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New records of two *Amphora* taxa from Ulleungdo and Dokdo, Korea

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A study was conducted to investigate the species diversity of the genus *Amphora* in relation to environmental settings in Ulleungdo and Dokdo. Although *Amphora* is one of the most speciose genera in marine habitats, its recorded diversity in Korean waters has been relatively low compared to similar ecosystems. In this study, light microscopy (LM) and scanning electron microscopy (SEM) were employed to examine the morphology and ultrastructure of *Amphora* taxa. Specimens were collected from four stations across intertidal and subtidal habitats. As a result, *Amphora arcuata* and *Amphora bigibba* var. *interrupta* were documented for the first time in Korean waters. *Amphora arcuata* was found at two subtidal sites (20 m depth), whereas *A. bigibba* var. *interrupta* occurred at all four stations, including one intertidal location (0 m depth). These findings contribute to a more comprehensive understanding of *Amphora* biodiversity in Ulleungdo and Dokdo, which harbor unique island ecosystems.

Keywords: *Amphora arcuata*, *Amphora bigibba* var. *interrupta*, diatom, taxonomy, Ulleungdo and Dokdo

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Introduction

Ulleungdo and Dokdo are among the most geologically isolated islands in Korea. Ulleungdo is located 130.3 km from the mainland, while Dokdo is 216.8 km away (Jung *et al*., 2013; Bang *et al*., 2022). Due to their geopolitical significance in the middle of the East Sea, numerous studies have been conducted on these islands (Cha *et al*., 2010; Jung *et al*., 2013; Kim and Kwon, 2013; Hwang and Lee, 2021; Bang *et al*., 2022). However, research on diatoms—the foundation of marine ecosystems—remains limited.

Diatoms contribute to more than 40% of primary production in marine environments (Tréguer *et al*., 2018) and serve as a primary food source for various herbivores, such as gastropods and copepods (Friedrichs *et al*., 2013). To date, over 10,000 diatom species have been identified, with an estimated global diversity exceeding 200,000 species (Mann and Droop, 1996). *Amphora sensu lato* is one of the most species-rich genera in benthic environments, occurring in epiphytic, epipellic, and epilithic habitats (Round *et al*., 1990; Levkov *et al*., 2009).

In Korea, marine *Amphora* was first reported by Choi (1990), and additional species have since been continuously recorded in Korean waters (Park and Koh, 2012; Joh, 2017). *Amphora* species have also been documented in numerous diatom flora studies (Lee *et al*., 1999; Park, 2011; Pandey *et al*., 2018; Kim, 2020). They are widely distributed and commonly found in Korean marine benthic environments.

In the present study, two *Amphora* taxa were recorded for the first time in Korean waters. Detailed observations using light microscopy (LM) and scanning electron microscopy (SEM) were conducted to describe their morphological characteristics.

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Materials and Methods

Sediment samples were collected from Ulleungdo and Dokdo by scraping the top 0−0.5 cm of sediment with a stainless-steel spatula and transferring it into 50 mL Falcon tubes (Fig. 1, Table 1). The samples were immediately fixed with 4% formaldehyde and transported to the laboratory for further processing.

To extract diatom frustules, the sediment samples were sonicated three times to detach the frustules from the sediment matrix. The samples were then treated with hydrochloric acid (HCl) and hydrogen peroxide (H_2O_2) to remove calcium carbonate and organic matter.

The cleaned diatom frustules were dried onto glass coverslips and mounted on glass slides using Naphrax resin to prepare permanent slides. Observations were conducted using a BX53 light microscope (Olympus, Tokyo, Japan), and images were captured with a ZEISS Axiocam 208c digital camera (Carl Zeiss, Oberkochen, Germany). Additionally, a few drops of cleaned frustules were dried onto aluminum stubs, coated with gold, and examined using a field emission scanning electron microscope (FE-SEM, MIRA-3, Tescan, Brno, Czech Republic).

For each station, a total of 500 diatom valves were examined under LM to assess the relative abundance of taxa. Based on this evaluation, representative frustules were selected for high-resolution imaging using LM and SEM to document diagnostic features.

Environmental parameters such as temperature, salinity, and pH were not measured during the sampling process.

Results

This study presents the first record of *Amphora arcuata* and *Amphora bigibba* var. *interrupta* in Korea. Structural features such as outline, raphe system, and striae density of both *Amphora* taxa were examined under light microscopy (LM) at 1000× magnification. Additionally, the ultrastructure of both *A. arcuata* and *A. bigibba* var. *interrupta* was analyzed using scanning electron microscopy (SEM).

Amphora arcuata A.W.F.Schmidt, 1875

Reference. A.W.F.Schmidt, 1875. pl. 26: figs. 27−29.
Description. Valve semi-lanceolate with dorsal margin convex with narrow fascia, ventral margin moderate, valve ends acute and bent dorsal margin with length of 60−68.5 µm and width of 16 µm, Raphe acute follow ventral margin, Striae slightly radiate with 18 per 10 µm, compose with a round to oblong areolae (Fig. 2).

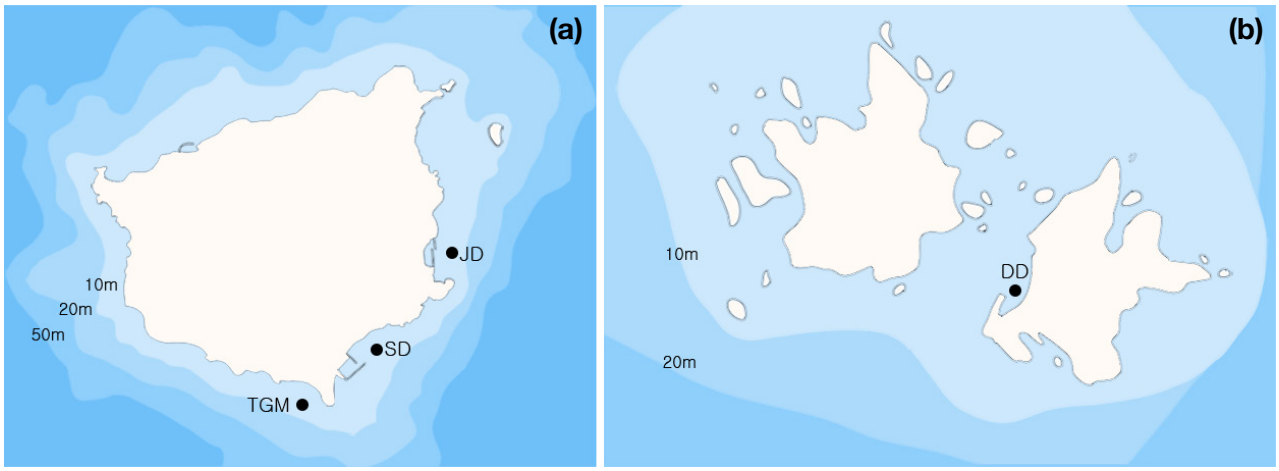

Fig. 1. Map showing the sampling locations on the Ulleungdo (a) and Dokdo (b) where *Amphora bigibba* var. *interrupta* and *A. arcuata* were observed.

Table 1. List of samples which have been analyzed in the present study.

Sampling date	Sites	Location	Latitude (N)	Longitude (E)	Depth (m)	*Amphora arcuata*	*A. bigibba* var. *interrupta*
Nov. 11, 2013	JD	Jeodong-ri, Gyeongsangbuk-do, Korea	37°29′49″	130°55′06″	20	v	v
Nov. 11, 2013	TGM	Namyang-ri, Gyeongsangbuk-do, Korea	37°27′20″	130°52′02″	20		v
Nov. 11, 2013	SD	Sadong-ri, Gyeongsangbuk-do, Korea	37°28′17″	130°53′25″	20	v	v
Jul. 07, 2018	DD	Dokdo-ri, Gyeongsangbuk-do, Korea	37°14′22″	131°52′05″	0		v

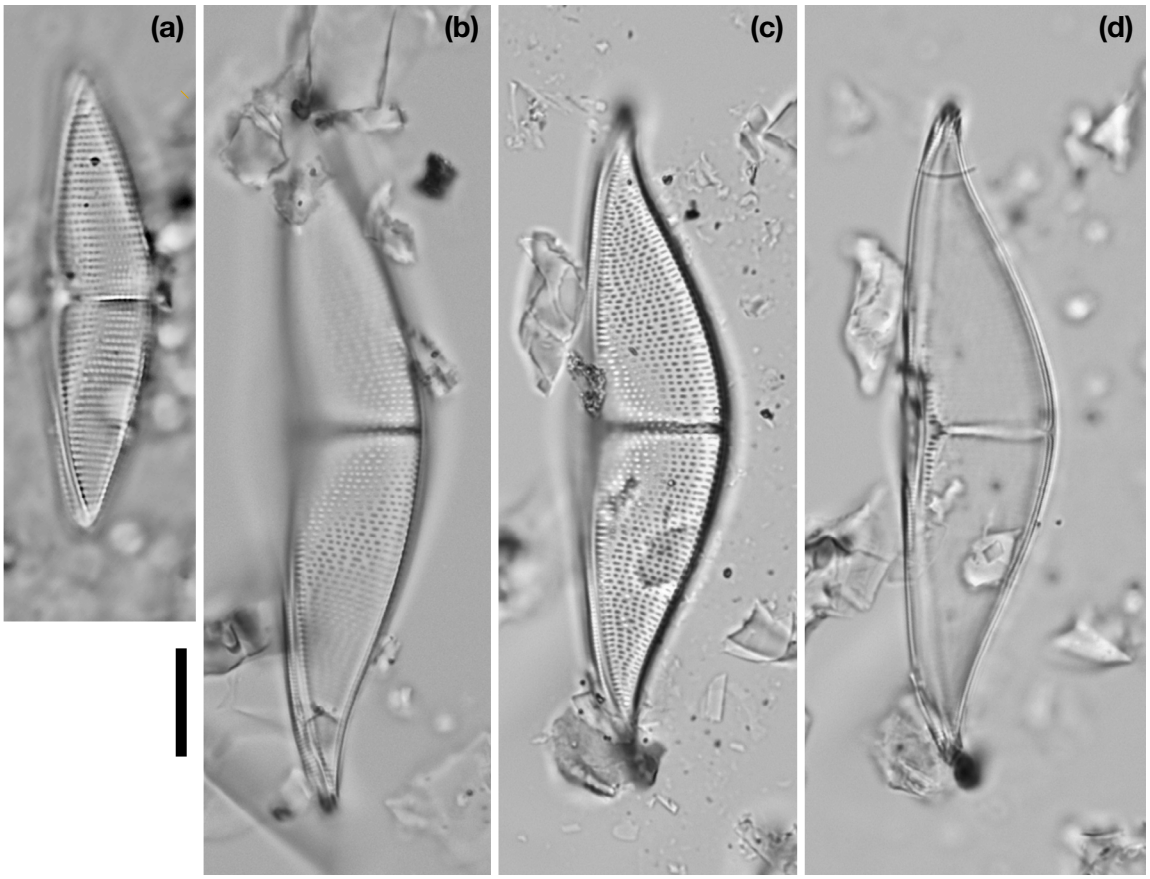

Fig. 2. Light microscope photographs of *Amphora arcuata* from Ulleungdo and Dokdo (a–d). Scale bar: 10 μm.

Taxonomic remarks. *Amphora arcuata* is similar to *A. aspera* Petit with slight differences in valve outline. However, *A. arcuata* has a dorsal valve fascia, whereas *A. aspera* lacks a fascia.

Distribution. *A. arcuata* has been reported from Philippines (Mann, 1925; Martinez-Goss, 2021), Guam (Lobban *et al*., 2012), Britain (Hartley *et al*., 1986), and U.S.A. (Wachnicka and Gaiser, 2007). In the present study, *A. arcuata* was observed from 2 stations in Ulleungdo subtidal zone.

Amphora bigibba var. *interrupta* (Grunow) Cleve, 1895

Reference. Cleve, 1895. pl. 25: fig. 65.

Description. Valves are semi-lanceolate with dorsal margin convex, constricted in middle, with ventral margin straight, protracted in middle, with rostrated apice with length of 17.5–33.5 μm and width of 2.7–3.3 μm (Figs. 4, 5A, C), Raphe straight with both central and terminal fissures hooked toward the dorsal margin in external view (Fig. 3B), whereas internally, the raphe ends simple (Fig. 5C, D). Striae parallel, 20–24 in 10 μm, with areolae that are not resolved under LM (Fig. 4A–F).

Taxonomic remarks. *Amphora bigibba* var. *interrupta* is similar to the original species *A. bigibba*, which also exhibits constriction in the middle of the dorsal margin. However, *A. bigibba* var. *interrupta* has distinctive protraction in the middle ventral margin, yet *A. bigibba*'s ventral margin is straight.

Distribution. *A. bigibba* var. *interrupta* has been recorded from warm water coast in Bosnia-Herzegovina (Hafner *et al*., 2018), U.S.A. (Wachnicka and Gaiser, 2007; López-Fuerte *et al*., 2020), Mexico (López-Fuerte and Siqueiros-Beltrones, 2016), Turkey (Kaleli and Akçaalan, 2021), India (Gupta and Das, 2020), and New Zealand (Harper *et al*., 2012). In the present study, *A. bigibba* var. *interrupta* was observed from 4 stations in Ulleungdo and Dokdo.

Discussion

This study reports two *Amphora* taxa, *Amphora bigibba* var. *interrupta* and *Amphora arcuata*, previously unrecorded in Korean coastal waters. According to the 2024 edition of the Korean National Species List (NIBR, 2024), 59 taxa

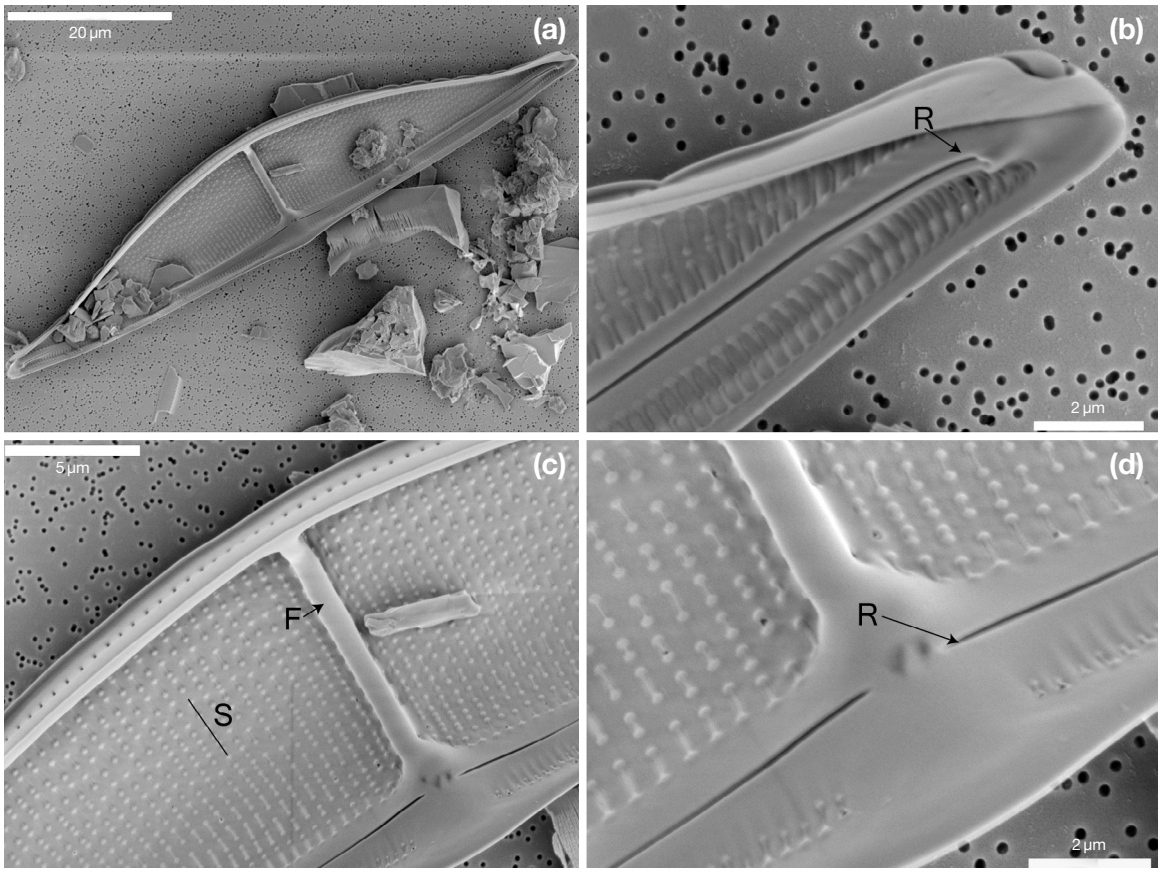

Fig. 3. Scanning electron micrographs of *Amphora arcuata*. (a) Internal view of the entire valve. (b) Terminal raphe fissure, labeled R, showing dorsal deflection. (c) Dorsal fascia (F) and parallel striae (S). (d) Central raphe endings, labeled R, at the mid-valve region.

Table 2. Morphological differences between *A. arcuata* and the related species *A. aspera*.

Characteristic	*A. arcuata*	*A. aspera*
Valve outline	Semi-lanceolate	Semi-lanceolate, gibbous
Valve length (μm)	17.5–33.5	40–85
Valve width (μm)	2.7–3.3	12–18
Dorsal fascia	Present	Absent
Raphe	Straight; ends hooked dorsally (external)/simple internally	Straight, slightly dorsally deflected
Striae orientation	Parallel	Slightly radiate
Striae density (10 μm)	20–24	15–16 (dorsal), 22–24 (ventral)
Areolae resolution in LM	Not resolved	Not resolved
Source	This study	Literature

of *Amphora* have been documented. With the addition of the two taxa described in this study, the total number increases to 61, highlighting the ongoing need to explore and document diatom diversity in Korea's subtidal habitats. Both taxa were identified based on detailed morphological observations using light microscopy (LM) and scanning electron microscopy (SEM), enabling accurate taxonomic resolution.

Amphora bigibba var. *interrupta* was observed at all four sampling stations, including both subtidal sites (JD, TGM, SD) and an intertidal site (DD). This broad spatial distribution suggests that the taxon tolerates a range of ecological conditions. Its occurrence at Dokdo, a site with no apparent subtidal zone, supports previous records that re-

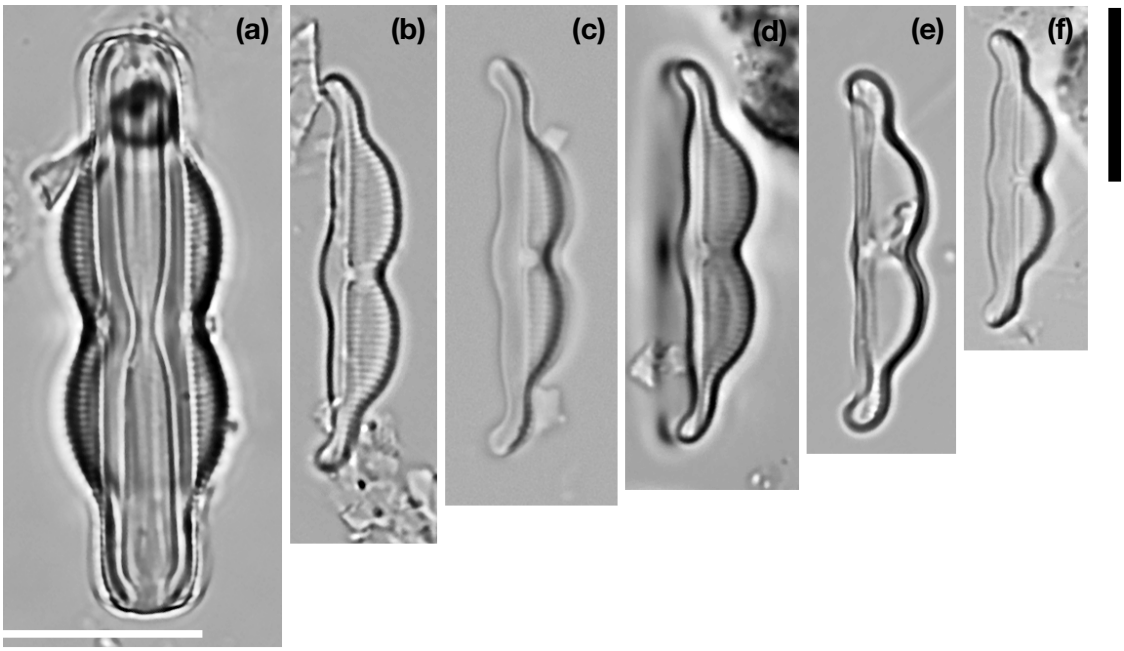

Fig. 4. Light microscope photographs of *Amphora bigibba* var. *interrupta* from Ulleungdo and Dokdo (a–f). Scale bar: 10 μm.

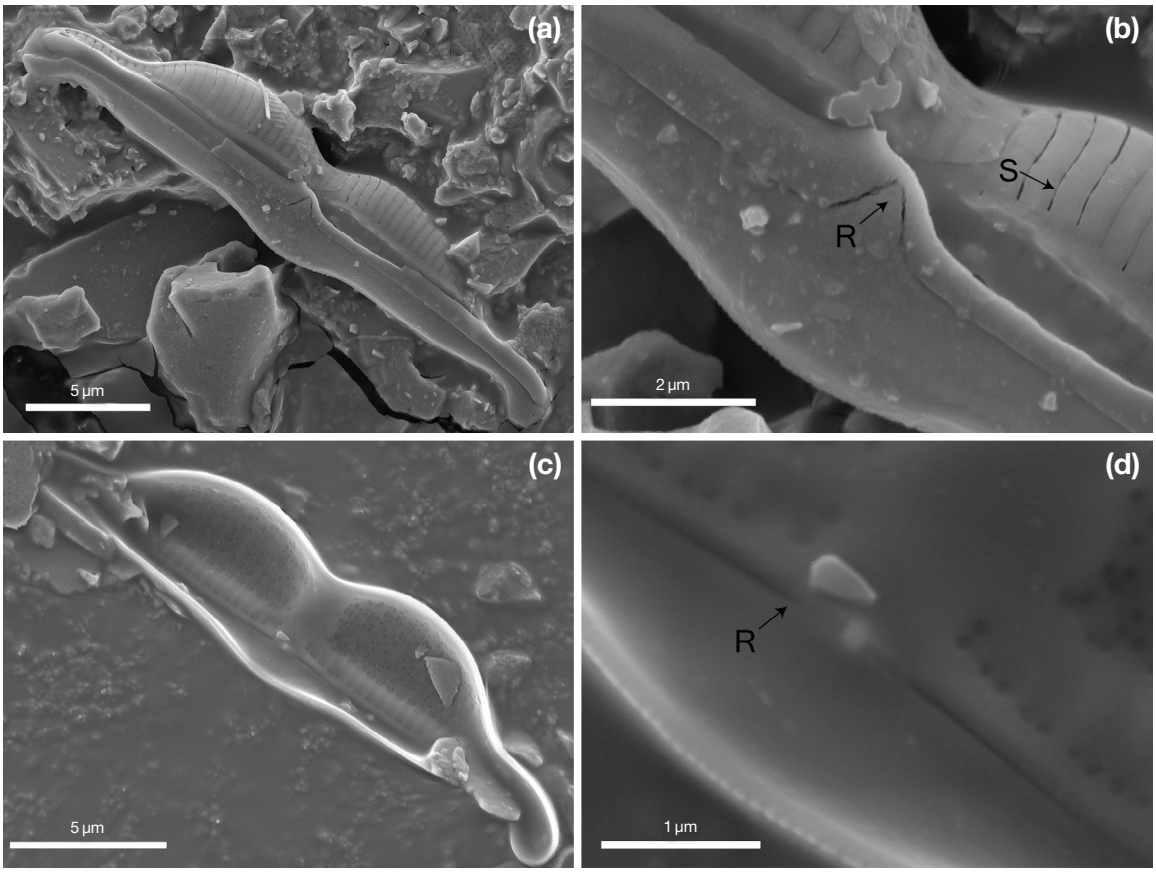

Fig. 5. Scanning electron micrographs of *Amphora bigibba* var. *interrupta*. (a) External view of the entire valve. (b) Terminal raphe fissure (R) and parallel striae (S) on the external valve surface. (c) Internal view of the entire valve. (d) Central raphe endings, labeled R, on the internal valve surface.

gard this taxon as a warm-water species (Witkowski *et al*., 2000). This finding may reflect the influence of the East Korea Warm Current, which transports warm waters northward along the eastern coast of Korea and contributes to the presence of warm-affinity diatoms in offshore areas. The presence of *A. bigibba* var. *interrupta* across diverse habitats, including intertidal zones, may also suggest ecological shifts influenced by regional warming. Such occurrences align with broader trends in diatom biogeography responding to ocean warming, and warrant further investigation under a climate change context.

In contrast, *Amphora arcuata* was found only at two subtidal stations (JD and SD), both sampled at a depth of 20 m. While this distribution suggests a potential ecological association with subtidal environments, the limited number of sites precludes definitive conclusions regarding habitat specificity. Further observations across a broader range of depths and seasons are necessary to clarify its ecological niche. Morphologically, *A. arcuata* closely resembles *A. aspera* Petit, but differs in the presence of a dorsal fascia and a slightly narrower valve outline.

These distinctions support its recognition as a separate taxon and demonstrate the value of high-resolution SEM in distinguishing among closely related *Amphora* species.

Overall, the discovery of *A. bigibba* var. *interrupta* and *A. arcuata* underscores the underappreciated diversity of benthic diatoms in Korean waters, particularly within subtidal environments. This study reinforces the importance of integrating fine-scale morphological techniques and ecological context in taxonomic research, and calls for continued diatom monitoring efforts to uncover additional unrecorded taxa in Korean coastal ecosystems.

It should be noted that no environmental variables such as water temperature, salinity, or nutrient concentrations were recorded during sampling. As a result, interpretations regarding the ecological tolerance or habitat specificity of the identified species remain preliminary. Future studies incorporating environmental data are essential for a more robust understanding of benthic diatom distribution in Korean coastal waters.

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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Taxonomic review of the genus *Bembix* (Hymenoptera: Crabronidae) in Korea

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The Korean species of the genus *Bembix* Fabricius, 1775 are taxonomically reviewed. Two species, *B. nipponica puncticollis* and *B. formosana*, are confirmed. The latter is recorded from Korea for the first time, marking its second record in the Palearctic region. A key to species and descriptions based on Korean material are provided. Additionally, some external features and the presumed current status of *B. formosana* in Korea are discussed.

Keywords: Bembicini, *Bembix formosana*, new record, sand wasps

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Introduction

The genus *Bembix* Fabricius, 1775 is the largest cosmopolitan group within the subfamily Bembicinae (Hymenoptera: Crabronidae). A total of 331 species are currently known worldwide (Pulawski, 2025), including 19 species recorded from the eastern Palearctic region (Nemkov, 2016).

Among the members of Bembicinae characterized by a single apical spur on the mid tibia, a median longitudinal ridge on sternum 1 basally, a long prestigmal portion of the first submarginal cell (well exceeding half the cell length, rendering the stigma comparatively small), an exerted labrum at least as long as broad, and deformed ocelli, species of the genus *Bembix* are comparatively large-sized, robust wasps with abundant whitish to yellowish markings, including distinctly extensive facial markings. The following combination of external features is diagnostic for the genus: in both sexes, anterior ocellus reduced to a curved (arcuate) line, labrum distinctly longer than broad, palpal formula 4-2 (rarely 3-1), sessile metasoma, very tiny stigma, basal veinlet of the second submarginal cell bent ventrally into the first submarginal cell (lower pocket of basal veinlet of submarginal cell 2), hindwing media vein diverging from cu-a at a distance approximately equal to the length of cu-a; in males, tergum 7 with a distinct spiracular lobe.

Species of the genus *Bembix* are solitary wasps, though they often nest in aggregations. Females construct nests by burrowing into sandy soil and progressively provision them with multiple prey items, primarily adults Diptera, including members of Sarcophagidae, Muscidae, Calliphoridae, Syrphidae, and others, as the larva develops (Bohart and Menke, 1976; O'Neill, 2001; Evans and O'Neill, 2007).

In this study, a taxonomic review of the Korean *Bembix* is presented. Until now, only a single species, *Bembix nipponica puncticollis*, has been recorded from Korea. Herein, *B. formosana* is newly recorded from Korea, marking its second occurrence in the Palaearctic region following Yasumatsu and Narisida (1935). Based on Korean material, an identification key and species descriptions, supplemented by illustrations, are provided. Differences in certain external features among the Korean material, Japanese material, and the original description are examined and discussed to support future taxonomic studies. Addi-

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tionally, the need for further research on the conservation status of this species is emphasized.

Materials and Methods

Higher classification follows the treatment of Pulawski (2025). For species or subspecies, references to the original publication of the valid name are provided, together with type information. The rest of the synonymic list includes references that indicate occurrences on the Korean Peninsula based on actual specimens, as well as those that merely mention Korea in the distribution.

The terminology for the general morphology, including the wing veins and cells, follows that of Bohart and Menke (1976). The terminology for the interocular distance in the frontal view is from Evans (1950, Fig. 1)

All measurements were taken as the maximum length of the part being considered. Specimens were measured and photographed (with image stacking) using an image analyzer and a digital camera mounted on a Leica DMS 1000a.

Abbreviations of morphological terms are as follows: F-flagellomere; LID-lower minimal interocular distance; MID-middle maximal interocular distance; S-metasomal sternum; SMC-submarginal cell; T-metasomal tergum; UID-upper minimal interocular distance.

Acronyms for type depositories and institutions are as follows: BMNH - The Natural History Museum, formerly British Museum (Natural History), London, Great Britain; DHU - Dongnam Health University, suwon, South Korea; NIBR - National Institute of Biological Resources, Incheon, South Korea; ZIN - Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia; ZMHU - Zoologisches Museum der Humboldt Universität, currently Museum für Naturkunde der Humboldt Universität zu Berlin, Berlin, Germany.

Abbreviations of Korean province names are as follows: GB - Gyeongsangbuk-do; GW - Gangwon-do; GG - Gyeonggi-do; CN - Chungcheongnam-do; IC - Incheon Metropolitan City; JB - Jeollabuk-do; JN - Jeollanam-do; PN - Pyeongannam-do.

Except a female specimen of *B. fomosana* (NIBRRORX0000006244), all specimens examined herein are currently housed at Insect Collection of DHU (private collection of the author).

Results

Order Hymenoptera
Family Crabronidae Latreille, 1802
Subfamily Bembicinae Latreille, 1802
Tribe Bembicini Latreille, 1802
Genus *Bembix* Fabricius, 1775

Bembix Fabricius, 1775: Characteres Generum, p. [xxiii], no included species. Type species: *Bembex rostrata* of Fabricius, 1781 [=*Apis rostrata* Linnaeus, 1758], designated by Latreille, 1810: 438 (one of three species included in *Bembyx* by Fabricius, 1775: 361). Morice and Durrant (1915: 400) gave the first type species designation for the spelling of *Bembix*.

Bembyx Fabricius, 1775: 361. Lapsus for *Bembix* Fabricius, 1775.

Bembex Fabricius, 1777: 122. Emendation of *Bembix* Fabricius, 1775.

Apobembex Pate, 1937: 9. Type species: *Bembex oculata* of Latreille, 1805 [=*Bembex oculata* Panzer, 1801], by original designation.

Epibembex Pate, 1937: 26. Type species: *Apis rostrata* Linnaeus, 1758, by original designation.

Key to species

♀♀

1. Median part of S2 and apical parts of S3−6 largely smooth and bare (Fig. 1C). Apical half of clypeus yellow (Fig. 1B); T6 black, without marking (Fig. 1A)···· ····· *Bembix formosana* Bischoff
− Entire faces of metasomal sterna, except median linear area of S2, densely punctate and setose, scarcely smooth (Fig. 2C). Clypeus entirely yellow (Fig. 2B); almost entire face of T6 yellow (Fig. 1A)····· ····· *Bembix nipponica puncticollis* (F. Morawitz)

♂♂

1. Metasomal sterna not armed, without longitudinal keels (Fig. 1H); S7 flat, medially without any other structure, and posteriorly prolonged (Fig. 3A, B); apical half of S8 (usually exposed part) spinous (Fig. 2I). F7−9 thickened, but not strongly delated (Fig. 1F, G). Gonostyle in dorsal view curved inward, tapering, and narrow strap-like (Fig. 1J). Apical half of clypeus yellow (Fig. 1E); T6−7 black, without marking (Fig. 1D), at most S6 with evanescent small yellow marking ····· ····· *Bembix formosana* Bischoff
− S2 and S6 medially with shark fin-like keels, that on S6 much smaller than that of S2 (Fig. 2H); S7 with a long triangular, flat, smooth elevation well outlined, but not posteriorly prolonged (Fig. 2H); apical half of S8 sphere head-like (Fig. 2I). F7−11 strongly delated (Fig. 2F, G). Gonosyle parallel-sided, broader and shorter. Clypeus entirely yellow (Fig. 2E); Apical band of T6 and almost entire faces of T7 yellow (Fig. 2D)····· ····· *Bembix nipponica puncticollis* (F. Morawitz)

***Bembix formosana* Bischoff, 1913**

Bembex formosana Bischoff, 1913: 714, ♀, ♂ (syntypes), Taiwan: Takao (ZMHU)

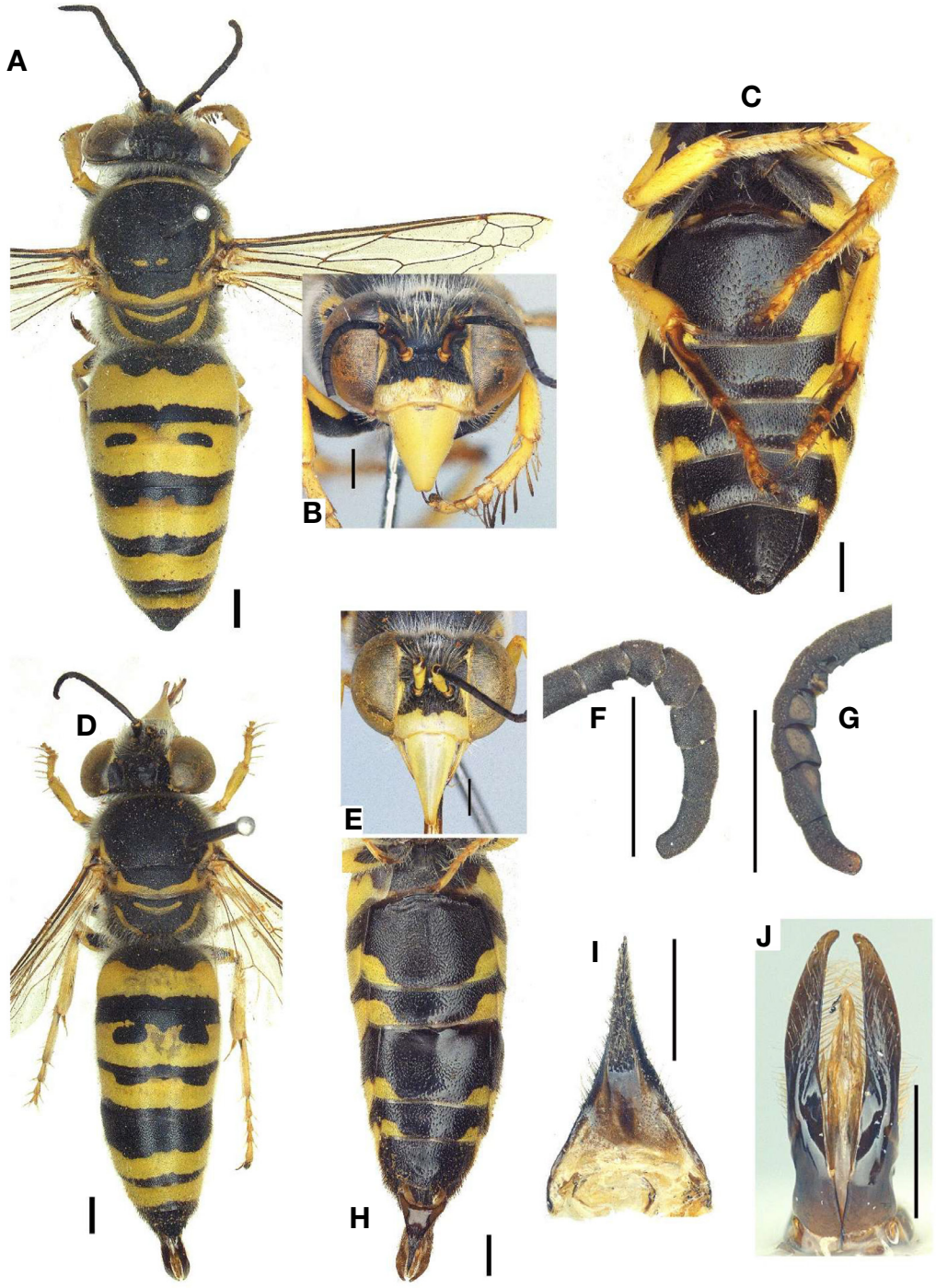

Fig. 1. *Bembix formosana*. A, Whole body in dorsal view, ♀. B, Head in frontal view, ♀. C, Metasomal sterna, ♀. D, Whole body in dorsal view, ♂. E, Head in frontal view, ♂. F, F6–11 in dorsal view, ♂. G, F6–11 in ventrolateral view, ♂. H, Metasomal sterna, ♂. I, S8 in ventral view, ♂. J, Genitalia in dorsal view, ♂. Scale bars: 1 mm.

Description. Female. Body 14.4–17.2 mm long, forwing 9.6–12.0 mm long. Head in frontal view transverse, 1.5 × as broad as high (excluding labrum). F1 4.1 × as long as broad at apex, 1.45–1.50 × as long as F2; F10 weakly depressed laterally in its posterior one-third, in lateral view slightly curved, apical margin obliquely cut, 1.3 × as long as F9. UID : MID : LID = 1 : 0.9 : 1. Clypeus in frontal view 2.0 × as broad as high. Labrum 1.8–1.9 × as long as broad at base. Fore basitarsus in dorsal view almost parallel-sided (its outer posterior corner not

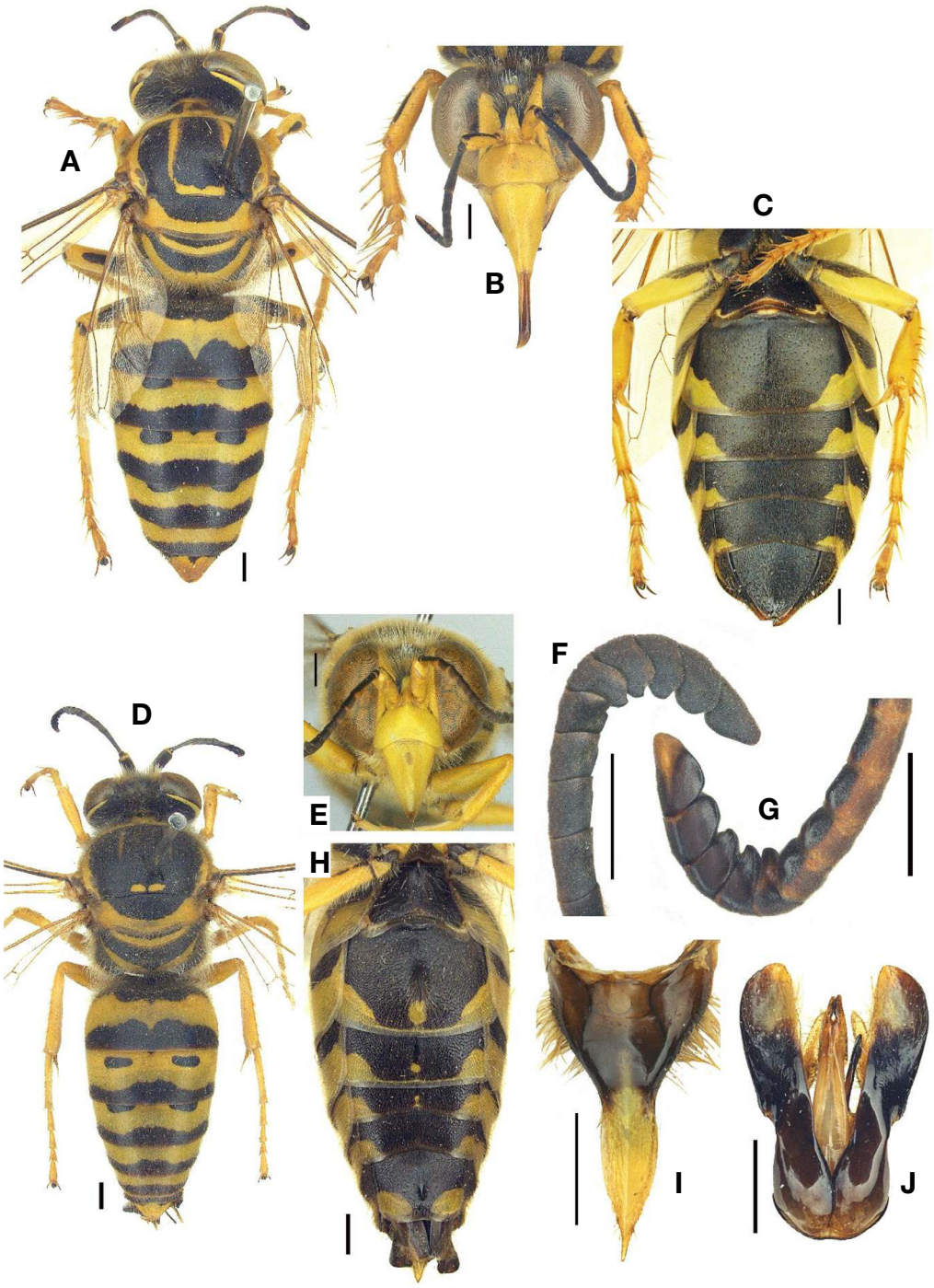

Fig. 2. *Bembix nipponica puncticollis*. A, Whole body in dorsal view, ♀. B, Head in frontal view, ♀. C, Metasomal sterna, ♀. D, Whole body in dorsal view, ♂. E, Head in frontal view, ♂. F, F3–11 in dorsal view, ♂. G, F3–11 in ventral view, ♂. H, Metasomal sterna, ♂. I, S8 in dorsal view, ♂. J, Genitalia in dorsal view, ♂. Scale bars: 1 mm.

distinctly dilated), with rake that are composed of six blade-like spines, first two ones not distinctly flattened but almost cylindrical, first one shortest, and last two ones closest each other.

Wing hyaline, lower pocket of basal veinlet of SM2 shallow, at most as deep as one-fourth of length of anterior veinlet of SMC2.

Body setae primarily whitish, but partially brownish

white especially in mesosoma and metasoma. Frons, vertex and occiput with dense long erect whitish setae; setae on vertex longest. Clypeus with dense (but not conceal tegument) appressed white setae. Mesosoma with dense, long (but shorter than those on vertex), erect, white to brownish white setae. T1−5 primarily with dense, short (much shorter than those on mesosoma, except for those on anterior margin of T1), erect, white setae, partially with dark brown setae especially in their posterior marginal parts; T6 dorsally with moderate, suberect, dark brown setae and laterally with dense, stiff bristles. S1−5 primarily with moderate, suberect, brownish setae, partially with several blackish setae on lateral parts of S3−5; S6 with suberect, blackish brown setae.

Frons with dense (almost touching each other), small, setigerous punctures. Ocellar region with distinct, dense punctures that are larger than those on frons, sloping areas lateral to inner upper half of eyes moderately punctate, but punctures not distinct as in ocellar region. Occiput sparsely to moderately punctate, punctures shallow. Pronotum and propleuron more or less polished without distinct punctures. Scutum, mesopleuron, scutellum, metanotum, propodeal dorsum and propodeal posterior declivity densely punctate, punctures large but shallow, appearing to be clathrate. Metapleuron and propodeal side without distinct punctures, appearing to be weakly clathrate. T1−5 densely punctate, punctures almost touching each other, shallower and smaller than those on mesosoma; T6, except apicomedian part and apical rim, densely punctate, punctures distinctly larger and deeper than those on remainder terga. S1−6 more or less polished, densely punctate laterally but larger posterior median parts of S2−5 and median longitudinal part of S6 sparsely punctate to largely smooth.

Body black and extensively bright yellow in the following parts and markings. Antennal sclerite, spots on antennal scape ventrally, stripes along lower three-fourths of inner orbits (almost touching clypeal marking), apical half of clypeus, labrum, mandible except apical teeth, gena, posterior and sublateral bands of pronotum, anterior half of propleuron, dorsoposterior spot on mesopleuron, posterior half of propodeal side (marking extend to lateral margin of propodeal posterior declivity), posterolateral margin and paired subapical median spots of scutum, lateral and posterior margin of scutellum, posterior margin of metanotum, posterior margin of propodeal dorsum, T1−2 except basal and apical margins (yellow band of T2 with paired inner unmarked black transversely oblong spots), exposed T3−5 except apical margin, lateral spots of S2−5, all legs except coxa, trochanter and basal parts of femur.

Male. Body 16.5−17.5 mm long, forewing 10.5−11.0 mm long. Head in frontal view transverse, 1.5 × as broad as high. F1 3.5 × as long as broad at apex, 1.5 × as long as F2; F7−9 broadened in dorsal view; ventral apical half of F6, ventral parts throughout F7−9 and ventral basal half of F10 excavated; in dorsal view F6 medially edged acutely; apical segment weakly depressed laterally in its posterior one-third, in lateral view slightly curved (more curved than in female) and its apical margin rounded. UID : MID : LID = 1 : 0.9 : 1. Clypeus 2.3 × as broad as long. Labrum 1.7 × as long as broad at base. Mid-femur simple, not serrated or toothed ventrally. S7 posteriorly prologed, with a distict median longitudinal carina and dull ridges parallel to the median carina (Fig. 3A, also refer to Discussion section below).

Wings as in female.

Body setae nearly same as in female, but basolateral part of clypeus with long, erect, whitish setae, in addition to white appressed setae. T1−5 primarily with dense, short (much shorter than those on mesosoma, except for those on anterior margin of T1), erect, white setae, partially with dark brown setae especially in their posterior marginal parts; T6 with moderate, suberect, stiff, dark brown to blackish setae, and laterally (except for apical one-fourth of exposed tergum) with dense, short, black spines. S1−6 primarily with moderate, suberect, brownish setae, partially with several blackish setae on lateral parts of S4−6 (blackish setae more abundant in S6); S7 with long, erect, brownish setae apically curved.

Punctures on head and mesosoma nearly same as in female. T1−6 densely (almost touching each other) punctate, punctures slightly shallower and smaller than those on mesosoma; T7, except larger median area nearly smooth, strongly punctate, punctures spaced by less than puncture diameter and distinctly larger and deeper than those on remainder terga. S1−6 more or less polished, primarily densely punctate, but apicomedian parts of S3−5 and S6 sparsely punctate to largely smooth.

Coloration nearly as in female. But metasomal segment 6−7 entirely black.

Material examined. [South Korea] 2♀♀, Sindu-ri, Wonbuk-myeon, Taean-gun, CN, 2001 ix 1, J-K Kim; ♀, 2♂♂, same as for precedent, 2005 viii 14−15, Tripotin P; ♀, Byeongsunman, Jungjang-ri, Anmyeon-eup, Taean-gun, CN, 2022 vii 18, J-K Kim. [Japan] 2♂♂, Nakano, Iriomotejima, Yayema Is. Ryukyus, 1991 vii 19, Sk Yamane.

Distribution. Korea (CN), Japan (Southern Ryukyus: Iriomote-jima), NE China (southern Manchuria).

Remarks. This species is newly recorded from Korea, marking only the second record of its occurrence in the Palearctic region. The first record was by Yasumatsu and Narisida (1935), who reported it from northeastern China (southern Manchuria: “Chin-chou”).

In the two Japanese male specimens examined herein, S6 bears a pair of apical bands, whereas the Korean specimen lacks any such markings.

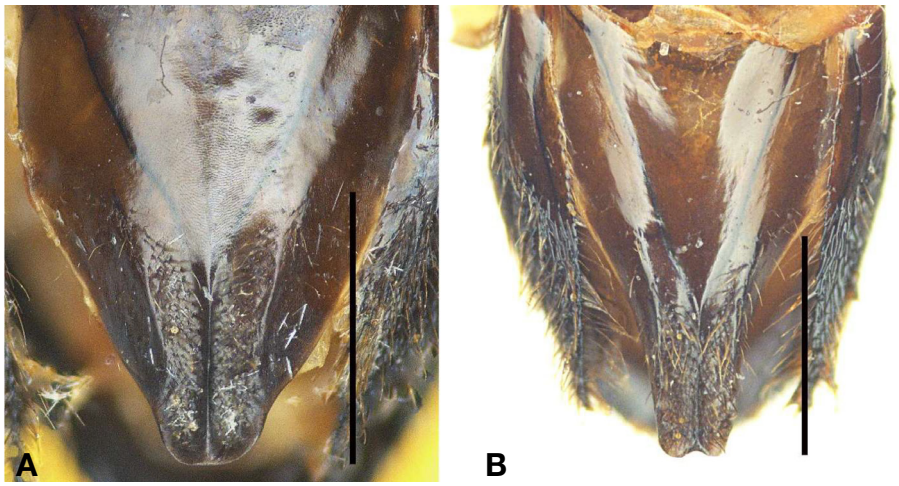

Fig. 3. S7 of *Bembix formosana*, ♂. A, Korean specimen. B, Japanese specimen. Scale bars: 1 mm.

According to the original description of this species, based on Taiwanese specimens, males possess an evanescent median longitudinal ridge on S2. Among the two Japanese specimens examined, one exhibits a very low, smooth, median longitudinal ridge (not keeled), while the other lacks it entirely. In contrast, all Korean specimens have a completely flat S2, at most showing an impunctate smooth longitudinal line. This characteristic appears to be variable and thus lacks diagnostic value.

Morphologically, this species superficially resembles *Bembix oculata*, which is widely distributed in the Palearctic region. However, it can be readily distinguished from *B. oculata* by the hyaline forewings in females, the absence of longitudinal keel on the sterna, and the lack of ventral teeth on the mid-femur in males. In contrast, *B. oculata* is characterized by basally or medially infuscate forewings in females, and longitudinal keels on the sterna and a ventral row of teeth on the mid-femur in males, as noted by Parker (1929) and Nemkov *et al.* (1995).

***Bembix nipponica puncticollis* (F. Morawitz, 1889)**

Bembex nipponica Smith, 1873: 194, ♀, ♂ (syntypes), Japan: Hyogo [BMNH].

Bembix nipponica Smith: Kim, 1970: Pl. 61, Fig. 742, 620 (diagnosis, Korea: GW: Naeseolak), 817 (listed); Kim, 1980: Pl. xx HYBE 01a, 143 (specific name incorrectly as *niphonica*, diagnosis, Korea: GW, GG, JB, JN); Yamane, 1999: 534 (incl. Korea in distribution); Terayama, 2006: 18 (incl. Korea in distribution); Terayama *et al.*, 2016: 17 (incl. Korea in distribution).

Bembex picticollis F. Morawitz, 1889: 144, ♀, ♂ (lectotype ♀, China: Chetschuen [probably Sichuan] (ZIN), designated by Nemkov, 2016: 15). Synonymized with *Bembix nipponica* by Meade-Waldo in Meade-Waldo, Morley, and Turner, 1915: 335 and Nemkov, 2016: 15.

Bembix niponica picticollis (F. Morawitz): Tsuneki, 1965: 27 (new status, in key, incl. Korea in distribution); Kim, 1970: Pl. 61, Fig. 743, 620 (diagnosis, S Korea: GB: Mt. Taebaeksan); Tsuneki, 1974: 361 (North Korea: PN: "Sa-gam"); Tsuneki, 1976: 295–296 (variation in maculation, incl. Korea in distribution); Tsuneki, 1982: 11 (♀, North Korea: PN: Pyeongseong-si: Baekseung-ri: Zamosan), 18 (listed); Paik, 1985: 202 (listed); Tsuneki, 1991: 199 (listed); Nemkov *et al.* (1995) (in key, incl. Korea in distribution); Wu and Zhou, 1996: 15 (incl. Korea in distribution); Nemkov, 2009: 142 (incl. Korea in distribution); Nemkov, 2012: 446 (incl. Korea in distribution); Kim, 2014: 421 (listed with previous Korean records).

Description. Female. Body 17.5–21.0 mm long, forwing 12.0–13.0 mm long. Head in frontal view transverse, 1.5 × as broad as high. F1 4.0–4.3 × as long as broad at apex, 1.9–2.0 × as long as F2; F10 weakly depressed laterally in its posterior one-third, in lateral view slightly curved, apical margin obliquely cut, 1.3 × as long as F9. UID : MID : LID = 1 : 0.9 : 1.1. Clypeus in frontal view 2.1 × as broad as long. Labrum 1.5–1.6 × as long as broad at base. Fore basitarsus in dorsal view almost parallel-sided (its outer posterior corner not distinctly dilated), with rake that are composed of six blade-like spines, first one shortest, and 5th and 6th ones closest each other.

Wing hyaline, lower pocket of basal veinlet of SMC2 often deep, almost as deep as half the length of anterior veinlet of SMC2.

Body primarily with erect, pale yellow to yellowish brown setae, but those on occiput, mesopleuron, propodeum, T1 and S1 paler, whitish to whitish-yellow; setae on head (except clypeus and labrum), ventral part of mesosoma, T1 and S1 much longer than those on remainder body parts. Clypeus with moderate to dense, suberect,

yellow setae laterally, larger mid triangular area nearly bare. S2−6 with both dense (but not obscure tegument), appressed, brassy setae and suberect longer setae, longer setae densest in S2. T6 laterally with thick, black spines in its basal half.

Frons (except inter-antennal area) and ocellar region with dense, small, setigerous punctures. Clypeus except median triangular area densely punctate, punctures shallow, not distinct. Occiput sparsely to moderately punctate, punctures shallow, not distinct. Pronotal dorsum and side (except lateral lobe) and propleuron more or less polished without distinct punctures. Pronotal lobe, scutum, mesopleuron, scutellum, metanotum, propodeal dorsum and propodeal posterior declivity densely punctate, punctures large but shallow, appearing to be clathrate. Metapleuron and propodeal side without distinct punctures, appearing to be weakly clathrate. T1−5 densely punctate, punctures almost touching each other, shallower and smaller than those on mesosoma; lateral part of T6 densely punctate, punctures larger and deeper than those on remainder terga, larger apicomedian part of S6 with punctures shallower and sparser than those on lateral part. S2−6 with dense, setigerous punctures and pores, scattered with larger punctures; larger punctures on S6 denser than those on S2−5.

Body black and extensively bright yellow in the following parts and markings. Antennal sclerite, scape except dorsal black line, flagellomeres ventrally, clypeus, labrum, thick inner orbital lines continue to clypeal marking, longitudinal inter-antennal bar continue to clypeal marking, mandible except for apical one-third, posterior dorsal band of pronotum and its paired longitudinal thick bars extending to neck, propleuron except anterior part, oblique thick bar in posterior half of mesopleuron, two large spots on metapleuron (upper spot larger than lower one), lateral marginal lines and a large median U-shaped marking of scutum (sometimes interrupted in its posterior corners to completely lacking), posterior and lateral margins of scutellum, posterior and lateral margins of metanotum, spot on upper anterior part and posterior two-thirds of propodeal side, posterior margin of propodeal dorsum, posterior part of propodeal declivity, median thick transverse bands of T1−5, yellow band of T2 often with a pair of inner black spots, almost entire face of T6, posterolateral spots on T1−5, all legs except small basal parts of femur (black part larger in hind femur) and inner linear faces of tibiae.

Male. Body 17.5−19.5 mm long, forewing 12.5−13.5 mm long. Head in frontal view transverse, 1.4 × as broad as high. F1 4.1 × as long as broad at apex, 2.3 × as long as F2; F2−6 ventrally tuberculate; F7−11 distinctly dilated as described in key above, and ventral apical one-third of F6 (shortly spinous on basal border of excavation in dorsal view) and entire ventral faces of F7−11 excavated. UID : MID : LID = 1 : 0.9 : 1.1. Clypeus in frontal view 2.3 × as broad as high. Labrum 1.5−1.6 × as long as broad at base. Mid-femur ventrally toothed, teeth variable in shape (spinose to triangular) and size.

S2 and S6 medially with longitudinal keels and S7 with a flat elevation as described in key above; apical margin of S7 notched; S8 apically sphere head-like as described in key above. Rake in fore basitarsus nearly as in female.

Wings as in female.

Body setae nearly same as in female, but setae on S2−8 suberect, and yellowish to yellowish golden.

Punctures on head and mesosoma nearly as in female. But punctures on clypeus often much sparser. T1−6 densely punctate, punctures almost touching each other, shallower and smaller than those on mesosoma; T7 except apicomedian part and marginal rim densely punctate, punctures spaced by less than puncture diameter, distinctly larger and deeper than those on remainder terga. S1−6 densely punctate; S7 moderately punctate, punctures larger and slightly deeper than those on remainder sterna.

Coloration nearly as in female. In addition to markings in female, following parts yellow. T6 also with median thick transverse band; T7−8 almost entirely yellow; legs almost entirely yellow, only coxa and small dorsal parts of trochanter and femur not marked. F1−6 and apical segment ventrally reddish yellow to ferruginous.

Material examined. ♀, Han-taek-sik-mul-won, Jangpyeong-ri, Baekyang-myeon, Yongin-si, GG, 2002 ix 3 YB Lee; 3♀♀, Seonyoudo, Gunsan-si, JB, 2003 vii 31, Tripotine; ♀, ♂, Gamdun1-ri, Nam-myeon, Inje-gun, GW, 2005 viii 5, Tripotin; ♂, Yonsei Univ., Maeji-ri, Heungeop-myeon, Wonju-si, GW, 2003 vii 13, OY Lim; ♀, same as for prceding, 2007 viii 1 DS Choi & JS Lim; ♂, same as for preceeding, 2011 vii 20, HS Lee *et al*.; 6♀♀, 2♂♂, Guleopdo, Onjin-gun, IC, 2010 vii 12, HL Cho, JK Kim, HH Ha, EY Jeong; 7♀♀, Jebudo, Seosin-myeon, Hwaseong-si, GG, 2010 viii 15, JK Kim; ♀, Myeongho-ri, Hyeonnae-myeon, Goseong-gun, GW, 2011 viii 29, JK Kim; 3♀♀, Sohwang-ri, Ungcheon-eup, Boryeong-si, CN, 2018 vii 20, OC Kwon; ♀, Sindu-ri, Wonbuk-myeon, Taean-gun, CN, 2005 viii 14, Tripotin; 5♀♀, 10♂♂, same as for preceding, 2018 vii 20, JK Kim, OC Kwon.

Distribution. Korean Peninsula (PN, GW, GG, IC, GB, JN, JB), Russia (Krasnoyarskii Krai, Buryatiya, Amurskaya Oblast, Khabarovskii Krai, Primorskii Krai), Kazakhstan, Uzbekistan, Turkmenistan, Mongolia, China (Qinghai, Sichuan, Inner Mongolia, Heilongjiang, Liaoning, Beijing, Tianjin); nominotypical subspecies in Japan (Honshu, Kyushu, Ryukyu) and Taiwan.

Remarks. I dug up a nest of this species in a sand dune of Sinduri (South Korea: Taean-gun) in 2018. All of the

prey items were exclusively *Eristalis cerealis* (Diptera: Syrphidae).

Discussion

The external features of the Korean male specimens identified as *B. formosana* are almost identical to those of the Japanese *B. formosana*, with the only noticeable difference being the shape of the apical part of S7, as shown in Fig. 3. The images illustrate the extremes of this variation, from the shortest to the longest posterior prolongation. In Japanese males, the posterior prolongation of S7 is longer, and slenderer, with a notched apical margin (Fig. 3B). In contrast, the Korean specimens exhibit a shorter and broader prolongation with a truncated apical margin (Fig. 3A).

However, the length-to-breadth ratios of the posterior prolongation of S7 are not consistent, showing slight variation within both Korean and Japanese specimens. This suggests that the characteristics requires further examination with a larger sample size. Only four specimens are compared herein. Ultimately, as no differences were observed in coloration (particularly on clypeus and metasomal segments 6−7), the shape of the genitalia, S8 and antennal flagellomeres, I confirm the Korean specimens as *B. formosana* herein. To establish a definitive identification of the Korean form, a future molecular comparison is highly recommended.

Bembix formosana is listed as *Near Threatened* in Japan (Ministry of the Environment, Japan, 2012, 2020), and the same conservation status likely applies to the Korean population. As detailed in the *Materials Examined* section, only five Korean specimens of this species are currently known. Since first observing *B. formosana* in Korea in 2001, I have collected only one additional specimen, from a sand dune habitat along the mid-western coast (South Korea: CN: Taean-gun: Byeongsulman) in 2020. Despite repeated efforts to collect additional specimens in various sand dune habitats, including Sinduri where I first encountered the species, no further individuals have been found, suggesting that the species is extremely rare and possibly restricted to very specific localities. The other three specimens from Sinduri, included in this study, were also collected nearly two decades ago, in 2005, and were recently donated by Pierre Tripotin. This extreme rarity highlights the urgent need for further research into the current status of sand-dwelling wasps in Korea, as also emphasized by Kim (2021).

Conflicts of Interest

The author of this paper has no affiliation with any interests and is solely responsible for the paper.

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First record of the genus *Lycaea* (Amphipoda, Hyperiidea, Lycaeidae) from Ulleungdo Island, Korea, with description of newly recorded species, *Lycaea pulex*

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This study aims to discover and document amphipods from Korea, contributing to the clarification of the Korean amphipod taxonomy. As part of this effort, a newly recorded species of the lycaeid amphipod genus *Lycaea* Dana, 1852 was collected during a survey of Ulleungdo Island, Korea, conducted in the spring of 2023. The newly recorded species, *Lycaea pulex* Marion, 1874, is characterized by the structure of the propodus on both gnathopods and the inner ramus of uropod 2. This species is morphologically similar to *L. bovallii* Chevreux, 1900, *L. intermedia*, Zeidler, 2021, and *L. vincentii* Stebbing, 1888. However, it can be distinguished from its congeners by differences in peduncular article 3 of antenna 1, the length ratio of pereopod 4, and the morphology of the inner ramus of uropod 2. To date, only one species of the family Lycaeidae, *Simorhynchotus antennarius* (Claus, 1871) has been recorded in Korea. This study represents the first record of the genus *Lycaea* in Korean waters. Additionally, a key to species of the family Lycaeidae from Korean waters is provided.

Keywords: Crustacea, hyperiid, lycaeid, plankton, taxonomy

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Introduction

The family Lycaeidae Claus, 1879 can be distinguished from other families within the superfamily Platysceloidea Spence Bate, 1863 by fused inner ramus of uropod 3 and fused urosomites 2–3 with telson (Zeidler, 2016). To date, two genera within the family Lycaeidae, *Lycaea* Dana, 1852 and *Simorhynchotus* Stebbing, 1888 have been recorded worldwide (Horton *et al*., 2025). The genus *Lycaea* consists of ten species and is characterized by a rounded head in both males and females (Zeidler, 2021). The genus *Simorhynchotus* remains monotypic and is distinguished by a rounded head in females, and a slightly produced head in males.

The genus *Lycaea* still presents many taxonomic challenges that require resolution (Zeidler, 2016). It has been studied by various scholars, beginning with Dana, 1879, followed by Harbison, Vinogradov, and others. Harbison and Madin (1976) and Vinogradov *et al*. (1982; 1996) attempted to resolve some of the taxonomic issues within the genus and compiled a key to *Lycaea* species. However, due to the limited availability of specimens and references in the study by Harbison and Madin (1976), discrepancies remain between their findings and those of Vinogradov *et al*. (1982; 1996) (Zeidler, 2016). The genera *Pseudolycaea* Claus, 1879 and *Metalycaea* Stephensen, 1925 have been synonymized with *Lycaea*. As a result, following the synonymization of species within the genus *Lycaea*, a total of ten species are currently recognized worldwide. Recently, Zeidler (2021) provided descriptions and illustrations for

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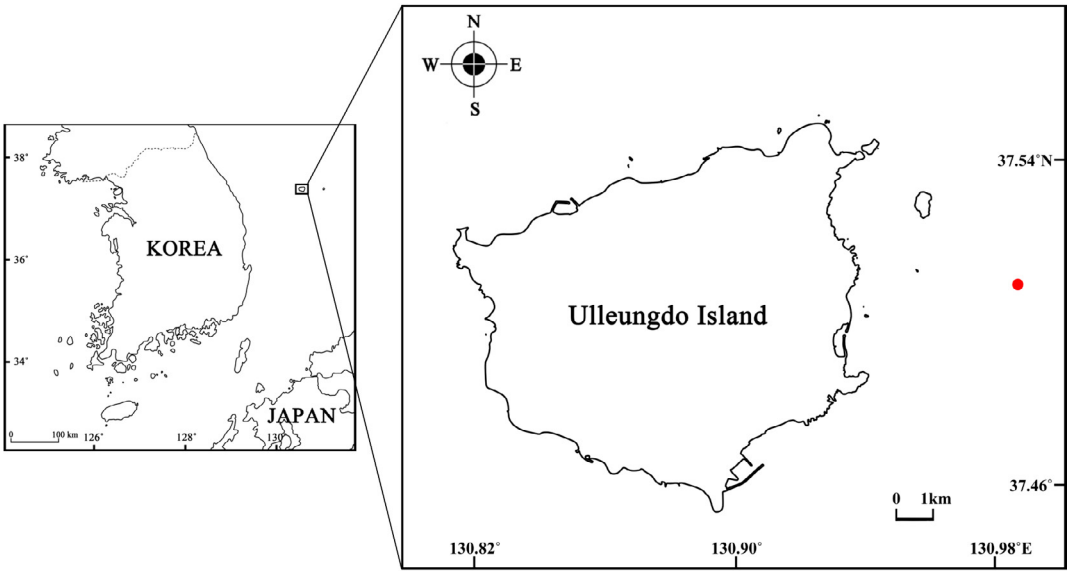

Fig. 1. Distribution of the *Lycaea pulex* (●: Ulleungdo Island).

all species, along with a key to *Lycaea* species.

Currently, only one genus and one species of Lycaeidae have been recorded in Korean waters: *Simorhynchotus antennarius* (Claus, 1871) (Yoo, 1972). In contrast, a total of six species belonging to two genera have been reported from Chinese waters adjacent to Korea, including five species of *Lycaea* and one species of *Simorhynchotus* (Shih and Chen, 1995; Lin *et al*., 1996). Although the genus *Lycaea* Dana, 1852 had not previously been recorded in Korea, specimens of *Lycaea* were collected during a survey conducted around Ulleungdo Island, Korea, in the spring of 2023 (Fig. 1). This paper represents the first record of the genus *Lycaea* in Korea, adding a newly recorded species to the Korean hyperiid amphipod fauna. Furthermore, this study also provides a key for identifying species of the family Lycaeidae found in Korean waters.

Materials and Methods

Specimens were collected using a conical net from subtidal waters around Ulleungdo Island, Korea (Fig. 1). The specimens were fixed in 95% ethanol and dissected in glycerol on Cobb's aluminum hole slides. The materials were examined under stereoscopic microscope (Olympus SZX 10) and compound microscope (Olympus BX 51). Drawings and measurements were made with the aid of a drawing tube and line drawings were produced using the program Clip Studio Paint (Celsys, Japan). Body length was measured from the tip of the rostrum to the end of the urosome, along the dorsal parabolic line of the body. The examined specimens are deposited at the Marine Biodiversity institute of Korea (MABIK) in Seocheon, Korea.

Systematic Accounts

Order Amphipoda Latreille, 1816
Suborder Hyperiidea H. Milne Edwards, 1830
Superfamily Platysceloidea Spence Bate, 1862
Family Lycaeidae Claus, 1879
Genus *Lycaea* Dana, 1852 이리옆새우속 (신칭)

***Lycaea pulex* Marion, 1874 (Figs. 2, 3)**
이리옆새우 (신칭)

Lycaea pulex Marion, 1874: 13, pl. 2, fig. 2; Stebbing, 1888: 1567; Harbison and Madin, 1976: 167, figs. 1B, 3C, 4E; Madin and Harbison, 1977: 455, fig. 4; Vinogradov *et al*., 1982: 382; Vinogradov *et al*., 1996: 472; Zeidler, 2016: 48, figs. 18–20; Zeidler, 2021: 34, figs. 16–17.

Lycaea robusta Claus, 1879: 186; Harbison and Madin, 1976: 169.

Lycaea similis Claus, 1879: 185; Harbison and Madin, 1976: 169.

Lycaea pauli Stebbing, 1888: 1566; Harbison and Madin, 1976: 169.

Material examined. 1♂, dissected (appendages on one slide), MABIK CR00259138, Ulleung Island, 37°30′29″ N, 130°58′11″E, 24 May 2023 by KW Kim.

Description. Adult male (MABIK CR00259138), body (Figs. 2, 3A) 8.9 mm long, dorsally smooth. Head ovate, slightly deeper than long, length slightly longer than pereonites 1–3 combined; eyes well developed, covering most of head, grouped in one field on each side of head. Urosomite 2 fused with urosomite 3.

Antenna 1 (Fig. 3B), peduncular article 3 expanded with-



Fig. 2. *Lycaea pulex* Marion, 1874, adult male, 8.9 mm, habitus. Scale bar = 1.0 mm.

out anterodistal corner, posterodistal corner slightly produced, flagellum 3-articulate, terminal article with 3 setules. Antenna 2 (Fig. 3C) elongate, strongly zig-zagged, 4-articulate, most articles fold back on each other.

Gnathopod 1 (Fig. 3D) characteristic in form, carpochelate; basis expanded, subrectangular, anterior margin with pouch; ischium short, 0.27× basis; merus short, 0.93× ischium; carpus trapezoidal, 1.74× merus, anterior margin convex, posterodistal corner acutely produced and serrulated along its margin; propodus subrectangular, 1.19× carpus, anterior margin convex, palm short, transverse; dactylus falcate, relatively slender, 0.53× propodus.

Gnathopod 2 (Fig. 3E) similar to gnathopod 1, but basis elongate.

Pereopod 3 (Fig. 3F) slender; coxa expanded, wider than long; basis elongate, slender, subrectangular; ischium short, 0.18× basis, anterior margin concave; merus 2.91× ischium, anteroproximal margin slightly concave; carpus subrectangular, 0.83× merus; propodus slender, slightly narrowing distally, 1.15× carpus; dactylus falcate, short, 0.21× propodus.

Pereopod 4 (Fig. 3G) similar to pereopod 3, but slightly elongated.

Pereopod 5 (Fig. 3H), basis elongate-ovate, expanded posteriorly; ischium trapezoidal, short, 0.27× basis, posterior margin concave; merus elongate, moderate, 2.24× ischium; carpus subrectangular, 0.85× merus; propodus relatively slender, 1.21× carpus; dactylus narrow, falcate, short, 0.16× propodus.

Pereopod 6 (Fig. 3I) similar to pereopod 5, but merus to propodus shorter, carpus and propodus, anterior margins with serrulation.

Pereopod 7 (Fig. 3J) short, reduced in size, all articles present; basis large, subovate, expanded posteriorly; ischium short, 0.13× basis; merus short, 1.06× ischium; carpus subrectangular, 1.31× merus; propodus 0.93× carpus, anterodistal corner produced, posterior margin slightly curved; dactylus falcate, relatively short and slender, 0.27× propodus.

Uropod 1 (Fig. 3K), peduncle subrectangular, widening distally, lateral margin with serration; outer ramus lanceolate, 0.52× peduncle, medial and lateral margins with serration; inner ramus lanceolate, subequal in length to outer ramus, medial and lateral margins with serration.

Uropod 2 (Fig. 3K) shorter than uropod 1, peduncle subrectangular, widening distally, medial margin with serration; outer ramus lanceolate, 0.87× peduncle, medial margin with serration; inner ramus characteristic in form, lanceolate, 1.33× outer ramus, medial and lateral margins with serration.

Uropod 3 (Fig. 3K) shorter than uropod 2, peduncle fused with inner ramus; outer ramus lanceolate, slender, 1.83× peduncle, medial margin with serration; inner ramus lanceolate, 1.51× outer ramus, lateral and medial margins with serration.

Telson (Fig. 3K) fused with urosomite 3, entire, elongate, isosceles triangle in shape, unarmed.

Distribution. Worldwide.

Remarks. *Lycaea pulex* Marion, 1874 is similar to *L. bovallii* Chevreux, 1900, *L. intermedia*, Zeidler, 2021, and *L. vincentii* Stebbing, 1888 in having produced posterodistal corner on the carpus of gnathopods 1–2. However, *L. pulex* can be distinguished from its congeners by the following features (different characteristics of *L. bovallii*, *L. intermedia*, and *L. vincentii* in brackets): 1) in males, peduncular article 3 of antenna 1 without anterodistal corner (vs. with anterodistal corner in *L. bovallii* and *L. vincentii*); 2) gnathopods 1–2, posterodistal corner with serrulation (vs. without serrulation in *L. intermedia*); 3) pereopod 4, dactylus short, about 0.2× propodus (vs. more than 0.4× propodus in *L. bovallii* and *L. vincentii*); 4) uropod 1, outer ramus moderate, about 0.5× peduncle (vs. short, about 0.3× outer ramus in *L. bovallii*, *L. intermedia*, and *L. vincentii*); and 5) uropod 2, inner ramus articulated with peduncle (vs. fused in *L. bovallii* and *L. intermedia*). Our specimen is accorded with the original descriptions provided by Marion (1874) and later revisions by Zeidler (2016; 2021).

Key to species of the family Lycaeidae from Korean waters

– Head slightly produced and pointed in male, rounded in female; gnathopod 1 simple; uropod 2, inner ramus fused with peduncle ····· ····· *Simorhynchotus antennarius* (Claus, 1871)

– Head rounded in male and female; gnathopod 1 subchelate; uropod 2, inner ramus articulated with peduncle····· ····· *Lycaea pulex* Marion, 1874

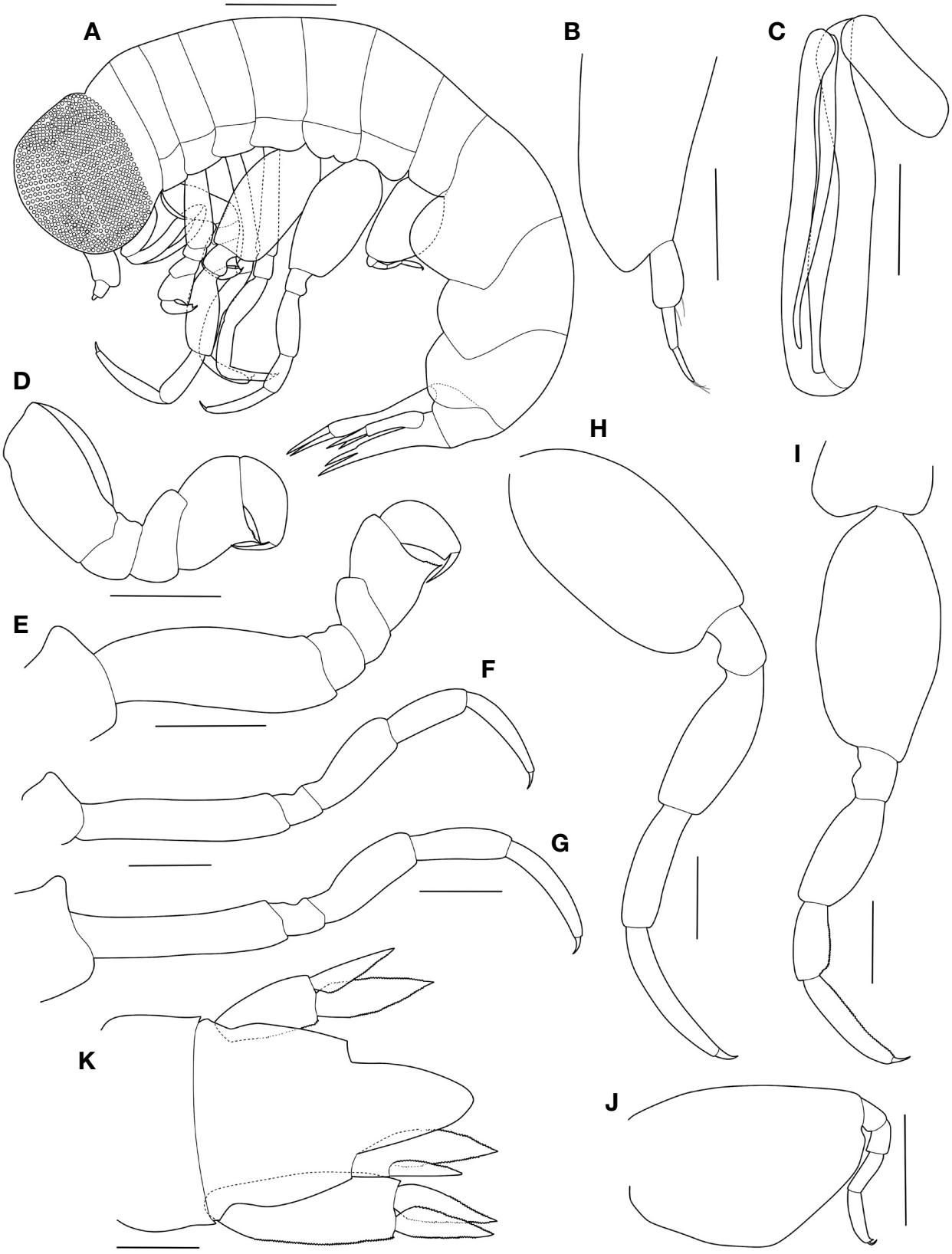

Fig. 3. *Lycaea pulex* Marion, 1874, adult male, 8.9 mm. A, habitus, lateral; B, antenna 1; C, antenna 2; D, gnathopod 1; E, gnathopod 2; F, pereopod 3; G, pereopod 4; H, pereopod 5; I, pereopod 6; J, pereopod 7; K, urosomites, uropods and telson, dorsal. Scale bars: A = 1.0 mm; C−K = 0.4 mm; B = 0.2 mm.

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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New records of eighteen invertebrate species from South Korea: Ciliates, copepods, ostracods, rotifers, and oligochaetes

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During the field survey to explore invertebrate diversity in South Korea, we identified eighteen species from various habitats (terrestrial, freshwater, and saline water), all new records for the country. These include two ciliates, two copepods, eight ostracods, three rotifers, and three oligochaetes, representing four invertebrate phyla. The specimens were taxonomically examined using taxon-specific methods, such as silver impregnation, staining, dissection, and scanning electron microscopy. This study provides morphological descriptions, remarks, and micrographs and/or illustrations for each species.

Keywords: Ciliophora, Harpacticoida, Podocopida, Bdelloidea, Naididae

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Introduction

Korea's biodiversity has officially exceeded 60,000 species, largely due to substantial government support (National Institute of Biological Resources, 2023). Among these, 10,754 species are invertebrates (excluding insects), and 2,575 species are protozoa. However, many species, including new ones, remain undiscovered. Foissner *et al.* (2008) estimated that 83–89% of ciliate diversity is still undescribed. Furthermore, Bae *et al.* (2021) suggested that approximately 100,000 species may inhabit Korea.

As part of the ongoing project 'Discovery of Korean Indigenous Species' led by the National Institute of Biological Resources (NIBR) under the Ministry of Environment (Chae *et al.*, 2023), we conducted field surveys and discovered eighteen invertebrate species newly recorded in South Korea. These species belong to four phyla and were taxonomically examined using taxon-specific methods. In this study, we provide morphological descriptions, remarks, and micrographs for each species.

Materials and Methods

Ciliates. The two species were collected from coastal waters, the detailed locality information is provided in the "Material examined" section for each species. The sample was transferred to the laboratory and incubated in Petri dishes. Cells were isolated from the raw culture and transferred into six-well plates containing 0.2 μm-filtered seawater and small pieces of mealworms to establish clonal cultures. They were examined using a stereomicroscope (Olympus SZ11, Japan) and light microscopes (Olympus BX53, Japan), under bright-field and differential interfer-

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ence contrast (DIC) at magnification ranging from 50× to 1000×. Synthesized protargol powder (Kim and Jung, 2017) and wet silver nitrate impregnation were used to reveal the ciliary pattern, nuclear apparatus, and silverline system (Corliss, 1953; Foissner, 2014).

Copepods. *Arenosetella bidenta* was collected from the sandy bottoms of shallow water and *Eupelte simile* was obtained from algal beds using a light trap. All specimens were fixed in 95% ethanol. In the laboratory, the samples were sorted under an Olympus SZ11 (Japan) stereo microscope. Specimens were cleared, dissected, drawn, and measured in glycerin. All drawings were prepared using a drawing tube on an Olympus BX53 (Japan) differential interference contrast microscope equipped with Nomarski optics.

Ostracods. Samples were collected at the intertidal, using the algae rinsing method: a bucket was filled with algae and sea water, stirred, and filtered through a 63 μm mesh hand-net. All samples were placed in 250 mL plastic bottles and fixed in 99% ethanol. Sorting was done under a stereomicroscope (Olympus SZX12, Japan) in the laboratory of Hanyang University. SEM photographs of representative valves were taken at Eulji University with Hitachi S-4700 (Japan), after platinum coating. Identifications were done using various publications on the East Asian ostracod fauna (Ishizaki, 1968; Okubo, 1980; 1988; etc.).

Rotifers. The samples were collected from lichens, mosses, mushrooms, soil and tree barks at three different locations in Korea as detailed in the material examined section of each species. The bdelloids were extracted from samples according to a previously described method (Song, 2014). We examined and identified all of the living bdelloids under a light microscope with a magnification of 400× to 600×. The photography and motion records of living specimens were performed using an Infinity 2 digital camera (Lumenera Corporation, Canada). Measurements were made by using GIMP 2.8 (the GNU Image Manipulation Program, USA). The specimens were killed with head, foot, and toes extended, by using the boiling water fixation method (Edmondson, 1959) instead of narcotization as previously described (Song and Min, 2015). The classification scheme is based on those of Melone and Ricci (1995) and Segers (2002).

Oligochaetes. Samples were collected from fine, organic-rich sand and mud sediments in freshwater areas. The collection was carried out at the waterside using shovels and hand nets, and the samples were transported alive to the laboratory. The decision to transport live specimens was made to enable their distinction from other similar organisms and oligochaetes in the sample, in addition to observation of their biological characteristics in their live state. The live oligochaetes were sorted under a dissecting microscope using a Leica S9i research microscope fitted with a Leica DMC2900 Camera & SW Kit (Leica, Wetzlar, Germany). Subsequently, they were fixed in 10% formalin and 80% ethanol. Specimens were initially stained with a 10% formalin solution mixed with Rose Bengal, followed by borax carmine through a series of alcohol solutions and finally mounted in Canada balsam (Ersèus, 1993). Morphological observations and measurements were performed using a BX41 research microscope fitted with an Olympus DP73 camera system. Images were edited with the InnerViewTM-i series image analysis software (Innerview Co. Ltd, Gyeonggi-do, South Korea).

Results and Discussion

Phylum Ciliophora Doflein, 1901 섬모충문
Class Spirotrichea Bütschli, 1889 선모강
Subclass Euplotia Jankowski, 1979
Order Euplotida Small and Lynn, 1985 자라하모충목
Family Euplotidae Ehrenberg, 1838 자라하모충과
Genus *Euplotes* Ehrenberg in Hemprich and Ehrenberg, 1831 자라하모충속

1. *Euplotes versatilis* Tuffrau *et al*., 2000 (Fig. 1)

다재자라하모충 (신칭)

Euplotes versatilis Tuffrau *et al*., 2000: 355–366, figs. 1–18.

Material examined. Korea: Incheon, Jung-gu (37°27′0.9″N, 126°35′38.4″E); collected by Jeong Hyeon Yeo on August 2, 2021.

Identifier. Jeong Hyeon Yeo.

Deposition. NIBRPR0000111148, NIBRPR0000111150.

World distribution. Martinique (France Lesser Antilles) (Tuffrau *et al*., 2000), Korea (this study).

Diagnosis. Small cells (typical) body size 55–70×20–40 μm in vivo, on average 40×25 μm; medium cells size 65×55 μm; giant cells size 110×95 μm after protargol impregnation (n=5) (Fig. 1A–C). Body shape broadly oval. One C-shaped macronucleus, with a single small spherical micronucleus attached (Fig. 1C). 26–32 adoral membranelles; 10 frontoventral, 5 transverse, 2 caudal and 2 marginal cirri (Fig. 1B). 8 or 9 dorsal kineties with 12 or 13 dikinetids in the middle one; dorsal argyrome pattern of single-*vannus*, double-*eurystomus* and complex or mixed type (Fig. 1B–F).

Habitat. Marine.

Remarks. *Euplotes versatilis* exhibits extensive morphological variation due to cannibalism. The small cell (general; on average 40×35 μm) exhibits single-*vannus* type, medium cells (on average 65×60 μm) with double-*eurystomus* type, and giant cells (on average 125×125 μm) with complex or mixed type after silver nitrate impregnation.

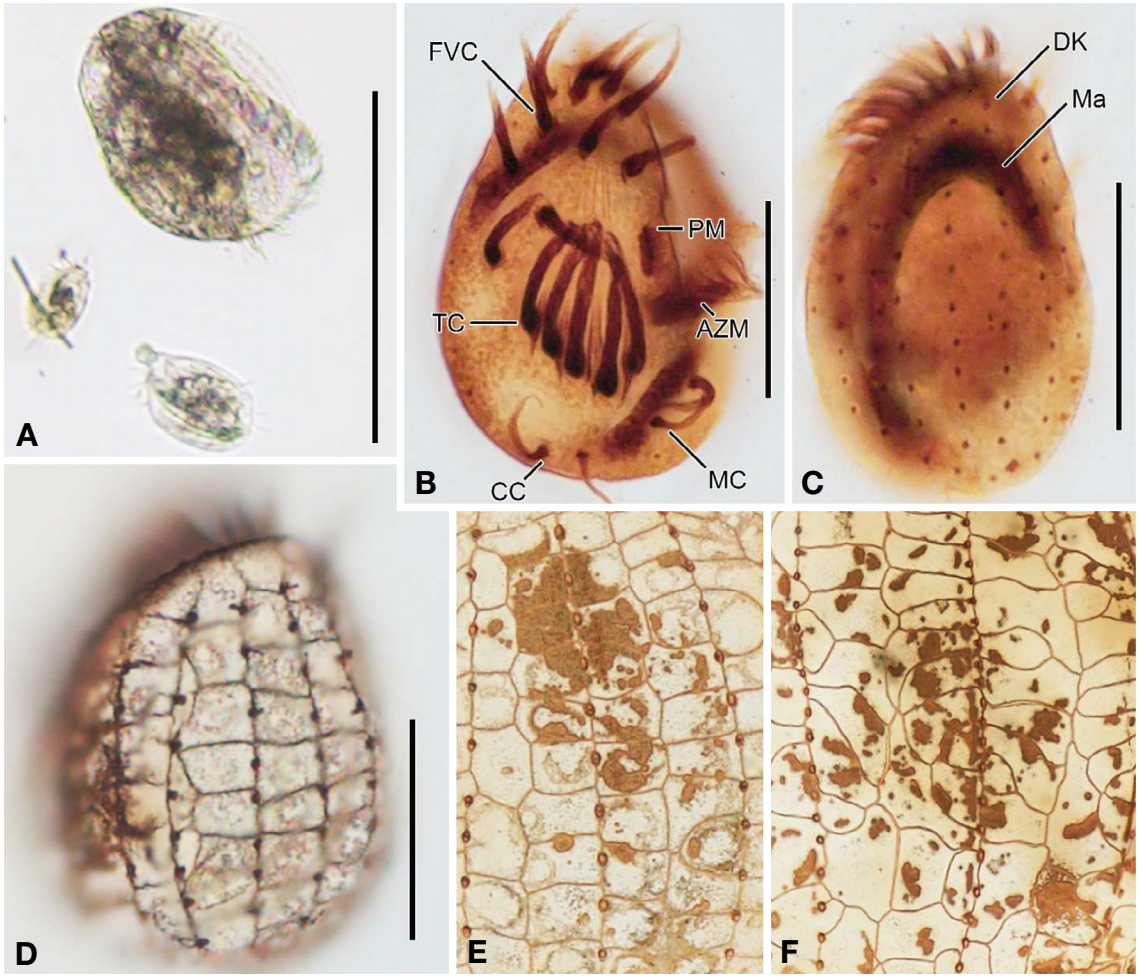

Fig. 1. *Euplotes versatilis* from life (A), after protargol (B, C), and silver nitrate impregnation (D–F). (A) Showing the body shape, cilia, oral apparatus, and the different sizes of the ordinary cells and giants. (B–F) Ventral (B) and dorsal (C–F) views showing the infraciliature and silverline. AZM, adoral zone of membranelles; CC, caudal cirri; DK, dorsal kineties; FVC, frontoventral cirri; Ma, macronucleus; MC, marginal cirri, PM, paroral membrane; TC, transverse cirri. Scale bars: 100 μm (A), 20 μm (B–D).

The Korean population corresponds well with the French type population described by Tuffrau *et al*. (2000) in several aspects: number of adoral membranelles (26–32 vs. 20–30); frontoventral cirri (10 vs. 10); dorsal kineties (8 or 9 vs. 9); dorsal argyrome pattern (single-*vannus*); and habitat (marine). In comparison to congeners, *E. minuta* Yocom, 1930 resembles *E. versatilis* but can be easily distinguished by the absence (vs. presence) of cannibalistic behavior. *Euplotes focardii* Valbonesi and Luporini, 1990, the only congener in which cannibalistic behavior has been described, resembles *E. versatilis* but can be easily distinguished by the number of dorsal kineties (8 or 9 vs. 10) and dorsal argyrome pattern (single-*vannus* vs. double-*eurystomus*).

Class Oligohymenophorea de Puytorac *et al*., 1974 빈막강
Subclass Scuticociliatia Small, 1967 채찍섬모충아강
Order Philasterida Small, 1967 필막모충목
Family Pseudocohnilembidae Evans and Thompson, 1964
Genus *Pseudocohnilembus* Evans and Thompson, 1964

2. *Pseudocohnilembus binucleatus* Foissner, 2002 (Fig. 2)
이핵평행입섬모충 (신칭)

Pseudocohnilembus binucleatus Foissner, 2002: 530–533, fig. 121a–h, table 103.

Material examined. Korea: Gyeongsangnam-do, Tongyeong-si, Hansan-myeon (34°32′6.6″N, 128°43′46.8″E); collected by Jeong Hyeon Yeo on August 22, 2023.
Identifier. Jeong Hyeon Yeo.
Deposition. NIBRPR0000111187, NIBRPR0000111188.
World distribution. Namibia (Foissner, 2002), Korea (this study).

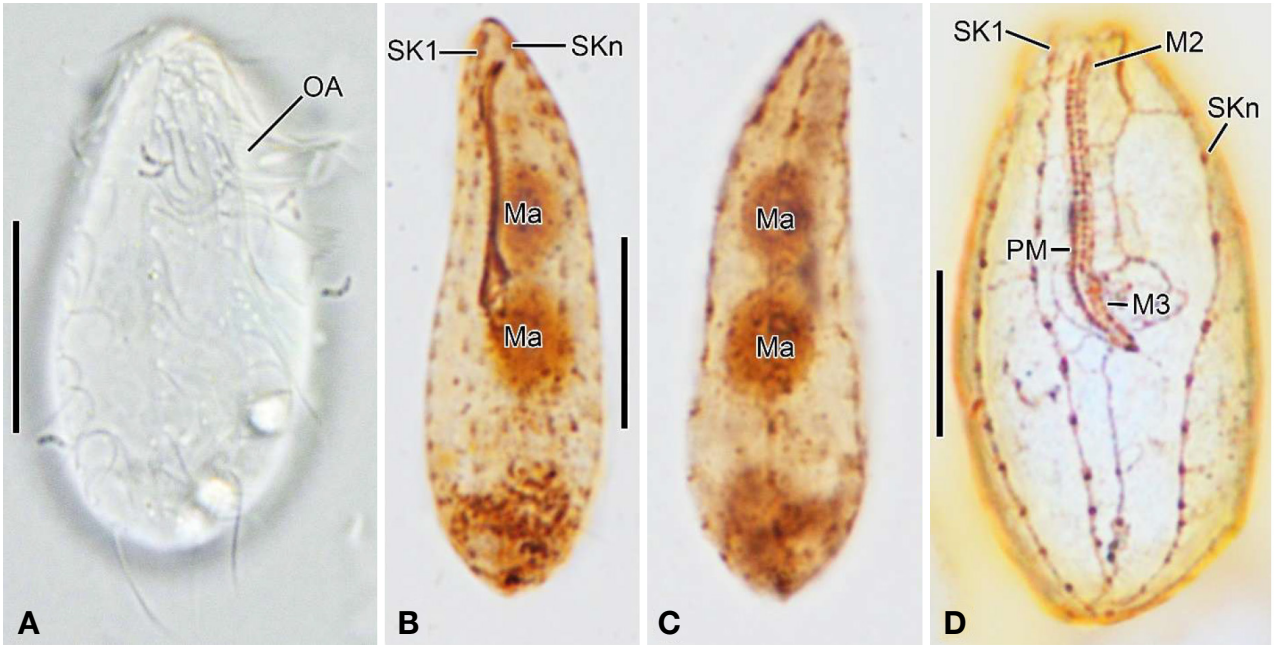

Fig. 2. *Pseudocohnilembus binucleatus* from life (A), after protargol (B, C), and Chatton-Lwoff silver nitrate impregnation (D). (A) Ventral view of a representative specimen, showing the body shape, cilia, and oral apparatus. (B, D) Ventral (B) and dorsal (C) view showing the infraciliature, nuclear apparatus, and silverline. M2 and 3, membranelles 2 and 3; Ma, macronucleus; OA, oral apparatus; PM, paroral membrane; SK1 and n, somatic kineties 1 and n. Scale bars: 10 μm.

Diagnosis. Body size 30–40 × 10–15 μm in vivo, on average 22 × 7 μm after protargol impregnation (n = 5) (Fig. 2A–C). Body shape slender oval with pointed anterior end and broadly rounded posterior end (Fig. 2A–D). Two globular macronuclei, each about 4 μm across on average after protargol impregnation, located slightly above the body center; nucleoli globular to ellipsoidal and evenly distributed; micronucleus is absent or indistinguishable (Fig. 2B, C). Cytoplasm with food vacuoles, crystals, and lipid droplets (Fig. 2A). Somatic and caudal cilia on average 4 μm and 6 μm long in vivo, respectively; invariably seven bipolar somatic kineties; kineties 1 and 7 with 17–19 and 16–18 mono/dikinetids, respectively. (Fig. 2A–C). Oral apparatus occupies about 56% of body length after silver nitrate impregnation, composed of two adoral membranelles and paroral membrane (Fig. 2B, D). Silverline consists of primary meridians (Fig. 2D).
Habitat. Marine.
Remarks. The Korean population corresponds well with the Namibian type population described by Foissner (2002) in several aspects: body size after protargol impregnation (18–27 μm × 20–32 μm); number of somatic kineties (7 vs. 7) and macronuclei (2 vs. 2). In comparison to other species in the genus, *P. persalinus* Evans and Thompson, 1964 resembles *P. binucleatus* but can be easily distinguished by the number of macronuclei (2 vs. 1) (Evans and Thompson, 1964; Song, 2000).

Phylum Arthropoda Gravenhorst, 1843 절지동물문
Class Hexanauplia Oakley, Wolfe, Lindgren and Zaharof, 2013
Order Harpacticoida Sars, 1903 갈고리노벌레목
Family Ectinosomatidae Sars, 1903 날씬장수노벌레과
Genus *Arenosetella* C. B. Wilson, 1932
모래날씬장수노벌레속

3. *Arenosetella bidenta* Ito, 1972 (Fig. 3)
두이빨모래날씬장수노벌레 (신칭)
Arenosetella bidenta Ito, 1972: 331, figs. 17, 18.

Material examined. Korea: Gangwon-do, Gangneung-si, Okkye (37°37′47.0″N, 129°2′57.0″E); collected by Sung Joon Song on May 21, 2002.
Identifier. Sung Joon Song.
Deposition. NIBRIV0000910947.
World distribution. Hokkaido, Japan (Ito, 1972), East Sea, Korea (this study).
Diagnosis. Body size 0.57 mm. Female body cylindrical and somewhat laterally depressed. Anal somite with peculiar chitinous structure as depicted. Caudal ramus longer than wide. Antennule 6-segmented. Antenna with basis and 3-segmented exopod (1, 1, 2 setae). Leg 1 with 3-segmented exopod and endopod; exopod much shorter than endopod, exp-2 with inner seta, exp-3 with 5 setae/spines; endopod with 1, 1, and 4 setae. Leg 3 exp-3 with 1 inner seta. Leg 4 exp-3 with 2 inner setae and enp-2

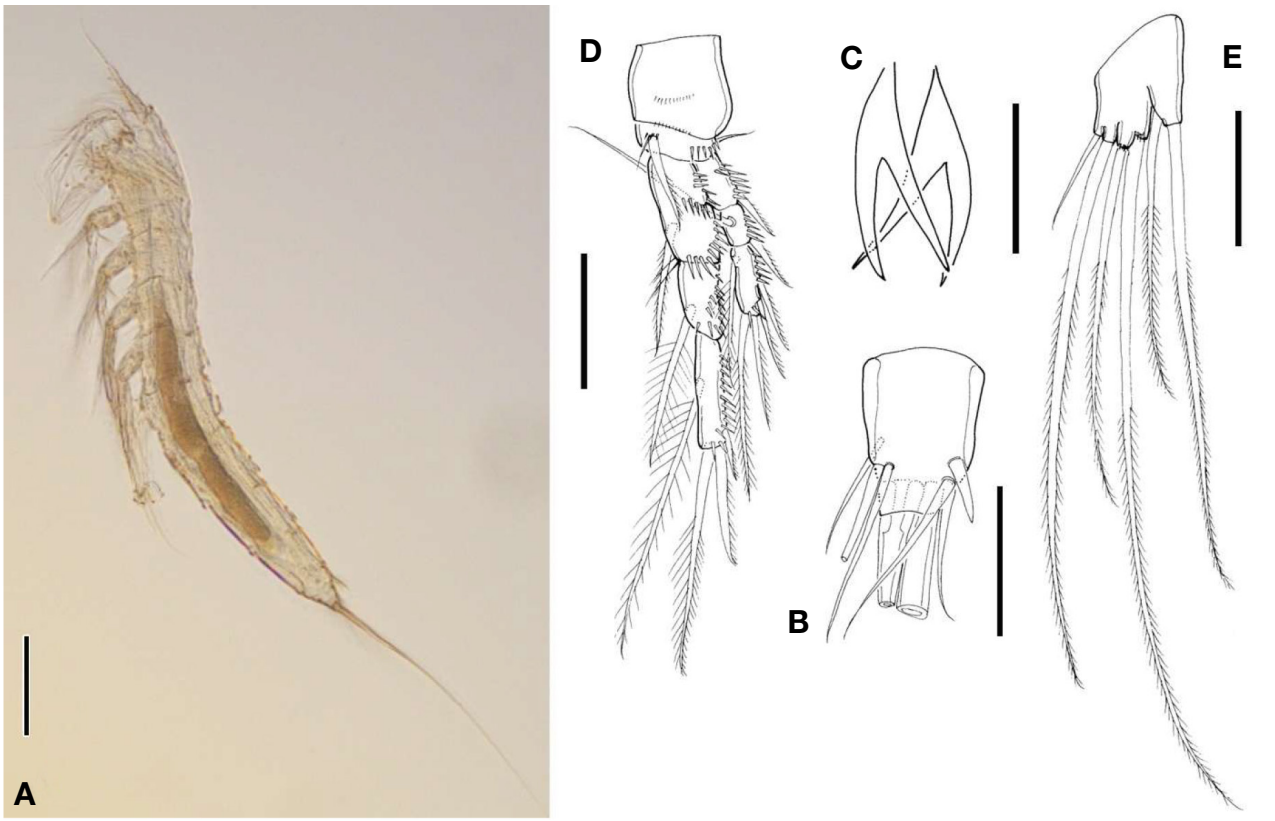

Fig. 3. Lateral view of *Arenosetella bidenta* female (A), caudal ramus, dorsal view (B), chitinous structure of anal somite (C), leg 1 (D), leg 5 (E). Scale bars: 100 μm (A), 20 μm (B, C), 30 μm (D, E).

with 1 inner seta. Leg 5 both rami fused, bearing 5 setae in total.

Habitat. Marine (sandy beach), Estuary (sandy bottom).

Remarks. The Korean material coincides with Ito's (1972) original description collected from the intertidal zone of the sandy beach at Rumoi, Hokkaido. However, Korean specimens have some minor differences compared with Ito's as follows: 1) caudal ramus has a strong spinule on inner surface, and 2) third outermost seta of leg 5 is much shorter than Japanese specimen.

Family Peltidiidae Claus, 1860 갑옷장수노벌레과
Genus *Eupelte* Claus, 1860 진갑옷장수노벌레속

4. *Eupelte simile* (Monk, 1941) (Fig. 4)
유사진갑옷장수노벌레 (신칭)

Paralteutha simile Monk, 1941: 88, pl. 2, figs. 5–11; Ito, 1974, 619, figs. 37–41.

Alteutha simile (Monk, 1941): Hicks, 1986, 358.

Material examined. Korea: Gangwon-do, Goseong-gun, Gajin (38°22′3.0″N, 128°30′45.0″E); collected by Sung Joon Song on March 13, 2006.

Identifier. Sung Joon Song.

Deposition. NIBRIV0000910949.

World distribution. Californian coast, U.S.A. (Monk, 1941), Hokkaido, Japan (Ito, 1974), East Sea, Korea (this study).

Diagnosis. Body size: female 1.39 mm and male 1.17 mm. Female body dorsoventrally depressed, shield form. Rostrum trapezoid with serrate margin. Caudal ramus longer than wide. Antennule 9-segmented, Antenna with basis and exopod 2-segmented bearing 1 and 3 setae, respectively. Maxilla proximal endite with 4 setae. Leg 1 with 3-segmented exopod and 2-segmented endopod; exopod somewhat longer than endopod; exp-3 with 4 claws and 1 seta; and enp-2 with 5 setae. Leg 2-4 enp-2 with 2 inner setae. Female leg 5 baseoendopod with 6 setae, exopod with 5 spines and 1 seta. Male P5 baseoendopod with 2 setae and exopod with 4 spines/setae.

Habitat. Marine (algal bed).

Remarks. *Eupelte simile* was originally described from Californian coast by Monk (1941) under the name *Paralteutha simile*. Later, Ito (1974) fully re-described it based on the specimens obtained from Akkeshi Bay, Hokkaido with detailed figures. The Korean specimens are very similar to Japanese one in almost appendages.

However, our species has some discrepancies with orig-

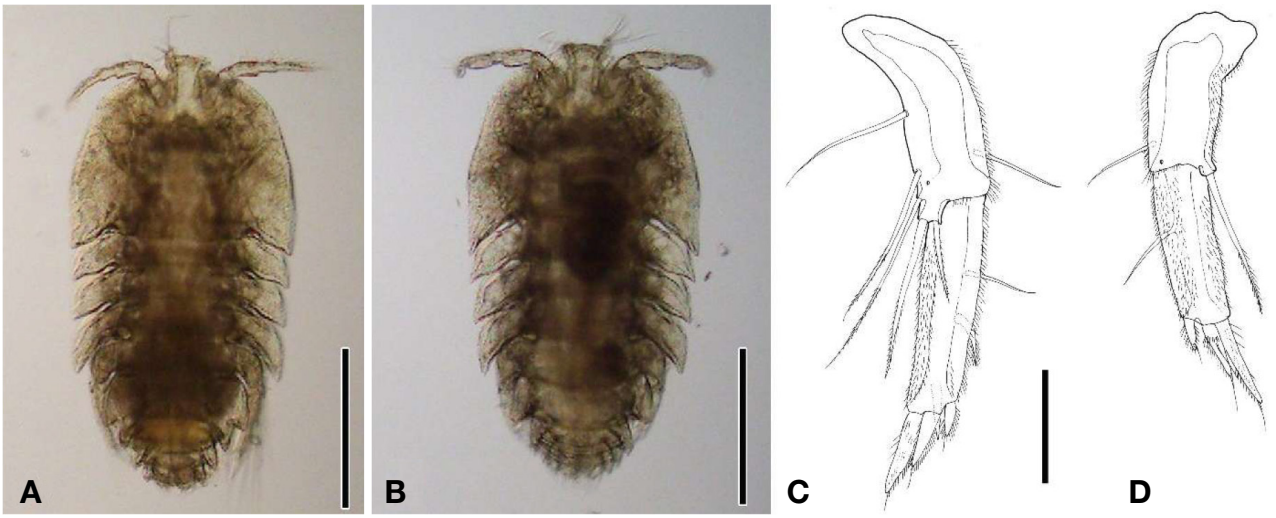

Fig. 4. Dorsal view of *Eupelte simile* female (A), dorsal view of male (B), posterior view of female leg 5 (C), posterior view of male leg 5 (D). Scale bars: 500 μm (A, B), 100 μm (C, D).

inal description by Monk (1941) as follows: 1) rostrum with serrated platform tip (vs. round tip in Monk's), 2) P4 enp-2 and enp-3 with long outer setules (vs. with normal setules), 3) female P5 exopod with 5 spines and 1 seta (vs. 5 spines), and 4) outermost spine of P5 exopod with sharp tip (vs. blunt tip).

Class Ostracoda Latreille, 1802 패충강
Order Podocopida Sars, 1866 절병목
Family Cytheridae Baird, 1850 얇은씨벌레과
Genus *Cythere* Müller, 1785 얇은씨벌레속

5. *Cythere nishinipponica* Okubo, 1976 (Fig. 5)
해면무늬일본씨벌레 (신칭)
Cythere nishinipponica Okubo, 1976: 113, figs. 1–3.

Material examined. Korea: Jeollanam-do, Yeosu-si (34°42′59.0″N, 127°38′12.0″E); depth 5–10 cm, algae rinsing; collected by Hyunsu Yoo on October 9, 2019.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000904525.
World distribution. Japan (Okubo, 1976), Korea (this study).
Diagnosis. Size approximately 0.7 mm. Surface ornamented with large and small punctuations. Valves asymmetrical in lateral view. Left valve subreniform, right valve subtrapezoidal. Radial pore canals unbranched, straight. Antennula 5-segmented with claw-like setae. Antenna with two claws on the terminal segment. Hemipenis with curved ejaculatory process, with pointed end. Distal lobes asymmetrical, right rounded, left elongated with a terminal spine.
Habitat. Marine.

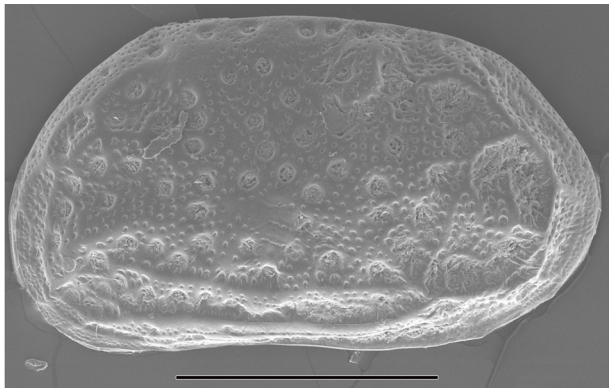

Fig. 5. External view of *Cythere nishinipponica*, male, lateral view of the left valve. Scale bars: 300 μm.

Remarks. Our specimens correspond to the original description of Okubo (1976), both in the shell and hemipenis morphology. It was originally described from the intertidal zone of the Inland Sea, Japan.

Family Hemicytheridae Puri, 1953 반곰보씨벌레과
Genus *Aurila* Pokorny, 1955 반곰보씨벌레속

6. *Aurila ikeyai* Okubo, 1988 (Fig. 6)
작은반곰보씨벌레 (신칭)
Aurila ikeyai Okubo, 1988: 142, figs. 1 (d–i), 5 (e, f).

Material examined. Korea: Busan-si, Kijang-gu, Ilkwang-myeon (35°16′4.6″N, 129°14′43.3″E); collected by Hyunsu Yoo on January 18, 2018.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000904524.

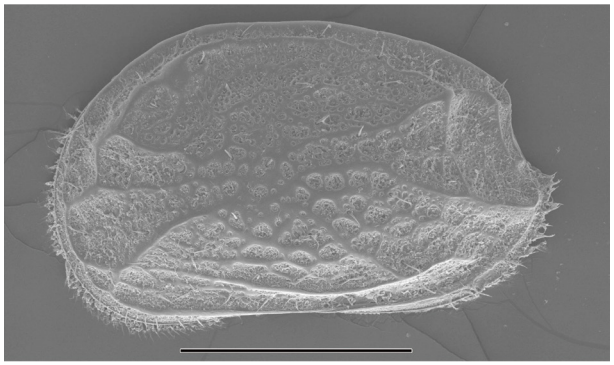

Fig. 6. External view of *Aurila ikeyai*, male, lateral view of the left valve. Scale bars: 300 μm.

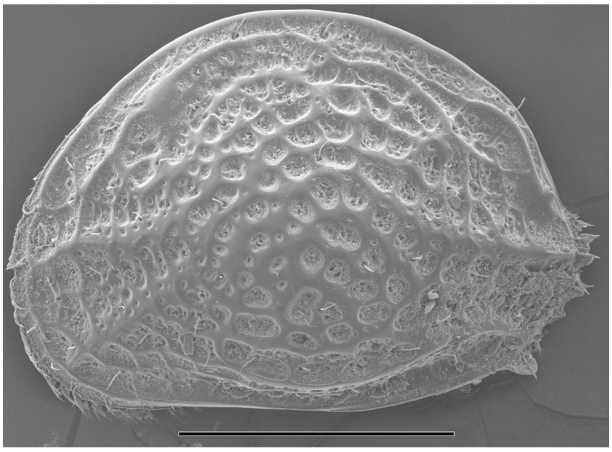

Fig. 7. External view of *Aurila munechikai*, male, lateral view of the left valve. Scale bars: 300 μm.

World distribution. Japan (Okubo, 1988), Korea (this study).
Diagnosis. Size approximately 0.6 mm. Surface ornamented with several pits and ridges. Valves distinctly asymmetrical. Left valve sub-quadrate, dorsal margin slightly convex, right valve sub-trapezoidal, dorsal margin straight. Antennula 5-segmented with strong claws. Antenna with three claws on the terminal segment. Both left and right hemipenis with terminally rounded distal processes. Sexual dimorphism not remarkable.
Habitat. Marine.
Remarks. The species is very similar to *A. hatai* Ishizaki, 1968 but they differ in hemipenis morphology: in *A. hatai* distal lobe of the hemipenis has an elongated tip, while in *A. ikeyai* the distal lobe is rounded (Ishizaki, 1968).

7. *Aurila munechikai* Ishizaki, 1968 (Fig. 7)
작은반곰보씨벌레 (신칭)
Aurila munechikai Ishizaki, 1968: 23, pl. 4, figs. 7, 8.

Material examined. Korea: Busan-si, Kijang-gu, Ilkwang-myeon (35°16′4.6″N, 129°14′43.3″E); algae rinsing; collected by Jaehyun Kim on January 18, 2018.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000904523.
World distribution. Japan (Ishizaki, 1968), Korea (this study).
Diagnosis. Size approximately 0.6 mm. Surface ornamented with several pits and ridges. Valves distinctly asymmetrical. Left valve sub-quadrate, dorsal margin slightly convex, right valve sub-trapezoidal, dorsal margin straight. Sexual dimorphism not remarkable. Both left and right hemipenis with terminally rounded distal processes, copulatory process folded towards the last third.
Habitat. Marine.
Remarks. The species was originally described on carapace only (Ishizaki, 1968). The soft body was described by Okubo (1988) from Uranouchi Bay. It differs from all other congeners by the shape of the copulatory process, which is folded on its last third.

Genus *Robustaurila* Yajima, 1982
강낭콩구릉무늬씨벌레속

8. *Robustaurila ishizakii* (Okubo, 1980)
제주강낭콩구릉무늬씨벌레 (신칭)
Mutilus ishizakii Okubo, 1980: 405, figs. 6, 7 (c, d), 11 (e–g).
Robustaurila ishizakii (Okubo, 1980) Yajima *et al.*, 1986: 606.

Material examined. Korea: Jeju Island, Seogwipo-si, Munseom Isle, diving (33°13′34.0″N, 126°33′53.0″E); algae rinsing; collected by Jaehyun Kim on January 20, 2018.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000909883.
World distribution. Japan (Okubo, 1980), Korea (this study).
Diagnosis. Size about 0.6 mm. Surface with ridges and unequal pits: larger on the posterior side of the valves. Eye ridge prominent. Both valves with posterior extensions, more prominent on the left valve. Valves sub-rectangular. Greatest height situated at the front, with dorsal margin sloping evenly towards posterior end. Right valve lower than the left, posterior margin projecting toward posterior end.
Habitat. Marine.
Remarks. The species was originally reported from Japan, and it is very similar to another species from Japan, *Robustaurila assimilis* (Kajiyama, 1913). The latter was

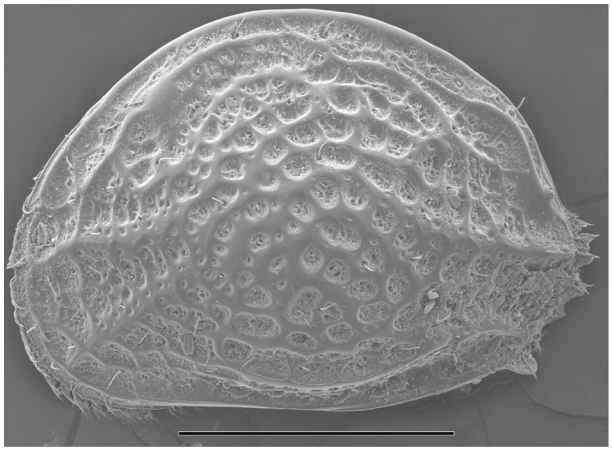

Fig. 8. External view of *Robustaurilla ishizaki*, female, lateral view of the left valve. Scale bars: 300 μm.

already reported from Korea. They mostly differ in ornamentation where *R. assimilis* has less pronounced ridges. Hemipenis morphology is also important, but we collected only females.

Family Krithidae Mandelstam, 1958 무절개씨벌레과
Genus *Parakrithella* Hanai, 1961
무절개방사무늬씨벌레속

9. *Parakrithella pseudadonta* (Hanai, 1959) (Fig. 9)
제주무절개방사무늬씨벌레 (신칭)
Neocyprideis pseudadonta Hanai, 1959: 300, pl. 14, figs. 2 (a, b), 5–9.
Parakrithella pseudadonta (Hanai, 1959): Tanaka, 2016, 37, figs. 3 (c, d), 4 (c, d), 5 (e–h), 6 (b, c), 9.

Material examined. Korea: Jeju Island, Seogwipo-si, Munseom Isle, diving (33°13′34.0″N, 126°33′53.0″E); collected by Jaehyun Kim on January 20, 2018.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000909874.
World distribution. Japan (Hanai, 1959), Korea (this study).
Diagnosis. Size around 0.5 mm. Surface smooth. Valves sub-reniform, greatest height behind the middle. Anterior margin rounded obliquely. Hingment pseudodont. Posterior margin narrow, sloping steeply to postero-ventral corner. A1 5-segmented; A2 4-segmented, terminal segment with three claws. Hemipenis with broad distal lobes in the basis, tapering distally. Slightly asymmetrical.
Habitat. Marine.
Remarks. The original description was based only on shell morphology (Hanai, 1959), and Okubo (1980) described soft parts for the first time. Our specimens differ slightly in the hemipenis morphology by having a broader basis of the distal process.

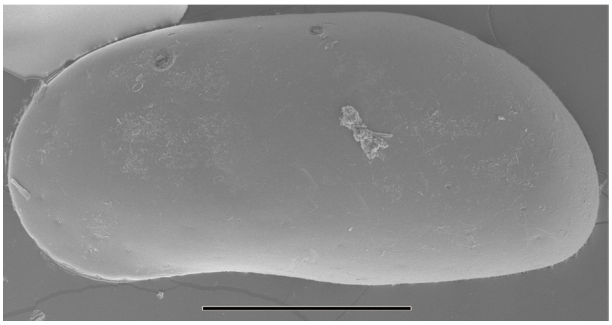

Fig. 9. External view of *Parakrithella pseudadonta*, male, lateral view of the shell from the left side. Scale bars: 200 μm.

Family Leptocytheridae Hanai, 1957 얇은씨벌레과
Genus *Calistocythere* Ruggieri, 1953 파도무늬씨벌레

10. *Callistocythere angulata* Okubo, 1979 (Fig. 10)
글로벌파도무늬씨벌레 (신칭)
Callistocythere angulata Okubo, 1976: 18, fig. 6, pl. 1 (i–l).

Material examined. Korea: Jeollanam-do, Yeosu-si (34°42′59.0″N, 127°38′12.0″E); depth 5–10 cm, algae rinsing; collected by Hyunsu Yoo on October 9, 2019.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000909873.
World distribution. Japan (Okubo, 1976), Korea (this study).
Diagnosis. Size approximately 0.5 mm. Surface covered with relatively large pits, often subdivided. Behind adductor muscle scars four small pits arranged in a rhomb forming a large pit. Left valve sub-rectangular, dorsal margin slightly arched, posterior cardinal angle distinct. Anterior and posterior margins rounded, posterior narrower than anterior. Radial pore canals poly furcated.
Habitat. Marine.
Remarks. *Callistocythere angulata* resembles *C. hosonosuensis* Okubo, 1979, which was already reported from Korea. The two species differ mostly in the hemipenis morphology, but also in *C. angulata* being tumide, and has a specific ornament behind muscle scar imprint.

Family Loxoconchidae Sars, 1925 경사씨벌레과
Genus *Loxoconcha* Sars, 1866 경사씨벌레

11. *Loxoconcha optima* Ishizaki, 1968 (Fig. 11)
길쭉한경사씨벌레 (신칭)
Loxoconcha optima Ishizaki, 1968: 30, pl. 2, fig. 2, pl. 6, figs. 8, 9.

Material examined. Korea: Gangwon-do, Gangneung

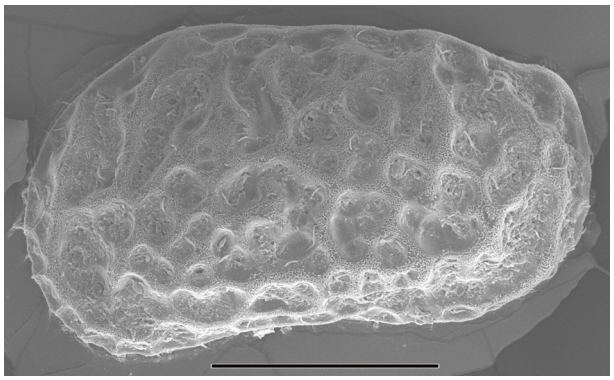

Fig. 10. External view of *Calistocythere angulata*, female, lateral view of the left valve. Scale bars: 200 μm.

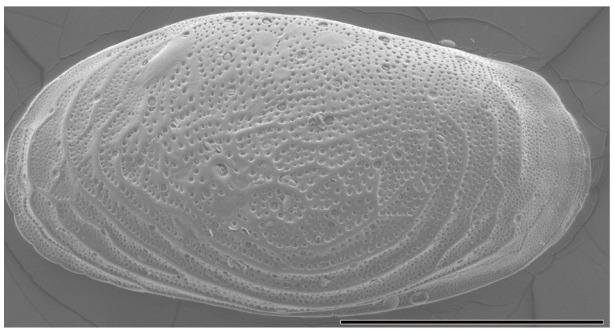

Fig. 11. External view of *Loxoconcha optima*, sex unknown, lateral view of the left valve. Scale bars: 300 μm.

Beach (37°48′20.0″N, 128°54′28.0″E); interstitial; collected by Ivana Karanovic on October 9, 2019.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000904536.
World distribution. Japan (Ishizaki, 1968), Korea (this study).
Diagnosis. Size approximately 0.5 mm. Valves elliptical in lateral view. Surface ornamented with pits and ridges. Ridges concentrical, especially prominent ventrally. Dorsal margin gently curved, with greatest height in front of the middle. Anterior margin finely crenulated, wider than posterior. Transition between dorsal and posterior margin angular. Shell slightly inflated medially. Eye-tubercle prominent. Pores system around the eye tubercle typical for species.
Habitat. Marine.
Remarks. This species is very similar to *L. taiwanensis* Zhao, 1988 already reported from Korea. It is possible that the two are synonyms, however, according to Ishii *et al*. (2005) each *Loxoconcha* has a specific pore pattern on the shell.

Family Pectocytheridae Hanai, 1957 얇은이빨씨벌레과

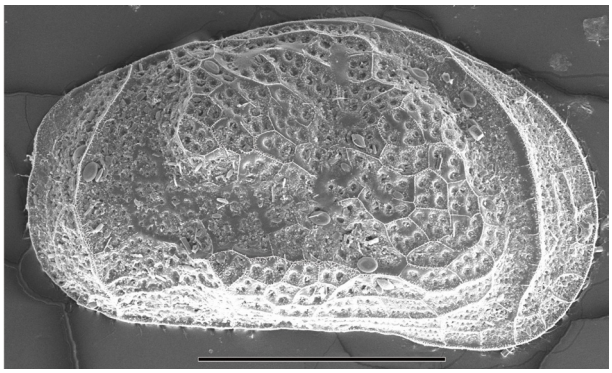

Fig. 12. External view of *Pectocythere quadrangulata*, female, lateral view of the left valve. Scale bars: 200 μm.

Genus *Pectocythere* Hanai, 1957 얇은이빨씨벌레속

12. *Pectocythere quadrangulata* Hanai, 1957 (Fig. 12) 사각형얇은이빨씨벌레 (신칭)
Pectocythere quadrangulata Hanai, 1957: 474, fig. 6 (a, b), pl. 11, figs. 3 (a, b).

Material examined. Korea: Gangwon-do, Gangneung, Aninji-ri, river mouth, St. 2 (37°44′25.0″N, 128°59′5.0″E); interstitial; collected by Hyunsu Yoo on October 4, 2015.
Identifier. Ivana Karanovic.
Deposition. NIBRIV0000909885.
World distribution. Japan (Hanai, 1957), Korea (this study).
Diagnosis. Shell strongly calcified, rectangular in lateral view. Surface covered with pits and two distinct ridges present, one running parallel to the anterior, another parallel to the posterior margin. In dorsal view, laterally inflated. Dorsal margin slightly sloping towards posterior end, angular at transition to the anterior margin. Anterior margin broadly rounded, posterior margin almost square.
Habitat. Marine.
Remarks. This species was originally described from Quaternary deposit of Japan (Hanai, 1957). No soft parts were reported until now (not illustrated here).

Phylum Rotifera Cuvier, 1817 윤형동물문
Class Eurotatoria De Ridder, 1957 진윤충강
Subclass Bdelloidea Hudson, 1884 질형아강
Order Philodinida Melone and Ricci, 1995 선윤충목
Family Habrotrochidae Bryce, 1910 협관윤충과
Genus *Habrotrocha* Bryce, 1910 협관윤충속

13. *Habrotrocha quinquedens quinquedens* De Koning, 1947 (Fig. 13) 다섯니협관윤충 (신칭)
Habrotrocha quinquedens quinquedens De Koning, 1947: 194, pl. 4, fig. 19a–d.

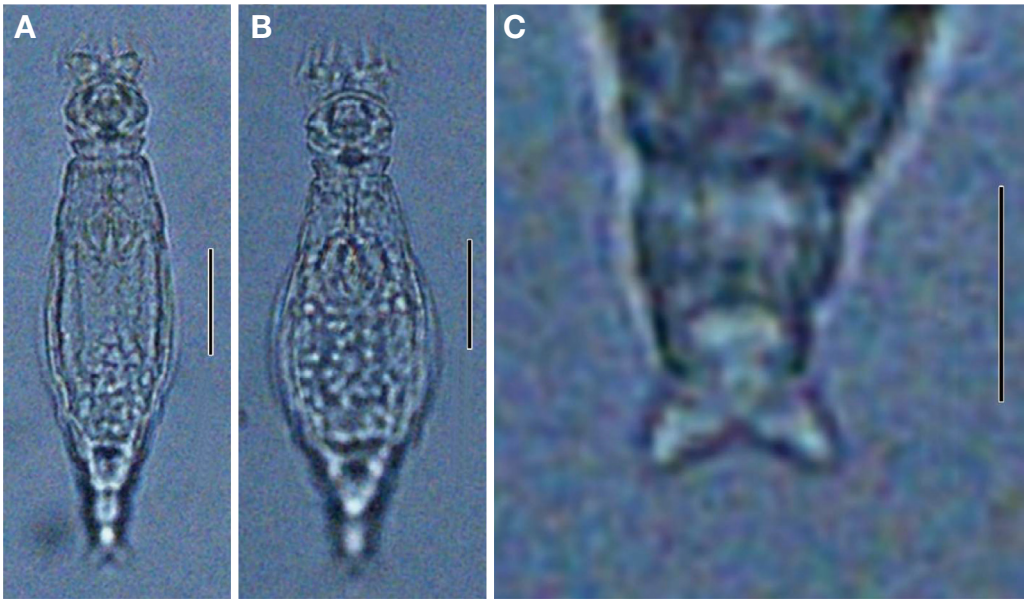

Fig. 13. *Habrotrocha quinquedens quinquedens* De Koning, 1947: (A, B). feeding, dorsal view; (C). foot and spurs, ventral view. Scale bars: 25 μm (A, B), 10 μm (C).

Material examined. Korea: Gangwon-do, Seongsan-myeon (37°42′27.4″N, 128°47′56.5″E); collected by CH Lee and MO Song on May 7, 2023.
Identifier. Min Ok Song.
Deposition. NIBRIV0000910359.
World distribution. Czech Republic (Devetter *et al*., 2020), the Netherlands (De Koning, 1947) and Korea (this study).
Diagnosis. Corona narrower than cingulum pad width. Upper lip rimmed, arched and without a median notch; much lower than trochal discs. Cingulum pad round laterally; with a bulge in the middle laterally. Sulcus slightly narrower than half of pedicel width. Pedicel short. Pharyngeal tube much shorter than trophi length in feeding. Foot very short and about 1/7 of total length in feeding. Spurs conical and with narrow interspace; outer margin rather straight and inner margin plump proximally; interspace slightly narrower than 1/3 of spur base width.
Habitat. Mosses and soil.
Remarks. *Habrotrocha q. quinquedens* is quite rare and was reported only from Czech Republic (Devetter *et al*., 2020) after its original description from the Netherlands by De Koning (1947). This species is new to Asia.

Genus *Otostephanos* Milne, 1916 고리관윤충속

14. *Otostephanos auriculatus bilobatus* Hauer, 1939 (Fig. 14) 두갈래작은귀고리관윤충 (신칭)
Otostephanos auriculatus var. *bilobatus* Hauer, 1939: 173–174, abb. 10.

Material examined. Korea: Gangwon-do, Jeongseon-gun (37°25′28.0″N, 128°34′24.6″E); collected by CH Lee and MO Song on May 25, 2024.
Identifier. Min Ok Song.
Deposition. NIBRIV0000920309.
World distribution. Germany (Hauer, 1939), New Zealand (Donner, 1965) and Korea (this study).
Diagnosis. Median lobe of upper lip narrow and bilobed; each lobe round and without interspace; slightly lower than trochal discs. Fine ring between corona and cingulum expanded, disconnected laterally and lobster claw-shaped in frontal view. Corona slightly wider than cingulum. Cingulum as wide as cingulum pad. Lateral margins of cingulum pad rather parallel. Teeth 10/10. Pharyngeal tube shorter than trophi length in feeding. Spurs conical and with narrow interspace.
Habitat. Mosses and lichens.
Remarks. *Otostephanos auriculatus bilobatus* has been reported only once from New Zealand (Donner, 1965) after the description from Germany (Hauer, 1939). The present study is the third record of it. This subspecies is new to Asia.

Order Adinetida Melone and Ricci, 1995
납작머리윤충목
Family Adinetidae Hudson and Gosse, 1886
납작머리윤충과
Genus *Adineta* Hudson, 1886 납작머리윤충속

15. *Adineta tuberculosa* Janson, 1893 (Fig. 15)
종기납작머리윤충 (신칭)

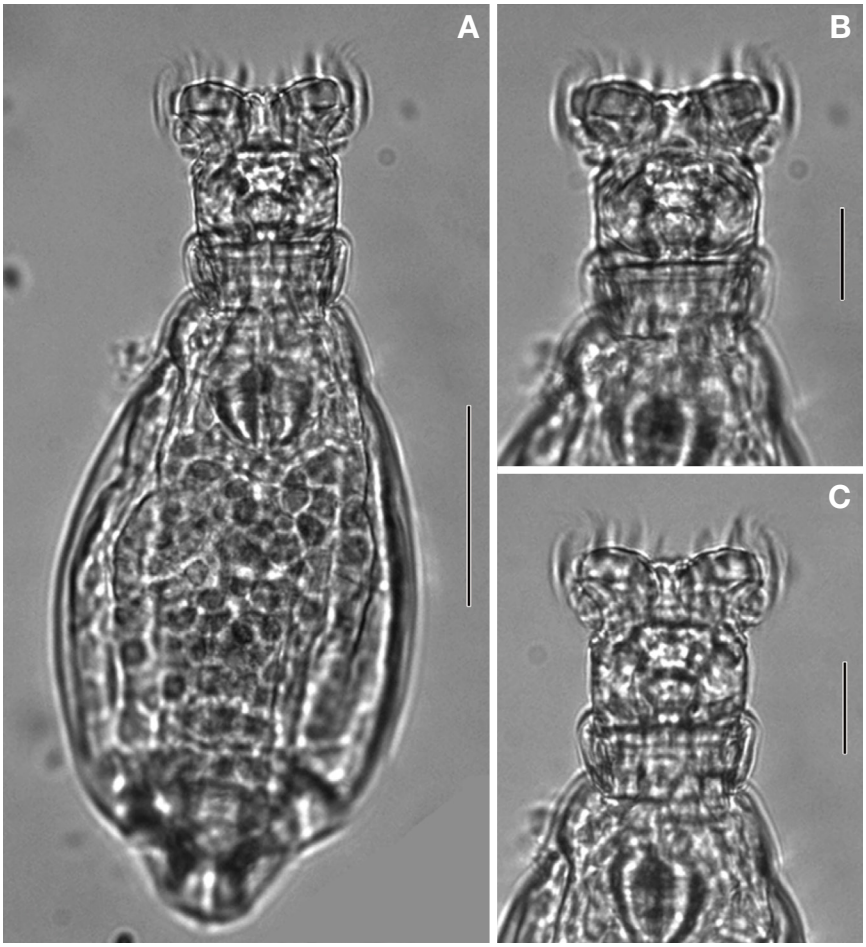

Fig. 14. *Otostephanos auriculatus bilobatus* Hauer, 1939: (A). feeding, dorsal view; (B, C). feeding head and neck, dorsal view. Scale bars: 50 μm (A), 20 μm (B, C).

Adineta tuberculosa Janson, 1893: 73–74, pl. 5, figs. 72–75.

Material examined. Korea: Gangwon-do, Pyeongchang-gun (37°41′41.1″N, 128°45′15.3″E); collected by CH Lee and MO Song on May 20, 2023.
Identifier. Min Ok Song.
Deposition. NIBRIV0000910358.
World distribution. Germany (Janson, 1893), New Zealand (Shiel and Green, 1996), South Africa (Koste, 1996), Switzerland (Donner, 1965), the Netherlands (De Koning, 1929) and Korea (this study).
Diagnosis. Rostrum without sensilla; slightly wider than anterior end of head and much narrower than the greatest head width; ratio of rostrum width to head width about 1 : 1.5–1 : 1.8. Neck, trunk, rump, foot and dorsal area of head covered with coarse granules. Rump much narrower than the greatest trunk width. Foot gradually tapering to spur pseudosegment. Spurs small, narrow and conical; interspace as wide as spur base.
Habitat. Mosses, mushrooms and tree barks.
Remarks. This species can be easily distinguished from its congeners by the coarse granules that cover neck, trunk, rump, foot and the dorsal area of flat head (Janson, 1893). This species is new to Asia.

Class Clitellata Linnaeus, 1740 환대강
Order Haplotaxida Grube, 1850 지렁이목
Family Naididae Ehrenberg, 1828 물지렁이과
Subfamily Tubificinae Vejdovský, 1884 실지렁이아과
Genus *Aulodrilus* Bretscher, 1899 서관지렁이속 (신칭)

16. *Aulodrilus limnobius* Bretscher, 1899 (Fig. 16)
두깃서관지렁이 (신칭)
Aulodrilus limnobius Bretscher, 1899: 388, figs. 8.23G–H.

Material examined. Korea: Gyeonggi-do, Yangpyeong-gun, Gangsang-myeon Daeseok-ri (37°30′6.5″N, 127°27′11.9″E); collected by Jeounghee Lee on June 25, 2022.

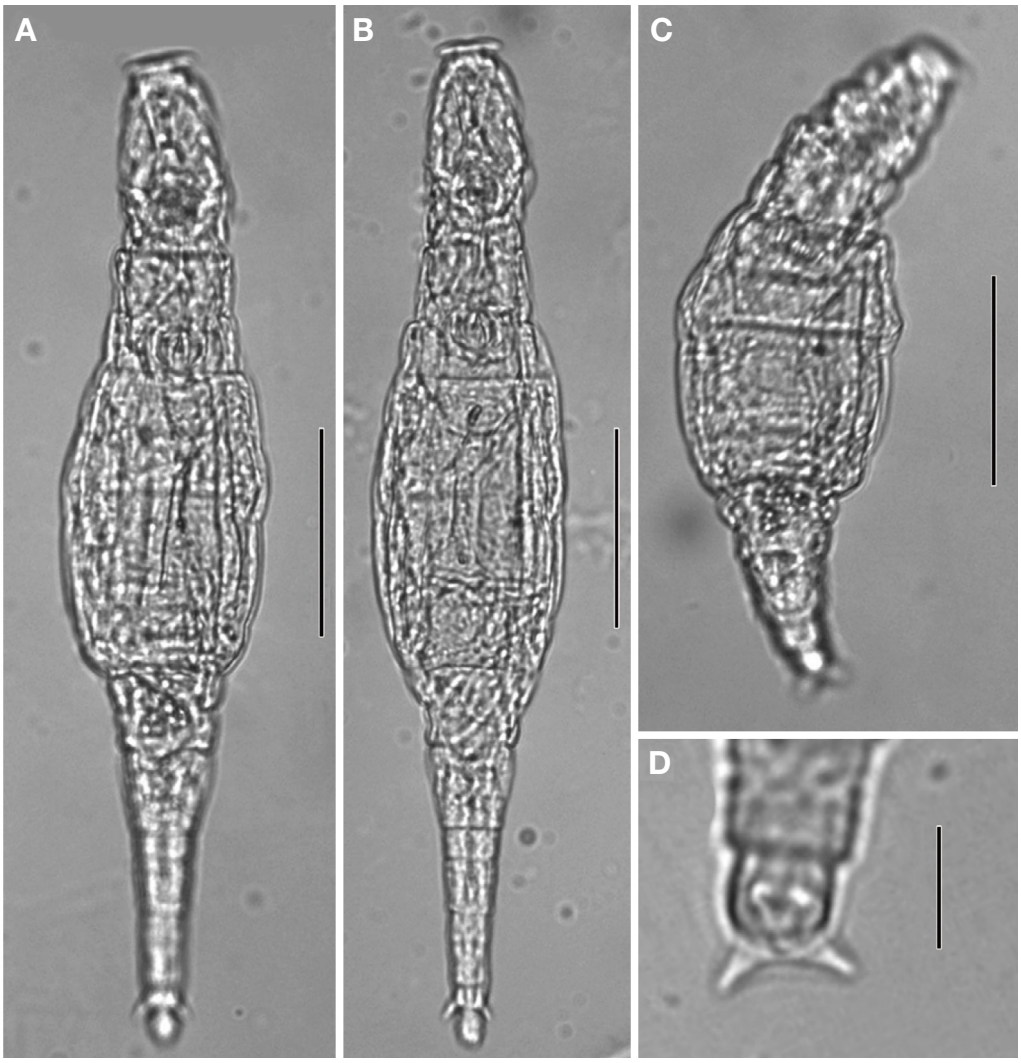

Fig. 15. *Adineta tuberculosa* Janson, 1893: (A–C). creeping, dorsal view; (D). foot and spurs, ventral view. Scale bars: 50 μm (A–C), 10 μm (D).

Identifier. Jeounghee Lee.
Deposition. NIBRIV0000910360.
World distribution. Cosmopolitan (Pinder and Brinkhurst, 2000).
Diagnosis. Prostomium is small (Fig. 16A). Pharynx has a complex, folded configuration. Ventral and dorsal chaetae are only bifid, with the upper tooth shorter and lower. Chaetae 7–10 per bundle in preclitellar and mid-body segments, 2–4 in posterior ones, with distally often dilated, forming lateral wings which appear as narrow oar-shaped blades (Fig. 16B). No modified genital chaetae. Clitellum over 1/2VI–VIII. Spermathecal pores are in front of the dorsal chaetae of VI. Male openings on VII, lateral to the ventral chaetae.
Habitat. Freshwater.
Remarks. This is the first Korean record of this species, which is widely distributed worldwide (Pinder and Brinkhurst, 2000).

Genus *Limnodrilus* Claparède, 1862 실지렁이속

17. *Limnodrilus tortilipenis* Wetzel, 1987 (Fig. 17)
꼬인장대실지렁이 (신칭)
Limnodrilus tortilipenis Wetzel, 1987: 182–185, figs. 1–11.

Material examined. Korea: Jeollanam-do, Sinan-gun, Jaeun-myeon, Guyeong 1 Reservoir (34°44′44.5″N, 126°7′4.4″E); collected by Jeounghee Lee on May 10, 2024.
Identifier. Jeounghee Lee.
Deposition. NIBRIV0000920318.
World distribution. America (Wetzel, 1987), Europe (Munts and Soes, 2012), Korea (this study).



Fig. 16. *Aulodrilus limosus*. (A) total body; chaetae (B). Scale bars: 300 μm (A), 30 μm (B).



Fig. 17. *Limnodrilus tortilipenis*. (A) total body; (B) penial sheath in XI–XVI; (C) top of penial sheath; (D) ventral chaetae. Scale bars: 2 mm (A), 200 μm (B), 100 μm (C), 40 μm (D).

Diagnosis. Prostomium short, triangular in dorsal view (Fig. 17A). All chaetae bifid. Anterior chaetae 6–8 per bundle, with upper tooth longer, thinner than proximal; posteriorly chaetae 3–4 per bundle, with equal teeth or subequal teeth (Fig. 17D). Penis sac with spiralled muscle bands. Penial sheaths not especially thick-walled, extremely elongate, length 20–48 times maximum diameter (Fig. 17B). Base of head resembling corkscrew, with a thin spiral appendage, and two short digitiform projections on distal head (Fig. 17C). Bases of penes originate around posterior portion of XVI.

Habitat. Freshwater.

Remarks. The most notable difference between this species and other species is its very long penial sheaths. This unique feature of *L. tortilipenis* is unmatched by any other *Limnodrilus* species, as it possesses a distinctly different length and shape of the head (Munts and Soes, 2012).

Subfamily Phallodrilinae Brinkhurst, 1971
Genus *Gianius* Erséus, 1992 쎈털물지렁이속 (신칭)

18. *Gianius riparius* (Giani and Martinez-Ansemil, 1981) (Fig. 18) 짧은쎈털물지렁이 (신칭)

Phallodrilus riparius Giani and Martinez-Ansemil, 1981: 202–205, fig. 1A–D.

Gianius riparius (Giani and Martinez-Ansemil, 1981) comb. n. Erséus, 1992: 24.



Fig. 18. *Gianius riparius*. (A) total body; (B) chaetae. Scale bars: 200 μm (A), 40 μm (B).

Material examined. Korea: Gyeongsangbuk-do, Gyeongju-si, Seomyeon, Cheonchon-ri, Deokcheon Reservoir (35°51′54.0″N, 129°2′13.6″E); collected by Jeounghee Lee on March 26, 2021.
Identifier. Jeounghee Lee.
Deposition. NIBRIV0000920317.
World distribution. Spain (Giani and Martinez-Ansemil, 1981), Korea (this study).
Diagnosis. All chaetae 2–4 in anterior bundles and by 1–3 in posterior bundle, with upper tooth short than lower. Penial chaetae 4 per bundle, with thick and straight. Atrial cylindrical and bent, each equipped with two prostate glands. Spermathecae as cylindrical sacs with roundish bulge in distal end, short, narrow duct.
Habitat. Groundwater.
Remarks. This species was first reported from the Iberian Peninsula (Giani and Martinez-Ansemil, 1981). Since then, it has been rarely found in some European regions. It was first discovered in Asia.

Conflicts of Interest

The author of this paper has no affiliation with any interests and is solely responsible for the paper.

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Morphological and molecular characteristics of *Calanopia minor* (Calanoida, Pontellidae) from Dokdo Island in the East Sea, Korea

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Calanopia minor Scott A., 1902 is newly reported from Dokdo Island, Korea. This species can be identified by following morphological characteristics: 1) absence of cuticular lenses on dorsal surface of cephalosome, 2) antennary exopod longer than half endopod, 3) leg 1 endopod 2-segmented, 4) female leg 5 exopod one-segmented and armed with three spine-like processes, 5) male leg 5 4-segmented on both sides, distal two exopodal segments of right leg forming a chela, 6) left leg of male leg 5 longer than right, and 7) left basis of male leg 5 swollen on proximal margin. This species is considered as an unrecorded species in Korea, since no taxonomic studies of this species have been conducted. We herein provided detailed descriptions and illustrations of the species. As well as partial sequences of the mitochondrial COI gene were obtained. Molecular comparisons using mtCOI sequences and publicly available *Calanopia* data from the GenBank database confirmed that the specimen described in this study is *C. minor*.

Keywords: *Calanopia*, Korean fauna, mtCOI, planktonic copepod, taxonomy

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Introduction

The family Pontellidae Dana, 1852−1853 is a planktonic copepod, common in the coastal region and neuston (Boxshall and Halsey, 2004; Soh, 2010). A total of 182 pontellid species have been reported from tropical to warm temperate waters (Razouls *et al*., 2025), and these species have been allocated to the following 10 genera: *Anomalocera* Templeton, 1837; *Calanopia* Dana, 1852−1853, *Epilabidocera* Wilson C.B., 1932; *Isocope* Brady, 1915; *Ivellopsis* Claus, 1893; *Labidocera* Lubbock, 1853; *Pontella* Dana, 1846; *Pontellina* Dana, 1852−1853; *Pontellinae* Dana, 1853−1855; and *Pontellopsis* Brady, 1883 (Walters and Boxshall, 2025). Among these genera, the genus *Calanopia* comprises 17 species: *C. americana* Dahl F., 1894; *C. asymmetrica* Mulyadi & Ueda, 1996; *C. aurivilli* Cleve, 1901; *C. australica* Bayly & Greenwood, 1966; *C. biloba* Bowman, 1957; *C. elliptica* (Dana, 1849−1952); *C. herdmani* Scott A., 1909; *C. kideysi* Ünal & Shmeleva, 2002; *C. levantina* Uysal & Shmeleva, 2004; *C. media* Gurney, 1927; *C. metu* Uysal & Shmeleva, 2004; *C. minor* Scott A., 1902; *C. sarsi* Wilson C.B., 1950; *C. sewelli* Jones E.C. & Park, 1967; *C. seymouri* Pillai P.P., 1969; *C. thomposni* Scott A., 1909; and *C. tulina* El-Sherbiny & Al-Aidaroos, 2017. Notably, only two species (*C. elliptica* and *C. thompsoni*) have been recorded in Korean waters (NIBR, 2025).

During a study of the diversity of planktonic copepods at Dokdo Island, Korea, we newly collected an unrecorded species, *C. minor*. In this study, we redescribed the morphological characteristics of the species based on Korean material. Partial mtCOI sequences were obtained and compared with previously reported sequences.

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Materials and Methods

Sample collection and identification

Samples were collected from coastal water at Dokdo Island using a light trap and preserved in 99% ethanol. Specimens were dissected in lactic acid and mounted on slides with lactophenol. Preparations were sealed with transparent nail varnish. All drawings were prepared using a drawing tube attached to a BX53 differential interference contrast microscope (Olympus, Japan). For scanning electron microscope (SEM) preparation, specimens were dehydrated in a series of graded ethanol solutions, then placed in hexamethyldisilazane (HMDS), dried, mounted on stubs, coated in gold, and observed an EM-30 SEM (Coxem, Korea) at Hanyang University, Seoul, Korea. Descriptive terminology was adopted from Huys and Boxshall (1991).

DNA extraction and amplification

Two *Calanopia* species (*C. elliptica* and *C. minor*) were collected from the sampling site and used for molecular comparison. For genomic DNA extraction, each of the individuals was used non-destructively. Genomic DNA was extracted individually using DNeasy Blood & Tissue Kit (Qiagen, Germany) following the manufacturer's instructions. The COI fragments were amplified using Polymerase chain reaction (PCR) in 25 μL reaction volumes containing extracted DNA and a primer pair, jgLCO1490 (5′-TITCIACIAAYCAYAARGAYATTGG-3′) and jgHCO 2198 (5′-TAIACYTCIGGRTGICCRAARAAYCA-3′) (Geller *et al*., 2013). PCR conditions comprised initial denaturation at 94°C for 2 min, followed by 40 cycles of denaturation at 94°C for 1 min, annealing at 48°C for 1 min, and extension at 72°C for 1 min. This was followed by a final extension step at 72°C for 5 min. PCR products were evaluated by electrophoresing amplification products on 1% agarose.

Molecular comparison

Sequences were aligned using CLUSTAL W (Thompson *et al*., 1994) implemented in MEGA X (Kumar *et al*., 2018). Aligned sequences were compared with public information for *Calanopia* species on the GenBank database (Table 1). Pairwise genetic distances were calculated using the Tamura-Nei (Tamura and Nei, 1993). A phylogenetic analysis was constructed using the Maximum Likelihood method and Tamura-Nei model. Codon position included $1^{st}+2^{nd}+3^{rd}+$Noncoding. *Pontellopsis yamadae* Mori, 1937 was used as an outgroup.

Results

Systematics

Order Calanoida Sars G.O., 1903
Family Pontellidae Dana, 1852−1853
Genus *Calanopia* Dana, 1852−1853

Calanopia minor Scott A., 1902 (Figs. 1−6)

Calanopia minor Scott A., 1902, P. 397−428, Plate I, Figs. 1−5.

Materials examined. All specimens were collected at the pier on Dokdo Island, Korea (37°14′22″N, 131°52′03″E), on 13 October 2022. One ♀ (NIBRIV0000926141) and one ♂ (NIBRIV0000926142) were dissected and mounted on twelve and four slides, respectively. Twenty individuals (10♀♀, 10♂♂) were used for length measurement. Eight individuals were used for molecular comparison.

Description of female. Total body length 1,431 to 1,521 μm (mean ± SD = 1,474 ± 29 μm, n = 10) as measured from anterior margin of cephalosome to posterior margin of caudal rami.

Prosome (Fig. 1A) 5-segmented; cephalosome and first pedigerous somite separate; fourth and fifth pedigerous somite fused; posterior corners of fifth pedigerous somite pointed.

Urosome (Figs. 1A, B, 2C, D, 6A) 2-segmented, genital somite symmetrical, slightly swollen laterally; second urosomite symmetrical and longer than genital somite. Caudal

Table 1. List of species analyzed in molecular comparison.

Species	Locality	Accession number	Reference
Calanopia elliptica	Red Sea	MN796254	El-Sherbiny and Al-Harbi, 2020
	Chennai coast	OP103961	Sivakumar *et al*., 2022 (unpublished)
	East Sea, Korea	PV643179−PV643180	Present study
Calanopia minor	Red Sea	MN796251−MN796253	El-Sherbiny and Al-Harbi, 2020
	East Sea, Korea	PV643171−PV643178	Present study
Pontellopsis yamadae	East China Sea	JQ714070	Jeong *et al*., 2014

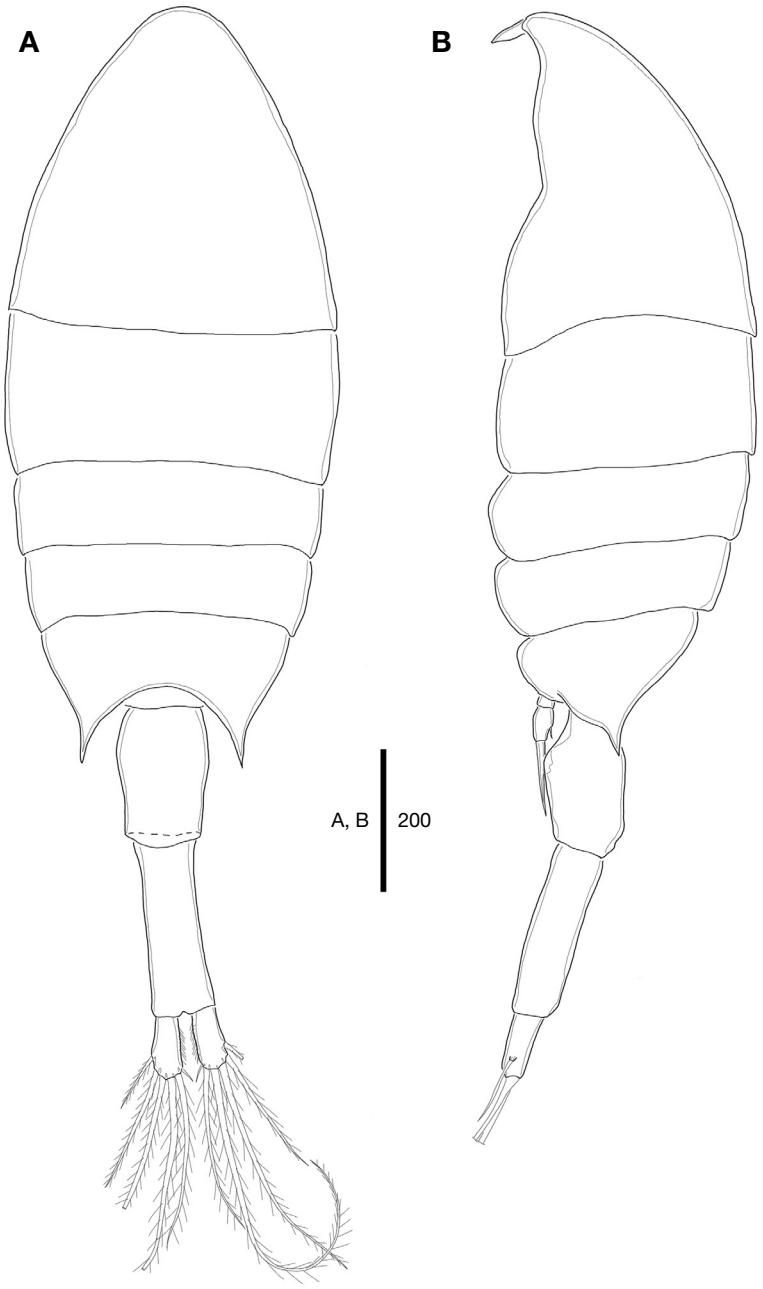

Fig. 1. *Calanopia minor*. Female. A: Habitus, dorsal; B: Habitus, lateral. Scale bar in μm.

rami bearing short hairs on inner lateral margin; symmetrical and approximately 2 times as long as wide. Proportional lengths of urosomites and caudal rami as 34 : 50 : 16 = 100.

Antennule (Fig. 2A) 18-segmented; segmentation and setation pattern as follows: (1) I-[3 + ae], (2) II−VI-[10 + 3ae], (3) VII−X-[6 + 2ae], (4) XI−XII-[4 + 2ae], (5) XIII-[2 + ae], (6) XIV-[2 + ae], (7) XV-[2 + ae], (8) XVI-[2 + ae], (9) XVII-[2 + ae], (10) XVIII-[2 + ae], (11) XIX-[2 + ae], (12) XX-[2 + ae], (13) XXI-[2 + ae], (14) XXII-[1], (15) XXIII-[1], (16) XXIV-[2 (1 + 1)], (17) XXV-[2 (1 + 1) + ae], (18) XXVI−XXVIII-[5 + ae].

Antenna (Fig. 2B). Coxa with one seta; basis with two setae at distal margin; endopod 2-segmented, first endopodal segment with two unequal setae at distal margin, second endopodal segment with eight and six setae on medial and distal lobes, respectively; exopod 5-segmented, setation formula as 1, 5, 1, 1, 3.

Mandible (Fig. 3A). Gnathobasis well-developed and bearing eight teeth, unequal spinules on surface; basis with

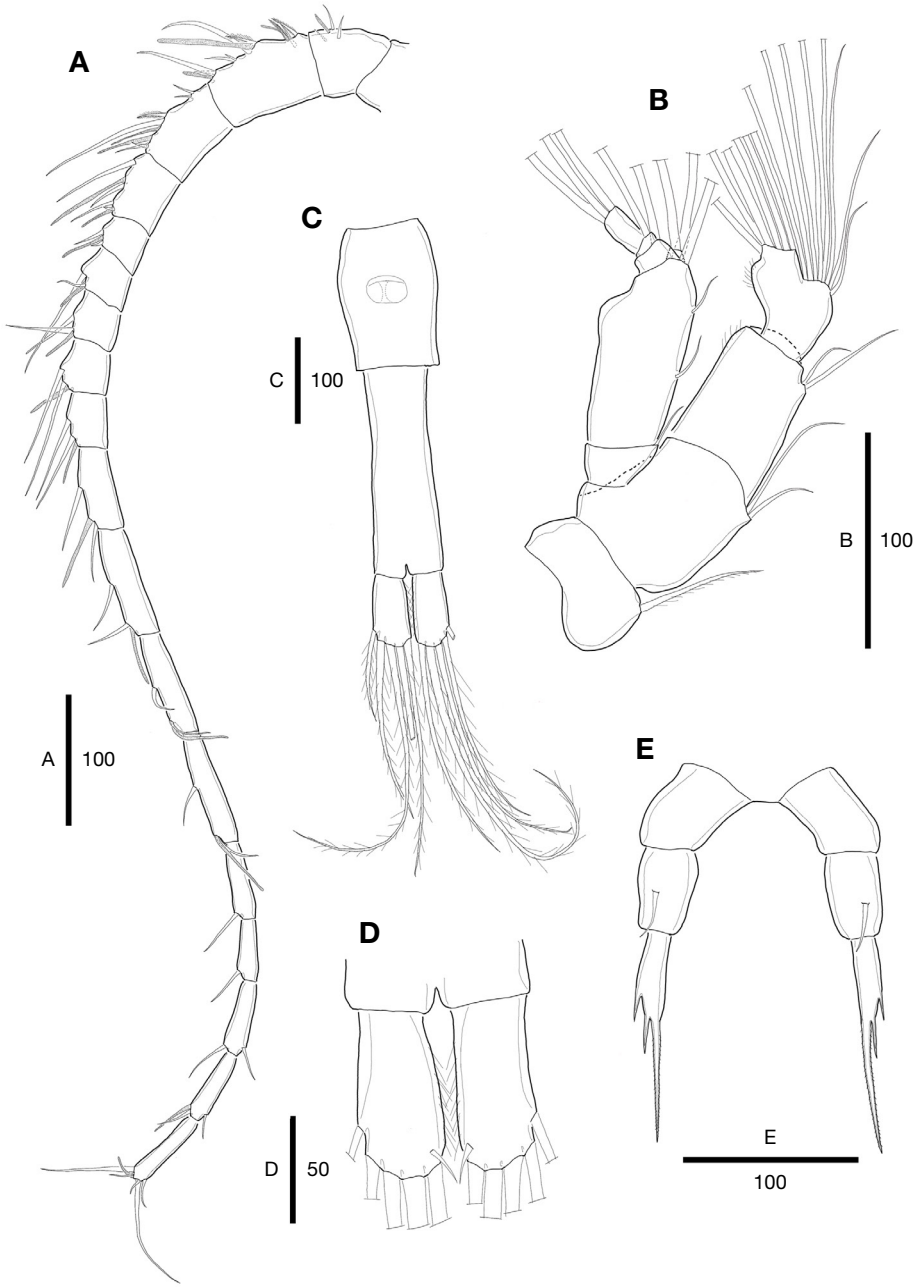

Fig. 2. *Calanopia minor*. Female. A: Antennule; B: Antenna; C: Urosome, ventral; D: Caudal rami, dorsal; E: Leg 5. Scale bars in μm.

four setae on lateral margin; endopod 2-segmented, first endopodal segment with four setae, second endopodal segment with six setae; exopod 5-segmented, setation formula as 1, 1, 1, 1, 2.

Maxillule (Fig. 3B). Praecoxal arthrite with twelve elements (eight marginal, four on medial surface; coxal epipodite with nine setae; coxal and basal endites with three and two setae, respectively; basal excite with one seta. Endopod incorporated into basis with four setae on lateral margin and seven setae on distal margin. Exopod bearing nine setae on distal margin.

Maxilla (Fig. 3C). Praecoxa and coxa incompletely fused, setation formula of endites 5, 3, 3, 3; basal endite with three setae; endopod 3-segmented with setation formula 1, 1, 4.

Maxilliped (Fig. 3D). Syncoxa with three endites carrying each two setae; basis elongate with two setae at distal margin; endopod 4-segmented, setation formula as 2, 1, 2, 2.

Legs 1−4 (Fig. 4A−D): biramous, with 3-segmented

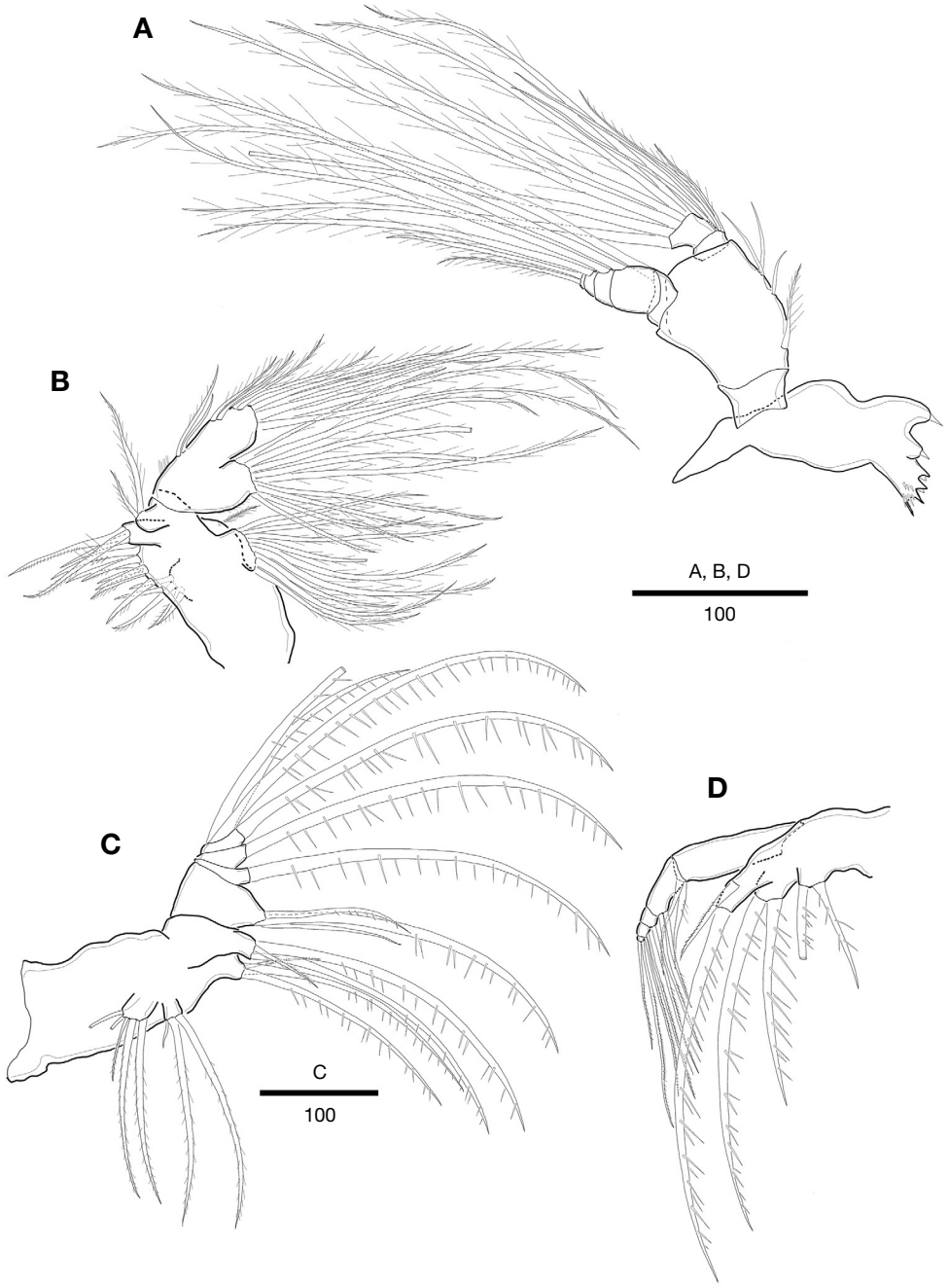

Fig. 3. *Calanopia minor*. Female. A: Mandible; B: Maxillule; C: Maxilla; D: Maxilliped. Scale bars in μm.

exopod and 2-segmented endopod. Coxa of legs 1−2 with unequal spinules on outer margin as illustrated. Intercoxal sclerites well developed. Spine and seta formula as follows (spine, Roman numerals; seta, Arabic numerals):

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	0-0	I-1; I-1; II-I-4	0-3; 1-2-3
Leg 2	0-1	0-0	I-1; I-1; III-I-5	0-3; 2-2-4
Leg 3	0-1	0-0	I-1; I-1; III-I-5	0-3; 2-2-4
Leg 4	0-1	0-0	I-1; I-1; III-I-5	0-3; 2-2-3

Leg 1 (Fig. 4A). Coxa with one seta on inner margin. Basis unarmed. Endopod 2-segmented; enp-1 with three inner setae; enp-2 with three inner setae, two distal setae, and one outer seta. Exopod 3-segmented; exp-1 with one inner seta and one outer spine; exp-2 with one inner seta and one outer spine; exp-3 with four inner setae, one distal spine, and two outer spines.

Leg 2 (Fig. 4B). Coxa with one seta on inner margin. Basis with hairs on inner margin. Endopod 2-segmented;

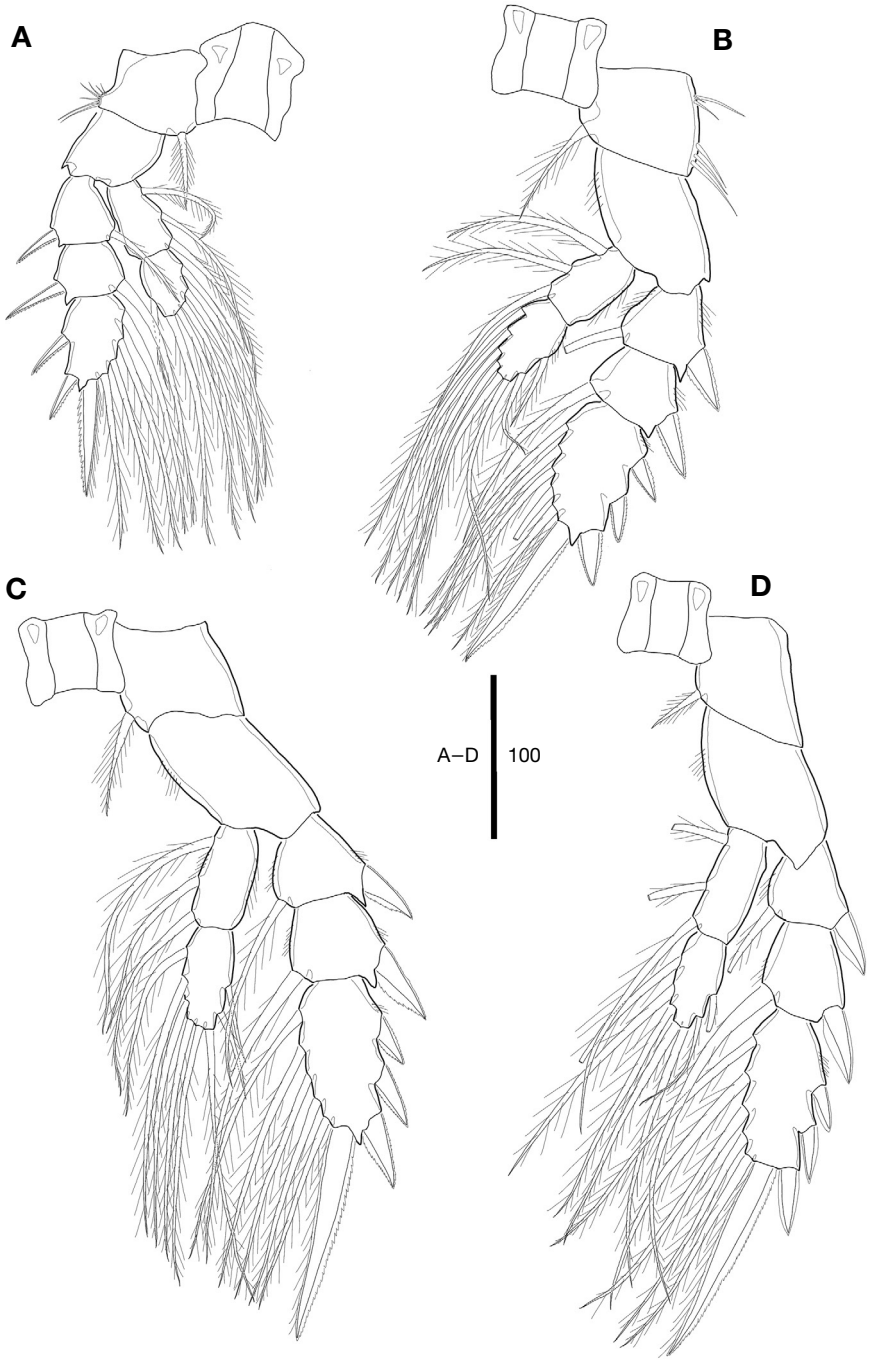

Fig. 4. *Calanopia minor*. Female. A: Leg 1; B: Leg 2; C: Leg 3; D: Leg 4. Scale bar in μm.

enp-1 with three inner setae and hairs on outer margin; enp-2 with four inner setae, two distal setae, two outer setae, and hairs on outer margin. Exopod 3-segmented; exp-1 with one inner seta, one outer spine, and hairs on inner and outer margins; exp-2 with one inner seta and one outer spine, and hairs on outer margin; exp-3 with five inner setae, one distal spine, three outer setae, and hairs on outer margin proximally.

Leg 3 (Fig. 4C). Coxa with one inner seta. Basis with hairs on inner margin. Endopod 2-segmented; enp-1 with three inner setae and hairs on inner and outer margins; enp-2 with four inner setae, two distal setae, and two outer setae. Exopod 3-segmented; exp-1 with one inner seta, one outer spine, and hairs on inner and outer margins; exp-2 with one inner seta, one outer spine, and hairs on inner and outer margins; exp-3 with five inner setae, one distal spine,

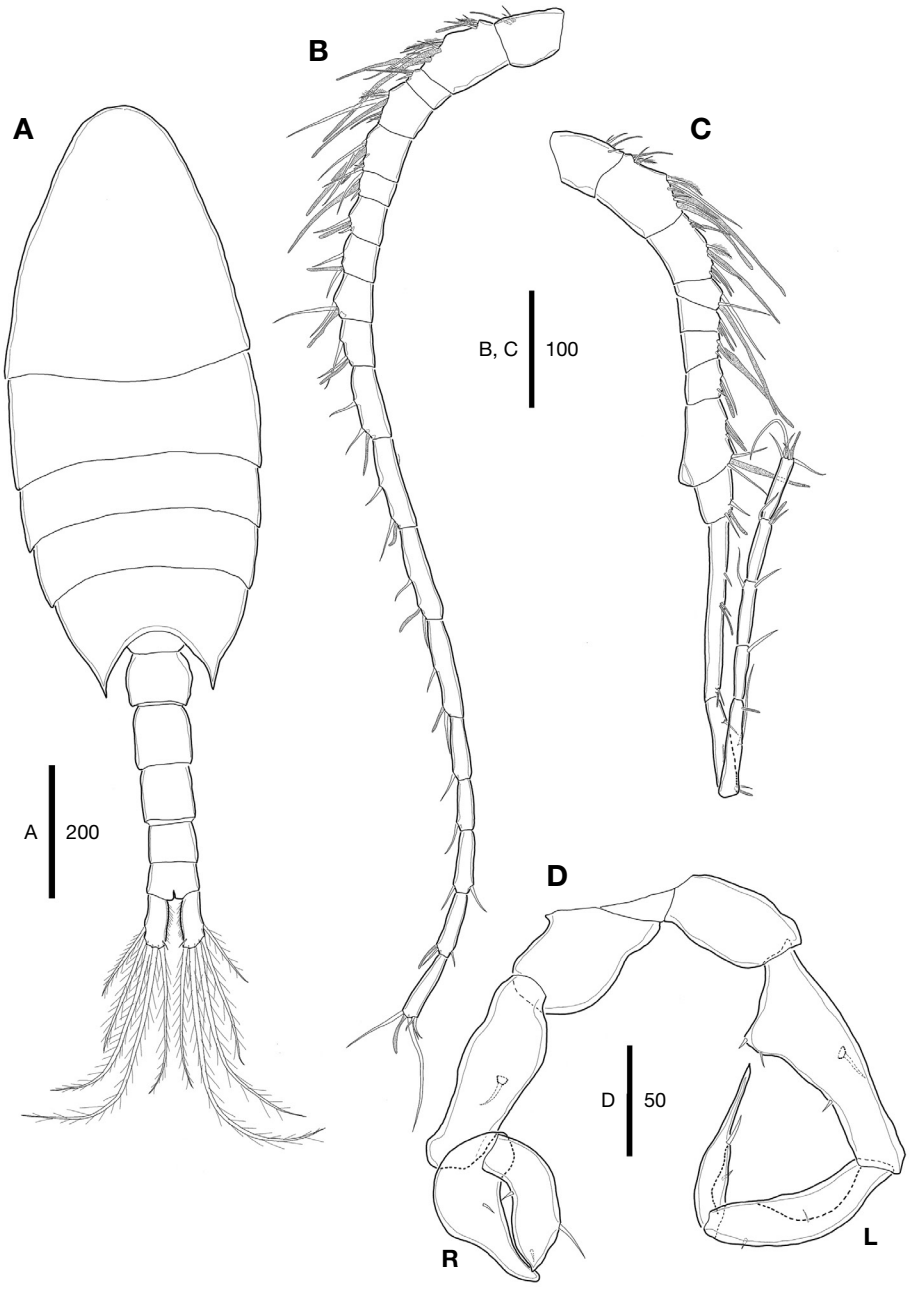

Fig. 5. *Calanopia minor*. Male. A: Habitus, dorsal; B: Antennule (left); C: Antennule (right); D: Leg 5. Scale bars in μm.

and three outer spines.

Leg 4 (Fig. 4D). Coxa with one inner seta. Basis with hairs on inner margin. Endopod 2-segmented; enp-1 with three inner setae; enp-2 with three inner setae, two distal setae, and two outer setae. Exopod 3-segmented; exp-1 with one inner seta, one outer spine, and hairs on inner margin; exp-2 with one inner seta, one outer spine, and hairs on inner margin; exp-3 with five inner setae, one distal spine, and three outer spines.

Leg 5 (Figs. 2E, 6B) symmetrical, comprising coxa, basis, and exopod. Coxa naked, longer than wide. Basis with fine seta on posterior surface. Exopod with three spine-like processes, two small processes on lateral margin and strong serrated process on distal margin.

Description of male. Total body length 1,230 to 1,353 μm (mean ± SD = 1,295 ± 43 μm, n = 10) as measured from anterior margin of cephalosome to posterior margin of caudal rami.

Prosome (Fig. 5A) 5-segmented as in female.

Urosome (Fig. 5A) 5-segmented. Second urosomite lon-

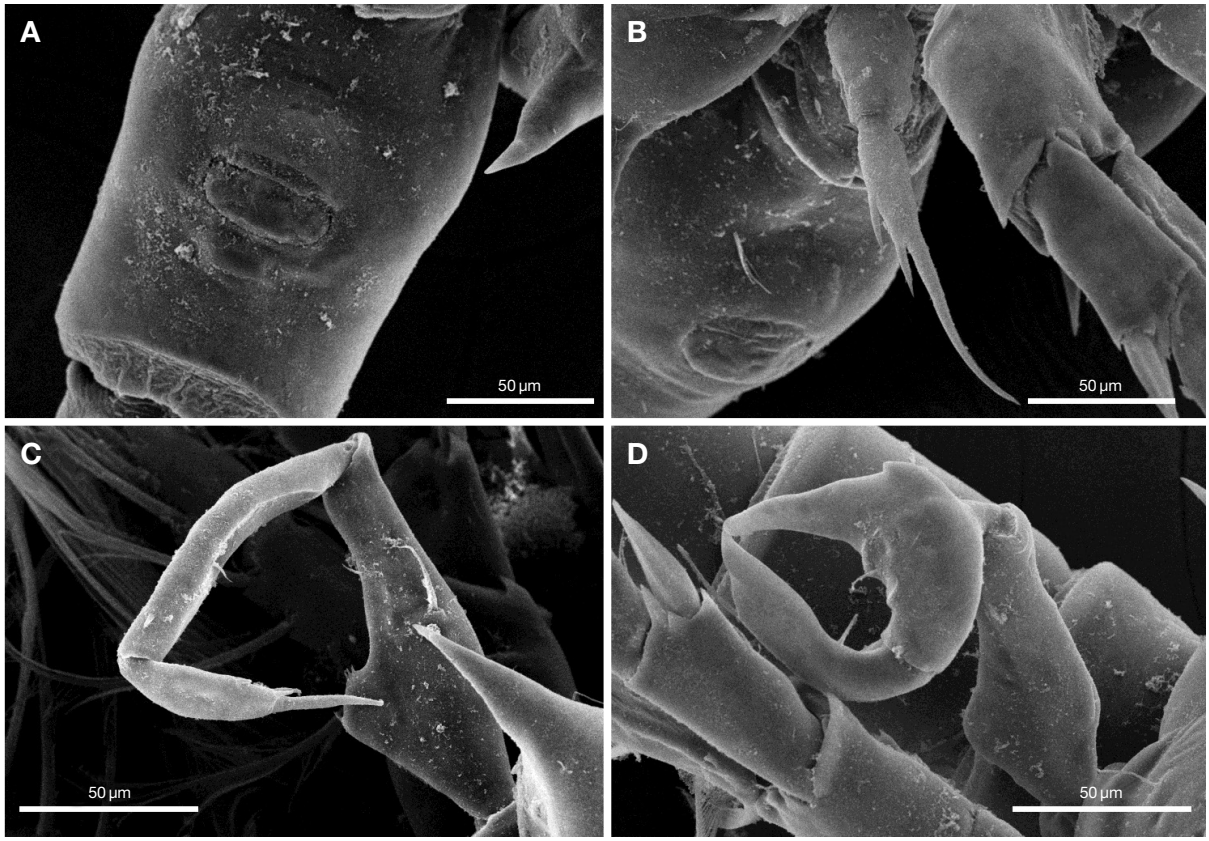

Fig. 6. *Calanopia minor*. Scanning electron micrographs. A: Female, genital somite, ventral; B: Female, leg 5 (right) and genital somite; C: Male, leg 5 (left); D: Male, leg 5 (right).

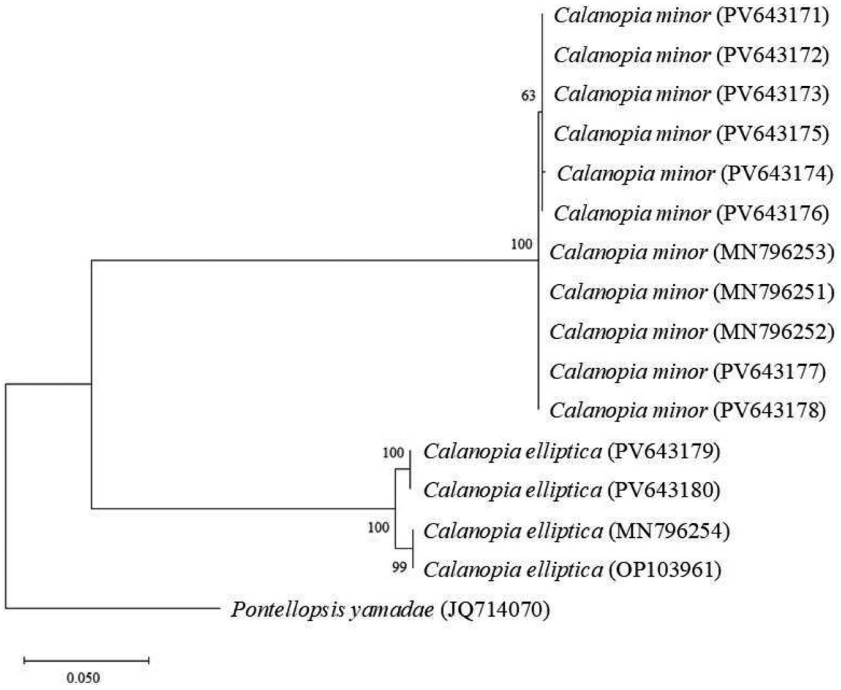

Fig. 7. Phylogenetic tree based on mtCOI sequences of *Calanopia* species including *Pontellopsis yamadae* as an outgroup. One thousand bootstrap replicates were performed by MEGA X using the Maximum Likelihood method and Tamura-Nei model.

Table 2. Pairwise distance of *Calanopia* species based on mitochondrial cytochrome c oxidase subunit I (COI) sequences.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. *Calanopia minor* (PV643171)															
2. *Calanopia minor* (PV643172)	0.000														
3. *Calanopia minor* (PV643173)	0.000	0.000													
4. *Calanopia minor* (PV643174)	0.002	0.002	0.002												
5. *Calanopia minor* (PV643175)	0.000	0.000	0.000	0.002											
6. *Calanopia minor* (PV643176)	0.000	0.000	0.000	0.002	0.000										
7. *Calanopia minor* (PV643177)	0.002	0.002	0.002	0.003	0.002	0.002									
8. *Calanopia minor* (PV643178)	0.002	0.002	0.002	0.003	0.002	0.002	0.000								
9. *Calanopia minor* (MN796251)	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000							
10. *Calanopia minor* (MN796252)	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000						
11. *Calanopia minor* (MN796253)	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000					
12. *Calanopia elliptica* (PV643179)	0.304	0.304	0.304	0.307	0.304	0.304	0.301	0.301	0.302	0.301	0.301				
13. *Calanopia elliptica* (PV643180)	0.304	0.304	0.304	0.307	0.304	0.304	0.301	0.301	0.302	0.301	0.301	0.000			
14. *Calanopia elliptica* (OP103961)	0.297	0.297	0.297	0.300	0.297	0.297	0.297	0.297	0.298	0.297	0.297	0.013	0.013		
15. *Calanopia elliptica* (MN796254)	0.297	0.297	0.297	0.300	0.297	0.297	0.297	0.297	0.298	0.297	0.297	0.013	0.013	0.000	
16. *Pontellopsis yamadae* (JQ714070)	0.282	0.282	0.282	0.285	0.282	0.282	0.279	0.279	0.276	0.275	0.275	0.237	0.237	0.243	0.243

ger than other urosomites. Caudal rami bearing short hairs on inner lateral margin; symmetrical and approximately 3 times as long as wide. Length proportions of urosomites to caudal rami as 18 : 21 : 19 : 13 : 12 : 17 = 100.

Left antennule (Fig. 5B) 19-segmented; segmentation and setation pattern as follows: (1) I-[2 + ae], (2) II−VI-[10 + 3ae], (3) VII-[2 + ae], (4) VIII−X-[4 + 2ae], (5) XI−XII-[4 + 2ae], (6) XIII-[2 + ae], (7) XIV-[2 + ae], (8) XV-[2 + ae], (9) XVI-[2 + ae], (10) XVII-[2 + ae], (11) XVIII-[2 + ae], (12) XIX-[2 + ae], (13) XX-[2 + ae], (14) XXI-[2 + ae], (15) XXII-[1], (16) XXIII-[1], (17) XXIV-[2 (1 + 1)], (18) XXV-[2 (1 + 1) + ae], (19) XXVI−XXVIII-[5 + ae].

Right antennule (Fig. 5C) 16-segmented, geniculated between eleventh and twelfth segments; segmentation and setation pattern as follows: (1) I-[3 + ae], (2) II−VI-[8 + 3ae], (3) VII−X-[6 + 3ae], (4) XI-[2 + ae], (5) XII-[2 + ae], (6) XIII-[2 + ae], (7) XIV-[2 + ae], (8) XV−VI-[4 + ae], (9) XVII-[2 + ae], (10) XVIII−XIX-[3 + 2ae], (11) XX-[2 + ae], (12) XXI−XXII-[1 + ae], (13) XXXIII-[1], (14) XXIV-[2 (1 + 1)], (15) XXV-[2 (1 + 1) + ae], (16) XXVI−XXVIII-[5 + ae].

Antennae, other mouthparts, and Leg 1−4 as in female.

Leg 5 (Fig. 5D) asymmetrical and uniramous, left leg longer than right. Intercoxal sclerite distinct. Left leg (Fig. 6C) 4-segmented, comprising coxa, basis, and 2-segmented exopod; basis with inner lobe carrying two small spines, one small inner spine on medial margin, one seta on posterior surface; exp-1 with small spine on distal half of outer margin, small seta on medial surface; exp-2 with two unequal spines on inner margin and tapering distal process. Right leg (Fig. 6D) 4-segmented, as in left leg; basis with one seta on posterior surface; 2-segmented exopod forming a stout chela; exp-1 with one small spine on medial surface; exp-2 with three unequal spines, one spine on inner margin, one spine on distal surface, and one longer spine on outer lateral margin.

Molecular comparison

A 658 bp partial region of COI was obtained from *C. elliptica* and *C. minor*. To confirm species identification, these sequences were compared to the public data of each species in the NCBI database. As a result, intraspecific genetic distances were shown as 0−1.3% in *C. elliptica* and 0−0.3% in *C. minor* (Table 2). Interspecific distances ranged from 29.7% to 30.4%. The phylogenetic tree showed that each species formed a monophyletic clade (Fig. 7).

Discussion

Calanopia species share the following features: (1) cephalosome without cuticular lenses on dorsal surface; (2) antennary exopod longer than half endopod; (3) leg 1 endo-

Table 3. Morphological differences among *Calanopia* species recorded from Korea.

	C. elliptica	*C. minor*	*C. thompsoni*
Female			
Body length (μm)	1800–1890	1431–1521	1920–1980
Lateral hooks on the cephalosome	Absence	Absence	Presence
Leg 5			
Symmetry of left and right legs	Asymmetrical (left longer)	Symmetrical	Symmetrical
Number of segments of exopod	2-segmented	1-segmented	2-segmented
Urosome			
Length ratio of 1st urosomite/2nd urosomite	1.2	0.65	1.2
Male			
Body length (μm)	1760–1780	1230–1353	1790–1830
Lateral hooks on the cephalosome	Absence	Absence	Presence
Leg 5			
Symmetry of left and right legs	Asymmetrical (right longer)	Asymmetrical (left longer)	Asymmetrical (right longer)
Urosome			
Spiniform process on 2nd urosomite	Presence	Absence	Absence
Reference	Soh, 2010	Present study	Al-Aidaroos *et al*., 2016

pod two-segmented; and (4) male leg 5 four-segmented on both sides, distal two segments of right leg forming stout chela (Bradford-Grieve *et al*., 1999; Boxshall and Halsey, 2004). The specimens described in this study had all morphological characteristics mentioned above and clearly fitted the diagnostic characteristics of *C. minor* as follows: 1) female leg 5 exopod one-segmented; 2) female leg 5 exopod with two small lateral spines and one long distal spine; 3) left ramus of male leg 5 longer than right one; and 4) left basis of male leg 5 swollen proximally.

The species can be found across a very wide range of waters and considerable have been studied. However, those studies have focused on specific parts such as habitus, rostrum, Leg 5, urosome, and geniculate segment of male antennule (Scott, 1909; Tanaka, 1964; Chen and Zhang, 1965; Silas and Pillai, 1973; Bradford *et al*., 1999; Mulyadi, 2002; Razouls *et al*., 2025). In the present study, we provided the detail of the morphological characteristics of *C. minor* based on the Korean material collected from Dokdo Island of East Sea. This description would be valuable for future phylogenetic studies utilizing morphological traits of the genus *Calanopia*.

Since Scott, A. (1902) described *C. minor* collected from the Red Sea, Gulf of Aden, and Arabian Sea, this species has been reported across a wide range of regions, including the Atlantic Ocean (South Africa), the Indian Ocean (Gulf of Aden, India, Mozambique Channel, Red Sea, South Africa, Suez Canal), the Pacific Ocean (Colombia, East China Sea, Gulf of California, Gulf of Thailand, Indonesia, Japan, Malaysia, New Caledonia, Polynesia, South China Sea, Straits of Malacca, and Taiwan), and the Mediterranean (Razouls *et al*., 2025). Soh (2010) reported that three species of *Calanopia* (*C. elliptica*, *C. minor*, and *C. thompsoni*) had been recorded in Korea and provided a taxonomic key for their identification. However, no taxonomic study of *C. minor* has been conducted in Korea to date. Given this situation, it is reasonable to consider only *C. elliptica* and *C. thompsoni* as officially recognized in Korea (NIBR, 2025).

In this study, *Calanopia* species were collected using a light trap. Previous ecological studies reported that *Calanopia* species exhibit a diel vertical migration (DVM) pattern, with high abundance occurring near the surface at night (Turner *et al*., 1979; Pessoa *et al*., 2014; El-Sherbiny and Al-Harbi, 2020). This pattern is known to occur to avoid light, ultraviolet light B (UVB), and predators, as well as to find a favorable environment (Bollen and Frost, 1989; El-Sherbiny and Al-Harbi, 2020). According to a review of *Calanopia* species in the Northwest Pacific, including Korean waters, there are at least seven species in this region (Razouls *et al*., 2025). However, only three species have been recorded in Korea so far, including *C. minor*. This suggests that more species may be present in Korean waters. Given the DVM pattern of *Calanopia*, expanding light trap sampling to various regions would provide a more comprehensive understanding of *Calanopia* species diversity in Korean waters.

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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First record of the family Platyscelidae (Crustacea, Amphipoda, Hyperiidea) from Jeju Island, Korea, with description of newly recorded species, *Tetrathyrus arafurae*

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This study aims to discover and document amphipods from Korea, contributing to the clarification of the Korean amphipod taxonomy. As part of this effort, a newly recorded species belonging to the platyscelid amphipod genus *Tetrathyrus* Claus, 1879 was collected during a pelagic zooplankton survey from off Jeju Island, Korea. The newly recorded species, *Tetrathyrus arafurae* Stebbing, 1888, is characterized by the morphology of the carpi on both gnathopods 1 and 2, and the inner rami on both uropods 1 and 2. This species is morphologically similar to *T. focipatus* Claus, 1879, but can be distinguished by differences in the structure of the basis of pereopod 5, inner rami of uropods 1 and 2, and length ratio of telson. This study represents the first record of both the genus *Tetrathyrus* and the family Platyscelidae in Korean waters. Additionally, a keys to the families of the superfamily Platysceloidea occurring in Korean waters, the family Platyscelidae, and the genus *Tetrathyrus* are provided.

Keywords: Crustacea, hyperiid, plankton, Platysceloidea, taxonomy

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Introduction

The superfamily Platysceloidea is characterized by the both antennae 1 and 2 being positioned on the ventral margin of the head. In addition, males usually possess a strongly zig-zagged, five-articulated antenna 2. The taxonomy of Platysceloidea has presented substantial challenges (Shih and Chen, 1995). Several genera have historically been grouped into families based on superficial morphological similarity and loosely defined characters rather than robust phylogenetic evidence. As a result, the current classification system of families within this superfamily requires systematic revision, and the phylogenetic relationships among the genera need to be carefully reexamined (Zeidler, 2016). Nonetheless, to date, 12 families, Amphithyridae Zeidler, 2016, Anapronoidae Bowman & Gruner, 1973, Brachyscelidae Stephensen, 1923, Eupronoidae Zeidler, 2016, Lycaeidae Claus, 1879, Lycaeopsidae Chevreux, 1913, Oxycephalidae Bate, 1863, Parascelidae Bovallius, 1887, Platyscelidae Bate, 1863, Pronoidae Dana, 1852, Thamneidae Zeidler, 2016, and Tryphanidae Boeck, 1871 have been recorded worldwide (Horton *et al*., 2025).

Among the 12 families, the family Platyscelidae Bate, 1863 can be distinguished from other families within the superfamily Platysceloidea by its reduced pereopod 7 and the presence of a fissure on pereopod 6 (Zeidler, 2016). The nomenclature of the family Platyscelidae has undergone several historical revisions. It was originally referred to as Typhidae Dana, 1853 (Claus, 1879; Stebbing, 1888; Chevreux, 1900; Chevreux and Fage, 1925), a name based on the genus *Typhis* Risso, 1816. However, as *Typhis* had already been used for a molluscan genus by Montfort (1810), the name was invalidated under the rules of zoological nomenclature. In response, Bate (1862) introduced

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the family name Platyscelidae, based on *Platyscelus* Bate, 1861, which was the next available and valid genus name. Later, Claus (1879) erroneously established the genus *Eutyphis* to consolidate several existing genera, including *Platyscelus*, which led Bovallius (1887) to propose the family name Eutyphidae, incorrectly attributing its authorship to Dana (1853). At present, following Bate's original designation, the family is officially recognized as Platyscelidae, based on the valid genus *Platyscelus*.

To date, 11 species belonging to four genera, *Hemityphis* Claus, 1879, *Paratyphis* Claus, 1879, *Platyscelus* Bate, 1862, and *Tetrathyrus* Claus, 1879 have been recorded worldwide within the family Platyscelidae (Horton *et al*., 2025). The genus *Amphithyrus* was previously included in Platyscelidae, however, following a comprehensive review by Zeidler (2016), it was reassigned to the newly established family Amphithyridae due to significant morphological differences from the other genera in Platyscelidae. As a result, only four genera are currently retained within Platyscelidae. Among these, the genus *Tetrathyrus* comprises two species and was established by Claus (1879), with *T. forcipatus* designated as the type species. The genus *Tetrathyrus* is characterized by the absence of a carpal process on gnathopod 1 and the absence of a fissure on pereopod 6.

Until now, no species of the genus *Tetrathyrus* had been recorded from Korean waters. However, *Tetrathyrus forcipatus* has been reported from neighboring regions, including Chinese and North Korean waters (Choi, 1973; Shih and Chen, 1995). Although the genus *Tetrathyrus* had not previously been recorded in South Korea, *Tetrathyrus arafurae* Stebbing, 1888 was collected during a pelagic zooplankton survey conducted in the Southern Sea near Jejudo Island (Fig. 1). This paper thus represents the first record of both the genus *Tetrathyrus* and the family Platyscelidae from Korean waters, adding a newly recorded species to the Korean hyperiid amphipod fauna. In addition, keys to the families of the superfamily Platysceloidea occurring in Korean waters, genera of the family Platyscelidae, and species of the genus *Tetrathyrus* are provided.

Materials and Methods

Specimens were collected with a MOCNESS net from subtidal waters of the South Sea, Korea (Fig. 1). The specimens were fixed in 95% ethanol and dissected in glycerol on Cobb's aluminum hole slides. The materials were examined under stereoscopic (Olympus SZX 10) and compound microscopes (Olympus BX 51), and drawings and measurements were made with the aid of a drawing tube. Line drawings were produced using the program Clip Studio Paint (Celsys, Japan). Body length was measured from the end of the rostrum to the end of the urosome, along the dorsal parabolic line of the body. The examined specimens are deposited at the Marine Biodiversity Institute of Korea (MABIK) in Seocheon, Korea and the Department of Biological Science, Dankook University (DKU), Cheonan, Korea.

Systematic Accounts

Order Amphipoda Latreille, 1816
Suborder Hyperiidea H. Milne Edwards, 1830
Superfamily Platysceloidea Spence Bate, 1862
Family Platyscelidae Spence Bate, 1863
공옆새우과 (신칭)
Genus *Tetrathyrus* Claus, 1879
둥근머리공옆새우속 (신칭)

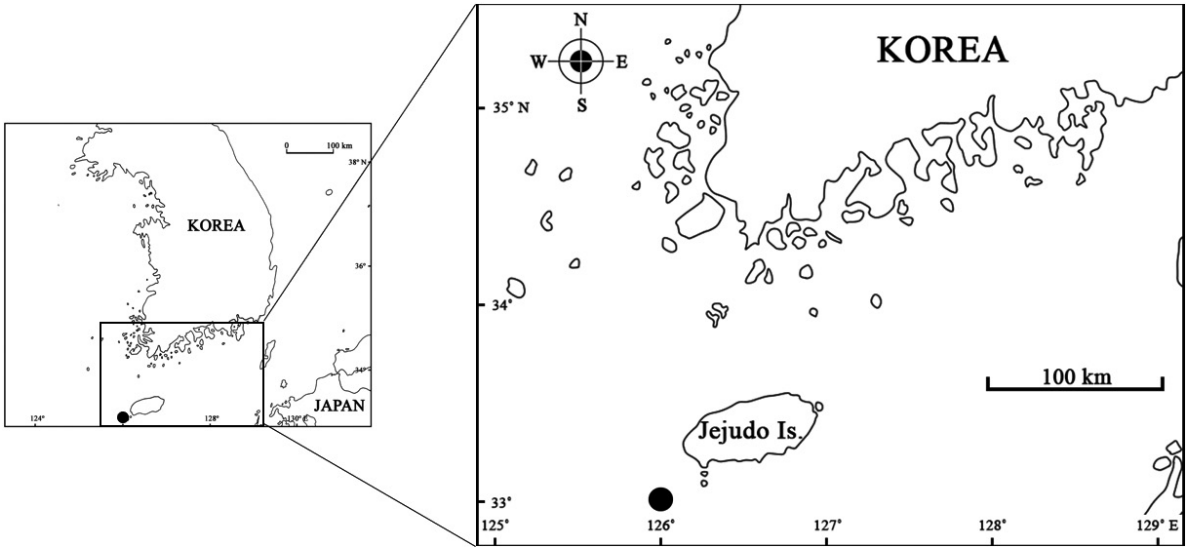

Fig. 1. Distribution of the *Tetrathyrus arafurae* (●: Jeju sea).

***Tetrathyrus arafurae* Stebbing, 1888 (Figs. 2–4)**
긴다리공옆새우 (신칭)
Tetrathyrus arafurae Stebbing, 1888: 1483.

Material examined. 1♂, dissected (appendages on one slide), MABIK CR00259792, 1♂, DKU202515, Jeju sea, 32°59′53″N, 125°59′43″E, 14 Jun 2019, by MOCNESS net, collected by SH Choo.

Description. Adult male (MABIK CR00259792), body (Figs. 2, 3A) 6.1 mm long, dorsally smooth. Head ovate, slightly deeper than long, subequal in length to pereonites 1–4 combined; eyes well developed, covering most of head. Urosomite 3, and Telson fused with urosomite 2. Antenna 1 (Fig. 3B), peduncle reduced to one article, lateral margin convex, flagellum 4-articulate, with large, expanded, crescent-shaped callynophore, with rows of aesthetascs on lateral and posterior margins. Antenna 2 (Fig. 3C) elongate, slender, strongly zig-zagged, 5-articulate, with most articles fold back on each other.

Gnathopod 1 (Fig. 3D) subchelate; ischium short, trapezoidal, posterior margin with 1 seta; merus relatively expanded, broadening distally, 2.82× ischium, anterodistal corner with 1 seta, posterior margin with 5 setae; carpus longish ovate, 0.67× merus, posterior margin with 4 setae; propodus subrectangular, relatively slender, 0.76× carpus, anterior margin convex, posterodistal corner excavate; dactylus falcate, short, 0.08× propodus.

Gnathopod 2 (Fig. 3E) similar to gnathopod 1, but elongate.

Pereopod 3 (Fig. 3F) slender; basis elongate, anterior margin concave, posterior margin strongly curved; ischium short, 0.12× basis, anterior margin concave; merus 4.93× ischium, anteroproximal margin slightly concave, anterior margin curved; carpus subrectangular, 0.82× merus; propodus slender, anterior margin slightly curved, 0.67× carpus; dactylus falcate, short, 0.15× propodus.

Pereopod 4 (Fig. 3G) similar to pereopod 3, but elongated.

Pereopod 5 (Fig. 3H), basis characteristic in form, elongate, expanded, 2.44× longer than wide, midanterior margin convex, anterodistal margin with 6 setae; ischium trapezoidal, short, 0.05× basis, posterior margin concave; merus subrectangular, 5.59× ischium; carpus subrectangular, 1.43× merus; propodus relatively slender, 0.86× carpus; dactylus narrow, falcate, 0.17× propodus.

Pereopod 6 (Fig. 4A) basis elongate-ovate, expanded, 2.07× longer than wide, narrowing distally, anteroproximal margin convex; ischium trapezoidal, short, 0.07× basis, posterior margin concave; merus subrectangular, 2.62× ischium, anterior margin with serration; carpus longish oval, 0.57× merus, half of anterior margin with serration; propodus relatively slender, 0.83× carpus, half of anterior margin with serration; dactylus narrow, falcate, 0.21× propodus.

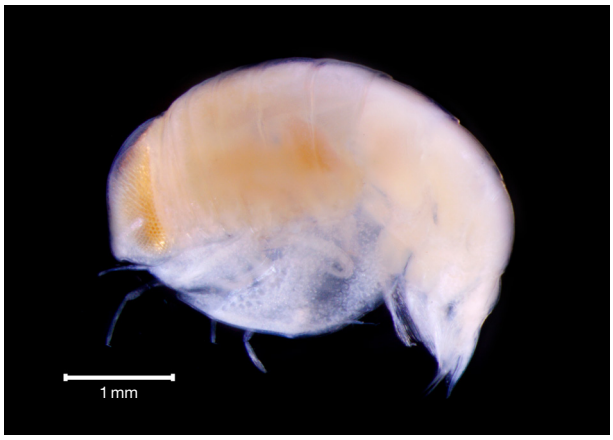

Fig. 2. *Tetrathyrus arafurae* Stebbing, 1888, adult male, 6.1 mm, habitus. Scale bar = 1.0 mm.

Pereopod 7, lost.

Uropod 1 (Fig. 4B), peduncle subrectangular, widening distally, laterodistal corner slightly produced; outer ramus lanceolate, 0.93× peduncle, lateral and medial margins with serrulation; inner ramus lanceolate, broader than outer ramus, 1.12× outer ramus, lateral and one third of medial margins with serration.

Uropod 2 (Fig. 4B) characteristic in form, shorter than uropod 1; peduncle subrectangular, widening distally; outer ramus lanceolate, 1.18× peduncle, medial margin with serrulation; inner ramus lanceolate, broader than outer ramus, 1.76× outer ramus, half of lateral and medial margins with serrulation.

Uropod 3 (Fig. 4B) characteristic in form, shorter than uropod 2; peduncle subrectangular; outer ramus lanceolate, slender, 1.36× peduncle, medial margin with serrulation; inner ramus lanceolate, broader than outer ramus, 1.21× outer ramus, lateral and medial margins with serrulation.

Telson (Fig. 4B) characteristic in form, fused with urosomite 2–3, 1.24 × urosomite 2–3 combined, entire, elongate, isosceles triangle in shape, unarmed.

Distribution. Cosmopolitan (Tropical and Subtropical waters).

Remarks. *Tetrathyrus arafurae* Stebbing, 1888 is similar to *T. forcipatus* Claus, 1879 in that both species lack a carpal process on gnathopods 1 and 2. However, *T. arafurae* can be distinguished from its congener by the following features (different characteristics of *T. forcipatus* in brackets): 1) pereopod 5, basis 2.3–2.8× longer than wide (vs. about twice as long as wide); 2) uropod 2, inner ramus articulated with peduncle (vs. fused); 3) uropod 3, inner ramus articulated with peduncle (vs. fused); and 4) telson longer than urosomites 2–3 combined (vs. shorter). Despite the limited number of specimens, due to the characters of uropods 2 and 3 with the outer ramus fused to the pe-

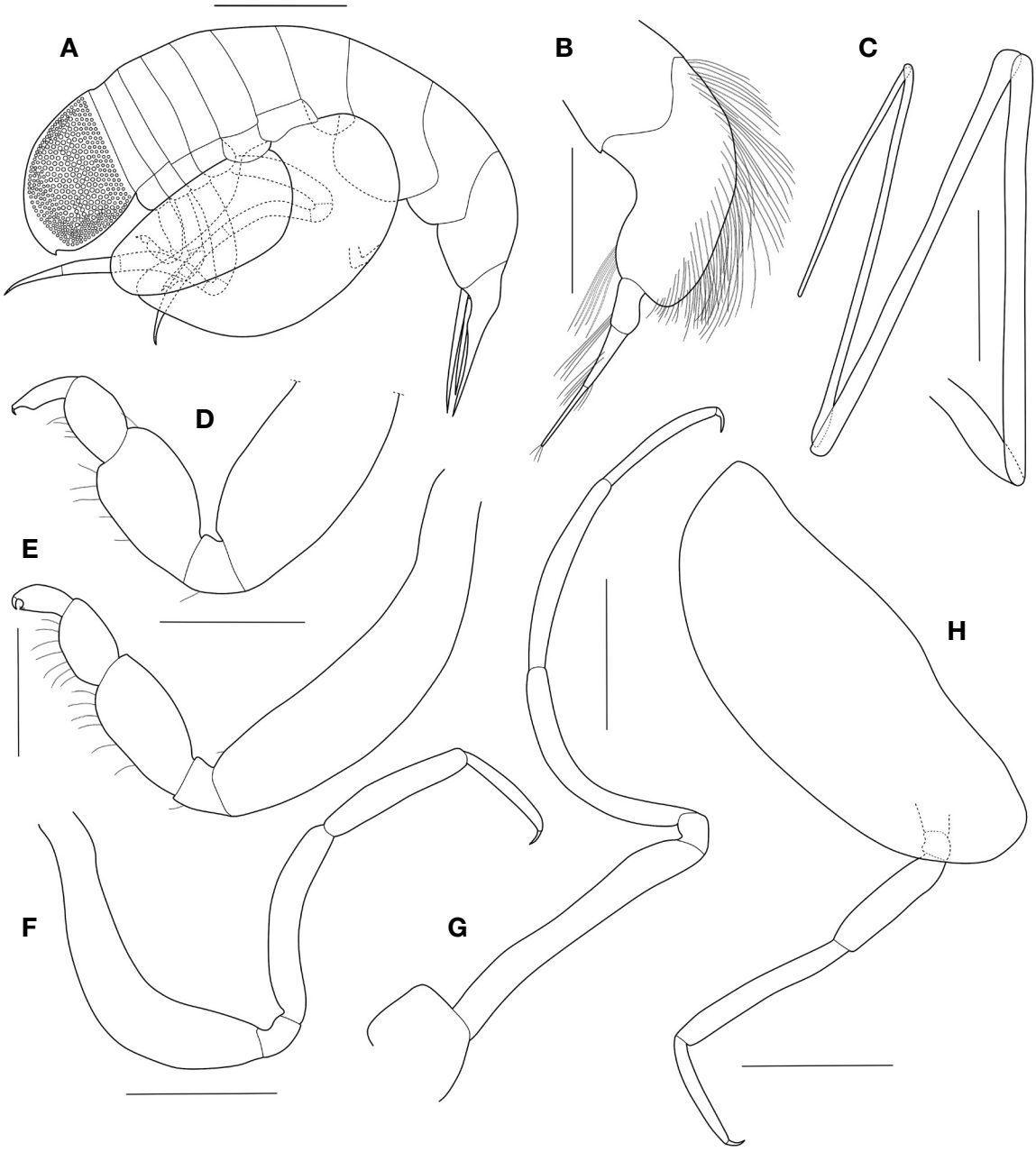

Fig. 3. *Tetrathyrus arafurae* Stebbing, 1888, adult male, 6.1 mm. A, habitus, lateral; B, antenna 1; C, antenna 2; D, gnathopod 1; E, gnathopod 2; F, pereopod 3; G, pereopod 4; H, pereopod 5. Scale bars: A = 1.0 mm; B = 0.2 mm; C, F–H = 0.5 mm; D, E = 0.3 mm.

duncle, a telson shorter than urosomites 2–3 combined, and pereopod 5 with an oval basis about twice as long as wide, our specimens accord with the original description provided by Stebbing (1888).

Key to families of the superfamily Platysceloidea from Korean waters

1. Head produced into elongated rostrum in male and female ····· Oxycephalidae Bate, 1863
– Head rounded in male and female or slightly produced in male ····· 2
2. Body rolled into ball; pereopods 5–6 bases covering other articles ····· 3
– Body curved; pereopods 5–6 bases not covering other articles ····· 4
3. Gnathopods 1–2, simple ····· Parascelidae Bovallius, 1887
– Gnathopods 1–2, subchelate ···· Platyscelidae Bate, 1863
4. Telson articulated with double urosomites 2–3 ····· Brachyscelidae Stephensen, 1923

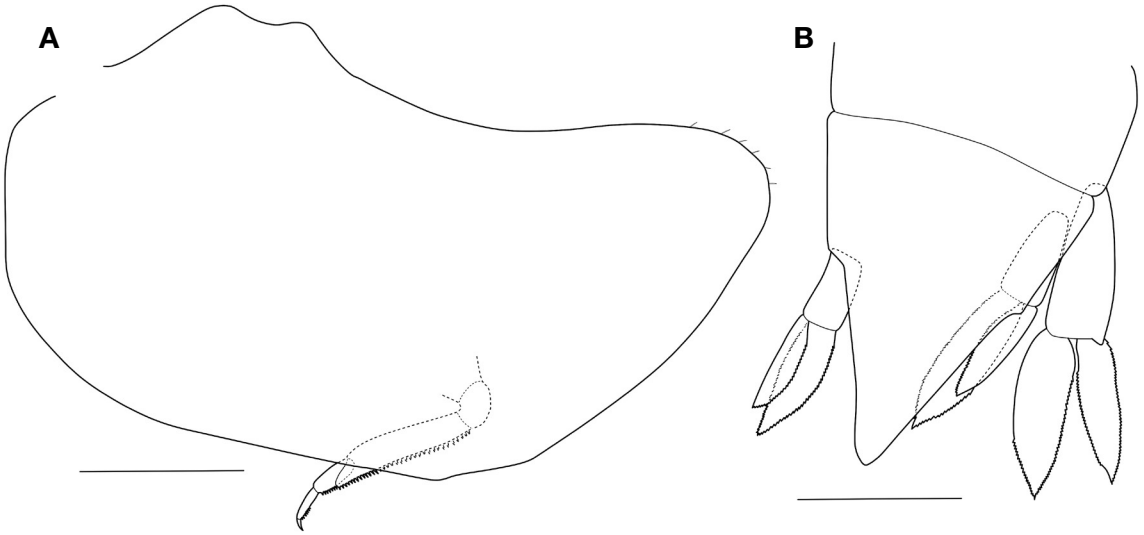

Fig. 4. *Tetrathyrus arafurae* Stebbing, 1888, adult male, 6.1 mm. A, pereopod 6; B, urosomites, uropods, and telson, dorsal. Scale bars: A, B = 0.5 mm.

– Telson fused with double urosomites 2–3 ····· ····· Lycaeidae Claus, 1879

Key to genera of the family Platyscelidae

1. Pereopod 6, basis without fissure ····· ····· *Tetrathyrus* Claus, 1879
– Pereopod 6, basis with fissure ····· 2
2. Gnathopod 1 simple ····· *Paratyphis* Claus, 1879
– Gnathopod 1 carpochelate ····· 3
3. Gnathopod 2, carpal process about 0.7 × propodus ····· ····· *Hemityphis* Claus, 1879
– Gnathopod 2, carpal process as long as propodus ····· ····· *Platyscelus* Bate, 1862

Key to species of the genus *Tetrathyrus*

– Uropods 2–3, inner ramus articulated with peduncle; telson longer than urosomites 2–3 combined ····· ····· *Tetrathyrus arafurae* Stebbing, 1888
– Uropods 2–3, inner ramus fused with peduncle; telson shorter than urosomites 2–3 combined ····· ····· *Tetrathyrus forcipatus* Claus, 1879

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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Open Access

New records of ten species of the subfamily Ctenopelmatinae (Hymenoptera: Ichneumonidae) from South Korea

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The subfamily Ctenopelmatinae, one of the large subfamilies of Ichneumonidae (Hymenoptera: Ichneumonoidea), are comprised of about 1,600 species, 111 genera and nine tribes worldwide. The subfamily is one of the morphologically diverse groups among ichneumon wasps and they are cosmopolitan group. Many species have been recorded from Europe and Western Palaearctic region with 769 species and 792 species respectively. In the Eastern Palaearctic region 458 species are recorded, among them only 46 species in seven tribes from Korea. Species of Ctenopelmatinae are known as endoparasitoids of Hymenoptera (especially sawflies) and a few Coleoptera and Lepidoptera. This paper reports ten unrecorded species belong to eight genera (*Glyptorhaestus*, *Hadrodactylus*, *Lethades*, *Metopheltes*, *Perilissus*, *Pion*, *Sympherta*, and *Xenoschesis*) of Ctenopelmatinae from Korea. Among them, two genera (*Metopheltes* and *Pion*) are newly identified from Korean fauna. Photographs of habitus in lateral view and head in frontal view are provided. We also described diagnostic charactereristics of ten newly recorded species from South Korea.

Keywords: Eastern Palaearctic, ichneumon wasp, parasitic wasp, taxonomy, unrecorded species

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Introduction

The subfamily Ctenopelmatinae is one of the large families consisting of approximately 1,600 species in 111 genera (Li *et al*., 2022). The subfamily is subdivided into nine tribes, seven have been reported in Korea. Uchida (1955), Kim (1955), Townes *et al*. (1965), and Townes (1970) reviewed Korean Ctenopelmatinae, and 46 species in 23 genera have been recorded (Choi *et al*., 2016; Kasparyan *et al*., 2016; Yu *et al*., 2016; Reshchikov *et al*., 2017).

The genus *Xenoschesis* belongs to the tribe Ctenopelmatini and comprises 18 species, including one species distributed in Korea (Uchida, 1928). The genus *Hadrodactylus* belongs to the tribe Euryproctini and comprises 47 species, including one distributed in Korea (Uchida, 1930). The genera *Metopheltes* and *Perilissus* belong to the tribe Perilissini comprising three and 58 species, respectively. Among them, only *Perilissus* has been recorded from Korea with one species (Uchida, 1930). The genera *Glyptorhaestus*, *Lethades*, *Pion*, and *Sympherta* are groups of tribe Pionini comprised of 10 species, 18 species, 8 species, and 29 species, respectively. Three species, a species, and two species were recorded in the genera *Glyptorhaestus*, *Lethades*, and *Sympherta* from South Korea (Hinz, 1975; 1996; Aubert, 2000; Choi *et al*., 2016). Ctenopelmatine species are usually known as the koinobiont endoparasitiods of sawflies, particularly Pamphilioidea and Tenthredinoidea (Yu *et al*., 2016; Li and Sun, 2022; Li *et al*., 2022).

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This paper reports 10 unrecorded species of Ctenopelmatinae from Korea. These species belong to eight genera (*Glyptorhaestus*, *Hadrodactylus*, *Lethades*, *Metopheltes*, *Perilissus*, *Pion*, *Sympherta*, and *Xenoschesis*). Among them, two genera (*Metopheltes* and *Pion*) were newly recorded from Korean fauna. This study showed that the Korean fauna of Ctenopelmatinae consisted of 56 species in 25 genera. Photographs of habitus and diagnoses of newly recorded species from Korea are provided.

Materials and Methods

The wasps investigated in this study were collected using a sweep net and Malaise trap and deposited in the Georim Entomological Institute (GEI, Daegu, South Korea). Distributional data were obtained by Yu *et al*. (2016). The abbreviations were as follows: AEI, American Entomological Institute, Gainesville, Florida, U.S.A.; HU, Entomological Institute, Faculty of Agriculture, Hokkaido University, Sapporo, Japan; NHM, The Natural History Museum, Department of Entomology, United Kingdom; NHRM, Naturhistoriska Riksmuseet, Sektionen för Entomologi, Stockholm, Sweden; ZMB, Zoologisches Museum (Museum für Naturkunde), Humboldt Universität, Berlin, Germany; ZISP, Zoological Institute, Academy of Sciences, Russia; ZI, Zoologiska Institutionen, Sweden; ZSM, Zoologisches Staatsammlung, Munchen, Germany.

The abbreviations of the Korean provinces and indices used in the paper are as follows: GB, Gyeongsangbuk-do; GG, Gyeonggi-do; GN, Gyeongsangnam-do; GW, Gangwon-do; TD: Type depository; TL: Type locality. The specimens were examined using an AxioCam MRc5 camera attached to a stereo microscope (Zeiss SteREO Discovery. V20; Carl Zeiss, Göttingen, Germany), processed using the AxioVision SE64 software (Carl Zeiss), and optimized with a Delta imaging system (i-solution, IMT i-Solution Inc., Vancouver, Canada). The morphological terminology was applied according to the American Entomological Institute website (http://www.amentinst.org/GIN/morphology.php).

Taxonomy

Order Hymenoptera
Family Ichneumonidae Latreille, 1802
Subfamily Ctenopelmatinae Förster, 1869
짧은자루맵시벌아과 (개칭)

Genus *Glyptorhaestus* Thomson, 1894
고려뿔자루맵시벌속
Glyptorhaestus Thomson, 1894: 1976. Type species: *Rhaestus punctatus* Viereck.
Loxoneurus Schmiedeknecht, 1913: 2711. Type species: *Loxoneurus thuringiacus* Schmiedeknecht.
Oocenteter Cushman, 1935: 555. Type species: *Oocenteter tomostethi* Cushman.

1. *Glyptorhaestus nigrifemur* Hinz, 2000
흑다리고려뿔자루맵시벌 (신칭) (Figs. 1A, 3A)
Glyptorhaestus nigrifemur Hinz, 2000. Type: female, TL: Russia; TD: ZISP.

Diagnosis. Body length 8.0 mm. Body black. Antenna brown. Clypeus and mandible yellow with dark basal and apical margin. Tegula yellow. Wings hyaline. Fore and mid legs yellow with dark brown coxae and brown mid femur. Hind leg dark brown with yellow broad band of tibia. Metasoma with thin brown apical part of each tergite. Head entirely coriaceus with coarse punctures. Antenna with 36 flagellomeres. Face weakly convex. Apical margin of clypeus truncate, with a strongly concaved base. Occipital carina completely developed, joining oral carina at mandibular base. Mesosoma relatively stout, with fine punctures. Pronotum with developed transverse wrinkles. Mesoscutum strongly convex. Epicnemial carina upper end reaching more than half of mesopleuron. Propodeum stout, with coarse and dense punctures, tending to rugose partly. Metasoma densely and coarsely punctate. First tergite 0.8 times as long as apical width. Ovipositor sheath short.
Material examined. 1♀, GN, Jinju-si, Gajwa-dong, 19.v. 1990, JS Park (NIBR_NIBRIN0000984090).
Distribution. South Korea (new record), Russia.

Genus *Hadrodactylus* Förster, 1869
연분홍배뭉툭맵시벌속
Hadrodactylus Förster, 1869: 199. Type species: *Ichneumon typhae* Fourcroy.
Dizemon Förster, 1869: 199. Type species: *Mesoleptus typhae* Gravenhorst.
Zemiodes Förster, 1869: 200. Type species: *Mesoleptus erythropus* Kriechbaumer.
Narcopoea Förster, 1869: 204. Type species: *Mesoleptus typhae* Gravenhorst.
Meropaches Schmiedeknecht, 1913: 2705. Type species: *Meropaches bulsanensis* Schmiedeknecht.

2. *Hadrodactylus paludicola* (Holmgren, 1856)
노랑마디연분홍배뭉툭맵시벌 (신칭) (Figs. 1B, 3B)
Mesoleptus paludicola Holmgren, 1856: 68. Neotype: female, TL: Sweden; TD: NR.
Hadrodactylus paludicola var. *sachalinensis* Uchida, 1930: 286. Type: male, TL: Russia; TD: HU.
Hadrodactylus subalpinus Schmiedeknecht, 1913: 2679. Lectotype: male, TL: Germany; TD: ZMHU.

Diagnosis. Body length 12.0−13.5 mm. Body entirely

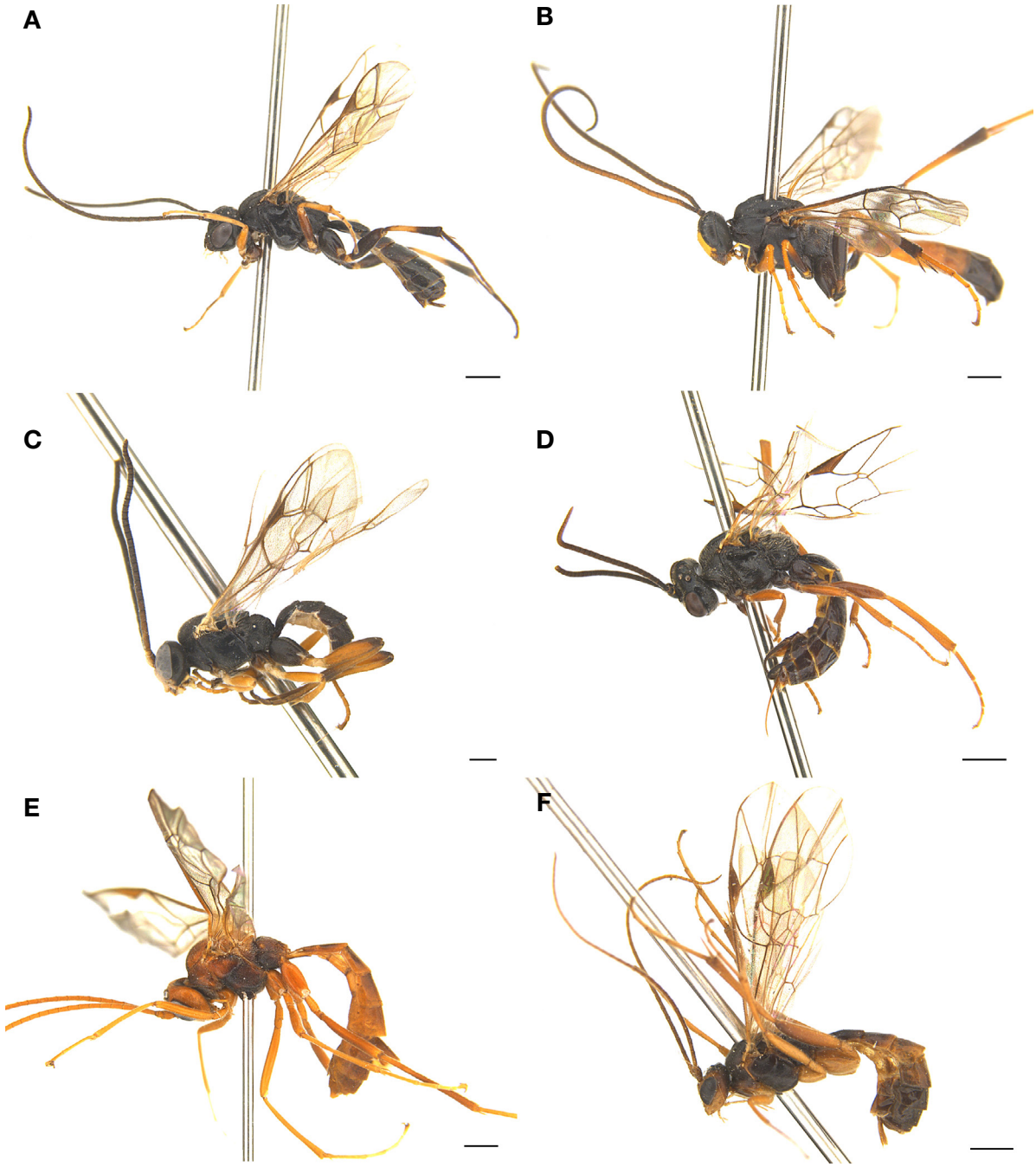

Fig. 1. Habitus in latertal view. A. *Glyptorhaestus nigrifemur*; B. *Hadrodactylus paludicola*; C. *Lethades buriator*; D. *Lethades erichsonii*; E. *Metopheltes chinensis*; F. *Perilissus spilonotus*. Scale bars: A, B, D–F = 1.0 mm; C = 0.5 mm.

black with reddish brown metasoma. Head black with yellow face, clypeus, and mandible (except brown mandibular teeth). Antenna yellow that black basally. Mesosoma black. Tegula and scutellum yellow. Wings hyaline. Fore and mid legs yellow with brown coxae. Hind leg yellow with black coxa, femur, and apical part of tibia. Metasoma black with reddish brown second to third tergites. Head entirely coriaceus with dense punctures. Face flat, inner margin of compound eye parallel. Clypeus 4.0 times as wide as median length. Occipital carina completely developed, joining oral carina at mandibular base. Mesosoma entirely coriaceus with dense, fine punctures. Scutellum strongly convex. Propodeum with fine, dense punctures, only posterior transverse carina present. Metasoma smooth. First tergite 2.3 times as long as apical width. Ovipositor sheath very short.

Material examined. [South Korea] 1♂, GB, Yeongju-si, Punggi-eup, Mt. Sobaeksan, Huibangsa, Birobong, 30.vii.1986, HG Kim; 1♂, GB, Mt. Sobaeksan, 31.vii.1988, HG Kim (NIBR_NIBRIN0000984091). [North Korea] 1♀1♂, Mt. Baekdusan top, 16.viii.1989, JW Lee.
Distribution. South Korea (new record), Austria, Belarus, Belgium, Finland, France, Germany, Ireland, Isle of Man, Netherlands, Norway, Poland, Russia, Sweden, Ukraine, and the United Kingdom.

Genus *Lethades* Davis, 1897 선자루맵시벌속
Lethades Davis, 1897: 204. Type species: *Adelognathus texanus* Davis.

3. *Lethades buriator* Aubert, 1987
이마돌기선자루맵시벌 (신칭) (Figs. 1C, 3C)
Lethades buriator Aubert, 1987: 33. Type: male, TL: Russia; TD: ZISP.

Diagnosis. Body entirely black. Antenna black with yellow basally. Head black. Face, clypeus, and mandible whitish yellow with brown mandibular teeth. Mesosoma black. Tegula whitish yellow. Fore and mid legs yellow with dark brown coxae and whitish yellow trochanter. Hind leg yellow with black coxa and dark brown each apical. Wings hyaline. Metasoma entirely black. Body length 5.0 mm. Head entirely with coarse and dense punctures. Face weakly convex with a very small median projection. Apical margin of clypeus weakly convex. Antenna with 24 flagellomeres. Occipital carina complete, joining oral carina distinctly above base of mandible. Mesosoma stout, with fine dense punctures. Mesoscutum and scutellum strongly convex. Propodeum very stout, with dense and coarse punctures, apical transverse carina, and lateromedian longitudinal carina present posteriorly. Metasoma densely coarsely punctata. First tergite 1.2 times as long as apical width.
Material examined. 1♀, GW, Yanggu-gun, Duta-myeon, 30.v.1992, JW Lee (NIBR_NIBRIN0000984092).
Distribution. South Korea (new record), Russia.

4. *Lethades erichsonii* Hinz, 1996
노랑다리선자루맵시벌 (신칭) (Figs. 1D, 3D)
Lethades erichsonii Hinz, 1996: 276. Type: male, TL: Austria; TD: NHM.

Diagnosis. Black with dark brown metasoma. Head black. Mandible yellow with brown mandibular teeth. Antenna brown. Tegula yellow. Wings hyaline. All legs yellow with dark brown coxae. Metasoma dark brown with black first tergite. Each tergite with thin yellow line apically. Body length 6.0 mm. Head smooth with dense punctures. Dace weakly convex. Apical part of clypeus convex. Antenna with 31 flagellomeres. Occipital carina complete, joining oral carina distinctly above base of mandible. Mesosoma smooth with dense, fine punctures. Mesoscutum weakly convex. Scutellum strongly convex. Propodeum stout, only posterior transverse carina completely present. Metasoma very smooth with thin punctures. First tergite 1.2 times as long as apical width. Ovipositor sheath 0.6 times as long as hind tibia.
Material examined. 1♀, GW, Yanggu-gun, Gachilbong, 31.v.1992, JW Lee (NIBR_NIBRIN0000984093).
Distribution. South Korea (new record), Austria.

Genus *Metopheltes* Uchida, 1932
넓적뺨자루맵시벌속 (신칭)
Metopheltes Uchida, 1932: 162. Type species: *Metopheltes petiolaris* (Uchida).

5. *Metopheltes chinensis* (Morley, 1913)
넓적뺨자루맵시벌 (신칭) (Figs. 1E, 3E)
Opheltes chinensis Morley, 1913: 135. Type: male, TL: China; TD: NHM.

Diagnosis. Body yellow with brown and black spots. Frons with black part near antennal socket. Interocella area and occiput black. Mesosoma yellow with brown and black spots. Pronotum yellow. Propleuron brown. Mesoscutum yellow with a median longitudinal black mark. Scutellum bright yellow. Mesopleuron yellow with dark brown apical half. Propodeum brown with dark basally. All legs entirely yellow. Metasoma yellowish brown with yellow each apically. Head with sparse and dense punctures. Face flat. Gena 3.3 times as long as width of malar space. Occipital carina completely developed, joining oral carina slightly above base of mandible. Antenna with 42 flagellomeres. Epomia slightly present. Mesoscutum strongly convex. Propodeum stout, smooth with fine punctures. All propodeal carina well developed except median anterior carina. Areolet large without petiole. First tergite slender, 3.8 times as long as apical width.
Material examined. 1♂, GB, Gyeongsan-si, Dae-dong, Yeungnam Univ., 24.iv–1.v.2009, JW Lee (NIBR_NIBRIN0000984094).
Distribution. South Korea (new record), China.

Genus *Perilissus* Förster, 1855 홍다리뭉툭맵시벌속
Perilissus Förster, in Holmgren, 1857: 63. Type species: *Ichneumon filicornis* Gravenhorst.
Spanotecnus Förster, 1869: 197. Type species: *Ichneumon filicornis* Gravenhorst.
Ichnaeops Förster, 1869: 197. Type species: *Perilissus lutescens* Holmgren.
Polyoncus Förster, 1869: 197. Type species: *Tryphon erythrocephalus* Gravenhorst.
Udenia Förster, 1869: 202. Type species: *Perilissus* (*Udenia*) *herrichii* Kriechbaumer.
Exacrodus Förster, 1869: 210. Type species: *Exacrodus*

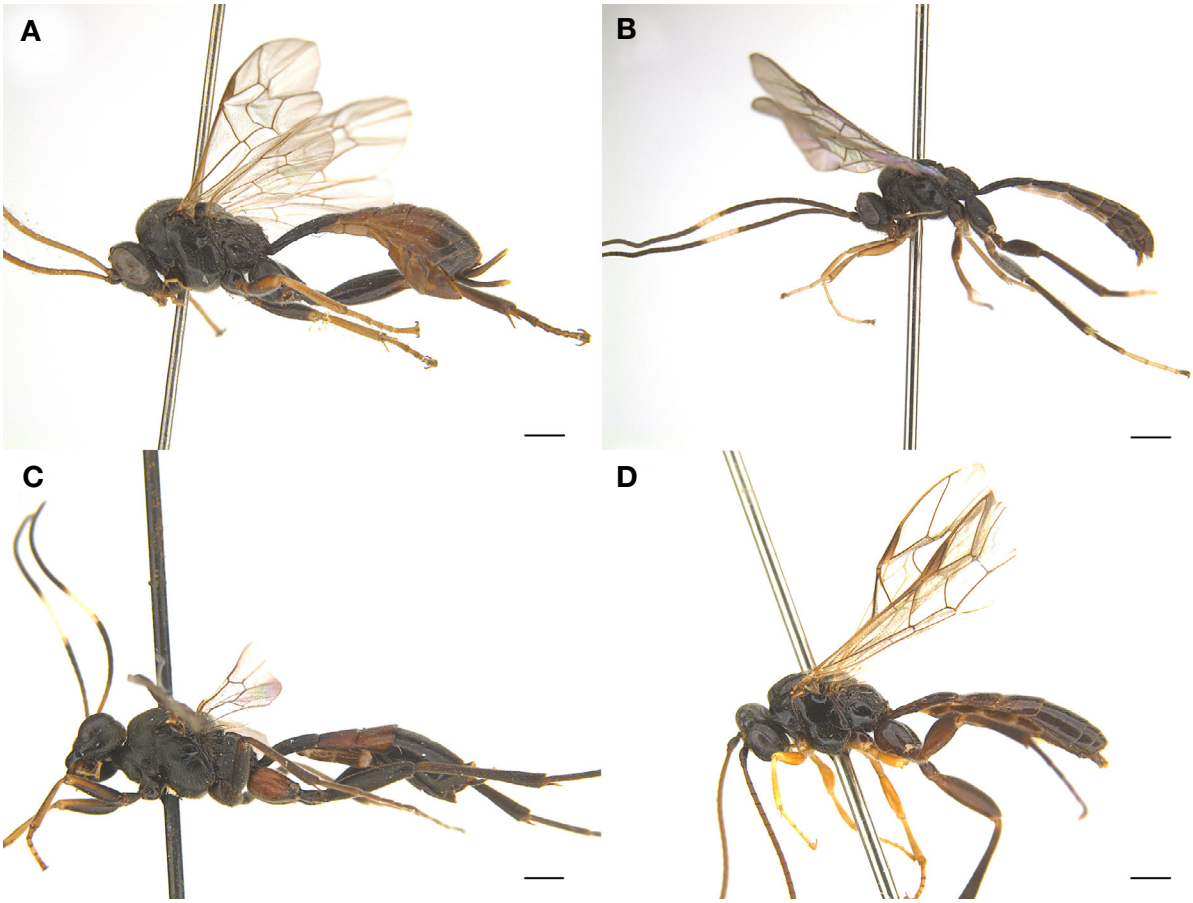

Fig. 2. Habitus in latertal view. A. *Pion nigripes*; B. *Sympherta nigritor*; C. *Sympherta sulcata*; D. *Xenoschesis* (*Polycinetis*) *ustulata*. Scale bars: A–D = 1.0 mm.

populans Morley.

Daugna Seyrig, 1935: 29. Type species: *Daugna alluaudi* Seyrig.

Pseudochorus Rao, 1953: 195. Type species: *Pseudochorus kuriani* Rao.

6. *Perilissus spilonotus* (Stephens, 1835)
노랑홍다리뭉툭맵시벌 (신칭) (Figs. 1F, 3F)

Mesoleptus spilonotus Stephens, 1835: 227. Lectotype: female, TL: United Kingdom; TD: NHM.

Diagnosis. Body length 6.5–7.5 mm. Body entirely brown with yellow marks. Face, inner orbit, clypeus, and mandible yellow with dark brown mandibular teeth. Antenna yellow with brown basally. Mesosoma dark brown. Scutellum brown. Tegula yellow. Fore and mid legs entirely bright yellow. Hind leg yellow with brown femur. Wings hyaline. Metasoma brown with black first tergite. Inner margin of compound eye almost parallel. Clypeus truncated apically. Mandible moderately elongate. Malar space as long as basal mandibular width. Antenna elongated with 31 flagellomeres. Mesoscutum moderately convex with dense fine punctures. Propodeum stout, coriaceus with dense punctures. Propodeal carina completely present, posterior transverse carina very weak medially. First tergite 2.3 times as long as its apical width. Ovipositor sheath short, almost as long as the end of the metasoma (slightly exposed).

Material examined. 1♀, GB, Cheongdo-gun, Unmun-myeon, Unmunsa, 28.v.1989, JW Park; 1♂, GB, Gyeongsan-si, Dae-dong, Yeungnam Univ., 19–25.v.1993, KI Suh; 1♀, GN, Cheonggoksa, 28.v.1983; 1♀, GN, Jinju-si, Gajwa-dong, 12–19.v.1987, KI Suh (NIBR_NIBRIN0000984095); 1♂, GW, Yanggu-gun, Mt. Daeamsan, Yongneup, 30.v.1992, JW Lee.

Distribution. South Korea (new record), Belarus, Belgium, Czech Republic, Slovakia, Finland, France, Germany, Ireland, Norway, Switzerland, Türkiye, Ukraine, and the United Kingdom.

Genus *Pion* Schiødte, 1839
붉은마디자루맵시벌속 (신칭)

Pion Schiødte, 1839: 318. Type species: *Mesoleptus fortipes* Gravenhorst.

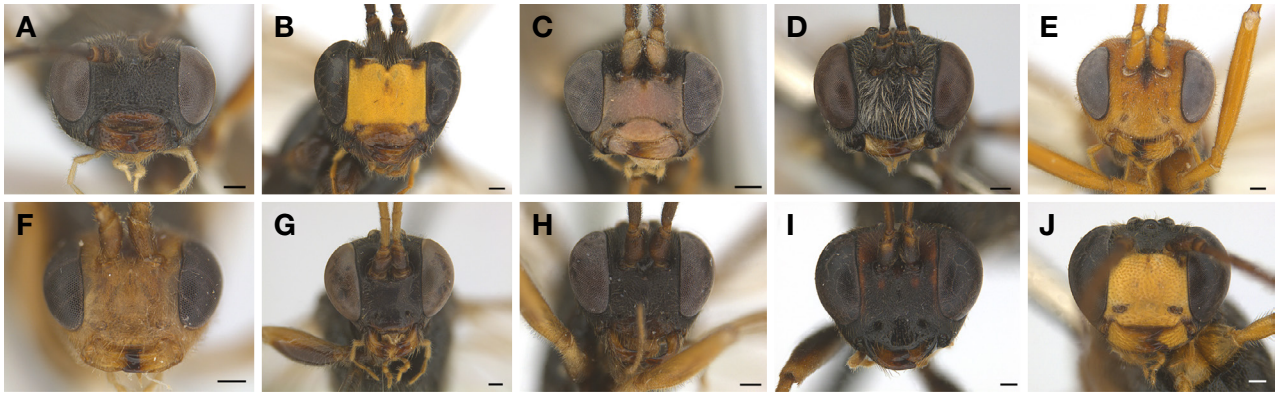

Fig. 3. Head in frontal view. A. *Glyptorhaestus nigrifemur*; B. *Hadrodactylus paludicola*; C. *Lethades buriator*; D. *Lethades erichsonii*; E. *Metopheltes chinensis*; F. *Perilissus spilonotus*; G. *Pion nigripes*; H. *Sympherta nigritor*; I. *Sympherta sulcata*; J. *Xenoschesis* (*Polycinetis*) *ustulata*. Scale bars: A–J = 0.2 mm.

7. *Pion nigripes* Schiødte, 1839

붉은마디자루맵시벌 (신칭) (Figs. 2A, 3G)

Pion nigripes Schiødte, 1839: 309. Type: lost, TL: Denmark.

Catoglyptus crassipes Holmgren, 1857: 93. 106. Type: unknown.

Diagnosis. Body length 9.5–10.0 mm. Body black with reddish brown tergites. Head black. Mandible brown with yellow mandibular teeth. Antenna yellow with black scape. Fore and mid-leg yellow with black coxae and brown femora. Hind leg brown with black coxa. Wings hyaline. Metasoma black with second to fourth reddish brown tergites. Frons strongly concave. Inner margin of compound eye parallel. Clypeus separated with groove, truncated apically. Mandible elongated, upper teeth shorter than lower teeth. Malar space 0.5 times as long as basal mandibular width. Antenna with 30 flagellomeres. Mesoscutum convex with dense fine punctures. Propodeum coriaceus with shine median part. Lateromedian longitudinal carina of propodeum parallel. First tergite petiolated, 3.0 times as long as apical width. Second tergite 0.7 times as long as its apical width. Ovipositor sheath short, slightly exposed.

Material examined. 2♀♀, GB, Cheongdo-gun, Unmun-myeon, Mt. Unmunsan, Ssalbawi, 9–28.vi.2012, JW Lee; 1♀, GW, Pyeongchang Alpine. Exp. Stat., 21–26.vi.1997, JY Choi (NIBR_NIBRIN0000984096); 2♀♀, GW, Sokcho-si, Seolaksan National Park, Misiryeong, 1.iv–24.vi.2010, JC Jeong.

Distribution. South Korea (new record), Austria, Belarus, Belgium, Bulgaria, the Czech Republic, Slovakia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Russia, Sweden, Switzerland, Türkiye, and the United Kingdom.

Genus *Sympherta* Förster, 1869 긴빰뿔자루맵시벌속

Sympherta Förster, 1869: 196. Type species: *Tryphon burrus* Cresson.

Atrestes Förster, 1869: 209. Type species: *Catoglyptus* (*Stiphrosomus*) *sulcatus* Thomson.

Campogenes Förster, 1869: 209. Type species: *Mesoleptus antilope* Gravenhorst.

Stiphrosomus Förster, 1869: 198. Type species: *Ichneumon fuscicornis* Gmelin.

Trapezocora Förster, 1869: 208. Type species: *Mesoleptus antilope* Gravenhorst.

Provancherella Dalla Torre, 1902: 305. Type species: *Baryceros rhopalocerus* Provancher.

8. *Sympherta nigritor* Hinz, 1991

검정긴빰뿔자루맵시벌 (신칭) (Figs. 2B, 3H)

Sympherta nigritor Hinz, 1991: 27. Type: female, TL: Japan; TD: AEI.

Diagnosis. Body entirely black. Head black. Clypeus brown. Mandible yellow with brown mandibular teeth. Antenna brown with a white median band. Mesosoma black. Fore and mid legs yellow with black coxae and brown femur dorsally. Hind leg brown with black coxa and yellow second to fourth tarsal segments. Wings hyaline. Metasoma brown with black first tergite. Inner margin of compound eye parallel. Clypeus large, separated from face with groove, truncated apically. Face smooth with dense punctures. Mandible slightly convex, lower teeth larger than upper teeth. Mesoscutum slightly convex with weak notaulus basally. Propodeum with posterior transvers carina. Tarsal claws simple. First tergite slender, 3.0 times as long as its apical width. Ovipositor sheath short, almost as long as the end of the metasoma, upcurved.

Material examined. 1♂, GB, Yeongju-si, Punggi-eup, Jungnyeong, 21.v–3.vi.2009, JW Lee (NIBR_NIBRIN000

0984097).
Distribution. South Korea (new record), Japan, Russia.

9. *Sympherta sulcata* (Thomson, 1894)
두점긴빰뿔자루맵시벌 (신칭) (Figs. 2C, 3I)
Catoglyptus (*Stiphrosomus*) *sulcatus* Thomson, 1894: 1973. Type: male, TL: Sweden; TD: ZI.

Diagnosis. Body black with partly red. Head black. Mandible dark brown with yellow medially. Inner orbit red. Face with a pair of red spot. Antenna black with a white median band and yellow basally. Mesosoma black. Mesoscutum with red longitudinal mark. First leg yellow with entirely black coxa and basal half of femur. Mid-leg entirely dark brown. Hind leg black with red coxa. Metasoma black with red second to third tergites. Face with dense and fine punctures, polish. Inner margin of compound eye parallel. Clypeus separated from face with groove, truncated apically. Malar space about 1.3 times as long as basal mandibular width. Mesopleura slightly polish, longitudinally striated. First tergite slender, 2.7 times as long as its apical width. Second tergite finely punctated, partly polish. Ovipositor sheath short, almost as long as the end of the metasoma, upcurved.
Material examined. 1♀, GB, Gunwi-gun, Bugye-myeon, Dongsan-ri, San 75 Odoam, 9−22.v.2015, JW Lee (NIBR_NIBRIN0000984098).
Distribution. South Korea (new record), Finland, France, Germany, Hungary, Japan, Norway, Poland, Russia, Switzerland, and the United Kingdom.

Genus *Xenoschesis* Förster, 1869 바수염뭉툭맵시벌속
Xenoschesis Förster, 1869: 158. Type species: *Exetastes fulvipes* Gravenhorst.
Homobia Förster, 1869: 203. Type species: *Colpotrochia cinctiventris* Ashmead.
Glyptocentrus Kriechbaumer, 1894: 61. Type species: *Exetastes fulvipes* Gravenhorst.

10. *Xenoschesis* (*Polycinetis*) *ustulata* (Desvignes, 1856)
붉은바수염뭉툭맵시벌 (신칭) (Figs. 2D, 3J)
Tryphon ustulus Desvignes, 1856: 38. Type: female, TL: United Kingdom; TD: NHM
Notopygus resplendens Holmgren, 1857: 93. Type: female, TL: Sweden; TD: NR.
Erigloea polita Kriechbaumer, 1891: 299. Type: female, TL: Sweden; TD: ZS.
Hadrodactylus montanus Habermehl, 1922: 348. Type: male, TL: Germany; TD: ZS.

Diagnosis. Body length 11.0 mm. Body entirely black. Clypeus and mandible yellow with black mandibular teeth. Antenna yellow with black basally and scape. Fore and mid legs yellow with black coxa. Hind leg dark brown with black coxa. Wings hyaline. Metasoma black with dark brown each apically. Face 2.0 times as wide as length with dense and coarse punctures. Lateral margin of face parallel with dense coarse creases, sublateral and lower parts slightly concave. Clypeus coarsely punctated with truncated margin. Base of mandible coarsely wrinkled, and sparsely punctated with brown hairs, upper teeth slightly shorter than lower teeth. Malar space about 0.3 times as long as basal mandibular width. Antenna with 33 flagellomeres. Mesosoma slightly stout. Mesoscutum strongly convex with sparse dense punctures. Epomia strongly developed. Propodeum stout, convex, shine with fine punctures. Only lateral longitudinal carina of propodeum developed apically. Metasoma entirely shine with few fine punctures. First tergite 2.3 times as long as its apical width. Ovipositor sheath short, almost as long as the end of the metasoma (slightly exposed).
Material examined. 1♂, GB, Yeongju-si, Mt. Sobaeksan, Jukgyegyegok, 4.vii.1994, KI Suh (NIBR_NIBRIN0000984099); 1♀, GG, Yangpyeong-gun, Yongmun-dong, Yeonsu-ri, Mt. Yongmunsan, 26.vi−16.vii.2009, JO Lim.
Distribution. South Korea (new record), China, Germany, Türkiye, and the United Kingdom.

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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First record species of the genus *Thrinax* Konow (Hymenoptera, Tenthredinidae, Selandriinae) from South Korea

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The genus *Thrinax* belonging to the subfamily Selandriinae, was first described by Konow in 1885 and comprised about 27 species worldwide. Three species of *Thrinax*, *T. angustatus* (Zhelochovtsev, 1951), *T. flexa* Lee & Ryu, 1996, and *T. paucipunctatus* (Malaise, 1931), have been recorded from South Korea until now. Females of this genus are known to lay eggs in clusters on the upper surfaces of leaves, and the larvae feed on the leaves and overwinter in the wood or bark of nearby plants. *Thrinax athyrii* (Naito, 1971) is diagnosed from South Korea for the first time. Diagnosis and photographs of newly recorded species of this genus are provided.

Keywords: *athyrii*, sawfly, taxonomy, *Thrinax*

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Introduction

Thrinax Konow, 1885 is a moderately medium-sized genus of Selandriinae (Hymenoptera, Tenthredinidae), 27 described species worldwide and three species occur in South Korea (Taeger *et al*., 2010). The specific biology of this genus is unknown but, according to Smith (1969), female lay eggs on the upper side of the leaf in groups up to 12 per leaf. Also, larvae feed externally and then overwinter in the wood or pith of a nearby plant. This genus can be recognized as such by the occipital ridge present, antennal pedicel as long as wide, epicnemial furrow straight, mesoscutum lateral lobe without pits, and fore wing anal cell with almost perpendicular crossvein. *Thrinax* is similar to genus *Strongylogaster* but, it can be distinguished by the anal cell of fore wing with a crossvein (Fig. 3E, red arrow) (anal cell of fore wing of *Strongylogaster* without crossvein), occipital carina well defined (genus *Strongylogaster* without occipital carina). In this study, diagnosis of *Thrinax athyrii* (Naito, 1971) and photographs of four species of South Korean *Thrinax* are provided.

Materials and Methods

Materials used in this study were collected by sweep-netting, after which they were deposited in the Daegu National University of Education, Daegu_Insect Inquiry Education Institute, Daegu (DNUE_IIEI). The specimens are examined using a Leica MC190 HD Camera attached to a Leica M125 Microscope (Leica Microsystems, Germany), processed using LEICA LAS X software (Leica).

Systematic Accounts

Genus *Thrinax* Konow, 1885 가는줄잎벌속

Thrinax Konow, 1885: 19, 22–23. Type species: *Thrinax contigua* Konow, 1885 [= *Sahlbergia struthiopteridis* Forsius, 1910], subsequent designation by MacGillivray (1908) = *Strongylogaster* (*Thrinax*).

Hemitaxonus Ashmead, 1898: 311. Type species: *Taxonus dubitatus* Norton, 1868, by original designation.

Epitaxonus MacGillivray, 1908: 365–366. Type species:

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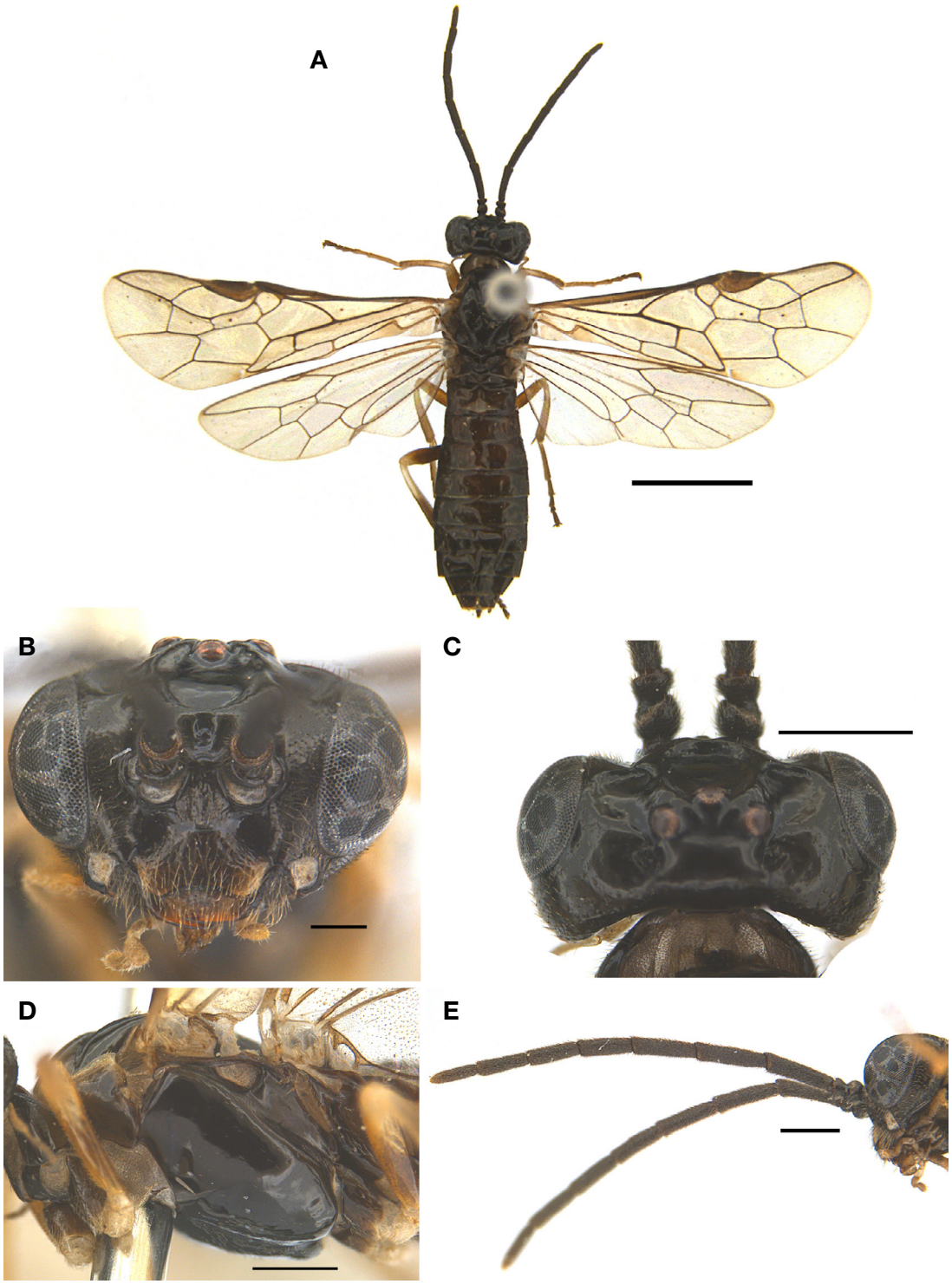

Fig. 1. *Thrinax athyrii* (Naito, 1971). A, Habitus in dorsal view; B, Head in frontal view; C, Head in dorsal view; D, Mesopleuron in lateral view; E, Antenna. Scale bars: A, 2.0 mm; B, 0.2 mm; C−E, 0.5 mm.

Taxonus albidopictus Norton, 1868, by original designation. Synonymy by Tohwer (1911).

Sahlbergia Forsius, 1910: 49−50. Type species: *Sahlbergia struthiopteridis* Forsius, 1910, designation by monotypy = Sajlberghia, type error. Synonymy by Enslin (1913).

Canonarea Malaise, 1947: 37-38. Type species: *Canonarea albooralis* Malaise, 1947, by original designation. Synonymy by Naito (1990).

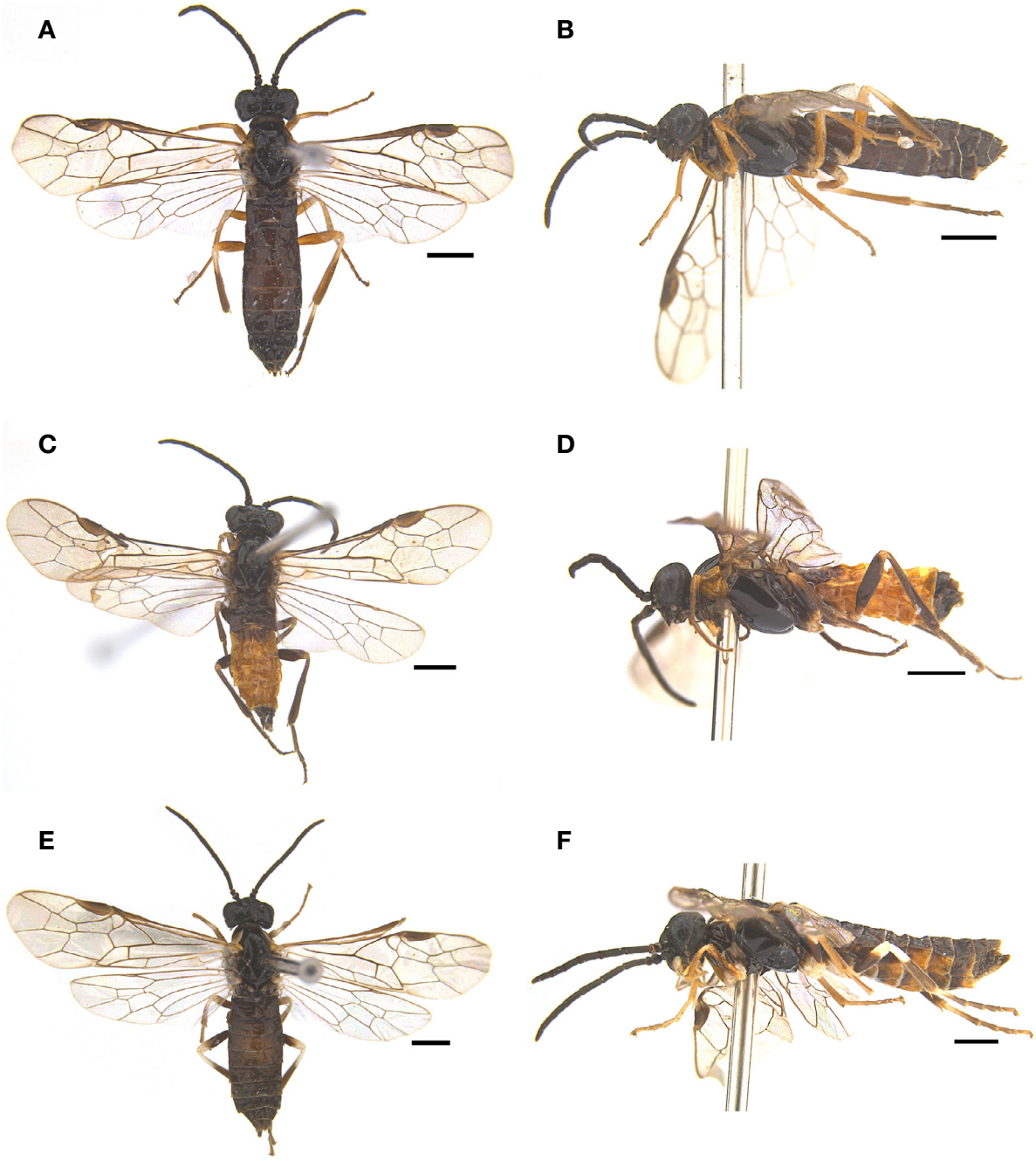

Fig. 2. South Korean *Thrinax* spp. A, B, *Thrinax angustatus* (Zhelochovtsev, 1951): A, Habitus in dorsal view; B, Habitus in lateral view; C, D, *Thrinax flexa* Lee & Ryu, 1996: C, Habitus in dorsal view; D, Habitus in lateral view; E, F, *Thrinax paucipunctatus* (Malaise, 1931): E, Habitus in dorsal view; F, Habitus in lateral view. Scale bars: 1 mm.

Trearea Malaise, 1947: 2, 35-36. Type species: *Trearea compressicornis* Malaise, 1947, by original designation. Synonymy by Naito (1990).

Key to species of the Korean *Thrinax*

1. Pronotum entirely yellowish brown (Fig. 3C); abdomen with yellowish brown tergum and sternum except last tergite (Fig. 2C, 2D) ····· *T. flexa*
– Pronotum dark brown to black, except upper posterior corner of pronotum yellowish brown (Fig. 3A, 3B, 3D); abdomen mostly blackish brown to black····· 2
2. Fore wing with 2r vein opposite or distal to 3r-m vein (Fig. 3F); tegula brown to reddishi brown····· *T. athyrii*
– Fore wing with 2r vein basal to 3r-m vein (Fig. 3E, 3G, 3H); tegula yellowish brown ····· 3
3. Hind wing with cu-a vein posterior to the junction of the

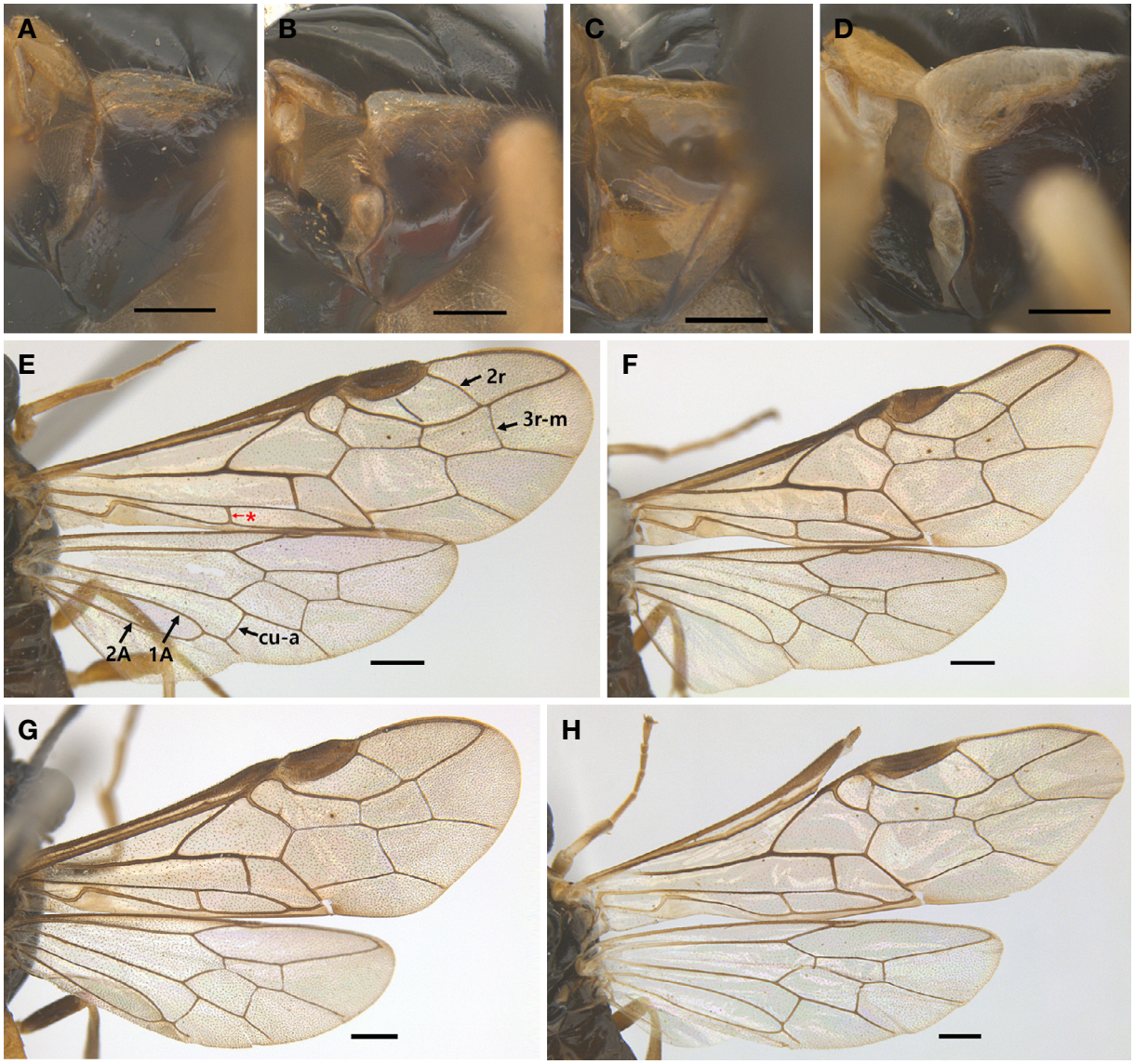

Fig. 3. Pronotum and wings of South Korean *Thrinax* spp. A–D, Pronotum: A, *Thrinax angustatus* (Zhelochovtsev, 1951); B, *Thrinax athyrii* (Naito, 1971); C, *Thrinax flexa* Lee & Ryu, 1996; D, *Thrinax paucipunctatus* (Malaise, 1931); E–H, Wings: E, *Thrinax angustatus* (Zhelochovtsev, 1951); F, *Thrinax athyrii* (Naito, 1971); G, *Thrinax flexa* Lee & Ryu, 1996; H, *Thrinax paucipunctatus* (Malaise, 1931). Scale bars: A–D, 0.2 mm; E–H, 0.5 mm.

1A and 2A veins (Fig. 3E); hind femur yellowish brown (Fig. 2B) ····· *T. angustatus*

– Hind wing with cu-a vein anterior to the junction of the 1A and 2A veins (Fig. 3H); anterior half of hind femur black and posterior half of hind femur pale yellow (Fig. 2F)····· *T. paucipunctatus*

***Thrinax athyrii* (Naito, 1971)** 검정가는줄잎벌 (신칭)
Hemitaxonus athyrii Naito, 1971: 26.

Diagnosis (female). Length about 5–7 mm. Head black; mandible dark brown and apex dark rufous, apical margin of clypeus concave; malar space with pale yellow spot (Fig. 1B). Antenna black, antennae with seven antennomeres; flagellomere 1 1.1× length of flagellomere 2 (Fig. 1E). Postocular areas sparsely punctate with short hairs; postocellar area smooth and shiny (Fig. 1C). POL (the shortest distance between medial margins of the two lateral ocelli) : OOCL (the shortest distance between posterior margin of a lateral ocellus and the hind margin of the head) = 0.9 : 1. DML (the shortest distance between median and lateral ocelli) : POL = 0.43 : 1 (Fig. 1C). Thorax black, with following yellowsish brown: posterolateral corner of dorsal pronotum, and anepimeron. Tegula brown to reddish brown. Legs yellowish brown, with coxae (except for narrow apical margin) black; trochanters and apical area of femur, basal

area of tibiae, and basal of tarsomere 1 yellow. Wings hyaline, veins and stigma dark brown. Abdomen black.

Material examined. South Korea: 1♀, Seoul, Seongbuk-gu, Donam-dong, 11.vii.1996, J.Y. Jeong (DNUE_IIEI); 1♀, Seoul, Seocho-gu, Yangjae Park, 9.vi.1996, S.R. Park (DNUE_IIEI); 1♀, Gangwon-do, Taebaek-si, Mt. Hambaeksan, 11.vii.1999, S.M. Ryu (DNUE_IIEI); 1♂, Jeollabuk-do, Jeongeup-si, Sinjeong-dong, Jirisan National Park, 15.vi.2004, M.K. Yun (DNUE_IIEI).

Distribution. South Korea (new record), East Palaearctic.

List of South Korean *Thrinax*

Thrinax angustatus (Zhelochovtsev, 1951) 가는줄잎벌
Thrinax athyrii (Naito, 1971) 검정가는줄잎벌*
Thrinax flexa Lee & Ryu, 1996 배넓은홍줄잎벌
Thrinax paucipunctatus (Malaise, 1931) 점배기잎벌

Conflicts of Interest

The author of this paper has no affiliation with any interests and is solely responsible for the paper.

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Two species of *Endotricha* Zeller, 1897 (Lepidoptera, Pyralidae, Pyralinae) new to Korea

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Two species of the pyraline genus *Endotricha*, *E. theonalis* (Walker, 1859) and *E. inouei* Yoshiyasu, 1987, are recorded for the first time from Korea. The records of *E. theonalis* were based on five specimens from Yeosu, Jeonnam Province and Chuja Islands, Jeju Province. The records of *E. inouei* were based on four specimens from Chuja Islands, Jeju Province. *Endotricha inouei* has been known as endemic to Japan but it is reported for the first time outside the country. Photos and redescriptions of the habitus and genitalia of both sexes are provided for those two species of *Endotricha*. To sum up, the Korean species of *Endoricha* comprise nine species.

Keywords: *Endotricha*, Korea, new records, Pyralidae, taxonomy

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Introduction

Endotricha is the principal and largest genus of Endotricini in Pyralinae. The genus was designated by Zeller (1847) with the type species, *Pyralis flammealis* Schiffermüller from Europe. Whalley (1963) reviewed it and modernized the generic definition. He suggested that *Endotricha* is distinguished from other genera of Endotrichini in having the apparent gnathos and gnathal arms and the conspicuous saccular process in the male genitalia. The adult moths are mostly reddish or brownish with white or pale yellow fasciae on both pairs of wings. They are one of the moth groups frequently-encountered in the temperate forests but their immature stages remain little-known. No significant economic damage caused by *Endotricha* has been reported.

The *Endotricha* from the Old World include about 100 species (Sun and Li, 2012). Lee *et al.* (2007) reviewed the Korean congeners and listed a total of seven species in *Endotricha*. This estimate seems underscored, given their species diversity from the neighboring countries: 12 species from Japan (Yoshiyasu, 2013) and 38 species from China (Sun and Li, 2012). In the present study, two species of *Endotricha* are reported for the first time from Korea.

Materials and Methods

The insect collection used for this study was established from the National Survey Program of the Jeju Marine Regional Parks, sponsored by the Korea National Park Service in 2019. Dried specimens were deposited in two Korean insect collections: the Gongju National University of Education, Gongju (GJUE) and the National Institute of Biological Resources, Incheon (NIBR). The genitalia were prepared and mounted on slide glasses, following Clarke (1941), except that Chlorazol black and Euparal were used as stain and mounting medium, respectively. Terms for genitalia follow Klots (1970).

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Taxonomic Accounts

Family Pyralidae Latreille, 1809
Subfamily Pyralinae Latreille, 1809

Endotricha theonalis (Walker, 1859)
남방뾰족명나방 (Figs. 1A, 2A, 2C)

Pyralis theonalis Walker, 1859: 900. Type locality: China, Shanghai.
Pyralis thermusalis Walker, 1859: 912. Type locality: China, Shanghai.
Zania unicalis Walker, 1866: 1257. Type locality: China, Shanghai.
Doththa thermusalis; Butler, 1880: 682.
Endotrichodes perustalis Ragonot, 1891: 522. Type locality: China, Shanghai.
Endotricha thermusalis; Ragonot, 1891: 525.
Endotricha theonalis; Hampson, 1896: 482; Whalley, 1963: 410.
Endotricha hypogrammalis Hampson, 1906: 209. Type locality: China.
Endotricha anpingia Strand, 1919: 55. Type locality: Taiwan.

Description. Habitus (Fig. 1A) - Head: Vertex gray, intermixed with pinkish gray scales; frons fuscous. Antenna 3/4 as long as forewing, short-ciliate in males, filiform in female; scape dark-grayish brown, intermixed with grayish red scales ventrally; basal 10–11 flagellomeres dark-grayish brown on basal half, pale gray on distal half; remaining flagellomeres pale gray. Labial palpus upcurved; 1st segment pale-brownish gray laterally, dark-grayish yellow mesally, with purplish brown and purplish red scale-tufts; 2nd segment as long as 1st, broadened at middle, dark-purplish brown, intermixed with purplish red and grayish yellow scales terminally; 3rd segment 1/3 as long as 2nd, obtuse apically, pale-grayish yellow, sparsely intermixed with pale-purplish red scales. Thorax: Patagium pale-grayish brown, intermixed with pale-purplish red scales in males, grayish brown in females; tegula and mesonotum pale-grayish red, speckled with pale-brownish gray in males, grayish brown in females. Forewing length 8.5–10.4 mm in males (n = 2), 8.9–9.8 mm in females (n = 2), broadened to termen, with dorsal margin broadly round in males, straight in females; ground color purplish red in males, dark-brownish purple, tinged with purplish red on terminal area in females; antemedian and subterminal line faint, pale pink in males, pale-grayish yellow in females; costa with a row of pale-grayish yellow dots; discal spot faint in males, apparent in females; terminal line present in females, dark brown; cilia purplish red in males, pale orange, intermixed with purplish red scales on middle of termen and tornus in females. Hindwing broad, oval in males, semi-elliptical in females, colorous with forewing; median and postmedian lines slightly diverging anteriorly, pale-grayish pink; pale-brownish gray androconia present above the distal angle of discal cell in males, elliptical; terminal line present in females, dark brown; cilia dark-purplish red in males, pale yellow, intermixed with purplish red scales basally, dark brown scales along with ends of veins in females. Male genitalia (Fig. 2A) - Uncus elongate-rectangular, slightly constricted at basal 3/5, with broad lateral zone densely setose in distal 2/3. Tegumen wide-subrectangular, with bulge posterolaterally. Valva spatulate, emarginated at distal 1/3 of costa, densely setose; sacculus 4/5 as long as valva, broadened basally, with digitiform process distally. Vinculum inverted-subtrapezoidal. Phallus broad, of even width except coecum; cornutus as elongate, sclerotized plate with curved spine along distal 1/2. Female genitalia (Fig. 2C) - Ovipositor telescopic. Papillae anales subtriangular, setose. Apophyses posteriores 2.2× longer than apophyses anteriores. Ostium bursae wide, with deep, thimble-shaped emargination before antrum. Antrum columnar, with longitudinal slit on one side.

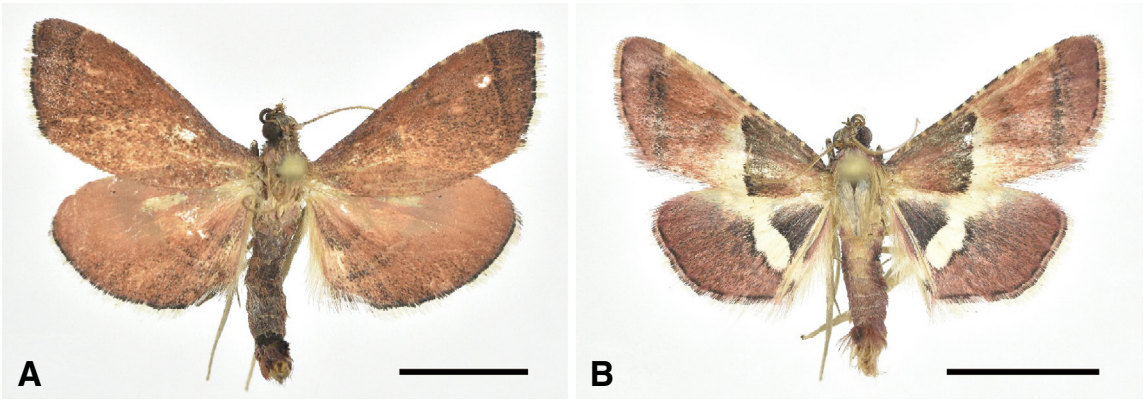

Fig. 1. Adults of *Endotricha*. A. *E. theonalis* (Walker, 1859), male. B. *E. inouei* Yoshiyasu, 1987, male. Scale bars = 5 mm.

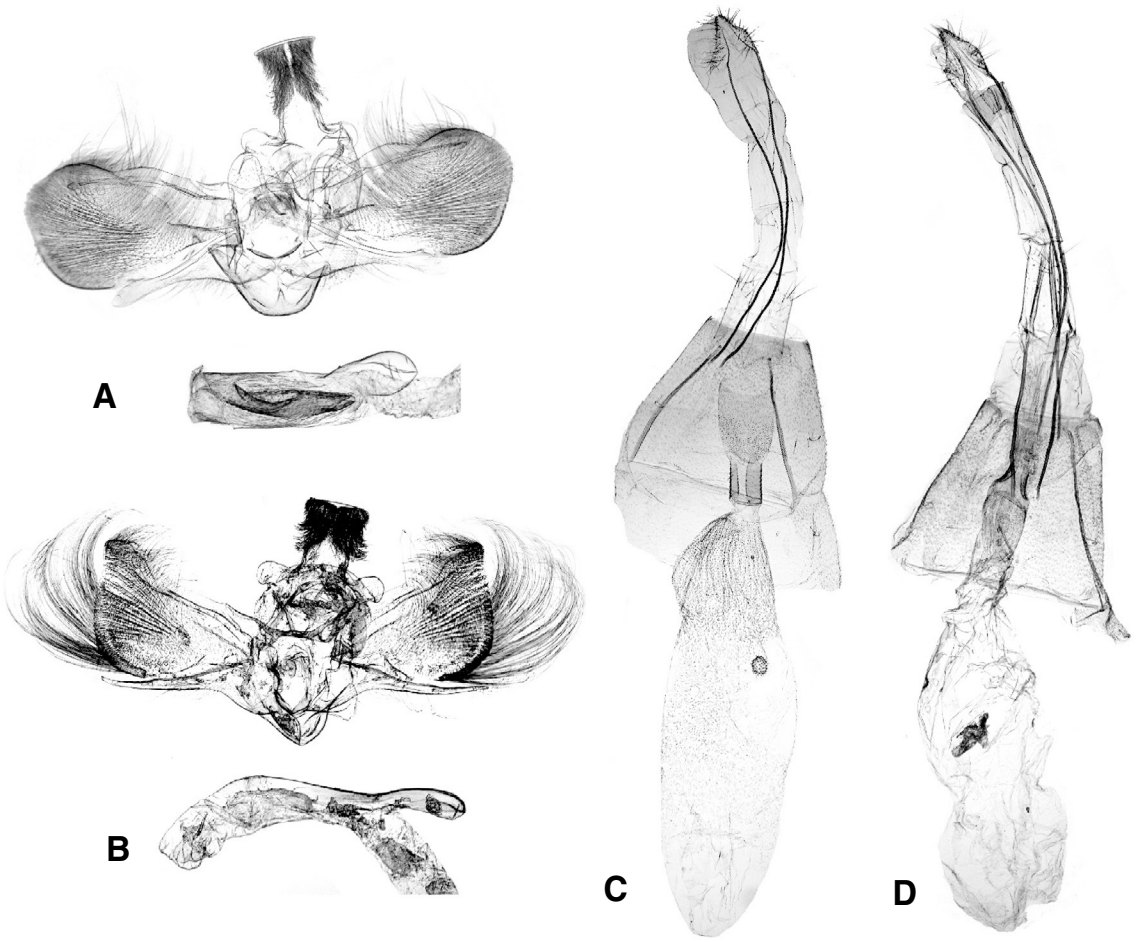

Fig. 2. Genitalia of *Endotricha*. A. *E. theonalis* (Walker, 1859), male. B. *E. inouei* Yoshiyasu, 1987, male. C. *E. theonalis* (Walker, 1859), female. D. *E. inouei* Yoshiyasu, 1987, female.

Membranous part of ductus bursae very short. Corpus bursae cucumiform, spinulate except surrounding area of signum and anterior 1/4, longitudinally wrinkled on posterior 1/4; signum, small, round, scobinate.

Material examined. 1♂, Jeonnam Prov., Yeosu-si, Hwayang-myeon, Imog-ri (N34°39′03.02″ E127°34′10.2″, alt. 44 m), 6−7.x.2021 (JC Sohn), [GSN] SJC-1549, GJUE; 1♀, Jeonnam Prov., Yeosu-si, Hwayang-myeon, Is. Baekyado (N34°36′38.3″ E127°39′03.8″), 6.x.2021 (JC Sohn), [GSN] SJC-1595, GJUE; 1♂2♀, Jeju Prov., Jeju-si, Chuja-myeon, Is. Jiggudo (N33°59′13.6″ E126° 14′52.7″), 11.vi.2019 (JC Sohn), GJUE & NIBR (RORX-IN0000000537).

Distribution. Korea (new record), Japan, China, Taiwan.

Host plants. Dead leaves of various trees (Yoshiyasu, 2013) and detritus in owl nests (Nasu *et al*., 2012).

Remarks. This species exhibits a remarkable sexual dimorphism in the shape and coloration of wings. One of the online resources (https://mothtaiwan.blogspot.com) mentioned its possible association with coastal habitats.

Endotricha inouei Yoshiyasu, 1987
비바리뾰족명나방 (Figs. 1B, 2B, 2D)

Endotricha inouei Yoshiyasu, 1987: 200. Type locality: Japan, Kyoto Pref., Kanmuri-jima.

Description. Habitus (Fig. 1B) - Head: Vertex fuscous, intermixed with purplish red scales; frons fuscous. Antenna 2/3 as long as forewing, short-ciliate in males; scape dark brown, intermixed with purplish red scales; basal 10−11 flagellomeres dark brown; remaining flagellomeres pale fuscous. Labial palpus upcurved, dark fuscous laterally, intermixed with pale fuscous scales on mesal surfaces of 1st and 2nd segments; 1st segment as long as 2nd; ventral scale-tufts on 1st and 2nd segments purplish red, intermixed with fuscous scales; 3rd segment 1/2 as long as 2nd, obtuse apically, fuscous, intermixed with pale-grayish orange scales terminally. Thorax: Patagium purplish red, intermixed with fuscous scales;

tegula elongate, lustrous, fuscous, tinged with pale-pinkish gray on basal 1/3; mesonotum with pale orange scale-tufts posteriorly. Forewing 8.4–9 mm (n = 3), gradually broadened to termen, pale-purplish red, intermixed with purplish brown scales; costa purplish brown, with a row of pale yellow dots; antemedian line nearly straight, pale yellow, spread outwards posteriorly, accompanying with dark-purplish brown zone along inner margin; postmedian line faint, dark-purplish brown; terminal dashes dark brown; cilia grayish pink, intermixed with purplish brown scales. Hindwing pale-purplish red, intermixed with purplish brown scales; anterior area suffused with pale yellow; inner zone of median line purplish brown; median line broadened posteriorly, pale yellow; androconial line along 1A + 2A vein pale yellow; terminal line purplish brown; cilia pinkish brown in basal 1/3, pale gray in distal 2/3. Male genitalia (Fig. 2B) - Uncus rectangular, slightly dilated posteriorly, with broad setal zone along lateral area on distal 2/3. Tegumen broadly round laterally, with subquadrate protrusion posterolaterally. Valva subparallelogram-shaped, broadened distally, densely setose, with upcurved hairs along distal margin; costa broadly curved at distal 1/3; sacculus as long as valva, broadened basally, with spiniform process distally. Vinculum inverted-subtriangular. Phallus broadened distally, sinuous; coecum elongate; cornutal zone small, scobinate. Female genitalia (Fig. 2D) - Papillae anales lanceolate, setose. Apophyses posteriores 2 × longer than apophyses anteriores. Ostium bursae moderate, surrounded by emargination. Antrum trapezoidal. Ductus bursae 2/5 as long as corpus bursae, of even width. Corpus bursae long, elliptical, slightly constricted at anterior 2/5; signum at caudal 1/4 of corpus bursae, small, round, scobinate.

Material examined. 2♂1♀, Jeju Prov., Jeju-si, Chujamyeon, Is. Jiggudo (N33°59′13.6″ E126°14′52.7″), 11.vi.2019 (JC Sohn), [GSN] SJC-1550 (♀), GJUE & NIBR (RORXIN0000000538); 1♂, Jeju Prov., Jeju-si, Chuja-myeon, Is. Cheongdo (N33°54′43.8″ E126°19′27.2″), 11.vi.2019 (JC Sohn), [GSN] SJC-1547, GJUE.

Distribution. Korea (new record), Japan.

Host plants. Unknown.

Remarks. This species has been known as an endemic species for Japan before the present study. It is distinguished from all other congeners from Korea in having the darker coloration on an area interior to the antmedian line of the wings.

Conflicts of Interest

The author of this paper has no affiliation with any interests and is solely responsible for the paper.

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Research trends in Korean amphibian and reptile studies using text mining

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Amphibians and reptiles, with their unique morphology, physiology, and developmental processes, play a vital role in biodiversity conservation. Globally, research on these taxa spans across fields such as ecology, histology, genetics, and veterinary medicine, and they are also widely utilized in literature and engineering as sources of inspiration. This study applies text mining techniques to analyze the characteristics and trends of publications related to amphibians and reptiles in Korea. We identified major research periods, academic disciplines, and focal species. The analysis revealed that literature on amphibians and reptiles in Korea began in the 1950s and has increased exponentially every decade through 2020. A total of 984 amphibian-related and 644 reptile-related publications were recorded from 1959 to 2022 and from 1960 to 2022, respectively. Among them, 563 amphibian studies (88.66%) focused on Anura, while 162 reptile studies (52.09%) focused on Testudines. The most frequently mentioned amphibian species was Oriental Fired-bellied Toad *Bombina orientalis*, and for reptiles, it was Reeves' Turtle *Mauremys reevesii*. In terms of academic disciplines, amphibian studies were predominantly published in the natural sciences (657 papers, 66.77%), whereas reptile studies had the highest proportion in the field of literature (290 papers, 45.03%). The most frequently occurring word in both amphibian and reptile texts was "species." Overall, the trends in amphibian and reptile research in Korea have been influenced by changing societal interests and contemporary issues, and the findings of this study may help guide future research directions for these important taxa.

Keywords: bibliometric analysis, big-data, Korea, research trends, text-mining

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Introduction

The term "Amphibian" is derived from the Greek word *Amphibios*, where *amphi-* means "both" and *-bios* means "life," referring to organisms that live both in water and on land. The term "Reptile" comes from the Latin word *reptilis*, derived from *rept-* meaning "to crawl," referring to small crawling animals (Wareham, 2005; Pough *et al*., 2016). Amphibians and reptiles include animals such as turtles, snakes, lizards, frogs, and salamanders. Unlike mammals such as humans, these animals have either scaly or moist skin, which makes them morphologically distinct (Alibardi, 2003; Pough *et al*., 2016). These groups are ectothermic animals whose body temperature varies with their environment, and depending on the species, they may reproduce via oviparity (egg-laying) or ovoviviparity (live-bearing with eggs developing internally). Some species even possess lethal toxins for survival (Bullock, 1955; Packard *et al*., 1977; Debono *et al*., 2019). Globally, amphibians and reptiles are the focus of intensive biological research concerning their unique physiology, development, and ecology, and they are also utilized as materials in fields such as histology, genetics, veterinary science, literature, and engineering (Park *et al*., 2011; Shin, 2011; 2013; Lee *et al*., 2022).

Amphibians and reptiles play an important role in biodiversity conservation, as they occupy a mid-level position in the food web—acting both as prey for birds, fish, and mammals, and as predators of terrestrial and aquatic insects (Katayama *et al*., 2012; 2013; Valencia-Aguilar *et al*., 2013; Cortés-Gomez *et al*., 2015; Do *et al*., 2022b). Moreover, most terrestrial amphibians and reptiles are known to have limited dispersal ability due to their short movement range and small home range, making them highly vulnerable to habitat destruction and climate change (Parmesan, 2006; Hoffmann and Sgrò, 2011; Do *et al*., 2017; Lee *et al*., 2021). In recognition of the importance of biodiversity, the Korean Ministry of Environment began designating endangered species for legal protection in 1989 to enhance the conservation and management of wildlife. Currently, four species of amphibians and four species of reptiles are designated as legally protected endangered wildlife (Ministry of Environment, 2015). In Korea, there are 28 species of amphibians across 2 orders, 7 families, and 12 genera, and 36 species of reptiles across 2 orders, 11 families, and 26 genera, including nine marine reptile species and three introduced reptile species (Do *et al*., 2022b; NIBR, 2022). While a wide range of taxonomic and ecological research on amphibians and reptiles has been conducted in Korea, no comprehensive study has yet summarized the main research periods, academic disciplines, or target species over time. Therefore, a systematic review focusing on the characteristics and trends of amphibian- and reptile-related publications in Korea is necessary (Park and Ko, 2015; Lee *et al*., 2021; Park and Oh, 2021; Do *et al*., 2022a; 2023).

With the recent surge in big data applications, text mining—a big data analytical technique—has been increasingly employed across various academic disciplines to uncover intellectual structures and analyze research trends (Rajman and Besancon, 1998; Sahadevan *et al*., 2012; Nalon *et al*., 2021). Text mining is particularly suitable for analyzing unstructured textual data such as titles, keywords, and abstracts, enabling the identification of public perception, research trends, and academic directions, while minimizing researcher subjectivity and enhancing objectivity (Do *et al*., 2020; Son *et al*., 2023a; 2023b). Furthermore, it allows for the discovery of new knowledge and perspectives through visualization techniques based on pattern analysis and helps prioritize future research directions (Rajman and Besancon, 1998; Ko and Eo, 2017).

Since the 1950s, numerous publications on amphibians and reptiles in Korea have appeared across diverse disciplines, including natural sciences, literature, engineering, and medicine (Kang, 1959; Paik *et al*., 1990; Shin *et al*., 2011; Park and Oh, 2021). However, no study has systematically synthesized this body of literature to identify the major publication fields, time periods, research characteristics, and overall trends. Therefore, the application of text-mining methods is necessary to provide readers with insights into research patterns and emerging trends. In this study, we applied text mining to analyze the research characteristics and trends of amphibian and reptile literature published in Korea. Specifically, we collected Korean publications related to amphibians and reptiles and examined the publication trends and research characteristics, focusing on key time periods, academic fields, and target species.

Materials and Methods

Collection of amphibian and reptile research data

To collect literature related to amphibians and reptiles published in Korea, we used the Harzing's *Publish or Perish 3* (PoP3) software (source: www.harzing.com/index.htm). This free tool allows for efficient acquisition of scientometric information and can be integrated with Google Scholar for data retrieval. For the data collection, we conducted keyword searches in Korean using the following terms: "양서류" (Amphibian), "도롱뇽" (Salamander), "두꺼비" (Toad), "맹꽁이" (Narrow-mouthed Toad), "개구리" (Frog), "파충류" (Reptile), "뱀" (Snake), "살모사" (Viper), "구렁이" (Rat Snake), "거북" (Turtle), "자라" (Softshell Turtle), and "남생이" (Reeves' Turtle). In this study, species that were the primary focus of each document were defined as "focal species." These could include single or multiple species depending on the research topic. All focal species were recorded using currently accepted scientific names (NIBR, 2022). For Soft-shelled Turtle

Pelodiscus maackii and Chinese Soft-shelled Turtle *P. sinensis*, which were often not clearly distinguished in the literature, we classified them collectively as the genus *Pelodiscus* spp..

The types of collected documents included journal articles, academic presentation abstracts, literary magazines, and books. From each document, we extracted the title and abstract (in Korean or English), year of publication, journal name, and publisher, thereby compiling a corpus composed entirely of text data. We also classified each document according to its academic field. The academic fields were broadly categorized into four main areas: Literature, Natural Sciences, Engineering, and Medicine. These were further subdivided as follows: Literature into essays, novels, and poetry; Engineering into robotics, materials science, landscape architecture, environmental engineering, and biotechnology; Medicine into veterinary science and emergency medicine; and Natural Sciences into paleontology, embryology, pathology, physiology, ecology, genetics, and histology.

Analysis of the compiled data

To identify important keywords in scientific and literary publications related to amphibians and reptiles in Korea, we analyzed the frequency of word occurrences found in the titles and abstracts. A word cloud was generated to visually represent the frequency of these keywords, with weights assigned based on the number of occurrences within each individual publication. This weighted approach allows for the assessment of not only the overall word frequency but also the relative importance of terms across different publications (Do *et al*., 2020; Son *et al*., 2023a; 2023b). In the resulting word cloud, terms with higher frequencies appear larger in size and are positioned closer to the center. All analyses were conducted using the R statistical software (version 3.6.2) (R Core Team, 2023), and the word cloud visualization was created using the wordcloud2 package (Dawei and Guan-tin, 2018).

Results

Temporal trends in research

An examination of Korean publications related to amphibians and reptiles revealed an exponential increase in the number of publications over time for both taxa (Fig. 1). For amphibians, a total of 984 publications were recorded between 1959 and 2022, with natural science studies consistently accounting for the highest proportion across all decades (Fig. 1A, C). In the case of reptiles, 644 publications were recorded from 1960 to 2022. While literature-related studies dominated from the 1950s through the 2000s, natural science research has taken the lead from the 2010s onward (Fig. 1B, D).

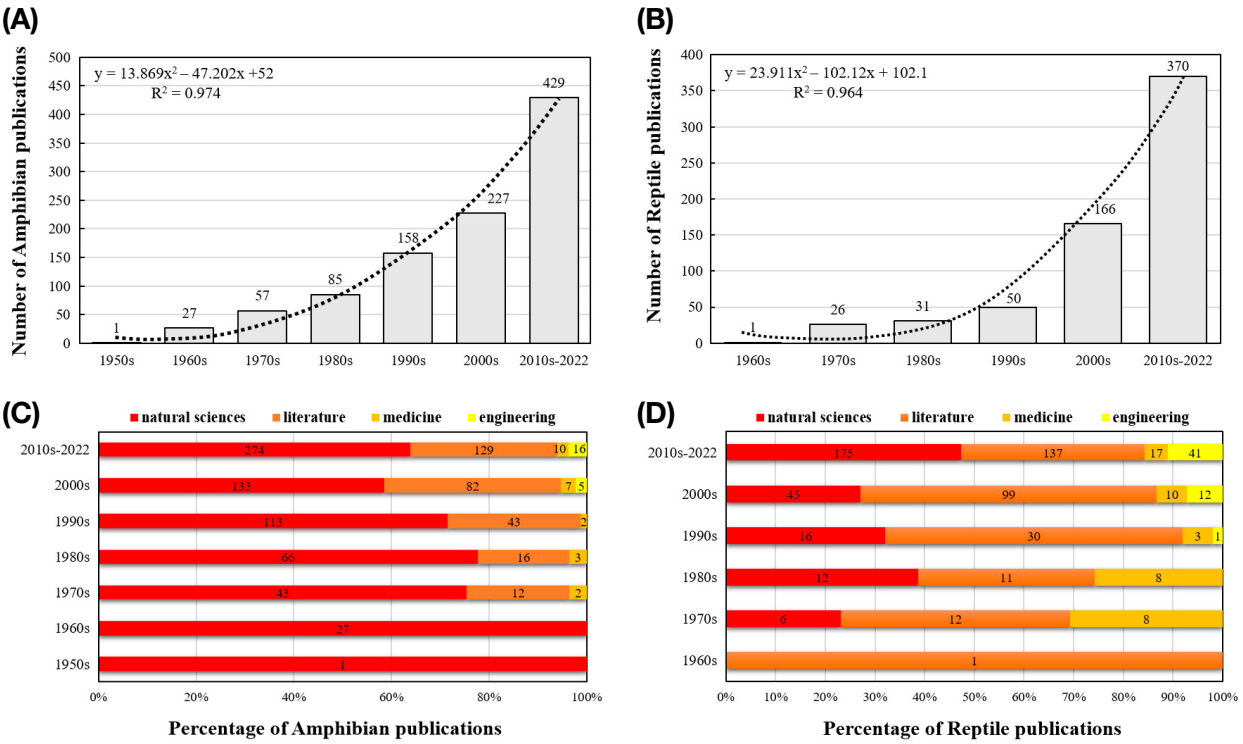

Fig. 1. Research article publication trends in Korea for (A) amphibians and (B) reptiles. Publication frequency by academic field for (C) amphibians and (D) reptiles research.

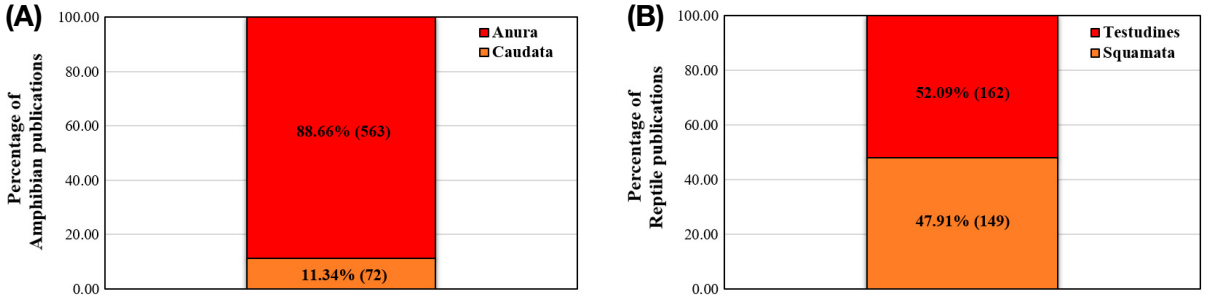

Fig. 2. Proportion of publications by taxonomic group for (A) amphibians and (B) reptiles.

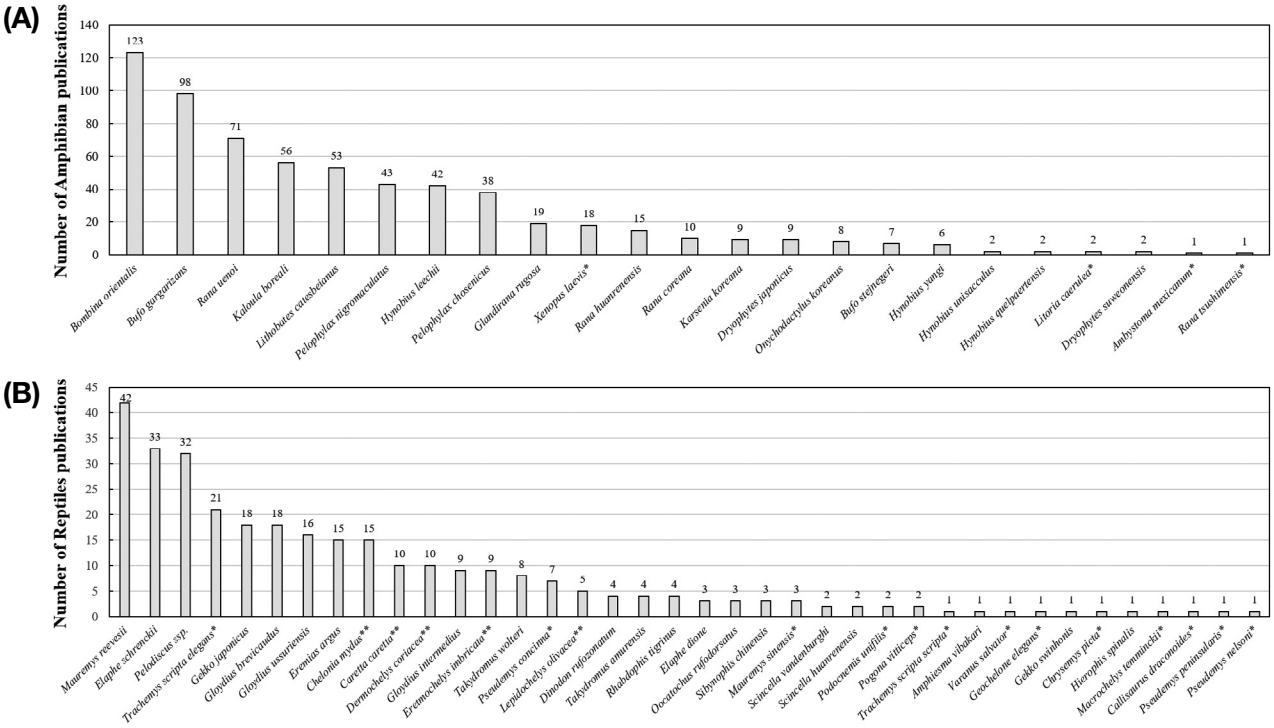

Fig. 3. The number of publications by species in (A) amphibians and (B) reptiles. Note: *Pelodiscus* spp. includes both *P. sinensis* and *P. maackii*. *: Invasive species, **: Marine reptiles.

Taxonomic trends in research

All publications focused on 23 amphibian species from 14 genera across 2 orders, and 38 reptile species from 28 genera across 2 orders. Among amphibian-related studies, 563 papers (88.66%) focused on Anura, followed by 72 papers (11.34%) on Caudata. Among reptile studies, 162 papers (52.09%) addressed Testudines, followed by 149 papers (47.91%) on Squamata (Fig. 2).

A review of the most frequently studied species revealed that Oriental Fire-bellied Toad was the most commonly mentioned amphibian, appearing in 123 publications. This was followed by Asiatic Toad *Bufo gargarizans* in 98 papers and Korean Large Brown Frog *Rana uenoi* in 71 papers (Fig. 3A). For reptiles, Reeves's Turtle *Mauremys reevesii* was the most frequently mentioned species with 42 papers, followed by Amur Rat Snake *Elaphe schrenckii* with 33 papers, and Softshell Turtles *Pelodiscus* spp. with 32 papers (Fig. 3B).

Research trends by academic field

When examining the academic fields by taxonomic group, amphibian studies were most frequently published in the natural sciences (657 publications, 66.77%), followed by literature (282 publications, 28.66%), medicine (24 publications, 2.44%), and engineering (21 publications, 2.13%). Within the natural sciences, the major fields were ecology (248 publications, 37.75%), physiology (166 publications, 25.27%), and embryology (128 publications,

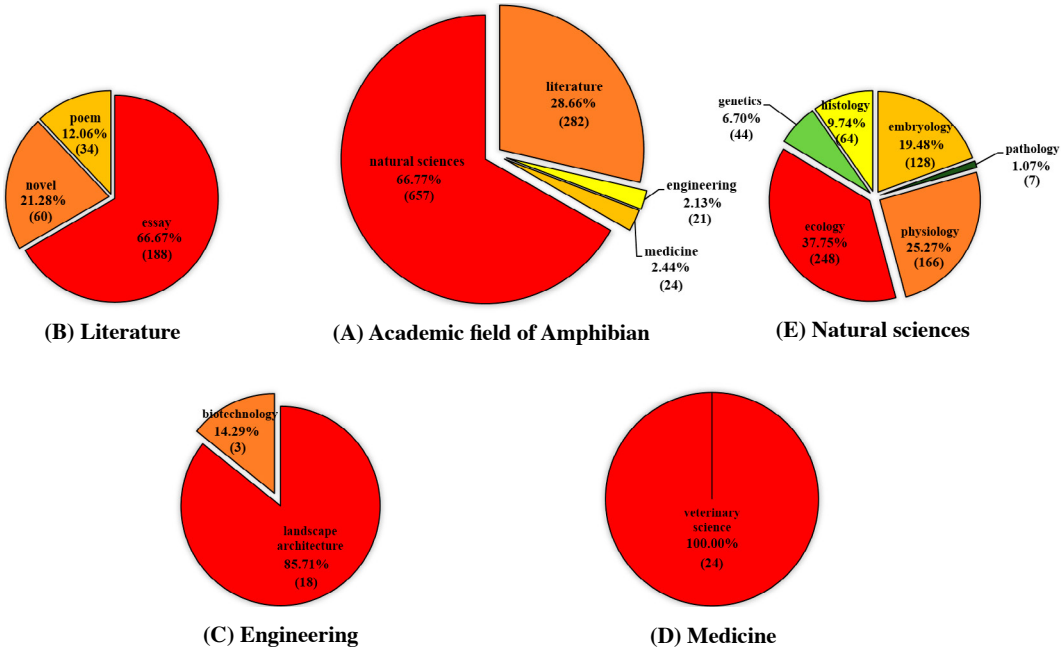

Fig. 4. (A) Relative number of publications about Amphibians by academic field, (B) Literature, (C) Engineering, (D) Medicine, and (E) Natural sciences: The numbers in parentheses indicate the number of publications.

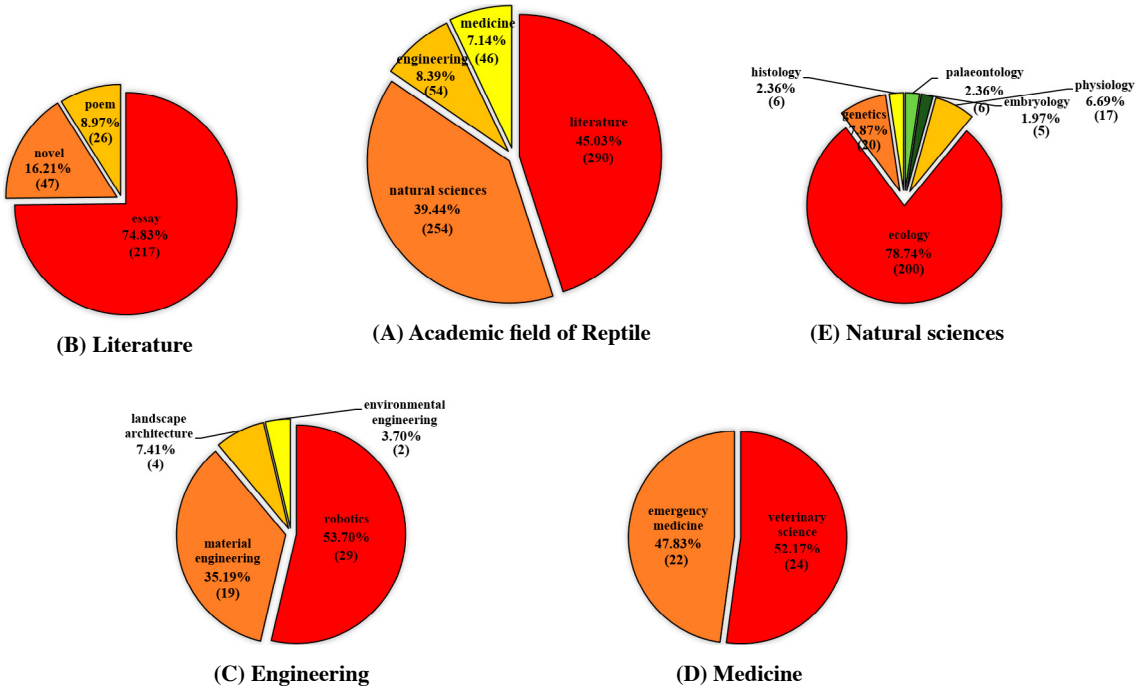

Fig. 5. (A) Relative amount of publication about Reptile by academic field, (B) Literature, (C) Engineering, (D) Medicine, and (E) Natural sciences: The numbers in parentheses indicate the number of publications.

19.48%) (Fig. 4).

Reptile studies were primarily published in literature (290 publications, 45.03%) and natural sciences (254 publications, 39.44%), followed by engineering (54 publications, 8.39%) and medicine (46 publications, 7.14%). In literature, essays accounted for the largest portion (217 publications, 74.83%), and in natural sciences, ecology was the dominant field (200 publications, 78.74%) (Fig. 5).

Table 1. The number of publication related to the Amphibian and Reptile by journal.

Rank	Journal name	Subject	No. paper
Amphibian			
1	Korean Journal of Herpetology	Biology	114
2	Korean Journal of Environment and Ecology	Ecology	83
3	Korean Journal of Zoology	Biology	76
4	Korean Journal of Environmental Biology	Ecology	68
5	Criticism of Korea Children's Literature	Literature	23
6	Korean Journal of Genetics	Genetics	20
7	Korean Journal of Microscopy	Natural science	15
8	Korean Journal of Veterinary Research	Medicine	14
9	Korean Journal of Limnology	Ecology	13
10	Chonbuk University Medical Journal	Medicine	12
11–269	Other journal	–	546
Total		–	984
Reptile			
1	Korean Journal of Herpetology	Biology	53
2	Korean Journal of Environment and Ecology	Ecology	25
3	Korean Journal of Veterinary Research	Medicine	18
4	Journal of Mechanical Science and Technology	Engineering	12
5	Journal of the Korean Society for Precision Engineering	Engineering	10
6	Poetry and World	Literature	9
7	Poem and Photo	Literature	7
8	Korean Journal of Ecology and Environment	Engineering	6
9	Samtoh Magazine	Literature	6
10	Chung-Ang Journal of Medicine	Medicine	6
11–267	Other journal	–	492
Total		–	644

The journal with the highest number of amphibian and reptile-related publications was the *Korean Journal of Herpetology* (114 amphibian papers and 97 reptile papers), followed by the *Korean Journal of Environment and Ecology* (83 amphibian papers and 47 reptile papers) (Table 1).

Major keywords

An analysis of weighted word frequency revealed that for amphibians, the most frequently occurring terms were "species" and "frog," followed by "rana" and "cell," as well as "temperature" and "toad." For reptiles, "species" and "snake" were the most frequent, followed by "turtle," with other notable terms including "serpent" and "population" (Fig. 6).

Discussion

In this study, we examined the publication trends and research characteristics of amphibian and reptile literature published in Korea, focusing on key periods, academic fields, and target species. The number of studies and publications related to amphibians and reptiles has gradually increased over time. Among amphibians, the most frequently studied group was the order Anura, particularly Fire-Bellied Toad, while among reptiles, the order Testudines and the species Reeves' Turtle were the most frequently featured. The most common keyword across both groups was "species," with "frog" frequently appearing in amphibian-related literature and "snake" in reptile-related literature. In terms of academic focus, a majority of publications for both taxa fell under the categories of natural sciences and literature, with essays dominating the literary field and ecology being the primary subfield within the natural sciences.

Amphibian- and reptile-related literature in Korea first appeared in the 1950s and increased exponentially by decade through 2020 (Fig. 1). By taxonomic group, amphibian-related literature totaled 984 publications, with steady twofold increases every decade from the 1950s to the

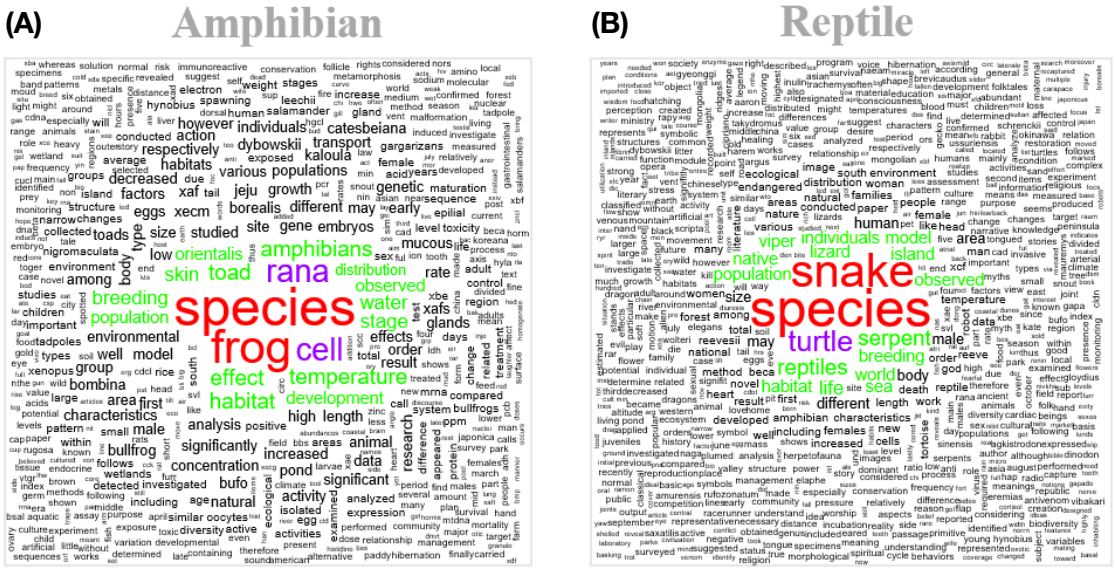

Fig. 6. Word cloud of (A) amphibian and (B) reptile publications. This word cloud illustrates the most frequently used words in the titles and abstracts of (A) 984 amphibian-related and (B) 644 reptile-related publications in Korea. Font size reflects word frequency, with more frequently occurring words appearing larger and closer to the center.

2010s. Fewer than 100 publications were produced up to the 1980s. Reptile-related literature totaled 644 publications, beginning in the 1960s, with fewer than 50 publications up to the 1990s. However, from the 2000s and especially the 2010s, the number of reptile publications grew by two- to threefold. In general, amphibians are easier to observe in the field than reptiles such as snakes and lizards, making it more feasible to collect data on them. As a result, studies on reptiles often face data acquisition challenges, require more time for analysis, and have slower research outputs (Pough *et al*., 2016; Do *et al*., 2020). Consequently, research on reptiles in the natural sciences is less active than on amphibians. On the other hand, snakes—due to their deep connections to mythology and religion—appear more frequently in literary works than in other academic disciplines (Kim, 2014; Kim, 2018). Overall, amphibians have been studied more actively than reptiles in Korea, as reflected in the larger number of publications and the earlier onset of amphibian-related literature by about a decade (Fig. 1A, B).

From the 1950s to the 2010s, amphibian research in Korea was predominantly conducted in the field of natural sciences each decade. In contrast, reptile-related publications were mainly concentrated in the field of literature from the 1960s to the 2000s. However, since the 2010s, the natural sciences have become the dominant field for reptile research (Fig. 1C, D). This shift in reptile research focus can be attributed to several factors: the rise of ecological issues such as endangered species conservation and the spread of invasive species, along with advances in research techniques. Methods such as radio telemetry, improved capture techniques, and the commercialization of tools like habitat prediction models have made ecological research more accessible and widely adopted (Do *et al*., 2016; Koo *et al*., 2017; Park *et al*., 2019). In general, the number and focus of research topics reflect researchers' interests and social contexts, which tend to vary over time (Neff and Corley, 2009). In Korea, studies on endangered species have been consistently conducted since the 1980s, and the volume of research has increased exponentially over time. More recently, easily observable invasive reptiles in the wild—especially turtles—have garnered attention in the media and academic research due to their ecological impact and safety concerns (Koo *et al*., 2017; Do *et al*., 2020; Park and Oh, 2021). As a result, the order Testudines was the most frequently mentioned reptile group in this study. The most frequently cited species included the endangered Reeves' Turtle and Amur Rat Snake, followed by *Pelodiscus* spp. and the invasive Red-eared Slider *Trachemys scripta elegans* (Fig. 3B). These findings indicate that reptile research has shifted from literature to natural sciences in recent years. In addition, engineering-related studies have shown an increasing trend. Prior to the 1990s, engineering research on amphibians and reptiles was virtually nonexistent. However, since the 2000s, fields such as robotics—drawing inspiration from snake locomotion—and materials science—utilizing adhesive toe pads of Gecko *Gekko japonicus*—have grown, alongside landscape architecture studies aimed at creating substitute habitats for endangered species like Narrow-mouthed Toad and Korean Golden Frog *Pelophylax chosenicus* (Shin, 2011; 2013; Shim *et al*., 2014). Overall, research trends on amphibians and rep-

tiles in Korea have appropriately reflected shifting societal contexts and interests over time. Technological development and emerging ecological issues have played a significant role in shaping changes in research focus and disciplinary trends.

An analysis of the research fields related to amphibians and reptiles in Korea shows that amphibian studies were most frequently conducted in the natural sciences (66.77%), with a primary focus on ecology (33.75%), particularly concerning species conservation, reproduction, and distribution. This was followed by physiology (25.27%), which addressed the effects of toxic substances such as mercury, nickel, and pesticides, and embryology (19.48%) (Park and Ko, 2015; Lee and Ko, 2017; Lee *et al*., 2021). For reptiles, literature (45.03%) accounted for the highest proportion, consisting mainly of essays on endangered species habitat conservation and reflections on myths and fiction involving snakes and turtles (74.83%) (Kim, 2014; Kim, 2018). The second most prominent field was the natural sciences (39.44%), primarily focused on ecological studies (78.74%) regarding the distribution, morphology, and conservation of reptiles (Do *et al*., 2016; Park and Oh, 2021). Both amphibian and reptile research was predominantly ecological in nature, and the journals with the highest number of related publications were the *Korean Journal of Herpetology* and the *Korean Journal of Environment and Ecology*, both of which emphasize ecological topics. The most frequently occurring word in the titles and abstracts was "species," indicating that amphibian and reptile studies in Korea have primarily been conducted at the species level rather than at the community level (Park and Ko, 2015; Park and Oh, 2021; Lee *et al*., 2021). For amphibians, other frequently occurring keywords included "frog," "rana," and "toad," all referring to members of the order Anura, which accounted for the majority of amphibian publications (88.66%). These keywords were directly associated with the three most frequently studied species: the Oriental Fire-bellied Frog, the Asiatic Toad, and the Korean Large Brown Frog. For reptiles, the most common keywords included "snake," "turtle," and "serpent," which correspond to the most frequently studied reptile subgroups—Testudines (52.09%) and Serpentes (30.55%)—and were linked to the two most frequently cited species: the Reeves' Turtle and the Amur Rat Snake. In conclusion, research on amphibians and reptiles in Korea has primarily focused on ecology, particularly in relation to species distribution, reproduction, and conservation. Most studies have been conducted at the species level, with reptile research centered on snakes and turtles, and amphibian research focused on frogs and toads.

In this study, we collected and analyzed literature using the Publish or Perish (PoP3) program linked to Google Scholar. However, since databases such as the Korea Citation Index (KCI), Research Information Sharing Service (RISS), DBpia, and Web of Science were not utilized, some studies or publications may have been omitted. Therefore, future research should address this limitation by incorporating multiple databases to enhance the completeness and reliability of the results.

In summary, amphibian and reptile-related literature in Korea first appeared in the 1950s and has increased exponentially every decade up to 2022. Amphibian research has consistently been most heavily focused on the natural sciences, while reptile publications were primarily centered on literature prior to the 2010s. However, since the 2010s, the proportion of natural science research on reptiles has surpassed that of literature, largely due to advancements in research technologies and methodologies. Additionally, studies in the field of engineering have increased for both amphibians and reptiles since the 2000s. These research trends appear to have been strongly influenced by the changing societal context, interests, and issues of each era. Research on amphibians and reptiles in Korea has commonly focused on ecological topics, with reptile studies concentrating on snakes and turtles, and amphibian studies on frogs and toads, primarily at the species level. Moving forward, it is hoped that continued ecological research with a focus on amphibian and reptile conservation will yield tangible outcomes at the species level, contributing meaningfully to biodiversity conservation.

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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Two new subspecies of the red-tongued pit viper *Gloydius ussuriensis* (Emelianov, 1929) (Viperidae, Crotalinae) in the Republic of Korea: Genetics, morphology, and ecology

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This red-tongued pit viper (*Gloydius ussuriensis*) inhabits the Korean Peninsula, including inland areas as well as Baengnyeongdo, Jeju-do, and Gapado Islands. However, the taxonomic status of *Gloydius ussuriensis* populations, including their subspecies classification, remains unclear, as few phylogenetic or taxonomic studies have compared inland and island populations. To address this gap, we analyzed 513 individuals sampled between 2018 and 2022. Mitochondrial DNA revealed two major lineages: (1) inland, Baengnyeongdo, and Chinese populations and (2) Jeju-do and Gapado populations. Nuclear DNA analysis (K = 3) identified three genetic groups, namely, inland, Baengnyeongdo, and Gapado, whereas the Jeju-do population exhibited an admixture of the inland and Gapado groups. Discriminant analysis of the 11 morphological traits indicated clear differences among the Baengnyeongdo, Gapado, Jeju-do, and inland populations. The snout-vent length was the longest in Baengnyeongdo and the shortest in the Gapado group. The ecological niche overlap between the populations was low (PI = 0.4075). Based on these findings, three subspecies have been identified: *G. ussuriensis ussuriensis*, *G. ussuriensis baengnyeongensis*, and *G. ussuriensis jejuensis*. The Tsushima Island pit viper (*G. tsushimaensis*) from Japan, although classified as a separate species, showed genetic and morphological similarities to the Jeju-do-Gapado group. Further phylogenetic and taxonomic studies are needed for *G. ussuriensis* island populations in southwestern Korea, which were not included in this study.

Keywords: Asian herpetology, island population, isolated evolution, mtDNA, pit viper

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Introduction

Taxonomically, a subspecies is defined as a population within a species that is isolated by geographical barriers, such as mountain ranges or oceans, and exhibits genetic, morphological, or ecological differences. Such populations are in the process of speciation but have not yet undergone reproductive isolation (Pianka, 2011; Grant, 2017). Islands serve as important spaces for understanding species differentiation in evolutionary biology and have gained widespread attention in zoology, taxonomy, geography, ecology, and genetics (Shine *et al*., 2002; Coonan *et al*., 2005; Phillimore and Owens, 2006). The Korean Peninsula, surrounded by the sea on three sides, contains approximately 3,300 large and small islands, with the majority located in the South and West Seas (Cho *et al*., 2013). Many organisms on these islands became isolated due to rapid changes in sea level from the last glacial maximum (LGM) to the Holocene (Bloom and Park, 1985; Pirazzoli, 1991; Cho *et al*., 2013). Phylogenetic studies have elucidated the evolutionary history of various flora and fauna (Isogawa *et al*., 1994; Koh *et al*., 2000; Shine *et al*., 2002), particularly in the southwestern islands, which have yielded important geographical and evolutionary insights and led to the discovery of new species and subspecies (Koh *et al*., 2000; Wagner *et al*., 2016; Asadi *et al*., 2019).

Reptile species are less conspicuous than mammals, fish, and amphibians, which can limit sample collection, genetics, and evolutionary analysis (Friars and Diamond, 2011; Asadi *et al*., 2019; Morales-Martínez *et al*., 2021; Wagner *et al*., 2021). In particular, species of the family Viperidae are less active than others of the Serpentes suborder, exhibit a narrower range of behavior, and therefore have a narrower distribution range. They provide a useful model for studying the extent of genetic variation caused by geographical barriers and isolation (Reinert and Rupert, 1999; Gibbons *et al*., 2000; Wang *et al*., 2015; Do *et al*., 2017). Vipers are difficult subjects for research because of the relative lethality of their venom (Shim *et al*., 1998; Debono *et al*., 2019; Zhang *et al*., 2022). Nevertheless, over the past two decades, considerable efforts have been made in China, Japan, Russia, and other countries to elucidate the taxonomic intricacies and evolutionary history of Viperidae in Asia (Isogawa *et al*., 1994; Ding *et al*., 2011; Wang *et al*., 2015; Asadi *et al*., 2019; Zhang *et al*., 2022). However, few phylogenetic and taxonomic studies have considered Viperidae inhabiting the Korean Peninsula (Lee *et al*., 2022).

At least 23 species of the genus *Gloydius* (Viperidae) have been described (Orlov and Barabanov, 1999; Zhao, 2006; David and Vogel, 2015; Shi *et al*., 2017; 2018). The genus is taxonomically divided into two major groups. The red-tongued pit viper (*Gloydius ussuriensis*) belongs to the Brevicaudus group and is characterized by four palatine teeth and 21 dorsal scales. In contrast, the intermedius group is characterized by three palatine teeth and 23 dorsal scales (Gloyd and Conant, 1982; Guo and Zhang, 2002). The distribution of *G. ussuriensis* extends from Jeju-do Island in the Republic of Korea (southern limit) to North Korea, northeastern China, and the Russian Far East. In China, its geographical distribution range is very narrow, leading to its designation as an endangered species and legal protection (Emelianov, 1929; Zhao, 1998; Orlov and Barabanov, 1999). In the Republic of Korea, *G. ussuriensis* is widely distributed across the entire inland Korean Peninsula, as well as Jeju-do Island and several other large and small islands in the southwest. It is primarily found in mountainous areas at elevations of 0−1,200 m, as well as in adjacent rivers, valleys, and farmlands (Do and Yoo, 2014; Do *et al*., 2016; Do and Lee, 2023). This species exhibits greater morphological variation than the other vipers, particularly in terms of regional body size and head shape. However, few studies have compared specific morphological characteristics between regions (Kim *et al*., 2010; Kim and Oh, 2014b; David and Vogel, 2015; Do *et al*., 2023). Therefore, further research is needed to clarify regional differences and resolve the phylogenetic classification system of *G. ussuriensis* through genetic research.

This study examined the genetic, morphological, and ecological characteristics of *G. ussuriensis* populations from inland Korea and Baengnyeongdo, Jeju-do, and Gapado Islands. We aimed to elucidate the genetic variation and taxonomic status of populations isolated from geographical barriers. The phylogenetic relationships of *G. ussuriensis* were examined using mitochondrial DNA (mtDNA), while nuclear DNA was used to analyze the genetic diversity, structure, and differentiation levels. Major morphological factors, such as body length and scale number, were measured to distinguish the morphological characteristics of each group. Climatic and geomorphological environmental data for the study area were used to determine the ecological characteristics and niche of each population. The findings make a valuable contribution to clarifying the phylogenetic classification system of *G. ussuriensis* inhabiting the Republic of Korea, focusing on its genetic, morphological, and ecological characteristics.

Materials and Methods

Sample collection

Biological tissue samples for morphological and genetic analyses were obtained from the Biobanks of the National Institute of Biological Resources (NIBR BIOBANK) and Jeju National University. From 2018 to 2022, individuals were captured from forest valleys, rivers, and graveyards

Table 1. Genetic, morphological, and ecological information for *G. ussuriensis* by region.

Topography	Site	Code name				Number of information			
		mtDNA	ssrDNA	Morphology	Ecology	mtDNA	ssrDNA	Morphology	Ecology
Island	Baengnyeongdo	BI	BI	BI	BI	35	35	28	35
Korean Peninsula	Chungcheongbuk-do	CN	CN	KP	KP		27	7	48
Korean Peninsula	Chungcheongnam-do	CS	CS	KP	KP	28	42	18	59
Korean Peninsula	Gyeonggi-do	GG	GG	KP	KP	12	28		28
Island	Gapado	GI	GI	GI	GI	30	34	33	55
Korean Peninsula	Gyeongsangbuk-do	GN	GN	KP	KP	28	39	2	41
Korean Peninsula	Gyeongsangnam-do	GS	GS	KP	KP	20	28	1	30
Korean Peninsula	Jeju-do	JI	JI	JI	JI	18	31	35	66
Korean Peninsula	Jeollanam-do	JS	JS	KP	KP			7	46
Korean Peninsula	Northern Gangwon-do	KN	KN	KP	KP	34	33	7	34
Korean Peninsula	Southern Gangwon-do	KS	KS	KP	KP	54	55	2	55
Island	Heuksando	SHI	SHI	–	SHI		4	–	4
Island	Jangdo	SJI	SJI	–	SJI		9	–	9
					Total	259	365	140	510

Korean Peninsula (KP) Baengnyeongdo Island (BI), Chungcheongbuk-do (CN), Chungcheongnam-do (CS), Gyeonggi-do (GG), Gapado Island (GI), Gyeongsangbuk-do (GN), Gyeongsangnam-do (GS), Jeju-do Island (JI), Northern Gangwon-do (KN), Southern Gangwon-do (KS), Heuksando Island (SHI), and Jangdo Island (SJI).

across Korea using snake tongs or hooks (Do and Yoo, 2014). For genetic analysis, 0.2 cm of tail tip tissue was excised and preserved in 75% alcohol. Morphological information was collected only for adults with a total length of $\geq$40 cm (Kim and Oh, 2014b; Do *et al*., 2023). In total, 513 individuals were examined for genetic, morphological, and ecological characteristics and classified according to inland mountainous areas, administrative districts, and island regions (Table 1; Appendix). All animals were handled in accordance with legal regulations and released at the capture site and all procedures were approved by the Institutional Animal Care and Use Committee of the National Institute of Biological Resources (No. NIBR IACUC 20220001).

mtDNA testing was conducted on 259 individuals divided into five groups: Baengnyeongdo Island (BI; n = 35), inland (Group A; n = 105), inland (Group B; n = 71), Gapado Island (GI; n = 30), and Jeju-do Island (JI; n = 18). Nuclear DNA analysis was performed on 365 individuals divided into 12 groups: Chungcheongbuk-do (CN; n = 27), Chungcheongnam-do (CS; n = 42), Gyeonggi-do (GG; n = 28), Gyeongsangbuk-do (GN; n = 39), Gyeongsangnam-do (GS; n = 28), Gangwon-do Northern Region (KN; n = 33), Gangwon-do Southern Region (KS; n = 55), Jeju-do (JI; n = 31), Baengnyeongdo (BI; n = 35), Gapado Island (GI; n = 34), Heuksando Island (SHI; n = 4), and Jangdo Island (SJI; n = 9). Morphological analyses were conducted on 140 individuals divided into four groups: Korean Peninsula KP (n = 44), BI (n = 28), JI (n = 35), and GI (n = 33). Ecological characteristics were assessed using 510 samples divided into five groups: KP (n = 341), JI (n = 66), BI (n = 35), GI (n = 55), and SHI and SJI (n = 13).

Genetic characteristics

For the genetic analysis (Appendix), all tissue samples were extracted using a QIAamp® Micro kit (QIAGEN) according to the manufacturer's protocol.

mtDNA. PCR amplification of the mitochondrial cytochrome b gene (cytb, 936 bp) was performed using a specific forward primer L14724 (5′-TGACTTGAAGAACCACCGTTG-3′) and reverse primer H16064 (5′-CTTTGGTTTACAAGAACAATGCTTTA-3′) (Eskandar *et al*., 2018). The PCR reaction mixture (total volume: 20 µL) contained 1 µL template DNA (20–50 ng/µL), 10 µL 2X Bioneer PreMix (containing 100 µM of dNTP, 1.5 mM of $MgCl_2$, and 1 unit of Taq polymerase), and 1 µL each of the forward and reverse primers (10 × concentration). The PCR reaction conditions were as follows: denaturation at 95°C for 5 min, followed by 35 cycles of 1 min at 95°C, 1 min at 55°C, and 1 min at 72°C, with a final extension step at 72°C for 5 min.

The amplified cytb gene product was purified using ethanol (Genorech Corp., Republic of Korea) and the base sequence was analyzed using an ABI PRISM 3730XL (Applied Biosystems, Foster, CA, USA).

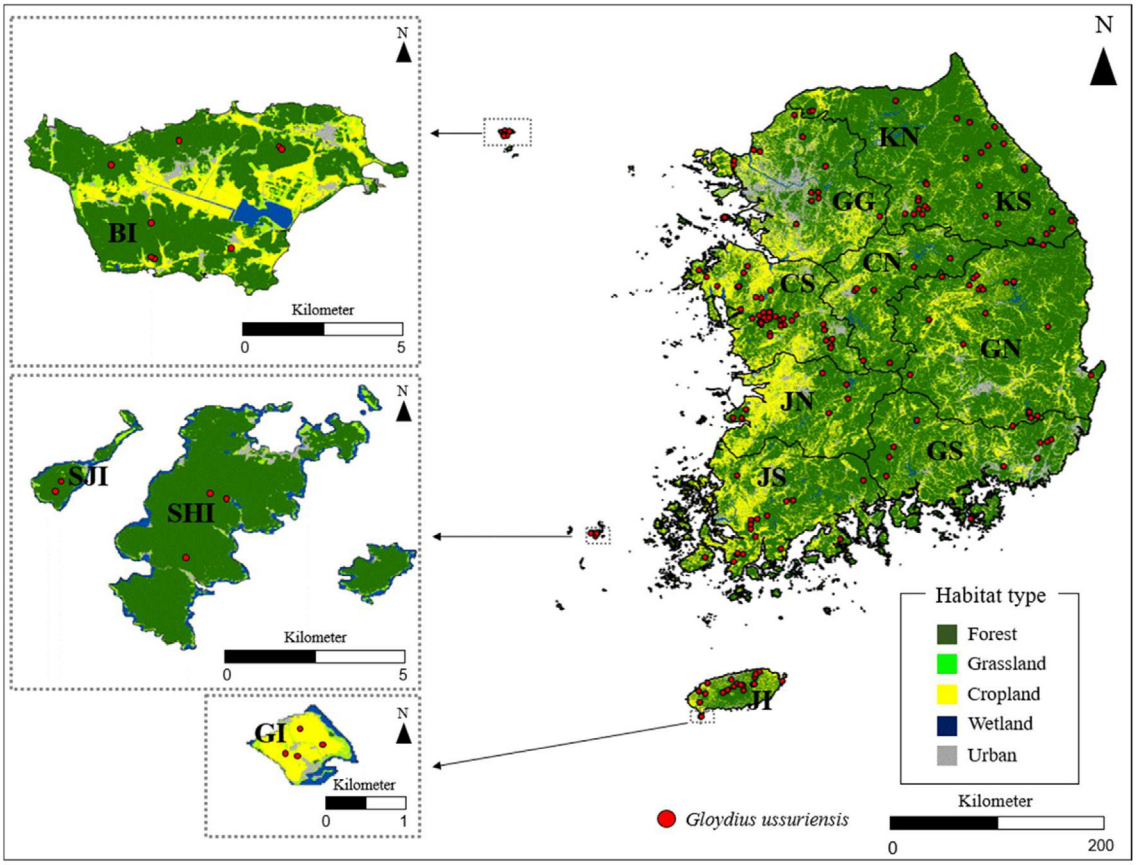

Fig. 1. Topography of the Republic of Korea, including regions and islands such as Baengnyeongdo Island (BI), Chungcheongbuk-do (CN), Chungcheongnam-do (CS), Gyeonggi-do (GG), Gapado Island (GI), Gyeongsangbuk-do (GN), Gyeongsangnam-do (GS), Jeju-do Island (JI), Northern Gangwon-do (KN), Southern Gangwon-do (KS), Heuksando Island (SHI), and Jangdo Island (SJI).

Nuclear DNA. Seventeen species-specific simple sequence repeat (SSR) markers (Kim *et al*., 2023; Jeon *et al*., 2024a) were amplified according to QIAGEN® Multiplex PCR Kit protocols to amplify multiplex panel DNA fragments (Jeon *et al*., 2024b). Each forward primer (5′) was tagged with a universal dye-labeled primer (M13-6FAM, Hill-VIC, Neomycin-PET, and T3-NED) for annealing. The reaction mixture (total volume: 50 µL) comprised 2 µL template DNA (10 ng/µL), 18 µL RNase-free water, 25 µL 2X QIAGEN Multiplex PCR Master Mix (QIAGEN® Multiplex PCR Kit), and 5 µL 10X primer mix. All primers were diluted with TE (10 mM Tris, 1 mM EDTA, pH 8.0) to prepare a 100 µM stock solution. Each marker, consisting of three primer stocks, was prepared as a 2 µM primer mix (labeled forward primer : reverse primer : dye-labeled universal primer = 1 : 4 : 4). Multiplex PCR was performed using combinations of two to four primers. The PCR reaction conditions were as follows: denaturation at 95°C for 15 min; 10 cycles of 95°C for 30 s, 60−50°C for 90 s (with annealing temperature decreased by 1°C per cycle), and 72°C for 60 s; 25 cycles of 95°C for 30 s, 50°C for 90 s, and 72°C for 60 s; and a final extension step at 60°C for 30 min using touchdown PCR.

※Universal dye-labeled primer used in the SSR marker multiplex panel
M13: 6FAM-5′-GGATAACAATTTCACACAGG-3′
Hill: VIC-5′-TGACCGGCAGCAAAATTG-3′
Neomycin: PET-5′-AGGTGAGATGACAGGAGATC-3′
T3: NED-5′-AATTAACCCTCACTAAAGGG-3′

PCR products amplified using SSR markers were subjected to DNA fragment analysis using GeneScan 500 LIZ Size Standard (Applied Biosystems) and an ABI PRISM 3730XL Analyzer (Applied Biosystems). Raw data were used to identify key alleles using Geneious Pro v8.1.9 (Kearse *et al*., 2012).

Morphological characteristics

Morphological differences between groups were determined based on head, body, and tail lengths, and scale counts, as previously described for *Gloydius* (Isogawa *et al*., 1994; Shi *et al*., 2018; Wang *et al*., 2019). However,

Table 2. mtDNA information for domestic samples of *G. ussuriensis* and GenBank accession numbers for each individual.

Locality	N	H	Haplotype	GenBank accession no.
Chungcheongnam-do	28	4	Hap9–10, Hap12–13	MZ770931–MZ770932, MZ770934–MZ770935, MZ770922, MZ770930, MZ770933 PV867537–PV867547, PV867552–PV867561
Gangwon-do	88	9	Hap8, Hap16–20, Hap24–26	MZ770966–MZ770999, PV867588–PV867589, PV867513–PV867534, PV867536, PV867580–PV867586, PV867588–PV867593, PV867596–PV867601, PV867604–PV867609, PV867611–PV867614, PV867620–PV867621
Gyeonggi-do	12	3	Hap8, Hap11–12	MZ771010–MZ771011, PV867535, PV867548–PV867566
Gyeongsangbuk-do	32	6	Hap15, Hap18–19, Hap21–23	MZ770895, MZ770936–MZ770948, MZ770965, PV867568, PV867569, PV867575, PV867576, PV867578, PV867579, PV867587, PV867594, PV867595, PV867602, PV867603, PV867610, PV867615–PV867619
Gyeongsangnam-do	16	2	Hap14–15	MZ770949, MZ770957–MZ770964, PV867567, PV867570–PV867574, PV867577
Incheon Ongjin-gun (BI)	35	3	Hap5–7	MZ770896–MZ770921, PV867504–PV867512
Jeju Jeju-si (JI)	18	3	Hap28–30	MZ771002–MZ771004, PV867644–PV867658
Jeju Seogwipo-si (GI)	30	2	Hap27, 31	PV867622–PV867643, PV867659–PV867666

N, sample size; H, number of haplotypes.

as the number of dorsal scales was 21 across the groups, this trait was excluded from the analysis. The following traits were measured: total length (TTL; length from the tip of the snout to the tail tip), snout-vent length (SVL; length from the tip of the snout to the cloaca), tail length (TL; length from the cloaca to the tail tip), head length (HL; length from the tip of the snout to the temporomandibular joint), head width (HW; width of the head at the widest point near the temporomandibular joint), interorbital space (IOS; widest distance between two points on either side), and ventral scales (V; number of ventral scales) were measured. TTL, SVL, and TL were measured using a tape measure in increments of 0.1 cm and converted to 1 mm increments, whereas HL, HW, and IOS were measured using a caliper (CD-15APX; Mitutoyo, Kawasaki, Japan) in increments of 0.01 mm. The TL/TTL, TL/SVL, HL/TTL, HL/SVL, HL/HW, and HW/HL ratios were used to minimize errors in individual body size measurements and verify differences between groups (Shi *et al*., 2018; Wang *et al*., 2019).

Ecological characteristics

Ecological characteristics were analyzed using ArcGIS (Ver. 10.3; ESRI, Redlands, CA, USA). The coordinates of each individual were projected onto climate maps to extract pertinent environmental factors (Do *et al*., 2016; Do *et al*., 2022a). An elevation map was created using a digital elevation model provided by the National Geographic Information Institute (cell size: 10 m). A habitat map was created using Global Land Cover 2021 v 2.0, provided by the European Space Agency (cell size: 10 m). Climate data were obtained from WorldClim v.1.4, using 19 climate maps (cell size: 1 km) representing the current climate (average 1960–1990) (Fig. 1).

Statistical analysis

Genetic characteristics. The individual consensus sequences of the mtDNA cytb gene of *G. ussuriensis* and the nucleotide sequences of closely related species and other groups registered in NCBI were assembled using Geneious Pro v8.1.9 (Kearse *et al*., 2012). Genetic distance and phylogenetic tree analyses were performed using the assembled 936 bp sequence; cytb sequences from 259 individuals were registered in GenBank (Table 2). Haplotype diversity (h), nucleotide diversity (π), and polymorphic sites (P) of domestic copperhead snakes and related species were calculated using DNAsp v6. The assembled nucleotide sequences (saved as FASTA files) were used to construct a phylogenetic tree using Kimura's two-parameter model (Kimura, 1980) through neighbor-joining (Saitou and Nei, 1987) and the Hasegawa-Kishino-Yano model through maximum likelihood (ML) estimation in MEGA X v10.1.8 (Kumar *et al*., 2018). For maximum accuracy, 1,000 bootstraps were

Table 3. Reference sequence information for *G. ussuriensis*, *G. tsushimaensis*, *G. blomhoffi*, *G. brevicauda*, and *G. saxatilis* registered in GenBank.

Species	Locality	Haplotype	GenBank accession no.
G. ussuriensis	China	Hap3	HS11054
	China	Hap1	HS11204
	China	Hap3	HS11212
	China	Hap4	SYNU21
	China	Hap2	SYNU23
	China	Hap3	WS029
	China	Hap3	GP1326
	China	Hap3	Wbh11002
G. tsushimaensis	Japan	Hap32	JN870203
G. blomhoffi	China	–	EU913477
G. brevicauda	China	–	KF997885
G. saxatilis	South Korea	–	MZ770876

performed. The degree of differentiation between each nucleotide sequence was calculated in terms of genetic distance using Kimura's two-parameter model in MEGA X v10.1.8. Reference sequences for 12 *Gloydius* individuals were obtained from GenBank (Table 3) and analyzed using GenAlex v6.5 (Peakall and Smouse, 2006) for the number of alleles (N_A), number of effective alleles (N_E), predicted heterozygosity (H_E), and observed heterozygosity (H_O) using species-specific SSR markers. The genetic structures of the *G. ussuriensis* groups were analyzed using STRUCTURE v2.3.4 (Pritchard *et al*., 2000) with the following parameters: length of burn-in period = 10,000, number of MCMC reps after burn-in = 100,000, K = 1 to 5, and iterations = 3. A structure Harvester was used to calculate the optimal genetic structure. The Hardy-Weinberg exact test was applied using marker-specific and group-specific heterozygote and allele frequencies in GENEPOP v4.2 (Raymond and Rousset, 1995). The linkage disequilibrium (LD) between each gene pair was verified as previously described (Weir, 1979).

Morphological characteristics. SVL was compared between groups using one-way ANOVA. The main traits distinguishing the groups were quantitatively verified using linear discriminant analysis (LDA), as previously described (Mitteroecker and Bookstein, 2011; Tepos-Ramírez *et al*., 2021).

Gloydius ussuriensis is sexually dimorphic in the Republic of Korea. We compared the morphology of females and males within each group (Kim and Oh, 2014b; Do *et al*., 2023). Since body and head shape vary depending on the body length of each individual, SVL was set as a covariate and the remaining traits were used as the main factors for the analysis of covariance (Bradshaw *et al*., 2004; Strine *et al*., 2015; Do *et al*., 2023). The Bonferroni correction was performed for group-specific traits. All morphological characteristics are presented as mean± standard deviation (numerical range).

Ecological characteristics. Because the 19 climate variables showed high correlations, we extracted three principal components (PCs) with eigenvalues >1 according to Kaiser's criteria using principal component analysis (PCA) (Table 4). A kernel probability density plot was used to verify the degree of overlap between the altitudes and climatic environments of each group in both the inland and island areas.

We assessed the degree of ecological niche overlap among the *G. ussuriensis* groups using the Pianka index (PI), calculated using the geographic and climatic variables of each group in EcoSim (Entsminger, 2012). A PI of 1.0 indicates complete ecological niche overlap, whereas 0 indicates complete niche separation. The statistical significance of the ecological niche overlap was calculated using a random algorithm in EcoSim (Entsminger, 2012). All statistical tests of morphological and ecological characteristics were performed using R v4.1.3 (R Core Team, 2024).

Results

Genetic characteristics

mtDNA. A total of 259 domestic *G. ussuriensis* were used to determine the base sequence of Cytb. Diversity analysis showed that the Chinese *G. ussuriensis* (8 individuals) had 4 haplotypes, whereas the domestic *G. ussuriensis* (259 individuals) had 27 (Table 2). Three haplotypes were observed on three islands (Baengnyeongdo, Jeju-do, and Gapado) that were geographically distinct from the Chinese and domestic groups, except for four domestic inland haplotypes: Hap8 (Gangwon-do, Gyeonggi-do), Hap12 (Chungcheongnam-do, Gyeonggi-do), Hap18 (Gangwon-do, Gyeongsangbuk-do), and Hap19 (Gangwon-do, Gyeongsangbuk-do). Chinese *G. ussuriensis* showed high haplotype diversity (h = 0.964) and relatively low nucleotide diversity (π = 0.0021) (Table 5). Among the domestic groups, inland regions showed relatively high haplotype diversity (h = 0.835, 0.868) and nucleotide diversity (π = 0.0037, 0.0043). However, the Baengnyeongdo and Gapado Island groups showed low haplotype diversity (h = 0.519, 0.405) and nucleotide diversity (π = 0.0011, 0.0017). To determine the phylogenetic status of the South Korean *G. ussuriensis*, we constructed an ML tree that included its closest relatives, the Chinese copperhead, *G. tsushimaensis*, *G. blomhoffi*, *G. brevicauda*, and *G. saxatilis* (Fig. 2). Two major lineages of *G. ussuriensis* were identified. The domestic inland, Baengnyeongdo,

Table 4. PCA of 19 bioclimatic variables associated with red-tongued pit viper (*G. ussuriensis*) occurrence in South Korea.

Climatic variable		PC1	PC2	PC3
Eigenvalue		3.1301	2.2446	1.7094
% Variance explained		51.57	26.52	15.38
bio1	Annual mean temperature (°C)	**0.259**	0.204	0.207
bio2	Mean diurnal range (°C)	−0.260	−0.023	**0.268**
bio3	Isothermality (%)	−0.166	−0.066	**0.367**
bio4	Temperature seasonality (SD × 100; °C)	**−0.312**	0.045	0.057
bio5	Max temperature of warmest month (°C)	0.052	0.314	**0.400**
bio6	Min temperature of coldest period (°C)	**0.309**	0.099	0.018
bio7	Temperature annual range (°C)	**−0.307**	0.018	0.138
bio8	Mean temperature of wettest quarter (°C)	0.060	0.302	**0.401**
bio9	Mean temperature of driest quarter (°C)	**0.310**	0.063	0.066
bio10	Mean temperature of warmest quarter (°C)	0.152	0.307	**0.308**
bio11	Mean temperature of coldest quarter (°C)	**0.302**	0.116	0.101
bio12	Annual precipitation (mm)	0.188	**−0.329**	0.181
bio13	Precipitation of wettest month (mm)	−0.102	**−0.305**	0.295
bio14	Precipitation of driest month (mm)	**−0.250**	0.245	0.047
bio15	Precipitation seasonality (%CV; mm)	**−0.289**	0.086	0.043
bio16	Precipitation of wettest quarter (mm)	−0.003	**−0.379**	0.282
bio17	Precipitation of driest quarter (mm)	**0.266**	−0.227	0.013
bio18	Precipitation of warmest quarter (mm)	−0.058	**−0.349**	0.308
bio19	Precipitation of coldest quarter (mm)	**0.267**	−0.226	0.003

The first four PCs with eigenvalues >1 are presented here. The percentages in parentheses indicate the amount of variation explained by each PC and the components that were loaded most highly for *G. ussuriensis*.

and Chinese groups formed one lineage, whereas the Jeju-do and Gapado Island groups formed another. Multiple clades were identified in the former lineage. The domestic inland group was further divided into the A-group (KN, KS, GN, GS, GG, and CN) and B-group clades (KN, KS, GG, and CS). The Chinese group belonged to the same clade as the B group but formed a single branch within the clade. The Baengnyeongdo Island group formed a single clade in a country close to China. Based on the phylogenetic tree, a genetic distance analysis was performed for domestic *G. ussuriensis* (A-group, B-group, Baengnyeongdo, Jeju-do Island, and Gapado Island), Chinese *G. ussuriensis*, and Japanese *G. tsushimaensis* (Table 6). The Chinese group was genetically similar to the Baengnyeongdo (0.0104) and the domestic inland groups (A: 0.0147, B: 0.0140). The Jeju-do and Gapado Island groups showed a very close genetic distance (0.003), while both island groups showed a notable genetic distance (≥0.0459) from the inland, Baengnyeongdo, and Chinese groups. The Japanese group was genetically closer to the Jeju-do (0.0220) and Gapado Island groups (0.0246) than to the Chinese (0.0320), domestic inland (A: 0.0309, B: 0.0333), and Baengnyeongdo Island groups (0.0302).

Genetic diversity. The H_O and H_E values for domestic *G. ussuriensis* were 0.672 and 0.673, respectively. The genetic diversity within populations was lowest in the Gapado Island population (H_O: 0.33 0.339, H_E: 0.316), followed by Jeju-do Island (H_O: 0.606, H_E: 0.595), Heuksando Island (H_O: 0.618, H_E: 0.636), Jangdo Island (H_O: 0.634, H_E: 0.603), and Baengnyeongdo Island (H_O: 0.689, H_E: 0.669), all of which exhibited higher genetic diversity than the average (Table 7). The N_A and N_E values were highest in the Chungcheongnam-do group (10,824 and 6,666, re-

Table 5. Genetic diversity of mtDNA cytb base sequences in *G. ussuriensis*.

Locality	N	H	h	π(%)
China	8	7	0.964	0.0021
BI	35	4	0.519	0.0011
Group-A	105	24	0.868	0.0043
Group-B	71	17	0.835	0.0038
GI	30	2	0.404	0.0017
JI	18	6	0.745	0.0015

N, sample size; H, number of haplotypes; h, haplotype diversity; π, nucleotide diversity.

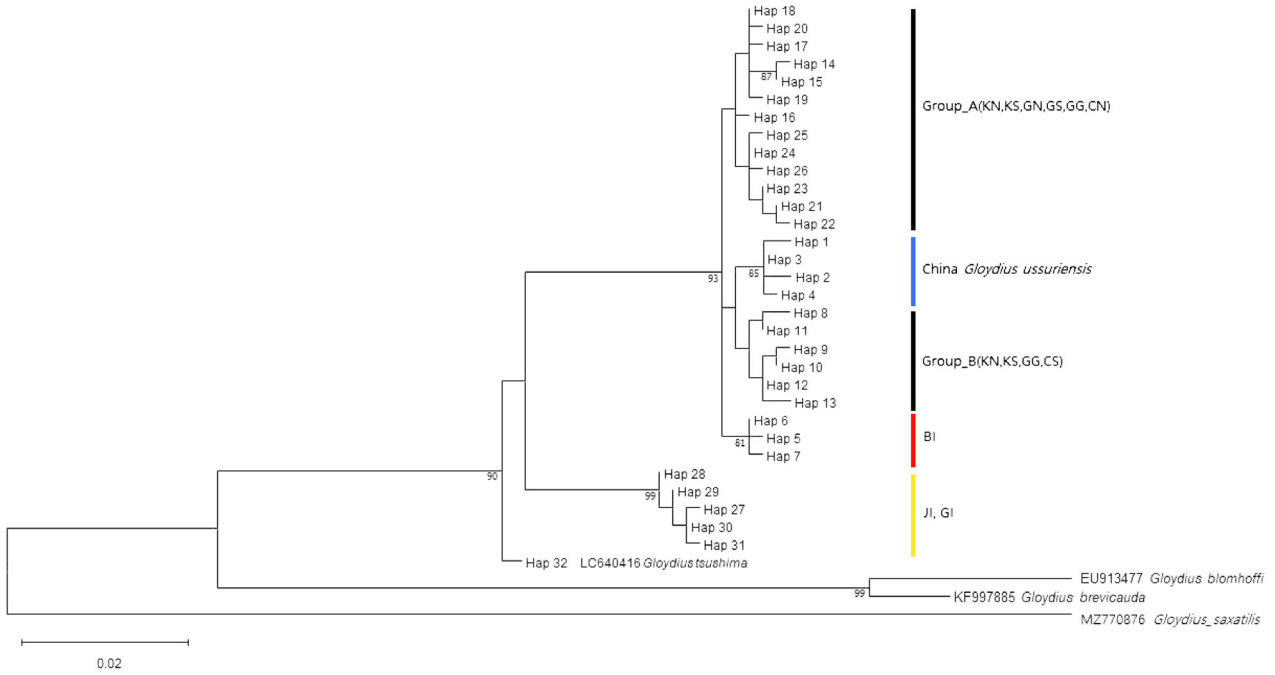

Fig. 2. Phylogenetic tree of *G. ussuriensis* haplotypes based on mtDNA cytochrome b gene (ML) Group_A: Gangwon-do, Gyeongsangbuk-do, Gyeongsangnam-do, Gyeonggi-do, Chungcheongnam-do; Group_B: Gangwon-do, Gyeonggi-do, Chungcheongnam-do, BI: Baengnyeongdo Island, JI: Jeju-do Island, GI: Gapado Island.

Table 6. Genetic distance of mtDNA cytb base sequences in *G. ussuriensis*.

	China	BI	B-group	A-group	GI	JI	Japan
China							
BI	0.0104						
B-group	0.0140	0.0115					
A-group	0.0147	0.0102	0.0085				
GI	0.0507	0.0459	0.0463	0.0459			
JI	0.0523	0.0476	0.0479	0.0475	0.0030		
Japan	0.0320	0.0302	0.0333	0.0309	0.0246	0.0220	

BI, Baengnyeongdo Island; GI, Gapado Island; JI, Jeju-do Island; A group (Northern Gangwon-do, Southern Gangwon-do, Gyeongsangbuk-do, Gyeongsangnam-do, Gyeonggi-do, Chungcheongbuk-do), B group (Northern Gangwon-do, Southern Gangwon-do, Gyeonggi-do, Chungcheongbuk-do).

spectively) and lowest in the Gapado Island group (3,059 and 1,811, respectively; Table 7). The genetic structures of the groups could be classified into three distinct groups (K = 3): Baengnyeongdo Island, Gapado Island, inland, and other island groups. The Baengnyeongdo and Gapado Island groups showed different genetic structures from those of the inland group, whereas the Jeju-do Island group had genetic structures similar to those of both the inland and Gapado Island groups (Fig. 3). The PCA of the genetic relationships between groups clustered eight of the 13 inland groups, whereas the Gapado and Baengnyeongdo Island groups were clustered separately. In contrast, the Jeju-do, Heuksando, and Jangdo Island groups clustered closer to the inland group than to the Gapado and Baengnyeongdo Island groups (Fig. 4A). In addition, individuals from inland areas, Heuksando Island, and Jangdo Island formed a single group, whereas those from Gapado Island, Baengnyeongdo, and Jeju-do Island formed separate groups (Fig. 4B). The level of genetic differentiation among the inland groups was low (Fst $\leq$ 0.0230), whereas the Gapado Island group was significantly differentiated from the inland groups (Fst $\geq$ 0.2745), much like the Baengnyeongdo and Jeju-do Island groups (Fst = 0.0886 and 0.1092, respectively; Table 8).

Table 7. Genetic diversity of *G. ussuriensis* by group.

Site	N	N_A	N_E	H_o	H_E	F_{IS}
BI	35	5.941	3.770	0.689	0.669	−0.031
CN	27	8.765	6.050	0.762	0.757	−0.024
CS	42	10.824	6.666	0.755	0.768	0.012
GG	28	9.645	6.145	0.742	0.758	−0.002
GI	34	3.059	1.811	0.339	0.316	−0.067
GN	39	10.294	6.483	0.736	0.757	0.027
GS	28	10.353	6.419	0.731	0.754	0.032
JI	31	7.765	4.276	0.606	0.595	−0.017
KN	33	8.941	5.940	0.737	0.720	−0.009
KS	55	10.529	6.341	0.711	0.739	0.039
SHI	4	4.294	3.626	0.618	0.636	0.019
SJI	9	4.294	3.093	0.634	0.603	−0.051
Total	365	7.892	5.052	0.672	0.673	−0.005

N_A, number of alleles relative to the number of individuals included in the analysis for genotype determination (N); N_E, effective number of alleles; H_O, observed heterozygosity; H_E, estimated heterozygosity; F_{IS}, fixation index; BI, Baengnyeongdo; CN, Chungcheongbuk-do; CS, Chungcheongnam-do; GG, Gyeonggi-do; GI, Gapado; GN, Gyeongsangbuk-do; GS, Gyeongsangnam-do; JI, Jeju-do Island; KN, northern Gangwon-do; KS, southern Gangwon-do; SHI, Heuksando Island; SJI, Jangdo Island.

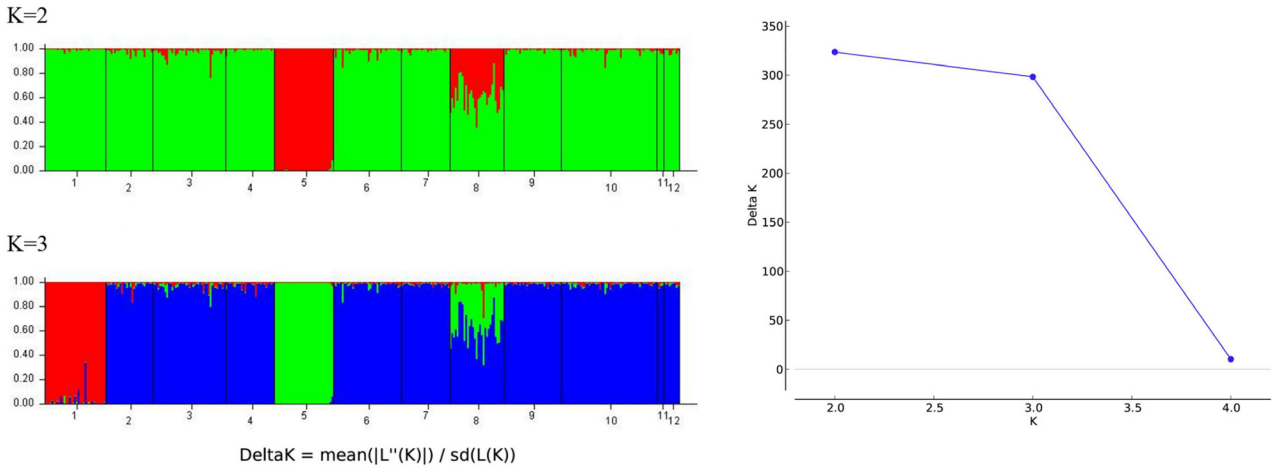

Fig. 3. Results of genetic population structure analysis for *G. ussuriensis* pop1: Baengnyeongdo Island, pop2: Chungcheongbuk-do, pop3: Chungcheongnam-do, pop4: Gyeonggi-do, pop5: Gapado Island, pop6: Gyeongsangbuk-do, pop7: Gyeongsangnam-do, pop8: Gyeongsangbuk-do, pop9: Northern Gangwon-do, pop10: Southern Gangwon-do, pop11: Heuksando Island, pop12: Jangdo Island.

Morphological characteristics

The SVL of *G. ussuriensis* was highest in the Baengnyeongdo and Jeju-do Island groups, followed by the inland group, whereas it was lowest in the Gapado Island group ($F = 27.810$, $p < 0.001$; Table 9). LDA showed that the four groups differed in terms of form (kappa = 0.845, $p < 0.0001$; Fig. 5). The explanatory power for the two axes was 94.2%, with axis 1 representing TL/SVL, HL/TTL, and HL/SVL and axis 2 representing TTL, HL/TTL, and HL in order of importance (Table 10).

Males in the Baengnyeongdo Island group had the highest SVL, followed by the inland and Jeju-do Island groups, with the Gapado Island population exhibiting the lowest size ($F = 19.500$, $p < 0.001$; Table 9). Body shape traits TL ($F = 14.438$, $p < 0.001$) and TTL ($F = 8.755$, $p < 0.01$); head shape traits HL ($F = 51.498$, $p < 0.001$) and IOS ($F = 23.644$, $p < 0.001$); body scale trait V ($F = 967.199$, $p < 0.001$); and body and head ratios TL/TTL ($F = 52.890$, $p < 0.001$), TL/SVL ($F = 36.143$, $p < 0.001$), HL/TTL ($F = 476.159$, $p < 0.001$), HL/SVL ($F = 497.390$, $p < 0.001$), and HW/HL ($F = 12.649$,

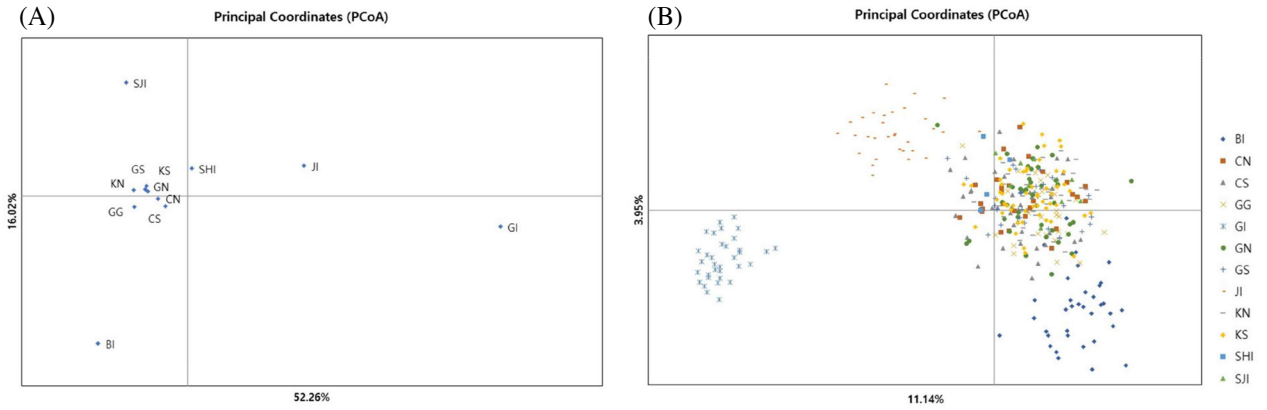

Fig. 4. PCA of regional *G. ussuriensis* populations (A, B). BI: Baengnyeongdo Island, CN: Chungcheongbuk-do, CS: Chungcheongnam-do, GG: Gyeonggi-do, GI: Gapado Island, GN: Gyeongsangbuk-do, GS: Gyeongsangnam-do, JI: Gyeongsangbuk-do, KN: Northern Gangwon-do, KS: Southern Gangwon-do, SHI: Heuksando Island, SJI: Jangdo Island.

Table 8. Level of genetic differentiation between *G. ussuriensis* groups.

	BI	CN	CS	GG	GI	GN	GS	JS	KN	KS	SHI	SJI
BI	0	*	*	*	*	*	*	*	*	*	*	*
CN	0.1037	0	*	*	*	*	*	*	*	*	NS	*
CS	0.0929	0.0048	0	*	*	*	*	*	*	*	NS	*
GG	0.0886	0.0089	0.0110	0	*	*	*	*	*	*	NS	*
GI	0.4021	0.3046	0.2745	0.3245	0	*	*	*	*	*	*	*
GN	0.1025	0.0072	0.0089	0.0108	0.2975	0	NS	*	*	*	NS	*
GS	0.0987	0.0050	0.0048	0.0139	0.3151	0.0066	0	*	*	*	NS	*
JI	0.2206	0.1161	0.1092	0.1363	0.2663	0.1302	0.1232	0	*	*	*	*
KN	0.1096	0.0130	0.0210	0.0117	0.3302	0.0087	0.0230	0.1420	0	NS	*	*
KS	0.1074	0.0105	0.0184	0.0076	0.2895	0.0070	0.0165	0.1252	0.0028	0	NS	*
SHI	0.1370	0.0329	0.0205	0.0314	0.3969	0.0332	0.0216	0.0952	0.0489	0.0303	0	NS
SJI	0.1758	0.0981	0.0936	0.0915	0.4526	0.0831	0.0825	0.2120	0.0976	0.0887	0.1059	0

BI, Baengnyeongdo; CN, Chungcheongbuk-do; CS, Chungcheongnam-do; GG, Gyeonggi-do; GI, Gapado; GN, Gyeongsangbuk-do; GS, Gyeongsangnam-do; JI, Jeju-do Island; KN, northern Gangwon-do; KS, southern Gangwon-do; SHI, Heuksando Island; SJI, Jangdo Island; P values obtained after 1320 permutations; adjusted nominal level (5%) for multiple comparisons: 0.000758; NS, not significant

$p < 0.001$) varied significantly between groups (Table 11).

Females had the highest SVL in the Baengnyeongdo Island group, followed by those in the Jeju-do Island and inland groups, with the Gapado Island population exhibiting the lowest size ($F = 8.416$, $p < 0.01$; Table 9). Head shape traits HL ($F = 9.752$, $p < 0.001$) and IOS ($F = 4.753$, $p < 0.05$); body scale trait V ($F = 1638.668$, $p < 0.001$); and body and head ratios TL/TTL ($F = 190.027$, $p < 0.001$), TL/SVL ($F = 146.787$, $p < 0.001$), HL/TTL ($F = 249.160$, $p < 0.001$), HL/SVL ($F = 270.559$, $p < 0.001$), and HW/HL ($F = 21.817$, $p < 0.001$) varied significantly between groups (Table 12).

Ecological characteristics

The Gapado Island group was distributed exclusively in Cropland (100.00%), whereas all other groups were observed most frequently in tree cover areas (Baengnyeongdo: 88.57%, inland: 84.59%, Heuksando: 100.00%, Jeju-do: 70.58%) (Fig. 6A). The Jeju-do Island group occurred at the highest mean elevation (391.98±304.47 m; range: 0–990 m), followed by the inland group (320.53±230.24 m; range: 6–950 m), the Heuksando Island group (139.23±41.76 m; range: 60–183 m), the Baengnyeongdo Island group (43.86±29.04 m; range: 15–103 m), and the Gapado Island group, which occurred at the lowest elevations (12.04±1.99 m; range: 10–14 m) (Fig. 6B).

Among the 19 climatic variables analyzed, the mean annual temperature was highest in the Gapado Island group (18.00±0.00°C; range: 18.00–18.00°C), followed by the Heuksando Island group (15.30±0.09°C; range: 15.10–15.39°C), Jeju-do Island group (13.80±2.12°C;

Table 9. Sample sizes (N) and mean±standard deviation (range: minimum−maximum) SVL of red-tongued pit viper (*G. ussuriensis*) populations and sex in South Korea.

SVL	N	BI	N	KP	N	JI	N	GI
All	28	473.64±54.89^{a} (388−575)	44	415.22±36.13^{bc} (343−480)	35	419.77±30.07^{b} (350−467)	33	361.00±17.92^{d} (338−430)
				F = 27.810, p < 0.001				
Female	16	488.25±54.15^{a} (388−575)	24	431.17±28.31^{bc} (372−480)	21	420.05±26.37^{c} (365−461)	13	364.69±10.86^{d} (350−390)
				F = 19.500, p < 0.001				
Male	12	454.17±51.70^{a} (395−545)	20	396.10±35.77^{b} (343−460)	14	419.36±35.97^{ab} (350−467)	20	358.60±21.24^{c} (338−430)
				F = 8.416, p < 0.01				
SSD		0.075		0.089		0.002		0.016

SVL, snout vent length; KP, Korean Peninsula; BI, Baengnyeongdo Island; GI, Gapado Island; JI, Jeju-do Island.

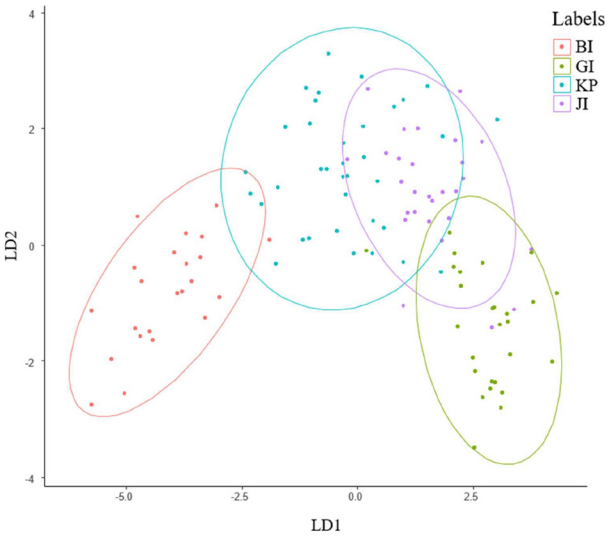

Fig. 5. Scatterplot based on LDA for red-tongued pit viper (*G. ussuriensis*) populations in the Republic of Korea, including Baengnyeongdo Island (BI), Korean Peninsula (KP), Jeju-do Island (JI), and Gapado Island (GI).

Table 10. LDA loadings of morphological characteristics for different red-tongued pit viper (*G. ussuriensis*) populations in South Korea.

Morphological variable	Axis 1	Axis 2
% explained variance	77.0	17.2
SVL	−2.491	2.161
TL	2.327	3.569
TTL	−0.959	**−15.610**
HL	0.457	**8.093**
HW	−0.026	0.198
IOS	0.578	0.491
V	−1.291	−0.105
TL/TTL	7.663	−1.601
TL/SVL	**−12.153**	−1.629
HL/TTL	**−13.048**	**−14.462**
HL/SVL	**12.418**	5.035
HW/HL	−0.432	−0.906

Total length; SVL: snout-vent length; TL: tail length; HL: head length; HW: head width; IOS: interorbital space; V: ventral scale.

range: 11.89−17.39°C), Baengnyeongdo Island group (13.40±0.08°C; range: 13.30−13.60°C), and inland group (12.97±1.61°C; range: 8.39−16.00°C). The mean annual precipitation was highest in the Jeju-do Island group (1928.18±100.65 mm; range: 1709−2010 mm), followed by the Gapado Island group (1740.00±0.00 mm; range: 1740−1740 mm), inland group (1342.19± 62.66 mm; range: 1136−1597 mm), Heuksando Island group (1164.92±11.28 mm; range: 1154−1187 mm), and Baengnyeongdo Island group (793.23±5.13 mm; range: 786−807 mm).

The PCA of the climate variables associated with the habitats of *G. ussuriensis* identified three PCs with eigenvalues >1, explaining 93.47% of the total variance (Table 4). PC1 best explained the seasonal variations in the average annual temperature, winter temperature, precipitation, and other climatic factors. As PC1 increased, the annual average temperature, winter temperature, and precipitation increased, and seasonality decreased. PC2 correlated with annual average precipitation and summer precipitation. As PC2 increased, annual average

Table 11. Sample sizes (N) and mean±standard deviation (range: minimum-maximum) of morphological characteristics for female red-tongued pit viper (*G. ussuriensis*) populations in the Republic of Korea.

Morphological variable	BI (N = 16)	KP (N = 24)	JI (N = 21)	GI (N = 13)	F-Value	p
	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)		
TL	83.00±11.62 (60−106)[a]	66.79±9.40 (50−83)[b]	64.24±5.02 (55−73)[b]	54.00±4.56 (41−61)[c]	14.438	<0.001
TTL	**567.69±64.23 (443−666)[a]**	**496.63±36.16 (421−561)[b]**	**484.29±29.70 (423−528)[b]**	**418.69±13.53 (401−451)[c]**	**8.755**	**<0.01**
HL	**23.68±1.93 (18.9−26.8)[ab]**	**23.09±1.51 (20.2−26.45)[b]**	**24.41±1.64 (21.36−27.49)[a]**	**22.42±0.80 (21.54−24.68)[b]**	**51.498**	**<0.001**
HW	17.62±1.86 (14.25−20.52)[a]	14.05±1.92 (11.34−18.80)[c]	16.42±1.17 (14.79−18.52)[ab]	15.06±1.03 (12.98−16.94)[bc]	0.105	0.746
IOS	9.28±0.95 (7.6−11.11)[a]	8.87±0.87 (7.7−12)[ab]	9.44±0.55 (8.53−10.31)[a]	8.49±0.36 (7.77-9.16)[b]	23.644	<0.001
V	153.38±3.03 (149−162)[a]	149.50±2.83 (145−156)[b]	144.86±3.14 (139−150)[c]	143.46±1.71 (140−147)[c]	967.199	<0.001
TL/TTL	14.60±0.88 (13.45−16.08)[a]	13.40±1.2 (11.06−14.95)[b]	13.27±0.72 (11.97−14.32)[b]	12.89±0.88 (10.15−13.53)[b]	52.890	<0.001
TL/SVL	**16.98±1.20 (15.18−18.87)[a]**	**15.45±1.59 (12.44−17.44)[b]**	**15.31±0.96 (13.60−16.71)[b]**	**14.80±1.13 (11.29−15.64)[b]**	**36.143**	**<0.001**
HL/TTL	**4.19±0.23 (3.85−4.64)[d]**	**4.66±0.26 (3.86−5.15)[c]**	**5.04±0.22 (4.65−5.45)[b]**	**5.36±0.18 (5.04−5.66)[a]**	**476.159**	**<0.001**
HL/SVL	**4.87±0.28 (4.48−5.4)[d]**	**5.36±0.27 (4.51−5.82)[c]**	**5.81±0.24 (5.33−6.22)[b]**	**6.15±0.18 (5.82−6.35)[a]**	**497.390**	**<0.001**
HW/HL	74.45±5.55 (64.22−84.27)[a]	60.98±8.65 (49.22−85.45)[c]	67.38±4.31 (60.26−76.97)[b]	67.20±4.27 (56.76−76.27)[b]	12.649	<0.001

TTL, total length; SVL, snout-vent length; TL, tail length; HL, head length; HW, head width; IOS, interorbital space; V, ventral scales; BI, Baengnyeongdo Island; KP, Korean Peninsula; JI, Jeju-do Island; GI, Gapado Island.

Table 12. Sample sizes (N) and mean±standard deviation (range: minimum−maximum) of morphological characteristics for male red-tongued pit viper (*G. ussuriensis*) populations in the Republic of Korea.

Morphological variable	BI (N = 12)	KP (N = 20)	JI (N = 14)	GI (N = 20)	F-Value	p
	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)		
TL	90.50±10.62 (79−112)[a]	71.65±7.71 (59−86)[bc]	74.57±4.75 (64−82)[b]	66.75±4.41 (62−82)[c]	0.497	0.483
TTL	**540.00±61.97 (475−651)[a]**	**467.80±41.24 (410−540)[b]**	**493.93±40.01 (418−544)[b]**	**425.35±25.13 (400−512)[c]**	**0.384**	**0.537**
HL	**22.69±2.16 (20.24−26.24)[ab]**	**21.62±2.41 (17.3−26.8)[b]**	**24.58±2.16 (20.54−28.27)[a]**	**21.52±0.91 (20.18−24.1)[b]**	**9.752**	**<0.001**
HW	16.48±1.49 (13.95−19.2)[ab]	14.19±2.99 (9.8−21.9)[b]	17.00±1.96 (13.93−20.66)[a]	14.41±1.54 (12.58−18.75)[b]	1.661	0.202
IOS	9.00±1.00 (7.6−10.54)[a]	8.55±1.20 (6.98−11.5)[b]	9.60±0.86 (7.8−10.92)[ab]	8.60±0.41 (7.85−9.61)[b]	4.753	<0.05
V	151.17±2.44 (148−157)[a]	147.50±2.33 (143−152)[b]	142.93±1.86 (140−147)[c]	141.35±1.69 (138−144)[c]	1638.668	<0.001
TL/TTL	16.76±0.47 (16.07−17.33)[a]	15.32±1.00 (13.78−17.49)[b]	15.13±0.62 (14.15−16.27)[b]	15.69±0.44 (14.71−16.47)[b]	190.027	<0.001
TL/SVL	**19.93±0.74 (18.75−21.01)[a]**	**18.11±1.38 (15.97−21.20)[b]**	**17.83±0.87 (16.49−19.43)[b]**	**18.62±0.62 (17.24−19.72)[b]**	**146.787**	**<0.001**
HL/TTL	**4.21±0.21 (3.93−4.46)[c]**	**4.62±0.34 (3.91−5.29)[b]**	**4.98±0.18 (4.62−5.22)[a]**	**5.07±0.19 (4.71−5.39)[a]**	**249.160**	**<0.001**
HL/SVL	**5.01±0.25 (4.58−5.36)[c]**	**5.46±0.40 (4.61−6.20)[b]**	**5.86±0.23 (5.38−6.15)[a]**	**6.01±0.23 (5.60−6.39)[a]**	**270.559**	**<0.001**
HW/HL	72.83±5.27 (65.93−82.02)[a]	65.56±10.54 (51.47−86.13)[a]	69.09±3.55 (61.53−74.15)[a]	66.96±6.29 (57.02−79.08)[a]	21.817	<0.001

TTL, total length; SVL, snout-vent length; TL, tail length; HL, head length; HW, head width; IOS, interorbital space; V, ventral scales; BI, Baengnyeongdo Island; KP, Korean Peninsula; JI, Jeju-do Island; GI, Gapado Island.

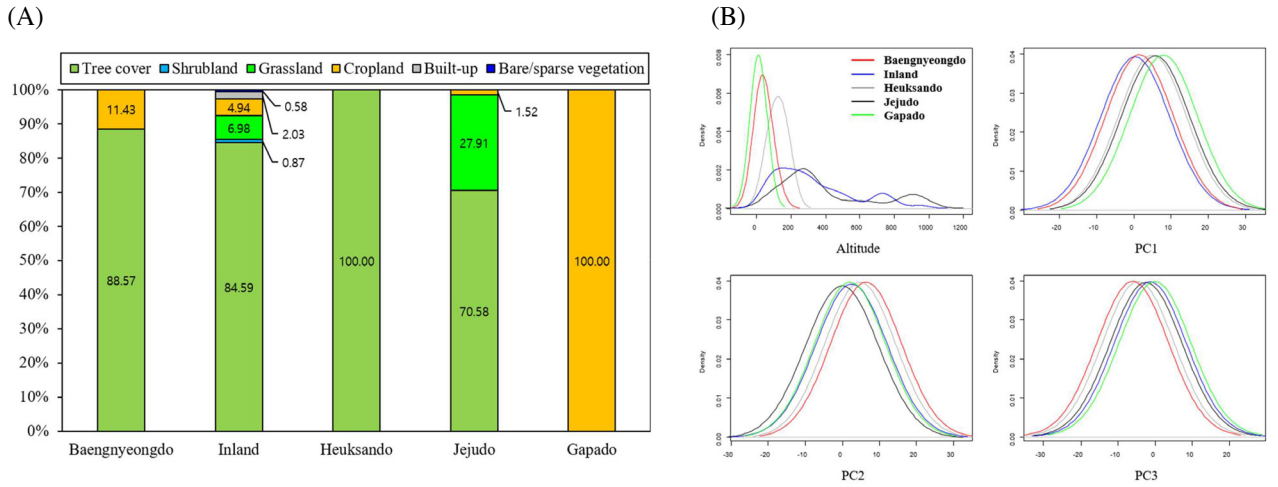

Fig. 6. (A) Occurrence of red-tongued pit viper (*G. ussuriensis*) populations according to habitat type. (B) Smoothed frequency distributions (kernel density plot) of altitudes and principal components (PC1, PC2, and PC3) associated with red-tongued pit viper (*G. ussuriensis*) in the Republic of Korea, including Baengnyeongdo (BI), Korean Peninsula (KP), Jeju-do Island (JI), Gapado Island (GI), Heuksando Island (SHI), and Jangdo Islands (SJI).

precipitation and summer precipitation decreased. PC3 explained the variables related to summer temperature and temperature variability, and was positively correlated with summer temperature, annual temperature range, and daily temperature range (Table 4).

The ecological niches of *G. ussuriensis* showed overlap among groups according to their specific climatic environments (PI = 0.4075). In terms of habitat (PI = 0.5673, $p < 0.01$), the Gapado Island group had lower PI values than the other groups, whereas for altitude (PI = 0.3225, $p < 0.05$), the PI values between the Baengnyeongdo and Gapado Island groups were relatively high but still lower than those of other groups. PC3 (PI = 0.3065, $p < 0.05$) indicated low PI values between most groups, except for the Baengnyeongdo and Heuksando Island groups and the inland and Jeju-do Island groups (Table 13). The degree of intergroup overlap was also reflected in the habitat distribution ratio, altitude, and probability density estimated for the three PCs (Fig. 6B).

Discussion

This study investigated the genetic, morphological, and ecological characteristics of *G. ussuriensis* inhabiting inland and island regions of the Republic of Korea. Island groups exhibited lower genetic diversity than the inland group, with the Gapado Island group exhibiting the lowest diversity among the island groups. The genetic structure was divided into three groups: Baengnyeongdo, inland, and Gapado Island. The genetic structure of the Jeju-do Island group was shared by both the inland and Gapado Island groups. The genetic characteristics were consistent with the morphological trends. Notably, the Jeju-do and Gapado Island groups showed no major morphological differences compared with the inland group in either females or males. In terms of climatic environment, the Baengnyeongdo and Gapado Island groups showed low overlap with other populations for most environmental factors.

Genetic characteristics

The genetic diversity of *G. ussuriensis* was lower in island groups than in inland groups, with genetic structure revealing differentiation between the Baengnyeongdo, inland, and Gapado Island groups. Similar patterns of reduced diversity in island populations have been observed in many other taxa (Grazziotin *et al*., 2006; Hurston *et al*., 2009; Lee *et al*., 2022; Wen *et al*., 2022). Geographic isolation affects the distribution of genes and promotes differentiation. Owing to the small size of the islands and the high density of island populations, island species are particularly vulnerable (Simberloff, 2000). For example, a study using nuclear DNA found that *G. shedaoensis* on Shetang Island, China, has low genetic diversity owing to its limited distribution range (Wen *et al*., 2022). Previous mtDNA studies on *G. ussuriensis* in the Republic of Korea also reported that island populations, such as Jeju-do and Baengnyeong Island, had lower genetic diversity than inland populations, with the latter particularly vulnerable to population decline due to its low genetic diversity (Lee *et al*., 2022). Together, these results emphasize that Korean island populations of *G. ussuriensis* have lower genetic diversity than inland populations. Detailed genetic studies (e.g., inbreeding) are required to verify their vulnerability

Table 13. Pinaka index (PI) showing degree of overall niche overlap according to environmental variables for red-tongued pit viper (*G. ussuriensis*) populations in the Republic of Korea.

Environmental variable	Species	PI	Mean of PI		ES[2]	p
			Observed	Simulated[1]		
Land	BI VS KP	0.9938	0.5673	0.2156	3.2825	**< 0.01**
	BI VS SHI and SJI	0.9917				
	BI VS JI	0.8110				
	BI VS GI	0.1279				
	KP VS SHI and SJI	0.9945				
	KP VS JI	0.8593				
	KP VS GI	0.0581				
	SHI and SJI VS JI	0.8149				
	SHI and SJI VS GI	0.0000				
	GI VS JI	0.0214				
Altitude	BI VS KP	0.3516	0.3225	0.1697	2.8395	**< 0.05**
	BI VS SHI and SJI	0.1670				
	BI VS JI	0.1319				
	BI VS GI	0.9622				
	KP VS SHI and SJI	0.6001				
	KP VS JI	0.5792				
	KP VS GI	0.2180				
	SHI and SJI VS JI	0.1790				
	SHI and SJI VS GI	0.0000				
	GI VS JI	0.0360				
PC1	BI VS KP	0.3700	0.4745	0.4914	−0.1541	N/A
	BI VS SHI and SJI	0.8479				
	BI VS JI	0.7682				
	BI VS GI	0.0000				
	KP VS SHI and SJI	0.3138				
	KP VS JI	0.2843				
	KP VS GI	0.0000				
	SHI and SJI VS JI	0.9907				
	SHI and SJI VS GI	0.5299				
	GI VS JI	0.6401				
PC2	BI VS KP	0.4511	0.3667	0.4455	−0.6587	N.A
	BI VS SHI and SJI	0.9998				
	BI VS JI	0.0000				
	BI VS GI	0.0000				
	KP VS SHI and SJI	0.4561				
	KP VS JI	0.4841				
	KP VS GI	0.8778				
	SHI and SJI VS JI	0.0000				
	SHI and SJI VS GI	0.0000				
	GI VS JI	0.3987				
PC3	BI VS KP	0.0247	0.3065	0.4417	1.0989	**< 0.05**
	BI VS SHI and SJI	0.9997				
	BI VS JI	0.0610				
	BI VS GI	0.0000				
	KP VS SHI and SJI	0.0247				
	KP VS JI	0.9623				
	KP VS GI	0.5865				
	SHI and SJI VS JI	0.0610				
	SHI and SJI VS GI	0.0000				
	GI VS JI	0.3460				

KP: Korean Peninsula; BI: Baengnyeongdo Island; JI: Jeju-do Island; GI: Gapado Island; SHI: Heuksando Island; SJI: Jangdo Island.

Table 14. Ratios of head to snout-vent length (HL/SVL) and head length to width (HL/HW) for red-tongued pit viper *G. ussuriensis*, *G. brevicaudus*, *G. intermedius*, and *G. tsushimaensis*.

Species	N	HL/SVL			HL/HW			Ref.
		Range	Mean	SD	Range	Mean	SD	
G. brevicaudus	40	4.44–7.07	5.67	0.61	1.08–2.56	1.81	0.33	Do *et al*. (2024)
G. intermedius	28	4.14–6.25	5.14	0.42	1.32–2.70	1.68	0.32	Do *et al*. (2024)
G. tsushimaensis	32	5.10–6.60	5.90	0.36	1.30–1.77	1.46	0.11	Isogawa *et al*. (1994)
G. ussuriensis								
KP group	49	5.30–6.70	6.00	0.25	1.26–1.73	1.42	0.11	Isogawa *et al*. (1994)
BI group	**28**	**4.48–5.40**	**4.93**	**0.27**	**1.19–1.56**	**1.36**	**0.10**	**Present study**
KP group	44	4.52–6.20	5.41	0.34	1.16–2.03	1.62	0.23	Present study
JI group	**35**	**5.33–6.22**	**5.83**	**0.24**	**1.30–1.66**	**1.48**	**0.09**	**Present study**
GI group	**33**	**5.60–6.39**	**6.07**	**0.22**	**1.26–1.76**	**1.50**	**0.12**	**Present study**

KP, Korean Peninsula; BI, Baengnyeongdo Island; JI, Jeju-do Island; GI, Gapado Island.

and inform the conservation of island populations.

Morphological characteristics

The body length (SVL) and total length (TTL) of *G. ussuriensis* varied among populations, with the longest individuals recorded in the Baengnyeongdo Island group (SVL: 388–575 mm, TTL: 443–666 mm). The Gapado Island population were the smallest group (SVL: 338–430 mm), whereas the inland (SVL: 343–480 mm, TTL: 400–561 mm) and Jeju-do Island groups (SVL: 350–467 mm, TTL: 418–544 mm) exhibited similar characteristics (Tables 9, 11, and 12). Consistent with previous findings for *G. ussuriensis*, the Baengnyeongdo Island group had consistently longer TTLs than inland groups. Conversely, the Gapado Island group exhibited a shorter body length than the Jeju-do Island group (Kim *et al*., 2010; Kim and Oh, 2014b).

The length of a snake's body is proportional to the size of the food resources (Pough and Groves, 1983; Shine, 1991; King, 2002). Among the three *Gloydius* species identified in the Republic of Korea, *G. brevicaudus* (mean SVL: 47.35±5.34 cm) and *G. ussuriensis* (44.38±2.96 cm) primarily prey on frogs, lizards, and small invertebrates, whereas *G. intermedius* (56.13±9.03 cm) primarily preys on rodents, which are comparatively larger prey resources (Mori *et al*., 1989; Choi *et al*., 2022; Do and Nam, 2021). Previous studies indicated that *G. ussuriensis* of the inland and Jeju-do Island regions feed on amphibians, whereas the Gapado Island population feeds only on small centipedes and lizards (Do and Yoo, 2014; Kim and Oh, 2014a). This could be attributed to the different distributions of available food sources associated with the distinct eco-geological characteristics of the islands, promoting the evolution of morphological differences between regions (Lomolino, 2005; Oh and Banjade, 2021). The number of amphibian species (23 species in the mainland, seven species in Jeju, and two species in Gapado Island) serving as the primary food source for *G. ussuriensis* may vary geographically. Given the higher species diversity on Jeju-do Island and the inland regions compared to Gapado Island, the primary food sources of *G. ussuriensis* inhabiting Jeju-do Island and the inland regions are also expected to differ (Kim and Oh, 2014a; Do *et al*., 2022b). Because only three amphibian species have been recorded on Baengnyeongdo Island, further research on the food sources and their sizes is needed (Park *et al*., 2019). The Gapado and Baengnyeongdo Island groups exhibited distinct morphologies compared to the other groups. The disparities in body size among these groups were likely associated with the types and quantities of available food sources. Future studies on the ecological niche of food resources used between groups will be important for elucidating the evolutionary causes of morphological differences.

The morphological characteristics of *G. ussuriensis* varied among groups, with HL/SVL and V demonstrating the most significant disparities between females and males. HL/TTL was identified as a significant morphological factor for distinguishing populations (Tables 11 and 12). HL/SVL was lowest in the Baengnyeongdo Island group (4.48–5.40), followed by the inland (4.51–5.82), Jeju-do Island (5.33–6.22), and Gapado Island groups (5.82–6.35). In males, the ratio was lowest in the Baengnyeongdo Island (4.58–5.36) and inland (4.61–6.20) groups and highest in the Gapado (5.60–6.39) and Jeju-do Island groups (5.38–6.15). The HL/SVL ratio of Baengnyeongdo Island was lower than that of the South Korean inland group, as well as the phylogenetically similar *G. brevicaudus*, *G. intermedius*, and *G. tsushimaensis* groups. HL/HW was also the lowest in this group (Emelianov, 1929; Isogawa *et al*., 1994; Do *et al*., 2024, Table 14). However, since

Table 15. Ratios of tail to total body length (TL/TTL) and number of ventral scales for red-tongued pit viper *G. ussuriensis*, *G. brevicaudus*, *G. intermedius*, and *G. tsushimaensis*.

Species	Female				Male				Ref.
	N	Range	Mean	SD	N	Range	Mean	SD	
Ventral scales									
G. brevicaudus	23	138–150	144.13	3.40	17	140–154	145.76	3.87	Do *et al.* (2024)
G. intermedius	12	152–167	159.17	4.93	16	149–164	156.31	3.77	Do *et al.* (2024)
G. tsushimaensis	18	144–153	147.50	2.10	14	140–151	145.30	2.80	Isogawa *et al.* (1994)
G. ussuriensis									
Russian group	18	149–157	153.20	2.40	14	146–152	149.50	2.10	Emelianov (1929)
Russian and Chinese groups	23	149–157	152.70	–	19	146–153	149.60	–	Gloyd and Conant (1990)
BI group	**16**	**149–162**	**153.38**	**3.03**	**12**	**148–157**	**151.17**	**2.44**	**Present study**
KP group	57	142–151	147.20	3.50	52	142–150	147.00	2.20	Paik *et al.* (1979)
KP group	24	145–156	149.50	2.83	20	143–152	147.50	2.33	Present study
JI group	**21**	**139–150**	**144.86**	**3.14**	**14**	**140–147**	**142.93**	**1.86**	**Present study**
GI group	**13**	**140–147**	**143.46**	**1.71**	**20**	**138–144**	**141.35**	**1.69**	**Present study**
TL/TTL									
G. brevicaudus	23	9.68–12.77	11.17	0.93	17	13.07–19.22	14.64	1.68	Do *et al.* (2024)
G. intermedius	12	10.14–14.62	11.79	1.33	16	11.01–13.55	12.36	0.57	Do *et al.* (2024)
G. tsushimaensis	17	11.80–14.30	13.20	0.80	14	14.00–17.50	15.50	1.00	Isogawa *et al.* (1994)
G. ussuriensis									
Russian group	18	12.10–14.70	13.50	0.60	14	11.60–17.40	14.80	1.40	Emelianov (1929)
Russian and Chinese groups	22	12.00–15.00	13.80	–	19	12.00–17.00	15.10	–	Gloyd and Conant (1990)
BI group	**16**	**13.45–16.08**	**14.60**	**0.88**	**12**	**16.07–17.33**	**16.76**	**0.47**	**Present study**
KP group	57	11.00–16.00	13.20	–	52	8.00–16.00	13.80	–	Paik *et al.* (1979)
KP group	24	11.06–14.95	13.40	1.20	20	13.78–17.49	15.32	1.00	Present study
JI group	**21**	**11.97–14.32**	**13.27**	**0.72**	**14**	**14.15–16.27**	**15.13**	**0.62**	**Present study**
GI group	**13**	**10.15–13.53**	**12.89**	**0.88**	**20**	**14.71–16.47**	**15.69**	**0.44**	**Present study**

KP, Korean Peninsula; BI, Baengnyeongdo Island; JI, Jeju-do Island; GI, Gapado Island.

the HL/SVL of the lectotype (ZISP 13327) of *Gloydius ussuriensis* recorded in Russia is very low at 3.98, further comparative studies with the Russian population are required to verify the major morphological traits of the Baengnyeongdo population (Orlov and Barabanov, 1999).

The Baengnyeongdo Island group (F: 149–162, M: 148–157) exhibited the highest number of scales, whereas the Jeju-do (F: 139–150, M: 140–147) and Gapado Island groups (F: 140–147, M: 138–144) exhibited the lowest. Both inland females (145–156) and males (143–152) differed from the other groups (Table 15). The Jeju-do and Gapado Island groups had fewer abdominal scales on average in both females and males than the other *G. ussuriensis* groups, and the phylogenetically similar *G. tsushimaensis* and *G. intermedius*. The Baengnyeongdo Island group had more abdominal scales than other *G. ussuriensis* groups, *G. tsushimaensis*, and *G. brevicaudus* (Emelianov, 1929; Gloyd and Conant, 1990; Isogawa *et al.*, 1994; Do *et al.*, 2024, Table 15). Meanwhile, the Baengnyeongdo Island group (F: 13.45–16.08, M: 16.07–17.33) had a higher TL/TTL than the inland (F: 11.06–14.95, M: 13.78–17.49), Jeju-do Island (F: 11.97–14.32, M: 14.15–16.27), and Gapado Island groups (F: 10.15–13.53, M: 14.71–16.47). The Baengnyeongdo Island group had a higher average TL/TTL for both females and males than all other *G. ussuriensis* groups, as well as *G. tsushimaensis*, *G. intermedius*, and *G. brevicaudus* (Emelianov, 1929; Gloyd and Conant, 1990; Isogawa *et al.*, 1994; Do *et al.*, 2024, Table 15).

In conclusion, the morphological characteristics of the Baengnyeongdo Island group were distinct from those of other groups and phylogenetically similar species. The inland, Jeju-do, and Gapado Island groups exhibited some overlapping morphological factors (e.g., TL/TTL and TL/SVL), whereas the Jeju-do and Gapado Island groups demonstrated greater similarities (e.g., V, HL/

TTL, and HL/SVL) than the inland group. These similarities were reflected in the LDA results; the Baengnyeongdo Island group was independent, the inland group exhibited a significant overlap with the Jeju-do Island group, and the Jeju-do Island group partially overlapped with the Gapado Island group (Fig. 5).

Ecological characteristics

The environmental niche of *G. ussuriensis* differed between the inland and island areas. The Baengnyeongdo, Gapado, and Heuksando Island groups inhabited lower altitudes than the inland and Jeju-do Island groups. In general, *G. ussuriensis* prefers valleys, rivers, and grasslands at altitudes of 0−1302 m within forested regions (Do *et al*., 2016; 2022b). However, on Gapado Island, all individuals were observed in cultivated fields (Kim *et al*., 2010). Island geography helps explain these differences. Gapado Island (0.84 km^2), located 5.5 km south of Jeju-do Island, is characterized by flat land, including grasslands and farmland, with no mountains (Koh and Park, 2010). Gapado and Baengnyeongdo Island (45.84 km^2), located in the northwest sea, and Heuksando (19.70 km^2) and Jangdo Island (2.23 km^2), located in the southwest sea, comprise low mountain ranges ($\leq$200 m). In contrast, inland regions include the Jirisan Mountain (elevation: 1915 m) and Taebaeksan Mountains, while Jeju-do Island contains Hallasan Mountain (elevation: 1947 m) (Song *et al*., 2006; Kim *et al*., 2013; Woo and Lee, 2016).

Climatic conditions also varied by latitude and altitude. For example, the average annual temperature, winter temperature, and precipitation were the highest on Gapado Island, which has the lowest latitude, and the lowest inland, which has a relatively high altitude. The average annual and summer precipitation was highest on Jeju-do Island (low latitudes) and lowest on Baengnyeongdo Island (highest latitude). The summer temperature, annual temperature range, and daily temperature range were the highest on Gapado Island and lowest on Baengnyeongdo Island.

Because of these habitat differences between the inland and island regions, ecological niches between populations overlapped, although to a lesser degree than in previous studies on the ecological niches of Viperidae species (PI 0.95) (Do *et al*., 2016; Do and Nam, 2021). Consequently, each *G. ussuriensis* group tended to have separate ecological niches depending on the climate and habitat associated with their location, with the Baengnyeongdo and Gapado Island groups showing the greatest separation from other groups.

Taxonomic implications

Understanding the evolution, origin, and boundaries of a species requires evidence from biogeography, genetics, morphometrics, and ecology (Padial *et al*., 2010; Shi *et al*., 2018; Wang *et al*., 2019). The *G. halys* complex, which extends from Azerbaijan and Iran to various countries in Central Asia, Eastern Siberia, Mongolia, and China, is classified into five distinct subspecies, largely shaped by geographical barriers (Orlov and Barabanov, 1999; Wagner *et al*., 2016; Asadi *et al*., 2019): (1) *G. h. halys* (Pallas, 1776), (2) *G. h. boehmei* Nilson, 1983, (3) *G. h. caraganus* Eichwald, 1831, (4) *G. h. cognatus* Gloyd, 1977, and (5) *G. h. stejnegeri* Rendahl, 1933. These subspecies share some traits (e.g., 23 dorsal fin rays) but differ in morphological characteristics (e.g., size, number of pelvic fins, and body color), distribution ranges, and habitat characteristics (altitude range and habitat) (Wagner *et al*., 2016). For example, *G. h. halys*, distributed from eastern Kazakhstan through southern Siberia to Mongolia, has a maximum length of 750 mm and 164−178 abdominal scales, whereas *G. h. stejnegeri*, distributed from southeastern Inner Mongolia to the Shaanxi and Hebei provinces in China, has a maximum length of 625 mm and 147−165 abdominal scales. The smallest, *G. h. boehmei*, endemic to high mountainous regions (2500 m) in eastern Afghanistan, has a maximum length of 487 mm and 155 abdominal scales (Orlov and Barabanov, 1999; Wagner *et al*., 2016). In addition, *Gloydius shedaoensis* in China is classified into two subspecies: *G. s. shedaoensis* (Zhao, 1979), which inhabits Shedao Island located approximately 8 km offshore from the mainland, and *G. s. qianshanensis* Li, 1999, which inhabits Liaoning Province on the mainland (Uetz *et al*., 2025). The two subspecies are clearly distinguished morphologically and ecologically. *G. s. shedaoensis* reaches a maximum total length of 850 mm, has 153−162 ventral scales, and inhabits mountainous areas below 215 m in elevation, whereas *G. s. qianshanensis* attains a smaller maximum total length of 742 mm but has more ventral scales (153−170) and inhabits mountainous areas above 400 m in elevation (Li, 1999; Qiu *et al*., 2023).

Previous studies reported that *G. ussuriensis* has a maximum length of 650 mm and 139−161 abdominal scales (Orlov and Barabanov, 1999). The morphological characteristics of *G. ussuriensis* in the Republic of Korea fell within this range but the Baengnyeongdo, Jeju-do, and Gapado Island groups differ in key morphological traits such as head length ratio and number of abdominal scales. In addition, the Gapado Island group has unique habitat preferences. These patterns are consistent with historical isolation: during the LGM, the Yellow Sea was approximately 120 m lower than today. The subsequent Holocene sea level rise created islands such as Baengnyeongdo and Gapado Island groups (Bloom and Park, 1985; Pirazzoli, 1991), leading to genetic isolation and niche differentiation (Pirazzoli, 1991; Cho *et al*., 2013).

Our findings also indicate morphological affinities between Japanese *G. tsushimaensis* (Isogawa *et al*., 1994) and the Jeju-do and Gapado Island populations (e.g., HL/SVL, HL/HW, and TL/TTL) (Figs. 2 and 6, Tables 14 and 15). Further research is needed to reclassify the taxonomy of *G. ussuriensis* and *G. tsushimaensis* through divergence time estimation and to confirm their origin and distribution patterns using phylogenetic analysis.

Taken together, the results suggest that the Baengnyeongdo Island and Jeju-do-Gapado Island region populations represent a new subspecies. We therefore propose recognizing three subspecies: *G. ussuriensis ussuriensis*, *G. ussuriensis baengnyeongensis*, and *G. ussuriensis jejuensis*, as part of the *G. ussuriensis* complex. Nuclear DNA analysis indicates that the Gapado Island group may have undergone recent differentiation. Further ecological studies are needed to investigate the habitat preferences between groups. Furthermore, we recommend conducting taxonomic studies on *G. ussuriensis* inhabiting various island regions in the southwestern part of the country that were not included in the present study.

This study has several taxonomic limitations. First, genetic comparisons with specimens from the type locality were not conducted, and the diversity of genetic markers was limited. Future studies should include type locality specimens and apply a wider range of mitochondrial and nuclear DNA markers for more precise phylogenetic analyses (e.g., Shi *et al*., 2017; Wang *et al*., 2019). Second, morphological comparisons should be expanded to include detailed and quantitative traits not addressed in this study, such as scale counts from specific regions, hemipenial morphology, X-ray—based skeletal structures, and coloration and pattern characteristics, to better clarify interpopulation morphological differences (e.g., Shi *et al*., 2018; Qiu *et al*., 2023). Finally, to elucidate ecological correlates of subspecific differentiation, more detailed data on ecological factors such as microhabitat use and preferred prey resources are needed (e.g., Li, 1999). Such information would help to refine our understanding of ecological differences among populations and provide essential baseline data for interpreting the background and evolutionary pathways of subspecies differentiation.

Taxonomic Account

Viperidae Gray, 1825
Gloydius Hoge and Romano-Hoge, 1981
Gloydius ussuriensis (Emelianov, 1929)

***Gloydius ussuriensis baengnyeongensis*, Do and Lee, ssp. nov.**

Etymology. *Gloydius ussuriensis baengnyeongensis* ssp. (Fig. 7A, B) is named after Baengnyeongdo, an island



Fig. 7. Individuals observed on (A) August 26, 2021, during the day; (B) May 25, 2019, at night by Min Seock Do and Sang-Cheol Lee on Baengnyeongdo Island. (C) Forest area and paddy field wetlands; (D) field inhabited by *G. ussuriensis baengnyeongensis* ssp. nov.

located in the West Sea of the Korean Peninsula, where it occurs. The English name is "Baengnyeon red-tongued pit viper" and the Korean name is "백령쇠살모사" in Korean.

Description of the holotype. *Gloydius ussuriensis baengnyeongensis* ssp. nov. holotype, deposited in the National Institute of Biological Resources (NIBR), Species Diversity Research Division, Incheon (catalog number NIBRRP0000101143). Adult male preserved in 75% ethanol. Total length 605 mm (SVL: 506 mm, TL: 99 mm). Head length 25.40 mm, head width 15.51 mm, ventral scales 152. Ratio of head length to head width (HL/HW) 1.64; ratio of head length to snout-vent length (HL/SVL) 5.02; ratio of tail length to total length (TL/TTL) 16.36. Collected from Baengnyeong-do, Ongjin, Incheon, Gyeonggi Province, South Korea (37°55′42.18″N, 124°39′19.72″E) on 26 August 2021 by Min Seock Do and Sang-Cheol Lee.

Comparison. The holotype differs from the lectotype of *G. ussuriensis* (ZISP 13327; adult male) by having a shorter total length (605 mm vs. 645 mm) and body length (506 mm vs. 570 mm), but a longer tail (99 mm vs. 75 mm) and head length (25.40 mm vs. 22.7 mm), a wider head (15.51 mm vs. 14.5 mm), and more ventral scales (152 vs. 145). In addition, the ratios HL/HW (1.64 vs. 1.57), HL/SVL (5.02 vs. 3.98), and TL/TTL (16.36 vs. 11.63) are all greater in the holotype than in the lectotype.

Diagnosis. The new subspecies, *G. ussuriensis baengnyeongensis* ssp., is assigned to *Gloydius* because of its small body size and bilateral pit holes between the eyes and nose. The brevicaudus classification is based on 21 dorsal scales; Guo and Zhang, 2002). The specimen has a light pink tongue and brown or blackish-brown tail, consistent with the taxonomic classification of the *G. ussuriensis* complex. This new subspecies differs from *G. ussuriensis* in the following morphological characteristics: (1) long body and tail, (2) long tail length relative to body length (15.18%−21.01%), and (3) high number of ventral scales (148−162).

Coloration. Both eyes have distinct white-yellow stripes behind them, and the tongue is light pink. The dorsal region exhibits a predominantly reddish-brown hue accompanied by brown and yellow tones. Distinct circular patterns extend from the neck to the tail on the left and right sides. The circular patterns may be blurred in some individuals or integrated on both sides to form a single pattern. The centers of the circular patterns are light grayish brown and the edges are dark blackish brown. The ventral region is characterized by white or yellowish-white pigmentation and occasionally marked by small blackish-brown spots distributed in an irregular pattern. No discernible patterns are present. The tail is brown or blackish-brown.



Fig. 8. Individuals observed on (A) September 26, 2020; (B) October 13, 2022, during the day by Min Seock Do and Sang-Cheol Lee on Jeju-do and Gapado Islands. (C) Geumoreum, Jeju-do Island, and (D) grassland of Gapado Island, where *G. ussuriensis jejuensis* ssp. nov. individuals were observed.

Distribution and ecology. *Gloydius ussuriensis baengnyeongensis* is endemic to the Republic of Korea and is found only in Baengnyeongdo. It primarily inhabits forested areas (Fig. 6A). Within 1 km of the main habitat are rice paddies, fields, greenhouses, residential areas, and roads. The area is rich in water resources, including rivers, valleys, and reservoirs (Fig. 7C, D). Individuals are mainly observed between April and October and are more active at night than during the day.

***Gloydius ussuriensis jejuensis*, Do and Oh, ssp. nov.**

Etymology. *Gloydius ussuriensis jejuensis* ssp. is named after the Jeju-do and Gapado Islands in the South Sea of the Korean Peninsula where it occurs (Fig. 8A, B). It is named "Jeju red-tongued pit viper" in English and "제주 쇠살모사" in Korean.

Description of the holotype. *Gloydius ussuriensis jejuensis* ssp. nov. holotype, deposited in the National Institute of Biological Resources (NIBR), Species Diversity Research Division, Incheon (catalog number NIBR RP0000101144). Adult male preserved in 75% ethanol. Total length 400 mm (SVL: 338 mm, TL: 62 mm). Head length 20.18 mm, head width 12.58 mm, ventral scales 143. Ratio of head length to head width (HL/HW) 1.60; ratio of head length to snout-vent length (HL/SVL) 5.97; ratio of tail length to total length (TL/TTL) 15.50. Collected from Gapa-do, Daejeong, Seogwipo, Jeju-do, South Korea (33°10′19.32″N, 126°16′12.01″E) on 13 October 2022 by Min Seock Do and Hong Shik Oh.

Comparison. The holotype differs from the lectotype of *G. ussuriensis* (ZISP 13327; adult male) by having a shorter total length (400 mm vs. 645 mm), shorter body length (338 mm vs. 570 mm), and shorter tail length (62 mm vs. 75 mm). The head is also shorter (20.18 mm vs. 22.7 mm) and narrower (12.58 mm vs. 14.5 mm), with fewer ventral scales (143 vs. 145). In contrast, the ratios HL/HW (1.60 vs. 1.57), HL/SVL (5.97 vs. 3.98), and TL/TTL (15.50 vs. 11.63) are all greater in the holotype than in the lectotype.

Diagnosis. The new subspecies *G. ussuriensis jejuensis* ssp. is assigned to *Gloydius* because of its small body size and bilateral pit holes between the eyes and nose. The Brevicaudus classification is based on 21 dorsal scales (Guo and Zhang, 2002). It has a light pink tongue and brown or blackish-brown tail, consistent with the taxonomic classification of the *G. ussuriensis* complex. It differs from *G. ussuriensis* in the following morphological characteristics: (1) longer head length relative to body length (5.33−6.39) and (2) fewer ventral scales (138−150).

Coloration. Both eyes have distinct white-yellow stripes behind them, and the tongue is light pink. The dorsal region exhibits a predominantly reddish-brown hue accompanied by brown and yellow tones. Distinct circular patterns extend from the neck to the tail on the left and right sides. The centers of the circular patterns are light grayish brown and the edges are dark blackish brown. The ventral region is characterized by white or yellowish-white pigmentation and occasionally marked by small blackish-brown spots distributed in an irregular pattern. No discernible patterns are observed. The tail is brown or blackish-brown.

Distribution and ecology. *Gloydius ussuriensis jejuensis* is endemic to the Republic of Korea and is found on the Gapado and Jeju-do islands. On Jeju-do Island, this species mainly inhabits forested areas (Fig. 6A). Within 1 km of the main habitat, there are cultivated areas, such as grasslands and fields, residential areas, roads, rivers, and valleys, with abundant water resources. On Gapado Island, it mainly inhabits grasslands, graveyards, and barley fields (Fig. 8C, D). It is mainly observed between April and October and is more active at night than during the day.

Conflicts of Interest

The author of this paper have no affiliation with any interests and are solely responsible for the paper.

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Appendix. Sampling localities and genetic, morphological, and ecological data for each individual of *Gloydius ussuriensis*.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
1	IN06474	Chungcheongnam-do	Gongju-si	CS	○	○		○	C
2	IN06475	Chungcheongnam-do	Gongju-si	CS				○	C
3	IN06476	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
4	IN06477	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
5	IN06478	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
6	IN06479	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
7	IN06480	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
8	IN06481	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
9	IN06482	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
10	IN06483	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
11	IN06484	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
12	IN06485	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
13	IN06486	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
14	IN06487	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
15	IN06488	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
16	IN06489	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
17	IN06490	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
18	IN06491	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
19	IN06492	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
20	IN06493	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
21	IN06494	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
22	IN06495	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
23	IN06496	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
24	IN06497	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
25	IN06498	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
26	IN06499	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
27	IN06500	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
28	IN06501	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
29	IN06502	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
30	IN06503	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
31	IN06504	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
32	IN06505	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
33	IN06506	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
34	IN06507	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
35	IN06508	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
36	IN06509	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
37	IN06510	Incheon metropolitan city	Ongjin-gun	BI	○	○	○	○	C
38	IN06511	Incheon metropolitan city	Ongjin-gun	BI	○	○		○	C
39	IN06539	Chungcheongnam-do	Buyeo-gun	CS	○	○		○	C
40	IN06540	Chungcheongnam-do	Buyeo-gun	CS		○		○	C
41	IN06541	Daejeon metropolitan city		CN			○	○	C
42	IN06542	Daejeon metropolitan city		CN			○	○	C
43	IN06543	Daejeon metropolitan city		CN				○	C
44	IN06544	Daejeon metropolitan city		CN			○	○	C
45	IN06545	Daejeon metropolitan city		CN			○	○	C
46	IN06546	Daejeon metropolitan city		CN				○	C
47	IN06547	Chungcheongnam-do	Gongju-si	CS				○	C
48	IN06548	Chungcheongnam-do	Gongju-si	CS				○	C

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
49	IN06549	Chungcheongnam-do	Gongju-si	CS				○	C
50	IN06550	Chungcheongnam-do	Hongseong-gun	CS	○	○		○	C
51	IN06551	Chungcheongnam-do	Seosan-si	CS	○	○	○	○	C
52	IN06552	Chungcheongnam-do	Seosan-si	CS	○	○		○	C
53	IN06553	Chungcheongnam-do	Seosan-si	CS	○		○	○	C
54	IN06554	Chungcheongnam-do	Seosan-si	CS			○	○	C
55	IN06555	Chungcheongnam-do	Seosan-si	CS	○		○	○	C
56	IN06556	Chungcheongnam-do	Seosan-si	CS			○	○	C
57	IN06557	Chungcheongnam-do	Seosan-si	CS	○	○	○	○	C
58	IN06558	Chungcheongnam-do	Seosan-si	CS	○	○	○	○	C
59	IN06559	Chungcheongnam-do	Seosan-si	CS	○	○		○	C
60	IN06560	Chungcheongnam-do	Seosan-si	CS	○	○	○	○	C
61	IN06561	Chungcheongnam-do	Seosan-si	CS	○	○	○	○	C
62	IN06562	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○	○	○	C
63	IN06563	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
64	IN06564	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
65	IN06565	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
66	IN06566	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
67	IN06567	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
68	IN06568	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
69	IN06569	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
70	IN06570	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
71	IN06571	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
72	IN06572	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
73	IN06573	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
74	IN06574	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
75	IN06575	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
76	IN06576	Gyeongsangnam-do	Yangsan-si	GS	○	○	○	○	C
77	IN06577	Jeollanam-do	Haenam-gun	JS			○	○	C
78	IN06578	Jeollanam-do	Haenam-gun	JS			○	○	C
79	IN06579	Jeollanam-do	Haenam-gun	JS			○	○	C
80	IN06580	Jeollanam-do	Haenam-gun	JS			○	○	C
81	IN06581	Jeollanam-do	Haenam-gun	JS			○	○	C
82	IN06582	Jeollanam-do	Haenam-gun	JS			○	○	C
83	IN06583	Jeollanam-do	Haenam-gun	JS				○	C
84	IN06584	Jeollanam-do	Haenam-gun	JS				○	C
85	IN06585	Jeollanam-do	Haenam-gun	JS				○	C
86	IN06586	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
87	IN06587	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
88	IN06588	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
89	IN06589	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
90	IN06590	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
91	IN06591	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
92	IN06592	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
93	IN06593	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
94	IN06594	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
95	IN06595	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○	○	○	C
96	IN06596	Gangwon-do	Gangneung-si	KN	○	○		○	C
97	IN06597	Gangwon-do	Gangneung-si	KN	○	○		○	C

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
98	IN06598	Gangwon-do	Gangneung-si	KN	○	○		○	C
99	IN06599	Gangwon-do	Gangneung-si	KN	○	○		○	C
100	IN06601	Gangwon-do	Gangneung-si	KN	○	○		○	C
101	IN06602	Gangwon-do	Gangneung-si	KN	○	○		○	C
102	IN06603	Gangwon-do	Gangneung-si	KN	○	○		○	C
103	IN06604	Gangwon-do	Gangneung-si	KN	○	○	○	○	C
104	IN06605	Gangwon-do	Gangneung-si	KN	○	○	○	○	C
105	IN06606	Gangwon-do	Gangneung-si	KN	○	○		○	C
106	IN06607	Gangwon-do	Gangneung-si	KN	○	○		○	C
107	IN06608	Gangwon-do	Gangneung-si	KN	○	○	○	○	C
108	IN06609	Gangwon-do	Gangneung-si	KN	○	○	○	○	C
109	IN06610	Gangwon-do	Gangneung-si	KN	○	○	○	○	C
110	IN06611	Gangwon-do	Gangneung-si	KN	○	○		○	C
111	IN06612	Gangwon-do	Gangneung-si	KN	○	○	○	○	C
112	IN06613	Gangwon-do	Gangneung-si	KN	○		○	○	C
113	IN06614	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
114	IN06615	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
115	IN06616	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
116	IN06617	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
117	IN06618	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
118	IN06619	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
119	IN06620	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
120	IN06621	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
121	IN06622	Gangwon-do	Hoengseong-gun	KS		○		○	C
122	IN06623	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
123	IN06624	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
124	IN06625	Gangwon-do	Jeongseon-gun	KS	○	○		○	C
125	IN06626	Gangwon-do	Jeongseon-gun	KS	○	○		○	C
126	IN06627	Gangwon-do	Jeongseon-gun	KS	○	○		○	C
127	IN06628	Gangwon-do	Jeongseon-gun	KS	○	○		○	C
128	IN06629	Gangwon-do	Samcheok-si	KS	○	○		○	C
129	IN06630	Gangwon-do	Samcheok-si	KS	○	○		○	C
130	IN06631	Gangwon-do	Samcheok-si	KS	○	○	○	○	C
131	IN06632	Gangwon-do	Samcheok-si	KS	○	○	○	○	C
132	IN06633	Gangwon-do	Wonju-si	KS	○	○		○	C
133	IN06634	Gangwon-do	Wonju-si	KS	○	○		○	C
134	IN06635	Gangwon-do	Wonju-si	KS	○	○		○	C
135	IN06636	Gangwon-do	Wonju-si	KS	○	○		○	C
136	IN06637	Gangwon-do	Wonju-si	KS	○	○		○	C
137	IN06638	Gangwon-do	Wonju-si	KS	○	○		○	C
138	IN06639	Gangwon-do	Wonju-si	KS	○	○		○	C
139	IN06640	Gangwon-do	Wonju-si	KS	○	○		○	C
140	IN06641	Gangwon-do	Wonju-si	KS	○	○		○	C
141	IN06642	Gangwon-do	Samcheok-si	KS	○	○		○	C
142	IN06643	Gangwon-do	Wonju-si	KS	○	○		○	C
143	IN06644	Jeollabuk-do	Buan-gun	JN			○	○	C
144	IN06645	Jeollabuk-do	Buan-gun	JN				○	C
145	IN06646	Jeju-do	Jeju-si	JI		○		○	C
146	IN06647	Jeju-do	Jeju-si	JI	○	○		○	C

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
147	IN06648	Jeju-do	Jeju-si	JI	○	○		○	C
148	IN06649	Jeju-do	Jeju-si	JI	○	○		○	C
149	IN06650	Jeju-do	Seogwipo-si	JI	○	○		○	C
150	IN06651	Jeollanam-do	Jangheung-gun	JS			○	○	C
151	IN06652	Jeollanam-do	Jangheung-gun	JS				○	C
152	IN06653	Jeollanam-do	Jangheung-gun	JS				○	C
153	IN06654	Jeollanam-do	Yeongam-gun	JS				○	C
154	IN06655	Jeollanam-do	Yeongam-gun	JS				○	C
155	IN06656	Gyeonggi-do	Gimpo-si	GG	○	○		○	C
156	IN06657	Gyeonggi-do	Gimpo-si	GG	○	○		○	C
157	IN06658	Jeollanam-do	Yeongam-gun	JS				○	C
158	IN06659	Jeollanam-do	Yeongam-gun	JS				○	C
159	IN06685	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
160	IN06686	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
161	IN06687	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
162	IN06688	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
163	IN06689	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
164	IN06690	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
165	IN06691	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
166	IN06692	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
167	IN06693	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
168	IN06694	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
169	IN06695	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
170	IN06697	Chungcheongbuk-do	Chungju-si	CN			○	○	C
171	IN06699	Chungcheongbuk-do	Danyang-gun	CN		○		○	C
172	IN06700	Chungcheongbuk-do	Danyang-gun	CN		○		○	C
173	IN06701	Chungcheongnam-do	Cheongyang-gun	CS		○	○	○	C
174	IN06702	Chungcheongnam-do	Taean-gun	CS	○		○	○	C
175	IN06703	Chungcheongnam-do	Taean-gun	CS	○	○		○	C
176	IN06704	Chungcheongnam-do	Taean-gun	CS	○		○	○	C
177	IN06705	Chungcheongnam-do	Taean-gun	CS		○		○	C
178	IN06706	Chungcheongnam-do	Taean-gun	CS			○	○	C
179	IN06707	Chungcheongnam-do	Yesan-gun	CS		○		○	C
180	IN06827	Jeollabuk-do	Buan-gun	JN			○	○	C
181	IN06828	Chungcheongnam-do	Cheongyang-gun	CS		○	○	○	C
182	IN06829	Chungcheongnam-do	Cheongyang-gun	CS	○	○	○	○	C
183	IN06830	Chungcheongnam-do	Cheongyang-gun	CS	○	○	○	○	C
184	IN06997	Gyeongsangbuk-do	Cheongdo-gun	GS	○	○		○	C
185	IN06998	Gyeonggi-do	Yeoncheon-gun	GG		○		○	C
186	IN07001	Gangwon-do	Wonju-si	KS	○	○		○	C
187	IN07002	Gangwon-do	Hoengseong-gun	KS	○	○		○	C
188	IN07003	Gangwon-do	Wonju-si	KS	○	○		○	C
189	IN07008	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
190	IN07009	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
191	IN07010	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
192	IN07011	Gangwon-do	Inje-gun	KN	○	○		○	C
193	IN07012	Gangwon-do	Yanggu-gun	KN	○	○		○	C
194	IN07013	Gangwon-do	Gangneung-si	KN	○	○		○	C
195	IN07017	Gangwon-do	Gangneung-si	KN	○	○		○	C

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
196	IN07018	Gangwon-do	Gangneung-si	KN	○	○		○	C
197	IN07019	Gangwon-do	Gangneung-si	KN	○	○		○	C
198	IN07020	Gangwon-do	Gangneung-si	KN	○	○		○	C
199	IN07021	Gangwon-do	Gangneung-si	KN	○	○		○	C
200	IN07022	Gangwon-do	Gangneung-si	KN	○	○		○	C
201	IN07025	Gyeongsangbuk-do	Cheongdo-gun	GS	○	○		○	C
202	IN07026	Ulsan metropolitan city	Ulju-gun	GS	○	○		○	C
203	IN07027	Ulsan metropolitan city	Ulju-gun	GS	○	○		○	C
204	IN07028	Ulsan metropolitan city	Ulju-gun	GS	○	○		○	C
205	IN07029	Ulsan metropolitan city	Ulju-gun	GS	○	○		○	C
206	IN07030	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
207	IN07031	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
208	IN07032	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
209	IN07033	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
210	IN07034	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
211	IN07035	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
212	IN07036	Jeollanam-do	Gangjin-gun	JS				○	C
213	IN07037	Jeollanam-do	Gangjin-gun	JS				○	C
214	IN07038	Jeollanam-do	Gangjin-gun	JS				○	C
215	IN07039	Jeollanam-do	Gangjin-gun	JS				○	C
216	IN07040	Jeollanam-do	Gangjin-gun	JS				○	C
217	IN07041	Jeollanam-do	Gangjin-gun	JS				○	C
218	IN07042	Jeollanam-do	Gangjin-gun	JS				○	C
219	IN07043	Jeollanam-do	Gangjin-gun	JS				○	C
220	IN07044	Jeollanam-do	Haenam-gun	JS				○	C
221	IN07045	Jeollanam-do	Haenam-gun	JS				○	C
222	IN07046	Jeollanam-do	Haenam-gun	JS				○	C
223	IN07047	Jeollanam-do	Haenam-gun	JS				○	C
224	IN07048	Jeollanam-do	Haenam-gun	JS				○	C
225	IN07049	Jeollanam-do	Haenam-gun	JS				○	C
226	IN07050	Jeollanam-do	Haenam-gun	JS				○	C
227	IN07051	Jeollanam-do	Haenam-gun	JS				○	C
228	IN07052	Jeollanam-do	Haenam-gun	JS				○	C
229	IN07053	Jeollanam-do	Yeongam-gun	JS				○	C
230	IN07054	Jeollanam-do	Hampyeong-gun	JS				○	C
231	IN07055	Jeollanam-do	Hampyeong-gun	JS				○	C
232	IN07056	Jeollanam-do	Hampyeong-gun	JS				○	C
233	IN07057	Jeollabuk-do	Buan-gun	JN				○	C
234	IN07059	Jeju-do	Jeju-si	JI		○		○	C
235	IN07060	Jeju-do	Jeju-si	JI	○	○		○	C
236	IN07061	Jeju-do	Jeju-si	JI		○		○	C
237	IN07062	Jeju-do	Jeju-si	JI		○		○	C
238	IN07063	Jeju-do	Jeju-si	JI		○		○	C
239	IN07064	Jeju-do	Jeju-si	JI		○		○	C
240	IN07065	Jeju-do	Jeju-si	JI	○	○		○	C
241	IN07066	Jeju-do	Jeju-si	JI		○		○	C
242	IN07067	Jeju-do	Jeju-si	JI	○	○		○	C
243	IN07068	Jeju-do	Jeju-si	JI		○		○	C
244	IN07069	Jeju-do	Jeju-si	JI		○		○	C

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
245	IN07070	Jeju-do	Jeju-si	JI		○		○	C
246	IN07071	Jeju-do	Jeju-si	JI		○		○	C
247	IN07072	Jeju-do	Jeju-si	JI	○	○		○	C
248	IN07073	Jeju-do	Jeju-si	JI	○	○		○	C
249	IN07074	Jeju-do	Jeju-si	JI	○	○		○	C
250	IN07075	Jeju-do	Jeju-si	JI	○	○		○	C
251	IN07076	Jeju-do	Jeju-si	JI	○	○		○	C
252	IN07077	Jeju-do	Jeju-si	JI	○	○		○	C
253	IN07078	Jeju-do	Jeju-si	JI		○		○	C
254	IN07079	Jeju-do	Jeju-si	JI		○		○	C
255	IN07080	Jeju-do	Jeju-si	JI	○	○		○	C
256	IN07081	Jeju-do	Jeju-si	JI	○	○		○	C
257	IN07082	Jeju-do	Jeju-si	JI	○	○		○	C
258	IN07148	Gangwon-do	Gangneung-si	KN	○	○		○	C
259	IN07149	Gangwon-do	Jeongseon-gun	KS	○	○		○	C
260	IN07150	Gyeongsangnam-do	Yangsan-si	GS	○	○		○	C
261	IN07151	Chungcheongnam-do	Dangjin-si	CS	○	○		○	C
262	IN07152	Chungcheongnam-do	Seosan-si	CS	○	○		○	C
263	IN07153	Chungcheongnam-do	Seosan-si	CS	○	○		○	C
264	IN07154	Chungcheongnam-do	Seosan-si	CS		○		○	C
265	IN07155	Chungcheongnam-do	Seosan-si	CS	○	○		○	C
266	IN07156	Chungcheongnam-do	Seosan-si	CS	○	○		○	C
267	IN07157	Chungcheongnam-do	Seosan-si	CS	○	○	○	○	C
268	IN07158	Chungcheongnam-do	Hongseong-gun	CS		○		○	C
269	IN07159	Chungcheongnam-do	Hongseong-gun	CS	○	○		○	C
270	IN07160	Chungcheongnam-do	Buyeo-gun	CS		○		○	C
271	IN07161	Chungcheongnam-do	Gongju-si	CS	○	○		○	C
272	IN07162	Daejeon metropolitan city		CN				○	C
273	IN07163	Daejeon metropolitan city		CN				○	C
274	IN07164	Daejeon metropolitan city		CN				○	C
275	IN07165	Daejeon metropolitan city		CN				○	C
276	IN07166	Daejeon metropolitan city		CN				○	C
277	IN07167	Daejeon metropolitan city		CN				○	C
278	IN07168	Daejeon metropolitan city		CN				○	C
279	IN07169	Daejeon metropolitan city		CN				○	C
280	IN07170	Daejeon metropolitan city		CN				○	C
281	IN07171	Daejeon metropolitan city		CN				○	C
282	IN07220	Gyeonggi-do	Pocheon-si	GG		○		○	C
283	IN07221	Gyeonggi-do	Pocheon-si	GG		○		○	C
284	IN07222	Gyeonggi-do	Pocheon-si	GG		○		○	C
285	IN07223	Gyeonggi-do	Pocheon-si	GG		○		○	C
286	IN07224	Gyeonggi-do	Pocheon-si	GG		○		○	C
287	IN07225	Gyeonggi-do	Pocheon-si	GG		○		○	C
288	IN07226	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
289	IN07227	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
290	IN07228	Gyeongsangbuk-do	Bonghwa-gun	GN	○	○		○	C
291	IN07230	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
292	IN07231	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
293	IN07232	Chungcheongbuk-do	Cheongju-si	CN		○		○	C

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
294	IN07233	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
295	IN07234	Gyeongsangbuk-do	Sangju-si	GN		○		○	C
296	IN07242	Gangwon-do	Samcheok-si	KS	○	○		○	C
297	IN07243	Gangwon-do	Samcheok-si	KS	○	○		○	C
298	IN07244	Gangwon-do	Samcheok-si	KS	○	○		○	C
299	IN07245	Gangwon-do	Samcheok-si	KS	○	○		○	C
300	IN07246	Gangwon-do	Samcheok-si	KS	○	○		○	C
301	IN07247	Gangwon-do	Samcheok-si	KS	○	○		○	C
302	IN07248	Gangwon-do	Samcheok-si	KS	○	○		○	C
303	IN07249	Jeju-do	Jeju-si	JI	○	○		○	C
304	IN07250	Jeju-do	Jeju-si	JI	○	○		○	C
305	IN07251	Gyeongsangbuk-do	Cheongdo-gun	GS		○		○	C
306	IN07255	Chungcheongbuk-do	Cheongju-si	CN		○		○	C
307	IN07912	Gyeongsangbuk-do	Yecheon-gun	GN		○		○	C
308	IN07914	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
309	IN07915	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
310	IN07919	Jeollabuk-do	Wanju-gun	JN				○	C
311	IN07920	Jeollabuk-do	Jinan-gun	JN		○		○	C
312	IN07921	Chungcheongnam-do	Cheongyang-gun	CS	○	○		○	C
313	IN07922	Gyeongsangbuk-do	Cheongdo-gun	GS	○	○		○	C
314	IN07923	Gyeongsangbuk-do	Cheongdo-gun	GS	○	○		○	C
315	IN07924	Gyeongsangbuk-do	Andong-si	GN	○	○		○	C
316	IN07925	Gyeongsangbuk-do	Andong-si	GN	○	○		○	C
317	IN07926	Gyeongsangbuk-do	Andong-si	GN	○	○		○	C
318	IN07934	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
319	IN07935	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
320	IN07936	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
321	IN07937	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
322	IN07938	Chungcheongnam-do	Cheongyang-gun	CS	○	○		○	C
323	IN07939	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
324	IN07940	Chungcheongnam-do	Cheongyang-gun	CS	○	○		○	C
325	IN07941	Chungcheongnam-do	Cheongyang-gun	CS		○	○	○	C
326	IN07942	Chungcheongnam-do	Cheongyang-gun	CS		○		○	C
327	IN07943	Chungcheongnam-do	Cheongyang-gun	CS	○	○		○	C
328	IN07947	Gyeongsangbuk-do	Andong-si	GN	○	○		○	C
329	IN07948	Jeollanam-do	Gwangyang-si	JS				○	C
330	IN07949	Jeollanam-do	Gwangyang-si	JS				○	C
331	IN07955	Gyeongsangbuk-do	Yecheon-gun	GN		○		○	C
332	IN07956	Gyeongsangbuk-do	Yecheon-gun	GN		○		○	C
333	IN07970	Chungcheongnam-do	Cheongyang-gun	CS				○	C
334	IN07971	Chungcheongnam-do	Cheongyang-gun	CS				○	C
335	IN07972	Chungcheongnam-do	Cheongyang-gun	CS				○	C
336	IN07978	Gyeongsangbuk-do	Yecheon-gun	GN		○		○	C
337	IN07985	Gyeongsangbuk-do	Yecheon-gun	GN		○		○	C
338	IN07986	Gyeongsangbuk-do	Yecheon-gun	GN	○	○		○	C
339	IN07989	Chungcheongnam-do	Cheongyang-gun	CS				○	C
340	IN07990	Chungcheongnam-do	Cheongyang-gun	CS				○	C
341	IN07991	Chungcheongnam-do	Cheongyang-gun	CS				○	C

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No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
342	IN07992	Gyeongsangbuk-do	Yeongju-si	GN		○		○	C
343	IN07993	Gyeongsangbuk-do	Andong-si	GN	○	○		○	C
344	IN08206	Gyeongsangbuk-do	Mungyeong-si	GN		○		○	C
345	IN08207	Incheon metropolitan city	Ongjin-gun	CS		○			C
346	IN08208	Gangwon-do	Inje-gun	KN	○	○		○	C
347	IN08209	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
348	IN08210	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
349	IN08211	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
350	IN08212	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
351	IN08213	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
352	IN08214	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
353	IN08215	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
354	IN08216	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
355	IN08217	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
356	IN08218	Gangwon-do	Yanggu-gun	KN	○	○		○	C
357	IN08219	Jeollabuk-do	Jinan-gun	CN		○		○	C
358	IN08220	Jeollabuk-do	Jinan-gun	CN		○		○	C
359	IN08221	Jeollanam-do	Gangjin-gun	JS				○	C
360	IN08222	Jeollanam-do	Gangjin-gun	JS				○	C
361	IN08223	Jeollanam-do	Gangjin-gun	JS				○	C
362	IN08224	Jeollanam-do	Gangjin-gun	JS				○	C
363	IN08225	Jeollanam-do	Gangjin-gun	JS				○	C
364	IN08226	Gangwon-do	Inje-gun	KN	○	○		○	C
365	IN08227	Gyeongsangnam-do	Hadong-gun	GS		○		○	C
366	IN08228	Jeollanam-do	Gwangyang-si	JS				○	C
367	IN08229	Gyeonggi-do	Yeoncheon-gun	GG		○		○	C
368	IN08230	Gyeonggi-do	Dongducheon-si	GG		○		○	C
369	IN08231	Jeollanam-do	Jindo-gun	JS					C
370	IN08232	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
371	IN08233	Gangwon-do	Pyeongchang-gun	KS	○	○		○	C
372	IN08235	Gyeongsangnam-do	Miryang-si	GS	○	○		○	C
373	IN08236	Gyeonggi-do	Yeoncheon-gun	GG		○		○	C
374	IN08248	Gyeonggi-do	Namyangju-si	GG	○	○		○	D (N)
375	IN08249	Gyeonggi-do	Namyangju-si	GG	○	○		○	D (N)
376	IN08251	Gangwon-do	Yangyang-gun	KN	○	○		○	D (N)
377	IN08252	Gyeongsangbuk-do	Gumi-si	GN		○		○	D (N)
378	IN08253	Gyeongsangbuk-do	Gumi-si	GN		○		○	D (N)
379	IN08254	Gyeongsangbuk-do	Cheongsong-gun	GN	○	○		○	D (N)
380	IN08255	Gyeonggi-do	Yeoju-si	GG		○		○	D (N)
381	IN08256	Gangwon-do	Hongcheon-gun	KN	○	○		○	D (N)
382	IN08257	Jeollabuk-do	Imsil-gun	CN				○	D (N)
383	IN08258	Gangwon-do	Hongcheon-gun	KN	○	○		○	D (N)
384	IN08259	Jeollanam-do	Hwasun-gun	JS				○	D (N)
385	IN08260	Gyeongsangnam-do	Gimhae-si	GS		○		○	D (N)
386	IN08261	Gyeongsangnam-do	Gimhae-si	GS		○		○	D (N)
387	IN08262	Gyeongsangnam-do	Sancheong-gun	GS		○		○	D (N)
388	IN08263	Gyeongsangnam-do	Sancheong-gun	GS		○		○	D (N)
389	IN08264	Gyeongsangnam-do	Tongyeong-si	GS		○			D (N)
390	IN08265	Gyeonggi-do	Namyangju-si	GG	○	○		○	D (N)

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
391	IN08267	Gyeonggi-do	Namyangju-si	GG	○	○		○	D (N)
392	IN08268	Gyeonggi-do	Namyangju-si	GG	○	○		○	D (N)
393	IN08269	Gyeonggi-do	Gwangju-si	GG		○		○	D (N)
394	IN08270	Gyeonggi-do	Gwangju-si	GG		○		○	D (N)
395	IN08271	Gyeonggi-do	Gwangju-si	GG		○		○	D (N)
396	IN08272	Gyeonggi-do	Gwangju-si	GG		○		○	D (N)
397	IN08276	Gyeongsangnam-do	Hapcheon-gun	GS		○		○	D (N)
398	IN08277	Gyeonggi-do	Paju-si	GG	○	○		○	D (N)
399	IN08278	Gyeonggi-do	Paju-si	GG	○	○		○	D (N)
400	IN08279	Gyeonggi-do	Paju-si	GG	○	○		○	D (N)
401	IN08280	Gyeonggi-do	Hwaseong-si	GG		○		○	D (N)
402	IN08281	Jeollanam-do	Goheung-gun	JS				○	D (N)
403	IN08282	Jeollanam-do	Goheung-gun	JS				○	D (N)
404	IN08283	Gyeonggi-do	Seongnam-si	GG	○	○		○	D (N)
405	IN08284	Jeollanam-do	Hwasun-gun	JS				○	D (N)
406	IN08285	Gyeongsangbuk-do	Gimcheon-si	GN		○		○	D (N)
407	IN08286	Gangwon-do	Yangyang-gun	KN	○	○		○	D (N)
408	IN08288	Gyeongsangbuk-do	Pohang-si	GN	○	○		○	D (N)
409	IN08289	Gyeongsangbuk-do	Pohang-si	GN	○	○		○	D (N)
410	IN08290	Gyeonggi-do	Paju-si	GG	○	○		○	D (N)
411	IN09824	Jeju-do	Jeju-si	JI			○	○	D (J)
412	IN09825	Jeju-do	Jeju-si	JI			○	○	D (J)
413	IN09826	Jeju-do	Jeju-si	JI			○	○	D (J)
414	IN09827	Jeju-do	Jeju-si	JI			○	○	D (J)
415	IN09828	Jeju-do	Jeju-si	JI			○	○	D (J)
416	IN09829	Jeju-do	Jeju-si	JI			○	○	D (J)
417	IN09830	Jeju-do	Jeju-si	JI			○	○	D (J)
418	IN09831	Jeju-do	Jeju-si	JI			○	○	D (J)
419	IN09834	Jeju-do	Jeju-si	JI			○	○	D (J)
420	IN09835	Jeju-do	Jeju-si	JI			○	○	D (J)
421	IN09836	Jeju-do	Jeju-si	JI			○	○	D (J)
422	IN09837	Jeju-do	Jeju-si	JI			○	○	D (J)
423	IN09838	Jeju-do	Jeju-si	JI			○	○	D (J)
424	IN09839	Jeju-do	Jeju-si	JI			○	○	D (J)
425	IN09840	Jeju-do	Jeju-si	JI			○	○	D (J)
426	IN09841	Jeju-do	Jeju-si	JI			○	○	D (J)
427	IN09842	Jeju-do	Jeju-si	JI			○	○	D (J)
428	IN09844	Jeju-do	Jeju-si	JI			○	○	D (J)
429	IN09845	Jeju-do	Jeju-si	JI			○	○	D (J)
430	IN09846	Jeju-do	Jeju-si	JI			○	○	D (J)
431	IN09847	Jeju-do	Jeju-si	JI			○	○	D (J)
432	IN09848	Jeju-do	Jeju-si	JI			○	○	D (J)
433	IN09850	Jeju-do	Jeju-si	JI			○	○	D (J)
434	IN09851	Jeju-do	Jeju-si	JI			○	○	D (J)
435	IN09853	Jeju-do	Jeju-si	JI			○	○	D (J)
436	IN09854	Jeju-do	Jeju-si	JI			○	○	D (J)
437	IN09855	Jeju-do	Jeju-si	JI			○	○	D (J)
438	IN09857	Jeju-do	Jeju-si	JI			○	○	D (J)
439	IN09858	Jeju-do	Jeju-si	JI			○	○	D (J)

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
440	IN09859	Jeju-do	Jeju-si	JI			○	○	D (J)
441	IN09860	Jeju-do	Jeju-si	JI			○	○	D (J)
442	IN09861	Jeju-do	Jeju-si	JI			○	○	D (J)
443	IN09863	Jeju-do	Jeju-si	JI			○	○	D (J)
444	IN09864	Jeju-do	Jeju-si	JI			○	○	D (J)
445	IN09865	Jeju-do	Jeju-si	JI			○	○	D (J)
446	IN09875	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
447	IN09876	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
448	IN09880	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
449	IN09881	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
450	IN09882	Jeju-do	Seogwipo-si	GI	○		○	○	D (J)
451	IN09883	Jeju-do	Seogwipo-si	GI			○	○	D (J)
452	IN09884	Jeju-do	Seogwipo-si	GI			○	○	D (J)
453	IN09885	Jeju-do	Seogwipo-si	GI			○	○	D (J)
454	IN09886	Jeju-do	Seogwipo-si	GI			○	○	D (J)
455	IN09888	Jeju-do	Seogwipo-si	GI			○	○	D (J)
456	IN09891	Jeju-do	Seogwipo-si	GI			○	○	D (J)
457	IN09892	Jeju-do	Seogwipo-si	GI			○	○	D (J)
458	IN09893	Jeju-do	Seogwipo-si	GI			○	○	D (J)
459	IN09898	Jeju-do	Seogwipo-si	GI			○	○	D (J)
460	IN09899	Jeju-do	Seogwipo-si	GI			○	○	D (J)
461	IN09900	Jeju-do	Seogwipo-si	GI			○	○	D (J)
462	IN09902	Jeju-do	Seogwipo-si	GI			○	○	D (J)
463	IN09903	Jeju-do	Seogwipo-si	GI			○	○	D (J)
464	IN09905	Jeju-do	Seogwipo-si	GI			○	○	D (J)
465	IN09907	Jeju-do	Seogwipo-si	GI			○	○	D (J)
466	IN09908	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
467	IN09909	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
468	IN09910	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
469	IN09911	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
470	IN09912	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
471	IN09913	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
472	IN09914	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
473	IN09915	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
474	IN09916	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
475	IN09917	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
476	IN09918	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
477	IN09919	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
478	IN09920	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
479	IN09921	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
480	IN09922	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
481	IN09923	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
482	IN09924	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
483	IN09925	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
484	IN09926	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
485	IN09927	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
486	IN09928	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
487	IN09929	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
488	IN09930	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)

Appendix. Continued.

No.	ID	Province	District	Population code	Information				Note*
					mtDNA	ssrDNA	Morphology	Ecology	
489	IN09931	Jeju-do	Seogwipo-si	GI	○	○	○	○	D (J)
490	IN09932	Jeju-do	Seogwipo-si	GI	○	○		○	D (J)
491	IN09936	Jeju-do	Seogwipo-si	GI			○	○	D (J)
492	IN09937	Jeju-do	Seogwipo-si	GI			○	○	D (J)
493	IN09939	Jeju-do	Seogwipo-si	GI			○	○	D (J)
494	IN09945	Jeju-do	Seogwipo-si	GI			○	○	D (J)
495	IN09948	Jeju-do	Seogwipo-si	GI			○	○	D (J)
496	IN09951	Jeju-do	Seogwipo-si	GI		○		○	D (J)
497	IN10358	Jeollanam-do	Sinan-gun	SJI		○		○	C
498	IN10359	Jeollanam-do	Sinan-gun	SJI		○		○	C
499	IN10360	Jeollanam-do	Sinan-gun	SJI		○		○	C
500	IN10361	Jeollanam-do	Sinan-gun	SJI		○		○	C
501	IN10362	Jeollanam-do	Sinan-gun	SJI		○		○	C
502	IN10363	Jeollanam-do	Sinan-gun	SJI		○		○	C
503	IN10364	Jeollanam-do	Sinan-gun	SJI		○		○	C
504	IN10365	Jeollanam-do	Sinan-gun	SJI		○		○	C
505	IN10366	Jeollanam-do	Sinan-gun	SJI		○		○	C
506	IN10367	Jeollanam-do	Sinan-gun	SHI		○		○	C
507	IN10368	Jeollanam-do	Sinan-gun	SHI		○		○	C
508	IN10369	Jeollanam-do	Sinan-gun	SHI		○		○	C
509	IN10370	Jeollanam-do	Sinan-gun	SHI		○		○	C
510	IN10541	Jeju-do	Seogwipo-si	GI		○		○	C
511	IN10542	Jeju-do	Seogwipo-si	GI		○		○	C
512	IN10543	Jeju-do	Seogwipo-si	GI		○		○	C
513	IN10544	Jeju-do	Seogwipo-si	GI		○	○	○	C
Total					259	365	140	510	

C, collection; D(N), distribution (National Institute of Biological Resources); D(J), distribution (Jeju National University).

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Groison, A.-L., M. Suquet, J. Cosson, J.-R. Le Coz, A. Jolivet and F. Garren. 2008. Biological characteristics of European hake (*Merluccius merluccius*) sperm. Cybium 32(2)suppl.:178.

4) Books
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6) Books or dissertation under printing
Blaker, A.A. Handbook for Scientific Photography, Springer-Verlag, Berlin (in press).

7) Website
Williams, P.H. 1998. An annotated checklist of bumble bees with an analysis of patterns of description (Hymenoptera: Apidae, Bomini). Bulletin of The Natural History Museum (Entomology) 67:79-152 [Available from: http://nhm.ac.kr/research-cuation/projects/bumbus/, accessed 14 August 2009].

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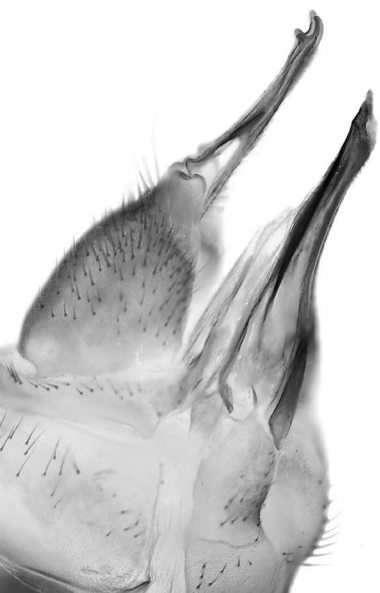

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Front Cover

This cover features photographs of *Gloydius ussuriensis baengnyeongensis* (left) from Baengnyeongdo Island and *Gloydius ussuriensis jejuensis* (right) from Jeju-do Island, Republic of Korea. These newly described subspecies are distinguished based on genetic, morphological, and ecological evidence. The related article can be found on pages 83–116. Photos by Min Seock Do and Sang-Cheol Lee.