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Two new *Byrathis* species (Copepoda: Calanoida) from the deep South Atlantic and Southern Ocean and first description of an adult male

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Abstract

Two new species, *Byrathis divae* **sp. nov.** and *B. penicillatus* **sp. nov.,** are described from females collected in the deep waters and at abyssal depths above the sea bed, and are the first representatives of the genus recorded from the South Atlantic. Species of *Byrathis* Markhaseva & Ferrari, 2005 are divided into 2 groups. The first group, which includes both new species, contains medium sized copepods (from 2.1 to 4.9 mm) with a nude genital double somite, maxillule proximal basal endite with 3 setae, maxillule exopod with 6 or more setae, and maxilla endopod with 3 worm-like and 5 brush-like sensory setae. The second group contains small species (less than 1.4 mm) that share the surface ornamentation of the genital double somite, maxillule proximal basal endite with 2 setae, maxillule exopod with 5 setae or less, and maxilla endopod with 5 worm-like plus 3 brush-like sensory setae. For the first time an adult *Byrathis* male is described after *Byrathis arnei* Schulz, 2006 from the Southern Ocean. Among males of Clausocalanoidea that possess sensory setae on maxilla and maxilliped, the *Byrathis* male is well defined by symmetric antennules (ancestral segments XXII–XXIII fused on both sides) and poorly expressed P5 coxa and basis asymmetry, with both exopods 3-segmented and the right leg uniramous.

Key words: Clausocalanoidea, Diaixidae, calanoids, taxonomy, benthopelagic, zoogeography

Introduction

The near-bottom calanoid copepod fauna from the deep-sea habitats is still poorly known, but our knowledge of the biodiversity of this habitat slowly increases with the increasing number of benthopelagic collections (Bradford-Grieve 2004 and references therein). Each new deep-sea expedition adds new information on the diversity of the near-bottom calanoid copepods, e.g. in recent DIVA cruises rich calanoid collections were obtained by an epibenthic sledge (Brenke, 2005). Processing of these samples is still in progress and, while numerous new species and genera have already been described (Markhaseva *et al*. 2008; Markhaseva & Schulz 2009, 2010), a great number of new taxa still awaits description. Studied samples contain deep water benthopelagic calanoid genera, all of which are usually low in abundance. New findings in the South Atlantic are registered for ten near-bottom genera: *Paramisophria* T. Scott, 1897, *Lamiantennula* Markhaseva & Schulz, 2006, *Alrhabdus* Grice, 1973, *Bradyetes* Farran, 1905, *Pseudotharybis* T. Scott, 1909, *Parkius* Ferrari & Markhaseva, 1996, *Omorius* Markhaseva & Ferrari, 2005, *Brodskius* Markhaseva & Ferrari, 2005, *Sensiava* Markhaseva & Schulz, 2006 and among these also the genus *Byrathis*.

Recent studies of the benthopelagic copepod fauna showed that the deep-water calanoid genus *Byrathis* is widespread. Members of this genus were found in the vicinity of the sea bed at depths between 1535 and 3022 m in the western North Atlantic and North Pacific, and in the Arctic and Southern oceans (Grice & Hulsemann 1970; Markhaseva 1998; Markhaseva & Ferrari 2005; Schulz 2006). Herein are given first records from the South Atlantic, and at the same time from the greatest depths registered for the genus (5415m). Two new species of *Byrathis* are found in the collections of the German expeditions DIVA–I, DIVA–II and DIVA–III (Latitudinal Gradients of

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Deep-Sea Biodiversity in the Atlantic Ocean) obtained in the years 2000, 2005, and 2009 in the abyss of the South Atlantic, and in ANDEEP II–III (ANTarctic benthic DEEP-sea biodiversity) samples collected in 2002 and 2005 in the Southern Ocean. *Byrathis* now includes an unnamed female specimen (Markhaseva & Ferrari 2005) and 7 named species, including 2 new species described here and *B. arnei* Schulz, 2006; *B. laurenae* Markhaseva & Ferrari, 2005; *B. laptevorum* (Markhaseva, 1998); *B. macrocephalon* (Grice & Hulsemann, 1970); *B. volcani* Markhaseva & Ferrari, 2005.

In the sample from the near-bottom collected by a closing epibenthic sledge in 2008 by the German expedition ANDEEP-SYSTCO in the Southern Ocean at a depth of 2152 m we have found 12 females and 9 males of *B. arnei*, the first male specimens found for the genus.

Material and methods

Female specimens of the new species of *Byrathis* were collected during the RV Meteor expeditions DIVA–I, DIVA–II and DIVA–III in 2000, 2005 and 2009 and by RV Polarstern in ANDEEP II–III expeditions in 2002 and 2005. Samples were collected close to the sea bed in the abyss of the tropical Atlantic at depths between 4482 and 5415 m, and in the Southern Ocean between 2965 and 4743 m by a closing epibenthic sledge (Brenke 2005). Male specimens of the genus were found in the sample collected during the ANDEEP-SYSTCO expedition in 2008 at 64°29'S 02°53'E, at a depth of 2152 m. Specimens were fixed in 96% ethanol and later stained by adding a solution of chlorazol black E dissolved in 70% ethanol/30% water. Oral parts and swimming legs were dissected in glycerine and figures were drawn using a *camera lucida*.

Type material and additional specimens are deposited in the Zoological Museum Hamburg (ZMH) and the Zoological Institute, Russian Academy of Sciences, St. Petersburg (ZIN).

The following abbreviations are used in the descriptions: P1–P5, swimming legs 1–5. Arcticulating segments of the antennules are designated by Arabic numerals, ancestral segments by Roman numerals. One seta and 1 aesthetasc on a segment of the antennule are designated: 1s + 1ae; "1?" indicates that a setal element was broken so that its identity on the antennule could not be determined and only the scar at its former position was counted. Maxilla segments are labeled considering Ferrari and Ivanenko 2008 (previously used terms are given in parenthesis for easier understanding) and the syncoxa of the maxilliped is considered to have 3 praecoxal endites and 1 coxal endite (Ferrari and Markhaseva 2000a,b; Ferrari and Ivanenko 2001).

PanMap software is used to show distribution of *Byrathis* http://www.pangaea/de/Software/PanMap (Diepenbroek, Grobe & Sieger 2000).

Taxonomy

Superfamily Clausocalanoidea Giesbrecht, 1893

Family Diaixidae Sars, 1902

Genus *Byrathis* Markhaseva & Ferrari, 2005

Byrathis divae sp. nov.

(Figs 1–4, 9)

Holotype. Dissected adult female, body length 2.39 mm. ZMH Reg. no. K–41630. Collected on 28 July 2000 by the DIVA–I expedition above the sea bed at abyssal depths (5390 m).

Paratypes, body length 2.23–2.47 mm. ZMH Reg. no. K–41631, 9 adult females, the same label data as for the holotype; ZIN–91092, 8 adult females. Collected 25 July 2000 by the DIVA–I expedition in the South Atlantic (17º06.2'S 04º41.7'E), above the sea bed at abyssal depth (5415 m). Additional material: 9 females, body length 2.10–2.30 mm, collected in the South Atlantic from the equator to about 41ºS between 05ºW–09ºE at depths from 4469 to 5395 m and 6 females, body length 2.00–2.28 mm, found in the Southern Ocean between about 58º–65ºS and 24º–51ºW at depths from 2965 to 4748 m.

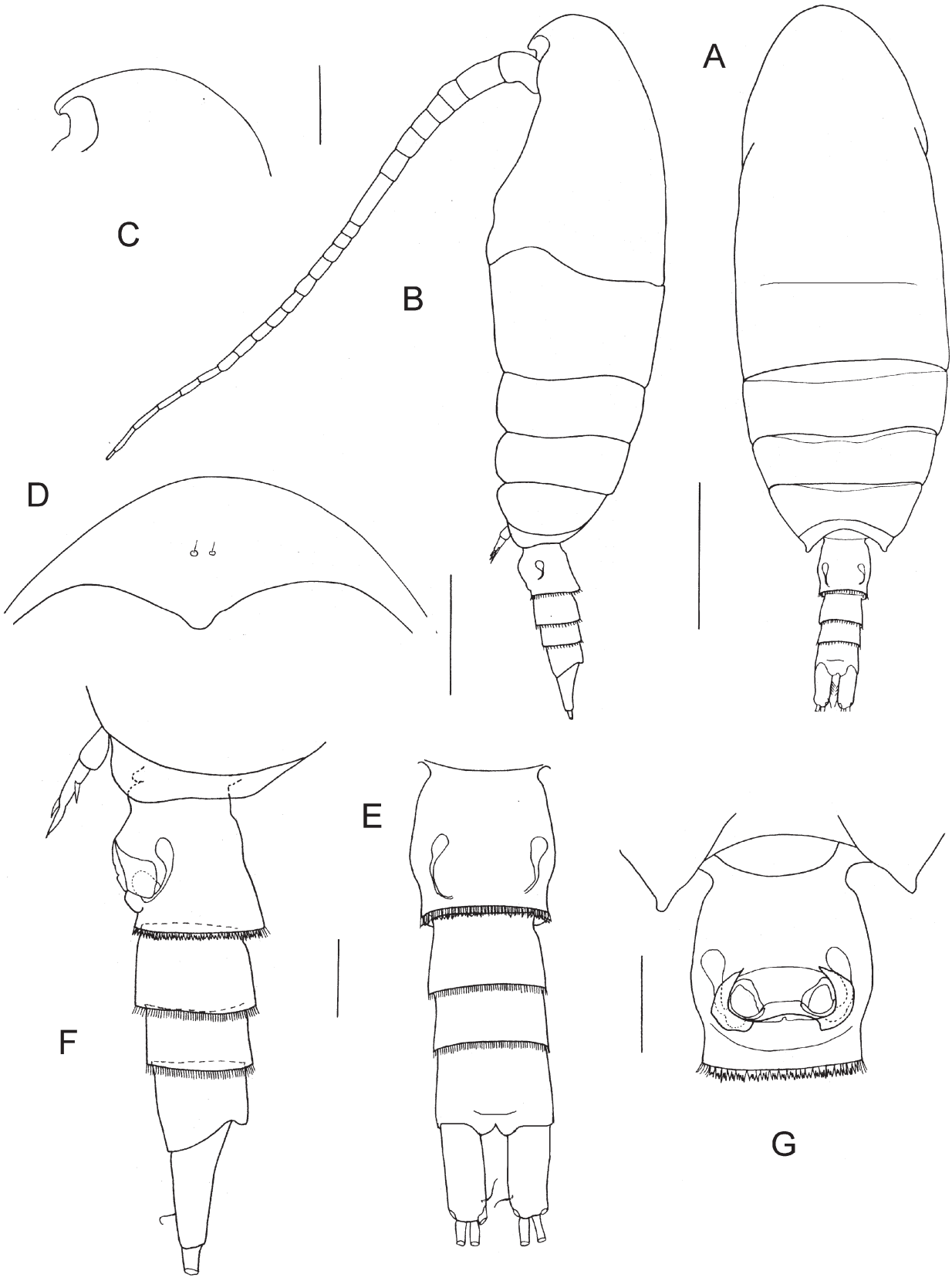

FIGURE 1. *Byrathis divae* **sp. nov.** Female, holotype. A, habitus, dorsal view; B, habitus, lateral view; C, rostrum, lateral view; D, rostrum, anteroventral view; E, urosome, dorsal view; F, posterior prosome and urosome, lateral view; G, posterior prosome and genital double somite, ventral view. Scale bars: A–B 0.5 mm, C–G 0.1 mm.

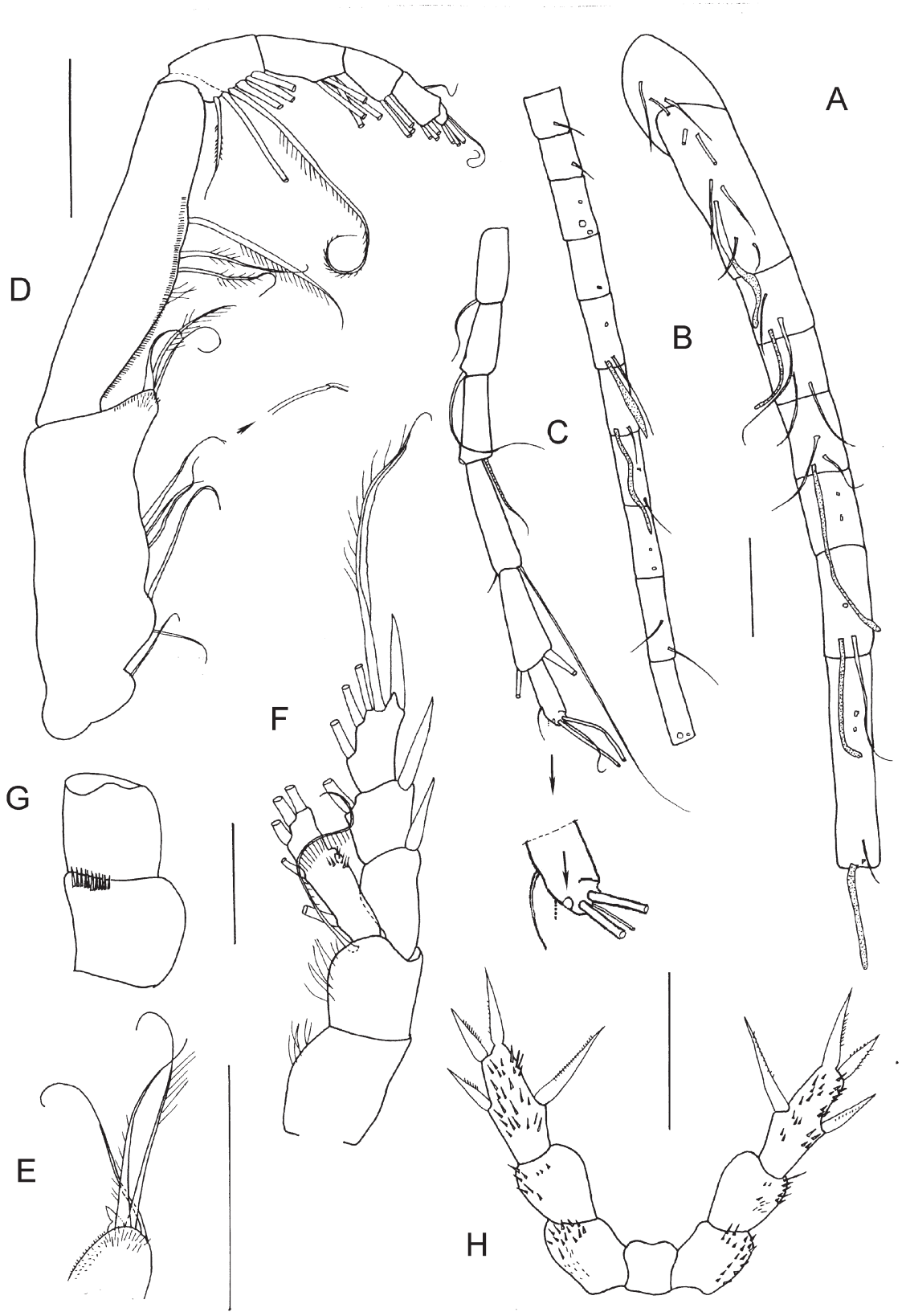

FIGURE 2. *Byrathis divae* **sp. nov.** Female, A, antennule, articulating segments 1–8 (ancestral segments I–XI); B, antennule, articulating segments 9–18 (ancestral segments XII–XXI); C, antennule, articulating segments 19–24 (ancestral segments XXII–XXVIII); D, maxilliped; E, maxilliped, distal part of coxal endite of maxilliped syncoxa; F, P1, posterior; G, P1, coxa and basis, anterior surface; H, P5. Arrows mark enlarged distal part of segment XXVII–XXVIII and scar for aesthetasc. A–D, F, H, holotype; E, paratype. Scale bars 0.1 mm.

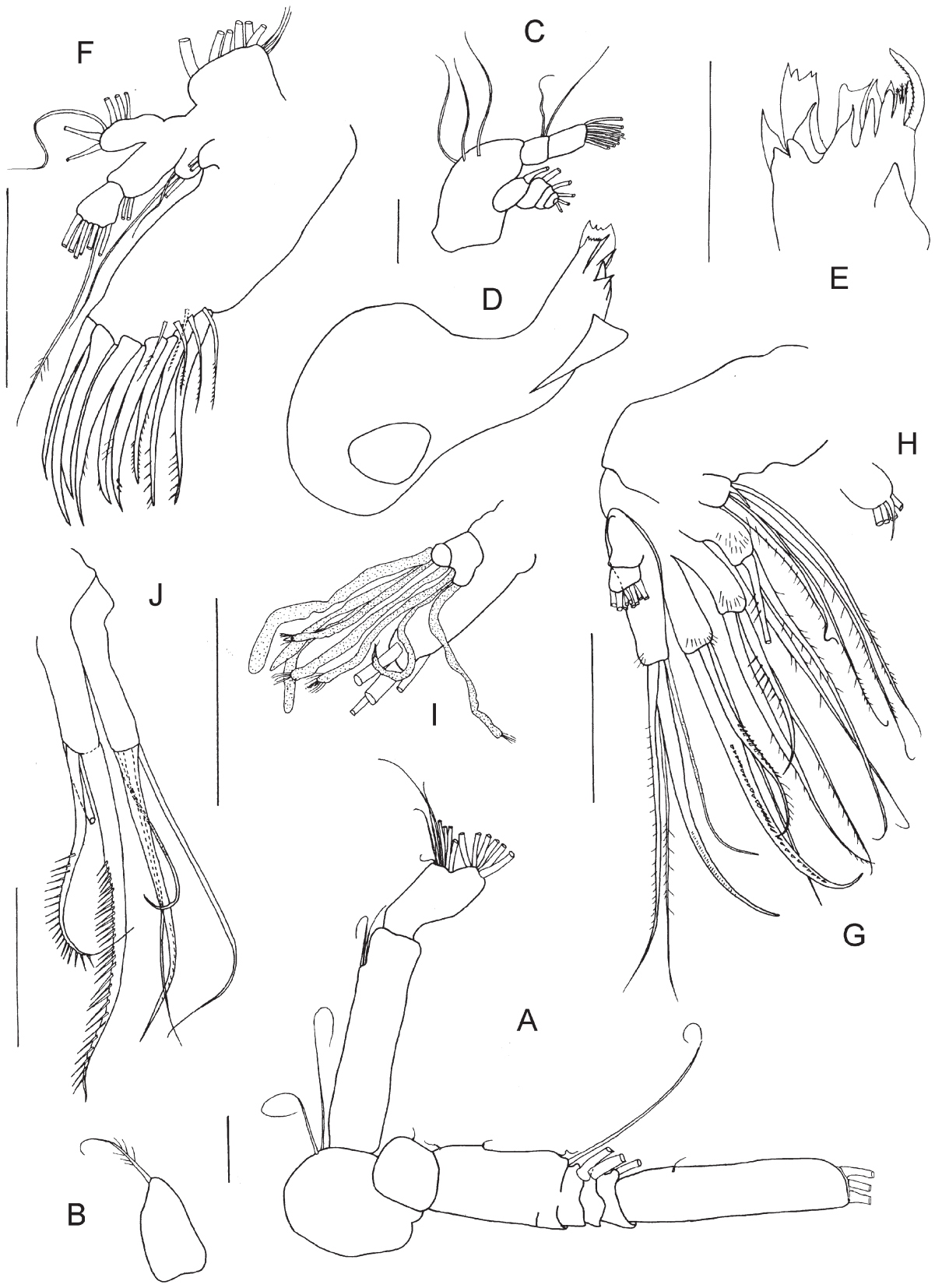

FIGURE 3. *Byrathis divae* **sp. nov.** Female: A, antenna, basis, endo- and exopod; B, antenna, coxa; C, mandiular palp; D, mandibular gnathobase; E, mandibular gnathobase, cutting edge; F, maxillule; G, maxilla, sensory setae of endopod are not figured; H, maxilla praecoxal endite; I, maxilla, endopod, sensory setae; J, maxilla, distal basal endite (previously considered as distal coxal endite) and enditic-like lobe of proximal endopodal segment (previously considered as proximal basal endite). A, C–D, F–G, I, holotype; B, E, H, J, paratype. Scale bars 0.1 mm.

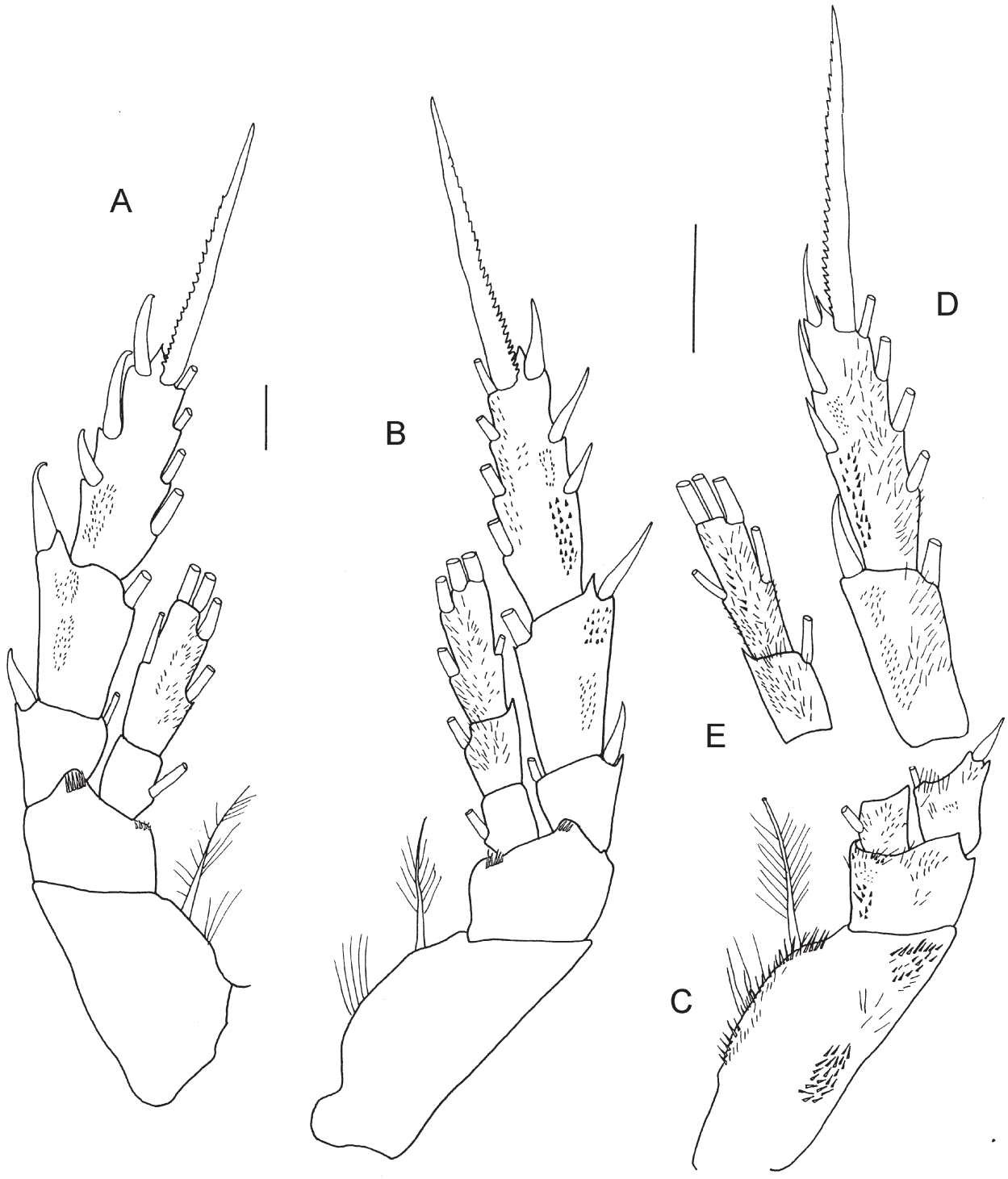

FIGURE 4. *Byrathis divae* **sp. nov.** Female, holotype; A, P2; B, P3, C, P4, coxa, basis, exopod and endopod segment 1; D, P4 exopod segments 2–3; E, P4 endopod segments 2–3. Scale bar 0.1 mm.

Type locality. South Atlantic (16º18'S 05º27'E).

Description. Female. Body length 2.10–2.47 mm. Prosome 2.8–3.3 times as long as urosome (Fig. 1A–B). Rostrum absent (Fig. 1C–D). Cephalosome and pedigerous somite 1 and pedigerous somites 4 and 5 separate; posterior corners as short rounded lobes in lateral view, obtuse triangular in dorsal view (Fig. 1F–G). Urosome of 4 somites (Fig. 1E). Caudal rami with 1 dorsal seta (later broken in studied specimens), 1 ventral seta, and 4 terminal setae.

Antennule (Fig. 2A–C) extending to distal margin of urosomal somite 3–4, of 24 articulating segments; armature as follows: I–3s, II–IV–6s + 1ae, V–2s + 1ae, VI–2s , VII–2s + 1ae, VIII–2s, IX–2s + 1ae, X–XI–4s + 1ae, XII–1s, XIII–1s, XIV–2s + 1ae, XV–1s, XVI–2s + 1ae, XVII–1s + 1ae (or 2s), XVIII–2s, XIX–2s, XX–2s, XXI–1s + 1ae, XXII–1s, XXIII–1s, XXIV–2s, XXV–2s, XXVI–2s, XXVII–XXVIII–5s + 1ae (setation on Fig. 2A–C is based on the holotype and supplemented considering the paratypes and additional females).

Antenna (Fig. 3A–B), coxa with 1 seta, basis with 2 setae; exopod of 7 segments with 1, 1-1-1-1, 1, 1, 1, 1, and 3 setae, seta on proximal exopod segment rudimentary, following complex segment with 3 rudimentary setae, and is partly fused with first short segment bearing long seta; first endopodal segment with 2 setae, second with 8 + 6 setae.

Mandible (Fig. 3C–E), gnathobase with crest, cutting edge with 5 large and 3 small teeth near thick dorsal seta; basis with 3 setae; exopod 5-segmented with 1, 1, 1, 1, and 2 setae; endopod segment 1 with 2 setae, segment 2 with 8 long and 1 short setae.

Maxillule (Fig. 3F), praecoxal arthrite with 9 marginal, 4 posterior and 1 anterior setae; coxal endite with 2 setae; coxal epipodite with 6 long and 3 short setae; proximal basal endite with 3 setae, distal basal endite with 2 setae; endopod with 7 setae; exopod with 6–7 setae.

Maxilla (Fig. 3G–J), praecoxal endite (previously considered as proximal praecoxal endite) with 4 setae and a short attenuation; coxal endite (previously considered as distal praecoxal endite) with 3 setae; basal endites (previously considered as coxal endites) with 3 setae each, 1 seta of distal basal endite thicker, spine-like; enditic-like lobe of proximal endopodal segment (previously considered as proximal basal endite) with 4 setae, 1 is thicker and 1 is partly sensory; endopod with 3 worm-like and 5 poorly developed brush-like sensory setae.

Maxilliped (Fig. 2D–E), syncoxa with 1 seta on proximal praecoxal lobe, 2 setae on middle praecoxal endite and 2 sclerotized setae and 1 poorly developed brush-like seta on distal praecoxal endite; coxal lobe with 3 setae and small attenuation. Basis with 3 setae. Endopod 6-segmented with 2, 4, 4, 3, 3+1, and 4 setae.

Swimming legs. P1 (Fig. 2F–G), coxa with anterior row of spinules along distolateral margin; basis with medial distal seta curved with setules; endopod 1-segmented with lateral lobe, its lateral margin with spinules; exopod segments 1 to 3 with 1 lateral spine each, spine of segment 1 the shortest, exceeding base of following spine; spine of exopod segment 2 exceeding base of distal-most spine. P2–P4 (Fig. 4A–D), coxa with 1 seta; basis without seta; endopod 2-segmented in P2, 3-segmented in P3–P4; exopods 3-segmented. Posterior surfaces of P2–P3 poorly spinulate, of P4 densely spinulate.

P5 (Fig. 2H) 3-segmented, coxa and basis of equal length; coxa and basis with distolateral patch of spinules, exopod ornamented with rare surface spinules, 3 distal spines and terminal attenuation.

Etymology. The species name "*divae*" refers to the name of the DIVA expeditions where the studied specimens were obtained.

Remarks. Some specimens from the Antarctic samples differ from those of the type series in setation details of antennule and oral parts: i) distal segment of antennule (XXVII–XXVIII) bears 5s +1 ae (vs. 4s + 1ae in type specimens); ii) maxillule distal basal endite with 3 setae (vs. 2 setae in type specimens), and iii) seta of the medial praecoxal endite of maxilliped syncoxa exceeding coxal endite (seta is shorter in type specimens).

Byrathis divae **sp. nov.** shares with *B. penicillatus* **sp. nov.** and *B. laptevorum* the following feautres: i) size usually more than then 2.10 mm (*vs.* size less than 1.40 mm in the other congeners); ii) surface of genital double somite without denticles (*vs.* surface ornamented with denticles in the other congeners); iii) maxillule proximal basal endite with 3 setae (*vs.* 2 setae in the other congeners); iv) maxillule exopod with 6 setae or more (*vs.* with 5 setae or less in other congeners), and v) maxilla endopod with 3 worm-like (1 worm-like in *B. laptevorum*) and 5 brush-like sensory setae (*vs.* 5 worm-like and 3 brush-like setae in the other congeners).

Byrathis divae **sp. nov.** differs from *B. penicillatus* **sp. nov.** and *B. laptevorum* in: i) smaller size (2.10–2.47 mm *vs.* 2.70 mm in *B. laptevorum* and 3.20–4.90 in *B. penicillatus* **sp. nov.**); ii) rounded posterior corners of prosome (*vs.* sharp triangular in *B. laptevorum* and *B. penicillatus*; iii) rostrum absent (*vs.* rostral filaments present in *B. penicillatus* **sp. nov.** and *B. laptevorum*), and iv) poorly developed brush-like seta in the distal praecoxal setal group of the maxilliped syncoxa (*vs.* well developed brush-like seta in *B. penicillatus* **sp. nov.** and *B. laptevorum*).

***Byrathis penicillatus* sp. nov.**
(Figs 5–9)

Holotype. Partly dissected adult female, body length 4.05 mm. ZMH Reg. no. K–42157. Collected on 15 March 2005 by the DIVA–II expedition above the sea bed at abyssal depths (5058 m).

Paratypes, 1 partly dissected adult female, body length 3.95 mm. ZMH Reg. no. K–42158. Collected on 15 March 2005 by the DIVA–II expedition above the sea bed at abyssal depths (5050 m) in the South Atlantic (00º08.5'S 02º30.2'W); 1 partly dissected adult female, body length 3.35 mm. ZIN–91103. Collected 23 July 2009 by the DIVA–III expedition in the South Atlantic (26º35'S 35º14'W), above the sea bed at abyssal depths (4482–4489 m). Additional material: 4 females, body length 3.20–4.90 mm, collected in the South Atlantic from the equator to about 36ºS at depths from 4601 to 5395 m.

Type locality. South Atlantic (00º01.2'S, 02º28.7'W).

Description. Female. Body length 3.35–4.90 mm. Prosome 3.7–4.1 times as long as urosome. Rostrum as a triangular plate with 2 filaments (Fig. 5C–D). Cephalosome and pedigerous somite 1 and pedigerous somites 4 and 5 partly separate; posterior corners sharply triangular in dorsal and lateral view (Fig. 5A–B, E–G). Urosome of 4 somites. Caudal rami with 4 terminal setae, 1 ventral seta and 1 small dorsolateral seta (Fig.5E–F).

Antennule (Fig. 6A–C) extending to distal margin of pedigerous somites 4–5, of 24 articulating segments; armature as follows: I–3s, II–IV–6s + 1ae, V–2s + 1ae, VI–2s , VII–2s + 1ae, VIII–1s+1?, IX–2s + 1ae, X–XI–4s + 1ae, XII–1?, XIII–1?, XIV–2s + 1ae, XV–1?, XVI–2s + 1ae, XVII–1?, XVIII–2?, XIX–1?, XX–2?, XXI–1s + 1ae, XXII–1?, XXIII–1s, XXIV–1s + 1?, XXV–2s, XXVI–2s, XXVII–XXVIII–4s + 1ae, (setation on Fig. 6A–C is given for segments II–IV, VI, VII, IX–XI, XIV, XVI and XXIII after the holotype and supplemented from the paratypes).

Antenna (Fig. 6D), coxa with 1 seta, basis with 2 setae; exopod of 7 free segments with 1, 1-1-1-1, 1, 1, 1, 1, and 3 setae, seta on proximal exopod segment rudimentary, following complex segment with 3 rudimentary setae, partly fused with first short segment bearing long seta; first endopodal segment with 2 setae, second with 8 + 7 setae.

Mandible (Fig. 6E–G), gnathobase with crest, number of teeth on cutting edge of holotype difficult to follow, paratype bearing 4 large and 3 small teeth near dorsal seta, lateral tooth situated apart from the remaining teeth; basis with 3 setae; exopod 5-segmented with 1, 1, 1, 1, and 2 setae; endopod segment 1 with 2 setae, segment 2 with 9 setae and distal rows of small surface spinules.

Maxillule (Fig. 6H–I), praecoxal arthrite with 9 terminal, 4 posterior, and 1 anterior setae; coxal endite with 2 setae; coxal epipodite with 9 setae; proximal basal endite with 3 setae, distal basal endite with 3 setae; endopod with 9 setae; exopod with 8 setae.

Maxilla (Fig. 7A–C), praecoxal endite (previously considered as proximal praecoxal endite) with 4 setae and a short attenuation; coxal endite (previously considered as distal praecoxal endite) with 3 setae; basal endites (previously considered as coxal endites) with 3 setae each, 1 seta on the proximal basal endite very short, 1 seta on distal basal endite very strong, spine-like, enditic-like lobe of proximal endopodal segment (previously considered as proximal basal endite) with 4 setae, 1 is thicker and 1 is sensory; all endites with a patch of long spinules at the base of the setae; endopod with 3 worm-like and 5 brush-like sensory setae: 2 setae shorter with large brushes, 3 setae longer with smaller brushes.

Maxilliped (Fig. 7D), syncoxa with 1 seta and a row of spinules on proximal praecoxal endite, 2 setae (1 sensory in distal part) and a patch of spinules on the middle endite and 2 sclerotized and 1 large brush-like seta on the distal praecoxal endite; coxal endite with 3 setae. Basis with 3 setae, proximal row of long spinules extended to the proximal basal seta and row of small spinules extended from the proximal to the distal-most basal seta. Endopod 6-segmented with 2, 4, 4, 3, 3+1, and 4 setae.

Swimming legs. P1 (Fig. 8A), coxa with anterior row of spinules along the distal margin; basis with medial distal seta strongly curved with setules; endopod 1-segmented with lateral lobe, its lateral margin with spinules; exopod segments 1 to 3 with 1 lateral spine each, spine of segment 1 reaching base of following spine; spine of exopod segment 2 not reaching the base of distal-most spine. P2–P4 (Fig. 8B–D), coxa with 1 seta; basis without seta; endopod 2-segmented in P2, second segment on posterior surface with patch of long spinules; exopods 3-segmented. Endopods 3-segmented in P3–P4, segment 2 with a patch of long spinules on the posterior surface, segment 3 posterior surface densely spinulate, although with shorter spinules. Posterior surface of P4 coxa, basis and exopod densely spinulate.

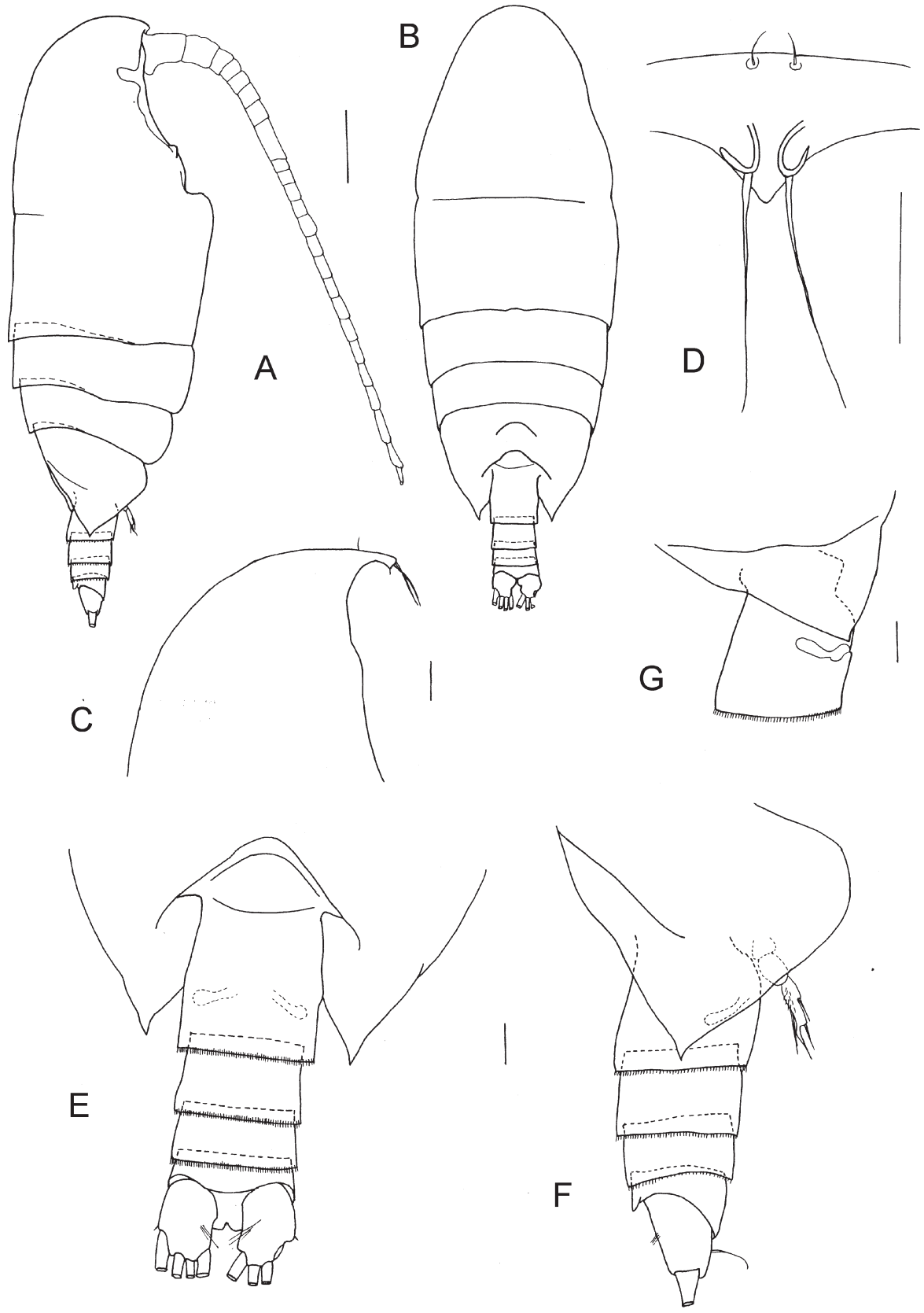

FIGURE 5. *Byrathis penicillatus* **sp. nov.** Female. A, habitus, lateral view; B, habitus, dorsal view; C, rostrum, lateral view; D, rostrum, ventral view; E, posterior prosome and urosome, dorsal view; F, posterior prosome and urosome, lateral view; G, posterior prosome and genital double somite, lateral view. A–B, D, E–F, holotype; C, G, paratype. Scale bars: A, B, 0.5 mm, C–F, 0.1 mm.

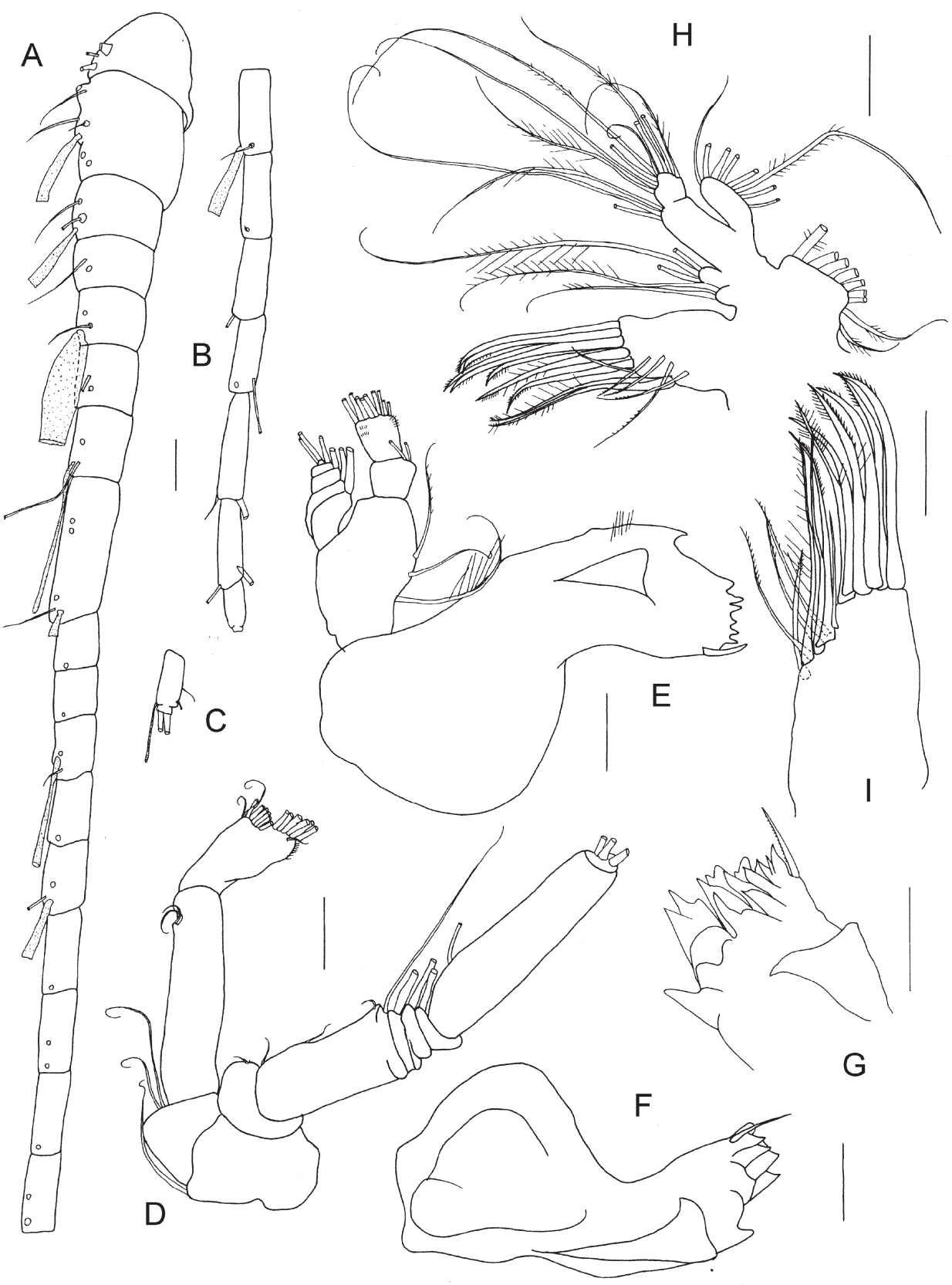

FIGURE 6. *Byrathis penicillatus* **sp. nov.** Female. A, antennule, articulating segments 1–17 (ancestral segments I–XX); B, antennule, articulating segments 18–24 (ancestral segments XXI–XXVIII); C, antennule, segment 24 (ancestral segment XXVII–XXVIII); D, antenna; E, mandible; F, mandible, gnathobase; G, mandible, gnathobase, cutting edge; H, maxillule; I, maxillule, praecoxal arthrite. D, E, H, holotype; A–C, F–G, I, paratype; G, for smaller size (3.35 mm) paratype. Scale bars: 0.1 mm.

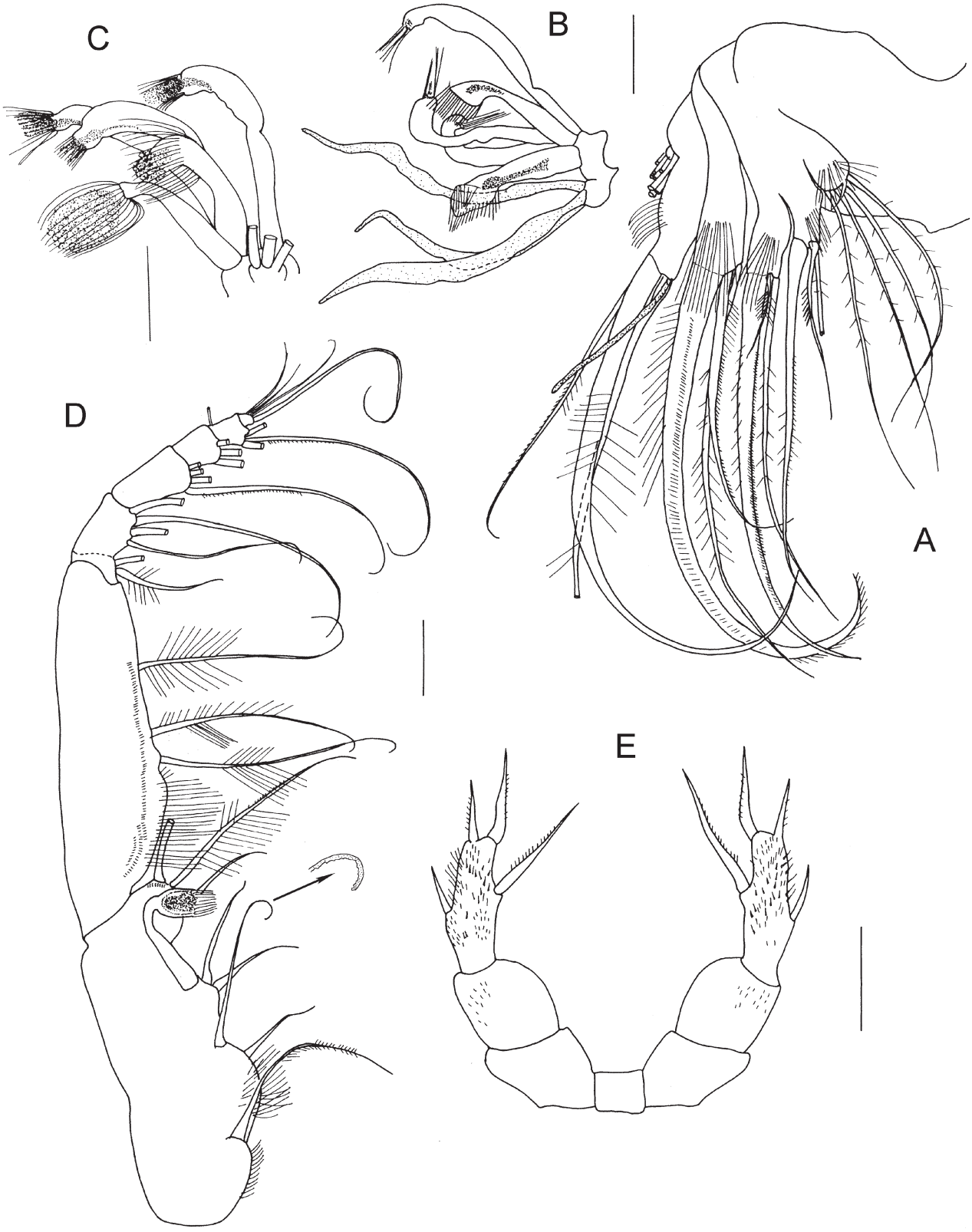

FIGURE 7. *Byrathis penicillatus* **sp. nov.** Female. A, maxilla (sensory setae are not figured); B, maxilla, sensory setae on endopod; C, maxilla, sensory setae on endopod, worm-like setae are not figured); D, maxilliped; E, P5. A, D, holotype; B–C, E, paratype ; C, for smaller size (3.35 mm) paratype. Scale bars 0.1 mm.

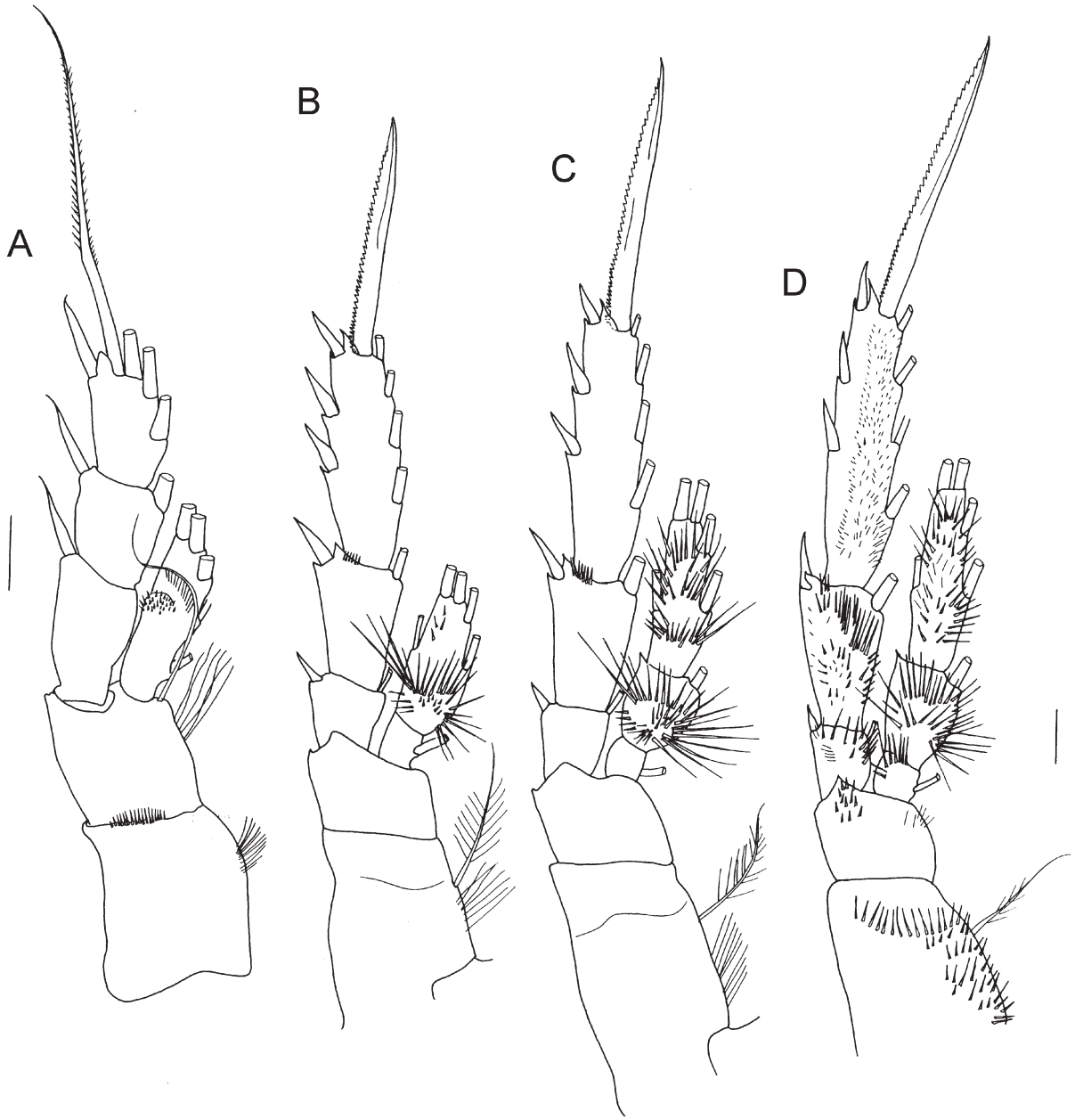

FIGURE 8. *Byrathis penicillatus* **sp. nov.** Female, holotype. A, P1; B, P2; C, P3; D, P4. Scale bars 0.1 mm.

P5 (Fig. 7E) 3-segmented, coxa and basis of equal length; coxa and basis with a patch of minor spinules disto-laterally; exopod ornamented with surface spinules, 4 distal spines, medial terminal spine is curved, about 1.7 times longer than lateral terminal spine.

Etymology. The species name "*penicillatus*" refers to a large brush-like sensory seta on the syncoxa of the maxilliped.

Remarks. *B. penicillatus* **sp. nov.** is more closely related to its most geographically distant congener *B. laptevorum* (Fig. 9) and shares with this species the following distinguishing characters: i) maxilla distal basal endite (previously considered as distal coxal endite) and enditic-like lobe of proximal endopodal segment (previously considered as proximal basal endite), each with 1 very strong, spine-like setal element (*vs.* these setal elements are neither strong nor spine-like in congeners); ii) each maxilla endite with a patch of long surface spinules (*vs.* surface spinule patch is absent in the other species of the genus); iii) medial praecoxal endite of maxilliped syncoxa with a patch of spinules (*vs.* no spinule patch in congeners).

B. penicillatus **sp. nov.** differs from *B. laptevorum* in: i) large brush-like sensory seta on distal praecoxal endite (*vs.* poorly developed brush in *B. laptevorum*); ii) maxilliped basis with a patch of long spinules proximally (*vs.*

spinules absent in *B. laptevorum*), and iii) P5 medial terminal spine curved, about 1.7 times longer than lateral terminal spine (*vs.* straight spine, nearly twice as long as lateral terminal spine in *B. laptevorum*). Maxilla endopod of single known specimen of *B. laptevorum* is described as bearing 1 worm-like sensory seta (*vs.* 3 brush-like setae in *B. penicillatus* **sp. nov.**), but this character should be re-examined for the species when new specimens of *B. laptevorum* are obtained.

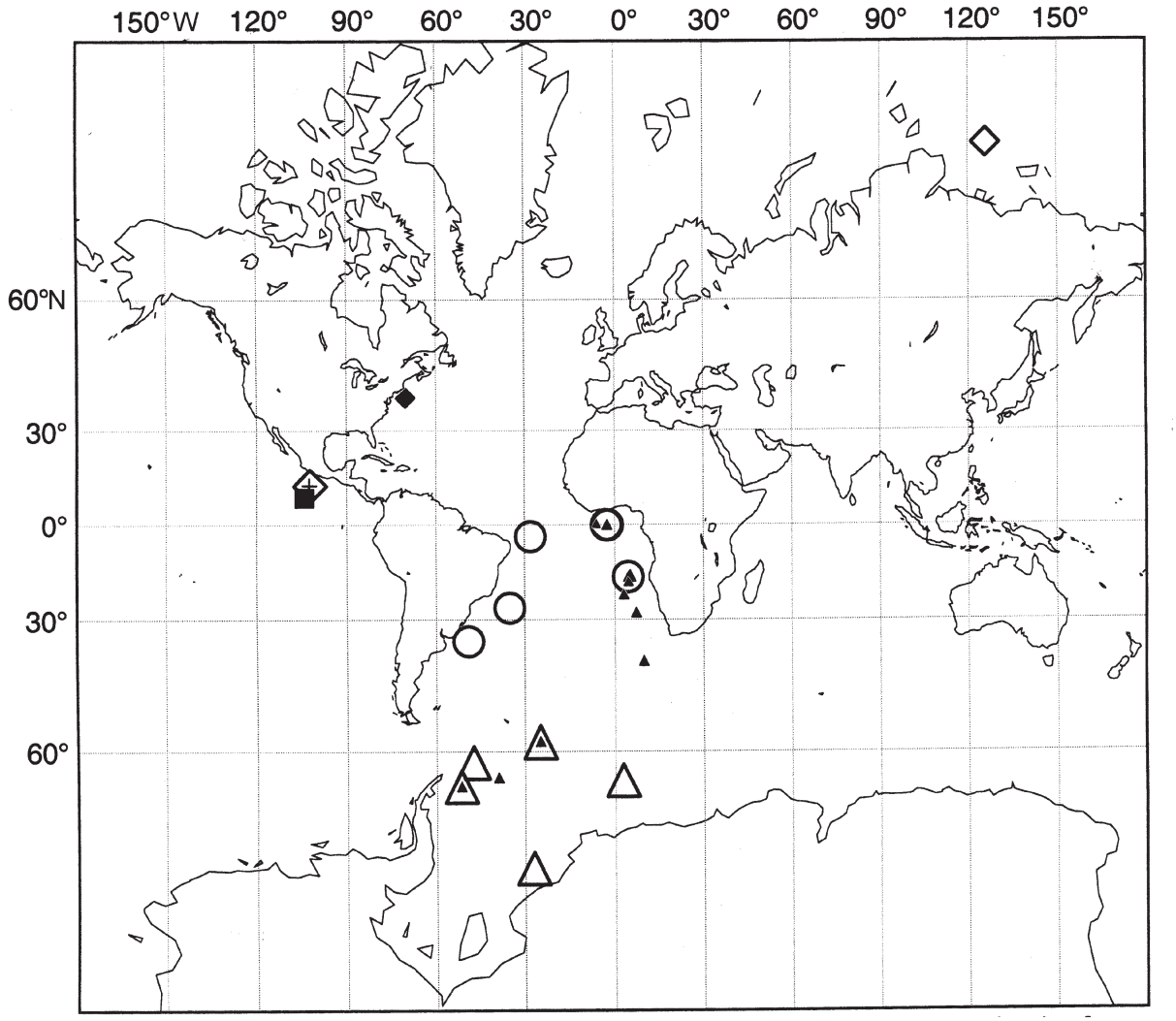

FIGURE 9. Distribution of species of *Byrathis* in the World Ocean: black rhomboid *B. macrocephalon* (Grice & Hulsemann, 1970); circle outlined, *B. penicillatus* **sp. nov.**; black square, *B. laurenae* Markhaseva & Ferrari, 2005; big triangle outlined, *B. arnei* Schulz, 2006; black small triangle, *B. divae* **sp. nov.**; rhomboid outlined, *B. laptevorum* (Markhaseva, 1998); rhomboid outlined with crest, *B. volcani* Markhaseva & Ferrari, 2005.

Byrathis arnei Schulz, 2006

(Figs 10–13)

Material. 12 adult females, body length 1.25–1.35 mm, and 9 adult males, body length 1.40–1.55 mm collected above the sea bed by the ANDEEP–SYSTCO expedition at a depth of 2152 m, on 04 January 2008 in the South Ocean (64º29'S 02º53'E) and 23 adult females, body length 1.33–1.67 mm, from 3 samples obtained by ANDEEP II–III expeditions at depths from 2006 to 3050 m between 58–65ºS and 25–64ºW.

Description. Male. Prosome 2.30–2.75 times as long as urosome. Rostrum a plate with 2 filaments (Fig. 10A). Cephalosome and pedigerous somite 1 fused, pedigerous somites 4 and 5 separate; posterior corners rounded. Urosome of 5 somites, anal segment very short (Fig. 10A–B). Caudal rami with 4 terminal setae, 1 ventral seta and 1 dorsolateral seta.

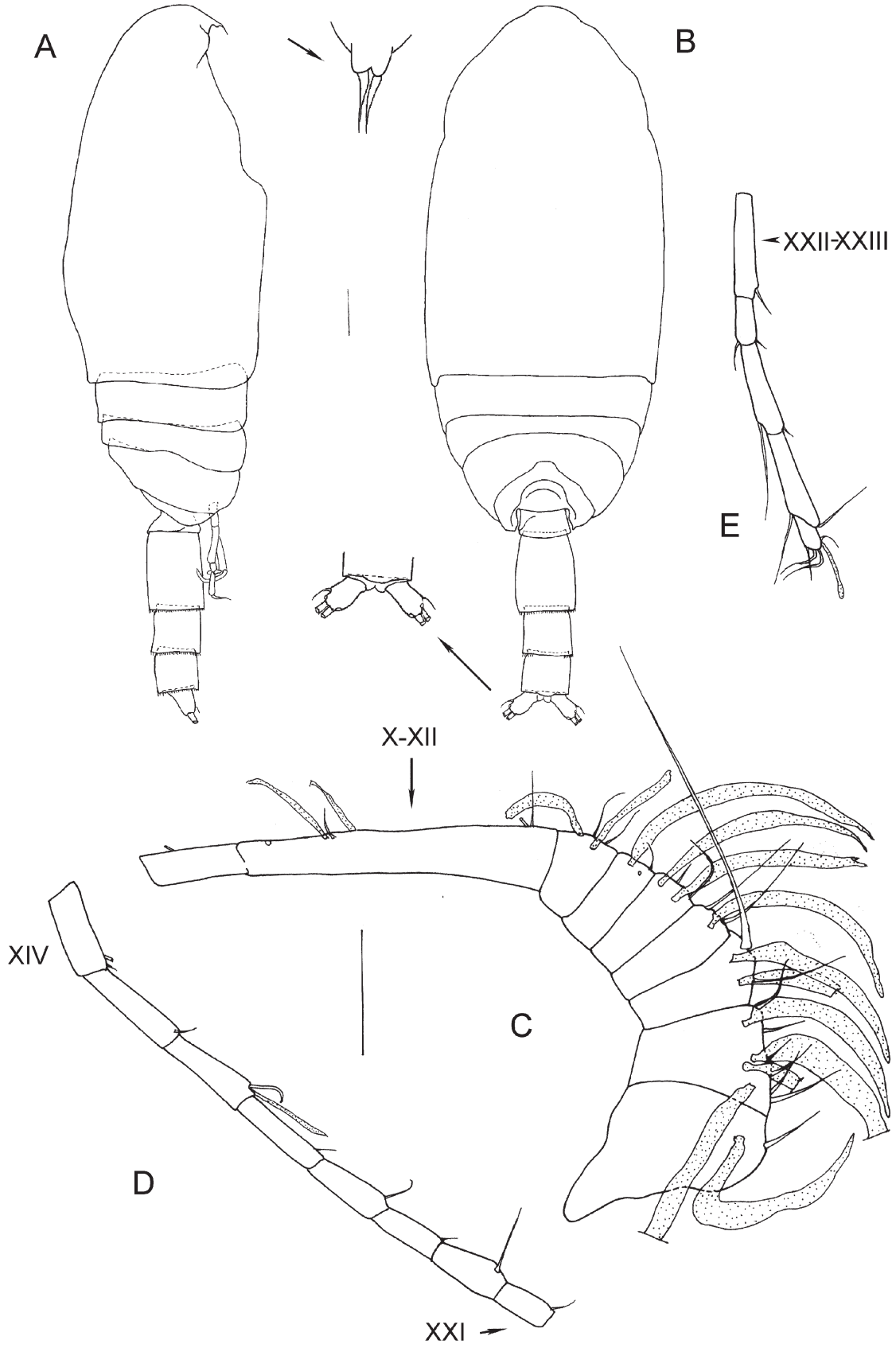

FIGURE 10. *Byrathis arnei* Schulz, 2006. Male. A, habitus, lateral view, rostrum, ventral view, marked by arrow; B, habitus, dorsal view; C, antennule, articulating segments 1–9 (ancestral segments I–XIII); D, antennule, articulating segments 10–17 (ancestral segments XIV–XXI); E, antennule, articulating segments 18–22 (ancestral segments XXII–XXVIII). Scale bars 0.1 mm.

FIGURE 11. *Byrathis arnei* Schulz, 2006 . Male. A, antenna; B, mandubular palp; C, mandibular gnathobase; D, maxillule; E, maxilla. Scale bars 0.1 mm.

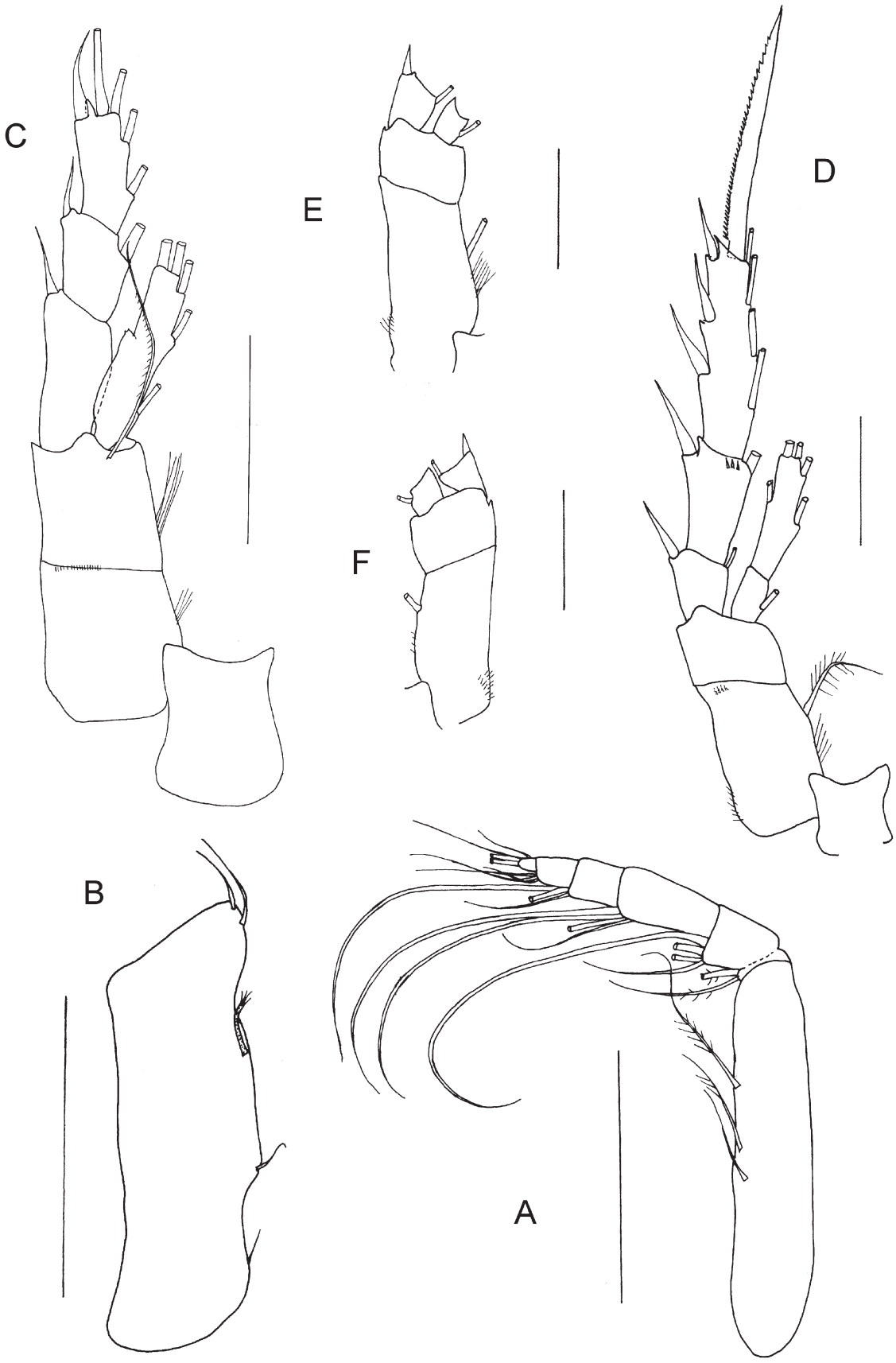

FIGURE 12. *Byrathis arnei* Schulz, 2006. Male. A, maxilliped, basis and endopod; B, maxilliped, syncoxa; C, P1; D, P2; E, P3, coxa, basis, segment 1 of endopod and exopod; F, coxa, basis, segment 1 of endopod and exopod. Scale bars 0.1 mm.

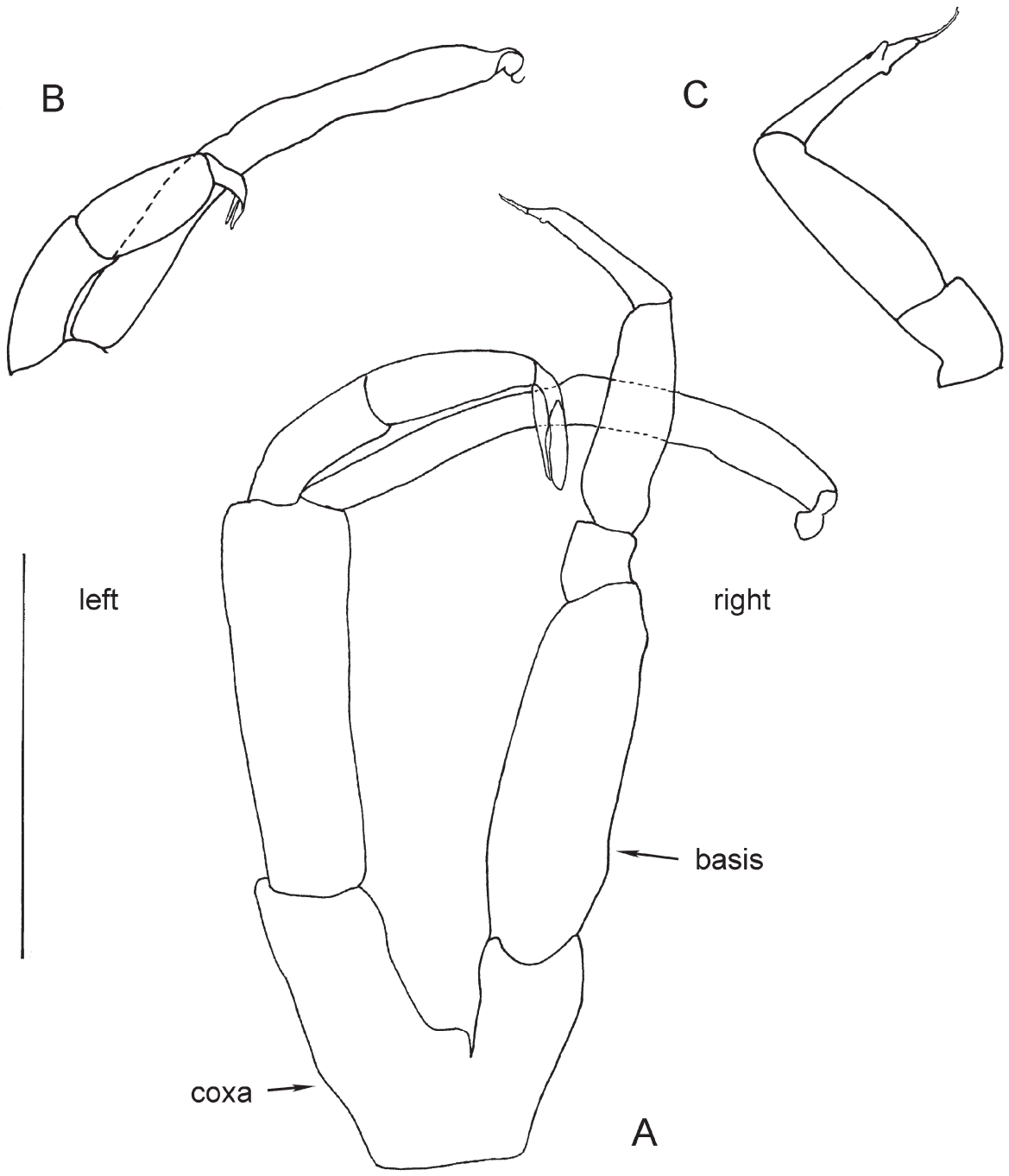

FIGURE 13. *Byrathis arnei* Schulz, 2006. Male. A, P5; B, left P5 endo- and exopod, other specimen; C, right P5 exopod, other specimen. Scale bar 0.1 mm.

Antennule (Fig. 10C–E) extending to anterior, or posterior edge of urosome somite 2. Right and left antennules of 22 articulating segments, symmetrical; armature as follows: I–1s + 1ae, II–IV–6s + 4ae, V–2s + 2ae, VI–2s + 1ae, VII–2s + 2ae, VIII–1s + 1ae + 1?, IX–2s + 2ae, X–XII–3s + 1? + 2ae, XIII–1s, XIV–2s, XV–1s, XVI–1s + 1ae, XVII–1s, XVIII–1s, XIX–1s, XX–1s, XXI–1s, XXII–XXIII–1s, XXIV–2s, XXV–2s, XXVI–2s, XXVII–XXVIII–4s + 1ae.

Antenna (Fig. 11A), coxa with 1 seta, basis with 2 setae, 1 very small; exopod 8-segmented with 1, 1-1-1, 1, 1, 1, 1, 1, and 3 setae; first endopodal segment without seta, second with 6 + 7 setae.

Mandible (Fig. 11B–C), gnathobase with low crest and 7 teeth on cutting edge plus dorsal seta, lateral tooth situated apart from the remaining teeth; basis with 2 rudimentary setae; exopod 5-segmented with 1, 1, 1, 1, and 2 setae; endopod segment 1 with 2 setae, segment 2 with 9 setae.

Maxillule (Fig. 11D), praecoxal arthrite with 9 terminal; coxal endite with 2 setae; proximal basal endite with 2 setae, distal basal endite with 2 setae; endopod with 7 setae; exopod with 5 setae; coxal epipodite with 4 setae.

Maxilla (Fig. 11E), praecoxal endite (previously considered as proximal praecoxal endite) with 4 setae; coxal endite (previously considered as distal praecoxal endite) with 3 setae; proximal basal endite (previously considered as proximal coxal endite) with 2 setae; distal basal endite (previously considered as distal coxal endite) with 3 setae; enditic-like lobe of proximal endopodal segment (previously considered as proximal basal endite) with 4 setae, 2 sensory; endopod with 5 worm-like and 3 brush-like sensory setae.

Maxilliped (Fig. 12A–B), syncoxa with 1 seta on proximal praecoxal endite, 1 seta on middle praecoxal endite, and 1 brush-like seta on distal praecoxal lobe; coxal lobe with 2 setae. Basis with 3 setae. Endopod 6-segmented with 2, 4, 4, 3, 3, and 4 setae.

Swimming legs. P1 (Fig. 12C), coxa with anterior row of small spinules along distal margin; basis with medial distal seta slightly curved with setules; endopod 1-segmented with lateral lobe lacking spinules; exopod segments 1 to 3 with 1 lateral spine each, spine of segment 1 nearly reaching base of following spine; spine of exopod segment 2 reaching midlength of exopod segment 3. P2 (Fig. 12D), coxa with 1 seta; basis without seta; endopod 2-segmented; exopod 3-segmented; exopod segment 2 with 3 small surface denticles along distomedial edge. Endopods and exopods 2–3 in P3–P4 of all male specimens broken, coxa of P3–P4 (Fig. 12 E–F) with small proximal spinules laterally, basis and segment of 1exopod and endopod nude.

P5 (Fig. 10A, 13A–C) nearly half as long as the urosome, legs of about equal lengths; in left coxa and basis only slightly longer than right. Right leg uniramous, exopod 3-segmented; left leg biramous, exopod 3-segmented, distal segment with subdivided chitinous lamella; endopod 1-segmented, much longer than exopod.

Remarks. *B. arnei* was described after females from the near-bottom of the high Antarctic (74º36.2'S 27º15.8'S) by Schulz (2006) and in the present study is recorded more northerly (Fig. 9). The species was collected by ANDEEP II–III and ANDEEP–SYSTCO expeditions (2002, 2005, 2007–2008) between 58º–65ºS and 02ºE–51ºW at depths from 1991 to 3050 m. One sample from ANDEEP–SYSTCO contained *Byrathis* females and males. We attribute them to *B. arnei*, although they differ somewhat from females defined as *B. arnei* by Schulz (2006) and specimens studied by us. Females from the ANDEEP–SYSTCO sample differ in: i) smaller size (1.25–1.35 mm *vs.* 1.38–1.40 mm in type specimens); ii) maxillule coxal epipodite with 8 setae (*vs.* 9 setae in specimens from the type series); iii) maxilla praecoxal endite with 4 setae (*vs.* 5 setae in type specimens), and iv) distal seta on middle praecoxal endite of maxilliped syncoxa is slightly longer than figured for type specimen (Schulz 2006, Fig.10A). However, we would prefer to postpone the discussion on the taxonomic status of the specimens from the ANDEEP–SYSTCO, until more specimens of *B. arnei* can be obtained. Additional collections from different localities are necessary to discuss whether the variability observed is interspecific, or whether a new species should be established for ANDEEP–SYSTCO specimens.

Discussion

The genus *Byrathis* can be divided into two groups. The first, at present of 3 species, is of medium sized copepods: *B. divae* **sp. nov.**, *B. penicillatus* **sp. nov.** and *B. laptevorum.* Their genital double somite has no surface ornamentation, the maxillule proximal basal endite and exopod are with 3 and 6 (or more) setae respectively, and the maxilla endopod bears 5 brush-like sensory setae. The second group includes the smaller species *B. arnei*, *B. laurenae*, *B. macrocephalon*, *B. volcani*, and an unnamed female specimen of *Byrathis*. These species are characterized by the presence of surface ornamentation on the genital double somite, the maxillule proximal basal endite and exopod with 2 and 5 (or less) setae respectively, and the maxilla endopod with only 3 brush-like sensory setae.

The adult male of *Byrathis,* which is described for the first time here, is distinguished from all other clausocalanoideans that possess sensory setae on the maxilla and maxilliped (bradfordian families) in the morphology of antennule and P5. Right and left antennules are symmetrical, of 22 free, articulated segments. In this genus the ancestral segments XXII–XXIII are fused on both sides. This is a unique case for bradfordian genera with known males in which segments XXII–XXIII are fused only in the right antennule as in Scolecitrichidae *s.s.* and Diaixidae *s.l.* (*sensu* Markhaseva & Ferrari, 2005), and as in *Brodskius*, *Tharybis* Sars, 1902, *Plesioscolecithrix* Markhaseva & Dahms, 2004, and *Xanthocalanus* Giesbrecht, 1893. In *Kirnesius* Markhaseva & Semenova, 2005 they are fused only in the left antennule. The symmetry of both antennules with a fusion of the ancestral segments XXII–XXIII on the right and on the left is therefore an apomorphy for *Byrathis*.

P5 of *Byrathis* males differs from the other bradfordians in the following combination of characters: i) weak asymmetry of coxa and basis; ii) right and left exopods 3-segmented; iii) left endopod present, significantly longer than exopod; and iv) right leg uniramous.

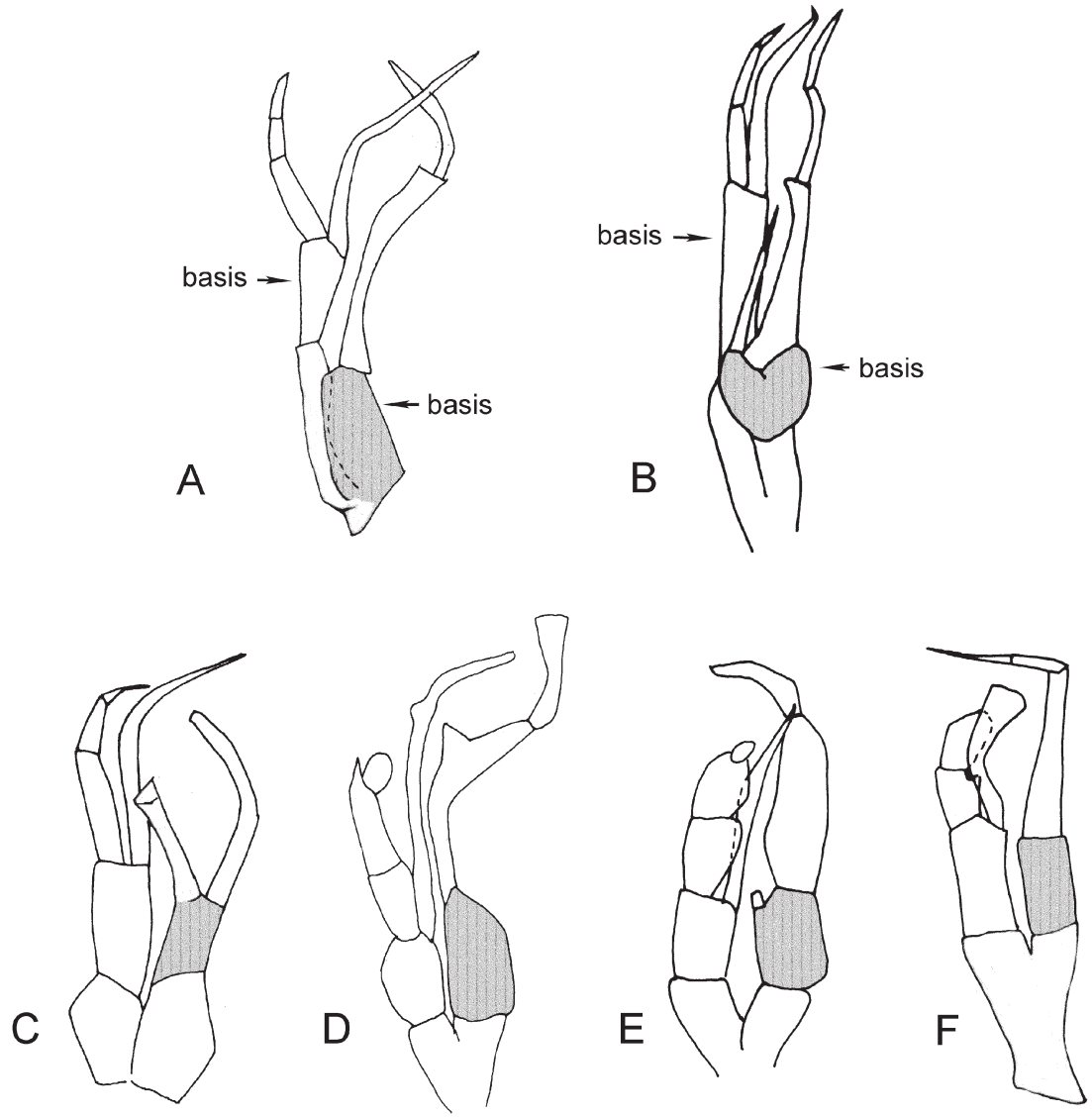

FIGURE 14. Male P5. A, *Tharybis macrophthalma* Sars, 1902 (P5 right basis here and in B–F in grey); B, *Scaphocalanus farrani* Park, 1982; C, *Parundinella emarginata* Grice & Hulsemann, 1970; D, *Undinella oblonga* Sars, 1900; E, *Brodskius* sp.; F, *Sensiava longiseta* Markhaseva & Schulz, 2006. A, C–D changed and schematized after Andronov (2002); B, changed and schematized after Park (1982); E, changed and schematized after Markhaseva & Ferrari (2005); F, changed and schematized after Markhaseva & Schulz (2006).

Males of *B. arnei* share a biramous left P5, with a well developed endopod distinctly longer than exopod, with the bradfordian genera *Brodskius*, *Parundinella* Fleminger, 1957, *Sensiava*, *Tharybis*, *Undinella* Sars, 1900 and Scolecitrichidae s.s. (e.g., *Scaphocalanus* Sars, 1900) (Fig. 14). The P5 coxal and basal segments in *Byrathis* (Fig. 13) express weak asymmetry and are nearly symmetrical in both legs contrary to those of *Tharybis* and Scolecitrichidae s.s. where the coxal and basal segments are strongly asymmetrical, with the right basis of P5 much shorter than the left one. *Byrathis* shares a P5 with nearly symmetrical coxal and basal segments with *Parundinella*, *Brodskius*, *Undinella* and *Sensiava* (Figs 13, 14). However, *Byrathis* differs from these genera in details of the P5 segmentation: the left exopod is 3-segmented (*vs.* 2-segmented in *Sensiava*) and the right P5 uniramous with 3-segmented exopod (*vs.* leg is biramous in *Parundinella* and with with 2-segmented exopod in *Brodskius* and *Undinella*).

The morphology of *Byrathis* combines primitive (e.g., setation of antenna exopod proximal segments as 1, 1-1-1 in both sexes; maxilla praecoxal endite in *B. arnei* female with 5 setae (Schulz 2006); females maxilliped praecoxal endites setation with 1,2,3 setae from proximal to distal, and male P5 coxa and basis nearly symmetrical) and derived characters. The derived are *Byrathis* mandibular gnathobase of female with crest (shares with *Omorius* and *Rostrocalanus* Markhaseva, Schulz & Martinez Arbizu, 2008) and maxillule distal basal endite with only 2–3 setae (shares with *Tharybis*, *Omorius* and *Phaenna* Claus, 1863). Apomorphies for the genus are male antennules with both ancestral segments XXII–XXIII fused (see above herein) and female maxillule praecoxal arthrite with 2 proximal marginal setae curved proximally (Markhaseva & Ferrari 2005). This mosaic combination of primitive and derived features is an additional example of heterobathmy typical of these benthopelagic clausocalanoideans.

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