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Research Article

Phytoplankton (except Bacillariophyceae) Flora of Lake Gölköy (Bolu)

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Abstract: The phytoplankton composition of Lake Gölköy was studied by monthly sample collection from 3 littoral and 2 pelagic stations during a 2-year period (June 2003-June 2005). In total, 152 taxa belonging to Chlorophyta (61.8%), Euglenophyta (12.5%), Cyanoprokaryota (10.5%), Pyrrophyta (5.3%), Chrysophyta (4.6%), Cryptophyta (3.9%), Xanthophyta (0.7%), and Prasinophyta (0.7%) were identified. *Spirogyra* and *Scenedesmus* were the most abundant genera, with 13 and 10 species, respectively. Some species found in the lake were new records for the Bolu region (e.g., *Gonium pectorale* Müller, *Polytoma cylindraceum* Pasher 1927, *Provasoliella ovata* (Jacobsen) Loeblich, and *Anabaena crassa* (Lemmermann) Komárková-Legnerová & Cronberg).

Key Words: Phytoplankton composition, algal taxonomy, Lake Gölköy, Bolu

Gölköy Gölü (Bolu) Fitoplankton (Bacillariophyceae hariç) Florası

Özet: Gölköy Gölü fitoplankton komposizyonu üç kıyısal ve iki vertikal istasyonda aylık olarak iki yıl boyunca (Haziran 2003-Haziran 2005) çalışılmıştır. Tanımlanan toplam 152 taksondan % 61,8'i Chlorophyta, % 12,5'i Euglenophyta, % 10,5'i Cyanoprokaryota, % 5,3'i Pyrrophyta, % 4,6'i Chrysophyta, % 3,9'i Cryptophyta, % 0,7'i Xanthophyta ve % 0,7'i Prasinophyta filumlarına aittir. *Spirogyra* ve *Scenedesmus* sırasıyla 13 ve 10 tür ile en fazla tür zenginliği olan cinslerdir. Gölden bulunan bazı türler (örneğin, *Gonium pectorale* Müller, *Polytoma cylindraceum* Pasher 1927, *Provasoliella ovata* (Jacobsen) Loeblich ve *Anabaena crassa* (Lemmermann) Komárková-Legnerová & Cronberg) Bolu bölgesi için yeni rapor edilmiştir.

Anahtar Sözcükler: Fitoplankton kompozisyonu, Algal taksonomi, Gölköy Gölü, Bolu

Introduction

Although limnological studies began about 6 decades ago (Geldiay, 1949; Tanyolaç & Karabatak, 1974), the pioneering phycological study was carried out by Aykulu & Obalı (1981) in Turkish inland waters. While a few earlier phycological studies in different ecosystems, such as in lakes (Obalı et al., 2002; Kılınç, 2003; Atıcı et al., 2005; Çelekli & Külköylüoğlu, 2006a), in a reservoir (Çelekli, 2006), and in a karstic spring (Çelekli & Külköylüoğlu, 2006b), were carried out in the Bolu region, many different aquatic habitats have not yet been studied.

Until the present study, nothing was known about the phytoplankton of Lake Gölköy, which is one of the largest dam lakes in Bolu. The present study aimed to investigate net phytoplankton (except Bacillariophyceae) species composition and their seasonal occurrences in Lake Gölköy, Bolu, Turkey.

Materials and Methods

Lake Gölköy (lat 31°31'E, long 40°42'N, 730 m asl), which is about 10 km east of Bolu, was created when a dam was built on a wetland area in the early 1970s

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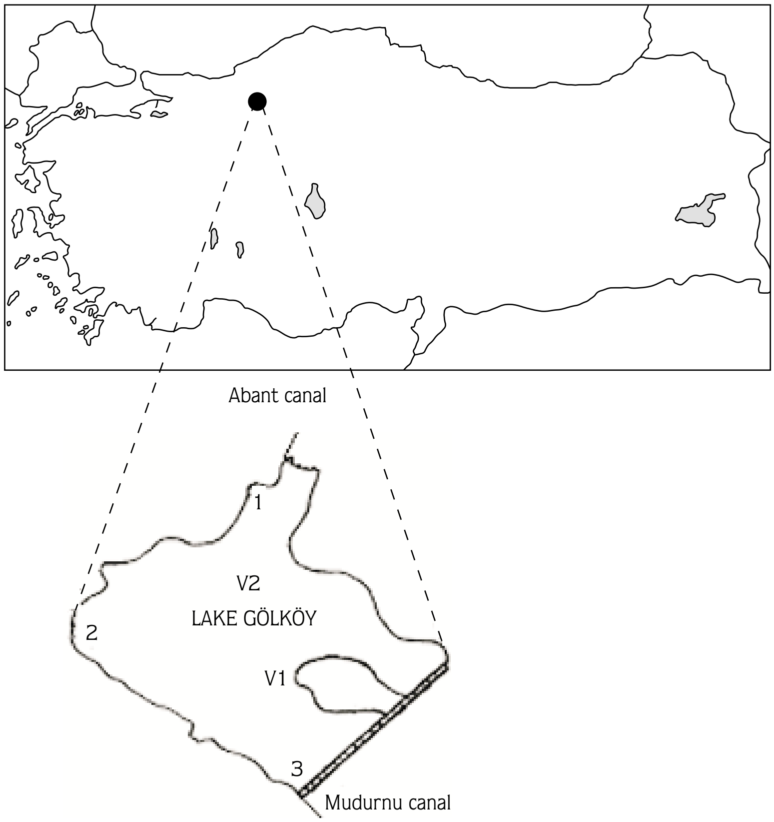

Figure 1. Map of Lake Gölköy and location of the sampling stations.

(Figure 1). The lake receives 2 major inflows: from Abant creek to the northeast and Mudurnu creek to the southwest of the lake. Both creeks carry nutrient-rich water from chicken farms, agricultural areas, and villages (Külköylüoğlu, 2005). The lake area fluctuates between 150 and 180 ha and has a maximum depth of 20 m. During summer and autumn, the lake depth decreases to about 8-9 m.

Monthly samples of phytoplankton were collected from 3 littoral sites and 2 pelagic sites on the lake between June 2003 and June 2005. Water samples collected using a plankton net (45 µm mesh size and 20 cm diameter) were preserved with acetic lugol-glycerol solution in polyethylene bottles. The samples were taken at depths of 0.3, 4, 7, and 10 m with a 2.5-l Van Dorn bottle and were concentrated with a plankton net. Some of the phytoplankton were photographed (200-400X magnification) with a camera attached to an Olympus BX 51 microscope. Only photographed species plus *Polytoma cylindraceum* and *Provasoliella ovata* are described in this study. Sampling was not performed when ice covered the lake from February to March 2004 and January to March 2005.

Identification of phytoplankton from net samples was based on the taxonomic keys of Prescott (1982), Ettl, (1983), Komárek & Fott (1983), Popovsky & Pfiester (1990), Komarek & Anagnostidis (1998), John et al. (2002), and Wehr & Sheath (2003). Additionally, some other sources were also used for classification of phytoplankton (Geitler, 1930-1932; Bourrelly, 1972). The AlgaeBase (2006) data base was also used to check the taxonomy of algae. The cell size and shape, number and type of chloroplasts and pyrenoids, pigmentation, structure of cell wall, zygospore size and shape, and conjugation type (for Zygnematales) were generally used during the classification of taxa. Measurements and other ecological information from taxonomic books and studies are given in brackets.

Results

During the study period, 152 taxa in 65 genera belonging to Chlorophyta (61.8%), Euglenophyta (12.5%), Cyanoprokaryota (10.5%), Pyrrophyta (5.3%), Chrysophyta (4.6%), Cryptophyta (3.9%), Xanthophyta (0.7%), and Prasinophyta (0.7%) were identified.

Cyanoprokaryota

Chroococcales

Microcystis Kützing 1833 ex Lemmermann 1907 nom. cons.

M. aeruginosa (Kützing) Kützing 1846 (Figure 2a)

Ovate, spherical or irregularly lobed colonies include numerous spherical cells surrounded by a mucilage matrix, spherical granular cells 3.5-6 (4-9) µm in diameter, sometimes found, especially in mid summer and autumn (Prescott 1982, 102: 1-4; John et al., 2002, 3: K-L).

Snowella Elenkin 1938

S. lacustris (Chodat) Komarek & Hindak 1988 (Figure 2b)

(Syn.; Gomphosphaeria lacustris Chodat)

Spherical colonies, 41-56 (up to 80) µm in diameter, ellipsoidal cells 2-3 x 2-2.5 (1.5-3.5 x 1.5-4) µm, seldom observed in summer (common plankton in mesotrophic or slightly eutrophic lakes) (John et al., 2002, 4: D-E).

Oscillatoriales

Oscillatoria (Vaucher) Gomont 1892

O. formosa (Bory) Gomont 1892 (Figure 2c).

Straight, tapering at ends, filament and end cell blunt with adjacent granules, calyptra-absent cells 3-4.5 (2.5-5) µm long and 4-5 (4-6) µm wide, widespread (John et al., 2002, 11: D).

O. limosa (Agard) Gomont 1892 (Figure 2d)

Straight or less straight, rounded ends, trichome and end cell rounded with slightly thickened membrane, cells 3.5-4.5 (2.5-5) µm long and 10.5-12.5 (11-22) µm wide, usually found (observed in nutrient-rich water) (Prescott 1982, Pl. 109: 17: John et al., 2002, 11: G, H).

O. princeps (Vaucher) Gomont 1892 (Figure 2e)

Mostly straight, abruptly bent at the apex, trichome and the end cell flatly rounded without adjacent granules, cells 4.5-6.5 (3.5-7) µm long and 16-24 (16-60) µm wide, seldom found (prefers moderately nutrient-rich water) (Prescott 1982, Pl. 110: 1; John et al., 2002).

Spirulina (Turpin) Gomont 1892

S. maior (Kützing) Gomont 1892 (Figure 2f)

Loosely spiralled trichome 0.9-1.4 (1-2) µm in diameter, helix 3.5 (2.5-4) µm wide, distance between regular spirals 3.5-5 (2.7-5) µm, sometimes observed (Prescott, 1982, Pl. 108; 11: John et al., 2002, 13: F-H).

Nostocales

Anabaena (Bory) Bornet 1886

A. crassa (Lemmermann) Komárková-Legnerová & Cronberg 1992 (Figure 2g)

Under the name of *Anabaena spiroides* var. *crassa* Lemmermann 1898, John and colleagues (2002) described the species as trichome single, helical consists of spherical cells 12 (6.5-15) µm wide, 11-12 (5-12) µm long, heterocyst 13-14 (13-25) µm wide, 13-14 (13-33) µm long, rarely found (John et al., 2002, 15: I, AlgaeBase, 2006).

Euglenophyta

Euglenales

Euglena Ehrenberg 1833.

E. acus Ehrenberg 1830 (Figure 3a)

Cells 7.5-11 (7-28.3) µm wide, 56-78 (52-311) µm long, needle and elongate spindle-shaped cell, anterior end narrowed and truncate, posterior end tapering to a point, chloroplasts numerous, disc-like without pyrenoids, seldom monitored (indicates moderately polluted water) (John et al., 2002, 34: A)

E. chlamydophora Mainx 1927 (Figure 3b)

Cells 10-12.5 (9-20) µm wide, 36-43 (32.2-54) µm long, spindle-shaped cell, rounded anterior end narrowed, posterior end tapering to a point, disc-shaped chloroplasts numerous without pyrenoids, and long flagellum, seldom found (indicates moderately polluted water) (John et al., 2002, 35: I-J)

E. oblonga F.Schmitz 1884 (Figure 3c)

Broadly ellipsoidal cells 32-38 (23-44) µm wide, 54-66 (48-79) µm long, both ends of cell rounded, 7-12 (8-15) chloroplast lobs with pyrenoid, and long flagellum, rarely monitored (John et al., 2002, 36: H)

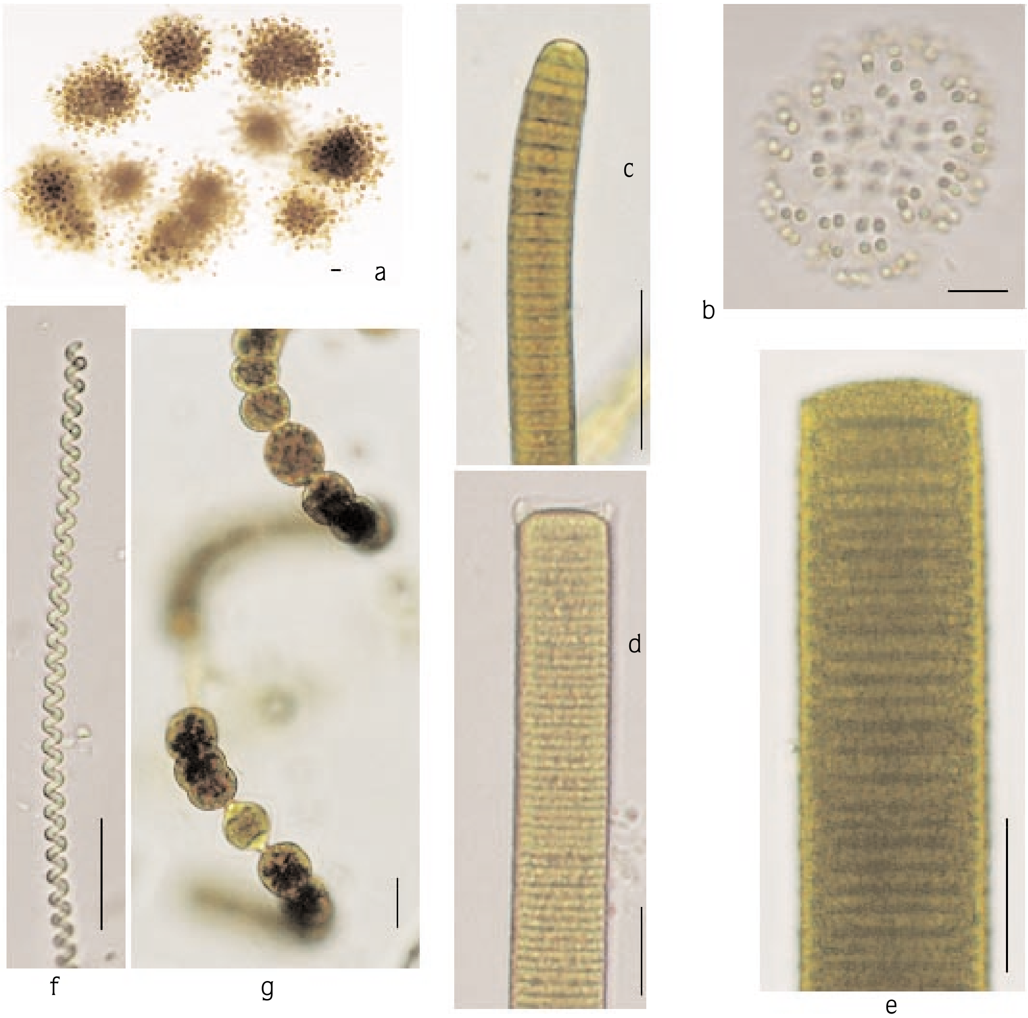

Figure 2. a) *Microcystis aeruginosa*; b) *Snowella lacustris*, c) *Oscillatoria formosa*, d) *O. limosa*, e) *O. princepsprinces*; f) *Spirulina maior*, g) *Anabaena crassa* (Scale = 10 µm).

E. viridis Ehrenberg 1830 (Figure 3d)

Spindle-shaped slightly twisted cells 13.5-15 (9-22) µm wide, 36-46 (30-89) µm long, anterior end tapering rounded, posterior end gradually tapering to a point, star-like solitary chloroplast with pyrenoids, and long flagellum (John et al., 2002, 37: A-B)

Lepocinclis Perty 1852

L. ovum (Ehrenberg) Lemmermann 1901 (Figure 3e)

Cells 21-23 (13-25) µm wide, 28-30 (20-43.3) µm long, broadly ovate cell, anterior end rounded, posterior end a short blunt tail piece 6-6.4 (6-7) µm long, flagellum, rarely observed (cosmopolitan, indicates moderately polluted water) (John et al., 2002, 38: B, C)

Phacus Dujardin 1841

P. curvicauda Svirenko 1915 (Figure 3f)

Cells 20-25 (18.7-27) µm wide, 24-28 (22.5-37.5) µm long, ovate cell, slightly narrowing anterior end rounded, posterior end tapering to a curved tail-piece, disc-shaped numerous chloroplasts, short flagellum, rarely found (cosmopolitan, found in humic water) (John et al., 2002, 39: B-C)

Trachelomonas Ehrenberg 1833

T. hispida (Perty) Stein emend. Deflandre 1926 (Figure 3g)

Ellipsoidal cells 17-18 (15-26) µm wide, 26-31 (20-42) µm long, both ends rounded, cell wall covered with short spines, apical pore without collar, chloroplast with pyrenoid, long flagellum, rarely found (John et al., 2002, 42: D).

T. volvocina Ehrenberg 1833 (Figure 3h)

Cells 15-19 (12.5-32) µm in diameter, spherical cells, smooth apical pore without a collar, flagellum 2-3 times the length of cell, usually found (widespread, indicates mildly to heavily polluted water) (John et al., 2002, 43: A).

Cryptophyta

Campylomonas Hill 1991

C. rostratiformis Hill 1991 (Figure 4a-b)

Cells 17.5-27 (16-40) µm wide, 44-56 (45-80) µm long, cells are slightly recurved, at posterior end wide rounded, anterior end rostrate, flagella unequal, 2 chloroplasts with numerous pyrenoids, nucleus near centre of cell, slightly curved furrow towards the left, usually present, especially in autumn (Wehr & Sheath, 2003, 5B, 7B).

Cryptomonas Ehrenberg 1838

C. marssonii Skuja 1948 (Figure 4c)

Cells 8-11 (8-14) µm wide, 17-24 (16-33) µm long, anterior end slightly dorsal, protuberance rounded, posterior end usually acute and dorsally bent, contractile vacuole at cell dorsal site, flagella usually unequal, chloroplast 2 at the lateral side of cell without pyrenoid, nucleus in the posterior and centre of cell, seldom monitored (John et al., 2002, 45: E).

C. ovata Ehrenberg 1838 (Figure 4d-f)

Cells 7.5-16.5 (5-20) µm wide, 15-33 (14-80) µm long, cell with moderate degree of lateral swelling, anterior end slightly acute, dorsal protuberance rounded, posterior end rounded, contractile vacuole at cell dorsal anterior, flagella generally equal to and shorter than cell, chloroplast 2 at the lateral site of cell without pyrenoids, nucleus posterior, commonly monitored (probably cosmopolitan) (John et al., 2002, 45: B).

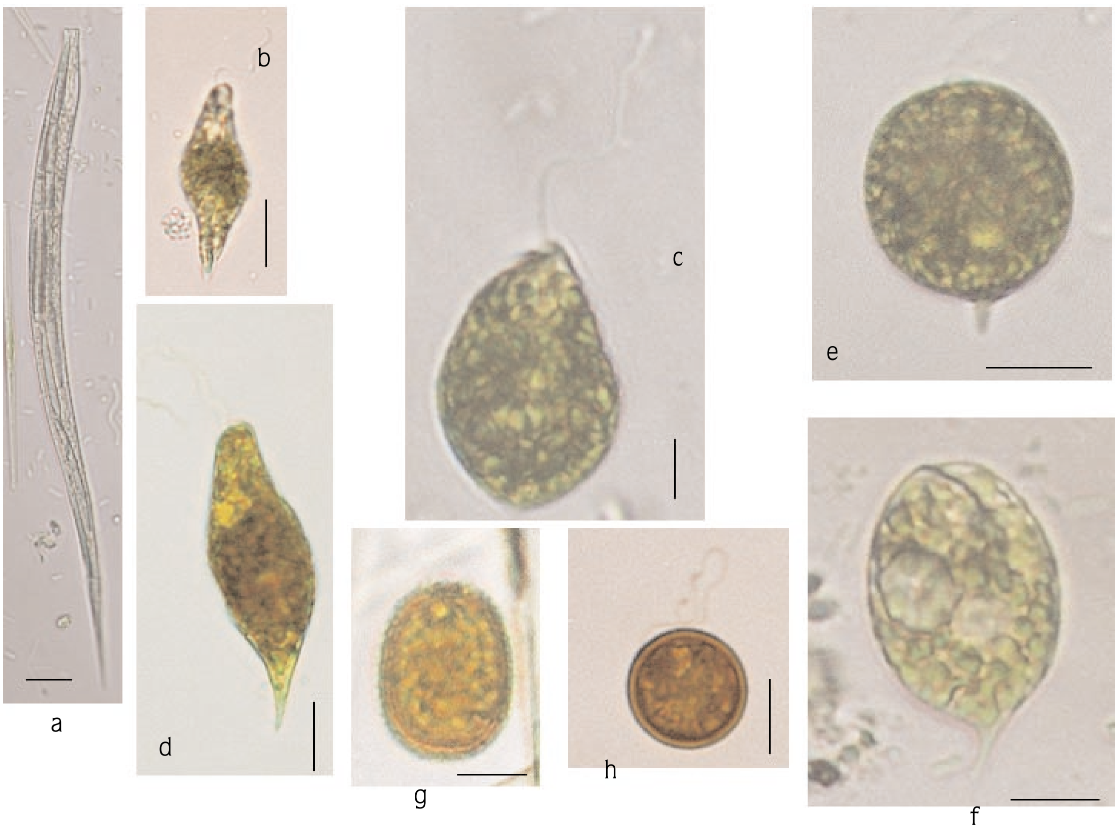

Figure 3. a) *Euglena acus*, b) *E. chlamydophora*, c) *E. oblonga*, d) *E. viridis*, e) *Lepocinclis ovum*, f) *Phacus curvicauda*, g) *Trachelomonas hispida*, h) *T. volvocina* (Scale = 10 µm).

Table 1. Non-diatom phytoplankton taxa observed in Lake Gölköy, June 2003-June 2005.

Cyanobacteria
Chroococcales
Chroococcus turgidus (Kützing) Nageli 1849
Merismopedia tenuissima Lemmermann 1898
Microcystis aeruginosa (Kützing) Kützing 1846
Snowella lacustris (Chodat) Komarek & Hindak 1988
Oscillatoriales
Oscillatoria formosa (Bory) Gomont 1892
O. limosa (C.Agard) Gomont 1892
O. minima Gicklhorn 1921
O. princeps (Vaucher) Gomont 1892
O. rubescens (de Candolle) Gomont 1892
O. sancta (Kützing) Gomont 1892
O. subbveris Schmidle 1901
O. tenuis Schmidle 1901
Phormidium sp.
Spirulina maior (Kützing) Gomont 1892
Nostocales
Anabaena crassa (Lemm) Komárková-Legnerová & Cronberg 1992
Anabaena sp.
Euglenophyta
Euglenales
Euglena acus Ehrenberg 1830
E. agilis Carter 1856
E. chlamydophora Mainx 1927
E. geniculata (Schmitz) Dujardin 1841
E. gracilis Klebs 1883
E. limnophila var. *swirenkoi* (Anoldi) Popova 1955
E. oblonga Schmitz 1884
E. viridis Ehrenberg 1830
Lepocinclis ovum (Ehrenberg) Lemmermann 1901
L. playfairiana Deflandre 1932
L. steinii Lemmermann 1901
Phacus caudatus Hübner 1886
P. curvicauda Svirenko 1915
P. haemelii Allorge & Lefevre 1930
P. pseudonordstedtii Pochmann 1941
Trachelomonas armata Stein 1878
T. dubia (Svirenko) Deflandre 1926
T. hispida (Perty) Stein emend. Deflandre 1926
T. volvocina Ehrenberg 1833
Cryptophyta
Cryptomonadales
Campylomonas reflexa Hill 1991
C. rostratiformis Hill 1991
Cryptomonas marssonii Skuja 1948
C. ovata Ehrenberg 1838
C. platyuris Skuja 1948
Plagioselmis nannoplanctica (Skuja) Novarino

Pyrrophyta
Gonyaulacales
Ceratium coralinianum (Bailey) Jorgensen 1911
C. cornutum (Ehrenberg) Claparede 1858
C. furcoides (Lavender) Langhans 1925
C. hirundinella (Müller) Dujardin 1841
Gymnodiniales
Gymnodinium cnecoides Harris 1940
Peridiniales
Peridiniopsis thompsonii (Thompson) Bourrelly 1968
Peridinium cinctum (Müller) Ehrenberg 1838
P. willei Huitfeldt-Kaas 1900
Chrysophyta
Chromulinales
Dinobryon bavaricum Imhof 1890
D. divergens O.E.Imhof 1887
D. sertularia Ehrenberg 1838
D. sociale Ehrenberg 1838
D. sociale var. *americanum* (Brunnthaler) Bachmann 1911
D. sociale var. *spitatum* (Stein) Lemmermann 1903
Uroglena volvox Ehrenberg 1834
Xanthophyta
Mischococcales
Ophiocytium capitatum Wolle 1887
Prasinophyta
Dunalliellales
Tetraselmis cordiformis (Carter) Stein 1878
Chlorophyta
Volvocales
Carteria klebsii (Dangeard) France emend. Troitzkaya 1921
Chlamydomonas globosa Snow 1902
C. leptobasis Skuja 1956
C. passiva Skuja 1956
Chlaydomonas sp.
Sphaerellopsis sp.
Eudorina elegans Ehrenberg 1831
Gonium pectorale O.F.Müller 1773
Hyaliella polytomoides Pascher 1931
Monomastix opisthostigma Scherffel 1912
Pandorina morum (Müller) Bory 1824
Pleodorina californica Shaw 1894
Polytoma cylindraceum Pasher 1927
Provasoliella ovata (Jacobsen) Loeblich 1967
Volvox aureus Ehrenberg 1832
V. globator Linnaeus 1758
V. polychlamys Korschikoff 1939
Tetrasporales
Pseudosphaerocystis lacustris (Lemmermann) Novakovas 1965

Table 1. (continued)

Chlorococcales

Ankistrodesmus falcatus (Corda) Ralfs 1848
A. fusiformis Corda ex Korshikov 1953
A. spiralis (Turner) Lemmermann 1908
Ankyra judayi (Smith) Fott 1957
A. lanceolata (Smith) Fott 1957
Botryococcus braunii Kützing 1849
Characium ensiformis Braun 1855
Elakatothrix gelatinosa Wille 1898
Geminella sp.
Golenkinia paucispina W.West & G.S.West 1902
Golenkiniopsis solitaria Korsikov 1953
Kirchneriella obesa (G.S.West) Schmidle 1893
Korshikoviella limnetica (Lemmermann) Silva 1959
K. michailovskoensis (Elenkin) P.C.Silva 1959
Micractinium crassisetum Hortobagyi 1973
Monoraphidium arcuatum (Korshikov) Hindák 1970
M. irregulare (Smith) Komarkova-Legnerova 1969
Nephrocytium agardhianum Nageli 1849
Oocystis apiculata West 1893
O. borgei Snow 1903
O. marssonii Lemmermann 1898
O. parva West & West 1898
Pediastrum boryanum (Turpin) Meneghini 1840
P. boryanum var. *cornutum* (Raciborski) Sulek 1969
P. boryanum var. *longicorne* Reinsch 1867
P. integrum Nageli1849
P. tetras (Ehrenberg) Ralfs 1844
Radiococcus planktonicus Lund 1956
Scenedesmus acutus Meyen var. *globosus* Hortobagyi 1959
S. arcuatus (Lemmermann) Lemmermann 1899
S. bicaudatus Dedusenko 1925
S. brevispina (Smith) Chodat 1926
S. communis Hegewald 1977
S. dimorphus (Turpin) Kützing 1833
S. ellipticus Corda 1835
S. falcatus Chodat 1894
S. obliquus (Turpin) Kützing 1833
S. subspicatus Chodat 1926
Schroederia robusta Korshikov 1953
Sphaerocystis planctonica (Korshikov) Bourrelly 1966
Tetrachlorella alternans (Smith) Korshikov 1939
Tetrastrum komarekii Hindak 1977

Oedogoniales

Bulbochaete sp.

Zygnematales

Closterium aciculare T.West 1860
C. gracile Brebisson ex Ralfs 1848
C. moniliferum (Bory) Ehrenberg ex Ralfs 1848
Cosmarium bioculatum Brebisson 1848
C. botrytis Meneghini 1848
C. granatum Brebisson 1848
C. impressulum Elfving 1881
C. laeve Rabenhorst 1868
C. subcrenatum Hantzsch 1861
C. venustum (Brebisson) W.Archer 1861
Gonatozygon brebissonii Barry 1858
G. monotaenium de Bray 1856
Mougeotia boodlei (West) Collins 1921
M. capucina (Bory) Agardh 1824
M. parvula Hassall 1843
M. quadrangulata Hassall 1843
M. scalaris Hassall 1842
Spirogyra communis (Hassall) Kützing 1849
S. dubia Kützing 1855
S. fluviatilis Hilse 1863
S. longata (Vaucher) Kützing 1843
S. majusculas Kützing 1849
S. mirabilis (Hassall) Kützing 1849
S. porticalis (Müller) Cleve 1868
S. pratensis Transeau 1914
S. rivularis (Hassall) Rabenhorst 1868
S. setiformis (Roth) Kützing 1845
S. subechinata Godward 1956
S. tenuissima (Hassall) Kützing 1849
S. weberi Kützing 1843
Staurastum armigerum fo. *furcigerum* (Ralfs) Teiling 1957
S. lunatum Ralfs 1848
Zygnema conspicuum (Hassall) Transeau 1934

Plagioselmis Hill 1990

P. nannoplanctica (Skuja), Novarino, Lucas & Morrall 1994 (Figure 4g)

(Rhodomonas minuta var. *nannoplanctica Skuja 1948)*

Cells 4-5 (3.5-5.5) µm wide, 7.5-11 (8-12) µm long, anterior end slightly tapering, slightly curved at posterior end, flagella unequal, chloroplast with a pyrenoid, nucleus in the posterior and centre of cell, usually found (probably cosmopolitan in plankton) (Wehr & Sheath, 2003, 15: A, B, 16: A, 17: A; AlgaeBase, 2006).

Pyrrophyta

Gonyaulacales

Ceratium Schrank 1793.

C. furcoides (Lavender) Langhans 1925 (Figure 4h)

Cells 31-41 (28-56) µm wide, 131-178 (123-222) µm long, spindle-shaped cell, epitheca narrow with a horn, broad and short hypotheca separated into 2 horns

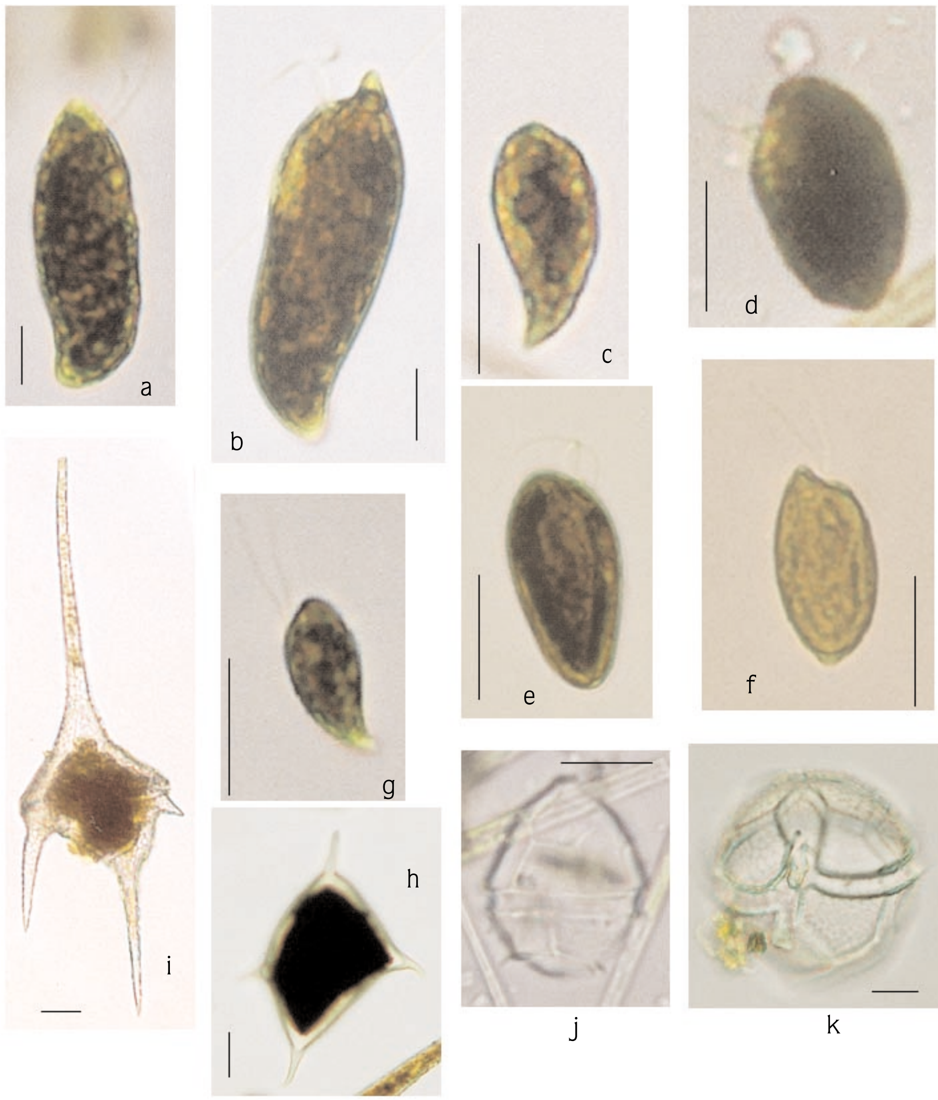

Figure 4. a, b) *Campylomonas rostratiformis;* c) *Cryptomonas marssoni;* d-f) *C. ovata;* g) *Plagioselmis nannoplanctica;* h) *Ceratium furcoides;* i) *C. hirundinella;* j) *Peridiniopsis thompsonii;* k) *Peridinium willei* (Scale = 10 µm).

(short lateral and long central), seldom observed (John et al., 2002, 49: B. C).

C. hirundinella (Müller) Dujardin 1841 (Figure 4i)

Cells 38-48 (28-55) µm wide, 91-197 (40-450) µm long, broadly spindle-shaped cell, epitheca narrow with an apical horn, hypotheca broad below the cingulum extending into 2 or 3 apical horns (lateral horns shorter than central), widespread (common, found in nutrient poor to nutrient-enriched water) (John et al., 2002, 49: E).

Peridiniales

Peridiniopsis Lemmermann 1904

P. thompsonii (Thompson) Bourrelly 1968 (Figure 4j)

Ovoid cells 18-21 (18.5) µm wide, 30-34 (31-38) µm long, epitheca with a narrowing apical and larger than rounded hypotheca with 4-6 (2-6) spines on the antapex, cell wall net-like ornamented plates, cingulum wide, chloroplast present, usually found (Popovsky & Pfiester, 1990, 209: a-d; John et al., 2002, 50: G).

Peridinium Ehrenberg 1832

P. willei Huitfeldt-Kaas 1900 (Figure 4k)

Cells 48-67 (36-80) µm wide, 45-63 (38-78) µm long, rounded cells usually wider than long, epitheca longer than hypotheca, separated by a narrow cingulum, cell wall net-like ornamented plates, apical pore absent, widespread (commonly distributed in plankton of lakes, ponds, and reservoirs) (John et al., 2002, 50: G).

Chrysophyta

Chromulinales

Dinobryon Ehrenberg 1834

D. bavaricum Imhof 1890 (Figure 5a)

Prolonged lorica 7-8.5 (6-10) µm wide, 51-59 (50-120) µm long, anterior cylindrical tapering to a point at posterior, lorica lying parallel in the erect colonies, seldom observed (Prescott, 1982, 98: 6; John et al., 2002, 58: N).

D. sertularia Ehrenberg 1838 (Figure 5b)

Prolonged lorica 10-12 (10-14) µm wide, 31-36 (30-40) µm long, oblique basal colonies, lorica lying divergence in the colonies, sometimes found (Prescott, 1982, 98: 10; John et al., 2002, 59: E).

D. sociale Ehrenberg var. *americanum* (Brunnthaler) Bachmann 1911 (Figure 5c)

Lorica 8-8.5 (8-10) µm wide, 35-44 (30-70) µm long, relatively shorter and wider lorica lying erect in the colonies, posterior tapering to a sharp point, sometimes found (Huber-Pestalozzi, 1941, 300; Prescott, 1982; John et al., 2002, 59: F).

D. sociale Ehrenberg var. *stipitatum* (Stein) Lemmermann 1903 (Figure 5d).

Lorica 8-9 (8-10) µm wide, 31-45 (30-70) µm long, relatively shorter and wider lorica lying about erect in the colonies, posterior tapering to a sharp point, lorica conical shaped, rarely found (Huber-Pestalozzi, 1941, 299; John et al., 2002, 59: G).

Uroglena Ehrenberg 1834

U. volvox Ehrenberg 1834 (Figure 4e)

Cells tapering towards base, cells 9-11 (8-13) µm wide, 12.5-15 (12-20) µm long, colonies 294-324 (up to 400) µm, spherical cysts smooth, a double collar surrounds pore, chloroplast single, rarely observed (John et al., 2002, 55: B).

Prasinophyta

Prasinophyceae

Tetraselmis F.Stein 1878

T. cordiformis (Carter) F.Stein 1878 (Figure 5f)

Heart or cherry-shaped cells 15-16.5 (16-23) µm wide, 15-18 (14-20) µm long, cup-shaped chloroplast basally thickened with a basal large pyrenoid and 2 pairs of equal flagella from anterior part, sometimes found (probably cosmopolitan, found in nutrient-enriched water bodies) (Ettl, 1983, 118: John et al., 2002, 75: D)

Chlorophyta

Eudorina Ehrenberg 1830

E. elegans Ehrenberg 1831 (Figure 6a)

Ellipsoidal or spherical coenobium 62.5-75 (60-200) µm diameter, consists of 16-33 (4-64) cells: spherical cells 12.5-15.5 (12-24) µm diameter, cup-shaped chloroplast with pyrenoids, commonly found, especially spring and autumn (cosmopolitan, found in nutrient-enriched waters) (Ettl, 1983, 1108; John et al., 2002, 81: G).

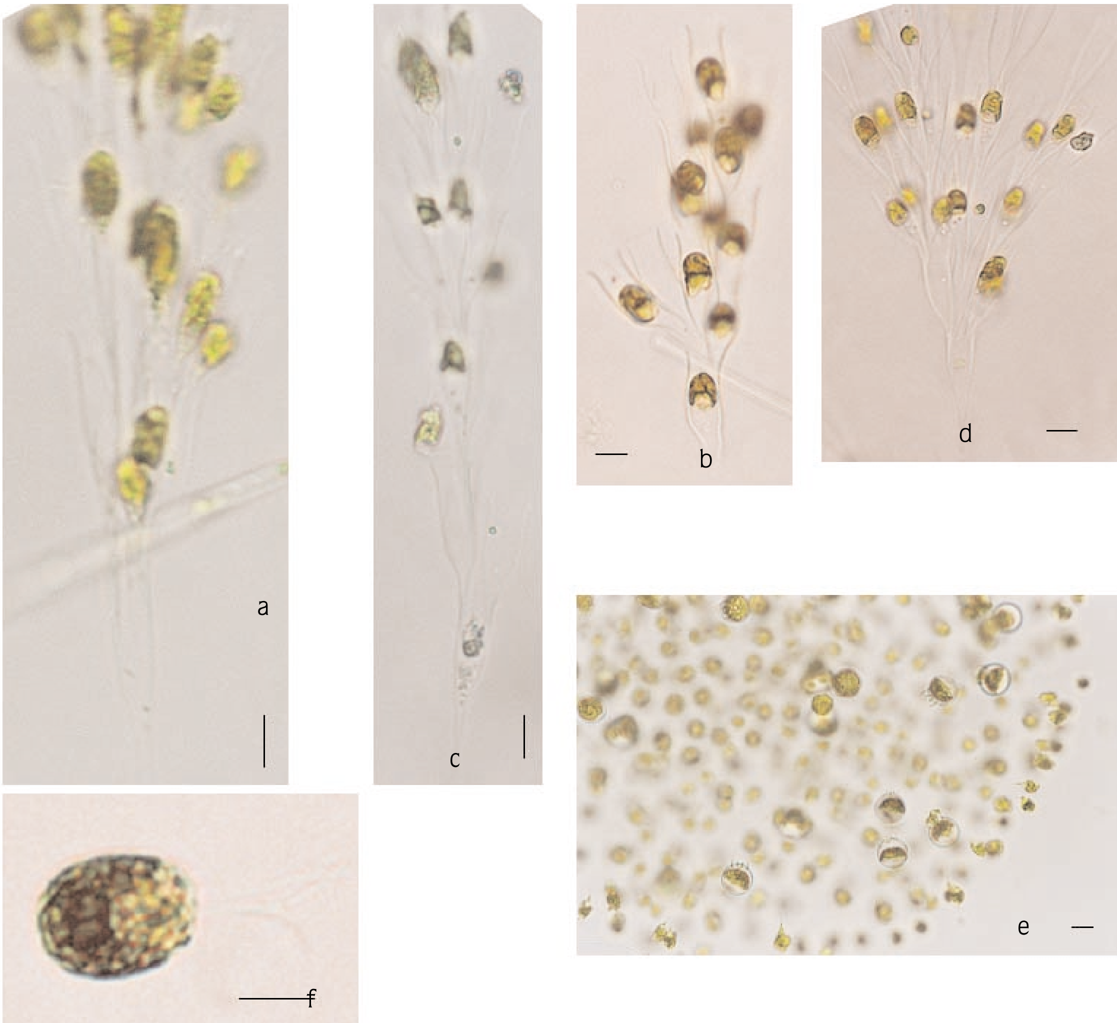

Figure 5. a) *Dinobryon bavaricum;* b) *D. sertularia;* c) *D. sociale* var. *americanum;* d) *D. sociale* var. *stipitatum;* e) *Uroglena volvox;* f) *Tetraselmis cordiformis* (Scale = 10 µm).

Gonium Müller 1773

G. pectorale Müller 1773 (Figure 6b)

Coenobia 62.5-75 (70-100) µm wide, consists of 16 (16) cells, 12 (12) cells arranged peripherally, others at the centre of the coenobium, pear-shaped cells 12.5-14 (up to 18) µm wide, 15-15.5 (15-20) µm long, chloroplast cup-shaped, rarely observed (monitored in nutrient-enriched lakes, ponds, and ditches) (Prescott, 1982, 1: 21; John et al., 2002, 81; G).

Polytoma Ehrenberg 1838

P. cylindraceum Pascher 1927

Ovoid cylindrical cells 17-19 (16-30) µm long, 7.5-9 (5-13) µm wide, papilla present, peripheral chloroplast basally thickened with basal ellipso-discoid pyrenoid and 2 equal flagella (Ettl, 1983, 260).

Provasoliella Loeblich 1967

P. ovata (Jacobsen) Loeblich 1967

Ovate, egg-shaped cells 16-21 (15-25) µm long, 8-12 (8-15) µm wide, papilla present, rounded apical site, narrowing rounded posterior, numerous chloroplasts, and 2 pairs of flagella (Ettl, 1983, 912).

Volvox (Linne) Ehrenberg 1830

V. globator Linnaeus 1758 (Figure 6c-e)

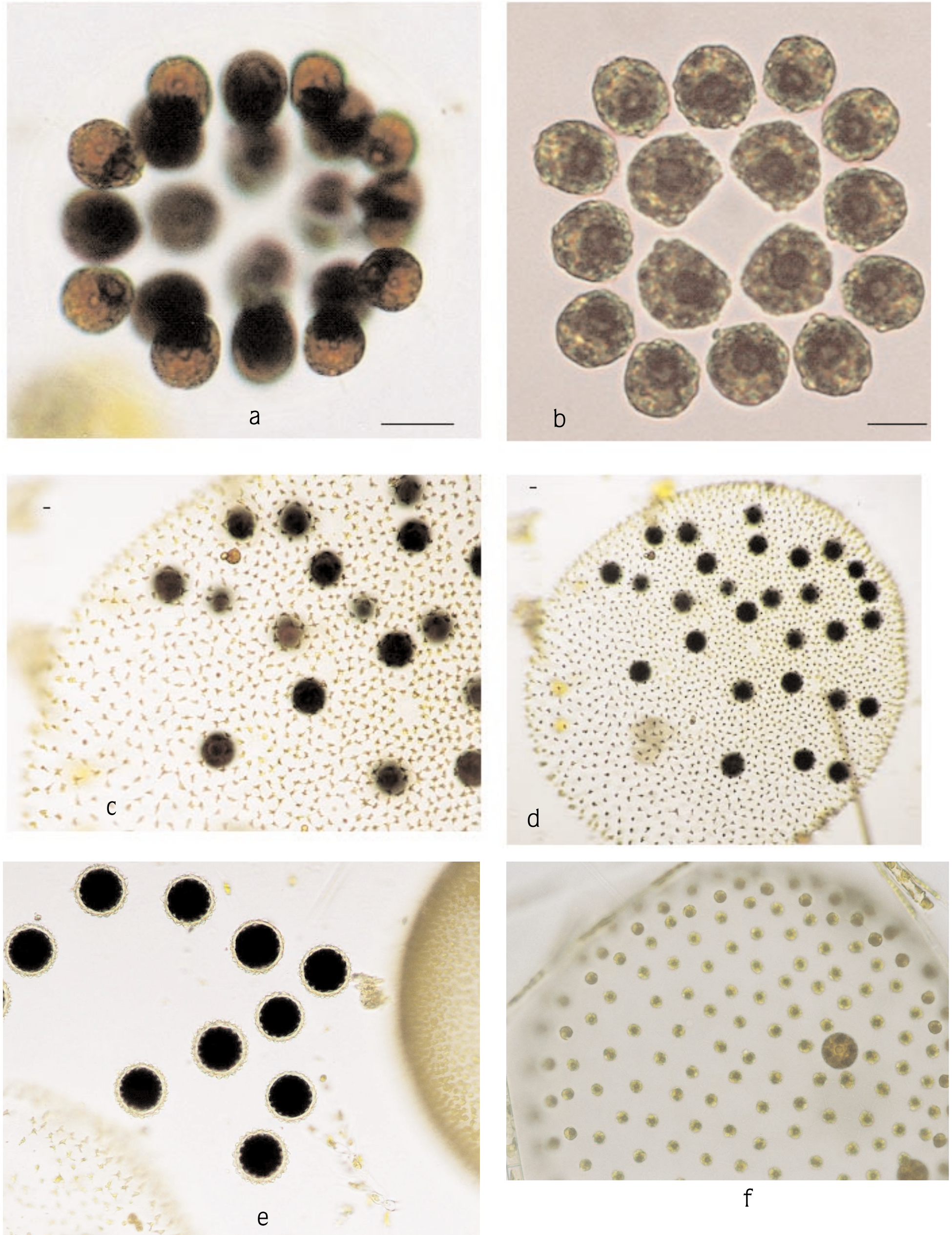

Figure 6. a) *Eudorina elegans*; b) *Gonium pectorale;* c-e) *Volvox globator*; f) *V. polychlamys* (Scale = 10 µm).

Spherical coenobium 521-548 (500-1000) µm diameter, consists of numerous spherical and pear-shaped cells 3.75-5 (3-8) µm diameter, each cell interconnected via rounded mucilage zone and cells in the polygonal network, parietal chloroplast with pyrenoid, zygote with rough cell wall, 43-47 (40-60) µm in diameter, seldom found (Bourrelly, 1972, 8: 3; Ettl, 1983, 1117; John et al., 2002, 81: I).

V. polychlamys Korschikoff 1939 (Figure 6f)

Ellipso-discoid coenobia 187-224 (150-500) µm diameter, consists of numerous spherical and pear-shaped cells 7-7.5 (7-9) µm diameter, parietal chloroplast with pyrenoid, zygote with rough cell wall, 57-62 (60-65) µm diameter, rarely found (Ettl, 1983, 1120).

Chlorococcales

Oocystis Braun 1855

O. marssonii Lemmermann 1898 (Figure 7a)

Cells solitary or 2-4 (2, 4 or 8) celled coenobia, broadly spindle-shaped with narrowed apices, cells with polar wall thickening, 5-8.5 (4-14.4) µm wide, 7.5-13 (6.4-20.8) µm long, grooved chloroplast 2-4 (2-8) with pyrenoid in each groove (John et al., 2002, 92: F).

Pediastrum Meyen 1829

P. boryanum (Turpin) Meneghini 1840 (Figure 7b-d)

Coenobia 29-88 (16-208) µm diameter, consists of 16-64 polygonal cells, marginal cells 7-9.5 x 9-11.5 (5-40 x 5-31) µm diameter, inner cells 6-8.5 x 6-8.5 (5-26 x 4-27) µm diameter, intercellular spaces absent, chloroplast with a pyrenoid in each cell, sometimes found (usually observed in meso-eutrophic water) (Huber Pestalozzi, 1983, 87: 1; John et al., 2002: 93: C).

P. integrum Nageli 1849 (Figure 7e)

Coenobia consists of 8-32 (4, 8, 16, 32, or 128) cells, 41-84 (up to 125) µm long extension lying cells, 7.5-12.5 (up to 38) µm wide, cells irregularly arranged, chloroplast with a pyrenoid in each cell, rarely found (Huber Pestalozzi, 1983).

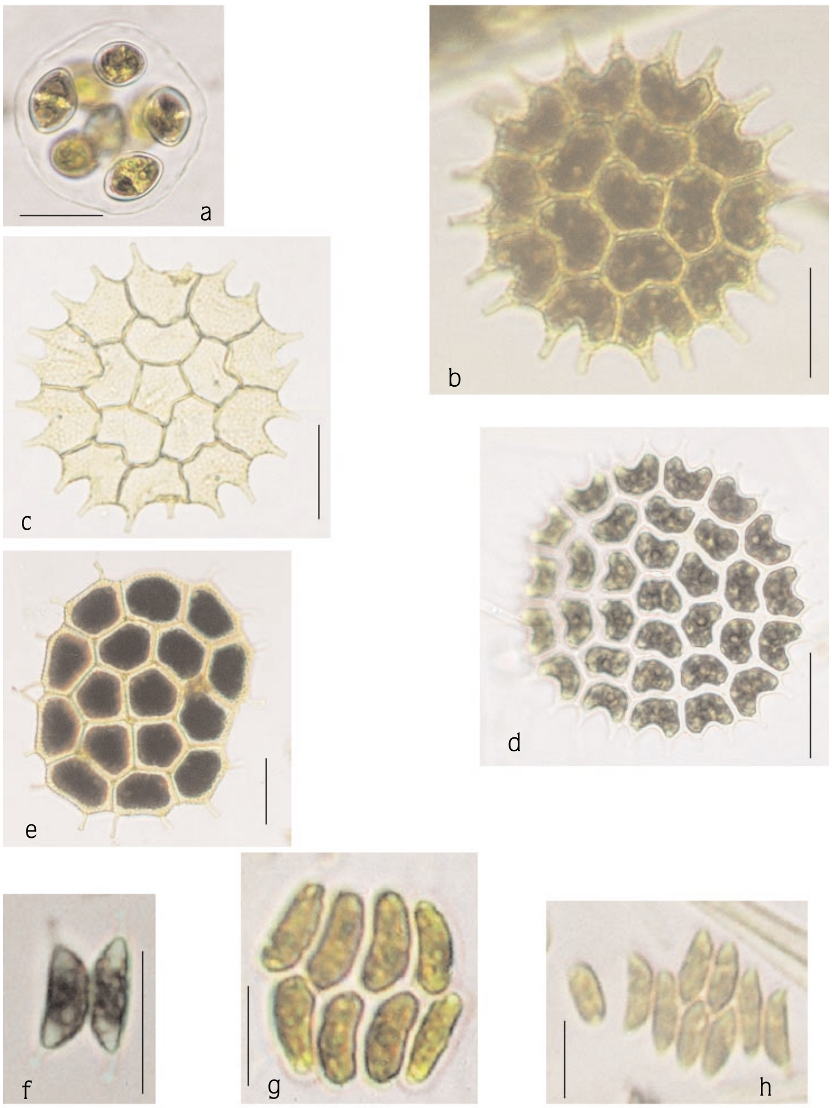

Figure 7. a) *Oocystis marssonii;* b-d) *Pediastrum boryanum; e*) *P. integrum;* f) *Scenedesmus acutus* var. *globosus*; g) *S. arcuatus*; h) *S. obliquus* (Scale = 10 µm).

Scenedesmus Meyen 1829

S. acutus Meyen 1829 var. *globosus* Hortobagyi 1959 (Figure 7f)

Cells 2 (2, 4, or 8) linearly arranged in coenobium, acute apices, spindle-shaped cells, 5-7.5 (2-14) µm wide, 10-12.5 (5-27) µm long, cell, and rarely found (cosmopolite) (Komárek & Fott, 1983, 228: 2).

S. arcuatus (Lemmermann) Lemmermann 1899 (Figure 7g)

Coenobia consist of 8 (4, 8, or 16) cells in 2 rows, broadly rounded, slightly curved cells, 4.5 µm (2-9.5 µm) wide, 10.5 µm (7-18 µm) long, rarely found (John et al., 2002, 97: C).

S. obliquus (Turpin) Kützing 1833 (Figure 7h)

Cells 4 and 8 (2, 4 or 8) linearly or alternately arranged in coenobia, acute apices, spindle-shaped cells, 4.5-7.5 (2.2-11) µm wide, 10-16 (4-25) µm long (John et al., 2002, 96: O).

Zygnematales

Cosmarium Corda 1848

C. botrytis Meneghini 1848 (Figure 8a)

Cells 58-63.5 (51-85) µm wide, 75-89 (60-111) µm long, deep sinus, narrow towards outside, oval pyramidal semicells, cell wall with 32-34 (30-36) small rounded granules, round semicell margin (Bourrelly, 1972, 97: 6, 7; John et al., 2002, 135: P).

C. subcrenatum Hantzsch 1861 (Figure 8b)

Cells 20-27 (18-34) µm wide, 28-32 (21-38) µm long, narrow sinus, lateral margin with 4-5 (4-6) crenations, apex with 4-6 (4-5) undulations, and upper crenations larger than lower part of cell, rarely found (John et al., 2002, 135: A).

Gonatozygon Barry 1858

G. monotaenium de Bray 1856 (Figure 8c)

Cylindrical cells 8-10 (8-12.5) µm wide, (90-300) µm long, truncate apices, ribbon-like chloroplast with 8-16 (6-16) series pyrenoids (John et al., 2002, 128: M).

Mougeotia Agardh 1824

M. boodlei (West) Collins 1921 (Figure 9a)

Cells 5 (4-6) µm wide, 78-135 (25-225) µm long. Chloroplast filled half or more of cell length with a series of 4-6 (4-6) pyrenoids in the cell. Species sometimes found in the lake (John et al., 2002, 121: I).

M. quadrangulata Hassall 1843 (Figure 9b)

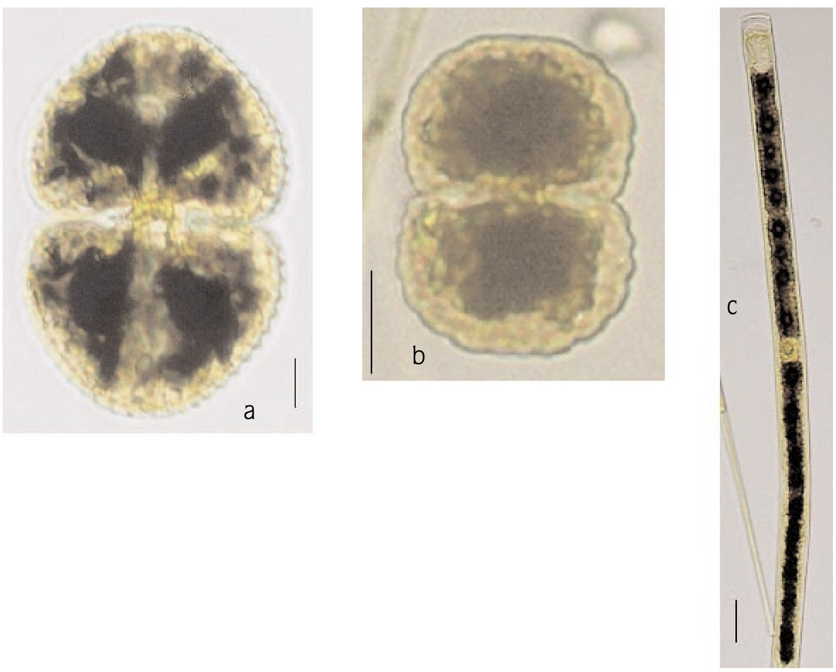

Figure 8. a) *Cosmarium botrytis*; b) *C. subcrenatum*; c) *Gonatozygon monotaenium* (Scale = 10 µm).

Cells 7-10 (7-13) µm wide, 57-102 (50-180) µm long, chloroplast with a median series of 8-14 (8-16) pyrenoids, rarely found (John et al., 2002, 121: F).

M. scalaris Hassall 1842 (Figure 9c)

Cells 22.5-27 (20-35) µm wide, 53-89 (40-180) µm long, chloroplast with a median series of 4-10 (4-10) pyrenoids, sometimes observed (John et al., 2002, 119: C).

Spirogyra Link 1820

S. longata (Vaucher) Kützing 1843 (Figure 9d, e)

Cells 25.2-30 (26-38) µm wide, 57-84 (45-280) µm long with plane end cell wall. Single chloroplast making 2-4 (2-5) turns in the cell, conjugation tubes occurred from both gametangia, ovoid smooth zygospores 30-34 (28-38) µm wide, 53-61 (50-85) µm long. Species occasionally found in lake (probably cosmopolitan) (John et al., 2002, 122: D).

S. setiformis (Roth) Kützing 1845 (Figure 9f)

Cells 91-112 (90-115) µm wide, 116-164 (100-225) µm long with plane end wall. Four (4) chloroplasts making 1-3.5 (0.5-4) turns in the cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospores 87-96 (85-100) µm wide, 118-132 (115-160) µm long. Species seldom found in the lake (John et al., 2002, 125: C).

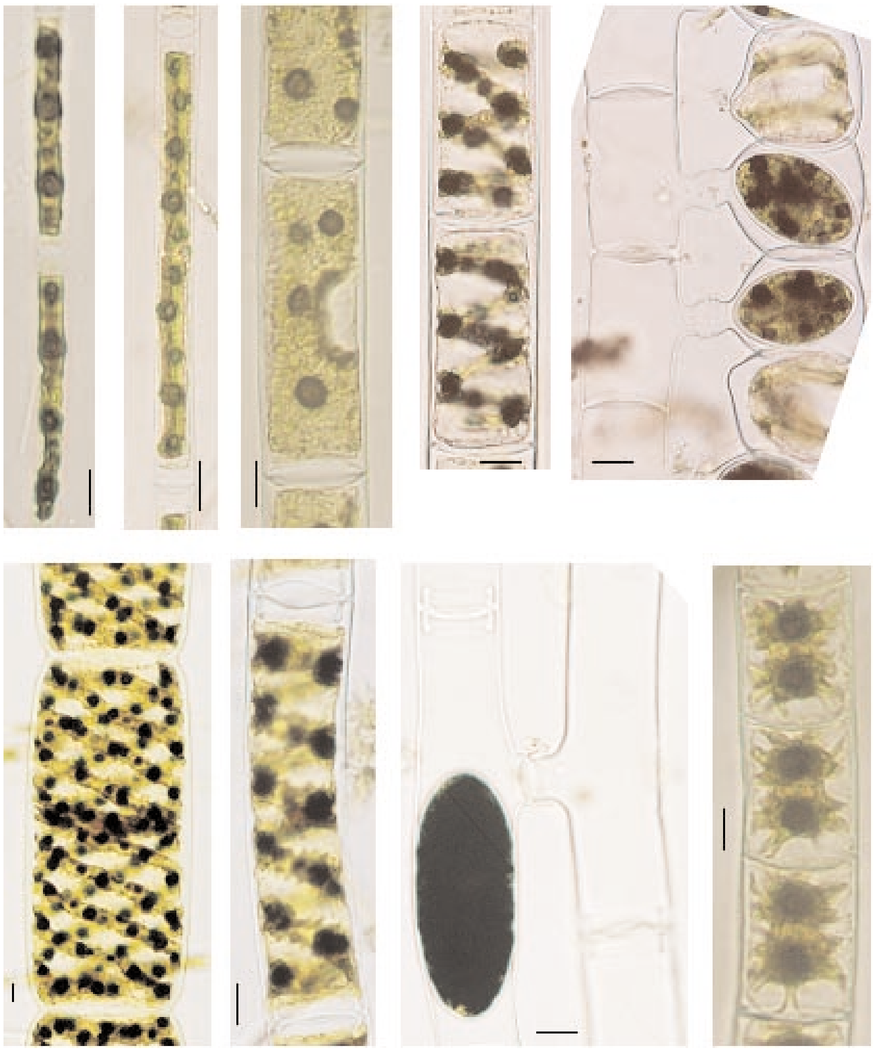

Figure 9. a) *Mougeotia boodlei;* b) *M. quadrangulata;* c) *M. scalaris;* d, e) *Spirogyra longata;* f) *S. setiformis*; g, h) *S. weberi;* i) *Zygnema conspicuum* (Scale = 10 µm).

S. weberi Kützing 1843 (Figure 9g, h)

Cells 21-27 (19-30) µm wide, 96-169 (80-480) µm long with replicate end cell walls. Single chloroplast making 3-5.5 (3-6.5) turns in the cell, conjugation tubes occurred from both gametangia, ovoid smooth zygospores 26-29 (25-36) µm wide, 34-46(32-67) µm long. Species seldom found in the lake (probably cosmopolitan) (John et al., 2002, 122: E).

Zygnema Agardh 1824

Z. conspicuum (Hassall) Transeau 1934 (Figure 9i)

Cells 22.5-27 (22-27) µm wide, 56-69 (50-90) µm long, star-shaped chloroplast with central pyrenoid, occasionally found (John et al., 2002, 127: I).

Discussion

Phytoplankton were characterized with the tremendous species diversity of 152 taxa in Lake Gölköy during 2 years from June 2003 to June 2005. Chlorophyta was the dominant phytoplankton group showing the greatest species richness with 95 species and 42 genera. Green algae contained a great number of morphologically diverse organisms. The numbers of green phytoplankton increased to 29 species, particularly in autumn of 2003-2004 and late summer 2004; however, there were more members of Chlorophyta in 2004 than in 2003. The highest species richness was recorded with 29 taxa in September 2004. Some species (e.g., *Spirogyra mirabilis, Pandorina morum,* and *Eudorina elegans*) were commonly found during the study. *Spirogyra mirabilis* was generally recorded in the summer and early autumn, while *P. morum* and *E. elegans* showed frequent occurrence almost the entire seasons of spring and autumn. Both taxa have wide range of tolerance and are very common in different aquatic habitats in Turkey (Gönülol et al., 1996). It is known that *E. elegans* was found in more eutrophic lakes (Hutchinson, 1967) and prefers nutrient-rich waters; it was usually observed in spring or autumn.

The second dominant group was Euglenophyta with 4 genera and 19 species. Species numbers of euglenophytes were high in autumn 2003 and reached a maximum in July 2004 with 12 taxa. *Trachelomonas volvocina* was the most common taxon found throughout the sampling period in all sites. Hutchinson (1967) points out that *T. volvocina* is widespread in the open water of lakes. This taxon was recorded in different aquatic ecosystems in Turkey (Gönülol et al., 1996). *Euglena* was the most abundant genus with 8 species of this phylum. It is known that this genus prefers organically rich water (Wetzel, 1975; John et al., 2002; Zimba et al., 2004).

Cyanoprokaryota was represented with 8 genera and 16 species. Species richness was high in August 2003, and the number of blue-greens usually increased in late summer and early autumn. *Oscillatoria* was the most common genus with 8 species, and *O. formosa* and *O. limosa* were frequently found during the study. John et al. (2002) stated that both species prefer slightly brackish, nutrient-rich waters.

Pyrrophyta, Chrysophyta, and Cryptophyta were represented by 8, 7, and 6 taxa, respectively. Pyrrophyta was mostly found in spring, early summer, and autumn in 2004. *Ceratium hirundinella*, *Peridinium willei*, and *Dinobryon divergens* were the widespread taxa during the study. Species richness of Chrysophyta increased particularly in April-May 2004, and April 2005. *D. divergens* is widely distributed in moderate to high nutrient-rich waters (John et al., 2002). Cryptophyta were not recorded in September and November 2003; however, *Cryptomonas ovata* and *Plagioselmis nannoplanctica* were the most abundant species in 2004 and 2005.

Most Lake Gölköy phytoplankton species are cosmopolitan and have a wide range of tolerance, although they prefer nutrient-rich waters (Gönülol et al., 1996). In the present study, species composition, which mostly preferred nutrient-rich waters, increased in the second year compared to the first year (2003) in Lake Gölköy. Although it is difficult to understand the trophic status of the lake using only species composition results, other studies concerning the ostracod fauna (Külköylüoğlu, 2005) and diatom flora (Çelekli, 2006) in Lake Gölköy supported the results of this study. Külköylüoğlu (2005) showed that this lake was mesotrophic, which could be a problem for lake quality when considering it as a potential drinking water resource for the city of Bolu in the future.

The highest number of species was recorded in summer, while the lowest species richness was found in winter. Spring and autumn had similar numbers of species during the study.

Compared with other similar aquatic bodies, Lake Gölköy has high algal diversity (total of 271 taxa) with 152 non-diatom and 119 diatom taxa (Çelekli, 2006). Similar results were also found in Lake Abant, where Çelekli et al. (2007) recorded a relatively large number (162 non-diatoms) of phytoplankton species. On the other hand, the benthic and planktonic algal composition of Lake Abant was studied by Obalı et al. (2002) and they reported 83 taxa, of which only 49 belonged to non-diatom phytoplankton. Moreover, Atıcı & Obalı (2002) stated that 43 and 29 non-diatom algae were identified in Lake Abant and Lake Yedigöller, respectively. Two other recent phycological studies (Kılınç, 2003; Saygı-Başbuğ & Demirkalp, 2004) were carried out between October 1997 and August 1999 in Lake Yeniçağa, where 59 and 18 non-diatom phytoplankton taxa were recorded, respectively. In a study in a similar habitat outside the Bolu region, Albay & Akçaalan (2003) identified 78 phytoplankton taxa from Ömerli reservoir (İstanbul), of which 60 were non-diatom taxa. Although several factors can affect species diversity, differences among the numbers of species reported from these other studies and the present study could be explained as follows: first, fluctuations in water depth can influence both vertical and horizontal distribution of species; second, trophic status can affect phytoplankton diversity; third, sampling time and seasonal differences. All 3 factors can be applied to Lake Gölköy.

Although variations exist, the contributions of all these previous studies are very important for the algal flora of Turkey. For example, some species (e.g., *Gonium pectorale, Provasoliella ovata,* and *Anabaena crassa*) found in Lake Gölköy are new records for the Bolu region (Gönülol et al., 1996; Kılınç, 2003, Çelekli et al., 2007). Additionally, this indicates that phytoplankton composition is important for evaluating the ecological condition of Lake Gölköy. As a result, these results can also be used to understand the importance of long-term monthly (or even weekly) sampling. Such reports increase the need for taxonomic studies that demonstrate how phytoplankton play an important role in the species richness of an environment.

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