Taxonomic survey on ciliate diversity in eastern area of Kangwon-province, Korea: Brief records of fifteen species unrecorded from Korea

Ji-Yeong Kim and Jae-Ho Jung*

Department of Biology, Gangneung-Wonju National University, Gangneung 25457, Republic of Korea

*Correspondent: jhjung@gwnu.ac.kr

Based on the taxonomic survey to uncover the ciliate diversity in the eastern Kangwon-province, twenty-six species were identified from moss-covered soils and assigned to 5 classes, 9 orders, 12 families, and 15 genera. Of these, fifteen species are first records from Korea, and brief remarks with photographs were provided.

Keywords: morphology, protargol impregnation, soil ciliates

INTRODUCTION

In terms of the ciliate diversity in Korea, more than 200 species have been reported (National Institute of Biological Resources, 2012) and new species were increasingly discovered using modern techniques (e.g., DNA analyses, silver staining) (for new species published in 2015, see Ji et al., 2015; Jo et al., 2015; Jung et al., 2015; Nam et al., 2015). However, because of ciliate’s small size and fragile body, the taxonomic study in Korea was slow in progress and needs well-trained taxonomic experts to uncover the hidden diversity (See Aescht, 2013 - more than 1,000 species were reported in Austria).

Unexplored environments for the ciliate diversity in Korea have been remained for huge area and few studies, usually from marine ecosystems, were reported from the eastern area of Kangwon-province, Korea (National Institute of Biological Resources, 2012; Park and Min, 2015). To uncover the hidden diversity of inhabitants in that area, here we focused on soil environments and identified twenty-six ciliates based on the observation of living cells and stained specimens. Of the species, fifteen ciliates are newly recorded from Korea.

MATERIALS AND METHODS

Thirteen moss-covered soil samples were collected from the eastern area in Kangwon-province (for details see Table 1). The samples were air-dried for days before rewetting. Raw cultures were maintained using the non-flooded Petri dish culture method at room temperature or 18°C (Foisssner et al., 2002) while pure cultures were unsuccessful.

For species identification, the living cells and protargol-impregnated specimens were observed according to Foisssner (2014). We followed the ‘procedure A’ with the acetone developer for the protargol-staining (Foisssner, 2014). To synthesize the protargol, the core chemical for the cytological staining, we followed Pan et al. (2013). Casually we fixed supernatant waters in samples using Bouin’s fluid or ethanol, and centrifuged the fixed samples to obtain smaller ciliates. After the centrifugation (3,000 rpm for 1 min; Beckman GS-15R, CA), the supernatant was discarded. Stereomicroscope (Olympus SZ11, Japan) was used to observe cell movement and shape, and for the handling of staining procedure. The light microscope (Olympus BX53, Japan) and the digital cameras (Sony α7R, Japan; Nikon DS-Ri2, Japan) were used to observe and capture the other morphological features which can be observed at high magnification (40× to 1,000× with differential interference contrast). Helicon Focus software (HeliconSoft Ltd, Ukraine) was used to merge sequential through-focal images of the stained specimens.

General terminology and classification follows Lynn (2008). For the specific terms, we followed the references mentioned in Table 1.
RESULTS AND DISCUSSION

From the non-flooded Petri dish cultures, we identified twenty-six ciliates (Table 1). Of these, fifteen species were newly recorded from Korea. To examine and obtain smaller ciliates, we casually used the centrifugation of the fixed samples and successfully obtained the species with <50 μm in length (e.g., Drepanomonas, Leptopharynx). In addition, as mentioned by Foissner (2014), some ciliates were not fixed well using the Bouin’s fluid. For example, Urosoma emarginata burst in the fluid while ethanol was very effective for the fixation. Classifications of the twenty-six species are as follows: 5 classes, 9 orders, 12 families (for Saudithrix, incertae sedis at family-level in order Stichotrichida; for the classification in detail see Berger et al. (2006) and Berger (2011)), and 15 genera.

In terms of the diversity, unrecorded ciliates in Korea would be much higher than the number of previously reported ciliates from Korea (National Institute of Biological Resources, 2012) because of the broad terrestrial area unexplored yet and the marine ecosystems surrounding the country. For example in this study, we observed and obtained the specimens belonging to the class Nassophorea for the first time in Korea. They were maintained only in raw cultures (e.g., non-flooded Petri dish method) and we failed to establish pure cultures.

Of the twenty-six species, Cyrtohymena quadrimuscorum, Gonostomum affine and Urosoma emarginata were most commonly occurred from our samples and showed higher abundances than the others (see Table 1). They were already reported in Korea (Shin and Kim, 1995; 1996; Shin, 2012).

Brief remarks for the fifteen unrecorded species are as follows (Table 1; Figs. 1, 2):

Phylum Ciliophora Doflein, 1901
Class Colpodea Small and Lynn, 1981
Order Colpodida de Puytorac et al., 1974
Family Grossglockneriidae Foissner, 1986

Table 1. Ciliate fauna in the 13 moss-covered samples collected from mountains (for details, see footnotes).

| Species                              | GU1 | GU2 | Do | D1 | D2 | D3 | D4 | TB1 | TB2 | TB5 | TB6 | TB9 | TB10 | Ref                  |
|--------------------------------------|-----|-----|----|----|----|----|----|-----|-----|-----|-----|-----|------|----------------------|
| Anteholosticha distyla*              |     |     |    |    |    |    |    |     |     |     |     |     |      | Berger (2006)        |
| Anteholosticha intermedia            |     |     | +  | +  |    |    |    |     |     |     |     |     |      | Berger (2006)        |
| Caudiholostycha sylvatica            |     |     |    | +  | +  |    |    |     |     |     |     |     |      | Berger (2006)        |
| Cultellothrix coemeterii*            |     |     |    |    |    |    | +  |     |     |     |     |     |      | Foissner and Xu (2007) |
| Cyrtomyctena muscorum                |     |     |    |    |    |    |    |     |     |     |     |     | +    | Berger (1999)        |
| Cyrtomyctena quadrimuscorum          |     |     |    |    |    |    |    |     |     |     |     |     |      | Berger (1999)        |
| Drepanomonas hymenofera hymenofera*  |     |     |    |    |    |    |    |     |     |     |     |     |      | Omar and Foissner (2013) |
| Blepharisma hyalinum*                |     |     |    |    |    |    |    |     |     |     |     |     |      | Aescht and Foissner (1998) |
| Blepharisma steini                   |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner (1989)      |
| Frontonia depressa*                  |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner et al. (2002) |
| Furgasonia rubens*                   |     |     |    |    |    |    |    |     |     |     |     |     |      | Dragesco and Dragesco-Kernéis (1986) |
| Gonostomum affine                    |     |     |    |    |    |    |    |     |     |     |     |     | +    | Berger (2011)        |
| Gonostomum gonostomoidum             |     |     |    |    |    |    |    |     |     |     |     |     |      | Berger (2011)        |
| Grossglockneria acuta*               |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner (1993)      |
| Halteria grandinella                 |     |     |    |    |    |    |    |     |     |     |     |     |      | Petz and Foissner (1992) |
| Holostichides chardezi               |     |     |    |    |    |    |    |     |     |     |     |     |      | Berger (2006)        |
| Leptopharynx costatus costatus*      |     |     |    |    |    |    |    |     |     |     |     |     | +    | Omar and Foissner (2012b) |
| Monomicrocaryon balladynea           |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner (2016)      |
| Nivaliella plana*                    |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner (1993)      |
| Notothyena antarctica*               |     |     |    |    |    |    |    |     |     |     |     |     |      | Berger (1999)        |
| Obertrumia gracilis*                 |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner (1989)      |
| Oxytrichella mahadjacola*            |     |     |    |    |    |    |    |     |     |     |     |     |      | Foissner (2016)      |
| Periholosticha paucidistata*         |     |     |    |    |    |    |    |     |     |     |     |     | +    | Berger (2006)        |
| Phacodinium metrichoidefi*           |     |     |    |    |    |    |    |     |     |     |     |     |      | Fernandez-Galiano and Calvo (1992) |
| Saudithrix terricola*                |     |     |    |    |    |    |    |     |     |     |     |     | +    | Berger et al. (2006) |
| Urosoma emarginata                   |     |     |    |    |    |    |    |     |     |     |     |     |      | Berger (1999)        |

*first record in Korea. GU1 and GU2 - two samples from a mountain near the Gangneung-Wonju University (37°46′N/128°52′E; Oct, 2015); Do - a sample from a mountain near the Donghae-youth training center (37°32′N/129°4′E; Mar, 2016); DC1-4 - four samples from near the entrance of trail the Chorock peak (37°32′N/129°5′E; Mar, 2016); TB1, TB2, TB5, TB6, TB9, TB10 - samples from the trail of Taeback mountain (37°6′N/128°54′E; May, 2016); Ref - references used for species identification.
Genus *Grossglockneria* Foissner, 1980

1. *Grossglockneria acuta* Foissner, 1980 (Fig. 1A)

**Diagnosis:** Body size 35 × 15 μm in protargol preparations; body fusiform, anterior and posterior body ends narrowly rounded. Macronuclear nodule spherical to elliptical, positioned at posterior half-body. Contractile vacuole at posterior body end. Cytoplasm colorless. Usually 10 somatic kineties, composed of dikinetid; spi-

---

**Fig. 1.** Protargol-stained specimens. A. *Grossglockneria acuta*, right side view, 35 μm in length; B. *Nivaliella plana*, right side view, 12 μm in length; C. *Blepharisma hyalinum*, right side view, 65 μm in length; D. *Cultellothrix costatulii*, left side view, 55 μm in length; E. *Drepanomonas hymenofera hymenofera*, right side view, 30 μm in length; F. *Leptopharynx costatus costatus*, right side view, 25 μm in length; G. *Obertrumia gracilis*, ventral view, 65 μm in length; H. *Furgasonia rubens*, ventral view, 45 μm in length.
3. **Blepharisma hyalinum** Perty, 1849 (Fig. 1C)  

**Diagnosis:** Body size 50-75 × 10-25 μm in protargol preparations; body shape roughly elliptical to fusiform; anterior end bluntly pointed and slightly curved. Nuclear apparatus composed of broadly elliptical macronuclear nodule and several micronuclei. Contractile vacuole at posterior body end. Cytoplasm colorless. Adoral zone composed of 19-25 membranelles and linear paroral membrane; buccal field about 50% of cell in length. Somatic kinetics consisted of 11-15 rows which curved at anterior half body.  

**Remark:** Of the species belonging to the genus *Blepharisma*, three species were reported from Korea (Lee and Shin, 2009; Shazib et al., 2014). They are usually reddish or bluish. However, depending on the culture condition, their color could be changed (Foissner et al., 2002). *Blepharisma hyalinum* is colorless and can be distinguished from the congeners by the color, and number of adoral membranelles and somatic kinetics (Aescht and Foissner, 1998).  

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107126, NIBRPR0000107127).  

Class Litostomatea Small and Lynn, 1981  
Order Haptorida Corliss, 1974  
Family Arcuospathidiidae Foissner and Xu, 2007  
Genus *Cultellothrix* Foissner, 2003

4. **Cultellothrix coemeterii** (Kahl, 1943) Foissner and Xu, 2007 (Fig. 1D)  

**Diagnosis:** Body size 55 × 18 μm in protargol preparations; body narrowly spatulate with oblong oral bulge. Macronuclear nodule reniform. Contractile vacuole at posterior body end. Cytoplasm colorless. Usually 12 ciliary rows; dorsal brush positioned distinctly lateral side; anterior cilia moderately reduced. Extrusomes cylindrical, colorless. Circumoral kinety closed.  

**Remark:** It is first record of member belonging to the family Arcuospathidiidae from Korea. Other spathidiids were frequently occurred from our moss samples and they seem to be very diverse (Foissner and Xu, 2007). The other spathidiids occurred in our samples will be reported later with further investigation.  

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107140, NIBRPR0000107141).  

Class Nassophorea Small and Lynn, 1981  
Order Microthoracida Jankowski, 1967  
Family Microthoracidae Jankowski, 1967  
Genus *Drepanomonas* Fresenius, 1858

5. **Drepanomonas hymenofera hymenofera** (Horváth, 1956) Omar and Foissner, 2013 (Fig. 1E)  

**Diagnosis:** Body size 30 × 10 μm in protargol preparations; body oblong, posterior body end rounded; rigid. Macronuclear nodule spherical to elliptical, positioned at posterior body end. Cytoplasm colorless. Somatic kineties composed of dikinetid; cilia along with somatic kineties. Feeding tube distinct, positioned at anterior body end. Paroral membrane semicircular. Extrusomes recognized in protargol preparation; along with somatic kinetics. Feeding tube distinct, positioned at anterior body end. Paroral membrane semicircular.  

**Remark:** The observation of the species belonging to the family Grosslockneridae is first record from Korea. Their feeding tube is a diagnostic feature of the family (Foissner, 1993). The Korean population co-occurred with *Nivaliella plana* from the single sample out of 13 ones. Other species in *Colpodea* were commonly occurred days from the samples after the rewetting and we will report them with further investigation.  

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107136, NIBRPR0000107137).  

Genus *Nivaliella* Foissner, 1980

2. **Nivaliella plana** Foissner, 1980 (Fig. 1B)  

**Diagnosis:** Body size 12 × 6 μm in protargol preparations; body reniform to oblong. Macronuclear nodule spherical to elliptical, positioned at posterior half-body. Contractile vacuole at posterior body end. Cytoplasm colorless. Somatic kinetics composed of dikinetid; cilia strongly reduced. Feeding tube distinct, positioned at anterior body end. Paroral membrane semicircular.  

**Remark:** It was the smallest species (ca. 12 μm in length) of this report and co-occurred with *G. acuta* belonging to the same family. Based on the co-occurrence of the two species from a single moss sample only, it is assumed that their ecological niche is not broad and Foissner (1993) mentioned that *G. acuta* prefers acidic substrates.  

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107138, NIBRPR0000107139).  

Class Heterotrichida Stein, 1859  
Order Heterotrichida Stein, 1859  
Family Blepharismidae Jankowski in Small and Lynn, 1981  
Genus *Blepharisma* Perty, 1849

3. **Blepharisma hyalinum** Perty, 1849 (Fig. 1C)  

**Diagnosis:** Body size 30-75 × 10-25 μm in protargol preparations; body shape roughly elliptical to fusiform; anterior end bluntly pointed and slightly curved. Nuclear apparatus composed of broadly elliptical macronuclear nodule and several micronuclei. Contractile vacuole at posterior body end. Cytoplasm colorless. Adoral zone composed of 19-25 membranelles and linear paroral
Genus *Obertrumia* de Fromentel, 1874
Family Nassulidae de Fromentel, 1874
Order Nassulida Jankowski, 1967

**Genus** *Obertrumia* *gracilis* Foissner, 1989 (Fig. 1G)

**Diagnosis:** Body size 65 × 35 μm in protargol preparations; body ellipsoidal, anterior and posterior body ends rounded; rigid. Macronuclear nodule spherical to elliptical, positioned at mid-body with spherical to elliptical micronucleus. Contractile vacuole at mid-body, one excretory pore. Cytoplasm colorless. Usually 60 somatic kineties and bipartite nassulid organelles.

**Remark:** The genus *Obertrumia* can be distinguished from *Nassula* mainly by the feature of nassulid organelles (bipartite in *Obertrumia*; Foissner et al., 2002). *Obertrumia gracilis* has similar morphology to the congener *O. kahl* while the latter species differs from the former by the proportion of the number of bipartite nassulid organelles (Foissner, 1989).

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107132, NIBRPR0000107133).

Family Furgasoniidae Corliss, 1979
Genus *Furgasonia* Jankowski, 1964

**8. Furgasonia rubens* Perty, 1852 (Fig. 1H)**

**Diagnosis:** Body size 45 × 15 μm in protargol preparations; body ellipsoidal, anterior and posterior body ends rounded; rigid. Macronuclear nodule spherical to elliptical, positioned at posterior half-body with spherical to elliptical micronucleus. Contractile vacuole at mid-body, one excretory pore. Cytoplasm colorless. Usually 40 somatic kineties and 3 nassulid organelles.

**Remark:** The Korean populations showed slightly less number of somatic kineties than *F. rubens* sensu Dragesco and Dragesco-Kernéis, 1986 while *Cyclograma protectissima* sensu Grolière, 1974 seems to be conspecific to the Korean one. Further investigation using modern techniques are necessary for precise identification and description.

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107134, NIBRPR0000107135).

Class Oligohymenophorea de Puytorac et al., 1974
Order Peniculida Faure-Fremiet in Corliss, 1956
Family Frontoniidae Kahl, 1926
Genus *Frontonia* Ehrenberg, 1838

**9. *Frontonia depressa* (Stokes, 1886) Kahl, 1931 (Fig. 2A)**

**Diagnosis:** Body size 65 × 30 μm in protargol preparations; body ellipsoidal to lightly ovate, posterior body end rounded. Macronuclear nodule spherical to elliptical, positioned at mid-body. Contractile vacuole at mid-body with single excretory pore. Cytoplasm colorless. Oral apparatus slightly above mid-body.

**Remark:** It is first record of the genus from Korea. Foissner et al. (2002) provided detailed comparison to separate congeners mainly by 1) buccal cavity; 2) postoral suture; and 3) excretory pore.

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107142, NIBRPR0000107143).
Class Spirotrichea Bütschli, 1889
Order Stichotrichida Fauré-Fremiet, 1961
Family Holostichidae Fauré-Fremiet, 1961
Genus Anteholosticha Berger, 2003

10. Anteholosticha distyla (Buitkamp, 1977) Berger, 2003 (Fig. 2B)

**Diagnosis:** Body size 125 × 25 μm in protargol preparations; body shape elongated ellipsoidal, flattened dorsoventrally, both body ends rounded; flexible. Nuclear apparatus composed of ca. 20 macronuclear nodules with several micronuclei at left mid-body. Cytoplasm colorless. Movement, without any peculiarities, crawling on soil surface. Cirri, on average, composed of three frontal cirri, one buccal cirri, two frontoterminal cirri, fifteen midventral cirral pairs, two pretransverse ventral cirri, two transverse cirri, one left and one right marginal cirral row.

**Remark:** The genus Anteholosticha is one of the species-rich groups in the class Spirotrichea. More than 40 species belonging to the genus have been described and they are non-monophyletic (Park et al., 2013). Eight species including *A. distyla* have been recorded in Korea (Shin and Kim, 1993; Li et al., 2011; Park et al., 2012; Shin, 2012; Kim et al., 2013; Park et al., 2013).

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107116, NIBRPR0000107117).

Genus Periholosticha Hemberger, 1985

11. Periholosticha paucicirrata Foissner, Berger, Xu and Zechmeister-Boltenster, 2005 (Fig. 2C)

**Diagnosis:** Body size 70 × 10 μm in protargol preparations; body shape very narrowly elongated, flattened dorsoventrally; flexible. Nuclear apparatus composed of ca. 15 macronuclear nodules with several micronuclei at left mid-body. Cytoplasm colorless. Movement, without any peculiarities, crawling on soil surface. Cirri, on average, composed of three frontal cirri, two frontoterminal cirri, four midventral cirral pairs, one left and one right marginal cirral row.

**Remark:** It is first record of the genus Periholosticha from Korea. They have roughly elongated body shape (Berger, 2006). Of the morphologically related congeners, *Periholosticha lanceolata* differs from *P. paucicirrata* mainly by the number of dorsal kineties (Berger, 2006).

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107120, NIBRPR0000107121).

Family incertae sedis in Stichotrichida
Genus Saudithrix Foissner, Al-Rasheid and Berger, in Berger, Al-Rasheid and Foissner, 2006

12. Saudithrix terricola Foissner, Al-Rasheid and Berger in Berger, Al-Rasheid and Foissner, 2006 (Fig. 2D)

**Diagnosis:** Body size 220 × 80 μm in protargol preparations, flattened dorsoventrally; both body ends rounded; flexible. Nuclear apparatus composed of two macronuclear nodules with several micronuclei at left mid-body. Contractile vacuole at left margin of mid-body. Cytoplasm colorless. Movement, without any peculiarities, crawling on soil surface. Cirri, on average, composed of frontal multicorona, two buccal cirri, five frontal-ventral rows (including right marginal cirral row), one left marginal cirral row, and seven transverse cirri. Oral apparatus *Cyrtohymena* pattern of undulating membranes.

**Remark:** The genus Saudithrix consists of a single species (monotypy) and it is first record from Korea. *Saudithrix terricola* is one of large hypotrichs and has many frontal-ventral rows. The Korean population showed slightly small size and less number of frontal-ventral rows (number of the rows in 5 specimens: 4, 4, 4, 4, 5). It emphasizes further investigation with morphometrical analyses between the two populations.

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107114, NIBRPR0000107115).

Order Sporadotrichida Fauré-Fremiet, 1961
Family Urosomoididae Foissner, 2016
Genus Oxytrichella Foissner, 2016

13. Oxytrichella mahadjacola Foissner, 2016 (Fig. 2E)

**Diagnosis:** Urosomoidae with a single micronucleus. Body size 35 × 15 μm in protargol preparations; body shape ellipsoidal, flattened dorsoventrally, both body ends rounded; flexible. Nuclear apparatus composed of two macronuclear nodules with a single micronucleus at left mid-body. Cytoplasm colorless. Movement, without any peculiarities, crawling on soil surface. Seventeen frontal-ventral-transverse cirri composed of three frontal, one buccal, four frontoventral, three postoral ventral, two pretransverse ventral, and four transverse cirri. One left and one right marginal cirral row. Four dorsal kineties with three caudal cirri.

**Remark:** *Oxytrichella mahadjacola* is one of the smallest hypotrichs (Berger, 1999; Foissner, 2016). Foissner (2016) reported the species from Venezuela (type locality). Based on the observation in vivo, it is very similar
to *Oxytricha balladyna* (= *Monomicrocaryon balladyna*). Protargol impregnation is necessary for precise identification between the two species. Foissner (2016) estab-

lished the genus *Monomicrocaryon* and transferred *O.
*balladyna* to the new genus *Monomicrocaryon*.

**Voucher slides:** Two slides including protargol-impreg-
nated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000 107118, NIBRPR0000107119).

Family Oxytrichidae Ehrenberg, 1838
Genus Notohymena Blatterer and Foissner, 1988

14. Notohymena antarctica Foissner, 1996 (Fig. 2F)

**Diagnosis:** Body size 80 × 20 μm in protargol preparations; body shape ellipsoidal, flattened dorsoventrally, both body ends rounded; flexible. Nuclear apparatus composed of two macronuclear nodules at left mid-body. Cytoplasm colorless. Movement, without any peculiarities, crawling on soil surface. Eighteen frontal-ventral-transverse cirri composed of three frontal, one buccal, four frontoventral, three postoral ventral, two pretransverse ventral, and five transverse cirri. One left and one right cirral row. Oral apparatus Notohymena type of undulating membranes.

**Remark:** Of the species in Notohymena, Kwon and Shin (2010) reported N. australis in Korea. The Korean population of N. antarctica were very rarely observed from our samples and only two stained samples with brief observation in vivo were obtained. For precise description and identification, further investigation is necessary for the Korean population.

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107122, NIBRPR0000107123).

Order Phacodiniidae Small and Lynn, 1985
Family Phacodiniidae Corliss, 1979
Genus Phacodinium Prowazek, 1900

15. Phacodinium metchnikoffi Certes, 1891 (Fig. 2G)

**Diagnosis:** Body size 100 × 60 μm in protargol preparations; body shape broadly elliptical to ovate, flattened dorsoventrally. Nuclear apparatus composed of curved cylindrical macronuclear nodule, which run along with adoral zone of membranelles, and several micronuclei. Cytoplasm colorless. Movement, without any peculiarities, crawling on soil surface or swimming. Buccal cilia composed of adoral zone of membranelles and paroral cilia which connected to proximal end of adoral zone.

**Remark:** In fact, our record of Phacodinium metchnikoffi is not first in Korea. Even though Shin et al. (2000) reported the nuclear SSU rDNA sequences of a Korean population without morphological description, the species was not listed in ‘National list of species of Korea (Protozoa)’ (National Institute of Biological Resources, 2012).

**Voucher slides:** Two slides including protargol-impregnated specimens have been deposited in the National Institute of Biological Resources in Korea (NIBRPR0000107124, NIBRPR0000107125).

**ACKNOWLEDGEMENTS**

This work was supported by grants from the National Institute of Biological Resources (NIBR) funded by the Ministry of Environment (MOE) of the Republic of Korea (NIBR No. 2016-02-001), and from the full-time graduate student scholarship from Gangneung-Wonju University.

**REFERENCES**

Aescht, E. 2013. Checklists of the Austrian fauna, No. 7. Erna Aescht: Ciliophora. Austrian Academy of Sciences Press, Wien.

Aescht, E. and W. Foissner. 1998. Divisional morphogenesis in Blepharisma americanum, B. undulans, and B. hyalinum (Ciliophora : Heterotrichida). Acta Protozoologica 37: 71-92.

Berger, H. 1999. Monograph of the Oxytrichidae (Ciliophora, Hypotrichia). Monographiae Biologicae 78:i-xii, 1-1080.

Berger, H. 2006. Monograph of the Urostylidea (Ciliophora, Hypotrichia). Monographiae Biologicae 85:i-xv, 1-1303.

Berger, H. 2011. Monograph of the Gonostomatidae and Kahliellidae (Ciliophora, Hypotricha). Monographiae Biologicae 90:i-xiv, 1-741.

Berger, H., K.A.S. Al-Rasheid and W. Foissner. 2006. Morphology and cell division of Saudithrix terricola n. gen., n. sp., a large, stichotrich ciliate from Saudi Arabia. Journal of Eukaryotic Microbiology 53:260-268.

Dragesco, J. and A. Dragesco-Kernéis. 1986. Ciliés libres de l’Afrique intertropicale. Introduction à la connaissance et à l’étude des ciliés. Faune tropicale (Éditions de l’ORSTOM) 26:1-559.

Fernandez-Galiano, D. and P. Calvo. 1992. Redescription of Phacodinium metchnikoffi (Ciliophora, Hypotrichida): General morphology and taxonomic position. Journal of Protozoology 39:443-448.

Foissner, W. 1989. Morphologie und Infraclitatur einiger neuer und wenig bekannter terrestrischer und limnischer Ciliaten (Protozoa, Ciliophora). Sitzungsberichte Österreichische Akademie der Wissenschaften Mathematisch-Naturwissenschaftliche Klasse Abteilung 1, Biologische Wissenschaften und Erdwissenschaften 196 (year 1987): 173-247.

Foissner, W. 1993. Colpodea (Ciliophora). Protozoenfauna 4/1:3-x, 1-798.
Foissner, W. 2014. An update of ‘basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa’. International Journal of Systematic and Evolutionary Microbiology 64:271-292.

Foissner, W. 2016. Terrestrial and semiterrestrial ciliates (Protozoa, Ciliophora) from Venezuela and Galápagos. Denisia 35:1-912.

Foissner, W., S. Agatha and H. Berger. 2002. Soil ciliates (Protozoa, Ciliophora) from Namibia (Southwest Africa), with emphasis on two contrasting environments, the Etosha region and the Namib desert. Part I: Text and line drawings. Denisia 5:1-1063.

Foissner, W. and K. Xu. 2007. Monograph of the Spathidiida (Ciliophora, Haptoria) Vol I: Protospathidiidae, Arcuospatidiidae, Apertospatidiidae. Monographiae Biologicae 81:i-ix, 1-487.

Grolïere, C.-A. 1974. La stomatogenèse du cilié Cyrtophorina Cyclogramma protectissima Penard 1922 et ses incidences dans la compréhension de l’évolution des infusoires. Comptes rendus des seances de l’Academie des Sciences 278:2299-2303.

Ji, D., J.H. Kim, S.U.A. Shazib, P. Sun, L. Li and M.K. Shin. 2015. Two new species of Zooothamnium (Ciliophora, Peritrichia) from Korea, with new observations of Z. parahentschelii Sun et al., 2009. Journal of Eukaryotic Microbiology 62:505-518.

Jo, E., J.-H. Jung and G.-S. Min. 2015. Morphology and molecular phylogeny of two new brackish water ciliates of Bakuella (Ciliophora: Urostylida: Bakuellidae) from South Korea. Journal of Eukaryotic Microbiology 62:799-809.

Jung, J.-H., K.-M. Park and G.-S. Min. 2015. Morphology and molecular phylogeny of Pseudocorythoymena koreana n. g., n. sp. and Antarctic Neokeronopsis asiatica Foissner et al., 2010 (Ciliophora, Sporadotrichida), with a brief discussion of the Corythoymena undulating membranes pattern. Journal of Eukaryotic Microbiology 62:280-297.

Kim, K.-S., J.-H. Jung and G.-S. Min. 2013. New record of two marine ciliates (Ciliophora: Spirotrichea) from South Korea. Animal Systematics, Evolution and Diversity 29:144-151.

Kim, K.-S. and G.-S. Min. 2015. New record of three colpodcean ciliates (Ciliophora: Colpodacea) from Korea. Korean Journal of Environmental Biology 33:375-382.

Kwon, C.B. and M.K. Shin. 2010. Description of two oxytrichid ciliates (Ciliophora: Sporadotrichida: Oxytrichiidae) newly reported from Korea. Korean Journal of Systematic Zoology 26:307-316.

Lee, E.S. and M.K. Shin. 2009. New record of ciliates, Blepharisma undulans and B. steini (Ciliophora: Heterotrichida: Blepharismidae) from Korea. Korean Journal of Systematic Zoology 25:41-47.

Li, L., S.N. Khan, D. Ji and M.K. Shin. 2011. Morphology and SSU rRNA gene sequence of the new brackish water ciliate, Anteholosticha pseudomonilata n. sp. (Ciliophora, Hypotrichida, Holostichidae) from Korea. Zootaxa 2739:51-59.

Lynn, D.H. 2008. The ciliated protozoa: Characterization, classification, and guide to the literature. Springer, New York.

Nam, S.W., W. Shin, M. Kang, W. Yih and M.G. Park. 2015. Ultrastructure and molecular phylogeny of Mesodinium coasi sp. nov., a benthic marine ciliate. Journal of Eukaryotic Microbiology 62:102-120.

National Institute of Biological Resources. 2012. National list of species of Korea (Protozoa).

Omar, A. and W. Foissner. 2012a. Description of Leptopharynx brasiliensis nov. spec. and Leptopharynx costatus gonohymen nov. subsp. (Ciliophora, Microthoracida). European Journal of Protistology 48:30-47.

Omar, A. and W. Foissner. 2012b. Neotypification and on-genesis of Leptopharynx costatus costatus Mermod, 1914. Journal of Eukaryotic Microbiology 59:268-286.

Omar, A. and W. Foissner. 2013. Description of two new Drepanomonas taxa and an account on features defining species in Drepanomonas Fresenius, 1858 (Ciliophora, Microthoracida). European Journal of Protistology 49:420-437.

Pan, X., W.A. Bourland and W. Song. 2013. Protargol synthesis: An in-house protocol. Journal of Eukaryotic Microbiology 60:609-614.

Park, K.-M., J.-H. Jung and G.-S. Min. 2012. Redescription of two urostylic ciliates (Ciliophora: Urostylida, Anteholosticha pulchra and Metaurostylopsis struederkypkeae) from Korea. Animal Systematics, Evolution and Diversity 28:20-28.

Park, K.-M., J.-H. Jung and G.-S. Min. 2013. Morphology, morphogenesis, and molecular phylogeny of Anteholosticha multicirrata n. sp. (Ciliophora, Spirotrichea) with a note on morphogenesis of A. pulchra (Kahl, 1932) Berger, 2003. Journal of Eukaryotic Microbiology 60:564-577.

Park, M.-H. and G.-S. Min. 2015. New records of three dysterids (Ciliophora: Phyllopharyngea) from Korea. Korean Journal of Environmental Biology 33:189-196.

Petz, W. and W. Foissner. 1992. Morphology and morphogenesis of Stroblidium caudatum (Fromentel), Meseres corlissi n. sp., Halteria grandinella (Müller), and Strombidium rehwaldi n. sp., and a proposed phylogenetic system for oligotrich ciliates (Protozoa, Ciliophora). Journal of Protozoology 39:159-176.

Shazib, S.U.A., P. Vd’ačný, J.H. Kim, S.W. Jang and M.K. Shin. 2014. Phylogenetic relationships of the ciliate class Heterotrichae (Protista, Ciliophora, Postciliodesmato- phora) inferred from multiple molecular markers and multifaceted analysis strategy. Molecular Phylogenetics and Evolution 78:118-135.

Shin, M.K. 2012. Stichotrichs (Ciliophora: Intramacronucleata: Spirotrichea: Stichotrichia). Invertebrate fauna of Korea 1:1-193.
Shin, M.K., U.W. Hwang, W. Kim, A.-D.G. Wright, C. Krawczyk and D.H. Lynn. 2000. Phylogenetic position of the ciliates *Phacodinium* (Order Phacodiniida) and *Protocruzia* (Subclass Protocruziidia) and systematics of the spirotrich ciliates examined by small subunit ribosomal RNA gene sequences. European Journal of Protistology 36:293-302.

Shin, M.K. and W. Kim. 1993. Redescription of two holostichid species of genus *Holosticha* Wrzesniowski 1877 (Ciliophora, Hypotrichida, Holostichidae) from Seoul, Korea. Korean Journal of Systematic Zoology 9:251-259.

Shin, M.K. and W. Kim. 1995. Hypotrichs (Ciliophora, Hypotrichida) from Ullung Island, Korea. Korean J Zool 38:160-166.

Shin, M.K. and W. Kim. 1996. Terrestrial hypotrichous ciliates from Chindo Island, Korea. Korean Journal of Systematic Zoology 12:17-24.

Submitted: July 12, 2016
Revised: August 17, 2016
Accepted: October 13, 2016