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Twenty-four new records for the freshwater algae of Turkey

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Abstract: Twenty-four new records for freshwater algae of Turkey were determined in a study conducted from February 2007 to January 2009 in Çaygören Reservoir, Balıkesir, Turkey. Among these, 3 were Cyanobacteria, 3 Euglenophyta, 15 Chlorophyta, 1 Charophyta, 1 Heterokontophyta, and 1 was Dinophyta.

Key words: Çaygören Reservoir, new record, freshwater algae, Turkey

Türkiye tatlısu algleri için yirmidört yeni kayıt

Özet: Şubat 2007 ile Ocak 2009 tarihleri arasında Çaygören Barajı'nda (Balıkesir, Türkiye) yapılan bu çalışmada Türkiye tatlısu algleri için 24 yeni kayıt olan fitoplanktonik tür belirlenmiştir. Teşhis edilen alglerden 3 tanesi Cyanobacteria, 3 tanesi Euglenophyta, 15 tanesi Chlorophyta, 1 tanesi Charophyta, 1 tanesi Heterokontophyta, 1 tanesi de Dinophyta bölümüne aittir.

Anahtar sözcükler: Çaygören Barajı, yeni kayıt, tatlısu algleri, Türkiye

Introduction

Turkey has a great potential of algal diversity in inland waters, but a complete list of the algal flora of Turkey has not yet been completed. Thus, it is necessary to study the flora of Turkey to contribute to the knowledge of freshwater algae of Turkey.

Çaygören Reservoir (ÇR) is located between 28°19′16″E and 39°17′24″N in the province of Balıkesir, Turkey (Figure 1). It is 273.5 m above sea level. It is mainly fed by Simav Stream and is also fed by Demyan Stream. It was constructed in 1971 for irrigation, energy production, and flood prevention. The total length of the ÇR is approximately 658 m. The reservoir has a surface area of 8148 km^2 with a maximum depth of 53.5 m, an annual mean water capacity of 392 hm^3, and a total volume of 142,569 hm^3 (DSİ, 1987).

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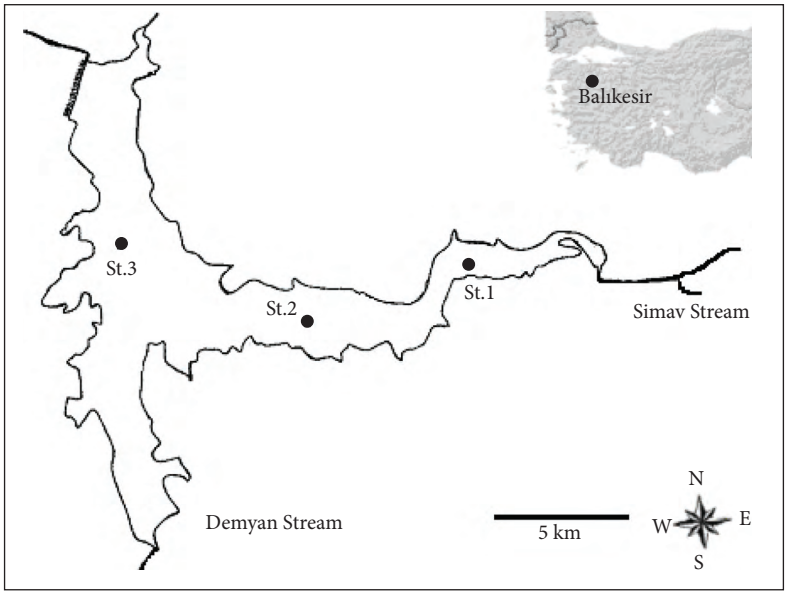

Figure 1. Map of the Çaygören Reservoir showing the locations of sampling stations.

Materials and methods

Three stations were chosen in different areas of the reservoir. Samples were taken from these stations every month from February 2007 to January 2009 with 10 m vertical intervals using a plankton net with a pore diameter of 55 µm. In the field, phytoplankton samples were placed in dark bottles and fixed with the mixture of Lugol's and formaldehyde solution. In the laboratory, 0.05 mL of water was poured into objective slides for microscopic analysis. Identification of the samples was performed on a compound microscope, equipped with water immersion lenses and a phase contrast attachment. Identification of algae was carried out according to John et al., 2003; Huber-Pestalozzi, 1962, 1969, 1974, 1976, 1982, 1983; Komarek & Anagnostidis, 1999; Komárek, 2005; Conforti, 1993; Conforti & Nudelman, 1994; Pasztaleniec & Poniewozik, 2004; Takano et al., 2008. Taxa were photographed with a camera attached to an Olympus BX 51 microscope.

Identified taxa were checked with the checklist of Gönülol et al., (1996) and Aysel (2005) and determined as new taxa for Turkish algal flora.

Water temperature, pH, and dissolved oxygen were measured using a YSI 6600 multi-probe. Total hardness, total alkalinity, orthophosphate, nitrate and sulphate were analyzed according to standard methods (APHA, 1995).

Results

During the sampling period, water temperature varied from 4.6 to 27.6 °C and pH and dissolved oxygen ranged from 7.4 to 11.6 and from 6.3 to 12.8 mgL^{-1}, respectively. Total hardness was 12.5-22.0 F° and total alkalinity values ranged from 130 to 201 mg $CaCO_3L^{-1}$. Orthophosphate, nitrate, and sulphate concentrations ranged from 0.05 to 0.89 mg L^{-1}, from 0.50 to 2.9 mg L^{-1}, and from 50.5 to 70.2 mg L^{-1}, respectively.

A total number of new records for freshwater algae is 24: Cyanobacteria: 3, Euglenophyta: 3, Chlorophyta: 15, Charophyta: 1, Heterokontophyta: 1, and Dinophyta 1 taxa.

Division: Cyanobacteria

Class: Cyanophyceae

Order: Synechococcales

Family: Merismopediaceae

Genus: *Aphanocapsa* Nägeli, 1849.

A. holsatica (Lemmermann) Cronberg et Komárek, 1994 (Figure 2a).

Basionym: *Clathrocystis holsatica* Lemmermann

Synonyms: *Clathrocystis holsatica* Lemmermann 1903; *Microcystis holsatica* (Lemmermann) Lemmermann 1907

(Komárek & Anagnostidis, 1999).

Colonies irregular, lobate with clearly visible colourless mucilage of irregular outline; somewhat densely aggregated cells, having in the mass a pale greyish blue-green colour, 1.4 µm in diameter.

Genus: *Merismopedia* Meyen, 1839.

M. minima Beck, 1897 (Figure 2b).

(Komárek & Anagnostidis, 1999).

Colonies small, quadrate, in 8-16 µm dimensions, with somewhat densely arranged cells. Cells spherical, pale blue-green, 0.8–1.2 µm in diameter.

Order: Nostocales

Family: Nostocaceae

Genus: *Anabaenopsis* Woloszynska, 1923.

A. magna Evans, 1962 (Figure 2c).

(Komárek, 2005).

Trichomes solitary, short, screw-like coiled with 1 coil, slightly constricted at cross-walls; coil 40 µm wide. Cells almost cylindrical, blue-green, with finely granular content, 7.5 × 7.6 µm. Akinets in pair, near the middle of the trichome, barrel-shaped, 3.3 × 4.1 µm in diameter.

Division: Euglenophyta

Class: Euglenophyceae

Order: Euglenales

Family: Euglenaceae

Genus: *Strombomonas* Deflandre, 1930.

S. praeliaris (Palmer) Deflandre, 1930 (Figure 2d).

Basionym: *Trachelomonas praeliaris* Palmer 1925.

Synonym: *Trachelomonas praeliaris* Palmer 1925.

(Huber-Pestalozzi, 1969; Conforti, 1993).

Lorica 42.5 µm long, 25 µm wide; nearly spherical. Anterior end with a cylindrical collar (5 × 7 µm), widened toward the free end, with oblique and irregular margin. Posterior end rapidly tapering to a conical pointed cauda (10 × 5 µm). Wall totally covered by adhering exogenous particles.

Genus: *Trachelomonas* Ehrenberg, 1835.

T. granulosa Playfair var. *crenulatocollis* (Szabados) Huber-Pestalozzi, 1955 (Figure 2e) .

(Huber-Pestalozzi, 1969).

Lorica 20.3 µm long, 17.7 µm wide, almost spherical, covered with small granules, wall brown. Apical pore with a low collar (2.8 × 5.4 µm).

T. globularis (Averintsev) Lemmermann var. *crenulatocollis* Szabados (Figure 2f).

(Huber-Pestalozzi, 1969; Conforti & Nudelman, 1994).

Lorica 20 µm long, 18 µm wide, subspherical. Membrane dark green, closely punctuated, ornamented with short conical spines.

Division: Chlorophyta

Class: Chlorophyceae

Order: Chlorococcales

Family: Micractiniaceae

Genus: *Golenkiniopsis* Korshikov, 1953.

G. parvula (Woronichin) Korshikov, (Figure 2g).

Basionym: *Golenkinia parvula* Woronichin

Synonyms: *Golenkiniopsis minutissima* (Iyengar & Balakrishnan) Philipose; *Golenkinia minutissima* Iyengar & Balakrishnan.

(John et al., 2003).

Cells 6 µm in diameter, spherical. Spines 15 µm long, narrow, many per cell. Chloroplast parietal, one pyrenoid.

Family: Scenedesmaceae

Genus: *Komarekia* Fott, 1981.

K. appendiculata (Chodat) Fott, 1981 (Figure 2h).

Basionym: *Hofmania appendiculata* Chodat.

Synonym: *Crucigenia appendiculata* (Chodat) Schmidle.

(John et al., 2003).

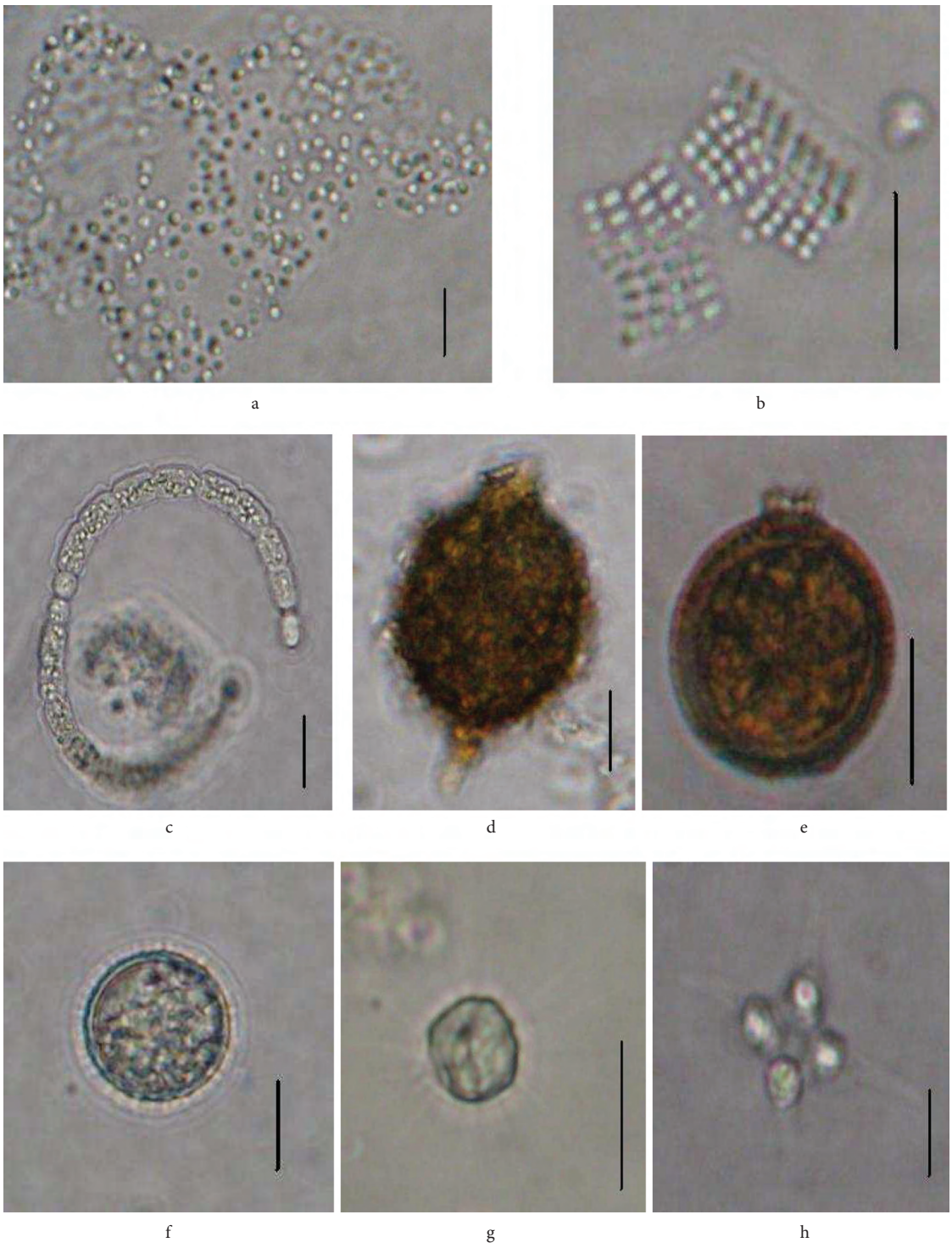

Figure 2. a. *Aphanocapsa holsatica*, b. *Merismopedia minima*, c. *Anabaenopsis magna*, d. *Strombomonas praeliaris*, e. *Trachelomonas granulosa* var. *crenulatocollis*, f. *Trachelomonas globularis* var. *crenulatocollis*, g. *Golenkiniopsis parvula,* h. *Komarekia appendiculata* (Scale 10 μm).

Coenobia consisting of 4 cells, 10 µm wide, cross-shaped; with remnants of mother cell wall persisting as colourless appendages attached to outer cell wall. Cells 3 µm wide, 5.6 µm long, ovoid, wall remnants 8 µm long.

Genus: *Scenedesmus* Meyen, 1829.

S. pseudodenticulatus Hegewald (Figure 3a).

(Huber-Pestalozzi, 1983).

Coenobia consisting of 4 cells; cells connected together to half length. Cells 11.7 µm long, 4 µm wide. Marginal cells bent, inner cells somewhat much bigger. Apex of cells rounded, with few little spines and teeth. Spines on outermost side of marginal cells straight or slightly concave, other small spines irregular.

S. pseudohelveticus Kırj. (Figure 3b).

(Huber-Pestalozzi, 1983).

Coenobia a single row of 4 linearly arranged cells; cells 13 µm long, 5 µm wide. Inner cells thin and long, ovoid-cylindrical, apices somewhat rounded, connected together to 3/4 length; outermosts of the inner cells slightly convex. Spines of the inner cells transverse, symmetric and short (3 µm). Marginal cells long with 2 apical spines (15 µm).

Genus: *Tetrastrum* Chodat, 1895.

T. elegans Playfair, 1917 (Figure 3c).

(John et al., 2003).

Coenobia 4–16 µm across, quadrate to rectangular in outline. Cells 2.5–4 µm wide, ovoid, with an indistinct space between cells and a long median spine (10–16 µm long) arising from convex outermost surface. Pyrenoid present.

Family: Hydrodictyaceae

Genus: *Pediastrum* Meyen, 1829.

P. duplex Meyen var. *gracillimum* W.West & G.S.West (Figure 3d).

Synonym: *Pediastrum gracile* A. Braun. (John et al., 2003).

Coenobia up to 160 µm across. Cells with concave side walls. Marginal cells 18 × 10 µm, very long projections bent in different directions. Inner cells 16 × 13 µm. Cell walls smooth, without granulations.

P. simplex Meyen var. *echinulatum* Wittrock, (Figure 3e).

(Huber-Pestalozzi, 1983; Pasztaleniec & Poniewozik, 2004).

Coenobia circular, 8 celled. Coenobia always with holes. Diameter of coenobia 116 µm. Marginal cells with one narrowed lobe. Dimensions of marginal cells 12.5 × 25 µm (with lobe). Diameter of inner cells 15 µm. Cell walls prominent, elongated granules.

Family: Oocystaceae

Genus: *Lagerheimia*, Chodat, 1895.

L. marssonii Lemmermann (Figure 3f).

Synonym: *Lagerhemia minor* Fott, 1933;

Chodatella marsonii (Lemm.) Ley 1948.

(Huber-Pestalozzi, 1983).

Cells 10 µm wide, 7.5 µm long, broadly spheroid, with a single spine at each apex and 2 opposite each other at equator. Spines straight, 20 µm long. Chloroplast parietal with one pyrenoid.

Family: Botryococcaceae

Genus: *Quadricoccus* Fott, 1948.

Q. ellipticus Hortobágyi, 1973 (Figure 3g).

(Huber-Pestalozzi, 1983).

Coenobia 4 celled. Cells attached to one another with cell wall remnants. Cells 6 µm long, 3.5 µm wide, elipsoidal; walls thin and smooth.

Order: Sphaeropleales

Family: Ankistrodesmaceae

Genus: *Kirchneriella* Schmidle, 1893.

K. dianae (Bohlin) Comas Gonzales, 1980 (Figure 3h).

Basionym: *Kirchneriella lunaris* var. *dianae* Bohlin.

Synonym: *Kirchneriella lunaris* var. *dianae* Bohlin 1897.

(Huber-Pestalozzi, 1983).

Coenobia irregularly shaped, consisting of 8 irregularly arranged cells, enclosed within a colourless mucilaginous envelope. Cells 20 µm long, 5 µm wide, spindle-shaped, gradually narrowing to acute apices, crescent. Chloroplast parietal with a pyrenoid.

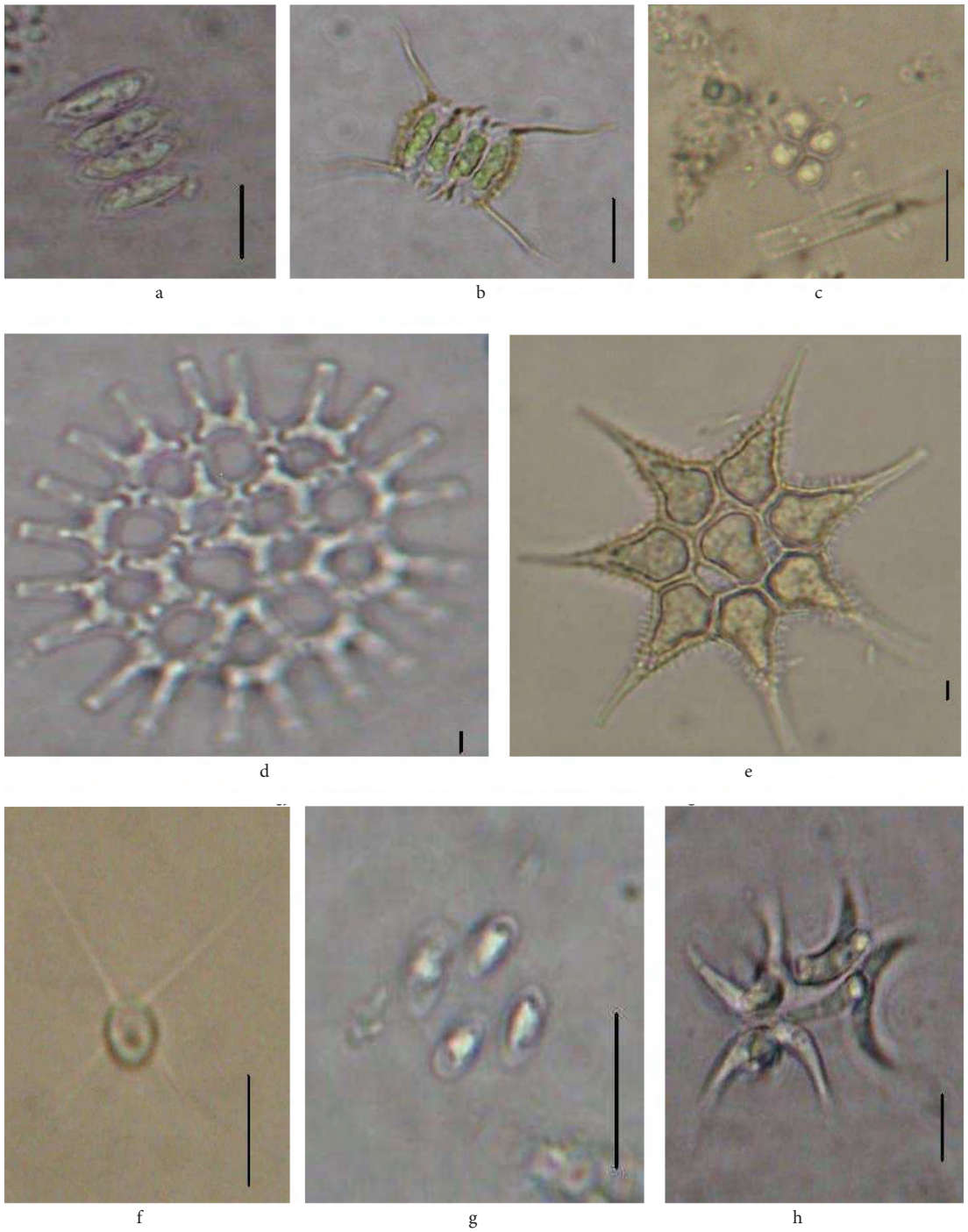

Figure 3. a. *Scenedesmus pseudodenticulatus*, b. *Scenedesmus pseudohelveticus*, c. *Tetrastrum elegans*, d. *Pediastrum duplex* var. *gracillimum*, e. *Pediastrum simplex* var. *echinulatum*, f. *Lagerheimia marssonii*, g. *Quadricoccus ellipticus*, h. *Kirchneriella dianae* (Scale 10 µm).

Order: Volvocales

Family: Chlamydomonadaceae

Genus: *Chlamydomonas* Ehrenberg, 1833.

C. deberyana Gorozhankin var. *atactogama* (Korshikov) Gerloff, (Figure 4a).

Synonym: *Chlamydomonas atactogama* Korsch.

(Huber-Pestalozzi, 1974).

Cell body ovoid, 14 µm long, 10 µm wide. Flagella nearly body-length. Chloroplast cup-shaped. Pyrenoid spherical, located at posterior half of the cell. Nucleus centrally located. Stigma disc-shaped at anterior half of the cell body.

C. microsphaera Pascher & Jahoda. f. *acuta* Bourrelly (Figure 4b).

(Huber-Pestalozzi, 1974).

Cell body almost spherical, 12 µm in diameter, with thick cell wall and a small visible papilla. Flagella nearly body-length. Chloroplast cup-shaped. Pyrenoid ellipsoid, located at the centre of chloroplast. Nucleus and stigma at anterior half of the cell body.

C. rodhei Skuja (Figure 4c).

(Huber-Pestalozzi, 1974).

Cell body ellipsoidal in shape, 13 µm long**,** 9 µm wide; with thick and flat cell wall. Small conical papilla present. Chloroplast parietal, pyrenoids absent. Nucleus located at the centre of the cell body. Stigma at anterior half of the cell.

C. umbonata Pascher (Figure 4d).

(Huber-Pestalozzi, 1974).

Cell body spherical, 12 µm in diameter. Cell wall firm, with thickening at the tip of the cell, papilla conical. Flagella 2 times longer than body-length. Chloroplast cup-shaped, pyrenoid massive, spherical, at the centre of chloroplast. Nucleus and stigma at anterior half of the cell.

Family: Volvocaceae

Genus: *Eudorina* C.G. Ehrenberg ex Ralfs, 1832.

E. cylindrica Korshikov (Figure 4e).

(Huber-Pestalozzi, 1974).

Colony consisting of 16 cells, cells arranging as 4 layers forming cylindrical structure, 125 µm long; cells spherical in shape, 17.5 µm in diameter. Gelatinous coat consisting of 2 layers, outer one more gelatinous showing fuzzy periphery, chloroplast cup-shaped, posteriorly thickened, where a large pyrenoid presents.

Division: Charophyta

Class: Zygnematophyceae

Order: Zygnematales

Family: Desmidiaceae

Genus: *Cosmarium* Ralfs, 1848.

C. contractum O.Kirchner var. *minutum* (Delponte) Coesel, 1989 (Figures 4f and 4g).

Basionym: *Cosmarium minutum* Delponte.

Synonyms: *Cosmarium contractum* var. *(ellipsoideum) f. minor* Raciborski; *C. minutum* Delponte 1877; *C. ellipsoideum f. minor* Raciborski 1885; *C. minutum f. novizelandica* Nordstedt 1888; *C. contractum* var. *ellipsoideum* f. I West & G.S.West 1905.

(Huber-Pestalozzi, 1982).

Cells 22–23 µm long, 17–18 µm width, 11–12 µm thickness circa, sinus deep and wide, narrowing gradually to sharp-angled interior; isthmus 6–7 µm wide. Semicells equally elipsoidal with broadly elipsoidal apex; wall finely punctate.

Division: Heterokontophyta

Class: Chrysophyceae

Order: Chromulinales

Family: Dinobryaceae

Genus: *Volvochrysis* Schiller

V. polyochla Schiller (Figure 4h).

(Huber-Pestalozzi, 1962).

Colonies spherical 50 µm in diameter; with cells densely packed and positioning radially; cells 12 µm long, 6 µm wide, ovoid; with 2 flagella; well developing cell wall delicate and flat.

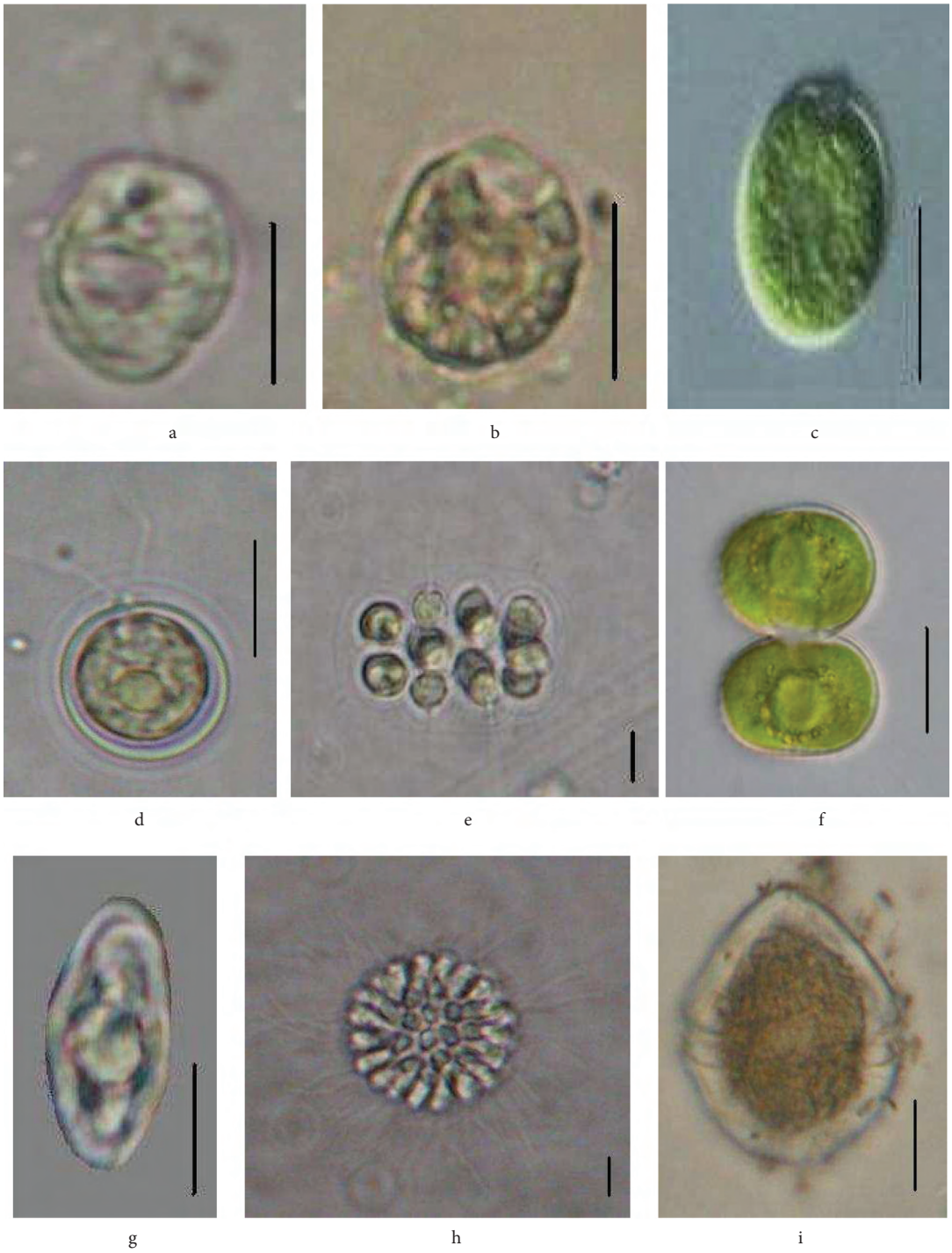

Figure 4. a. *Chlamydomonas deberyana* var. *atactogama,* b. *Chlamydomonas microsphaera* var. *acuta,* c. *Chlamydomonas rodhei*, d. *Chlamydomonas umbonata*, e. *Eudorina cylindrica*, f. *Cosmarium contractum* var. *minutum* (front view), g. *Cosmarium contractum* var. *minutum* (side view), h. *Volvochrysis polyochla*, i. *Peridiniopsis penardii* (Scale 10 µm).

Division: Dinophyta

Class: Dinophyceae

Order: Peridiniales

Family: Peridiniaceae

Genus: *Peridiniopsis* Lemmermann, 1904.

P. penardii (Lemmermann) Bourrelly, 1968 (Figure 4i) .

Basionym: *Glenodinium penardii* Lemmermann.

Synonyms: *Glenodinium penardii* Lemmermann 1900; *Peridinium penardii* (Lemmermann) Lemmermann 1910; *Peridinium andrzejowskii* Woloszynska 1920.

(Huber-Pestalozzi, 1976; Takano et al., 2008).

The cell has a conical epitheca and rounded hypotheca usually with more small antapical spines. The cingulum is median and is displaced only half its own width. Lenght: 28 µm, width: 23 µm.

Discussion

According to the measured physicochemical values, Çaygören Reservoir is a moderately hard, alkaline, and nutrient-rich eutrophic lake.

A total of 24 taxa belonging to 16 genera are new records for Turkish freshwater algae in the divisions of Cyanobacteria, Chlorophyta, Charophyta, Euglenophyta, Heterokontophyta, and Dinophyta.

The genus *Anabaenopsis* from Cyanobacteria was widespread in the tropics and subtropics (John et al., 2003). It was also found in lakes, ponds, and the lower Euphrates basin in Turkey (Ersanlı & Gönülol, 2003; Gürbüz & Kıvrak, 2004; Baykal et al., 2009).

It has been reported that *Strombomonas preeliaris*, *Trachelomonas granulosa* var. *crenulatocollis,* and *T. globularis* var. *crenulatocollis* from Euglenophyta have been found widespread in lakes and ponds of Europe, Asia, and North America. Of these, only 1 record was listed for *T. globularis* from Hungaria (Huber-Pestalozzi, 1969; John et al., 2003). *Strombomonas* species were found widespread in shallow lakes and *Trachelomonas* species in both shallow lakes and reservoirs of Turkey (Gönülol et al., 1996; Aysel, 2005; Ersanlı et al., 2006; Soylu et al., 2007a; Soylu & Gönülol, 2006; Çelekli et al., 2007a, 2007b; Atıcı & Çalışkan, 2007; Kolaylı & Şahin, 2009).

The division, Chlorophyta contains the highest records with 15 taxa. These taxa are dispersed into genus *Chlamydomonas* (4), *Scenedesmus* (2), *Pediastrum* (2), *Komarekia*, *Golenkiniopsis*, *Tetrastrum, Lagerheimia, Quadricoccus, Kirchneriella,* and *Eudorina*. These genera are widespread worldwide (John et al., 2003; Wehr & Sheath, 2003). It is reported that the species belonging to these genera were cosmopolitan in lakes, ponds, reservoirs, and stagnant and slow flowing running waters in Turkey (Gönülol et al., 1996; Aysel, 2005; Akar & Şahin, 2006; Çelekli et al., 2007a, 2007b; Atıcı & Çalışkan, 2007; Yılmaz, 2007; Çelik & Ongun, 2008). It is remarkable that *Komarekia* was reported as rare but cosmopolitan (John et al., 2003). Two species of *Scenedesmus* (*S. pseudodenticulatus* and *S. pseudohelveticus*) were found rare and *S. pseudohelveticus* was only reported from a fish pond in Bulgaria (Huber-Pestalozzi, 1983). *Scenedesmus* and *Pediastrum* species were densely found in oligomesotrophic reservoirs in Turkey (İşbakan et al., 2002; Kıvrak & Gürbüz, 2005). Four species of *Chlamydomonas* (*C. deberyana, C. microsphaera, C. rodhei* and *C. umbonata*) constitute the smallest species of this genus. They are between 14 µm and 9 µm in size. It has been reported that *C. deberyana* is attached to thecas of *Dinobryon* spp. and *C. rodhei* is filled in galleries of *Chonochiloides natans* (Seligo, 1900) from Rotifera (Huber–Pestalozzi, 1974). *Chlamydomonas* and *Eudorina* species were mostly found in shallow and nutrient-rich waters (Hutchinson, 1967). *Quadricoccus ellipticus* and *Kirchneriella dianae* were cosmopolitan and common component of plankton (Huber-Pestalozzi, 1983). It is considerable that the genus *Kirchneriella* was represented with seven species (Gönülol et al., 1996; Aysel, 2005; Soylu & Gönülol, 2006; Soylu et al., 2007a, 2007b; Çelekli et al., 2007a, 2007b) while the genus *Quadricoccus* was represented with only 1 from Lake Abant (*Q. verricosus*) in Turkey (Çelekli et al., 2007a).

Member of Zygnematales (Charophyta) of *Cosmarium contractum* var. *minutum* was an important component of phytoplankton and was common in nutrient-poor to medium-rich waters; pH 5.2–8.3, alkalinity 2–42 ppm $CaCO_3$ (John et al., 2003). However, it is known that members of Zygnematales are common in eutrophic and mesotrophic alkaline lakes in Turkey (Gönülol & Çomak, 1993).

The genus *Volvochrysis* (Heterokontophyta) and its species *V. polyochla* are both reported as a new record for the first time for Algal Flora of Turkey. *Peridiniopsis penardii* from Dinophyta was found in pH 7.5–7.8, 40-100 mg L^{-1} CaO, and 8-12 hardness levels and found in euplankton of great lakes that were not polluted with organic matter (Huber-Pestalozzi, 1976). Levels of pH, alkalinity and hardness of Çaygören Reservoir are within these ranges. Few *Peridiniopsis* species were reported in Turkey (Ersanlı & Gönülol, 2003; Karacaoğlu et al., 2004; Soylu & Gönülol, 2006; Çelekli et al., 2007a, 2007b; Atıcı & Çalışkan, 2007).

Algal flora studies require rigorous and long-term effort. Long-term monitoring and measuring of new records will prevent mistakes. Furthermore, for accuracy, experts need constantly updated databases.

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