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New records of 24 ciliate species (Protozoa, Ciliophora) collected in South Korea

Ji Hye Kim[1], Ji Hye Moon[2] and Jae-Ho Jung[2,*]

[1]*Natural Science Research Institute, Gangneung-Wonju National University, Gangneung, Republic of Korea*
[2]*Department of Biology, Gangneung-Wonju National University, Gangneung, Republic of Korea*

**Correspondent: jhjung@gwnu.ac.kr*

We collected ciliates from terrestrial and aquatic habitats in Korea. Morphology was examined based on observations of both living and stained specimens. As a result of the observations, we found 24 previously unrecorded ciliate species to Korea. The morphology of these species are briefly described here: *Tracheloraphis dracontoides*, *Condylostoma arenarium*, *Aspidisca steini*, *Australocirrus aspoecki*, *Sterkiella tricirrata*, *Stylonychia lemnae*, *Wallackia bujoreani*, *Bakuella marina*, *Anteholosticha sigmoidea*, *Holosticha pullaster*, *Urostyla grandis grandis*, *Chaenea vorax*, *Enchelys gasterosteus*, *Phialina salinarum*, *Mesodinium pulex*, *Aegyria oliva*, *Bryometopus pseudochilodon*, *Pinacocoleps tesselatus*, *Urozona buetschlii*, *Colpidium colpoda*, *Campanella umbellaria*, *Pseudovorticella difficilis*, *Zoothamnium parahiketes* and *Z. plumula*. Among these 24 ciliates, *S. tricirrata* and *U. grandis grandis* were studied based on both the morphology and the morphogenesis.

Keywords: infraciliature, protargol impregnation, redescription, taxonomy

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Introduction

The species list of Korean ciliates has been rapidly increasing due to strengthened governmental support, and more than 400 species have been reported to date (Jung *et al*., 2017; Kim and Jung, 2018). However, we believe this is still an underestimate of Korean ciliate diversity, and that numerous ciliate species await discovery.

During the study of ciliate diversity in Korea, we discovered 24 free-living ciliates from diverse habitats such as terrestrial moss, freshwater, and saline waters. The diverse ciliates are classified into 23 genera, 20 families, 13 orders, and eight classes (Berger, 1999; 2006; 2011; Lynn, 2008). Of these 24 species, a rare species *Sterkiella tricirrata* (Buitkamp, 1977) Berger, 1999 is described with some dividing stages (Berger, 1999; Kumar *et al*., 2015). Moreover, the dividing stages of *Urostyla grandis grandis* Ehrenberg, 1830 are examined to help assign it to subspecies level (Paiva *et al*., 2016). Here, we provide the brief descriptions and microphotographs of these 24 previously unrecorded ciliates species in Korea.

Materials and Methods

Samples for 24 ciliates were collected from terrestrial moss, freshwater, brackish water, and marine water in Korea. The specific locality and collection date of each samples are described in the 'Material examined' section for each species description.

The samples were transferred to our laboratory after sampling. Terrestrial samples were cultured using the non-flooded method (Foissner *et al*., 2002). For aquatic samples, about 200 mL, were cultured with ambient debris and 2 or 3 rice grains to enrich bacteria growth that serves as a food resource for ciliates. All samples were maintained at room temperature.

Ciliate morphology was observed from living and silver-impregnated specimens using a stereomicroscope (Olympus SZ11, Japan), an optical microscope (Olympus BX53, Japan) at low (×40-200) to high (×400-1000) magnifications, and a digital camera (Olympus DP74, Japan). Silver impregnations were performed according to the 'procedure A' protargol method, 'dry' silver nitrate method (for *Campanella umbellaria*, *Colpidium colpoda* and *Zoothamnium plumula*) and 'wet' silver nitrate method (for *Pseudovorticella difficilis* and *Zoothamnium parahiketes*) (Foissner, 2014; Kim and Jung, 2017). Additionally, a single species, *Pinacocoleps tesselatus*, was examined to reveal the presence of a spine by scanning electron microscopy (SEM) according to protocol of

Foissner (2014). The nuclear apparatus of *Bryometopus pseudochilodon* was revealed by DAPI staining (Morikawa and Yanagida, 1981). Differential through-focal images of protargol-impregnated specimens were merged using Helicon Focus software (HeliconSoft Ltd, Ukraine).

The terminology and taxonomic classification follow Berger (1999; 2006; 2011) and Lynn (2008).

Results and Discussion

Phylum Ciliophora Doflein, 1901
Class Karyorelictea Corliss, 1974
Order Protostomatida Small and Lynn, 1985
Family Trachelocercidae Kent, 1881
Genus *Tracheloraphis* Dragesco, 1960

1. *Tracheloraphis dracontoides* (Bullington, 1940) Borror, 1963 (Fig. 1)

Material examined. Marine water (salinity 29‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on June 7, 2018.

Diagnosis. Extended body size 800-1000 × 30-40 μm *in vivo*; body highly contractile and flexible with vermiform shape; 32-38 somatic kineties; glabrous stripe width about 15 μm; single nuclear group centrally located on main body and composed of 12-18 macronuclei and about 2 micronuclei; 2 types of cortical granules colorless: larger one disc-like shape, diameter about 1.5 μm; smaller one spherical to oval shape, size about 0.4 × 0.6 μm; cortical granules loosely arranged in middle line of glabrous zone; single circumoral kinety and obliquely arranged 2 or 3 brosse kineties.

Distribution. U.S.A., Korea.

Remarks. The Korean population of *T. dracontoides* is different from the American population in the shape of body cross section (cylindrical vs. bean-shaped) (Borror, 1963). The closest congener of *T. dracontoides* is *T. aragoi* (Dragesco, 1954) Dragesco, 1960 but they differ in the presence of macronuclear crystals (absent vs. present) and the distribution of cortical granules (regularly arranged vs. partially concentrated) (Foissner and Dragesco, 1996).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109426, NIBRPR0000109427) and three slides were deposited at the National Marine Biodiversity Institute of Korea (MABIK PR00043118-PR00043120).

Class Heterotrichea Stein, 1859
Order Heterotrichida Stein, 1859
Family Condylostomatidae Kahl in Doflein and Re-

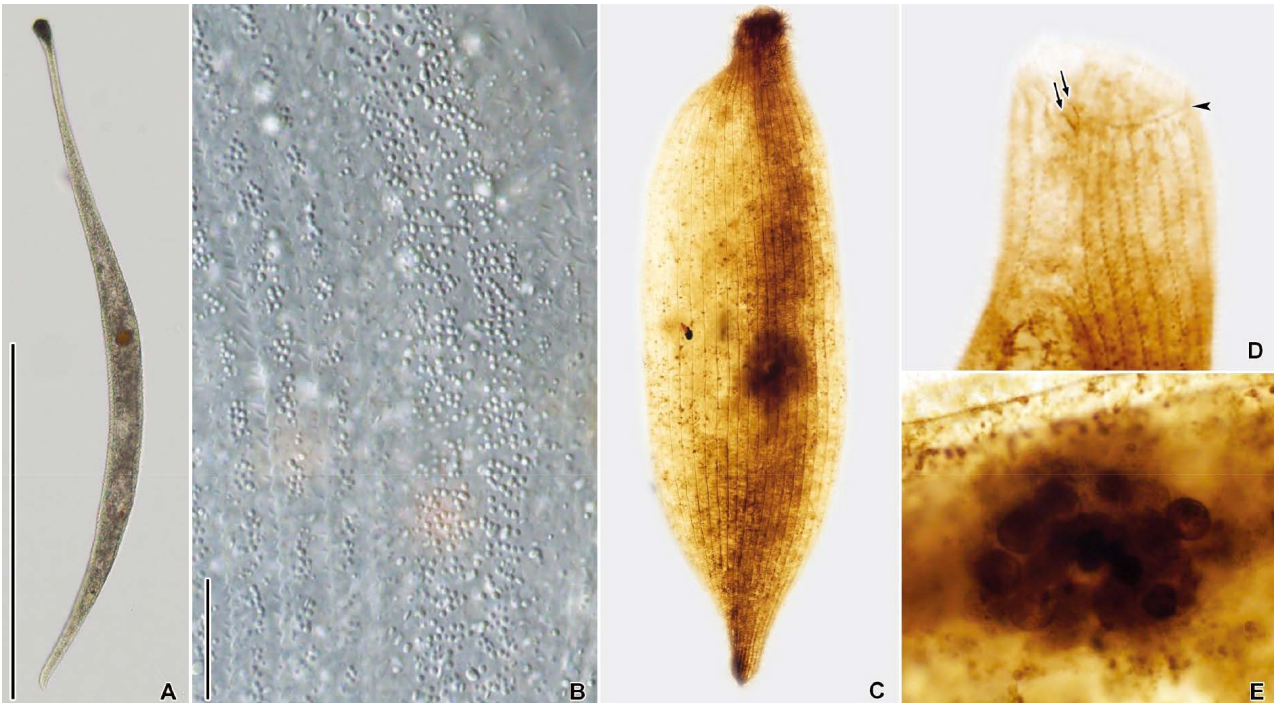

Fig. 1. *Tracheloraphis dracontoides in vivo* (A, B) and after protargol impregnation (C-E). A. Living individual to show extended body shape. B. Cortical granulation on glabrous stripe. C. Longitudinally arranged somatic kineties. D. Circumoral kinety (arrowhead) and brosse (arrows). E. Nuclear group. Scale bars = 500 μm (A); 30 μm (B).

ichenow, 1929
Genus *Condylostoma* Bory de St. Vincent, 1824

2. *Condylostoma arenarium* Spiegel, 1926 (Fig. 2)

Material examined. Marine water (salinity 29‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on June 7, 2018.
Diagnosis. Body size 495-860 × 90-110 μm *in vivo*; body contractile and flexible; elongated ellipsoidal shape; buccal cavity about 30% of body length; 16 macronuclear nodules moniliform; 103-130 adoral membranelles; 9-11 frontal cirri; 50-58 somatic kineties.
Distribution. Cosmopolitan.
Remarks. The Korean population of *C. arenarium* is different from the Brazilian population in the number of somatic kineties (50-58 vs. 30-45). The number of somatic kineties, however, shows high variation among population of *C. arenarium*, and is related to environmental conditions (Fernandes *et al*., 2015).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109424, NIBRPR0000109425) and three slides were deposited at the National Marine Biodiversity Institute of Korea (MABIK PR00043121-PR00043123).

Class Spirotrichea Bütschli, 1889
Order Euplotida Small and Lynn, 1985
Family Aspidiscidae Ehrenberg, 1830
Genus *Aspidisca* Ehrenberg, 1830

3. *Aspidisca steini* (Buddenbrock, 1920) Kahl, 1932 (Fig. 3)

Material examined. Marine water (salinity 29‰) collected from Jungjuhang Port, Hamdeok-ri, Jocheon-eup, Jeju-si, Jeju-do, Korea (33°32′81.2″N, 126°39′58.8″E) on July 14, 2018.
Diagnosis. Marine habitat, body about 40 × 25 μm *in vivo*, broadly ellipsoidal to bean shape with four dorsal ridges; inverted U-shape macronucleus; 7 frontoventral cirri polystyla-arrangement; 5 transverse cirri; 4 dorsal kineties; AZM1 composed of 4 membranelles; AZM2 composed of 9-11 membranelles.
Distribution. Benin, China, Germany, Korea.
Remarks. Park *et al*. (2017) reported a Korean population without the description of morphology, so that we did not compare with our population. Our Korean population of *A. steini* is slightly different from the Chinese population in the number of adoral membranelles in part 2 (9-11 vs. 12-15) (Song and Wilbert, 1997). *Aspidisca steini* is different from its closest congener, *A. aculeata* (Ehrenberg, 1982) Kahl, 1932, in the presence of a dor-

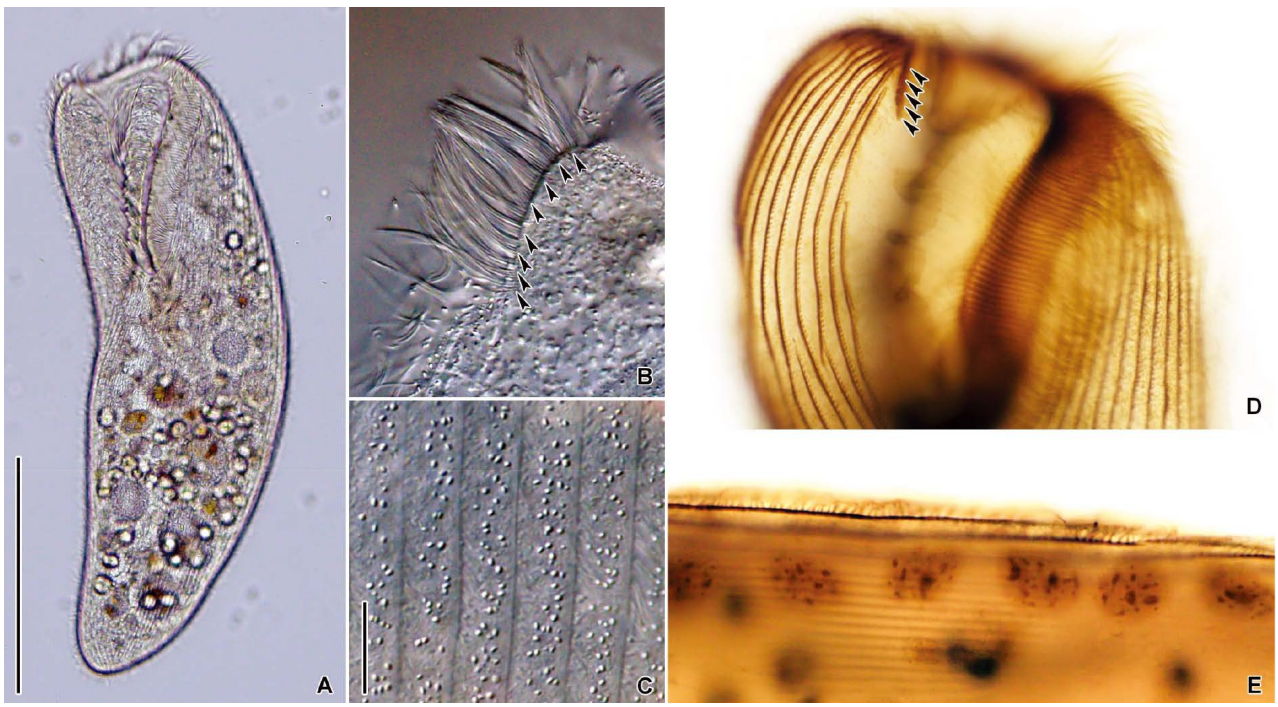

Fig. 2. *Condylostoma arenarium in vivo* (A-C) and after protargol impregnation (D, E). A. Typical individual. B. Frontal cirri (arrowheads). C. Cortical granulation. D. Oral and somatic ciliature on anterior part (arrowheads indicate frontal cirri). E. Macronuclear nodules. Scale bars = 200 μm (A); 10 μm (C).

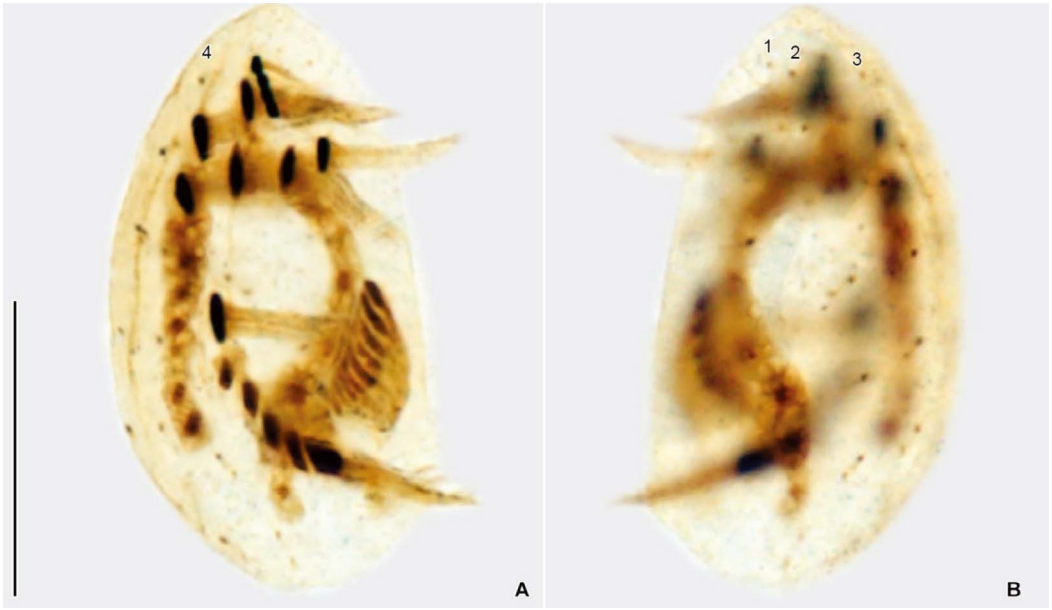

Fig. 3. *Aspidisca steini* protargol impregnated specimen (A, B). A. Ventral view of typical individual. B. Dorsal view. 1-4, dorsal kinety1-4. Scare bar = 20 μm.

sal thorn (absent vs. present) (Wu and Curds, 1979; Song and Wilbert, 1997).

Voucher slide. One slide of protargol-impregnated specimens was deposited at National Marine Biodiversity Institute of Korea (MABIK PR00043130).

Order Sporadotrichida Fauré-Fremiet, 1961
Family Oxytrichidae Ehrenberg, 1830
Genus *Australocirrus* Blatterer and Foissner, 1988

4. *Australocirrus aspoecki* (Foissner, 2004) Kumar and Foissner, 2015 (Fig. 4)

Material examined. Terrestrial moss collected from Gangneung-Wonju National University, Jibyeon-dong, Gangneung-si, Gangwon-do, Korea (37°46′3.23″N, 128° 52′1.66″E) on September 5, 2017.

Diagnosis. Body size 204-270 × 65-100 μm *in vivo*; about 140 × 63 μm after protargol impregnation; body ellipsoidal; contractile vacuole ahead of mid-body at left cell margin with 2 collecting canals; spherical cytoplasmic granules, cortical granules brilliant red, 0.5-0.7 μm in diameter; 2 ellipsoidal macronuclei; 4-6 spherical micronuclei; undulating membranes *Australocirrus*-like pattern; 60-66 adoral membranelles; 3 frontal cirri; 1 buccal cirrus; 4 frontoventral cirri; 3 postoral cirri; 2 pretransverse cirri; 5 obliquely arranged transverse cirri; 37-43 left marginal cirri; 33-39 right marginal cirri; 3 caudal cirri; 6 or 7 dorsal kineties.

Distribution. Austria, Korea.

Remarks. The Korean population of *A. aspoecki* differs from the Austrian population in the average number of postoral cirri (3 vs. 4) and the number of dorsal kineties (6 or 7 vs. 9-16) (Foissner, 2004). Considering the discrepancy on the number of dorsal kineties, further study is necessary to clarify its species identification. *Australocirrus aspoecki* differs from *A. shii* and *A. australis* mainly by the color of the cortical granules (reddish vs. yellowish vs. yellowish) (Berger, 1999; Foissner, 2004; Kumar and Foissner, 2015).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109415, NIBRPR 0000109416).

Genus *Sterkiella* Foissner, Blatterer, Berger and Kohmann, 1991

5. *Sterkiella tricirrata* (Buitkamp, 1977) Berger, 1999 (Table 1, Fig. 5)

Material examined. Terrestrial moss collected from Gagye Shore, Geumgye-ri, Gogun-myeon, Jeollanam-do, Korea (34°25′42″N, 126°21′05″E) on July 7, 2016.

Diagnosis. Body size 85-100 × 35-45 μm *in vivo*, 57-90 × 24-45 μm after protargol impregnation; elliptical shape; colorless; one contractile vacuole on left side of mid-body; cortical granule absent; 2 macronuclear nodules and 1-4 micronuclei; 22-29 adoral membranelles; 3 frontal cirri; 1 buccal cirrus; 4 frontoventral cirri; 3 postoral ventral cirri; 2 pretransverse ventral cirri; 3 transverse cirri; 15-21 left and 18-23 right marginal cirri; 6 dorsal

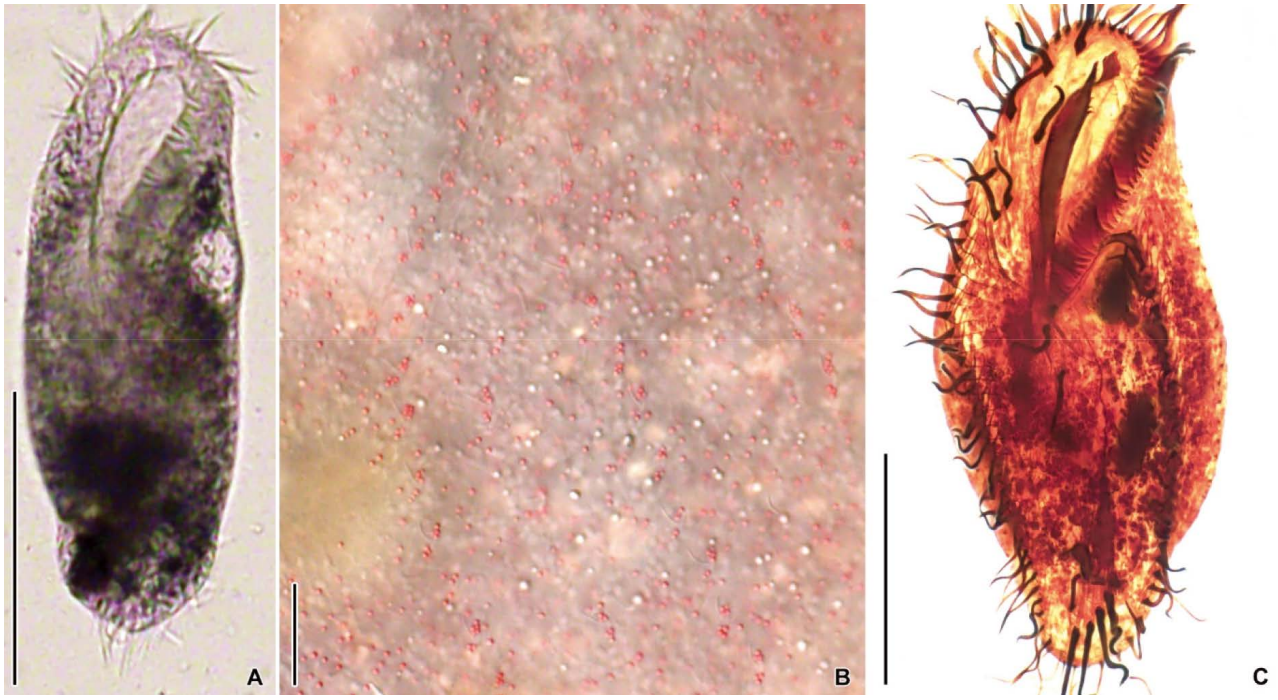

Fig. 4. *Australocirrus aspoecki in vivo* (A, B) and after protargol impregnation (C). A. Living cell to show body shape. B. Reddish cortical granules and dorsal brush. C. Ventral view. Scale bars = 100 μm (A); 50 μm (C); 10 μm (B).

Table 1. Morphometry of *Sterkiella tricirrata*.

Characteristics[a]	mean	M	SD	SE	CV	Min	Max	n
Body, length	69.3	69	8.6	2.0	12.3	57	90	19
Body, width	32.6	32	4.7	1.1	14.5	24	45	19
Body length:width, ratio	2.14	2.11	0.21	0.05	9.6	1.78	2.50	19
Adoral zone, length	23.6	23.0	1.48	0.34	6.30	21	26	19
Body length:adoral zone length, ratio	2.93	2.87	0.27	0.06	9.2	2.58	3.60	19
Largest adoral membranelle, width	5.0	5.0	0.12	0.03	2.28	5.0	5.5	19
Adoral membranelles, number	24.2	24.0	1.70	0.40	7.0	22	29	18
First macronuclear nodule, length	9.6	9.0	2.04	0.47	21.3	7.0	16.0	19
First macronuclear nodule, width	6.7	7.0	0.67	0.15	10.0	5.0	8.0	19
Macronuclear nodules, number	1.95	2.0	0.23	0.05	11.8	1	2	19
First micronucleus, diameter	1.66	1.50	0.24	0.06	14.4	1.50	2.00	19
Micronuclei, number	2.16	2.00	0.60	0.14	27.9	1	4	19
Frontal cirri, number	3	3	0	0	0	3	3	18
Buccal cirrus, number	1	1	0	0	0	1	1	19
Frontoventral cirri, number	4	4	0	0	0	4	4	19
Postoral ventral cirri, number	3	3	0	0	0	3	3	19
Pretransverse ventral cirri, number	2	2	0	0	0	2	2	19
Transverse cirri, number	3	3	0	0	0	3	3	19
Right marginal cirri	20	20	1.33	0.31	6.7	18	23	19
Left marginal cirri	18.1	18	2.26	0.52	12.5	15	21	19
Dorsal kineties, number	6	6	0	0	0	6	6	17
Dorsal bristles in dorsal kinety 1, number	17.7	17	1.45	0.37	8.2	15	21	15
Caudal cirri, number	3	3	0	0	0	3	3	19

[a]Data based on protargol preparations; all measurement in μm. CV = coefficient of variation (%); M = median; Max = maximum; mean = arithmetic mean; Min = minimum; n = number of specimens examined; SD = standard deviation; SE = standard error of arithmetic mean

kineties and 4 caudal cirri.

Morphogenesis. Oral primordium develops slightly above the leftmost transverse cirrus. Origin of the frontal-ventral-transverse primordia as follows: for proter,

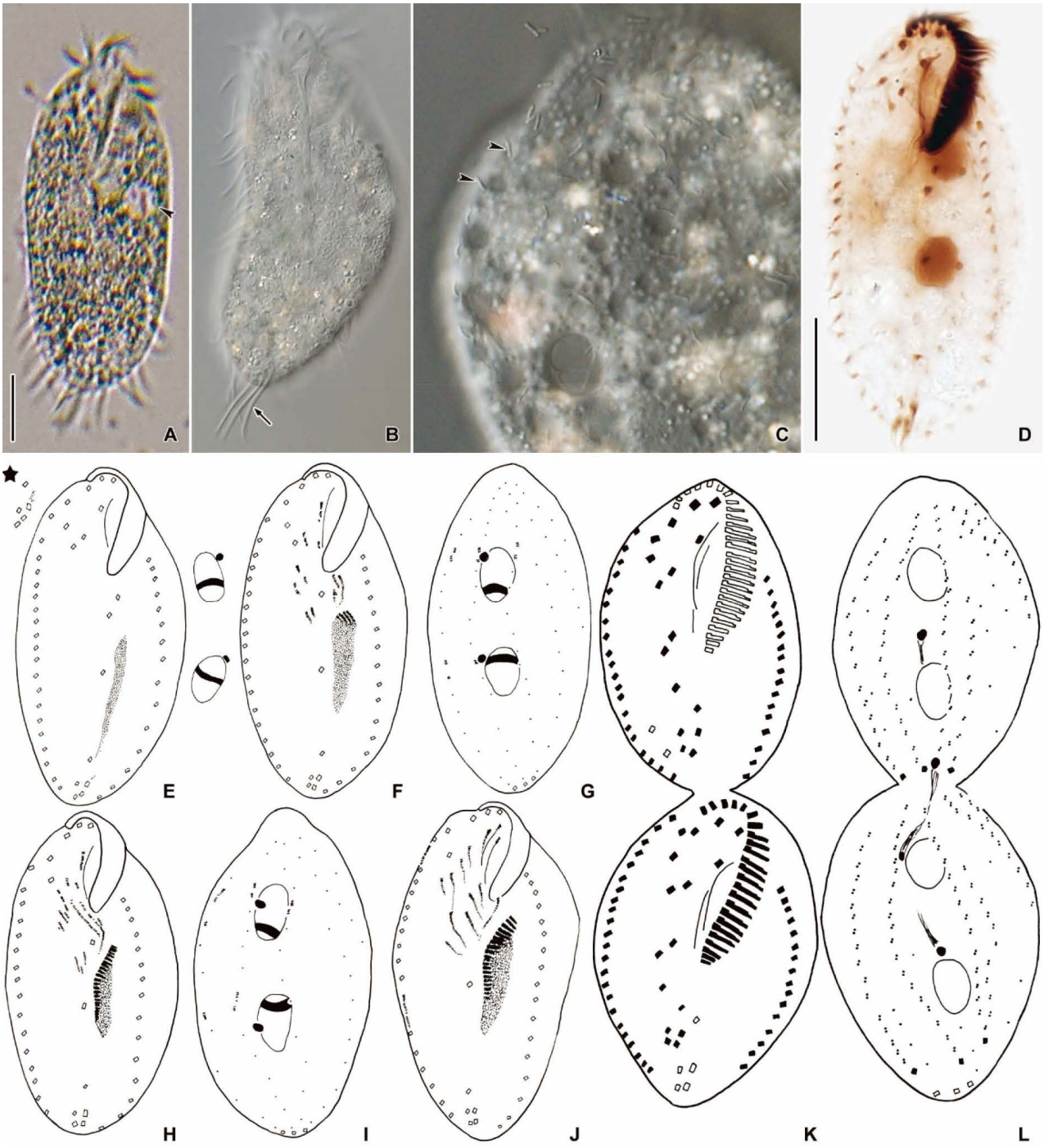

Fig. 5. *Sterkiella tricirrata in vivo* (A-C), protargol impregnated specimen (D-L) and morphogenetic stages (E-L). A. Typical individual to show ellipsoidal body shape (arrowhead indicates contractile vacuole). B. Transverse cirri (arrow). C. Dorsal bristles (arrowheads). D. Ventral view. E. Ventral view of early divider; asterisk indicates a very early divider to show oral primordium. F, H, J. Ventral views of middle dividers. G, I. Dorsal views of middle dividers. K. Ventral view of late divider. L. Dorsal view of late divider. Scale bars = 20 μm.

primordium I from undulating membranes, primordium II from cirrus II/2, primordium III from cirrus III/2?, primordium IV from cirrus IV/3?, primordium V from cirrus IV/3?, primordium VI from de novo?; for opisthe, primordia I-III from oral primordium, primordium IV from cirrus IV/2?, primordium V from cirrus V/4, primordium VI from cirrus V/4. Both primordia V of the two daughters are connected in a middle stage. Dorsal

ciliature follows typical *Oxytricha* pattern.
Distribution. Cote d'Ivoire, Korea.
Remarks. *Sterkiella tricirrata* (Buitkamp, 1977) Berger, 1999 is a poorly described species that has three transverse cirri. Kumar *et al*. (2015) considered that *S. tricirrata* and *S. histriomuscorum* could be separated from *Sterkiella* based on the decreased number of transverse cirri. However, the morphology and molecular data of *S. tricirrata* are not enough to clarify this issue. *Sterkiella tricirrata* is distinguishable from *S. histriomuscorum* in the number of transverse cirri (3 vs. 4 or 5) (Berger, 1999).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000107896, NIBRPR0000107897).

Genus *Stylonychia* Ehrenberg, 1830

6. *Stylonychia lemnae* Ammermann and Schlegel, 1983 (Fig. 6)

Material examined. Freshwater with some debris collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on January 28, 2017.
Diagnosis. Body size 145-230 × 60-85 μm *in vivo*; 84-195 × 32-91 μm after protargol impregnation; body ellipsoidal; one contractile vacuole at mid-body of left cell margin; 2 ellipsoidal macronuclei; about 3 spherical micronuclei; undulating membranes *Stylonychia*-like pattern; 30-69 adoral membranelles; 3 frontal cirri; 1 buccal cirrus; 4 frontoventral cirri; 3 postoral cirri; 2 pretransverse cirri; 5 transverse cirri; 20-23 left marginal cirri; 15-36 right marginal cirri; 3 caudal cirri; 6 dorsal kineties: kinety 3 composed of 35-40 dikinetids, kinety 4 composed of 40-46 dikinetids.
Distribution. Cosmopolitan.
Remarks. *Stylonychia lemnae* is very similar to the *S. mytilus* complex and, according to the key to species (Berger, 1999), differs in the number of dikinetids in dorsal kinety 3 (33-40 vs. 44-66) and 4 (30-39 vs. 40-56). The Korean population of *S. lemnae* exhibits an intermediate morphology between other *S. lemnae* populations and *S. mytilus*, i.e., the range of dikinetids in dorsal kinety 3 (35-40) is in *S. lemnae* and 4 (40-46) is in *S. mytilus*. However, the number of dorsal dikinetids in kinety 4 is relatively small even though the range is within *S. mytilus*. Therefore, we assigned this species in *S. lemnae*.
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109468, NIBRPR0000109469).

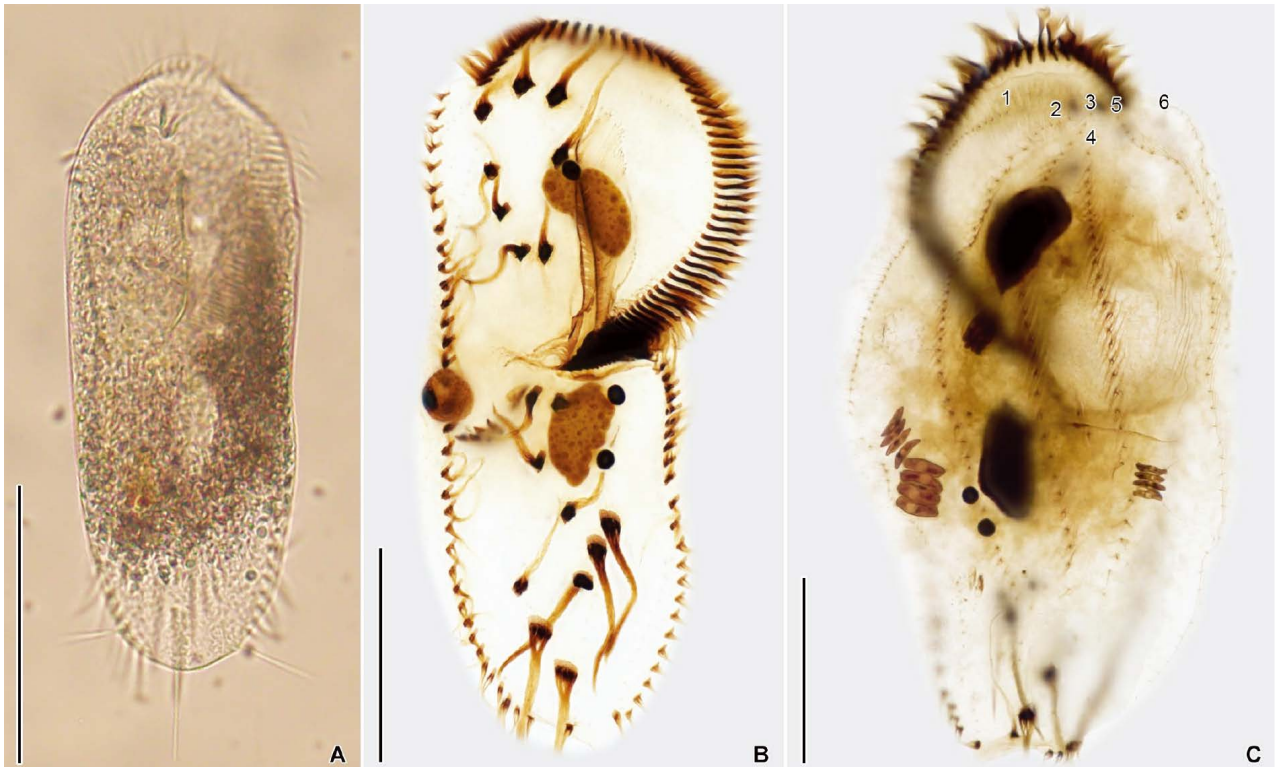

Fig. 6. *Stylonychia lemnae in vivo* (A) and after protargol impregnation (B, C). A. Typical individual. B. Oral and somatic ciliature on ventral view. C. Dorsal view. 1-6, dorsal kinety 1-6. Scale bars = 100 μm (A); 50 μm (B, C).

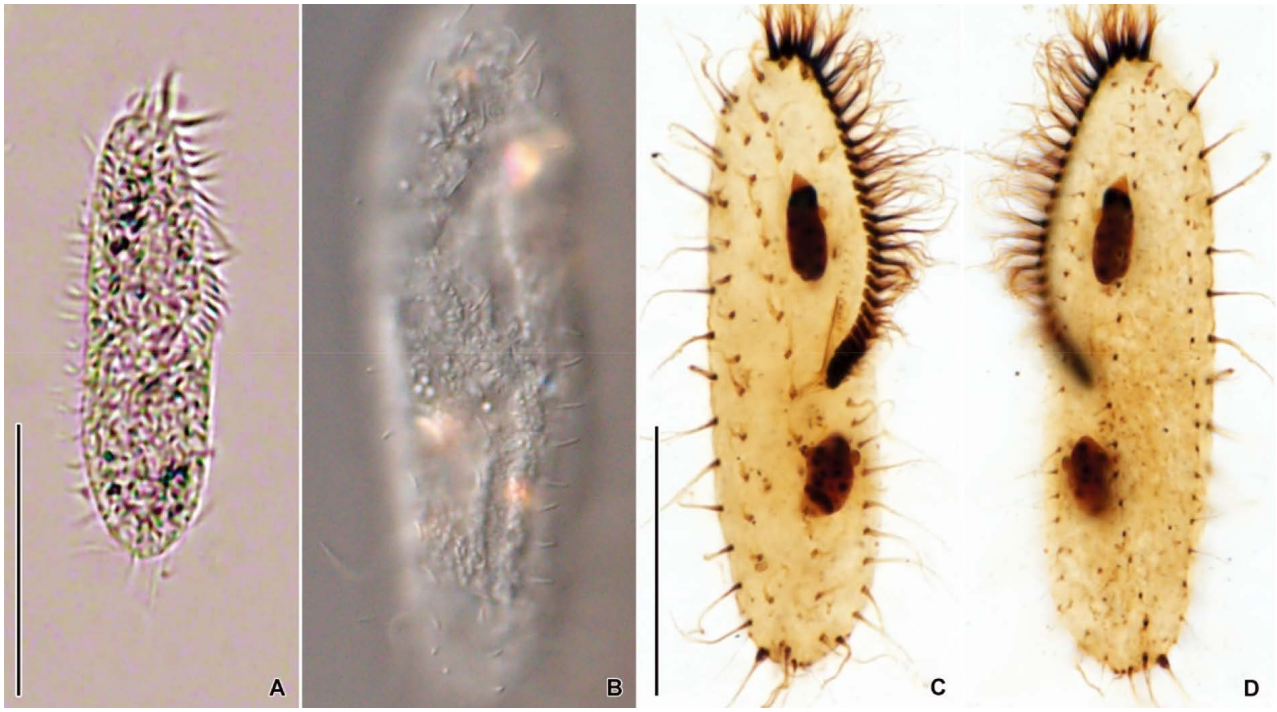

Fig. 7. *Wallackia bujureani in vivo* (A, B) and after protargol impregnation (C, D). A. Typical individual. B. Dorsal view. C. Ventral view. D. Dorsal view to show dorsal kineties and caudal cirri. Scale bars = 50 μm (A); 30 μm (C).

Order Stichotrichida Fauré-Fremiet, 1961
Family Gonostomatidae Small and Lynn, 1985
Genus *Wallackia* Foissner, 1976

7. *Wallackia bujoreani* (Lepsi, 1951) Berger and Foissner, 1989 (Fig. 7)

Material examined. Terrestrial moss collected from Gyodong, Gangneung-si, Gangwon-do, Korea (37°45′51.28″N, 128°52′31.59″E) on September 9, 2017.
Diagnosis. Body size 70-85 × 22-25 μm *in vivo*; 58-69 × 16-19 μm after protargol impregnation; body ellipsoidal shape; contractile vacuole at about left mid-body with 2 collecting canals; ellipsoidal cortical granules irregularly arranged on dorsal side, colorless; 2 ellipsoidal macronuclei, 2 spherical micronuclei; undulating membranes *Gonostomum*-like pattern; 28-30 adoral membranelles; 3 frontal cirri; frontoventral row 2 composed of 2 cirri; frontoventral row 3 consisted of 3-5 cirri; frontoventral row 4 composed of 12-14 cirri; frontoventral row 5 comprised of 15-16 cirri; 2 transverse cirri; 9-10 left marginal cirri; 10-14 right marginal cirri; 3 caudal cirri; 3 dorsal kineties.
Distribution. France, High Arctic, Namib Desert, Romania, Korea.
Remarks. The Korean population of *W. bujoreani* is different from the French and Namibian populations in the presence of contractile vacuole canals (present vs. absent vs. absent) (Berger and Foissner, 1989; Foissner *et al*., 2002). *Wallackia schiffmanni* Foissner, 1976 is the most similar to *W. bujoreani*, however the former can be distinguished from the latter by the habitat (limnetic vs. terrestrial), the number of cirri in frontoventral row 2 (6 in drawing vs. 2), frontoventral row 3 (6 in drawing vs. 3-5), the posteriorly elongated dorsal bristles (present vs. absent) and the shape of cortical granules (elongated ellipsoidal vs. short ellipsoidal) (Berger, 2011).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109417, NIBRPR0000109418).

Order Urostylida Jankowski, 1979
Family Bakuellidae Jankowski, 1979
Genus *Bakuella* Agamaliev and Alekperov, 1976

8. *Bakuella marina* Agamaliev and Alekperov, 1976 (Fig. 8)

Material examined. Brackish water (salinity 2.3‰) with debris collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on February 14, 2018.
Diagnosis. Body size 145-180 × 40-50 μm *in vivo*; body shape elongated ellipsoidal; dorsoventrally flattened; both body ends rounded; flexible; cytoplasm colorless;

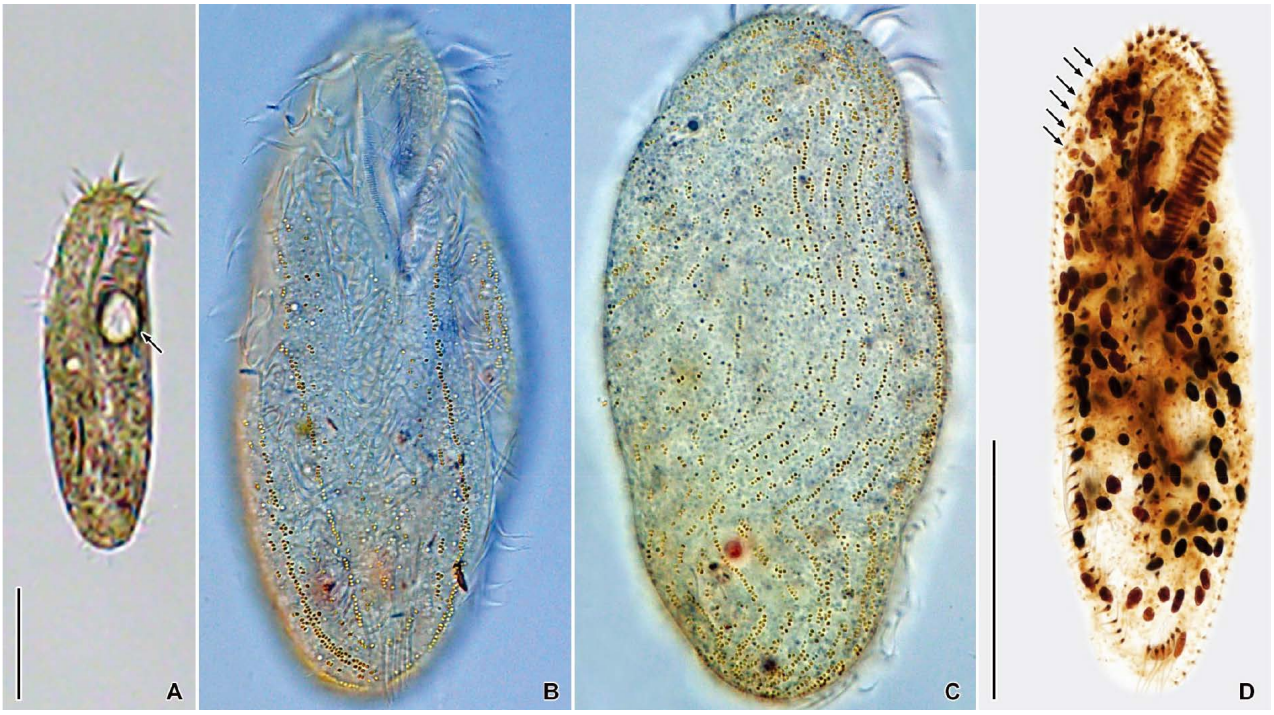

Fig. 8. *Bakuella marina in vivo* (A-C) and protargol impregnated specimen (D). A. Typical individual (arrow indicates contractile vacuole). B. Cortical granulation on ventral side. C. Cortical granulation on dorsal side. D. Oral and somatic ciliature on ventral view (arrows indicate frontoterminal cirri). Scale bars = 50 μm.

yellow cortical granules 1.2×0.8 μm in size; 96-158 macronuclear nodules; 33-37 adoral membranelles; 2-3 buccal cirri; 1 or 2 paramalar cirri; 6-8 frontoterminal cirri; 6-8 transverse cirri; midventral cirri composed 10-13 pairs; 5 or 6 midventral rows; 42-51 right and 42-49 left marginal cirri; 3 bipolar dorsal kineties.

Distribution. Azerbaijan, Canada, Caspian Sea, France, Korea.

Remarks. This Korean population of *B. marina* possesses yellowish cortical granules. The presence/absence of cortical granules was unknown in *B. marina* to date (Berger, 2006). *Bakuella marina* differs from the one of similar species *B. agamalievi* Borror and Wicklow, 1983 based on the number of buccal cirri (6-8 vs. 1) (Berger, 2006).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109465, NIBRPR 0000109466).

Family Holostichidae Fauré-Fremiet, 1961
Genus *Anteholosticha* Berger, 2003

9. *Anteholosticha sigmoidea* (Foissner, 1982) Berger, 2003 (Fig. 9)

Material examined. Freshwater with debris collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on November 16, 2017.

Diagnosis. Body size about 85×18 μm *in vivo*, 52-65×14-21 μm after protargol impregnation; body shape slightly curved left side; both body ends narrowly rounded; flexible; cytoplasm colorless; one contractile vacuole at left mid-body; colorless cortical granules size about 0.6 μm; 4 macronuclear nodules; about 3 micronuclei; 23-27 adoral membranelles; 3 frontal cirri; 1 buccal cirrus; 2 frontoterminal cirri; 6-8 transverse cirri; 2 pretransverse cirri; 10-12 midventral pairs; 20-29 right and 19-26 left marginal cirri; 4 dorsal kineties.

Distribution. Antarctica, Austria, Brazil, Germany, Namibia, Scotland, Spain, Korea.

Remarks. The Korean population of *A. sigmoidea* is different from the type population (Austria) in the body length (85 μm vs. 90-130 μm) and the number of macronuclear nodules (4 vs 6-9) (Foissner, 1982; Berger, 2006). *Anteholosticha sigmoidea* can be distinguished from the most similar species, *A. sphagni* (Grolière, 1975) Berger, 2003, based on the cortical granules (present vs. absent) (Berger, 2006).

Voucher slide. One slide of protargol-impregnated specimens was deposited at National Institute of Biological Resources, Korea (NIBRPR0000109472).



Fig. 9. *Anteholosticha sigmoidea in vivo* (A, B) and protargol impregnated specimen (C, D). A. Typical individual. B. Cortical granules on dorsal side. C. Ventral view to show macronuclear nodules. D. Somatic ciliature on ventral view. Scale bars = 30 μm.

Genus *Holosticha* Wrzesniowski, 1877

10. *Holosticha pullaster* (Müller, 1773) Foissner, Blatterer, Berger and Kohmann, 1991 (Fig. 10)

Material examined. Freshwater with debris collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on January18, 2018.
Diagnosis. Body size about 80 × 25 μm *in vivo*, 38-48 × 10-12 μm after protargol impregnation; body wide spindle shape; both body ends narrowly rounded; cytoplasm colorless; one contractile vacuole at left side of subterminal; cytoplasmic granules conspicuous under cortex; cortical granules lacking; 2 macronuclear nodules; 7-8 distal and 15 proximal membranelles; 3 frontal cirri; 1 buccal cirrus; 2 frontoterminal cirri; 9-10 transverse cirri; 7-9 midventral pairs; 10-11 right and 11-13 left marginal cirri; 4 dorsal kineties.
Distribution. Cosmopolitan.
Remarks. The Korean population of *H. pullaster* has cytoplasmic granules under the cortex were scattered throughout the whole body. *Holosticha pullaster* is the sole limnetic *Holosticha* species and the posteriorly located contractile vacuole differentiates from its congeners (Berger, 2006).
Voucher slide. One slide of protargol-impregnated specimens was deposited at National Institute of Biological Resources, Korea (NIBRPR0000109467).

Family Urostylidae Bütschli, 1889
Genus *Urostyla* Ehrenberg, 1830
Species *Urostyla grandis* Ehrenberg, 1830

11. *Urostyla grandis grandis* Ehrenberg, 1830 (Fig. 11)

Material examined. Freshwater with debris collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on January 4, 2018.
Diagnosis. Body size about 200 × 95 μm after protargol impregnation; body broadly ellipsoidal; flexible; cytoplasm colorless; yellowish cortical granules; numerous ellipsoidal to globular macronuclear nodules; 46-51 adoral membranelles; bicorona frontal rows; 4-6 left marginal rows; 5 or 6 right marginal rows; 8-13 transverse cirri; 4 dorsal kineties; marginal cirral row originated from intrakinetal cirral anlage.
Distribution. Cosmopolitan.
Remarks. A Korean population of *U. grandis* was previously described without morphogenesis (Shin, 1994; Berger, 2006). Recently, Paiva *et al.* (2016) established a new subspecies *U. grandis wiackowskii* Paiva *et al.*, 2016 based on the morphogenetic stages of left marginal

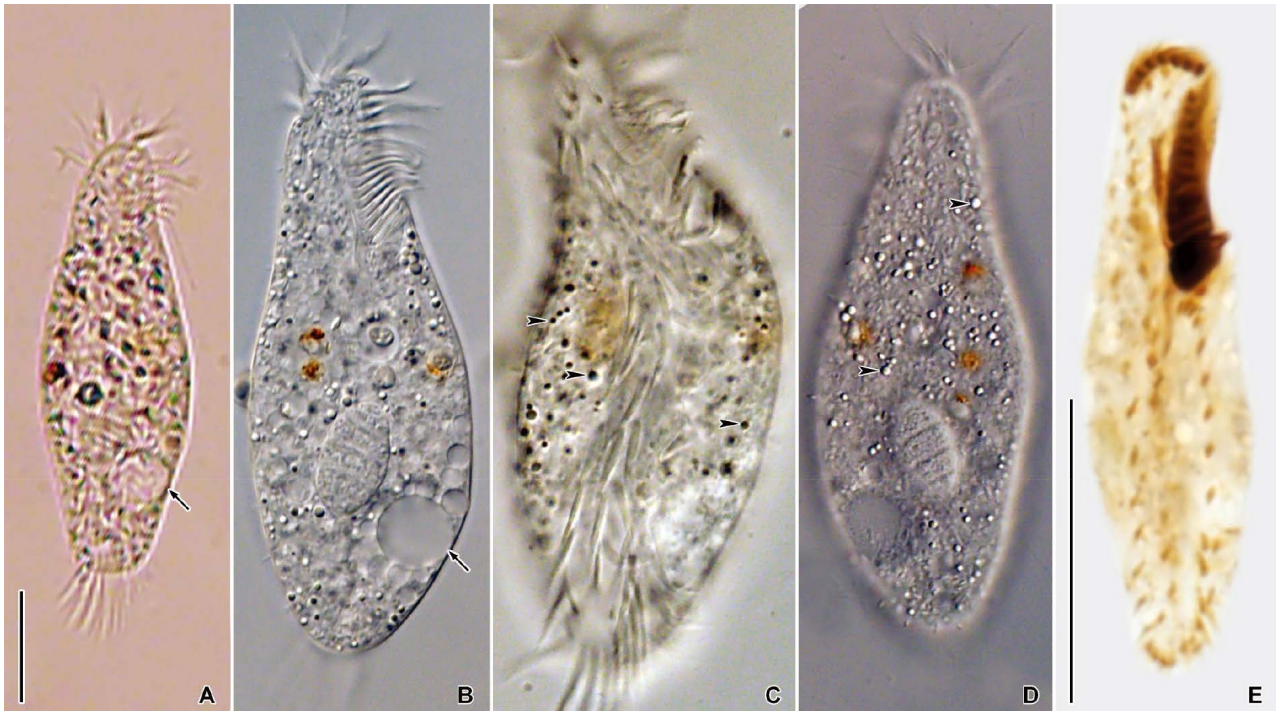

Fig. 10. *Holosticha pullaster in vivo* (A-D) and protargol impregnated specimen (E). A. Typical individual and contractile vacuole (arrow). B. Contractile vacuole (arrow). C. Ventral view (arrowheads indicate cytoplasmic granules). D. Dorsal view (arrowheads indicate cytoplasmic granules). E. Oral and somatic ciliature. Scale bars = 20 μm.

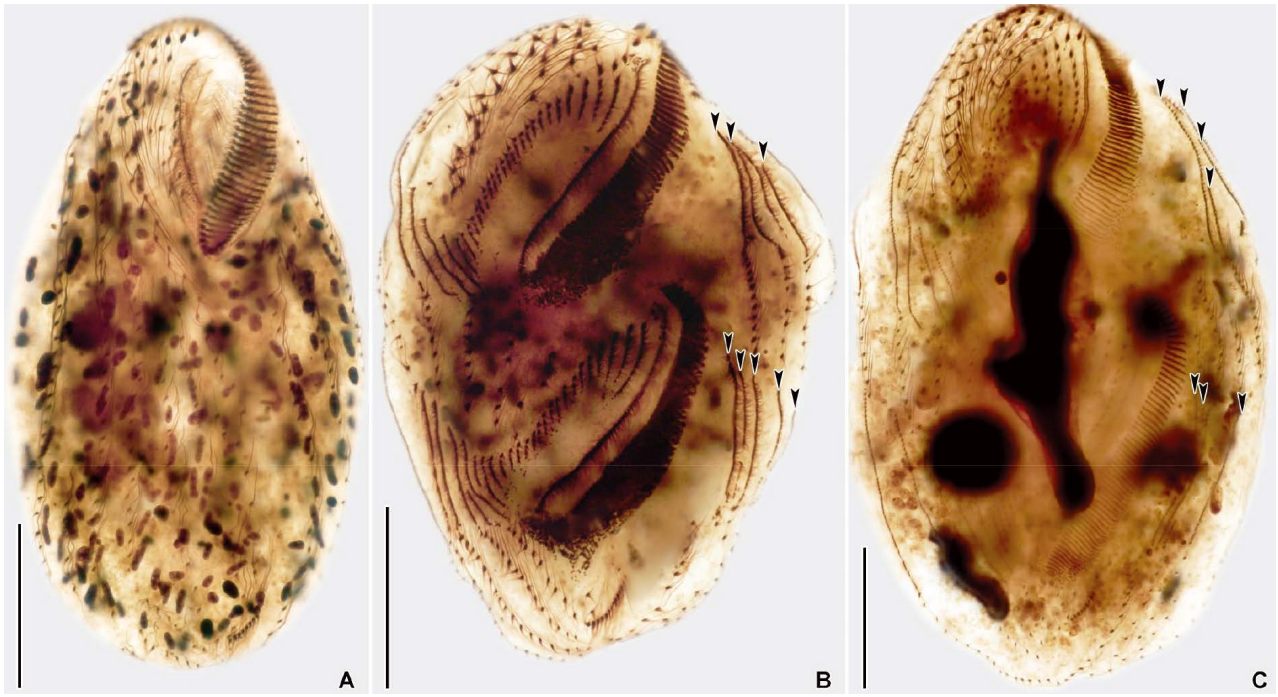

Fig. 11. *Urostyla grandis grandis* after protargol impregnation. A. Vegetative stage. B. Middle divider (arrowheads indicate anlagen of left marginal rows). C. Late divider (arrowheads indicate anlagen of left marginal rows). Scale bars = 20 μm.

rows. Therefore, we used morphogenesis to classify the subspecies level of the Korean population. This Korean population of *U. grandis grandis* has intrakinetal anlagen originated from each left marginal row. In contrast, *U. grandis wiakowskii* has multiple anlagen originated from innermost left marginal cirral row.

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109470, NIBRPR0000109471).

Class Litostomatea Small and Lynn, 1981
Order Haptorida Corliss, 1974
Family Acropisthiidae Foissner and Foissner, 1988
Genus *Chaenea* Quennerstedt, 1867

12. *Chaenea vorax* Quennerstedt, 1867 (Fig. 12)

Material examined. Marine water (salinity 29‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on June 7, 2018.

Diagnosis. Elongated body size about 90 × 10 μm *in vivo*; 65-85 × 11-13 μm after protargol impregnation; body contractile and flexible with vermiform; single contractile vacuole terminally located; oral extrusomes wedge-like shape and 5-6 μm in length; ellipsoidal numerous macronuclei; 14 somatic kineties; 3 or 4 short dorsal brush rows; dorsal brush about 2 μm in length.

Distribution. Cosmopolitan.

Remarks. The Korean population of *C. vorax* is different from the Chinese population in the body length (about 90 μm vs. 100-180 μm) and number of somatic kineties (14 vs. 11 or 12) (Song and Packroff, 1996/97). *Chaenea vorax* differs from the most similar species *C. teres* (Dujardin, 1841) Kent, 1881 by the shape of oral extrusomes (wedge-like shape vs. rod-like shape), the length of extrusomes (5-6 μm vs. 9 μm) and the length of dorsal brush (2 μm vs. 10 μm) (Fan *et al*., 2015).

Voucher slide. One slide of protargol-impregnated specimens was deposited at National Institute of Biological Resources, Korea (NIBRPR0000109439).

Family Enchelyidae Ehrenberg, 1838
Genus *Enchelys* O. F. Müller, 1773

13. *Enchelys gasterosteus* Kahl, 1926 (Fig. 13)

Material examined. Freshwater with debris collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on January 22, 2018.

Diagnosis. Body size 75-100 × 35-50 μm *in vivo*; body slightly contractile and flexible with oval to ellipsoidal

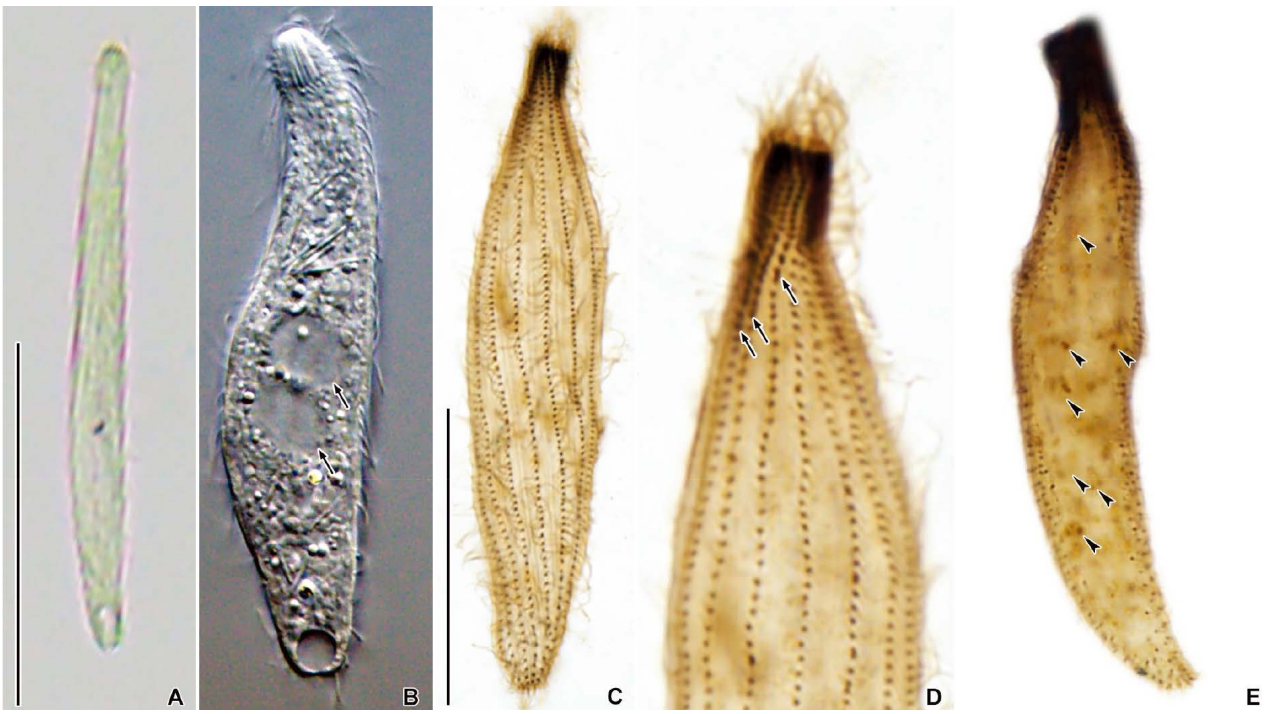

Fig. 12. *Chaenea vorax in vivo* (A, B) and after protargol impregnation (C-E). A. Typical individual. B. Oral and cytoplasmic extrusomes and contractile vacuole (arrows indicate food vacuoles). C. Somatic ciliature. D. Detail of dorsal brush rows (arrows). E. Macronuclear nodules (arrowheads). Scale bars = 50 μm (A); 30 μm (C).

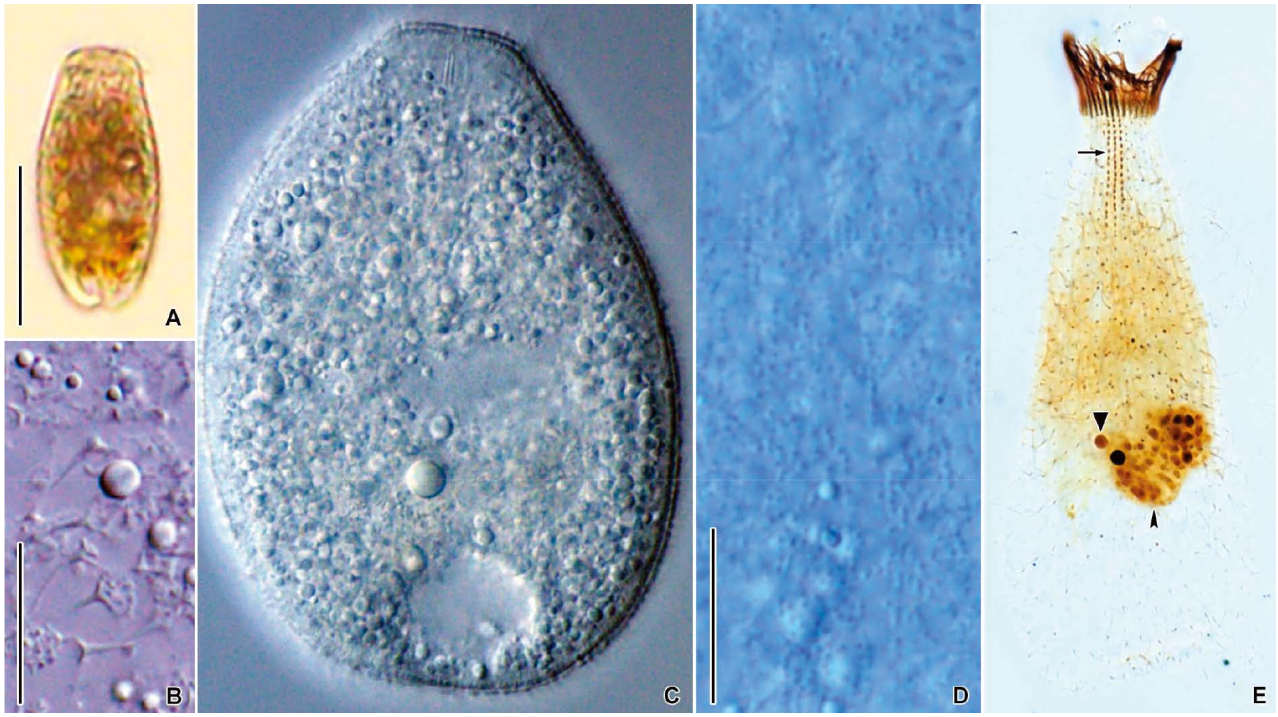

Fig. 13. *Enchelys gasterosteus in vivo* (A-D) and after protargol impregnation (E). A. Typical individual. B. Conical structure after specimen squashed. C. Cytoplasmic inclusions with extrusomes and contractile vacuole. D. Cortical granules. E. Somatic ciliature with dorsal brush row (arrow) and micro-(triangular arrowhead) and macronucleus (arrowhead). Scale bars = 50 μm (A); 10 μm (B, D).

shape; single contractile vacuole terminally located; oral bulge extrusomes rod-shaped; spherical cortical granules colorless 0.3-0.5 μm in diameter; single oval to ellipsoidal macronucleus, size about 13 × 9 μm; 7 micronuclei; 29-32 somatic kineties; circumoral kinety absent; 3 dorsal brush rows; conical structures inconspicuous in living cell but conspicuous after squashed.

Distribution. Austria, Germany, Korea.

Remarks. *Enchelys gasterosteus* is similar to *E. simplex* Kahl, 1926. The former is, however, smaller than the latter (70-100 μm vs. 150 μm) and has fewer number of somatic kineties (29-32 vs. 44-50) (Foissner, 1984; Foissner *et al*., 1995).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109419, NIBRPR0000109420).

Family Lacrymariidae de Fromentel, 1876
Genus *Phialina* Bory de St. Vincent, 1824

14. *Phialina salinarum* (Kahl, 1928) Hu, Gong and Song, 2003 (Fig. 14)

Material examined. Marine water (salinity 29.6‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on May 24, 2018.

Diagnosis. Body size 75-115 × 18-24 μm *in vivo*; body vase shape; contractile and flexible; phialinid ciliary wreath absent; single contractile vacuole terminally located; single ellipsoidal macronucleus; oral extrusome present; cortical granules colorless, spherical shape, size about 0.5 × 0.7 μm; 17 somatic kineties.

Distribution. China, Germany, Korea.

Remarks. *Phialina salinarum* differs from *P. coronata* (Claparède and Lachmann, 1858) in the body length (75-115 μm vs. 160-200 μm) and the shape of macronucleus (ellipsoidal vs. elongated ellipsoidal) (Long *et al*., 2009; Kahl, 1930; Foissner *et al*., 1995).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109428, NIBRPR0000109429) and two slides were deposited at the National Marine Biodiversity Institute of Korea (MABIK PR00043179, MABIK PR00043180).

Family Mesodiniidae Jankowski, 1980
Genus *Mesodinium* Stein, 1863

15. *Mesodinium pulex* Claparède and Lachmann, 1858 (Fig. 15)

Material examined. Marine water (salinity 28‰) col-

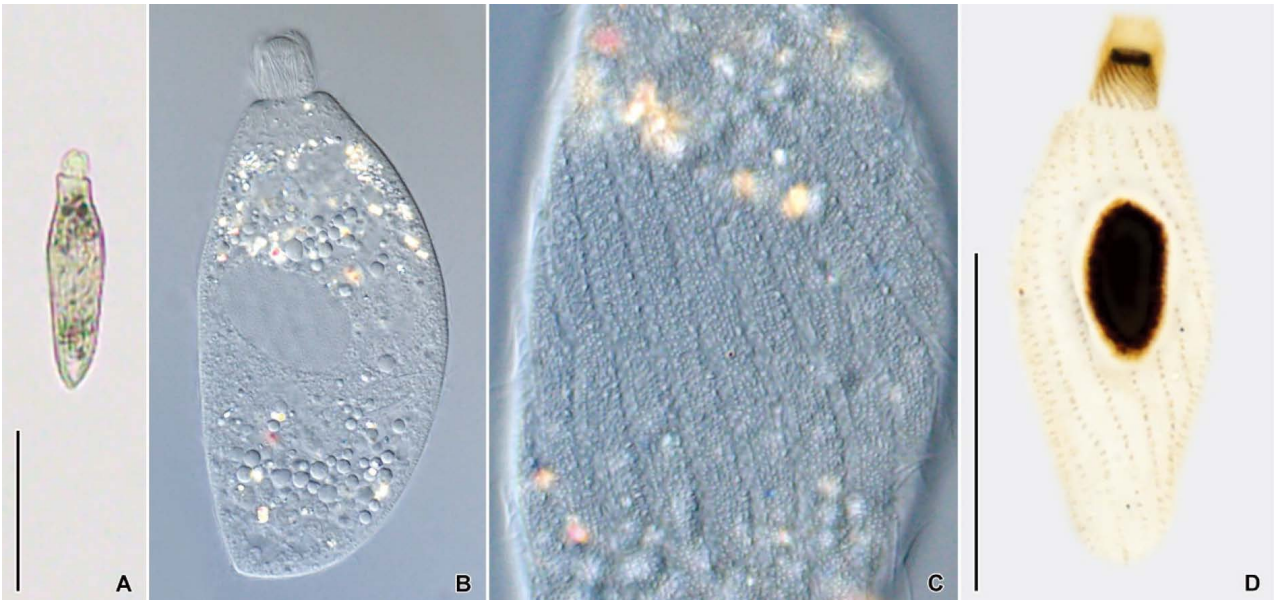

Fig. 14. *Phialina salinarum in vivo* (A-C) and after protargol impregnation (D). A. Typical individual. B. Details of oral extrusomes and macronucleus with cytoplasmic inclusions. C. Cortical granules. D. Oral and somatic ciliature with macronuclear apparatus. Scale bars = 50 μm (A); 30 μm (D).

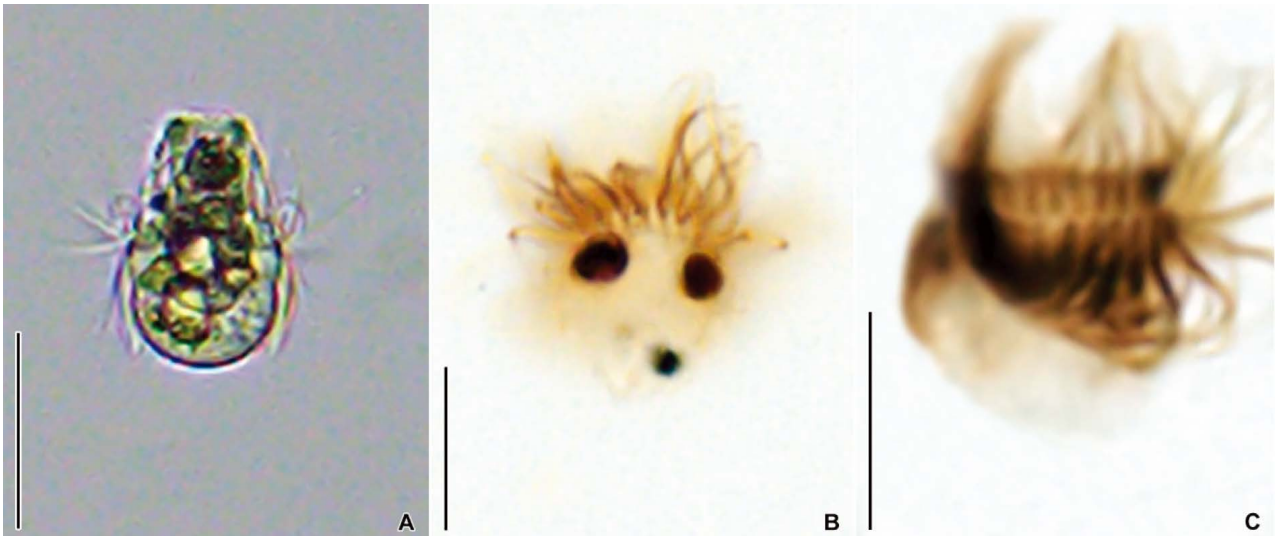

Fig. 15. *Mesodinium pulex in vivo* (A) and after protargol impregnation (B, C). A. Typical individual. B. Two macronuclear nodules. C. Somatic ciliature. Scale bars = 30 μm (A); 10 μm (B, C).

lected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on June 1, 2018.

Diagnosis. Body size about 38 × 23 μm *in vivo*; about 15 × 12 μm after protargol impregnation; body pyriform; 2 oval macronuclei; 2 distinct ciliary girdles consisted of 23-28 short rows: anterior-most tuft obliquely and anteriorly directed, middle tuft horizontally directed and posterior most tuft obliquely posteriorly directed.

Distribution. Cosmopolitan.

Remarks. *Mesodinium pulex* is different from the most similar species, *M. acarus* Stein, 1867, in the body length (38 μm vs. less than 20 μm) and number of macronuclei (2 vs. 1) (Foissner *et al*., 1999; Long *et al*., 2009).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109432, NIBRPR0000109433) and one slide was deposited at the National Marine Biodiversity Institute of Korea (MABIK PR00043185).

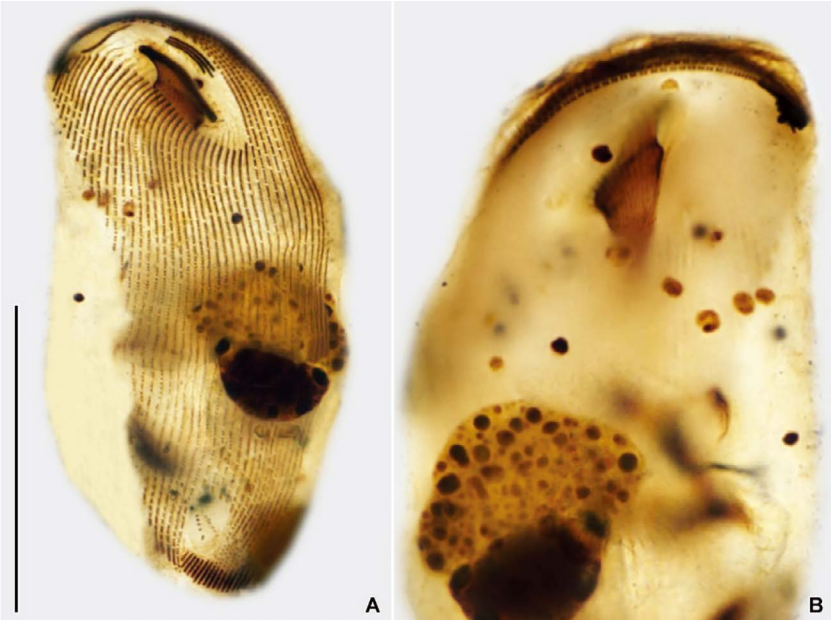

Fig. 16. *Aegyria oliva* after protargol impregnation. A. Ventral view. B. Dorsal view showing ciliature, pharyngeal rods and macronuclear apparatus. Scale bar = 50 μm.

Class Phyllopharyngea de Puytorac *et al*., 1974
Order Dysteriida Deroux, 1976
Family Hartmannulidae Poche, 1913
Genus *Aegyria* Claparède and Lachmann, 1859

16. *Aegyria oliva* Claparède and Lachmann, 1859 (Fig. 16)

Material examined. Marine water (salinity 29‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2′E) on June 7, 2018.
Diagnosis. Body size about 96 × 49 μm after protargol impregnation; body shape oval to roughly sigmoid; dark pigment spot on anterior left part; anterior left protrusion absent; single ellipsoidal macronucleus; about 42 somatic kineties; 1 preoral kinety; 3 circumoral kineties; about 7 transpodial segments; 30 nematodesmal rods.
Distribution. China, Germany, Korea.
Remarks. *Aegyria oliva* is similar to *A. apoliva* Chen Li, Al-Farraj, Ma and Pan, 2018. The former is, however, different from the latter by the anterior left protrusion (absent vs. present), the numbers of somatic kineties (about 42 vs. 48-69) and transpodial segments (7 vs. 9-13) (Gong *et al*., 2009; Chen *et al*., 2018).
Voucher slide. One slide of protargol-impregnated specimens was deposited at National Institute of Biological Resources, Korea (NIBRPR0000109436).

Class Colpodea Small and Lynn, 1981
Order Bryometopida Foissner, 1985
Family Bryometopidae Jankowski, 1980
Genus *Bryometopus* Kahl, 1932

17. *Bryometopus pseudochilodon* Kahl, 1932 (Fig. 17)

Material examined. Terrestrial moss collected from Samsan-ri, Yeongok-myeon, Gangneung-si, Gangwon-do, Korea (37°48′37.6″N, 128°41′54.4″E) on December 16, 2017.
Diagnosis. Body size about 65 × 25 μm *in vivo*, 39-61 × 19-27 μm after protargol impregnation; buccal field 19-26 μm in length; body roughly reniform; single contractile vacuole centrally located; 18 or 19 adoral membranelles; single oval to ellipsoidal macronucleus, size about 9 × 4 μm; single spherical micronucleus; 23-27 somatic kineties.
Distribution. Austria, Australia, Belgium, Bulgaria, Canada, Côte d'Ivoire, Germany, Greece, Hungary, New Zealand, Tibet, U.S.A., Korea.
Remarks. The Korean population of *B. pseudochilodon* is different from the Austrian population in the number of micronucleus (constantly 1 vs. 2-4). *Bryometopus pseudochilodon* differs from the most similar species *B. edaphonus* Foissner, 1980 by the location of contractile vacuole (centrally vs. subterminally), the number of somatic kineties (23-27 vs. 16-20), and centrally located single nucleolus (absent vs. present) (Foissner, 1993).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Bi-

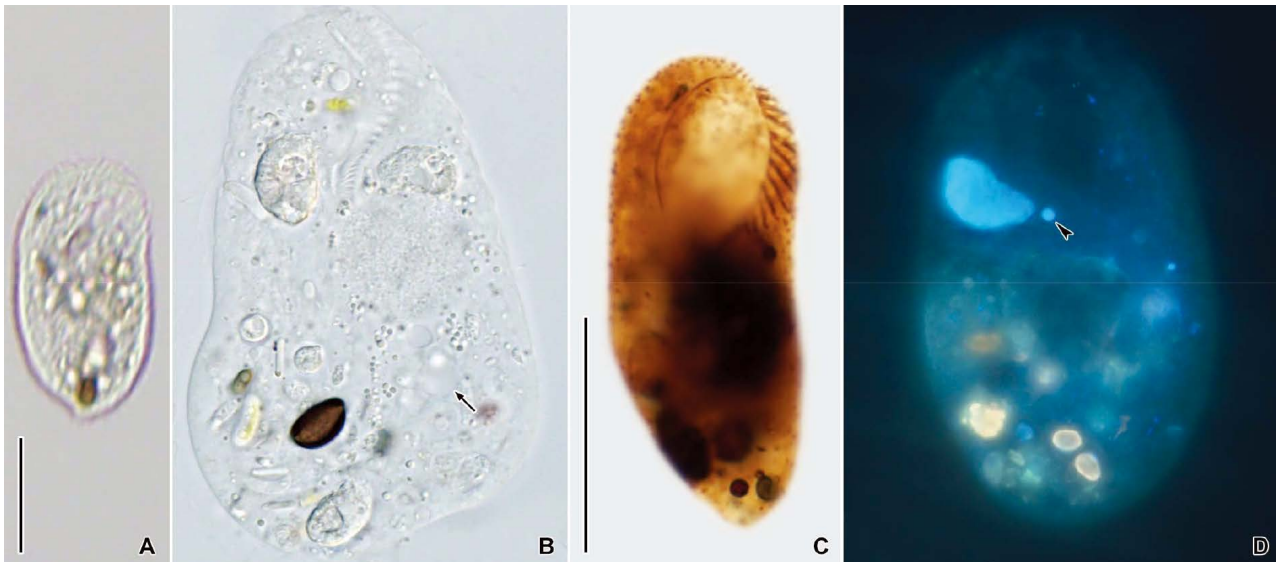

Fig. 17. *Bryometopus pseudochilodon in vivo* (A, B), after protargol impregnation (C) and DAPI staining (D). A. Typical individual. B. Contractile vacuole (arrow). C. Oral ciliature. D. Ellipsoidal macronucleus and single spherical micronucleus (arrowhead). Scale bars = 30 μm.

ological Resources, Korea (NIBRPR0000109430, NIBRPR0000109431).

Class Prostomatea Schewiakoff, 1896
Order Prorodontida Corliss, 1974
Family Colepidae Ehrenberg, 1838
Genus *Pinacocoleps* Diesing, 1865

18. *Pinacocoleps tesselatus* (Kahl, 1930) Foissner, Kusuoka and Shimano, 2008 (Fig. 18)

Material examined. Brackish water (salinity 8.6‰) collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on September 19, 2017.
Diagnosis. Body size 42-46 × 25-26 μm *in vivo*; about 30 × 20 μm after protargol impregnation; oval body shape; 23-25 ciliary rows, each composed of about 12 monokinetids; 1 macronucleus size 6-10 × 5-7 μm; one contractile vacuole terminally located; single caudal cilium length about 15-20 μm; anterior and posterior main plates with 3 teeth, respectively; about 2 posterior spines; habitat brackish water.
Distribution. China, Germany, U.S.A., Korea.
Remarks. The Korean population of *P. tesselatus* is slightly different from the Chinese population in the body length (42-46 μm vs. 60-85 μm) and number of monokinetids (12 vs. 11) (Lu *et al*., 2013). However, the Korean and American populations are similar in the body size, but different by the number of anterior plate teeth (3 vs. 5) (Borror, 1972).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109434, NIBRPR0000109435).

Class Oligohymenophorea de Puytorac *et al*., 1974
Order Philasterida Small, 1967
Family Urozonidae Grolière, 1975
Genus *Urozona* Schewiakoff, 1889

19. *Urozona buetschlii* Schewiakoff, 1889 (Fig. 19)

Material examined. Freshwater collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on April 12, 2018.
Diagnosis. Body size 12-15 × 9-12 μm after protargol impregnation; dumb-bell shape *in vivo*; single oval macronucleus; merged peniculi 2 + 3; undulating membrane present but inconspicuous; equatorially arranged girdle-like 23-25 somatic kineties; obliquely extended somatic kineties on right of oral field; longitudinally arranged somatic kineties on dorsal side; shortest somatic kineties on left of oral field.
Distribution. Austria, France, Germany, Hungary, Italia, Korea.
Remarks. The extended first somatic kinety on the right side was easily mistaken to be undulating membrane (Foissner *et al*., 1994; Olmo *et al*., 1998). *Urozona* is a monotypic genus and recognized by a dumb-bell shaped body and equatorially restricted somatic kineties (Foissner *et al*., 1994).
Voucher slide. One slide of protargol-impregnated spec-

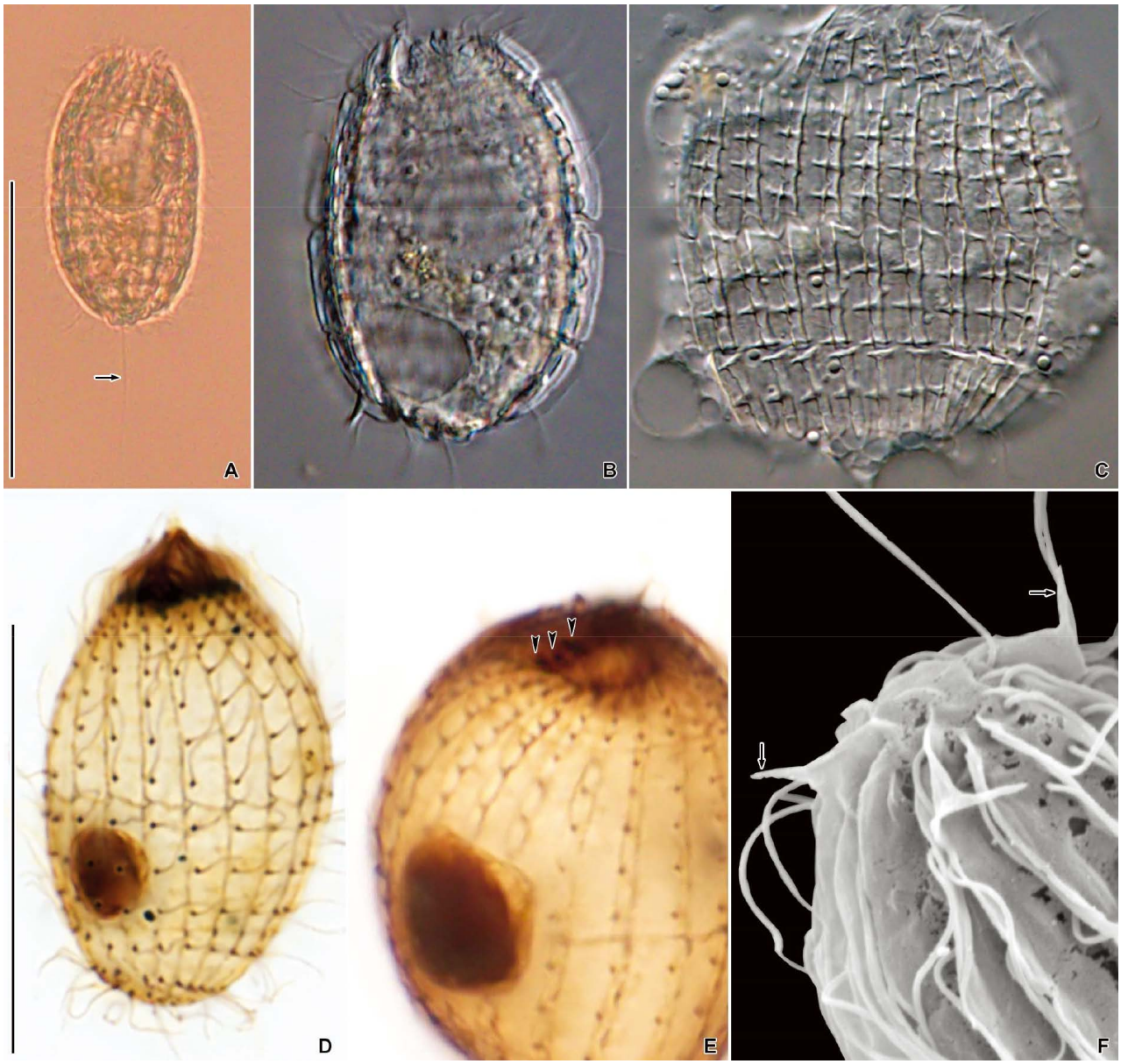

Fig. 18. *Pinacocoleps tesselatus in vivo* (A-C), after protargol impregnation (D, E) and scanning electron microscope (F). A. Typical individual and caudal cilium (arrow). B. Contractile vacuole and posterior spine. C. Surface of armor plates. D. Somatic kineties and macronucleus. E. Adoral organelles (arrowheads). F. Posterior spines (arrows). Scale bars = 50 μm (A), 30 μm (D).

imens was deposited at National Institute of Biological Resources, Korea (NIBRPR0000109423).

Order Tetrahymenida Fauré-Fremiet in Corliss, 1956
Family Turaniellidae Didier, 1971
Genus *Colpidium* Stein, 1860

20. *Colpidium colpoda* (Losana, 1829) Ganner and Foissner, 1989 (Fig. 20)

Material examined. Freshwater collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on November 9, 2017.

Diagnosis. Body size 62-73 × 29-32 μm after protargol impregnation; oval to reniform; single ellipsoidal macronucleus, size about 26 × 10 μm; single oval to spherical micronucleus size about 3-4.5 μm; 3 peniculi; semicircular undulating membrane; 60-66 somatic kineties; 2 secondary meridians between primary meridians in silverline system.

Distribution. Cosmopolitan.

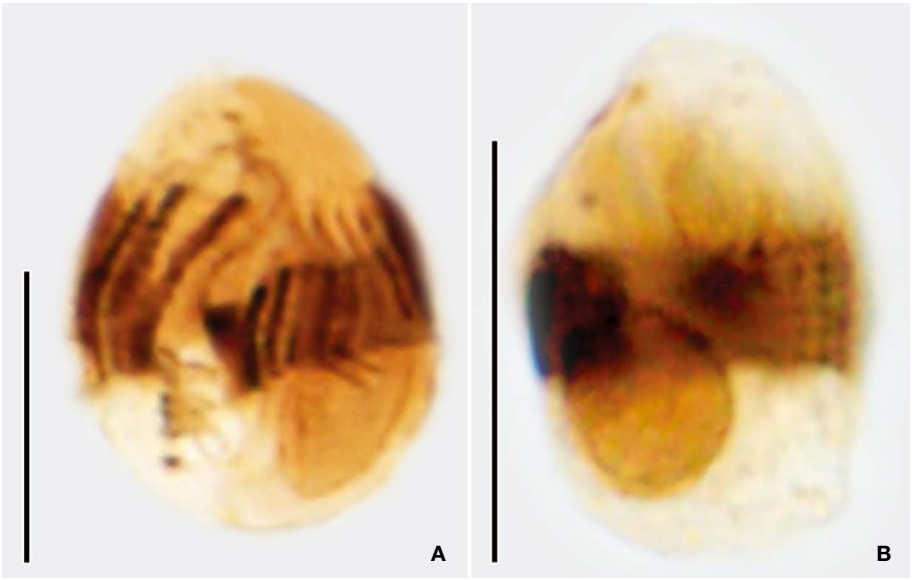

Fig. 19. *Urozona buetschlii* after protargol impregnation. A. Oral and somatic ciliature on ventral side. B. Equatorially restricted somatic ciliature on dorsal view and spherical macronucleus. Scale bars = 10 μm.

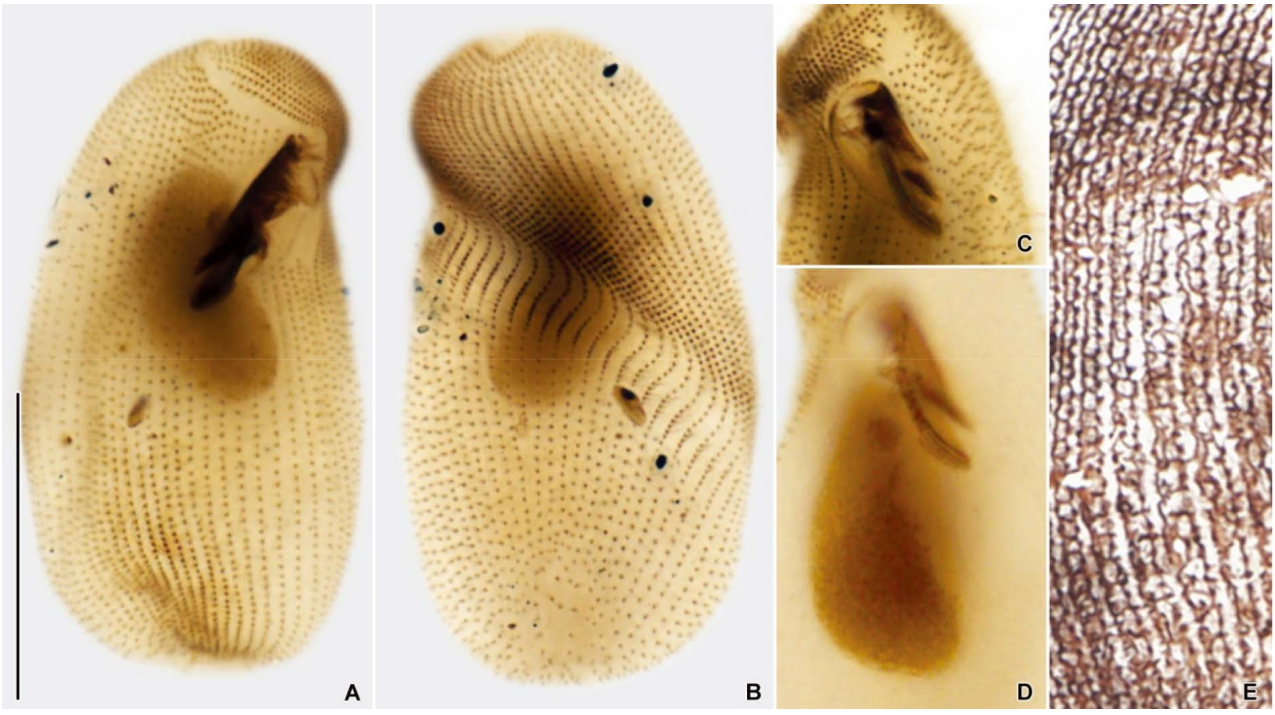

Fig. 20. *Colpidium colpoda* after protargol (A-D) and 'dry' silver nitrate impregnation (E). A. Ventral ciliature. B. Dorsal ciliature. C. Detail of oral ciliature. D. Macro- and micronucleus. E. Two secondary meridians between primary meridians in silverline system. Scale bar = 30 μm (A).

Remarks. *Colpidium colpoda* is similar to *C. kleini* Foissner, 1969 but different by the number of secondary meridians (2 vs. 1) and the number of somatic kineties (60-66 vs. 32-44) (Foissner *et al*., 1994).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109413, NIBRPR0000109414).

Order Sessilida Kahl, 1933
Family Epistylididae Kahl, 1933
Genus *Campanella* Goldfuss, 1820

21. *Campanella umbellaria* (Linnaeus, 1767) Godfuss, 1820 (Fig. 21)

Material examined. Freshwater collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on October 25, 2017.

Diagnosis. Colony height about 2000 μm; rigid stalk; zooids bell-shaped, measuring 190-225 × 100-110 μm *in vivo*; peristomial lip width 130-140 μm; macronucleus horizontal C-shape; one contractile vacuole dorsally located; rectangular silverline system about 37-42 horizontal striation between peristomial lip and trochal band, about 33-38 striation between trochal band and scopula; haplokinety and polykinety parallel and spiral in counterclockwise direction four and one-half times around peristomial disc; infundibular polykinety 1 (P1) and P2 consisted 3 kineties; P3 composed of more than

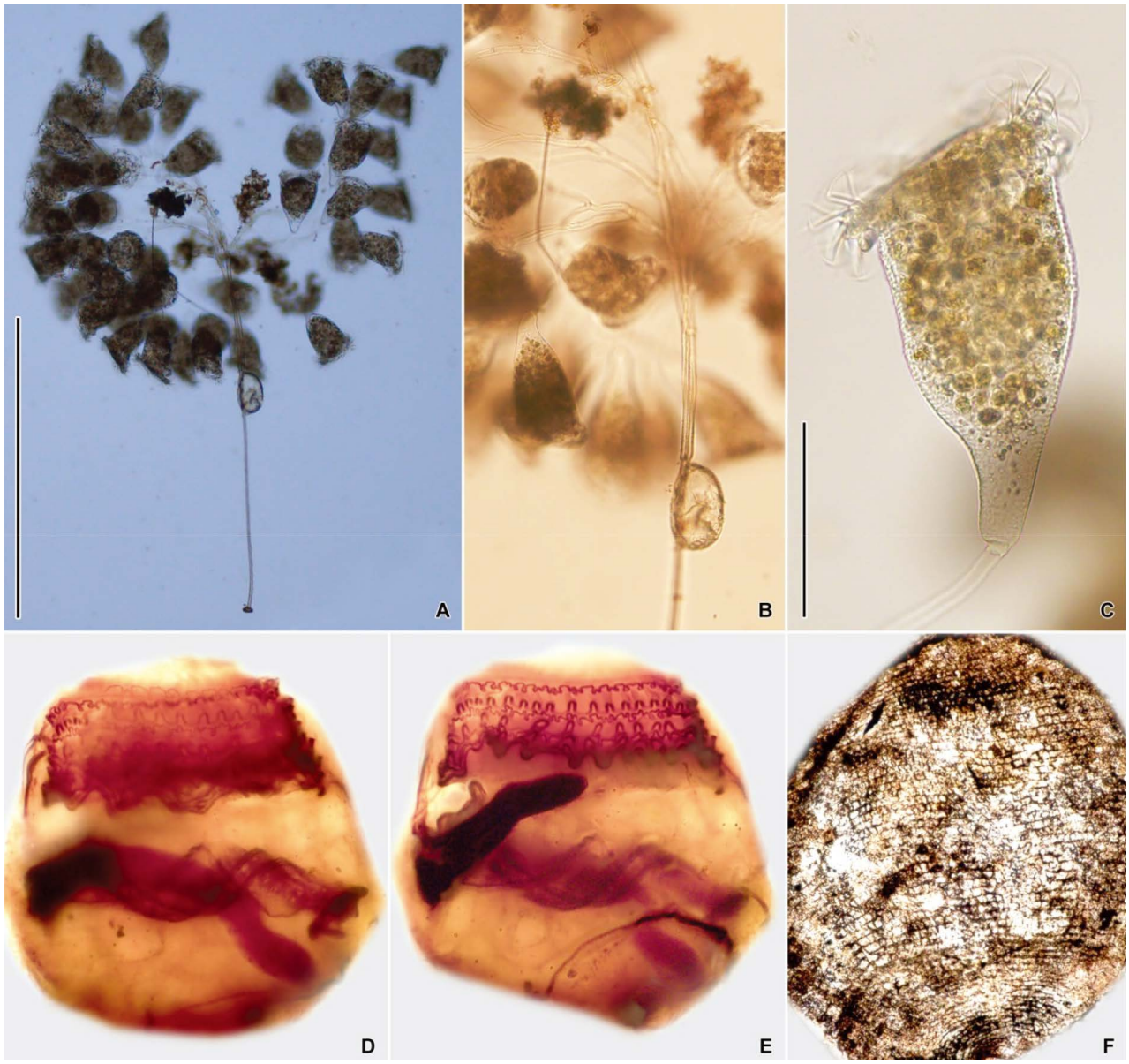

Fig. 21. *Campanella umbellaria in vivo* (A-C), after protargol (D, E) and 'dry' silver nitrate impregnation (F). A. Typical colony. B. Rigid stalk. C. Typical zooid. D. Infundibular polykinety. E. Haplo- and polykinety with macronucleus. F. Rectangular silverline system. Scale bars = 1000 μm (A), 100 μm (C).

5 kineties; P1-P3 1 turn of infundibulum; haplokinety of infundibulum accompanied belt-like filamentous reticulum.

Distribution. Cosmopolitan.

Remarks. *Campanella umbellaria* is common species in eutrophic freshwater environment (Shi *et al*., 2004). The main characters for the identification of this species are the four and one-half times turn haplokinety and polykinety on the peristomial disc (Foissner *et al*., 1992; Shi *et al*., 2004).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109411, NIBRPR0000109412).

Family Vorticellidae Ehrenberg, 1838
Genus *Pseudovorticella* Foissner and Schiffmann, 1975

22. *Pseudovorticella difficilis* (Kahl, 1933) Jankowski, 1976 (Fig. 22)

Material examined. Marine water (salinity 29.6‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on May 24, 2018.

Diagnosis. Zooid size 45-50 × 32-39 μm *in vivo*; inverted bell-shaped; peristomial lip width about 41-47 μm; annular swellings present on stalk; macronucleus longitudinally oriented J-shape; one contractile vacuole dorsally located; rectangular silverlines about 35 striations between peristomial lip and trochal band, about 18 striations between trochal band and scopula; P1-P3 consisted of 3 rows, shorter inner 1 row of P3, longer and closely spaced outer 2 rows of P3.

Distribution. China, Germany, Korea.

Remarks. The Korean population of *P. difficilis* is slightly different from the Chinese population in the zooid size (45-50 μm vs. 50-70 μm) (Ji *et al*., 2006; Sun *et al*., 2009). A freshwater *P. difficilis* var. *magnistriata* is larger than the marine Korean population (60-140 μm vs. 45-50 μm) and fewer transverse silverlines between peristomial lip and trochal band (25-31 vs. 35) (Foissner and Schiffmann, 1974; Ji *et al*., 2006).

Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109437, NIBRPR0000109438) and four slides were deposited at the National Marine Biodiversity Institute of Korea (MABIK PR00043196-PR00043199).

Family Zoothamniidae Sommer, 1951
Genus *Zoothamnium* Bory de St. Vincent, 1824

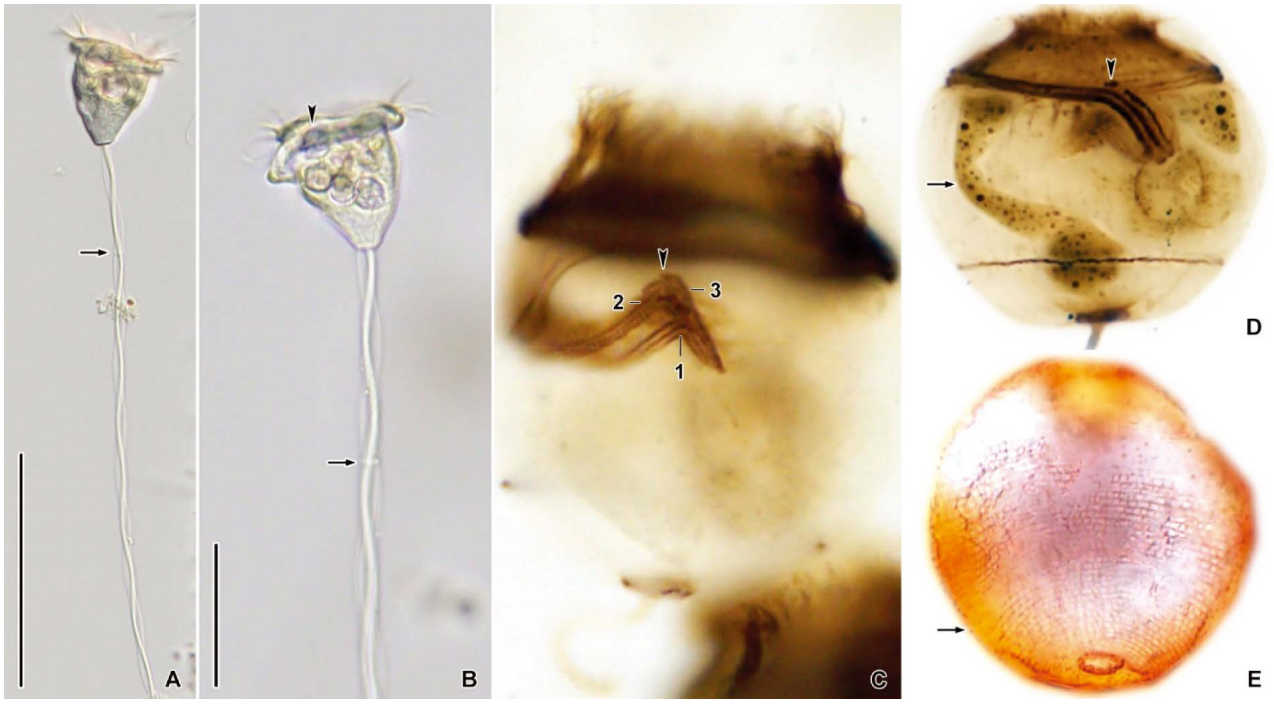

Fig. 22. *Pseudovorticella difficilis in vivo* (A, B), after protargol (C, D) and 'wet' silver nitrate impregnation (E). A. Typical individuals and annular swelling (arrow) on stalk. B. Contractile vacuole (arrowhead) and annular swelling (arrow) on stalk. C. Infundibular polykinety 1-3 (arrowhead indicates longer and closely spaced outer two rows). D. Epistomial membrane (arrowhead) and macronucleus (arrow). E. Rectangular silverlines (arrow indicates trochal band). Scale bars=100 μm (A), 50 μm (B).

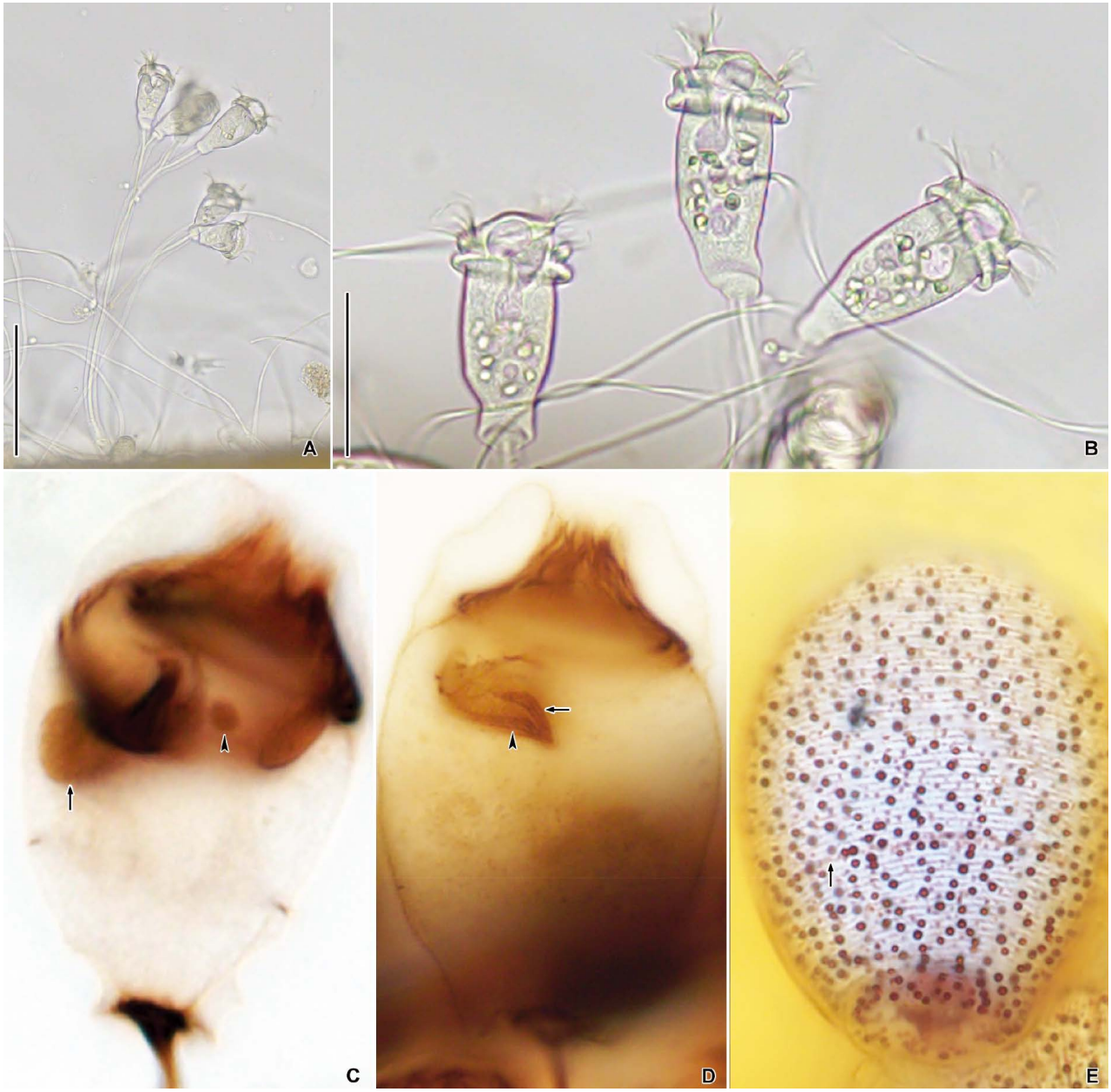

Fig. 23. *Zoothamnium parahiketes in vivo* (A, B), after protargol (C, D) and 'wet' silver nitrate impregnation (E). A. Colony shape. B. Shape of zooids. C. Macro-(arrow) and micronucleus (arrowhead). D. Infundibular polykinety 2 (P2) (arrowhead) and P3 (arrow). E. Silverline system (arrow indicates trochal band). Scale bars=100 μm (A), 50 μm (B).

23. *Zoothamnium parahiketes* Sun, Ji, Song and Warren, 2009 (Fig. 23)

Material examined. Marine water (salinity 29.6‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N, 128°59′24.2″E) on May 24, 2018.

Diagnosis. Colony height 300-500 μm; stalk dichotomously branched; zooid elongated bell-shaped, measuring 60-80 × 25-30 μm *in vivo*; double-layered peristomial lip width 34-38 μm; horizontal C-shaped macronucleus; one contractile vacuole dorsally located; transverse silverlines 49-63 striations between peristomial lip and trochal band, about 21-32 striations between trochal band and scopula; two epistomial membranes; P1-3 consisted 3 kineties; P3 slightly separated inner row and outer 2 rows.

Distribution. China, Korea.

Remarks. *Zoothamnium parahiketes* is different from *Z. hiketes* Precht, 1935 in the number of silverlines between

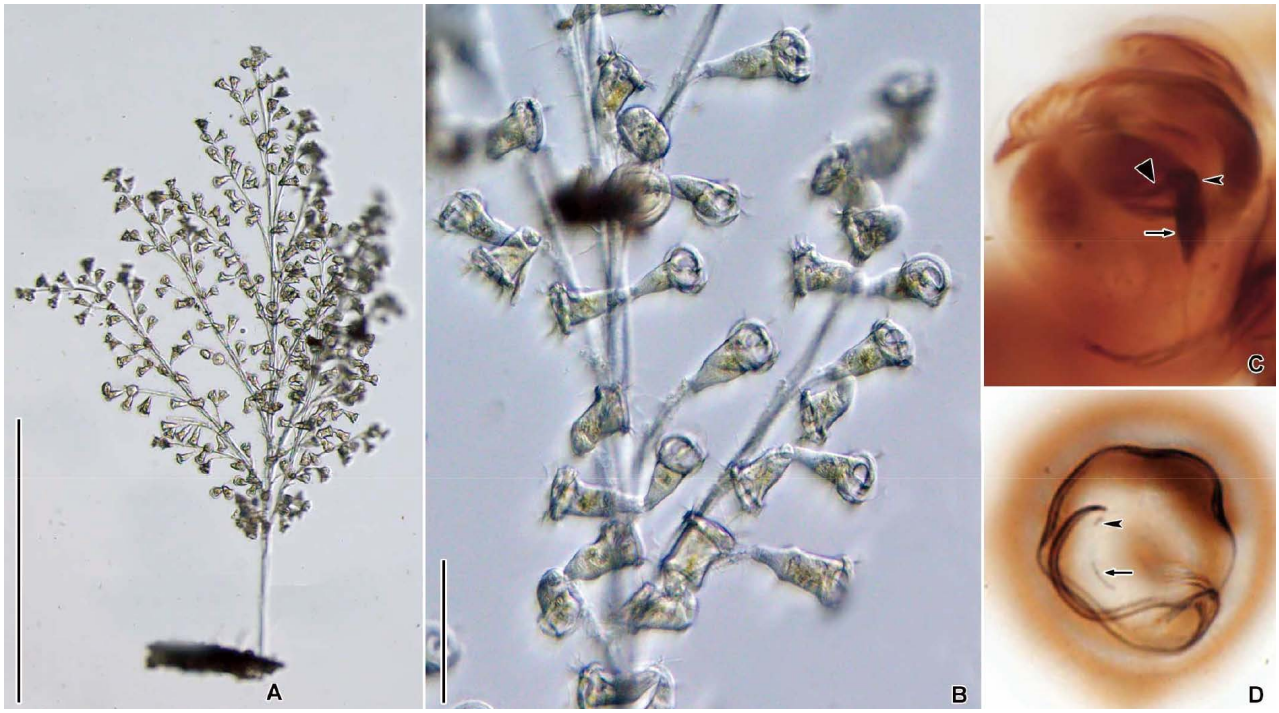

Fig. 24. *Zoothamnium plumula in vivo* (A, B) and after protargol impregnation (C, D). A. Colony shape. B. Zooids and branching patterns. C. Infundibular polykinety 1 (P1) (arrow), P2 (triangular arrowhead) and P3 (arrowhead). D. Haplo- and polykinety with epistomial membrane 1 (EM1) (arrow) and EM2 (arrowhead) on apical view. Scale bars=1000 μm (A), 100 μm (B).

the peristomial lip and trochal band (49-63 vs. 89-109) and between the trochal band and scopula (21-32 vs. 35-43), and a gap between of inner row and outer two rows of P3 (present vs. absent) (Sun *et al*., 2005; Ji *et al*., 2009).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109473, NIBRPR0000109474) and the two slides were deposited at the National Marine Biodiversity Institute of Korea (MABIK PR00043200, PR00043201).

24. *Zoothamnium plumula* Kahl, 1933 (Fig. 24)

Material examined. Brackish water (salinity 10‰) collected from Gyeongpocheon River, Unjeong-dong, Gangneung-si, Gangwon-do, Korea (37°47′20″N, 128°54′34″E) on July 13, 2017.
Diagnosis. Colony height about 2100 μm; colony fan-like shape; alternatively branched; contractile stalk; zooid elongated bell-shaped, measuring 55-72 × 25-27 μm *in vivo*; single-layered peristomial lip width 38-40 μm; horizontal C-shaped macronucleus; one contractile vacuole dorsally located; transverse silverlines about 60 striations between peristomial lip and trochal band, about 25 striations between trochal band and scopula; two epistomial membranes; P1 and P2 consisted 3 kineties; P3 slightly separated inner row and outer two rows.
Distribution. China, Germany, Korea.
Remarks. The Korean population of *Z. plumula* is slightly different from the Chinese population in the colony shape (fan-like vs. feather-like) (Song *et al*., 2002; Ji *et al*., 2009). The Korean population is possibly a well-developed form because the colony shape is sometimes changeable (Ji *et al*., 2015).
Voucher slides. Two slides of protargol-impregnated specimens were deposited at National Institute of Biological Resources, Korea (NIBRPR0000109421, NIBRPR0000109422).

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