



Flora and newly recorded species of three colonial genera (*Eutetramorus*, *Coenocystis*, and *Gloeocystis*) in freshwater chlorococcal green algae from Korea

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Abstract

This study was carried out on freshwater chlorococcal green algae in ponds, swamps, reservoirs, lakes and rivers (290 sites) from May 2012 to January 2014. The family Radiococaceae was identified and classified into 3 genera, 12 species and 1 variety at 23 sites. These taxa were *Eutetramorus nygaardii*, *E. tetraporus*, *E. planctonicus*, *E. fottii*, *E. globosus*, *E. polycoccus*, *Coenocystis planctonica*, *C. planctonica* var. *hercynica*, *C. micrococca*, *C. subcylindrica*, *Gloeocystis baneergattensis*, *G. papuana*, and *G. polydermatica*. These taxa may or not had remnants of the cell wall in the colonial gelatinous envelope for a short time. Of these, 2 taxa are newly recorded in Korea from this study: 1) *C. micrococca* and 2) *G. polydermatica*.

Key words: chlorococcal green algae, gelatinous envelope, newly recorded, Radiococaceae, remnants of the mother cell wall

INTRODUCTION

A great diversity of algal is expected to exist in the inland waters of Korea, but the freshwater algal flora has not been sufficiently investigated yet. The published check lists on the freshwater algal flora in Korea is include those of: Chung (1968, 1975, 1976, 1979, 1993), Chung et al. (1972a, 1972b), Chung and Lee (1986), Jeon and Chang (1995), Kawamura (1918), Kim (1996, 2013a, 2013b, 2013d, 2013e), Kim and Chung (1993), Kim and Chang (1997), Kim et al. (1998), Shin et al. (2013), and Wui and Kim (1987a, 1987b).

Few studies have reported on the family Radiococaceae in Korea, but a few taxa have been reported on the family Palmellaceae: *Gloeocystis ampla* (Chung 1993), *G. gigas* (Chung 1990), *G. vesiculosa* (Chung 1993), *Palmella mucosa* (Chung 1993), and *Palmodictyon varium* (Chung 1993). The genus *Gloeocystis*, *Palmella*, and *Palmodicty-*

on were included in the family Palmellaceae of the order Tetrasporales by Prescott (1962) and Smith (1950). Komarek and Fott (1983), however, merged the family Palmellaceae, which had not included pseudocillia into the family Radiococaceae. This study, therefore, is classified according to Komarek and Fott (1983), and Hindak (1977, 1980, 1984). *Coenochloris ovalis* has added newly reported species in the family Radiococaceae by Jeon and Chang (1995). Kim (2013c) has added 10 newly reported species: *Eutetramorus nygaardii*, *E. tetraporus*, *E. planctonicus*, *E. fottii*, *E. globosus*, *E. polycoccus*, *Coenocystis planctonica*, *C. planctonica* var. *hercynica*, *Gloeocystis baneergattensis*, and *G. papuana* which may or not had remnants of the cell wall in the colonial gelatinous envelope for a short time.

This study investigates chlorococcal algal flora and

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adds a few taxa of the family Radiococcaceae Chlorococcales, Chlorophyceae as a new recorded species from the swamps, ponds, reservoirs, lakes and rivers in Korea. I present the taxonomic information, illustration, classification, reference, synonym, basionym, and distribution in Korea.

MATERIALS AND METHODS

The samples of chlorococcal green algae were collected at 290 sites including ponds, swamps, reservoirs, lakes and rivers from May 2012 to January 2014. 12 species and 1 variety in these three genera were identified and clas-

Table 1. Sampling sites of the genus *Euteramorus*, *Coenocystis* and *Gloeocystis* from 2012 to 2014

Station	Collected data	Locality	Coordinate
Baengduimot	31 May 2014	Guemak, Hanrim, Jeju-do	33°26'14" N, 126°40'48" E
Banweol Reservoir	24 Apr. 2013	Dundae, Gunpo, Gyeonggi-do	37°14'10" N, 127°06'06" E
Pond in Bundang Jungang Park	02 Jun. 2012	Soonae, Boondang, Sungnam city, Gyeonggi-do	37°22'30" N, 127°07'32" E
Bukhan River	26 Aug. 2012	Yangsoori, Yangpyeong, Gyeonggi-do	37°32'25" N, 127°18'47" E
Daegok Reservoir	09 Jul. 2012	Daegokri, Sinji, Wando, Jeollanam-do	34°20'35" N, 126°49'56" E
Deokjin Reservoir	18 Apr. 2014	Deokjin, Jeonju, Jeollabuk-do	35°59'50" N, 127°07'23" E
Dongmyeong Reservoir	10 Jul. 2012	Gudeokri, Dongmyeon, Chilgok, Gyeongsangbuk-do	35°58'42" N, 128°33'50" E
Dongbaekdongsan	30 May. 2014	Seonheul, Jocheon, Jeju	33°30'52" N, 126°43'07" E
Dukgok Reservoir	28 Apr. 2012	Deokgok, Docheon, Changnyeong, Gyeongsangnam-do	35°26'28" N, 128°33'38" E
Euirim Reservoir	31 Aug. 2012	Mosandong, Jecheon, Chungcheongbuk-do	37°10'23" N, 127°12'37" E
Fishery of Woogum	06 May 2013	Gansan, Pocheon, Gyeonggi-do	37°49'33" N, 127°12'39" E
Galchi Reservoir	24 Apr. 2013	Daeya, Gunpo, Gyeonggi-do	37°19'06" N, 127°53'15" E
Gyodong Reservoir	31 May 2013	Donggodori, Geumma, Iksan, Jeollabuk-do	35°59'43" N, 127°03'49" E
Joeeul Reservoir	22 Jul. 2012	Gyenamri, Jain, Kungsan, , Gyeongsangbuk-do	35°48'05" N, 128°48'48" E
Lake 88	07 Sep. 2012	Olympic park, Songpa, Seoul city	37°31'14" N, 127°07'03" E
Lake Seoho	27 May 2012	Whaseo 2, Soowoon city, Gyeonggi-do	37°16'40" N, 126°59'15" E
Oknye Reservoir	22 Sep. 2012	Gaesadong, Gunsan, , Jeollabuk-do	34°19'34" N, 126°37'24" E
Oksan Reservoir	14 Aug. 2013	Oksan, Mujang, Gochang, Jeollabuk-do	35°23'34" N, 126°35'29" E
Pond and wet soil of Daejin university	26 Sep. 2012	Sundan, Pocheon, Gyeonggi-do	37°52'29" N, 127°09'28" E
Sajipo Swamp	27 Jun. 2014	Daehap, Changnyeong, Gyeongsangnam-do	35°33'27" N, 128°25'45" E
Seorang Reservoir	27 May. 2012	Seorangri, Osan, Gyeonggi-do	37°10'20" N, 127°00'29" E
Spring of Wall at tennis courts, Daejin University	26 Sep. 2012	Sundan, Pocheon, Gyeonggi-do	37°52'29" N, 127°09'28" E
Woogum Reservoir	21 Jun. 2012	Gansan, Pocheon, Gyeonggi-do	37°49'40" N, 127°12'41" E

sified from 23 sites (Table 1). Sampling sites are located throughout the country. All samples were collected using 10- or 20- μm mesh-sized plankton nets with vertical and/or horizontal towing, or submerged benthic or soil algae with spoid or brush. Chlorococcal green algae samples were immediately fixed with Lugol's iodine solution (0.5%) for immobilizing the cells to facilitate microscopic examination. To examine the fine structures and cellular shapes, and to identify and classify species of the chlorococcal green algae, a temporary slide was made using the following steps: 1) the phytoplankton samples (chlorococcal green algae) were mixed with glycerin in micro tubes; 2) the mixed samples were placed, drop-wise on a slide glass, and were fixed in position with cover slides. Permanent slides were made using the following steps: 1) the phytoplankton samples (chlorococcal green algae) were mixed with liquid glycerol gelatin for mounting histochemical slides (Sigma-Aldrich, St. Louis, MO, USA); 2) the mixed sample was placed drop-wise on a slide glass and was fixed in position with a cover slide; 3) it was cemented to the margin of a cover glass with manicure (Thecashop, Seoul, Korea). The temporary and permanent slides were observed at $\times 200$ to $\times 1,000$ magnification using light microscopy (LM) (Axioskop 20 and Axio Imager A2; Carl Zeiss, Jena, Germany) with an attached digital camera (AxioCam HRc; Carl Zeiss) being used to capture images. Specimens numbers are listed on the National Institute of Biological Resources (NIBR). The asterisk (*) mark indicates a newly recorded species in Korea.

At each site, physical and chemical factors of water were recorded during the sampling periods. Water temp. (Water temperature, $^{\circ}\text{C}$) and EC (electric conductivity) were measured in situ using a portable thermometer and EC meter (Orion 5-star; Thermo Scientific, Waltham, MA, USA) and pH was measured in situ by using a pH meter (Ultraprecise-5; Denver Instrument, Bohemia, NY, USA). The data of total nitrogen (TN) and total phosphate (TP) concentrations at each sampling site were referred in the water information system of the Ministry of Environment (NIER 2013).

Chlorococcal algal identification was mainly based on Komarek and Fott (1983), John and Tsarenko (2002), Hindak (1977, 1980, 1984, 1988), Prescott (1962), Hirose and Yamagishi (1977), and Yamagishi and Akiyama (1984–1997).

RESULTS AND DISCUSSION

This study has identified and classified the collected

algae into 3 genera, 12 species and 1 variety based on Komarek and Fott (1983), Hindak (1977, 1980, 1984, 1988), John and Tsarenko (2002), and Komarek and Jankovska (2001). 11 taxa of this family are recorded in Korea by Kim (2013c): *Eutetramorus nygaardii*, *E. tetraporus*, *E. planctonicus*, *E. fottii*, *E. globosus*, *E. polycoccus*, *Coenocystis planctonica*, *C. planctonica* var. *hercynica*, *C. subcylindrica*, *Gloeocystis baneergattensis*, and *G. papuana*. Two new reported species are added in this study: *Coenocystis micrococca* and *Gloeocystis polydermatica*.

This study described the taxonomic information, illustration, classification, reference, basionym, synonym, and distribution of new recorded species of these families.

Class Chlorophyceae

Order Chlorococcales

Family Radiococcaceae

Subfamily Radiococcoideae

Genus *Eutetramorus* Walton 1918

Synonym *Coenococcus* Korshikov 1953.

Eutetramorus nygaardii Komarek 1979 (Fig. 1a–1c)

Basionym: *Eutetramorus nygaardii* Komarek 1979.

Synonym: *Coenococcus planctonicus* Korshikov sensu Nygaard.

Illustration: Colonies consist of 4–8 or 16 cells, sometimes with 4 cells in spherical 2–4 groups enclosed within spherical mucilaginous envelope. Cells or colonies arrange in spherical to tetrahedral form with a distance from each other. Cells are spherical, and parietal, with a pyrenoid. Autospores in the mother cell wall are released by gelatinization of the mother cell wall. Cells are 7–10 μm in diameter, colonies are 30–100 μm in diameter.

Key Reference: Komarek (1979).

Specimens: KOSPCL0000105967, KOSPCL0000106193.

Information on sampling sites: Spring of wall at tennis courts, Daejin University (26 September 2012; no data), Dongmyung Reservoir (10 June 2012; water temp. 28.7 $^{\circ}\text{C}$, pH 7.3, EC 240.3 $\mu\text{S cm}^{-1}$, TN 2.321 mg L^{-1} , TP 0.046 mg L^{-1}), Bukhan River at Yangsoori (26 August 2012; water temp. 30.2 $^{\circ}\text{C}$, EC 238 $\mu\text{S cm}^{-1}$), Oknyu Reservoir (22 September 2012; water temp. 25.2 $^{\circ}\text{C}$, pH 9.0, EC 572 $\mu\text{S cm}^{-1}$, TN 0.855 mg L^{-1} , TP 0.194 mg L^{-1}), Eurim Reservoir (30 August 2012; water temp. 28.2 $^{\circ}\text{C}$, pH 7.6, EC 138 $\mu\text{S cm}^{-1}$), Jooeul Reservoir (22 September 2012; water temp. 22.7 $^{\circ}\text{C}$, EC 267 $\mu\text{S cm}^{-1}$), Pond in Bundang Jungang Park (02 June 2012; water temp. 26.3 $^{\circ}\text{C}$, pH 8.2, EC 407 $\mu\text{S cm}^{-1}$), Lake 88 in Olymphic Park (07 September 2013; water temp. 29.8 $^{\circ}\text{C}$, EC 572 $\mu\text{S cm}^{-1}$), Fishery of Woogeum (01 August 2013; water temp. 29.8 $^{\circ}\text{C}$, EC 193 $\mu\text{S cm}^{-1}$), and Deokjin Reservoir (17

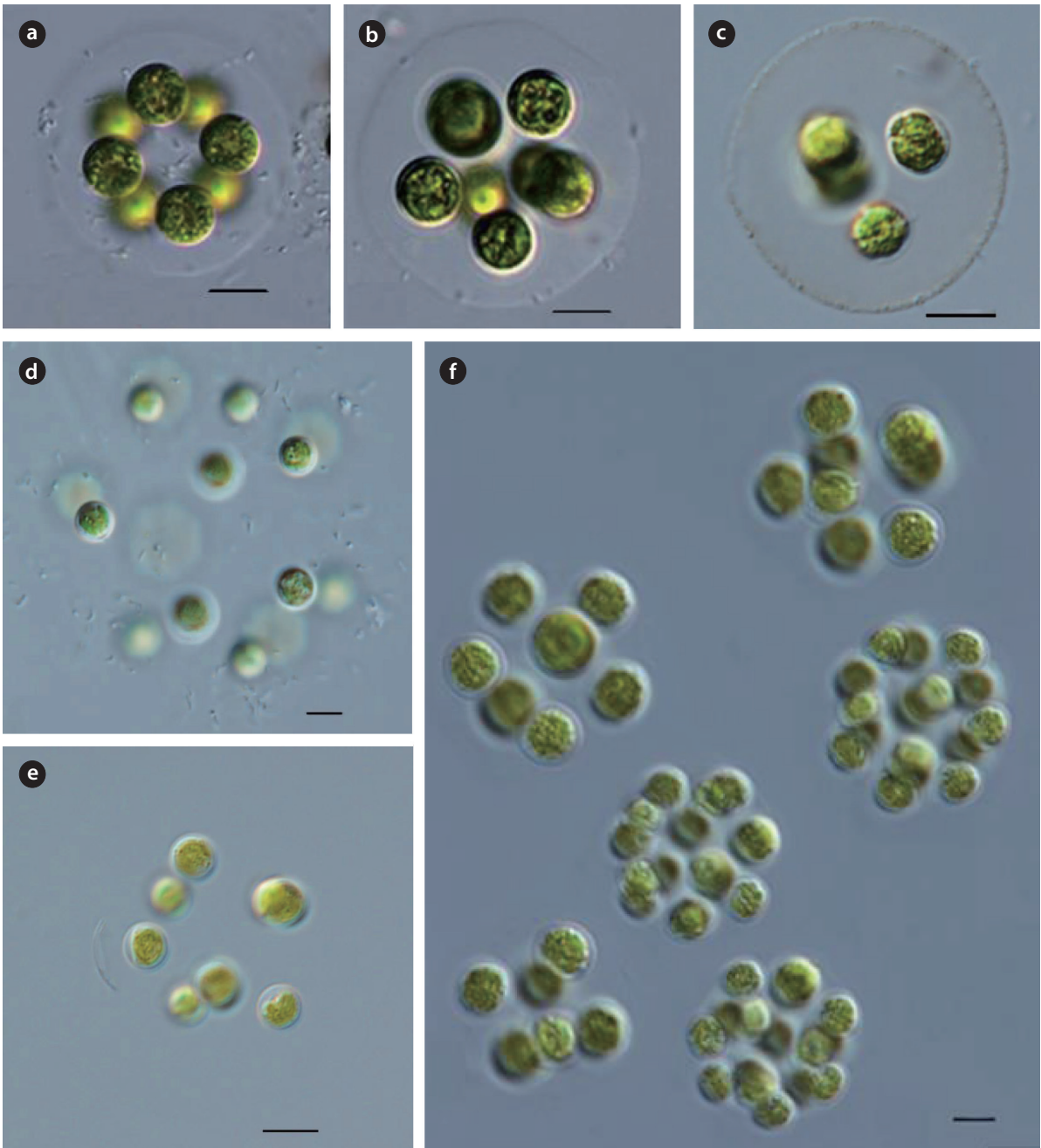


Fig 1. *Eutetramorus nygaardii* (a-c), *E. tetrasporus* (d-f). Scale bars, 10 μ m.

July 2014; water temp. 30.2°C, EC 342 μ S cm^{-1}).

Remarks: This species is widespread throughout the world as planktonic in lakes, ponds, slow flowing rivers and swamps. This species was first reported from ultra-oligotrophic lakes in Arctica (Groenlandia meridionalis, Narssaq) by Komarek (1979). It was also reported from oligotrophic lakes at South Greenland by Komarek and Fott (1983).

***Eutetramorus tetrasporus* Komarek 1983 (Fig. 1d–1f)**

Illustration: Colonies are spherical, or tetrahedral, consisting of 4–8 or 16 tetrahedrally cells. Cells are spherical, with a distance from each other. Cells are parietal, with a pyrenoid, consisting of 4–8 autospores within the mother cell wall, released by gelatinization of the mother cell wall. Cells are 5–10 μ m in diameter, colonies are 30–100 μ m in diameter.

Key Reference: Komarek (1983).

Specimens: KOSPCL0000106035, KOSPCL0000108484.

Information on sampling sites: Daegok Reservoir (09 July 2012; water temp. 24.0°C, pH 7.4, EC 151 $\mu\text{S cm}^{-1}$), Spring of wall at tennis courts, Daejin University (26 September 2012; no data), Dongmyung Reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 $\mu\text{S cm}^{-1}$, TN 2.321 mg L^{-1} , TP 0.046 mg L^{-1}), the Bukhan River at Yangsoori (26 August 2014; water temp. 30.2°C, EC 238 $\mu\text{S cm}^{-1}$), Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 $\mu\text{S cm}^{-1}$), Joeeul Reservoir (22 September 2012; water temp. 22.7°C, EC 267 $\mu\text{S cm}^{-1}$), Lake 88 in Olymphic Park (07 September 2013; water temp. 29.8°C, EC 572 $\mu\text{S cm}^{-1}$), and Galchi Reservoir (24 April 2013; water temp. 23.4°C, pH 6.9, EC 143.2 $\mu\text{S cm}^{-1}$).

Remarks: This species is widespread throughout the world as plankton in eutrophic lakes, ponds, slow flowing rivers, and swamps. This species was first reported from Ciudad de la Habana (Zoological Garden, eutrophic pool), province Habana (El Dique, eutrophic basin), Cuatro Caminos and Tapaste, Cuba, by Komarek (1983). It was reported from the artificial lakes at the municipality of Goiania from Brazil by Nogueira and Oliveira (2009).

***Eutetramorus planctonicus* (Korshikov) Bourrelly 1966 (Fig. 2a-2c)**

Basionym: *Coenococcus planctonicus* Korshikov 1953.

Illustration: Colonies consist of 4–16 or 32 or more cells, arranged in dense and irregular tetrahedrons within a spherical, ellipsoidal or irregular mucilaginous envelope. Cells are spherical, wide and ovoid, with a smooth wall. Chloroplast is cup-shaped, with a pyrenoid. Often 4–8 or sporadically 2 autospores are densely arranged in the mother cell walls, subsequently distributed at a distance from each other, and released by gelatinization of the cell wall. Cells are 5–10 μm in diameter, colonies are 30–100 μm in diameter.

Key Reference: Bourrelly (1966).

Specimens: KOSPCL0000102451, KOSPCL0000107294.

Information on sampling sites: Spring of wall at tennis courts, Daejin University (26 September 2012; no data), Lake 88 in Olymphic Park (07 September 2013; water temp. 29.8°C, EC 572 $\mu\text{S cm}^{-1}$), Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 $\mu\text{S cm}^{-1}$), Joeeul Reservoir (22 September 2012; water temp. 22.7°C, EC 267 $\mu\text{S cm}^{-1}$) and Sajipo swamp (27 June 2014; water temp. 32.0°C, EC 364 $\mu\text{S cm}^{-1}$).

Remarks: This species was firstly reported from Distrito Kharkivska, cerca de Lyubotina, Ukraine by Bourrelly (1966). It has been reported from several regions:

in a swamp at Escaleras de Jaruco and Zapata peninsula throughout Cuba (Komarek 1983), reservoir at Hrinova from Central Slovakia (Hindak 1977) and in ponds, lakes and canal throughout British Isles (John and Tsarenko 2002). This species was recorded in the report of the investigation and excavation of the native species by Kim (2013c), but Kim (2013a) reported *Coenococcus planctonicus* that was a synonym of *Euteramorus planctonicus*.

***Eutetramorus fottii* (Hindak) Komarek 1979 (Fig. 2d-2f)**

Basionym: *Coenococcus fottii* Hindak 1977.

Illustration: Colonies consist of 4–8 cells, arranged in a tetrahedron, and enclosed a spherical, or irregular, colorless mucilaginous envelope. Cells are cup-shaped with a pyrenoid. dense 4–8 or 16 autospores in the mother cell wall, subsequently distributed a distance from each other, and released by gelatinization of the mother cell wall. Cells are 5–8 μm in diameter, colonies are 30–100 μm in diameter.

Key Reference: Komarek (1979).

Specimens: KOSPCL0000105096, KOSPCL0000105962

Information on sampling sites: Dugok Reservoir (28 April 2012; water temp. 18.1°C, pH 9.2, EC 162.8 $\mu\text{S cm}^{-1}$), Dongmyung Reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 $\mu\text{S cm}^{-1}$, TN 2.321 mg L^{-1} , TP 0.046 mg L^{-1}), Bukhan River (26 August 2012; water temp. 30.2°C, EC 238 $\mu\text{S cm}^{-1}$), Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 $\mu\text{S cm}^{-1}$), and Pond in Bundang Jungang Park (02 June 2012; water temp. 26.3°C, pH 8.2, EC 407 $\mu\text{S cm}^{-1}$).

Remarks: This species was first reported *Coenococcus fottii* from the plankton of eutrophic waters, fish-pond of Želená Sudieka in Bratislava and some specimens of the Kunov water reservoir by Hindak (1977). Hindak (1977) merged *Sphaerocystis schroeterii* into *C. fottii*, which was mostly 8-celled, in the process of up to 64-cells, sporadically even multicelled, with cell groups of 8; vegetative cells shift from one another during autospore generation. Colonial mucilage structures, width around cell is up to 10 μm or wider, without remnants of the cell wall; only sporadically are gelatinized cell wall remnants seen at the boundary of the mucilage of a young colony. Komarek (1983) transferred *C. fottii* into *Euteramorus fottii* as a synonym. This study indentified and classified this species according to Komarek and Fott (1983).

***Eutetramorus globosus* Walton 1918 (Fig. 3a-3f)**

Illustration: Colonies consist of 4–8 or 16 cells, arranged flattened or in a tetrahedral form, and enclosed in a spherical, colorless, homogeneous mucilaginous envelope.

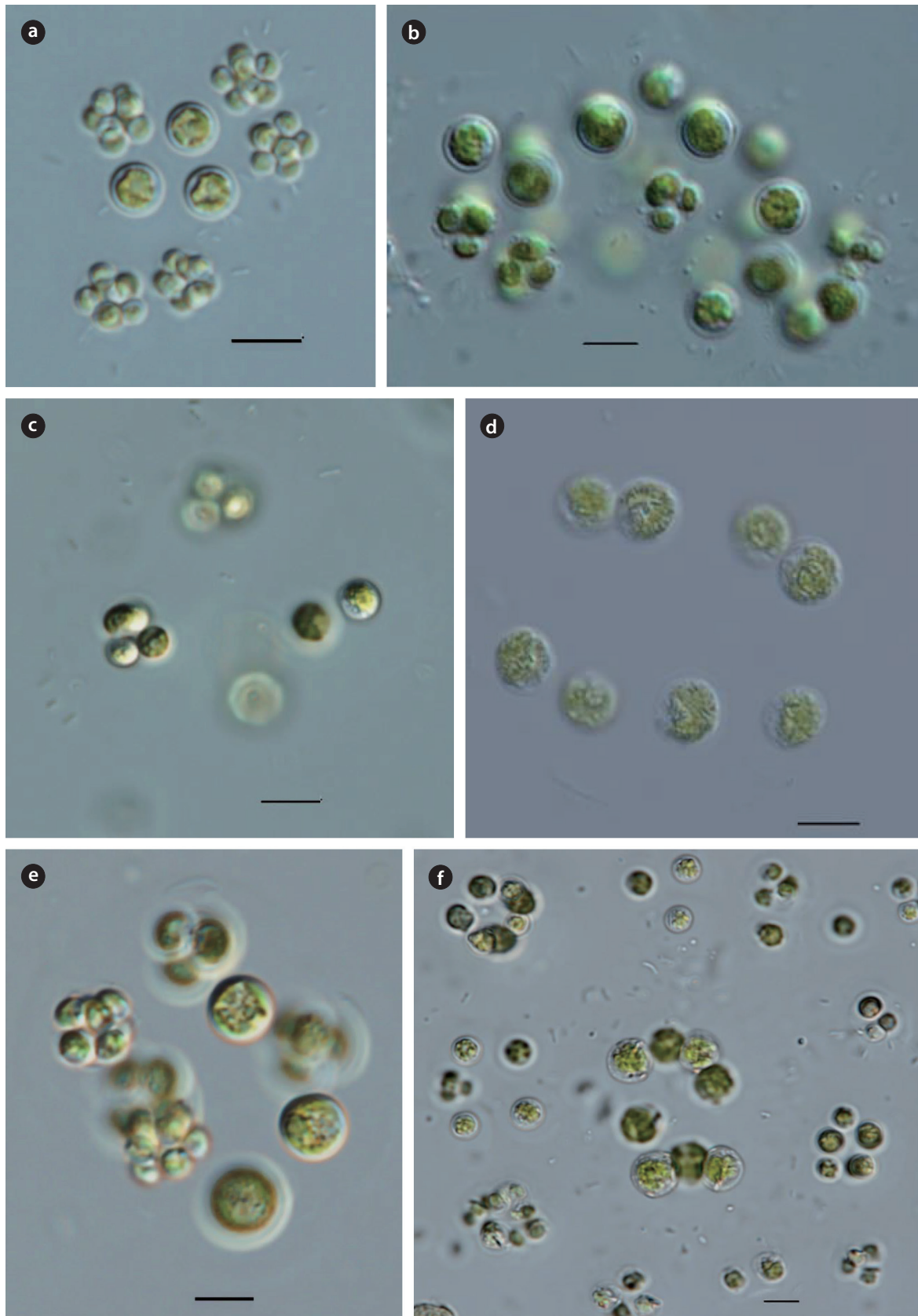


Fig. 2. *Eutetramorus planctonicus* (a-c), *E. fottii* (d-f). Scale bars, 10 μ m.

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lope. Cells are spherical, arranged at a distance from each other, densely with 4–8 or 16 autospores in the mother cell wall, and subsequently a distance from each other, and released by gelatinization of the mother cell wall. Chloroplast is cup-shaped, with a pyrenoid. Cells are 5–10 µm in diameter, colonies are 30–100 µm in diameter.

Key Reference: Walton (1918).

Specimens: KOSPCL0000105891, KOSPCL0000106162.

Information on sampling sites: Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 µS cm⁻¹), Pond in Bundang Jungang Park (02 June 2012; water temp. 26.3°C, pH 8.2, EC 407 µS cm⁻¹), and Jooeul Reservoir (22 September 2012; water temp. 22.7°C, EC 267 µS cm⁻¹).

Remarks: This species is widespread throughout the world as plankton in eutrophic lakes, ponds, slow flowing river and swamps. This species was first reported from Mirror Lake (a small pond on the campus of the State University at Columbus) Ohio, USA, by Walton (1918). The other researcher has reported from mesotrophic lakes in Austria (Komarek and Fott 1983).

***Eutetramorus polycoccus* (Korshikov) Komarek 1979 (Fig. 3d-3f)**

Basionym: *Sphaerocystis polycoccus* Korshikov 1953.

Synonym: *Coenococcus polycoccus* (Korshikov) Hindak.

Illustration: Colonies consist of 4–8 or 16 cells, enclosed in a spherical or irregular mucilaginous envelope. Cells are spherical, with a smooth wall, and arranged at a distance from each other. Chloroplast is cup-shaped, with 2 or more pyrenoids. 4–8 or 16 autospores are in the mother cell wall and released by gelatinization of the mother cell wall. Cells are 5–10 µm in diameter, colonies are 30–100 µm in diameter.

Key Reference: Komarek (1979).

Specimens: DJWG20120621.

Information on sampling sites: Woogeum Reservoir (21 July 2012; water temp. 27.8°C, pH 8.9, EC 123 µS cm⁻¹) and Gyodong Reservoir (31 May 2013; water temp. 25.4°C, EC 204 µS cm⁻¹).

Remarks: This species was first reported from Northern Europe; Russia (Silva 1996–to date) by Komarek (1979). This species was reported from eutrophic lakes, rivers, ditches, and ponds throughout the British Isles (John and Tsarenko 2002), in inundation lakes of Morava from Western and Southern Slovakia (Hindak 1977), and in lakes throughout Europe (Austria, Romania, Switzerland, Ukraina) and in Washington, USA (Komarek and Fott 1983).

Genus *Coenocystis* Korshikov 1953

***Coenocystis tapasteana* Komarek 1983 (Fig. 4a-4d)**

Illustration: Colonies consist of 4–8 or 32 cells, sometimes 4 or 8 cell groups, enclosed by colorless, irregular mucilaginous envelope. Cells are wide and ovoid, slightly asymmetrical or spherical, with a thin gelatinous layer around the cells. Reproduction is by 4–8 or 16 autospores, arranged parallel in the mother cell wall, and released by gelatinization of the mother cell wall, with no visible remnants of the mother cell wall. Chloroplast is cup-shaped, with a pyrenoid.

Key Reference: Komarek (1983).

Specimens: KOSPCL0000106052.

Information on sampling sites: Dongmyung Reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 µS cm⁻¹, TN 2.321 mg L⁻¹, TP 0.046 mg L), Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 µS cm⁻¹), Lake 88 in Olympic Park (07 September 2013; water temp. 29.8°C, EC 572 µS cm⁻¹), and Banwoel Reservoir (24 April 2013; water temp. 19.1°C, pH 8.3, EC 267 µS cm⁻¹).

Remarks: This species was first reported from Habana (Escaleras de Jaruco, swamp), province Mantanzas (Zapata peninsula, swamps), Cuba and swamps at Escaleras de Jarucp and Zapata throughout Cuba (Komarek 1983). This species was reported from eutrophic lake in Cuba (Komarek and Fott 1983) and the Bermejales reservoir in the Iberian Peninsula from Cuba (Trevino et al. 2010).

***Coenocystis planctonica* Korshikov 1953 (Fig. 4e and 4f)**

Synonym: *Coenochloris korshikovii* Hindak.

Illustration: Colonies consist of 4 or 8 cells located towards the center of a spherical or ellipsoidal mucilaginous envelope, with an indistinct edge. Cells are spherical or ovoid, and symmetrical. Chloroplast is parietal, with a pyrenoid. Reproduction is by 4 or 8 autospores in the mother cell wall, released by the splitting of the mother cell wall. Cells are 10–15 µm in length and 8–10 µm in width. Colonies are up to 80 µm in diameter.

Key Reference: Korshikov (1953).

Specimens: KOSPCL0000104313, KOSPCL0000105264.

Information on sampling sites: Dongmyung Reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 µS cm⁻¹, TN 2.321 mg L⁻¹, TP 0.046 mg L), Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 µS cm⁻¹), and Lake 88 in Olympic Park (07 September 2013; water temp. 29.8°C, EC 572 µS cm⁻¹).

Remarks: This species was first reported from Kharkov area, Lake Liman, Ukrainian, by Korshikov (1953). This species has been reported from lakes, rivers and ponds

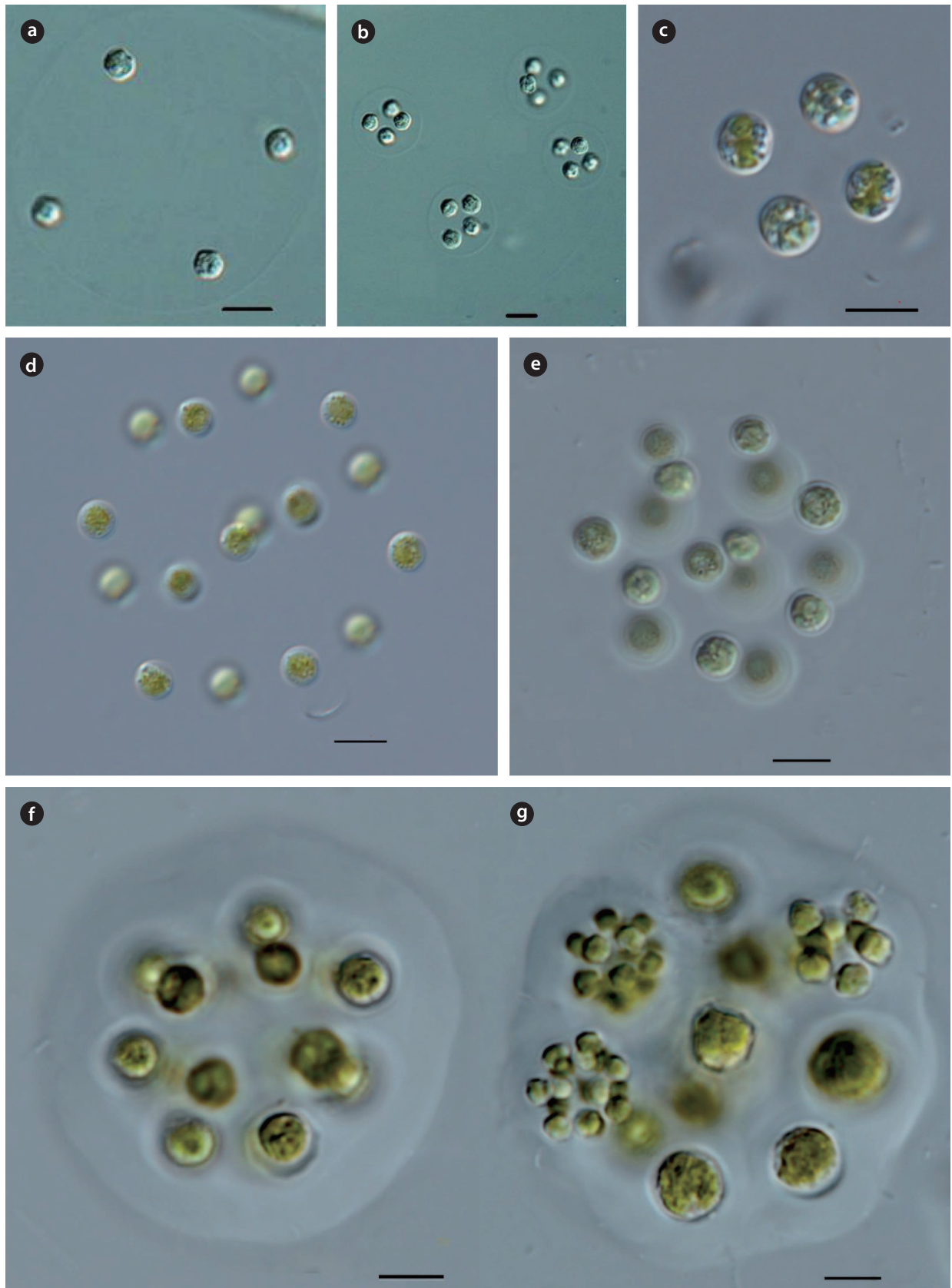


Fig. 3. *Eutetramorus globosus* (a-c), *E. polycoccus* (d-g). Scale bars, 10 μ m.

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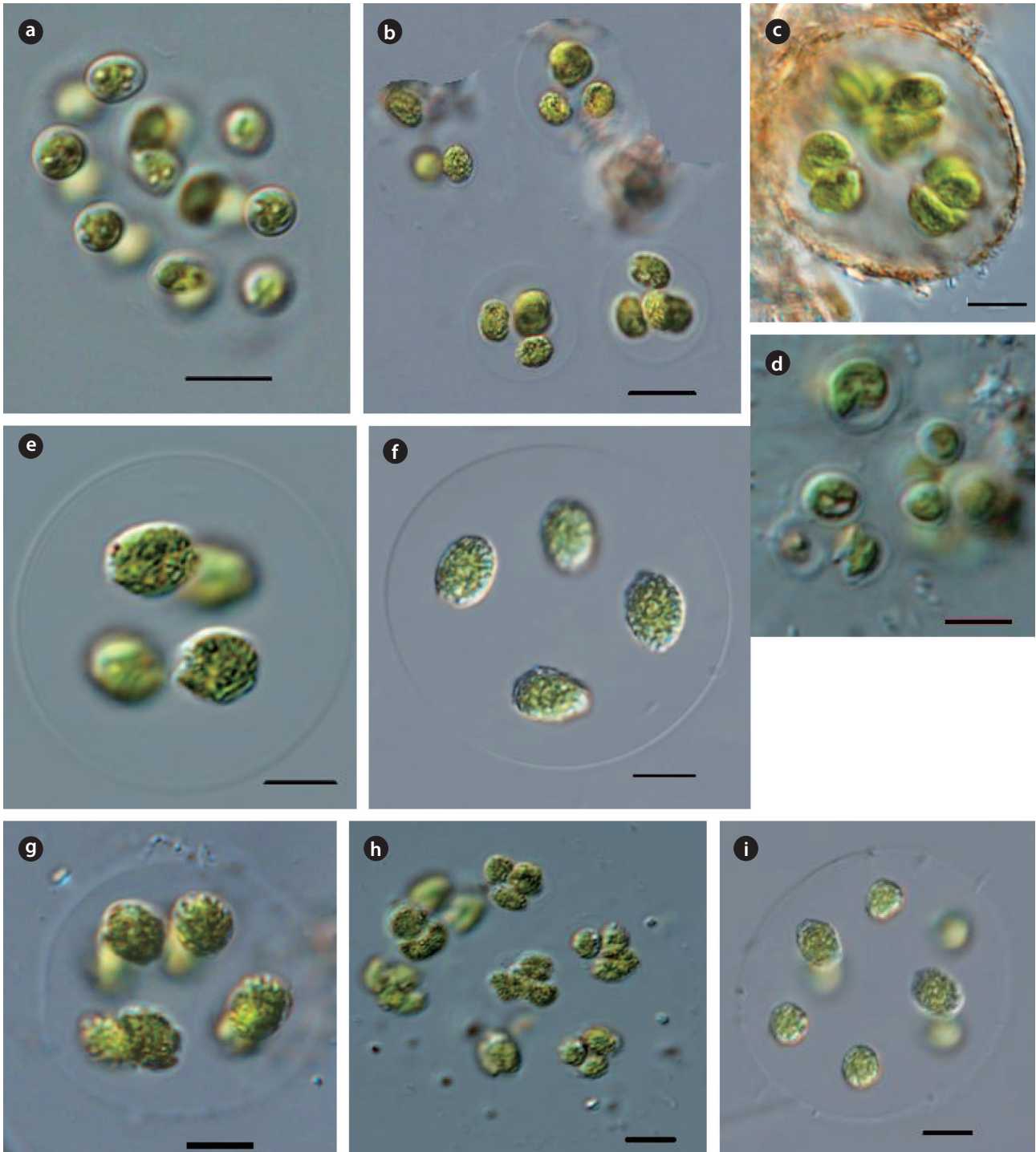


Fig. 4. *Coenocystis tepasteana* (a-d), *C. planctonica* (e, f), *C. planctonica* var. *hercynica* (g-i). Scale bars, 10 μm.

throughout the British Isles (John and Tsarenko. 2002), in lakes throughout Europe (Czech, Hungary, Poland, Ukraina) and America (USA, Canada, Cuba, Argentina) (Komarek and Fott 1983), and the inundation lakes at the Morava river into the Danube throughout Slovakia (Hindak 1984).

***Coenocystis planctonica* var. *hercynica* (Heynig) Fott 1974 (Fig. 4g-4i)**

Basionym: *Gloeocystis hercynica* Heynig 1962.

Synonym: *Coenocystis hercynica* (Heynig) Hindak.

Illustration: Colonies consist of 4 or 8 cells located towards the center of a spherical or ellipsoidal mucilaginous envelope, with an indistinct edge. Cells are spherical or ovoid, symmetrical. Chloroplast is parietal, with a pyrenoid. Reproduction is by 4 or 8 autospores in the mother cell walls, released by the splitting of the mother cell wall. Cells are 10–20 μm in length and 8–15 μm in width.

Key Reference: Fott (1974).

Specimens: KOSPCL0000106081, KOSPCL0000106129.

Information on sampling sites: Daejin University pond (26 September 2012; no data), Dongmyung Reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 $\mu\text{S cm}^{-1}$, TN 2.321 mg L^{-1} , TP 0.046 mg L^{-1}), Euirim Reservoir (30 August 2012; water temp. 28.2°C, pH 7.6, EC 138 $\mu\text{S cm}^{-1}$), Lake Seocho (27 May 2012; water temp. 30.4°C, pH 7.3, EC 569 $\mu\text{S cm}^{-1}$), Oknyu Reservoir (22 September 2012; water temp. 25.2°C, pH 9.0, EC 572 $\mu\text{S cm}^{-1}$, TN 0.855 mg L^{-1} , TP 0.194 mg L^{-1}), and Lake 88 in Olympic Park (07 September 2013; water temp. 29.8°C, EC 572 $\mu\text{S cm}^{-1}$).

Remarks: *Gloeocystis hercynica*, a basionym of this species, was first reported from GDR (Harz), Germany, by Heynig (1962). Fott (1974) reported this species as a new species from Czechoslovakia. Hindak (1984) described a new species from Cicovske Jazero Lake (Lyon), a backwater of the Danube. He also merged *C. planctonica* var. *hercynica* into *C. hercynica* as a synonym. This author compared the figures and the described contents on the new species of Hindak (1984) and Fott (1974) and classified it as *Coenocystis planctonica* var. *hercynica*. It has been reported from lakes throughout Europe (Czech, Hungary, Poland, Ukraina) (Komarek and Fott 1983), Lake Cicovske Jazero at Lyon Slovakia (Hindak 1984) and DDR (Harz) from Germany (Fott 1974).

***Coenocystis subcylindrica* Korshikov 1953 (Fig. 5a-5c)**

Synonym: *Gloeocystis hercynica* var. *minor* Heynig.

Illustration: Colonies are spherical, oval, slightly irregular or several subcolonies, arranged parallel in 1 or

2 planes, slightly irregularly, with a distance from each other. Cells are widely ovoid or sometimes slightly asymmetrical shape. Chloroplast is parietal, massive, without pyrenoid. Reproduction is by autospores arranged in 1 or 2 planes in the mother cell wall, and released by gelatinization of the mother cell wall. Cells are 5–15 μm in length and 5–10 μm in width.

Key Reference: Korshikov (1953).

Specimens: KOSPCL0000105269.

Information on sampling sites: The Bukhan River at Yangsoori (26 August 2012; water temp. 30.2°C, EC 238 $\mu\text{S cm}^{-1}$), Lake Seocho (27 May 2012; water temp. 30.4°C, pH 7.3, EC 569 $\mu\text{S cm}^{-1}$), Woogeum Reservoir (01 August 2013; water temp. 29.8°C, EC 193 $\mu\text{S cm}^{-1}$), and Lake 88 in Olympic Park (07 September 2013; water temp. 29.8°C, EC 572 $\mu\text{S cm}^{-1}$).

Remarks: This species is widespread throughout the world as plankton in eutrophic lakes, ponds, slow flowing rivers and swamps. This species was first reported from the Gorkij-district, USSR, by Korshikov (1953). It has been recorded from the several regions in lakes throughout Europe (Czech, Hungary, Poland, Ukraina, and Germany), America (Canada, USA, Cuba, and Argentina), and New Zealand (Komarek and Fott 1983). Hindak (1988) reported this species at two different typical localities. He collected the sample at the outflow of the mountain Lake Rohacske at Western Tatras in September 1982 and at the eutrophicated water reservoir at Boleraz near Trnava throughout Slovakia in the summer 1986 (Hindak 1988). This species was also collected in the eutrophicated reservoir and lake in Korea.

****Coenocystis micrococca* Komarek 1983: (Fig. 5d and 5e)**

Illustration: Colonies are spherical, oval, and irregular or 1-4 subcolonies, fine colorless, and with different gelatinous envelope. Cells are oval to widely oval, and old cells almost spherical. Autospores are ellipsoidal to oval, sometimes asymmetrical, and irregularly arranged from another. Chloroplast is single, parietal or cup shaped with a pyrenoid. Cells are 5 μm in length and 5–10 μm in width.

Key Reference: Komarek (1983).

Specimens: DJDB20140530.

Information on sampling sites: Dongbaekdongsan (30 May 2014; water temp. 32.0°C, pH 6.9, EC 69.6 $\mu\text{S cm}^{-1}$).

Remarks: Komarek (1983) collected the samples in the detritus eutrophic pool in Province Matanzas, Cuba, and reported a new species. This author collected the sample of this species from a swamp of Dongbaekdongsan in Jeju Island.

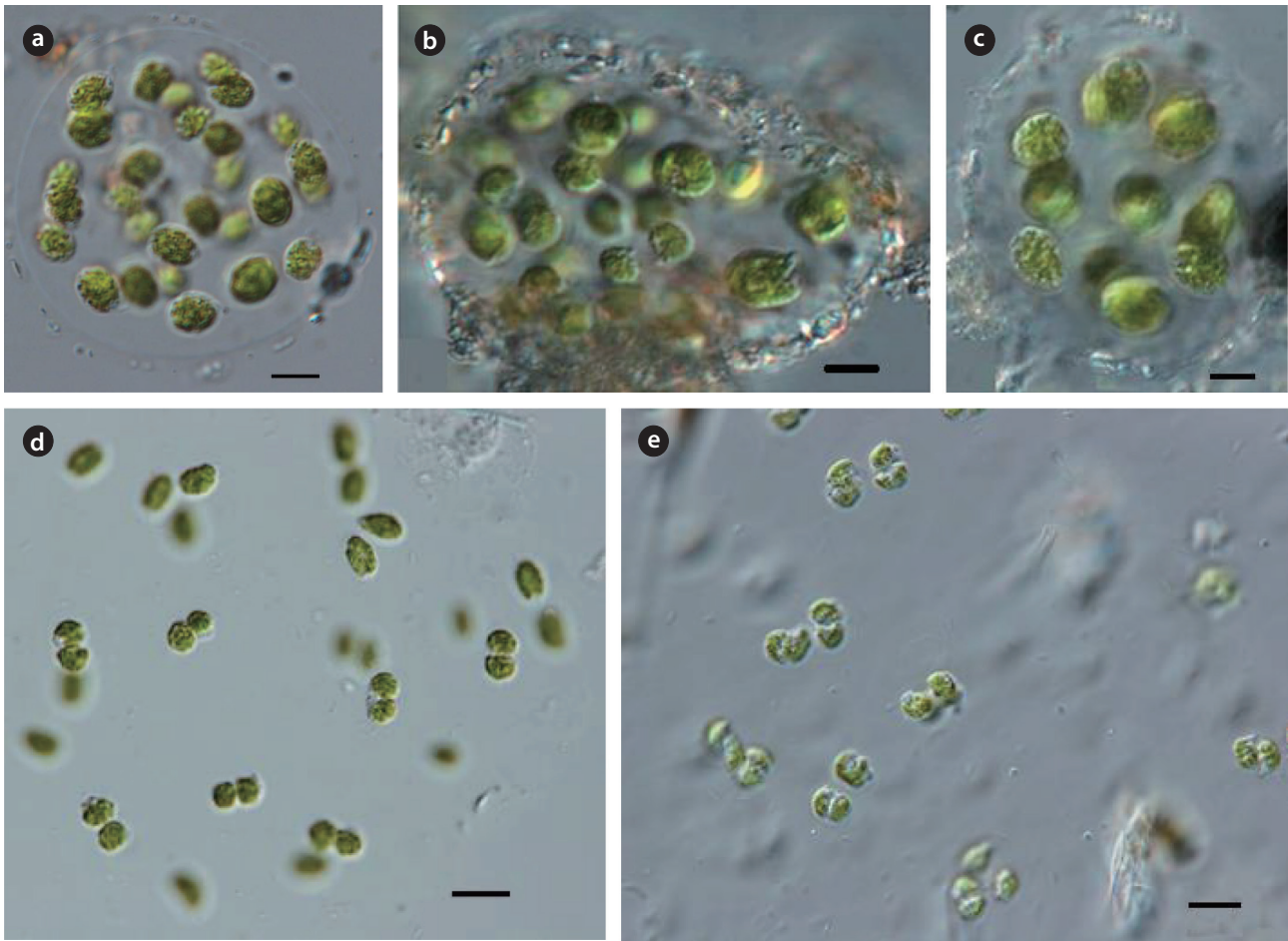


Fig. 5. *Coenocystis subcylindrica* (a-c), *C. micrococca* (d, e). Scale bars, 10 μ m.

Genus *Gloeocystis* Nägeli 1849: 65

Gloeocystis banneergattensis Iyengar 1971 (Fig. 6a-6c)

Illustration: Colonies consist of 4–8 or 16 cells, and are enclosed by a colorless, concentric circular mucilaginous envelope. Cells are spherical, with a gelatinous sheath around each cell, chloroplast is cup shaped, with a pyrenoid. Reproduction is by 4 or 8 autospores, arranged in a tetrahedron form, within oval or spherical the mother cell wall. Cells are 8–15 μ m in diameter.

Key Reference: Iyengar (1971) in Komarek and Fott (1983).

Specimens: DJDM20120710, DJOS20130814.

Information on sampling sites: Dongmyung Reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 μ S cm^{-1} , TN 2.321 mg L^{-1} , TP 0.046 mg L^{-1}), Seorang Reservoir (27 May 2012; water temp. 30.4°C, pH 7.0, EC 294.6 μ S cm^{-1}), Oksan Reservoir (14 August 2013; water temp. 30.2°C, EC 342 μ S cm^{-1}), and Deokjin Reservoir (17 July 2014; water

temp. 31.6°C, EC 110.0 μ S cm^{-1}).

Remarks: Iyengar (1971) collected samples from the pond at Bangalore in India, and identified it as a species of the genus *Gloeocystis*, which had a mucilaginous envelope and arranged the autospores in the mother cell wall as like the genus *Euteramorus*. He reported on a new species (Komarek and Fott, 1983).

Gloeocystis papuana (S. Watanabe) Ettl and Gärtner 1995 (Fig. 6d–6f)

Basionym: *Palmogloea papuana* S. Watanabe 1979.

Illustration: Colonies consist of 4–8–16 cells, enclosed in a spherical, colorless, concentric circular mucilaginous envelope. Cells are spherical, enclosed in a gelatinous sheath. Chloroplast is parietal, with a pyrenoid. Reproduction is by 4 or 8 autospores, arranged in a tetrahedron form, enclosed by an oval or spherical mother cell wall. Cells are 8–15 μ m in diameter.

Key Reference: Ettl and Gärtner (1995).

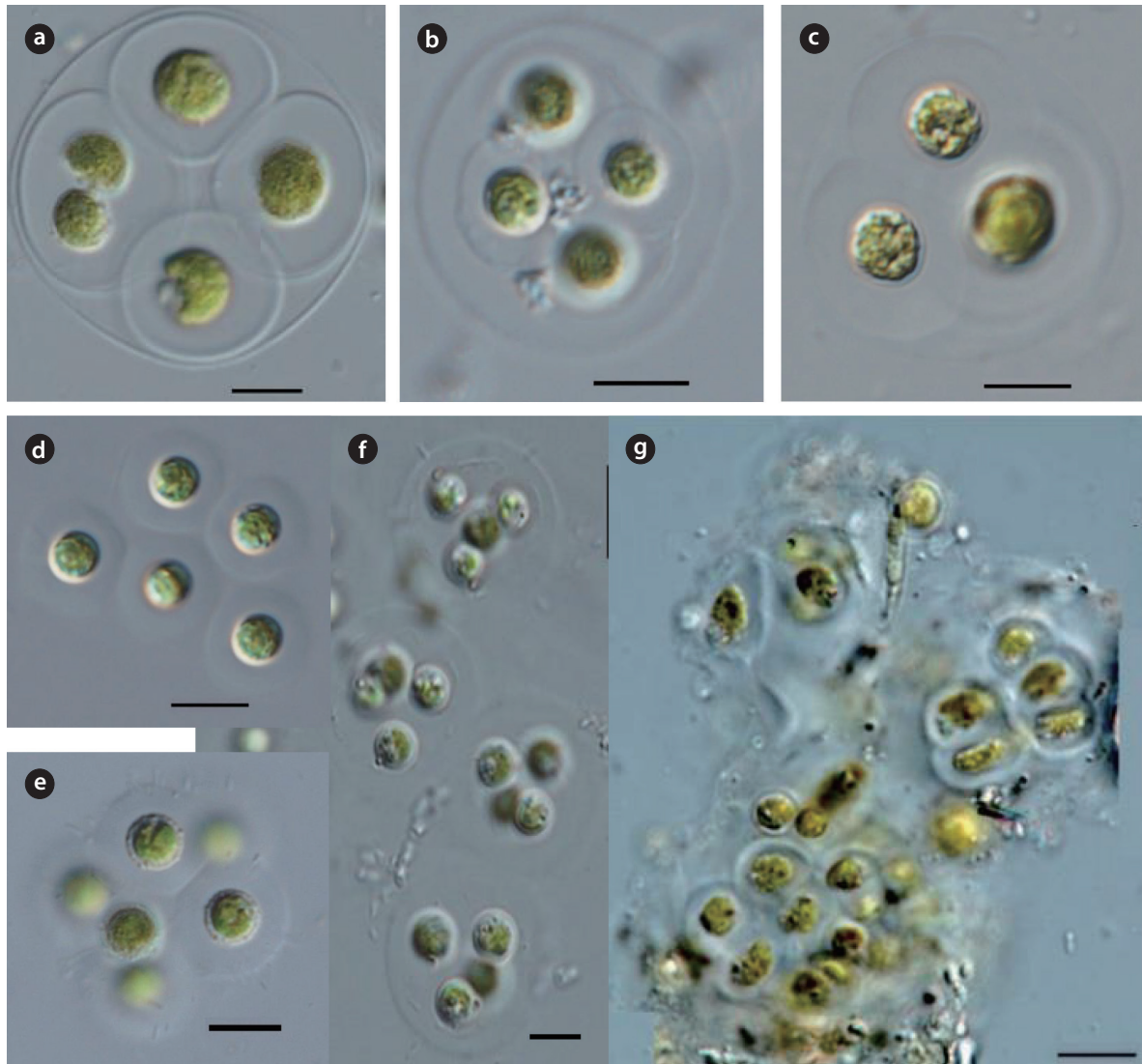


Fig. 6. *Gloeocystis banneergattensis* (a-c), *G. papuana* (d-f), *G. polydermatica* (g). Scale bars, 10 µm.

Specimens: DJDM20120710, DJBD20120602.

Information on sampling sites: Dongmyung reservoir (10 July 2012; water temp. 28.7°C, pH 7.3, EC 240.3 µS cm⁻¹, TN 2.321 mg L⁻¹, TP 0.046 mg L⁻¹), Pond in Bundang Jungang Park (02 June 2012; water temp. 26.3°C, pH 8.2, EC 407 µS cm⁻¹), Woogeum Reservoir (01 August 2013; water temp. 27.8°C, pH 8.9, EC 123 µS cm⁻¹), and Deokjin Reservoir (17 June 2014; water temp. 31.6°C, EC 110.0 µS cm⁻¹).

Remarks: Watanabe (1977) collected the sample from the Papua, and reported a new species *Palmogloea papuana*. Komarek and Fott (1983) identified the genus *Gloeocystis* based on *Palmogloea papuana*. It was merged *Palmogloea papuana* into *Gloeocystis papuana* by Ettl and Gärtner (1995). This author collected several samples

from eutrophic reservoir in Korea. The species in the samples were identified and classified to *Gloeocystis papuana* according to Ettl and Gärtner (1995).

****Gloeocystis polydermatica* (Kützing) Hindak 1978 (Fig. 6g)**

Basionym : *Gloeocapsa polydermatica* Kützing 1846.

Synonym : *Gloeocystis naegeliana* Artari; *Coccomyxa epigloea* Jaag and Thomas; *Gloeocystis vesiculosa* Nägeli sensu Fott; *Palmogloea protuberans* (Smith and Snow) Kützing.

Illustration: Colonies are amorphous, green mucilaginous, with scattered cells in a colorless gelatinous concentric envelope. Cells are composed with a single, pair or four, oval or ellipsoidal shapes. Cells are enclosed several

concentric gelatinous sheaths around cells, chloroplast is parietal, with a pyrenoid. Reproduction is by 4 or 8 autospores, enclosed by an oval or spherical mother cell wall. Cells are 5–8 µm in length and 4–6 µm in width.

Key Reference: Hindak (1978).

Specimens: DJBD20140530.

Information on sampling sites: Baengduimot (30 May 2014; water temp. 31.7°C, pH 7.7, EC 91.3 µS cm⁻¹).

Remarks: *Gloeocystis poldermatica* was described as a new species by Hindak (1978) based on *Gloeocapsa polydermatica*, which had been included Cyanophyceae and basionym of *Gloeocapsa caldariorum* Rabenhorst. The morphological characters of *Gloeocapsa polydermatica* were similar to *Gloeocystis polydermatica* but differed from the blue green color and lack of a pyrenoid. Hindak (1978) also merged *Palmogloea protuberans* into *G. poldermatica*, enumerating a number of reasons why the genus *Palmogloea* Kutz. was to be rejected, in accordance with the International Code of Botanical Nomenclature. And, the genus *Gloeocystis* was to be maintained as the representative of those chlorococcal algae that reproduced only by autospores. The species of the genus *Gloeocystis* are known often from green to dark greenish macroscopic mucilaginous coverings on subaerial to facultatively aerial habitats (Hindak 1978). This author collected the sample from Baengduimot in Jeju Island. These were not aerial or subaerial habitats but living mixed with other plants and humic materials in swamp. The sample of this species fitted within *G. polydermatica* as circumscribed by Hindak (1978) and Entwistle and Skinner (2001).

CONCLUSION

This study was carried out on freshwater chlorococcal green algae in ponds, swamps, reservoirs, lakes and rivers (290 sites) from May 2012 to January 2014. The family Radiococaceae was identified and classified into 3 genera, 12 species and 1 variety at 23 sites. These taxa were *Eutetramorus nygaardii*, *E. tetraporus*, *E. planctonicus*, *E. fottii*, *E. globosus*, *E. polycoccus*, *Coenocystis planctonica*, *C. planctonica* var. *hercynica*, *C. micrococca*, *C. subcylindrica*, *Gloeocystis baneergattensis*, *G. papuana*, and *G. polydermatica*. These taxa may or may not have the remnants of the cell wall in the colonial gelatinous envelope for a short time. Of these, 2 taxa are newly recorded in Korea from this study: 1) *C. micrococca* and 2) *G. polydermatica*.

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