

New records of freshwater algae from Korea

Jin Hee Kim¹ and Han Soon Kim^{2,*}

¹National Institute of Biological Resources, Incheon 22689, Republic of Korea

²Department of Biology, Kyungpook National University, Daegu 41566, Republic of Korea

*Correspondent: kimhsu@knu.ac.kr

The present study summarizes the taxonomic description and Korean distribution of 16 taxa that are recorded for the first time in Korea. These taxa classified into Chlorophyceae (*Astrephomene gubernaculifera*, *Botryococcus protuberans*, *Chlorangiella polychlora*, *Cylindrocapsa geminella*, *Kirchneriella contorta* var. *gracillima*, *Korshikoviella gracilipes*, *Oocystis naegelii*, *O. ovalis*, *Stylosphaeridium stipitatum*), Charophyceae (*Cosmarium moniliforme*, *Cosmocladium constrictum*, *C. perissum*), Xanthophyceae (*Tetraedriella tumidulum*, *T. spnigera*), Chrysophyceae (*Cyclonexis erinus*) and Cyanophyceae (*Arthrospira platensis*). Among these taxa, six genera including *Astrephomene*, *Chlorangiella*, *Cosmocladium*, *Cyclonexis*, *Stylosphaeridium*, and *Tetraedriella* are newly recorded in Korea.

Keywords: freshwater algae, Korea, newly recorded taxa

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INTRODUCTION

As of 2016, a total of 5,857 algal taxa were reported in Korea, including 348 cyanobacteria, 2,065 diatoms, 931 charophytes, 770 chlorophytes, 608 rhodophytes, 405 dinophytes, 360 ochrophytes, 348 euglenophytes, and 22 other taxa (such as cryptophytes) (Kim *et al.*, 2013; Kim, 2015; Lee and Joh, 2015; Lee and Kim, 2015a; 2015b; National Institute of Biological Resources, 2016). Among these taxa, freshwater algae accounted for about 65.9%.

Studies of freshwater algae were initiated by Kawamura (1918), who reported a species of *Centritractus* at Lake Seoho, Suwon. Since then, Skvortzow (1932) reported 65 flagellates including 1 new variety from a lake near Cheongryangri, and Ueda and Okada (1935) reported 47 taxa from rivers in various parts of Korea. Until the 1950s, a total of 487 of freshwater algal taxa were recorded in Korea by foreigner florists (Chang, 1986; Lee, 1986). Since then, many investigations of freshwater algal flora have been carried out in Korea by Korean florists (Chung, 1968; 1970; 1975; 1976; 1979; 1982; 1993; Chung *et al.*, 1972a; 1972b; Lee, 1978; Chung and Choi, 1979; Wui and Kim, 1987a; 1987b; Kim, 1993; 1996; Kim and Chung, 1993; 1994; Kim *et al.*, 2009). To date, about 3,860 taxa of freshwater algae have been recorded in Korea, composed of diatoms

(38.7%), charophytes (24.1%), chlorophytes (16.6%), euglenophytes (8.6%), cyanobacteria (7.7%), and other taxa (4.3%). However, this diversity is relatively low, considering that there are tens or perhaps hundreds of thousands of species of freshwater algae worldwide (Sheath and Wehr, 2015).

Recently, the importance of biological diversity has been emphasized, and identifying the indigenous species is essential to securing biological sovereignty. Therefore, continuous investigation of freshwater algae in Korea are necessary. In this study, samples were collected from 14 different water bodies and investigated for freshwater algal flora. We report a total of 16 taxa from 13 genera that are newly recorded in Korea.

MATERIALS AND METHODS

Samples were collected from 13 different water bodies, including lowland swamps, reservoirs, mountainous wetlands, sphagnum bogs, and Orum (small and shallow caldera lakes) from 2015 to 2016 (Table 1). Samples were collected using a spoid or plankton net (mesh size 25 µm). All living materials were immediately examined. Next, samples were fixed with 5% formalin for permanent preservation. Microscopic examinations were performed using a Zeiss Microscope (Axio Imager. A2) at

200-1,000x magnification and photomicrographs were obtained using an AxioCam HRC camera (Zeiss). All the taxa reported in the present study are illustrated with photomicrographs. The samples were deposited at the Department of Biology, Kyungpook National University.

RESULTS AND DISCUSSION

Class Chlorophyceae
Order Volvocales
Family Volvocaceae
Genus *Astrephomene*

Astrephomene gubernaculifera Pocock (Fig. 1A and B)

Reference: Yamagishi and Akiyama. 1984a. p. 5.

Description: Colonies ellipsoidal or spherical, 32 or 64 cells with two equal flagella and small non-reproductive cells consisting of 4 cells (of 64 cells) or 2 cells (of 32 cells) in posterior area. Cells almost spherical, surrounded the cellular sheaths with pentagonal or hexagonal shape in front view, adhered to each other and empty in central areas of colonies. Chloroplasts large cup-shaped, single stigma and many contractile vacuoles. Colonies 70 μm in diameter, reproductive cells up to 18 μm in diameter. Asexual reproduction formed daughter colonies.

Occurrence: Samrak Wetland, Samrak-dong, Sasang-gu, Busan (7, Aug. 2015).

Order Chlamydomonadales
Family Chlorangiellaceae
Genus *Stylosphaeridium*

Stylosphaeridium stipitatum (Bachmann) Geitler et Gimesi 1925 (Fig. 1C)

Reference: John *et al.* 2011. p. 379. pl. 96K.

Description: Cells ellipsoidal and epiphytic on planktonic algae by short and thin stalk. Chloroplasts flattened and cup-shaped, with a pyrenoid and two contractile vacuoles. Cells 5-10 μm in length and 4-8 μm in breadth. Stalks 5-10 μm in length. They are epiphytic on planktonic algae, particularly the blue-green alga *Coeasphaerium*, also on *Anabaena*.

Occurrence: Dalseongbo, Inan-ri, Gaejin-myeon, Goryeong-gun, Gyeongsangbuk-do (24, Jul. 2015).

Genus *Chlorangiella*

Chlorangiella polychlora (Skuja) Silva (Fig. 1D and E)

Reference: Ettl and Gärtner. 1988. p. 41. pl. 12. Fig. 23.

Description: Colonies containing two cells in the end of

mucous stalk, branched up to 5 times the length of cells. Cells elongated and ellipsoidal, 11-13 μm in length and 5-6 μm in breadth.

Distribution: Motjae, Naecheon-ri, Yulgok-myeon, Hapcheon-gun, Gyeongsangnam-do (16, Sep. 2015).

Order Ulotrichales
Family Microsporaceae
Genus *Cylindrocapsa*

Cylindrocapsa geminella Wolle (Fig. 2A)

Reference: Yamagishi and Akiyama. 1984b. p. 23.

Description: Filaments unbranched, cells arranged in a single series and occasionally multiseriated. Young cells cylindrical and surrounded with thin cell walls; old cells spherical, ovate or oblong and surrounded with thick cell walls. Chloroplast single with a pyrenoid in the form of mass. Cells 12-18 μm in length and 15-18 μm in breadth.

Occurrence: Ugeomji, Ugeom-ri, Namsan-myeon, Gyeongsan-si, Gyeongsangbuk-do (28, Jul. 2015).

Order Chlorococcales
Family Botryococcaceae
Genus *Botryococcus*

Botryococcus protuberans West et G.S. West (Fig. 2B)

Reference: Yamagishi and Akiyama. 1984b. p. 4; John *et al.* 2011. p. 500. pl. 113J.

Description: Colonies free-floating, formed irregular shapes with several botryoidal cell clusters and connected with long, hyaline, gelatinous strands. Cells ovoid or ellipsoidal, arranged radially in each cell clusters with 8, 16, 32 cells or more cells. The inner base of cells enveloped within gelatinous sheath, the outer end without the sheath and projected out of the colony. Chloroplasts single, laminate. Colonies green or yellowish-green in color. Cells 9-12 μm in length, and 6-9 μm in breadth.

Occurrence: Jangcheok Reservoir, Sinje-ri, Yeongsan-myeon, Changnyeong-gun, Gyeongsangnam-do (3 Aug. 2015).

Family Characiaceae
Genus *Korshikoviella*

Korshikoviella gracilipes (Lambert) Silva (Fig. 2C)

Reference: Komárek and Fott. 1983. p. 246. pl. 72. f. 1.

Description: Cells solitary and free-floating, fusiform with both ends of the different shape. The distal end tapered and elongated spine, and the proximal end has the base with two branches. The length of cells except for spines up to 8 times the breadth. Cells straight or

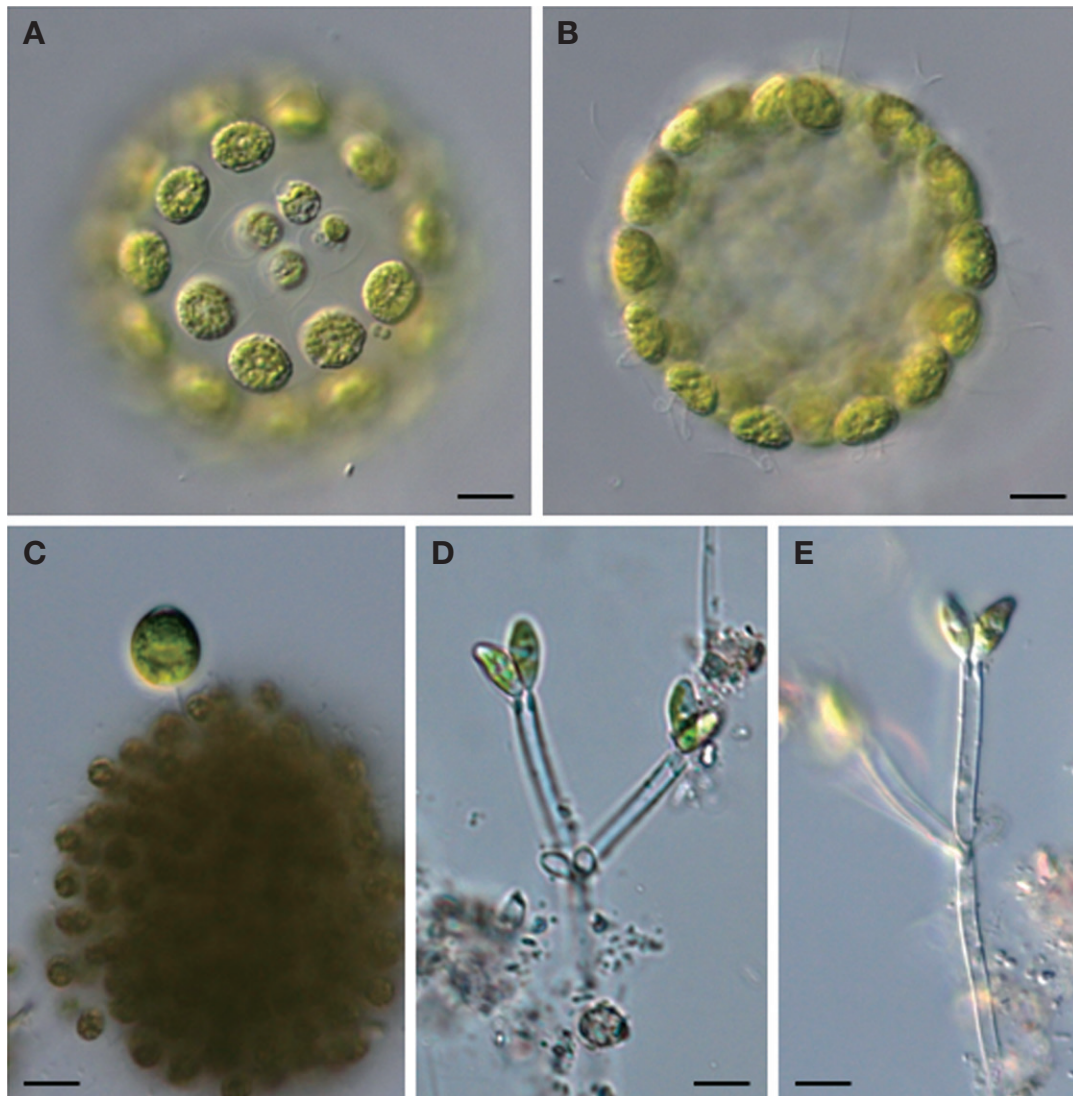


Fig. 1. A, B. *Astrephomene gubernaculifera*, C. *Stylosphaeridium stipitatum*, D, E. *Chlorangiella polychlora*. Scale bar = 10 μm .

curved. Stalks less than 1/3 of the length. Cells 50-80 μm in length and 5.5-8.5 μm in breadth.

Occurrence: Jangcheok Reservoir, Sinje-ri, Yeongsan-myeon, Changnyeong-gun, Gyeongsangnam-do (3, Jul. 2015).

Family Oocystaceae

Genus *Oocystis*

***Oocystis naegelii* Braun (Fig. 2D)**

Reference: Yamagishi and Akiyama. 1985. p. 57; John *et al.* 2011. p. 493. pl. 122H.

Description: Colonies free-floating, 2, 4 or 8 cells enclosed within a elliptical enlarged mother cell wall, rarely single cell. Cells elliptical to long elliptical, rounded

end and the peripheral edge somewhat swollen. One or two chloroplasts without the pyrenoids. Cells 25-30 μm in length and 12-15 μm in breadth. The length of the cells is 1.5-2 times the breadth.

Occurrence: A pond at Wonsan Island, Ocheon-myeon, Boryeong-si, Chungcheongnam-do (27, Jun. 2015).

***Oocystis ovalis* (Turner) West et G.S. West (Fig. 2E)**

Reference: Yamagishi and Akiyama. 1995. p. 36.

Description: Cells free-floating and solitary but sometimes 2 or 4 daughter cells (autospores) forming colonies surrounded with the oval wall of the mother cells. Cells oval to long oval, circular end and the peripheral edge somewhat swollen. Cell walls thick and flatten, and the interior of cells filled with many granular chloroplasts.

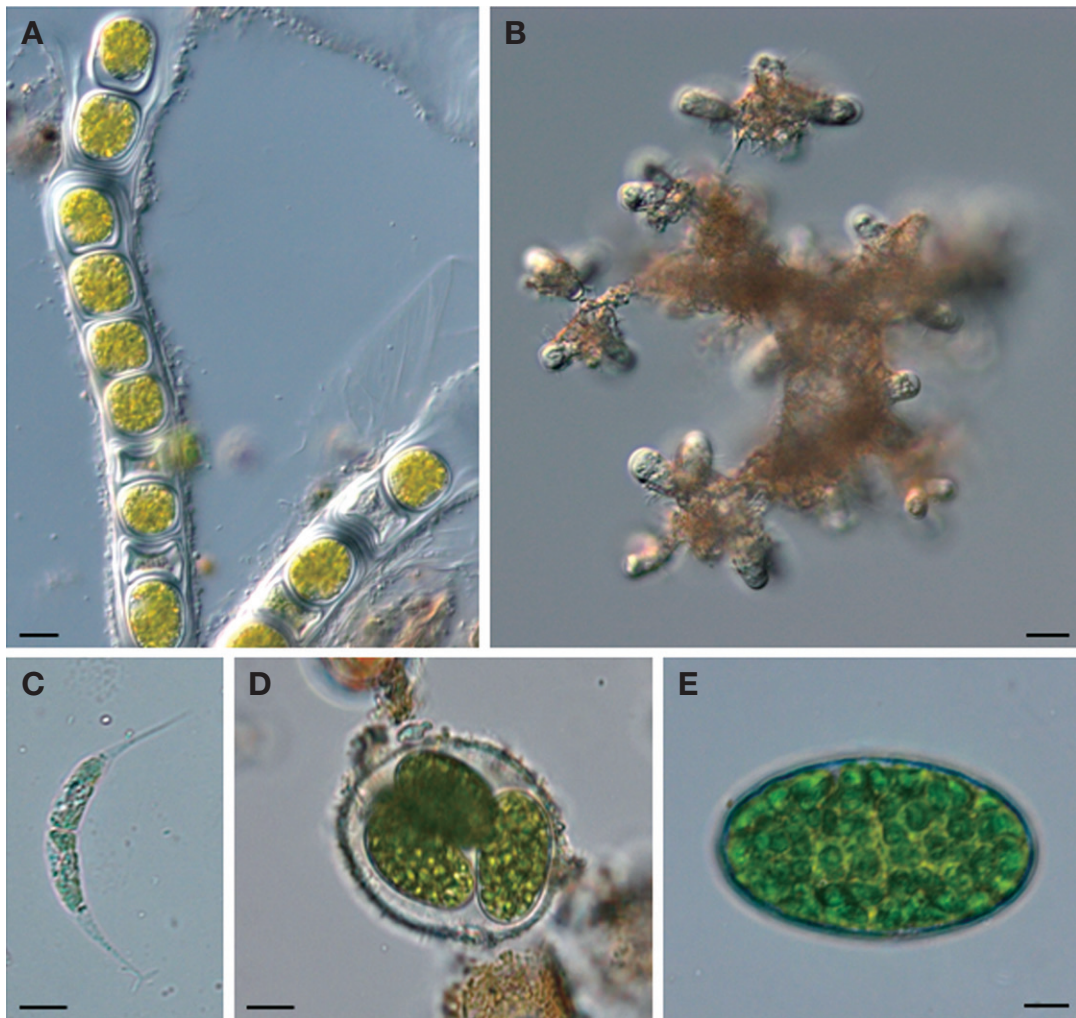


Fig. 2. A. *Cylindrocapsa geminella*, B. *Botryococcus protuberans*, C. *Korshikoviella gracilipes*, D. *Oocystis naegelii*, E. *O. ovalis*. Scale bars = 10 μm .

Cells 68 μm in length and 37-40 μm in breadth.

Occurrence: Gajeon Pond, Daegu Natural Science High school, Siji-dong, Suseong-gu, Daegu (26, Jul. 2015).

Family Pleurochloridaceae
Genus *Kirchneriella*

***Kirchneriella contorta* var. *gracillima* (Bohlin) Chodat (Fig. 3A and B)**

Reference: Yamagishi and Akiyama. 1989. p. 45; Komárék and Fott. 1983. p. 662. pl. 185. f. 3.

Description: Colonies 4, 8, 16 and 32 cells, enveloped with hyaline, gelatinous sheath and free-floating. Cells very thin cylindrical with almost parallel sides and rounded ends, much curved, spiral or irregularly twisted. Chloroplasts single without the pyrenoids. Cells 8-12 μm in length and 0.6-1.3 μm in breadth.

Occurrence: Wetland at Mulchat-orum, Gyora-ri, Jocheon-eup, Jeju-si, Jeju (21, May 2015).

Class Charophyceae
Order Desmiales
Family Desmidiaceae
Genus *Cosmarium*

***Cosmarium moniliforme* var. *limneticum* West et G.S. West (Fig. 3C)**

Reference: Prescott *et al.* 1981. p. 192. pl. 203. f. 9; Yamagishi and Akiyama 1989. p. 20.

Description: Cells small to medium in size, about 1.5-2 times longer than broad, sometimes connected with 2 or more cells, surrounded the thick, hyaline sheath and moderately constricted in the middle. Sinus open widely. Semicells almost circular to ellipsoidal. The apical part

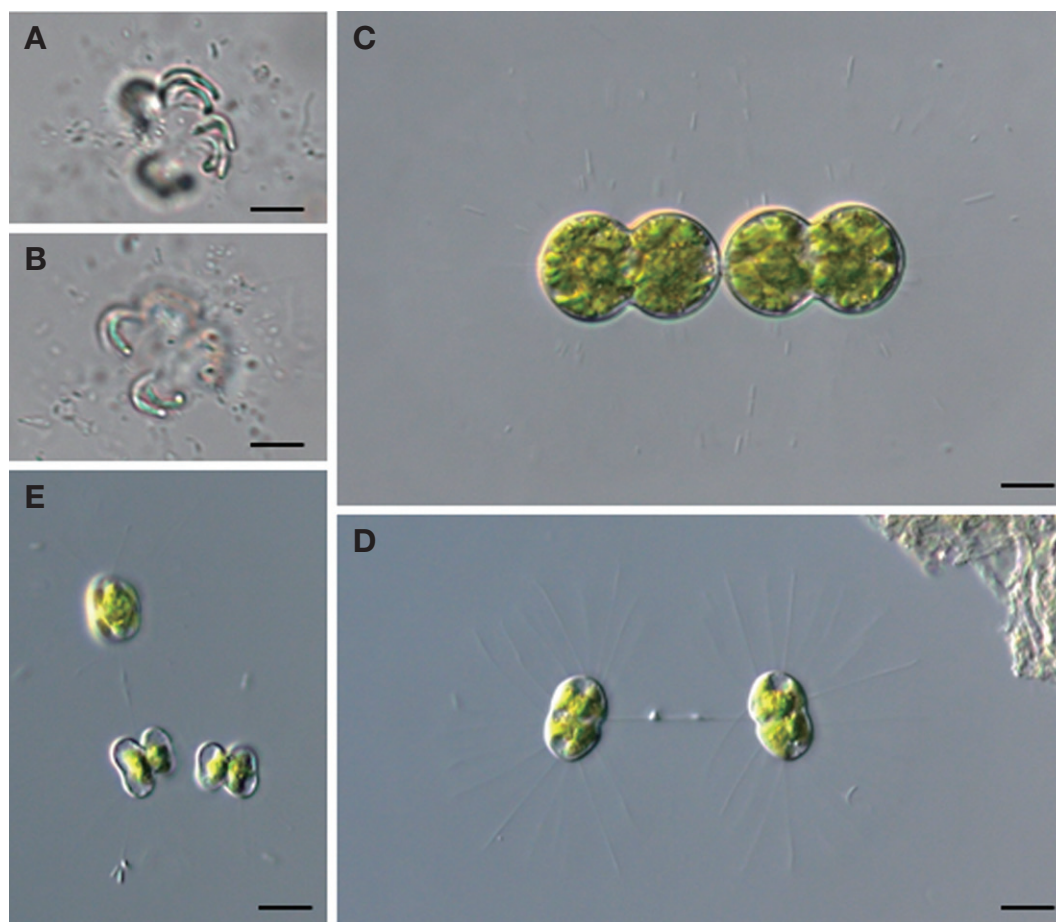


Fig. 3. A, B. *Kirchneriella contorta* var. *gracillima*, C. *Cosmariium moniliforme* var. *limneticum*, D. *Cosmocladium constrictum*, E. *C. perissum*. Scale bars = 10 μm .

of semicell slightly projected and angularly elongated, the vertical view circular. Cells 30-37 μm in length and 20-25 μm in breadth. Isthmus 10-15 μm in breadth.

Occurrence: Jangcheok Reservoir, Sinje-ri, Yeongsan-myeon, Changnyeong-gun, Gyeongsangnam-do (3, Aug. 2015).

Genus *Cosmocladium*

Cosmocladium constrictum (W. Archer) W. Archer ex Joshua (Fig. 3D)

Reference: West and West. 1923. p. 198. pl. 158. f. 1-3; Prescott *et al.* 1981. p. 354. pl. 290. f. 2-6.

Description: Cells small, almost 1.5 times longer than broad and slightly constricted in the middle. Semicells slightly tapered and rounded toward the apex. Chloroplasts single in semicell and axile-shaped with a pyrenoid in the middle of cell. The side view of semicells similar to the front view, the vertical view circular. Cells connected with mucilaginous strand. Cells 15-17

μm in length and 11-13 μm in breadth. Isthmus 8-10 μm in breadth.

Occurrence: Jinyang Reservoir, Naedong-myeon, Sanchong-gun, Gyeongsangnam-do (21, May 2015).

Cosmocladium perissum J. Roy et Bisset (Fig. 3E)

Reference: West and West. 1923. p. 200. pl. 158. f. 4-7.

Description: Cells small, formed the unbranched colonies and deeply constricted. The length of cells almost same the breadth. Semicells ellipsoidal to round-hexagonal, the vertical view ellipsoidal. Cells connected with very thin mucilaginous strand. Cells 12-13 μm in length and 10-13 μm in breadth.

Occurrence: Jinyang Reservoir, Naedong-myeon, Sanchong-gun, Gyeongsangnam-do (21, May 2015).

Class Xanthophyceae
Order Mischococcales
Family Pleurochloridaceae
Genus *Tetraedriella*

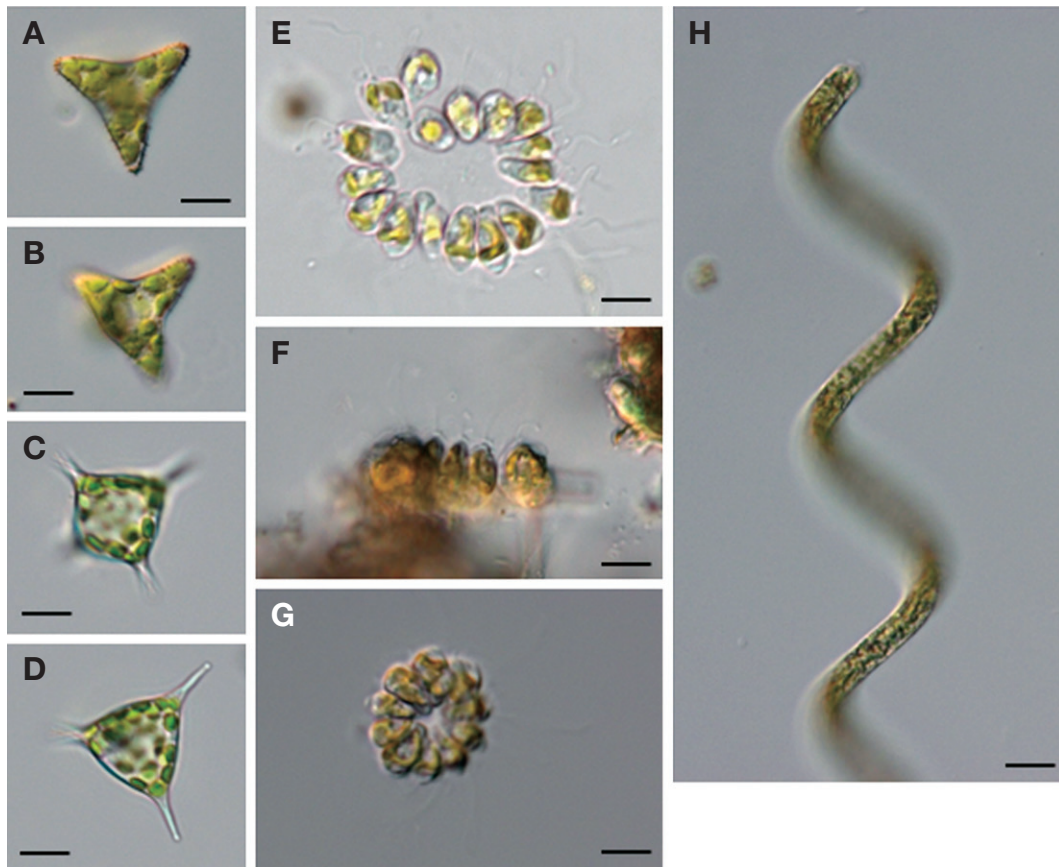


Fig. 4. A, B. *Tetraedriella tumidulum*, C, D. *T. spinigera*, E-G. *Cyclonexis erinus*, H. *Arthrospira platensis*. Scale bars = 10 μ m.

***Tetraedriella tumidulum* (Reinsch) Hansgirg (Fig. 4A and B)**

Reference: Yamagishi and Akiyama. 1984b. p. 91.

Description: Cells solitary and free-floating. The sides concave, rarely straight or slightly convex. Each apex round or truncate without the spines. Cell walls flattened. Cells 10-18 μ m in breadth.

Occurrence: Jwarang Pond, Yusuam-ri, Aewol-eup, Jeju-si, Jeju (21, May 2015).

***Tetraedriella spinigera* Skuja (Fig. 4C and D)**

Reference: Ettl. 1978. P. 218. Fig. 261.

Description: Cells solitary and free-floating, pyramidal and triangular in the bottom view. The sides straight to slightly convex and the corners tapered with thin, long spines in the apical part. Cell walls flattened. Chloroplasts small, disc-shaped, numerous and arranged along the cell wall, without the pyrenoids. Cells 20-30 μ m in breadth, spines 10-15 μ m in length.

Occurrence: A pond at Sandeokcheon, Seongsan-eup, Seogwipo-si, Jeju (29, Jun. 2015).

Class Chrysophyceae
Order Chromulinales
Family Chromulinaceae
Genus *Cyclonexis*

***Cyclonexis erinus* Jane (Fig. 4E-G)**

Reference: John *et al.* 2011. p. 290. pl. 74. fig. B.

Description: Colonies ring-shaped, having small and open space in the middle. Cells arranged densely side by side in colonies. The cohesion between cells somewhat weak, causing colonies to fracture easily. Cells 8-12 μ m in length.

Occurrence: Dongbaekdongsan Wetland, Gujwa-eup, Jeju-si, Jeju (1, Feb. 2016).

Class Cyanophyceae
Order Oscillatoriales
Family Phormidiaceae
Genus *Arthrospira*

***Arthrospira platensis* (Nordstedt) Gomont (Fig. 4H)**

Reference: Komárek and Anagnostidis. 2008. p. 349. f.

488.

Description: Trichomes regularly spirally-coiled, not tapered at towards ends with rounded end. Cross-walls visible, slightly constricted or not constricted. Cells short, 2-5 μm in length and 6-8 μm in breadth. Coils of trichomes 28-30 μm in breadth, distance between the coils 50-57 μm .

Occurrence: Wetland at Wolgok Ecological Park, Wolgok-ri, Haepyeong-myeon, Gumi-si, Gyeongsangbuk-do (22, Jun. 2015).

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