

Eight new records of monogonont and bdelloid rotifers from Korea

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The rotifers collected from a brackish water zone as well as various terrestrial habitats such as mosses, lichens, and leaf litter at seven different locations in Korea were investigated. Eight species/subspecies belonging to five genera in five families of monogonont and bdelloid rotifers new to Korea were identified: *Encentrum incisum*, *Encentrum uncinatum*, *Cephalodella innesi*, *Adineta gracilis*, *Macrotrachella timida timida*, *Macrotrachella timida inquires*, *Habrotrocha pavidata* and *Habrotrocha scabropyga*. Five bdelloids are new to Asia as well. Notably, these eight Korean new records included three rare species. *H. scabropyga* is recorded outside its type locality for the first time. For *M. timida timida*, this study is the third record after its description. In addition, *E. incisum* has been reported only from Austria, Germany and Russia before the present study.

Keywords: brackish and terrestrial habitats, Korea, new records, Rotifera, taxonomy

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INTRODUCTION

Owing to their ability to withstand harsh periods through anhydrobiosis, bdelloids can dwell in the water film covering terrestrial mosses, lichens, and soil, and be found in extraordinary habitats such as plant debris and wild mushrooms. This distinguishing feature makes them pioneering animals, able to colonize new environments (Ricci, 1987; Nogrady *et al.*, 1993). In the present study, two monogononts, *E. incisum* Wulfert, 1936 and *E. uncinatum* (Milne, 1886), were also found in some of these terrestrial habitats. It has been reported that several dicranophorids including *E. mucronatum* Wulfert, 1936, *E. incisum* and *E. mustela* (Milne, 1885) are dwelling in mosses on the ground, trees, holes in tree stumps, leaf litter and the top centimeters of different soils (De Smet, 1995).

Bdelloids have a vermiform body with pseudosegmentation that permits telescopic shortening and expansion, and well-developed paired trochal discs (corona), which are used in locomotion as well as food gathering. The taxonomy of bdelloids is based primarily on the morphology of alimentary system, corona, trophi, spurs, toes and body ornaments such as spines or cuticular knobs. Especially, the shape of corona, sulcus, upper lip and disc retractor are rather species-specific and very important diagnostic characters (Song, 1999). Since these characteristics can be observed only in creeping or feeding condition, bdelloids must be identified in live state, and it's almost

impossible to identify bdelloids preserved without narcotization. This may explain the poor record of bdelloids not only from Korea, but throughout the world.

Phylum Rotifera comprises about 2100 species/subspecies including about 1600 monogononts and 460 bdelloids (Segers, 2007; Jersabek and Leitner, 2013). To date, approximately 142 monogononts and 52 bdelloids have been reported from Korea (The Korean Society of Systematic Zoology, 1997; Song and Jin, 2000; Song and Kim, 2000). This record is still much lower than the substantial body of worldwide reports. Apparently, further taxonomic studies on rotifers are urgently required in Korea.

Here we report on eight new records of Korean rotifers with redescrptions and illustrations. We also present notes on the distribution of some rare species.

MATERIALS AND METHODS

For the present taxonomic study on Korean rotifers, specimens collected from a brackish water zone as well as various terrestrial habitats such as mosses, lichens and leaf litter were investigated. Samples were collected from seven locations in Korea from Feb. 26 to Oct. 17, 2013. The detailed habitat information and sampling date of each locality are listed in Table 1.

For the extraction of bdelloids from mosses, lichens and leaf litter, samples were soaked in tap or deionized

water for several hours or overnight depending on the dehydration state of the samples. The samples were agitated to detach any bdelloids from the surfaces of plants or plant debris, and then the plant material was squeezed and removed. After further removal of the particles and debris using a sieve of 1.2 mm mesh-size, the supernatant of wash water was filtered through a fine nylon membrane of 60 μm mesh-size. Brackish water samples were concentrated using a nylon membrane of 60 μm mesh-size as well. The filtered specimens on the membrane were transferred to a petri dish.

All rotifers were examined and identified alive under a light microscope with a magnification of $400\times$. All living specimens were recorded and photographed using Infinity 2 digital camera (Nikon). Both the photos and the computer-grabbed images were used for illustration. Measurements were made with Photoshop CS3. The boiling water fixation method (Pennak, 1978), instead of narcotics, was used to kill specimens with head, foot and toes extended. For preparation of permanent mounts, the method of Stemberger (1979) was used.

The classification scheme is based on Melone and Ricci (1995) for bdelloids, and De Smet (1997) and Nogrady and Pourriot (1995) for monogononts.

RESULTS AND DISCUSSION

As a result of the present study, three monogononts and five bdelloids are newly recorded from Korea: *Encentrum incisum*, *E. uncinatum*, *Cephalodella innesi* Myers, 1924, *Adineta gracilis* Janson, 1893, *Macrotrachella timida timida* Milne, 1916, *M. timida iniquies* Milne, 1916, *Habrotracha pavida* Bryce, 1915 and *H. scabropyga* Bartoš, 1958. These five bdelloids are new to Asia as well. Notably, these eight Korean new records included three rare species. *H. scabropyga* has never been reported again since its original description by Bartoš (Bartoš, 1959) until the present study. *M. timida timida* was reported only from Czech Republic after its description in South Africa by Milne (1916), and *E. incisum* has been restricted to three countries, Germany, Austria and Russia, so far (De Smet, 1997).

Here we present these eight Korean new records of rotifers with redescriptions and illustrations. We also comment on the taxonomy and distribution of those rare species.

Phylum Rotifera Cuvier, 1817
 Class Eurotatoria De Ridder, 1957
 Subclass Monogononta Plate, 1889
 Order Ploima Hudson and Gosse, 1886
 Family Dicranophoridae Harring, 1913
 Genus *Encentrum* Ehrenberg, 1838

1. *Encentrum incisum* Wulfert, 1936 (Fig. 1A-C)

Encentrum incisum Wulfert, 1936, pp. 423-425, figs. 16, 16 a-c (cited from De Smet, 1997); Donner, 1970, p. 226, figs. 13e-f; Koste, 1978, p. 495, pl. 176, figs. 1 a-e; De Smet, 1997, pp. 182-184, figs. 503-507, pl. 31, figs. 1-5; Jersabek, 1998, pp. 67-69, figs. 21-24.

Material examined. 2 specimens, a mountain in Gyo-1-dong, Gangneung-si, Gangwon-do (leaf litter, Min Ok Song), 26 Feb, 2013.

Description. Body spindle-shaped. Head about 1/2 of trunk length. Integument thin, smooth, transparent and with transverse folds defining head, trunk and foot. Rostrum short, V-shaped ventrally and decurved. Foot conical, short and about 1/6 of trunk length. Toes short, slender, about same length as foot, parallel-sided until half of length and tapering to pointed tips.

Trophi forcipate type. Rami outline round pyriform, each getting broader until 1/3 from base, abruptly tapering into slender and incurved single tooth after preuncinal tooth; preuncinal tooth long, narrow and sharp, emerging from outer margin of ramus ventrally and projecting towards axis of trophi; another preuncinal tooth present between apical tooth and ventral preuncinal tooth. Fulcrum short, about 2/5 of manubria length. Intramallei short, with round base and tapering ends. Unci stout, single-toothed, about 3/5 of manubria length. Manubria rod-shaped, long, longer than 2-fold of fulcrum length, incurved, knobby distally and expanded proximally.

Body length 202 μm . Toe length 19 μm .

Distribution. Austria, Germany, Russia and Korea.

Remarks. *E. incisum* has been reported only from Austria, Germany and Russia before the present study (De Smet, 1997). It is similar to *E. martoides* Fott, 1960 except the following differences: (1) Foot of *E. incisum* has a single pseudosegment, while that of *E. martoides* has two pseudosegments, (2) Inner margin of rami is outcurved near posterior 1/3 in *E. incisum*, while it is otherwise in *E. martoides*, and (3) Gastric glands of *E. incisum* are not fused nor connected with brain, while they are fused dorsally and connected with brain in *E. martoides* (De Smet, 1997).

2. *Encentrum uncinatum* (Milne, 1886) (Fig. 1D-F)

Diglena uncinata Milne, 1886, p. 141, pl. 2, figs. 1, 2, 8. *Dicranophorus uncinatus*: Donner, 1964, pp. 283-284, figs. 20a-d; Koste, 1978, p. 466, pl. 169, figs. 12a-d, pl. 172, figs. 7a-d.

Encentrum uncinatum: De Smet, 1997, p. 161, figs. 434-440, pl. 25, figs. 1-4.

Material examined. 8 specimens, a mountain in Gyo-1-dong, Gangneung-si, Gangwon-do (leaf litter, Min Ok Song), 26 Feb, 2013.

Table 1. List of sampling localities.

Locality	GPS coordinates	Sampling date	Habitat	Species
1. A mountain in Gyo-1-dong, Gangneung-si, Gangwon-do	37° 45' 56.07''N, 128° 52' 29.01''E	Feb. 26, 2013	Leaf litter	<i>E. incisum</i> , <i>E. uncinatum</i>
2. Hakik-dong, Incheon-si	37° 26' 23.55''N, 126° 39' 8.63''E	Oct. 17, 2013	Brackish water	<i>C. innesi</i>
3. A mountain in Jukheon-dong, Gangneung-si, Gangwon-do	37° 46' 52.83''N, 128° 51' 22.42''E	March 7, 2013	Mosses and lichens	<i>A. gracilis</i>
4. Hong-do, Sinan-gun, Jeonranam-do	34° 41' 35.67''N, 125° 12' 3.99''E	July 2, 2013	Mosses and soil	<i>M. timida timida</i>
5. Wanggok-ri, Goseong-gun, Gangwon-do	38° 22' 48.46''N, 128° 28' 2.78''E	Sep. 15, 2013	Mosses on a tree trunk	<i>M. timida inquires</i>
6. A mountain in Mongsanpo, Seosan-si, Chungcheongnam-do	36° 47' 4.20''N, 126° 27' 1.14''E	April 14, 2013	Mosses and leaf litter	<i>H. pavidia</i>
7. A mountain in Jeongan-myun, Gongju-si, Chungcheongnam-do	36° 36' 30.86''N, 127° 7' 12.42''E	April 14, 2013	Mosses	<i>H. scabropyga</i>

Description. Body elongate, half-moon-shaped and flattened laterally. Trunk subcylindrical, rather flat ventrally, convex dorsally, and with laterodorsal longitudinal folds. Transverse folds defining body into head, trunk and foot. Integument thin, smooth and transparent, but body outline rather fairly constant. Head big, about 2/5 of body length except toes. Eye-spots absent. Rostrum large, broad, triangular and decurved. Foot conical and 1/3 of trunk length. Toes sword-shaped, long and about 2-fold of foot length. Retrocerebral sac and duct present. Trophi forcipate type. Rami outline pyriform, each sickle-shaped and terminating into a long, tapering and incurved tooth; a needle-like preuncinal tooth emerging from outer margin and projecting towards axis of trophi at about 1/3 from a tip. Fulcrum short, about 1/3 of ramus length. Unci single-toothed, about 3/5 of manubria length. Intramallei short, with round base and tapering ends. Supramanubria large, thin, rhomboid-ovate and tapering into short needle-like tips distally. Manubria long, about 3-fold of fulcrum length, rod-shaped, curved and knobby distally and proximally.

Body length 250 µm, toe length 70 µm; trophi length 30 µm.

Distribution. Cosmopolitan, but, not recorded from Korea before.

Remarks. De Smet (1997) proposed that the genus *Dicranophorus* should only include species characterized by: elongate basal and subbasal chambers forming a dense conglomerate; basal chamber opening laterally; subbasal chamber opening ventrally; intramallei absent; unci single-toothed, interlocking with dorsal apical ramus tooth or its cardal apophyse and a cardal apophyse ventrally. Since the trophi parts of *Dicranophorus uncinatus* have characteristics different from those mentioned above, De Smet (1997) transferred it to genus *Encentrum*.

Family Notommatidae Remane, 1933

Genus *Cephalodella* Bory de St. Vincent, 1826

3. *Cephalodella innesi* Myers, 1924 (Fig. 1G-I)

Cephalodella innesi Myers, Haring and Myers, 1924, p. 470, figs. 26: 3-5; Nogrady and Pourriot, 1995, p. 92, Fig. 123.

Material examined. 5 specimens, brackish water, Hakik-dong, Incheon-si (Gi Sik Min), 17 Oct, 2013.

Description. Body elongate, slightly compressed laterally and gibbous dorsally; head and foot clearly defined. Head about a third of body length. Corona oblique and convex without projecting lips. Integument smooth, thin and flexible; lorica plate absent. Eye spots red, double, frontal and wide apart each other. Foot about a seventh of body length, conical, and with a short tail. Toes longer than foot, slender, and tapering gradually to pointed tips; ratio of total body length / toe length about 4.5. Trophi virgate type; manubria long and crutched.

Body length 138-144 µm. Toe length 24-25 µm. Trophi length 43 µm. Fulcrum length 29 µm.

Distribution. USA, Spain, Thailand, Tibet, Korea.

Remarks. This species has been reported from Balearic archipelago, Spain (De Manuel *et al.*, 1992), Thailand (Chittapun *et al.*, 1999), Tibet (reviewed in Zhuge *et al.*, 1998) since its original description from USA by Myers (Haring and Myers, 1924).

Subclass Bdelloidea Hudson, 1884

Order Adinetida Melone and Ricci, 1995

Family Adinetidae Bryce, 1910

Genus *Adineta* Hudson and Gosse, 1886

4. *Adineta gracilis* Janson, 1893 (Fig. 2A)

Adineta gracilis Janson, 1893, p. 77, pl. 5, figs. 76, 77;

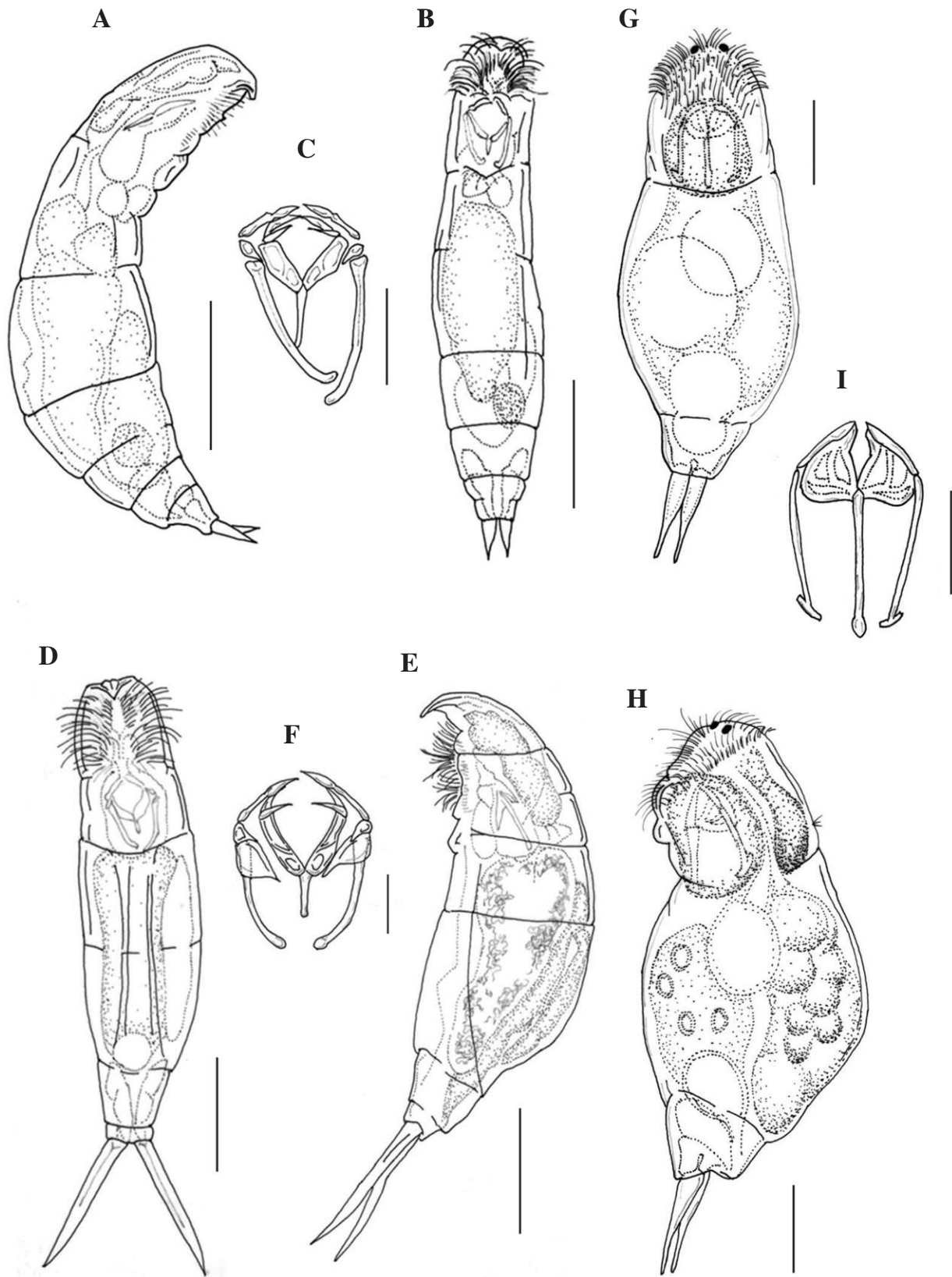


Fig. 1. *Encentrum incisum* Wulfert, 1936. A. lateral view. B. ventral view. C. trophi, ventral view. *Encentrum uncinatum* (Milne, 1886). D. ventral view. E. lateral view. F. trophi, ventral view. *Cephalodella innesi* Myers, 1924. G. ventral view. H. lateral view. I. trophi, ventral view (Scales: A, B, D, E=50 μ m; C, F=10 μ m; G-I=20 μ m).

Montet, 1915, p. 262, pl. 7, figs. 1a, b; Bartoš, 1951, p. 477, figs. 4B, 66D, H; Bartoš, 1959, p. 309, figs. 57 D-E; Donner, 1965, p. 274, figs. 199g-j.

Material examined. 8 specimens, a mountain in Jukheondong, Gangneung-si, Gangwon-do (moss and lichens, Chang-Ho Lee), 07 March, 2013.

Description. Eyes absent. Head oval, flat and thumb-shaped. Rostrum lamella like brim of hat, with even height

and without auricle-like structure laterally, incurved ventrally. Corona a ventral ciliary field and non-retractable. Rake apparatus absent. Two thin and long spine-like projections present anterior to mouth; each tip curved and pointing up. Integument around posterior part of ventral ciliary field and mouth extended like lamella forming rhomboidal collar-shaped structure. Dental formula 2/2. Preanal segment much narrower than preceding segment of trunk. Anal segment gradually tapering to foot. Foot

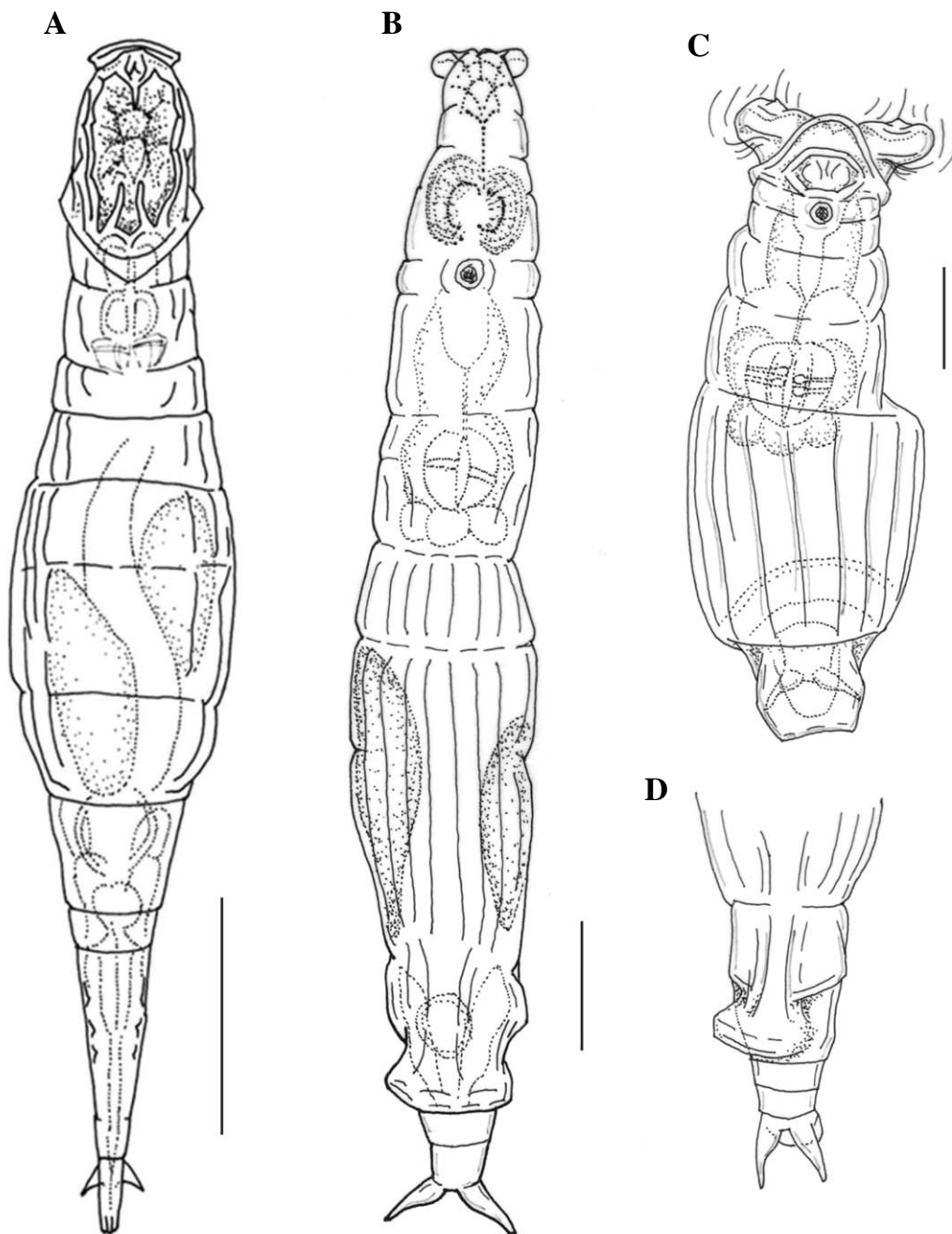


Fig. 2. A. *Adineta gracilis* Janson, 1893, ventral view. *Macrotrachela timida timida* Milne, 1916. B. creeping, dorsal view. C. feeding, dorsal view. D. rump, foot and spurs, dorsal view (Scales: A=50 μ m; B-C=20 μ m).

narrower than rump. Spurs small, triangular and decurved towards end. Three toes small.

Body length 256 μm . Trunk width 41 μm .

Distribution. Europe, Australia, New Zealand, Pacific Islands, the Antarctic, South and North America, and Korea.

Remarks. Cosmopolitan, but, new to Asia.

Order Philodinida Melone and Ricci, 1995

Family Philodinidae Bryce, 1910

Genus *Macrotrachela* Milne, 1886

5. *Macrotrachela timida timida* Milne, 1916 (Fig. 2B-D)

Macrotrachela timida timida Milne, 1916, pp. 152-154, Figs. 3-3a; Donner, 1965, p. 155, figs. 114a-b.

Material examined. 2 specimens, Hong-do, Sinan-gun, Jeonranam-do (mosses and soil, Chang-Ho Lee), 2 July, 2013.

Description. Body with smooth surface. Rostral lamella wider than rostrum end and quadruple-lobed; lateral lobes bigger than median ones and like auricles. Corona wider than cingulum pad. Upper lip rimmed and as high as disc retractor; with somewhat concave sides and U-shaped median lobe. Disc retractor bilobed. Dental formula 2/2. Rump 'crinoline-type' and with two deep longitudinal folds in the middle dorsally; anal segment extended dorsally forming like a hexagonal flange. Foot with four segments and three toes. Spurs conical, divergent, and somewhat longer than spur segment width; outer margin slightly convex; inner margin swollen like a shoulder until 1/3

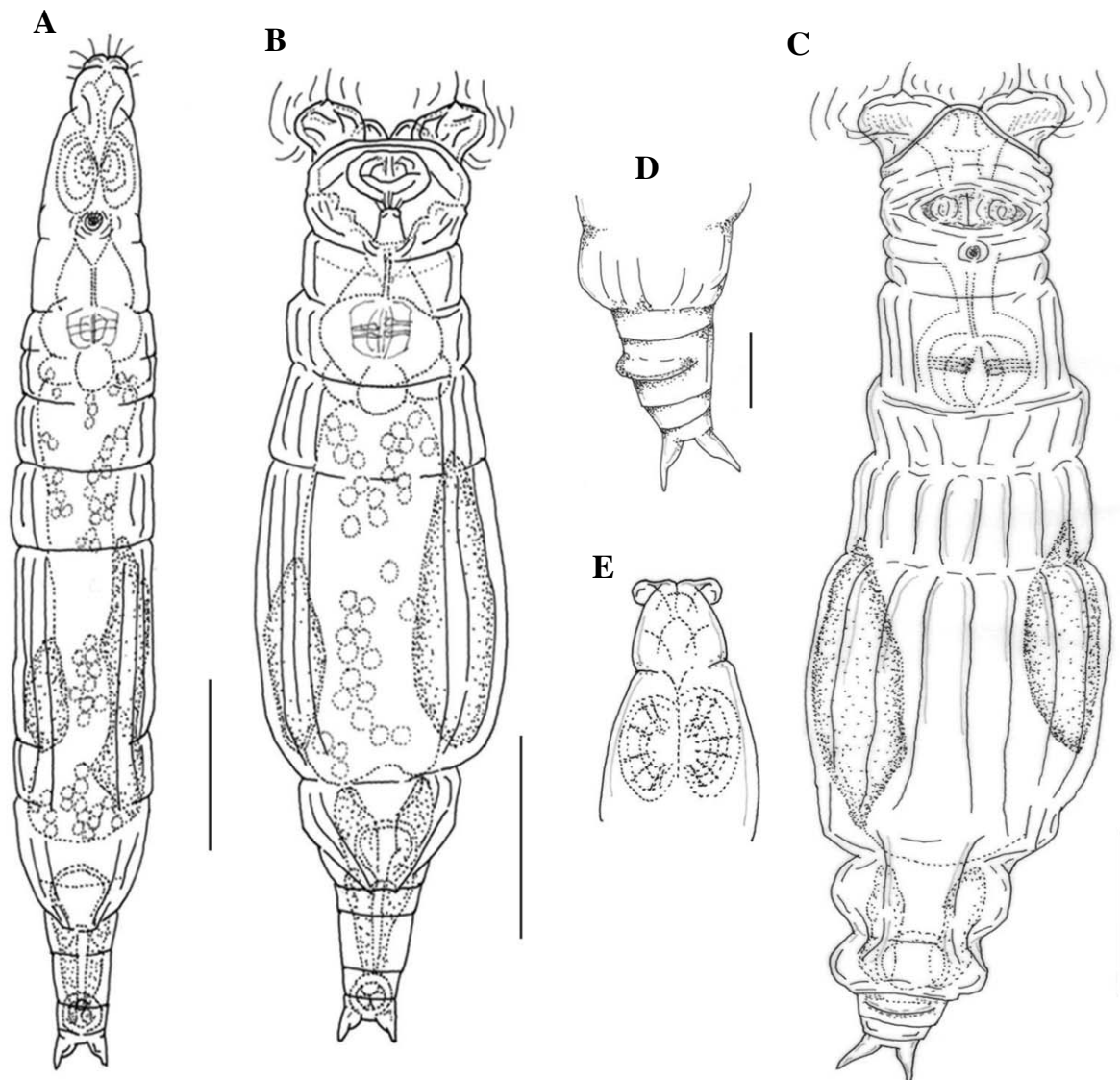


Fig. 3. *Habrotrocha scabropyga* Bartoš, 1958. A. creeping, dorsal view. B. feeding, dorsal view. *Macrotrachela timida inquires* Milne, 1916. C. feeding, dorsal view. D. rump, foot and spurs, dorsolateral view. E. rostrum and neck, dorsal view (Scales: A-C=50 μm ; D=20 μm).

from base and then abruptly tapering to narrow end; interspace narrower than spur base width.

Body length (in creeping) 205 μm . Trunk width (in creeping) 30 μm . Corona width 39 μm . Cingulum pad width 30 μm . Spur length 10 μm .

Distribution. South Africa, Czech Republic and Korea.

Remarks. New to Asia. After Milne (1916) described this species from South Africa, it has been reported only from Czech Republic (SüdMähren, Pollauer Berge) by Donner (1954; 1965) until the present study.

6. *Macrotrachela timida inquires* Milne, 1916 (Fig. 3C-E)

Macrotrachela timida inquires Milne, 1916, pp. 154-155, pl. 10, Fig. 4; Bartoš, 1959, pp. 251-252, figs. 38M, O; Donner, 1965, pp. 155-156, fig. 114c; Donner, 1972, pp. 104-105, figs. 9l; Donner, 1980, p. 139, fig. 5d.

Material examined. 5 specimens, Wanggok-ri, Goseong-gun, Gangwon-do (mosses on a tree trunk, Min Ok Song), 15 Sep., 2013.

Description. Body with smooth surface. Rostral lamella wider than rostrum end and quadruple-lobed; lateral lobes bigger than median ones and like auricles. Corona wider than cingulum pad. Upper lip rimmed, as high as disc retractor, with somewhat concave sides and with arched median lobe. Dental formula 2/2. Rump 'crinoline-type' and with two deep longitudinal folds in the middle dorsally; dorsal expansion of anal segment not as prominent as that of *M. timida timida*. Foot with four segments and three toes; first foot segment with a transverse protuberance dorsally. Spurs conical, divergent, as long as spur segment width; inner margin somewhat swollen like a shoulder until 1/3 from base and then gradually tapering to narrow end; interspace slightly narrower than spur base width.

Corona width 49 μm . Cingulum pad width 41 μm . Spur length 15 μm .

Distribution. South Africa, Austria, Czech Republic, Spain, Brazil and Korea.

Remarks. The present subspecies is different from *M. timida timida* as follows: (1) It has a transverse protuberance on the first foot segment dorsally, while *M. timida timida* does not have any dorsal bump or projection on foot; (2) The dorsal expansion of anal segment is not as noticeable as that of *M. timida timida*; (3) Spurs of the present subspecies is as long as its base width, while those of *M. timida timida* are longer than spur base width. New to Asia.

Family Habrotrochidae Bryce, 1910

Genus *Habrotrocha* Hudson and Gosse, 1886

7. *Habrotrocha pavida* Bryce, 1915 (Fig. 4)

Habrotrocha pavida Bryce, 1915, p. 637, pl. 38, fig. 2;

Bartoš, 1951, p. 318, figs. 21A-C; Bartoš, 1959, p. 144, figs. 17D-F; Donner, 1950, pp. 316-318, figs. 15a-e; Donner, 1965, pp. 40-41, Fig. 21.

Material examined. 2 specimens, a mountain in Mong-sanpo, Seosan-si, Chungcheongnam-do (mosses and leaf litter, Min Ok Song), 14 April, 2013.

Description. Inhabiting irregular shaped shelter or nest of mucus, detritus and extruded food pellets. Body with smooth surface. Rostrum rather short. Rostral lamella small, narrower than rostrum end and bilobed. Corona wider than cingulum pad. Upper lip lower than sulcus, rimmed, arched, and with triangular median lobe; each side of upper lip expanded like auricle. Disc retractor bilobed with convex sides and as high as trochal discs. Antenna rather short and with very prominent process on each side; each protuberance with expanded end. Pharyngeal tube as long as trophi length. Dental formula 4/4. Trunk spindle-shaped and with distinct longitudinal folds. Rump abruptly tapering into foot. Foot with 3 segments and 3 toes; first foot segment with a round process dorsally. Spurs finger-shaped, long, thin, about 3 times as long as its base, tapering gradually from base to blunt tip; interspace 2 times as wide as spur base.

Body length (in creeping) 280-285 μm . Corona width 47 μm . Cingulum pad width 35 μm . Antenna segment width 35 μm . Spur length 19 μm .

Distribution. Germany, Czech Republic, England, Austria, Rumania, North America and Korea.

Remarks. New to Asia. This species is very similar to *H. gracilis* in the general body structure and the same habit of taking shelter or nest in any available aggregations of debris, but it is distinguished from the latter by the following characteristics; (1) Cingulum of the present species has bulging lateral margins as well as a triangular median lobe, while that of the latter does not, (2) The first foot segment of the present species has a round process dorsally, while that of the latter has two transverse protuberances anterodorsally, (3) Disc retractor of the present species does not have any process medially, while that of the latter has three ones, and (4) Spurs of the present species are longer and thinner than those of the latter.

8. *Habrotrocha scabropyga* Bartoš, 1958 (Fig. 3A-B)

Habrotrocha scabropyga Bartoš, 1958, p. 71, Figs. A-C (From Bartoš, 1959, p. 149, Figs. 19A, B, F); Donner, 1965, pp. 53-54, Figs. 39c-d.

Material examined. 2 specimens, a mountain in Jeonganmyeon, Gongju-si, Chungcheongnam-do (mosses, Min Ok Song), 14 April, 2013.

Description. Body with smooth surface. Rostrum rather short. Rostral lamella small, as wide as rostrum end and bilobed. Corona wider than cingulum pad. Upper lip lower

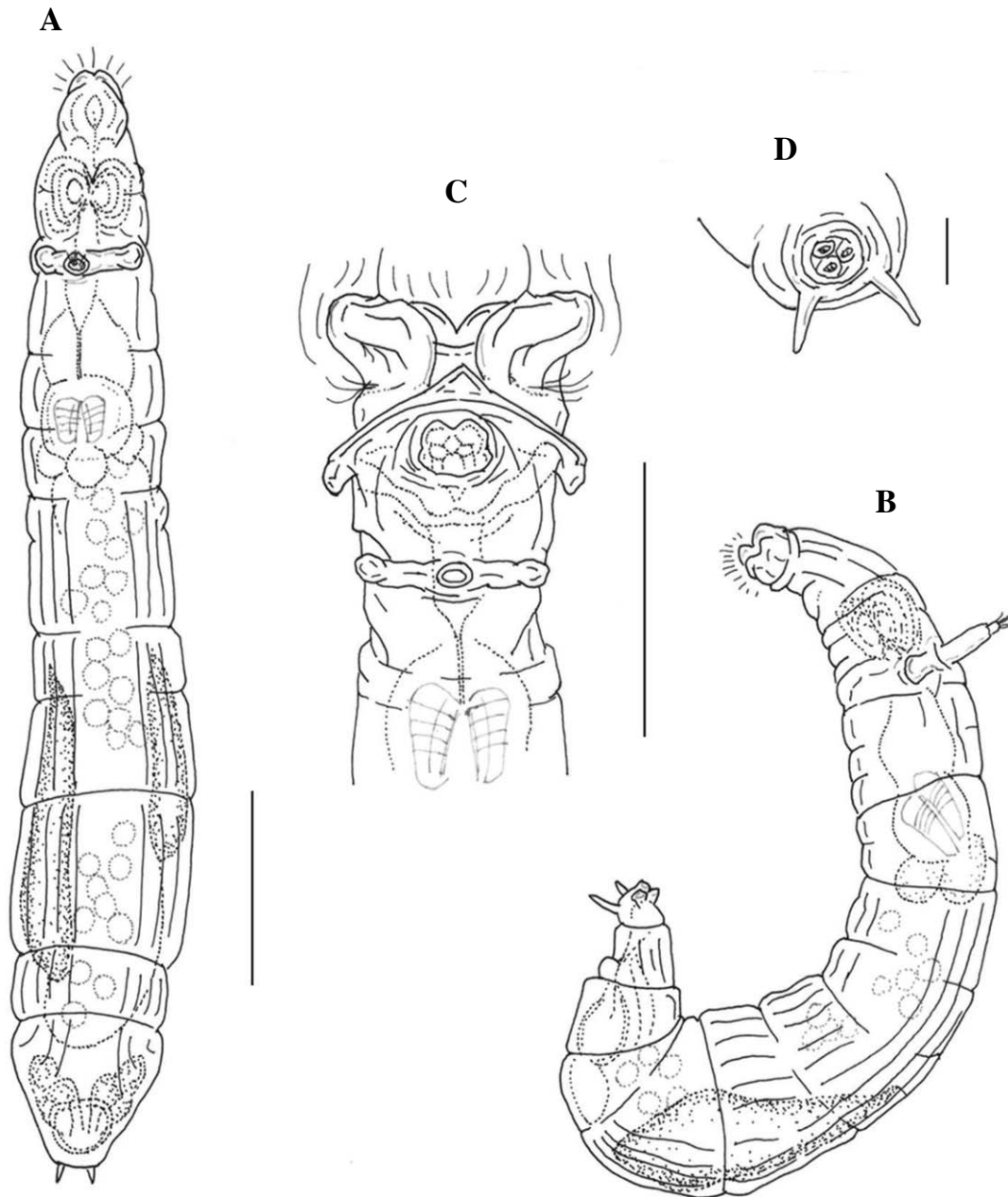


Fig. 4. *Habrotrocha pavida* Bryce, 1915. A. creeping, dorsal view. B. creeping, lateral view. C. feeding head and neck, dorsal view. D. spurs and toes, ventral view (Scales: A-C=50 μ m; D=20 μ m).

than disc retractor, higher than sulcus, rimmed, arched, and with rather flat median lobe. Disc retractor bilobed with convex sides and lower than trochal discs. Antenna rather short. Pharyngeal tube as long as trophi length. Dental formula 2/2. Trunk spindle-shaped and with distinct longitudinal folds. Anal segment tapering rather abruptly to its cuff-like last quarter; posterodorsal area protruded with oblique folds and ended with truncated angular margin. Foot with 4 segments and 3 toes. Spurs conical, with straight outer margin and convex inner mar-

gin, tapering abruptly to pointed tips; longer than its base width; interspace narrower than spur base width.

Body length (in creeping) 296 μ m. Corona width 46 μ m. Cingulum pad width 37 μ m. Trunk width (in feeding) 61 μ m. Spur length 7 μ m.

Distribution. Czech Republic and Korea.

Remarks. New to Asia. This species has never been reported again since its original description from Czech Republic until the present study.

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