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ABUZER ÇELEKLİ

OLCAY OBALI

OKAN KÜLKÖYLÜOĞLU

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Research Article

The Phytoplankton Community (except Bacillariophyceae) of Lake Abant (Bolu, Turkey)

Abuzer ÇELEKLİ[1*], Olcay OBALI[2] & Okan KÜLKÖYLÜOĞLU[1]

[1]Abant İzzet Baysal University, Faculty of Arts and Science, Department of Biology, Gölköy 14280 Bolu - TURKEY

[2]Ankara University, Faculty of Science, Department of Biology, Beşevler, Ankara - TURKEY

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Abstract: A total of 162 phytoplankton species found monthly from 3 littoral and 2 vertical stations between June 2003 and June 2005 were identified from Lake Abant (Bolu, Turkey). Some species, such as *Trachelomonas volvocina* Ehrenberg, *Cryptomonas ovata* Ehrenberg, and *Ceratium hirundinella* (Müller) Dujardin showed frequent occurrence almost every month, but others had specific seasonality. Phytoplankton composition of this lake was dominated by Chlorophyta, accounting for about 58.6% of the species richness. Phytoplankton composition in Lake Abant included many new reported (> 30) taxa for the algal flora of Turkey.

Key Words: Phytoplankton, taxonomy, Lake Abant, Bolu

Abant Gölü (Bolu-Türkiye) Fitoplankton Komünitesi (Bacillariophyceae hariç)

Özet: Haziran 2003 ve Haziran 2005 yılları arasında üç kıyısal ve iki vertikal istasyondan olmak üzere aylık olarak toplam 162 fitoplankton türü Abant Gölü'nden (Bolu, Türkiye) tespit edilmiştir. *Trachelomonas volvocina* Ehrenberg, *Cryptomonas ovata* Ehrenberg, ve *Ceratium hirundinella* (Müller) Dujardin gibi bazı türler bütün istasyonlarda hemen her ay sıklıkla görülürken, diğerleri özel mevsimsellik göstermiştir. Chlorophyta yaklaşık % 58,6 tür zenginliği ile bu gölün fitoplankton komposizyonunda baskın olmuştur. Abant Gölü'nde fitoplankton komposizyonu Türkiye algal florası için çok sayıda yeni taxa içermiştir.

Anahtar Sözcükler: Fitoplankton, taksonomi, Abant Gölü, Bolu

Introduction

Phytoplankton are found in a variety of aquatic habitats all over the world and are affected by different environmental factors, such as pH, light, and temperature (Graham & Wilcox, 2000; Buzzi, 2002; Wehr & Sheath, 2003; Pongswat et al., 2004). They are the basis of most aquatic food webs and are important in biogeochemical cycling (Wetzel, 1975).

Although studies of the biodiversity of phytoplankton have been conducted in some parts of Turkey for several decades (Altuner, 1988; Akbay et al., 1999; Aysel et al., 2002; Kılınç, 2003; Maraşlıoğlu et al., 2005), a few earlier works focused on some particular sites in Bolu. For example, Obalı et al. (2002) in Lake Abant, Atıcı & Obalı (2002) in Lake Yedigöller, Kılınç (2003) in Lake Yeniçağ, Atıcı et al. (2005) in Lake Abant, and Çelekli & Külköylüoğlu (2007) in Akkaya Spring. All these studies increased our understanding of algae species diversity in the Bolu region, but little attention has been given to phytoplankton species. Yet, the area is known for its potentially high species diversity. Thus, the aim of the present study was to investigate net-phytoplankton composition and their seasonal occurrence in Lake Abant in order to contribute to the knowledge of the algal flora of Turkey.

Materials and Methods

Lake Abant (lat 40°36'N, long 31°16'E, ca. 1340 m a.s.l.) (Figure 1), a natural lake with about 125 ha of surface area, is located about 30 km south-west of Bolu

*E-mail: celekli_a@ibu.edu.tr

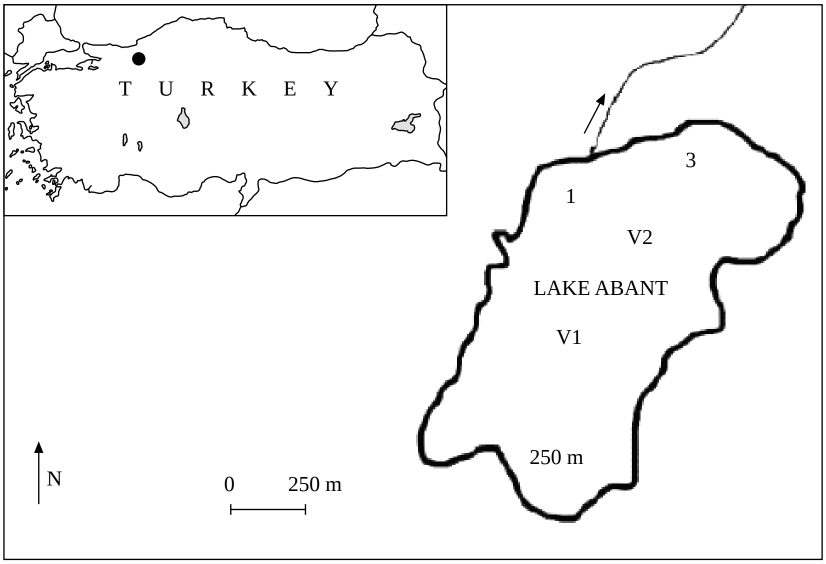

Figure 1. Five sampling stations (2 pelagic (V1, V2) and 3 littoral (1-3)) are shown in Lake Abant. ● Shows the study area.

(Turkey) (Akşıray, 1959; Erinç et al., 1961). The lake is known for its natural beauty and is surrounded by a rich flora and fauna in the Lake Abant Nature Park. The lake is an important geographical feature in the park and has a long geological history; therefore, it is thought that the lake has unique species richness, which will provide an important contribution to the algal flora of Turkey.

Phytoplankton sampling was carried out using a plankton net (45 µm mesh size, 20 cm diameter). Samples were collected monthly from 3 littoral and 2 vertical (0.3, 4, 7, and 10 m for each vertical) stations from June 2003 to June 2005. Vertical samplings from different depths were collected from a Zodiac boat in open water with a 2.5-l Van Dorn bottle (Wetzel & Likens, 1991). Water samples in Van Dorn Bottle for each station were concentrated using a plankton net. Lake water collected for composite plankton samples from pre-selected stations was preserved with acetic lugol-glycerol solution in polyethylene bottles. Concentrated samples were brought to the laboratory and examined for species identification 3 times under an Olympus BX 51 light microscope at 400X and 800X magnifications. The shapes of some phytoplankton organisms were photographed with a BX 51 Olympus microscope camera.

Identification of phytoplankton from net samples was based on the taxonomic keys of Geitler (1930-1932), Bourrelly (1972), Prescott (1982), Ettl (1983), Komarek & Fott (1983), Popovsky & Pfiester (1990), Komarek & Anagnostidis (1998), John et al. (2002), and Wehr & Sheath (2003). 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 identification of taxa. Measurements and other ecological information from taxonomic books and studies are given in parentheses.

Results

Phytoplankton assemblages: During the study period, we identified 162 taxa in 69 different genera, 39 of which include a dominant group, Chlorophyta (Table 1). Among the species, some taxa (e.g., *Trachelomonas volvocina, Cryptomonas ovata,* and *Ceratium hirundinella*) were observed at almost all sampling times, while others had specific seasonality. Photographs of some species are shown in Figures 2-8. Newly reported taxa from Lake Abant in the list of net-phytoplankton for Turkey are labelled with a star, whereas 2 stars indicate a second taxa report in Lake Abant, which was first reported in Lake Gölköy (Çelekli et al., 2007) (Table 1).

Table 1. Phytoplankton (except Bacillariophyceae) taxa observed in Lake Abant from June 2003 to June 2005. A total of 162 taxa were identified, and only photographed species were described in the results section. * indicates a new report for phytoplankton species, and ** indicates a second report for phytoplankton species in Lake Abant for the algal flora of Turkey.

Cyanoprokaryota
Chroococcales
Aphanocapsa litoralis Hansgirg 1892
Aphanothece clathrata W.West & G.S.West 1906
Chroococcus turgidus (Kützing) Nageli 1849
Coelosphaerium kuetzingianum Nägeli 1849
Merismopedia tenuissima Lemmermann 1898
Microcystis aeruginosa (Kützing) Kützing 1846
Snowella lacustris (Chodat) Komárek & Hindák 1988
Oscillatoriales
Oscillatoria formosa (Bory) Gomont 1892
O. limosa (C.Agardh) Gomont 1892
O. princeps (Vaucher) Gomont 1892
O. sancta (Kützing) Gomont 1892
O. tenuis C.Agardh ex Gomont 1892
Phormidium sp.
Pseudoanabaena sp.
Spirulina maior (Kützing) Gomont 1892
S. subsalsa (Oersted) Gomont 1892
Nostocales
Anabaena bergii Ostenfeld 1908
***A. crassa* (Lemmarmann) Komerkova-Lagnerova & Cranberg 1896
A. planctonica Brunnthaler 1903
A. smithii (Komárek) M.Watanabe
Anabaena sp.
Cryptophyta
Cryptomonadales
***Campylomonas reflexa* (M.Marsson) D.R.A.Hill 1991
***C. rostratiformis* Hill 1991
***Cryptomonas marssonii* Skuja 1948
C. ovata Ehrenberg 1838
***C. platyuris* Skuja 1948
Plagioselmis nannoplanctica (H.Skuja) G.Novarino, I.A.N.Lucas & S.Morrel
Pyrrophyta
Gonyaulacales
***Ceratium coralinianum* (Bailey) Jorgensen 1911
***C. cornutum* (Ehrenberg) Claparede & J.Lahman 1858
***C. furcoides* (Lavender) Langhans 1925
C. hirundinella (O.F.Müller) Dujardin 1841
Gymnodiniales
***Gymnodinium cnecoides* T.M.Harris 1940
Peridiniales
***Peridiniopsis thompsonii* (Thompson) Bourrelly 1968
Peridinium cinctum (O.F.Müller) Ehrenberg 1838
P. willei Huitfeldt-Kaas 1900
Chrysophyta
Chromulinales
***Dinobryon bavaricum* O.E.Imhof 1890
**Calothrix stagnalis* Gomont 1895
**Cylindrospermum minutissimum* Collins 1896
Euglenophyta
Euglenales
Euglena acus Ehrenberg 1830
***E. agilis* H.J.Carter 1856
**E. contabrica* E.G.Pringsheim 1955
**E. deses* Ehrenberg fo. *klebsii* (Lemmermann) T.G.Popova 1966
**E. granulata* (G.A.Klebs) F.Schmitz 1884
**E. obtusa* F.Schmitz 1884
E. proxima P.A.Dangeard 1901
E. sanguinea Ehrenberg 1830
Lepocinclis fusiformis (H.J.Carter) Lemmermann 1901
L. ovum (Ehrenberg) Lemmermann 1901
***L. playfairiana* Deflandre 1932
**L. steinii* Lemmermann 1901
Phacus caudatus K.Hübner 1886
***P. pseudonordstedtii* Pochmann 1941
**P. striatus* (Drezepolski) France 1893
**Trachelomonas acanthostoma* A.Stokes 1887
**T. armata* (Ehrenberg) F.Stein 1878
**T. granulosa* Playfair 1915
**T. planctonica* Svirenko 1914
T. pulchella Drezepolski 1925
T. volvocina Ehrenberg 1833
***D. sociale* Ehrenberg 1838
***D. sociale* var. *americanum* (Brunnthaler) Bachmann 1911
**Uroglena volvox* Ehrenberg 1834
Synurales
**Synura petersenii* Korshikov 1929
Xanthophyta
Mischococcales
***Ophiocytium capitatum* Wolle 1887
Prasinophyta
Chlorodendrales
***Tetraselmis cordiformis* (H.J.Carter) Stein 1878
Chlorophyta
Volvocales
Chlamydomonas globosa J.Snow 1902
***C. leptobasis* H.L.Skuja 1956
***C. passiva* Skuja 1956
Eudorina elegans Ehrenberg 1831
Pandorina morum (O.F.Müller) Bory 1824
***Polytoma cylindraceum* Pascher 1927
**Sphaerellopsis spiralis* J.H.Belcher & Swale 1963
Tetrasporales
Pseudosphaerocystis lacustris (Lemmermann) Novakova 1965
Chlorococcales

Table 1. (continued)

D. divergens O.E.Imhof 1887
D. sertularia Ehrenberg 1838
***Ankistrodesmus spiralis* (W.B.Turner) Lemmermann 1908
Botryococcus braunii Kützing 1849
**Characium ornithocephalum* A.Braun 1855
**Chonrosphaera lapponica* Skuja 1964
Crucigeniella rectangularis (Nageli) Komarek 1974
Elakatothrix gelatinosa Wille 1898
**Eremosphaera viridis* de Bary 1858
Geminella sp.
Golenkinia paucispina W.West & G.S.West 1902
Kirchneriella obesa (West) Schmidle 1893
Korshikoviella limnetica (Lemmermann) Silva 1959
K. michailovskoensis (Elenkin) Silva 1959
***Monoraphidium arcuatum* (Korshikov) Hindak 1970
Nephrocytium agardhianum Nageli 1849
**N. limneticum* (G.M.Smith) G.M.Smith 1933
Oocystis apiculata West 1893
O. borgei J.Snow 1903
***O. marssonii* Lemmermann 1898
O. parva W.West & G.S.West 1898
O. pusilla Hansgirg 1890
**O. tainoensis* Kommarek 1983
Oocyctis sp.
Pediastrum boryanum (Turpin) Meneghini 1840
***P. boryanum* var. *cornutum* (Raciborski) Sulek 1969
***P. boryanum* var. *longicorne* Reinsch 1867
C. incurvum Brebisson 1856
C. littorale F.Gay 1884
C. moniliferum (Bory) Ehrenberg ex Ralfs 1848
C. parvulum Nageli 1849
C. venus Kützing ex Ralfs 1848
Desmidiaceae
Cosmarium bioculatum Brebisson ex Ralfs 1848
C. botrytis Meneghini ex Ralfs 1848
**C. contractum* Kirchner var. *ellipsoideum* (Elfving) W.West & G.S.West 1902
*C. crenatum Ralfs ex Ralfs 1848
C. depressum var. *planctonicum* Reverdin 1919
C. granatum Brebisson 1848
C. meneghinii Rabenhorst 1868
**C. pygmaeum* Archer 1864
***C. venustum* (Brebisson) W.Archer 1861
***Staurastum armigerum* Brebisson fo. *furcigerum* (Ralfs) Teiling 1957
S. gracile Ralfs 1848
***S. lunatum* Ralfs 1848
Peniaceae
***Gonatozygon brebissonii* de Barry 1858
***G. monotaenium* de Bray in Rabenhorst 1856
Ankistrodesmus falcatus (Corda) Ralfs 1848
***A. fusiformis* Corda ex Korshikov 1953
P. dublex Meyen 1829
P. integrum Nageli 1849
P. tetras (Ehrenberg) Ralfs 1844
**Quadricoccus verrucosus* Fott 1948
***Radiococcus planktonicus* J.W.G.Lund 1956
Scenedesmus arcuatus (Lemmermann) Lemmermann 1899
S. bicaudatus Dedusenko 1925
S. communis E.H.Hegewald 1977
S. dimorphus (Turpin) Kützing 1833
S. ellipticus Corda 1835
S. obliquus (Turpin) Kützing 1833
S. subspicatus Chodat 1926
***Schroederia robusta* Korshikov 1953
Sorastrum americanum (Bohlin) Schmidle 1900
***Sphaerocystis planctonica* (Korshikov) Bourrelly 1966
***Tetrachlorella alternans* (G.M.Smith) Korshikov 1939
Tetrastrum komarekii Hindak 1977
**Thorakochloris nygardii* Komarek 1979
**Trochiscia hystrix* (Reinsch) Playfair
Oedogoniales
Bulbochaete sp.
Zygnematales
Closteriaceae
Closterium aciculare West 1860
**C. calosporum* Wittrock 1869
Zygnemataceae
***Mougeotia boodlei* (West) Collins 1921
M. capucina (Bory) Agardh 1824
M. nummuloides (Hassall) De Toni 1889
M. parvula Hassall 1843
M. quadrangulata Hassall 1843
M. scalaris Hassall 1842
Spirogyra communis (Hassall) Kützing 1849
***S. fluviatilis* Hilse 1863
**S. jugalis* (Dillwyn) Kützing 1845
S. longata (Vaucher) Kützing 1843
S. majusculas Kützing 1849
***S. mirabilis* (Hassall) Kützing 1849
***S. pratensis* Transeau 1914
S. rivularis (Hassall) Rabenhorst 1868
***S. setiformis* (Roth) Kützing 1845
**S. submargaritata* Godward 1956
S. tenuissima (Hassall) Kützing 1849
S. weberi Kützing 1843
** *Zygnema conspicuum* (Hassall) in Transeau et al. 1934

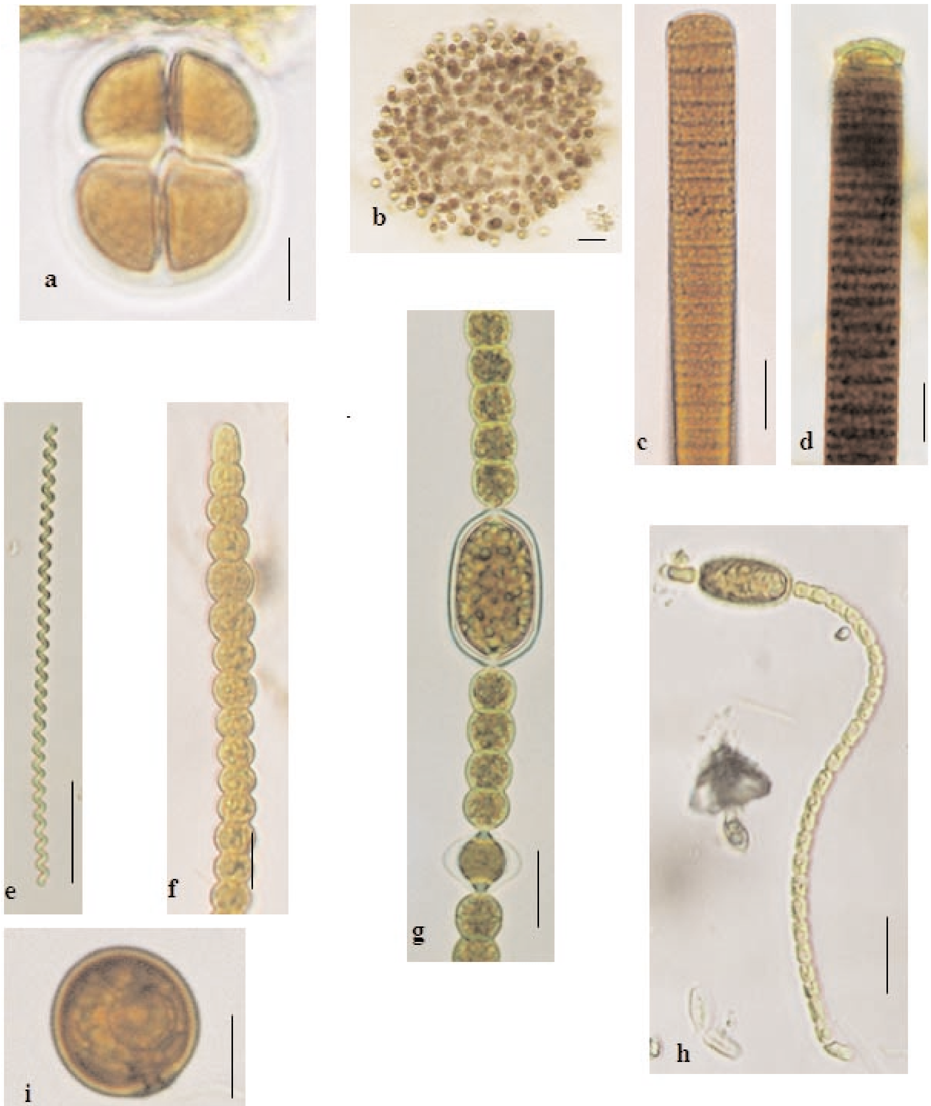

Figure 2. a) *Chroococcus turgidus*, b) *Microcystis aeruginosa*, c) *Oscillatoria limosa*, d) *O. sancta*, e) *Spirulina maior*, f) *Anabaena bergii*, g) *A. planctonica*, h) *Cylindrospermum minutissimum*, i) *Trachelomonas volvocina* (scale 10 µm).

Description of some phytoplankton taxa

Cyanoprokaryota

Chroococcales

Chroococcus Nägeli 1849

C. turgidus (Kützing) Nageli 1849 (Figure 2a).

Colony consisted of 2-8 (2-32) cells enclosed by a sheath, spherical and hemispherical cells 29-34 (6-45) µm in diameter. It was tychoplankter, seldom found (common in many lakes and bogs) (Prescot, 1982, 100: 19; Komarek & Anagnostidis, 1998, 407; John et al., 2002, 3: A, B; Wehr & Sheath, 2003, 14: g, h).

Microcystis Kützing 1833 ex Lemmermann 1907 nom. cons.

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

Ovate, spherical, or irregularly lobed colonies include numerous spherical cells surrounded by mucilage matrix, spherical granular cells 3.5-5.5 (4-9) µm in diameter, seldom observed during autumn and mid summer (fresh to moderately brackish water, blooms in mid to late summer) (Prescott, 1982, 102: 1-4; Komarek & Anagnostidis, 1998, 304; John et al., 2002, 3: K-L).

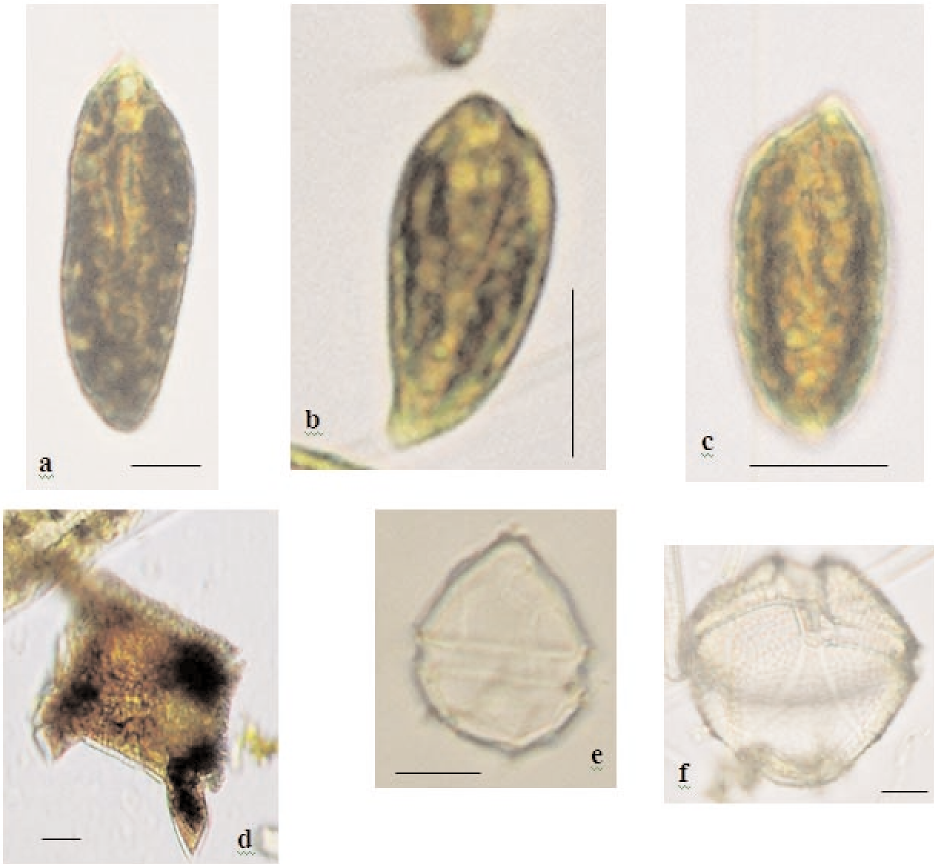

Figure 3. a) *Campylomonas rostratiformis,* b) *Cryptomonas marsoni*, c) *C. ovata,* d) *Ceratium cornutum,* e) *Peridiniopsis thompsonii,* f) *Peridinium willei* (scale 10 µm).

Oscillatoriales

Oscillatoria (Vaucher) Gomont 1892

O. limosa (C.Agardh) Gomont 1892 (Figure 2c).

Straight or less straight, round ended trichome, unbranched, and end cell rounded with slightly thickened membrane, cells 3.5-4 (2.5-5) µm in length and 10.5-12.5 (11-22) µm in width, trichome without sheath, mostly found in autumn and summer (slightly brackish nutrient-rich water plankton or attached, tychoplankton) (Prescott, 1982, 109, 17; John et al., 2002, 11: G, H; Wehr & Sheath, 2003, 16: a).

O. sancta (Kützing) Gomont 1892 (Figure 2d).

Straight, abruptly bent at the ends, weakly rounded filament, and end cell weakly rounded with adjacent granules. Cells 2.7-3.75 (2.5-6) µm in length and 12.5-15 (10-20) µm in width (Prescott 1982, 110, 4; John et al., 2002, 11: L; Wehr & Sheath, 2003, 16 e).

Spirulina (Turpin) Gomont 1892

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

Loosely spiralled trichome without sheath 0.85-1.2 (1-2) µm in diameter, helix 3.75 (2.5-4) µm wide, distance between regular spirals 4-5 (2.7-5) µm, heterocyst and akinete absent, generally observed in summer and autumn (Prescott, 1982, 108; 11; John et al., 2002, 13: F-H).

Nostocales

Anabaena (Bory) Bornet & Flahault 1886

A. bergii Ostenfeld 1908 (Figure 2f).

Straight, often aggregated trichomes and barrel-shaped cells 6.5-8 (up to 8) µm wide, ovoid heterocyst 10-10.5 (10) µm (Geitler, 1930-1932, 5: 3-4)

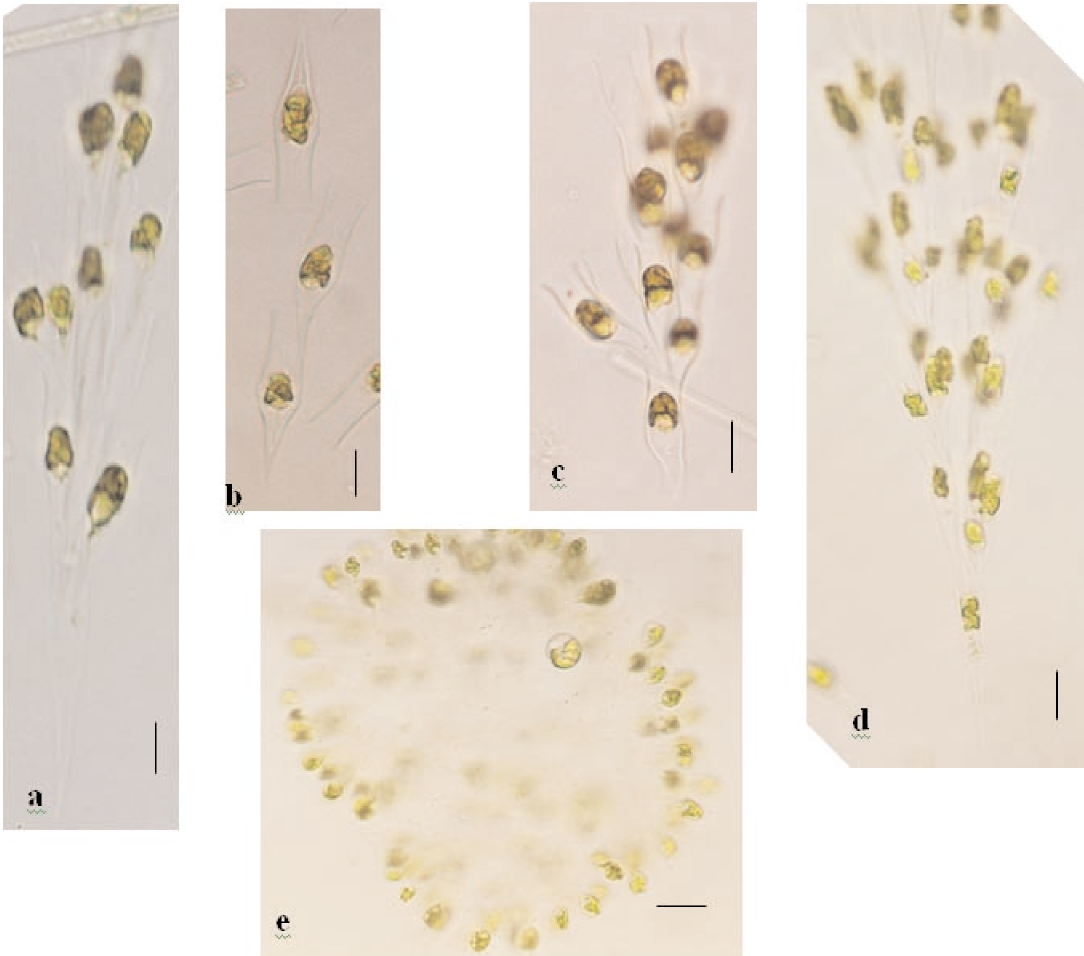

Figure 4. a) *Dinobryon bavaricum*, b) *D. divergens*, c) *D. sertularia*, d) *D. sociale* var. *americanum*, e) *Uroglena volvox* (scale 10 µm).

A. planctonica Brunnthaler 1903 (Figure 2g).

Straight trichomes and ellipsoidal cells 9-12 (9-15) µm wide, 7-8 (6-12) µm long, spherical heterocyst 14-15 (10-14) µm wide, 12-13 (10-14) µm long, and subspherical akinete distant from the heterocyst was 12-14 (10-20) µm wide and 15-18 (15-30) µm long. Observed in summer as plankter (free floating in freshwater) (Geitler, 1930-1932, 562; John et al., 2002, 15: C).

Cylindrospermum (Kützing 1843) Bornet & Flahault 1886

C. minutissimum Collins 1896 (Figure 2h).

Cells 3.5-4 (3-4.7) µm wide, 4-4.5 (4-5) µm long, terminal heterocyst 4.2 (4-5) µm wide, 5-6 (5-7) µm long, rounded at ends single ovoid akinetes 10-10.5 (9-12) µm wide, 15-17.5 (10-20) µm long, rarely found (tychoplankter) (Geitler, 1930-1932, 523: b; Prescott, 1982, 131, 13; John et al., 2002, 17: D-E).

Euglenophyta

Euglenales

Trachelomonas Ehrenberg 1833

T. volvocina Ehrenberg 1833 (Figure 2i).

Cells 15-18 (12.5-32) µm in diameter, spherical cells, smooth apical pore without a collar, flagellum 2-3 times diameter of cell, commonly found, especially late summer and autumn (generally distributed in ponds and ditches) (Prescott, 1982, 83: 1, 7, 8; John et al., 2002, 43: A).

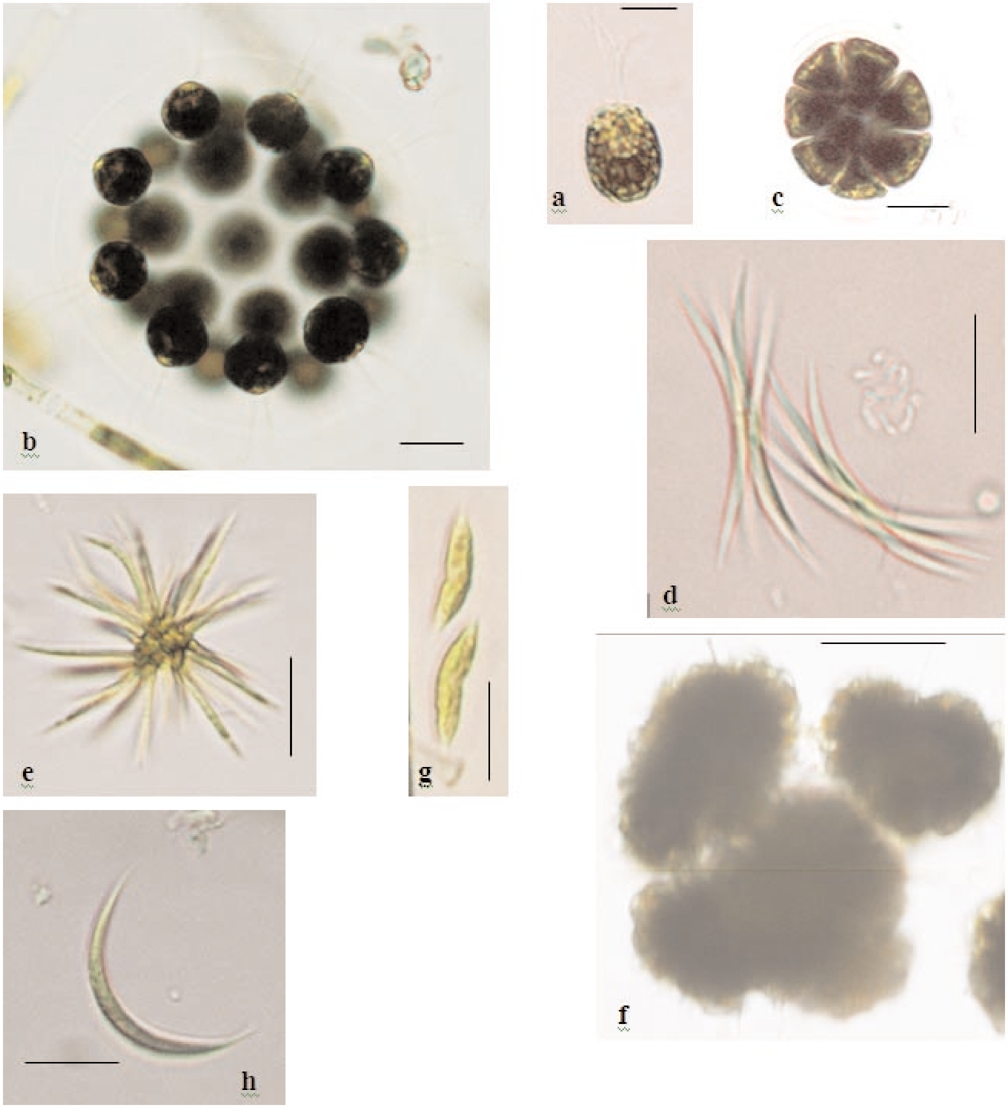

Figure 5. a) *Tetraselmis cordiformis*, b) *Eudorina elegans*, c) *Pandorina morum*, d) *Ankistrodesmus falcatus*, e) *A. spiralis*, f) *Botryococcus braunii*, g) *Elakototrix gelatinosa*, h) *Monoraphidium arcuatum* (scale 10 µm).

Cryptophyta

Cryptomonadales

Campylomonas Hill 1991

C. rostratiformis Hill 1991 (Figure 3a).

Cells 17.5-28 (16-40) µm wide, 46-52 (45-80) µm long, cells are slightly curved at wide rounded posterior end, anterior end rostrate, flagella unequal, 2 chloroplasts with numerous pyrenoids, nucleus near centre of cell, slightly curved furrow towards the left, and found usually in spring (Wehr & Sheath, 2003, 5:B, 7:B).

Cryptomonas Ehrenberg 1838

C. marssonii Skuja 1948 (Figure 3b).

Cells 8-10 (8-14) µm wide, 17-21 (16-33) µm long, anterior end slightly dorsal, protuberance rounded, posterior end usually acute and dorsally bent, contractile vacuole at cell dorsal side, flagella usually unequal, 2 chloroplasts at the lateral side of cell without pyrenoids, nucleus in the posterior and centre of cell, sometimes observed in Lake Abant (found as plankter in lakes and ponds, and not commonly distributed) (John et al., 2002, 45: E).

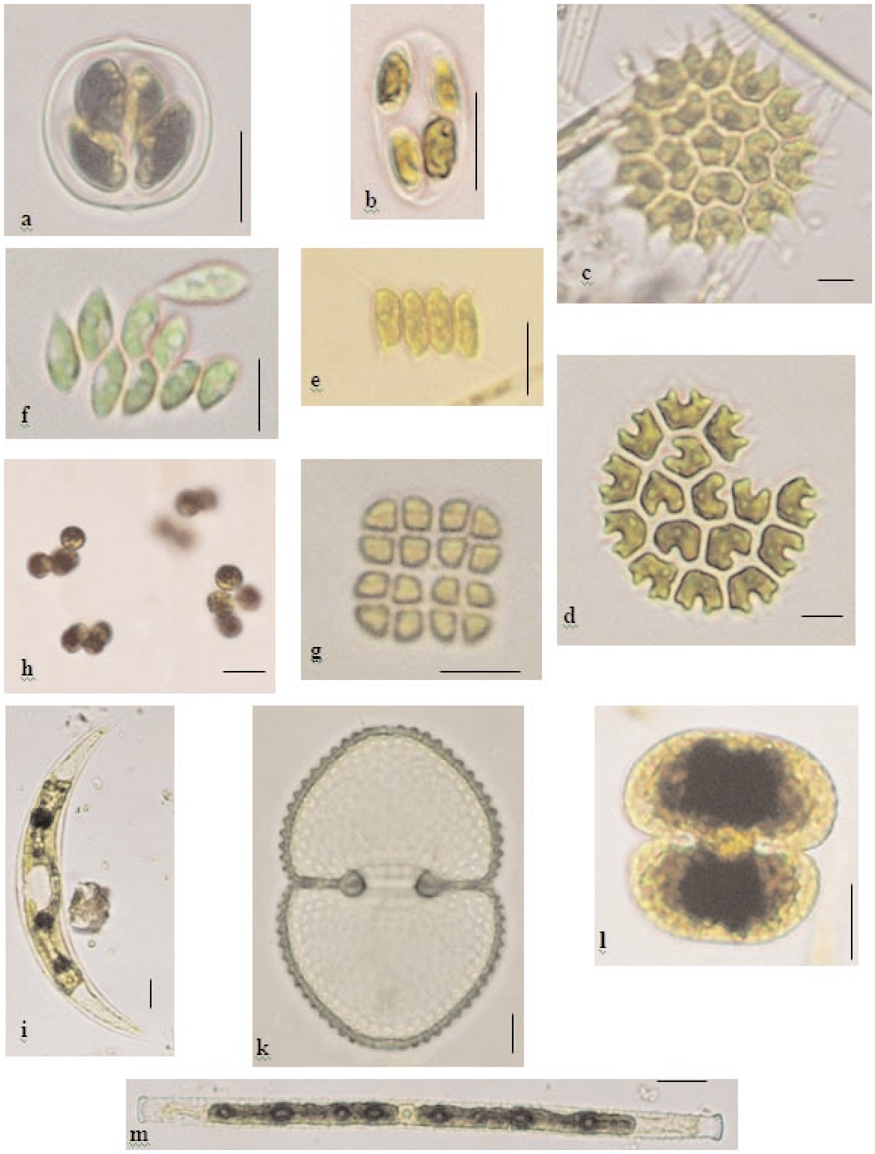

Figure 6. a) *Oocystis parva*, b) *O. tainoensis*, c) *Pediastrum boryanum*, d) *P. tetras*, e) *Scenedesmus communis*, f) *S. obliquus*, g) *Tetrastrum komarekii*, h) *Pseudosphaerocystis lacustris*, i) *Closterium parvulum*, k) *Cosmarium botrytis*, l) *C. contractum var. ellipsoideum*, m) *Gonatozygon brebissoni* (scale 10 µm).

C. ovata Ehrenberg 1838 (Figure 3c).

Cells 7.5-16 (5-20) µm wide, 15-30 (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 or shorter than cell, 2 chloroplasts without pyrenoid, nucleus posterior, commonly distributed and found all seasons; however, especially during the second year of this study (euplankter in lakes and ponds, probably cosmopolitan) (Prescott, 1982, 95: 40; John et al., 2002, 45: B).

Pyrrophyta

Gonyaulacales

Ceratium Schrank 1793

C. cornutum (Ehrenberg) Claparede & J.Lachmann 1858 (Figure 3d).

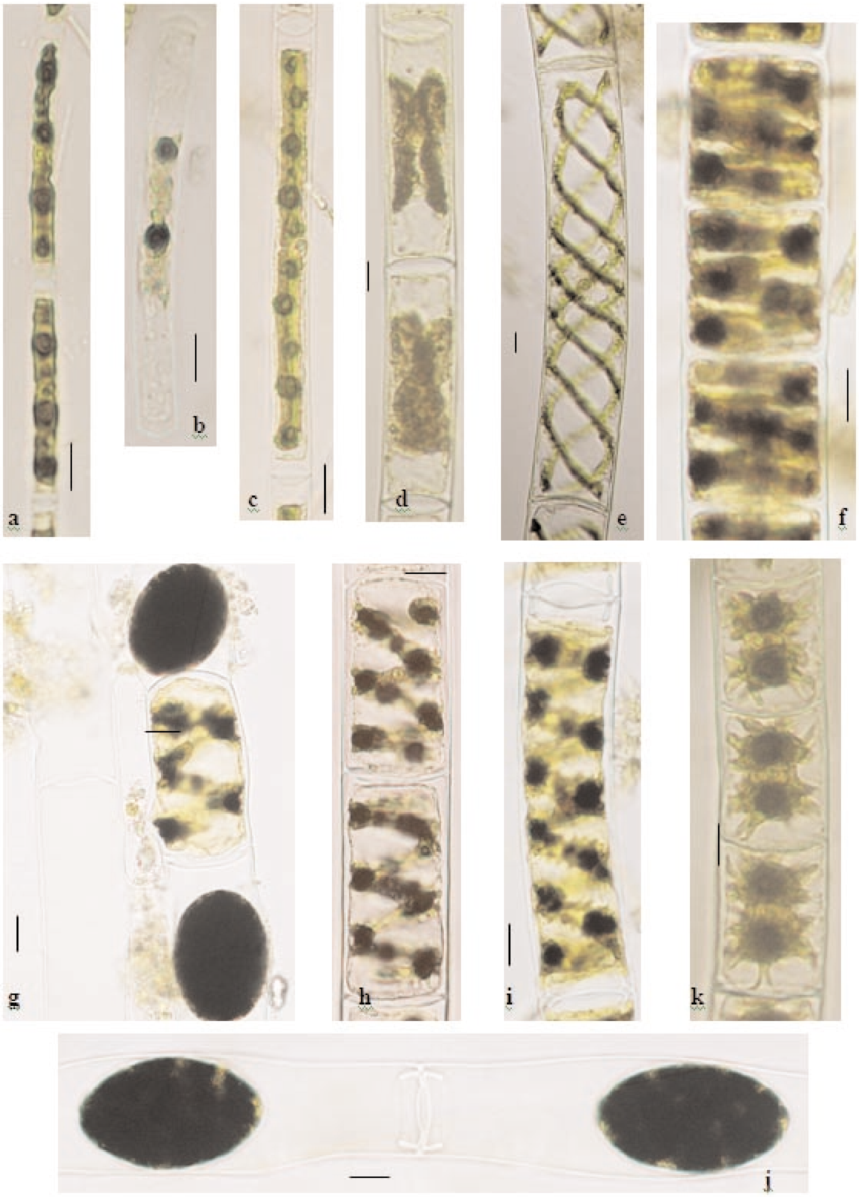

Figure 7. a) *Mougeotia boodlei*, b) *M. nummuloides*, c) *M. quadrangulata*, d) *M. scalaris*, e) *Spirogyra fluviatilis*, f-h) *S. longata*, i-j) *S. weberi*, k) *Zygnema conspicuum* (scale 10 µm).

Cells 50-65 (48-75) µm wide, 102-128 (97-150) µm long, spindle-shaped cell, narrowing epitheca wide above cingulum, apical horn slightly curved, hypotheca broad below the cingulum extending into 2 horns (lateral horn shorter than central), and only found in the summer and autumn of the second year (rare, plankton in soft water lakes) (John et al., 2002, 49: A).

Peridiniales

Peridiniopsis Lemmermann 1904

P. thompsonii (Thompson) Bourrelly 1968 (Figure 3e).

Ovoid cells 18-20 (18.5) µm wide, 31-33 (31-38) µm long, epitheca with a narrowing apical larger than rounded hypotheca with 4-6 (2-6) spines on the antapex, cell wall net-like ornamented plates, cingulum wide, chloroplast present (Popovsky & Pfiester, 1990, 209: a-d; John et al., 2002, 50: G).

Peridinium Ehrenberg 1832

P. willei Huitfeldt-Kaas 1900 (Figure 3f).

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 (John et al., 2002, 50: G).

Chrysophyta

Chromulinales

Dinobryon Ehrenberg 1834

D. bavaricum O.E.Imhof 1890 (Figure 4a).

Prolonged lorica 7-8 (6-10) µm wide, 51-58 (50-120) µm long, anterior cylindrical tapering to a point at posterior, lorica lying parallel in the erect colonies, found late summer and autumn of 2003, rarely observed in 2004 (common, euplankton in lakes) (Prescott, 1982, 98: 6; John et al., 2002, 58: N).

D. divergens O.E.Imhof 1887 (Figure 4b).

Fusiform lorica 7.5 (7-8) µm wide, 37-43 (35-50) µm long, anterior cylindrical and slightly tapering, posterior tapering to a sharply point, lorica lying divergent in the colonies, and commonly monitored comparing *D. bavaricum*, (euplankter, common in lakes) (Prescott, 1982, 98: 7).

D. sertularia Ehrenberg 1838 (Figure 4c).

Prolonged lorica 10-12 (10-14) µm wide, 32-37 (30-40) µm long, oblique basal colonies, lorica lying divergent in the colonies, and commonly observed, distributed with *D. sociale* var. *americanum* (common, plankton in hard water lakes, frequently founded with *D. sociale*) (Prescott, 1982, 98: 10; John et al., 2002, 59: E).

D. sociale Ehrenberg var. *americanum* (Brunnthaler) Bachmann 1911 (Figure 4d).

Lorica 8-8.5 (8-10) µm wide, 35-46 (30-70) µm long, relatively shorter and wider lorica lying erect in the colonies, posterior tapering to a sharp point, generally distributed (euplankter) (Prescott, 1982; John et al., 2002, 59: F)

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, and seldom monitored only spring months (probably cosmopolitan) (John et al., 2002, 55: B).

Prasinophyta

Chlorodendrales

Tetraselmis F.Stein 1878.

T. cordiformis (H.J.Carter) F.Stein 1878 (Figure 5a).

Heart or cherry-shaped cells 15-16.5 (16-23) µm wide, 15-18 (14-20) µm long, cup-shaped chloroplast basally thickened with basal large pyrenoid and equal pairs flagella from anterior part, and seldom monitored in summer and autumn (euplanktonic, widespread throughout the world) (Ettl, 1983, 118; John et al., 2002, 75: D; Wehr & Sheath, 2003, 1: 8)

Chlorophyta

Volvocales

Eudorina Ehrenberg 1830

E. elegans Ehrenberg 1831 (Figure 5b).

Ellipsoidal or spherical coenobium 62.5-73 (60-200) µm in diameter, 16-32 (4-64) celled: spherical cells 12.5-15 (12-24) µm in diameter, cup-shaped chloroplast with pyrenoids, sometimes found (common, euplankton in hard water lakes) (Ettl, 1983, 1108: Prescott, 1982, 1: 24-26; John et al., 2002, 81: G).

Pandorina Bory 1824.

P. morum (O.F.Müller) Bory 1824 (Figure 5c).

Subspherical coenobium 24-37.5 (20-60) µm wide consists of 8-16 (8-16) cells, pear-shaped cells 8-10 (8-17) µm long, chloroplast with basal pyrenoid, and occasionally observed, generally late summer and autumn (common in plankton in both soft and hard water, prefers nitrogen-rich water) (Ettl, 1983, 1104; John et al., 2002, 81: E).

Chlorococcales

Ankistrodesmus Corda 1838

A. falcatus (Corda) Ralfs 1848 (Figure 5d).

Clustered colonies consist of 2-8 (2-8) cells, needle-like: narrowly spindle-shape cells 1.5-2 (1-7) µm wide, 25-37.5 (20-165) µm long, a parietal type chloroplast, and commonly distributed during the study period (generally found in temperate lakes) (Prescott, 1982, 56: 5, 6; Huber-Pestalozzi, 1983, 192:3; John et al., 2002, 97: J).

A. spiralis (W.B.Turner) Lemmermann 1908 (Figure 5. e).

Spirally twisted 4-8 (2-16) cells in colonies, twisted at centre, narrowing to ends, spindle-shaped cells 1.5-2 (1-4.3) µm wide, 26-37 (20-68) µm long, a parietal type chloroplast without pyrenoid, and occasionally observed (tycho and euplanktonic, common in ponds and lakes) (Prescott, 1982, 56: 11, 12; Huber-Pestalozzi, 1983, 192:4; John et al., 2002, 97: M).

Botryococcus Kützing 1849

B. braunii Kützing 1849 (Figure 5f).

Ellipsoid or oval irregularly embedded cells in periphery 3-7 (2.5-9) µm wide, 6-9 (5.7-12) µm long, chloroplast with a pyrenoid, and usually observed in 2004 and 2005 (planktonic, cosmopolitan) (Huber-Pestalozzi, 1983, 113:4; John et al., 2002, 85: H).

Elakatothrix Wille 1898

E. gelatinosa Wille 1898 (Figure 5g).

Colonies of cells in a mucilaginous envelope: narrowly spindle-shaped cylindrical cells 3-3.2 (3-4) µm wide, 14-21 (12-26) µm long, tapering to sharply pointed ends, parietal chloroplast with pyrenoid (Bourrelly, 1972, 40:7; John et al., 2002, 114: K).

Monoraphidium Komarkova-Legnerova 1969

M. arcuatum (Korshikov) Hindák 1970 (Figure 5h).

Arched cells 2-2.5 (0.8-4.5) µm wide, 21-23 (18-90) µm long, cells spindle-shaped, gradually narrowing to pointed apices, and rarely found (Huber-Pestalozzi, 1983, 178:2; John et al., 2002, 90: I).

Oocystis A.Braun 1855

O. parva W.West & G.S.West 1898 (Figure 6a).

Cells solitary or 2-4-celled (2, 4, or 8) packed in coenobia, ellipsoidal, broadly spindle-shaped with rounded apices, cells with polar wall thickening 4-7 (1.5-10) µm wide, 7-10 (3.2-17) µm long, chloroplast with pyrenoid, and occasionally observed (common, tcyho and euplankton in lakes) (Prescott, 1982, 54: 3; Huber-Pestalozzi, 1983, 149:2; John et al., 2002, 92: J).

O. tainoensis Kommarek 1983 (Figure 6b).

Cells solitary or 2-4-celled (2, 4, or 16) packed in coenobia, ellipsoidal, broadly spindle-shaped with rounded apices cells 2.5-3 (2-4.8) µm wide, 5-6.5 (3.5-9.5) µm long, chloroplast with pyrenoid, occasionally found (periphyton, in eutrophic status lakes) (Prescott, 1982, 147: 1; Komarek & Fott, 1983, 147:1).

Pediastrum Meyen 1829

P. boryanum (Turpin) Meneghini 1840 (Figure 6c).

Coenobia 29-84 (16-208) µm in diameter, consists of 16-64 polygonal cells, marginal cells 7-9 × 9-11 (5-40 × 5-31) µm in diameter, inner cells 6-8 × 6-8.5 (5-26 × 4-27) µm in diameter, intercellular spaces absent, chloroplast with a pyrenoid for each cell, rarely observed (common, eu- and tychoplanktonic in lakes) (Prescott, 1982, 47: 9, 48: 1, 3; Komarek & Fott, 1983, 87:1; John et al., 2002: 93: C).

P. tetras (Ehrenberg) Ralfs 1844 (Figure 6d).

Coenobia contain 4-8 (4, 8, 16 or 32) cells, 16-37 (15-74) µm wide, marginal cells, 8-14 × 9-13 (4-18 × 5-18) µm in diameter, laterally united to apex, apex divided into 2 lobes, inner cells 8-10 × 8-10 (4-14 × 5-16) µm without intercellular spaces, seldom distributed during the study period (generally distributed, eu- and tychoplanktonic in lakes) (Prescott, 1982, 50: 3, 6; Huber Pestallozi, 1983, 91: 5; John et al., 2002, 93: N).

Scenedesmus Meyen 1829

S. communis E.H.Hegewald 1977 (Figure 6e).

Coenobia contain 4 (4 or 8) linearly arranged cells, rounded apices, ovoid-cylindrical cells, 4-5.5 (2.3-6.6) µm wide, 9-15 (7.8-20.4) µm long (John et al., 2002, 95: E)

S. obliquus (Turpin) Kützing 1833 (Figure 6f).

Coenobia contain 4 and 8 cells (2, 4, or 8) linearly or alternately arranged, acute apices, spindle-shaped cells, 4.5-7.5 (2.2-11) µm wide, 10-16 (4-25 µm) µm long, seldom monitoring, cultured in laboratory (cosmopolitan) (Huber-Pestalozzi, 1983, 227:3; John et al., 2002, 96: O).

Tetrastrum Chodat 1895

T. komarekii Hindák 1977 (Figure 6g).

Quadrate-shaped coenobia are 9-12 (5-15) µm in diameter, cells, 4-5 (3-6) µm wide, triangular cells, chloroplast without pyrenoid (John et al., 2002, 94: C).

Tetrasporales

Pseudosphaerocystis Worocnichin 1931

P. lacustris (Lemmermann) Nováková 1965 (Figure 6h).

Colonies 42-74 (20-100) µm in diameter, includes 8, 16, and 32 (2, 4, 8, 16 or 32) spherical tetrad group cells, spherical cells 7.5-8.5 (8-12) µm wide, 7-8 (7-10) µm long, cup-shaped chloroplast with a basal pyrenoid, biflagellate (John et al., 2002, 76: F).

Zygnematales

Closterium Nitzsch ex Ralfs 1848

C. parvulum Nägeli 1849 (Figure 6i).

Strongly curved cells, 14-15 (10-15) µm wide, 94-117 (90-130) µm long, rounded apices 2-2.5 (2-3) µm wide, cell tapering slightly towards ends, chloroplast with 2-3 (2-3) longitudinal ridges and 3-4 (2-6) axile pyrenoids (John et al., 2002, 129: M).

Cosmarium Corda ex Ralfs 1848

C. botrytis Meneghini ex Ralfs 1848 (Figure 6k).

Cells 57.8-62.5 (51-85) µm wide, 87.5 (60-111) µm long, deep sinus, narrow towards outside, oval pyramidal semicells, cell wall with small rounded granules, 30-34 (30-36) granules round semicell margin (Bourrelly, 1972, 97:6; John et al., 2002, 135: P).

C. contractum Kirchner var. *ellipsoideum* (Elfving) W.West & G.S.West 1902 (Figure 6l)

Cells 26-33 (24-54) µm wide, 33-41 (30-59) µm long, isthmus 14-17 (14-29) µm wide (John et al., 2002, 132: O).

Gonatozygon de Barry 1858

G. brebissonii de Barry 1858 (Figure 6m)

Spindle-shaped cells, 6-8 (6-9) µm wide, 87-124 (85-250) µm long, slightly swollen capitate apices, ribbon-like chloroplast with 8-16 (5-16) series pyrenoids, occasionally observed during the study (cosmopolitan) (John et al., 2002, 128: X).

Mougeotia C.Agardh 1824

M. boodlei (W.West & G.S.West) Collins 1921 (Figure 7a)

Cells 5 (4-6) µm wide, 78-135 (25-225) µm long, chloroplast filling half to more of cell length with a series of 4-6 (4-6) pyrenoids, generally observed, especially in autumn (John et al., 2002, 121: I).

M. nummuloides (Hassall) De Toni 1889 (Figure 7b)

Cells 8-12 (8-16) µm wide, 42-68 (32-160) µm long, chloroplast with a median series of 4-6 (2-6) pyrenoids, spherical, occasionally found (has a broad ecological tolerance) (John et al., 2002, 120: F).

M. quadrangulata Hassall 1843 (Figure 7c)

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

M. scalaris Hassall 1842 (Figure 7d)

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, commonly distributed, especially in summer and autumn (common in different aquatic habitats) (John et al., 2002, 119: C).

Spirogyra Link 1820

S. fluviatilis Hilse in Rabenhorst 1863 (Figure 7e)

Cells 36-40 (30-45) µm wide, 82-112 (70-240) µm long with end walls plane, 3 (3-4) chloroplasts making 2-3 (1.5-3.5) turns of cell, rarely found (probably cosmopolitan in lakes, slow-moving stream) (John et al., 2002, 124: B).

S. longata (Vaucher) Kützing 1843 (Figure 7f-h)

Cells 25.2-30 (26-38 µm) µm wide, 57-84 (45-280) µm in length with end walls plane, single chloroplast making 2-4 (2-5) spirals in cell, conjugation tubes occurred from both gametangia, ovoid smooth zygospore 30-34 (28-38) µm wide, 53-61 (50-85) µm in length, occasionally distributed (a broad tolerance range, widespread) (John et al., 2002, 122: D).

S. weberi Kützing 1843 (Figure 7i-j)

Cells 21-28 (19-30) µm wide, 97-159 (80-480) µm long with end walls replicate, single chloroplast making 3-

5 (3-6.5) spirals in cell, conjugation tubes occurred from both gametangia, ovoid smooth zygospore 26-29 (25-36) µm wide, 34-46 (32-67) µm length, occasionally distributed, especially in summer 2004 (probably cosmopolitan) (John et al., 2002, 122: E).

Zygnema C.Agardh 1824

Z. conspicuum (Hassall) Transeau in Transeau et al. 1934 (Figure 7k)

Cells 22.5-26 (22-27 µm) µm wide, 57-68 (50-90) µm long, star-shaped chloroplast with central pyrenoid, sometimes found in late summer and autumn (Prescott, 1982; John et al., 2002, 127: I).

Discussion

In all, the 162 phytoplankton (except Bacillariophyceae) taxa (Table 1) identified from Lake Abant belonged to Chlorophyta (58.6%), Cyanoprokaryota (14.2%), Euglenophyta (13%), Pyrrophyta (5%), Chrysophyta (4.3%), Cryptophyta (3.7%), Xanthophyta (0.6%), and Prasinophyta (0.6%). Chlorophyta, which consisted of 95 species, was the most abundant phylum, accounting for about 58.6% of the total species. The species richness of this phylum was high, especially during the autumn of 2003 and late summer and autumn of 2004. The second most dominant phylum was Cyanoprokaryota with 23 species belonging to 14 genera. Species number of blue-green algae was relatively high in the autumn of 2003 and late summer and autumn of 2004. In January 2004, members of Cyanoprokaryota were not detected. In another recent study conducted for about 10 months in Lake Abant, Obalı et al. (2002) reported 83 algae taxa, of which only 49 belonged to non-diatom phytoplankton. The authors reported 5 phyla belonging to Chlorophyta (53%), Cyanophyta (20.4%), Pyrrophyta (12.2%), Euglenophyta (8.2%), and Chrysophyta (6.1%). Although in their study, the most abundant phylum was also Chlorophyta, the phylum included relatively low numbers of species (26) in 18 genera. In addition, Cryptophyta, Xanthophyta, and Prasinophyta were not found in their study. Such differences between these 2 studies may be due to different sampling times and different numbers of stations sampled.

During the present study, total phytoplankton species belonged to 69 genera, most of which were Chlorophyta with 39 genera (56.5%). Finding some species (e.g., *T. volvocina, C. ovata,* and *C. hirundinella*) almost all year round during the study period may suggest a wide range of tolerance to the conditions in the lake. These species were also reported in this lake by Obalı et al. (2002). At the same time, some species, such as *Scenedesmus bijuga* (Turpin) Lagerheim (now referred to as *Scenedesmus ellipticus*) (John et al., 2002), *O. borgei,* and *M. tenuissima*, were commonly found in their study. However, these taxa were not widespread in the present study. Additionally, Huber-Pestalozzi (1983) reported that *S. bijuga* can be accepted as *S. linearis*, but later on John et al. (2002) argued against both species sharing a common structure and ecological features, and they used the term *S. ellipticus*. In our case, therefore, following John et al. (2002), we refer to both species as *S. ellipticus*, which was commonly found in Lake Abant throughout the study period. Most of the identified taxa in this study are commonly distributed in different parts of Turkey (Gönülol et al., 1996).

On average, 45 taxa occurred per month during our study. The highest number of taxa (75 taxa) was found in August 2004. Numbers of species increased particularly in late summer and autumn (e.g., September (64 taxa) and November (59 taxa) 2003, and August (74 taxa), September (61 taxa), and October (57 taxa) 2004). In addition, the lowest number of species was detected in January 2003, with 22 taxa. Some genera, such as *Spirogyra, Euglena, Scenedesmus, Oocystis,* and *Pediastrum*, included more species numbers, i.e. 12, 8, 7, 7, and 6 taxa, respectively. These genera (except *Euglena*) are filamentous and coenobium organisms. Generally, most members of these genera prefer nutrient-rich water; therefore, increasing numbers of species in these groups can provide indirect information about the environmental conditions of Lake Abant.

Gönülol et al. (1996) reported 1293 taxa belonging to 10 phyla in a check-list of the freshwater algae in Turkey. Non-diatom algae included 692 taxa in their check-list. Accordingly, Lake Abant algae flora, which was characterised by tremendous phytoplankton (except diatom) species, comprised 23.4% of the total number of non-diatom freshwater algae of Turkey. Earlier limnological studies in different water bodies showed lower species richness compared to Lake Abant. For example, 96 taxa were found in Lake Ladik (Maraşlıoğlu et al., 2005), 59 taxa in Lake Yeniçağ (Kılınç, 2003), 42 taxa in Keban Dam Reservoir (Akbay et al., 1999), 84 taxa in 3 lakes (Kalchev et al., 2000) in Bulgaria, 62 species in both Lake Abbadia and Como (Buzzi, 2002) in Italy, and 50 taxa in the Banglang Reservoir (Ariyadej et al., 2004) in Thailand (given algal taxa did not include diatom species).

Total numbers of species in each phylum changed from the first to second year of the study. The number of phytoplankton taxa was higher in littoral sampling stations compared to pelagic stations in the lake. The number of total taxa for all phyla was higher the second year than the first year. In particular, species richness of 3 phyla (Cyanoprokaryota, Euglenophyta, and Cryptophyta) was twice as great in the second year than in the first. It is known that blue-green algae, euglenoids, and cryptomonads prefer nutrient-rich water (John et al., 2002; Wehr & Sheat, 2003). Increasing numbers of species in these phyla suggest that nutrient input might be changing the water chemistry of Lake Abant. Determining the taxonomic composition of phytoplankton assemblages is important for gaining an understanding of the ecological conditions of Lake Abant; however, this requires detailed information about other groups based on the knowledge derived from long-term monthly (or even weekly) biomonitoring studies.

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