

# The larval development of the poisonous mosaic crab, *Lophozozymus pictor* (Fabricius, 1798) (Crustacea, Decapoda, Brachyura, Xanthidae, Zosiminae), with comments on familial characters for first stage zoeas

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## ABSTRACT

The four zoeal stages and megalopal phase of the xanthid crab *Lophozozymus pictor* (Fabricius, 1798) are described and fully illustrated. A comparison between the zoeal stages of *L. pictor* and *Atergatis reticulatus* is tabulated. Characters selected from larvae representing six subfamilies, which may define first stage Xanthidae MacLeay, 1838 (*sensu* Serène, 1984) zoea, are listed. The first stage zoeal appendages of *Palapedia valentini* Ng, 1993, considered to be diagnostic of a new Xanthidae subfamily Kraussiinae Ng, 1993, are reappraised and the chaetotaxy of the antennal exopod as a diagnostic character of the Xanthidae MacLeay, 1838 (*sensu* Serène, 1984) is discussed.

## KEY WORDS

Crustacea,  
Decapoda,  
Brachyura,  
Xanthidae,  
first stage zoea,  
familial diagnostic characters,  
*Lophozozymus*,  
*Palapedia*.

## RÉSUMÉ

Le développement larvaire du crabe vénéneux, *Lophozozymus pictor* (Fabricius, 1798) (Crustacea, Decapoda, Brachyura, Xanthidae, Zosiminae), et commentaires sur les caractères familiaux des premiers stades zoés. Les quatre stades zoés et la phase mégaloïpe du crabe Xanthidae *Lophozozymus pictor* sont décrits et illustrés de manière détaillée. Les stades zoés de *L. pictor* et d'*Atergatis reticulatus* sont comparés sous forme de tableau. À partir des larves de six sous-familles, les caractères pouvant définir le premier stade zoé des Xanthidae MacLeay, 1838 (au sens de Serène 1984) sont énumérés. Les appendices du premier stade zoé de *Palapedia valentini* Ng, 1993, considérés comme caractéristiques d'une nouvelle sous-famille de Xanthidae, les Kraussiinae Ng, 1993, sont réexaminés et l'utilisation de la chétotaxie de l'exopodite antennaire comme caractère diagnostique des Xanthidae est discutée.

## MOTS CLÉS

Crustacea,  
Decapoda,  
Brachyura,  
Xanthidae,  
premier stade zoé,  
caractères familiaux,  
*Lophozozymus*,  
*Palapedia*.

## INTRODUCTION

The poisonous Indo-West Pacific reef crab *Lophozozymus pictor* (Fabricius, 1798) (Xanthidae) has been the subject of many studies, but most of the work has focused on its taxonomy and biology (Guinot 1977, 1979; Yasumoto *et al.* 1986; Llewellyn & Endean 1989). As part of the studies on the ecology and toxic nature of this species in Singapore (Chia *et al.* 1993; Ng *et al.* 1990, 1992), several ovigerous females were obtained. From one of these females, four zoeal stages and the megalop phase were reared in the laboratory and this present paper serves to describe and figure these larvae. This is the first larval account of a *Lophozozymus* species and only the second of the Zosiminae (*sensu* Serène 1984); see the description by Terada (1980) of *Atergatis reticulatus*. The opportunity is also taken to redescribe the first stage zoea of *Palapedia valentini* Ng, 1993 (Krausinae).

## MATERIAL AND METHODS

The ovigerous female of *Lophozozymus pictor* was collected from a reef on Siloso Beach, Sentosa Island, Singapore, and is now deposited, together with remaining larvae, in the Zoological Reference Collection, National University of Singapore (ZRC 1997.771).

The ovigerous crab was isolated in a tank with strong aeration. First stage zoea hatched on the twenty-ninth January 1992 and development to megalop was completed by the end of February. The larvae were reared in 10 cm diameter plastic bowls in about 1 cm depth of 100% filtered sea water. All stages were fed with newly hatched brine shrimps (cysts filtered off). The water was changed daily and contained no additives. Average water temperature was about 26 °C. First and second zoeas were stocked at about twenty per bowl, third and fourth zoeas as well as the megalops at about ten per bowl. No crab stages were obtained. All specimens were initially preserved in buffered formalin and later transferred to 70% alcohol.

The larvae were dissected using an M5 Wild binocular microscope with a supplementary lens

( $\times 2$ ). Appendages were not stained and were mounted on slides using polyvinyl lactophenol. Cover slips were sealed with clear Sally Hansen nail varnish. Setal observations and drawings were made using an Olympus BH2 microscope with Nomarski interference contrast and *camera lucida* attachment. The long aesthetascs on the antennules, and the long plumose setae on distal exopod segments are not fully illustrated but are drawn truncated. The dorsal carapace spines of the third and fourth stages are not illustrated because they appeared not to survive the preservation process and therefore any setation on these could not be recorded. The zoeal description is based on the malacostracan somite plan and is ordered from anterior to posterior. Setal armature on appendages is described from proximal to distal segments and in order of endopod to exopod.

Seven first stage, seven second stage, five third stage, five fourth stage zoeas and three megalops of *Lophozozymus pictor* were dissected for this study. However, of the three extant first stage zoea of *Palapedia valentini* deposited in the Zoological Reference Collection, National University of Singapore (ZRC 1997.770), only two specimens were prepared for the redescription of appendages.

### *Lophozozymus pictor* (Fabricius, 1798) (Figs 1-21)

#### LARVAL DESCRIPTIONS

##### *Zoea I*

Carapace (Fig. 1A): dorsal spine long and straight, spinulation absent; rostral spine slightly shorter than dorsal spine, approximately equal in length to the protopod of antenna, spinulation absent; lateral spines present, much shorter than rostral and curving ventrally; anterodorsal setae absent; one pair of posterodorsal setae; each ventral margin without setae; eyes sessile.

Antennule (Fig. 2A): uniramous, endopod absent; exopod unsegmented with two broad, long, two shorter, slender terminal aesthetascs and one terminal seta.

Antenna (Fig. 8A, B): protopodal process devoid of spinulation, approximately equal in length to

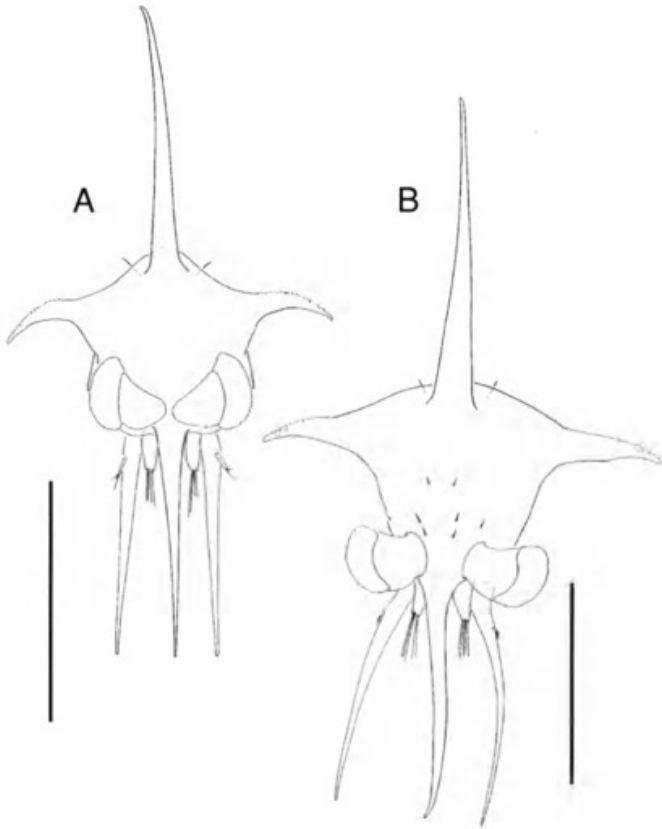


FIG. 1. — *Lophozozymus pictor* (Fabricius, 1798): anterior view of carapace; **A**, first zoea; **B**, second zoea. Scale bars: 1 mm.

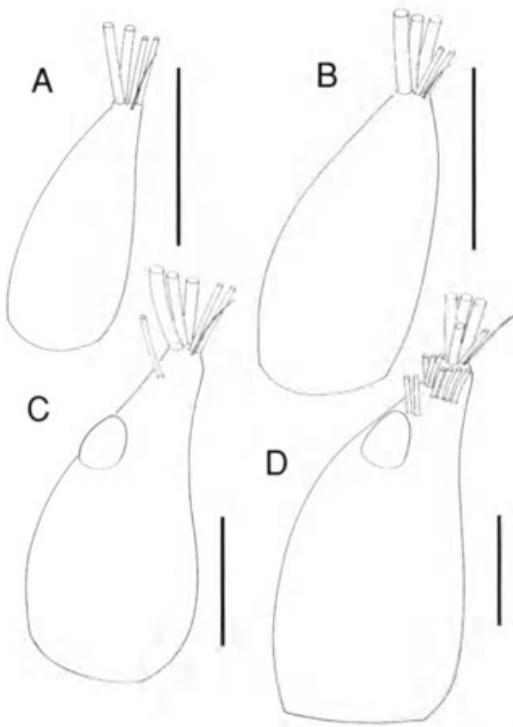


FIG. 2. — *Lophozozymus pictor* (Fabricius, 1798): antennule; **A**, first zoea; **B**, second zoea; **C**, third stage; **D**, fourth stage. Scale bars: 0.1 mm.

rostral spine; endopod absent; exopod rudimentary, unsegmented with three unequal setae, two smallest setae terminal, largest seta subterminal.

Mandible: palp absent.

Maxillule (Fig. 9A): coxal endite with seven setae; basal endite with five setal processes and two small teeth; endopod 2-segmented, proximal segment with one seta; distal segment with six (two subterminal, four terminal) setae; exopod seta absent.

Maxilla (Fig. 10A): coxal endite bilobed with 4 + 4 setae; basal endite bilobed with 5 + 4 setae; endopod bilobed with 3 + 5 (2 subterminal + 3 terminal) setae; exopod (scaphognathite) margin with four setae and one long distal stout process.

First maxilliped (Fig. 11A): coxa without setae; basis with ten setae arranged 2, 2, 3, 3; endopod 5-segmented with 3, 2, 1, 2, 5 (1 subterminal + 4 terminal) setae respectively; exopod 2-segmented, distal segment with four long terminal plumose natatory setae.

Second maxilliped (Fig. 12A): coxa without setae; basis with four setae; endopod 3-segmented, with 1, 1, 6 (3 subterminal + 3 terminal) setae respectively; exopod 2-segmented, distal segment with four long terminal plumose natatory setae.

Third maxilliped: absent.

Pereiopods: absent.

Abdomen (Figs 13A, 14A): five somites; somite 2 with one pair of dorsolateral processes directed anteriorly; somite 3 with one pair of dorsolateral processes directed posteriorly; somites 1-2 with short rounded and somites 3-5 with posterolateral spinous processes rudimentary; somites 2-5 with one pair of posterodorsal setae; pleopod buds absent.

Telson (Figs 13A, 14A, 15A): each fork long, gradually curved, not spinulated; two pairs of small lateral spines; one pair of dorsal medial spines larger than laterals; posterior margin with three pairs of stout spinulate setae.

### Zoea II

Carapace (Figs 1B, 3A): four pairs of anterodorsal setae; each ventral margin with four setae (one plumose anterior seta and three non-plumose posterior setae); eyes stalked; otherwise unchanged.

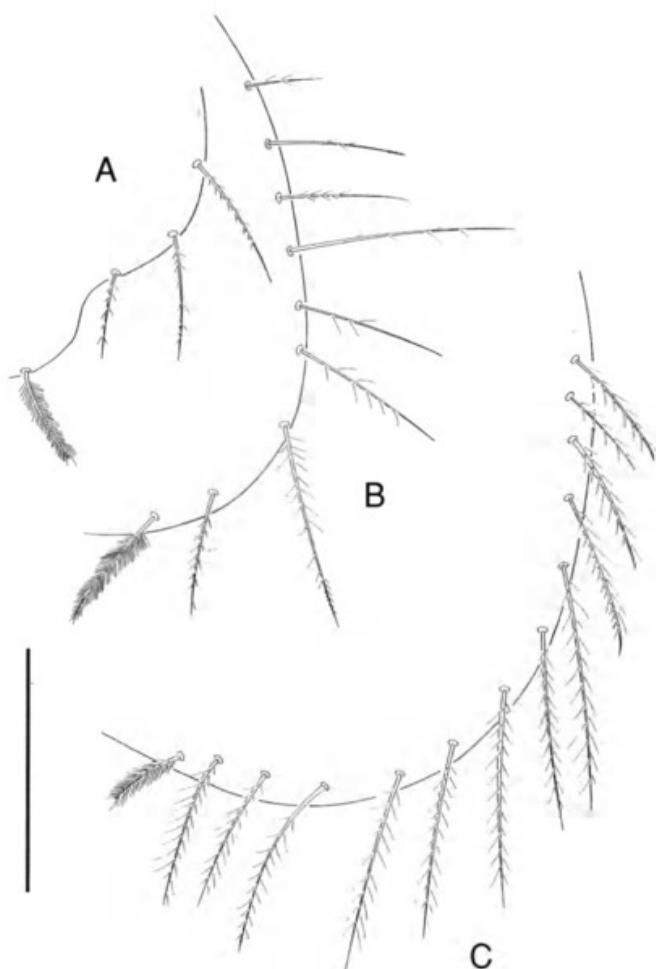


FIG. 3. — *Lophozozymus pictor* (Fabricius, 1798): chaetotaxy of ventral carapace margin; **A**, second zoea; **B**, third stage zoea; **C**, fourth stage zoea. Scale bar: 0.3 mm.

Antennule (Fig. 2B): exopod with one additional broad, long aesthetasc; otherwise unchanged.

Antenna (Fig. 8C, D): endopod present; exopod reduced; otherwise unchanged.

Mandible: unchanged.

Maxillule (Fig. 9B): coxal endite with eight distinct setae; basal endite with eight setal processes, inner margin with teeth no longer prominent; endopod unchanged; exopod seta present.

Maxilla (Fig. 10B): exopod (scaphognathite) margin with thirteen setae, long distal stout process no longer prominent; otherwise unchanged.

First maxilliped (Fig. 11B): exopod distal segment with six long terminal plumose natatory setae; otherwise unchanged.

Second maxilliped (Fig. 12B): exopod distal segment with six (occasionally seven) long terminal plumose natatory setae; otherwise unchanged.

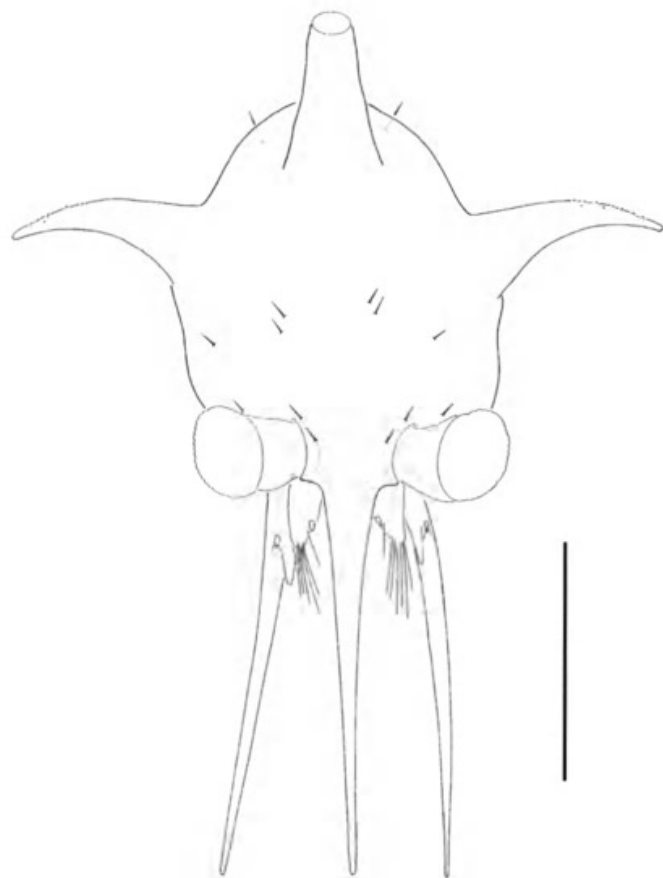


FIG. 4. — *Lophozozymus pictor* (Fabricius, 1798): anterior view of carapace, third zoea. Scale bar: 1 mm.

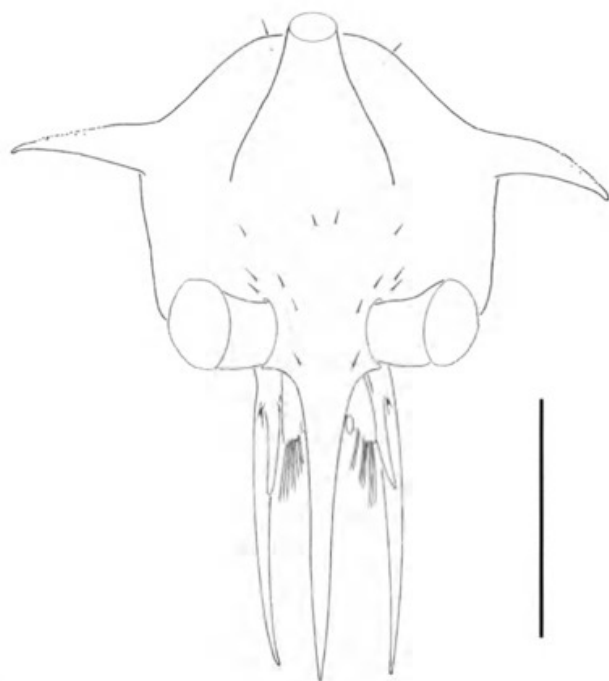


FIG. 5. — *Lophozozymus pictor* (Fabricius, 1798): anterior view of carapace, fourth zoea. Scale bar: 1 mm.

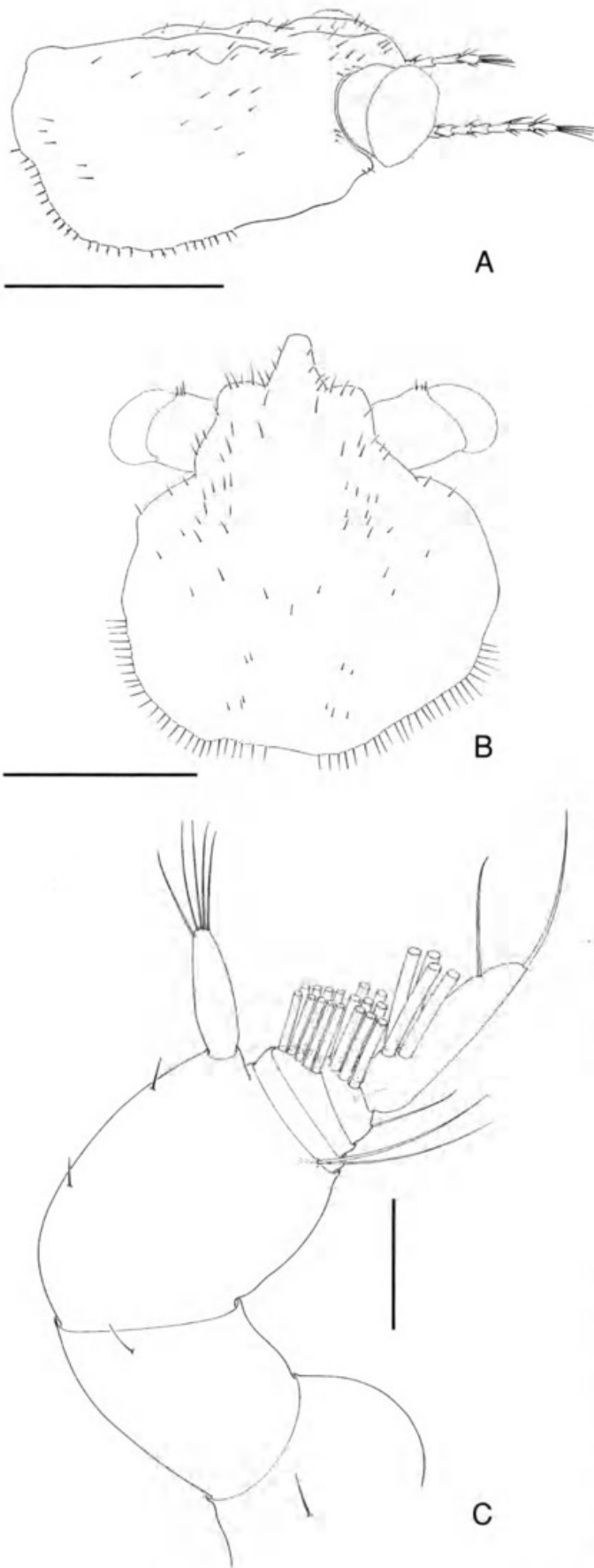


FIG. 6. — *Lophozozymus pictor* (Fabricius, 1798); **A**, lateral view of megalop carapace; **B**, dorsal view of megalop carapace; **C**, megalop antennule. Scale bars: A, B, 1 mm; C, 0.1 mm.

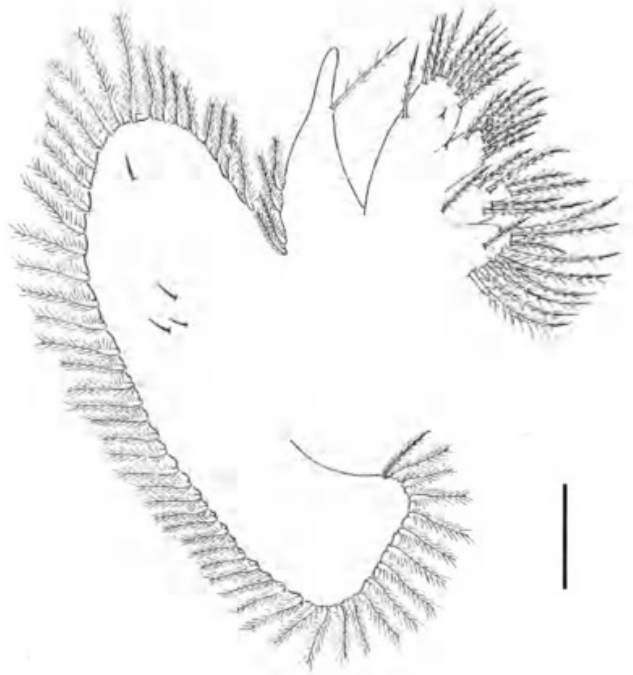


FIG. 7. — *Lophozozymus pictor* (Fabricius, 1798): maxilla of megalop. Scale bar: 0.1 mm.

Third maxilliped: absent.

Pereiopods: absent.

Abdomen (Figs 13B, 14B): somites 3-5 with posterolateral spinous processes more developed; somite 1 with one medial seta; otherwise unchanged.

Telson (Figs 13B, 14B, 15D): posterior margin with three pairs of stout spinulate setae plus one pair of medial setae; otherwise unchanged.

### *Zoea III*

Carapace (Figs 3B, 4): six pairs of anterodorsal setae; each ventral margin with nine setae (one plumose anterior seta and eight non-plumose posterior setae); otherwise unchanged.

Antennule (Fig. 2C): biramous; endopod bud present; exopod with one additional subterminal aesthetasc; otherwise unchanged.

Antenna (Fig. 8E, F): endopod longer; exopod reduced; otherwise unchanged.

Mandible: unchanged.

Maxillule (Fig. 9C): coxal endite with nine setae; basal endite with eleven setal processes; otherwise unchanged.

Maxilla (Fig. 10C): coxal endite with 5 + 4 setae; basal endite bilobed with 5 + 5 setae; endopod

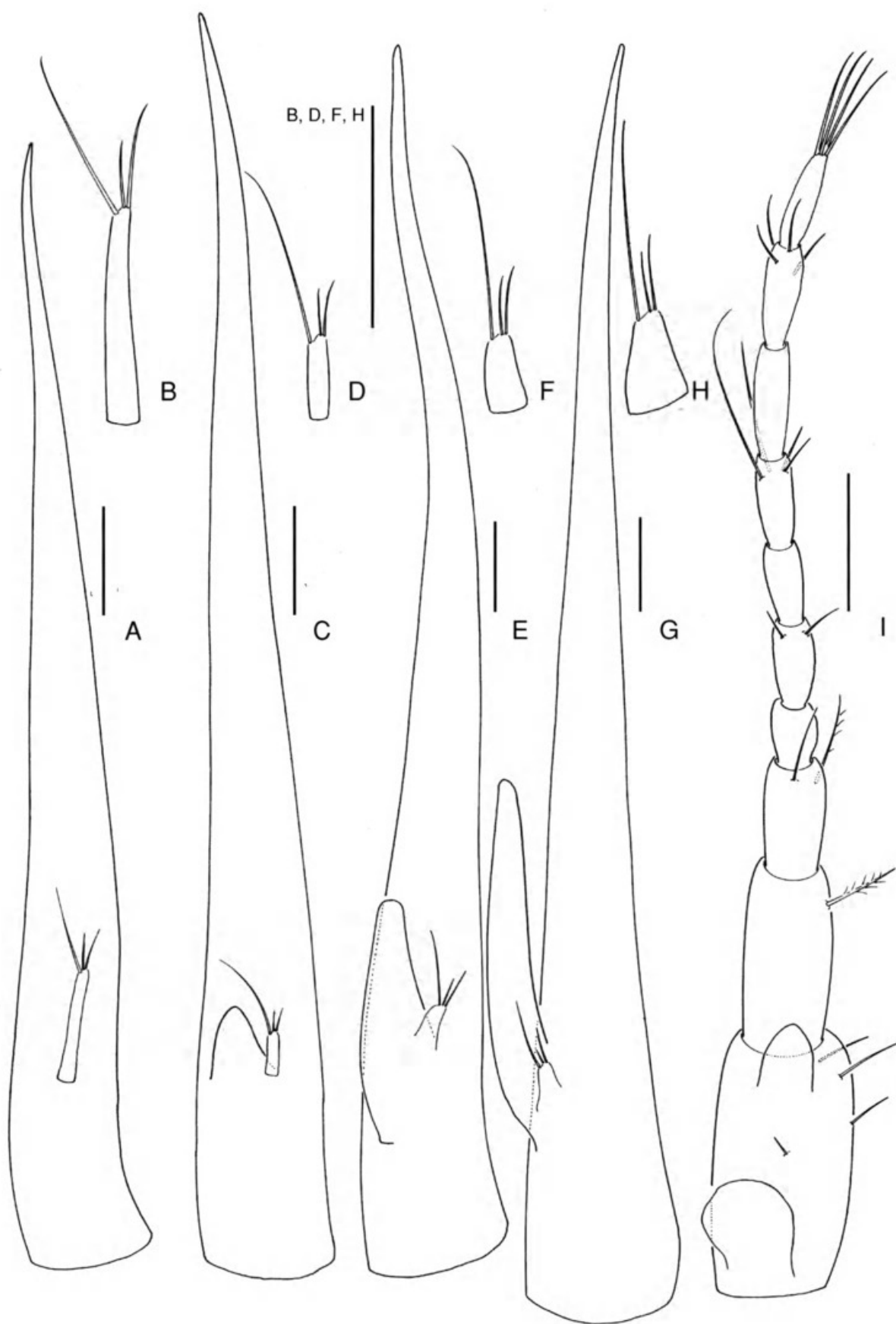


FIG. 8. — *Lophozozymus pictor* (Fabricius, 1798): A, C, E, G, I, antenna; B, D, F, H, antennal exopod; A, B, first zoea; C, D, second zoea; E, F, third zoea; G, H, fourth zoea; I, megalop. Scale bars: 0.1 mm.

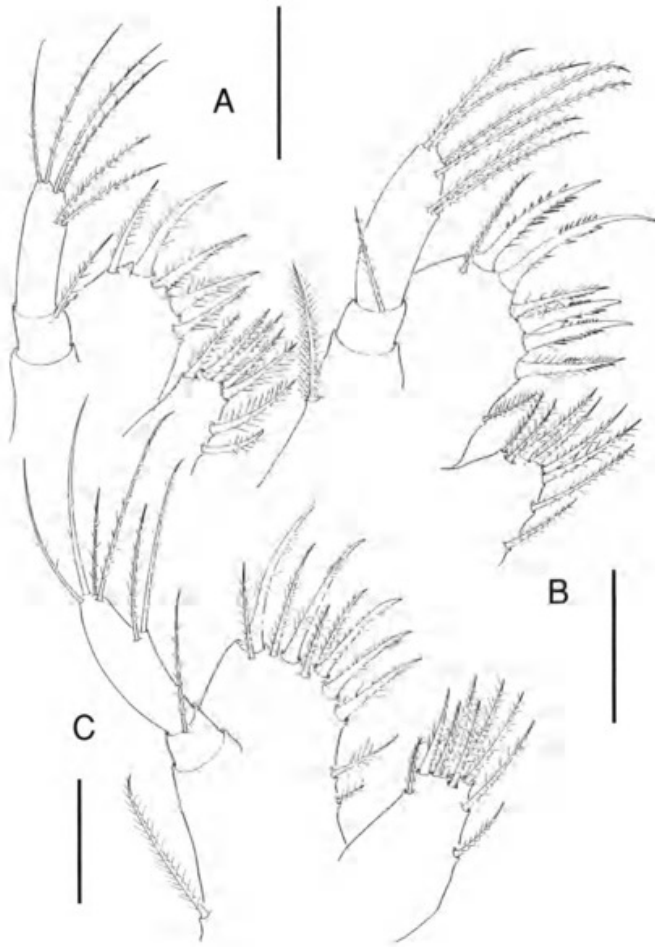


FIG. 9. — *Lophozozymus pictor* (Fabricius, 1798): maxillule; **A**, first zoea; **B**, second zoea; **C**, third zoea. Scale bars: 0.1 mm.

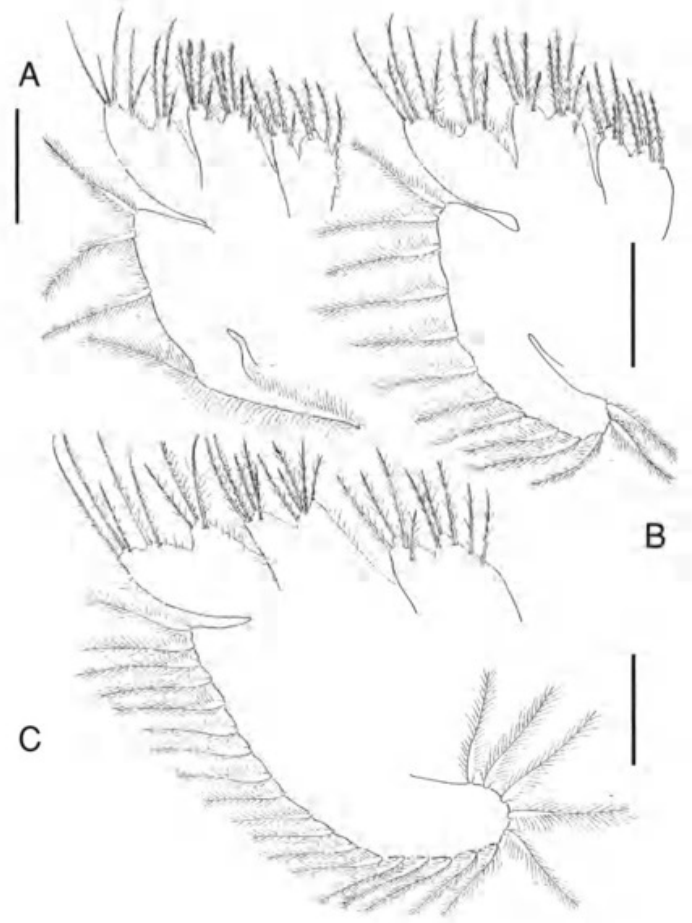


FIG. 10. — *Lophozozymus pictor* (Fabricius, 1798): maxilla; **A**, first zoea; **B**, second zoea; **C**, third zoea. Scale bars: 0.1 mm.

unchanged; exopod (scaphognathite) margin with twenty-three setae.

First maxilliped (Fig. 18A): endopod distal segment now with six (two subterminal and four terminal) setae; exopod distal segment with eight long terminal plumose natatory setae; otherwise unchanged.

Second maxilliped (Fig. 19A): exopod distal segment with nine long terminal plumose natatory setae; otherwise unchanged.

Third maxilliped (Fig. 17A): present, rudimentary and biramous; endopod slightly longer than exopod.

Pereiopods (Fig. 16C): present, rudimentary, undifferentiated into segments; cheliped bilobed; gills present on pereiopods 1-3.

Abdomen (Figs 13C, 14C): 6-segmented; somites 3-5 with posterolateral spinous processes more pronounced and extended posteriorly; somite 1 with three setae; somite 6 without setae;

pleopod buds present on somites 2-6, uniramous with endopods absent; otherwise unchanged.

Telson (Figs 13C, 14C, 15C): posterior margin with three pairs of stout spinulate setae plus two pairs of medial setae; otherwise unchanged.

#### Zoea IV

Carapace (Figs 3C, 5): seven pairs of anterodorsal setae; each ventral margin with thirteen setae (one plumose anterior seta and twelve non-plumose posterior setae); otherwise unchanged.

Antennule (Fig. 2D): endopod unchanged; exopod now with 2 + 7 thin subterminal aesthetascs, terminal aesthetascs unchanged.

Antenna (Fig. 8G, H): endopod longer; exopod reduced; otherwise unchanged.

Mandible (Fig. 16A): palp present.

Maxillule (Fig. 17D): coxal endite with twelve setae; basal endite with thirteen setal processes; otherwise unchanged.

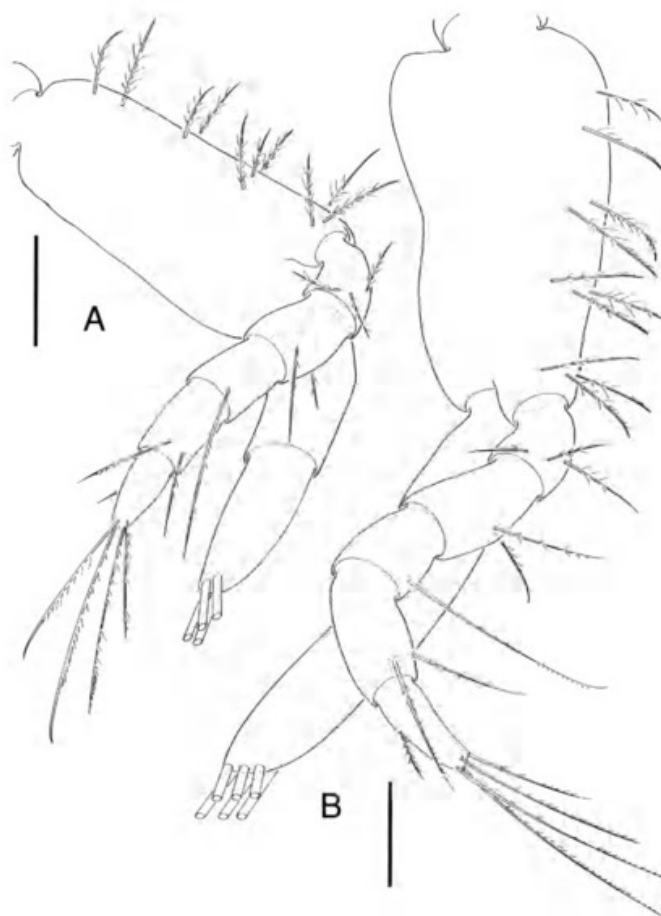


FIG. 11. — *Lophozozymus pictor* (Fabricius, 1798): first maxilliped; **A**, first zoea; **B**, second zoea. Scale bars: 0.1 mm.

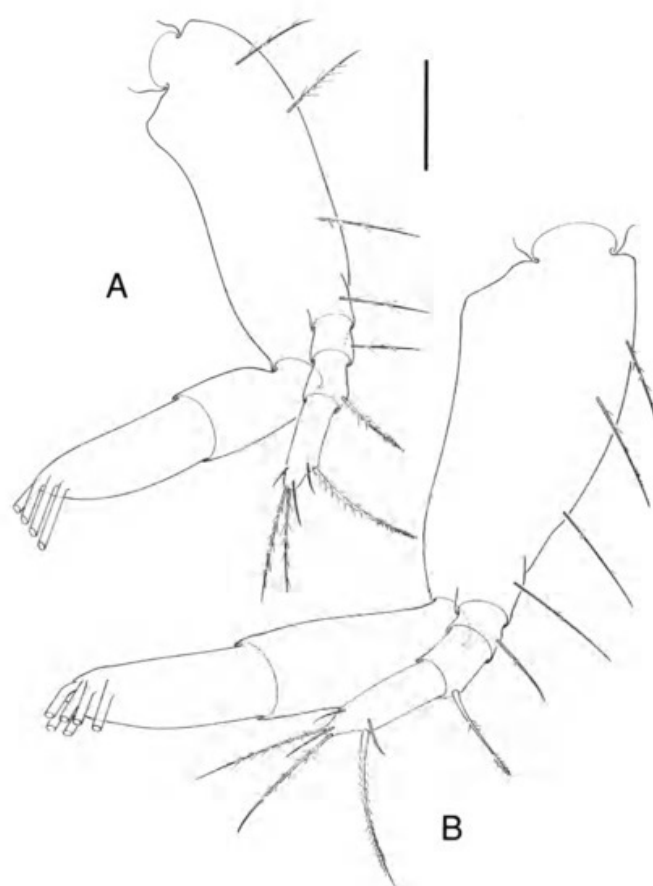


FIG. 12. — *Lophozozymus pictor* (Fabricius, 1798): second maxilliped; **A**, first zoea; **B**, second zoea. Scale bar: 0.1 mm.

Maxilla (Fig. 17F): coxal endite unchanged; basal endite bilobed with 5 + 7 setae; endopod unchanged; exopod (scaphognathite) margin with thirty-two setae.

First maxilliped (Fig. 18B): exopod distal segment with ten long terminal plumose natatory setae; otherwise unchanged.

Second maxilliped (Fig. 19B): exopod distal segment with eleven long terminal plumose natatory setae; otherwise unchanged.

Third maxilliped (Fig. 17B): developing; otherwise unchanged.

Pereiopods (Fig. 16D-H): developing with differentiation of segments, segments without setae; gill appendages not discernible.

Abdomen (Figs 17G, 20A, C, E, G, I, K): posterolateral spinous processes more pronounced and extended posteriorly; pleopods biramous with endopods present except on pleopod 5 (somite 6); otherwise unchanged.

Telson (Figs 17G, 20A, M): posterior margin with three pairs of stout spinulate setae plus four pairs of medial setae; one pair of medial setae present on dorsal surface; otherwise unchanged.

### *Megalop*

Carapace (Fig. 6A, B): short rostrum deflected posteriorly; setation as figured.

Antennule (Fig. 6C): peduncle 3-segmented with 1, 1, 4 (2 short + 2 long) setae respectively; endopod 1-segmented with five terminal setae; exopod 4-segmented, segments 2, 3, 4, with 9, 8 and 4 (subterminal) aesthetascs respectively, segments 3, 4 with 2, 2 (1 subterminal, 1 terminal) setae respectively.

Antenna (Fig. 8I): 3-segmented peduncle with 4, 1, 2 setae respectively; 7-segmented flagellum with 0, 2, 0, 4, 0, 4, 4 (terminal) setae respectively.

Mandible (Fig. 16B): palp 3-segmented, distal segment with eleven marginal setae.

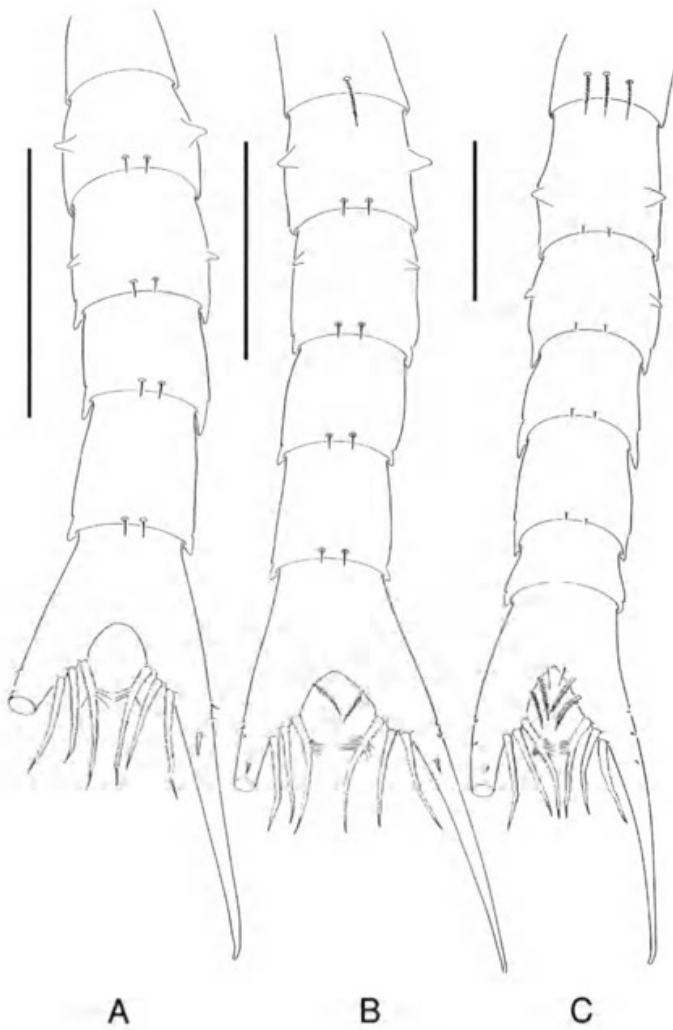


FIG. 13. — *Lophozozymus pictor* (Fabricius, 1798): dorsal view of abdomen; **A**, first zoea; **B**, second zoea; **C**, third zoea. Scale bars: 0.5 mm.

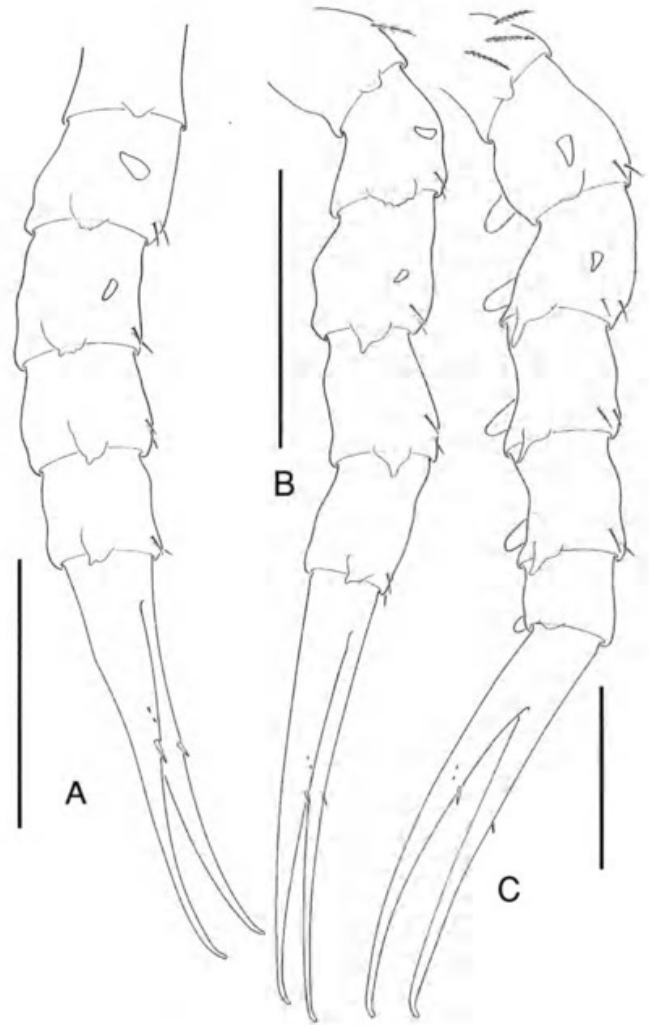


FIG. 14. — *Lophozozymus pictor* (Fabricius, 1798): lateral view of abdomen; **A**, first zoea; **B**, second zoea; **C**, third zoea. Scale bars: 0.5 mm.

Maxillule (Fig. 17E): coxal endite with seventeen setae; basal endite with twenty-two setal processes; endopod 2-segmented, proximal segment with three setae, distal segment with four (two subterminal and two shorter terminal) setae.

Maxilla (Fig. 7): coxal endite bilobed with 10 + 7 setae; basal endite bilobed with 7 long, 1 minute + 10 long, 1 minute setae; endopod simple with 1 subterminal seta + 4 setae on the lower external margin; exopod (scaphognathite) margin with fifty-three setae and four lateral setae.

First maxilliped (Fig. 21A): epipod with thirteen long setae; coxal endite with fourteen setae; basal endite with twenty-four setae; endopod unsegmented with four setae and a small terminal spine; exopod 2-segmented, proximal seg-

ment with one proximal and one distal seta; distal segment with one small subterminal seta and seven long terminal plumose feeding setae.

Second maxilliped (Fig. 21B): epipod with eleven long setae; prodobranch gill present; coxa and basis not differentiated, with two setae; endopod 5-segmented, ischium with two setae, merus with three setae, carpus with one seta, propodus with six setae, dactylus with seven setae; exopod 2-segmented, proximal segment with two marginal medial setae; distal segment with five long terminal plumose feeding setae.

Third maxilliped (Fig. 17C): epipod with twenty-three long setae and arthrobranch gill; coxa and basis not differentiated, with twenty-four setae; ischium inner margin with six teeth and twenty-two setae; merus with sixteen setae; carpus with

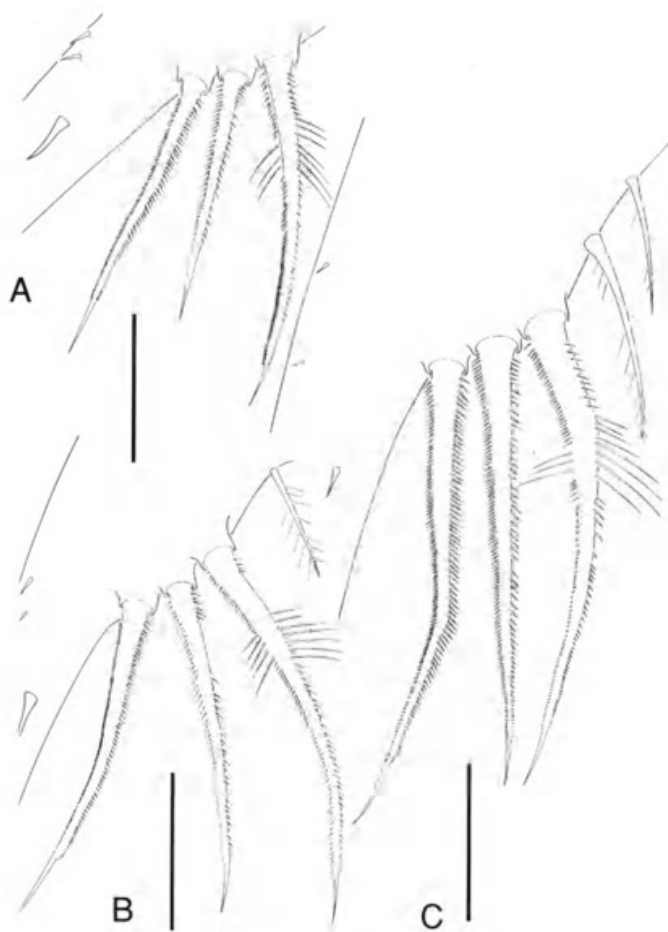


FIG. 15. — *Lophozozymus pictor* (Fabricius, 1798): dorsal view of telson; **A**, first zoea; **B**, second zoea; **C**, third zoea. Scale bars: 0.1 mm.

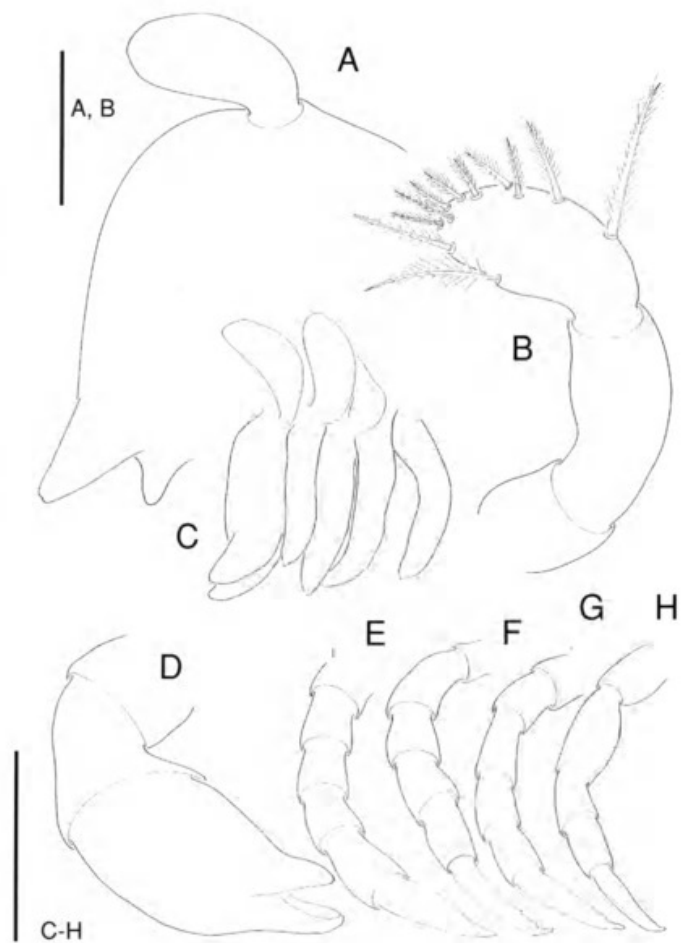


FIG. 16. — *Lophozozymus pictor* (Fabricius, 1798): mandibular palp; **A**, fourth zoea; **B**, megalop. pereopods; **C**, third zoea; **D-H**, fourth zoea. Scale bars: **A**, **B**, 0.1 mm; **C-H**, 0.5 mm.

eight setae; propodus with ten setae; dactylus with eight setae; exopod 2-segmented, proximal segment with four marginal setae, distal segment with two minute subterminal spines and five long terminal plumose raptatory setae.

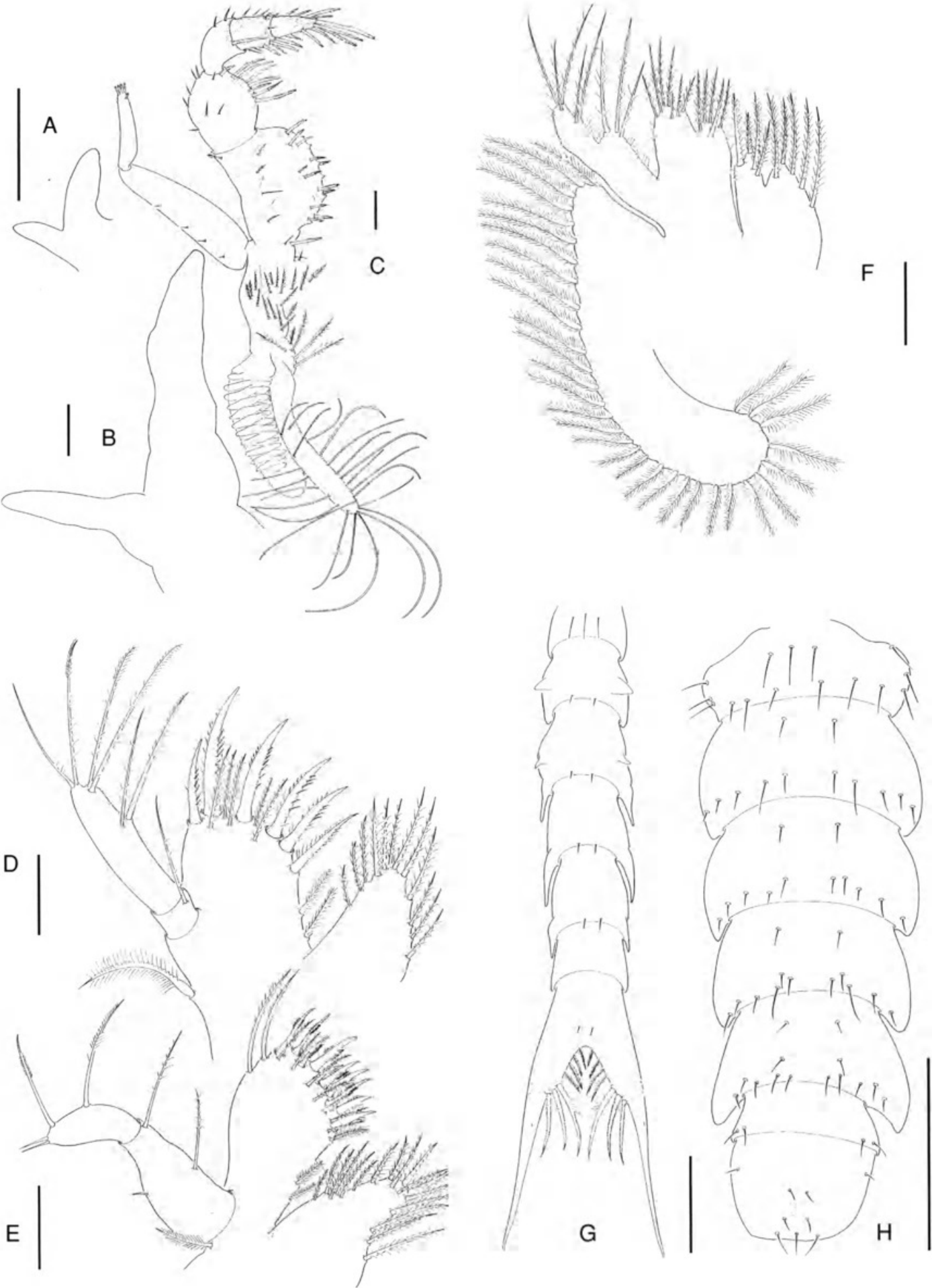
Pereopods (Fig. 21C-G): all segments well differentiated and with setae; ischium of chela with prominent hook; ischium of walking legs 1-3 with a single spine; propodus of fifth pereopod with three long subterminal setae.

Sternal plates: plates 1-3 fused with minute medial spine flanked with four pairs of setae; sternal plate 4 with a pair of minute medial spines and an outer pair of minute spines and with four pairs of setae; sternal plates 5 and 6 with one seta on each side; remaining sternal plates setae not observed but may be present.

Abdomen (Figs 17H, 20B, D, F, H, J, L): six somites present; somite 1 with three pairs of late-

ral setae, three medial setae and three pairs of posterior marginal setae; somites 2 and 3 with one pair of medial setae and five pairs of posterior marginal setae; somite 4 and 5 with two pairs of medial setae and five posterior marginal setae; somite 6 with two pairs of lateral setae; somites 2-5 each with one pair of biramous pleopods, endopod unsegmented with subterminal hooks on the internal margin; exopod unsegmented, pleopods 1-4 with 19, 20, 17, 15 long marginal plumose natatory setae respectively; uropod present on somite 6, biramous with an

FIG. 17. — *Lophozozymus pictor* (Fabricius, 1798): **A-C**, third maxilliped; **A**, third zoea; **B**, fourth zoea; **C**, megalop; **D, E**, maxillule; **D**, fourth zoea; **E**, megalop; **F**, maxilla of fourth zoea; **G, H**, dorsal view of abdomen; **G**, fourth zoea; **H**, megalop. Scale bars: **A**, **B**, 0.5 mm; **C-H**, 0.1 mm.



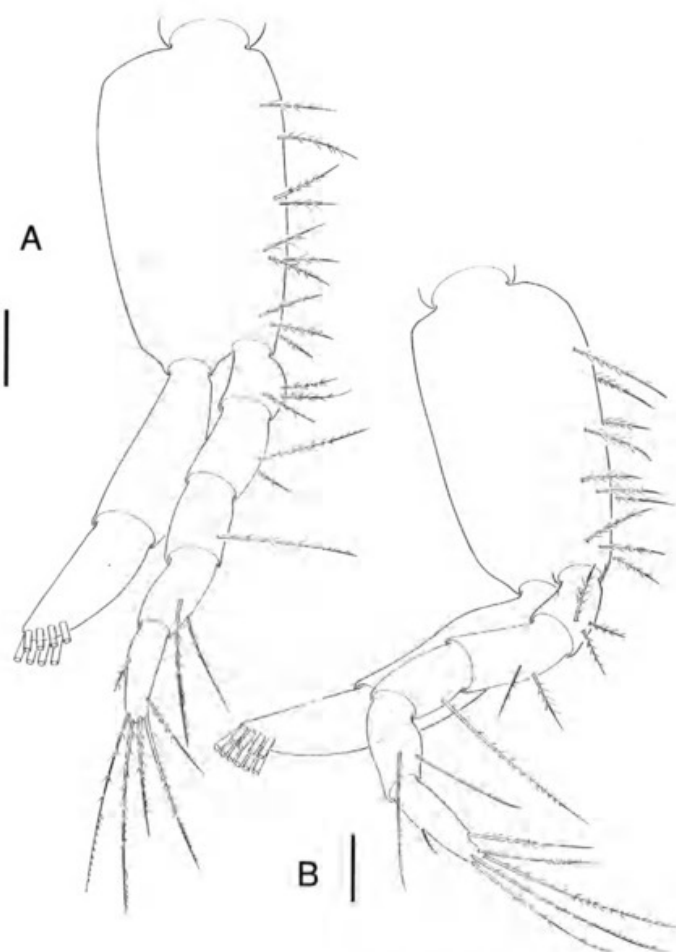


FIG. 18. — *Lophozozymus pictor* (Fabricius, 1798): first maxilliped; **A**, third zoea; **B**, fourth zoea. Scale bars: 0.1 mm.

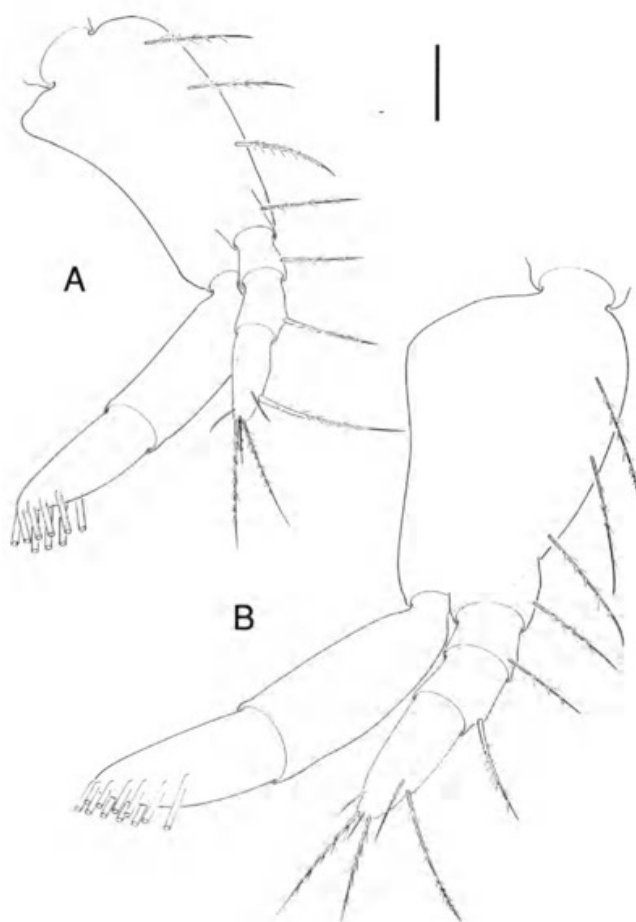


FIG. 19. — *Lophozozymus pictor* (Fabricius, 1798): second maxilliped; **A**, third zoea; **B**, fourth zoea. Scale bar: 0.1 mm.

endopod seta, exopod with nine long marginal plumose natatory setae,

Telson (Figs 17H, 20B, N): with two pairs of medial dorsal and ventral setae, one of lateral setae, three posterior marginal setae (variable in number).

*Palapedia valentini* Ng, 1993  
(Figs 22-25)

*Palapedia valentini* Ng, 1993: 145-147, fig. 5A-E.

REDESCRIPTION

*Zoea 1*

Carapace (Fig. 22A, E, F): dorsal spine long and curved distally with small tubercles, nearly twice as long as rostral spine; rostral spine much shorter than dorsal spine, approximately equal in

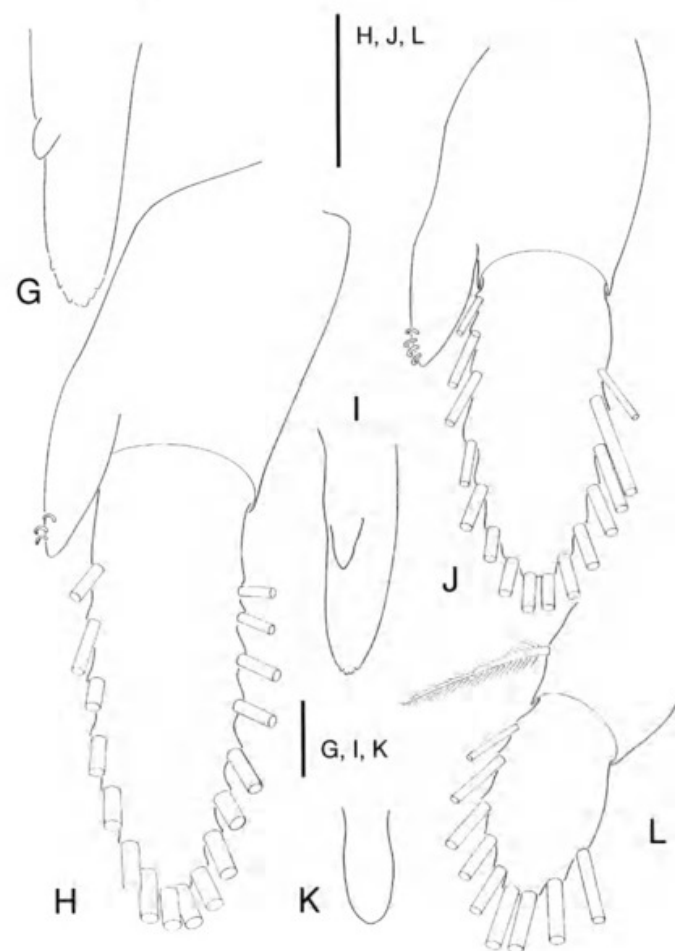
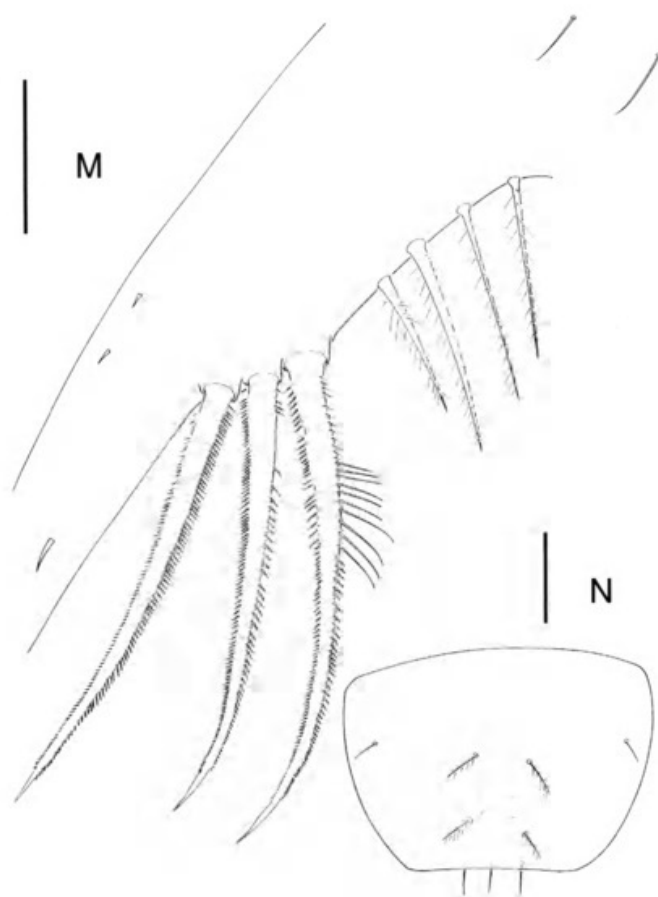
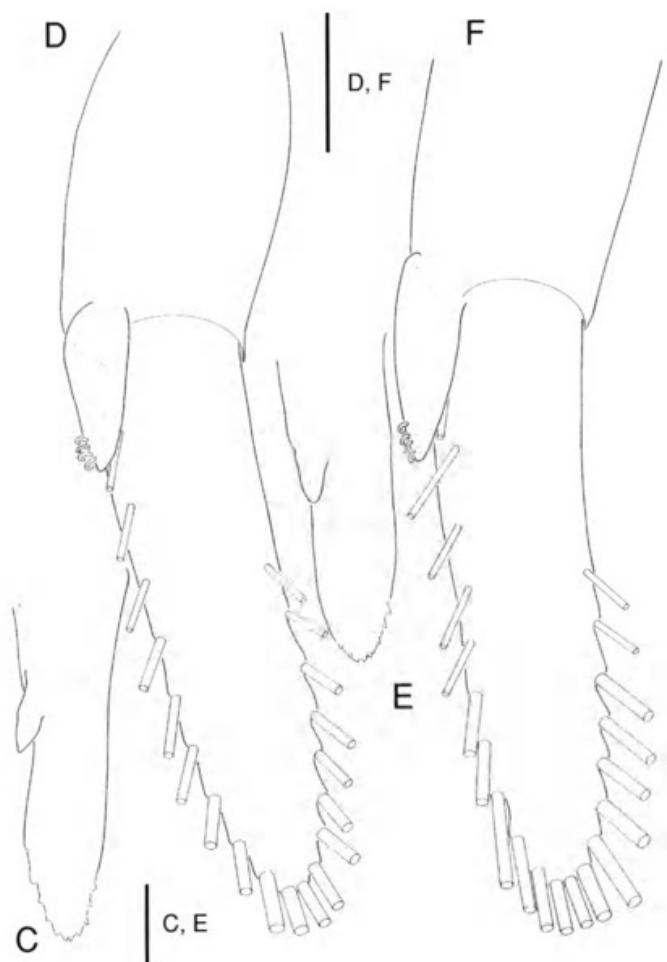
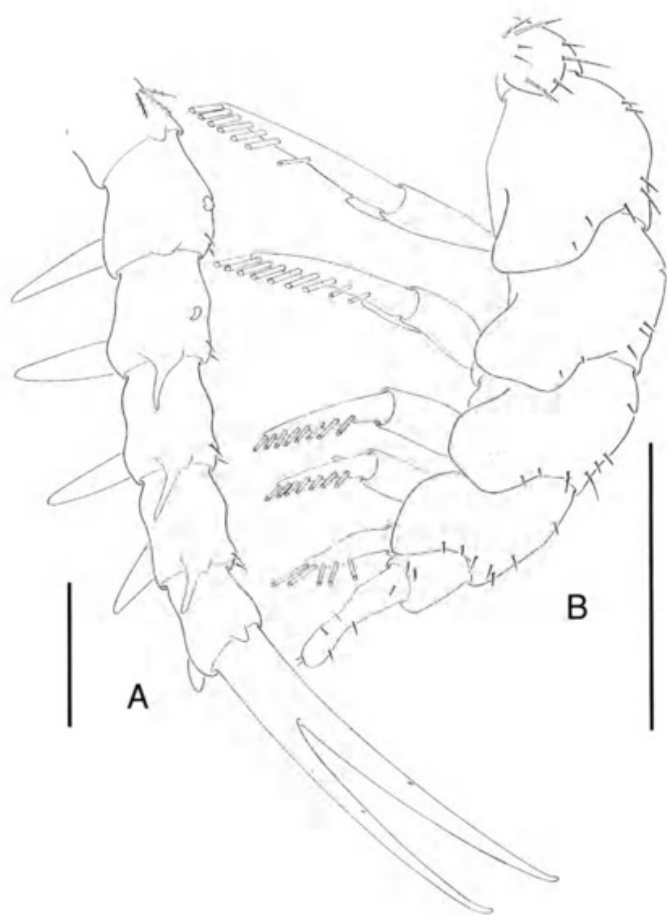
length to the protopod of antenna, with a few small tubercles; lateral spines present and distally curved posteriorly; one pair of posterodorsal setae; ventral margin without setae; eyes sessile.

Antennule (Fig. 22B): uniramous, endopod absent; exopod unsegmented with two broad, long, two shorter, slender terminal aesthetascs and one terminal setae.

Antenna (Fig. 22C, D): protopodal process distally spinulate, approximately equal in length to rostral spine; endopod absent; exopod rudimentary, unsegmented with two unequal terminal setae.

Mandible: palp absent.

FIG. 20. — *Lophozozymus pictor* (Fabricius, 1798): **A**, **B**, lateral view of abdomen; **A**, fourth zoea; **B**, megalop; **C**-**F**, first pleopod, somite 2; **C**, fourth zoea; **D**, megalop, second pleopod, somite 3; **E**, fourth zoea; **F**, megalop, **G**-**L**, third pleopod, somite 4; **G**, fourth zoea; **H**, megalop, fifth pleopod, somite 5; **I**, fourth zoea; **J**, megalop, sixth pleopod (uropod), somite 6; **K**, fourth zoea; **L**, megalop; **M**, **N**, dorsal view of telson; **M**, fourth zoea; **N**, megalop. Scale bars: **A**, **B**, 0.5 mm; **C**-**M**, 0.1 mm.



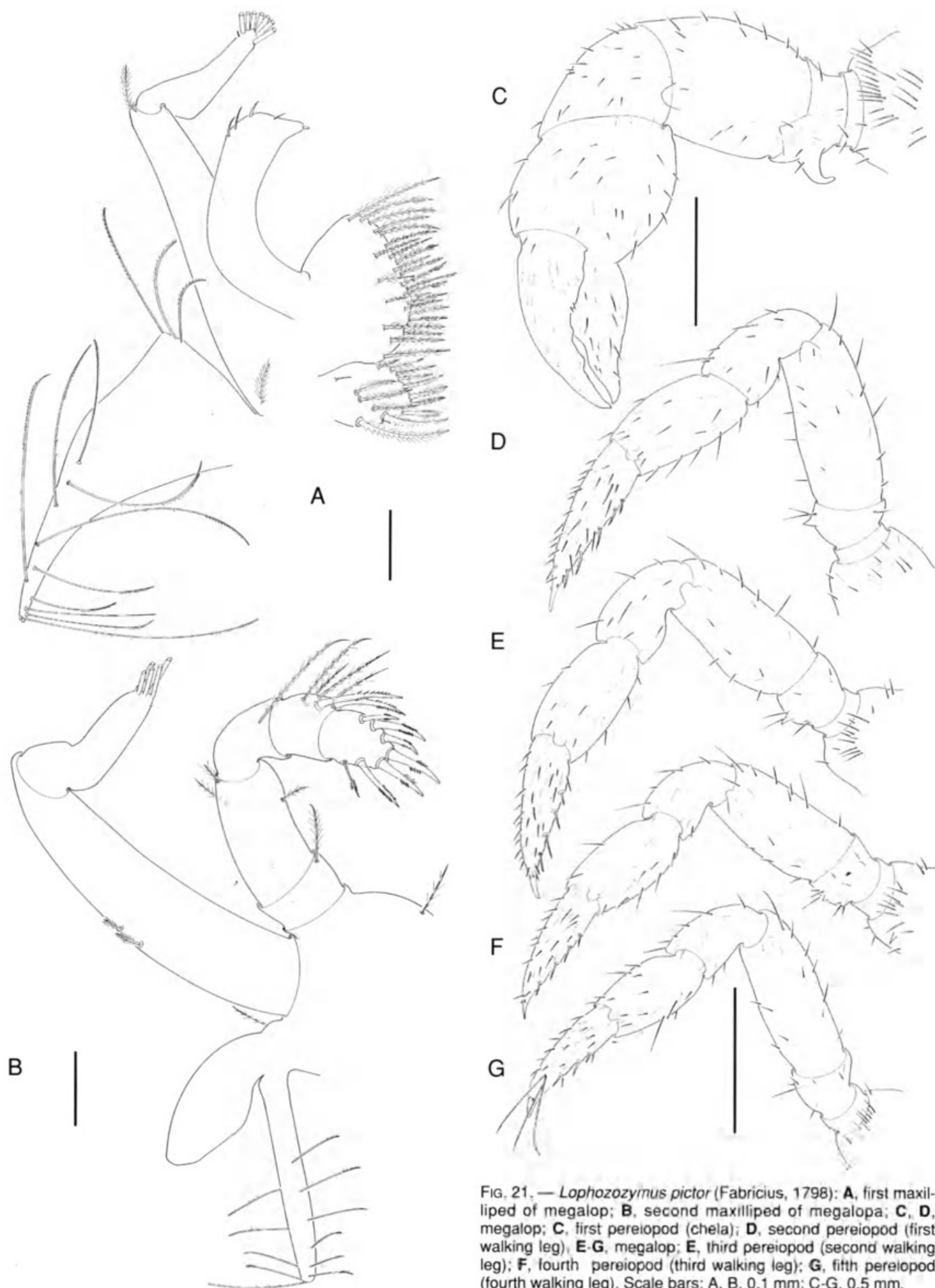


FIG. 21. — *Lophozozymus pictor* (Fabricius, 1798): A, first maxilliped of megalop; B, second maxilliped of megalopa; C, D, megalop; C, first pereopod (chela); D, second pereopod (first walking leg); E-G, megalop; E, third pereopod (second walking leg); F, fourth pereopod (third walking leg); G, fifth pereopod (fourth walking leg). Scale bars: A, B, 0.1 mm; C-G, 0.5 mm.

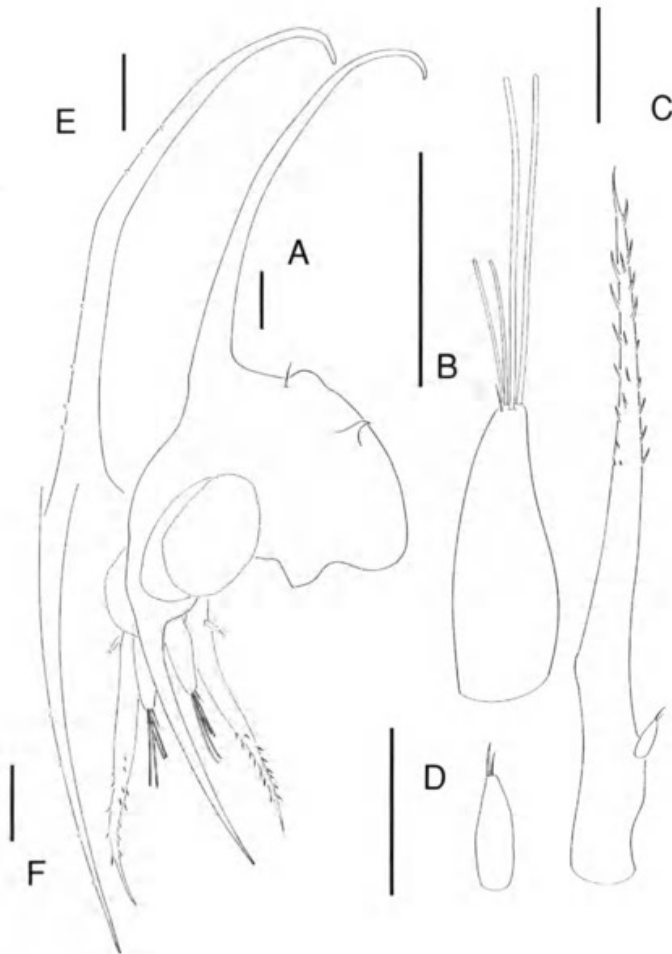


FIG. 22. — *Palapedia valentini* Ng, 1993: zoea I; A, lateral view of carapace; B, antennule; C, antenna; D, antennal exopod; E, dorsal spine; F, rostral spine. Scale bars: A-C, E, F, 0.1 mm; D, 0.05 mm.

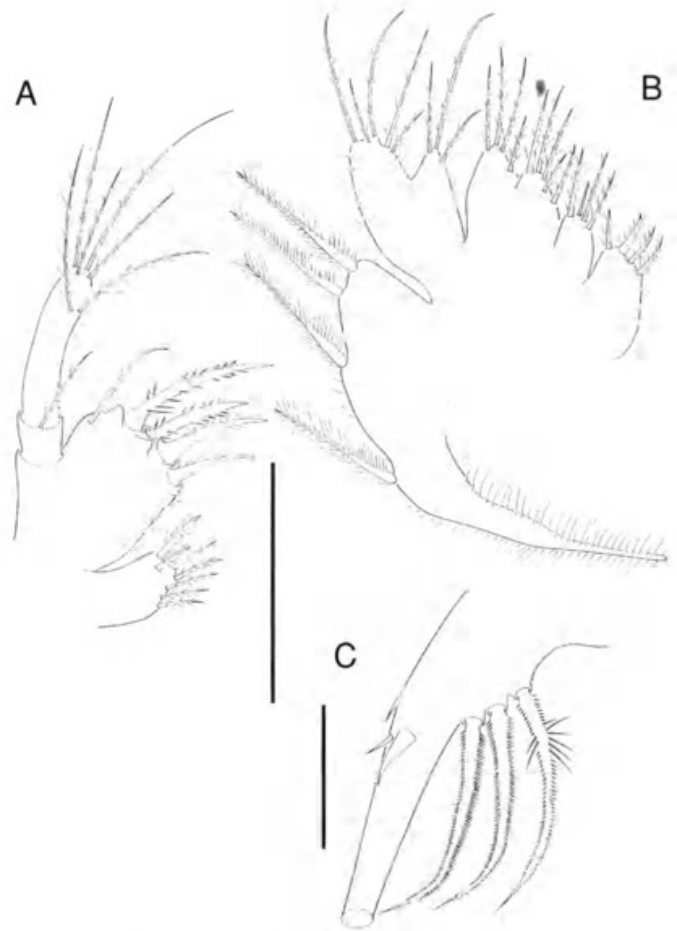


FIG. 23. — *Palapedia valentini* Ng, 1993: zoea I; A, maxillule; B, maxilla; C, telson. Scale bars: 0.1 mm.

Maxillule (Fig. 23A): coxal endite with seven setae; basal endite with five setal processes and two small teeth; endopod 2-segmented, proximal segment with one seta; distal segment with six (two subterminal, four terminal) setae; exopod seta absent.

Maxilla (Fig. 23B): coxal endite bilobed with 4 + 4 setae; basal endite bilobed with 5 + 4 setae; endopod bilobed, with 3 + 5 (2 subterminal + 3 terminal) setae; exopod (scaphognathite) margin with four setae and one long distal stout process.

First maxilliped: (Fig. 24A) coxa without setae; basis with ten setae arranged 2, 2, 3, 3; endopod 5-segmented with 3, 2, 1, 2, 5 (1 subterminal + 4 terminal) setae respectively; exopod 2-segmented, distal segment with four long terminal plumose natatory setae.

Second maxilliped (Fig. 24B): coxa without setae; basis with four setae; endopod 3-segmen-

ted, with 1, 1, 6 (three subterminal and three terminal) setae respectively; exopod 2-segmented, distal segment with four long terminal plumose natatory setae.

Third maxilliped: absent.

Pereopods: absent.

Abdomen (Fig. 25A, B): five somites; somite 2 with one pair of dorsolateral processes directed anteriorly; somite 3 with one pair of dorsolateral processes directed ventrally; somites 1-2 with rounded posterolateral processes and somites 3-5 with short posterolateral spinous processes; somite 1 without setae; somites 2-5 with one pair of posterodorsal setae; pleopod buds absent.

Telson (Figs 23C; 25A, B): each fork long, gradually curved distally; two minute lateral spines; large dorsal medial spine distally curved anteriorly, posterior margin with three pairs of stout spinulate setae.

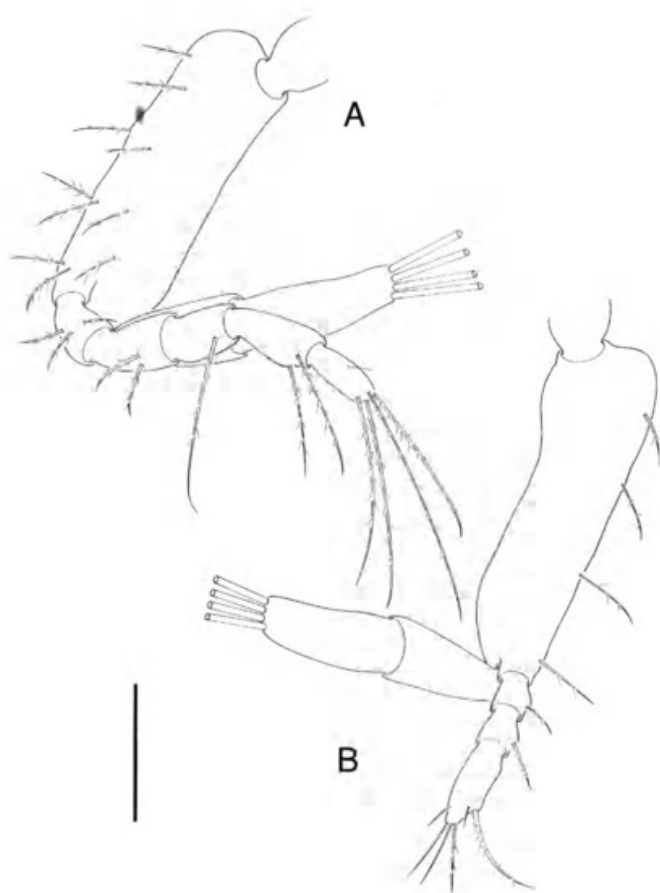


FIG. 24. — *Palapedia valentini* Ng, 1993: zoea I; **A**, first maxilliped; **B**, second maxilliped. Scale bar: 0.1 mm.

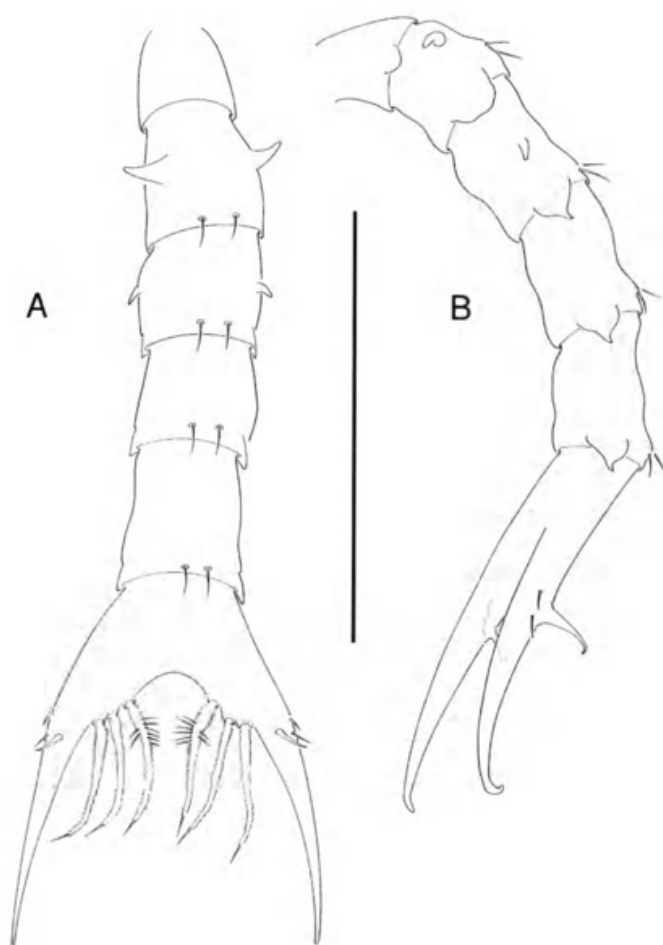


FIG. 25. — *Palapedia valentini* Ng, 1993: zoea I, abdomen; **A**, dorsal view; **B**, lateral view. Scale bar: 0.5 mm.

## DISCUSSION

Serène (1984) listed seven genera, *Atergatopsis*, *Atergatis*, *Paratergatis*, *Zozymodes*, *Platypodia*, *Zosimus* and *Lophozozymus* assigned to the Zosiminae, but until now the only genus for which the zoeal development is known for this xanthid subfamily is *Atergatis* from the description by Terada (1980) of *A. reticulatus*. From his figures (1-3, D1-D4), Terada (1980) overlooked a number of characters described in this present study including dorsal carapace setation, setation of the ventral carapace margin, the mandibular palp and the third maxilliped. Nevertheless, a comparison between the four zoeal stages of *A. reticulatus* and *L. pictor* is useful (see Table 1). However, speculating on zoeal subfamilial characters from only these two accounts of this taxon would be misleading.

Of the twelve subfamilies now attributed to the Xanthidae MacLeay, 1838 *s.str.* (Serène 1984; Ng 1993; Ng & Chia 1994), the zoea of six are known and these include Chlorodiinae Alcock, 1898; Xanthinae MacLeay, 1838; Zosiminae Alcock, 1898; Actaeinae Alcock, 1898; Euxanthinae Alcock, 1898 and Kraussinae Ng, 1993. One first stage zoea that meets modern day descriptions was selected to represent each of these subfamilies, *Pilodius nigrocrinitus* by Terada (1982); *Xantho incisus* by Ingle (1991); *Lophozozymus pictor* from this present study; *Gaillardielliellus orientalis* by Ng & Clark (1994); *Monodaeus couchi* by Ingle (1991) and *Palapedia valentini* by Ng (1993).

From the selected first zoea, only the endopod of the second maxilliped of *Monodaeus couchi* was re-examined because Ingle (1991: 235) described the distal segment of the endopod as "4 + 1

TABLE 1. — A list of characters that may separate the zoea of *Atergatis reticulatus* (from Terada 1980) and *Lophozozymus pictor* (from this present study).

	<i>A. reticulatus</i>	<i>L. pictor</i>
Antennule appearance of endopod	ZIV (fig. 2D4)	ZIII (Fig. 2C)
Antenna spinulation of protopod	present (fig. 2D'1-D'4)	absent (Fig. 8A, C, E, G)
Maxillule setation of coxal endite	ZII 7; ZIII 8 (fig. 2D''2, D''3)	ZII 8; ZIII 9 (Fig. 9B, C)
setation of basal endite	ZIII 9 (fig. 2D''3)	ZIII 11 (Fig. 9C)
Maxilla setation of coxal endite	ZIV 6 + 4 (fig. D'''4)	ZIV 5 + 4 (Fig. 21)
setation of basal endite	ZIV 6 + 7 (fig. D'''4)	ZIV 5 + 7 (Fig. 21)
Abdomen setation of somite 1	ZII 0; ZIII 0; ZIV 0 (fig. 3, D2-D4)	ZII 1; ZIII 3; ZIV 3 (Figs 13A, C; 22A)
Telson dorsal medial setation	ZIV 0 (fig. 3, D4)	ZIV 1 pair (Figs 22A; 26A)
posterior medial setation	ZII 0; ZIII 3; ZIV 4	ZII 2; ZIII 6; ZIV 8
of posterior margin	(fig. 3, D2-D4)	(Figs 13B, C; 15B, C; 22A; 26A)

(sometimes 5 + 1) setae". The distal segment was confirmed as 5 + 1 setae or, as recorded in this study for *Lophozozymus pictor*, 3 subterminal + 3 terminal setae. The above first stage zoeas share the same chaetotaxy for the following appendages: maxillule, maxilla, first maxilliped, second maxilliped and the somites of the abdomen. Table 2 lists these appendages with a description of their chaetotaxy and segmentation. Used in combination, these characters may define the Xanthidae MacLeay, 1838 *s.str.* Zoeal features not shared by these species are the antennal morphology, configuration of carapace spines and setation and armature of the telson forks. It is these features that may provide characters for the Xanthidae at subfamilial level.

Recently Ng (1993) established a new Xanthidae subfamily, Kraussiinae. He described the first stage zoea for one of the species assigned to this new taxon, *Palapedia valentini* and suggested (Ng 1993: 149) that several peculiar zoeal features supported the establishment of a new subfamily. These characters included the setal

formula of the first maxilliped basis and the first endopod segment of the first maxilliped. Two extant first stage zoea from the original study were dissected, the appendage characters reappraised, redescribed and figured in this present study. A number of zoeal characters were overlooked or misinterpreted by Ng (1993, fig. 5A) including absent dorsal carapace setation which are present (this study, Fig. 22A); absent (Ng 1993, fig. 5C) small terminal seta on the antennule which is present (this study, Fig. 22B); coxal setation of the maxilla with 5 + 2 (Ng 1993, fig. 5F) instead of 4 + 4 (this study, Fig. 23B); basal formula of the first maxilliped with 7 (2, 1, 2, 2) setae (Ng 1993, fig. 5H) instead of 10 (2, 2, 3, 3) (this study, Fig. 24A); first endopod segment setation of the first maxilliped with two setae (Ng 1993, fig. 5H) instead of three (this study, Fig. 24B); distal endopod segment setation of the second maxilliped with five (Ng 1993, fig. 5I) setae instead of six (this study, Fig. 24B) and the lateral processes on abdominal somites 1, 2 (Ng 1993, fig. 5K) instead of somites 2, 3 (this

TABLE 2. — A list of first stage zoeal characters that, used in combination, may define the Xanthidae MacLeay, 1838.

<b>Carapace</b>	1 pair of posterodorsal setae ventral carapace margin devoid of spines
<b>Antennule</b>	uniramous, endopod absent
<b>Mandible</b>	palp absent
<b>Maxillule</b>	coxal endite with 7 setae basal endite with 5 setal processes and 2 small teeth endopod 2-segmented, proximal segment with 1 seta distal segment with 5 (2 subterminal, 4 terminal) setae exopod seta absent
<b>Maxilla</b>	coxal endite bilobed with 4 + 4 setae basal endite bilobed with 5 + 4 setae endopod bilobed, with 3 + 5 (2 subterminal and 3 terminal) setae exopod (scaphognathite) margin with four setae and one long distal stout process
<b>First maxilliped</b>	basis with 10 setae arranged 2, 2, 3, 3 endopod 5-segmented with 3, 2, 1, 2, 5 (1 subterminal and 4 terminal) setae respectively exopod 2-segmented, distal segment with four long terminal plumose natatory setae
<b>Second maxilliped</b>	basis with 4 setae endopod 3-segmented, with 1, 1, 6 (3 subterminal and 3 terminal) setae respectively exopod 2-segmented, distal segment with 4 long terminal plumose natatory setae
<b>Third maxilliped</b>	absent
<b>Pereiopods</b>	absent
<b>Abdomen</b>	5 somites somite 2 with 1 pair of lateral processes directed anteriorly somite 3 with 1 pair of lateral processes directed posteriorly somites 2-5 with 1 pair of posterodorsal setae pleopod buds absent
<b>Telson</b>	posterior margin with 3 pairs of stout spinulate setae

study Fig. 25A, B). In fact the setal armature of *Palapedia valentini*, especially with respect to the chaetotaxy of the first maxilliped, does not differ from other Xanthidae as listed in table 2.

Martin (1984, fig. 1) figured features for six groups of xanthid zoeas and the first stage zoeal appendages of *Palapedia valentini* agree with all eight characters defining his group I which include (Martin 1984: 221): (1) dorsal, rostral and carapace spines all well-developed; (2) the rostral spine and the antennal protopod are approximately equal in length; (3) a reduced exopod with two short terminal setae; (4) two subterminal and four terminal setae on the distal segment of

the maxillule endopod; (5) eight setae on the endopod of the maxilla; (6) basal endopod segment of first maxilliped with three setae; (7) basal endopod segment of second maxilliped with a single seta; and (8) dorsolateral knobs (spines) on abdominal segments (somites) 1 and 2. *Lophozozymus pictor* first stage zoea conform to seven of Martin's eight group I characters. However, the definition by Martin (1984) of the antennal exopod character for his xanthid group I, "Antennal exopod reduced [...] never armed with more than two short terminal setae", is ambiguous. *Lophozozymus pictor* possesses one long subterminal seta in addition to the two

short terminal setae and therefore it is unclear whether this species would be placed by Martin in his xanthid group 1.

Rice (1980: 325) recognized three types of xanthid antennal exopod: (1) a rudimentary exopod with one or two terminal setae or unarmed; (2) an exopod subequal to or longer than spinous process and with a seta more or less midway along its length and (3) an exopod one third-one quarter the length of the spinous process with two or three terminal setae. The antennal exopod of *Palapedia valentini* conforms to definition (1), however, that of *Lophozozymus pictor* cannot be assigned to any of the xanthid criteria defined by Rice.

Current evidence suggests that the antennal exopod is not a zoeal character to define the Xanthidae MacLeay, 1838 (*sensu* Serène 1984) and its significance at subfamilial level remains unclear. The presence of two terminal setae on the antennal exopod is of interest, but the importance of this zoeal character within the Kraussiinae Ng, 1993, has yet to be established.

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