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First Record of Three *Pleuromamma* Species (Copepoda: Calanoida: Metridinidae) in Korea

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ABSTRACT

Three *Pleuromamma* copepods were newly collected from the South Sea of Korea in the summer when the Tsushima Warm Current was strong. They were identified as *Pleuromamma abdominalis* (Lubbock, 1856), *P. indica* Wolfenden, 1905, and *P. xiphias* (Giesbrecht, 1889). Although these species have been reported in world oceans, they were first reported from Korean waters. So far, four species of *Pleuromamma* (*P. borealis* Dahl, 1893, *P. gracilis* Claus, 1863, *P. piseki* Farran, 1929, and *P. robusta* (Dahl, 1893)) have been recorded in Korean waters. We provided re-description of these three species insufficiently described by previous authors and key characters for species identification in addition to species hitherto known in Korea.

Keywords: *Pleuromamma*, Metridinidae, copepoda, taxonomy, Korean fauna

INTRODUCTION

The calanoid copepod family Metridinidae consists of three genera, *Gaussia* Wolfenden, 1905, *Metridia* Boeck, 1865 and *Pleuromamma* Giesbrecht, 1898. The latter two genera occur in oceanic waters of East Sea and South Sea of Korea (Yoo, 1995; Soh, 2010). This family is one of the primitive groups contained in the superfamily of Arietelloidea. Between genera, they appear many morphological variations in element patterns of antennules and the fifth legs (Boxshall and Huys, 1998; Soh et al., 1999).

The genus *Pleuromamma* is easily recognized by the presence of a dark-pigmented convex spot on right or left side of the first pedigerous somite. Species in genus *Pleuromamma* are planktonic, free-living, and usually oceanic. There are 11 recognized species in this genus (Razouls et al., 2021): *P. abdominalis* (Lubbock, 1856), *P. gracilis* Claus, 1873, *P. xiphias* (Giesbrecht, 1889), *P. borealis* Dahl, 1893, *P. quadrungulata* (Dahl, 1893), *P. robusta* (Dahl, 1893), *P. indica* Wolfenden, 1905, *P. piseki* Farran, 1929, *P. antarctica* Steuer, 1931, *P. scutullata* Brodsky, 1950, and *P. johnsoni* Ferrari and Saltzman, 1998. So far, 4 species, *P. borealis* Dahl, 1893, *P. gracilis* Claus, 1863, *P. piseki* Farran, 1929, and *P. robusta* (Dahl, 1893), have been recorded in Korean waters (Yoo, 1995; Soh, 2010).

In this study, three species (*P. abdominalis*, *P. indica*, and *P. xiphias*) collected from the offshore of the South Sea of Korea were newly added. Re-descriptions of these three species insufficiently described by previous authors are provided and morphological differences among *Pleuromamma* speices are discussed.

MATERIALS AND METHODS

Zooplankton samples were collected from the South Sea of Korea (Fig. 1), using a conical net (mesh size 200 μm; mouth diameter 60 cm). Samples were preserved with 5% neutralized formaldehyde for morphological description. *Pleuromamma* species were dissected under a dissecting microscope (SMZ745T; Nikon, Tokyo, Japan) in CMC-10 aqueous mounting medium (Masters, Wood Dale, IL, USA), mounted on slides, and then sealed with high-quality nail varnish. Drawings were generated using a differential interference contrast microscope (ECLIPES 80i; Nikon) equipped with a drawing tube and digital pen display (Cintiq 22HD; Wacom,

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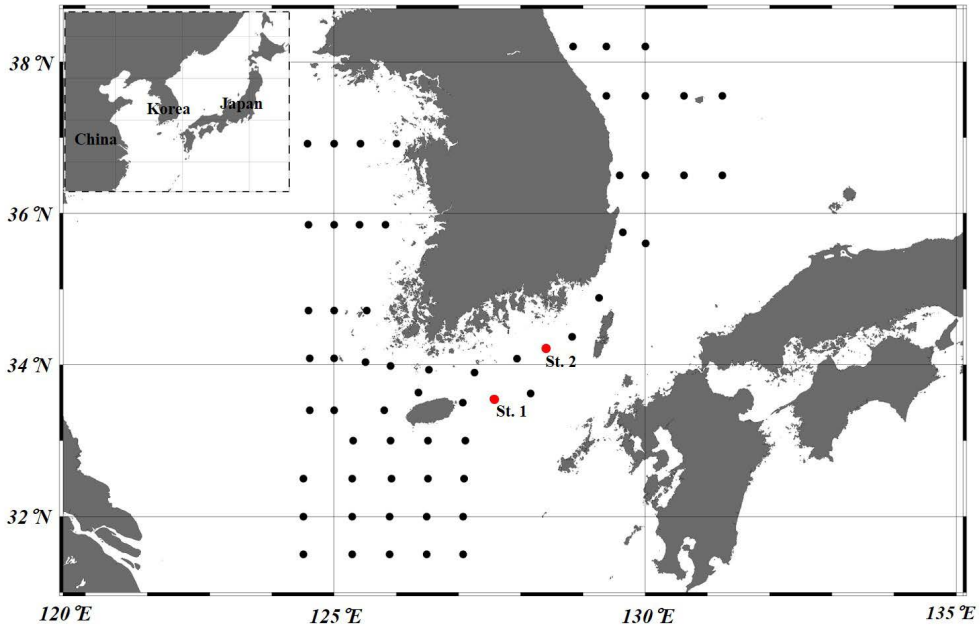

Fig. 1. Map of study area showing sampling location. Red circles represent stations where the *Pleuromamma* species found.

Kazo, Japan). Morphological terminology follows Huys and Boxshall (1991). Voucher specimens were deposited in the National Marine Biodiversity Institute of Korea (MABIK), Seocheon, Korea.

SYSTEMATIC ACCOUNTS

Order Calanoida Sars G. O., 1903
Family Metridinidae Sars G. O., 1902
Genus *Pleuromamma* Giesbrecht, 1898

[1]**Pleuromamma indica* Wolfenden, 1905 (Figs. 2–4)

Pleuromamma indica Wolfenden, 1905: 1011, Pl. 96, figs. 24–26, 31–33; Sewell, 1932: 264, fig. 89; Steuer, 1932: 17, 47, 61, 74, figs. 52–68; Grice, 1962: 215, Pl. 22; Tanaka, 1963: 24, fig. 160; Conway et al., 2003: 93; Prusova et al., 2012: 203, figs. 202, 203.

Material examined. 2♀♀ (MABIK CR00248421, CR00248422) and 1♂ (MABIK CR00248423) from Korean waters on 20 Aug 2020. Fourteen individuals (9♀♀, 5♂♂) from the same locality were used for length measurement.

Description. Female: Body length 2.10–2.46 mm (n = 11). Body elongated (Fig. 2A, B): cephalosome clearly separate from first pedigerous somite; cephalosome without tubercular rostrum in mid-anterior part; rostrum with paired filaments; first pedigerous somite with dark-pigmented convex spot on left side; fourth and fifth pedigerous somites fused; posterolateral corners symmetrical and rounded. Urosome 3-segmented: genital double somite widest at middle, protruded ventrally; anal segment with spinules on mid-posterior margin; caudal rami and anal segment separated; caudal rami symmetrical with 6 setae (Fig. 2A, B).

Antennule (Fig. 2C) symmetrical, 23-segmented, reaching about posterior margin of genital double somite: distal end of first and second segment with each large denticle; single small denticle on the 4th, 5th and 6th segments (Fig. 2D). Fusion pattern and setal formula as follows: I-III-7 + 3ae (aesthetasc), IV-2 + ae, V-2 + ae, VI-2 + ae, VII-2 + ae, VIII-2 + ae, IX-XI-6 + 3ae, XII-2 + ae, XIII-2 + ae, XIV-2 + ae, XV-2 + ae, XVI-2 + ae, XVII-2 + ae, XVIII + 2 + ae, XIX-2 + ae, XX + 2 + ae, XXI + 2 + ae, XXII-1, XXIII-1, XXIV-2, XXV-2 + ae, XXVI-2, XXVII-XXVIII-6 + ae.

Legs 1 to 4 (Fig. 3) biramous, each with 3-segmented endopod and 3-segmented exopod: coxa with inner marginal seta. Basis of leg 1 with inner marginal seta, lateral seta and spine-like process on the medial-posterior margin (Fig. 3A). Basis of leg 2 with very minute spinules on outer surface: first exopodal segment with spinules arrangement near basis on the anterior aspect; first endopodal segment incised and ornamented with 2 hook-like spinous processes (Fig. 3B). First exopodal segment of leg 3 with deep notch left distally (Fig. 3C). Setae and spine formula of legs 1 to 4 as follows (spines,

Korean name: [1]*작은배젖꼭지노벌레 (신칭)

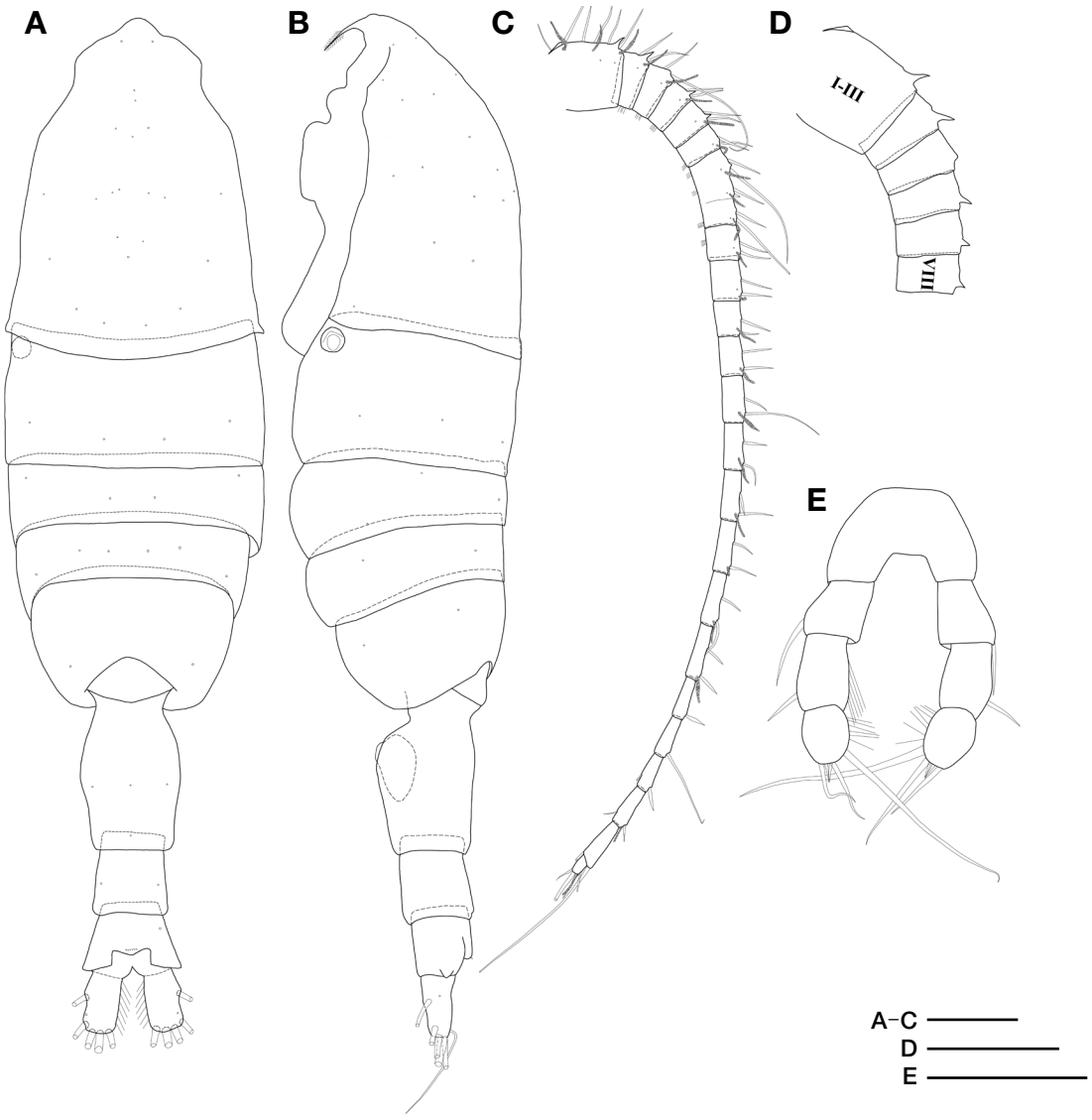

Fig. 2. *Pleuromamma indica*, female: A, Habitus, dorsal; B, Habitus, left lateral; C, Antennule; D, Ancestral segments I to VIII in antennule; E, Leg 5. Scale bars: A–D = 200 μm, E = 100 μm.

Roman numerals; setae, Arabic numerals):

	Coxa	Basis	Exopodal segments	Endopodal segments
Leg 1	0-1	1-1	I-1; I-1; II,I,4	0-1; 0-2; 1,2,2
Leg 2	0-1	0-0	I-1; I-1; III,I,5	0-0; 0-2; 2,2,4
Leg 3	0-1	0-0	I-1; I-1; III,I,5	0-1; 0-2; 2,2,4
Leg 4	0-1	0-0	I-1; I-1; III,I,5	0-1; 0-2; 2,2,3

Fifth leg (Fig. 2E) symmetrical: inner margin on the first and second exopodal segments with hairs; second one rounded with 3 unequal terminal setae and 2 small spines.

Male: Body length 1.97–2.16 mm (n = 6). Similar to habitus of female except urosome: first pedigerous somite with pigmented knob on right side (Fig. 4A, B). Urosome 5-segmented, symmetrical: anal segment with spinules on mid-posterior margin; caudal rami very divergent, each ramus with 6 setae (Fig. 4A). Legs 1 to 4 same as in female.

Left antennule (Fig. 4C) geniculate; 18-segmented, reaching about end of fourth urosomite. Fusion pattern and setal formula as follows: I-IV-7 + 5ae, V-2 + 2ae, VI-2 + ae, VII-2 + 2ae, VIII-2 + ae, IX-XI-6 + 5ae, XII-2 + ae, XIII-2 + 2ae, XIV-XV-4 + 2ae, XVI-2 + ae, XVII-2 + ae, XVIII-2 + ae, XIX-1 + ae, XX-1 + ae, XXI-XXIII-1 + ae, XXIV-XXV-4 + ae, XXVI-4, XXVII-XXVIII-6 + ae. Segment XX with long tooth ridge; compound segments XXI-XXIII with anterior tooth and 3 processes which distal process extending to

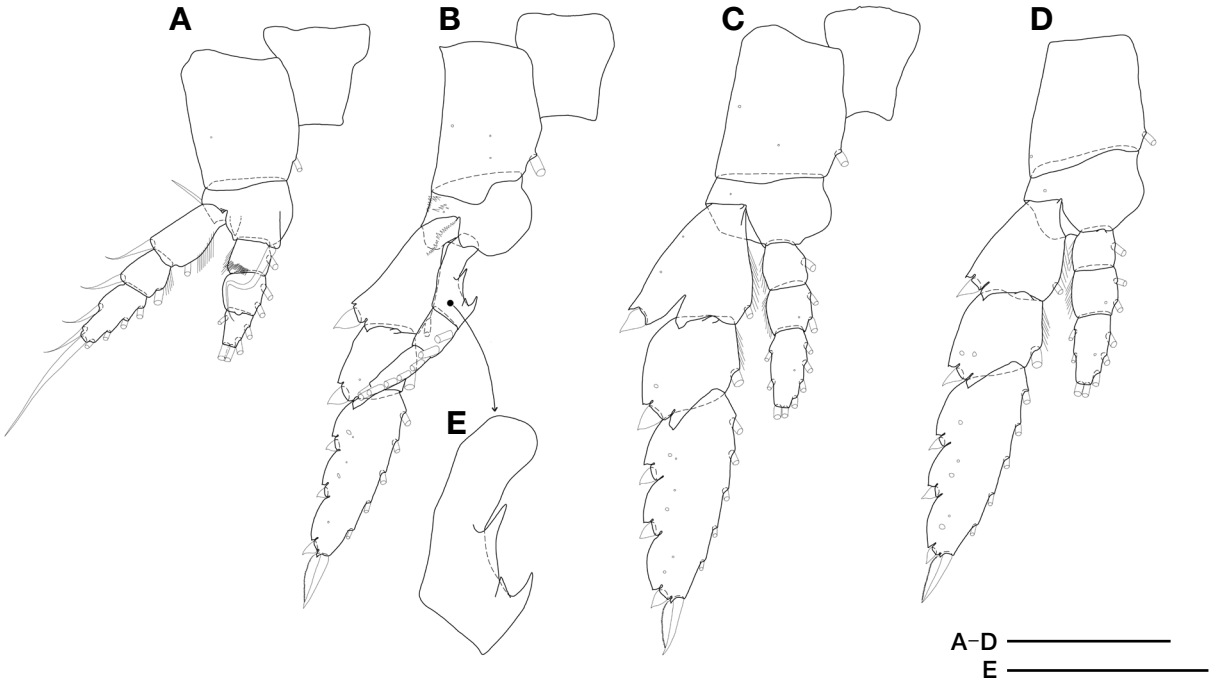

Fig. 3. *Pleuromamma indica*, female: A, Leg 1; B, Leg 2; C, Leg 3; D, Leg 4; E, First endopodal segment of leg 2. Scale bars: A–D = 200 μm, E = 100 μm.

distal 1/4 of next segment (Fig. 4D).

Fifth leg (Fig. 4E) asymmetrical, basis with outer seta and both rami 3-segmented: basis of right leg with inner margin haired; first segment with distal process and outer spine; second segment with a strong curved process anteriorly; third segment with bird's head process and 2 spinules distally; left first segment with triangular attenuation and outer seta; second segment with spinule; third segment with spine process and 2 spinules in distal margin.

Distribution. *Pleuromamma indica* was recorded in the Maldives Islands (Wolfenden, 1905), Indian Ocean (Sewell, 1932), Pacific Equator (Grice, 1962), Japanese waters (Tanaka, 1963), and Arabian Sea (Prusova et al., 2012) (Fig. 5). The present specimen was collected at a depth of 75 m in the South Sea, Korea with water temperature and salinity of about 18.3 ± 3.3°C and 33.5 ± 0.9 psu, respectively.

Remarks. *Pleuromamma indica* resembles *P. abdominalis*, but can be distinguished as follows: (1) smaller size and symmetrical urosome, (2) in female, less swollen genital segment, stouter segments in leg 5 and absence of recurved large denticle in anterior antennule, and (3) in male, presence of short tooth row on compound segment XXI–XXIII in geniculated antennule and absence of hairs on distal segment of right fifth leg.

The original description of *P. indica* by Wolfenden (1905) was insufficient to compare with the Korean specimen as it dealt with only a few characters. The present specimen is consistent with the description provided by Sewell (1932), Grice (1962), and Prusova et al. (2012). However, in the record of Prusova et al. (2012), the distal segment of female fifth leg exists with 3 unequal apical setae, but the Korean one has 3 unequal apical setae and 2 small spines, consistent with the record of Steuer (1932). Also, Wolfenden (1905) has explained that the male geniculated antennule is always on the right, but Korean specimens is present on the left or right side. It is known that the position of geniculated antennule was related to the position of a pigmented spot. When the geniculate one is on the right, pigment spot is on the left and vice versa (Saraswathy and Iyer, 1986).

[1]**Pleuromamma abdominalis* (Lubbock, 1856) (Figs. 6, 7)

Diaptomus abdominalis Lubbock, 1856: Pl. 10, figs. 1–8.

Pleuromma abdominale Brady, 1883: 46, figs. 1–13; Giesbrecht, 1892: Pl. 5, fig. 8; Pl. 32, figs. 1–3, 5, 13, 15, 16, 22, 23, 25–30; Pl. 33, figs. 43, 44, 46, 48, 49, 51, 52.

Pleuromamma abdominalis Esterly, 1905: 174, fig. 33; Steuer, 1932: 9, figs. 21–51; Mori, 1937 (1964): 69, Pl. 34,

Korean name: [1]*둥근배젖꼭지노벌레 (신칭)

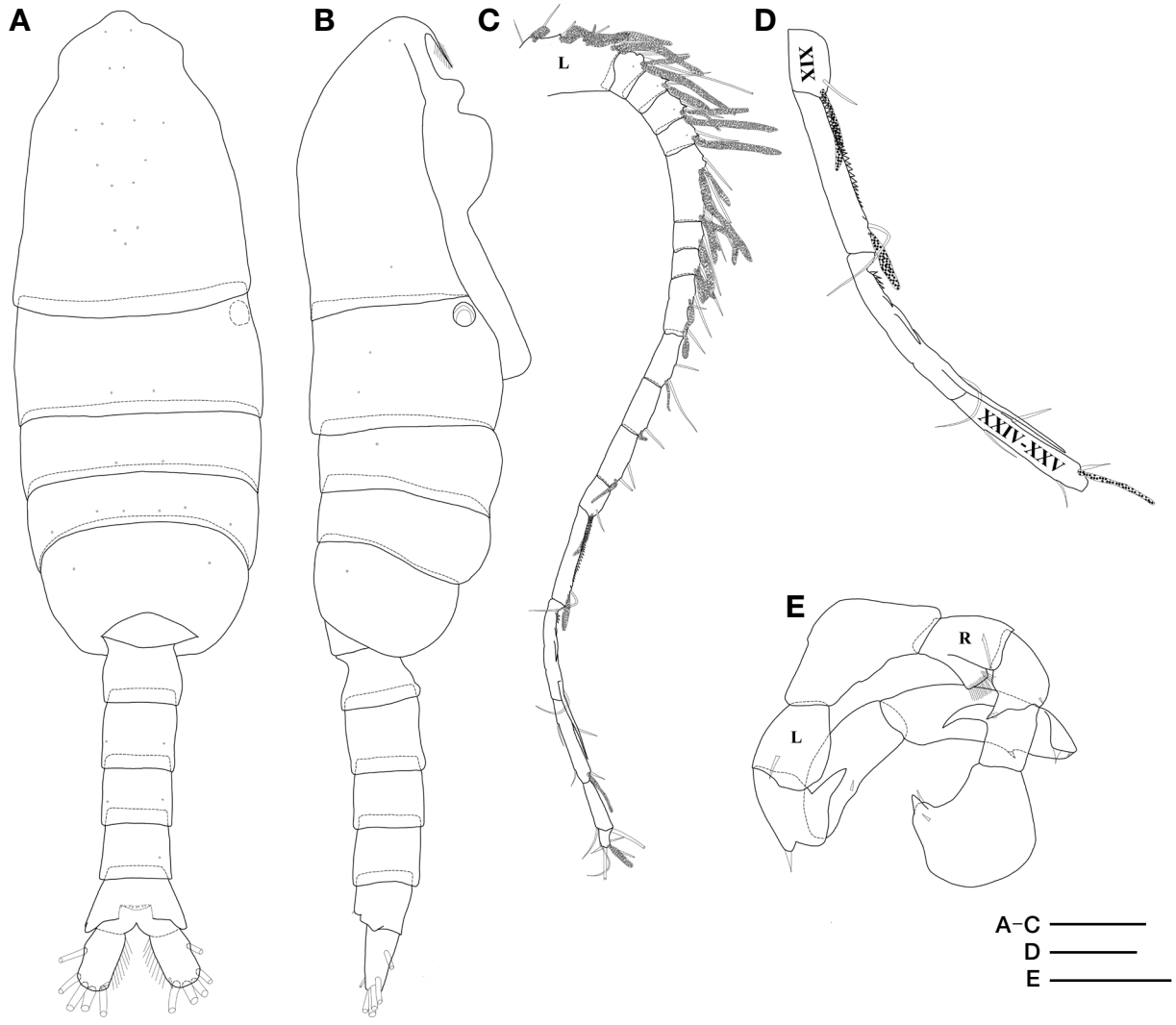

Fig. 4. *Pleuromamma indica*, male: A, Habitus, dorsal; B, Habitus, right lateral; C, Left antennule; D, Ancestral segments XIX to XXV in right antennule; E, Leg 5. Scale bars: A–C = 200 μm, D, E = 100 μm.

figs. 6–9, Pl. 35, figs. 6, 7; Brodsky, 1950 (1967): 306, fig. 212; Grice, 1962: 215, Pl. 21; Chen & Zhang, 1965: 68, Pl. 22, figs. 1–3; Bradford-Grieve, 1999: 119, fig. 80; Mulyadi, 2004: 61, fig. 34; Prusova et al., 2012: figs. 190, 191.

Material examined. 1♀ (MABIK CR00248425) and 1♂ (MABIK CR00248420) from Korean waters (Fig. 1, St. 1) on Oct 2020. Four individuals (3♀♀, 1♂) from the same locality were used for length measurement.

Description. Female: Body length 2.79–3.18 mm (n = 4) Body elongate (Fig. 6A, B): cephalosome without tubercular rostrum in mid-anterior part; dark-pigmented convex spot on left side. Urosome 3-segmented: genital double-somite swelling centrally, protruded ventrally; genital pore region with dark protruding cap; anal segment with spinules on mid-posterior margin (Fig. 6A, B). Other morphological characteristics on body shape and appendages similar to *P. indica*.

Antennule (Fig. 6C) symmetrical, 23-segmented, reaching about posterior end of anal somite: first two segments of antennule bearing two stout denticles of varying size and appearance, one on first segment stronger and more curved than that on second segment; second segment with a straight one; fourth to sixth segments each single small denticle (Fig. 6D, E). Fusion pattern and setal formula similar to *P. indica*.

Fifth leg (Fig. 6F) symmetrical, 3-segmented: distal segment with 3 apical setae which inner seta longest, and 2 thin spines.

Male: Body length 2.99–3.10 mm (n = 2). Prosome similar to female except urosome: dark-pigmented convex spot on left side; left posterior corner of prosome with long hairs

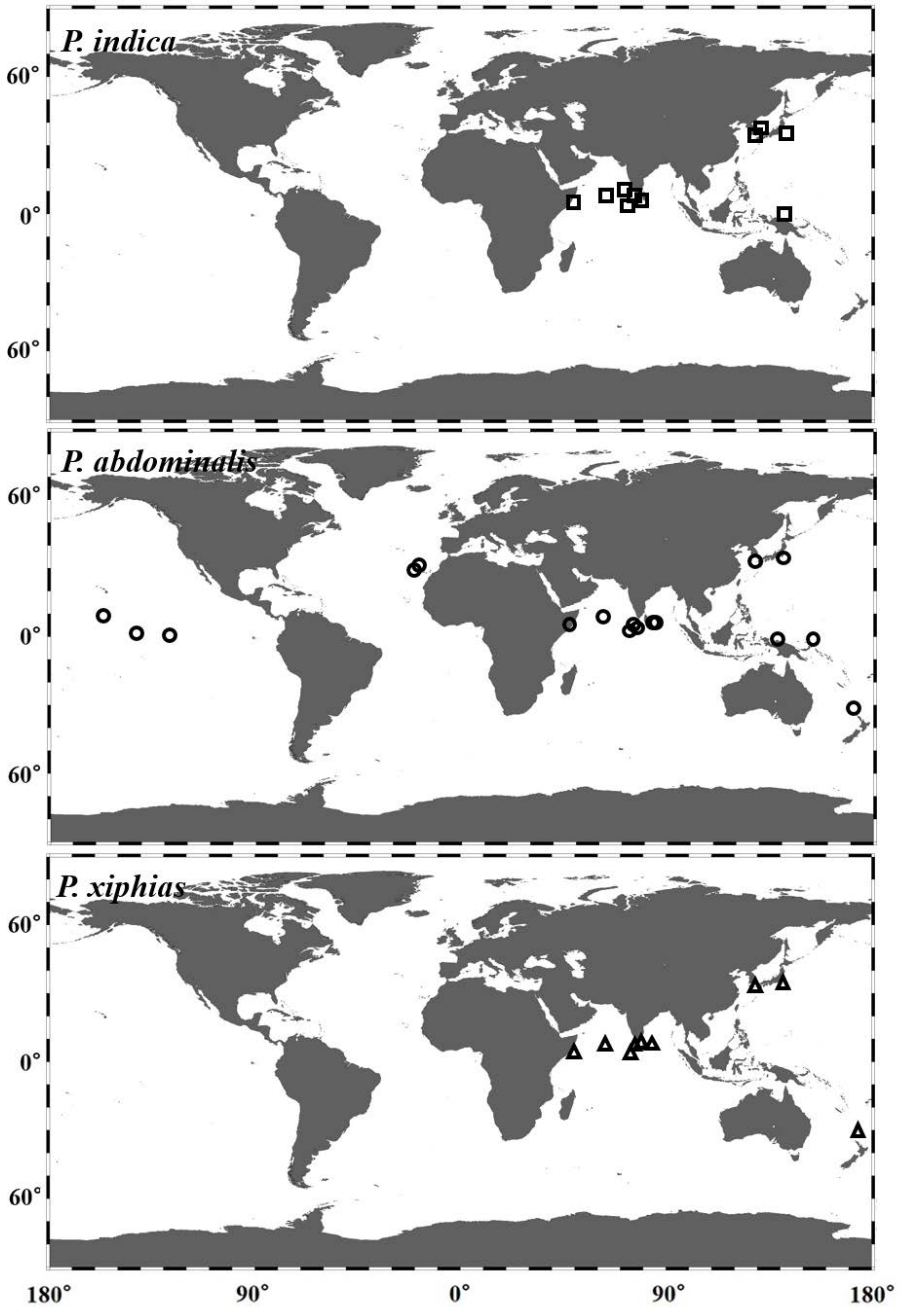

Fig. 5. Distribution of *Pleuromamma indica* (□), *P. abdominalis* (○) and *P. xiphias* (△) based on previous records and on the present study. References are as follows: Lubbock (1856), Giesbrecht (1889), Esterly (1905), Wolfenden (1905), Sewell (1932), Grice (1962), Tanaka (1963), Bradford-Grieve (1999), Mulyadi (2004), Prusova et al. (2012).

(Fig. 7A, B). Urosome 5-segmented, very asymmetrical: second to fifth urosomite bearing various knobs, protuberences and setal bundles; caudal rami asymmetrical, left ramus with recurved seta (Fig. 7A).

Right antennule (Fig. 7C) geniculate, reaching about posterior end of anal somite: segments XIV–XV with denticle distally; posterior margin of segment XIX with widen protrusion; segment XX with teeth arrangement; segments XXI–XXIII with 3 spinous processes which distal process extends anterior of next segment (Fig. 7D). Fusion pattern and setal formula same as *P. indica*.

Fifth leg (Fig. 7E) similar to *P. indica*: basis of left leg with

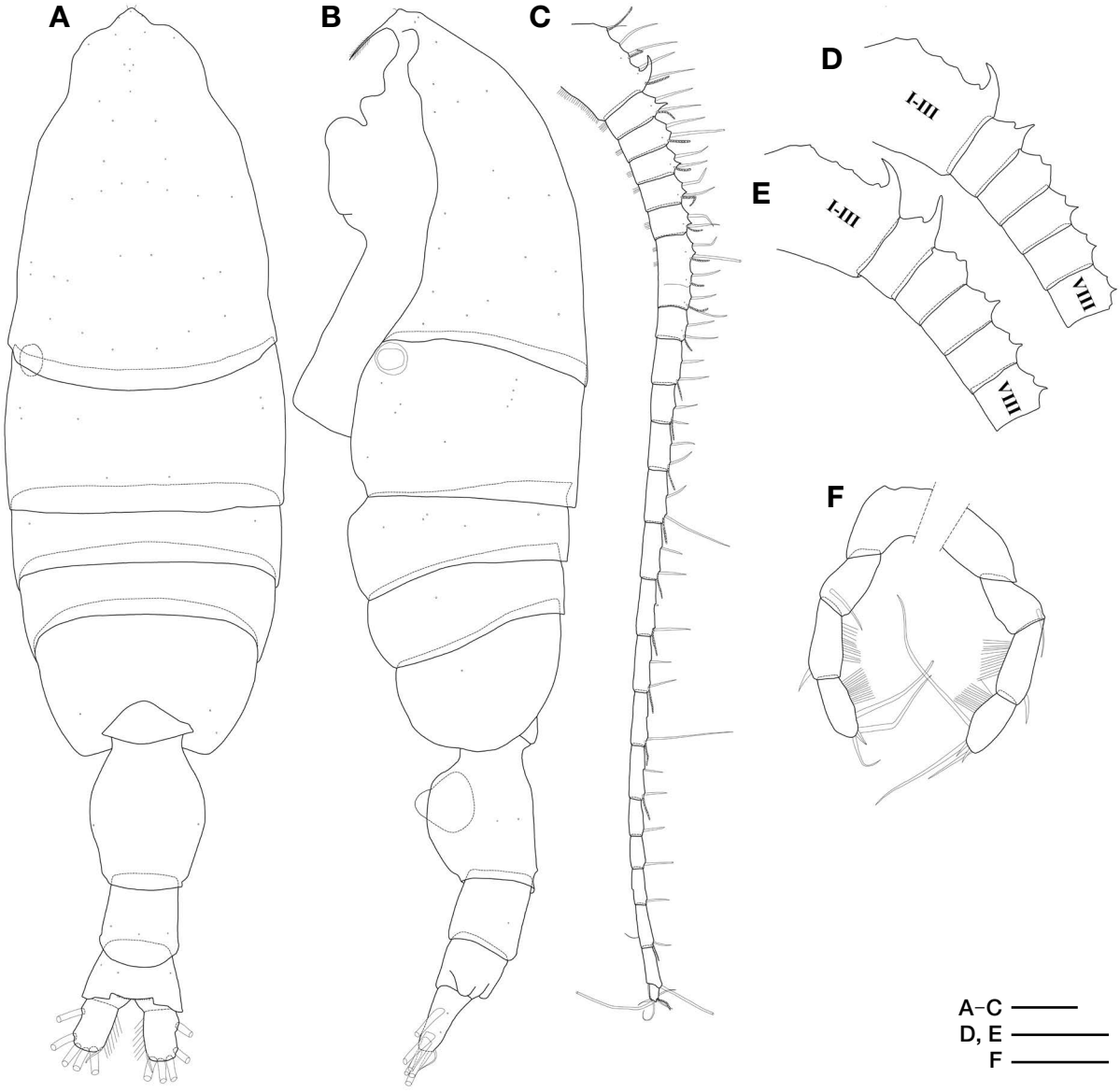

Fig. 6. *Pleuromamma abdominalis*, female: A, Habitus, dorsal; B, Habitus, left lateral; C, Antennule; D, Ancestral segments I to VIII in antennule; E, Ancestral segments I to VIII in antennule of another individual; F, Leg 5. Scale bars: A–E = 200 μm, F = 100 μm.

long and fine hairs; first segment without process; second and third segments with tufts of hairs; right first segment with bird-beaked protrusion and outer seta; distal segment with 2 apical spinules.

Distribution. *Pleuromamma abdominalis* was first recorded by Lubbock (1856) from Atlantic Ocean. It has a cosmopolitan distribution of the Atlantic, Indian, and Pacific Oceans (Brodsky, 1950 (1967); González et al., 2020; Razouls et al., 2021) (Fig. 5). The species preferably inhabits oceanic environments. The present specimen was collected at a depth of 100 m in the Tsushima Warm Current of the South Sea with water temperature and salinity of about 21.4 ± 2.6°C and 34.2 ± 0.2 psu, respectively.

Remarks. *Pleuromamma abdominalis* is the first known species and one of the common species of the genus. This species can be clearly distinguished from other co-distributed species by the shape of the rostrum, the presence and number of denticles on proximal segments of the antennule, body size, and the fifth leg.

In the female, *P. abdominalis* is very similar to *P. indica*, but has a larger size, very convex genital double somite, two large spiniform denticles in the first two segments of antennule, and slender fifth leg. Steuer (1932) described three types of *P. abdominalis*. The present specimens was similar to the

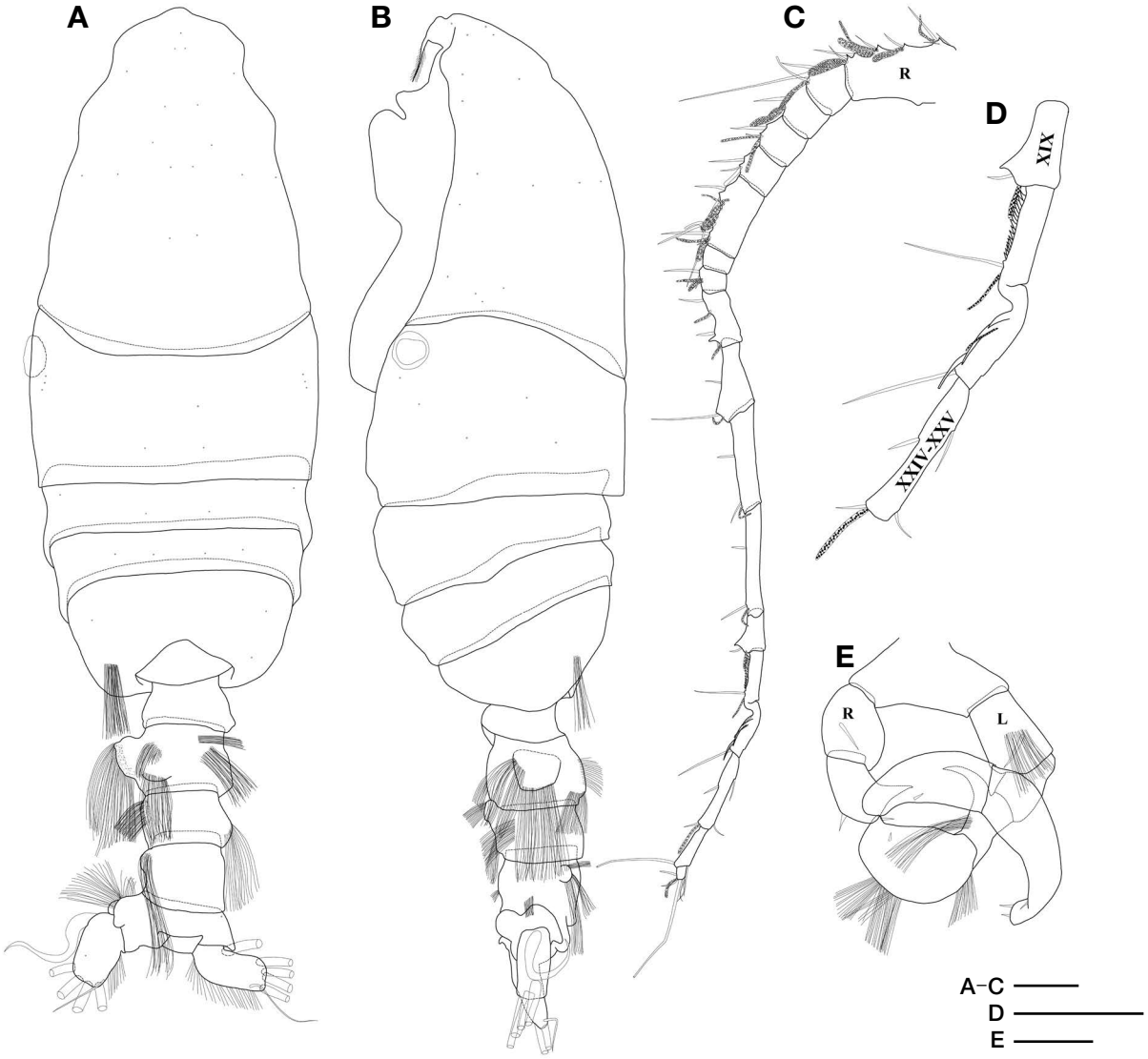

Fig. 7. *Pleuromamma abdominalis*, male: A, Habitus, dorsal; B, Habitus, left lateral; C, Right antennule; D, Ancestral segments XIX to XXV in right antennule; E, Leg 5. Scale bars: A–D = 200 μm, E = 100 μm.

forma *typica*, consistent with records of Giesbrecht (1892), Bradford-Grieve (1999) and Prusova et al. (2012). Also, Fornshell and Ferrari (2010) suggested morphological variation of the proximal segment in the female antennule. Korean specimens showed two types of antennule (Fig. 6D, E).

[1]**Pleuromamma xiphias* (Giesbrecht, 1889) (Figs. 8, 9)

Pleuromma xiphias Giesbrecht, 1889: 6; 1892: 347, 357, 774, Pl. 32, fig. 14; Pl. 33, figs. 42, 45, 50.

Pleuromamma xiphias Giesbrecht & Schmeil, 1898: 109; Esterly, 1905: 176, fig. 34; A. Scott, 1909: 124; Steuer, 1932: 5, 70, figs. 1–20; Sewell, 1947: 169, fig. 44; Brodsky, 1950 (1967): 307; Grice, 1962: 215, Pl. 20, figs. 18–21, Pl. 21, figs. 1–5; Tanaka, 1963: 23; Chen & Zhang, 1965: 69; Ferrari, 1985: 10, figs. 14–23; Bradford-Grieve, 1999: 124, figs. 85, 86; Conway et al., 2003: 96; Mulyadi, 2004: 66, fig. 37; Prusova et al., 2012: 209; figs. 210–213.

Material examined. 1♀ (MABIK CR00248426) and 1♂ (MABIK CR00248424) from Korean waters (Fig. 1, St. 1) on Oct 2020. Four individuals (3♀♀, 1♂) from the same locality were used for length measurement.

Description. Female: Body length 4.09–4.58 mm (n = 4). Body elongate (Fig. 8A, B): forehead with the pronounced

Korean name: [1]*이마돌기젖꼭지노벌레 (신칭)

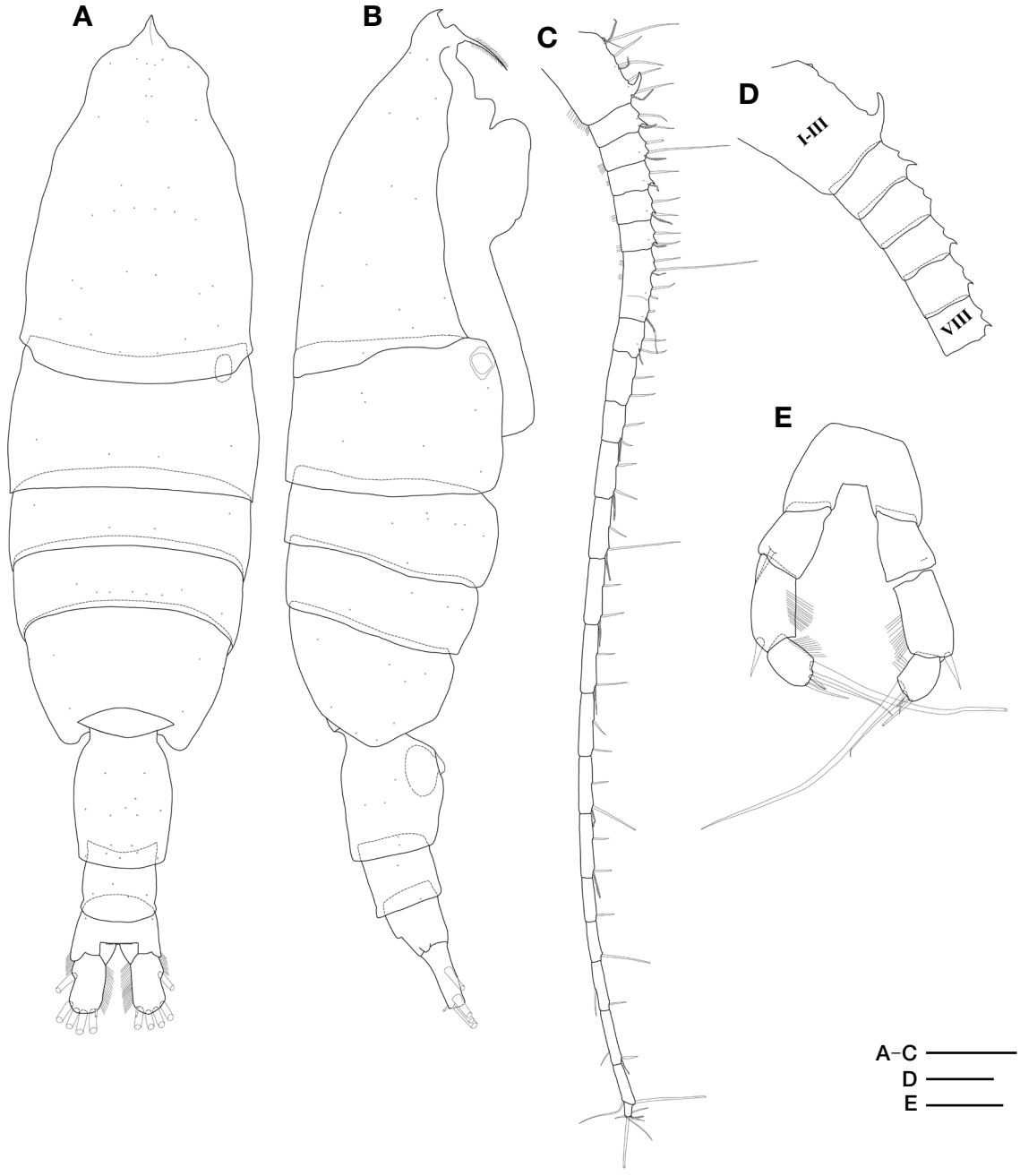

Fig. 8. *Pleuromamma xiphias*, female: A, Habitus, dorsal; B, Habitus, right lateral; C, Antennule; D, Ancestral segments I to VIII in antennule; E, Leg 5. Scale bars: A–C = 400 μm, D = 200 μm, E = 100 μm.

pointed process which is bent slightly downwards; rostrum with paired filaments; first pedigerous somite with dark-pigmented convex spot on right side. Urosome 3-segmented: genital double somite widest at middle with darkened ventral protuberance toward center; anal segment with spinules on mid-posterior margin (Fig. 8A, B). Other morphological characteristics on body shape and appendages similar to *P. indica*.

Antennule (Fig. 8C) longer than body length, symmetrical, 23-segmented: distal end of first segment with a large curved denticle; second segment with single denticle; third segment no denticle; fourth to sixth segments each single small denticle (Fig. 8D). Fusion pattern and setal formula similar to *P. indica*.

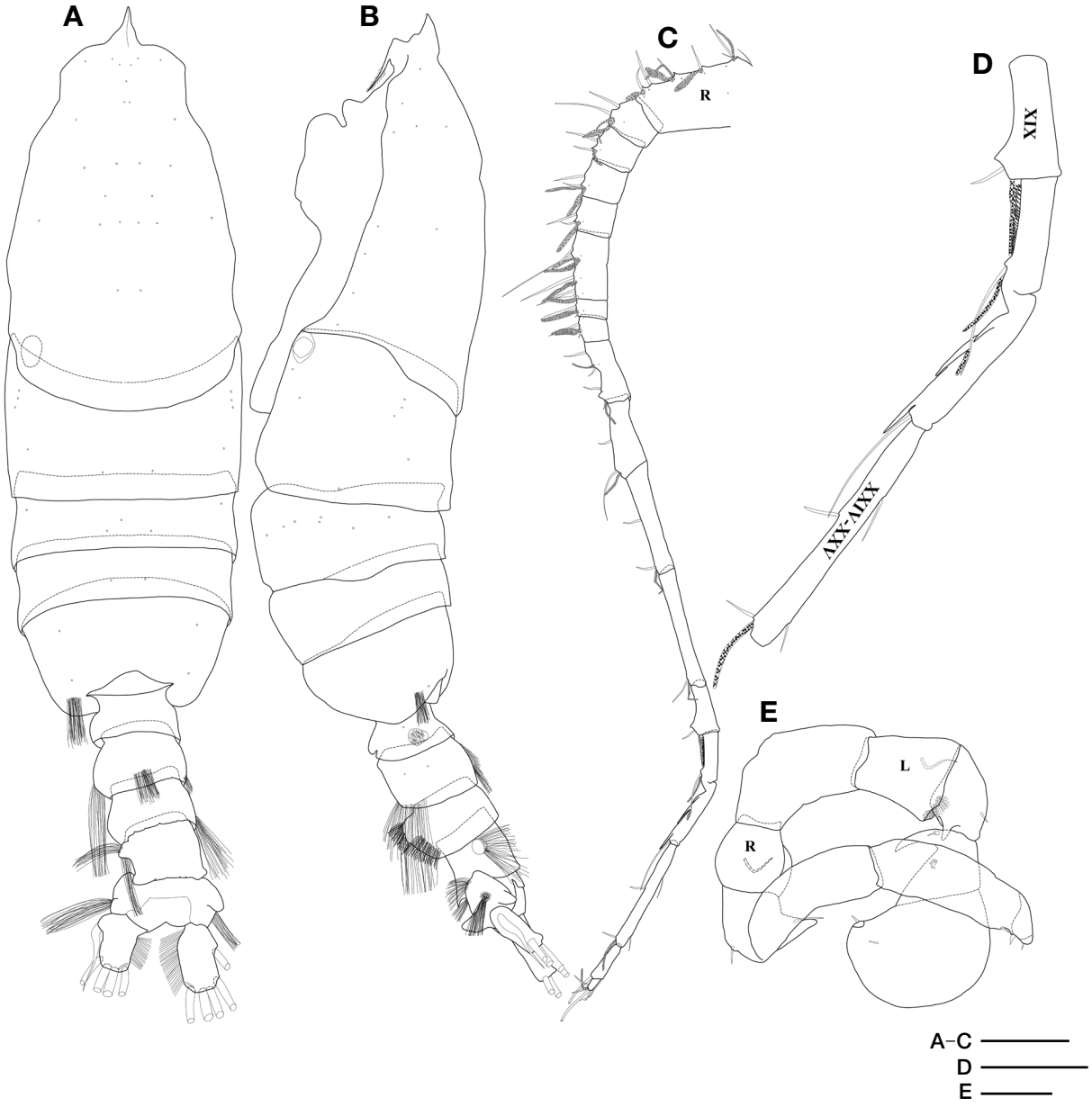

Fig. 9. *Pleuromamma xiphias*, male: A, Habitus, dorsal; B, Habitus, left lateral; C, Right antennule; D, Ancestral segments XIX to XXV in right antennule; E, Leg 5. Scale bars: A–C = 400 μm, D = 200 μm, E = 100 μm.

Fifth leg (Fig. 8E) symmetrical: distal segment with 3 subapical setae, medial hairs and 2 small spines.

Male: Body length 4.41–4.47 mm (n = 2). Similar to habitus of female except urosome: forehead as in female except it is directed forwards; dark-pigmented convex spot on left side (Fig. 9A, B). Urosome 5-segmented, asymmetrical: urosomal segment with various knobs, protuberences and long thick bundles of bristles; caudal rami asymmetrical, left ramus with a recurved seta (Fig. 9A).

Right antennule (Fig. 9C, D) geniculate, longer than body length; length of segment XVIII longer than *P. indica* and *P. abdominalis*; segment XIX with distal triangular swelling; segment XX with teeth arrangement; compound segments XXI–XXIII with 3 speciosus processes of similar length (Fig. 9C, D). Fusion pattern and setal formula same as *P. indica*.

Fifth leg asymmetrical (Fig. 9E): basis of left leg with outer seta and inner hirsute; first segment with process; second segment with speciosus process and minute spinules; distal segment hemispiral-shaped, larger than *P. indica* (Fig. 4E). Fifth

leg similar to *P. indica*.

Distribution. *Pleuromamma xiphias* was recorded generally between water depth of 100 and 200 m in (sub)tropical of the world oceans (Esterly, 1905; Wolfenden, 1905; Sewell, 1932; Tanaka, 1963; Bradford-Grieve, 1999; Mulyadi, 2004; Prusova et al., 2012) (Fig. 5). The present specimens were collected at a depth of 100 m of the South Sea with water temperature and salinity of about 21.4 ± 2.6°C and 34.2 ± 0.2 psu, respectively.

Remarks. The Korean specimen agrees well with the description of *P. xiphias* by Steuer (1932). *Pleuromamma xiphias* is easily distinguished from other species in the genus by the pointed crest on forehead in both sexes. This species is very similar to *P. abdominalis*, but can be identified by the small denticle on the second segment of female antennule and the less pronounced urosome of male.

Key to species of genus *Pleuromamma* in Korean waters

1. Anterior head with the pronounced pointed process ····· *P. xiphias* (F, M)
1a. Anterior head without the pronounced pointed process·· 2
2. Antennule symmetrical····· 3
2a. Antennule asymmetrical····· 8
3. Fifth leg 3-segmented····· 4
3a. Fifth leg 1- or 2-segmented····· 6
4. First segment of antennule with a large curved denticle ····· *P. abdominalis* (F)
4a. First segment of antennule with a small denticle····· 5
5. Genital swelling on medial part of genital double somite ····· *P. indica* (F)
5a. Genital swelling on anterior part of genital double somite····· *P. robusta* (F)
6. Fifth leg 1-segmented····· 7
6a. Fifth leg 2-segmented····· *P. borealis* (F)
7. Distal segment of fifth leg with 3 apical spines, middle spine the longest····· *P. gracilis* (F)
7a. Distal segment of fifth leg with 3 short stout spines, inner spine the longest····· *P. piseki* (F)
8. Urosome asymmetrical····· *P. abdominalis* (M)
8a. Urosome almost symmetrical····· 9
9. Segment XIX of prehensile antennule with toothed ridge ····· *P. gracilis* (M)
9a. Segment XIX of prehensile antennule without toothed ridge····· 10
10. Chitinous peg on first segment of fifth leg with distal knob····· *P. piseki* (M)
10a. Chitinous peg on first segment of fifth leg without distal knob····· 11
11. Compound segments XXI–XXIII of prehensile antennule with toothed ridge····· *P. indica* (M)
11a. Compound segments XXI–XXIII of prehensile antennule without toothed ridge ····· 12
12. Segment XX of prehensile antennule with a short row of small teeth····· *P. borealis* (M)
12a. Segment XX of prehensile antennule with toothed ridge ····· *P. robusta* (M)

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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