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NEBALIA PSEUDOTRONCOSOI N. SP. (MALACOSTRACA: LEPTOSTRACA), FROM SOUTH KOREA, WITH A PECULIAR SEXUAL DIMORPHISM

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ABSTRACT

A new crustacean, *Nebalia pseudotroncosoi* n. sp. (Malacostraca: Leptostraca), occurs along the southern coasts of Korea. The specimens were collected by light traps in harbors where the bottom consisted of fine sand with some algal mats. The new taxon is distinguished from all other known species of *Nebalia* by the following characteristics: a rectangular compound eye with two to three small distal lobes; an antennular flagellum that is clearly shorter than the peduncle, with up to 10 articles; the fourth article of the antennular peduncle has only two distal thick setae; the antennular scale is nearly oval with a length that is 1.8 times the width; the second article of the mandibular palp has three distally plumose setae; pleonites 3 to 7 have rounded denticles along their posterior dorsal margins; and the protopod of pleopod 4 lacks serration along the posterior margin. We discuss sexual dimorphism in the genus *Nebalia* and propose the necessity of describing male traits when reporting new species. We also provide partial sequences of the mitochondrial cytochrome *c* oxidase subunit 1 (CO1) gene from the new species that can be used as a molecular diagnostic characteristic.

KEY WORDS: CO1, *Nebalia pseudotroncosoi*, sexual dimorphism, South Korea

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INTRODUCTION

The order Leptostraca is characterized by the presence of a movable rostrum, six pairs of pleopods, conspicuous uropods, and a bivalved carapace that covers eight pairs of thoracopods and partially covers the lateral sides of seven pleomeres.

As it is currently understood, the order Leptostraca includes 57 extant species that have been classified into 10 genera and four families (Mess, 2012). In fact, more than half of the species (33 spp.) belong to the genus *Nebalia* Leach, 1814, in Nebaliidae Samouelle, 1819. *Nebalia* is found in various marine habitats such as estuarine mudflats (Haney and Martin, 2005; Moreira et al., 2007), sea grass beds (Dahl, 1985; Rainer and Unsworth, 1991), sponges (Ortiz et al., 2011), sandy bottoms with algal mats, organic-rich muddy sediments in harbor areas, gravel beaches and lagoons (Song et al., 2012).

Haney and Martin (2000) recommended that any sexual dimorphism had to be noted during description of new species. However, sexual dimorphisms in *Nebalia* have been based on somewhat restrictive characteristics in previous studies, such as morphologies of antennule, antenna, and carapace (Dahl, 1985; Martin et al., 1996; Vetter, 1996; Haney and Martin, 2000; Moreira et al., 2003; Haney and Martin, 2005; Moreira et al., 2007; Moreira et al., 2009; Lee and Bamber, 2011).

In this paper, we report a new species of *Nebalia* that was collected from South Korea, *Nebalia pseudotroncosoi* n. sp. Prior to this study, only one species, *Nebalia koreana* Song, Moreira and Min, 2012, had been recorded from South Korea (Song et al., 2012). Therefore, *N. pseudotroncosoi* is the second species of the genus to be reported from South Korea, and the fourth from all of Asia, along with *N. dahli* Kazmi and Tirmizi, 1989, reported from Pakistan; *N. mortoni* Lee and Bamber, 2011, from Hong Kong; *N. koreana*. In addition, we discuss sexual dimorphism in the genus *Nebalia* and recommend that male traits be described when reporting new species (Table 1). Also, we provide partial sequence of the mitochondrial cytochrome *c* oxidase subunit 1 (CO1) gene for the new species as supplementary data for molecular diagnostics.

MATERIALS AND METHODS

Sample Collection

Specimens were collected using light traps in 2011. The traps were made of polyvinylchloride (PVC) pipe and were 30-35 cm in length and 8.5 cm in diameter, with a narrow entrance approximately 3.3 cm in diameter to prevent the entry of unwanted larger animals. For collecting, the light traps were submerged 4-10 m for two hours at night. A SCUBA diving lantern (Model D14 7457M; LED LENSER; Germany) was used as the light source. Sampling occurred in harbors where the substrate was fine sand with some algal mats. The specimens described in this paper were collected from Dolsando Island, Jeollanam-do, South Korea. All specimens

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Table 1. Sexual dimorphisms in some species of *Nebalia*.

Species	Male characteristic compared to female characteristic	Reference
N. bipes (Fabricius, 1780)	Carapace: less elliptical Compound eye: larger and with the ommatidial area distinctly wider Antennular flagellum: stouter proximal part Antennal flagellum: distinctly longer, reaching nearly to end of uropods Uropods: distinctly longer	Dahl (1985)
N. borealis Dahl, 1985	Similar to *N. bipes*	Dahl (1985)
N. daytoni Vetter, 1996	Carapace: less elliptical Compound eye: larger Pleopods 1-4: larger Antennular flagellum: longer Antennal flagellum: much longer, reaching nearly to end of uropods	Vetter (1996)
N. gerkenae Haney & Martin, 2000	Carapace: less elliptical Antennal flagellum: articles notably shorter (more articles), with very different setation	Haney and Martin (2000)
N. herbstii Leach, 1814	Carapace: less elliptical Antennular flagellum: stouter proximal part	Dahl (1985)
N. hessleri Martin, Vetter & Cash-Clark, 1996	Carapace: less elliptical Antennal flagellum: curved rather sharply in an anterior direction	Martin et al. (1996)
N. kensleyi Haney & Martin, 2005	Carapace: less elliptical Antennal flagellum: curved rather sharply in an anterior direction with more articles	Haney and Martin (2005)
N. kocatasi Moreira, Kocak & Katagan, 2007	Carapace: less elliptical Antennular flagellum: longer Antennal flagellum: longer and with more than 30 articles	Moreira et al. (2007)
N. koreana Song, Moreira & Min, 2012	Carapace: less elliptical Antennular flagellum: stouter proximal part Antennal flagellum: longer and with more than 50 articles	Song et al. (2012)
N. mortoni Lee & Bamber, 2011	Carapace: less elliptical Antennular flagellum: articles with different setation Antennal flagellum: longer	Lee and Bamber (2011)
***N. pseudotroncosoi* n. sp.**	Carapace: less elliptical Antennular flagellum: distinctly longer with more and longer aesthetascs Antennal flagellum: distinctly longer and with more than 80 articles Mandibular palp & Maxilla 1 endites: clearly different setation Pleonites 5-7: distally acute denticles on dorsal border, becoming rounded along lateral and ventral posterior border Pleopod 1 exopod: clearly different spine type ('spine-row') Pleopod 5: second article distinctly longer Uropods: distinctly longer	This study
N. reboredae Moreira & Urgorri, 2009	Carapace: less elliptical Antennal flagellum: with more articles	Moreira et al. (2009)
N. strausi Risso, 1826	Similar to *N. herbstii*	Dahl (1985)
N. troncosoi Moreira, Cacabelos & Dominguez, 2003	Carapace: less elliptical Antennular flagellum: longer and with more and aesthetascs Antennal flagellum: distinctly longer, with more than 60 articles	Moreira et al. (2003)

were preserved in 95% ethyl alcohol. The type series of *N. pseudotroncosoi* is deposited in the National Institute of Biological Resources (NIBR).

Morphological Analysis

The specimens were observed and dissected under a stereomicroscope (Model SZX-7; Olympus, Tokyo, Japan). Illustrations of dissected appendages were made with a drawing tube that was connected to a light microscope (Model DM 2500; Leica, X50-630, Wetzlar, Germany) and appendage images were photographed with a microscope digital camera (Model Nikon D90; Nikon Corporation, Japan). Drawings of entire bodies were made using a drawing tube that was attached to a stereomicroscope (Olympus SZX-12). Photographs of whole bodies were taken with a microscope digital camera (Model Moticam 2000; Motic Incorporation Ltd., Hong Kong, China) and developed using the software Helicon Focus® (Helicon Soft Ltd., Kharkov, Ukraine). Measurements of appendages and whole body lengths were taken using a stage micrometer (Leica, Germany) and an ocular micrometer.

Total length (TL) was measured from the articulation between the rostrum and the carapace to the posterior end of the uropods, excluding setation. Dorsal carapace length (DCL) was recorded as the distance between the articulation of the rostrum and the margin of the posterodorsal cleft. Lateral carapace length (LCL) was the distance along the lateral surface between the anterior-most and posterior-most margins. Carapace height (CH) was measured between the dorsal and ventral margins. Rostrum length (RL) was measured along the midline.

Molecular Analysis

Genomic DNA was extracted from muscle tissue of each specimen using DNeasy Blood and Tissue Kits (Qiagen, Valencia, CA, USA) according to the manufacturer's instructions. A DNA fragment from the CO1 gene that was approximately 660-bp long, amplified by the polymerase chain reaction (PCR) method using the primers: LCO1490 5′-GGTCAACAAATCATAAAGATATTGG-3′ and HCO2198 5′-TAAAC TTCAGGGTGACCAAAAAATCA-3′ (Folmer et al., 1994). PCR amplification was conducted under the following conditions: 3 min at 94°C, 35 cycles of 95°C for 15 s, 42°C for 30 s, and 72°C for 90 s, with a final 72°C extension reaction for 7 min. PCR products were purified with the QIAquick® Gel Extraction Kit (Qiagen) and were sequenced with an ABI3100 automated sequencer (Perkin Elmer).

SYSTEMATICS

Nebaliidae Samouelle, 1819
Nebalia Leach, 1814
Nebalia pseudotroncosoi, n. sp.
(Figs. 1-7)

Type Locality.—Dolsando Island (34°36′N, 127°47′E), Jeollanam-do, South Korea, approximately 5 m in depth.

Type Material.—Holotype (NIBRIV0000257019): Ovigerous female (Fig. 1A, 6A), RL 1.1 mm, DCL 2.3 mm, LCL 3.0 mm, CH 2.1 mm, TL 7.3 mm. Allotype (NIBRIV0000257020): male (Fig. 1B, 6F), RL 1.2 mm, DCL 2.8 mm, LCL 3.5 mm, CH 1.9 mm, TL 8.9 mm, same sampling location as holotype. Paratypes (NIBRIV0000257021-0000257023): 2 females and 1 male, same sampling location as holotype. All collected on 23 Jun 2011.

Etymology.—The name of the new species indicates its close resemblance to *Nebalia troncosoi* Moreira, Cacabelos and Domínguez, 2003.

Diagnosis.—Carapace small compared to whole body size and covering lateral sides of pleonite 2, and some of lateral sides of pleonite 3. Rostrum long, length nearly 2.3 times width. Eye somewhat rectangular, with 2-3 small distal lobes. Antennular flagellum clearly shorter than peduncle. Antennular scale nearly oval, 1.8 times as long as wide. Two distal robust spines arising from fourth antennular article. Two thin setae and seven spine-like setae arising from external lateral side of third antennal article. Second maxilla endopod first article slightly longer than second article. Denticles along pleonites 3-7 posterior dorsal margins distally rounded. Pleopod 4 protopod with even posterior margin, lacking serrations; posterolateral corner with rectangular projection. Anal plates with no distinct lateral 'shoulder.' Uropods about 0.9 times as long as combined pleonite 7 and anal somite.

Description.—Female holotype (NIBRIV0000257019): TL 7.3 mm, RL 1.1 mm, DCL 2.3 mm, LCL 3.0 mm, CH 2.1 mm (Figs. 1A, 6A).

Carapace (Figs. 1A, 6A) oval, covering lateral sides of pleonite 2, and some of lateral sides of pleonite 3. LCL 3.0 mm; about 1.4 times longer than high.

Rostrum (Fig. 2A) long, clearly extending beyond distal margin of eyestalk; about 2.3 times as long as wide; with more or less parallel margins, tapering distally with rounded apex. Rostral keel projecting posteriorly, with medial furrow where supraorbital plates insert.

Compound eye (Fig. 2B) somewhat rectangular, with 2-3 small distal lobes; ommatidial part extending about one-half of total length of eyestalk, dark brown pigmentation present on almost entire ommatidial part.

Antennule (Figs. 2C, 6B) peduncle composed of four articles. First article stout, shorter than eyestalk. Second article with: 1) plumose seta on anterior margin of proximal fourth, 2) cluster of four simple setae and five plumose setae on lateral surface, and 3) subterminal cluster of about 13 short and long simple setae and one plumose seta. Third article shorter than the second, widest distally, with cluster of about nine simple setae on anterior distal margin, one long simple seta on posterior distal margin. Fourth article shorter than third, with: 1) eight simple setae on anterior margin, 2) two thick robust spines distally, 3) lateral row of five simple setae, and 4) one long simple seta on posterior distal margin, longer than antennular scale. Antennular scale oval, 1.8 times as long as wide; anterior margin convex, with: 1) row of 7-8 simple setae along medial surface, 2) row of setae with coarse teeth along margin of distal half, and 3) numerous simple setae of different lengths. Flagellum well developed, with up to 10 articles, distinctly shorter than peduncle; each article with: 1) 3-4 aesthetascs on anterodistal margin, 2) 1-2 simple setae arising from anterodistal margin, one much longer than the other, oriented backwards.

Antenna (Figs. 2D, 6C) peduncle composed of three articles. First article with dorsal hump, small acute process. Second article slightly rectangular, with distal large acute process. Third article longer than second, with different rows of setae along medial anterior margin (Figs. 2E, 6D): 1) proximal row of about 5-6 simple setae and one long plumose seta on inner surface; 2) two thin setae and seven spine-like setae longer and thicker than those of (3); 3) 14 spines along proximal half, the distalmost being the longest;

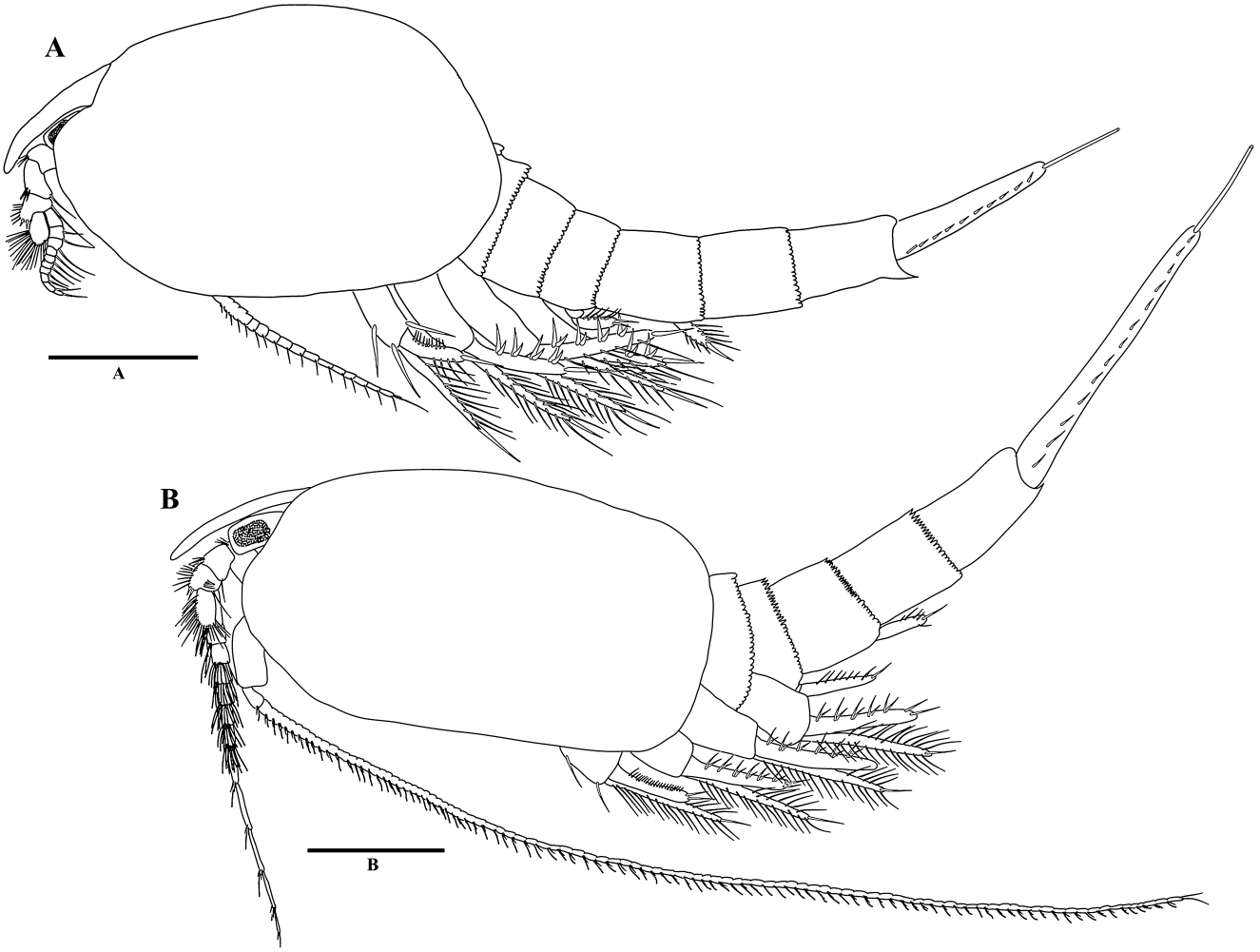

Fig. 1. *Nebalia pseudotroncosoi* n. sp. A, female holotype, lateral view; B, male allotype, lateral view. Scale bars = 1 mm (A, B).

4) 14-16 long simple setae each associated with two spines of (3), four simple setae next to distalmost spine of (3); and 5) terminal row of seven spines, increasing distally in length, the distalmost next to four simple setae; one long plumose seta on posterior margin; cluster of 12-13 plumose setae along distal inner margin. Flagellum well developed, composed of 14-16 articles; each article with four terminal setae, one shorter and thinner than the others, oriented posteriorly.

Mandibular palp (Fig. 3A) composed of three articles; second article about 1.4 times longer than first; three distally plumose setae (Fig. 7A): 1) one at mid-length on lateral side, 2) other two setae subterminally on anterior margin. Third article slightly longer than second, with margins slightly expanded; proximal half of anterior margin with row of setae shorter than others of palp; posterior margin with three types of setae: 1) row of setae arising from ending of proximal third extending to proximal half, distally plumose; 2) row of longer setae than those of (1) extending along distal half, distally plumose; and 3) about 7-8 curved, dentate setae on distal margin (Fig. 6E).

First maxilla (Fig. 3C) proximal endite with rounded margin bearing distally plumose setae. Distal endite (Figs. 3D, 7B) larger than proximal endite (Fig. 3E); medial margin with one plumose setae and two types of setae: 1) about 15-16 setae of increasing size with three notable teeth along distal posterior margin also provided with several smaller teeth, 2) about 5-6 spatulate setae and one short simple setae. Palp well developed, with proximal cluster of 6-7 setae and 7 widely spaced setae, setae numbering possibly about 14-15 (some part of palp broken) along its whole length; apex strongly curved distally.

Second maxilla (Fig. 3B) protopod composed of four endites with plumose setae, endites 1 and 3 being the largest nearly subequal in size; endites 2 and 4 smaller than both 1 and 3. Fourth endite the smallest, with six plumose setae, the distalmost seta somewhat longer than others. Endopod composed of two articles, longer than exopod, first article 1.9 times as long as second one; lateral and medial margins with numerous plumose setae; second article with two terminal setae distally. Exopod slightly longer than the first article of endopod; medial margin with numerous plumose setae, two distalmost setae shorter than exopod.

Thoracopods (Figs. 3F-M, 7C): endopod slightly longer than exopod; with numerous plumose setae along anterior margin. Distal article of endopod distinctly expanded,

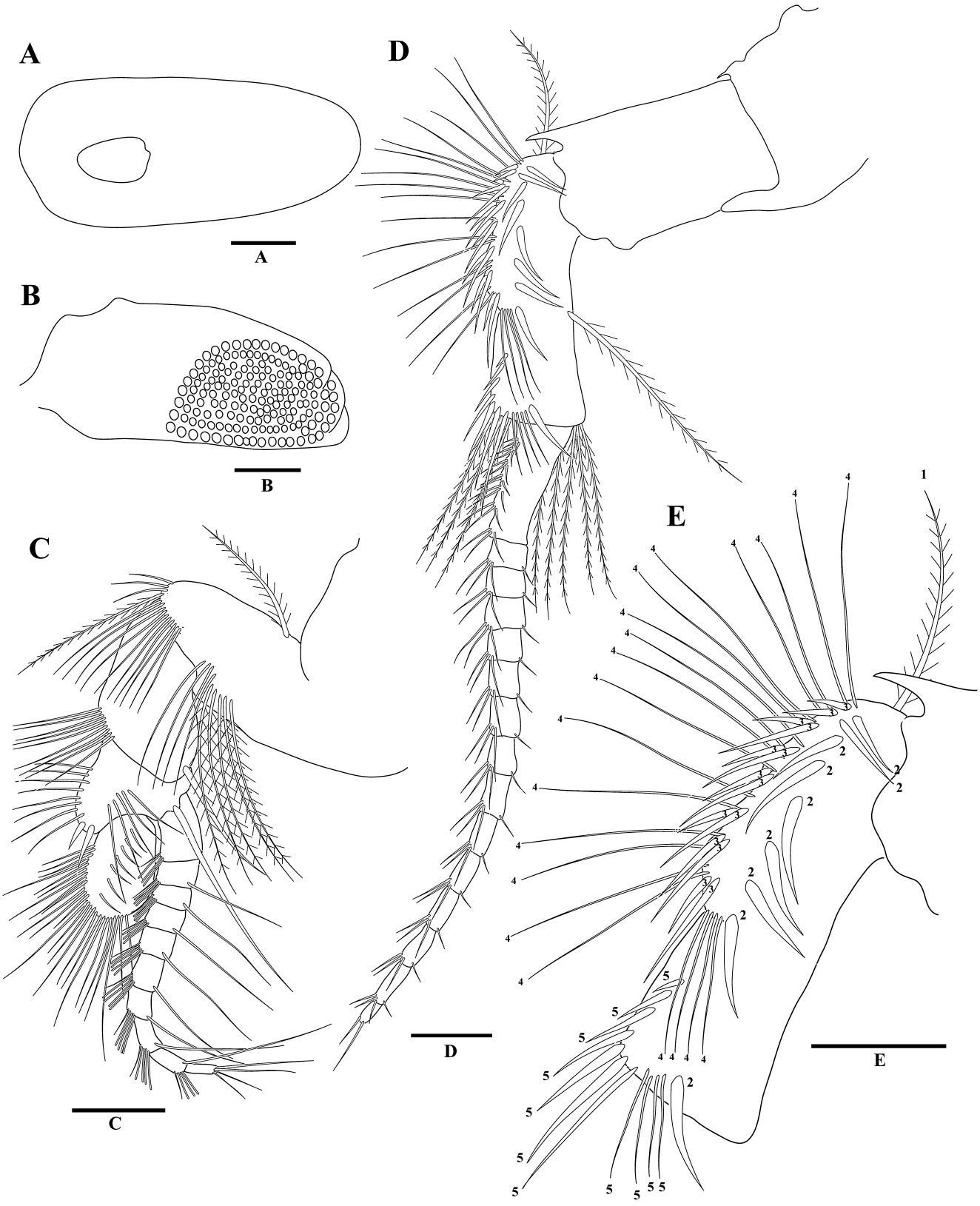

Fig. 2. *Nebalia pseudotroncosoi* n. sp., female holotype. A, rostrum, dorsal view; B, eye, lateral view; C, antennule, lateral view; D, antenna, lateral view; E, antenna, third article, external side, lateral view. Scale bars = 0.2 mm (A, C-E), 0.1 mm (B).

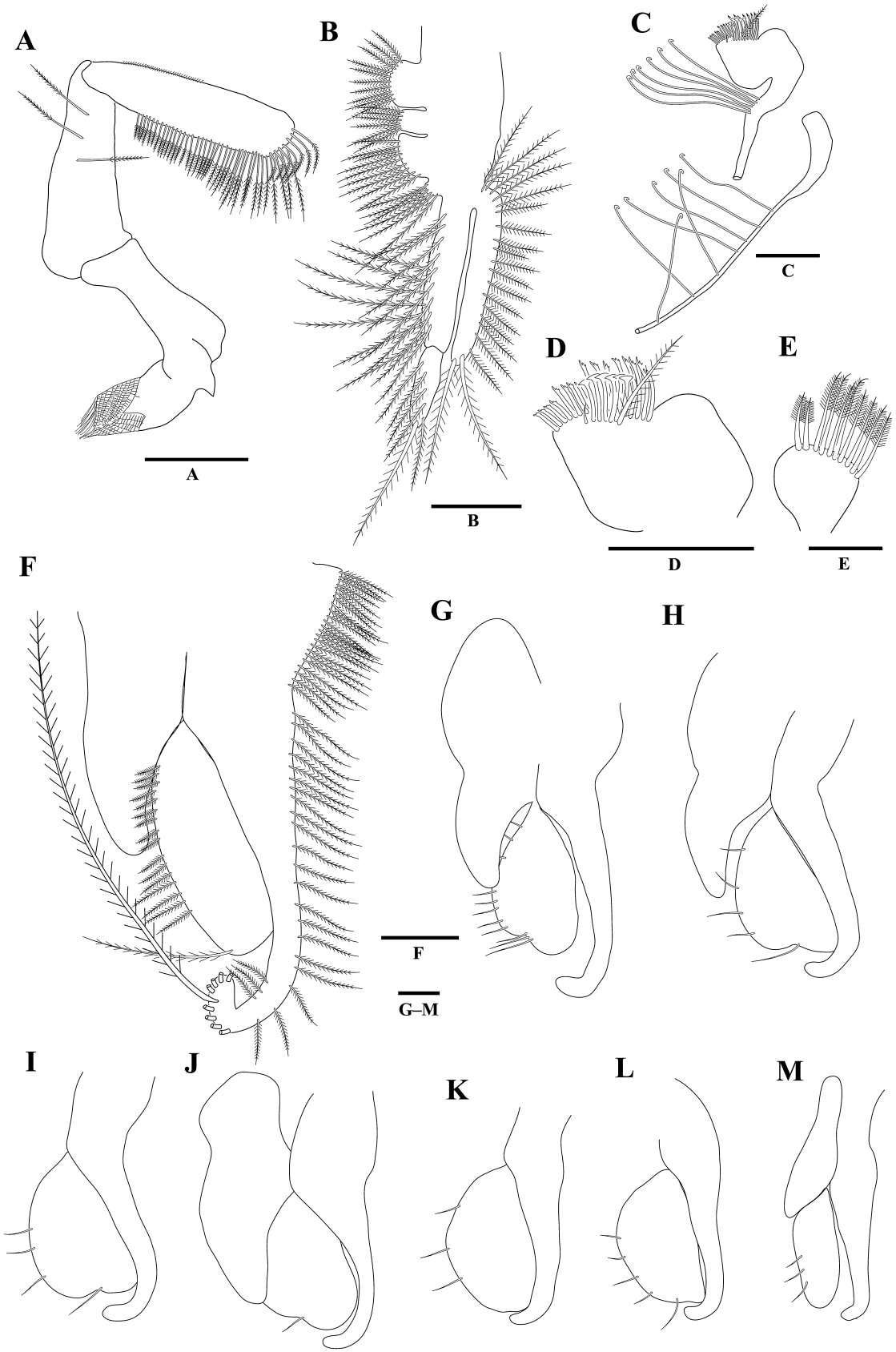

Fig. 3. *Nebalia pseudotroncosoi* n. sp., female holotype. A, mandibular palp; B, second maxilla; C, first maxilla; D, first maxilla, distal endite; E, first maxilla, proximal endite; F, thoracopod 1, showing setation; G, thoracopod 2; H, thoracopod 3; I, thoracopod 4; J, thoracopod 5; K, thoracopod 6; L, thoracopod 7; M, thoracopod 8. Scale bars = 0.2 mm (A-M).

slightly oriented backwards, with about 8-9 long plumose setae, with recurved apex. Exopod with 3-15 plumose setae along posterior margin. Thoracopod 8 epipod noticeably smaller than those of thoracopods 1-7.

Pleonites (Fig. 4I) 3-7 with denticles along posterior margin; denticles with somewhat parallel sides, distally rounded.

Pleopod 1 (Fig. 4A) composed of protopod, endopod and exopod. Protopod with posterior margin lacking serrations; three basal simple setae: 1) one long seta arising subdistally, 2) thicker seta near the base of endopod, and 3) longer seta near the base of exopod, almost reaching the distal end of exopod spine-row, posterior margin with one long simple seta on proximal third, five simple setae on medial surface. Endopod composed of two articles, longer than exopod; lateral and medial margins of second article each with about 24-27 plumose setae, 6-7 short setae on proximal medial margin with three small humps along distal half (see Song et al., 2012, Fig. 7J), distal margin with acute projection at apex and one long, stout terminal spine. First article shorter, appendix interna with three short recurved hooks. Exopod about 0.6 times length of protopod; with row of about 30-35 somewhat long serrate spines (Fig. 7D) along lateral margin ('spine-row'), each spine with tiny tridentate tip, central tooth bifid; four stout spines on distolateral margin, two long alternating with other two short spines; row of long plumose setae along medial margin.

Pleopods 2 and 3 similar (Fig. 4B, C). Protopods with: 1) 1-2 simple setae along posterior margin on proximal third, 2) 5-6 simple setae on anterior proximal margin, 3) cluster of 6-8 long setae subdistally near the base of endopod, and 4) one slightly thick seta near the base of exopod. Acute triangular process between endopod and exopod; posterior margin even. Endopod slightly longer than exopod, composed of two articles; proximal article distinctly short, provided with appendix interna with one margin somewhat expanded and serrated; lateral and medial margins of distal article each with about 21-24 plumose setae, ending in one long robust spine. Exopod with a row of six pairs of long thick setae, each pair composed of one long and one relatively shorter seta; medial border with row of long plumose setae, three distal stout spines, increasing distally in length.

Pleopod 4 (Fig. 4D) protopod with five simple setae along anterior margin on proximal third; cluster of 4-5 long setae subdistally near the base of endopod; posterior margin lacking serrations, posterolateral corner with rectangular projection. Setation and pattern of spine pairs on margins of endopod and exopod nearly same as pleopods 2-3.

Pleopods 5-6 (Fig. 4E, F): fifth pleopod uniramous, composed of two articles; second article about 3.2 times as long as wide, with 5-6 stout spines along distolateral and terminal borders, increasing distally in length; 34-38 simple setae along medial and distal borders, setae appearing more or less jointed at midlength. Sixth pleopod uniramous, composed of one article, with 5-6 stout spines along distolateral and terminal borders, increasing distally in length, with circlet of sharp teeth basally. Medial and terminal borders with 'jointed' setae similar to those of fifth pleopod.

Anal somite, anal plates and uropod (Figs. 1A, 4G, H): anal somite short, slightly longer than pleonite 7. Anal plates with relatively wide bases and acutely tapering distally, no distinct lateral 'shoulder.' Uropods short, about 0.9 times as long as combined pleonite 7 and anal somite. Uropods with about 20-22 robust setae along lateral margin increasing distally in length, about 13-15 simple setae and 13-14 plumose setae on lateral inner margin, cluster of three short spine-like setae on distolateral inner border.

Description.—Male allotype (NIBRIV0000257020): TL 8.9 mm, RL 1.2 mm, DCL 2.8 mm, LCL 3.5 mm, CH 1.9 mm (Figs. 1B, 6F). Male differing from female in the following.

Carapace (Figs. 1B, 6F) nearly rectangular; distinctly less elliptical than that of female. Compound eye (Fig. 5B) shorter and vaguely distally lobed. Antennule (Figs. 5C, 6G) flagellum distinctly longer than peduncle; each article with numerous and longer aesthetascs (3-4 shorter aesthetascs in female). Antenna (Figs. 1B, 5D, E, 6H, I) flagellum clearly longer, with more than 80 articles, articulation vague, nearly reaching the uropods; distribution of lateral row of spines and setae on third article of antennal peduncle different from that of female.

Mandibular palp (Figs. 5F, 7F) second article with four distally plumose setae (three distally plumose setae in female); setae on third article distal margin much shorter than those of female (Fig. 6J). First maxilla (Figs. 5H, 7G) with clearly different setation in endites 1, 2. Second maxilla (Fig. 5G) endopod more or less stout.

Thoracopod 1 (Figs. 5I, 7H) endopod more or less stout.

Pleonites 5-7 (Fig. 5J) with distally acute denticles on dorsal border, becoming rounded along lateral and ventral posterior border (pleonites 5-7 with distally rounded denticles along dorsal and lateral posterior border in female). Pleopod 1 (Figs. 5K, 7I) exopod lateral margin with spines of 'spine-row,' lacking tiny tridentate tip and central tooth bifid; spine tip acute instead. Pleopods 2-4 (Fig. 5L) protopod somewhat shorter than that of female, as long as exopod. Pleopod 5 (Fig. 5M) second article distinctly longer than female, about 5.8 times as long as wide (3.2 times as long as wide in female). Pleopod 6 (Fig. 5N) more or less longer than that of female. Uropods (Figs. 5O, 7J) distinctly longer than those of female, about 1.5 times as long as combined pleonite 7 and anal somite (0.9 times as long as combined pleonite 7 and anal somite in female).

Molecular data.—CO1 gene sequences were determined for five individuals (GenBank accession numbers: JX442539-JX442543). All specimens had 100% similar partial CO1 gene sequences and were similar to the holotype morphologically. The sequence alignment was straightforward, with no insertions and deletions. In the amino acid translation using the invertebrate mitochondrial code, no stop codons were found.

Morphological Variation.—The paratypes (females only) showed some morphological variation in comparison with the holotype in the number of articles in the antennular and antennal flagellum, the number of spines in the fourth article of antennule, and pleopods 5-6 (Table 2).

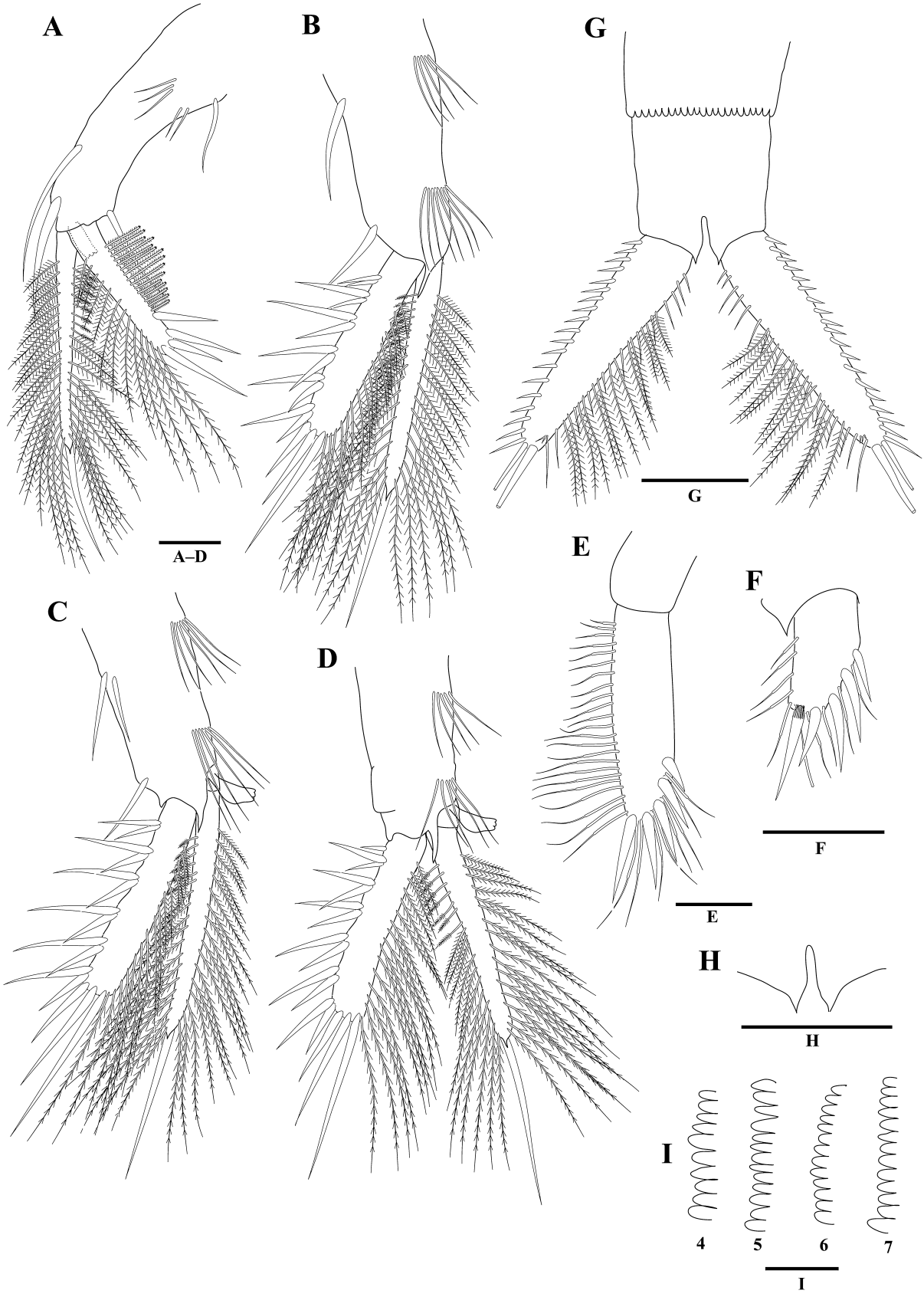

Fig. 4. *Nebalia pseudotroncosoi* n. sp., female holotype. A, pleopod 1, lateral view (only half of setae of spine row illustrated); B, pleopod 2, lateral view; C, pleopod 3, lateral view; D, pleopod 4, lateral view; E, pleopod 5; F, pleopod 6; G, uropods, ventral view; H, anal plates; I, pleonites 4-7, posterior lateral border, denticles. Scale bars = 0.2 mm (A-D, F), 0.1 mm (E, I), 0.5 mm (G, H).

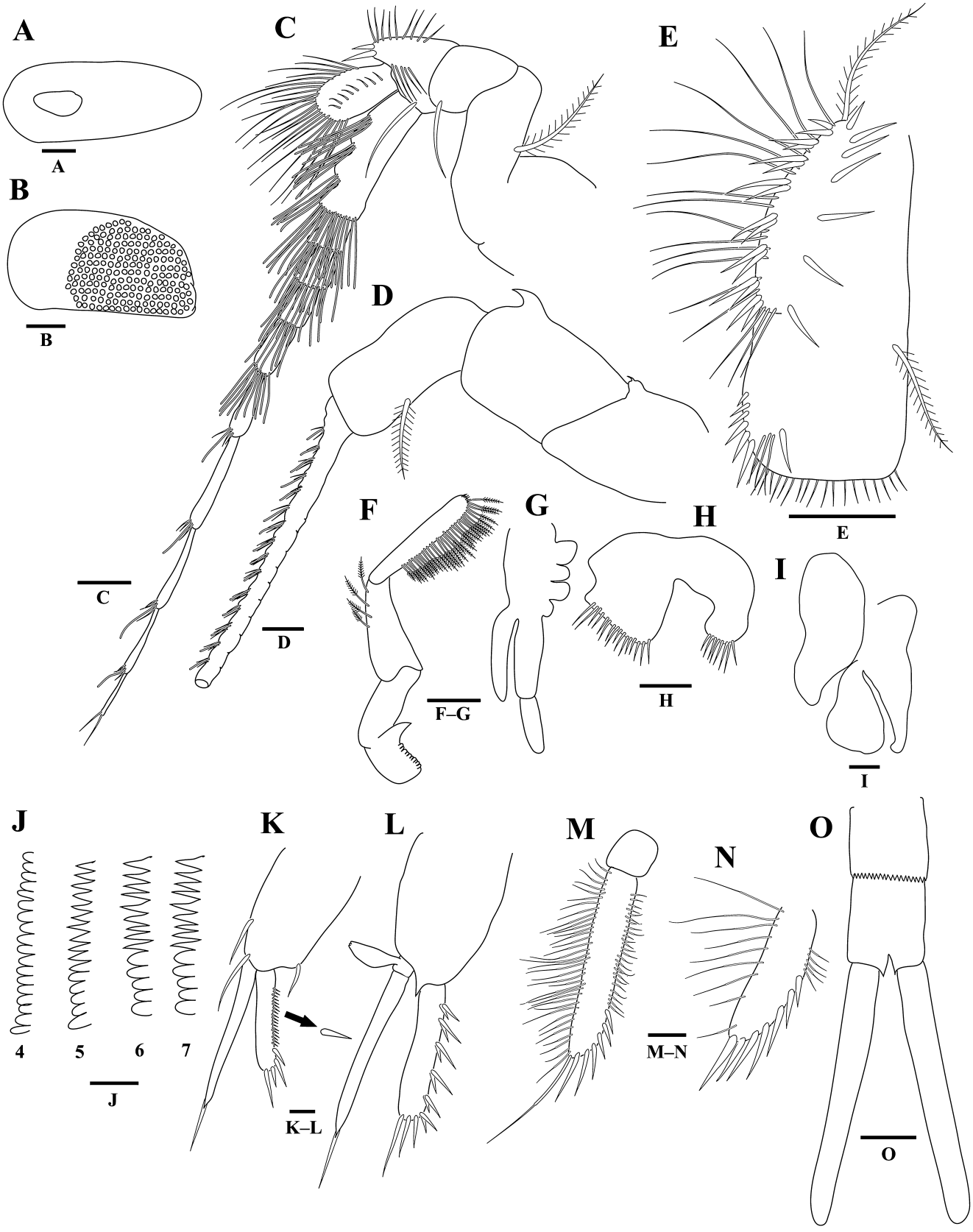

Fig. 5. *Nebalia pseudotroncosoi* n. sp., male allotype. A, rostrum, dorsal view; B, eye, lateral view; C, antennule, lateral view; D, antenna, lateral view; E, antenna, third article, external side, lateral view; F, mandibular palp; G, second maxilla; H, first maxilla, endites; I, thoracopod 1; J, pleonites 4-7, posterior lateral border, denticles; K, pleopod 1, lateral view; L, pleopod 2, lateral view; M, pleopod 5; N, pleopod 6; O, uropods, ventral view. Scale bars = 0.2 mm (A, C, E, F, G, I, K, L), 0.1 mm (B, D, H, J, M, N), 0.5 mm (O).

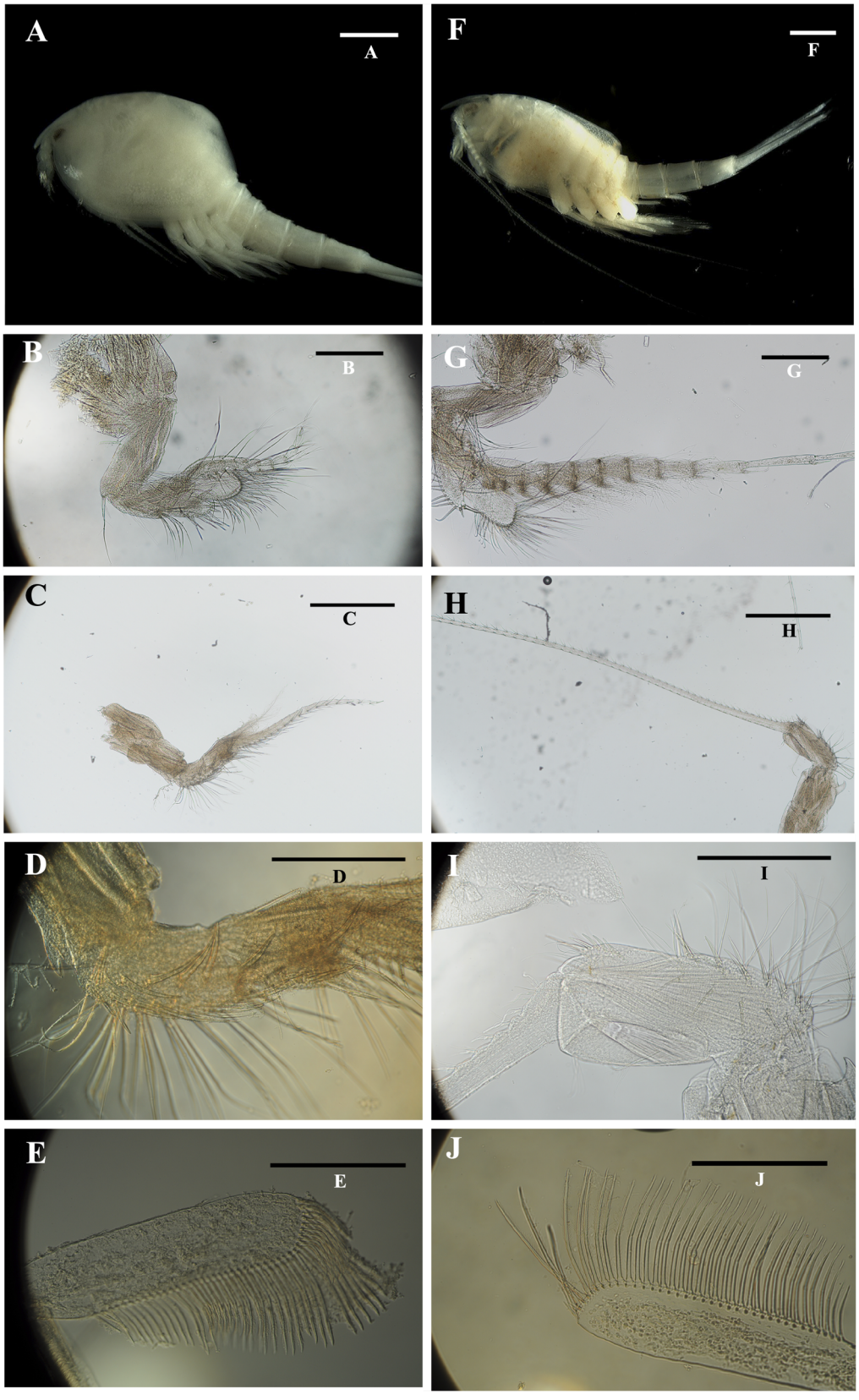

Fig. 6. *Nebalia pseudotroncosoi* n. sp. A, female holotype, lateral view; B, female holotype, antennule, lateral view; C, female holotype, antenna, lateral view; D, female holotype, antenna, third article, external side, lateral view; E, female holotype, mandibular palp 3, distal setation; F, male allotype, lateral view; G, male allotype, antennule, lateral view; H, male allotype, antenna, lateral view; I, male allotype, antenna, third article, external side, lateral view; J, male allotype, mandibular palp 3, distal setation. Scale bars = 1 mm (A, F), 0.2 mm (B, G), 0.5 mm (C, H), 0.1 mm (D, E, I, J). This figure is published in colour in the online edition of this journal, which can be accessed *via* http://booksandjournals.brillonline.com/content/1937240X.

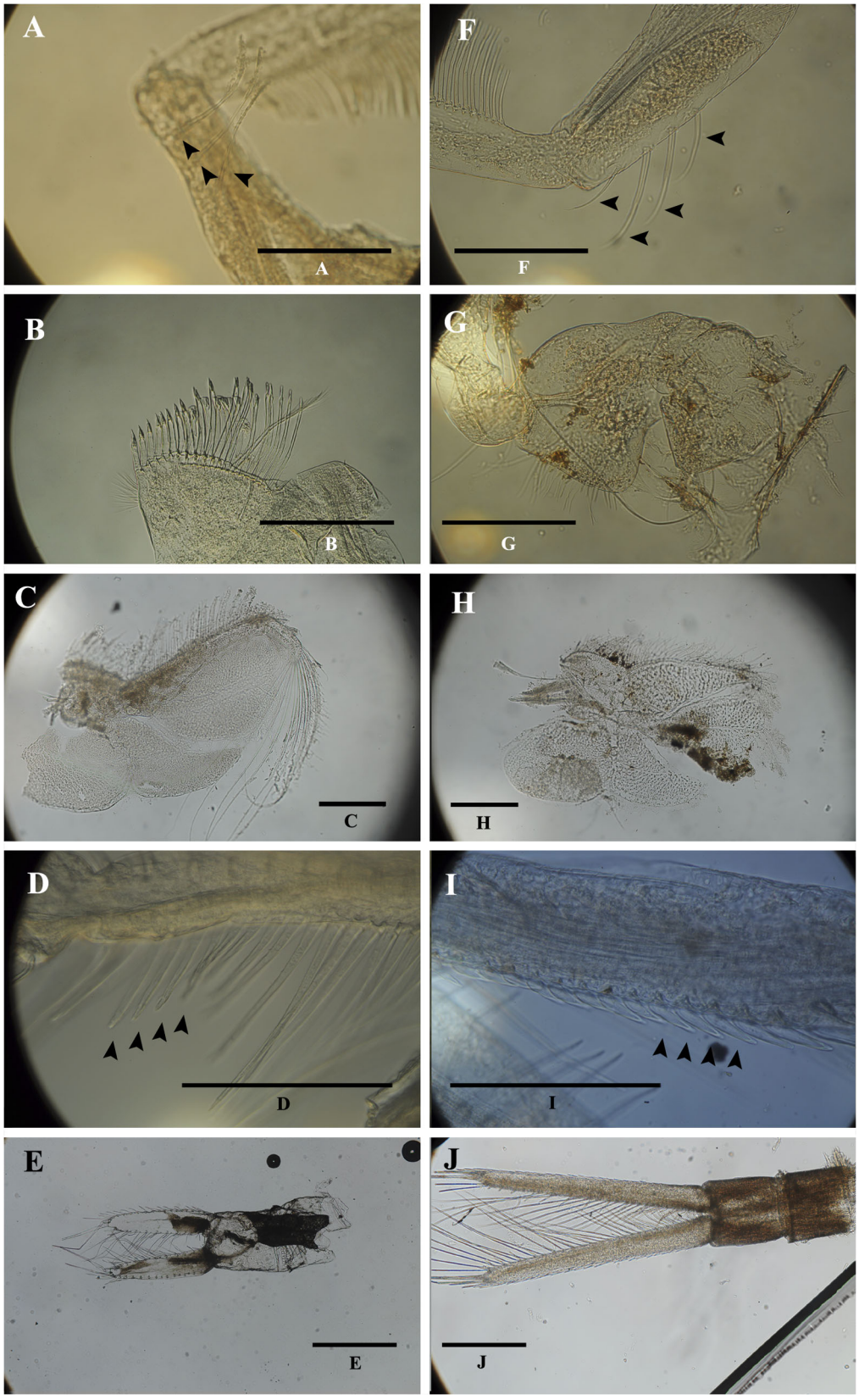

Fig. 7. *Nebalia pseudotroncosoi* n. sp. A, female holotype, mandibular palp 2, setation; B, female holotype, first maxilla, distal endite, setation; C, female holotype, thoracopod 1; D, female holotype, pleopod 1, exopod "spine-row"; E, female holotype, uropod, ventral view; F, male allotype, mandibular palp 2, setation; G, male allotype, first maxilla, endites, setation; H, male allotype, thoracopod 1; I, male allotype, pleopod 1, exopod "spine-row"; J, male allotype, uropod, ventral view. Scale bars = 0.1 mm (A, B, D, F, G, I), 0.2 mm (C, H), 0.5 mm (E, J). This figure is published in colour in the online edition of this journal, which can be accessed *via* http://booksandjournals.brillonline.com/content/1937240X.

Table 2. Morphological variation in *Nebalia pseudotroncosoi* n. sp. (only female).

	Antennular flagellum, number of articles	Antennal flagellum, number of articles	Antennule article 4, number of spines	Pleopod 5, number of spines	Pleopod 6, number of spines
Holotype (NIBRIV0000257019)	10	15	2	5-6	5-6
Paratype 1 (NIBRIV0000257021)	8	10	2	3-4	3-4
Paratype 2 (NIBRIV0000257022)	8	10	2	3-4	3-4

Habitat.—This species was collected from approximately 5 m depth on sedimentary bottoms composed of fine sand with some algal mat comprising *Ulva pertusa* and *Sargassum fusiforme*. The new species was collected together with other crustaceans, including the amphipods *Caprella acanthogaster* Mayer, 1890 and *C. penantis* Leach, 1814, the cumacean *Diastylis koreana* Calman, 1911, and an isopod *Cirolana* sp.

Distribution.—Currently, *N. pseudotroncosoi* is known only from the southern coasts of the Korean peninsula.

Discussion

Nebalia pseudotroncosoi differs from previously reported species of *Nebalia* in the following unique combination of characteristics: 1) a rectangular compound eye that is provided with two to three small distal lobes; 2) an antennular flagellum that is clearly shorter than the peduncle, with up to 10 articles; the fourth article of the antennule has only two distal spines; the antennular scale is nearly oval with a length that is 1.8 times its width; 3) the second article of the mandible palp bears three distally plumose setae; the posterior dorsal and lateral margins of pleonites 3 to 7 bear rounded denticles; and 4) the protopod of pleopod 4 has an even posterior margin. Among the aforementioned characteristics, the shape of the compound eye is the most differentiable characteristic in *Nebalia* because eye morphology tends to be relatively conservative, with most species having an eye that is slightly dilated and not subdivided or lobed (Haney et al., 2001). On the contrary, four species of *Nebalia* including the new species described here, have unusual eye morphology: *Nebalia daytoni* Vetter, 1996, is recognized by its eye, which has a flat anterior margin bordered by a superior and inferior protuberance; *N. schizophthalma* Haney, Hessler and Martin, 2001, has an eye that is distinctly invaginated distally; *N. troncosoi* and *N. pseudotroncosoi* possess two to three small distal lobes on the compound eye.

Nebalia pseudotroncosoi is most similar to *N. troncosoi* with regard to features related to external appearance. The two species are similar in the following characteristics: 1) the shape of the compound eye, 2) the number of distal thick spines on the antennule fourth article in adult specimens, and 3) the antennules bearing distinctly shorter flagella than the peduncles. The new species, however, differs from *N. troncosoi* in: 1) the shape of the denticles on the posterior and dorsal margins of pleonites 6 to 7, 2) the number of serrations along the posterior margin of the fourth pleopod protopod, and 3) the whole body size of mature females. In *N. troncosoi*, pleonites 6 to 7 have acute denticles along their posterior dorsal margins, the posterior margin of the fourth pleopod protopod is crenate, and the whole body size of holotype mature female is 3.55 mm. In comparison, in the new species, pleonites 6 to 7 have rounded denticles, the posterior border of the protopod of the fourth pleopod is even, without serration, and the whole body size of holotype mature female is 7.3 mm.

We also found a peculiar sexual dimorphism in *N. pseudotroncosoi* with females having rounded denticles along the posterior dorsal margin of pleonites 5 to 7 and males having clearly acute denticles. This difference among females and males was also confirmed in all paratypes and male allotype (see Description.—Male allotype; Figs. 4I, 5J). The shape of the denticles of pleonites 5 to 7 is regarded as an important characteristic for identifying species (Dahl, 1985, 1990). However, sexual dimorphism in this characteristic has not been reported in any other species of *Nebalia*; future descriptions should include an assessment of whether or not denticle shape differs among females and males. In fact, sexual dimorphism in leptostracans has not been studied intensively because most taxonomical studies have been based on female specimens and detailed descriptions of males have generally been limited to features of the carapace, antennule, and antenna (Haney and Martin, 2005; Lee and Bamber, 2011). According to previous studies (Dahl, 1985), the proportions of mature male specimens have been much lower than those of females in collections of Leptostraca. However, males are occasionally abundant in samples of Leptostraca, representing a significant portion of the population, and many unidentified specimens, in fact, have been males (Haney and Martin, 2000).

In conclusion, we suggest that additional information about male specimens, including sexual dimorphisms, will be useful for appropriately determining taxonomic status during descriptions of new taxa (Table 1).

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References

Calman, W. T. 1911. IV. On new or rare Crustacea of the order Cumacea from the collection of the Copenhagen Museum. Part II. The families Nannastacidae and Diastylidae. Transactions of the Zoological Society of London 18: 341-398.

Dahl, E. 1985. Crustacea Leptostraca, principles of taxonomy and a revision of European shelf species. Sarsia 70: 135-165.

———. 1990. Records of *Nebalia* (Crustacea Leptostraca) from the Southern Hemisphere – a critical review. Bulletin of the British Museum of Natural History 56: 73-91.

Folmer, O., M. Black, W. Hoeh, R. Lutz, and R. Vrijenhoek. 1994. DNA primers for amplification of mitochondrial cytochrome *c* oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294-299.

Haney, T. A., and J. W. Martin. 2000. *Nebalia gerkenae*, a new species of leptostracan (Crustacea: Malacostraca: Phyllocarida) from the Bennett Slough region of Monterey Bay, California. Proceedings of the Biological Society of Washington 113: 996-1014.

———, and ———. 2005. *Nebalia kensleyi*, a new species of leptostracan (Crustacea: Phyllocarida) from Tomales Bay, California. Proceedings of the Biological Society of Washington 118: 3-20.

———, R. R. Hessler, and J. W. Martin. 2001. *Nebalia schizophthalma*, a new species of Leptostracan (Malacostraca) from deep waters off the East Coast of the United States. Journal of Crustacean Biology 21: 192-201.

Kazmi, Q. B., and N. M. Tirmizi. 1989. A new species of *Nebalia* from Pakistan (Leptostraca). Crustaceana 56: 293-298.

Leach, W. E. 1814. Crustaceology, pp. 385-437. In, Sir D. Brewster (ed.), The Edinburgh Encyclopaedia; conducted by D. Brewster. 7. Edinburgh.

Lee, C. N. W., and R. N. Bamber. 2011. A new species of *Nebalia* (Crustacea: Phyllocarida: Leptostraca) from the Cape d'Aguilar Marine Reserve, Hong Kong. Zootaxa 3091: 51-59.

Martin, J. W., E. W. Vetter, and C. E. Cash-Clark. 1996. Description, external morphology, and natural history observations of *Nebalia hessleri*, new species (Phyllocarida: Leptostraca), from southern California, with a key to the extant families and genera of the Leptostraca. Journal of Crustacean Biology 16: 347-372.

Mayer, P. 1890. Die Caprelliden des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Fauna und flora des Golfes von Veapel 17: 1-55.

Mess, J. 2012. Leptostraca. World Register of Marine Species (WoRMS) [Online]. Available from http://www.marinespecies.org/aphia.php?p=taxdetails&id=146996. Acessed on 9 May 2012.

Moreira, J., E. Cacabelos, and M. Domínguez. 2003. *Nebalia troncosoi* sp. nov., a new species of leptostracan (Crustacea: Phyllocarida: Leptostraca) from Galicia, Iberian Peninsula (north-east Atlantic). Journal of the Marine Biological Association of the United Kingdom 83: 341-350.

———, G. Díaz-Agras, M. Candás, M. P. Señarís, and V. Urgorri. 2009. Leptostracans (Crustacea: Phyllocarida) from the Ria de Ferrol (Galicia, NW Iberian Peninsula), with description of a new species of *Nebalia* Leach, 1814. Scientia Marina 73: 269-285.

———, C. Kocak, and T. Katagan. 2007. *Nebalia kocatasi* sp. nov., a new species of leptostracan (Crustacea: Phyllocarida) from Izmir Bay (Aegean Sea, eastern Mediterranean). Journal of the Marine Biological Association of the United Kingdom 87: 1247-1254.

Ortiz, M., I. Winfield, and S. Chazaro-Olvera. 2011. A new sponge-inhabiting leptostracan species of the genus *Nebalia* (Crustacea: Phyllocarida: Leptostraca) from the Veracruz Coral Reef System, Gulf of Mexico. Zootaxa 3027: 52-62.

Rainer, S. F., and P. Unsworth. 1991. Ecology and production of *Nebalia* sp. (Crustacea: Leptostraca) in a shallow-water seagrass community. Marine and Freshwater Research 42: 53-68.

Song, J. H., J. Moreira, and G. S. Min. 2012. A new species of Leptostraca, *Nebalia koreana* (Malacostraca: Phyllocarida), from South Korea. Journal of Crustacean Biology 32: 641-653.

Vetter, E. W. 1996. *Nebalia daytoni* n. sp. a leptostracan from Southern California (Phyllocarida). Crustaceana 69: 379-386.

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