Journal of Species Research 8(2):215-224, 2019

Three feather mites (Acari: Sarcoptiformes: Astigmata) isolated from *Tringa glareola* in South Korea

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We describe three feather mites recovered from a wood sandpiper *Tringa glareola* that was stored in a −20°C freezer at the Chungnam Wild Animal Rescue Center. These feather mites are reported for the first time in South Korea: *Avenzoaria totani* (Canestrini, 1978), *Ingrassia veligera* Oudemans, 1904 and *Montchadskiana glareolae* Dabert and Ehrnsberger, 1999. In this study, we provide morphological diagnoses and illustrations. Additionally, we provide partial sequences of the mitochondrial cytochrome *c* oxidase subunit I (*COI*) gene as molecular characteristics of three species.

Keywords: *Avenzoaria totani*, *COI*, feather mite, *Ingrassia veligera*, *Montchadskiana glareolae*, wood sandpiper, South Korea

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DOI:10.12651/JSR.2019.8.2.215

Introduction

The wood sandpiper *Tringa glareola* (Linnaeus, 1758) inhabits swamp and marshes (wet heathland, spruce or birch forest) in the northern Eurasian continent (Pulliainen and Saari, 1991; del Hoyo *et al*., 1996; Snow and Perrins, 1998; Remisiewicz *et al*., 2010). This species mostly uses freshwater inland habitats during migration and non-breeding season, and migrates to Africa, Southern Asia, India and Australia (Remisiewicz *et al*., 2010; Lee *et al*., 2014; Park, 2014). In South Korea, it is recorded as a passage migrant bird (Lee *et al*., 2014).

Until now, 41 species of feather mites have been recorded in Korea, but none from the wood sandpiper (Atyeo and Gaud, 1971; McClure *et al*., 1973; Atyeo and Peterson, 1976; Cho, 1980; Lee and Choi, 1980; Hwang *et al*., 1986; Noh and Sohn, 1992; Sohn and Noh, 1994a; 1994b; Sohn, 1995; KSSZ, 1997; Han *et al*., 2016; Han and Min, 2017; Han *et al*., 2017).

The genus *Avenzoaria* belonging to the family Avenzoariidae Oudemans, 1905 that is comprises of 14 valid species and two of unclear taxonomic identities status (*A. grallatois, A. limicolae*) generally associated with birds in the orders Charadriiformes (Badek and Dabert, 2005). The genus *Avenazaria* has the following diagnostic characteristics: (1) epimerites I are free and almost straight; (2) terminal membrane consist of rounded and acute teeth, or only acute teeth in males; and (3) paragenital apodeme is absent in males (Vasjukova and Mironov, 1991).

The genus *Montchadskiana* is one of five genera that belong to the subfamily Magimeliinae Gaud, 1972 and contains 17 species (Gaud and Atyeo, 1996; Dabert and Ehrnsberger, 1999). This genus was found on flight feathers on the birds of order Charadriiformes. The genus *Montchadskiana* has the following diagnostic characteristics: (1) setae *h2* and *ps2* are leaf-shaped in males; (2) adanal discs are circular-shaped with radial striated corollae in males; and (3) length of lateral setae *e2* are usually shorter than idiosoma width in females (Dabert and Ehrnsberger, 1999).

The genus *Ingrassia* is one of 25 genera that belong to the family Ingrassiinae Gaud and Atyeo, 1981 that comprise 28 species associated with aquatic birds of six orders: Anseriformes, Charadriiformes, Pelecaniformes, Podicipediformes, Procellariiformes and Sphenisciformes (Gaud and Atyeo, 1996; Stefan *et al*., 2013; Hernandes and Pedroso, 2017). The genus *Ingrassia* has the following diagnostic characteristics in males: (1) prodorsal shield is narrow longitudinal plate with posterior part rounded or pointed protrusion; (2) setae *se* are situated outside prodorsal shield or on small sclerites; (3) setae *c1* and *h1* are absent; and (4) epimerites I are fused into a Y (Vasjukova and Mironov, 1991).

Here, we recovered *A. totani*, *M. glareolae* and *I. veligera* from the wood sandpiper and provided descriptions and illustrations of these three feathers mites based on

morphology. Additionally, we provide partial sequences of the mitochondrial cytochrome *c* oxidase subunit I (*COI*) as DNA barcodes.

Materials and Methods

A wood sandpiper (CWARC no. CN16-278) rescued from Hongseong-gun by the Chungnam Wild Animal Rescue Center (CWARC) passed away and was stored in a −20°C freezer at the center. Specimens of *Avenzoaria totani*, *Montchadskiana glareolae* and *Ingrassia veligera* were collected from wing and tail feathers using a vacuum machine. The collected mites were preserved directly in 95% ethyl alcohol. The mite specimens were cleared by lactic acid for 24 hours and then mounted on micro slides using PVA (PVA stock solution 56%, lactic acid 22% and phenol 22%) as the mounting medium (Downs, 1943). The specimens were photographed using a microscopic digital camera (Leica, Wetzlar, Germany) and a scanning electron microscope (SEM) (Model Hitachi S-4300SE; Japan). Prior to SEM imaging, we used a TWEEN 20 (Model 036K00963; Sigma, USA) to remove debris on the specimens. The specimens were dehydrated using an ascending alcohol series (70%, 80%, 90%, 95%; and 100% ethyl alcohol; 30 min each), and followed by using hexamethyldisilazane (Sigma, St. Louis, USA) for one hour. The specimens were then dried in a sealed box with silica gel for 24 hours. The morphological terms and measurements follow Gaud and Atyeo (1996) and Norton (1998). All measurements are given in μm. All examined specimens were deposited in the National Institute of Biological Resources (NIBR) and at Inha University in Korea.

DNA sequencing

DNA was extracted from a leg of each specimen using a Tissue DNA Purification Kit (Cosmogenetech Inc., Seoul, Korea) according to the manufacturer's instructions. PCR amplification, purification and sequencing were performed according to the methods described by Han *et al*. (2016).

Results and Discussion

Order Sarcoptiformes Canestrini, 1891 옴진드기목
Family Avenzoariidae Oudemans, 1905
날개깃진드기과
Genus *Avenzoaria* Oudemans, 1905
날개깃진드기속(신칭)

1. *Avenzoaria totani* (Canestrini, 1878)

붉은발도요날개깃진드기(신칭) (Figs. 1, 2)

Synonyms. *Dermaleichus totani*: Canestrini, 1878, p. 60; *Pterolichus totani*: Canestrini, 1879, p. 36, pl. I-III, fig. 10; Mégnin and Trouessart, 1884, p. 338; *Avenzoaria totani*: Dubinin, 1951, p. 186-191, fig. 44; Dubinin, 1956, p. 335-340, figs. 156-157; Gaud and Mouchet, 1959, p. 499; Gaud, 1972, p. 38, figs. 16c, 17c, 18e; Vasjukova and Mironov, 1991, p. 30-31, figs. 5, 13a; Dabert, 1992, p. 1-11; Dabert, 2000, p. 305; Badek and Dabert, 2005, 119-130.

Material examined. Korea: 2♂♂, 3♀♀, Gyeolseong-myeon, Hongseong-gun, Chungcheongnam-do, 36°31′36″N, 126°33′41″E, May 11, 2016, collected using vacuum machine from flight feathers on the wings of wood sandpiper *Tringa glareola* by Han Y.-D.

Diagnosis. Male: Length 475 of idiosoma from anterior end to bases of setae *h3*, width 215-225 at level of humeral shields (Fig. 1A). Prodorsal shield (Fig. 1B, 1D): Triangular shaped, posterior margin with medial projection, posterior angles extending laterally the bases of setae *se*, length 115-125 along midline, width 115-120 at posterior part. Hysteronotal shield (Fig. 1B): Anterior part straight, lateral parts with small rounded extensions at level of setae *cp*, length 325-335 from anterior margin to bases of setae *h3*, width 130-135 at level of setae *d1*. Interlobar cleft transverse ovoid, with anterior margin concave. Interlobar membrane expanded at the distal ends of the lobes. Incision in interlobar membrane elongated oval-shaped, anterior margin round-shaped lateral margins with shallow incisions in midlength. Postlobar membranes with one rectangular and two acute teeth. Sternum (Fig. 1C): Epimerites I not fused, with distal edges curved outwards. Genital apparatus located between levels of trochanters III and IV. Genital papillae situated on anterior to base of genital apparatus. Adanal shields absent.

Female: Idiosoma length 430-450, width 215-225 (Fig. 2A). Prodorsal shield (Fig. 2B): Mostly shaped as in male, length along middle line 120, width 125 at posterior part. Hysteronotal shield (Fig. 2B): Shaped as in male, posterior part with stronger sclerotization, length 310-320, width 145-155. Opisthosoma terminus rounded. Terminal cleft semicircular. Sternum (Fig. 2C): epimerites I shaped as in male. Epigynum arch-shaped, length 38-43, width 63-68.

Remarks. *Avenzoaria totani* was originally described by Canestrini (1878) based on specimens collected from *Tringa totanus* (= *Totanus totanus*). Thereafter, this species was reported by several mite taxonomists from birds of families Anatidae and Scolopacidae (Mégnin and Trouessart, 1884; Dubinin, 1951; 1956; Gaud and Mouchet, 1959; Gaud, 1972; Vasjukova and Mironov, 1991; Dabert, 1992; 2000; Badek and Dabert, 2005).

Avenzoaria totani is distinguishable from other species in the genus *Avenzoaria* by several characteristics in males: (1) posterior angles of prodorsal shield are extend-

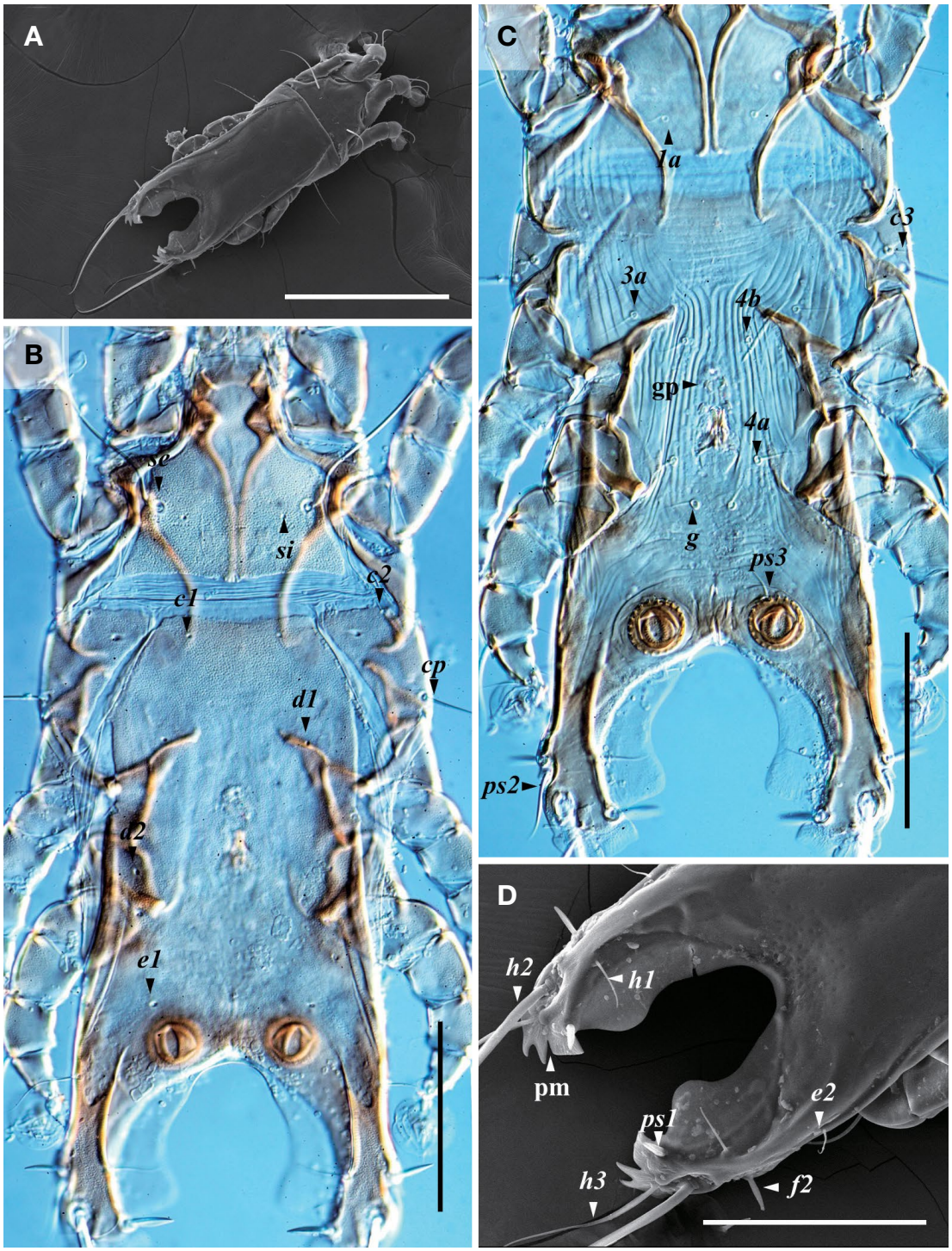

Fig. 1. *Avenzoaria totani*, male. A, dorsal view; B, dorsal view of idiosoma; C, vetral view of idiosoma; D, dorsal view of opisthosoma. gp - genital papillae, pm - postlobar membranes. Scale bars: A, 0.25 mm; B-D, 0.1 mm.

ed laterally at the base of setae *se*; (2) postlobar membranes are comprised of one rectangular and two acute teeth; and (3) genital papillae are situated on anterior to base of genital apparatus (Vasjukova and Mironov, 1991; Badek and Dabert, 2003). The Korean specimens were morphologically consistent with the descriptions and illustrations provided by Vasjukova and Mironov (1991) and had partial *CO1* sequences (565 bp) identical with those of *Avenzoaria totani* (GenBank no. GQ864348.1) registered in GenBank.

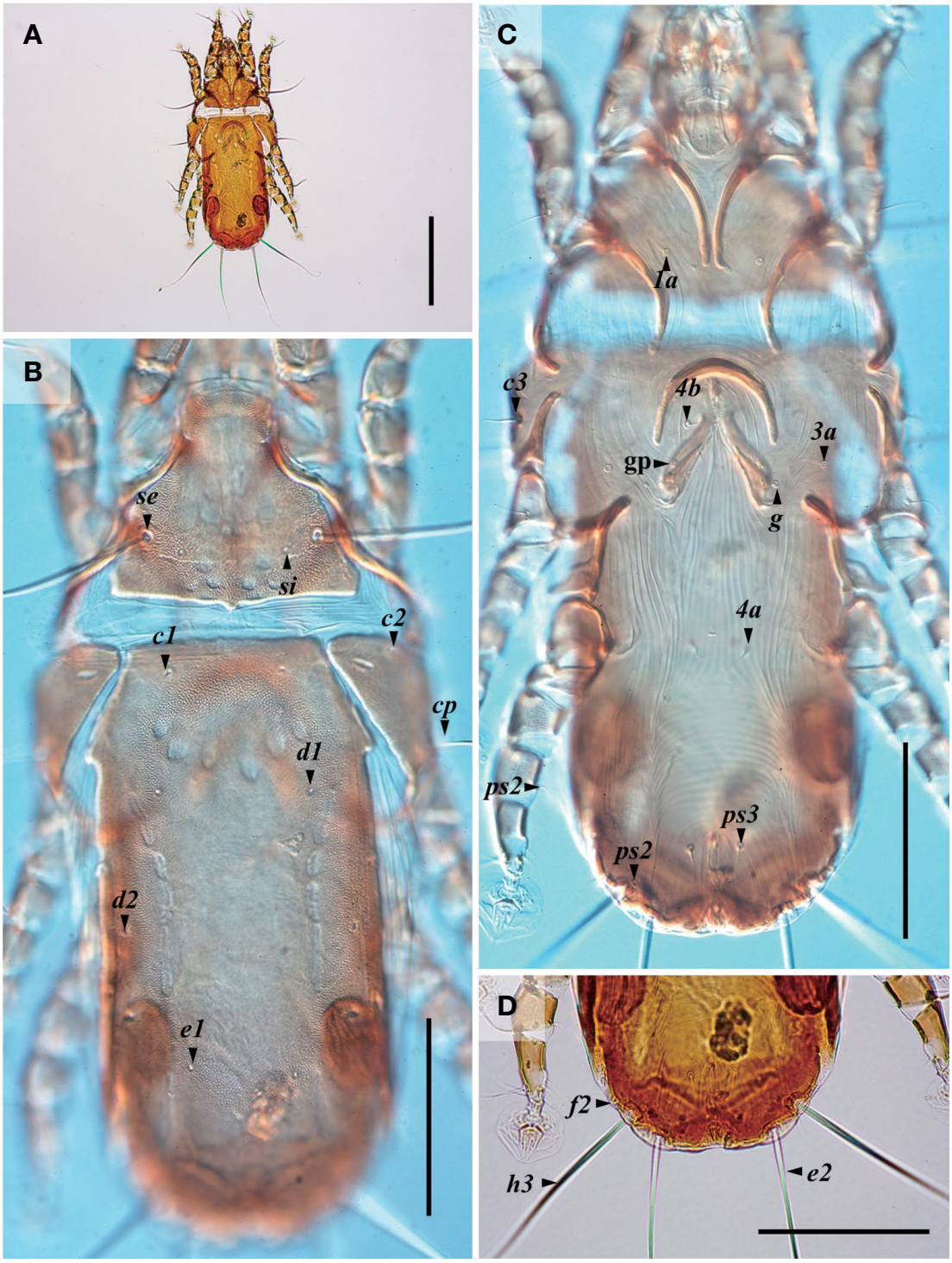

Fig. 2. *Avenzoaria totani*, female. A, dorsal view; B, dorsal view of idiosoma; C, ventral view of idiosoma; D, ventral veiew of opisthosoma. gp - genital papillae. Scale bars: A, 0.2 mm; B-D, 0.1 mm.

Host. This species was found on wings feathers in the wood sandpiper *Tringa glareola*.
Distribution. Cameroon, Congo (Gaud and Mouchet, 1959; Gaud, 1972), Italy (Canestrini, 1878; Dubinin, 1956), Russia (Dubinin, 1951; 1956; Vasjukova and Mironov, 1991), Poland (Dabert, 2000; Badek and Dabert, 2006), Korea (this study).
Deposition. NIBR No. NIBRIV0000812908, NIBRIV00

00820666-0000820669.

Molecular characteristics. The *COI* sequences were obtained from two individuals and deposited in GenBank with accession numbers of MK031702 and MK031703.

Family Pterolichidae Trouessart and Mégnin, 1884
깃사이진드기과
Genus *Montchadskiana* Dubinin, 1951
도요깃사이진드기속(신칭)

2. *Montchadskiana glareolae* Dabert and Ehrnsberger, 1999 알락도요깃사이진드기(신칭) (Figs. 3, 4)

Synonyms. *Montchadskiana glareolae* Dabert and Ehrnsberger, 1999, p. 228-233, figs. 10, 14.

Material examined. Korea: 3♂♂, 3우우, Gyeolseong-myeon, Hongseong-gun, Chungcheongnam-do, 36°31′36″N, 126°33′41″E, May 11, 2016, collected using vac-

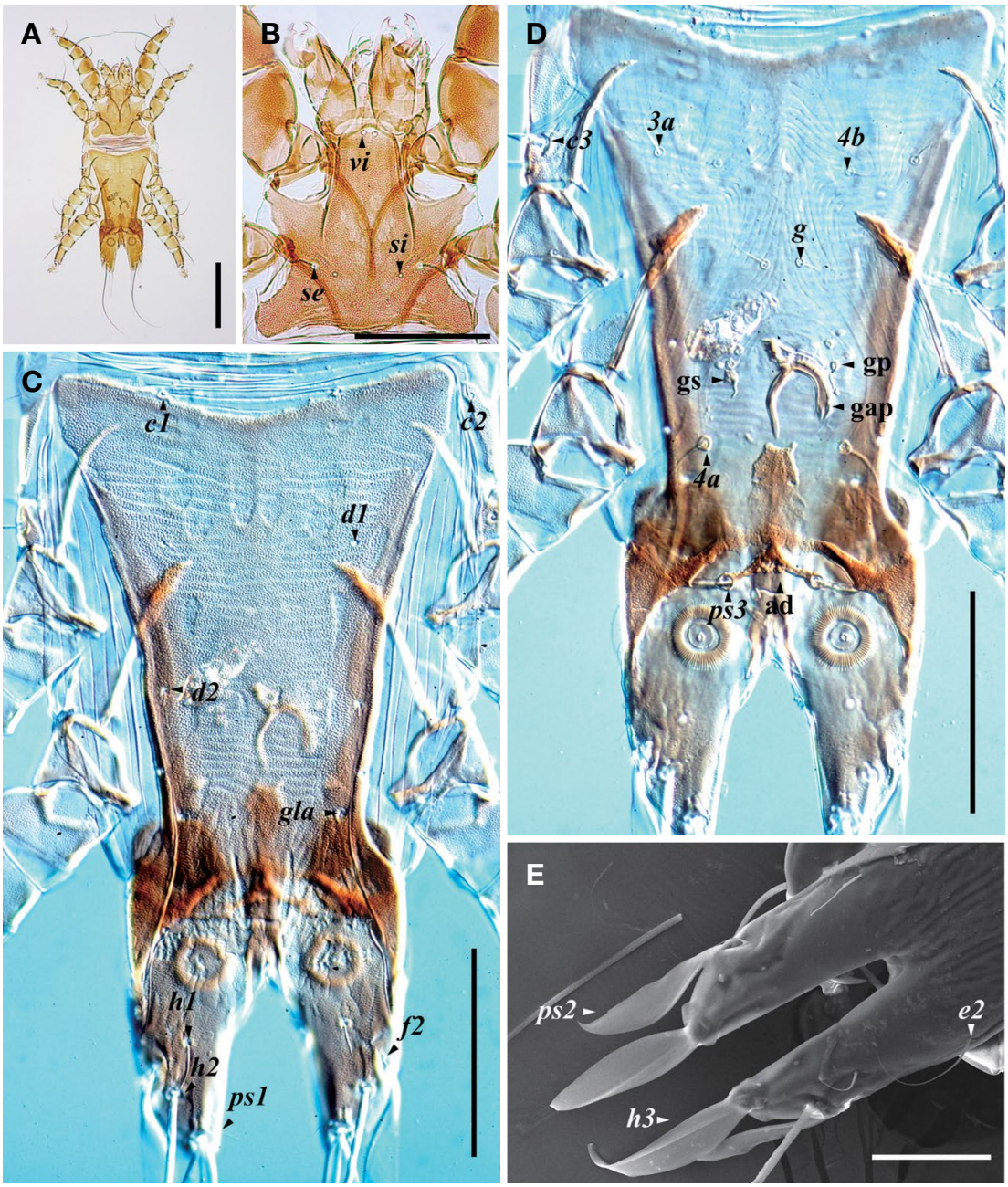

Fig. 3. *Montchadskiana glareolae*, male. A, dorsal view; B, dorsal view of prodorsal shield; C, dorsal view of hysterosoma; D, ventral viewe of hysterosoma; E, ventral view of opisthosoma. ad - adanal shield, gap - gentital apparatus, gp - genital papillae, gs - genital sclerites. Scale bars: A, 0.2 mm; B-D, 0.1 mm; E, 0.05 mm.

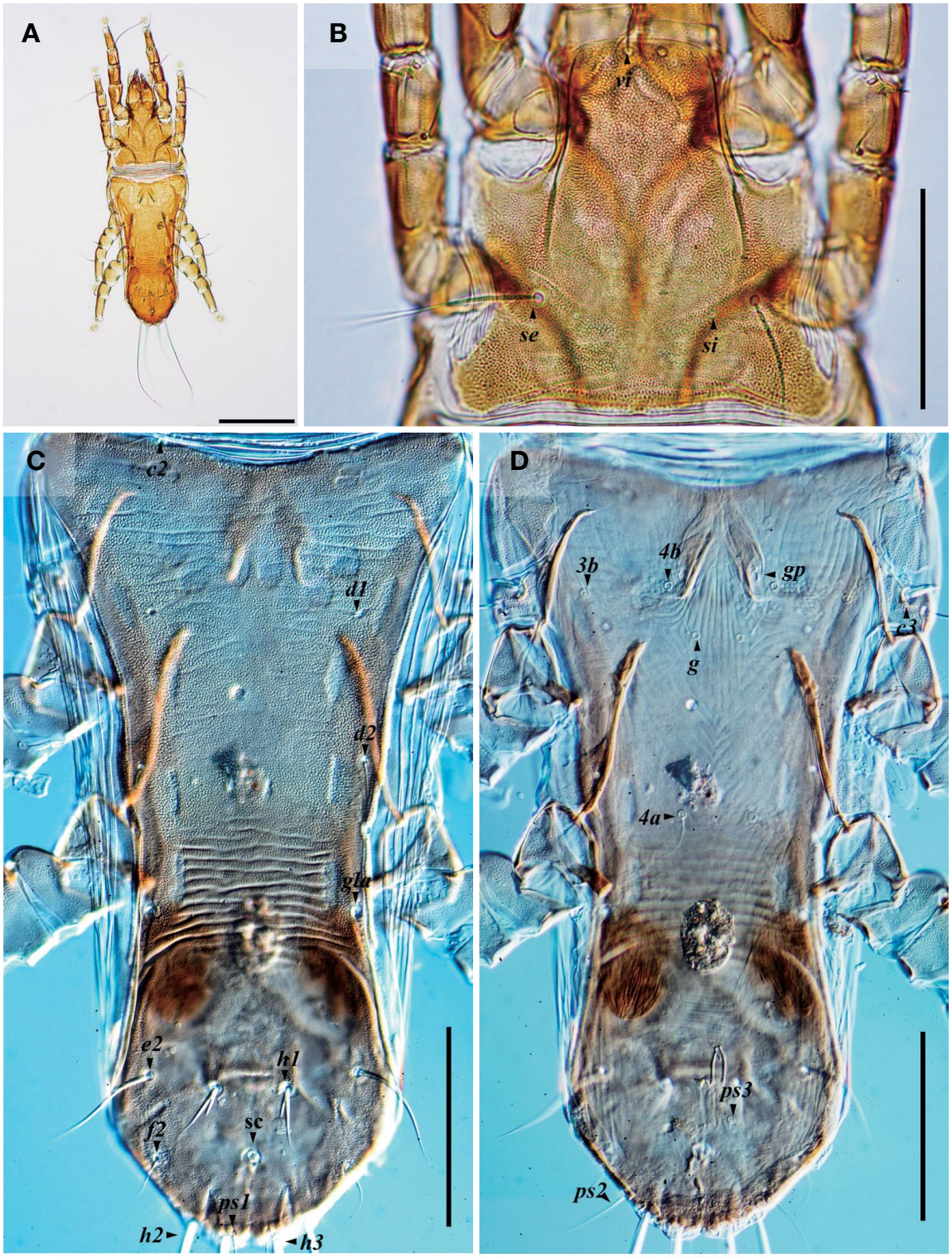

Fig. 4. *Montchadskiana glareolae*, female. A, dorsal view; B, dorsal view of prodorsal shield; C, dorsal view of hysterosoma; D, ventral viewe of hysterosoma. gp - genital papillae, sc - supranal concavity. Scale bars: A, 0.2 mm; B-D, 0.1 mm.

uum machine from flight feathers on the wings of wood sandpiper *Tringa glareola* by Han Y.-D.

Diagnosis. Male: Length 550-560 of idiosoma from anterior end to ends of terminal membranes, width 210-230 at level of humeral shields, length to width ratio 2.4-2.5 (Fig. 3A). Prodorsal shield (Fig. 3B): Triangle-shaped,

covers the entire pronotum, posterior part with transversal striation, length 145-150 along midline, width 155-160, with two internal vertical seta (*vi*). Hysteronotal shield (Fig. 3C): Anterior part concave, with transversal striation excluding lobar part, length 355-365 from anterior margin to base of setae *h3*, width 175-185 at level of setae *c2*. Opisthosomal lobes rounded lateroposterior ends with narrow terminal membranes. Setae *ps2* and *h3* leaf-like (Fig. 3E). Sternum (Fig. 3B, D): Epimerites I fused. Genital apparatus long and massive, located between trochanters IV. Genital papillae situated on anterior to genital apparatus between bases of legs IV. One to two pair of small irregular genital sclerites located laterally to the base of genital apparatus. Adanal shield shaped inverted as V, fused with medial irregular sclerite, with medial sclerite two times longer than its width.

Female: Length 550-570 of idiosoma from anterior end to bases of setae *h3*, width 200-230 at level of setae *c2*, length to width ratio 2.4-2.7 (Fig. 4A). Prodorsal shield (Fig. 4B): Shaped as in male. Length 155-165 at based of setae *vi*, width 160-170 at posterior part. Hysteronotal shield (Fig. 4C): Anterior part concave, with transversal striation excluding the area between setae *d2* and Opisthosoma part, length 395-405, width 190-210 at based of setae *c2*. Setae *h1* divided into two branches at the base, the longest branch twice as longer than the shorter branch. Terminus rounded with shallow medial incision. Sternum (Fig. 4D): Epigynum absent. Supranal concavity circular-shaped and separated from terminal terminus. Small ventroterminal shield located behind the posterior opisthosoma.

Remarks. *Montchadskiana glareolae* was separated from *M. ulitae* Dubinin, 1951 by Dabert and Ehrnsberger (1999) and was described based on specimens collected from *T. glareola* in Poland. *Montchadskiana glareolae* is very similar to *M. ulitae* with regard to external traits. However, *M. glareolae* can be clearly distinguished from *M. ulitae* by the following characteristics: (1) genitoanal region has small irregular genital sclerites in male; (2) length of adanal shield is two times longer than the width of this shield; and (3) setae *h1* are divided into two branches at the base in the female (Dabert and Ehrnsberger, 1999). Korean specimens were morphologically consistent with the original description and illustrations (Dabert and Ehrnsberger, 1999). However, the idiosoma width of Korean males were slightly wider than the original description. We consider this to be intraspecific variation.

Host. Specimens were collected from the surface of flight feathers on the wings of wood sandpiper *Tringa glareola*.

Distribution. India, Poland, Russia, Thailand (Dabert and Ehrnsberger, 1999), Korea (this study).

Deposition. NIBR No. NIBRIV0000812906, NIBRIV0000820670-820674.

Molecular characteristics. The *COI* sequences were obtained from two individuals and deposited in GenBank with accession numbers of MK031704 and MK031705.

Family Xolalgidae Dubinin, 1953
알통다리깃털진드기과(신칭)
Genus *Ingrassia* Oudemans, 1905
민머리솜털진드기속(신칭)

3. *Ingrassia veligera* (Oudemans, 1904)
군함민머리솜털진드기(신칭) (Figs. 5, 6)

Synonyms. *Megninia veligera*: Oudemans, 1904, p. 194; *Ingrassia veligera*: Vasjukova and Mironov, 1991, p. 69-72, fig. 49; Dabert, 2000, p. 310, fig. 3.

Material examined. Korea: 3♂♂, 2♀♀, Gyeolseong-myeon, Hongseong-gun, Chungcheongnam-do, 36°31′36″N, 126°33′41″E, May 11, 2016, collected using vacuum machine from tail feathers of wood sandpiper *Tringa glareola* by Han Y.-D.

Diagnosis. Male: Length 380-395 of idiosoma from anterior end to ends of terminal membranes, width 150-155 at level of humeral shields (Fig. 5A). Prodorsal shield (Fig. 5B): Narrow longitudinal plate with rounded posterior margin, posterior part extending beyond the level of setae *si*, length 85-92 along midline, width 17-23. Setae *se* situated on small sclerites. Scapular shield narrow with broad and blunt posterior part. Hysteronotal shield (Fig. 5C): Anterior margin sinuous, with incisions of long and soft tegument at level of setae *d2*, length 212-220 from anterior part to base of setae *h3*. Sternum (Fig. 5D): Epimerites I fused. Inner ends of epimerites IIIa sparated from each other. Genital papillae located in front of the pregential apodeme. Pregential apodeme bow-shaped, width 20-25. Adanal shields small L-shaped, between levels of setae *g* and *ps3*.

Female: Length 340-350 of idiosoma from anterior end to bases of setae *h3*, width 120-135 at level of setae *c2* (Fig. 6A). Prodorsal shield (Fig. 6B): Shaped as in male, Length 77-80, width 22. Hysteronotal shield (Fig. 6B, 6D): Anterior margin rounded, lateral margins slightly sinuous, posterior margin slightly concave, extending beyond the level of setae *e2*, length 122-125, width 42-45. Setae *d1* and *e1* located on the hysteronotal shield, and setae *d2* on lateral margins. Epigynum shaped as transverse sclerite, almost straight and thin, width 20 (Fig. 6C). Posterior ends of oviporus apodemes not extending to the level of setae *4a*.

Remarks. *Ingrassia veligera* was originally described without illustration by Oudemans (1904) based on specimens collected from the lesser yellowlegs (*Tringa flavipes*) in Guyana, then was redescribed by Vasjukova and Mironov (1991) with partial illustrations from several sandpipers of the genus *Tringa* (*T. glareola, T. nebularia*

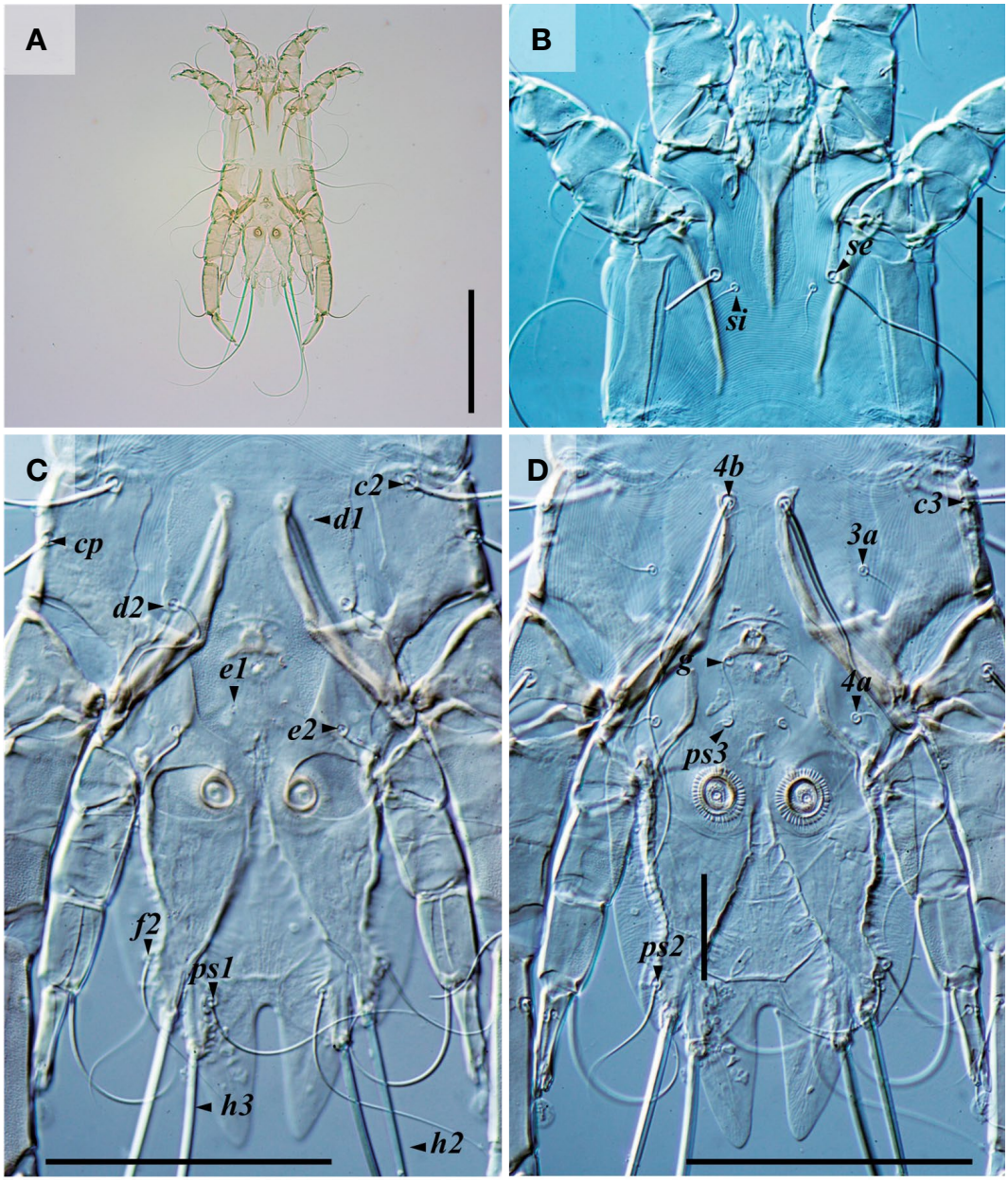

Fig. 5. *Ingrassia veligera*, male. A, dorsal veiw; B, dorsal view of prodorsal shield; C, dorsal view of hysterosoma; D, ventral viewe of hysterosoma. Scale bars: A, 0.2 mm; B-D, 0.1 mm.

and *T. ochropus*). Thereafter, the dorsum part of this species was re-illustrated by Dabert (2000) from *T. stagnatilis* in Poland.

Ingrassia veligera can be clearly distinguished from *I. slonskiana* by the following characteristics: (1) posterior margins of scapular shields are widened and blunted; (2) hysteronotal shield has long desclerotized incisions from anterior margin to level of setae *d2* in males; (3) lengths of setae *d2* and *e2* are similar in females (Dabert, 2000). The Korean specimens were consistent with the descriptions and illustrations provided by previous mite taxonomists (Oudemans, 1904; Vasjukova and Mironov, 1991; Dabert, 2000).

Host. Specimens were collected from down feathers of wood sandpiper *Tringa glareola*.

Distribution. Guyana (Oudemans, 1904), Russia (Vasjukova and Mironov, 1991), Poland (Dabert, 2000), Korea (this study).

Deposition. NIBR No. NIBRIV0000820675-820679.

Molecular characteristics. The *COI* sequence was obtained from single individual and deposited in GenBank with accession number of MK031706.

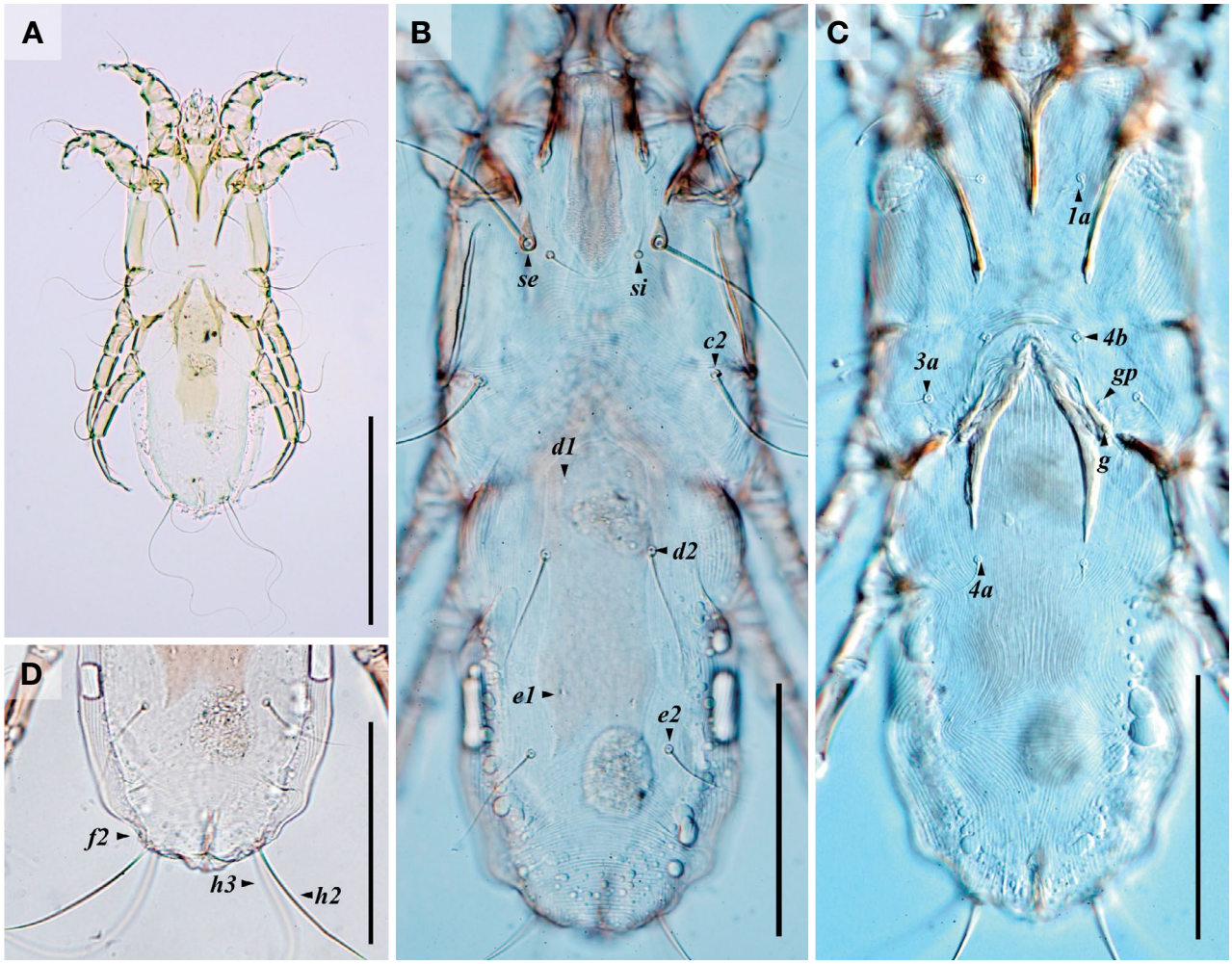

Fig. 6. *Ingrassia veligera*, female. A, dorsal veiw; B, dorsal view of idiosoma; C, ventral view of idiosoma; D, ventral viewe of opisthosoma. gp - genital papillae. Scale bars: A, 0.2 mm; B-D, 0.1 mm.

Acknowledgements

The authors wish to thank Jin-Ho Jang (Chungnam Wild Animal Rescue Center, Korea), Prof. Keeseon S. Eom and Dr. Seongjun Choe (Chungbuk National University School of Medicine, Korea) for sample collection, and Dr. Sergey Mironov (Zoological Institute, Russian Academy of Sciences, Russia) for advice and help in identifying the species.

This work was supported by a grant from the National Institute of Biological Resources (NIBR), funded by the Ministry of Environment (MOE) of the Republic of Korea (NIBR201701201, 201801202).

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Submitted: October 11, 2018
Revised: October 25, 2018
Accepted: November 2, 2018