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A new species of the genus *Nannopus* (Copepoda, Harpacticoida, Nannopodidae) from the mudflat of Ganghwa Island, Korea

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Abstract.—During a study of the harpacticoid copepods from the intertidal mudflat of Ganghwa Island, in the Yellow Sea of Korea, a new species of the genus *Nannopus* was discovered. *Nannopus ganghwaensis* shared the character of seven elements in P4 exp-3 with *N. flexibilis* Lilljeborg, 1902, *N. didelphis* Fiers & Kotwicki, 2013, and *N. hirsutus* Fiers & Kotwicki, 2013. However, the new species was clearly distinguished from the three congeners by the combination of the following character states: (1) absence of the integumental window on the dorsal surface of cephalothorax, (2) the lateral margins of urosomites is not densely hirsute, (3) the distal small seta of P4 endopod is naked, (4) the innermost seta of P5 exopod fused to the segment, (5) the inner most distal seta of P2 enp-2 is 1.7 times longer than the outer spine of its segment, and (6) caudal seta IV slightly inflated at its insertion site, and pinnate. Additionally, the male of new species differed from *N. didelphis* by the following characters: (1) the P2 exp-2 with an inner seta, (2) the inner most seta of P2 enp-2 is pinnate, (3) the distal pinnate seta of P3 enp-2 is 2.6 times longer than the one in *N. didelphis,* (4) P6 is asymmetrical with one spermatophore at one side, and without a notch at the distal margin of P6. The male of new species also differed from *N. flexibilis* in having the sharper distal apophysis in P3 enp-2. A key to the species of *Nannopus* including new species and eight valid congeners is provided.

Keywords: Taxonomy, Nannopodidae, Meiofauna, Biodiversity, CLSM, SEM, Ludox method.

Since Brady (1880) proposed *Nannopus* as a genus within the family Harpacticidae, its complex history has begun. For a while, *Nannopus* was regarded to Cletodidae (Sars 1909a) and later transferred to Huntemanniidae (Por 1986). As Huys (2009) synonymised Huntemanniidae and Nannopodidae, the genus *Nannopus* was transferred from Huntemanniidae to Nannopodidae.

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At present, the family Nannopodidae consists of seven genera: *Nannopus* Brady, 1880, *Huntemannia* Poppe, 1884, *Pontopolites* Scott, 1894, *Rosacletodes* Wells, 1985, *Laophontisochra* George, 2002, *Acuticoxa* Huys & Kihara, 2010, and *Talpacoxa* Corgosinho, 2012. *Nannopus* Brady, 1880 as type genus of the family, comprises eight valid species: *N. palustris* Brady, 1880, *N. flexibilis* Lilljeborg, 1902 [syn. *N. palustris tiberiadis* Por, 1968, *N. palustris* Sars, 1927, Damian-Georgescu,

1970, and *Nannopus spec*. Hemsen, 1952, (see Fiers & Kotwicki 2013)], *N. perplexus* Sars, 1909b, *N. unisegmentatus* Shen & Tai 1964, *N. didelphis* Fiers & Kotwicki, 2013, *N. scaldicola* Fiers & Kotwicki, 2013, *N. procerus* Fiers & Kotwicki, 2013 [syn. *N. palustris* Sars, 1909a (see Fiers & Kotwicki 2013)], and *N. hirsutus* Fiers & Kotwicki 2013.

Nannopus species are distributed almost from the tropic to the arctic (see distribution map in Gárlitska et al. 2012). These species occurs over a range of salinities from the marine intertidal mudflats (*N. didelphis*) to estuarine brackish waters (*N. palustris, N. scaldicola, N. procerus* and *N. hirsutus*), river mouths (*N. unisegmentatus)* and fresh water lakes (*N. flexibilis* and *N. perplexus*). In Korea, Yoo & Lee (1995) reported *N. palustris* from the brackish mud flats in Youngjong island of west coast, and in Bongyoung of south coast.

During a survey to reveal the biodiversity of meiofauna in the West Coast of Korea, several specimens of *Nannopus* were collected from intertidal mudflats of Ganghwa Island. The present study aims to describe a new species based on both sexes collected from Ganghwa Island. In addition, a species key to the genus *Nannopus* including the new species was presented.

Materials and Methods

Specimens.—Sediment samples were collected from intertidal mudflats of Ganghwa Island (37°35′55.93″N, 126°30′49.24″E). The top 4 to 7 cm of the sediment were sampled. Immediately at the sampling site, an initial extraction of the meiofauna from the sediment was done according to the method of decantation (Pfannkuche and Thiel 1988), and fixed with 99% ethanol. Later in the laboratory, each sample was washed with freshwater over a 38 μm mesh size sieve to separate the fine sediment. After a final extraction was carried out by differential flotation with Ludox (Burgess 2001), the overlaying material was collected in a sieve of 38 μm, washed with fresh water and fixed with 99% ethanol.

Harpacticoids were sorted under a dissecting microscope Olympus SZX12 and stored in 99% ethanol at 4°C. Observations and drawings were made from whole and dissected specimens mounted in lactopehnol using an Olympus BX51 microscope equipped with a drawing tube. Permanent slides were sealed using transparent nail varnish. The morphological terminology follows Huys & Boxshall (1991). Abbreviations used in the text are: Enp, endopod; Exp, exopod; exp (enp)-1 (2, 3) to denote the proximal (middle, distal) segments of a exopods and endopods; P1–P6 (first to sixth thoracopod). Specimens were deposited in the National Institute of Biological Resources (NIBR).

Scanning Electron Microscopy (SEM).—In total, five *Nannopus* specimens were prepared for SEM. The specimens were dehydrated through a graded ethanol series, critical point dried, mounted on stubs and sputter-coated with platinum. The material was photographed using a Hitachi S-4700 scanning electron microscope at Eulji University, Seoul, Korea. Digital photographs were processed and combined into plates using Adobe Photoshop CS6.

Confocal Laser Scanning Microscopy (CLSM).—In total, two adult specimens of both sexes were used for CLSM. Each specimen was stained with Congo Red and Acid Fuchsin, using procedures adapted from Michels & Büntzow (2010). The whole specimens were mounted onto slides with glycerine, and self-adhesive plastic reinforcement rings were used to support the coverslip (Kihara & Rocha 2009). The material was examined with a Leica TCS SPV equipped with a Leica DM5000 B upright microscope and 3 visible-light lasers (DPSS 10 mW 561 nm, HeNe 10 mW 633 nm, Ar 100 mW 458 nm, 476 nm,

488 nm and 514 nm), combined with the software LAS AF 2.2.1. Leica Application Suite Advanced Fluorescence. Different objectives were used, depending on the size of the material scanned. Images were obtained using only 561nm excitation wavelength with acousto-optic tunable filter (AOTF) at 80%, excitation beam splitter DD 488/561 and detected emission wavelength 570–717 nm. Series of stacks were obtained, collecting overlapping optical sections throughout the whole preparation with optimal number of sections according to the software. The acquisition resolution was 2048 × 2048 pixels. Final images were obtained by maximum projection, and CLSM illustrations were composed and adjusted for contrast and brightness using the software Adobe Photoshop CS6.

Results

Order Harpacticoida Dana, 1846
Family Nannopodidae Brady, 1880
Genus *Nannopus* Brady, 1880
Nannopus ganghwaensis, new species
Figs. 1–11

Type locality.—South Korea, Yellow Sea, Ganghwa Island, intertidal mudflats, 37°35′55.93″N, 126°30′49.24″E.

Specimens examined.—Female holotype (NIBRIV 0000694332) and male allotype (NIBRIV 0000694331) in 70% ethanol. Paratypes: 2 females dissected on 8 and 3 slides (NIBRIV 0000694330), 2 males dissected on 5 and 1 slides (NIBRIV 0000694329), 14 females and 4 males in 70% ethanol (NIBRIV 0000694328), 5 females and 3 males in 70% ethanol (NIBRIV 0000694327), 3 females and 2 males on SEM stub (NIBRIV 0000694326), 1 female and 1 male used for CLSM (NIBRIV 0000694325), coll. 20 November 2013. An additional 3 males in 70% ethanol (NIBRIV 0000694324), coll. 03 March 2015. All samples were collected by Vinod Vakati.

Description of female (based on holotype and paratypes).—Total body length measured from tip of rostrum to posterior margin of caudal rami ranging from 692 to 831μm (mean = 772μm, $n = 22$, holotype: 821μm), maximum width measured at posterior margin of cephalothorax and ranging from 261 to 323μm (mean = 287μm, $n = 22$, holotype: 257μm). Body fusiform (Figs. 1A–C, 2A–B). Prosome 4-segmented comprising cephalothorax and 3 free pedigerous somites. Cephalothorax (Fig. 2A) anteriorly attenuated in dorsal view, about 0.8 times as long as wide, comprising 25.8 % of total body length, surface of cephalothorax covered with dense carpet of setules and with few paired sensilla, posterior margin serrate. Urosome comprising first urosomite, genital double-somite and 3 free urosomites. Boundary between prosome and urosome clearly visible, urosome / prosome length ratio 0.6 times (Fig. 2A). Body ornamentation (Figs. 3A–D, 7A) consisting of dorsal carpet of setules and denticles (Fig. 3A–B). Posterodorsal and lateral margins of each somite coarsely serrate except for anal somite. Posteroventral margins of urosomites ornamented with single row of spinules (Fig. 7A).

Genital and third urosomite (Fig. 7A) completely fused ventrally, but with suture indicating original segmentation between genital and third urosomite dorsolaterally, 1.6 times as wide as long, with a pair of copulatory pores medially (arrowed in Fig. 7A).

Anal somite (Fig. 7A–B) with well-developed operculum bearing rows of setules, dorsal surface of somite with pair of sensilla and pore, medially clefted in posteroventral view, ventral surface covered with minute spinules and with transverse row of long spinules along posteroventral margin, on either side of anal sinus.

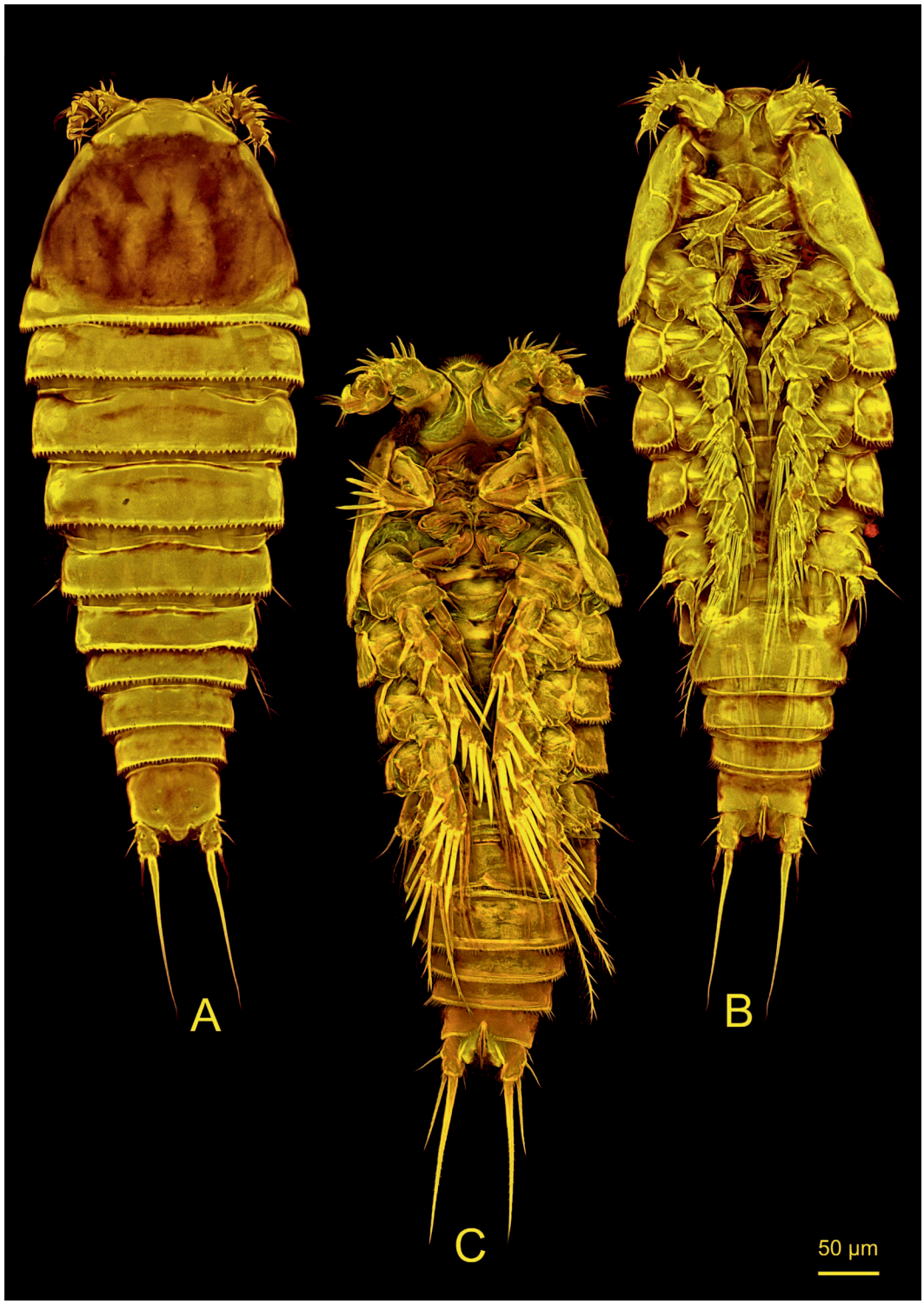

Fig. 1. *Nannopus ganghwaensis*. Female. CLSM images. A, habitus, dorsal; B, habitus, ventral. Male C, habitus, ventral.

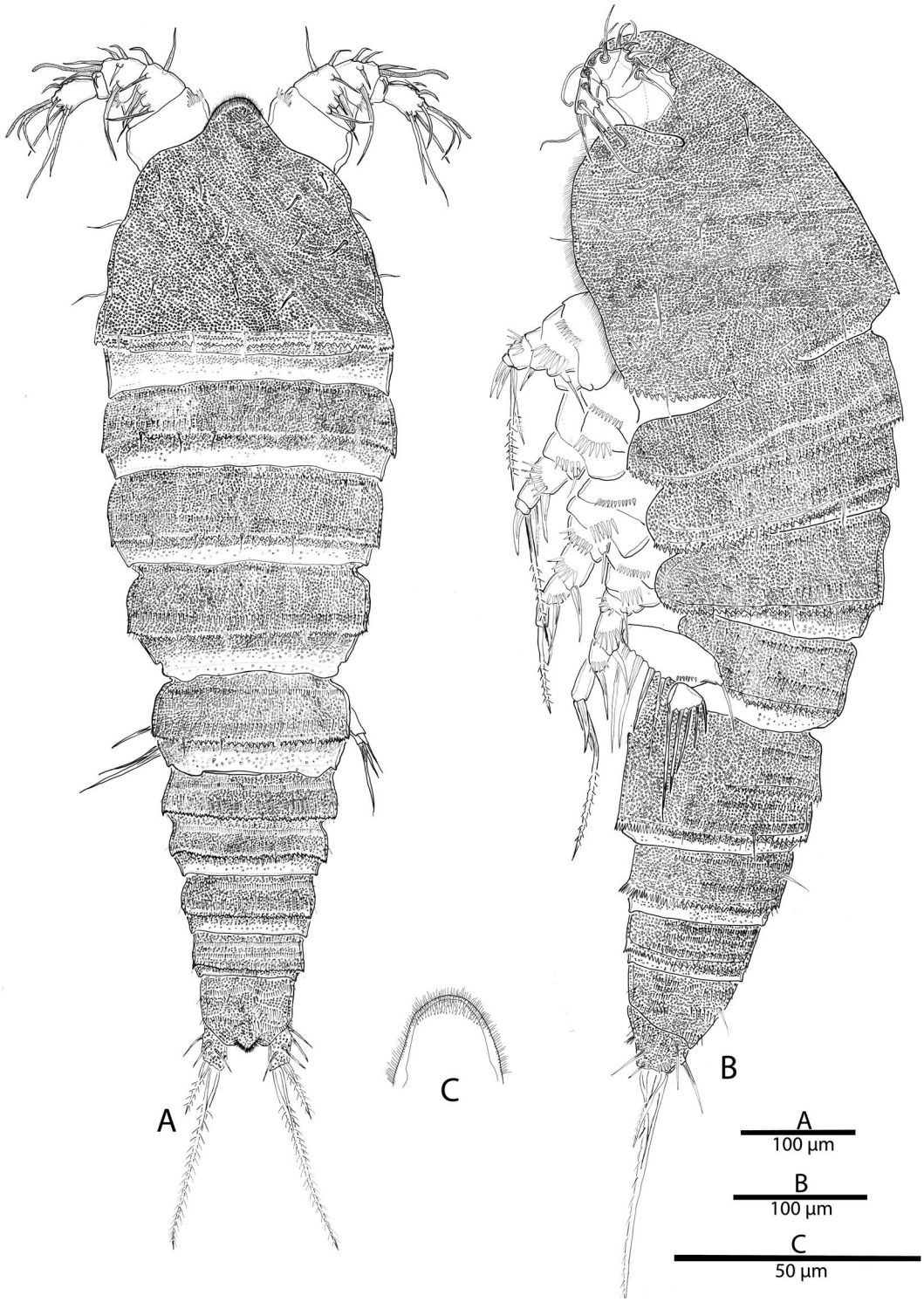

Fig. 2. *Nannopus ganghwaensis*. Female. Line drawings. A, habitus, dorsal; B, habitus, lateral; C, rostrum, dorsal.

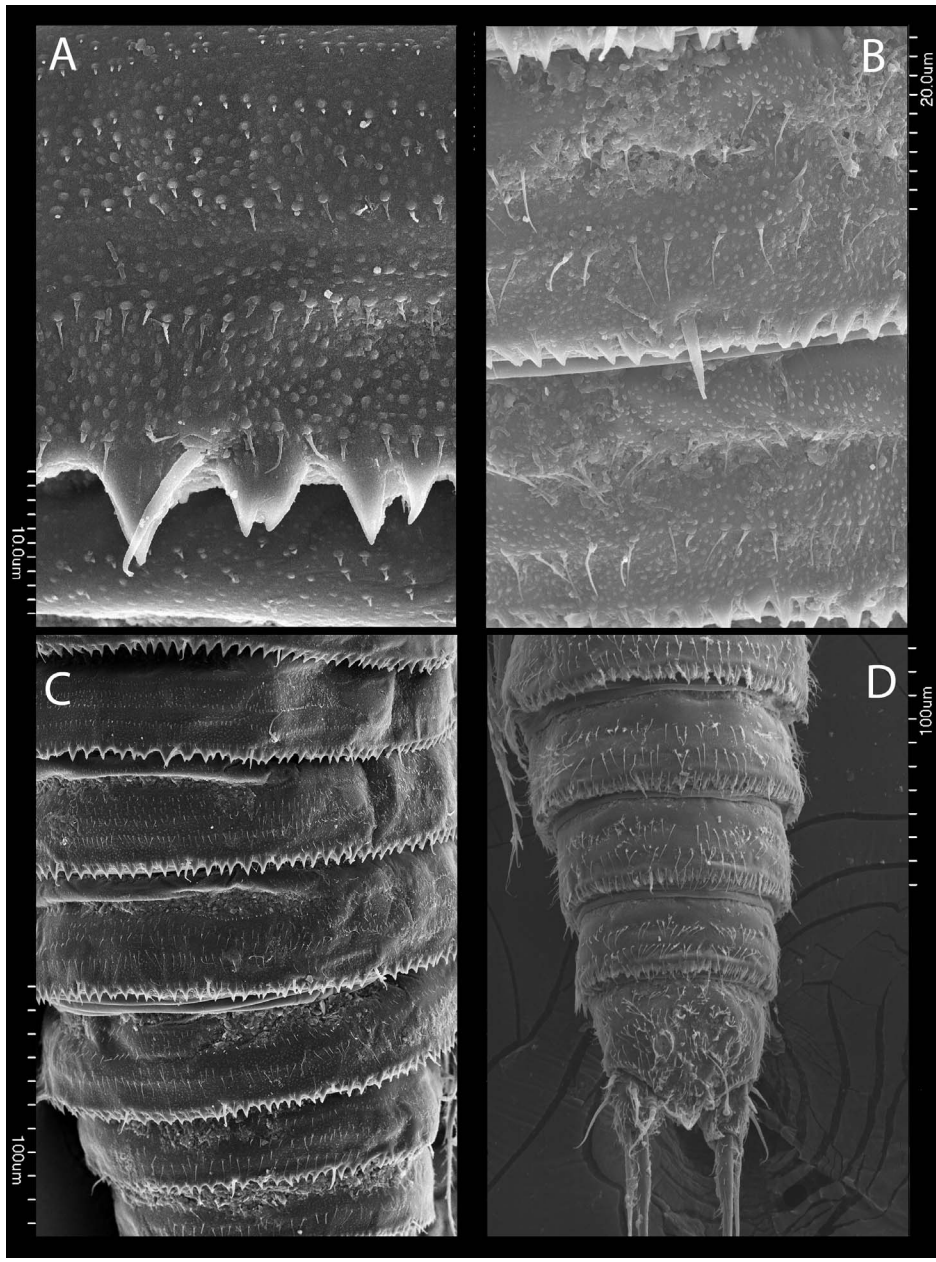

Fig. 3. *Nannopus ganghwaensis*. Female. SEM photographs. A, denticle ornamentation of prosomites, dorsal; B, denticle ornamentations of second and third prosomites, dorsal; C, setule pattern of urosomites, dorsal; D, setule pattern of urosomites and anal somite, dorsal.

Caudal rami (Figs. 7A–C, 8A–C) cylindrical and slightly enlarged proximally, with clear separation between anal somite and ramus, 1.5 (in dorsal view) and 2 (in ventral view) times as long as wide, ornamentation consisting of setules (Fig. 8A–C) and row of spinules along posterodorsal (Fig. 7B) and posteroventral

Fig. 4. *Nannopus ganghwaensis*. Female. Line drawings. A, antennule, dorsal; B, antenna; C, mandible; D, maxillule; E, maxilla; F, maxilliped.

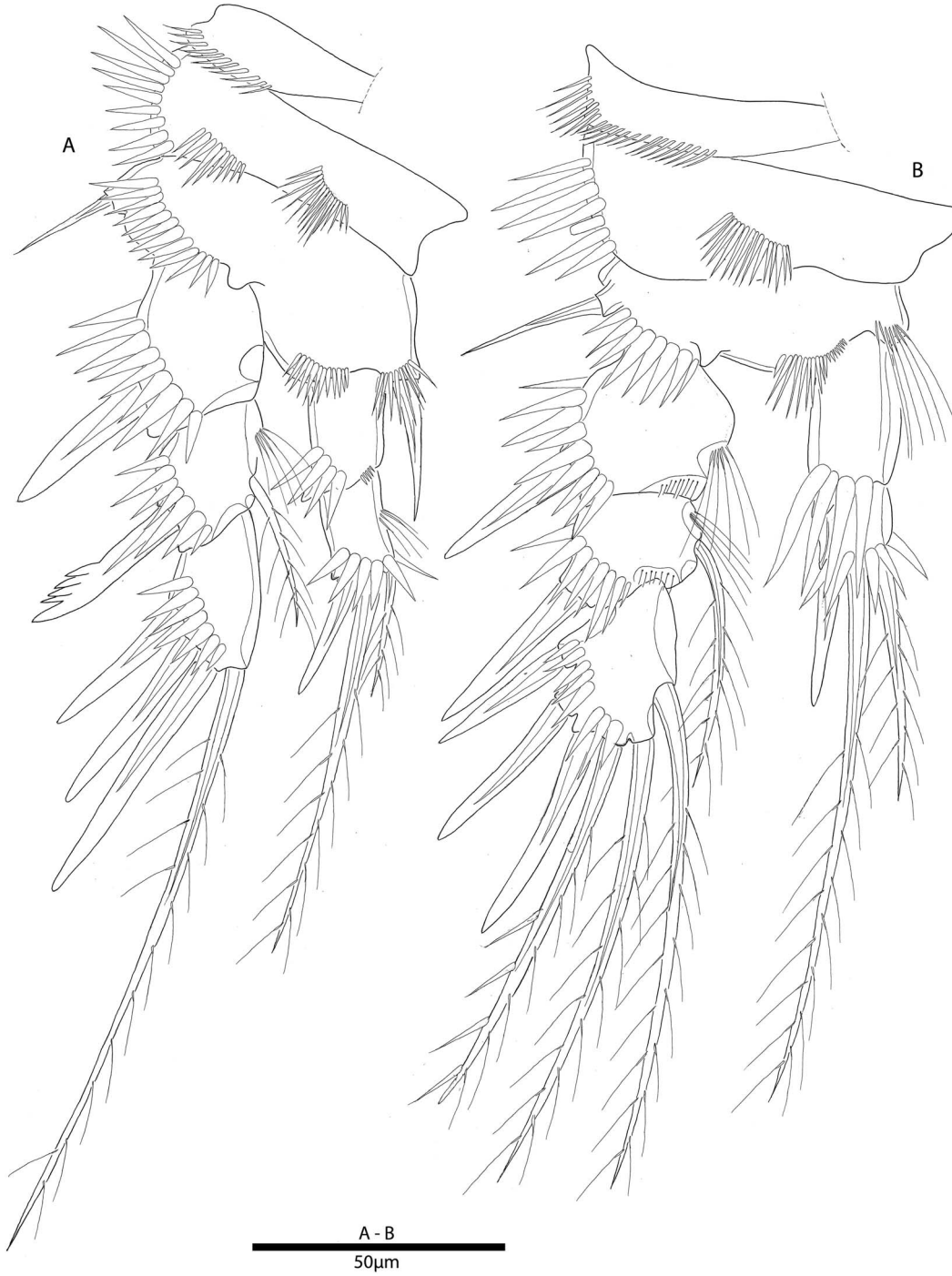

Fig. 5. *Nannopus ganghwaensis*. Female. Line drawings. A, P1; B, P2.

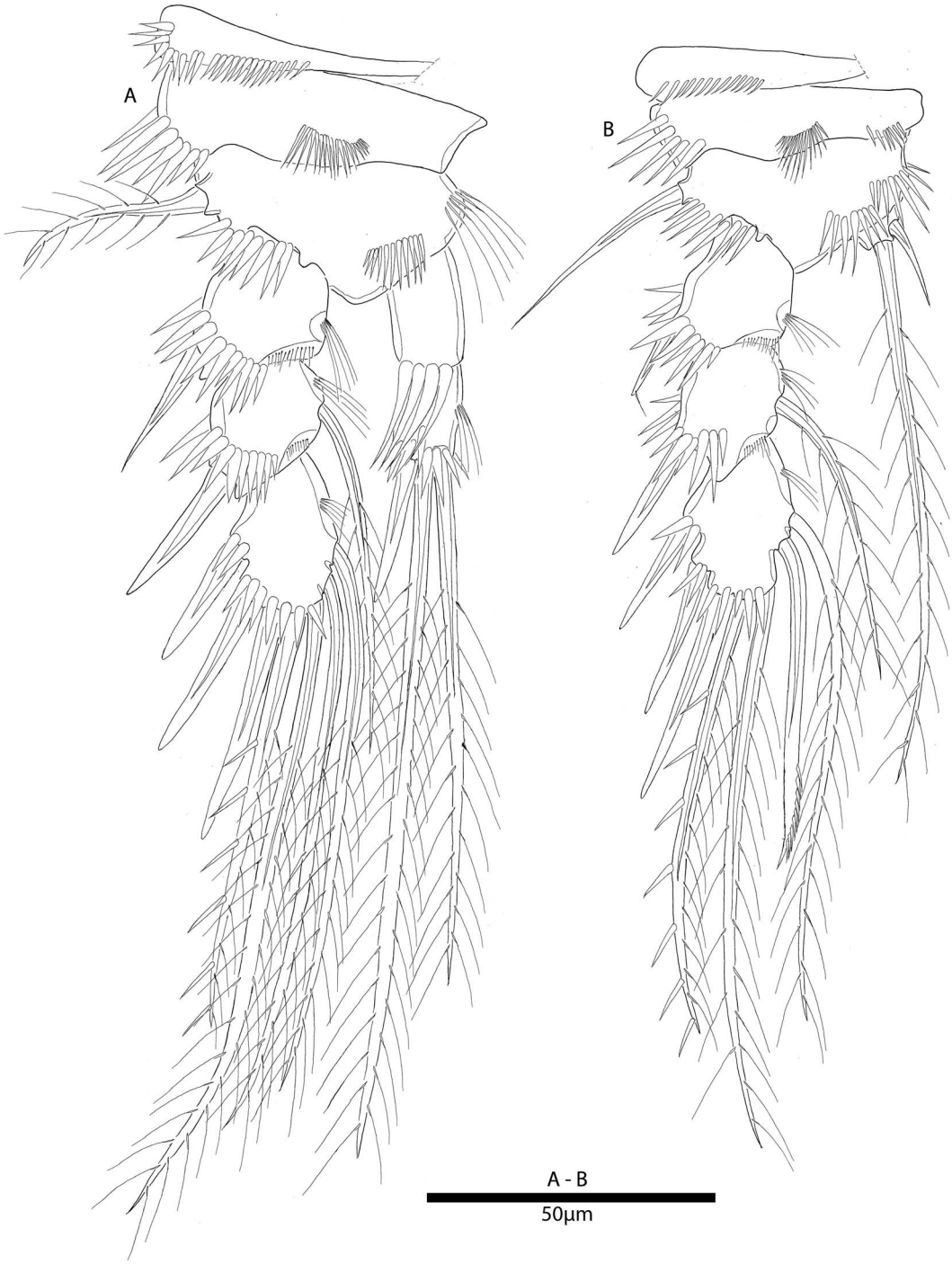

Fig. 6. *Nannopus ganghwaensis*. Female. Line drawings. A, P3; B, P4.

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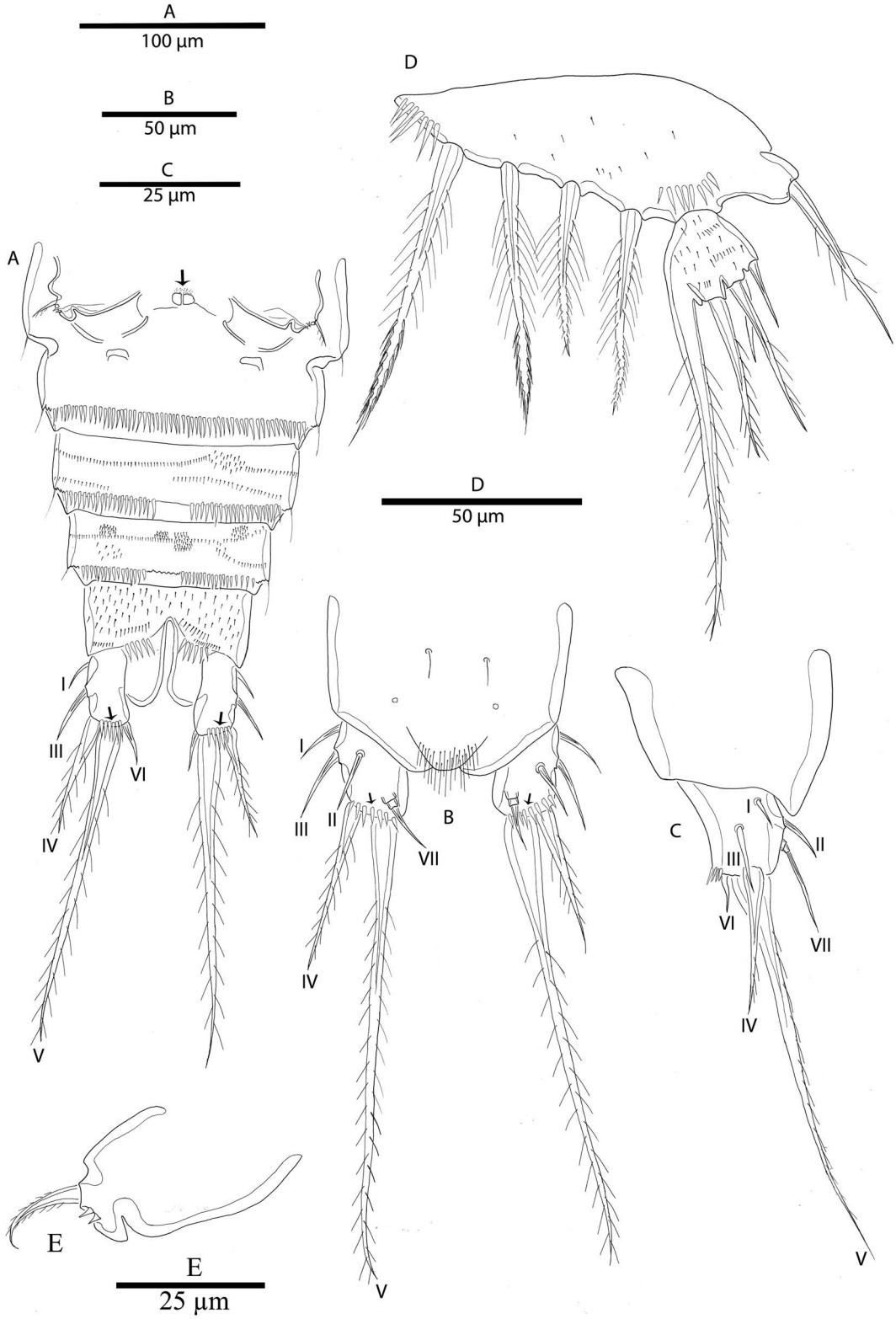
Fig. 7. *Nannopus ganghwaensis*. Female. Line drawings. A, genital double-somite (arrow indicates pair of copulatory pore), P6 and caudal rami (arrow on both ramus indicates posteroventral spinules) ventral; B, anal



somite and caudal rami (arrow on both ramus indicates posterodorsal spinules), dorsal; C, anal somite and caudal rami, lateral; D, P5, anterior; E, P6 (right one, enlarged).

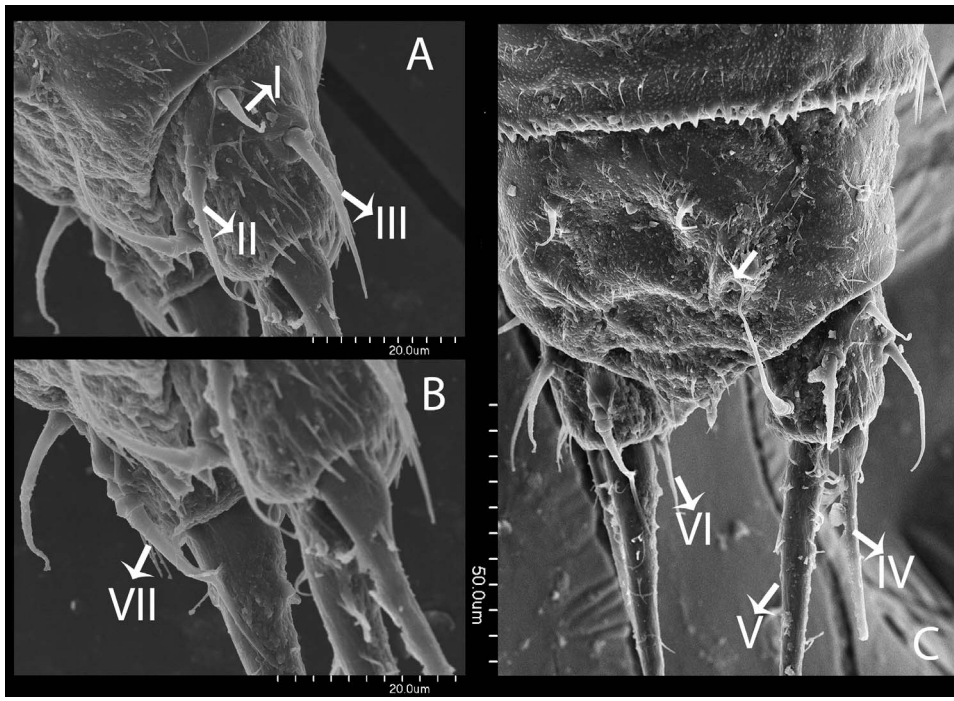


Fig. 8. *Nannopus ganghwaensis*. Female. SEM photographs. A–B, caudal rami, lateral; C, anal somite (arrow indicates a pore) and caudal rami, dorsal.

margins (Fig. 7A). Caudal ramus bearing 7 setae: seta (I) naked, shorter than ramus width, inserted close to ramus articulation with somite, located anterolaterally; seta (II) naked, almost as long as ramus width, inserted at midlength of ramus, located anterolaterally; seta (III) naked, almost as long as ramus width, inserted at midlength of outer margin, located anterolaterally; seta (IV) bipinnate, 2 times as long as ramus (in dorsal view), located at outer posterior margin, and slightly inflated at its insertion site; seta (V) strongest, inflated at its insertion site, bipinnate with anterior part rather wide and smooth, 3 times as long as seta IV, and located at inner posterior margin. Seta (VI) naked, small, located at inner posterior corner; dorsal seta (VII) triarticulate, naked, located midlength of ramus close to inner margin.

Rostrum (Fig. 2C) prominent, fused to cephalothorax, recurved ventrally, lateral and distal margins densely hirsute with multiple rows of long and slender setules.

Antennule (Fig. 4A) 5-segmented, short and compact, approximately 0.6 times as long as cephalothorax, first and second segments strong and wide, first and third segments with row of spinules, and other segments without ornamentations. Armature formula as follows: 1–[1], 2–[9], 3–[6+(1+ae)], 4–[1], 5–[8 + acrothek].

Antenna (Fig. 4B) relatively short, composed of allobasis, 1-segmented endopod and 1-segmented exopod. Allobasis with outer proximal setular cluster, 2 abexopodal pinnate setae. Endopod 1.8 times as long as wide, with cluster of long, slender spinules in proximal half of outer margin, row of robust spinules on inner and outer distal corners, armed with 5 strong, rigid naked elements and single naked, slender element. Exopod 1.5 times as long as wide, with 4 elements (1 sparsely bipinnate, 3 naked).

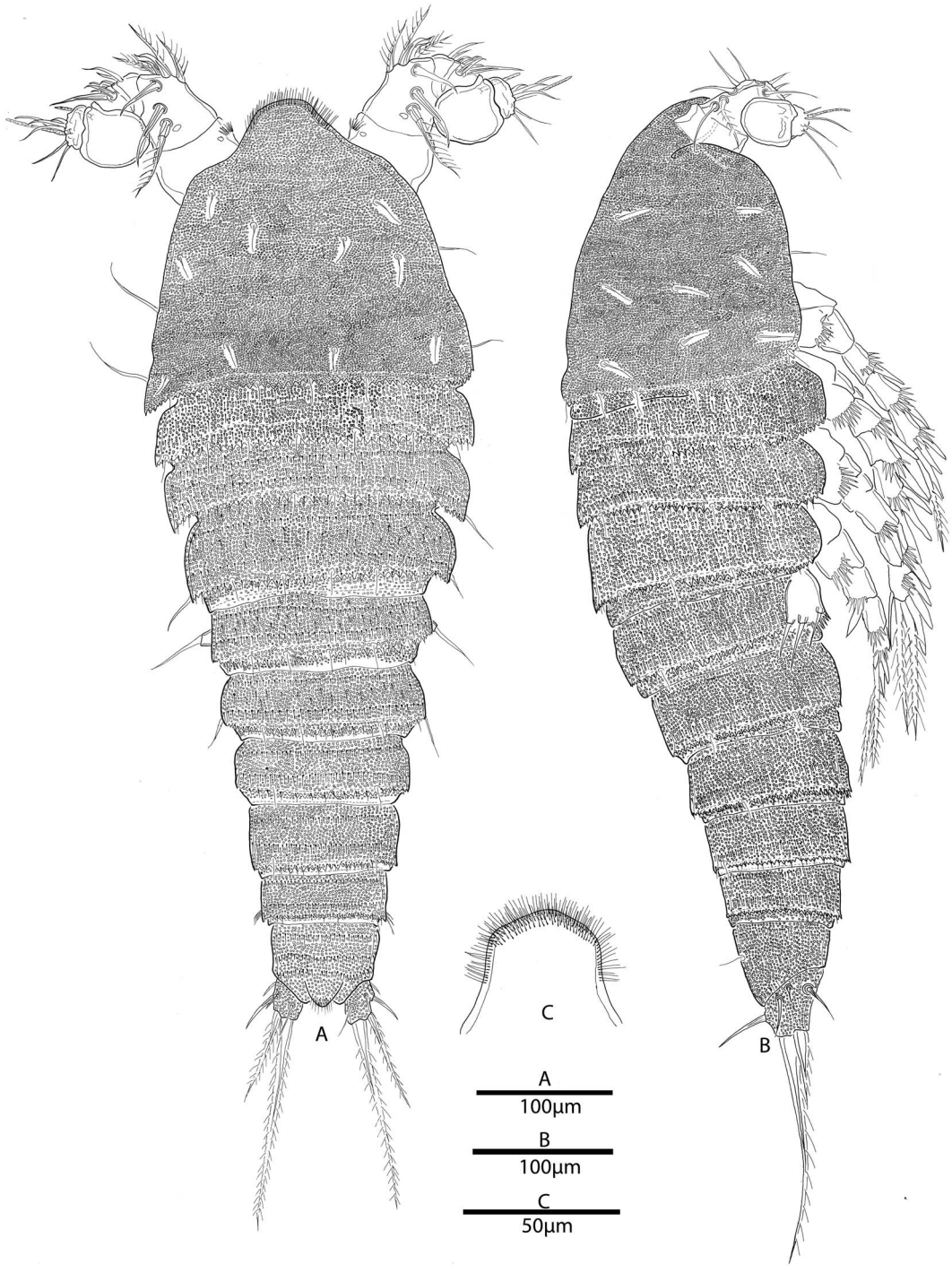


Fig. 9. *Nannopus ganghwaensis*. Line drawings. Male. A, habitus, dorsal; B, habitus, lateral; C, rostrum, dorsal.

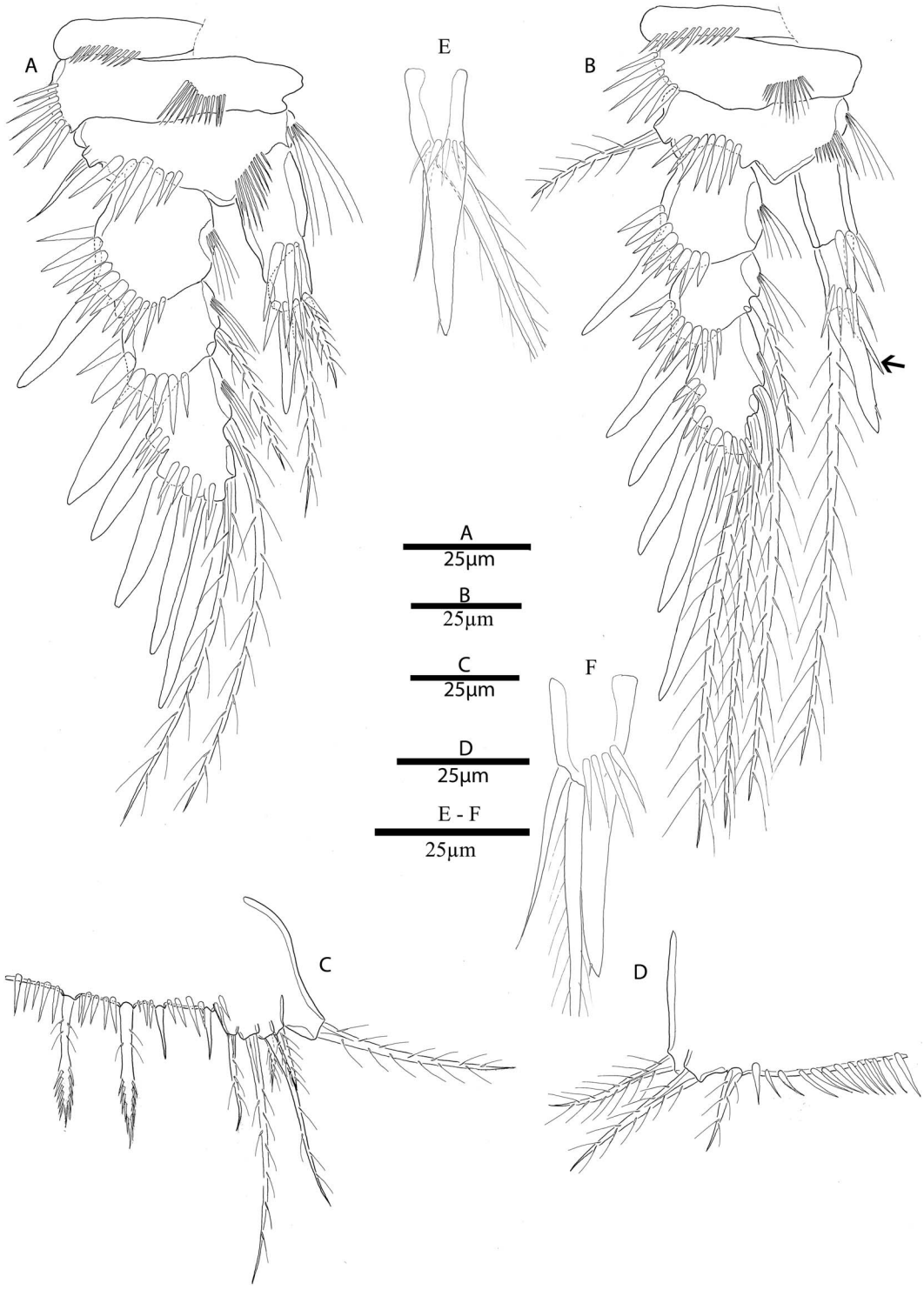


Fig. 10. *Nannopus ganghwaensis*. Line drawings. Male. A, P2; B, P3 (arrow indicates seta on posterior surface of spine); C, P5; D, P6; E, P3 endopod (showing distal apophysis); F, P3 endopod (showing distal apophysis with slight movement based on additional paratype).

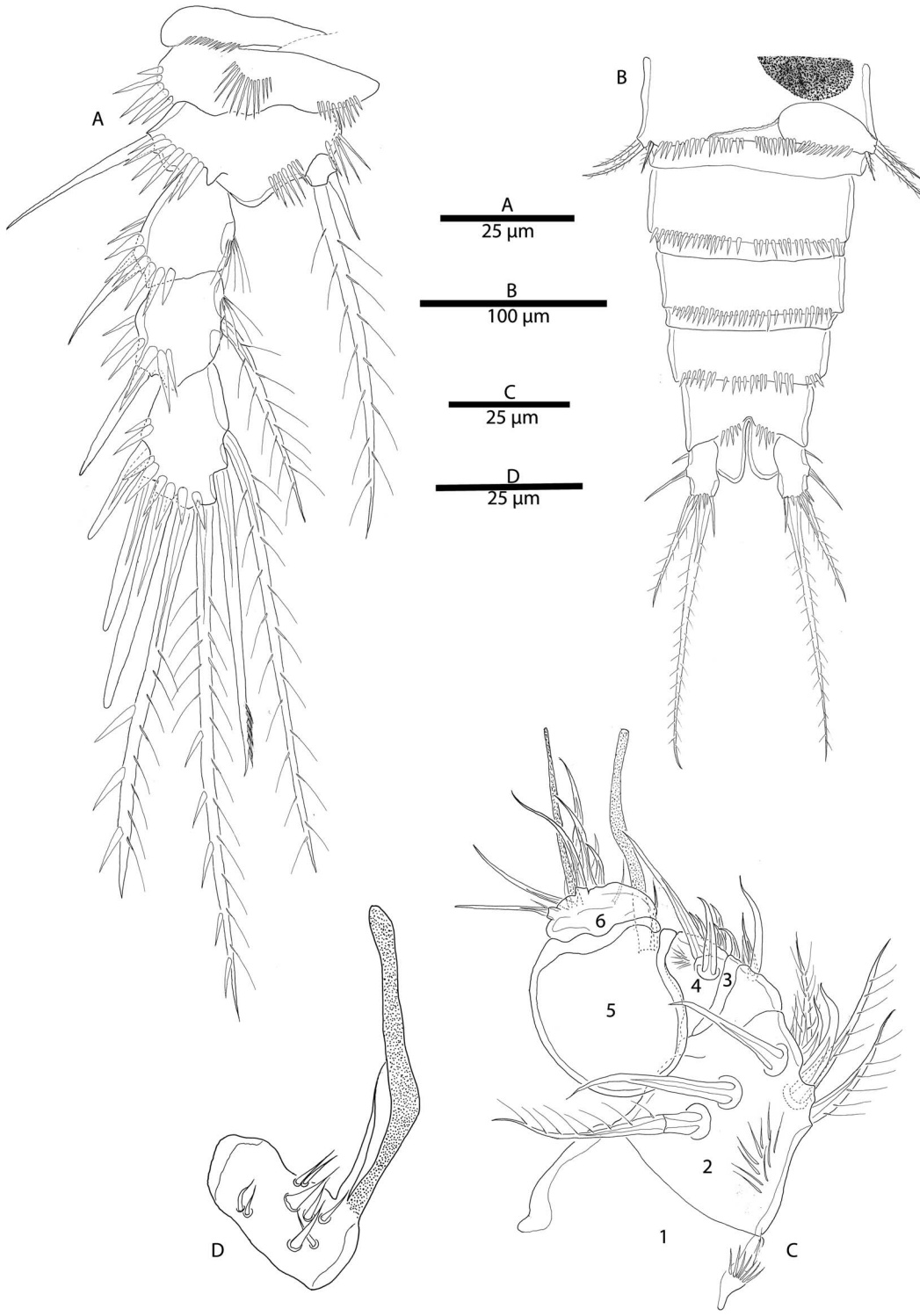


Fig. 11. *Nannopus ganghwaensis*. Line drawings. Male. A, P4; B, urosomite, ventral (showing a part of spermatophore on right side; C, antennule, dorsal; D, antennule fifth segment, lateral.

Mandible (Fig. 4C) with well developed gnathobasis, with row of setules near articulation of basis, cutting edge composed by 4 rigid, multicuspidate teeth and 1 serrate seta. Mandibular palp 1-segmented, rami incorporated to basis, surface with rows of spinules, armed with 4 bipinnate setae (1 basal, 2 exopodal, and 1 endopodal).

Maxillule (Fig. 4D) with well developed praecoxal arthrite, ornamented with row of spinules, armed with 2 slender and naked surface setae, 8 stout naked spines, and 2 bipinnate elements. Coxal endite bearing 2 setae. Basis and rami fused (exopod and endopod), surface with rows of spinules, armed with 8 setae: 5 basal (3 naked, 1 pinnate, 1 unipinnate), 1 endopodal unipinnate seta and 2 exopodal bipinnate setae.

Maxilla (Fig. 4E) with large syncoxa, ornamented with rows of spinules, bearing 2 endites, each with 3 elements, all confluent with segment, proximal endite with 2 spinulose and 1 slender naked elements, distal endite with 2 spinulose elements and 1 blunt naked elements. Allobasis with row of spinules, strong claw and accompanying naked seta. Endopod incorporated into basis, represented by short projection bearing 2 naked setae.

Maxilliped (Fig. 4F) subchelate, 3-segmented. Syncoxa shorter than basis, with 1 short distal seta. Basis 2 times as long as wide, row of spinules along inner margin and outer distal corner. Endopod with strong, curved claw ornamented with rigid spinules in distal half and two naked accessory setae at proximal region.

P1–P4 (Figs. 5A–B, 6A–B) with smooth and short concave intercoxal sclerite (not illustrated). Praecoxa somewhat triangular and shorter than coxa, ornamented with row of spinules along outer third of distal margin. Coxa with 1 (P2 and P3) or 2 spinular rows (P1 and P4) on anterior surface, and row of strong spinules along outer margin. Basis with row of strong spinules along outer margin near insertion of exopod, with row of spinules along distal margin near insertion of endopod, row of spinules (P1 and P4) or setules (P2 and P3) on inner distal corner; outer seta naked (P1, P2, P4) or bipinnate (P3), inner spine present on P1. Exopod 3-segmented, all segments with same size, exp-1 to -3 with robust spinules along outer distal margins, row of setules along inner margins (P1 exp-2, P2 exp-1 to -2, P3 and P4 exp-1 to -3). P1 exp-2 with serrate spine, P4 exp-1 spine with small distal setule, exp-3 with inner subdistal pectinate seta. Endopod 2-segmented in P1–P3 and 1-segmented in P4, P1–P3 endopods with robust spinules along outer distal margins, row of setules along inner margins (P1 and P3 enp-2). Spine and setal formula as below:

	Exopod	Endopod
P1 (Fig. 5A)	0.1.013	0.111
P2 (Fig. 5B)	0.1.123	0.111
P3 (Fig. 6A)	0.1.223	0.111
P4 (Fig. 6B)	0.1.223	020

P5 (Fig. 7D) baseoendopod represented by transversely elongated plate with spinules along inner distal margin and close to exopod insertion (Fig. 7D). Endopodal lobe with 4 elements (2 pectinate and 2 bipinnate). Exopod articulating with baseoendopod, semicircular in shape and about as long as wide, scattered with setules on anterior surface, bearing 5 elements, innermost element strongest, bipinnate and fused to exopod, next 2 bipinnate and 2 outermost naked.

P6 (Fig. 7A and E) semi-triangular with protruding outer distal edge bearing 1 short bipinnate element, and 2 hyaline remnants.

Description of male (based on allotype and paratypes).—Almost as in female except for total body length measured from tip of rostrum to posterior margin of caudal rami ranging from 584 to 730μm (mean = 667 μm, $n = 10$, allotype: 676μm), maximum width measured at posterior margin of cephalothorax ranging from 230 to 253μm (mean = 240 μm, $n = 10$,

allotype: 242μm), body fusiform (Figs. 1C, 9A–C); with one spermaduct.

Ornamentation as in female, with tiny round denticles and horizontal rows of slim setules on the surface of somites (Fig. 9A–B).

Genital somite (Fig. 9B) well segmented in both dorsal and ventral views (i.e., second and third urosomites).

Anal somite (Fig. 9A–B) as in female.

Caudal rami (Fig. 9B) almost as in female except seta V twice as long as seta IV.

Rostrum (Fig. 9C) as in female.

Antennule (Fig. 11C–D) 6-segmented, short and compact, second segment longer than in female, strongly geniculate between fourth and sixth segment, first and second segments, strong and wide. First, second and fourth segments with some spinules, other segments without additional ornamentations. Armature formula as follows: 1–[1], 2–[12], 3–[1], 4–[6], 5[9 +(1+ ae)], 6[7 +acrothek].

Antenna, mandible, maxillule, maxilla, maxilliped and P1 as in female (not illustrated).

P2–P4 (Figs. 10A–B, E–F, 11A) intercoxal sclerite (not illustrated), praecoxa, coxa, basis and exopods and endopods as in female. Exp-1 to -3 with robust spinules along outer distal margins, row of setules along inner margins (P2 and P3 exp-1 to -3, P4 exp-1 to -2). Exp-3 with 3 outer spines and 1 distal spine (P2 and P3). P3 enp-2 distal spine robust, fused and forming an apophysis and below spine with 1 long bipinnate and 1 small naked setae, P4 endopod distal seta reaching to only distal margin of exp-3.

P5 (Fig. 10C) baseoendopod fused and confluent with somite, spinules along posterior margin. Endopodal lobe with 4 elements (2 sub-equal pectinate and 2 naked). Exopod fused with baseoendopod, bearing 5 unequal pinnate elements.

P6 (Figs. 10D, 11B) asymmetrical with left leg operational forming a simple flap, the latter apparently confluent or fused with somite; furnished with spinules along distal margin, 3 bipinnate elements. Single spermatophore observed underneath of left flap.

Variability.—Fine setules are located variably on the ventral surface of urosomites midventrally, posteroventrally or slightly scattered along posterior surface. The number of spinules at the either side of the anal sinus varies from 3 to 5. Spinules along outer distal margin of all exopodal segments of P1–P4 also vary being slightly smaller in few specimens.

Etymology.—The species name refers to the type locality, Ganghwa Island.

Discussion

The new species was placed in the genus *Nannopus* based on the combination of following character sets: (1) the bell-shaped rostrum having the multiple rows of long setules along anterior margin, (2) the short 5-segmented antennule of the female, (3) 1-segmented mandibular palp with only 4 setae, (4) the 2-segmented endopods in P1–P3 endopods and 1-segmented in P4, and (5) the two distal elements on the P4 endopod, and (6) the baseoendopod of P5 represented by a narrow transverse plate in both sexes.

The new species shares the presence of seven elements in P4 exp-3 with three congeners, *N. flexibilis*, *N. didelphis,* and *N. hirsutus* (see Table 1). The remaining characters are widely shared with congeners including the shape of habitus, 5-segmented antennule in females, the total number of elements in antenna, mandibular palp, maxillule, maxilla and maxilliped, its setal ornamentations in exp-3 and enp-2 of P1–P3, and shape of caudal ramus (see Table 1 and 2).

However, *Nannopus ganghwaensis* well differs from *N. flexibilis, N. didelphis,* and *N. hirsutus* based on the combination of following character states: (1) the dorsal surface of cephalothorax has no integumental window in the new species, *N. didelphis*, and *N. hirsutus*, whereas *N.*

Table 1.—Morphological characters representing setal formula and ornamentation of P1–P5 in the new species and valid congeners.

Characters			*N. palustris* s. str.	*N. flexibilis*	*N. perplexus*	*N. didelphis*
P1:P2:P3:P4 inner seta ornamentation ♀		Exp-2	? : 1N : 1N : 1N	1 : 1 : 1 : 1	× : 1N : 1N : 1N	1P : 1P : 1P : 1P
Setal formula and ornamentation (order goes from outer margin to inner margin) ♀	P1	Exp-3		II, I +1 = 4	II, I+1P = 4	II, I +1P = 4
		Enp				
		Enp-2		I, 1, 1 = 3	I, 0, 0 = 1	I,1P,1P = 3
	P2	Exp-3	III, 2P,1P = 6	III, 2, 1 = 6	II, 2P, 2P = 6	III, 2P,1P = 6
		Enp-2	I, 1N, 1N = 3	I, 1, 1 = 3	I, 1P, 1N = 3	I, 1P, 1P = 3
	P3	Exp-3		III, 2, 2 =7	II, 2P, 2P = 6	III, 2P, 2P = 7
		Enp-2		I, 1, 1 =3	I, 1P, 1N = 3	I, 1P, 1P = 3
	P4	Exp-3	II, 2P, 2N = 6	III, 2, 2 = **7**	II, 2P, 2(Pe+P) = 6	III, 2P, 2(Pe+P) = **7**
		Enp	0, 1P, 0 = 1	0, 2P, 0 = 2	0, 1P, 0 = 1	0, 2P, 0 = 2
Total no of elements (outer margin to inner margin) and ornamentation ♀	P5	Exp		5	P, P, P, P = 4	P, P, P, P, P(F) = 5
		Enp		4	P, P, P? = 3	P, P, Pe P, Pe, Pe, Pe = 3 to 4 (#) P, Pe, Pe

Roman letters indicate spines, Arabic letter indicates seta, N: naked seta, P: pinnate seta, Pe: pectinate seta, X: absent, F: fused, ?: details should be confirmed, # ornamentation and setae number is variable in P5 endopod.

Note: a) *N. palustris* Brady, 1880, plate 77, Fig. 19 considered as P2 (see explanation in plate 58, 1st column, Fiers & Kotwicki, 2013), however, this assumption should be confirmed in the future study.

b) The ornamentation of setae in P1–P5 of *N. flexibilis* is not clear; therefore, only setal numbers have been included.

Table 2.—Morphological characters representing similarities and dissimilarities of the new species against valid congeners.

Characters	*N. palustris* s. str.	*N. flexibilis*	*N. perplexus*	*N. didelphis*
Shape of habitus ♀	Fusiform, flattened (dorsally)	Fusiform, less flattened (dorsally)	Fusiform , less cylindrical (dorsally)	Fusiform, flattened (dorsally)
Body Length (μm) ♀			490μm	618μm
A1 no of segments ♀	5	5	5	5
A1 armature formula ♀	1−[1], 2−[9], 3−[6+ (1+ae)], 4−[1], 5−[8 + acrothek]			
A2 exopodal setae ♀		4 (?)	3 (N)	4 (3N + 1P)
A2 endopodal spines ♀		6 (unmodified)	7 (unmodified)	6 (unmodified)
A2 abexopodal seta		2 (?)	1 (N)	2 (P)
Mandibular palp total no. of elements ♀		4 (?)	3 (N)	3 to 4 (P)
Integumental windows on cephalothorax ♀		1 integumental window	1 integumental window	Absent
P1 endopod segments		2-segmented	2-segmented	2-segmented
P5 exopod articulation to baseoendopod		Not fused	Fused	Not fused
P2 enp-2 inner most seta ♀	0.7 times as long as the outer spine of its segment		0.5 times as long as the outer spine of its segment	as long as the outer spine of its segment
References	Brady 1880	Lilljeborg 1902	Sars 1909b	Fiers & Kotwicki 2013

Table 1.—Extended.

N. scaldicola	*N. procerus*	*N. hirsutus*	***N. ganghwaensis*new species**	*N. unisegmentatus*
1P : 1P : 1P : 1P	1P : 1N : 1P : 1P	1P : 1P : 1P : 1P	1P : 1P : 1P : 1P	× : 1P : 1P : ×
II, I +1P = 4	II, I +1P = 4	II, I +1P = 4	III, 1P = 4	III, 1P = 4 0, I, 0 = 1
I,1P,1P = 3	I,1P,1P = 3	I,1P,1P = 3	I,1P,1P = 3	
III, 2P, 1P = 6	III, I+1P, 1P = 6	III, 1P+1P, 1P = 6	III, 2P, 1P = 6	II+1P, 1P, 1P = 5
I, 1P, 1P = 3	I, 1P, 1P = 3	I, 1P, 1P = 3	I, 1P, 1P = 3	I, 1P, 0 = 2
III, 2P, 2P = 7	III, I+1P, 1P = 6	III, 1P+1P, 2P = 7	III, 2P, 2P = 7	II, 2P, 2P = 6
I, 1P, 1P = 3	I, 1P, 1P = 3	I, 1P, 1P = 3	I, 1P, 1P = 3	I, 1P, 1P = 3
III, 1P+1P, 1P = 6	III, 2P, 1Pe = 6	III, 2P, 2(Pe+P) = **7**	III, 2P, 2(Pe+P) = **7**	II, 2P, 2(Pe+P) = 6
0, 2P, 0 = 2	0, 1P+1P, 0 = 2	0, 2P, 0 = 2	0, 1P+1N, 0 = 2	0, 2P, 0 = 2
P, P, P, P, P = 5	P, P, N, N, P(F) = 5	P, P, P, P, P = 5	N, N, P, P, P(F) = 5	P, P, P, P = 4
P, P, Pe, Pe= 4	P, P, Pe, Pe= 4	P, P, Pe, Pe = 3 to 4(#) P, P, Pe	P, P, Pe, Pe = 4	P, P, P? = 3

Table 2.—Extended.

N. scaldicola	*N. procerus*	*N. hirsutus*	***N. ganghwaensis***	*N. unisegmentatus*
Overall ovate (dorsally)	Fusiform, cylindrical (dorsally)	Fusiform, flattened (dorsally)	Fusiform, flattened (dorsally)	Fusiform, Flattened (dorsally)
487μm	625μm	445μm	772μm (n=22)	540μm
5	5	5	5	5
	1−[1], 2−[9], 3−[6+ (1+ae)], 4−[1], 5−[8 + acrothek]			
4 (3N + 1P)	4 (3N + 1P)	4 (3N + 1P)	4 (3N + 1P)	4 (N)
6 (unmodified)	6 (unmodified)	6 (unmodified)	6 (unmodified)	6 (modified)
2 (P)	2 (P)	2 (P)	2 (P)	
3 to 4 (P)	3 to 4 (P)	3 to 4 (P)	4 (P)	5 (2P+3N)
1 integumental window	Absent	Absent	Absent	Absent
2-segmented	2-segmented	2-segmented	2-segmented	1-segmented
Not fused	Not fused	Not fused	Not fused	Not fused
3 times as long as the outer spine of its segment	0.4 times as long as the outer spine of its segment	0.8 times as long as the outer spine of its segment	**1.7 times as long as the outer spine of its segment**	Absent
Fiers & Kotwicki 2013	Fiers & Kotwicki 2013	Fiers & Kotwicki 2013	**Present study**	Shen & Tai 1964

flexibilis has one integumental window, (2) the lateral margins of urosomites are not densely hirsutus in the new species and *N. didelphis*, whereas in *N. hirsutus* the lateral margins of urosomites are densely hirsutus. It is not clear in *N. flexibilis* due to incomplete description, (3) the distal small seta of P4 endopod is naked in the new species, while in *N. didelphis* and *N. hirsutus* the homologous element is pinnate. In *N. flexibilis* it is not reliable due to poor description (see Table 2), (4) the innermost seta of P5 exopod is fused in the new species and *N. didelphis*, while in *N. hirsutus* it is well separated. In *N. flexibilis* it is not reliable due to poor description, (5) the inner most distal seta of P2 enp-2 in the new species is 1.7 times as long as the outer spine, while in *N. didelphis* it is just as long as the outer spine. In *N. hirsutus* it is 0.8 times as long as the outer spine. In the case of *N. flexibilis* P2 is not described (see Table 2), (6) the caudal seta IV is slightly inflated and without globular expansion at its insertion site in the new species, while *N. flexibilis* and *N. hirsutus* have a small globular expansion at the insertion site (see Fiers & Kotwicki, 2013: p. 63 fig. 26 B; p. 62 fig. 25A–B). In *N. didelphis* it is normal type (see Fiers & Kotwicki, 2013: p. 40, fig. 3A and C) (see table 2), (7) the caudal seta IV is pinnate in the new species, *N. didelphis*, and *N. hirsutus*, while it is naked in *N. flexibilis*, (8) the shape of caudal seta V is inflated at the anterior region in the new species (see Fig. 8C), while in *N. flexibilis* it is inflated, but with a heavy globular expansion at its insertion site (see Fiers & Kotwicki, 2013: p. 63 fig. 26B–C); whereas in *N. didelphis* it is also inflated, but with a restricted globular expansion, and with a spur at the insertion site (see Fiers & Kotwicki, 2013: p. 40, fig. 3A and C); in *N. hirsutus* it is also inflated but heavily cylindrical and densely ornamented with circlets of setules (see Fiers & Kotwicki, 2013: p. 62 fig. 25A–B) (see Table 2).

The male of *N. ganghwaensis* also shares most of the morphological features with the male of *N. didelphis*, including P3 enp-2 [distal seta (pinnate), inner distal seta (naked)]. However, the male of the new species also differs from *N. didelphis* by the presence of inner seta in P2 exp-2, whereas in *N. didelphis* it is absent. Also, the innermost seta of P2 enp-2 is pinnate in the new species, while in *N. didelphis* it is naked. In addition, the distal pinnate seta of P3 enp-2 in males of *N. ganghwaensis* is 2.6 times as long as in male of *N. didelphis*. Consistently, the male of new species differed by having only one spermaduct, while *N. didelphis* has two spermaducts. Males P6 of *N. ganghwaensis* is asymmetrical and without a notch along its distal margin in the new species, while the male P6 of *N. didelphis* is symmetrical and with a small notch (Fiers & Kotwicki, 2013: p. 46, fig. 9G). Unfortunately, the males of *N. hirsutus* are unknown.

Although the male of *N. ganghwaensis* cannot be compared in detail with the male of *N. flexibilis* due to poor descriptions, it can be easily discriminated based on the distal spine of P3 enp-2. In the male of new species P3 enp-2 is rectangular in shape and with a distal spine fused to the segment forming a sharp apophysis; while in *N. flexibilis* the male P3 enp-2 is square or globular in shape and with a distal spine fused to the segment forming a triangular apophysis (see Fiers & Kotwicki, 2013: p. 63 fig. 26E).

Fiers & Kotwicki (2013) hypothesized that the *Nannopus* may have two different lineages based on the inner subdistal element in P4 exp-3, the male P6, and the male genital apparatus. The one lineage sustains based on the presence of either naked or pinnate unmodified long inner seta in P4 exp-3 (*N. palustris* s. str., *N. palustris* sensu lato Canu, 1892, *N. scaldicola*); the asymmetric male P6, and with one spermaduct (*N. scaldicola*). The other lineage is based on the presence of inner subdistal pectinate seta in P4 exp-3 (*N.*

flexibilis, *N. perplexus*, *N. didelphis*, *N. procerus, N. hirsutus*), the symmetric male P6, and with two spermaducts (*N. didelphis*, *N. procerus*). Simultaneously, Fiers & Kotwicki (2013) suggested that the lineage with inner subdistal pectinate element in P4 exp-3 should be transferred to *Ilyophilus* Lilljeborg, 1902 by reinstating with *I. flexibilis* Lilljeborg, 1902 (as the type) and remaining all species which ever has an inner subdistal pectinate seta in P4 exp-3, also, the males with symmetrical P6 and two spermaducts. However, the present new species has asymmetric male P6 and one spermaduct like in *N. scaldicola* with the functional valve on the right side (ventrally), on the other hand, P4 exp-3 with inner subdistal pectinate seta appears exactly as in *N. flexibilis*, *N. perplexus*, *N. didelphis*, *N. procerus,* and *N. hirsutus*. Therefore, the assumption of two lineages within *Nannopus* by Fiers & Kotwicki (2013) is not supported by the new species.

Although Brady (1880) describes *N. palustris* poorly, the new species differs from *N. palustris* s. str. based on several characters including the lengths of inner most seta of P2 enp-2 (0.7 times longer than outer seta in *N. palustris*, and 1.7 times in *N. ganghwaensis*), the setal numbers in P4 exp3 (only 6 elements in *N. palustris*, and 7 in *N. ganghwaensis*), and the shape of caudal seta IV at its insertion site in female (normal, cylindrical in *N. palustris*, and inflated in *N. ganghwaensis*). Unfortunately other characters are not comparable due to absence of descriptions and type specimen of *N. palustris*.

Yoo & Lee (1995) reported *N. palustris* from two brackish mud flats, Youngjong island in the west coast, and Bongyoung in the south coast of Korea. Although Youngjong island located only about ten km away from present study site, Ganghwa islands, however two species, *N. palustris* sensu Yoo & Lee, 1995 and *N. ganghwaensis* showed some discrepancies (see Yoo & Lee, 1995, Fig. 16A–F). *N. palustris* sensu Yoo & Lee, 1995 has normal, non-inflated caudal seta IV (Fig.7A–C, inflated in *N. ganghwaensis*), a shorter endopod P1 only reaching to distal margin of exp-2 (Fig. 5A, reaching to the middle of exp-3 in *N. ganghwaensis*), a longer inner spine on the endopod of P4 exceeding the distal margin of exp-1 (Fig. 6B, a short one not reaching to distal margin of exp-1 in *N. ganghwaensis*), and the inner most seta on the P5 exopod clearly articulated from the segment in the female (Fig. 7D, fused to the exopod segment in *N. ganghwaensis*). Considering their close localities, those discrepancies between two species are exceptionally huge and they support a probability of coexistences of sibling species in the region. *N. palustris* sensu Yoo & Lee, 1995 also differed from *N. palustris* s. str. by two distinct characters, seven elements on the P4 exp-3 (six elements in *N. palustris* s. str., see Brady, 1880, Plate LXXVII, Fig. 20), and a longer inner spine on the endopod of P4 (very short in *N. palustris* s. str., see Brady, 1880, Plate LXXVII, Fig. 20). Unfortunately both species have incomplete descriptions and *N. palustris* sensu Yoo & Lee, 1995 needs to be revised in a further study.

A key to the species of *Nannopus* is prepared including new species and eight valid congeners. We regard that the inner subdistal seta on the P4 exp-3 is not pectinate but pinnate in *N. palustris* Brady, 1880 based on the Fig. 20 Plate LXXVII (Brady, 1880) as it is also recognized in Fiers & Kotwicki (2013).

1) P4 exp-3 without inner subdistal pectinate seta **2**
– P4 exp-3 with inner subdistal pectinate seta **3**
2) P2 and P4 exp-2 inner seta naked; male unknown ..... *N. palustris* Brady, 1880
– P2 and P4 exp-2 inner seta pinnate in both sexes .....
..... *N. scaldicola* Fiers & Kotwicki, 2013

3) P1 endopod 1-segmented..... *N. unisegmentatus* Shen & Tai, 1964
– P1 endopod 2-segmented **4**
4) Antenna abexopod with 1 element and exopod with 3 elements, P1 exp-2 without inner seta, P4 endopod with 1 seta, P5 exopod fused to baseoendopod. . . . . *N. perplexus* (Sars, 1909b)
– Antenna abexopod with 2 element and exopod with 4 elements, P1 exp-2 with inner seta, P4 endopod with at least 2 seta, P5 exopod not fused to baseoendopod..... **5**
5) P4 exp-3 with total 6 elements in both sexes, caudal rami seta V with notch like process at the anterior third in females only..... *N. procerus* Fiers & Kotwicki, 2013
– P4 exp-3 with a total of 7 elements in both sexes, caudal rami seta V without notch like process at the anterior third **6**
6) Lateral margins of urosomites are densely hirsute; caudal rami seta V long, inflated, semi cylindrical, pinnate, densely hirsutus proximally, without notch; male unknown..... *N. hirsutus* Fiers & Kotwicki, 2013
– Lateral margins of urosomites are not densely hirsutus; caudal rami seta V long, inflated, globular (heavy and to restricted nature), pinnate, not hirsute proximally... **7**
7) Caudal rami seta IV naked in females; while in male it is pinnate (sexually dimorphic); male P3 enp-2 with triangular apophysis . . . . *N. flexibilis* (Lilljeborg, 1902)
– Caudal rami seta IV is pinnate in females and males (not sexually dimorphic); male P3 enp-2 with sharp apophysis **8**
8) P2 enp-2 inner most seta just as long as the outer spine of its segment (enp-2), caudal rami seta V with a spur, inflated and restricted globular expansion at its insertion site in female; P3 exp-2 inner seta absent, P2 enp-2 inner most distal seta naked, P3 enp-2 distal seta as long as the overall length of exopodite, male with two spermaducts and symmetrical P6, and P6 distal margin with a small notch like process in male ..... *N. didelphis* Fiers & Kotwicki, 2013
– P2 enp-2 inner most seta 1.7 times as long as the outer spine of its segment (enp-2) caudal rami seta V with a spur, and only inflated at its insertion site in females; P3 exp-2 inner seta present, P2 enp-2 inner most distal seta pinnate, P3 enp-2 distal seta 1.4 times as long as the exopodite, male with one spermaduct and asymmetrical P6, and P6 distal margin without notch like process in male . . . . *N. ganghwaensis,* new species

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