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Four new *Schizopera* (Copepoda, Harpacticoida) from marine interstitial habitats in Korea

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Abstract

With more than 100 valid species, the predominantly marine genus *Schizopera* Sars, 1905 has a near global distribution. The genus is also relatively successful in invading estuarine and freshwater ecosystems. In Korea only two widely distributed estuarine species have been recorded previously: *S. clandestina* (Klie, 1924) and *S. neglecta* Akatova, 1935. Four rare new species discovered in marine interstitial habitats are reported herein. *Schizopera daejinensis* **sp. nov.** and *S. yeonghaensis* **sp. nov.** are described after a single female and one specimen of each sex respectively. These two species were found living simpatrically in Daejin beach, near Yeong Hae city, on the East Coast of Korea. The minute *S. gangneungensis* **sp. nov.** is described after three females from a beach in Gangneung city, also on the East Coast of Korea. *Schizopera sindoensis* **sp. nov.** is described after one female and five males from a tiny beach on Jeju Island, on the South Coast of Korea. Our detailed survey of Korean beaches and the absence of any of these species in other localities suggest them to be either short range endemics or anthropogenic relics. We discuss the need for further study and protection of these neglected habitats, and the role they might play in harbouring disproportionate levels of diversity. A variety of phenotypic features for comparative descriptions of the four new species were used, including all cuticular organs (sensilla and pores) on the somites. These minute and underutilized structures provide as much resolution on the species level as traditionally used characters do, with an added bonus of an almost complete lack of sexual dimorphism. This might provide useful directions for future pairing of opposite sexes in these and other copepods, especially in cases of sympatric congeners or missing sexes.

Key words: cuticular organs, intertidal zone, new species, stygofauna, taxonomy

Introduction

The genus *Schizopera* was established by Sars (1905), with *S. longicauda* Sars, 1905 as the type species. Today, there are more than 100 valid species and subspecies worldwide (Wells 2007; Karanovic and Cooper 2012; Karanovic and McRae 2013; Walter and Boxshall 2015). They are distributed in a variety of marine, brackish and freshwater habitats around the world, and have probably invaded freshwater habitats on multiple occasions (Karanovic and Cooper 2012). The genus is, however, predominantly marine, with only two significant inland water species flocks, one in the ancient African Lake Tanganyika (Sars 1909; Gurney 1928; Lang 1948; Rouch and Chappuis 1960) and the other in subterranean waters of Western Australia (Karanovic 2004, 2006; Karanovic and Cooper 2012; Karanovic and McRae 2013). There are also isolated cases of freshwater members, such as the one recently discovered in subterranean waters near the ancient Lake Biwa in Japan (Karanovic et al. 2015a). Unfortunately, a great number of species descriptions are incomplete and/or inadequate. Because of that, and because of the normal expansion of generic boundaries resulting from the inclusion of new species, systematics of the genus *Schizopera* has been very difficult at times. Lang (1948, 1965) maintained clarity in the generic diagnosis by suggesting the presence of a "transformed spine" on the male third leg exopod as a synapomorphy. It was later proven that this structure is, in fact, an enormously enlarged tubular pore (Karanovic and Cooper 2012), similar in nature (although not in shape) to those observed in some other members of the same subfamily, Diossacinae Sars, 1906 (see Gee and Fleeger 1990). Attempts to split the genus based on the segmentation of endopods of first and fourth swimming legs (Apostolov 1982; Wells and Rao 1976; Bodin 1997; Boxshall and Halsey 2004) were subsequently questioned both based on morphological (Mielke 1992, 1995; Karanovic 2004; Wells 2007; Huys 2009) and molecular evidence (Karanovic and Cooper 2012; Karanovic and McRae 2013; Karanovic et al. 2015), and are now abandoned. The only exception is the genus *Eoschizopera* Wells and Rao, 1976, which was originally proposed to accommodate all doubtful members of the genus *Schizopera*, but was later redefined by Karanovic (2004) to include only four species. Its validity has been supported by a set of morphological synapomorphies (see Wells 2007) but the subgeneric division proposed by Apostolov (1982) has also been abandoned (Boxshall and Halsey 2004; Wells 2007; Huys 2009).

The genus *Schizopera* was known from Korea only after two widely distributed species, *S. clandestina* (Klie, 1924) and *S. neglecta* Akatova, 1935, collected in various marshes and estuaries by Chang (2009, 2010). The former species was originally described from the Baltic Sea by Klie (1924) and later found in other parts of Europe (Lang 1948; Monchenko 1967; Dussart 1967) and Asia (Tai and Song 1979). This species was reported also from Australia (Halse et al. 2002), but those records have to be verified (see Karanovic and Cooper 2012). *Schizopera neglecta* was originally described from the Caspian Sea by Akatova (1935), but is also known from other parts of Europe (Monchenko 1967, Apostolov and Marinov 1988) and Asia (Tai and Song 1979).

Four new species of *Schizopera* are reported herein. They were discovered in marine interstitial habitats of three beaches in Korea. This discovery resulted from an ongoing extensive survey of these habitats around the peninsula and on most major islands, funded by the National Institute of Biological Resources (NIBR). These represent our only records of this genus in more than 100 beaches sampled so far, making them exceptionally rare harpacticoids.

Material and methods

All specimens were collected by the senior author from the intertidal zone, using the Karaman-Chappuis method. It consisted of digging a hole down to the water level and then decanting the inflowing interstitial water and filtering it through a plankton hand net (mesh size 30 µm). All samples were fixed in 99 % ethanol, sorted in the laboratory also in 99 % ethanol using an Olympus SZX12 dissecting microscope with PLAPO objectives and magnification of up to 200x. Locality data and number of specimens are listed for each species separately and all types are deposited in NIBR.

Some specimens were dissected and mounted on microscope slides in Faure's medium (see Stock and von Vaupel Klein 1996), and dissected appendages were then covered by a coverslip. For the urosome or the entire animal, two human hairs were mounted between the slide and coverslip, so the parts would not be compressed. All line drawings were prepared using a drawing tube attached to a Leica MB2500 phase-interference compound microscope, equipped with N-PLAN (5x, 10x, 20x, 40x and 63x dry) or PL FLUOTAR (100x oil) objectives. Specimens that were not drawn were examined in glycerol and, after examination, were stored in 99.9 % ethanol. Specimens for scanning electron microphotography (SEM) were transferred into pure isoamyl-acetate, critical-point dried, mounted on stubs, coated in gold, and observed under a Hitachi S-4700 scanning microscope on the in-lens detector, with an accelerating voltage of 10 kV and working distances between 12.3 and 13.4 mm; microphotographs were taken with a digital camera.

The terminology for macro-morphological characters follows Huys and Boxshall (1991), except for the numbering of setae on the caudal rami and small differences in the spelling of some appendages (antennula, mandibula, maxillula instead of antennule, mandible, maxillule), as an attempt to standardise the terminology for homologous appendages in different crustacean groups. Sensilla and pores on each somite (body segment), the rostrum, and the caudal rami were numbered consecutively from the anterior to the posterior end of body and from the dorsal to the ventral side, to aid in the recognition of homologous structures between species and serially homologous structures within species; sensilla were numbered using Arabic numerals; pores were numbered using Roman numerals. The same numbers on different somites do not necessarily indicate serially homologous structures; serial homology was hypothesised in the description of cuticular organs (see below). As a tentative terminology for cuticular organs in the description, we combined abbreviations for the rostrum (R), cephalothorax (C), free prosomites (FP1 to FP3), and urosomites (U1 to U6) hyphenated with a given Arabic or Roman numeral (for example, sensilla pair FP1-3; see Karanovic et al 2015).

Systematics

Order HARPACTICOIDA G.O. Sars, 1903

Family MIRACIIDAE Dana, 1846

Subfamily DIOSACCINAE Sars, 1906

Genus *Schizopera* Sars, 1905

***Schizopera daejinensis* sp. nov.**
(Figs. 1–3, 16B)

Type locality. East Coast of Korea, Gyeongsangbuk-do province, Yeong Hae city, Daejin beach, mouth of Songcheon River, 36°33.959'N 129°25.518'E.

Specimen examined. Holotype female (NIBR IV 0000287246) dissected on one slide, collected from the type locality, 21 September 2011, leg. T. Karanovic.

Etymology. The species is named after the type locality, Daejin beach, with the addition of the Latin suffix for place "-*ensis*". The specific name consequently is an adjective for place.

Description. Female (holotype). Total body length, measured from tip of rostrum to posterior margin of caudal rami about 490 µm. Colour of preserved specimen yellowish. Nauplius eye not visible. Prosome comprising cephalothorax with completely fused first pedigerous somite and 3 free pedigerous somites; urosome comprising fifth pedigerous somite, genital double-somite (fused genital and first abdominal somites) and 3 free abdominal somites. Habitus (Figs. 1A, B, 16B) spindle-shaped, not particularly slender, without distinct demarcation between prosome and urosome; prosome/urosome ratio about 1.15 (in dorsal view); greatest width at posterior end of cephalothorax; cephalothorax only about 1.3 times as wide as genital double-somite. Body length/width ratio about 3.6. Free pedigerous somites without pronounced lateral or dorsal expansions. Integument of all somites relatively well sclerotized, generally very smooth, without cuticular windows or pits. First two urosomites, anal somite, and caudal rami, with rows of minute spinules. Hyaline fringe of all somites broad; those of cephalothorax and pedigerous somites smooth, others finely serrated. Surface of somites, rostrum, and caudal rami with total of 75 pairs of cuticular organs (16 pairs of cuticular pores and 59 pairs of sensilla), one unpaired dorsal sensillum, and one unpaired dorsal pore.

Rostrum (Fig. 1C) long and clearly demarcated at its base, anterior tip nearly reaching distal margin of second antennular segment, linguiform, about twice as long as wide, with smooth tip and single dorsal pair of sensilla (R-1) at about 2/3 of its length.

Cephalothorax (Fig. 1A, B) smooth, about as long as wide in dorsal view; representing 26 % of total body length, tapering towards anterior end in dorsal view. Hyaline fringe of cephalothoracic shield wide and smooth. Cephalothoracic shield (Fig. 1A, B) with 7 pairs of pores (C-I to C-VII), 28 pairs of sensilla (C-2 to C-11 and C-13 to C-30), and one unpaired dorsal sensillum (C-12); sensilla C-19 and C-20 very close to each other, as well as sensilla C-22 and C-23; pores C-I to C-IV all in anterior ventral part, close to sensilla C-7; pores C-VI and C-VII about same size and more than twice as large as any other prosomal pore; sensilla C-2 at base of rostrum; sensilla C-22 to C-30 probably belonging to first pedigerous somite, incorporated into cephalothorax; lateral marginal zone includes sensilla C-5, C-7, C-11, C-21, and C-26 (see Fig. 1A); posterior marginal zone includes sensilla C-27 to C-30 (see Fig. 1A, B).

Pleuron of first free prosomite (second pedigerous somite) (Fig. 1A, B) smooth, with one unpaired dorsal pore (FP1-I) and seven pairs of long sensilla (FP1-1 to FP1-7); posterior marginal zone including sensilla FP1-1, FP1-2, and FP1-4 to FP1-7; sensilla pair FP1-3 situated slightly more anteriorly; sensilla FP1-1 and FP1-7 probably serially homologous to sensilla C-27 and C-30, respectively, on first pedigerous somite; other serial homologies difficult to determine; hyaline fringe wide and smooth.

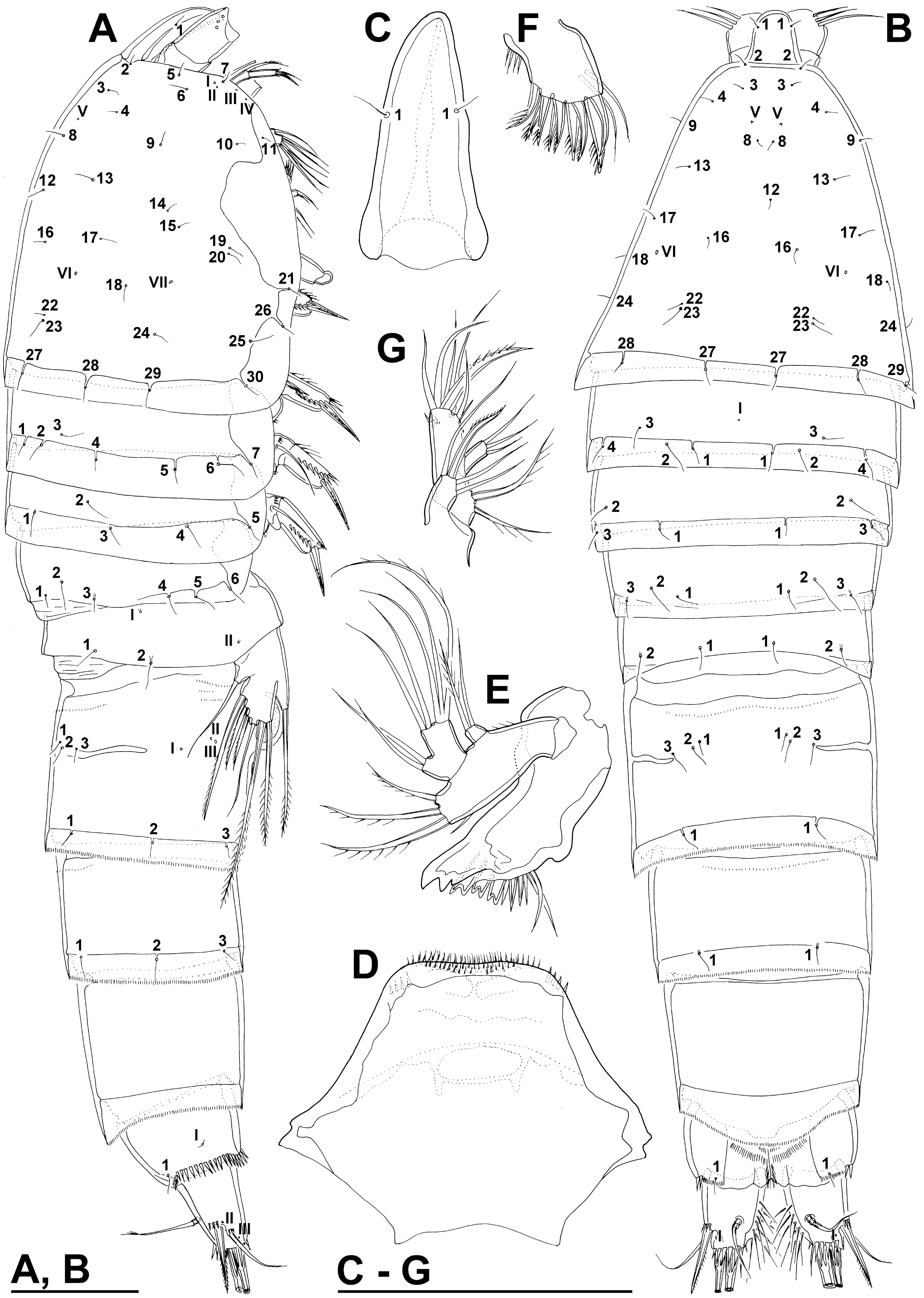

FIGURE 1. *Schizopera daejinensis* **sp. nov.**, line drawings: A, habitus, lateral; B, habitus, dorsal; C, rostrum, dorsal, slightly deformed by compression; D, labrum, anterior; E, mandibula, anterior; F, maxillular palp, anterior; G, maxillular praecoxa, posterior. Arabic numerals for sensilla and Roman numerals for pores assigned consecutively from anterior to posterior end of each somite and caudal ramus, and from dorsal to ventral side. Scale bars 50 µm.

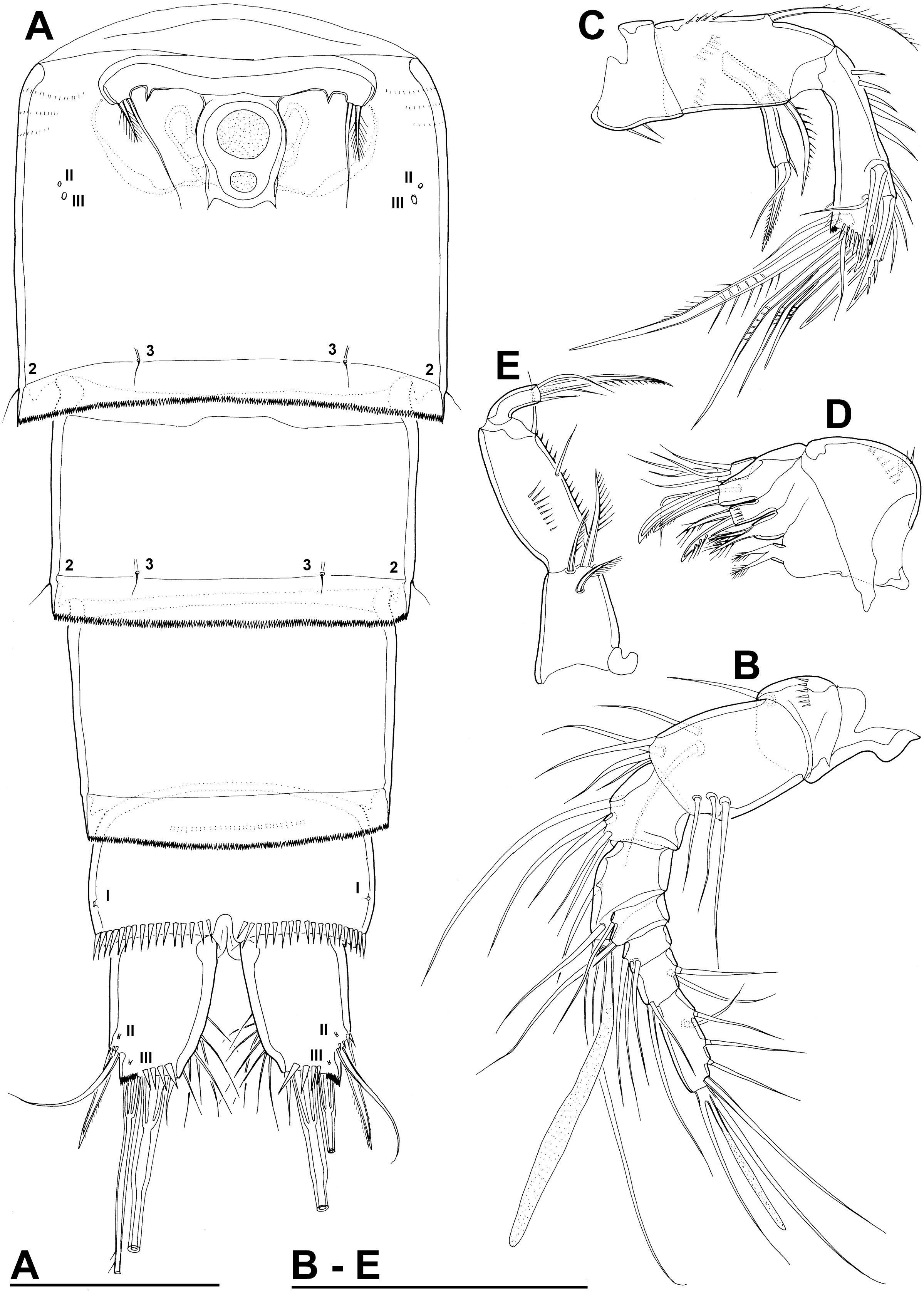

FIGURE 2. *Schizopera daejinensis* **sp. nov.**, holotype female, line drawings: A, urosome, ventral; B, antennula, dorsal; C, antenna, posterior; D, maxilla, anterior; E, maxilliped, anterior. Arabic numerals for sensilla and Roman numerals for pores assigned consecutively from anterior to posterior end of each somite and caudal ramus, and from dorsal to ventral side. Scale bars 50 µm.

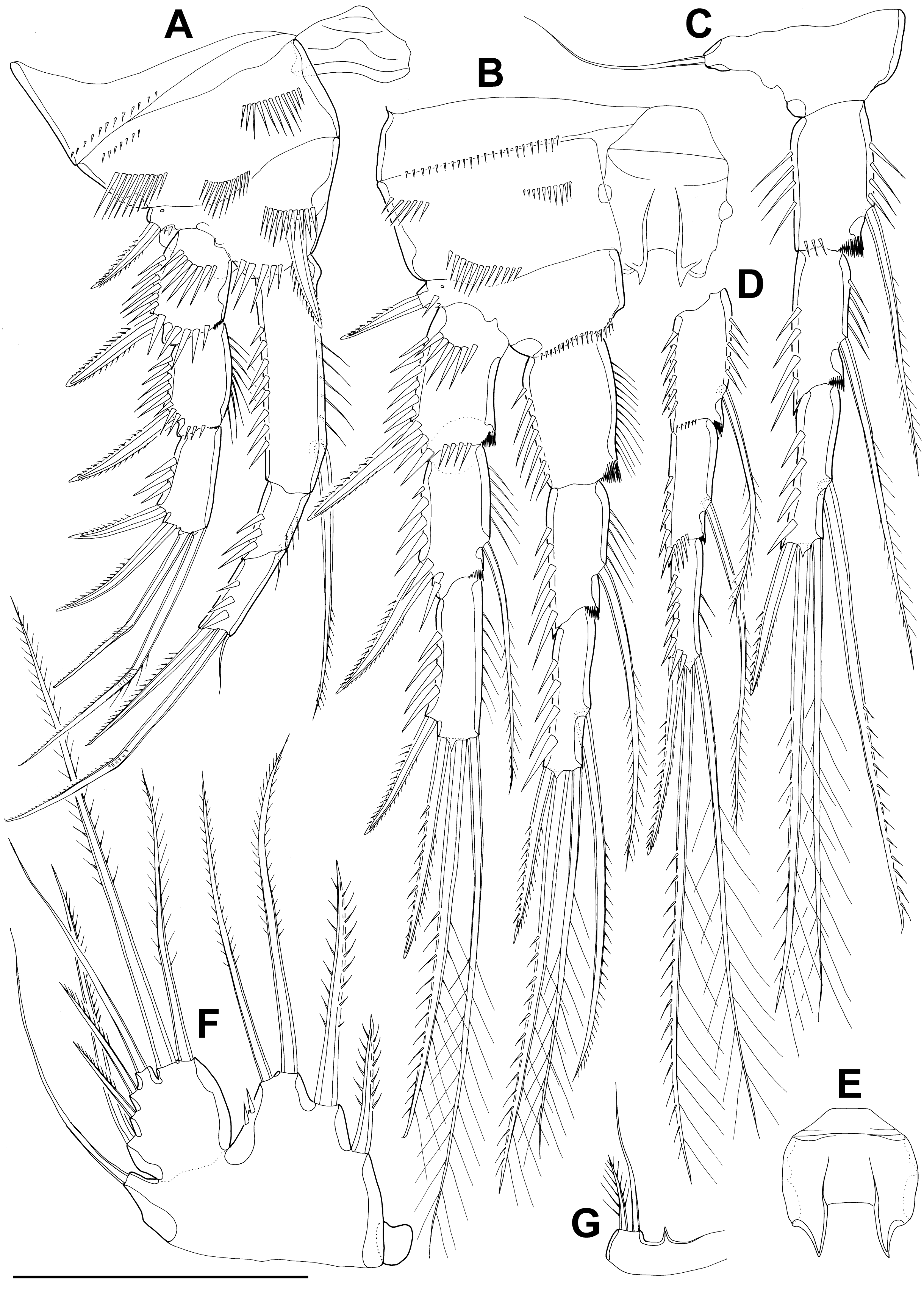

FIGURE 3. *Schizopera daejinensis* **sp. nov.**, holotype female, line drawings: A, first swimming leg, anterior; B, second swimming leg, anterior; C, basis and endopod of third swimming leg, anterior; D, endopod of fourth swimming leg, anterior; E, intercoxal sclerite of fourth swimming leg, anterior; F, fifth leg, anterior; G, sixth leg, anterior. Scale bar 50 µm.

Pleuron of second free prosomite (third pedigerous somite) (Fig. 1A, B) smooth, slightly narrower and shorter than pleuron of first free prosomite, without pores, with only five pairs of long sensilla (FP2-1 to FP2-5); posterior marginal zone includs sensilla FP2-1 and FP2-3 to FP2-5; sensilla pair FP2-2 longer than any other pair and situated slightly more anteriorly; dorsalmost pair of sensilla more widely spaced than on pleuron of first free prosomite but recognition of serially homologous pairs relatively easy (FP2-1 = FP1-1, FP2-2 = FP1-3, FP2-3 = FP1-4, FP2-4 = FP1-5, and FP2-5 = FP1-7); hyaline fringe wide and smooth.

Pleuron of third free prosomite (fourth pedigerous somite) (Fig. 1A, B) also smooth but slightly narrower and significantly shorter (especially dorsally) than pleuron of second free prosomite, with six pairs of long sensilla (FP3-1 to FP3-6); all sensilla probably serially homologous to their counterparts with same Arabic numerals on pleuron of second free prosomite, except that FP3-5 has no counterpart and that FP3-6 = FP2-5; hyaline fringe smooth, narrow dorsally but wide laterally.

First urosomite (fifth pedigerous somite) (Fig. 1A, B) slightly shorter than pleuron of third free prosomite but also smooth, with one pair of anterior lateral pores (U1-I), one pair of ventro-lateral pores near base of fifth legs (U1-II), and two pairs of dorsal sensilla (U1-1 and U1-2); sensilla pair U1-1 probably serially homologous to sensilla pair FP3-1, but serial homology of sensilla pair U1-2 not obvious (perhaps FP3-3); hyaline fringe very narrow and smooth.

Second urosomite (Figs. 1A, B, 2A) completely fused with third urosomite into genital double-somite, with one dorsal and three ventro-lateral rows of minute spinules, with three pairs of dorsal posterior sensilla (U2-1 to U2-3) of uncertain serial homology, one pair of lateral pores (U2-I) and two pairs of ventro-lateral pores (U2-II and U2-III); pores U2-II and U2-III close to each other. No remnant of hyaline fringe. Genital complex (Fig. 2A) with single copulatory pore posterior to epicopulatory bulb (latter also serving as copulatory duct), two small seminal receptacles inside large, paired, genital apertures; apertures with two ventral gonopores, each covered by reduced sixth leg. Epicopulatory bulb large, ovoid with wider anterior part, strongly sclerotized, about 1.3 times as long as wide. Seminal receptacles very small, kidney-shaped, reaching anterior margin of epicopulatory bulb, about 0.65 times as long as epicopulatory bulb.

Third urosomite (Figs. 1A, 2A) fused with second urosomite, smooth, with wide and finely serrated hyaline fringe and three pairs of posterior sensilla: one dorsal (U3-1), one lateral (U3-2), and one ventral (U3-3); establishing serially homologous sensilla of third and second urosomites not easy (possibly, U3-1 = U2-2). Genital double-somite about 0.8 times as long as wide (ventral view), with only small internal ridge dorso-laterally (but no external suture) indicating original segmentation.

Fourth urosomite (Figs. 1A, B, 2A) narrower and shorter than genital double-somite, with single dorsal row of minute spinules, wide and finely serrated hyaline fringe, and three pairs of posterior sensilla (U4-1 to U4-3); all sensilla with homologous pairs on third urosomite (i.e., U4-1 = U3-1, U4-2 = U3-2, and U4-3 = U3-3).

Fifth urosomite (preanal) (Figs. 1A, B, 2A) smooth, slightly narrower and longer than third urosomite, without sensilla or pores; hyaline fringe sharply serrated, ventrally as wide as that in third urosomite but dorsally extended into wide and long pseudoperculum, significantly overlapping sixth urosomite.

Sixth urosomite (anal) (Figs. 1A, B, 2A) slightly narrower and only about 0.6 times as long as fifth urosomite (ventral view), slightly cleft medially in posterior part, with one pair of large dorsal sensilla (U6-1), one pair of large lateral pores (U6-I), and posterior row of spinules at base of each caudal ramus; anal operculum very short, narrow, and convex, completely covered by pseudoperculum, with posterior row of numerous hair-like minute spinules, representing 46 % of somite's width; anal sinus widely opened, without any chitinous projections, with weakly sclerotized walls and two diagonal rows of long, hair-like spinules.

Caudal rami (Figs. 1A, 2A) strongly sclerotized, about 1.4 times as long as greatest width in ventral view, almost cylindrical (somewhat tapering towards caudal end in posterior third and with slightly convex inner margin), with space between them slightly less than one quarter of one ramus width; ornamented with posterior row of large spinules (four large ventral spinules and five dorsal), several small spinules at base of lateral setae, numerous long and slender spinules along posterior half of inner margin, and three pairs of pores: one pair of posterior dorsal pores (CR-I), and two pairs of posterior ventral pores (CR-II and CR-III); armed with six elements (two lateral, one dorsal, and three apical). Dorsal seta slender and apically pinnate, about as long as ramus, inserted at about 2/3 of ramus length in shallow recess, triarticulate at base (i.e., inserted on two pseudojoints). Lateral proximal spine stout, bipinnate, inserted at 2/3 of ramus length, and 0.7 times as long as ramus. Lateral distal seta slender, smooth, inserted slightly ventro-laterally at 3/4 of ramus length, and about as long as ramus. Innermost apical seta smooth, slender, and small, about 0.35 times as long as ramus. Central (principal) apical seta with breaking plane, very strong, distally pinnate, about five times as long as caudal ramus. Outer apical seta more slender than central apical seta, pinnate along outer margin in distal half, about three times as long as caudal ramus.

Antennula (Fig. 2B) 8-segmented, approximately half as long as cephalothorax, with slender aesthetasc on eighth segment fused basally to two apical setae, robust aesthetasc on fourth segment reaching far beyond tip of appendage and fused basally to slightly longer seta; setal formula 1.9.5.3.2.3.4.7. Two lateral setae on seventh segment and four on eighth segment biarticulate (i.e., inserted on short pseudojoint). All setae slender and smooth. One diagonal row of spinules on dorsal surface of first segment as only ornamentation. Length ratio of antennular segments, from proximal end and along caudal margin, 1 : 1.6 : 0.6 : 0.6 : 0.4 : 0.3 : 0.6 : 1.5. Second segment about 1.3 times as long as wide.

Antenna (Fig. 2C) comprising coxa, allobasis (fused basis and first endopodal segment), one-segmented endopod, and much smaller two-segmented exopod. Coxa short, 0.9 times as long as wide, without armature, with two slender spinules on outer margin. Allobasis most robust segment, almost twice as long as wide and also twice as long as coxa, ornamented with four small spinules along inner margin, and two diagonal anterior rows of small spinules in proximal half. Endopod 3.5 times as long as wide and about 1.2 times as long as allobasis, more slender proximally, with two surface frills distally; lateral armature consisting of two strong, unipinnate spines flanking small, slender seta; apical armature consisting of seven elements: one smooth, slender, short seta, one smooth short spine, and four geniculate setae, longest fused basally to another smooth, slender, and much shorter seta; longest geniculate seta also most robust, and bipinnate; other geniculate setae smooth. Ornamentation of second endopodal segment consisting of longitudinal row of large spinules along inner margin and posterior row of small spinules between lateral and apical armature elements. Both exopodal segments of about same width, slender in comparison to other antennal segments; second segment about 3.7 times as long as wide and 1.25 times as long as first segment; first segment armed with 1 unipinnate subapical seta, unornamented; second segment ornamented with transverse apical row of slender spinules, armed apically with one smooth, slender seta and one strong, bipinnate spine of about same length as former, both about 1.3 times as long as segment.

Labrum (Fig. 1D) large, trapezoidal, rigidly sclerotized, with straight cutting edge, ornamented with numerous slender apical and subapical spinules, as well as several rows of spinules of various lengths and orientations along posterior surface.

Mandibula (Fig. 1E) with cutting edge of coxa wide, armed with one tricuspidate tooth in ventral part, three bicuspidate teeth in central part, four simple (unicuspidate) teeth (or large spinules?) in dorsal part, and two smooth dorsalmost setae; coxa unornamented. Basis smaller and shorter than coxa, about 2.6 times as long as wide, armed with three unipinnate slender setae along inner margin; ornamented with single large spinule at base of ventralmost seta. Endopod one-segmented, as long as wide, armed with two lateral and five apical smooth setae. Exopod very small but distinct segment, armed with two slender apical setae (one smooth, one bipinnate).

Maxillula (Fig. 1F, G) with large praecoxa, arthrite highly mobile, armed apically with nine strong spines, one of which smooth, other unipinnate; armed laterally with two smooth, slender setae and ornamented with four spinules at base of arthrite. Coxa small, armed with four inner elements, three of which smooth and slender setae, while one very strong, spiniform, and unipinnate. Inner margin of basis with one strong, curved, unipinnate spine, five smooth, slender setae, one tubular pore, and several small spinules. Endopod one-segmented, small, about twice as long as wide, armed with three apical smooth setae, innermost seta longest. Exopod fused to basis, armed with two slender and unipinnate apical setae.

Maxilla (Fig. 2D) composed of syncoxa, basis and two-segmented endopod. Syncoxa ornamented with two outer rows of spinules on outer margin, large, ovoid, with three endites, each armed with two subequal pinnate setae; distal endite ornamented with posterior row of spinules, other two endites unornamented; proximal seta on distal endite strongest. Basis much smaller than syncoxa, elongate, armed with two apical claw-like spines (both unipinnate along convex margin) and one smooth and slender apical seta; longest basal spine about as long as basis and 1.35 times as long as smaller basal spine; basal seta slightly longer than longer basal spine. Endopod very small, short and wide, first segment about as long as wide and twice as long as second segment, armed with five slender and smooth setae, two on first segment and three on second segment.

Maxilliped (Fig. 2E) prehensile, three-segmented, composed of coxobasis and two-segmented endopod. Coxobasis 1.3 times as long as wide, cylindrical, unornamented, armed with three strong, unipinnate setae on inner (median) margin, longest one nearly as long as coxobasis. First endopodal segment about 2.4 times as long as wide and 1.5 times as long as coxobasis, slightly ovoid, ornamented with one longitudinal row of large spinules on anterior surface and one row of smaller spinules along inner margin; armed with two short, slender setae, one centrally on inner margin and other subapically on posterior surface. Second endopodal segment smallest, only 0.35 times as long as first and three times as long as wide, armed apically with one claw-like unipinnate spine and three smooth, slender setae; spine more than twice as long as second endopodal segment and 1.7 times as long as longest seta.

All swimming legs (Figs. 3A, B, C, D, E, 16B) slender, short in comparison to body length and width, composed of small unarmed triangular praecoxa, large unarmed quadrate coxa, smaller armed basis, three-segmented exopod, and three-segmented endopod. Coxae in all pairs of legs connected by unornamented intercoxal sclerite. All exopodal and endopodal segments of about same length, except for much longer first endopodal segment of first leg.

First swimming leg (Fig. 3A) with small, short, and wide intercoxal sclerite, concave at distal end and without spiniform protrusions. Praecoxa ornamented with posterior row of minute spinules on anterior surface. Coxa more than twice as wide as long, ornamented with four rows of spinules on anterior surface; spinules in outer proximal row small and widely spaced, other three rows with 10 to 11 long and slender spinules. Basis with one inner and one outer strong, pinnate spine, inner one stronger and about 1.2 times as long as outer; ornamentation consisting of several minute spinules at base of outer spine, row of long spinules at base of inner spine, one row of large spinules along distal margin between endopod and exopod, and one cuticular pore at base of outer spine, all on anterior surface. Exopod armed with single outer-distal spine on first and second segments, and with two outer spines and two apical geniculate setae on third segment; all exopodal segments ornamented with strong spinules along outer margin and subdistally, and along inner margin of second segment; first exopodal segment with additional arched row of strong spinules on anterior surface proximally; inner geniculate seta on third segment about as long as entire exopod and about 1.45 times as long as outer geniculate seta. Endopod geniculate, with first segment nearly 0.8 times as long as entire exopod, 2.8 times as long as second endopodal segment, about 3.6 times as long as wide; third endopodal segment about 1.3 times as long as second endopodal segment; endopodal armature consisting of one strong and long inner seta on first segment (inserted at about 4/5), and three setae on third segment (innermost slender and smooth, middle longest and geniculate, outermost spiniform seta (or spine?) half as long as middle one); endopodal ornamentation consisting of strong spinules along outer margin on all segments, and along inner margins of first two segments.

Second swimming leg (Fig. 3B) with smaller praecoxa than in first leg, also ornamented with posterior row of spinules on anterior surface. Coxa ornamented with three short horizontal rows of large spinules on anterior surface. Intercoxal sclerite with paired, pointed, distal protrusions. Basis armed only with outer bipinnate spine, ornamented with single large spinule at base of outer spine, with minute spinules along distal margin at base of endopod, and single cuticular pore at base of outer spine. Distal inner corners of first and second exopodal and endopodal segments with serrated hyaline frills. All exopodal and endopodal segments ornamented with strong spinules on outer margins; first and second endopodal and second and third exopodal segments also with weaker spinules along inner margins. Exopod armed with outer-distal spine on first and second segments, inner seta on second segment, two outer spines and two apical setae on third segment; all spines and setae strong and bipinnate; outer apical seta on third segment appearing transitional in form between spine and seta, with outer margin furnished with short spinules and inner margin with long, slender spinules. Endopod about as long as exopod, armed with single inner seta on second segment, and four elements on third segment: outer-distal short spine, two apical long setae, and one inner strong seta (inserted at 2/3).

Third swimming leg (Fig. 3C) very similar to second, except for basis armed with outer slender seta instead of spine and first endopodal segment with one inner seta.

Fourth swimming leg (Fig. 3D, E) similar to third leg, except for intercoxal sclerite with less sharp distal protrusions, endopod slightly smaller, and third endopodal segment without inner seta.

Fifth leg (Fig. 3F) biramous, composed of large, broad baseoendopod and small, ovoid exopod, with division line visible on posterior surface only. Baseoendopod with outer basal smooth seta arising from relatively short setophore. Endopodal lobe almost triangular, extending to 3/4 of exopod, armed with four spiniform elements (two inner ones probably spines, two outer ones probably spiniform setae); length ratio of endopodal armature elements, from inner side, 1 : 1.8 : 2.5 : 2.3. Exopod about 1.1 times as long as maximum width, armed with six elements: two innermost apical ones strong and bipinnate, outer apical one smooth and slender, distal and central outer ones short, unipinnate, and spiniform, and proximal outer one long, strong and also unipinnate; length ratio of exopodal armature elements, from inner side, 1 : 1.7 : 0.9 : 0.45 : 0.3 : 1.

Sixth leg (Fig. 3G) very small cuticular plate covering gonopore, armed with two slender setae and innermost minute spine; inner seta smooth, about twice as long as outer bipinnate seta; minute spine fused to cuticular plate. Male. Unknown.

***Schizopera yeonghaensis* sp. nov.**
(Figs. 4–6, 16A)

Type locality. East Coast of Korea, Gyeongsangbuk-do province, Yeong Hae city, Daejin beach, mouth of Songcheon River, 36°33.959'N 129°25.518'E (same as for *S. daejinensis* **sp. nov.**).

Specimens examined. Holotype female (NIBR IV 0000287247) and allotype male (NIBR IV 0000287248), each dissected on one slide, and both collected from the type locality, 21 September 2011, leg. T. Karanovic.

Etymology. The species is named after the type locality, Yeong Hae city, with the addition of the Latin suffix for place "-*ensis*". The specific name consequently is an adjective for place.

Description. Female (holotype). Total body length, measured from tip of rostrum to posterior margin of caudal rami about 405 µm. Colour of preserved specimen, nauplius eye, body segmentation, integument thickness, surface and general shape of somites, and rostrum as in *S. daejinensis*. Habitus (Figs. 4A, 16A) almost cylindrical, slender, without distinct demarcation between prosome and urosome; prosome/urosome ratio about 0.95 (in dorsal view); greatest width at posterior end of cephalothorax but difficult to establish; cephalothorax only about 1.2 times as wide as genital double-somite. Body length/width ratio about 4.2. All somites devoid of any spinules, except for anal somite and caudal rami. Hyaline fringe of all somites broad; those of all prosomites smooth, those of urosomites finely serrated. Surface of somites, rostrum, and caudal rami with total of 73 pairs of cuticular organs (15 pairs of cuticular pores and 59 pairs of sensilla) and one unpaired dorsal sensillum.

Cephalothorax (Fig. 4A) smooth, about 1.2 times as long as wide in dorsal view; representing 23 % of total body length, tapering towards anterior end only in anterior half (in dorsal view). Hyaline fringe of cephalothoracic shield smooth, slightly wider than in *S. daejinensis*. Cephalothoracic shield with five pairs of pores (C-I, C-V, C-VI, C-VIII, and C-IX), 31 pairs of sensilla (C-2 to C-11 and C-13 to C-31), and one unpaired dorsal sensillum (C-12); as in *S. daejinensis* sensilla C-19 and C-20 very close to each other, as well as sensilla C-22 and C-23; all sensilla homologous to those in *S. daejinensis* except for C-31 (in anterior part, between C-5 and C-7); four pores present in *S. daejinensis* missing (C-II, C-III, C-IV, and C-VII), while two novel ones present (C-VIII and C-IX; both in anterior part); relative position of some sensilla and pores slightly different than in *S. daejinensis* (for example pores C-V closer to sensilla C-8, and sensilla C-29 and C-30 closer to each other).

Pleuron of first free prosomite (Fig. 4A) as in *S. daejinensis*, except for lack of sensilla pair FP1-5 and unpaired dorsal pore (FP1-I).

Pleuron of second free prosomite (Fig. 4A) as in *S. daejinensis*, with five pairs of sensilla (FP2-1 to FP2-5).

Pleuron of third free prosomite (Fig. 4A) as in *S. daejinensis*, except for lack of sensilla pair FP3-3 and for sensilla FP3-1 and FP3-2 closer to each other.

First urosomite (Fig. 4A) as in *S. daejinensis*, except for hyaline fringe serrated.

Second urosomite (Fig. 4A, B) as in *S. daejinensis* completely fused with third urosomite into genital double-somite, with three pairs of dorsal posterior sensilla (U2-1 to U2-3) and two pairs of ventro-lateral pores (U2-II and U2-III), but without lateral pore (U2-I) or spinules. Genital complex (Fig. 4B) similar to that in *S. daejinensis*; epicopulatory bulb large about 1.3 times as long as wide; seminal receptacles reaching beyond anterior margin of epicopulatory bulb, about 0.75 times as long as epicopulatory bulb.

Third urosomite (Fig. 4A, B) fused with second urosomite and very similar to that in *S. daejinensis*, except for ventral pair of sensilla (U3-3) with larger relative distance between them. Genital double-somite about as long as wide (ventral view).

Fourth urosomite (Fig. 4A, B) narrower than genital double-somite and only about 0.7 times as long, with three pairs of posterior sensilla (U4-1 to U4-3), as in *S. daejinensis*, but with additional pair of minute anterior dorso-lateral pores (U4-I) and one pair of very closely spaced anterior ventral pores (U4-II).

Shape of fifth urosomite (Fig. 4A, B) as in *S. daejinensis*, about 1.2 times as long as fourth urosomite (ventral view), and ornamented with two pairs of pores (U5-I and U5-II) serially homologous to those on fourth urosomite.

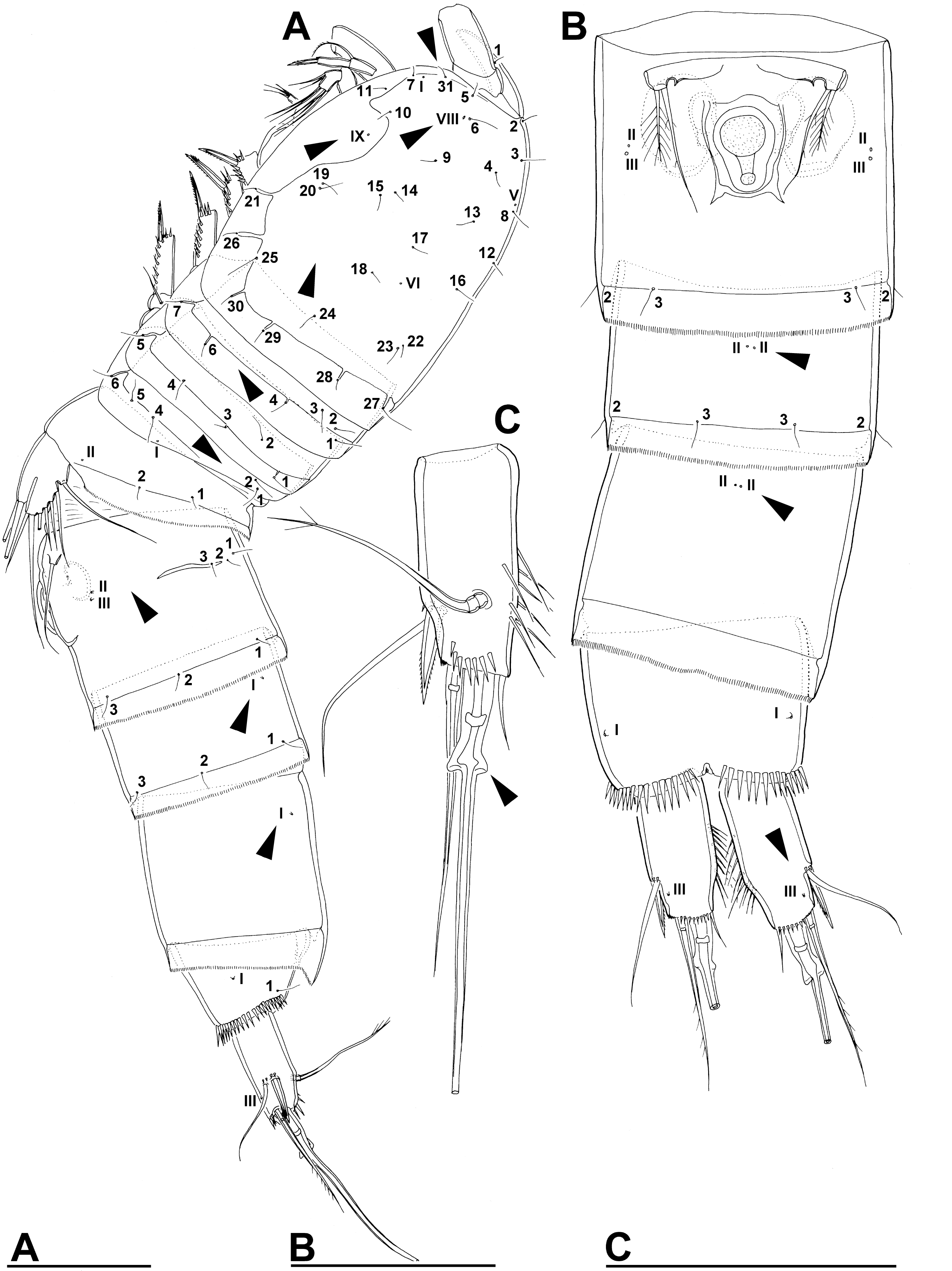

FIGURE 4. *Schizopera yeonghaensis* **sp. nov.**, holotype female, line drawings: A, habitus, lateral; B, urosome, ventral; C, left caudal ramus, dorsal. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.** assigned the same Arabic and Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side. Arrowheads pointing some of the most prominent specific features. Scale bars 50 µm.

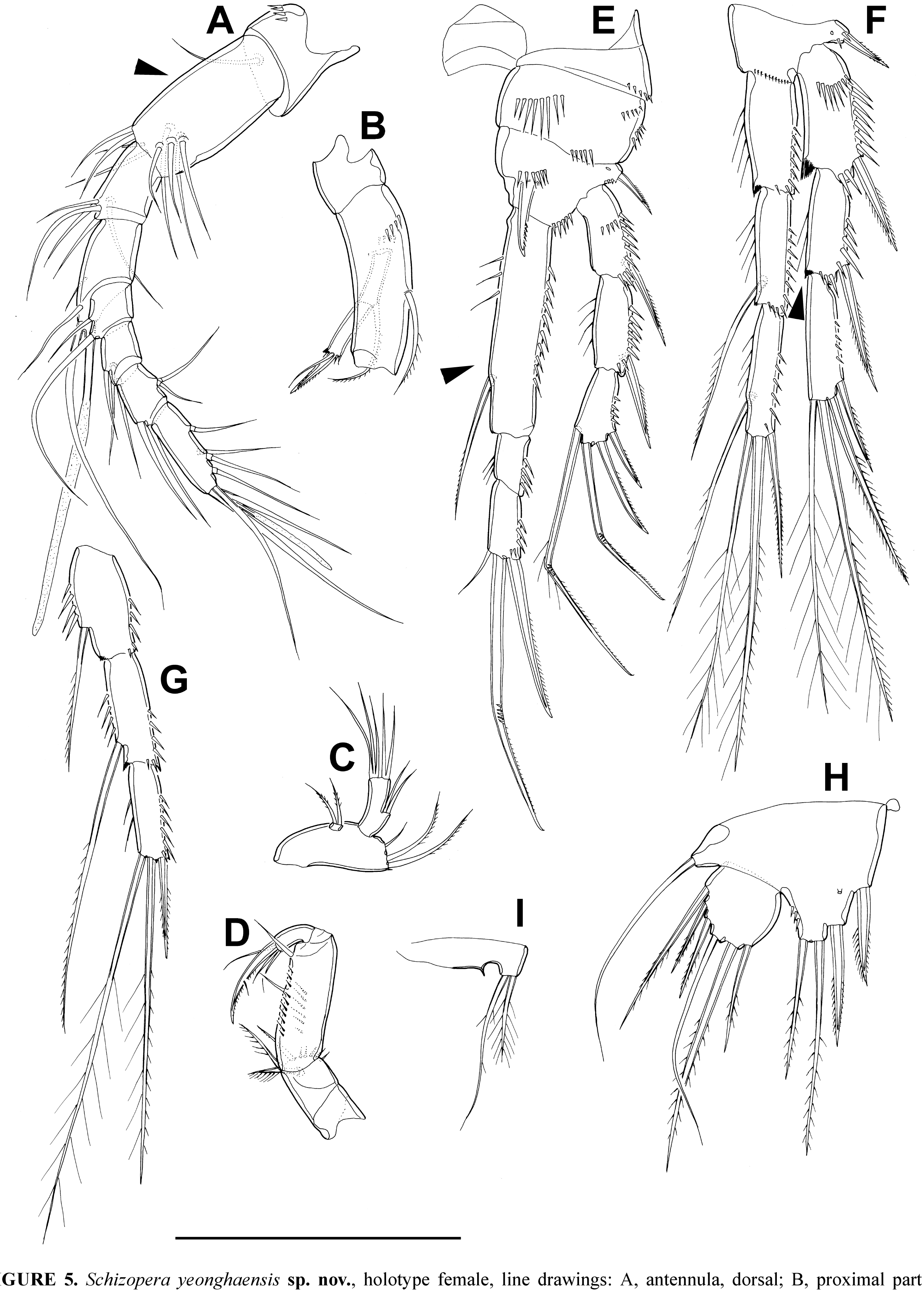

FIGURE 5. *Schizopera yeonghaensis* **sp. nov.**, holotype female, line drawings: A, antennula, dorsal; B, proximal part of antenna, posterior; C, mandibular palp, anterior; D, maxilliped, posterior; E, first swimming leg, anterior; F, basis, endopod, and exopod of second swimming leg, anterior; G, endopod of fourth swimming leg, anterior; H, fifth leg, anterior; I, sixth leg, anterior. Arrowheads pointing some of the most prominent specific features. Scale bar 50 µm.

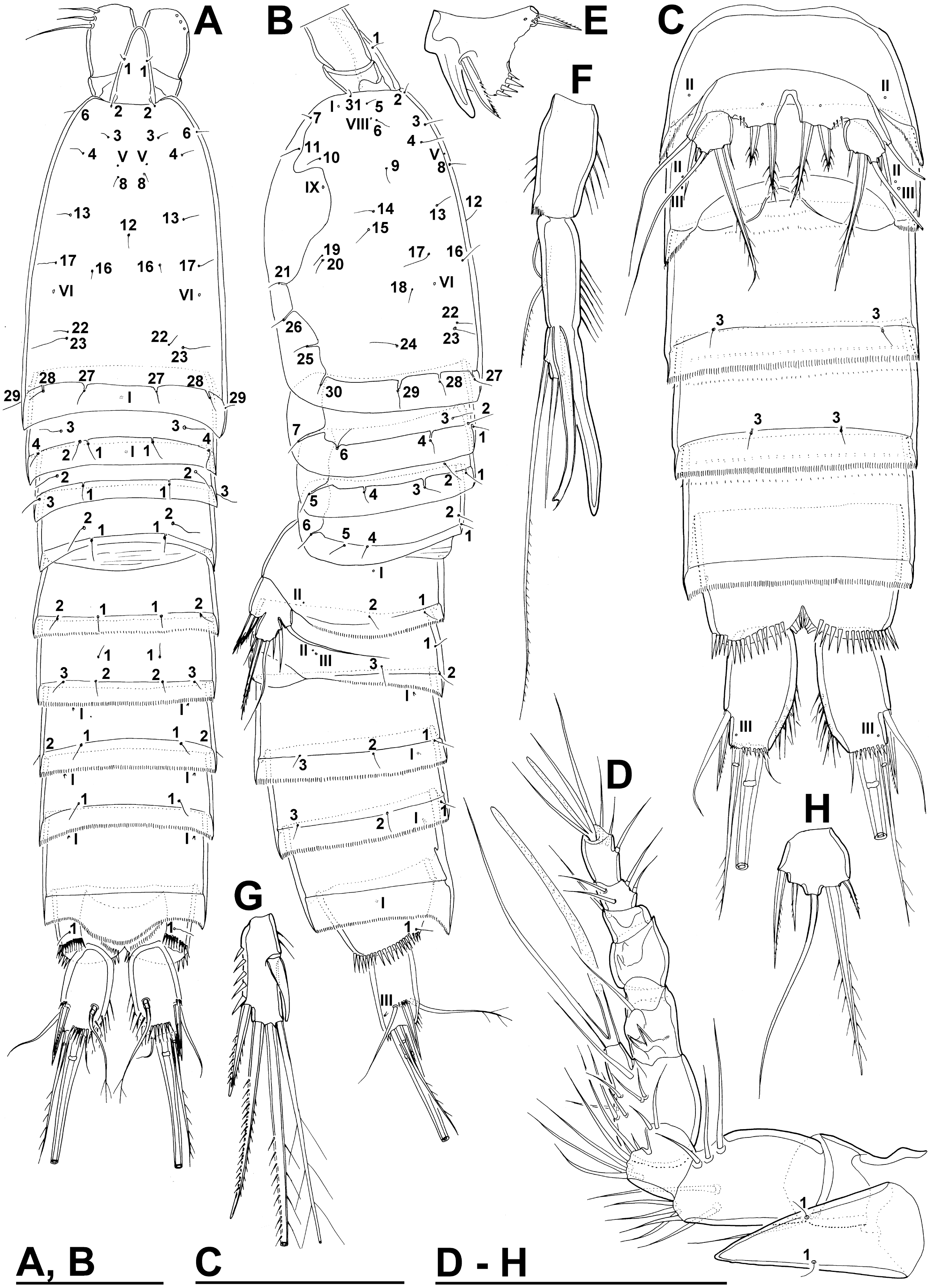

FIGURE 6. *Schizopera yeonghaensis* **sp. nov.**, allotype male, line drawings: A, habitus, dorsal; B, habitus, lateral; C, urosome, ventral; D, rostrum and antennula, dorsal; E, basis of first swimming leg, anterior; F, endopod of second swimming leg, anterior; G, third exopodal segment of third swimming leg, anterior; H, exopod of fifth leg, anterior. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* sp. nov. assigned the same Arabic and Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side. Scale bars 50 µm.

Sixth urosomite (Fig. 4A, B) as in *S. daejinensis*, except for lateral pores (U6-I) situated much more anteriorly, minute anterior ventral spinules missing, and posterior spinules slightly more robust.

Caudal rami (Fig. 4A, B, C) strongly sclerotized, about twice as long as wide in ventral view, almost cylindrical (somewhat tapering towards caudal end in posterior third and with convex inner margin), with space between them slightly less than one third of one ramus width; general ornamentation as in *S. daejinensis*, except for lack of pores CR-I and CR-II, ventral posterior spinules smaller; armed as in *S. daejinensis* with six elements, but their proportions somewhat different. Dorsal seta about as long as ramus; lateral proximal spine only 0.4 times as long as ramus; lateral distal seta inserted at about same level as lateral spine and slightly shorter than ramus; innermost apical seta only about 0.27 times as long as ramus; central apical seta with wing-like outgrowth near breaking plane, about three times as long as caudal ramus; outer apical seta only about 1.4 times as long as caudal ramus.

Antennula (Fig. 5A) segmentation, ornamentation and armature formula as in *S. daejinensis*, but appendage much more slender and aesthetasc on fourth segment also more slender; second segment nearly twice as long as wide; length ratio of antennular segments, from proximal end and along caudal margin, 1 : 2.3 : 0.7 : 0.9 : 0.5 : 0.6 : 0.7 : 1.4.

Antenna (Fig. 5B) segmentation, armature and most ornamentation as in *S. daejinensis*; coxa unornamented, 0.8 times as long as wide; allobasis almost three times as long as wide and 3.5 times as long as coxa, ornamented with single row of spinules on anterior surface; second exopodal segment about 3.7 times as long as wide and 1.1 times as long as first segment.

Labrum as in *S. daejinensis* (not illustrated).

Mandibula (Fig. 5C) as in *S. daejinensis*, except for distalmost seta on basis very small, exopod minute, and endopod much more elongated (about 2.5 times as long as wide).

Maxillula and maxilla as in *S. daejinensis* (not illustrated).

Maxilliped (Fig. 5D) segmentation, armature, and most ornamentation as in *S. daejinensis*; coxobasis 1.8 times as long as wide, ornamented with posterior row of spinules on anterior surface; first endopodal segment about 2.7 times as long as wide and 1.6 times as long as coxobasis, cylindrical, slightly ovoid, ornamented as in *S. daejinensis*; second endopodal segment 0.3 times as long as first and twice as long as wide; apical spine 2.3 times as long as second endopodal segment and 1.5 times as long as longest seta.

All swimming legs (Fig. 5E, F, G) proportions, segmentation, most armature, and most ornamentation as in *S. daejinensis*.

First swimming leg (Fig. 5E) as in *S. daejinensis*, except for coxa only about 1.8 times as wide as long and with row of smaller outer spinules; first endopodal segment nearly 0.9 times as long as entire exopod, 3.8 times as long as second endopodal segment, about 4.6 times as long as wide.

Second swimming leg (Fig. 5F) and third swimming leg as in *S. daejinensis*, except for slightly more slender and with less robust outer spinules, and without inner seta on second exopodal segment.

Fourth swimming leg (Fig. 5G) as in *S. daejinensis*, except for outer apical seta on third endopodal segment shorter than inner apical seta on that segment, and (as in second and third swimming legs) without inner seta on second exopodal segment.

Fifth leg (Fig. 5H) shape, segmentation, armature, and most ornamentation as in *S. daejinensis*; ovoid exopod with division line visible on both posterior and anterior surfaces; length ratio of endopodal armature elements, from inner side, 1 : 1.2 : 2.2 : 1.4; exopod about as long as wide, length ratio of exopodal armature elements, from inner side, 1 : 2.2 : 2 : 0.8 : 0.7 : 1.3.

Sixth leg (Fig. 5I) as in *S. daejinensis*, except for inner seta about 1.8 times as long as outer seta.

Male (allotype). Body length 345 µm. Segmentation as in female, except for genital somite and third urosomite not fused. Habitus (Fig. 6A, B) slightly more slender than in female, but also cylindrical, and with similar proportions; body length/width ratio about 4.9 in dorsal view. Ornamentation of rostrum (Fig. 6A, B), prosomites (Fig. 6A, B), and first urosomite (Fig. 6A, B, C), as well as colour and nauplius eye, as in female.

Genital somite (Fig. 6A, B, C) more than twice as wide as long; ornamentation consists of three pairs of large dorsal sensilla (U2-1 to U2-3) and two pairs of ventro-lateral pores (U2-II and U2-III) as in female, but sensilla much further apart.

Third urosomite (Fig. 6A, B, C) ornamented as in female, but not fused to second (genital) urosomite.

Fourth and fifth urosomites (Figs. 6A, B, C) as in female, except for lack of ventral pair of pores (U4-II and U5-II).

Anal somite (Figs. 6A, B, C) as in female.

Caudal rami (Figs. 6A, B, C) slightly shorter in comparison with anal somite and less slender than in female but without any difference in armature or ornamentation, except for principal apical setae without any wing-like structure near breaking plane.

Antennula (Fig. 6D) half as long as cephalothorax, strongly prehensile and 9-segmented (basically, female's sixth segment subdivided in male), with geniculations between fourth and fifth and seventh and eighth segments; segments participating in geniculations strengthened with cuticular plates along anterior surface, with largest such plates on fifth segment; aesthetascs as in female, on fourth and last segments; first two and last two segments similar to female; setal formula: 1.9.8.8.1.0.1.4.6.

Antenna, labrum, mandibula, maxillula, maxilla, maxilliped, exopod and endopod of first swimming leg, exopod of second swimming leg, endopod of third swimming leg, and fourth swimming leg as in female.

First swimming leg (Fig. 6E) with modified basis, inner margin very rigidly sclerotized, with spiniform smooth distal process and smaller process at its base. Inner spine on basis smaller than in female, without spinules at its base, inserted more proximally, and about as long as larger spiniform process.

Second swimming leg (Fig. 6F) with transformed second and third endopodal segments. Second segment with part of inner margin protruded as rounded indistinct lobe, without ornamentation; inner seta shorter and more slender than in female. Third segment completely modified; inner seta unipinnate and longer than in female, inner apical seta missing, outer apical seta smooth and strong, much shorter that in female, outer apical spine transformed into smooth, lanceolate implement; outer distal corner produced into long, blunt spiniform process, about as long as lanceolate outer spine. As result of these transformations, third segment medially cleft.

Third swimming leg (Fig. 6G) with very characteristic element on anterior surface of third exopodal segment, probably representing hugely enlarged tubular pore: swollen in basal part, with pore on tip, inserted at 2/5 and close to inner margin, reaching distal margin of third segment.

Fifth legs (Fig. 6C, H) with medially fused baseoendopods. Endopodal lobe much smaller and shorter than in female, trapezoidal, reaching first third of exopod, armed with two very strong and bipinnate apical spines; inner spine about 1.9 times as long as outer one. Exopod (Fig. 6H) slightly wider than long, armed with only five elements (one short lateral element missing); length ratio of exopodal armature elements, from inner side, 1: 4.8 : 5.4 : 1.2 : 2.5.

Sixth legs (Fig. 6C) expressed as pair of small, short cuticular plates, without armature or ornamentation; left one larger, better demarcated at base, and probably functioning as genital flap.

Variability. Only one female and one male of this species were collected and examined. Besides normal sexual dimorphism for this group of copepods (in urosomal segmentation, antennula, basis of first leg, endopod of second leg, exopod of third leg, fifth leg, and sixth leg) the male does not have ventral cuticular pores on urosomites (U4-II and U5-II). It is impossible at this stage to determine if this is also part of sexual dimorphism, or if the lack of ventral cuticular pores on these urosomites is part of sex-independent intraspecific variability. All other cuticular organs were identical in both sexes.

***Schizopera gangneungensis* sp. nov.**
(Figs. 7–9, 12A, 16C)

Type locality. East Coast of Korea, Gangwon-do province, Gangneung city, beach, mouth of Kyeongpo River, 37°47.824'N 128°55.085'E.

Specimens examined. Holotype female (NIBR IV 0000287249) dissected on one slide, two paratype females together on one SEM stub (NIBR IV 0000287250), all collected from the type locality, 29 March 2013, leg. T. Karanovic.

Etymology. The species is named after the type locality, Gangneung city, with the addition of the Latin suffix for place "-*ensis*". The specific name consequently is an adjective for place.

Description. Female (based on holotype and two paratypes). Total body length, measured from tip of rostrum to posterior margin of caudal rami ranging from 280 to 295 μm. Colour of preserved specimen, nauplius eye, body segmentation, integument thickness, surface and general shape of somites, and rostrum (Fig. 9B) as in *S. daejinensis*. Habitus (Figs. 7A, 8A, 16C) cylindrical, slender, without distinct demarcation between prosome and urosome; prosome/urosome ratio about 0.95 (in dorsal view); greatest width at posterior end of cephalothorax but difficult to establish; cephalothorax only about 1.1 times as wide as genital double-somite. Body length/width ratio about 4.7. All somites, except for cephalothorax, ornamented with at least one transverse row of minute spinules, in additon to sensilla and pores. Hyaline fringe of all somites broad; those of all prosomites smooth, those of urosomites finely serrated (see also Fig. 8C). Surface of somites, rostrum, and caudal rami with total of 65 pairs of cuticular organs (14 pairs of cuticular pores and 51 pairs of sensilla) and one unpaired dorsal sensillum; all sensilla and pores, except for one pair of pores on third urosromite and one on caudal rami, homologous to those in *S. daejinensis* andr *S. yeonghaensis*.

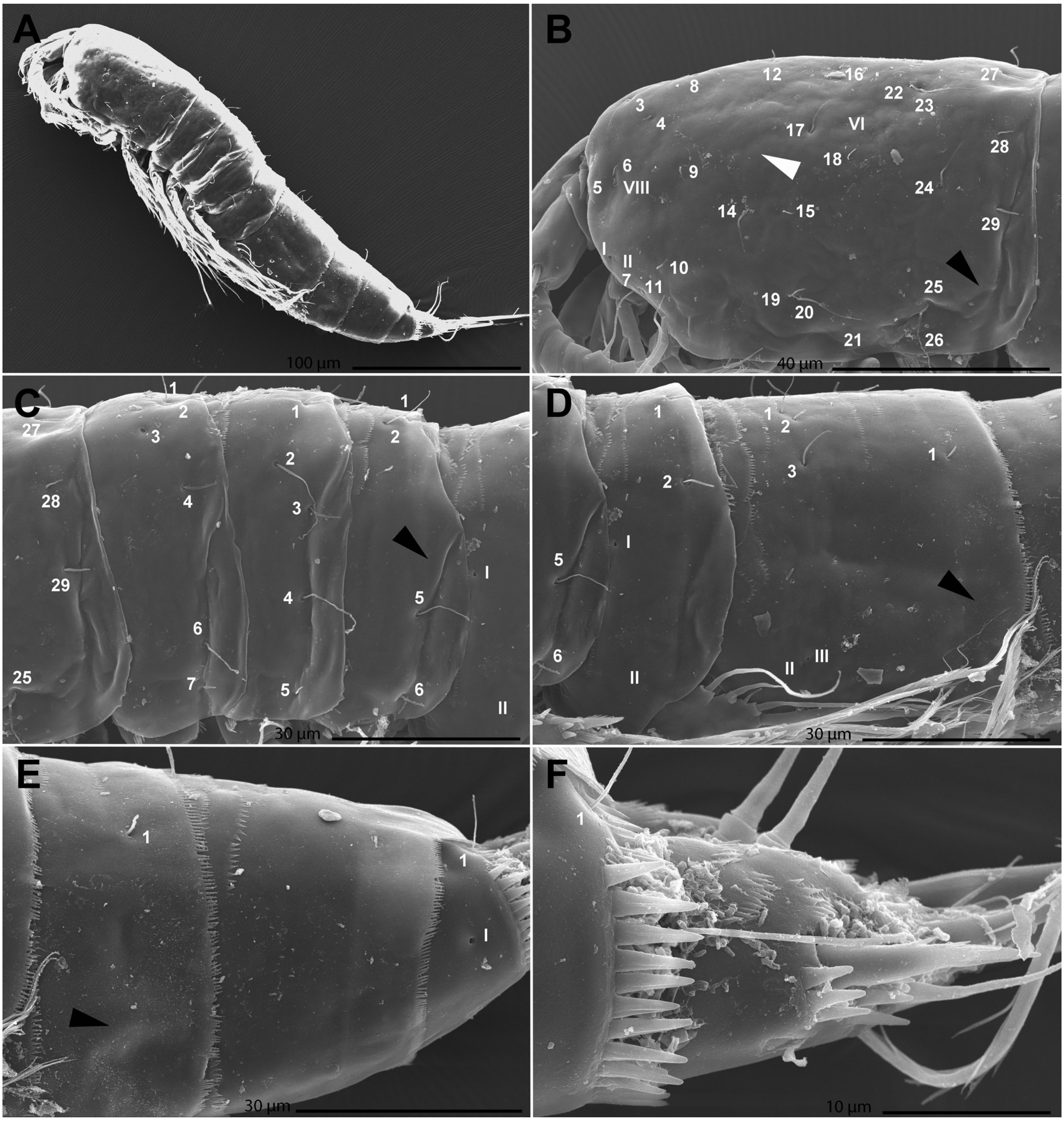

FIGURE 7. *Schizopera gangneungensis* **sp. nov.**, paratype female 1, SEM photographs: A, habitus, lateral; B, cephalothorax, lateral; C, free prosomites, lateral; D, anterior part of urosome, lateral; E, posterior part of urosome, lateral; F, caudal rami, lateral. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.** and *S. yeonghaensis* **sp. nov.** assigned the same Arabic and Roman numerals. Black arrowheads pointing some of the most prominent specific features; white arrowhead poiting intraspecific variability.

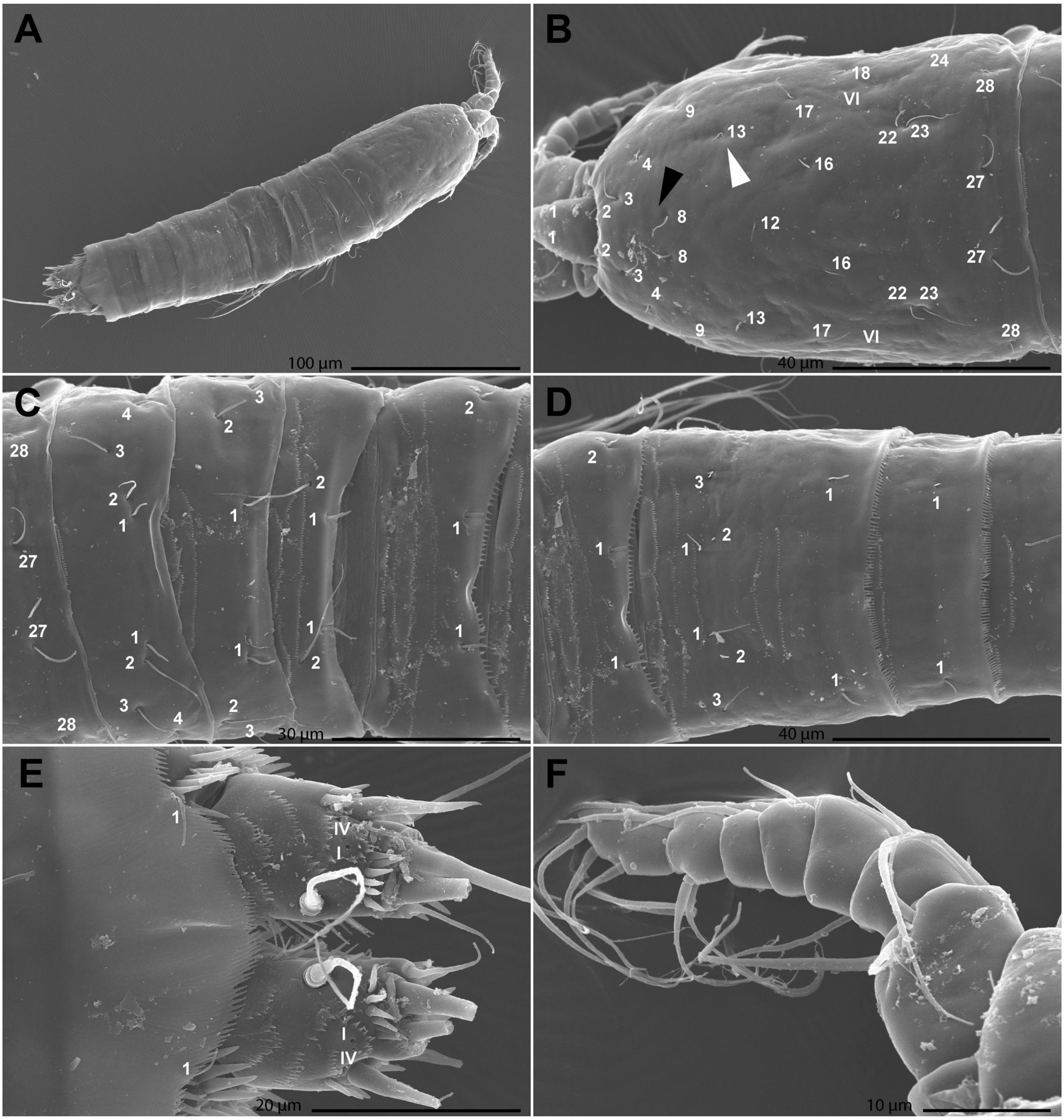

FIGURE 8. *Schizopera gangneungensis* **sp. nov.**, paratype female 2, SEM photographs: A, habitus, dorsal; B, cephalothorax, dorsal; C, free prosomites, dorsal; D, anterior part of urosome, dorsal; E, posterior part of urosome and caudal rami, dorsal; F, antennula, dorsal. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.** and *S. yeonghaensis* **sp. nov.** assigned the same Arabic and Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side. Black arrowhead pointing one of the prominent specific features; white arrowhead poiting intraspecific variability.

Cephalothorax (Figs. 7B, 8B) smooth, about 1.3 times as long as wide in dorsal view (without rostrum); representing 28 % of total body length, tapering towards anterior end only in anterior quarter (in dorsal view). Hyaline fringe of cephalothoracic shield smooth, slightly wider than in *S. daejinensis*. Cephalothoracic shield with four pairs of pores (C-I, C-II, C-VI, and C-VIII), 28 pairs of sensilla (C-2 to C-11 and C-13 to C-29), and one unpaired dorsal sensillum (C-12); sensilla C-19 and C-20, as well as sensilla C-22 and C-23, very close to each other as in *S. daejinensis* and *S. yeonghaensis*; four pores present in *S. daejinensis* missing (C-III, C-IV, C-V, and C-VII); one pore present in *S. yeonghaensis* also missing (C-IX); posterior lateral pair of sensilla present in *S.*

daejinensis and *S. yeonghaensis* missing (C-30); one anterior pair of sensilla present in *S. yeonghaensis* missing (C-31); relative position of sensilla and pores more similar to that of *S. yeonghaensis* than *S. daejinensis*.

Pleuron of first free prosomite (Figs. 7C, 8C) as in *S. yeonghaensis*, without sensilla pair FP1-5 and unpaired dorsal pore (FP1-I), but with additional anterior dorsal row of minute spinules.

Pleuron of second free prosomite (Figs. 7C, 8C) as in *S. daejinensis* and *S. yeonghaensis*, with five pairs of sensilla (FP2-1 to FP2-5), but with additional anterior dorsal row of minute spinules.

Pleuron of third free prosomite (Figs. 7C, 8C) as in *S. yeonghaensis*, except for lack of sensilla pair FP3-4 and with additional three anterior dorsal rows of minute spinules.

First urosomite (Figs. 7D, 8C) as in *S. yeonghaensis*, except lateral pore U1-I inserted more ventrally than lateral sensilla U1-2 and ornamented additionally with three anterior dorsal rows of minute spinules.

Second urosomite (Figs. 7D, 8D, 9A) as in *S. yeonghaensis* completely fused with third urosomite into genital double-somite, with three pairs of dorsal posterior sensilla (U2-1 to U2-3) and two pairs of ventro-lateral pores (U2-II and U2-III), but with additional ventral pair of pores (U2-IV) and three anterior dorsal row of minute spinules. Genital complex (Fig. 9A) similar to that of *S. daejinensis* and *S. yeonghaensis*; epicopulatory bulb about 1.5 times as long as wide and much larger in proportion to somite; seminal receptacles reaching anterior margin of epicopulatory bulb, about 0.6 times as long as epicopulatory bulb.

Third urosomite (Figs. 7D, 8D, 9A) fused with second urosomite, similar to that of *S. daejinensis*, but ornamented with single pair of sensilla (U3-1); without ventral pair of sensilla (U3-3) and lateral pair of sensilla (U3-2), dorsal surface with two anterior rows of minute spinules; genital double-somite about 0.8 times as long as wide.

Fourth urosomite (Figs. 7E, 8D, 9A) narrower than genital double-somite and only about 0.7 times as long, with single pair of posterior sensilla (U4-1); as in third urosomite without lateral (U4-2) and ventral (U4-3) sensilla; with additional anterior minute spinules on dorsal and ventral surfaces.

Fifth urosomite (Figs. 7E, 8D, E, 9A) as in *S. daejinensis*, slightly longer than fourth urosomite (ventral view), ornamented with anterior rows of minute spinules both on dorsal and ventral surface.

Sixth urosomite (Figs. 7E, 8E, 9A) as in *S. daejinensis*.

Caudal rami (Figs. 7F, 8E, 9A) strongly sclerotized, only about 1.4 times as long as wide in ventral view, almost cylindrical (somewhat tapering towards caudal end, but with nearly straight inner margin), with space between them slightly less than one half of one ramus width; general ornamentation as in *S. daejinensis*, except for one additional dorsal pair of pores (CR-IV), inner spinules short and distributed more centrally, and dorsal surface covered with several short rows of minute spinules; armed as in *S. daejinensis* with six elements, but their proportions somewhat different. Dorsal seta about 1.5 times as long as ramus; lateral proximal spine 0.7 times as long as ramus; lateral distal seta slightly longer than ramus; innermost apical seta about half as long as ramus; central apical seta about five times as long as caudal ramus; outer apical seta 3.3 times as long as caudal ramus.

Antennula (Figs. 8F, 9B, 12A) segmentation, length ratio of antennular segments, and armature formula as in *S. daejinensis*, except for second segment with eight instead of nine setae; first segment without spinules; second segment about 1.4 times as long as wide; one antennula in holotype abnormal, with reduced segmentation and armature in distal part (Fig. 9C).

Antenna (Fig. 9D) segmentation, armature and most ornamentation as in *S. daejinensis*; coxa about as long as wide; allobasis almost 2.6 times as long as wide and 2.6 times as long as coxa; second exopodal segment about 2.9 times as long as wide and 0.9 times as long as first segment.

Labrum as in *S. daejinensis* (not illustrated).

Mandibula (Fig. 9E) as in *S. daejinensis*, except for distalmost seta on basis very small, exopod minute, with single apical seta, and endopod more elongated (about 2.3 times as long as wide).

Maxillula (Fig. 9F) as in *S. daejinensis*, except for coxa with only two elements, exopod distinct but minute, and endopod only twice as large as exopod; basis with only five elements but also with tubular pore.

Maxilla as in *S. daejinensis* (not illustrated).

Maxilliped (Fig. 9G) segmentation, armature, and most ornamentation as in *S. daejinensis* but much more slender; coxobasis 1.4 times as long as wide, ornamented with row of spinules along inner margin; first endopodal segment about 3.5 times as long as wide and 2.1 times as long as coxobasis, cylindrical, slightly ovoid, ornamented with spinules only in proximal half; second endopodal segment 0.35 times as long as first and 3.5 times as long as wide; apical spine twice as long as second endopodal segment and 1.5 times as long as longest seta, with only two spinules.

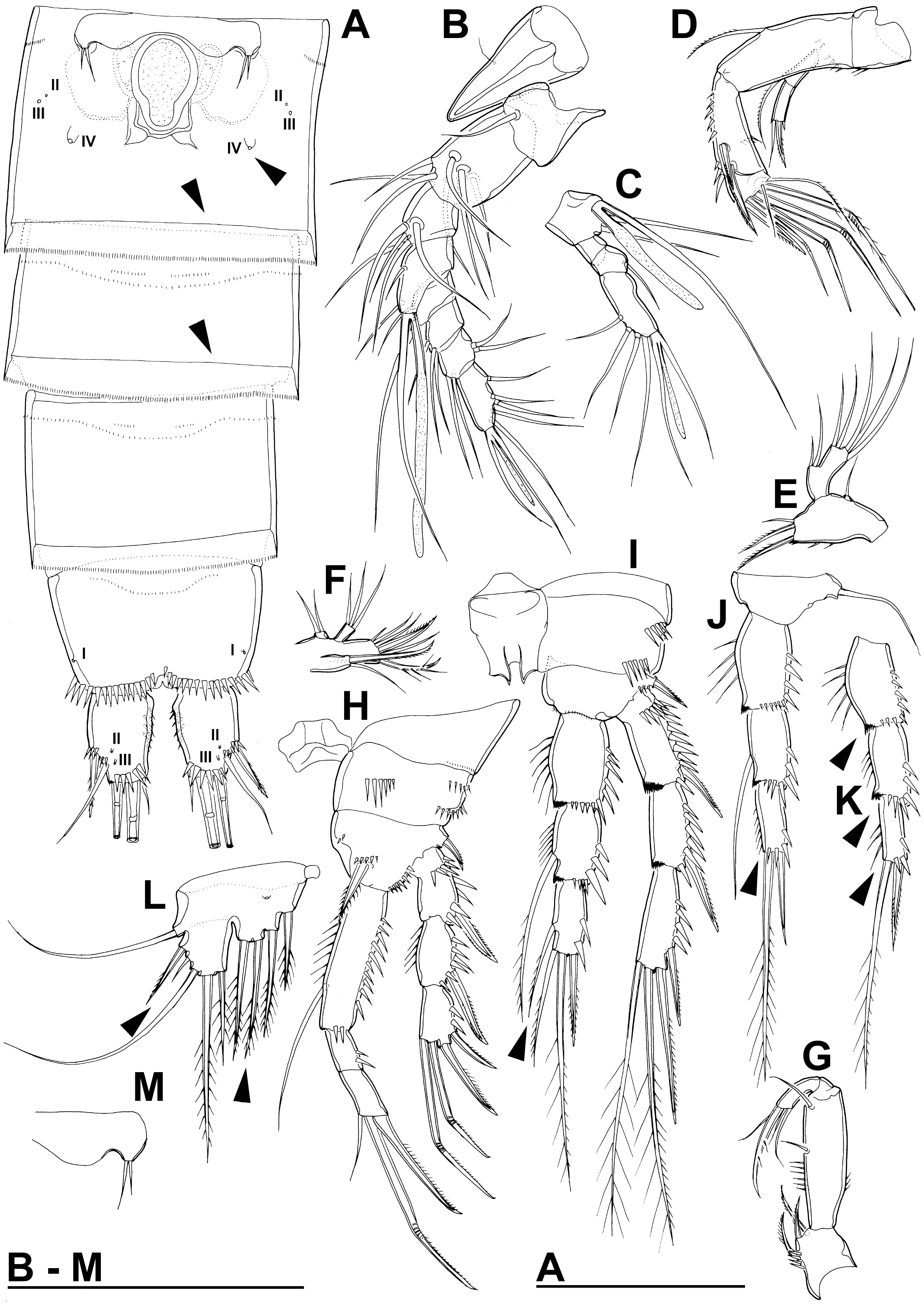

FIGURE 9. *Schizopera gangneungensis* **sp. nov.**, holotype female, line drawings: A, urosome, ventral; B, rostrum and antennula, ventral; C, anterior part of abnormal antennula, ventral; D, antenna, posterior; E, mandibular palp, anterior; F, maxillular palp, anterior; G, maxilliped, posterior; H, first swimming leg, anterior; I, second swimming leg, anterior; J, basis and endopod of third swimming leg, anterior; K, endopod of fourth swimming leg, anterior; L, fifth leg, anterior; M, sixth leg, anterior. Pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.** and *S. yeonghaensis* **sp. nov.** assigned the same Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side. Arrowheads pointing some of the most prominent specific features. Scale bars 50 µm.

All swimming legs (Fig. 9H, I, J, K) proportions, segmentation, most armature, and most ornamentation as in *S. yeonghaensis*, but most segments less slender.

First swimming leg (Fig. 9H) as in *S. yeonghaensis*, except for coxa without distal row of spinules; first endopodal segment 0.8 times as long as entire exopod, 3.8 times as long as second endopodal segment, about 3.6 times as long as wide.

Second swimming leg (Fig. 9I) as in *S. yeonghaensis*, except for shorter innermost apical and inner seta on third endopodal segment.

Third swimming leg (Fig. 9J) as in *S. yeonghaensis*, but with only two elements on third endopodal segment and without armature on first endopodal segment.

Fourth swimming leg (Fig. 9K) as in *S. yeonghaensis*, but with only two elements on third endopodal segment and no armature on first and second endopodal segment. Outer apical seta on third endopodal segment shorter than inner apical seta, and (as in second and third swimming legs) without inner seta on second exopodal segment.

Fifth leg (Fig. 9L) general shape, segmentation, most armature, and most ornamentation as in *S. daejinensis*; exopod much less ovoid and more pentagonal in shape, but also with division line visible only on posterior surface; endopodal lobe only reaching first third of exopod, without spinules, but with cuticular pore on anterior surface; length ratio of endopodal armature elements, from inner side, 1 : 1.5 : 1.7 : 1.7; exopod about as long as wide, armed with only five elements (one small lateral seta missing), length ratio, from inner side, 1 : 2 : 2.3 : 0.3 : 0.7.

Sixth leg (Fig. 9M) as in *S. daejinensis*, but no innermost spine visible, both setae smooth, and inner seta about 1.5 times as long as outer seta.

Male. Unknown.

Variability. One antennula in the holotype female was abnormal (Fig. 9C), with a reduced armature and segmentation in the distal part, but the opposite appendage in the same specimen (Fig. 9B), and in all paratypes (Fig. 8F) was normal. One paratype female was missing the sensilla pair C-13 on the cephalothorax, which was present in other specimens (Fig. 8B). All other cuticular organs were identical in all specimens, including the lack of lateral and ventral posterior sensilla on urosomites.

***Schizopera sindoensis* sp. nov.**
(Figs. 10, 11, 12B–D, 13-15, 16D)

Type locality. South Coast of Korea, Jeju Island, Sindo port, exposed small beach just north from port, 33°16.690'N 126°10.185'E.

Specimens examined. Holotype female (NIBR IV 0000287251), allotype male (NIBR IV 0000287252), and one paratype male (NIBR IV 0000287253), each dissected on one slide; two paratype males (NIBR IV 0000287255) together on one SEM stub; one paratype male and one paratype copepodid together in ethanol (NIBR IV 0000287256); all collected from the type locality, 25 April 2014, leg. T. Karanovic.

Etymology. The species is named after the type locality, Sindo port, with the addition of the Latin suffix for place "-*ensis*". The specific name consequently is an adjective for place.

Description. Female (holotype). Total body length about 515 µm. Colour of preserved specimen, habitus, nauplius eye, body segmentation, integument thickness, and surface and general shape of somites as in *S. daejinensis*. Rostrum (Fig. 13B) about 2.5 times as long as wide, with more pointed tip than in *S. daejinensis*. All somites, except for cephalothorax, besides sensilla and pores ornamented also with at least one row of minute spinules in anterior half. Hyaline fringe of all somites broad; those of all prosomites smooth, those of urosomites finely serrated. Surface of somites, rostrum, and caudal rami with total of 71 pairs of cuticular organs (13 pairs of cuticular pores and 58 pairs of sensilla) and one unpaired dorsal sensillum. All sensilla and pores homologous to those in *S. daejinensis*, *S. yeonghaensis*, and *S. gangneungensis*.

Cephalothorax without pair of sensilla at base of rostrum (C-2), and with only one pair of pores (C-VI), all other sensilla (C-2 to C-30) as in *S. daejinensis*.

Pleurons of free prosomites as in *S. daejinensis*, with seven (FP1-1 to FP1-7), five (FP2-1 to FP2-5) and six (FP3-1 to FP3-6) pairs of sensilla respectively, additionally ornamented with one or two dorsal anterior rows of minute spinules.

First urosomite as in *S. daejinensis*, but with anterior dorsal row of minute spinules.

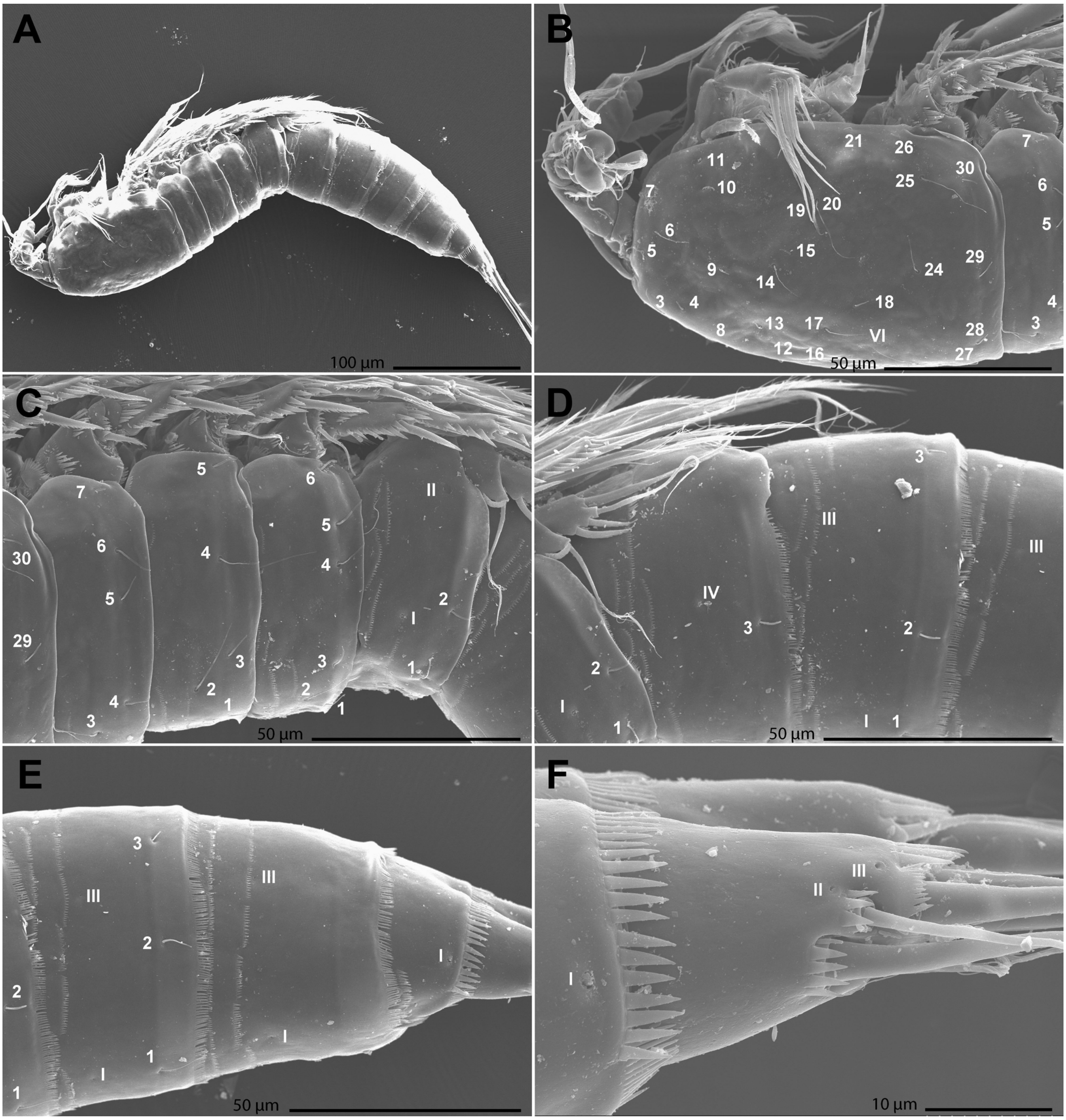

FIGURE 10. *Schizopera sindoensis* **sp. nov.**, paratype male 1, SEM photographs: A, habitus, lateral; B, cephalothorax, lateral; C, free prosomites, lateral; D, anterior part of urosome, lateral; E, posterior part of urosome, lateral; F, caudal rami, lateral. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.**, *S. yeonghaensis* **sp. nov.**, and *S. gangneungensis* **sp. nov.** assigned the same Arabic and Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side.

Second urosomite (Fig. 13A) as in *S. daejinensis* completely fused with third urosomite into genital double-somite, with three pairs of dorsal posterior sensilla (U2-1 to U2-3) but only one pair of ventral pores, probably homologous to those in *S. gangneungensis* (U2-IV). Genital complex similar to that of *S. daejinensis*; epicopulatory bulb large about 1.5 times as long as wide; seminal receptacles reaching anterior margin of epicopulatory bulb, about 0.6 times as long as epicopulatory bulb.

Third, fourth, fifth, and sixth urosomites (Fig. 13A) as in *S. daejinensis*, but with more minute spinules in anterior part.

Caudal rami (Fig. 13A) not very strongly sclerotized, short and wide, only about 1.1 times as long as wide in ventral view, almost conical (tapering towards caudal end continuously from base and along both outer and inner margins), with space between rami very small; general ornamentation as in *S. gangneungensis* (i.e. with two ventral and two dorsal pair of pores), but without dorsal rows of minutes spinules and with inner spinules more slender; armed as in *S. daejinensis* with six elements, but their proportions somewhat different. Dorsal seta about as long as ramus; lateral proximal spine 0.6 times as long as ramus; lateral distal seta slightly longer than ramus; innermost apical seta about 0.35 times as long as ramus; central apical seta about 3.5 times as long as caudal ramus; outer apical seta about twice as long as caudal ramus.

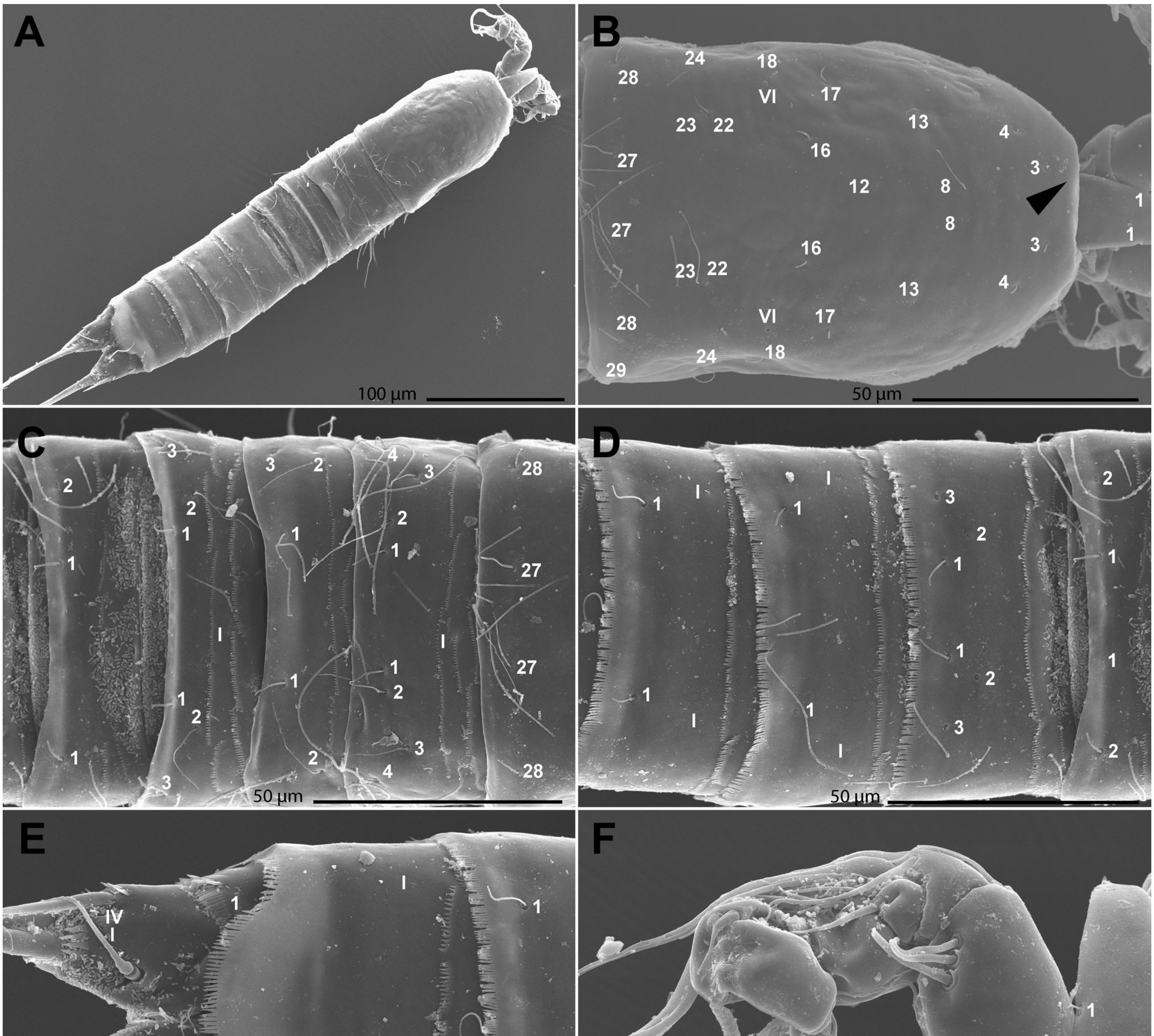

FIGURE 11. *Schizopera sindoensis* **sp. nov.**, paratype male 2, SEM photographs: A, habitus, dorsal; B, cephalothorax, dorsal; C, free prosomites, dorsal; D, anterior part of urosome, dorsal; E, posterior part of urosome and caudal rami, dorsal; F, antennula and part of rostrum, dorsal. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.**, *S. yeonghaensis* **sp. nov.**, and *S. gangneungensis* **sp. nov.** assigned the same Arabic and Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side. Arrowheads pointing some of the most prominent specific features.

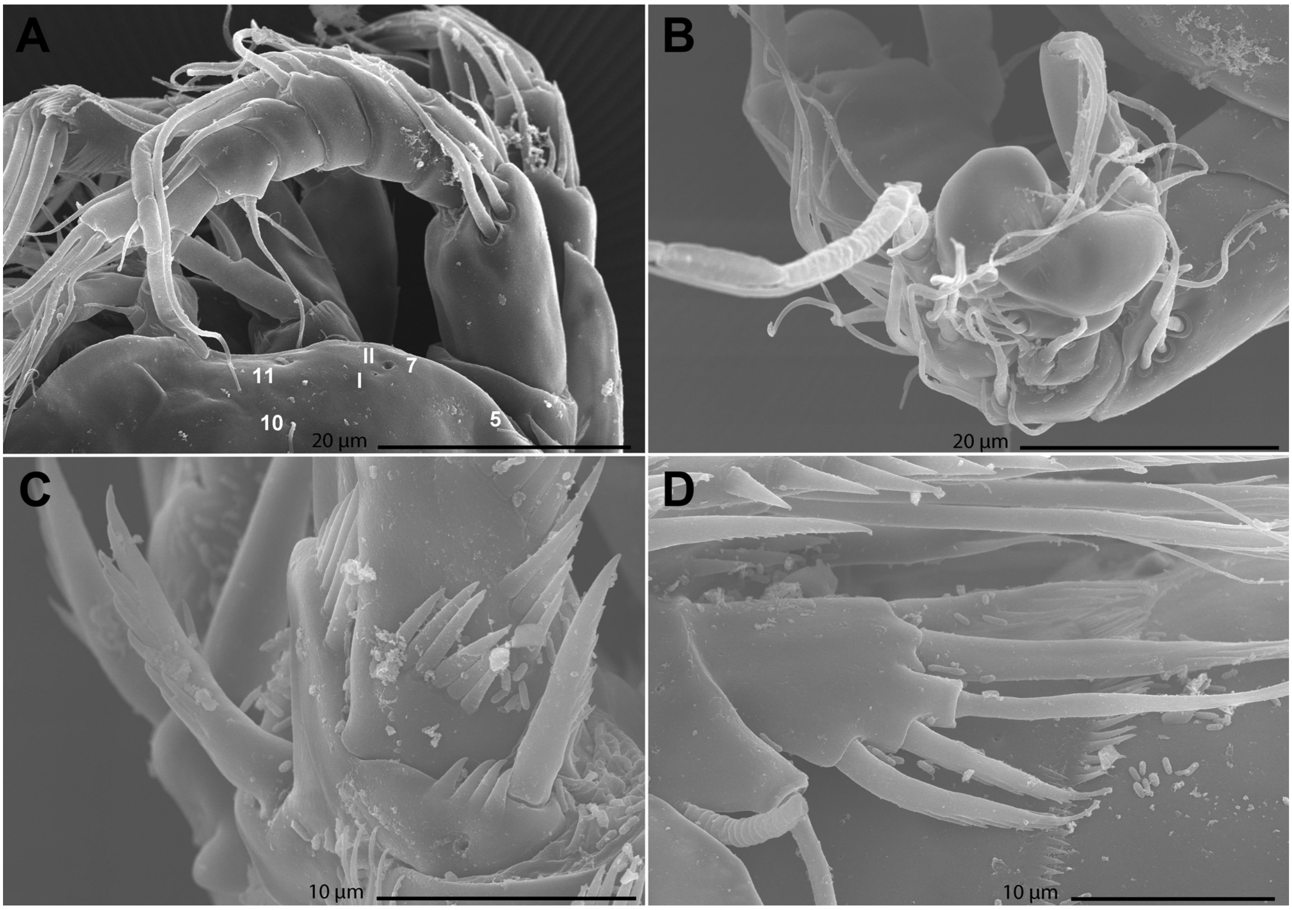

FIGURE 12. *Schizopera gangneungensis* **sp. nov.** (A), paratype female 1; and *Schizopera sindoensis* **sp. nov.** (B – D) paratype male 1; SEM photographs: A, anterior part of cephalothorax, lateral; B, antennula, lateral; C, bases of first swimming legs, lateral; D, exopod of fifth leg, lateral. Sensilla and pores on cephalothorax homologous to those in *S. daejinensis* **sp. nov.** assigned the same Arabic and Roman numerals.

Antennula (Fig. 13B) segmentation, ornamentation and armature formula as in *S. daejinensis*, except for one additional seta present on third segment, and for first segment without spinules. One antennula abnormal, with reduced armature and ornamentation in distal part (Fig. 13C).

Antenna (Fig. 13D) segmentation, armature and most ornamentation as in *S. daejinensis*; coxa about 0.8 times as long as wide; allobasis 1.9 times as long as wide and 2.2 times as long as coxa; second exopodal segment with more distal spinules, about three times as long as wide and 1.1 times as long as first segment.

Labrum, mandibula, maxillula, and maxilla as in *S. daejinensis* (not illustrated).

Maxilliped (Fig. 13E) segmentation, armature, and most ornamentation as in *S. daejinensis*; first endopodal segment about 3.2 times as long as wide and 1.6 times as long as coxobasis, slightly ovoid, ornamented as in *S. daejinensis*; second endopodal segment 0.35 times as long as first and three times as long as wide; apical spine 1.9 times as long as second endopodal segment and 1.5 times as long as longest seta.

All swimming legs (Fig. 14A, B, C) proportions, segmentation, most armature, and most ornamentation as in *S. daejinensis*.

First swimming leg (Fig. 14A) as in *S. daejinensis*, except for much shorter inner seta on first endopodal segment , and for first endopodal segment about as long as entire exopod, 4.7 times as long as second endopodal segment, and about 4.5 times as long as wide.

Second swimming leg (Fig. 14B) as in *S. daejinensis*, except for second exopodal segment without inner seta and second endopodal segment with shorter inner seta.

Third swimming leg (Fig. 14B) similar to second swimming leg, except for basis with slender outer seta and first endopodal segment with short and strong inner seta.

Fourth swimming leg as in *S. daejinensis*, except for with shorter inner setae on first two endopodal segments.

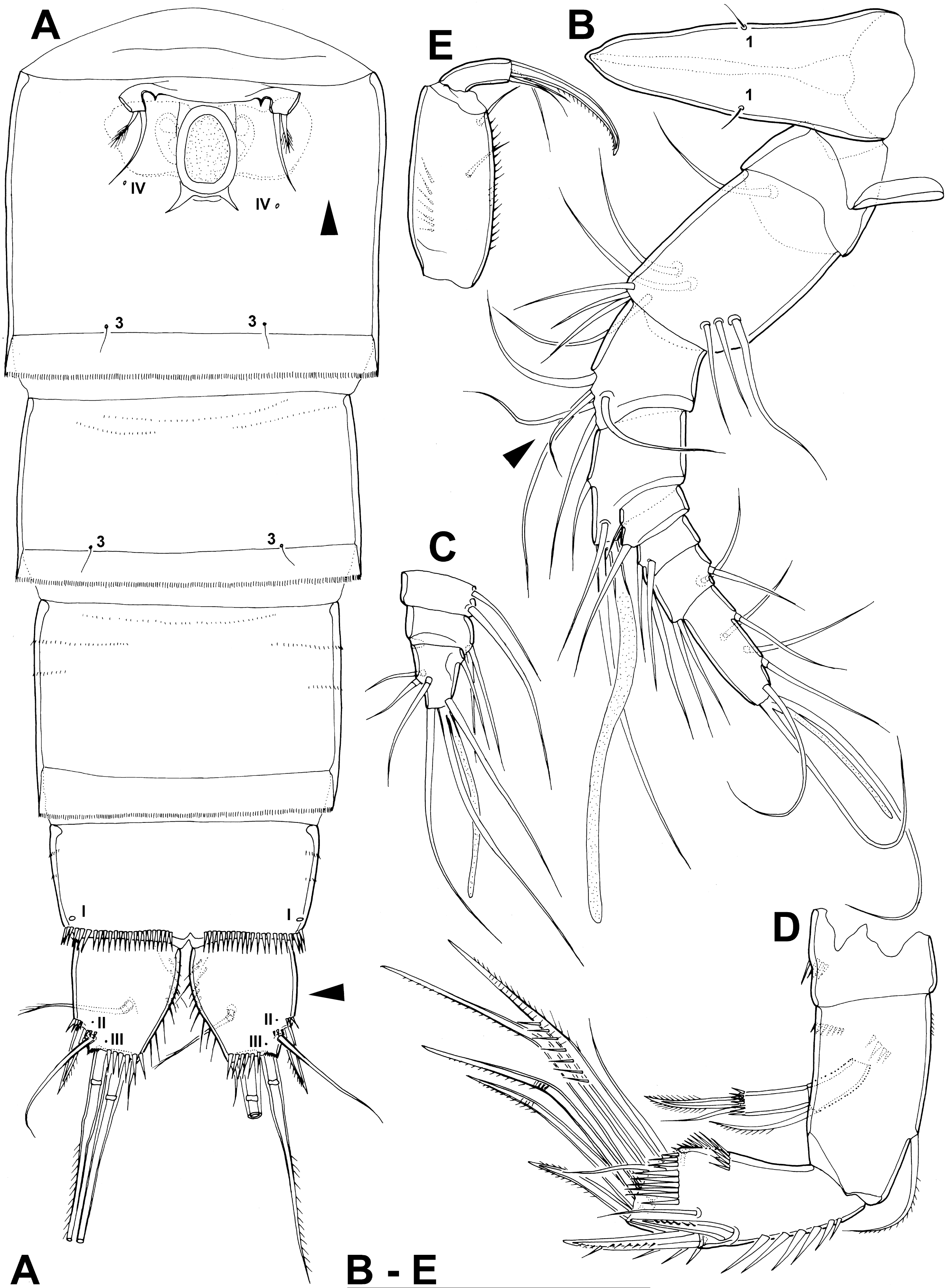

FIGURE 13. *Schizopera sindoensis* **sp. nov.**, holotype female, line drawings: A, urosome, ventral; B, rostrum and antennula, dorsal; C, anterior part of abnormal antennula, dorsal; D, antenna, posterior; E, distal par of maxilliped, anterior. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.**, *S. yeonghaensis* **sp. nov.**, and *S. gangneungensis* **sp. nov.** assigned the same Arabic and Roman numerals. Arrowheads pointing some of the most prominent specific features. Scale bars 50 µm.

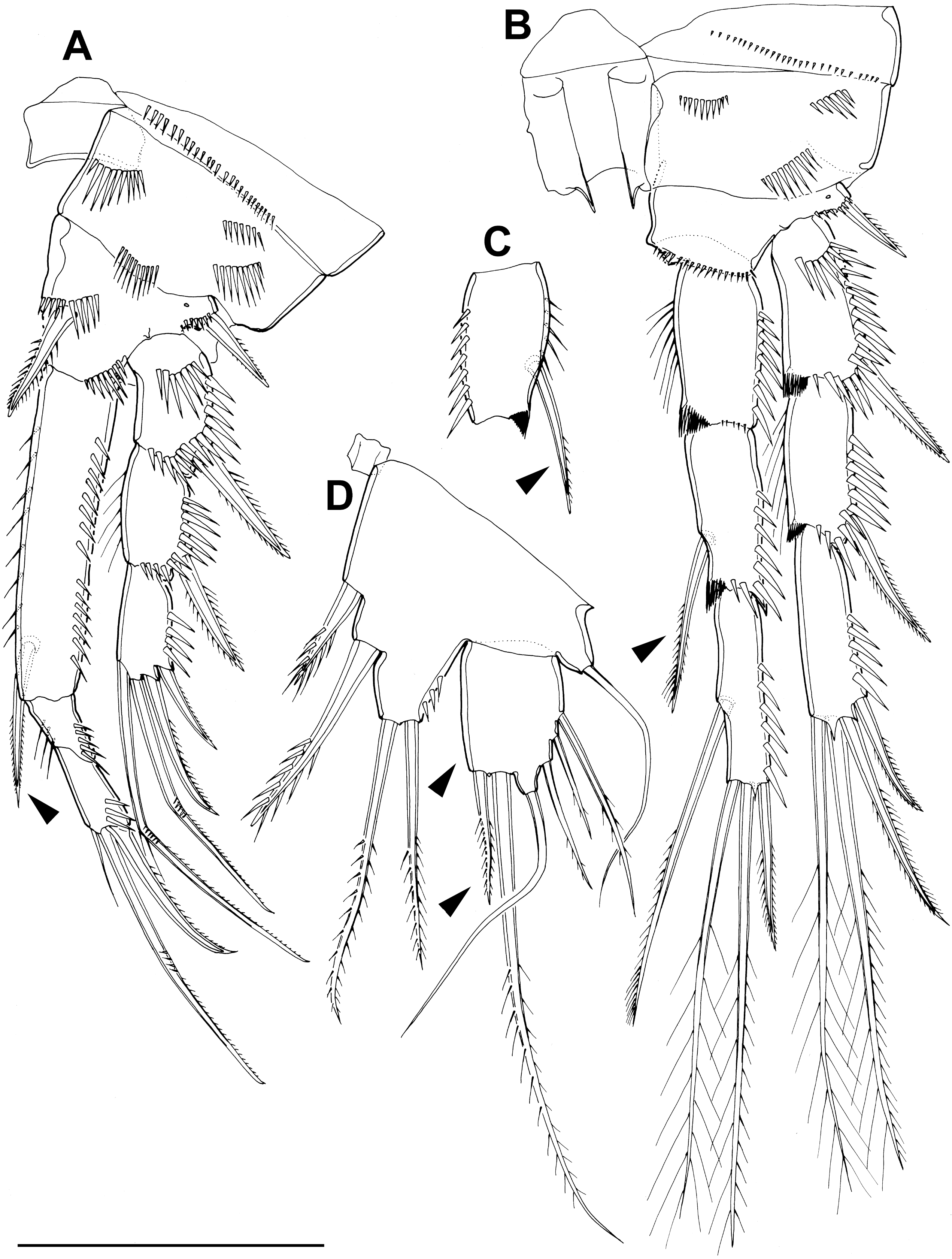

FIGURE 14. *Schizopera sindoensis* **sp. nov.**, holotype female, line drawings: A, first swimming leg, anterior; B, second swimming leg, anterior; C, first endopodal segment of third swimming leg, anterior; D, fifth leg, anterior. Arrowheads pointing some of the most prominent specific features. Scale bar 50 µm.

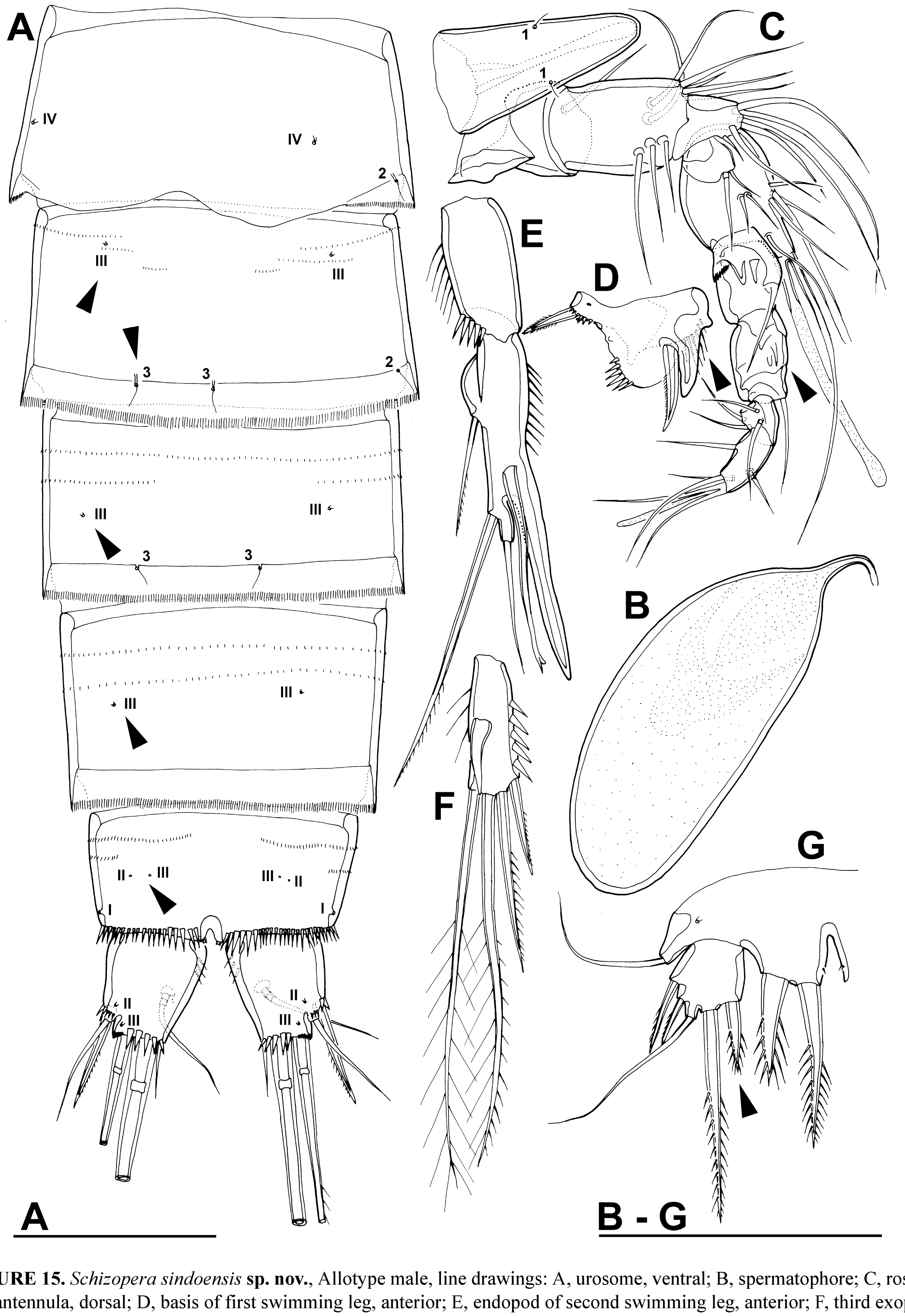

FIGURE 15. *Schizopera sindoensis* **sp. nov.**, Allotype male, line drawings: A, urosome, ventral; B, spermatophore; C, rostrum and antennula, dorsal; D, basis of first swimming leg, anterior; E, endopod of second swimming leg, anterior; F, third exopodal segment of third swimming leg, anterior; G, fifth leg, anterior. Sensilla and pores on somites and caudal rami homologous to those in *S. daejinensis* **sp. nov.**, *S. yeonghaensis* **sp. nov.**, and *S. gangneungensis* **sp. nov.** assigned the same Arabic and Roman numerals; novel ones numbered consecutively from anterior to posterior end and from dorsal to ventral side. Arrowheads pointing some of the most prominent specific features. Scale bars 50 µm.

FIGURE 16. Light microscope photograph of four *Schizopera* species from Korea together: A, *S. yeonghaensis* **sp. nov.**, holotype female; B, *S. daejinensis* **sp. nov.**, holotype female; C, *S. gangneungensis* **sp. nov.**, paratype female 3; D, *Schizopera sindoensis* **sp. nov.**, paratype male 3.

Fifth leg (Fig. 14D) shape, segmentation, armature, and most ornamentation as in *S. daejinensis*; exopod less ovoid, 1.45 times as long as wide, with division line visible on both posterior and anterior surfaces; length ratio of exopodal armature elements, from inner side, 1 : 3.6 : 2.3 : 1 : 0.8 : 1.6; length ratio of endopodal armature elements, from inner side, 1 : 1.9 : 2.7 : 2.2.

Sixth leg (Fig. 13A) as in *S. daejinensis*, except for inner seta about 2.1 times as long as outer seta.

Male (based on allotype and two paratypes). Body length from 380 to 415 µm. Segmentation as in female, except for genital somite and third urosomal somite not fused. Habitus (Figs. 10A, 11B) slightly more slender than in female, but also cylindrical, and with similar proportions; body length/width ratio about 5.3 in dorsal view. Ornamentation of rostrum (Figs. 11F, 15C), prosomites (Figs. 10B, C, 11B, C), and first urosomite (Figs. 10C, 11C), as well as colour and nauplius eye, as in female; cephalothorax without pair of sensilla at base of rostrum (C-2).

Genital somite (Figs. 10D, 11D, 15A) more than twice as wide as long; ornamentation consists of three pairs of large dorsal sensilla (U2-1 to U2-3) and single pairs of ventral pores, probably homologous to those in female (U2-IV). Ovoid spermatophore (Fig. 15B) longitudinally placed inside genital somite, about 2.4 times as long as wide.

Third urosomite (Figs. 10D, 11D, 15A) ornamented as in female, but not fused to second (genital) urosomite, with ventral pair of sensilla (U3-3) less widely spaced, with dorsolateral pair of pores probably homologous to those of *S. yeonghaensis* (U3-I) and one novel pair of anterior ventral pores (U3-III).

Fourth and fifth urosomites (Figs. 10E, 11E, 15A) as in female, but with dorsolateral and ventral pairs of pores (U4-I, U4-III, U5-I, and U5-III), serially homologous to those on third urosomite.

Sixth urosomite (Figs. 10E, F, 11E, 15A) as in female, but with two additional ventral pairs of pores (U6-II and U6-III) as novel structures among Korean species.

Caudal rami (Figs. 10F, 11E, 15A) slightly shorter in comparison with anal somite and less bulbous than in female but hardly any difference in armature or ornamentation, except for inner margin with fewer spinules.

Antennula (Figs. 11F, 12B, 15C) similar to that of *S. yeonghaensis* but 8-segmented (female's sixth segment not fully subdivided); however without observable difference in armature or ornamentation.

Antenna, labrum, mandibula, maxillula, maxilla, maxilliped, exopod and endopod of first swimming leg, exopod of second swimming leg, endopod of third swimming leg, and fourth swimming leg as in female.

First swimming leg (Figs. 12C, 15D) with modified basis, similar to that of *S. yeonghaensis* but with large spinules along inner margin and with inner spine significantly longer than spiniform process.

Second swimming leg (Fig. 15E) with transformed endopod as in *S. yeonghaensis*, although slightly less slender and with shorter and more robust inner seta on third segment.

Third swimming leg (Fig. 15F) as in *S. yeonghaensis* with very characteristic element on anterior surface of third exopodal segment.

Fifth legs (Figs. 12D, 15G) segmentation, armature and most ornamentation as in *S yeonghaensis*, except for anterior pore not on endopodal lobe but on outer basal part, and innermost exopodal spine much more robust; exopod slightly longer than wide, length ratio of exopodal armature elements, from inner side, 1: 3 : 2.6 : 0.7 : 1.1.

Sixth legs (Figs. 10D, 15A) expressed as pair of small, short cuticular plates, without armature, ornamentation or demarcation; left one larger and probably functioning as genital flap.

Variability. Only one female of this species was collected and examined, and it had one antennula abnormal, with a reduced armature and segmentation in the distal part (Fig. 13C), while the other antennula was normal (Fig. 13B). This is probably a developmental anomaly resulting from physical or chemical damage. All males had additional urosomal pores, not observed in the single female studied. It is impossible at this stage to determine if these are also part of sexual dimorphism, or if they are part of sex-independent intraspecific variability. All other urosomal and all prosomal cuticular organs were identical in both sexes.

Discussion

The presence of a large, transformed tubular pore on the male third leg exopod (Figs. 6G, 15F) shows that these new species unquestionably belong to the genus *Schizopera*. This conclusion is further supported by a number of morphological characters shared with nearly all 100 congeners: the shape of the female genital field with a large and characteristically shaped epicopulatory bulb (Figs. 2A, 4B, 9A, 13A), the segmentation and armature of the antennula (Figs. 2B, 5A, 9B, 13B), antenna (Figs. 2C, 5B, 9D, 13D), mouth appendages, the segmentation and most armature of the swimming legs, the shape and armature of the fifth leg (Figs. 3F, 5H, 9L, 14D), and the armature of the caudal rami (Figs. 2A, 4B, 9A, 13A). Even though we are missing males for two species described here, their generic placement is not in doubt.

The four new species differ from each other markedly in size (see Fig. 16), with *S. gangneungensis* being hardly half as large as *S. daejinensis* or *S. sindoensis*, and *S. yeonghaensis* being an intermediate form. The size differentiation was proven to be important in this genus for sympatric coexistence (see Karanovic and Cooper 2012) and *S. daejinensis* and *S. yeonghaensis* do indeed live sympatrically (see above). This is an important mechanism for avoiding (or minimizing) interspecific competition in these environments through niche partitioning, and we speculate that at some point in their evolutionary history on this peninsula even *S. gangneungensis* was living simpatrically with *S. daejinensis* and *S. yeonghaensis*. All three species live on the East Coast of Korea, and their current extremely short ranges might be a result of a truncation caused by anthropogenic factors.

In addition to their size, the four new species can be distinguished by a number of macro-morphological features. For example, *S. daejinensis* is the only species with an inner seta on the second exopodal segment of second to fourth swimming legs (Fig. 3B), *S. yeonghaensis* has the most slender caudal rami (Fig. 4A, B, C), *S. gangneungensis* has only two elements on the third endopodal segments of third and fourth legs (Fig. 9J, K) and only five setae on the fifth leg exopod (Fig. 9L), and *S. sindoensis* has six setae on the third antennular segment (Fig. 13B) and very short and spiniform setae on the first and second exopodal segments of all swimming legs (where present; see Fig. 14A, B, C). All species also have a different shape of the caudal rami and proportions of the caudal armature (Figs. 2A, 4B, 9A, 13), different proportions of the fifth leg armature (Figs. 3F, 5H, 9L, 14D), and different proportions of the first endopodal segment of the first swimming leg (Figs. 3A, 5E, 9H, 14A).

They can also be distinguished by the absence/presence of some pores and sensilla and their relative position. For example, both *S. gangneungensis* and *S. sindoensis* have a full complement of four pores on their caudal rami (CR-I to CR-IV; see Figs. 8E, 9A, 10F, 11E), while *S. daejinensis* lacks dorsal-anterior pore (CR-IV; see Fig. 1B), and *S. yeonghaensis* lacks all but one ventral pair (CR-III; see Fig. 4B). Likewise, *S. gangneungensis* lacks ventral and lateral sensilla on the third and fourth urosomites (U3-2, U3-3, U4-2, U4-3; see Figs. 7D, 8A), which are present in the other three species. *Schizopera sindoensis* lacks the ventro-lateral pairs of pores on the genital somite (U2-II, U2-III; see Fig. 13A), as well as a pair of sensilla at the base of rostrum (C-2; see Fig. 11B, F), which are present in the other three species. No other species has pores C-VII on the cephalothorax except for *S. daejinensis* (see Fig. 1A), and all species, except for *S. yeonghaensis,* have dorsolateral pores FP3-3 on the third free prosomite (see Fig. 4A). In addition to these autapomorphies, many other differences were observed. For example, *S. gangneungensis* and *S. sindoensis* lack dorsal pores C-V (see Figs. 8B, 11B), which are present in both *S. daejinensis* and *S. yeonghaensis* (Figs. 1B, 4A). However, most of the sensilla and pores were identical in all four species and their homologisation is relatively simple, and confirms some recent claims for other copepod groups that these minute characters have a remarkable phylogenetic signal (Karanovic and Kim 2014a). For example, sensilla C-19 and C-20 are always very close to each other in all four species, as are sensilla C-22 and C-23 (all on the cephalothorax). This was observed in some other *Schizopera* species where cuticular organs were studied in detail (Karanovic and Cooper 2012; Karanovic and McRae 2013; Karanovic et al. 2015a). In addition to the presence/absence and fairly obvious differences in relative position of sensilla and pores, it was recently demonstrated that even minute variations in their relative positions might be useful for species delineation, and is as sensitive as some fast evolving mitochondrial molecular markers (Karanovic et al. 2015b); cuticular organs when used as landmarks for geometric morphometric analyses, could even separate sexes of cryptic species – which is something we are not able to do using mitochondrial DNA. We only had males and females of *S. yeonghaensis* and *S. sindoensis*, and in both species we did not observe any sexual dimorphism in cuticular organs on prosomites, and only a few differences on their urosomites (presence/absence of some cuticular pores). However, our sample sizes in both cases were inadequate to establish if the latter is a result of sexual dimorphism or sex-unrelated intraspecific variability. This apparent lack of sexual dimorphism might provide useful directions for future pairing of opposite sexes in these and other copepods, especially in cases of sympatric congeners or missing sexes, and is in line with other studies that examined sexual dimorphism of cuticular organs in copepods (Karanovic and Cho 2012; Karanovic and Lee 2012; Karanovic *et al.* 2012; Karanovic and McRae 2013; Karanovic et al. 2013a, b; Karanovic and Kim 2014a, b; Karanovic et al. 2015a). Other forms of variability in our four new species are similar to asymmetries reported by Karanovic et al. (2015b); for example one female of *S. gangneungensis* lacks at least one sensilla C-13 (Fig. 7B), while this organ is present in all other specimens (Fig. 8B).

Distinct phenotypes (both based on macro- and micro-structures) of the four new Korean species suggest that they are probably not closely related to each other. Here we provide a brief outline of their significant similarities with other congeners. *Schizopera sindoensis* has quite similar caudal rami to those of the widely distributed *S. clandestina*, recorded in Korea by Chang (2009; 2010), but differs in the absence of an inner seta on the second exopodal segment of second to fourth legs (which is similar to *S. daejinensis*), longer first endopodal segment of the first leg, and also longer fifth leg exopod but with shorter outermost and innermost armature elements on it. The other previously reported Korean congener, *S. neglecta*, also has an inner seta on the second exopodal segment of second to fourth legs, just as our *S. daejinensis*, but the latter differs from the former in the endopodal armature of these legs (i.e. without seta on the first segment).

Schizopera daejinensis is most similar to *S. knabei* Lang, 1965, described by Lang (1965) from Monterey Bay, California, USA. These two species share an identical armature formula of their swimming legs, fifth leg, and a very similar shape and armature of the caudal rami and mouth appendages; the latter differs from the former in the longer first endopodal segment of the first leg, as well as in the following minor differences: antenna with shorter setae on allobasis and first exopodal segment, coxa of the first leg with only two rows of large spinules, coxa of the second to fourth legs without inner row of large spinules, female fifth leg with shortest innermost seta and with shorter exopod. Another species that is morphologically very similar to *S. daejinensis* is *S. costaricana* Karanovic, 2004, originally reported as *Schizopera sp. A* by Mielke (1995) from the Pacific coast of Costa Rica, and described as a new species by Karanovic (2004). It shares with *S. daejinensis* and *S knabei* the same armature formula of all swimming legs, shape and armature of the caudal rami and most mouth appendages; it differs from *S. daejinensis* in the following features: wider epicopulatory bulb, absence of long spinules on the caudal rami, longer mandibular endopod, wider (but not much longer) first endopodal segment of the first leg, shorter armature on the fifth leg. At this stage it would seem that this Northern Pacific trio forms a tight group, possibly originating from a single widely distributed ancestor. However, some of the similarities are clearly plesiomorphic features in a wider group of congeners, and caution is needed in their interpretation. For example, in addition to these three species and those mentioned by Lang (1965), the same armature formula of the swimming legs was recorded for 11 species described from the Murchison region in Western Australia (Karanovic 2004; Karanovic and Cooper 2012), as well as for two species from the Pilbara region in Western Australia (Karanovic 2006; Karanovic and McRae 2013).

Schizopera yeonghaensis seems also to be most closely related to a Pacific congener, sharing the greatest number of morphological features with *S. hawaiiensis* Kunz, 1995, as far as can be judged from a relatively rudimentary original (and only) description of this species by Kunz (1995). These two share the same armature formula of all swimming legs, and the shape and armature of the caudal rami. The latter differs from the former in the following features: only one seta on the mandibular exopod, third endopodal segment of third leg in male with shorter inner seta, longer fourth and fifth setae from inner side on the female fifth leg exopod; and longer spines on the male fifth leg endopodal lobe. Without knowing anything about fine structures (especially pores and sensilla) on the somites of *S. hawaiiensis* it is difficult to judge whether this species is closely related to *S. yeonghaensis*. For example, *S. sindoensis* shares the same armature formula of the swimming legs with these two species, but our analysis of cuticular organs shows it to be only distantly related to *S. yeonghaensis* (see above). After all, the armature formula of the swimming legs differs from that of *S. daejinensis* only by the absence of an inner seta on the second exopodal segment of second to fourth leg, and it is easy to imagine how this character might have originated convergently from the plesiomorphic state found in *S. daejinensis* (and many other congeners). A molecular analysis of these and other species would be necessary to resolve their phylogenetic relationships, as shown for some congeners by Karanovic and Cooper (2012). Unfortunately, we did not have enough specimens for molecular analyses, but that is a priority for our future studies.

At the moment, *S. sindoensis* and *S. gangneungensis* have no close relatives among extant known congeners, as far as we can judge from their morphology. The latter has a unique armature formula of the swimming legs in the genus *Schizopera*, while the former can easily be distinguished from all congeners by a combination of its armature formula, shape of caudal rami, and short and strong armature elements on the swimming legs and the fifth leg (Fig. 14).

Our long-term survey of Korean beaches and lack of any of these species in other localities would suggest them to be either short range endemics or anthropogenic relics. Whatever the case, we need to further study and protect these neglected habitats. Microscopic life between sandy sediments is a discovery of the 20th century (Remane 1933; Wilson, 1935; Nicholl, 1935), with 23 higher metazoan taxa reported from interstitial environments (Vincx, 1986). Today, several hundreds of scientists are working on this fauna (www.meiofauna.org), which is also sometimes called meiofauna (the term that defines groups of organisms by their size and has very little relationship with taxonomic or ecological groupings (Preker 2005)), but wide areas in Africa, South America, Australia, and Asia remain terra incognita (Giere 2009). The macrofauna and the interstitial fauna of sandy beaches comprise distinct communities, with few or no trophic links (Brown & McLachlan 1990). The prime function of the interstitial system is the processing of organic materials flushed into the sand, which is mineralized by a food chain having heterotrophic bacteria at its base and predatory meiofauna (including copepods) at the apex. In the process, nutrients are recycled to the sea. The interstitial system should, therefore, be seen as a carbon sink (Brown & McLachlan 1990), which has significant implications in the age when we are trying to fight carbon levels in the atmosphere. The interstitial system may be seen as a large natural filter, cleansing and purifying surface waters - it mineralizes the organic materials it receives and returns the nutrients to the sea. Copepods, as all top predators in an ecosystem, are crucially important for the health of the marine interstitial. Some three-quarters of the world's ice-free coastlines consist of sandy shores (Brown & McLachlan, 1990) and Korea has 12,478 kilometres of coastline along three seas (http://web.archive.org/web/20120419075053/http://earthtrends.wri.org/text/coastal-marine/variable-61.html), a significant proportion of which is represented by sandy beaches. Like in most other developed economies, these ecosystems are under constant anthropogenic pressure and, being a marginal habitat, are rarely included in protected natural reserves. However, as ours and other studies show marine interstitial habitat harbours disproportionate level of biodiversity.

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