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A new species of the genus *Goniopsyllus* Brady (Copepoda, Harpacticoida, Clytemnestridae) from Korean waters

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Abstract.—A new species, *Goniopsyllus dokdoensis*, is described from the adjacent waters of Dokdo Island in the East Sea of Korea. The new species is closely related to *G. clausi* in the triangular shape of the rostrum, the length of the thoracopod 5 exopod, and the constricted genital double somite. However *G. dokdoensis* is distinguished from *G. clausi* by its smaller body size, genital field with additional pores adjacent to the copulatory pore, urosomites without dorsal ornamentation, and differences in the length of caudal setae. Also, the sixth pair of legs in the male has two setae at the outer distal corner of each lobe. This study is the first to report the presence of the genus *Goniopsyllus* in Korean waters.

Members of the family Clytemnestridae are typically found in the epipelagic zone of all oceans. The family was established by Scott (1909) to accommodate the distinct copepod species found during the pioneering oceanographic expeditions, such as the U.S. Exploring Expedition (Dana 1854) and the Voyage of the H.M.S. *Challenger* (Brady 1883). Clytemnestrids were placed in the order Poecilostomatoida until Claus (1891) demonstrated that they actually belong to the order Harpacticoida. There were only two known species, *Clytemnestra scutellata* Dana, 1847, and *C. rostrata* (Brady 1883) before the recent revision of the family (Huys & Conroy-Dalton 2000). Huys & Conroy-Dalton (2000) declared Clytemnestridae as a nomen protectum and recognized at least ten valid species in two genera of the family. They revived *Goniopsyllus*, which Brady (1883) originally erected for *G. rostratus*, and also placed *G. clausi*, *G. brasiliensis*, and *G. tenuis* in the genus. Two genera, *Clytemnestra* and *Goniopsyllus*, can be distinguished by their antennule segmentation and by morphological differences in the genital field and the armature of the antenna, maxillule, maxilla, and thoracopods 1 and 2.

Two cosmopolitan species in the family, *Clytemnestra scutellata* and *Goniopsyllus rostratus*, are known from various localities. For instance, *C. scutellata* was reported from near the Gilbert Islands, east of Tuamotu in the Pacific Ocean, and in the South China Sea (Dana 1847). Farran (1936) also recorded *C. scutellata* from the Great Barrier Reef. Most of the records for *C. rostrata* are presently assigned to *Goniopsyllus clausi* rather than *G. rostratus* (Huys & Conroy-Dalton 2000). The distribution of *G. rostratus* is

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limited to the South Atlantic, whereas *G. clausi* was reported from various areas, including the Cape Verde Islands and the Bay of Cadiz in the Atlantic Ocean, Naples in the Mediterranean, the Adriatic Sea, and the Pacific Ocean (Brady 1883, Breeman 1908, Farran 1936, Bradford 1972, Boxshall 1979). Both species, *C. scutellata* and *C. rostrata*, have also been recorded in Korean waters but only in the species lists of ecological reports on the zooplankton community of various localities (Shim et al. 1988, Yoo 1991, Kim et al. 1993).

During a serial study of the zooplankton community around Dokdo Island in the East Sea of Korea, a new species of the genus *Goniopsyllus* was collected. This study is intended to provide an illustrated description of the new species and to discuss its relationships with other members of the genus.

Materials and Methods

During a research cruise for the "Study on the marine ecosystem of Dokdo Island" in November 2004, zooplankton was collected at station A17 (37°15′N, 131°46′E) near Dokdo Island in the East Sea of Korea, from depths of up to 200 m, by a vertical haul of a bongo net (mesh aperture 300 μm). The collected specimens were immediately fixed with 5% formalin on board. Copepods were sorted under a microscope (Zeiss Semi 2000-C) in the laboratory. The sorted specimens were dissected with tungsten needles and mounted in lactophenol. All drawings were prepared using a drawing tube attached to a Leica DM2500 interference microscope. The new species described herein was also examined by scanning electron microscopy (Hitachi S2380N). Specimens were dehydrated through a graded acetone series and dried using a critical-point dryer, and the dried specimens were mounted on stubs and coated with gold using an ion sputter.

The descriptive terminology is adopted from Huys et al. (1996). Abbreviations used in the text are: A1, antennule; A2, antenna; ae, aesthetasc; enp, endopod; P1–P6, first to sixth thoracopod; exp, exopod; exp (enp)-1(2, 3) to denote the proximal (middle, distal) segment of a three-segmented ramus. Specimens are deposited in the National Institute of Biological Resources (NIBR), Korea. Scale bars in the figures are indicated in μm.

Systematics

Family Clytemnestridae A. Scott, 1909
Genus *Goniopsyllus* Brady, 1883
Goniopsyllus dokdoensis, new species
Figs. 1–9

Type species.—*G. rostratus* Brady, 1883; additional species: *G. clausi* Huys & Conroy-Dalton, 2000, *G. brasiliensis* Huys & Conroy-Dalton, 2000, *G. tenuis* (Lubbock, 1860), *G. dokdoensis*.

Type locality.—Station A17 (37°15′N, 131°46′E) near Dokdo Island in the East Sea of Korea.

Material examined.—Holotype. 1 ♀ (NIBRIV0000193203) dissected on 13 slides. Paratypes. 1 ♀ (NIBRIV0000193205) and 1 ♂ (NIBRIV0000193204) dissected on 13 slides, respectively. Five ♀♀ (NIBRIV0000193206) and 1 ♂ (NIBRIV0000193484) preserved in 70% alcohol. Females were from the type locality on 4 Nov 2004 and males from St. 12 (37°09′N, 132°01′E) on 15 Aug 2009; all samples were collected by K. H. Cho.

Description of female.—Body length 820–915 μm ($\overline{X}$ = 860 μm; n = 10, measured from anterior margin of rostrum to posterior margin of caudal rami). Body slightly depressed dorsoventrally, tapering posteriorly. Largest width measured at posterior margin of cephalic shield: 302 μm. Posterolateral angles of cephalothorax slightly expanded (Fig. 1A). Somites bearing P2–P4 successively decreasing in width posteriorly, with weakly produced alate processes, less protuberant

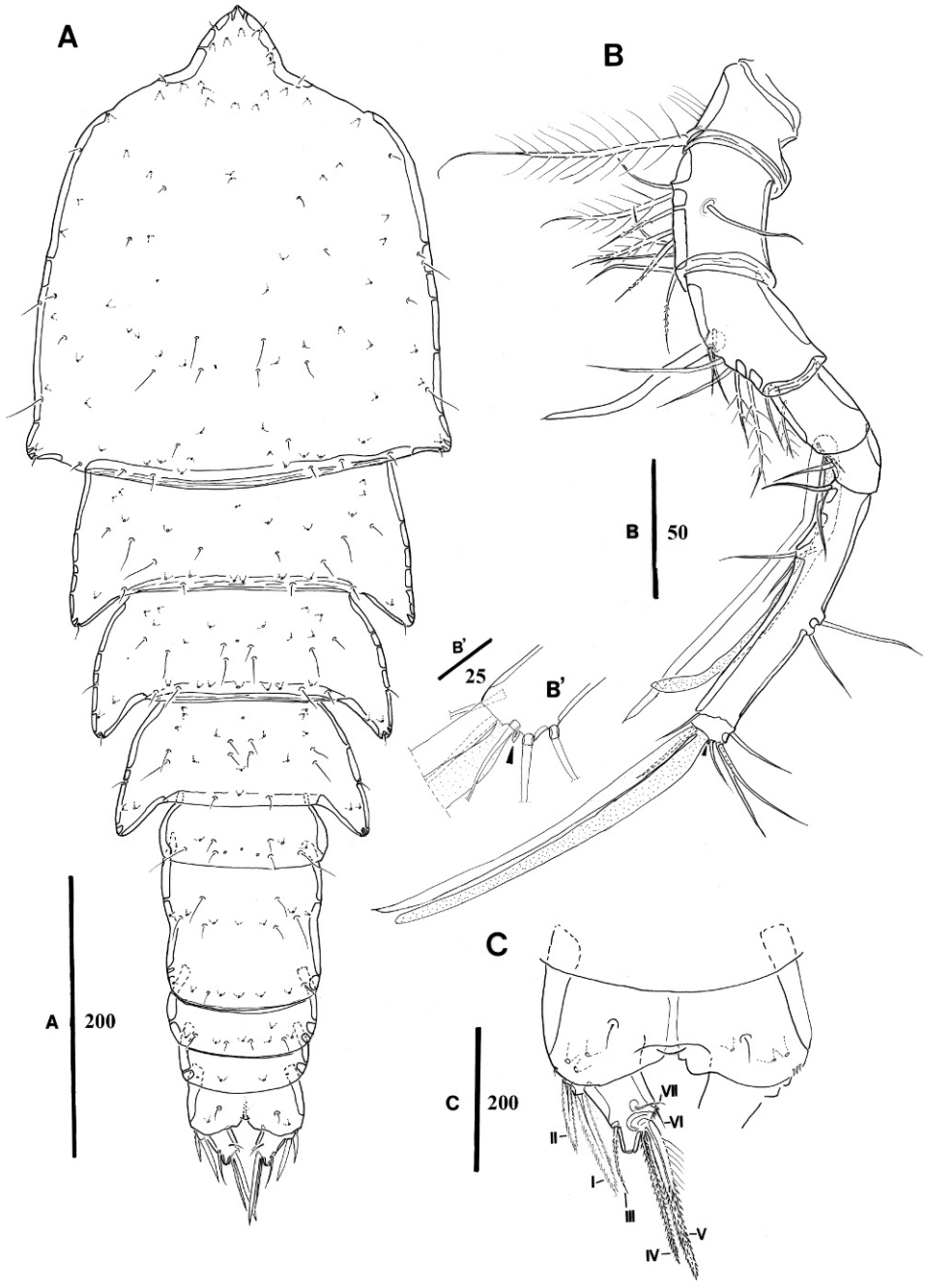

Fig. 1. *Goniopsyllus dokdoensis* (♀). A, Habitus, dorsal. B, Antennule, dorsal. B′, Distal portion of antennule segment 6 (arrowhead indicates rudimentary element). C, Telson and caudal ramus, dorsal; setae I–VII indicated.

than those in *G. clausi* (see Huys & Conroy-Dalton 2000, Fig. 19A).

Urosome armed with pores and sensilla as in Fig. 1A, however without dorsal ornamentation of spinular patches. Urosome 5-segmented, comprised of P5-bearing, genital double, and 3 free abdominal somites. Three posterior somites with patches of dense spinules along posterior margin ventrally (Figs. 2H, 9A, B).

Genital double-somite (Fig. 2H) slightly constricted bilaterally with discontinuous internal chitinous structure indicating original segmentation. Copulatory pore (Figs. 2H, 9C) located medially in large circular depression, with additional pores flanking copulatory pore. Genital apertures located near anterior margin of genital double-somite, consisting of small opercula derived from vestigial P6. Each P6 with 1 naked seta (Fig. 2H).

Telson, without well-developed anal operculum, flanked by a pair of sensilla dorsally (Fig. 1C). Multiple rows of spinules along posterior margin ventrally (Fig. 2H).

Caudal rami slightly longer than wide (Figs. 1C, 9A), tilted inwardly; lozenge-shaped, produced into conical process bearing terminal pore; with several ventral pores (Fig. 2H). Setae I–II bipinnate, stout and strongly developed; seta I 1.5 times as long as seta II, extending beyond apex of caudal ramus. Seta III bipinnate. Setae IV and V basally fused, without fracture planes, multipinnate and spiniform; seta V about 1.5 times ramus length. Seta VI tiny, bare; seta VII bare, close to middle of inner lateral margin, and triarticulated.

Rostrum (Fig. 1A) triangular and convex along lateral margin, completely fused to cephalothorax; with numerous dorsal surface pores as illustrated, none on ventral surface; with pair of minute lateral sensilla near apex.

Antennule (Fig. 1B) 6-segmented, segment 1 with small pore near seta and row of long setules along anterior margin. Armature formula: 1-[1 plumose], 2-[6 + 1 plumose + 3 pinnate], 3-[5 + 2 plumose + 1 modified], 4-[1 + 1 plumose + (1 modified + ae)], 5-[1], 6-[11+ acrothek]. Apical acrothek consisting of 1 aesthetasc, 1 long modified seta, and 1 short bare seta. Modified setae, long aesthetasc-like in shape and with tiny spiniform tip, present on segments 3, 4, and 6; those on segments 4 and 6 basally fused to aesthetasc. Rudimentary element present at base of acrothek (arrowhead in Fig. 1B′).

Antenna (Fig. 2A) 4-segmented, comprising coxa, basis, and 2-segmented endopod. Coxa and basis well developed, without ornamentation. Exopod 1-segmented, forming small membranous peduncle bearing stout and recurved apical seta, located near membranous area between basis and endopod; exopodal seta multipinnate, spinules on proximal third clearly longer. Proximal endopodal segment with few scattered denticles. Distal endopodal segment 1.5 times longer than proximal one; distal segment with 4 large frills and minute spinules on outer surface; with 1 pinnate seta laterally, and 1 subapical and 3 apical, bipinnate or multipinnate elements.

Mandible (Fig. 2C) reduced; palp represented by single naked seta. Gnathobase long and narrow, with several cuspidate processes apically and subapically; dorsal seta absent.

Maxillule (Fig. 2D) reduced; represented by small lozenge-shaped segment bearing naked apical seta and with 1 pore near apical seta.

Maxilla (Fig. 2E) 2-segmented, comprising elongate syncoxa and allobasis. Syncoxa with relatively broad basal portion (Fig. 2B); coxal endite laterally lobate, with 2 naked setae apically. Allobasis with large strong naked claw distally, smaller inner spine, and pinnate seta along outer margin.

Maxilliped (Fig. 2F) large and elongated; 3-segmented, comprising syncoxa,

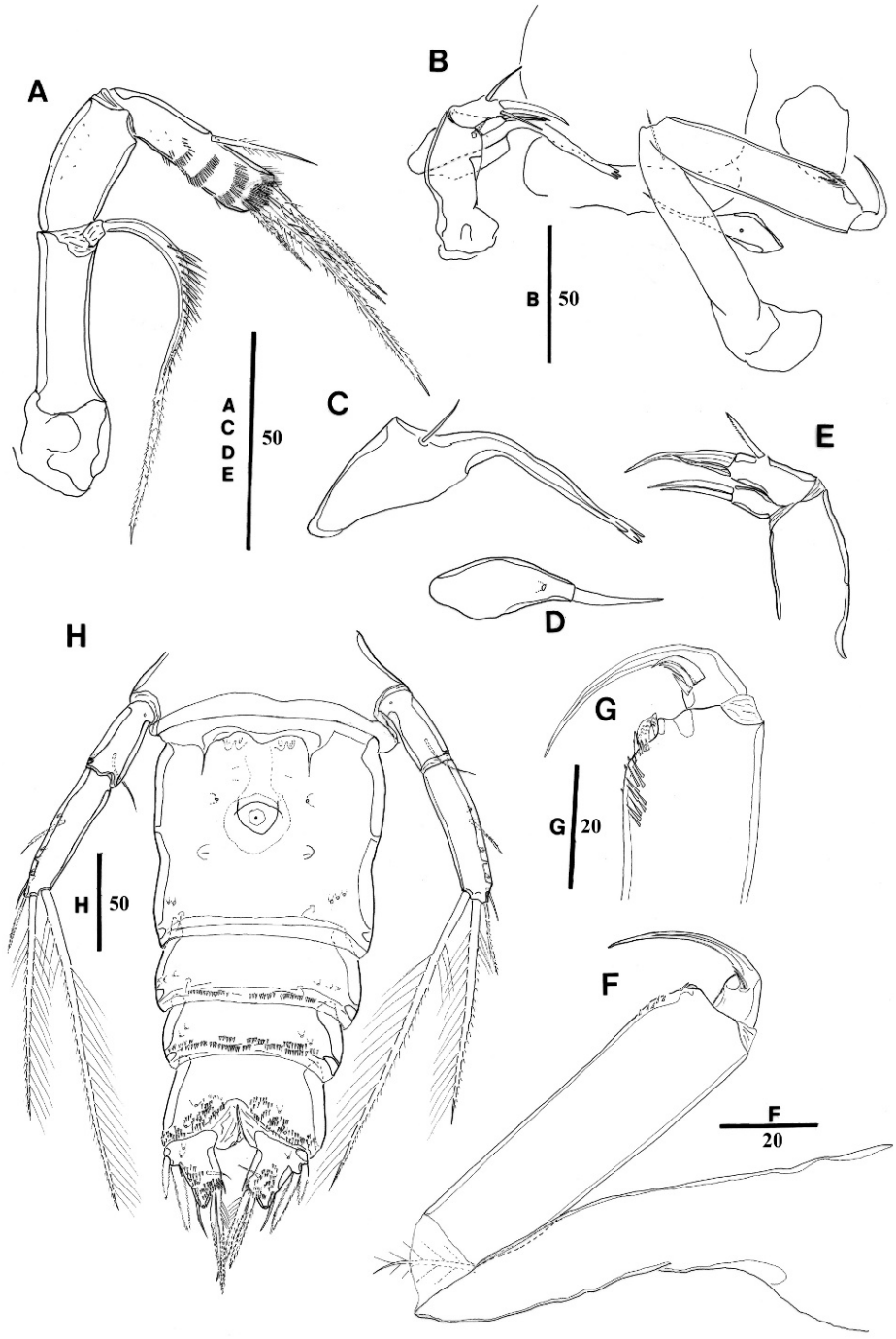

Fig. 2. *Goniopsyllus dokdoensis* (♀). A, Antenna. B, Oral area showing positions of mandible, maxillule, maxilla, and maxilliped. C, Mandible. D, Maxillule. E, Maxilla. F, Maxilliped, posterior. G, Maxilliped, anterior. H, Urosome, ventral (including P5-bearing somite).

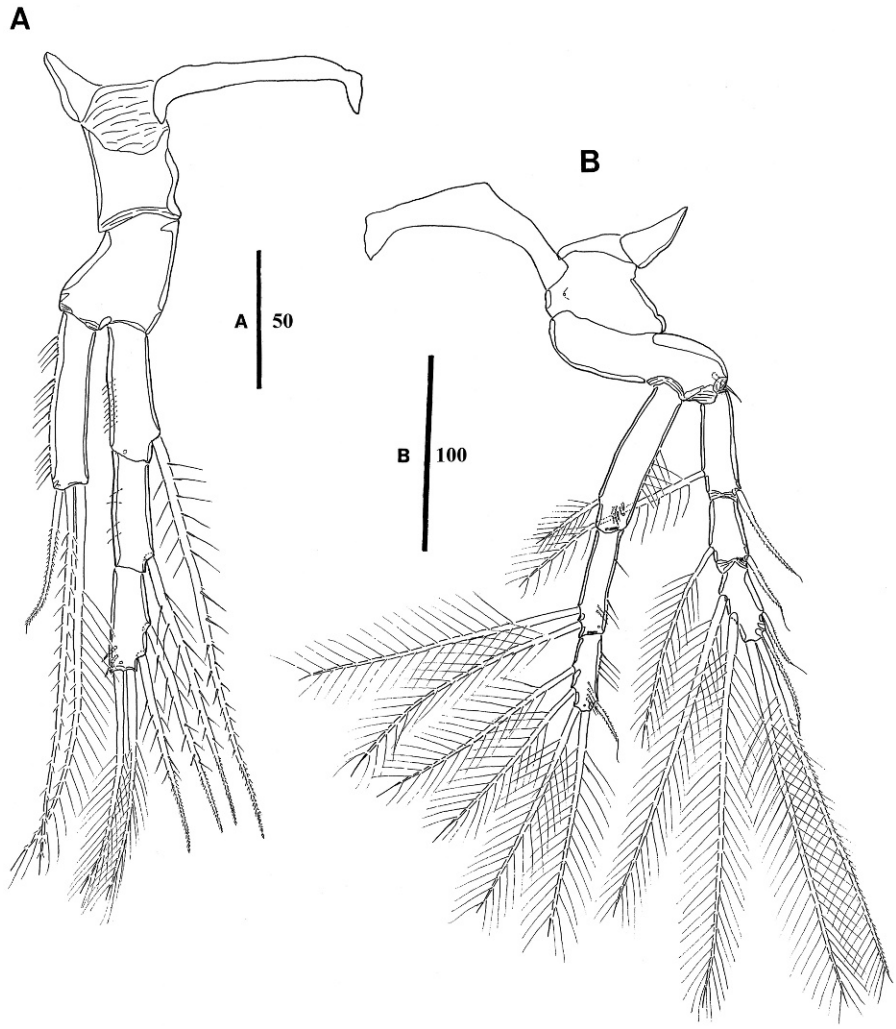

Fig. 3. *Goniopsyllus dokdoensis* (♀). A, P1, posterior. B, P2, anterior.

basis, and endopod. Syncoxa elongate, longer than basis, and well-developed proximal pedestal area; 1 anterior plumose seta near membranous articulation with basis. Basis elongate; distal area of palmar margin with dense spinule rows and 2 elements located close to articulation with endopod (Fig. 2F); proximal element spiniform and bare, distal element stocky and spinulose. Endopod represented by short segment bearing naked and hook-shaped claw; accessory armature consisting of 2 posterior and 3 anterior setae (Fig. 2F, G).

Swimming legs with wide, narrowly developed, naked intercoxal plates and triangular-shaped praecoxa without surface ornamentation. Each ramus 3-segmented except for P1 exopod.

P1 (Fig. 3A), coxa longer than wide, and rectangular without surface ornamentation. Basis longer than wide, without inner or outer seta (spine). Endopod 3-segmented, each with anterior pore and few spinules/setules along outer margin, segment 1 longest, enp-1 with 1 plumose seta near inner distal margin; enp-2 with 1 slender inner pinnate seta; enp-3 with 2

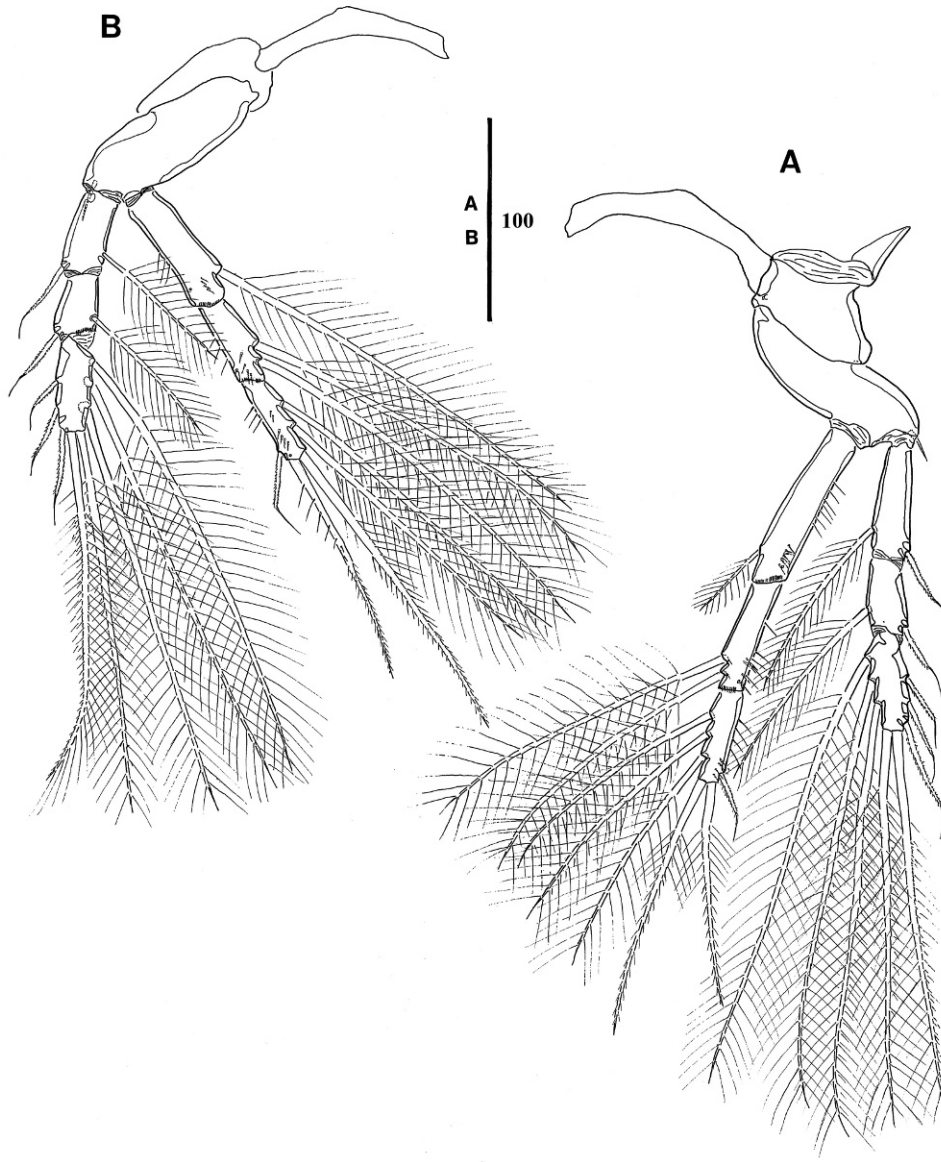

Fig. 4. *Goniopsyllus dokdoensis* (♀). A, P3, anterior. B, P4, anterior.

pinnate inner and 2 plumose apical setae. Exopod 1-segmented, represented by elongate segment bearing long setules along outer margin; reaching to proximal area of enp-2; with 3 plumose setae distally, outer one less than one-half length of others.

P2–P4 (Figs. 3B, 4A, B) with praecoxa, coxa, and basis without surface ornamentation, as illustrated. Basis transversely elongated, with short naked outer seta. Endopods distinctly longer than exopods; both rami 3-segmented. Enp-1 distinctly longer than succeeding two segments; each segment with setules along outer margin and spinules on posterior surface; inner seta on enp-1 of P2–P3 short, but corresponding seta on enp-1 of P4 very

long. Each exopodal segment without surface ornamentation; exopodal outer spines setiform with long thin flagellate tip; pore near outer distal corner of each exopod segment not distinct.

Spine and seta formula of swimming legs as follows:

	Exopod	Endopod
P1	021	1.1.220
P2	1.1.222	1.2.221
P3	1.1.323	1.2.321
P4	1.1.323	1.2.221

P5 (Fig. 2H) uniramous, laterally located; 2-segmented, comprising basis and 1-segmented exopod; not extending to distal margin of genital double-somite. Basis with short outer seta and pore near proximal margin on border of body somite. Exopod about 1.55 times as long as basis, diverging outwards; outer margin with 2 pinnate setae and 3 pores; inner margin with 1 long plumose seta; apex with 1 pinnate and 1 plumose seta.

Description of male.—Male slightly longer and larger than female (Fig. 5A). Body length, measured from anterior tip of rostrum to posterior margin of caudal rami: 960 μm (n = 1). Greatest width measured at posterior margin of cephalic shield: 364 μm. Sexual dimorphism in A1, maxilliped, P5, P6, and genital field.

Penultimate and telson with spinules around ventral hind margin (Fig. 5G); more pores present on dorsal surface of telson than in female (Fig. 5F).

Rostrum (Fig. 5A) slightly smaller, and more pointed than in female.

Antennule (Fig. 5B–E) slender, indistinctly 7-segmented with segment 4 only demarcated dorsally (Fig. 5C, arrowhead); haplocer, with geniculation located between segments 6 and 7. Plumose setae present on segments 1–5. Segment 1 with few long setules along anterior margin. Armature formula: 1-[1 plumose], 2-[5 + 5 plumose], 3-[5 + 2 pinnate + 1 transformed + 1 ae], 4-[2 plumose], 5-[4 plumose + 1 pinnate + (1 transformed + ae)], 6-[3 + 1 smooth spine + continuous patch of spinules], 7-[10 + 2 vestigial elements + acrothek]. Apical acrothek consisting of aesthetasc, 1 long transformed, and 1 short bare seta. Transformed setae on segments 3, 5, and 7 long and aesthetasc-like, with minutely spiniform tip; those on segments 5 and 7 basally fused to aesthetasc. Rudimentary element at base of apical acrothek as in *G. clausi*, not distinct.

Antenna, mandible, maxillule, and maxilla (Fig. 6A–D) same as those of female.

Maxilliped (Fig. 6E, F) 3-segmented, comprising syncoxa, basis, and endopod. Syncoxa elongated, with 1 anterior, plumose seta near membranous articulation with basis, and no additional surface ornamentation. Basis elongated, more swollen than in female, middle and distal thirds of palmar margin with row of spinules on both anterior and posterior sides; additional 2 elements located close to articulation with endopod; distal one stubby and spinulose. Endopod represented by 1 segment produced into very long naked claw; additional armature consisting of 3 anterior, and 2 posterior setae near proximal area.

P1–4 (Figs. 7A, B, 8A, B) with same armature formula as in female.

P5 (Fig. 6G) exopod slightly shorter than in female. Exopod 1.35 times longer than basis.

Sixth pair of legs (Fig. 6G) asymmetrical, represented by highly membranous non-articulating flaps covering single, large genital aperture; each lobe with 2 setae at outer distal corner.

Etymology.—The specific name refers to the type locality, the waters adjacent to Dokdo Island in the East Sea of Korea.

Discussion

The new species was placed in the genus *Goniopsyllus* based on the synapo-

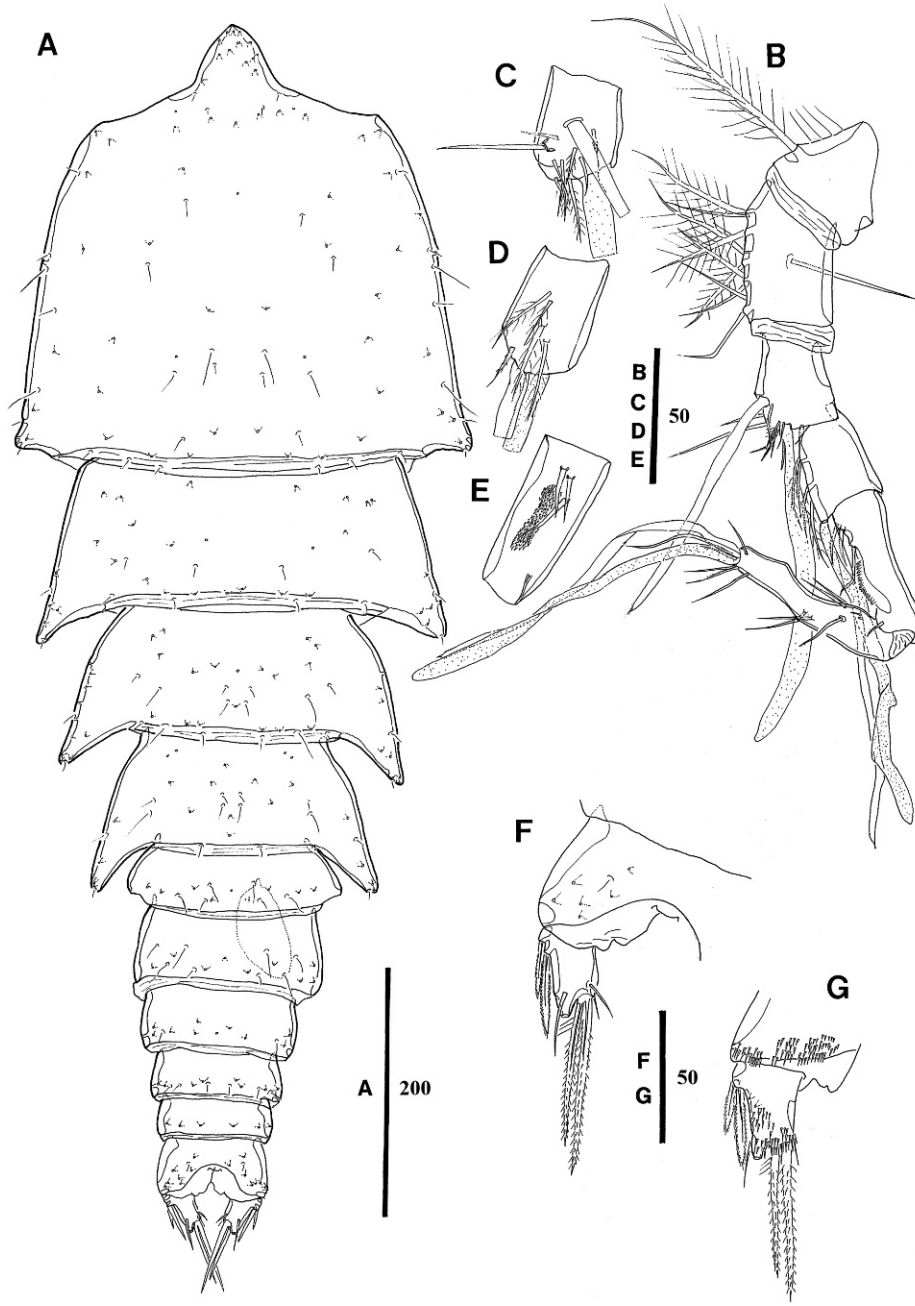

Fig. 5. *Goniopsyllus dokdoensis* (♂). A, Habitus, dorsal. B, Antennule, ventral. C, Antennule segments 3–4, anterior; arrowhead indicates segment 4. D, Antennule segment 5, anterior. E, Antennule segment 6, anterior. F, Telson and caudal ramus, dorsal. G, Telson and caudal ramus, ventral.

morphic characters, including the six-segmented female antennule, four apical elements on the distal endopod segment of the antenna, the antennary exopod bearing only a single long seta, the single apical spine on the maxillule, the absence of the maxillary proximal endite, only two setae on the distal endite of the maxilla,

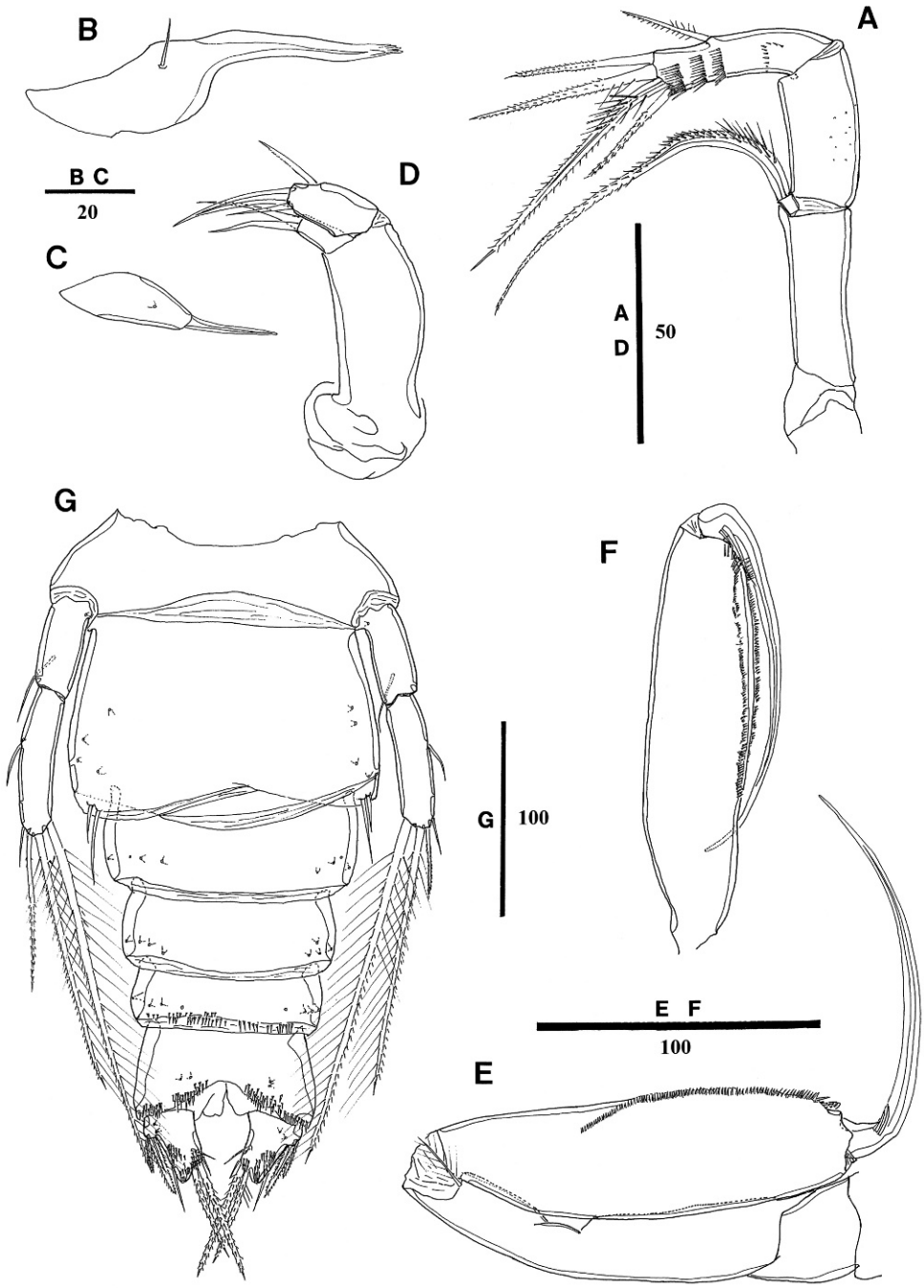

Fig. 6. *Goniopsyllus dokdoensis* (♂). A, Antenna. B, Mandible. C, Maxillule. D, Maxilla. E, Maxilliped, anterior. F, Maxilliped basis and endopod, posterior. G, Urosome, ventral (including P5-bearing somite).

no seta or spine on the basis of P1 (Figs. 3A, 7A), three setae on the exopod of P1, and the presence of an outer spine on the exp-1 of P2.

Huys & Conroy-Dalton (2000) provided the descriptions of the female for three *Goniopsyllus* species: *G. clausi*, *G. rostratus*, and *G. brasiliensis* (Table 1). The

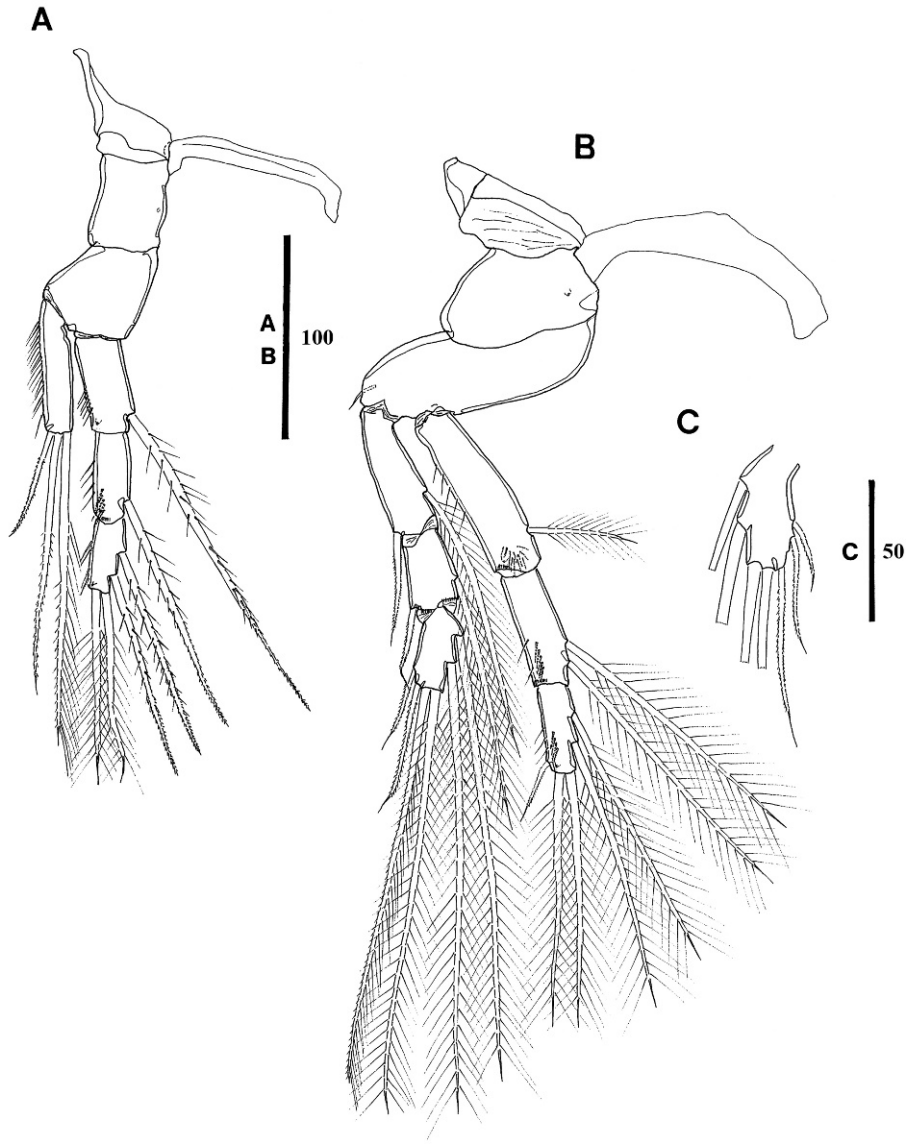

Fig. 7. *Goniopsyllus dokdoensis* (♂). A, P1, anterior. B, P2, anterior. C, Left P2 exp-3, anterior, aberrant.

species discrimination of *Goniopsyllus* is largely based on the size, maxillipedal ornamentation, and proportional lengths of the caudal ramus setae. Each species shows typical sets of apomorphies. *G. rostratus* has the longest body length in the genus and also has a relatively short genital double-somite in comparison with other congeners, although it is not constricted bilaterally. In addition, the caudal ramus seta V of *G. rostratus* is longer than those in the other congeners. The posterolateral angles of the cephalothorax and the tip of the rostrum are rounded in *G. brasiliensis* but are more prominent and triangular in *G. clausi* (unknown in *G. rostratus*). The caudal ramus seta I of *G. brasiliensis* does not extend beyond the apex of the caudal ramus, whereas it far exceeds the caudal ramus in the congeners.

Goniopsyllus dokdoensis is closely related to the above three species in appear-

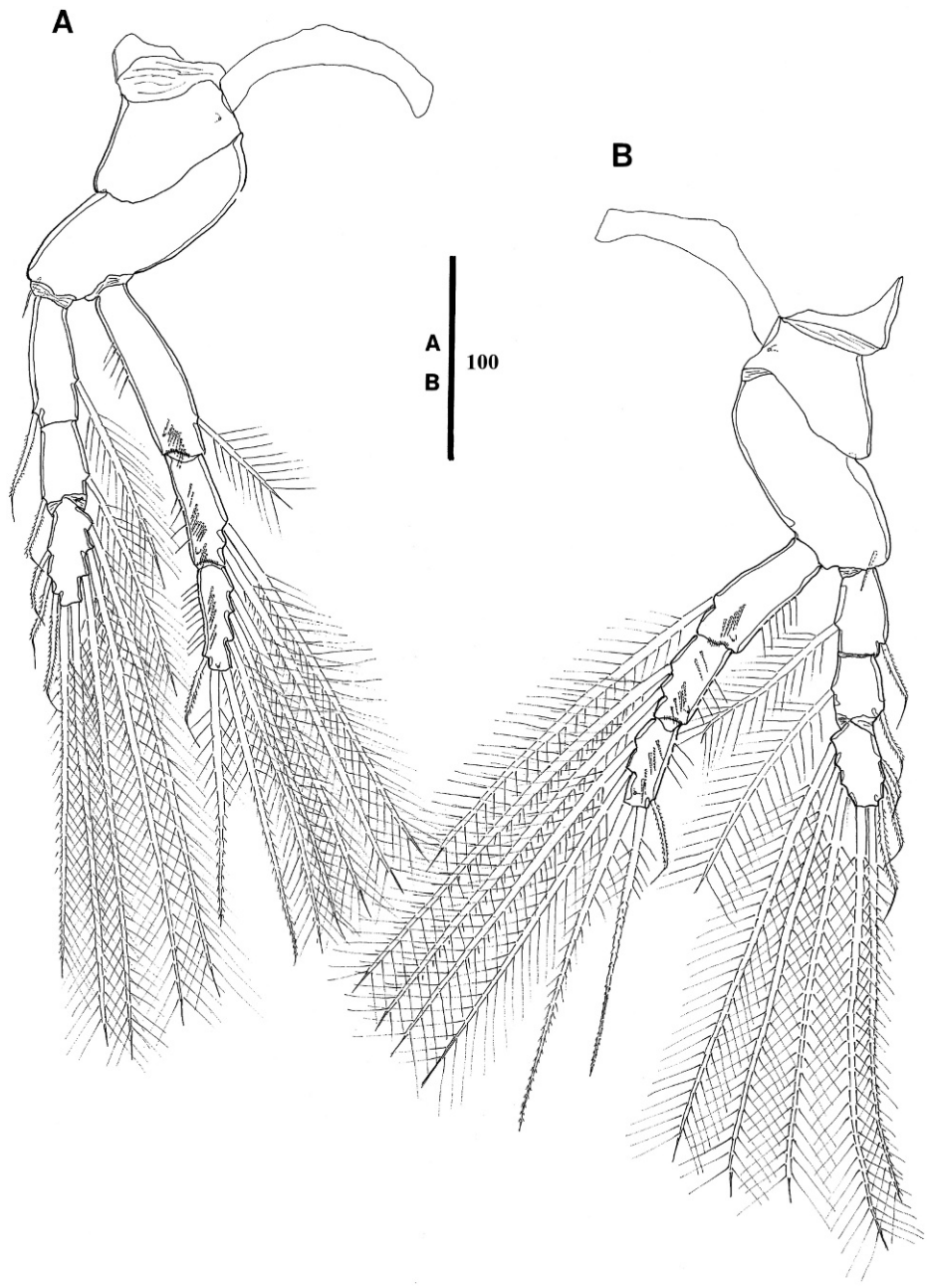

Fig. 8. *Goniopsyllus dokdoensis* (♂). A, P3, anterior. B, P4, anterior.

ance, especially to *G. clausi*; however, *G. dokdoensis* differs from its congeners with respect to several diagnostic characteristics. First, *G. dokdoensis* has the smallest body size of all of the species of *Goniopsyllus* (female: 860 μm, male: 960 μm). Second, the female of *G. dokdoensis* has additional pores around the copulatory pore (Fig. 9C). Third, there are differences in the patterns of spinular ornamentation on the urosomites between *G. dokdoensis* (Fig. 9A, B, D), and the other

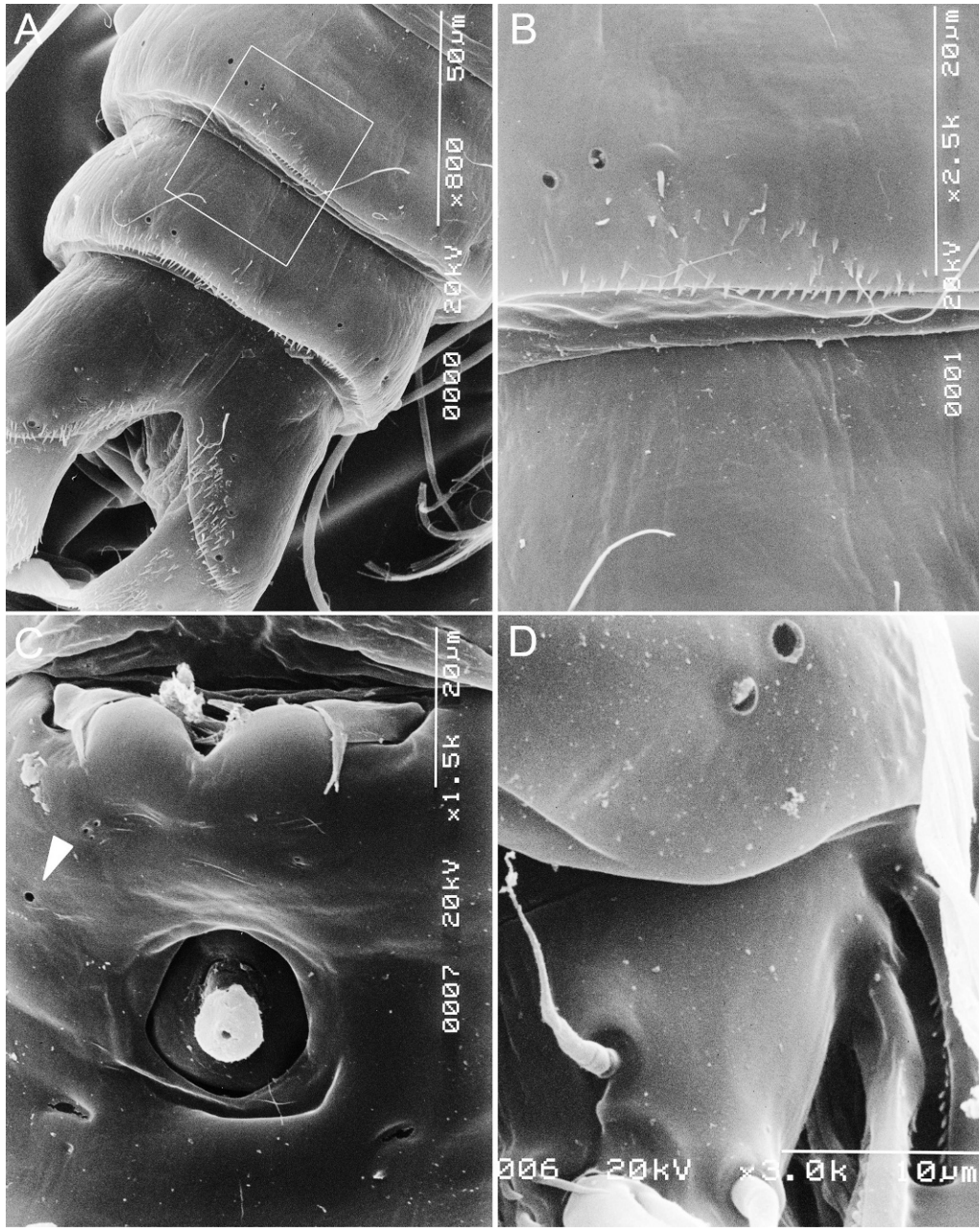

Fig. 9. *Goniopsyllus dokdoensis* (♀). SEM micrographs. A, Posterior urosomites, ventral view. B, Enlarged view of rectangular region in Fig. 9A. C, Copulatory pore area of genital double-somite, ventral view (arrowhead indicates additional pore near copulatory pore). D, Part of telson and right caudal ramus, dorsal view.

species (see Huys & Conroy-Dalton 2000). For instance, *G. dokdoensis* has spinular rows around the ventral hind margin of the penultimate urosomite and the telson, whereas *G. clausi* has these rows on the fourth and fifth urosomites and the telson. Fourth, there are differences in the relative lengths from seta II

Table 1.—Diagnostic characteristics of the *Goniopsyllus* species.

Characters	*G. clausi*	*G. rostratus*	*G. brasiliensis*	*G. dokdoensis*
Size ♀ (in μm)	979–1067	1160–1430	892–1057	820–915
Size ♂ (in μm)	1021	unknown	unknown	960
Posterolateral angles of the cephalothorax	triangular, weakly expanded laterally		round, not expanded	less pronounced than in *G. clausi*
Rostrum	triangular		round	triangular
Spinule pattern on the palmar margin of the maxilliped basis	double row	different spinular ornamentation, minute spinular patch	different spinular ornamentation	double row, more rows than in *G. clausi*
P5 apex ♀ vs. GDS posterior margin	not extending to distal margin	?	extending beyond distal margin	not extending to distal margin
Constriction of the GDS	bilaterally	straight	not bilaterally	bilaterally
Pore flanking copulatory pore in the GDS	absent	present	present	present
Spinules 2nd abdominal somite ♀	absent	absent	absent	present
Spinules 2nd abdominal somite ♂	present	?	?	absent
P5 exopod vs. basis	2	?	?	1.7
Dorsal ornamentation of the urosomites	small denticles around dorsal hind margin	small denticles around dorsal hind margin	small denticles around dorsal hind margin	absent
Caudal rami – seta I vs. seta II	1.85	1.7	1.2	1.5–1.7
Seta I vs. caudal rami	extending beyond apex	extending beyond apex	not extending beyond apex	extending beyond apex
Seta V vs. caudal rami	2.1	3	1.5	1.5–1.6
On the P6 of ♂	1 seta	unknown	unknown	2 setae

GDS = genital double-somite.

to seta I and from seta V to the caudal ramus (Table 1). Finally, the most striking apomorphy in the new species is present in the male. The male *G. dokdoensis* has two setae at the outer distal corner of P6 (Fig. 6G), but the male *G. clausi* has only one seta at this location (see Huys & Conroy-Dalton 2000, Figs. 11C, 26B for *G. clausi*; this feature is unknown in the other congeners). In addition, the distal endopod segment in the antenna of *G. dokdoensis* has four large surface frills and minute spinules on the outer surface but only three frills in *G. clausi* (unknown in the other species).

Additionally, the male of *G. dokdoensis* has some morphological variations. The outermost apical seta on the exopod of the right P5 is much longer than the one on the left P5 (Fig. 6G). The left exp-3 of P2 is aberrant and has one additional inner seta (Fig. 7C) than the corresponding right segment (Fig. 7B). Aberrant setation of the P2 was also reported in *Clytemnestra scutellata*, with the male right P2 exp-3 displaying a reduced number of outer setae (Huys & Conroy-Dalton 2000). Considering that *G. rostratus* also displays an aberrant number of setae in the female P3 and P4 (Huys & Conroy-Dalton 2000, p. 40, setal formula), clytemnestrid copepods are presumably highly variable with regard to the seta numbers on the swimming legs.

Presently, two clytemnestrids, *Clytemnestra scutellata* and *G. rostratus*, have been reported from Korean waters. Since only the names of both species appear in the ecological publications (Lee 1972, Shim & Lee 1986, Shim et al. 1988, Yoo 1991, Kim et al. 1993, Park & Choi 1997, Kang et al. 2002), it is difficult to determine the validities of the distributions of both species in Korean waters. Considering that Huys & Conroy-Dalton (2000) redefined the type locality of *C. scutellata* for the eastern Pacific including the South China Sea, perhaps the *C. scutellata* collected from previous studies in Korean waters (Lee 1972, Shim & Lee 1986, Shim et al. 1988) were identified properly. However, the distribution of *G. rostratus*, which has been reallocated to *Goniopsyllus*, is limited to the South Atlantic, off the Argentinean coast. Therefore, the records of *C. rostrata* in Korean waters in the previous studies are possibly misidentifications of the current new species, *G. dokdoensis*. This study confirms the occurrence of the genus *Goniopsyllus* in Korean waters for the first time.

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