, second to fourth segments with 6 rows of marginal aesthetascs arranged (7–9)+5, 3+3, (2–3)+1 (from proximal to distal), distal end with 3–7 setae.

Antenna (Fig. 12B): Peduncle 4-segmented (first segment not illustrated), flagellum with 21–25 articles, each with 0–5 setae distally, terminal segment with 4–6 subterminal and 2 long terminal setae.

Mandible (Fig. 12C, D): Subsymmetrically scoop-like process; palp 3-segmented, basal segment with 2 setae, distal part of third segment with 12–15 stout serrate setae.

Maxillule (Fig. 12E): Coxal endite with 22–27 plumodenticulate setae, lower part of coxal endite with 2 (rarely 3) long setae; basal endite with 16–21 cuspidate setae and 8–13 setae and 1 plumose seta directly proximal to endopod; endopod no longer segmented, with 1–6 setae.

Maxilla (Fig. 12F): Coxal and basal endites bilobed, setation highly variable, bearing 33–44+11–16 and 12–17+17–27 setae, respectively; endopod unsegmented, with 1–6 setae subterminally and 1 small seta proximally; scaphognathite with 36–49 plumose setae marginally.

First maxilliped (Fig. 12G): Coxal and basal endites with 12–17, 27–32 ventral marginal setae, respectively; endopod unsegmented, setal number varying from 0 to 9; exopod with 1–8 terminal setae, plus 1 plumose lateral setae.

Second maxilliped (Fig. 12H): Coxa with 2 setae; basis with 7–10 setae on ventral margin; endopod 4-segmented, with setation of 5–6, 3–5, 11–14, 11–14 (including stout serrate setae on distal 2 segments); exopod with 7–9 terminal plumose setae and with 2 plumose setae on middle part of exopod.

Third maxilliped (Fig. 12I): Coxa and

basis with 6–12 and 2–3 setae, respectively; endopod 5-segmented, ischium with 11–16 crista dentata and 3–9 setae; merus with 2 strong spines situated on flexor margin and 5–7 setae; carpus, propodus and dactyl with 11–20, 17–31, 20–34 setae (including stout serrate setae), respectively; exopod with 6–10 plumose setae.

Pereopods (Fig. 11A, B, D, E): All pereopods fully developed, similar and equal in size, sparsely setose; first pereopod long and slender, merus armed with 3–4 spines on mesial margin; second to fourth pereopods slender, propodus with 5 movable spines on flexor margin, dactyl with 4 movable and 2 immovable spines; fifth pereopod chelate, subcylindrical, palm with 3–4 long pectinate setae; no male/female gonopores.

Abdomen (Fig. 11A, B): Six segments, sparingly setose on dorsal surface; biramous pleopods present on segments 2–5 (Fig. 11F–I); exopods of pleopods well developed, bearing terminal plumose setae, setal formulae progressing posteriorly with 9–11, 10–12, 10–12, 10–12; endopods of pleopods increasing in length toward telson, with 3–4 small terminal hooks.

Tail Fan (Fig. 11C): Telson with 12 long plumose setae (6 pairs) on posterior margin and 1 large spine on each posterolateral margin, dorsal and ventral surface with short plumose setae; uropods biramous, endopod marginally with 13–18 plumose setae, dorsally with 1–3 simple setae and 1–3 spines, exopod marginally with 20–26 long plumose setae, 1–2 simple setae and 2–4 spines on posterodorsal surface.

Color: Specimens just after metamorphosed: carapace and abdomen generally transparent, scattered with orange or/and red chromatophores; telson transparent overall; appendages essentially transparent, but pereopods scattered with orange or red chromatophores; light-brown chromatophores present on antennule and an-

tennal peduncle; dark-brown chromatophores present on chela of first pereopod, and distal portion of ischium, carpus, merus and propodus of second to fourth pereopods.

Specimens in 8 days after metamorphosed: carapace and abdomen pale brown in ground color comprising red and light-brown chromatophores, bearing 2 broad stripes comprising yellow and white chromatophores on carapace extending on to abdomen; antennule scattered with yellow and brown chromatophores; first to fourth pereopods dark brown.

## Discussion

### *Larval morphology*

According to Konishi & Saito (2000), the descriptions of morphological characters of early larval studies are inexact. In this paper, the larval morphology of *G. inflata* was compared with those of *G. rostrata* and *G. intermedia* (see Gore, 1979; Christiansen & Anger, 1990), which are the only complete studies of larval development of the genus *Galathea* obtained from laboratory-reared material.

The zoeal morphology of *G. inflata* generally agrees with the diagnosis of the *Galathea* larvae proposed by Gore (1979). However, *G. inflata* are unique in that the rostrum bears lateral teeth in the second to fifth zoeal stages and that the abdomen, including telson, is covered with very minute spines in all zoeal stages. The appendages of the first to fourth zoeas of *G. inflata* resemble those of *G. rostrata* and *G. intermedia*, but the following differences are characteristic of *G. inflata*: (1) proximal segment of the maxillular endopod bears one short seta (without setae in *G. rostrata* and *G. intermedia*); (2) basis of the first maxilliped has setation of 3+3+3+3 (2+3+3+3 in *G. rostrata* and *G. intermedia*, but 3+3+3+3 in the fourth zoea of *G. rostrata*); (3) endopod of the second maxilliped has

no dorsal plumose setae except for the distal segment (second and/or third segments bearing dorsal plumose setae in the second to fifth zoeal stages of *G. rostrata* and *G. intermedia*); and (4) mandibular palp in the third zoea is a simple bud (not differentiated in *G. rostrata* and *G. intermedia*).

Fujita & Baba (1999) reported that the megalopa of *G. inflata* settled on their host crinoids and that its size (PCL) at that stage ranged between 0.96 and 1.20 mm. Our reared specimens were nearly the same (PCL = 0.95–1.16 mm).

The general morphology of the megalopa of *G. inflata* is very much like that of the adult, except for pleopods with natatory function and absence of gonopores. However, the following structures are not fully developed as in the adult: (1) the carapace lateral margin bears only five spines behind the anterior cervical groove (six in the adult); (2) the ischium of the third maxilliped has 11–16 denticles on the mesial ridge (more than 22 denticles in the adult); and (3) the merus of the third maxilliped possess only two flexor marginal spines (three flexor marginal and two extensor marginal spines in the adult). Just after metamorphosis from the fifth zoea stage, the megalopas were generally transparent with scattered red or orange chromatophores. Soon after (eight days) two yellow-white stripes appeared on the carapace and abdomen, a diagnostic character of the adult (Fujita & Baba, 1999). Thus, old megalopas can be recognized by their color pattern.

#### *Number of larval stages*

Laboratory-reared *Galathea inflata* had five zoeal stages and a megalopal stage before metamorphosing into the first juvenile. However, the fifth stage zoeas of *G. inflata* are unusual in that they have some megalopal characters: (1) endopod of antenna is very elongate and flagellum-like; (2) endopod of the third maxilliped is completely 5-segmented and

very setose; (3) pereopods are segmented (incompletely segmented in a few of the specimens examined); (4) pleopodal exopods bear marginal plumose setae and endopods have small terminal hooks. Moreover, the ventral setae on the basis of the first maxilliped, 14–18 in number, are irregularly arranged instead of being regularly arranged 3+3+3+3 in the first to fourth zoeal stages. None of these characters are present in the fifth stage zoeas of *G. rostrata* and *G. intermedia* (Gore, 1979; Christiansen & Anger, 1990).

Three to five zoeal stages are known in the genus *Galathea* (Lebour, 1930, 1931; Gurney, 1938; Al-Kholy, 1959). Lebour (1930) first documented that *G. dispersa* had four or five zoeal stages, although her study was based on plankton material. Gore (1979) reported two modes of development in *G. rostrata*. One includes a "regular" fourth stage which is followed by the molts to the fifth zoea and then a megalopa. The second includes an "advanced" fourth stage which has some of the features of the above fifth stage and which molts directly to megalopa. Christiansen & Anger (1990) also recorded that *G. intermedia* had four or five zoeal stages. According to Dr. Yasushi Fukuda, Kyushu Lutheran College, Kumamoto, *G. orientalis* Stimpson, 1858 has five zoeal stages (Fukuda, pers. comm.).

Variation in the number of larval stages has been reported in numerous decapod crustaceans. This variation is known to be influenced by environmental factors such as salinity, temperature, and food supply (Gore, 1985; Christiansen & Anger, 1990). The larvae of some decapods are also known to delay their metamorphosis when adequate cues (e.g. presence of conspecific adult, sediment, and shelter) are absent (Jensen, 1989; Gebauer *et al.*, 1998). Rearing experiments during the present study were conducted without host cues, so it may be one of the reasons why the abnormal fifth



zoeal stage of *G. inflata* appeared. On the other hand, the coconut crab *Birgus latro* (Linnaeus) is known to have four zoeal stages and sometimes an extra stage that possesses a mixture of zoeal and megalopal characters (Rees & Kinzie, 1968), as in the case of *G. inflata*. Therefore, it is assumed that the fourth zoea of *G. inflata* may proceed directly to the megalopa under favorable conditions. In order to determine the normal larval stages of *G. inflata*, more extensive experiments incorporating host cues and other environmental factors would be valuable.

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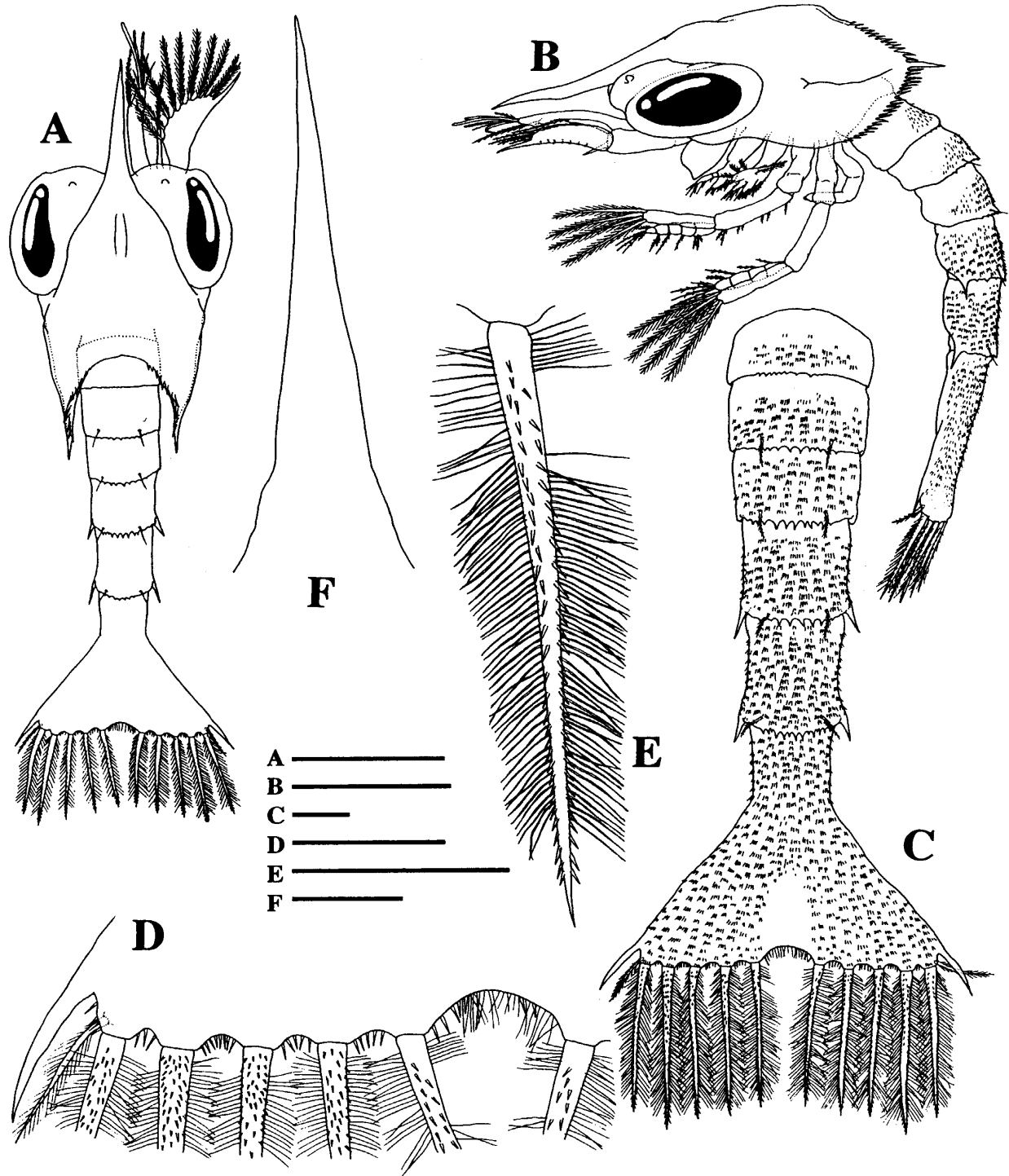


Fig. 1. *Galathea inflata* Potts, first zoea: A, carapace, abdomen and telson, dorsal view, very small spines on abdomen and telson omitted; B, entire animal, lateral view; C, abdomen and telson; D, posterior margin of telson; E, lateralmost plumose process of telson; F, rostrum. Scales A and B = 0.5 mm; scales C-F = 0.1 mm.

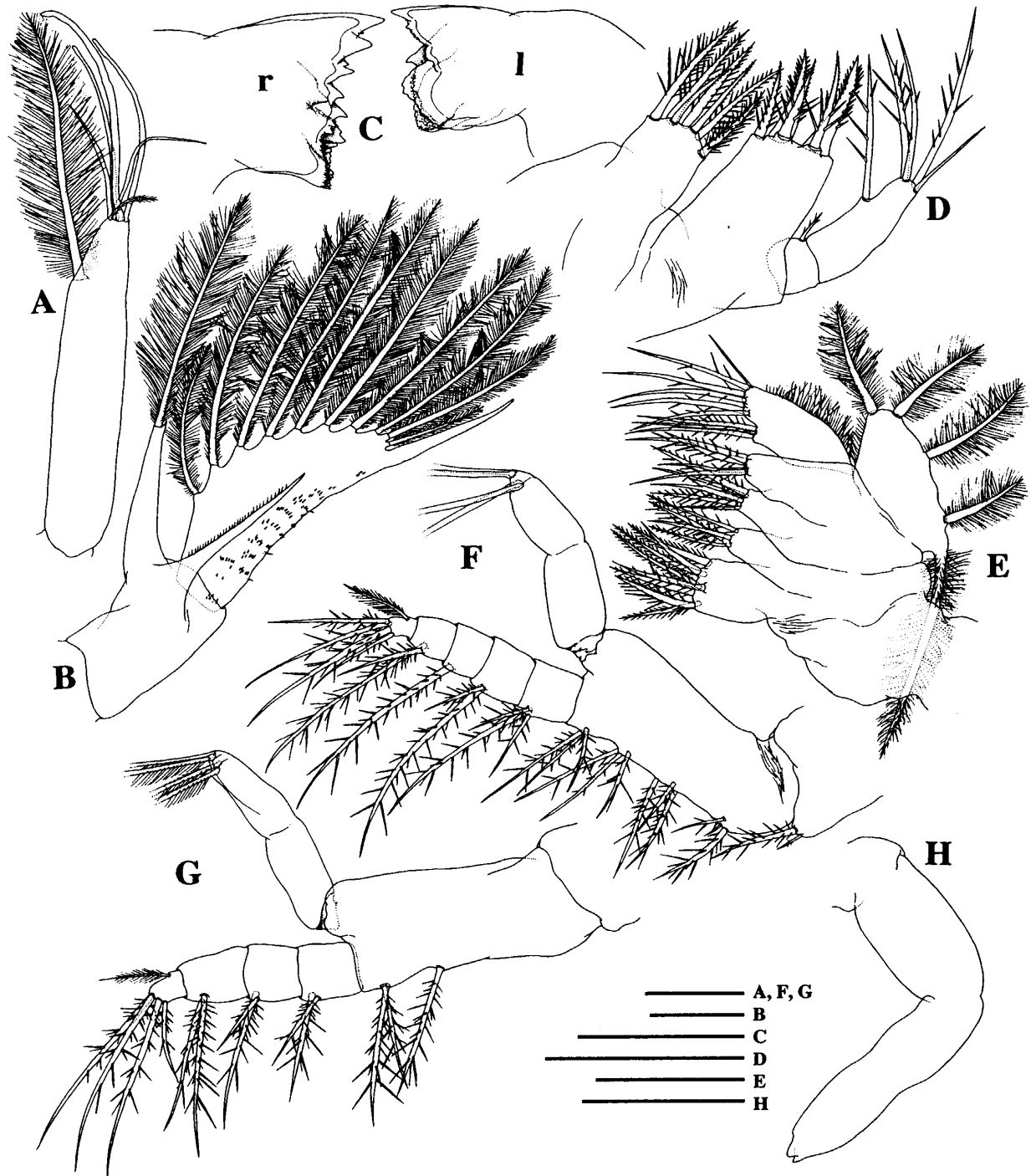


Fig. 2. *Galathea inflata* Potts, first zoea. A, antennule; B, antenna; C, mandibles (r, right; l, left); D, maxillule; E, maxilla; F, first maxilliped; G, second maxilliped; H, third maxilliped. Scales = 0.1 mm.

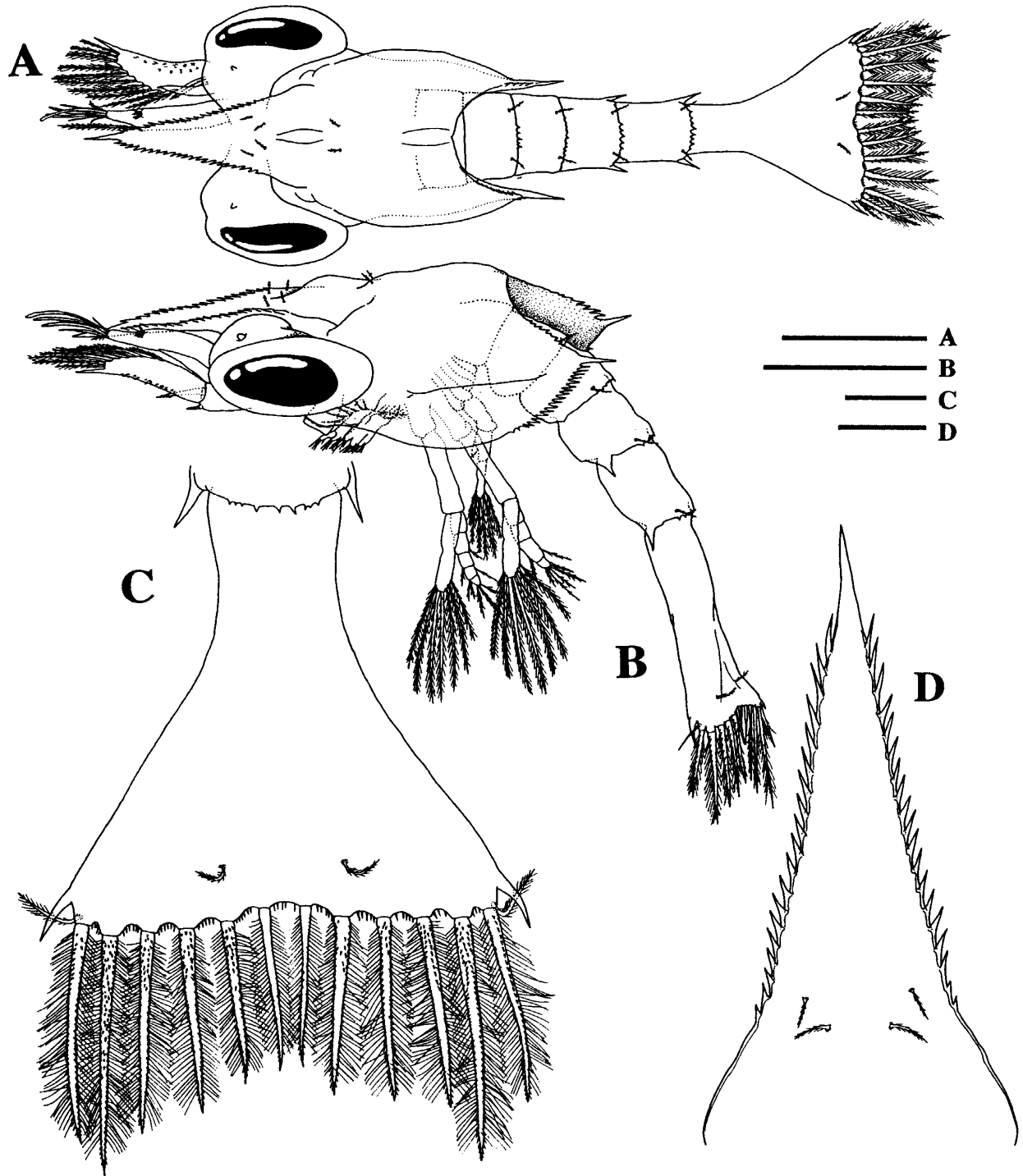


Fig. 3. *Galathea inflata* Potts, second zoea. A, carapace, abdomen and telson, dorsal view, very small spines on abdomen and telson omitted; B, entire animal, lateral view, very small spines on abdomen and telson omitted; C, telson, very small spines omitted; D, rostrum. Scales A and B = 0.5 mm; scales C and D = 0.1 mm.



Fig. 4. *Galathea inflata* Potts, second zoea. A, antennule; B, antenna; C, mandibles (r, right; l, left); D, maxillule; E, maxilla; F, first maxilliped; G, second maxilliped; H, third maxilliped; I, pereopods. Scales = 0.1 mm.

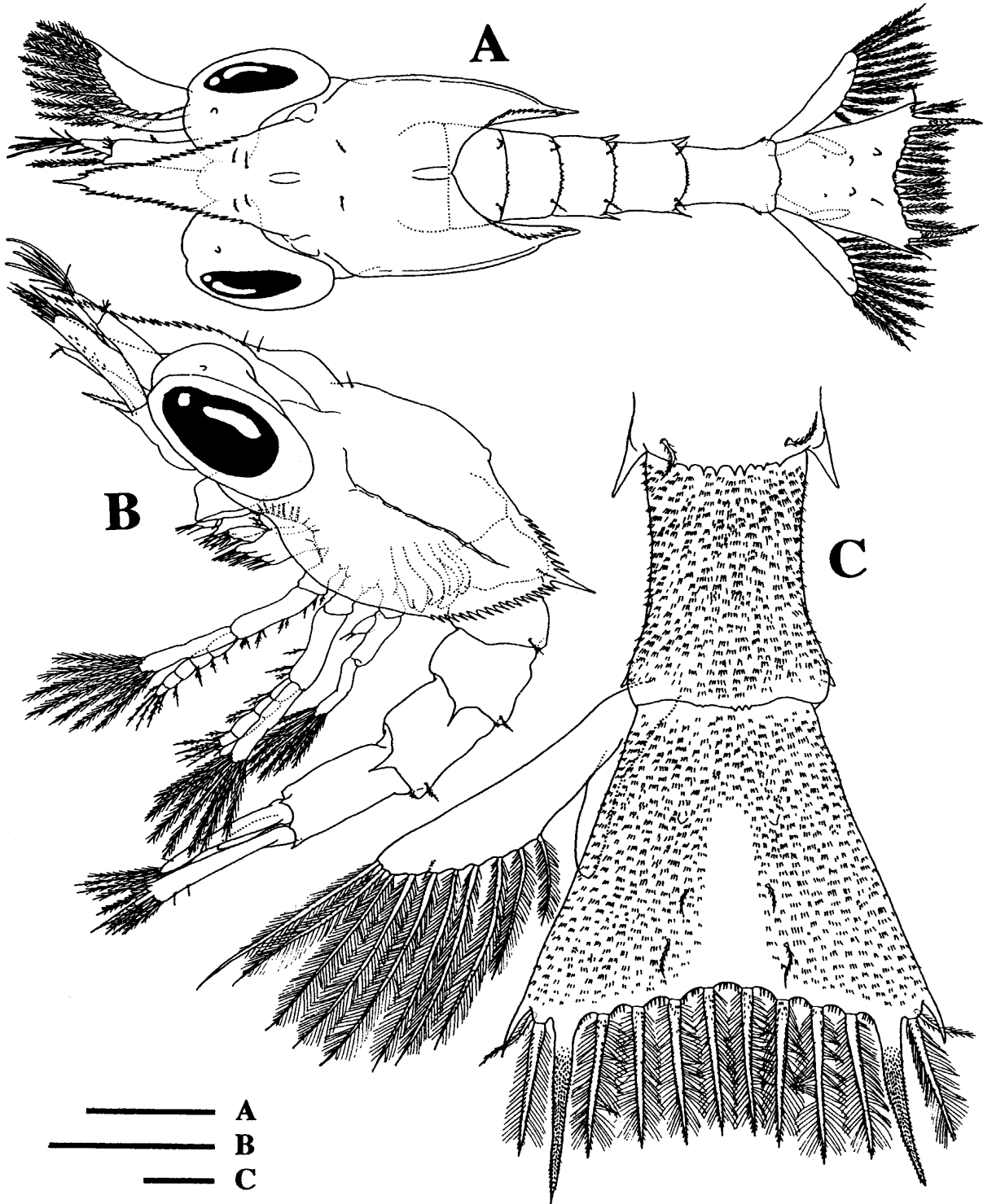


Fig. 5. *Galathea inflata* Potts, third zoea. A, carapace, abdomen and telson, dorsal view, very small spines on abdomen and telson omitted; B, entire animal, lateral view, very small spines on abdomen and telson omitted; C, sixth segment of abdomen, telson and left uropod. Scales A and B = 0.5 mm; scale C = 0.1 mm.

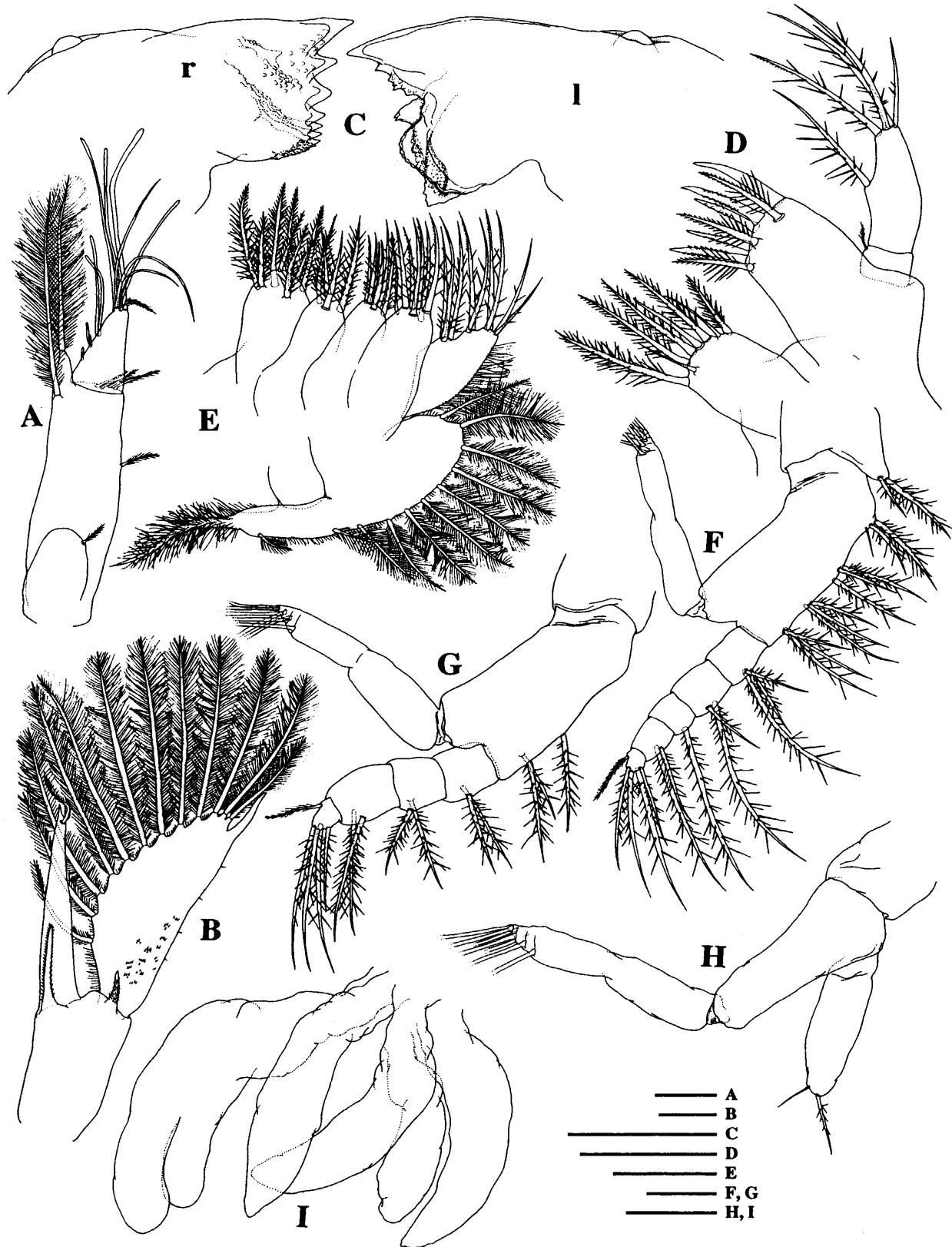


Fig. 6. *Galathea inflata* Potts, third zoea. A, antennule; B, antenna; C, mandibles (r, right; l, left); D, maxillule; E, maxilla; F, first maxilliped; G, second maxilliped; H, third maxilliped; I, pereopods. Scales = 0.1 mm.



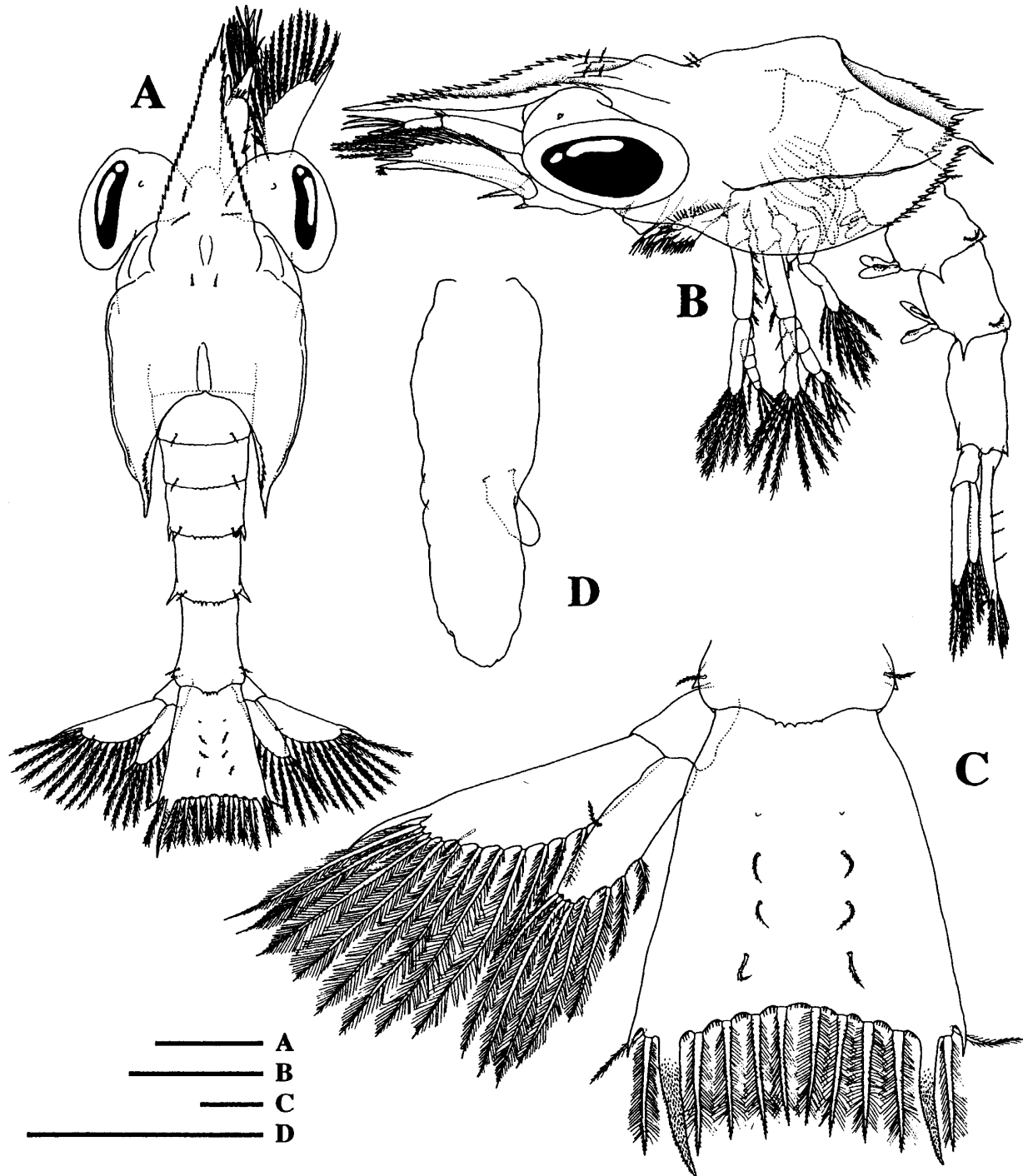


Fig. 7. *Galathea inflata* Potts, fourth zoea. A, carapace, abdomen and telson, dorsal view, very small spines on abdomen and telson omitted; B, entire animal, lateral view, very small spines on abdomen and telson omitted; C, telson and left uropod, very small spines on telson omitted; D, first pleopod. Scales A and B = 0.5 mm; scales C and D = 0.1 mm.

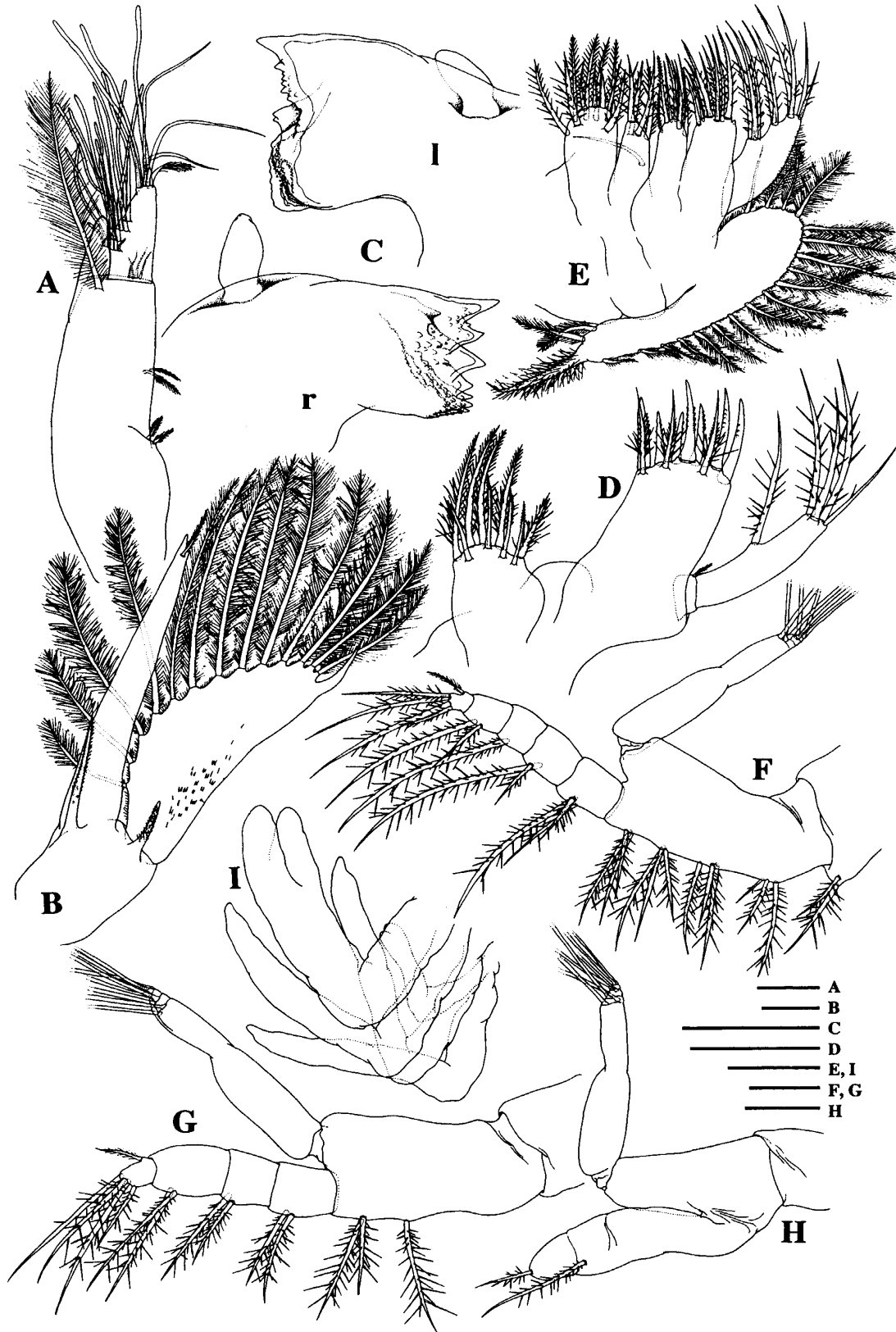


Fig. 8. *Galathea inflata* Potts, fourth zoea. A, antennule; B, antenna; C, mandibles (r, right; l, left); D, maxillule; E, maxilla; F, first maxilliped; G, second maxilliped; H, third maxilliped; I, pereopods. Scales = 0.1 mm.

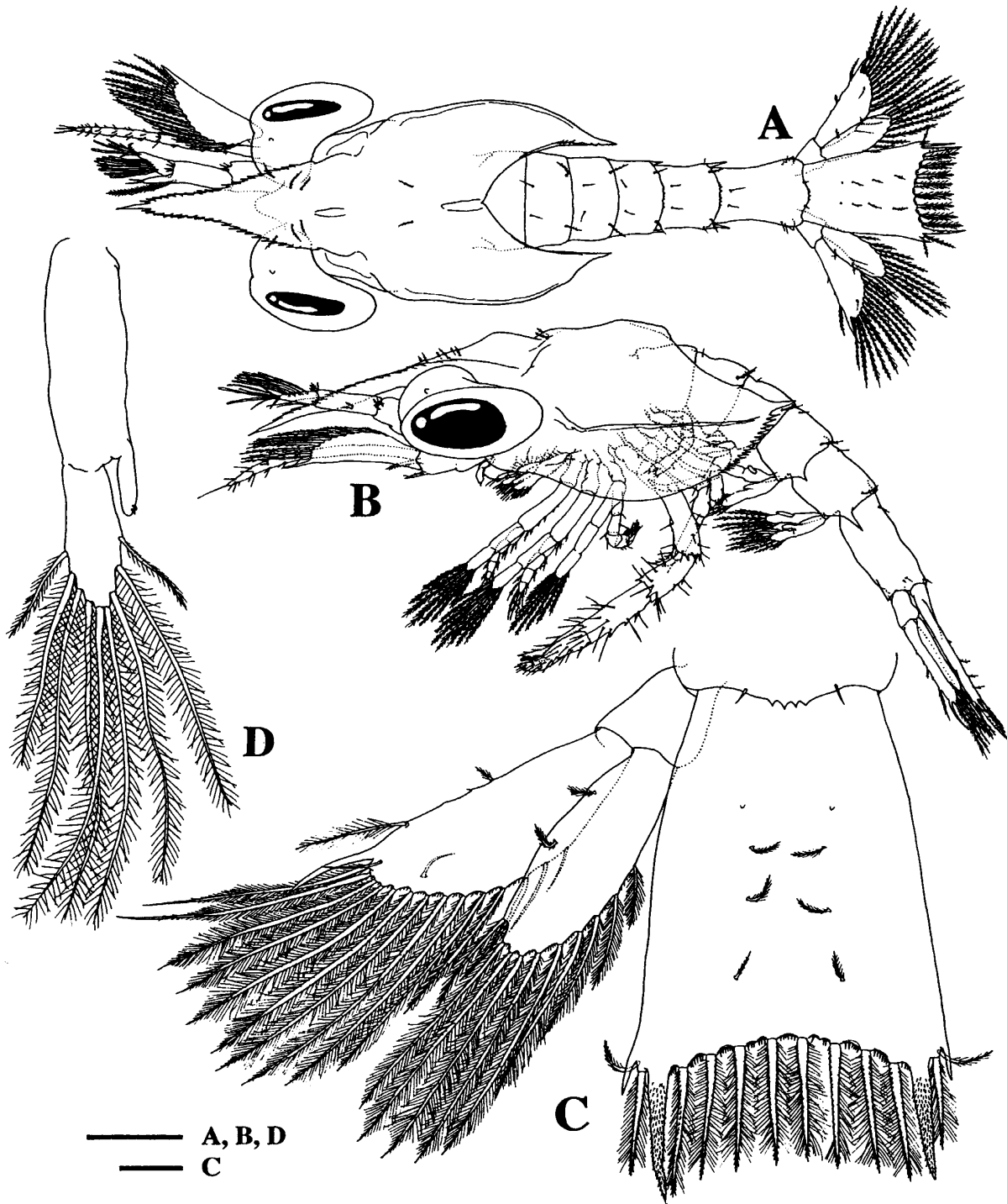


Fig. 9. *Galathea inflata* Potts, fifth zoea. A, carapace, abdomen and telson, dorsal view, spinules on abdomen and telson omitted; B, entire animal, lateral view, spinules on abdomen and telson omitted; C, telson and left uropod, very small spines on telson omitted; D, first pleopod. Scales A and B = 0.5 mm; scales C and D = 0.1 mm.

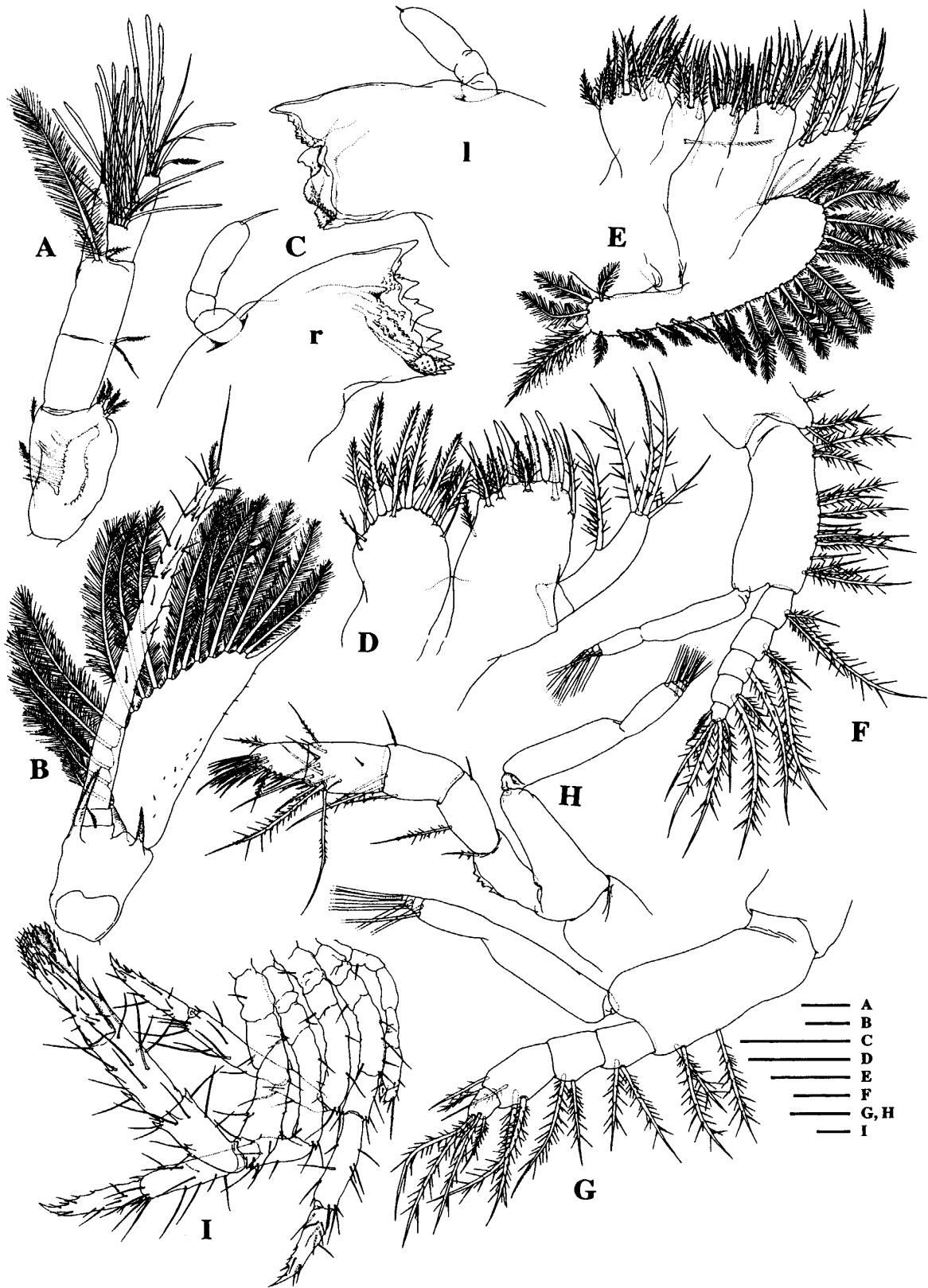


Fig. 10. *Galathea inflata* Potts, fifth zoea. A, antennule; B, antenna; C, mandibles (r, right; l, left); D, maxillule; E, maxilla; F, first maxilliped; G, second maxilliped; H, third maxilliped; I, pereopods. Scales = 0.1 mm.

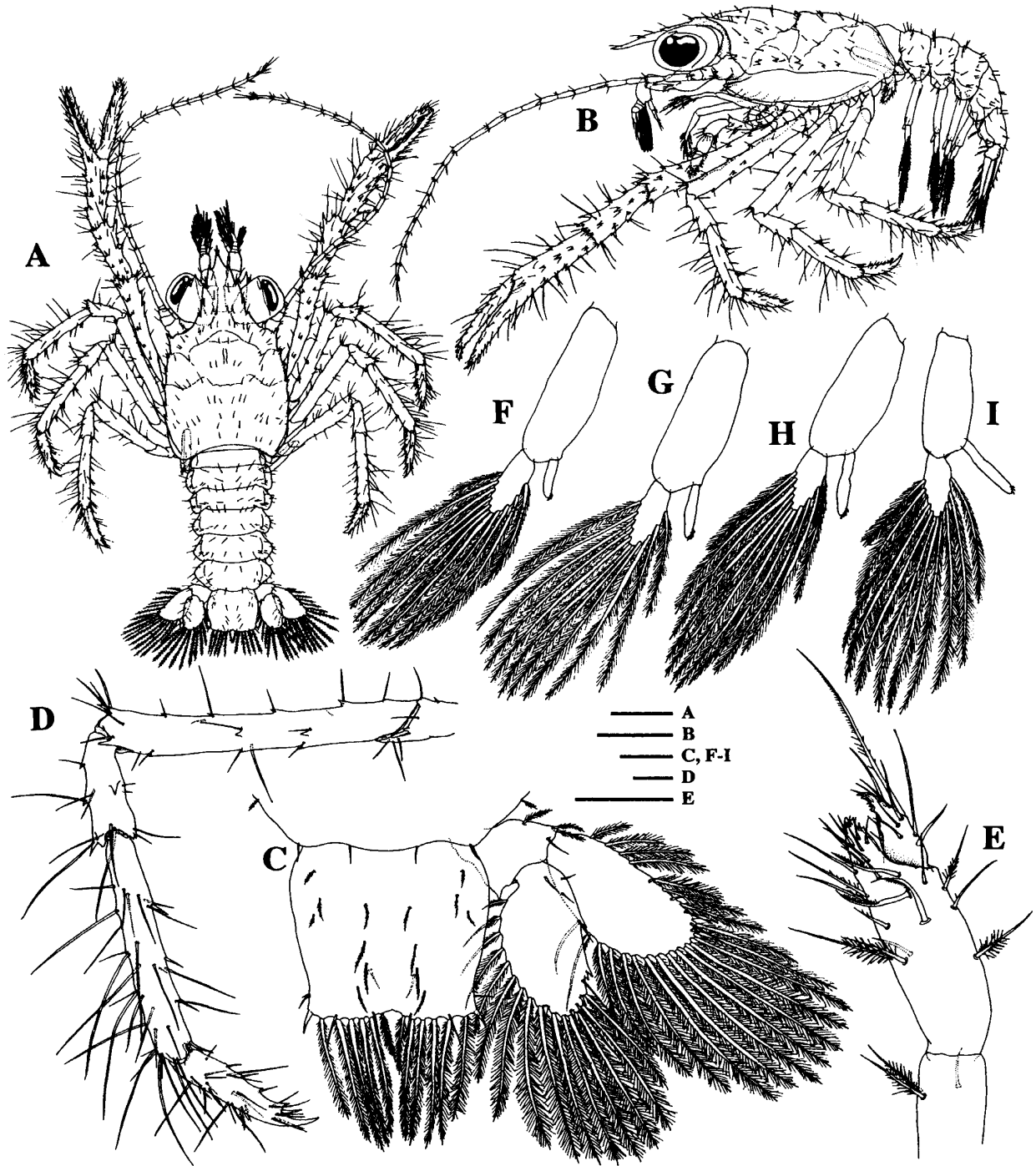


Fig. 11. *Galathea inflata* Potts, megalopa. A, entire animal, dorsal view; B, same, lateral view; C, telson and right uropod; D, second pereopod; E, fifth pereopod; F, first pleopod; G, second pleopod; H, third pleopod; I, fifth pleopod. Scales A and B = 0.5 mm; scales C-I = 0.1 mm.

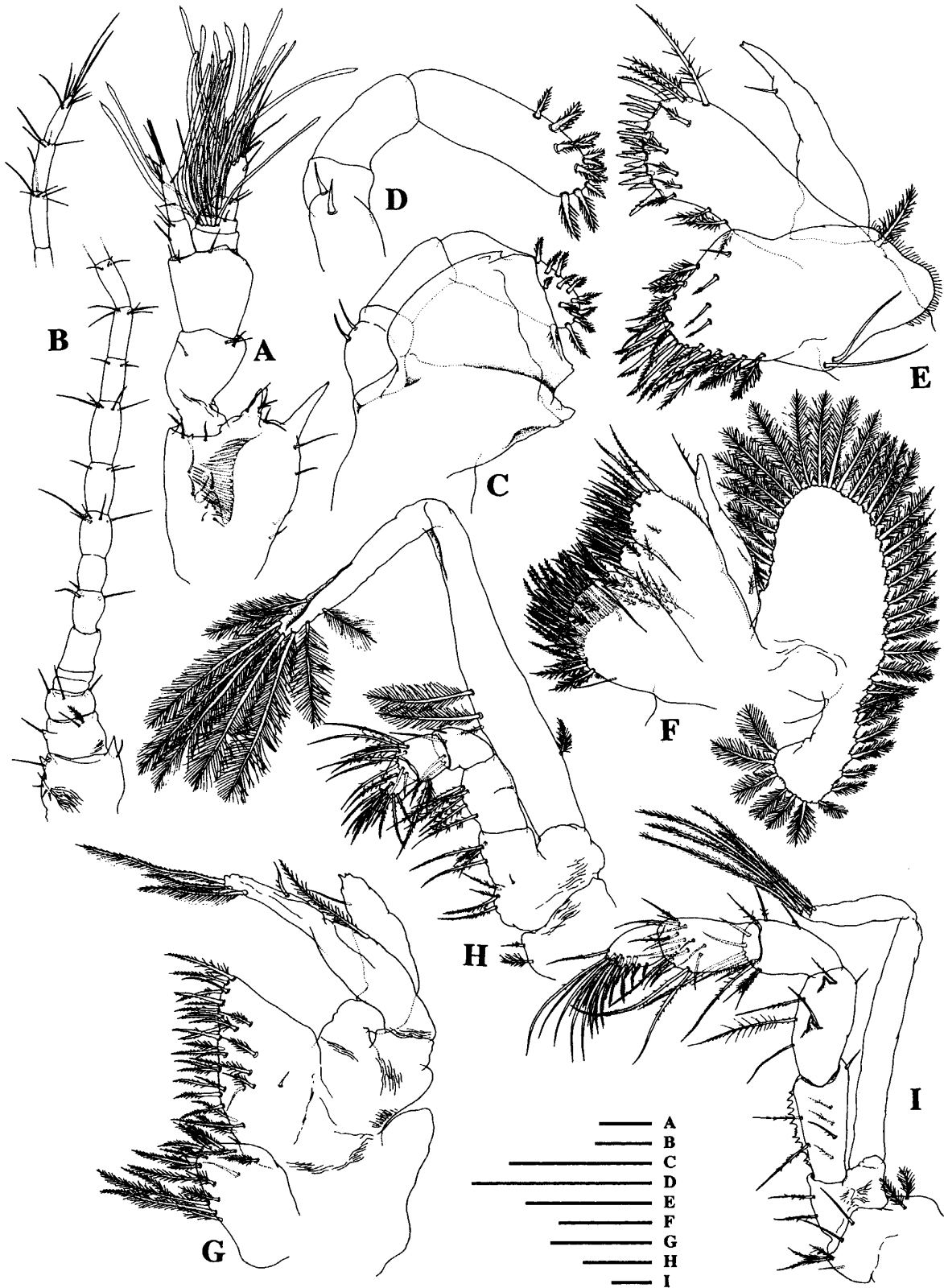


Fig. 12. *Galathea inflata* Potts, megalopa. A, antennule; B, antenna, middle segments omitted; C, mandible, right; D, same, palp; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped. Scales = 0.1 mm.