

# ***Giardella ricoensis* n. sp. from the West Indies and the Proposal of the New Genus *Goodingius* (Copepoda: Cyclopoida: Clausidiidae)**

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## **ABSTRACT**

A new genus *Goodingius* is proposed to incorporate *Hemicyclops adhaerens* (Williams), *H. arenicolae* Gooding, *H. elongatus* Wilson and *H. subadhaerens* Gooding, all of which bear the six-segmented female urosome, three mandibular elements (or three elements plus one rudimentary setule), five setae on the first antennular segment, and no inner coxal seta of leg 4. The genus *Giardella* Canu, a sister taxon of *Goodingius*, is redefined as possessing eight elements on the third exopodal segment of leg 3, only a single inner seta on the second endopodal segment of leg 4, four spines on the third endopodal segment of leg 4. To the genus *Giardella*, *Hemicyclops caissarum* Kihara and Rocha and *H. carinifer* Humes are assigned, in addition to *Giardella ricoensis* n. sp., *Giardella callianassae* Canu, and *G. thompsoni* A. Scott. Keys to the species of both genera are provided.

**Key words:** *Goodingius* n. gen., *Giardella ricoensis* n. sp., Copepoda, Cyclopoida, Clausidiidae, West Indies

## **INTRODUCTION**

Copepods of the family Clausidiidae are external associates of marine invertebrates (Boxshall and Halsey, 2004). Ho and Kim (2004) recognized 10 genera in this family. They are *Hemicyclops* Boeck, 1873; *Clausidium* Kossmann, 1874; *Hersiliodes* Canu, 1888; *Hippomolgus* G.O. Sars, 1917; *Leptinogaster* Pelsenner, 1929; *Conchylurus* Bocquet and Stock, 1957; *Hyphalion* Humes, 1987; *Pholadicola* Ho and Wardle, 1992; *Foliomolgus* Kim, 2001, and *Hemadona* Ho and Kim, 2004. Of these, Boxshall and Halsey (2004) excluded three genera, *Foliomolgus*, *Leptinogaster*, and *Pholadicola*, from the Clausidiidae and placed them within the "Teredicola group", and recognized *Giardella* Canu, 1888 as a valid genus in the family.

Prior to these works, Gooding (1963) included the genera *Giardella* and *Hersiliodes* in *Hemicyclops*. But he recognized three groups in the genus *Hemicyclops*: 1) *sensu stricto* group consisting of most species of the genus; 2) *adhaerens* complex to which he included two species of *Giardella* (*G. callianassae* Canu, 1888 and *G. thompsoni* A. Scott, 1906), along with *H. adhaerens* Williams, 1907, *H. subadhaerens* Gooding, 1960, *H. arenicolae* Gooding, 1960 and *H. elongatus* Wilson, 1937; and 3) *Hersiliodes* group consisting of *H. latericius* (Grube, 1869), *H. cylindraceus* (Pelsenner, 1929), and *H. livingstoni* T. Scott, 1894. Gooding considered the

subgeneric ranking for these groups but lumped all of them into the genus *Hemicyclops* because of the overlap or lack of group characters in some species.

Vervoort and Ramirez (1966) separated *Giardella* (only *G. callianassae* was included) and *Hersiliodes* (only *H. latericius* was included) as valid genera from *Hemicyclops*. Stock (1973) also recognized *Giardella* as a distinct genus to which he assigned *G. callianassae* and *G. thompsoni*. While describing a new species of Clausidiidae, Kim and Stock (1996) assigned their new species to *Hersiliodes* (as *H. exiguus*), along with *Hersiliodes latericius*. The validity of *Hersiliodes* as a genus was supported by the cladistic analysis of clausidiid genera carried out by Ho and Kim (2004).

Since the revision of clausidiid genera by Vervoort and Ramirez (1966), more than 20 new species and their new morphological data have been accumulated. Most of new species have been assigned to *Hemicyclops* which still contains heterogeneous species (Kim and Stock, 1996).

During the observation of copepod collection of the late Dr. A.G. Humes, I found a new species of the Clausidiidae collected from the West Indies. A comparison of this species with its relatives resulted in a conclusion that several species consisting of at least two different taxonomic groups were inappropriately included in the genus *Hemicyclops*. In this paper, some of them are reassigned to the genus *Giardella* with a redefinition of the genus and the rest to a new genus.

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## SYSTEMATIC ACCOUNTS

Order Cyclopoida  
 Family Clausidiidae  
*Goodingius* n. gen.

*Diagnosis.* Body slender. Urosome 6-segmented in both sexes. Caudal ramus at least twice as long as wide. Antennule 7-segmented, with 5 setae on first segment and 4 setae (without aesthetasc) on fifth segment. Antenna armed as in *Hemicyclops* but inner distal corner of third segment not projected and terminal segment elongated, more than twice as long as wide. Mandible distally armed with 3 or 4 elements; in latter case, dorsalmost one rudimentary. Maxilla without distinct sexual dimorphism. First segment of male maxilliped armed with 2 setae. Leg 1 showing no sexual dimorphism, with inner spine on basis in both sexes. Leg 4 without inner seta on coxa; third endopodal segment armed with 4 spines and 1 seta (armature formula I,III,1).

*Type species.* *Hemicyclops adhaerens* (Williams, 1907)

*Etymology.* The generic name *Goodingius* is dedicated to Dr. R.U. Gooding who first recognized this group of copepods. Gender masculine.

*Included species and synonyms.*

- 1) *Hemicyclops adhaerens* (Williams, 1907)  
*Lichomolgus adhaerens* Williams, 1907, p. 75, pl. 2.  
*Hemicyclops adhaerens*: Wilson, 1932, p. 345, fig. 206;  
 Gooding, 1960, p. 176, figs. 3d-j, 4.
- 2) *Hemicyclops elongatus* Wilson, 1937, p. 206, figs. 1-6;  
 Gooding, 1960, fig. 8.
- 3) *Hemicyclops subadhaerens* Gooding, 1960, p. 181, figs. 5-7.
- 4) *Hemicyclops arenicolae* Gooding, 1960, p. 188, figs. 9, 10.

*Remarks.* *Goodingius* is the replaced name for the “*adhaerens* complex” of Gooding (1960, 1963), but not including his “*Giardella* species”. The genera *Goodingius* and *Giardella* are sister taxa, sharing exclusively two significant apomorphic characters which are not shown by the species of *Hemicyclops* and its allies. First, both genera have lost the inner coxal seta of leg 4. Second, the mandible of these two genera is armed distally with three elements (one claw-like element, one plate-like element and one seta) or three elements plus 1 rudimentary dorsal setule. This armature is certainly resulted from the reduction or deletion of one of two dorsal setae both equipped in all species of *Hemicyclops*. Gooding (1963) reported that copepodid I of *Goodingius adhaerens* (recorded as *Hemicyclops adhaerens*) has the same morphology of mandible. In contrast, the same developmental stage of *Hemicyclops ctenidis* Ho and Kim, 1990 and *H. japonicus* Itoh and Nishida, 1993 were reported

to have four complete elements (reported by Kim and Ho, 1992, and Itoh and Nishida, 1995, respectively). Such an early determination of the mandibular morphology during the larval development suggests that the morphological feature of this appendage in adult is of high taxonomical value.

In addition, *Goodingius* and *Giardella* reveal the following combination of features in common: 1) the female urosome is 6-segmented; 2) the antennule is armed with five setae on the first segment; 3) the caudal rami and the terminal segment of antenna have a tendency of elongation; 4) male leg 1 is armed with a posteromedian spine on the basis, as in female; 5) the male maxilliped is armed with two setae on the first segment; 6) the maxilla shows little sexual dimorphism; 7) female leg 6 is well developed; 8) the antennule is armed with only four setae on the fifth segment (aesthetasc lost).

The differences between *Goodingius* and *Giardella* are mentioned in the “Remarks” of *Giardella*. Four known members of *Goodingius* can be distinguished by the following key.

### A key to the species of *Goodingius*

1. Caudal ramus more than 4 times as long as wide; genital double-somite as long as wide ..... *G. elongatus*  
 – Caudal ramus less than 4 times as long as wide; genital double-somite wider than long ..... 2
2. Second and third segments of antenna with large patch of spinules; free segment of leg 5 without spinules on sides ..... *G. arenicolae*  
 – Second and third segments of antenna without patch of spinules; free segment of leg 5 with spinules on sides ... 3
3. Length of female less than 1.5 mm; genital somite of male posteriorly angular ..... *G. adhaerens*  
 – Length of female more than 2 mm; genital somite of male posteriorly rounded ..... *G. subadhaerens*

Genus *Giardella* Canu, 1888

*Diagnosis* (redefined). Body slender. Urosome 6-segmented in both sexes. Caudal ramus at least 7 times as long as wide. Antennule 7-segmented, with 5 setae on first segment and 4 setae (without aesthetasc) on fifth segment. Antenna armed as in *Hemicyclops* but inner distal corner of third segment not projected and terminal segment elongated, more than 3 times as long as wide. Mandible distally armed with 3 elements and 1 rudimentary dorsal setule. Maxilla without distinct sexual dimorphism. First segment of male maxilliped armed with 2 setae. Leg 1 showing no sexual dimorphism, with inner spine on basis in both sexes. Third exopodal segment of leg 3 with 8 elements (armature formula II,I,5). Leg

4 without inner seta on coxa; second endopodal segment armed with 1 inner seta (armature formula 0-1); third endopodal segment armed with 4 spines (armature formula I,II,I).  
*Type species. Hemicyclops carinifer* Humes, 1965.

*Included species.*

- 1) *Giardella callianassae* Canu, 1888, p. 410, pl. 28; Stock, 1973, p. 39, figs. 1-3.
- 2) *Giardella thompsoni* A. Scott, 1906, p. 195, pl. 4; Stock, 1973, p. 40.
- 3) *Hemicyclops carinifer* Humes, 1965, p. 166, pl. 11, figs. 73-81, pls. 12-15, pl. 16, figs. 109-115; Huys and Boxshall, 1991, figs. 2-10-8A, 2-10-10C, 2-10-14A, 2-10-19, 2-10-20.
- 4) *Hemicyclops caissarum* Kihara and Rocha, 1993, p. 244, figs. 1-25.
- 5) *Giardella ricoensis* n. sp.

*Remarks.* Although the genus *Giardella* shares many important characters with the genus *Goodingius*, it possesses several significant apomorphic features typifying it as a distinct genus, as follows: 1) the exopod of leg 3 is armed with 8 elements (armature formula II,I,5), not 9 (III,I,5) as in *Goodingius*; 2) the second endopodal segment of 4 is armed with a single inner seta (armature formula 0-1), not two (0-2) as in *Goodingius*; 3) the third endopodal segment of leg 4 is armed with four spines (armature formula I,II,I), not five (I,III,1) as in *Goodingius*; 4) the terminal segment of antenna is more elongated, at least three times as long as wide (about twice as long in *Goodingius*); 5) the caudal rami is more elongated, more than seven times as long as wide (less than five as long in *Goodingius*).

#### ***Giardella ricoensis* n. sp. (Figs. 1, 2)**

*Material examined.* Three ♀♀ from burrows of callianassids (Crustacea), in the depth of 0.6-0.9 m, north side of Caballo Ahogado, Puerto Rico, August 1959, collected by A.G. Humes and R.U. Gooding. Holotype (♀) and paratype (1♀) have been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A. Dissected paratype (1♀) is kept in the collection of the author.

*Female.* Body (Fig. 1A) with narrow prosome. Body length of dissected largest specimen 1.76 mm. Prosome 4-segmented, 929 µm long, with greatest width 571 µm. Cephalothorax 576 µm long, nearly as long as wide. Urosome (Fig. 1B) slender and 6-segmented. Fifth pedigerous somite 191 µm wide. Genital double-somite 126 × 212 µm, distinctly shorter than wide, with outwardly expanded lateral margins and posterolateral point on posterior 3/4 region of each lateral margin (Figs. 1B, 2H). Genital area located dorsolaterally near 1/3 length of somite (Fig. 2H). Four abdominal somites

94 × 138, 73 × 126, 50 × 115, and 153 × 100 µm, respectively. Anal somite distinctly longer than preceding abdominal somites, distinctly tapering, with spinules on posterodorsal margin and 2 proximal patches of 3 or 4 spinules on ventral surface (Fig. 1C). Caudal ramus elongate, 288 × 27 µm (ratio 10.7 : 1), with 3 fine spinules near posteroventral margin (Fig. 1C), 1 fine outer proximal setule, 1 outer distal seta (located at 82% length of outer margin), 1 disterodorsal seta, and 4 terminal setae; 2 median terminal setae plumose; inner terminal seta weakly plumose; other setae naked. Egg sac (Fig. 1D) elongate, 573 × 130 µm, containing 3 series of eggs.

Rostrum triangular, directed ventrally, and shorter than wide. Antennule (Fig. 1E) 608 µm long, 7-segmented, with armature formula 5, 15, 6, 3, 4, 2+aesthetasc, and 7+aesthetasc; 3 of 5 setae on first segment weakly plumose; distinctly plumose setae: 1 on each third, fourth, and sixth segments, 2 on fifth, and 4 on last. Antenna (Fig. 1F) 4-segmented, with armature formula 1, 1, 4, and 7; inner distal corner of third segment not projected; fourth segment 89 × 25 µm, 3.56 times as long as wide.

Labrum (Fig. 1G) slightly tapered posteriorly, with various spinules on posterior margin. Mandible (Fig. 1H) armed distally with 1 stout ventral element, 1 spiniform element, and 1 dorsal seta; dorsal seta accompanied by 1 minute setule at base. Paragnath (Fig. 1I) bilobed; larger anterior lobe weakly articulated distally; smaller posterior lobe covered with setules. Maxillule (Fig. 1J) bilobed, with 5 setae on outer lobe and 3 setae on inner lobe. Maxilla (Fig. 2A) 2-segmented; first segment with 1 larger and 1 smaller setae; larger seta accompanied with 1 seta-like element at base; second segment armed distally with 4 elements, all elements spiniform and one of them not articulated at base. Maxilliped (Fig. 2B) 4-segmented; first 2 segments each armed with 2 setae; third segment small and unarmed; terminal segment with 2 setae, 1 spine, and 1 curved spiniform process.

Legs 1-4 (Fig. 2C-F) with 3-segmented rami, with armature formula as follows:

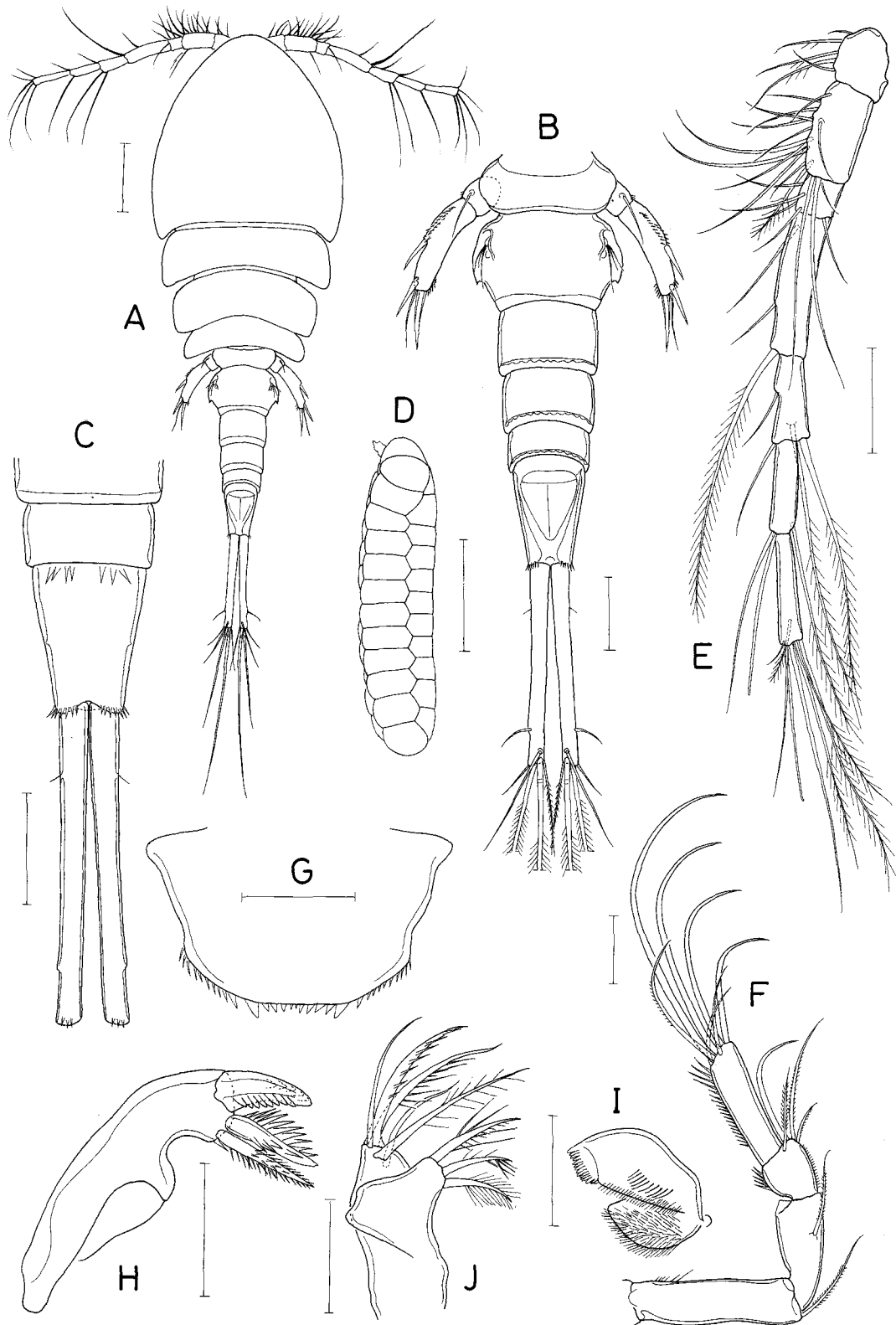
Leg 1: coxa 0-1; basis 1-I; exp. I-0; I-1; III,I,4;  
 enp. 0-1; 0-1; I,5

Leg 2: coxa 0-1; basis 1-0; exp. I-0; I-1; III,I,5;  
 enp. 0-1; 0-2; I,II,3

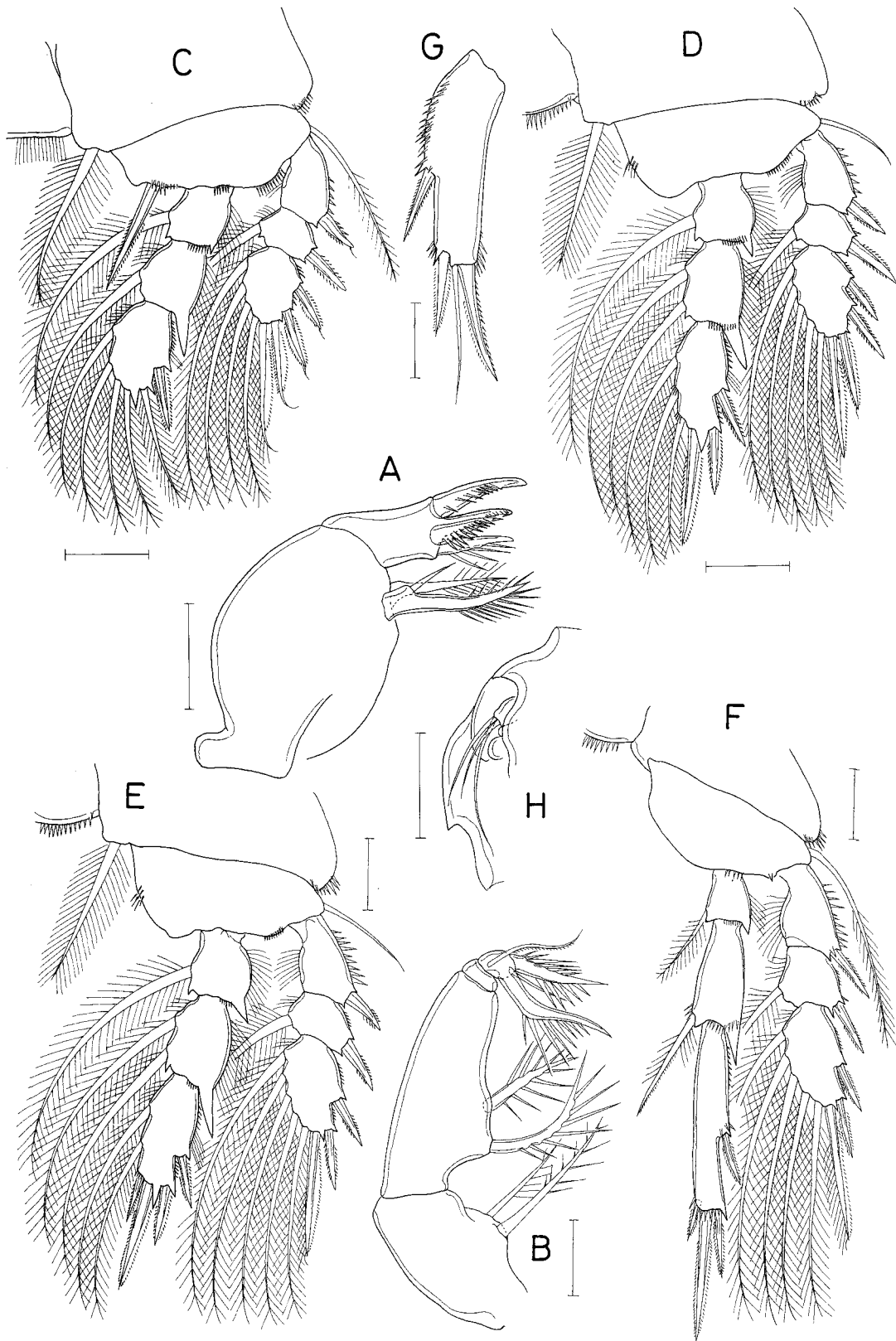
Leg 3: coxa 0-1; basis 1-0; exp. I-0; I-1; II,I,5;  
 enp. 0-1; 0-2; I,III,2

Leg 4: coxa 0-0; basis 1-0; exp. I-0; I-1; II,I,5;  
 enp. 0-1; 0-1; I,II,I

Inner distal process of second endopodal segment of legs 1-4 well developed. Inner coxal spine of leg 1 slender, 70 µm long, extending near posterior margin of second exopodal segment. Inner seta of second endopodal segment of leg



**Fig. 1.** *Giardella ricoensis* n. sp., female. A, habitus, dorsal; B, urosome, dorsal; C, distal part of abdomen, ventral; D, egg sac; E, antennule; F, antenna; G, labrum, dorsal; H, mandible; I, paragnath; J, maxillule. Scale bars=0.2 mm (A, D), 0.1 mm (B, C, E), 0.05 mm (F-J).



**Fig. 2.** *Giardella ricoensis* n. sp., female. A, maxilla; B, maxilliped; C, leg 1; D, leg 2; E, leg 3; F, leg 4; G, free segment of leg 5; H, left genital area, dorsal. Scale bars=0.05 mm (A-H).

4 stiff and spiniform; terminal endopodal segment of same leg elongated, 135 × 27 μm.

Leg 5 2-segmented; first segment with 1 dorsal seta; second segment (Fig. 2G) 142 × 43 μm (ratio 3.30 : 1), with 3 spines and 1 seta; outer lateral spine 50 μm; terminal spines 58 (outer) and 80 μm (inner), respectively. Leg 6 represented 3 distinct, naked setae in genital area (Fig. 2H).

*Male.* Unknown.

*Etymology.* The specific name *ricoensis* is from Puerto Rico where the type locality is located.

*Remarks.* The five known species of the genus *Giardella* are morphologically very homogeneous. Nevertheless, the new species can be differentiated from other four congeners as follows.

*Giardella ricoensis* n. sp. is very similar to *G. carinifer* in many important characters, but the latter species from Madagascar has rounded lateral margins (without pointed process) of genital double-somite in the female and shorter caudal ramus being eight times as long as wide (10.7 times as long as wide in *G. ricoensis*).

*Giardella callianassae* has elliptical egg sacs (Canu, 1888) (versus cylindrical in *G. ricoensis* and *G. carinifer*) and well developed, posterolaterally pointed, epimera of prosomal somites (not developed, and rounded in *G. ricoensis*).

*Giardella caissarum* has one spine and three setae on the third segment of antenna (four setae in *G. ricoensis*) and the genital double-somite in the female is as long as wide (distinctly wider than long in *G. ricoensis*).

*Giardella thompsoni* is known only by a male. The second segment of male leg 5 of *G. thompsoni* is, according to Stock (1973), armed with two spines on the outer margin and one spine plus one seta on the distal margin (versus one spine on the outer margin and two spines plus one seta on the distal margin in the female *G. ricoensis*). Because the arrangement of spines and seta on the free segment of this leg is rarely sexually dimorphic, this may be an differential feature.

**A key to the species of *Giardella***

- 1. Third segment of antenna with 1 claw and 3 setae; genital double-somite as long as wide ..... *G. caissarum*
- Third segment of antenna with 4 setae; genital double-somite wider than long ..... 2
- 2. Free segment of leg 5 with 2 spines on outer margin and 1 spine+1 seta on distal margin ..... *G. thompsoni*
- Free segment of leg 5 with 1 spine on outer margin and 2 spines+1 seta on distal margin ..... 3
- 3. Genital double-somite in female with angle on lateral margins ..... *G. ricoensis* n. sp.
- Genital double-somite in female without angle on lateral margins ..... 4

- 4. Egg sac elliptical; caudal ramus longer than abdomen in male ..... *G. callianassae*
- Egg sac cylindrical; caudal ramus shorter than abdomen in male ..... *G. carinifer*

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