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A new notodelphyid copepod, *Paranotodelphys illgi* n. sp. (Copepoda: Cyclopoida), parasitic in the ascidian *Corynascidia herdmani* Ritter in the North Pacific

Andrey Marchenkov[1] & Geoff A. Boxshall[2]
[1]*Zoological Institute, Russian Academy of Sciences, St Petersburg 199034, Russia*
[2]*Department of Zoology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK*

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Abstract

A new species of the Notodelphyidae belonging to *Paranotodelphys* Schellenberg, 1922 is described from both sexes. The new species, *Paranotodelphys illgi*, can be distinguished from its congeners by the combination of its 10-segmented female antennule, the bisetose fifth legs and the extreme elongation of the caudal rami of the female, which are more than 10 times longer than wide and 4.4 times longer than the anal somite. The male has non-geniculate antennules. The new species was collected at a depth of 508m in the North Pacific Ocean, from the ascidian *Corynascidia herdmani* Ritter.

Introduction

Some years ago the first author received a collection of ascidicolous copepods taken along the Russian coast of the North Pacific Ocean by Dr Karen Sanamyan. The collection included representatives of the families Ascidicolidae and Notodelphyidae. Among the Notodelphyidae in the collection were representatives of a new species belonging to *Paranotodelphys* Schellenberg, 1922. At present *Paranotodelphys* comprises just 10 species: *P. gracilis*, *P. scutiformis* and *P. longicauda* all described by Schellenberg (1922), *P. phallusiae* Gurney, 1927, *P. villosa* Ooishi, 1963, *P. furcifera* Stock, 1967, *P. saccata* Stock, 1967, *P. engeli* Stock, 1967, *P. constricta* Illg, 1970 and *P. procax* Stock & Humes, 1970. Species of the genus utilise different solitary ascidian hosts, except for *P. procax* which is associated with an octocoral host (Stock & Humes, 1970). The new species is only the fourth representative of the genus for which both sexes have been described, the other three being *P. villosa*, *P. scutiformis* and *P. saccata*.

Materials and methods

The copepods were dissected in lactic acid and mounted in lactophenol as temporary slide preparations. All drawings were made using an Olympus BH-2 microscope equipped with a camera lucida and differential interference contrast optics. The terminology and the system of identification of antennulary segmental homologies follow Huys & Boxshall (1991).

Order Cyclopoida Burmeister, 1834
Family Notodelphyidae Dana, 1853
Genus *Paranotodelphys* Schellenberg, 1922

Paranotodelphys illgi n. sp.

Type-material: Holotype female, 14 paratype females and 2 paratype males. Holotype female (Reg. No. 18003), 11 paratype females (Reg. Nos 18005-16) and 1 paratype male (Reg. No. 18004) stored in the collections of the Zoological Institute, St Petersburg; 3 paratype females and 1 paratype male stored in the collections of The Natural History Museum, London Reg. Nos BMNH 2002.249-252.

Type-locality: Russian research vessel *Academician Oparin*, Cruise 14, Station 4; 2nd August 1991; Komandorski Islands, east of Mednyi Island; 54°11′8″ N, 168°36′5″ E; depth 508 m; gear - Sygsbi trawl.
Type-host: *Corynascidia herdmani* Ritter.
Site in host: Unknown.
Etymology: This species is named for the late Professor Paul Illg, who made an enormous contribution to our knowledge of parasitic copepods belonging to the family Notodelphyidae.

Description of adult female (Figures 1A-C, 2A-B, 3A-D, 4A-D, 5A-C, 6A-B)

Adult female body (Figure 1A) dorsoventrally depressed, with urosome curved ventrally. General body shape similar to that of *Notodelphyopsis* Schellenberg, 1922 in lateral view. Mean body length (including caudal rami but excluding caudal setae) 2.37 mm, ranging from 2.12 to 2.48 mm, based on 4 females. Cephalosome longer than wide. First pedigerous somite free, but shorter than second and third somites (Figure 1A). Fourth somite produced dorsally into strongly expanded brood pouch in ovigerous females. Post-ovigerous female, after release of eggs/nauplii, apparently exhibiting distinctive form of spent brood pouch (Figure 1C) subdivided into 3 unequal parts, large anterior and posterior parts and small intermediate part. Urosome 5-segmented (Figure 1B): first urosomite with leg 5 located ventrolaterally and incorporated dorsally into brood pouch. Second urosomite, genital double-somite, longest, bearing paired ventrolateral rows of setules in anterior part and 3 medial rows posteriorly. Third and fourth urosomites gradually decreasing in size posteriorly. Anal somite trapezoidal in ventral view. Caudal rami extremely elongate, bearing numerous hair-like setules on ventral surface (Figure 1B); each ramus armed with 6 well-developed setae.

Rostrum (Figure 2B) a rounded lobe. Antennule (Figure 2A) 10-segmented; second segment compound, with incompletely expressed articulations; sixth (XVII-XX) and seventh (XXI-XXIII) segments particularly elongate and slender; antennules reaching as far as posterior border of second pedigerous somite: setal formula of expressed segments: 3 plumose setae; 8 plumose + 10 naked setae (including 1 sclerotised, spiniform element); 2 naked setae; 2 plumose + 2 naked setae; 3 plumose + 1 naked setae, plus 1 aesthetasc; 1 plumose + 3 naked setae; 2 naked setae; 2 naked setae + 1 aesthetasc; 7 naked setae + 1 aesthetasc.

Antenna (Figure 3A-B) 3-segmented, comprising coxobasis and 2-segmented endopod; exopod represented by 2 long plumose setae arising from common base. Proximal segment of endopod about half length of coxobasis and armed with naked seta at mediodistal corner of segment; distal endopodal segment as long as proximal, but much narrower, armed with simple seta inserted proximally; plumose seta inserted midway along segment close to group of 3 setae on posterior surface: longest and middle setae plumose, smallest seta naked (Figure 3B). Apical armature comprising 1 strongly sclerotised claw, 3 slender subequal claws and 3 plumose setae; distal segment ornamented with 3 oblique rows of fine setules near outer margin.

Labrum (Figure 4A) trapezoidal in outline, with rounded and slightly incised posterior margin; labrum produced into small lobes at lateral angles, ornamented with hair-like setules. Anterior surface of labrum ornamented with transverse rows of minute denticles.

Mandible (Figure 3C) consisting of well-developed coxal gnathobase and large biramous palp; medial biting margin of gnathobase comprising 4 acute teeth, single row of closely-set, fine denticles, plus 3 slightly-curved, dentate projections. Basis with single large plumose seta near middle of medial margin and ornamented with transverse rows and fields of minute spinules; endopod 2-segmented; first segment with 2 inner setae distally; second segment with 10 setae; all setae plumose; exopod irregular in form, retaining some traces of original segmental boundaries, carrying 5 large plumose setae.

Maxillule (Figure 4B) biramous; broad syncoxa formed by unseparated praecoxa and coxa; epipodite represented by stout, proximally-directed seta and small seta, both plumose. Praecoxal arthrite a large lobe armed with 7 sclerotised spine-like elements; coxal endite forms tapering lobe with plumose seta on apex. Medial margin of basis convex, bearing 3 setae: 1 small plumose seta proximally, plus 2 large setae each of which hirsute proximally and plumose distally. Endopod 2-segmented; first segment with 2 hirsute setae on medial margin; distal segment bears 4 plumose setae along apical margin. Exopod with 4 large plumose setae along distal margin, ornamented with fine setules along medial margin.

Maxilla (Figure 4C) 5-segmented, comprising syncoxa, basis and 3-segmented endopod. Syncoxa with broad base, narrowing distally; medial margin bear-

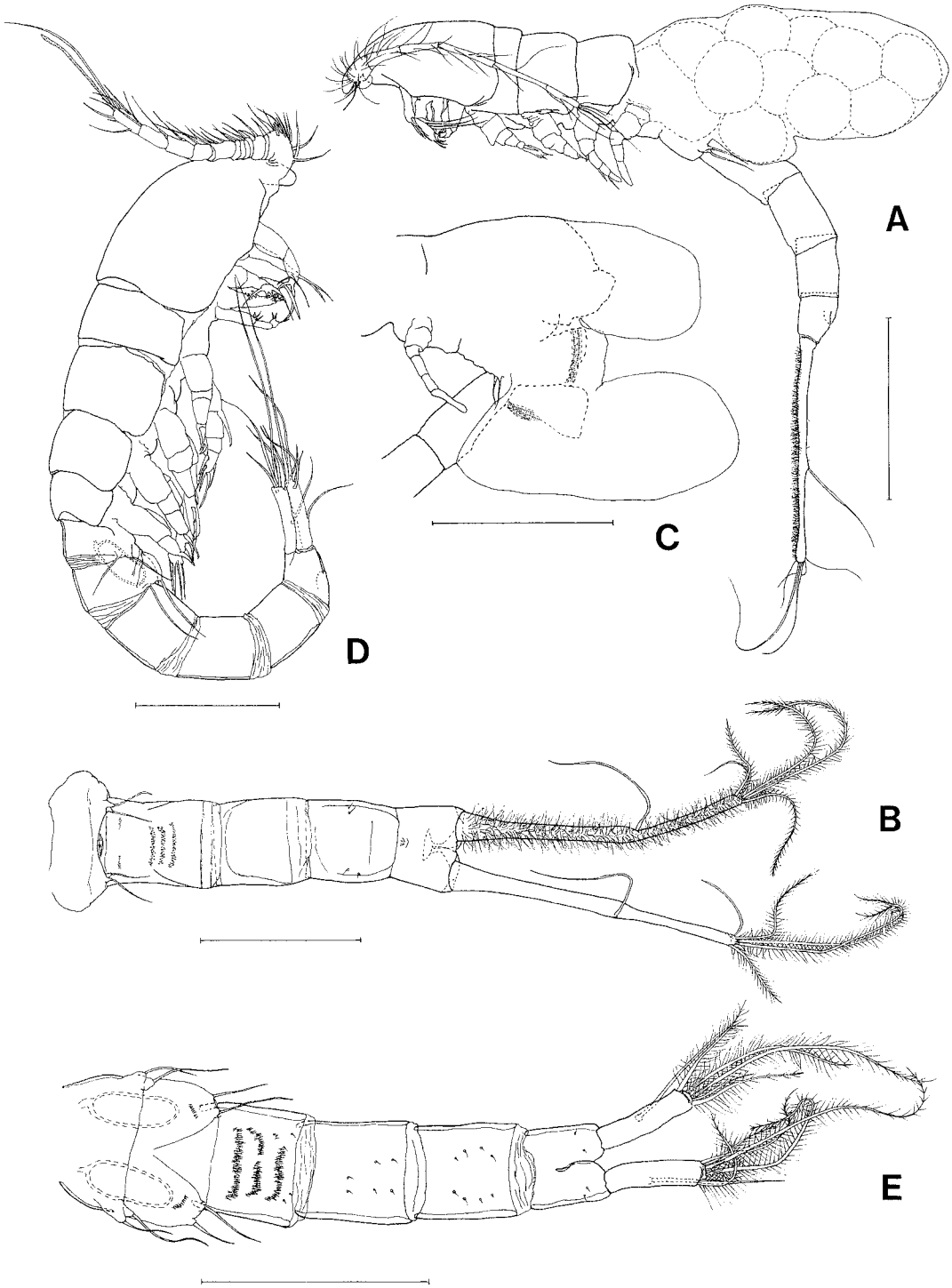

Figure 1. Paranotodelphys illgi n. sp. A, Adult female, lateral view showing full brood pouch; B, Female urosome, ventral view with surface ornamentation shown only on left caudal ramus; C, Prosome-urosome articulation region, lateral view of post-incubatory female showing distinctive bilobed shape of empty brood pouch; D, Adult male, lateral view with urosome reflexed; E, Male urosome ventral view. *Scale-bars*: A,C, 500μm; B, 400μm; D-E, 200μm.

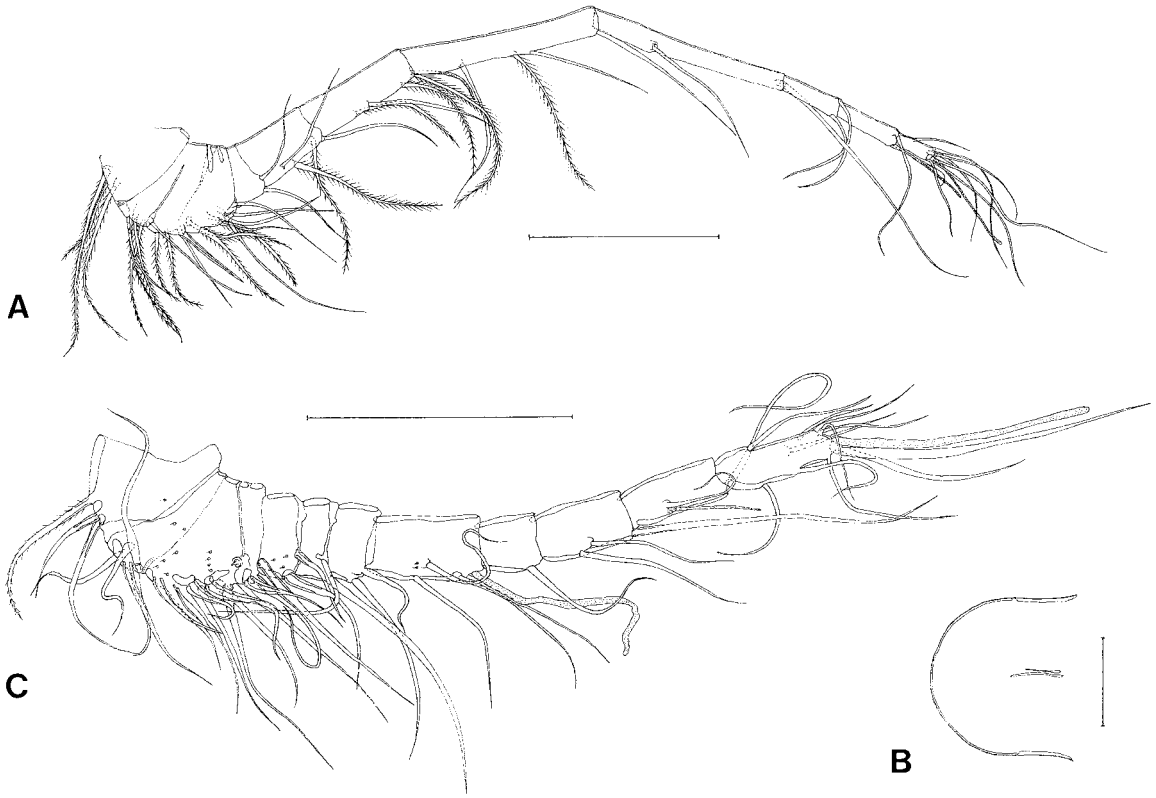

Figure 2. Paranotodelphys illgi n. sp. A, Female antennule; B, Female rostrum, frontal view; C, Male antennule. *Scale-bars*: A, 200μm; B, 150μm; C, 100μm.

ing 4 endites: first with 4 setae, 3 large hirsute and 1 small naked; second with 1 plumose seta; third with 2 setae; fourth endite well developed and bearing 1 hirsute small seta and 2 long plumose setae. Basis with inner distal angle produced into strong claw, serrated in middle part of concave margin; 2 subequal setae inserted at base of claw. First and second endopodal segments each with 1 plumose seta at inner distal angle; apical segment small, with 3 long setae (2 hirsute and 1 plumose) and 1 short naked seta.

Maxilliped (Figure 3D) distinctly 3-segmented, comprising syncoxa, basis and endopod. Syncoxa with proximal group of 4 setae (1 sclerotised, all hirsute) and distal group of 5 setae (1 sclerotised, all hirsute). Basis as long as syncoxa but narrower; inner margin ornamented with fine setules and field of smooth spinules near base of endopod. Endopod armed with 3 setae: inner seta plumose; medial and lateral setae hirsute.

Swimming legs 1-4 (Figures 5A-C, 6A-B) biramous, with 3-segmented rami. Spine and setal formula as follows:

	coxa	basis	endopod	exopod
Leg 1	0 – 1	1 – I	0 – 1; 0 – 1; 1, 2, 3	I – 1; I – 1; III, I, 4
Leg 2	0 – 1	1 – 0	0 – 1; 0 – 2; 1, 2, 3	I – 1; I – 1; III, I, 5
Leg 3	0 – 1	1 – 0	0 – 1; 0 – 2; 1, 2, 3	I – 1; I – 1; III, I, 5
Leg 4	0 – 1	1 – 0	0 – 1; 0 – 2; 1, 2, 2	I – 1; I – 1; II, I, 5

Coxae of legs 1-4 each bearing long plumose seta at inner distal angle. Inner distal angle of basis bearing large denticulate spine in leg 1, accompanied by spinules at base; outer margin of basis in legs 1-4 reduced, armed with naked seta; basis ornamented with row of spinules near base of endopod in all legs.

Leg 5 (Figure 4D) located on ventro-lateral surface of first urosomite; leg reduced, comprising single protopodal segment armed with lateral seta carried at tip of conical process; exopod 1-segmented with single apical seta. Leg 6 reduced, forming opercular plates closing off paired genital apertures.

Caudal rami (Figure 1B) extremely elongate, more than 10 times longer than maximum width (at base); ventral surface ornamented with numerous hair-like

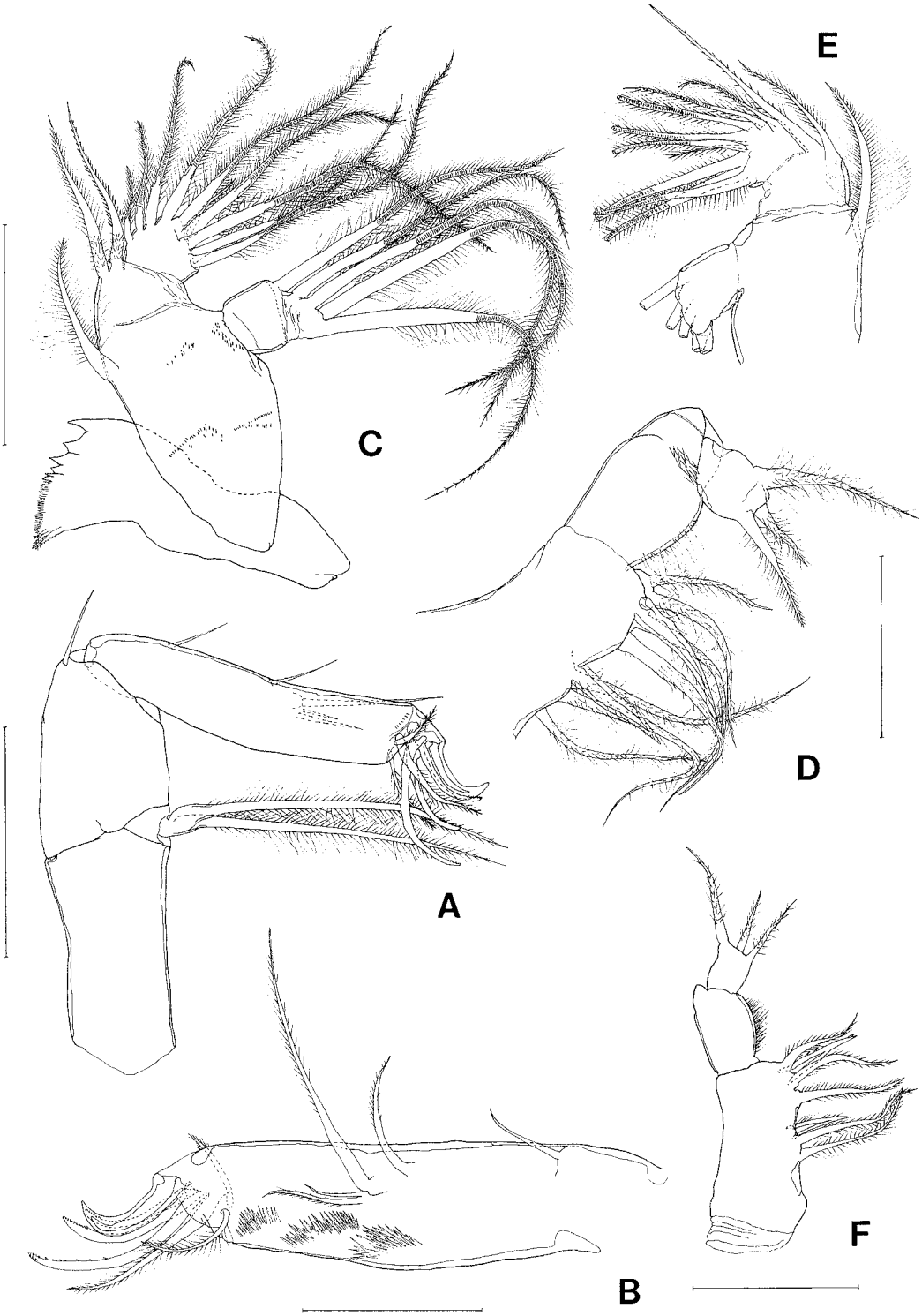

Figure 3. Paranotodelphys illgi n. sp. A, Female antenna; B, Same, detail of distal endopodal segment; C, Female mandible; D, Female maxilliped; E, Male mandibular palp, showing detail of endopodal setation; F, Male maxilliped. *Scale-bars*: A,C, 100μm; B, D-F, 50μm.

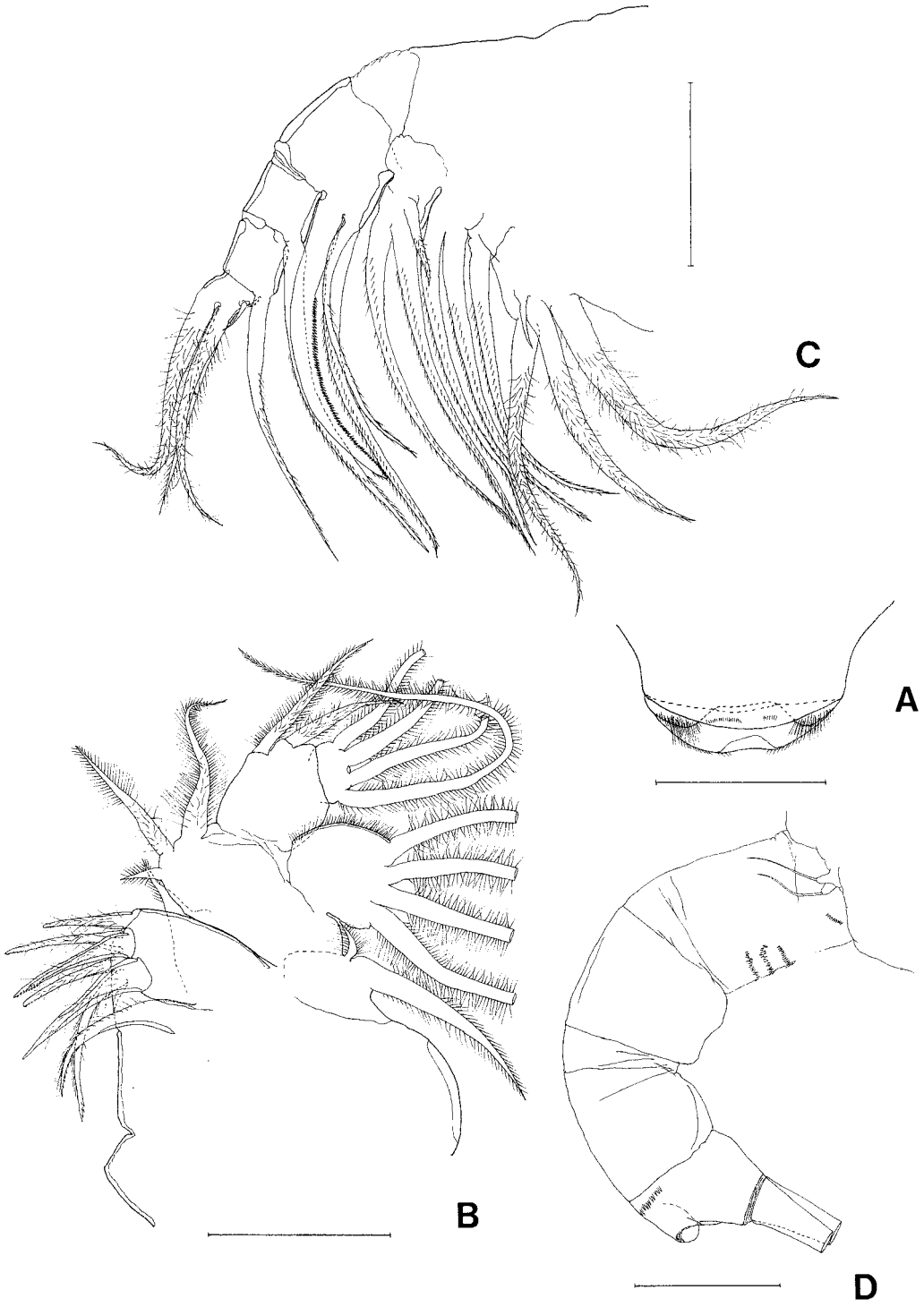

Figure 4. Paranotodelphys illgi n. sp. A, Female labrum; B, Female maxillule; C, Female maxilla; D, Female urosome, lateral view, showing fifth legs. *Scale-bars*: A, 100μm; B,C, 50μm; D, 200μm.

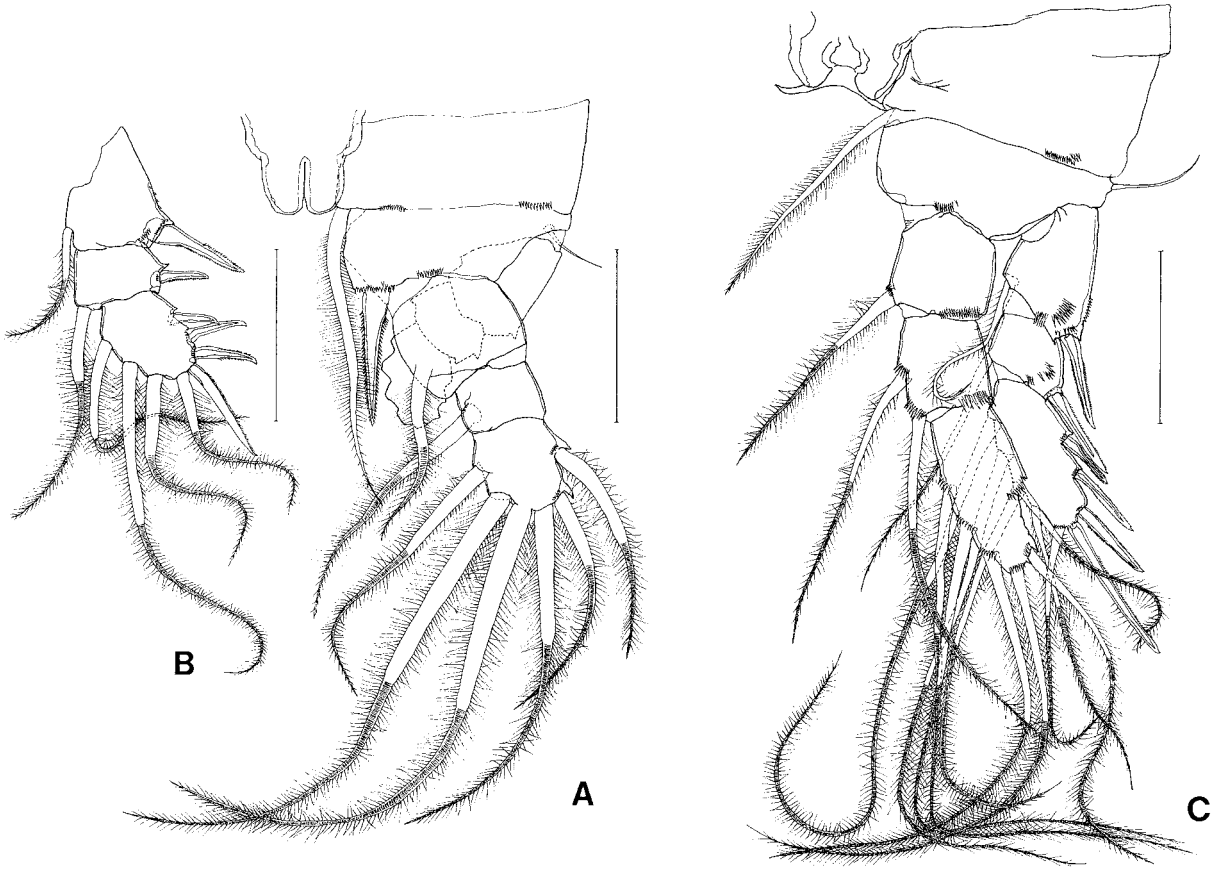

Figure 5. Paranotodelphys illgi n. sp., adult female. A, Leg 1 and intercoxal sclerite, with exopodal setation omitted; B, Leg 1 exopod showing setation; C, Leg 2 and intercoxal sclerite. *Scale-bars*: 100μm.

setules and sensillae; each ramus armed with 2 naked and 4 plumose setae.

Description of adult male (Figures 1D-E, 2C, 3E-F)

Body (Figure 1D) cyclopiform, slightly depressed, length 1.25 mm excluding caudal setae. Cephalosome separated from first pedigerous somite. Rostrum as in female. Pedigerous somites gradually narrowing posteriorly. Urosome (Figure 1E) 6-segmented; first urosomite bearing fifth legs, similar in structure to those of female. Genital somite bearing sixth legs, each forming broad genital operculum armed with 2 terminal setae plus tiny inner seta; ventral surface ornamented with transverse row of setules. Free abdominal somites more or less cylindrical, gradually narrowing posteriorly; ventral surface of first free abdominal somite ornamented with 3 transverse rows of setules. Ventral surface of all free abdominal somites ornamented with sensillae. Caudal rami (Figure 1E) shorter than in female, just over 4 times longer than wide; armed with 1 naked and 5 plumose setae, lacking dense surface ornamentation.

Antennule (Figure 2C) 10-segmented, without expressed geniculation; second segment compound, retaining partial suture lines marking unexpressed articulations. Setation formula as follows: 1 plumose + 2 naked; 19 + 1 reduced (20); 2; 2; 2; 4 + 1 aesthetasc; 1; 3; 2 + 1 aesthetasc; 11 + 1 aesthetasc.

Antenna, maxillule and maxilla as in female.

Mandibles similar to that of female but differing in setation of distal endopodal segment (Figure 3E) which carries only 9 setae.

Maxilliped (Figure 3F) similar to that of female in structure but differing in syncoxal setation; syncoxa with proximal group of 3 setae (1 sclerotised, all plumose) and distal group of 4 setae (1 sclerotised, all plumose); endopod armed with 3 hirsute setae as in female.

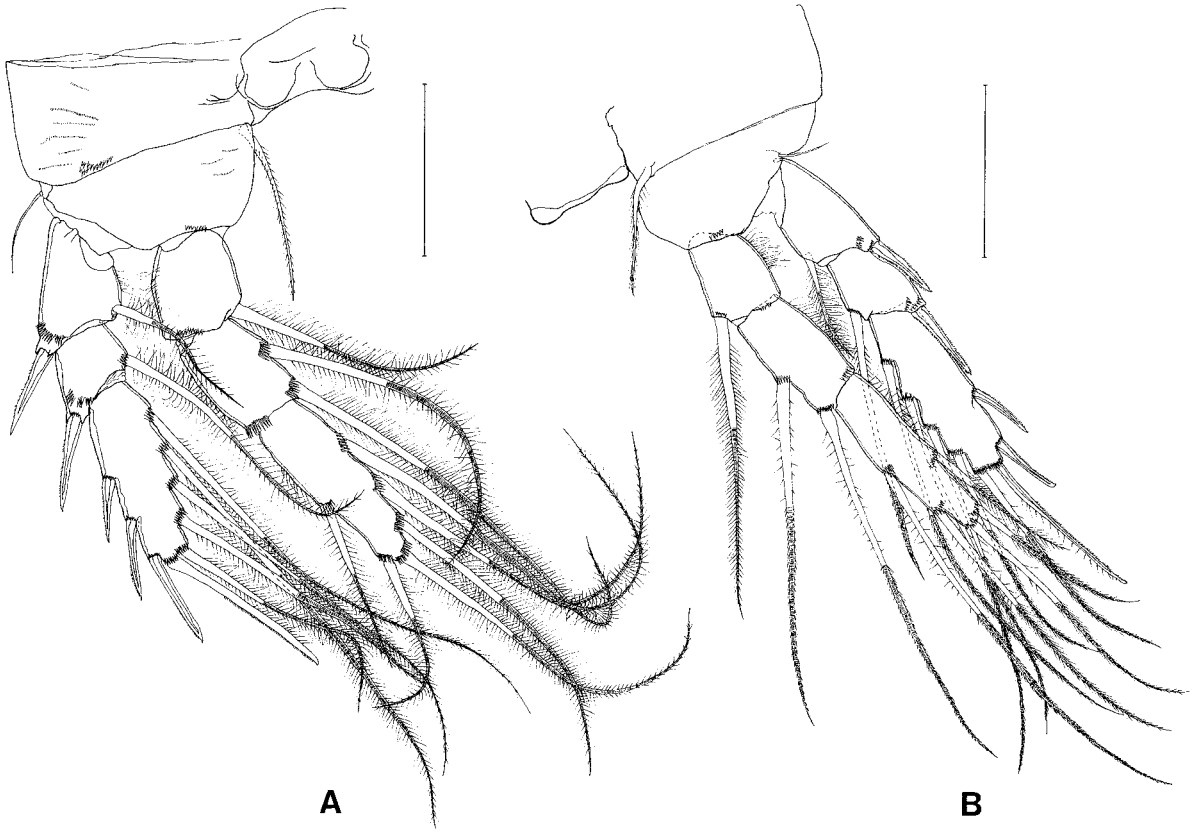

Figure 6. Paranotodelphys illgi n. sp., adult female. A, Leg 3 and intercoxal sclerite; B, Leg 4 and intercoxal sclerite. *Scale-bars*: 100μm.

Legs 1-4 well developed; structure and armature in general as in female, but differing from female in presence of spiniform processes at outer distal corner of endopod in legs 2 and 3.

Remarks

The new species differs from all described species of *Paranotodelphys* in its slender general body shape, in the elongate form of the antennule and in the extremely elongate shape of the caudal rami in the female. In addition, it is unique in the highly specific form of the spent brood pouch of the post-ovigerous females.

The new species can also be distinguished from the following seven known species, *P. scutiformis*, *P. phallusiae*, *P. villosa*, *P. engeli*, *P. procax*, *P. furcifera* and *P. constricta*, by differences in the antennulary segmentation of the adult female. The first five of these species have 9-segmented antennules, whereas in the new species this appendage is 10-segmented. The segmentation of the female antennule also serves to distinguish the new species from both *P. furcifera*, which has 11-segmented antennules (Stock, 1967), and *P. constricta*, which has only 8-segmented antennules (Illg, 1970). Unfortunately no data are available on the segmentation of the antennule in the remaining two species, *P. gracilis* and *P. longicauda* (see Schellenberg, 1922).

The distal endopodal segment of the mandibular palp is described as bearing eight setae in all species except *P. phallusiae*, which has seven setae. The setation of the mandibular endopod is unknown for *P. scutiformis* and for *P. longicauda*. In the new species the endopod carries a total of 10 setae in the female, but at least one of those setae is small and often concealed by the larger plumose setae. Therefore, this difference, which appears to distinguish between the new species and *P. gracilis*, may not be reliable.

The new species appears to be closely related to *P. longicauda*. Both species have elongate antennules and caudal rami, and both possess the same setation on the maxillulary palp and on the distal segment of the maxilliped. It differs from *P. longicauda* in having

only two setae on the fifth leg in the female, rather than three setae as in Schellenberg's species. The two species also differ in the length of the antennule and in the proportional length of the caudal rami relative to the anal somite. The antennule of *P. longicauda* is only slightly longer the cephalosome, whereas in *P. illgi* n. sp. the antennule reaches as far as the posterior margin of the second pedigerous somite. The caudal ramus of female *P. longicauda* is three times longer than the anal somite, whereas in *P. illgi* the ramus is 4.4 times longer.

The geographical ranges of these two species do not overlap. The new species is based on material collected from the North Pacific, whereas *P. longicauda* was collected from the Antarctic, in the vicinity of Gauss Station, Posadowsky Bay, Kaiser Wilhelm II Land.

Discussion

Parantodelphys exhibits a somewhat intermediate morphology between *Notodelphys* Allman, 1847 and *Notodelphyopsis* Schellenberg, 1922. Illg (1970) speculated that *Paranotodelphys* was more closely related to *Notodelphyopsis*. The most important difference between *Paranotodelphys* and *Notodelphyopsis* is the number of expressed urosomites in females, five and four respectively. The lack of information on development in these genera has prevented more detailed analysis of the developmental basis of this difference.

The male described here is the fourth known from the genus; the others being *P. scutiformis*, *P. villosa* (this species was originally described from the female only by Ooishi (1963) but Seo & Lee (1995) subsequently described the male) and *P. saccata*. Comparison of these three species and *P. illgi* n. sp. reveals a general pattern in sexual dimorphism. At the generic level, sexual dimorphism appears to be expressed in the smaller body size of the males, in the antennulary segmentation, in the better developed sixth leg of males and in the form of the caudal rami. *P. saccata*, *P. scutiformis* and *P. illgi* all have elongate caudal rami in the female but relatively short rami in the male. In addition to this length dimorphism, in *P. illgi* and in *P. saccata*, the male lacks the conspicuous ventral surface ornamentation present on the caudal rami of the female. Even this sexual dimorphism is not universal within *Paranotodelphys*, since the caudal rami of *P. villosa* differ little between the sexes. There is little sexual dimorphism expressed in the setation of the mouthparts; *P. illgi* seems to be unusual in having a dimorphic mandibular endopod, bearing 10 setae in the female and nine setae in the male.

The male of *P. scutiformis* apparently has prehensile antennules, referred to as 'Griefantenne' by Schellenberg (1922: 234). This character state requires confirmation since this is the only species of *Paranotodelphys* reported as having geniculate male antennules, although geniculate antennules are found in at least one member of the closely related *Notodelphyopsis*, namely *N. perplexa* Illg, 1958 (Illg, 1958). All three other known *Paranotodelphys* males have non-prehensile antennules. In *P. illgi* the distal four segments of the female antennule are identified here as representing ancestral segments XXI-XXIII, XXIV, XXIV and XXVI-XXVIII (Figure 2A). In the male, the homologous region of the antennule comprises only two compound segments representing XXI-XXIII and XXIV-XXVIII (Figure 2C). The distal fusions are interpreted here as evidence that the lack of the antennulary geniculation is a secondary state.

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