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Original Scientific Paper

New desmid records from two high mountain lakes in Çamlıhemşin/Rize (Turkey)

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ABSTRACT:
The benthic algal flora of Avusor Great Lake and Koçdüzü Great Lake in Rize was investigated on 21 August 2019. A total of 37 desmid taxa belonging to the genera *Actinotaenium* (2), *Closterium* (6), *Cosmarium* (12), *Euastrum* (4), *Micrasterias* (3), *Penium* (1), *Staurastrum* (8) and *Staurodesmus* (1) were assessed as new records for Turkey. In this paper, the morphotaxonomy, ecology, and distribution of each species is discussed in detail.

Keywords:
high mountain lakes, desmids, new records, Avusor Great Lake, Koçdüzü Great Lake, Turkey

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INTRODUCTION

The low temperatures, ice cover, darkness, high UV radiation, high pressure and low nutrient content make high mountain lakes extreme ecosystems (Psenner 2003). These extreme environmental conditions give rise to characteristic biota (especially desmids). In addition, they are very responsive to environmental changes and are used as early warning systems (Psenner 2003). All these properties make them different from other freshwater ecosystems.

Periphytic microalgae form part of the biota which function in the matter and energy cycle in the littoral region (Vercellino & Bicudo 2006). Desmids in particular are important elements of the periphyton microalgae, due to the high diversity of species and functional strategies (Felisberto *et al*. 2014).

Desmids are cosmopolitan and k-strategist organisms which exhibit a wide variety of forms, being either unicellular or pseudo-filamentous (Coesel 1996). They are more common and diverse in mesotrophic and oligotrophic waters which have a slightly acid pH, low nutrient concentration and low conductivity (Coesel 1982; Ngearnpat & Peerapornpisal 2007). In addition, they are sensitive to changes in the environment, and are thus used as bioindicators for monitoring water quality (Coesel 2001). For these reasons, taxonomic, floristic and ecological knowledge about desmids makes an important contribution to our understanding of their complex relationships with the environment (Meester & Declerck 2005).

The Eastern Black Sea Mountains, one of Turkey's important glaciated areas, have many active glaciers such as glacial valleys, glacial lakes and cirques. These mountains reach a height of approximately 4000 m inland 30 km from the sea and are also known as the "Little Caucasus" (Anonymous 2006; Geçen *et al*. 2018). According to Geçen *et al* (2018), these mountains have 685 glacier lakes, 85% of which are located at an altitude range of 2700-3200 m. The smallest of the lakes has an area of 114 m^2, while the largest covers an area of 115509 m^2. However, most of the lakes have a surface area smaller than 10000 m^2 (Geçen *et al*. 2018). These glacial lakes form very convenient habitats for desmids (Şahin 1998, 2000, 2002, 2007, 2009; Şahin & Akar 2007, 2019; Akar & Şahin 2014). However, so far no research has been carried out on the desmid flora of the glacial lakes in the Eastern Black Sea Mountains, which are within the borders of the Rize province. Therefore, this study will contribute to our knowledge of the Turkish desmid flora, in particular that of Turkish glacial lakes.

In this study, thirty-seven newly recorded desmid species were added to the desmid flora of Turkey and discussed in detail.

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MATERIALS AND METHODS

Study area. Located in the Eastern Black Sea Region, the Rize province is situated around a bay between Paşakuyusu Hill in the east and Kambursırtı in the west. It is surrounded by the Rize Mountains up to an altitude of 3000 m in the south. Due to these geographical conditions, Rize has a very different position in the Black Sea coastal zone in terms of climatic characteristics (Polat & Sunkar 2017) (Fig. 1).

According to Turkey's climate classification system (Erinç 1969), the Rize province falls into the very humid class, and is under the influence of the Eastern Black Sea climate. The Eastern Black Sea climate is characterised by cool summers, temperate winters and rain throughout the year. The fact that the mountains extend parallel to the shore is a relevant factor in this respect. The annual average temperature in Rize is 14.3°C. The lowest measured temperature was 3.4°C in February, and the highest was 26.7°C in August. While the annual average rainfall is recorded as 2254.4 mm, the annual average relative humidity is very high at 80% (Polat & Sunkar 2017).

The Rize province is located in the Eastern Black Sea Mountain System. Although the area mainly consists of Granodiorite and Cretaceous flysch, Neogene deposits are also encountered in patches. These structures came to the surface with the large mountain formation which started in the Paleozoic (I Period) and Cretaceous periods (III Period) (Anonymous 2006).

Rize has five main soil types: alluvial, colluvial, red-yellow podzolic, grey-brown podzolic, non-calcareous forest and high mountain meadow soils (Anonymous 2005). Due to the climatic conditions during Little Ice Age, glaciers are also common in the Eastern Black Sea Mountains. There are many glacial lakes in these mountains, which are over 3500 meters high (for example, the Kaçkar Mountains (3937 m). This has also contributed significantly to the region being declared a national park. Çamlıhemşin is the district with the most glacial lakes (Anonymous 2006).

In this study, epipelic, epilithic and epiphytic algae and water samples were taken from two lakes, Avusor Great Lake and Koçdüzü Great Lake. These lakes are 31 and 42 km from the Çamlıhemşin district, respectively.

Sampling and laboratory studies. A total of 13 epipelic, epilithic and epiphytic algal samples were taken from Avusor Great Lake and Koçdüzü Great Lake on 21 August 2019. Epipelic algae were taken from the surface of the sediments of both lakes with a glass tube. Epilithic samples were taken from Avusor Great Lake only and were scraped from randomly chosen stones with a toothbrush and placed in plastic bottles. Epiphytic species were collected by squeezing out the macrophytes (*Potamogeton* sp. and *Juncus* sp.) from Koçdüzü Great Lake only (Round 1953; Sladeckova 1962). All the samples were preserved with 4% (v/v) formaldehyde in 100 mL plastic bottles. The water temperature, dissolved oxygen, conductivity and pH were measured in the field using Thermo Orion-4-Star pH and YSI-55 portable meters. Analyses of other hydrochemical parameters were carried out in the DSI General Directorate Laboratories DSI 22nd Regional Directorate Quality Control and Laboratory Branch Office. In the lab, temporary slides were prepared using the appropriate methods and identified under a light microscope (Leica DM 2500). The desmid species were photographed using a Leica MC170 HD camera attached to the microscope. The abundance estimation was made according to a 6-point scale (Barinova & Medvedeva 1996), 1 – "single" with 1–5 cells per slide, 2 – "rare" with 10–15 cells, 3 – "com-

Fig. 1. The location of the study area (Polat & Sunkar 2017).

mon" with 25–30 cells, 4 – "frequent" with one cell over a slide transect, 5 – "very frequent" several cells over a slide transect, and 6 – "abundant" with one or more cells in each field of view.

The following abbreviations are used in the text: length (L), breadth (B), and isthmus (I). All of the taxa were identified following West & West (1904, 1905, 1908, 1912, 1923), Ružička (1977), Lind & Brook (1980), Förster (1982), Croasdale & Flint (1986, 1988, 1994), Ling & Tyler (1986), Dillard (1990, 1991a, b, 1993), Bourrelly & Couté (1991), Croasdale *et al*. (1994), Lenzenweger (1996, 1997, 1999), Kouwets (1997), Dingley (2001), John *et al*. (2003), Brook & Williamson (2010), Štastny (2010), Coesel & Meesters (2007, 2013), Kim (2012, 2015). The desmid species were carefully checked using the freshwater algae and desmids checklist of Turkey (Aysel 2005; Şahin 2019; Şahin & Akar 2019) and the algae of Turkey database (Maraşlioğlu & Gönülol 2021). The current status of the nomenclature of all the identified taxa has been checked in the Algaebase website (Guiry & Guiry 2021).

RESULTS

Physical and chemical analyses. The results of the physical and chemical analysis of the waters, and other properties of both lakes are given in Table 1.

Taxonomic account. In this study, a total of 112 desmid species were identified from two lakes. Thirty-seven of them are new records for the freshwater algal flora of Turkey. They belong to 8 genera, i.e., *Actinotaenium* (2), *Closterium* (6), *Cosmarium* (12), *Euastrum* (4), *Micrasterias* (3), *Penium* (1), *Staurastrum* (8) and *Staurodesmus* (1). The morphotaxonomy, ecology, and distribution of each species are given below.

Phylum: Charophyta
Class: Zygnematophyceae
Subclass: Zygnematophycidae
Order: Desmidiales
Family: Closteriaceae
Genus: *Closterium*

***Closterium abruptum* f. *nilssonii* (Borge) A.J.Brook & D.B.Williamson (Fig. 2a)**
References: Ružička 1977 (p. 221, pl. 33, figs. 17-19), Dillard 1990 (p. 112, pl. 36, fig.7), Lenzenweger 1996 (p. 46, pl. 5, fig. 6), Brook & Williamson 2010 (p. 197, pl. 82, figs. 4, 9-12)
Dimensions: L: 138.58-193.37 µm, B: 14.74-16.94 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, rare.

Cl. angustatum Kützing ex Ralfs **(Fig. 2b, c)**
References: West & West 1904 (p. 119, pl. 12, figs. 11-13), Ružička 1977 (p. 225, pl. 34, figs. 1-4), Förster 1982 (p. 67, pl. 6, figs. 2-7), Dillard 1990 (p. 95, pl. 36, fig.1), Bourrelly & Couté 1991 (p. 16, pl. 7, fig. 6), Lenzenweger 1996 (p. 33, pl. 6, fig. 6), John *et al*. 2003 (p. 519, pl. 131, fig. A), Coesel & Meesters 2007 (p. 39, pl. 25, fig. 4), Brook & Williamson 2010 (p. 204, pl. 86, fig. 1)
Dimensions: L: 520.38-574.24 µm, B: 23.22-27.74 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, rare.

***Cl. archerianum* var. *pseudocynthia* Ruzicka (Fig. 2d)**
References: Ružička 1977 (p. 202, pl. 28, figs. 4, 5), Brook & Williamson 2010 (p. 305).
Dimensions: L: 112.11 µm, B: 12.64 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***Cl. baillyanum* (Brébisson ex Ralfs) Brébisson (Fig. 2e, f)**
References: Ružička 1977 (p. 179, pl. 23, figs. 1-6), Förster 1982 (p. 69, pl. 5, fig. 12), Dillard 1990 (p. 96, pl. 31, fig. 9), Bourrelly & Couté 1991 (p. 17, pl. 6, figs. 11, 12), Lenzenweger 1996 (p. 34, pl. 6, fig. 11), John *et al*. 2003 (p. 519, pl. 130, fig. H), Coesel & Meesters 2007 (p. 40, pl. 24, fig. 2), Brook & Williamson 2010 (p. 207, pl. 88, figs. 5, 6), Kim 2012 (p. 36, fig. 34)
Dimensions: L: 435.96-513.58 µm, B: 42.84-45.14 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***Cl. closterioides* var. *intermedium* (J.Roy & Bisset) Ruzicka (Fig. 2g)**
References: Ružička 1977 (p. 93, pl. 6, figs. 3-6), Förster 1982 (p. 72, pl. 3, figs. 11-13), Croasdale & Flint 1986 (p. 55, pl. 4, figs. 11, 12), Bourrelly & Couté 1991 (p. 18, pl. 5, figs. 2, 3), Lenzenweger 1996 (p. 35, pl. 2, fig. 3), John *et al*. 2003 (p. 521, pl. 129, fig. B), Coesel & Meesters 2007 (p. 41, pl. 8, fig. 2), Brook & Williamson 2010 (p. 167, pl. 66, figs. 4, 5)
Dimensions: L: 140.63-154.99 µm, B: 28.93-37.24 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

Table 1. The characteristics of Avusor Great Lake and Koçdüzü Great Lake

Lake Parameters	Avusor Great Lake	Koçdüzü Great Lake
Geographic coordinates	N 40°56'11" E 41°12'01"	N 41°00'15" E 41°11'53"
Altitude (m a.s.l.)	2678	2382
Area (ha)	2.2422	8.1896
Temperature (°C)	15.9	21
Dissolved oxygen (mg/L)	10.2	9.2
pH	7.58	8.45
Conductivity (µS/cm)	45.3	104.7

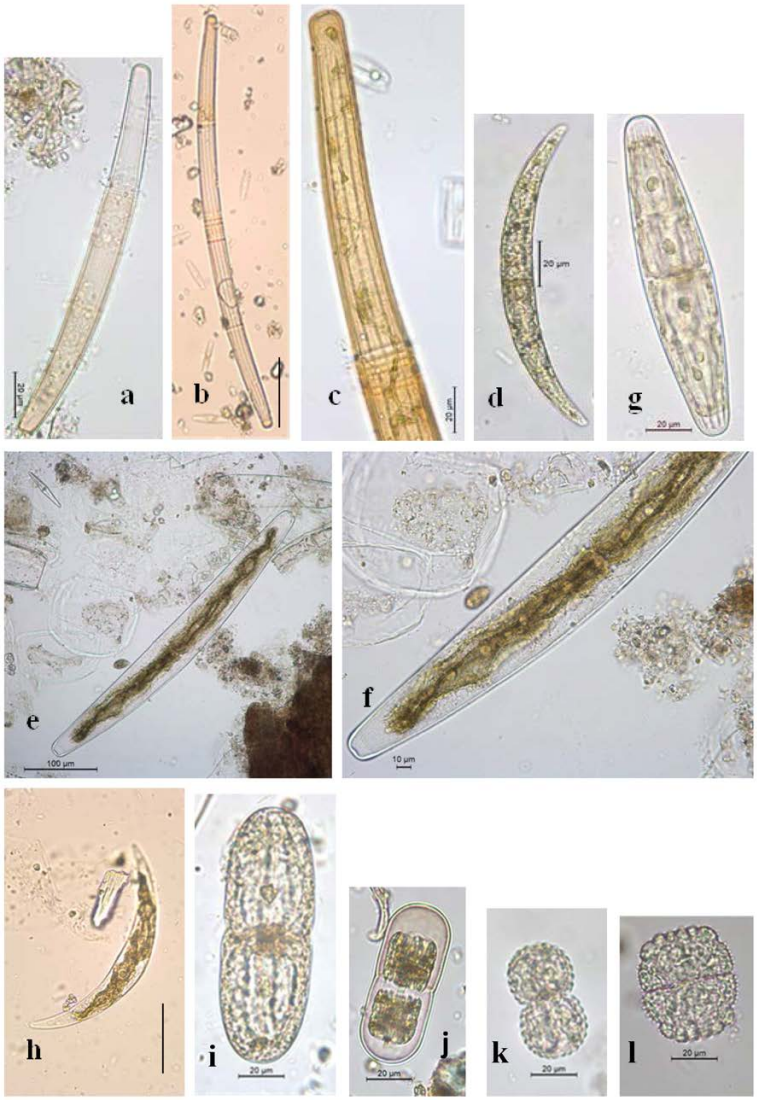

Fig. 2. a. *Closterium abruptum* f. *nilssonii*, **b**-**c**. *Cl. angustatum* (**b**. General view, **c**. End of the cell), **d**. *Cl. archerianum* var. *pseudocynthia*, **e**-**f**. *Cl. baillyanum* (**e**. General view, **f**. Middle part and end of the cell), **g**. *Cl. closterioides* var. *intermedium*, **h**. *Cl. dianae* var. *brevius*, **i**. *Actinotaenium cucurbitinum*, **j**. *A. rufescens*, **k**. *Cosmarium amoenum*, **l**. *C. caelatum*.

***Cl. dianae* var. *brevius* (S.P.Petkoff) Willi Krieger (Fig. 2h)**
References: Ružička 1977 (p. 135, pl. 13, figs. 7, 8), Bourrelly & Couté 1991 (p. 20, pl. 6, fig. 7), Brook & Williamson 2010 (p. 283, pl. 134, figs. 1-4)
Dimensions: L: 144.75-145.86 µm, B: 20.93-22.46 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

Family: Desmidiaceae
Genus: *Actinotaenium*
***Actinotaenium cucurbitinum* (Bisset) Teiling (Fig. 2i)**
References: West & West 1904 (p. 94, pl. 9, figs. 13, 14), Lind & Brook 1980 (p. 34, fig. 37), Förster 1982 (p. 140, pl. 17, fig. 6), Croasdale & Flint 1988 (p. 35, pl. 28, figs. 25, 26), Bourrelly & Couté 1991 (p. 57, pl. 24, fig. 5), Dillard 1991a (p. 15, pl. 2, fig. 2), Lenzenweger 1996 (p. 115, pl. 17, fig. 21), John *et al*. 2003 (p. 531, pl. 131, fig. M), Coesel & Meesters 2007 (p. 60, pl. 31, figs. 9, 10)
Dimensions: L: 101.22-112.31 µm, B: 38.85-39.99 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***A. rufescens* (Cleve) Teiling (Fig. 2j)**
References: West & West 1904 (p. 99, pl. 6, figs. 12, 13), Förster 1982 (p. 145, pl. 17, figs. 23, 24), Croasdale & Flint 1988 (p. 38, pl. 28, figs. 7, 13, 14), Dillard 1991a (p. 17, pl. 2, fig. 8), Lenzenweger 1996 (p. 119, pl. 17, fig. 17), Coesel & Meesters 2007 (p. 63, pl. 31, fig. 1)
Dimensions: L: 70.86 µm, B: 28.29 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

Genus: *Cosmarium*
***Cosmarium amoenum* Brébisson ex Ralfs (Fig. 2k)**
References: West & West 1912 (p. 29, pl. 102, figs. 1-4, pl. 103, fig. 9), Lind & Brook 1980 (p. 64, fig. 99), Förster 1982 (p. 166, pl. 29, fig. 10), Croasdale & Flint 1988 (p.

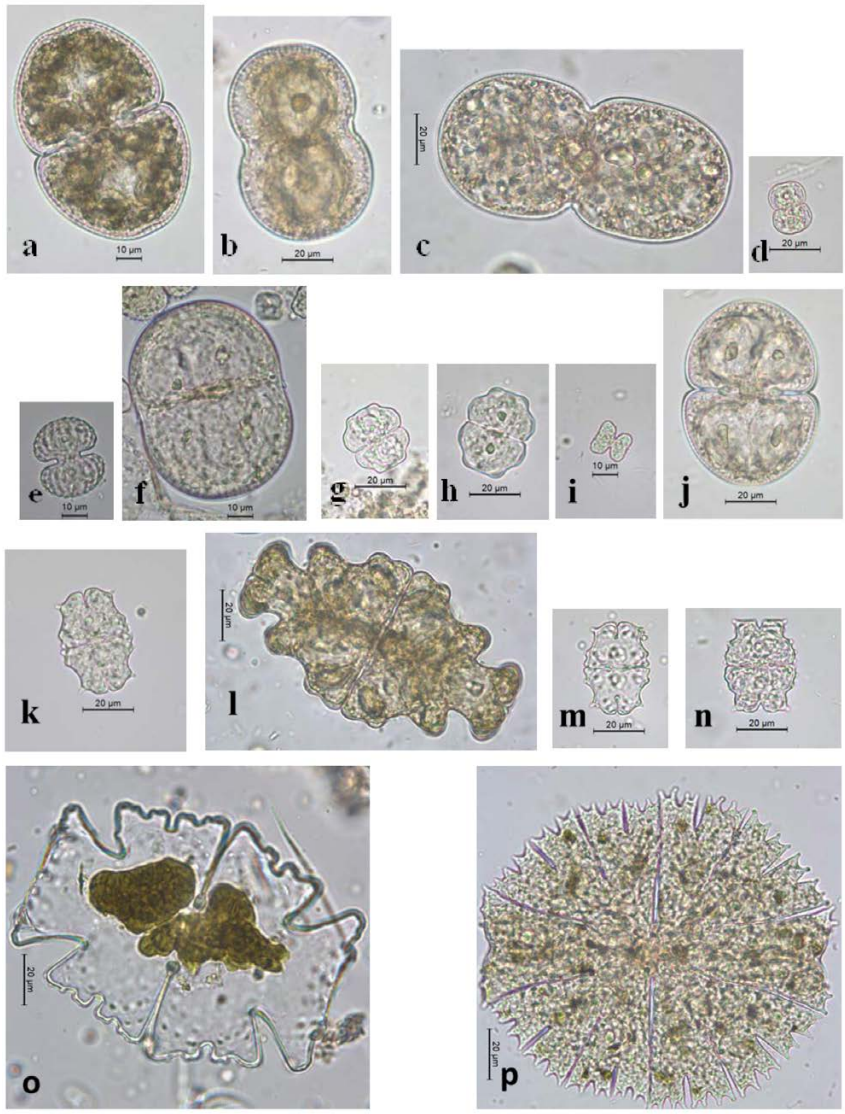

Fig. 3. a. *Cosmarium canaliculatum,* **b**. *C. connatum*, **c**. *C. debaryi*, **d**. *C. difficile* var. *messikommeri*, **e.** *C. porteanum* var. *nephroideum*, **f.** *C. pseudoconnatum*, **g.** *C. retusiforme* var. *retusiforme*, **h.** *C. retusiforme* var. *incrassatum*, **i.** *C. staurastroides*, **j**. *C. subcucumis*, **k**. *Euastrum elegans*, **l**. *E. humerosum*, **m**. *E. pulchellum*, **n**. *E. turneri*, **o**. *Micrasterias americana* var. *boldtii*, **p**. *M. papillifera.*

50, pl. 55, figs. 1-3), Dillard 1991a (p. 43, pl. 39, fig. 10), Lenzenweger 1999 (p. 108, pl. 60, figs. 5, 6), John *et al.* 2003 (p. 535, pl. 135, fig. J), Coesel & Meesters 2007 (p. 105, pl. 71, fig. 10)
Dimensions: L: 50.72-56.74 µm, B: 24.51-32.21 µm, I: 3.01-9.77 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, rare.

***C. caelatum* Ralfs (Fig. 2l)**
References: West & West 1908 (p. 134, pl. 76, figs. 5-7), Croasdale & Flint 1988 (p. 58, pl. 43, figs. 1-3), Dillard 1991a (p. 544, pl. 39, fig. 1), Lenzenweger 1999 (p. 130, pl. 64, figs. 1-4), John *et al.* 2003 (p. 536, pl. 134, fig. A), Coesel & Meesters 2007 (p. 109, pl. 78, fig. 13)
Dimensions: L: 49.59 µm, B: 41.84 µm, I: 15.59 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***C. canaliculatum* West & G.S.West (Fig. 3a)**
References: West & West 1905 (p. 198, pl. 64, fig. 4), Coesel & Meesters 2007 (p. 110, pl. 65, figs. 9, 10)
Dimensions: L: 75.51-87.69 µm, B: 54.54-61.00 µm, I: 15.72-18.93 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***C. connatum* Brébisson ex Ralfs (Fig. 3b)**
References: West & West 1908 (p. 25, pl. 67, figs. 15-17), Lind & Brook 1980 (p. 56, fig. 78), Förster 1982 (p. 182, pl. 19, figs. 1-3), Ling & Tyler 1986 (p. 20, pl. 17, figs. 1, 2), Croasdale & Flint 1988 (p. 60, pl. 37, fig. 30), Bourrelly & Couté 1991 (p. 66, pl. 24, fig. 18), Dillard 1991a (p. 57, pl. 16, fig. 7), Lenzenweger 1999 (p. 40, pl. 46, fig. 11), John *et al.* 2003 (p. 536, pl. 133, fig. G), Coesel & Meesters 2007 (p. 111, pl. 59, figs. 1, 2)
Dimensions: L: 71.26-79.12 µm, B: 52.90-64.29 µm, I: 43.97 µm.

Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, rare.

***C. debaryi* W.Archer (Fig. 3c)**
References: West & West 1908 (p. 61, pl. 70, figs. 14-16, pl. 93, fig. 2), Förster 1982 (p. 191, pl. 24, figs. 13, 14), Lenzenweger 1999 (p. 44, pl. 47, fig. 1), John *et al.* 2003 (p. 539, pl. 133. fig. Q), Coesel & Meesters 2007 (p. 114, pl. 59, figs. 4, 5)
Dimensions: L: 110.03-124.01 µm, B: 53.31-62.85 µm, I: 37.52 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***C. difficile* var. *messikommeri* (Croasdale) Kouwets (Fig. 3d)**
References: Kouwets 1997 (p. 41, figs. 69-76)
Dimensions: L: 20.77-21.93 µm, B: 12.41-15.31- µm, I: 4.37-4.79 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***C. porteanum* var. *nephroideum* Wittrock (Fig. 3e)**
References: West & West 1908 (p. 167, pl. 80, figs. 10, 11), Lind & Brook 1980 (p. 65, fig. 102), Dillard 1991a (p. 104, pl. 28, fig. 2), Lenzenweger 1999 (p. 118, pl. 60, fig. 17), Coesel & Meesters 2007 (p. 132, pl. 71, figs. 17, 18)
Dimensions: L: 32.26-33.87 µm, B: 26.38-28.40 µm, I: 7.72-8.93 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, rare.

***C. pseudoconnatum* Nordstedt (Fig. 3f)**
References: West & West 1908 (p. 26, pl. 67, figs. 19-21), Lind & Brook 1980 (p. 56, fig. 77), Förster 1982 (p. 243, pl. 19, figs. 4, 5), Bourrelly & Couté 1991 (p. 91, pl. 25, fig. 3), Dillard 1991a (p. 106, pl. 16, fig. 8), Lenzenweger 1999 (p. 57, pl. 46, fig. 12), John *et al.* 2003 (p. 544, pl. 133, fig. F), Coesel & Meesters 2007 (p. 134, pl. 59, figs. 6, 7)
Dimensions: L: 72.36-75.95 µm, B: 61.25-64.29 µm, I: 56.81-61.00 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***C. retusiforme* (Wille) Gutwinski var. *retusiforme* (Fig. 3g)**
References: West & West 1905 (p. 180, pl. 62, figs. 17, 18), Lenzenweger 1999 (p. 84, pl. 52, fig. 8)
Dimensions: L:30.80-34.43 µm, B: 23.77-27.81 µm, I: 5.58-9.08 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, rare.

***C. retusiforme* var. *incrassatum* Gutwinski (Fig. 3h)**
References: Dillard 1991a (p. 122, pl. 10, fig. 1), Lenzenweger 1999 (p. 84, pl. 52, fig. 9)
Dimensions: L: 32.23-33.38 µm, B: 26.50-27.81 µm, I: 8.64-8.84 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

***C. staurastroides* Eichler & Gutwinski (Fig. 3i)**
References: Lenzenweger 1999, p. 66, pl. 51, figs 1, 2.
Dimensions: L: 11.95-13.63 µm, B: 11.29-14.06 µm, I: 3.33-4.00 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic communities, single.

***C. subcucumis* Schmidle (Fig. 3j)**
References: West & West 1905 (p. 155, pl. 60, figs. 1-3), Croasdale & Flint 1988 (p. 104, pl. 31, figs. 6, 7), Dillard 1991a (p. 130, pl. 6, fig. 3), Lenzenweger 1999 (p. 67, pl. 47, figs. 14, 15), Coesel & Meesters 2007 (p. 143, pl. 65, figs. 1-3)
Dimensions: L: 74.06-79.50 µm, B: 47.36-55.51 µm, I: 14.94-18.57 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

Genus: *Euastrum*
***E. elegans* Ralfs (Fig. 3k)**
References: West & West 1905 (p. 48, pl. 38, figs. 16-21), Lind & Brook 1980 (p. 38, fig. 48), Förster 1982 (p. 321, pl. 42, fig. 1), Croasdale & Flint 1986 (p. 90, pl. 22, figs. 6, 7), Dillard 1993 (p. 34, pl. 3, fig. 1), Lenzenweger 1996 (p. 81, pl. 11, fig. 20), John *et al.* 2003 (p. 555, pl. 136, fig. G), Coesel & Meesters 2007 (p. 77, pl. 47, figs. 7-9)
Dimensions: L: 36.31-37.37 µm, B: 25.39-26.42 µm, I: 5.57-5.79 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***E. humerosum* Ralfs (Fig. 3l)**
References: West & West 1905 (p. 8, pl. 34, figs. 1, 2), Förster 1982 (p. 327, pl. 44, fig. 4), Dillard 1993 (p. 41, pl. 6, fig. 4), Lenzenweger 1996 (p. 83, pl. 9, fig. 12), Coesel & Meesters 2007 (p. 78, pl. 41, figs. 3, 4)
Dimensions: L: 112.94-118.25 µm, B: 62.88-73.56 µm, I: 18.64-22.24 µm.
Distribution in Turkey: Avusor Great Lake, in the epipelic community, single.

***E. pulchellum* Brébisson (Fig. 3m)**
References: West & West 1905 (p.46, pl. 38, figs. 14, 15), Dillard 1993 (p. 59, pl. 2, fig. 6), Lenzenweger 1996 (p. 89, pl. 11, fig. 12), Coesel & Meesters 2007 (p. 81, pl. 47, figs. 5, 6)
Dimensions: L: 35.11 µm, B: 27.20 µm, I: 9.49 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

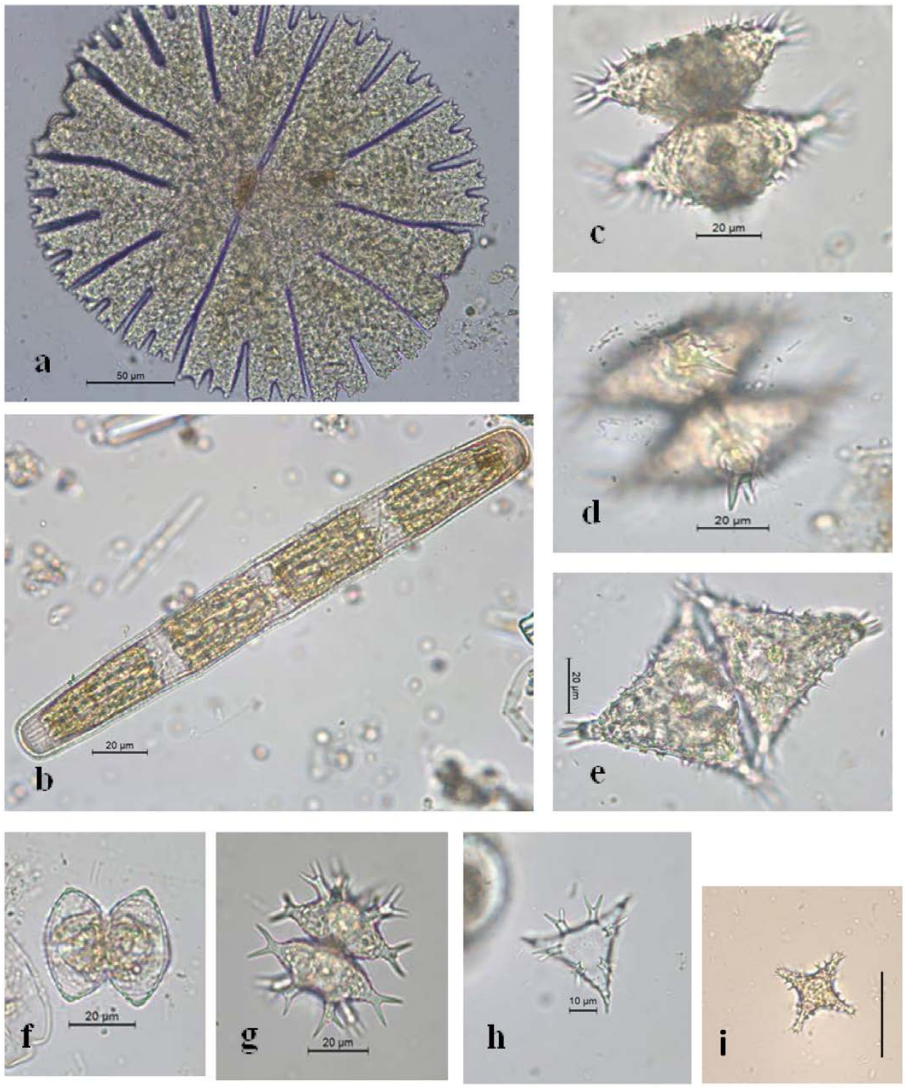

Fig. 4. a. *Micrasterias thomasiana* var. *notata*, **b**. *Penium spirostriolatum*, **c**-**e**. *Staurastrum aculeatum* (**c**. General view, **d**. Bifurcate denticulation, **e**. Apical view), **f**. *S. acutum*, **g**-**h**. *S. forficulatum* (**g**. General view, **h**. Apical view), **i**. *S. heimerlianum* var. *spinulosum*.

***E. turneri* West (Fig. 3n)**
References: West & West 1905 (p.37, pl. 37, figs. 9, 10), Croasdale & Flint 1986 (p. 102, pl. 21, figs. 1-4), Dillard 1993 (p. 69, pl. 3, fig. 10), Lenzenweger 1996 (p. 91, pl. 11, fig. 22)
Dimensions: L: 35.47 µm, B: 28.42 µm, I: 6.94 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

Genus: *Micrasterias*
***Micrasterias americana* var. *boldtii* Gutwinski (Fig. 3o)**
References: West & West 1905 (p. 120, pl. 53, fig. 6), Bourrelly & Couté 1991 (p. 45, pl. 21, fig. 2), Dillard 1993 (p. 82, pl. 12, fig. 12), Lenzenweger 1996 (p. 99, pl. 13, figs. 4-6), Coesel & Meesters 2007 (p.85, pl. 58, figs. 2, 3)
Dimensions: L: 121.30-136.38 µm, B: 97.49-110.10 µm, I: 35.05-48.21 µm.
Distribution in Turkey: Avusor Great Lake, in the epipelic community, single.

***M. papillifera* Brébisson ex Ralfs (Fig. 3p)**
References: West & West 1905 (p. 91, pl. 44, figs. 1, 2), Lind & Brook 1980 (p. 44, fig. 61), Förster 1982 (p. 381, pl. 60, figs. 5-7), Croasdale & Flint 1986 (p. 106, pl. 25, fig. 6), Dillard 1993 (p. 99, pl. 29, fig. 2), Lenzenweger 1996 (p. 105, pl. 15, figs. 1-4), John *et al*. 2003 (p. 559, pl. 137, fig. C), Coesel & Meesters 2007 (p. 89, pl. 56, figs. 1-4)
Dimensions: L: 119.61-133.44 µm, B: 109.90-123.22 µm, I: 41.55-50.13 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

***M. thomasiana* var. *notata* (Nordstedt) Grönblad (Fig. 4a)**
References: Förster 1982 (p. 390, pl. 63, figs. 4, 5), Croasdale & Flint 1986 (p. 109, pl. 27, fig. 2), Bourrelly & Couté 1991 (p. 51, pl. 22, fig. 4), Dillard 1993 (p. 111, pl. 30, fig. 1), Lenzenweger 1996 (p. 108, pl. 16, fig. 4), John *et al*. 2003 (p. 561, pl. 137, fig. H), Coesel & Meesters 2007 (p. 90, pl. 53, figs. 2, 3, pl. 54, fig. 1)

Dimensions: L: 288.81-328.48 µm, B: 167.40-304.96 µm, I: 91.85-101.25 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

Genus: *Penium*
***Penium spirostriolatum* J. Barker (Fig. 4b)**
References: West & West 1904 (p. 88, pl. 9, figs. 1-8), Ružička 1977 (p. 60, pl. 3, figs. 1-6), Lind & Brook 1980 (p. 19, fig. 9), Förster 1982 (p. 54, pl. 3, figs. 7, 8), Croasdale & Flint 1986 (p. 45, pl. 3, figs. 16, 17), Lenzenweger 1996 (p. 21, pl. 1, fig. 4), John *et al.* 2003 (p. 530, pl. 128, fig. W), Coesel & Meesters 2007 (p. 30, pl. 7, figs. 1, 2), Brook & Williamson 2010 (p. 141, pl. 65, figs. 1-6)
Dimensions: L: 205.17-211. 94 µm, B: 22.55-24.90 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic community, single.

Genus: *Staurastrum*
***Staurastrum aculeatum* Meneghini ex Ralfs (Fig. 4c, d, e).**
References: Lind & Brook 1980 (p. 106, fig. 157), Dillard 1991b (p. 34, pl. 13, fig. 11), Lenzenweger 1997 (p. 65, pl. 39, fig. 2), Coesel & Meesters 2007 (p. 173, pl. 109, figs. 4, 5), Coesel & Meesters 2013 (p. 59, pl. 83, figs. 1-7)
Dimensions: L: 57.79 µm, B: 74.54 µm, I: 18.83 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. acutum* Brébisson (Fig. 4f)**
References: West & West 1912 (p. 190, pl. 128, fig. 14), Lenzenweger 1997 (p. 92, pl. 25, fig. 10), Coesel & Meesters 2007 (p. 173, pl. 93, figs. 17, 18), Coesel & Meesters 2013 (p. 60, pl. 55, figs. 11-15), Kim 2015 (p. 34, fig. 33)
Dimensions: L: 38.91 µm, B: 37.44 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. forficulatum* P.Lundell (Fig. 4g, h)**
References: West & West 1923 (p. 187, pl. 154, figs. 14-16), Dillard 1991b (p. 71, pl. 13, fig. 4), Lenzenweger 1997 (p. 88, pl. 40, figs. 13-16), Coesel & Meesters 2007 (p. 183, pl. 98, fig. 13), Coesel & Meesters 2013 (p. 96, pl. 64, figs. 6-9)
Dimensions: L: 52.80 µm (with processes), B: 53.99 µm, I: 12.84 µm (with processes).
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. heimerlianum* var. *spinulosum* Lütkemüller (Fig. 4i)**
References: West & West 1923 (p. 165, pl. 149, fig. 16), Lenzenweger 1997 (p. 95, pl. 29, figs. 4-7), Coesel & Meesters 2013 (p. 104, pl. 74, figs. 9-11)
Dimensions: B: 51.70 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. spongiosum* Brébisson ex Ralfs var. *spongiosum* (Fig. 5a)**
References: West & West 1923 (p. 76, pl. 140, fig. 14), Dillard 1991b (p. 127, pl. 5, fig. 9), Lenzenweger 1997 (p. 131, pl. 30, fig. 9), John *et al.* 2003 (p. 576, pl. 139, fig.

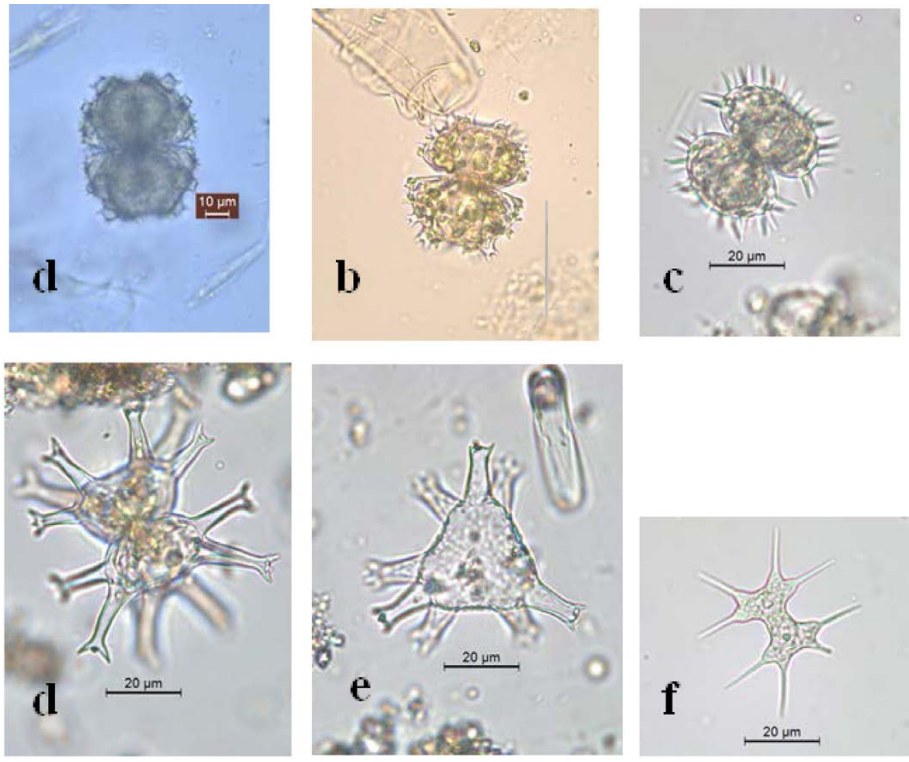

Fig. 5. a. *Staurastrum spongiosum* var. *spongiosum*, **b**. *S. spongiosum* var. *perbifidum*, **c**. *S. teliferum*, **d-e**. *S. tohopekaligense* (**d**. General view, **e**. Apical view), **f**. *Staurodesmus octocornis*.

H), Coesel & Meesters 2007 (p. 199, pl. 99, fig. 6), Coesel & Meesters 2013 (p. 151, pl. 60, figs. 1-6), Kim 2015 (p. 82, fig. 99)
Dimensions: L: 60.88 µm, B: 47.39 µm, I: 19.09 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. spongiosum* var. *perbifidum* West (Fig. 5b)**
References: West & West 1923 (p. 78, pl. 140, fig. 16), Lenzenweger 1997 (p. 131, pl. 30, figs. 10-12), Coesel & Meesters 2007 (p. 199, pl. 99, fig. 7), Kim 2015 (p. 84, fig. 101)
Dimensions: L: 53.14 µm, B: 46.76 µm, I: 14.47 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. teliferum* Ralfs (Fig. 5c)**
References: West & West 1923 (p. 58, pl. 136, figs. 2-6), Lind & Brook 1980 (p. 88, fig. 139), Dillard 1991b (p. 131, pl. 11, fig. 5), Lenzenweger 1997 (p. 136, pl. 27, fig. 10), John *et al*. 2003 (p. 576, pl. 139, fig. D), Coesel & Meesters 2007 (p. 201, pl. 95, figs. 3-5), Coesel & Meesters 2013 (p. 157, pl. 44, figs. 1-9)
Dimensions: L: 34.24-41.33 µm, B: 28.90-30.88 µm, I: 6.49-13.75 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epiphytic community, single.

***S. tohopekaligense* Wolle (Fig. 5d, e)**
References: West & West 1923 (p. 178, pl. 155, fig.12), Croasdale *et al*. 1994 (p. 142, pl. 88, figs. 1, 2, pl. 115, fig. 5), Lenzenweger 1997 (p. 137, pl. 41, fig. 13), Coesel & Meesters 2007 (p. 202, pl. 100, figs. 11-13), Coesel & Meesters 2013 (p. 159, pl. 38, figs. 7-10)
Dimensions: L: 54.65 µm, B: 40.32-41.10-43.33 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

Genus: *Staurodesmus*
***Staurodesmus octocornis* (Ehrenberg ex Ralfs) Stastny, Skaloud & Neustupa (Fig. 5f)**
References: West & West 1912 (p. 111, pl. 117, figs. 6-10), Dillard 1991a (p. 163, pl. 42, fig. 8), Lenzenweger 1997 (p. 4, pl. 18, fig. 3), John *et al*. 2003 (p. 585, pl. 142, fig. J), Coesel & Meesters 2007 (p. 155, pl. 85, figs. 9-11)
Dimensions: L: 20.81-24.88 (without spines)-46.56-47.63 (with spines) µm, B: 17.03-22.78 (without spines)-38.22-46.90 (with spines) µm, I: 7.33-9.18 µm.
Distribution in Turkey: Koçdüzü Great Lake, in the epipelic and epiphytic communities, single.

DISCUSSION

As for the number of species, *Cosmarium* was the most dominant genus (32.43%), followed by *Staurastrum* (21.62%), *Closterium* (16.21%), *Euastrum* (10.81%) and *Micrasterias* (8.10%). These five genera represented 89.17% of all the identified species. This is not surprising since this taxonomic composition is typical of the northern flora (Medvedeva 2001; Sterlyagova 2008; Šovran *et al*. 2013; Briskaite *et al*. 2016; Shakhmatov & Pavlovskiy 2019). The number of species of the genus *Actinotaenium* comprised 5.40% of all the recorded species. The remaining genera, *Penium* (2.70%) and *Staurodesmus* (2.70%), were found in much smaller numbers. A similar taxonomic composition was also previously observed in high mountain lakes in the Artabel Lakes Nature Park (Şahin & Akar 2019).

The genus *Cosmarium*, which is a very species-rich artificial genus and most probably of polyphyletic origin (Gontcharov 2008), is one of the first identified genera of Placoderm desmids and is also the largest (Prescott *et al*. 1981). *Cosmarium* is also one of the typical genera of the high mountain lakes in the northern region (Sterlyagova 2008; Briskaite *et al*. 2016; Şahin & Akar 2019). It thus comes as no surprise that the genus *Cosmarium* was represented by the highest number of species.

The genus *Staurastrum* comes third in the desmid flora of Turkey after *Cosmarium* and *Closterium* (Şahin 2019). The members of this genus generally prefer slightly acidic oligo-mesotrophic waters, but euplanktonic species are also found in eutrophic habitats (Coesel & Meesters 2013). *Staurastrum* species are also considered to be R-strategists. R-selected species have adapted to environmental conditions characterized by frequent changes in the physical environments such as low light intensity, low temperatures and high nutrient salts (Salmaso & Padisak 2007). In the research studies conducted in the high mountain lakes of the Eastern Carpathians (Ukraine) and the Polar Urals (Russia), *Staurastrum* species were found to be the most common (Briskaite *et al*. 2016; Tsarenko *et al*. 2019).

The physical and chemical characteristics of the lakes did not seem to affect the occurrence of desmids. Most of the determined desmid species are benthic or periphytic forms (Borics *et al*. 2003). However, it is interesting to note that a number of species (e.g. *Closterium archenianum* var. *pseudocynthia*, *Actinotaenium rufescens*, *Cosmarium pseudoconnatum*, *C. retusiforme* var. *incrassatum*, *Euastrum elegans*, *E. humerosum*, *E. pulchellum*, *E. turneri*, *Staurastrum aculeatum*, *S. forficulatum*, *S. heimerlianum* var. *spinulosum*, *S. spongiosum* var. *spongiosum*, *S. spongiosum* var. *perbifidum*, *S. teliferum*, *S. tohopekaligense* and *Staurodesmus octocornis*) which commonly occur in acidic waters are found here in lakes with a pH greater than 7 (Table 1). We assume that these species reached the lakes from their mountain tributaries and successfully adapted to these pH values. 34 out of 37 species were found only in Koçdüzü Great Lake, which has an alkaline character (Table 1). This represents another remarkable result of this study. According to Feher (2003), this is possible, because she also identified many

desmid species in alkaline lakes and wetlands in Southern Hungary.

The species *Actinotaenium cucurbitinum*, *Closterium angustatum*, *Cosmarium connatum*, *C. debaryi*, *C. pseudoconnatum*, *Micrasterias papillifera*, *Penium spirostriolatum*, *Staurastrum aculeatum* and *S. spongiosum* are included in the Red List of the Netherlands (Coesel 1998).

The desmid flora of Turkey comprises 19 genera and 347 species (Şahin 2019; Şahin & Akar 2019). However, when compared to other countries such as Austria (Lenzenweger 2003), the Netherlands (Coesel 1998) and Serbia (Stamenković 2008), there appears to be less data on the diversity, distribution, habitats and ecological relationships of desmids. This situation is related to the low number of studies.

In conclusion, this study provides an important contribution to Turkey's desmid flora. A total of 37 of the 112 identified desmid species are recorded for the first time in Turkey. For this reason, similar investigations are indispensable and make further study necessary to gain a better understanding of desmid diversity in Turkey.

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REZIME

Botanica SERBICA

Novi podaci o dezmidnim algama iz dva visokoplaninska jezera u Çamlıhemşin/Rize (Turska)

Bülent Şahin

Bentosna flora algi jezera Avusor Great Lake i Koçdüzü Great Lake u Rizeu istraživana je 21. avgusta 2019. Otkriveno je ukupno 37 dezmidnih algi novih za Tursku, i to u okviru rodova *Actinotaenium* (2), *Closterium* (6), *Cosmarium* (12), *Euastrum* (4), *Micrasterias* (3), *Penium* (1), *Staurastrum* (8) i *Staurodesmus* (1). Morfotaksonomija, ekologija i distribucija svake vrste su u radu detaljno diskutovani.

Ključne reči: visokoplaninska jezera, dezmide, novi nalazi, Avusor Great Lake, Koçdüzü Great Lake, Turska