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Desmids from Korea; 1. Desmidiaceae 1 (*Micrasterias*)

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Abstract

The present study summarizes the occurrence, distribution and autecology of the genus *Micrasterias* Ralfs among desmids collected from several swamps, reservoirs, rivers and high land wetlands in South Korea from 2009 to 2013. In total 21 taxa of *Micrasterias* including three new species, *Micrasterias spinosus* sp. nov., *M. jejuensis* sp. nov. and *M. koreanus* sp. nov., were identified. In this study, photomicrographs of all of these are provided and briefly discussed with regard to their taxonomy, distribution and ecology within South Korea.

Key words: desmids, *Micrasterias*, new species, photomicrograph, South Korea

INTRODUCTION

Since Kawamura (1918) reported a species of *Centritractus* at lake Seoho, Suwon, many investigations on the fresh-water algal flora have been done by a number of workers in different parts of Korea (Skvortzov 1932, Chung and Chang 1957, Chung 1968, 1970, 1975, 1976, 1979, 1982, Chung et al. 1972a, 1972b, Chung and Lee 1986, Wui and Kim 1987a, 1987b, Kim 1992, 1996, Kim and Chung 1993a, 1993b, 1994, Kim et al. 2009). The most floristic or taxonomic studies of desmids from Korea were investigated along with other taxonomic groups of fresh-water algae, and only a few studies on the desmids flora have been carried out in Korea (Choi 1976, Chung and Lee 1986, Kim 1996).

To date, about 1,800 taxa of fresh-water algae were reported excluding diatoms, and among them about 1,100 taxa of Chlorophytes including about 600 taxa of desmids have been recorded in Korea. However, this is only 13.7% of the green algae species (about more than 8,000 species) reported throughout the world (Van den Hoek et al. 1995), and it is also only about 10% of the desmids reported in world-wide (6,000 species) and 40% of the desmids reported in England (almost 1400 species) (John and Williamson 2011) although this number is similar to that of Japan (443 species) (Hirose and Yamagishi 1977). Moreover, most of desmids are cosmopolitan species, and many of these were recorded in acidic waters such as *Sphagnum* bogs, peat bogs, marsh, swamps, and mountainous wetlands. Also, many of these are especially abundant in acid bogs associated with *Sphagnum* and *Utricularia* species (Brook 1981, Brook and Williamson 2010). However, all of the most floristic or taxonomic studies on the desmids in Korea have been conducted at lowland artificial lakes, reservoirs, several swamps, and variable habitats including ditches, paddy field, and small ponds. In addition, correct geographic and ecological information on the sampling sites were not presented, in the most of the previous studies. Most of sampling sites surveyed in the present study including unusual environments (e.g., highland moorlands, mountainous *Sphagnum* bogs or wetlands, and small crater) were examined for the first time in Korea. These wetlands in the highland mountain are generally shows the characteristics of oligotrophic and acidic water

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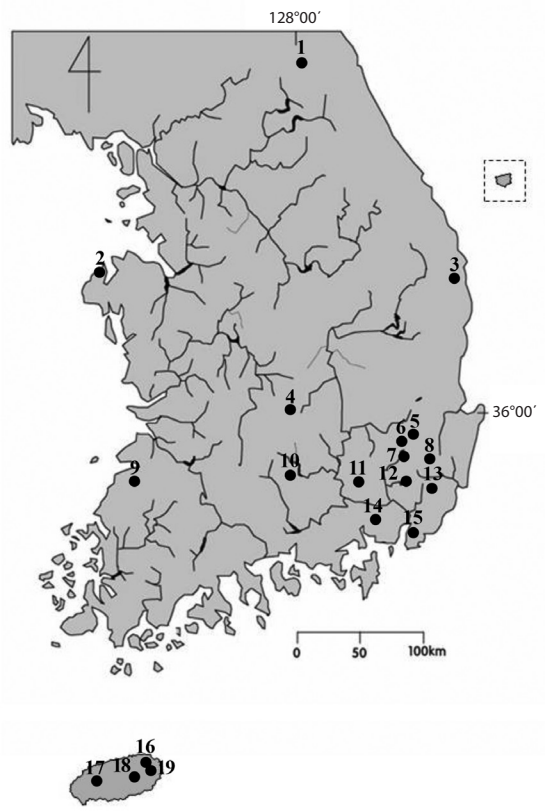

Fig. 1. Location of sampling sites in the territory of Korea. Numbers on the map represent as follow: 1, Yongneup; 2, Du-ung wet-lands; 3, Bakdal wet-lands; 4, Dogok weir; 5, Guryong reservoir; 6, Namsan reservoir; 7, Imdang weir; 8, Okbang wetlands; 9, Ungok wet-lands; 10, Motje; 11, Jangcheok reservoir; 12, Danjang stream; 13, Mujechineup; 14, Junam reservoir; 15, Samlak wet-lands; 16, Dongbaek-dongsan; 17, Sumenmulbangdi; 18, Mulyoungari; 19, Deokcheon pond. See detailed information of sampling sites in Table 1.

bodies.

More than 500 samples were collected from varies water bodies throughout the country for establishing freshwater algal flora of Korea. Altogether, 21 taxa of *Micrasterias* (desmids) including three new species (*M. spinosus* sp. nov., *M. jejuensis* sp. nov., and *M. koreanus* sp. nov) were reported.

MATERIALS AND METHODS

Over 500 samples were collected from 2009 to 2013 from varies types of wetland habitats, including eutrophic reservoirs, diverse swamps, oligotrophic and acidic mountainous wetlands, *Sphagnum* bogs, and orum (i.e., very small and shallow caldera lakes) (Fig. 1 and Table 1). The samples were obtained by means of plankton net (mesh size, 25 μm) and spoid or by squeezing submerged macrophytes, and the living materials was immediately examined. After first examination living materials, they were preserved in Lugol's solution for permanent preservation and detail identification. Microscopic examinations were made at × 200-1000 magnification under an Axio Imager A2 microsope (Carl Zeiss, Jena, Germany), and the photographs were taken with an AxioCam HRC camera (Carl Zeiss). Water temperature, pH, and conductivity were measured in the field by means of a HI8314 membrane pH meter (HANNA instruments, Smithfield, RI, USA) and a HI9835 EC meter (HANNA instruments). All the taxa recorded were illustrated with photomicrographs.

Table 1. Information of sampling sites

Site No.	location	Characteristic of Sampling site	pH	EC (μS/cm)	Altitude (m)
1	38°12′55″ N, 128°07′15″ E	Highland *Sphagnum* bog	5.5-6.5	20-50	1,200
2	36°50′10″ N, 126°11′50″ E	Small costal dune wet-lands	6.8-7.5	40-105	10
3	36°55′19″ N, 129°16′48″ E	Abandoned paddy field ditch located at Mt. Cheonchuk	5.6-7.0	36-55	560
4	35°58′50″ N, 128°01′00″ E	Puddle located at river-side	6.8-7.5	40-105	160
5	35°49′55″ N, 128°58′05″ E	Small shallow mesotrophic reservoir	6.5-7.8	60-150	560
6	35°46′55″ N, 128°50′05″ E	Mesotrophic agricultural reservoir	6.6-8.7	65-120	160
7	35°42′25″ N, 128°55′00″ E	Weir located at the middle part of the Dongchang stream	6.7-7.5	112-145	100
8	35°46′20″ N, 129°05′05″ E	Abandoned paddy field ditch located at highland	6.2-7.5	27-45	480
9	35°27′30″ N, 126°39′00″ E	Aabandoned paddy field	6.2-7.5	27-45	60
10	35°36′45″ N, 128°13′55″ E	Small shallow pond located at top area of small mountain	6.6-7.7	65-120	80
11	35°26′10″ N, 128°29′35″ E	Old shallow mesotrophic reservoir	7.2-8.3	103-155	30
12	35°29′40″ N, 128°55′30″ E	Weir located at the lower part of Mylyang dam	6.8-7.5	40-105	90
13	35°27′50″ N, 129°08′30″ E	Highland *Sphagnum* bog	5.2-6.7	25-35	650
14	35°18′35″ N, 128°39′50″ E	oOd shallow mesotrophic reservoir	6.8-7.5	160-197	30
15	35°10′40″ N, 128°58′20″ E	Artificial wet-lands located at river-side	6.7-7.5	44-121	5
16	33°31′10″ N, 126°42′30″ E	Natural oligotrophic rock pond	6.1-7.5	44-108	60
17	35°25′20″ N, 128°59′30″ E	*Sphagnum* bog located at near the middle of Mt. Hanla	5.4-6.6	25-45	860
18	33°22′50″ N, 126°41′20″ E	Oligotrophic adventive crater	5.6-7.0	36-55	480
19	33°30′20″ N, 126°46′30″ E	Artificial small shallow pond	6.5-7.4	90-140	100

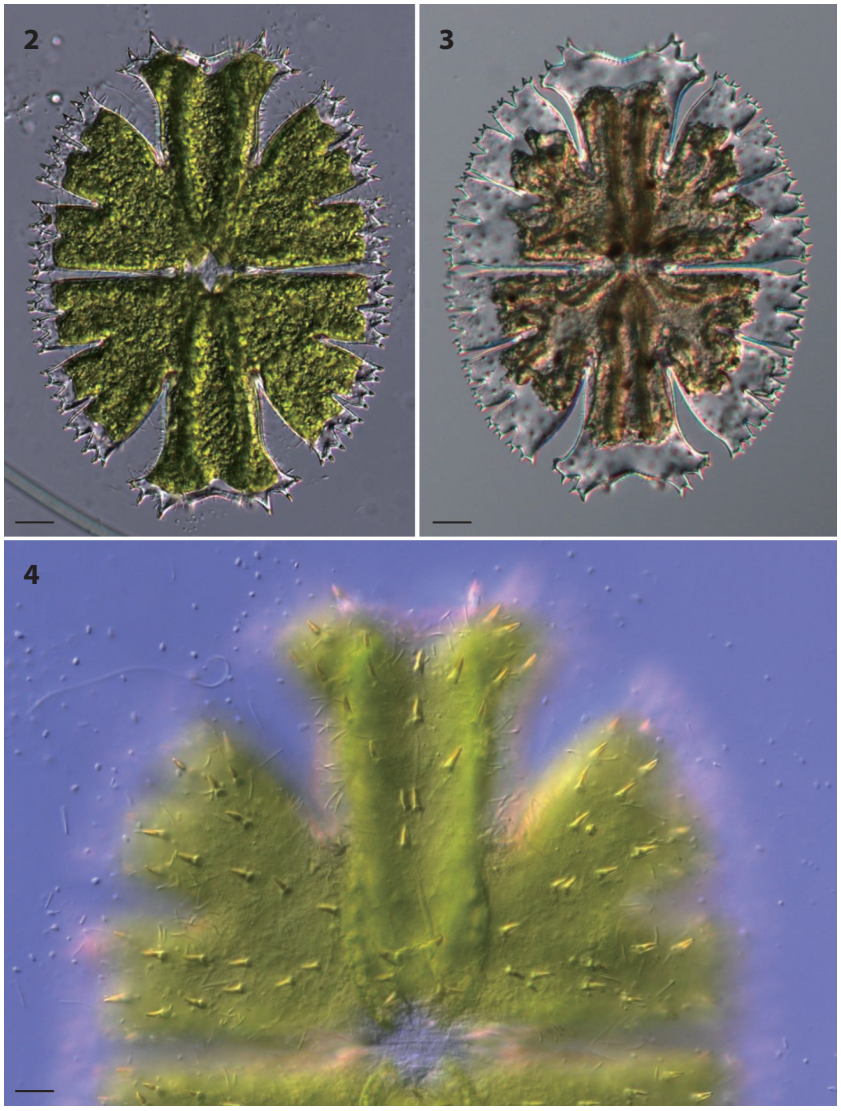

Plate 1. Figs. 2-4. *Micrasterias apiculata*. Scale bars represent 20 µm (Figs. 2, 3) and 10 µm (Fig. 4).

The materials were deposited in the National Institute of Biological Resources (NIBR) and Department of Biology Kyungpook National University. All dimensions were given in microns, and the following abbreviations were used: Dim., dimension; L, length; B, breadth; I, isthmus; Dist., distribution; rr, very rare; r, occasional; c, abundant; cc, very abundant; Bas., basionym; Syn. synonym. Distributions of the individual taxa within Korea were ascertained from all the previous publications addressing *Micrasterias* taxa (Skvortzov 1932, Chung et al. 1965, 1968, Chung 1970, Choi 1976, Lee 1978, Chung 1982, Kim and Chung 1982, Chung and Yang 1984, Chung and Lee 1986, Chung and Chung 1992, Chung and Park 1992, Kim and Chung 1993a, 1993b, Chung et al. 1994).

RESULTS AND DISCUSSION

Micrasterias apiculata Meneghini ex Ralfs (Pl. 1, Figs. 2-4)

References: West and West 1905, p. 97, pl. 47, figs. 1-2; Prescott et al. 1977, p. 141, pl. 120, fig. 6, pl. 121, figs. 1, 3; Hirose and Yamagishi 1977, p. 661, pl. 203, fig. 4, pl. 205, fig. 3; Förster 1982, p. 358, pl. 61, fig. 1; Yamagishi and Akiyama 1989a, p. 50; Coesel and Meesters 2007, p. 85, pl. 55, fig. 2.

Dim.: L, 230-250 µm; B, 180-200 µm; I, 30-34 µm.

Dist.: 13 (cc), 1 (c), 8 (c), 3 (r); numbers indicate sampling sites in Fig. 1 and Table 1.

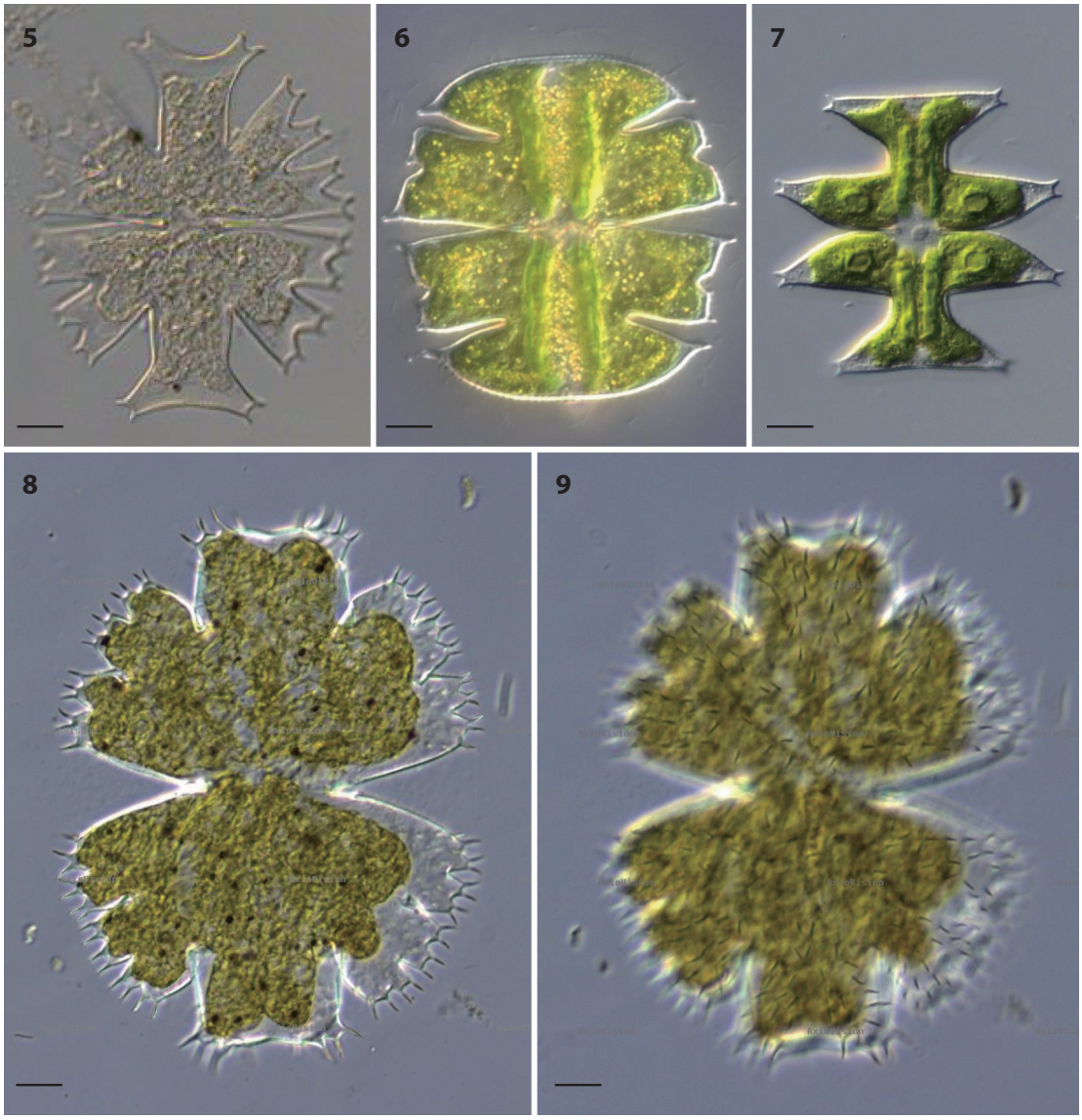

Plate 2. Fig. 5. *Micrasterias crux-melitensis*, **Fig. 6.** *M. decemdentata*, **Fig. 7.** *M. pinnatipida*, **Figs. 8, 9.** *M. spinosus* sp. nov. Scale bars represent 10 μm (Figs. 5-7) and 20 μm (Figs. 8, 9).

Description: Coesel and Meesters (2007) described this species occurred rarely in moorland pools and fen hollows. At present study, this species was observed at only highland acidic mountain wetlands. Two different outline-shaped forms, typical form and more widely opened isthmus, were also presented. Culture and molecular analysis of these two types are needed to certify correct identification of different form. Its only one previous finding was recorded from the study on several regions of Youngnam area in Korea (Chung 1970); however, it did not presented any infromation on the sampling site.

Micrasterias crux-melitensis Ralfs (Pl. 2, Fig. 5)

References: West and West 1905, p. 116, pl. 53, figs. 1-3; Prescott et al. 1977, p. 148, pl. 113, figs. 1-3; Hirose and Yamagishi 1977, p. 667, pl. 205, fig. 1; Förster 1982, p. 366, pl. 53, figs. 1-3; Yamagishi and Akiyama 1984, p. 52; Coesel and Meesters 2007, p. 86, pl. 57, figs. 3-4.

Dim.: L, 85-110 μm; B, 70-100 μm; I, 13-17 μm.

Dist.: 5 (r), 11 (r), 19 (r).

Description: This species is widely distributed in variable habitats throughout the Korea. The previous observations from Korea were reported from several swamps

and reservoirs of Youngnam area (Chung 1970, Chung and Lee 1986, Chung and Chung 1992, Chung and Park 1992, Kim 1992). In the present study, this species was commonly occurred within the genus from some lowland mesotrophic to eutrophic reservoirs.

Micrasterias decemdentata (Nägeli) W. Archer (Pl. 2, Fig. 6)

References: Prescott et al. 1977, p. 151, pl. 94, figs. 7-11; Hirose and Yamagishi 1977, p. 649, pl. 199, fig. 22; Förster 1982, p. 367, pl. 50, figs. 7-8; Yamagishi and Akiyama 1989a, p. 52; Coesel and Meesters 2007, p. 86, pl. 51, figs. 10-11.

Dim.: L, 60-80 µm; B, 50-70 µm; I, 15-20 µm.

Dist.: 2 (r), 5 (r), 6 (r), 8 (r), 9 (r),11 (r), 13 (r), 14 (r), 15 (r), 16 (r), 17 (r).

Description: This species was frequently reported from Korea by several workers (Skvortzov 1932, Chung 1970, Choi 1976, Kim and Chung 1993a, 1993b). In the present study, this species was most commonly occurred within the genus from variable habitats such as lowland mesotrophic to eutrophic reservoirs and high land wet-lands.

Micrasterias denticulata var. *angulosa* (Hantzsch) West et G.S. West (Pl. 3, Figs. 10 and 11)

References: West and West 1905, p. 105, pl. 49, figs. 1-7, pl. 50, figs. 1-2; Prescott et al. 1977, p. 151, pl. 134, figs. 7-9, pl. 135, figs. 1-5, 8-11; Hirose and Yamagishi 1977, p. 651, pl. 200, fig. 1; Růžička 1981, p. 667, pl. 116, figs. 1-6; Coesel and Meesters 2007, p. 87, pl. 54, fig. 2.

Dim.: L, 220-240 µm; B, 205-220 µm; I, 13-15 µm.

Dist.: 1 (r), 8 (c), 13 (r).

Description: This species has only been described by Yamaguchi (1941) at highland bog lake in North Korea. Present study, it rarely occurred in the acidic mountain wetlands. This species is considered to be rare at fen hollows in Europe (Coesel and Meesters 2007). This variety, var. *angulosa* differs from nominate variety of *M. denticulata*, in that with shallower incisions (lower than 1/3 of semicell length) and the polar lobe shorter. Its cells have a higher length/breadth ratio than the nominate variety.

Micrasterias foliacea Bailey ex Ralfs (Pl. 3, Fig. 12)

References: Prescott et al. 1977, p. 158, pl. 139, figs. 3-8; Hirose and Yamagishi 1977, p. 649, pl. 199, fig. 19; Förster 1982, p. 370, pl. 58, figs. 2-5; Yamagishi and Akiyama 1987a, p. 44.

Dim.: L, 70-80 µm; B, 70-80 µm; I, 13-15 µm.

Dist.: 16 (c), 18 (r).

Description: This species easily distinguished from other taxa by its peculiar apex, which interlocks polar lobes. The only previous observation of this species in Korea was reported by Chung et al. (1965, 1968) from Seoul and Chuncheon. However, they did not state any information on the sampling site. In the present study, this species abundantly occurred at only lowland wetlands and oreum (creative) in Jeju Island.

Micrasterias foliacea var. *ornata* Nordstedt (Pl. 3, Fig. 13)

References: Prescott et al. 1977, p. 159, pl. 140, figs. 1-1; Förster 1982, p. 371, pl. 58, figs. 6-8; Yamagishi and Akiyama 1993, p. 64.

Dim.: L, 70-80 µm; B, 70-80 µm; I, 12-15 µm.

Dist.: 16 (r).

Description: This variety differs from the nominal variety by the cell wall with 1 to 3 small spines along the sinus and on the upper margin of the upper lateral lobes. This taxon rarely occurred associated with *M. foliacea* at the same habitats.

Micrasterias jejuensis Han Soon Kim sp. nov. (Pl. 7, Fig. 32)

Description: Cells are medium sized, nearly circular outlined, deeply constricted, having a sinus slightly open outward, but linear towards its apex; semicells 5-lobed, polar lobe slightly exserted, the upper part slightly dilated, apex broadly concave, angles narrowly rounded, apex center with two conical process, incisions between polar lobe and upper lateral lobes narrow and deep; lateral lobes unequaly divided by primary insions, upper lobes distinctly larger than lower ones, each lobes subdivided into two second lobes by secondary incisions, secondary incision of upper lobes deeper than that of lower lobes, each lobules futher divided into two equal retuse or truncate lobule by very short incision. Cell wall punctate. Cell length 95-100 µm, breadth 95-100 µm, isthmus 13-15 µm. Cell shape of this species is similar to *M. koreanus* sp. nov. in their outline; however, it is distinguished from the latter in that the cells are smaller and with a pair of conical process at the center of polar lobe apex.

Type locality: Deokcheon pond (small shallow pond), Deokcheon-ri, Gujwa-eup, Jeju Island, South Korea (33°30´20˝ N, 126°46´30˝ E, 100 m above sea level (a.s.l.), pH = 6.5-7.0, water temperature = 25°C, The electrical

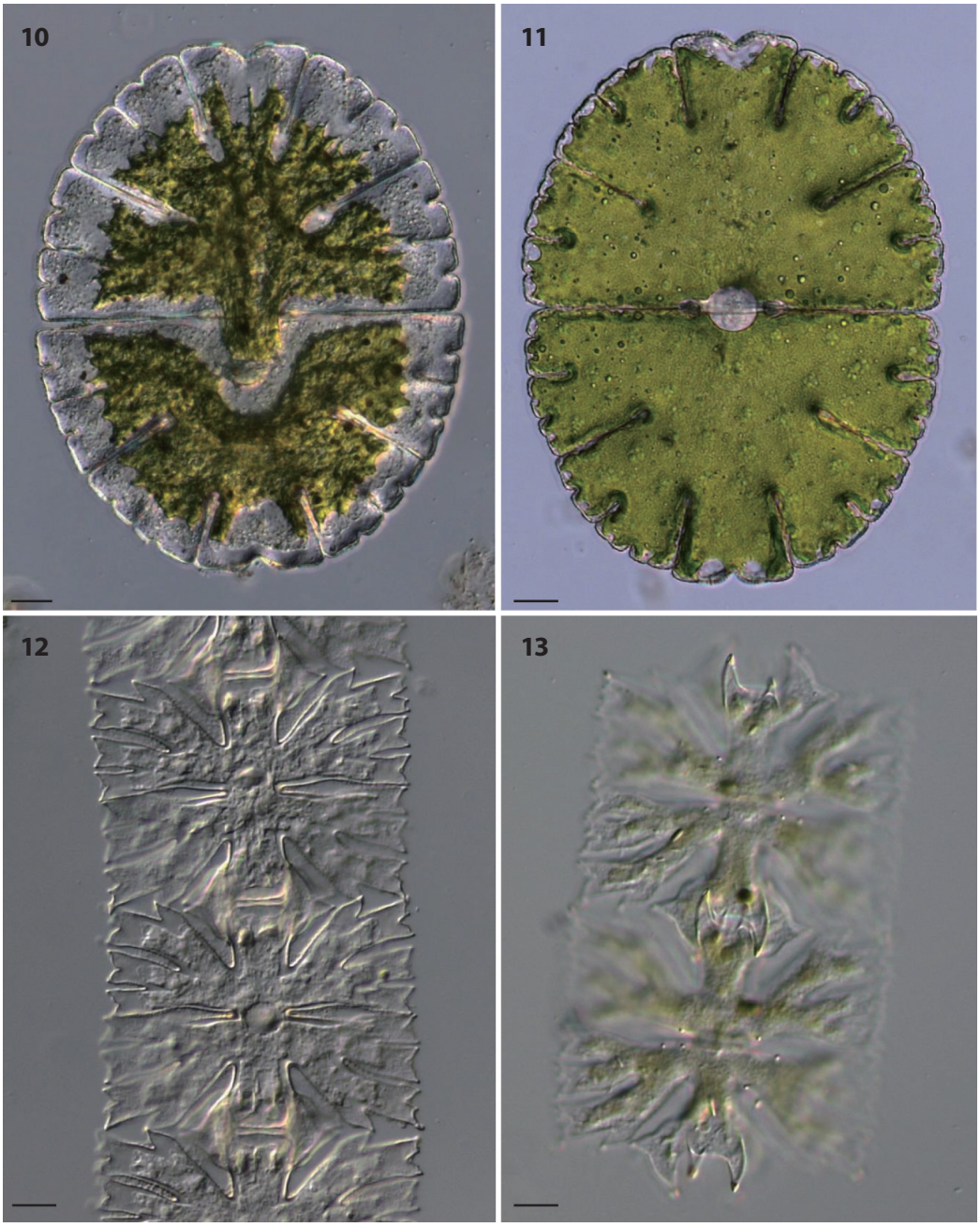

Plate 3. Figs. 10, 11. *Micrasterias denticulata* var. *angulosa*, **Fig. 12.** *M. foliacea*, **Fig.13.** *M. foliacea* var. *ornata*. Scale bars represent 20 μm (Figs. 10, 11) and 10 μm (Figs. 12, 13).

conductivity (EC) = 54-75 μS/cm).

Holotype: Fig. 32 from material collected on September 9, 2011 deposited at the Herbarium of Kyungpook National University (KNU), Daegu (KNUDC20110909).

Etymology: The specific epithet "jejuensis" refers to the fact that the species was first found in Jeju Island of South Korea.

Micrasterias koreanus Han Soon Kim sp. nov. (Pl. 7, Fig. 31)

Description: Cells are large, ellipsoid, slightly longer than broad, deep constricted, sinus slightly open outward but linear towards its apex; semicells 5-lobed, polar lobe broadly cuneate, lower portion with parallel sides, upper portion slightly dilated, apex slightly retuse at the center,

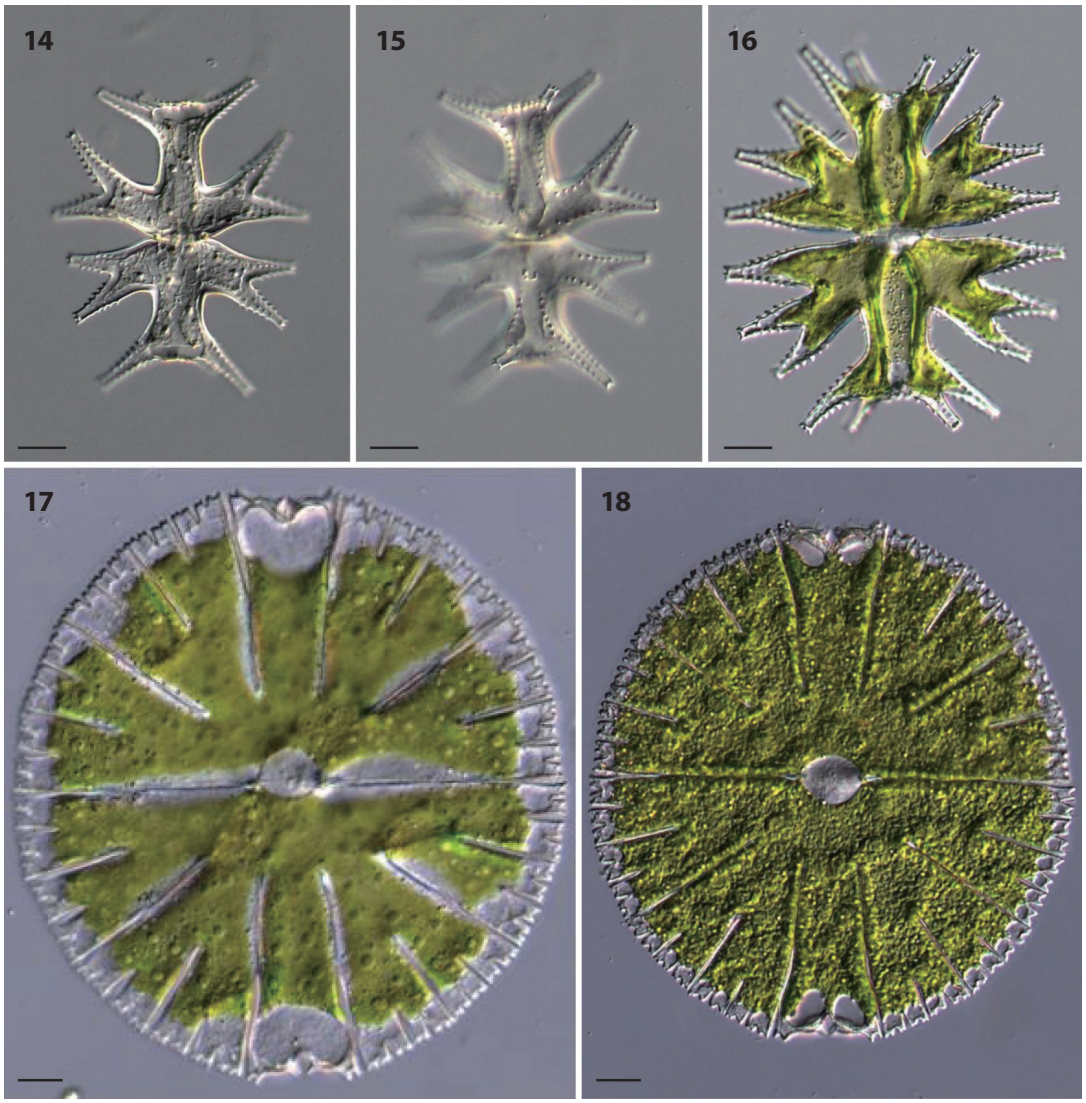

Plate 4. Figs. 14, 15. *Micrasterias mahabuleshwarensis*, **Fig. 16.** *M. mahabuleshwarensis* var. *wallichii*, **Figs. 17, 18.** *M. papillifera*. Scale bars represent 20 μm (Figs, 14-16) and 10 μm (Figs. 17, 18).

angles narrow rounded; lateral lobes unequaly divided by primary insions slightly open outwards, upper lobes distinctly broader than lower ones, each lobes divided into two second lobes by secondary incisions, secondary incision of upper lobes linear and deeper than that of lower lobes, second lobes futher divided into two equal retuse or truncate lobule by very short incision. Cell wall smooth. Cell length 230-250 μm, breadth 220-230 μm, isthmus 43-48 μm.

Type locality: Abandoned paddy field ditch, Naeil-ri, Sannae-myeon, Gyeongju city, South Korea (35°46´20˝N, 129°05´05˝E, 480 m a. s. l., pH 6.2-7.5, water temperature 26°C, EC 27-45 μS/cm).

Holotype: Fig. 31 from material collected on July 18, 2012 deposited at the Herbarium of Kyungpook National University (KNU), Daegu (KNUBJ20120718).

Etymology: The specific epithet "koreanus" refers to the fact that the species was first found in Korea.

Micrasterias mahabuleshwarensis Hobson (Pl. 4, Figs. 14 and 15)

References: Prescott et al. 1977, p. 164, pl. 143, figs. 1-2, 4-5; Hirose and Yamagishi 1977, p. 665, pl. 204, fig. 1; Förster 1982, p. 376, pl. 57, fig. 1; Yamagishi and Akiyama 1988, p. 50.

Dim.: L, 120-140 μm; B, 110-120 μm; I, 20-25 μm.

Dist.: 11 (r), 16 (r).

Description: The only previous observation of this species in Korea was reported by Chung et al. (1968) from Cheongpyeong, but they did not state any information on the sampling site. In the present study, this species occasionally rarely occurred at lowland oligo-mesotrophic old shallow reservoir and small shallow pond.

Micrasterias mahabuleshwarensis var. *wallichii* (Grunow) West et G.S. West (Pl. 4, Fig. 16)

References: West and West 1905, p. 122, pl. 54, figs. 7-8, pl. 55, figs. 1-3; Prescott et al. 1977, p. 166, pl. 145, figs. 1-2, 4-5; Hirose and Yamagishi 1977, p. 665, pl. 204, fig. 2; Förster 1982, p. 379, pl. 57, fig. 4; Růžička 1981, p. 593, 602, pl. 100, figs. 5-13; Yamagishi and Akiyama 1987a, p 45; Coesel and Meesters 2007, p 88, pl. 58, figs. 4-5.

Dim.: L, 150-160 µm; B, 120-150 µm; I, 20-25 µm.

Dist.: 4 (r), 7 (r), 11 (c), 12 (r), 16 (c).

Description: This variety differs from nominate variety in that both the upper first order lateral lobes are divided. This taxon has only been described rather recently in Korea (Chung and Lee 1986), and they was described that base center of the semicells elaborate protuberances, with two rings of granules. However, 4 short spines instead of two rings of granules were observed (Kim HS, personal observation). In the present study, this taxon occurred rather commonly in oligo-mesotrophic water bodies.

Micrasterias papilifera Ralfs (Pl. 4, Figs. 17 and 18)

References: West and West 1905, p. 91, pl. 44, figs. 1-2, 7; Prescott et al. 1977, p. 171, pl. 126, figs. 3, 5-6; Hirose and Yamagishi 1977, p. 667, pl. 205, fig. 4; Förster 1982, p. 381, pl. 60, figs. 5-7; Yamagishi and Akiyama 1994, p. 66; Růžička 1981, p. 639, pl. 107, figs. 15-21, pl. 108, figs. 1-5; Coesel and Meesters 2007, p. 89, pl. 56, figs.1-4.

Dim.: L, 120-170 µm; B, 100-160 µm; I, 12-20 µm.

Dist.: 8 (c), 13 (c).

Description: This is one of the most abundant species of the genus in England (West and West 1905) and it was reported abundantly in the previous study of Korea (Choi 1976, Lee 1978, Kim and Chung 1982, chung and Yang 1984). According to John and Williamson (2011) and West and West (1905) in England, this taxon might be acidophilic and common in small peat pools and bogs with *Sphagnum* although it occurred in lakes and it was considered as a tychoplankter (Förster 1982). In the present study, this species was also most frequently observed in acidic mountain wetlands.

Micrasterias pinnatifida (Kützing) Ralfs (Pl. 2, Fig. 7)

References: West and West 1905, p. 80, pl. 41, figs. 7-11; Hirose and Yamagishi 1977, p. 662, pl. 203, fig. 8; Förster 1982, p. 383, pl. 49, figs. 1-3, 66; Růžička 1981, p. 571, pl. 93, figs. 1-3; Yamagishi and Akiyama 1985, p. 58; Coesel and Meesters 2007, p. 89, pl. 52, fig. 3.

Dim.: L, 50-70 µm; B, 50-60 µm; I, 12-15 µm.

Dist.: 2 (r), 5 (c), 6 (r), 8 (r), 11 (c), 13 (r), 14 (r), 15 (c), 16 (r).

Description: This species is probably cosmopolitan and acidophilic in peaty pools and bogs usually associated with *Sphagnum* in England (John and Williamson 2011). Observations of this species were reported in Korea from several reservoir and swamps of Youngnam area (Chung 1982, Chung and Chung 1992, Kim and Chung 1993a, 1993b). In the present study, this was one of the most frequent species of the genus, and especially its occurrence was associated with submerged plants in the mountain wetlands and mesotrophic shallow old reservoirs.

Micrasterias radians Turner (Pl. 5, Fig. 22)

References: Prescott et al. 1977, p. 176, pl. 115, figs. 5-7; Förster 1982, p. 384, pl. 53, figs. 5-7; Yamagishi and Akiyama 1984, p. 54.

Dim.: L, 90-120 µm; B, 80-110 µm; I, 15-18 µm.

Dist.: 8 (r), 11 (r), 13 (r), 16 (r), 19 (c).

Description: The only one previous observation from Korea was reported from Bulkuk temple area of Gyeongju city located in Southeast Korea (Chung 1982). In the present study, this species was widely distributed and commonly occurred within the genus from variable habitats such as lowland mesotrophic to eutrophic reservoirs and mountain wetlands throughout Korea. This species is very similar to *M. cruxmelitensis* (Ehrenb.) Ralfs, but it is distinguished by exserted polar lobe and deeper incisions, as well as by having the apex more deeply concave and curved teeth.

Micrasterias radiosa Ralfs (Pl. 5, Fig. 19)

Syn: *Micrasterias sol* Ehrenberg ex Kützing.

References: West and West 1905, p. 97, pl. 46, figs. 3-4; Hirose and Yamagishi 1977, p. 661, pl. 203, fig. 2; Förster 1982, p. 385, pl. 59, fig. 2; Růžička 1981, p. 628, pl. 105, figs. 1-11; Coesel and Meesters 2007, p. 89, pl. 56, fig. 5.

Dim.: L, 123-150 µm; B, 110-130 µm; I, 13-17 µm.

Dist.: 8 (r), 13 (r), 17 (r).

Description: According to John and Williamson (2011),

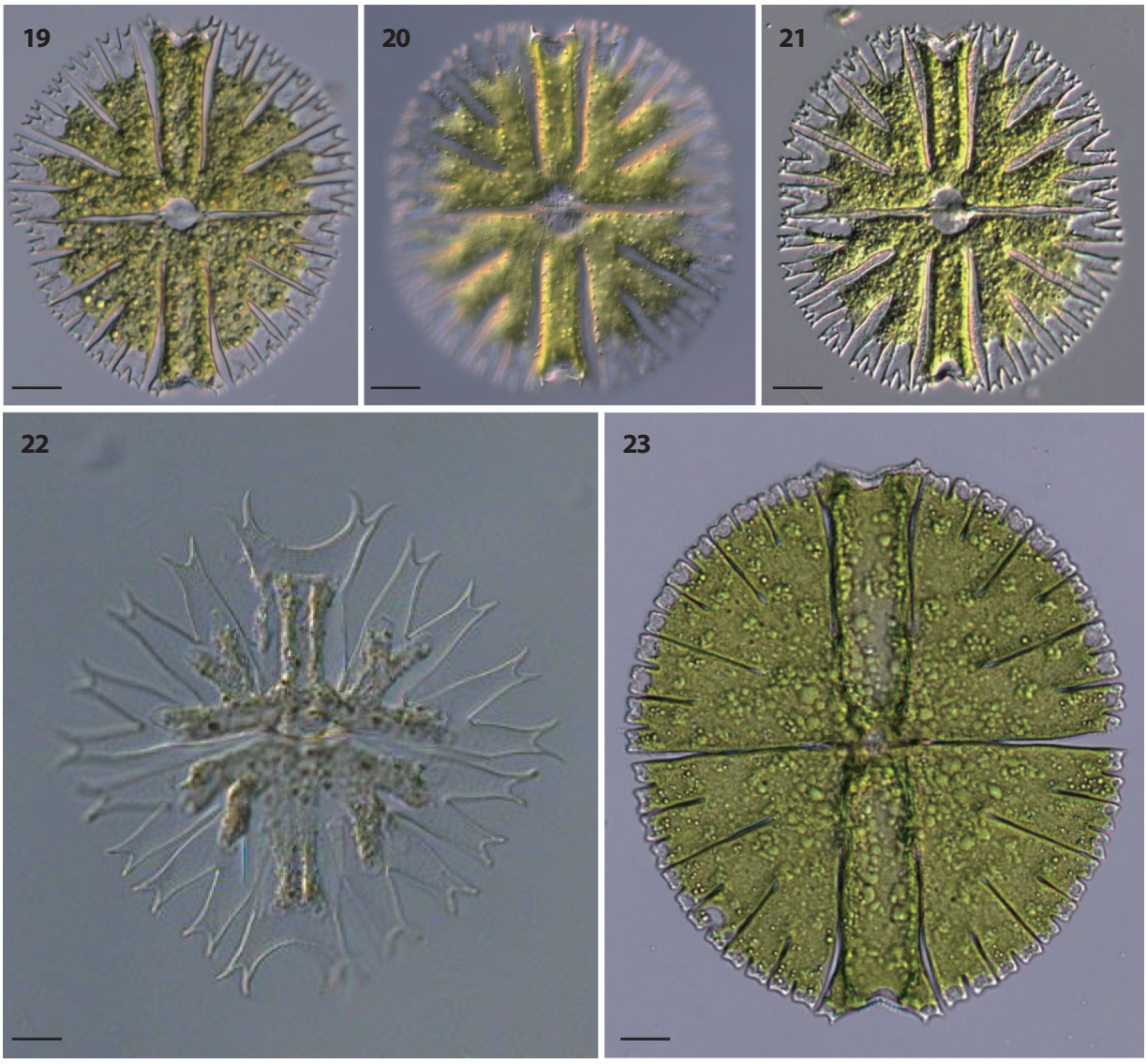

Plate 5. Fig. 19. *Micrasterias radiosa*, **Figs. 20, 21.** *M. radiosa* var. *elegantior*, **Fig. 22.** *M. radians*, **Fig. 23.** *M. rotata*. Scale bars represent 20 μm (Figs, 19-21, 23) and 10 μm (Fig. 22).

this is cosmopolitan and acidophilic species occurring in the acid ponds and bogs associated with *Sphagnum* and in planktons of nutrient-poor lakes from England, Scotland, Wales, and Ireland. The only previous observation of this species in Korea was reported by Chung et al. (1994) as *M. sol*. In the present study, this species was rarely observed only in the high land mountain wetlands.

Micrasterias radiosa var. *elegantior* (G.S. West) H.T. Croasdale (Pl. 5, Figs. 20 and 21)

Syn.: *Micrasterias radiosa* f. *ornata* (Nordstedt) Förster; *Micrasterias radiosa* var. *ornata* Nordstedt; *Micrasterias sol* var. *ornata* (Nordstedt) Nordstedt.

References: West and West 1905, p. 97, pl. 46, figs. 3-4; Prescott et al. 1977, p. 183, pl. 130, figs. 3-8, pl. 132, figs. 2-4; Růžička 1981, p. 635, pl. 105, figs. 7-11; Förster 1982, p. 386, pl. 60, figs. 1, 3-4.

Dim.: L, 140-160 μm; B, 130-150 μm; I, 13-15 μm.

Dist.: 13 (c).

Description: This is cosmopolitan and acidophilic species rarely occurring in England (John and Williamson 2011). In the present study, this species was rarely observed in acidic mountain wetlands. This variety was distinguished from the nominate variety in that its with intermarginal spines along the incision.

Micrasterias rotata (Greville) Ralfs (Pl. 5, Fig. 23)

References: West and West 1905, p. 102, pl. 48, figs. 1-6; Prescott et al. 1977, p. 185, pl. 133, figs. 1-8; Hirose and Yamagishi 1977, p. 655, pl. 201, fig. 1; Růžička 1981, p. 622, pl. 104, figs. 1-20; Förster 1982, p 387, pl. 62, figs. 2-5; Yamagishi and Akiyama 1998, p. 47; Coesel and Meesters 2007, p. 90, pl. 52, figs. 4-5.

Dim.: L, 220-250 µm; B, 200-220 µm; I, 29-35 µm.

Dist.: 8 (r), 13 (r).

Description: This species is occasional and widespread in acid habitats, especially associated with *Sphagnum*, and in the weedy margins of nutrient-poor lakes from England (John and Williamson 2011) and moorland pools, peat pits, and fen hollows (Coesel and Meesters 2007). In the present study, this species was rarely observed in two acidic high land mountain wetlands associated with *Sphagnum*.

Micrasterias spinosus Han Soon Kim sp. nov. (Pl. 2, Figs. 8 and 9)

Description: Cells are large, about 1.3-1.4 times longer than broad, moderately constricted, and sinus widely open outward and acute at the extremity; semicells 5-lobed; polar lobe stoutly quadrate, short and broad, 1.5 times broader than longer, lower portion with parallel sides, upper portion slightly dilated, apex slightly retuse at the center, angles slightly protrude, with a apir of spine, with 2 more spines on either side of the median retuse; incisions between polar lobe and upper lateral lobes widely open outward and linear at interior; lateral lobes unequaly divided by primary insions, very short and stout, upper lobes broader than lower ones, with short, V-shaped incisions between lobes, the margins of ultimate lobes with 2 stout sharply pointed spines; cell walls covered with numerous stout and sharply pointed spines. Cell length 230-250 µm, breadth 175-190 µm, and isthmus 50-60 µm. Shape of *M. spinosus* sp. nov. is similar to that of *M. brachyptera* Lundell. However, *M. spinosus* is distinguished from *M. brachyptera* covered with numerous stout spine throughout the cell surface and with two pairs stout spine at angles of polar lobe, but the latter with superficial spines in single sparse rows along the isthmus and outer margin of polar lobe, scattered over the surface, or completely absent.

Type locality: Mt. Jengjok Mujechineup, Sangdong-myeon, Ulju county, Ulsan megacity, South Korea (35°27´50″ N, 129°08´30″ E, , 650 m a.s.l., pH 5.5-6.5, water temperature 15-20°C, EC 20-35 µS/cm).

Holotype: Fig. 8 (iconotypus) from material collected on September 16, 2011 deposited at the Herbarium of Kyungpook National University (KNU), Daegu (KNUMJ20110916).

Etymology: The specific epithet "spinosus" refers to the fact that the cell wall is covered with numerous stout spines.

Micrasterias thomasiana W. Archer (Pl. 6, Figs. 24 and 25)

References: West and West 1905, p. 110, pl. 51, figs. 3-6; Prescott et al. 1977, p. 190, pl. 137, figs. 2-3; Hirose and Yamagishi 1977, p. 655, pl. 201, fig. 2; Růžička 1981, p. 658, 661, pl. 113, figs. 1-15; Förster 1982, p. 389, pl. 63, fig. 3; Yamagishi and Akiyama 1985, p. 59; Coesel and Meesters 2007, p. 90, pl. 53, fig. 1; Brook et al. 2011, p. 693, pl. 169, fig. G.

Dim.: L, 210-250 µm; B, 170-200 µm; I, 20-23 µm.

Dist.: 1 (c), 4 (r), 7 (r), 8 (r), 12 (r), 13 (r).

Description: This species is acidophilic and widely distributed in acid habitats, particularly in peaty pools and at the margins of nutrient-poor lakes associate with other algae from England (John and Williamson 2011) and rare in oligo-mesotrophic moorland pools (Coesel and Meesters 2007). In the present study, this species was rarely observed in two acidic highland mountain wetlands associated with *Sphagnum*.

Micrasterias thomasiana var. *notata* (Nordstedt) Grönblad (Pl. 6, Fig. 24)

Bas.: *Micrasterias denticulata* var. *notata* Nordstedt.

References: Prescott et al. 1977, p. 191, pl. 137, figs. 4-6; Růžička 1981, p. 662, pl. 114, figs. 1-8; Yamagishi and Akiyama 1989b, p. 54; Coesel and Meesters 2007, p. 90, pl. 53, figs. 2-3; Brook et al. 2011, p. 693, pl. 169, fig. H.

Dim.: L, 200-230 µm; B, 190-200 µm; I, 20-23 µm.

Dist.: 8 (r), 13 (r).

Description: This species is acidophilic, widely distributed in the British Isles, particularly in peaty pools and amongst other algae (John and Williamson 2011), and more common in moorland pools and fen hollows in the European (Coesel and Meesters 2007). The previous observation from Korea was reported from highland mountain wetlands (Kim and Chung 1993b). In the present study, this species was rarely observed in acidic highland mountain wetlands associated with *Sphagnum* and in highland abandoned paddy field ditch. This variety differs from the nominate variety in the absence of the processes

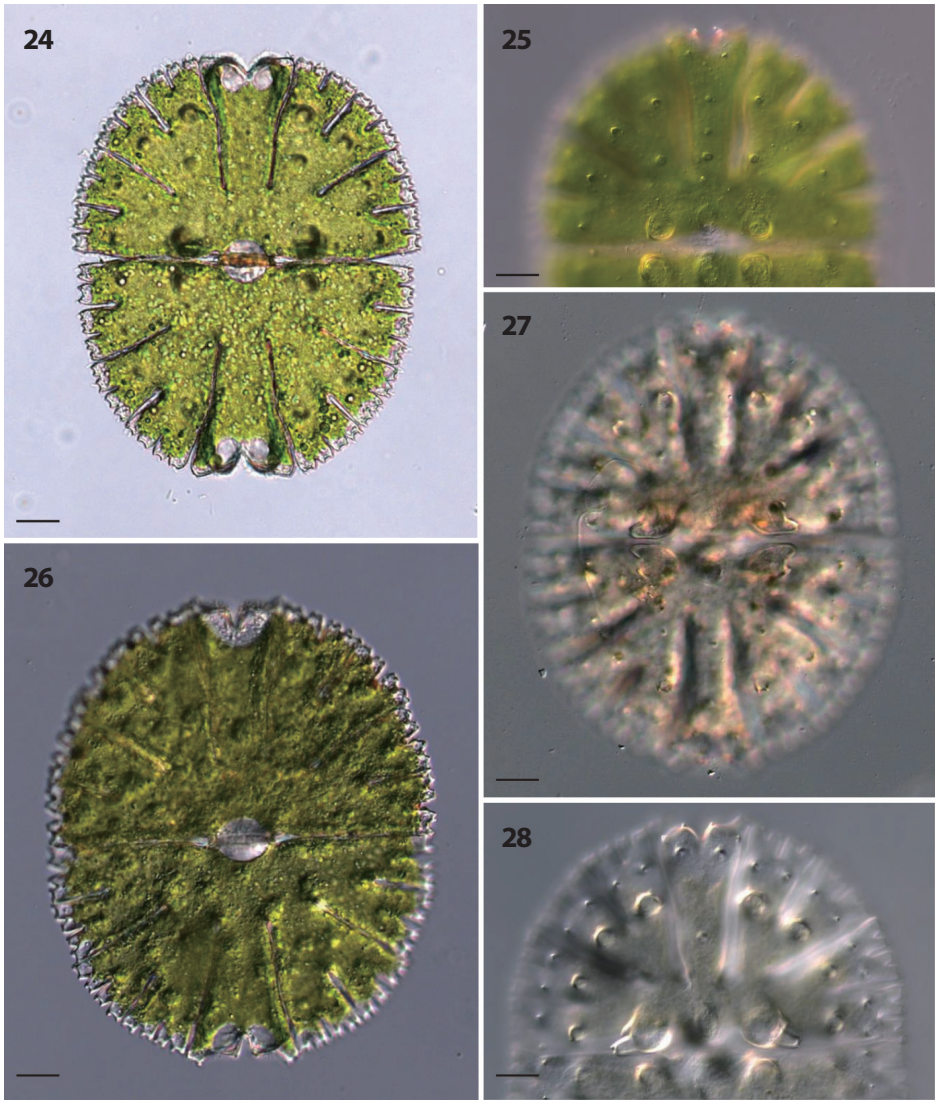

Plate 6. Figs. 24, 25. *Micrasterias thomasiana*, 26. *M. thomasiana* var. *notata*, 27, 28. *M. thomasiana* var. *pulcherrima*. Scale bars, 20 μm.

and by absent or reduced swelling at the median part of base of the semicells. This variety can hardly be distinguished from clearly related *M. denticulata*; however, it can be distinguished from the latter in that on either side of the median incision of polar lobes with a broad, flattened, and dentate swelling.

Micrasterias thomasiana var. *pulcherrima* G.S. West (Pl. 6, Figs. 27 and 28)

References: Prescott et al. 1977, p. 191, pl. 138, fig. 1; Hirose and Yamagishi 1977, p. 662, pl. 203, fig. 6; Yamagishi and Akiyama 1987b, p. 43.

Dim.: L, 200-230 μm; B, 190-200 μm; I, 20-23 μm.

Dist.: 8 (r), 13 (r).

Description: This species is acidophilic and widely distributed in acid habitats, particularly in peaty pools and at the margins of nutrient-poor lakes associated with other algae from England (John and Williamson 2011) and rare in oligo-mesotrophic moorland pools (Coesel and Meesters 2007). This variety is distinguished from the nominate variety in that it has a short bidentate process at the base of second-order lateral lobule and strongly bent and 2-parted lateral projections at the base of semicell. In the present study, this species was rarely observed in two acidic highland mountain wetlands associated with *Sphagnum*.

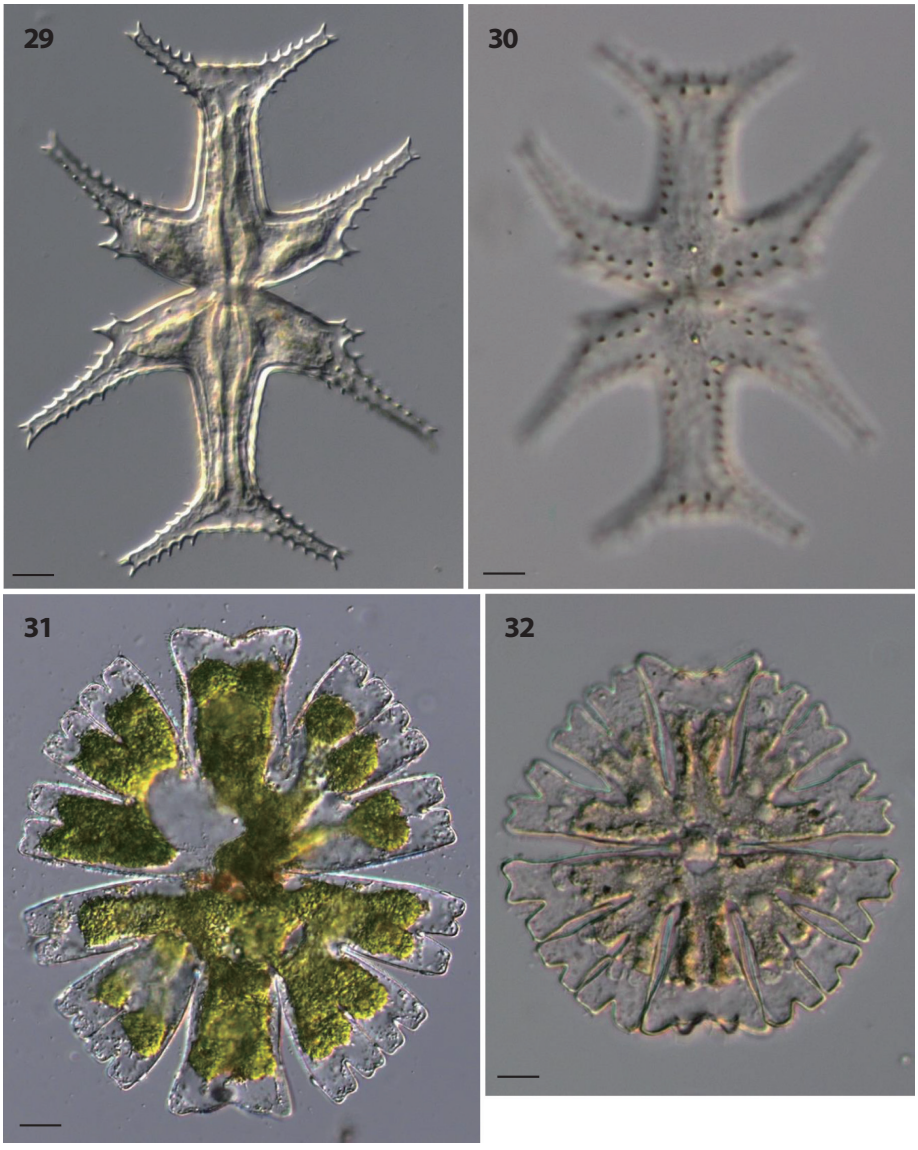

Plate 7. Figs. 29, 30. *Micrasterias tropica* var. *polonica*, **Fig. 31.** *M. koreanus* sp. nov., **Fig. 32.** *M. jejuensis* sp. nov.. Scale bars represent 10 μm (Figs, 29, 30, 32) and 20 μm (Fig. 31).

Micrasterias tropica var. *polonica* Eichler & Raciborski (Pl. 7, Figs. 29 and 30)

References: Hirose and Yamagishi 1977, p. 662, pl. 203, fig. 8; Růžička 1981, p. 592, pl. 97, figs. 6-10; Yamagishi and Akiyama 1987a, p. 46; Wei 2003, p. 159, pl. 41, fig. 1.

Dim.: L, 110-135 μm; B, 70-110 μm; I, 14-20 μm.

Dist.: 16 (r).

Description: This is very rare species in China (Wei 2003), Japan (Hirose and Yamagishi 1977, Yamagishi and Akiyama 1987), and Europe (Růžička 1981). This variety is distinguished from the nominate variety in that it has a process at the center just above the isthmus and 1 to 3 denticulations at the basal part of the lateral lobes. In the present study, this species was rarely observed in a small shallow pond from subtropical Jeju Island.

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