

**COMPARATIVE ANALYSIS OF SEASONAL WATER QUALITY
CHANGES AND ALGAE POTENTIAL BETWEEN LAKE ABANT AND
LAKE GÖLKÖY**

**by
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Approval of Graduate School of Arts and Sciences

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ABSTRACT
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The phytoplankton composition of the lakes Abant and Gök  y were studied monthly during two years (June 2003-June 2005) at 3 littoral and 2 open sites. A total of 285 and 271 net phytoplankton taxa were identified from Lake Abant and Lake G  lk  y, respectively. Bacillariophyceae is the most abundant class in Lake Abant with ca. 43 % and in Lake G  lk  y with ca. 43.9 %. Chlorophyceae is the second dominant class in both lakes with similar ratio. Some species of diatoms (*Asterionella formosa* Hassall, *Cymbella cistula* Kirchner, *Fragilaria biceps* (K  tzing) Lange-Bertalot, *F. dilata* (Brebisson) Lange-Bertalot, and *Navicula radiosa* K  tzing) showed frequent occurrence in almost every month for each station in both lakes. Some other than diatom species such as *Trachelomonas volvocina* Ehrenberg, *Cryptomonas ovata* Ehrenberg, and *Ceratium hirundinella* (M  ller) Dujardin were commonly distributed in both lakes during study period. In addition, *Oscillatoria limosa*, *Dinobryon divergens*, *Peridinium willei*, and *Pandorina morum* were frequently found in Lake G  lk  y than in Abant. Environmental variables were changed in both lakes during study period. According to Carlson and OECD Trophic State for Secchi depth, chlorophyll-a and phosphate concentrations, Lake Abant was showed mesotrophic characteristic and dimictic, while Lake G  lk  y had meso-to-eutrophic conditions and monomictic characteristic.

Key words: Phytoplankton, Lake Abant and G  lk  y, Algal Taxonomy

ÖZET

ABANT VE GÖLKÖY GÖLÜ ARASINDA ALG POTANSİYELİ VE SU KALİTESİ DEĞİŞİMİNİN KARŞILAŞTIRMALI ANALİZİ

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Abant ve Gököy Gölü fitoplankton kompozisyonu iki yıl süresince (Haziran 2003-Haziran 2005) üç kıyasal ve iki vertikal istasyonda çalışılmıştır. Sırasıyla Abant ve Gököy göllerine ait toplam 285 ve 271 net fitoplankton taksonu tanımlanmıştır. Bacillariophyceae, Abant Gölü'nde % 43 ve Gököy Gölü'nde % 43,9 oran ile en zengin sınıftır. Her iki gölde benzer oranda bulunan Chlorophyceae ikinci baskın sınıf olmuştur. Bazı diatom türleri (*Asterionella formosa* Hassall, *Cymbella cistula* Kirchner, *Fragilaria biceps* (Kützinger) Lange-Bertalot, *F. dilata* (Brebisson) Lange-Bertalot, ve *Navicula radiosa* Kützinger) her iki gölde de hemen hemen her ay her istasyonda sıklıkla bulundukları görülmüştür. *Trachelomonas volvocina* Ehrenberg, *Cryptomonas ovata* Ehrenberg, ve *Ceratium hirundinella* (Müller) Dujardin gibi diatom dışındaki bazı türler çalışma süresince her iki gölde yaygın olarak yayılmıştır. Ek olarak *Oscillatoria limosa*, *Dinobryon divergens*, *Peridinium willei*, ve *Pandorina morum* sıklıkla Gököy Gölü'nün örnekleme istasyonlarında bulunmuştur. Çalışma süresince çevresel değişkenler her iki gölde de değişmiştir. Seki Derinliği, klorofil a ve fosfat konsantrasyonu için Carlson ve OECD Trofik Durumlarına göre, Abant Gölü mesotrofik ve dimiktik yapı gösterirken, Gököy Gölü mezodan ötrofiye geçiş ve monomiktik yapıya sahiptir.

Anahtar Kelimeler: Fitoplankton, Abant ve Gököy Gölü, Alg Taksonomi

To My Family
Berfin and Fadime

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TABLE OF CONTENTS|

ABSTRACT	iii
ÖZET	iv
ACKNOWLEDGMENTS	vi
TABLE OF CONTENTS	vii
LIST OF FIGURES	xiv
LIST OF TABLES	xix
LIST OF APPENDIX	xxii
LIST OF PHOTOGRAPHES	xxiii
1 INTRODUCTION	1
2 MATERIALS AND METHODS	7
2.1 Site Description	7
2.2 Sampling and Methods	7
2.3 Chemical and Physical Variables	9
2.4 Chlorophyll-a Concentration	10
2.5 Water Quality Analysis	11
2.6 Sampling Preservation	12
2.7 Phytoplankton density net-plankton analysis	12
2.8 Net-plankton identification	13
2.9 Statistical Methods	14
CHAPTER I	16
TAXONOMY OF BACILLARIOPHYCEAE	16
Part A	16
ABSTRACT	16
NET PLANKTONIC DIATOM (BACILLARIOPHYTA) COMPOSITION OF LAKE ABANT (BOLU)	16
ÖZET	16

ABANT GÖLÜ NET PLANKTONİK DİYATOME (BACILLARIOPHYTA)	
KOMPOSİZYONU	16
3 INTRODUCTION.....	17
4 RESULTS	18
4.1 Composition of Diatom (Bacillariophyta).....	18
4.2 Bacillariophyta.....	18
4.2.1 Centrales	18
4.2.2 Pennales	20
5 DISCUSSION	44
Part B	48
ABSTRACT.....	48
NET DIATOM (BACILLARIOPHYTA) COMPOSITION OF LAKE	
GÖLKÖY (BOLU).....	48
ÖZET	48
GÖLKÖY GÖLÜ NET DİYATOME (BACILLARIOPHYTA)	
KOMPOSİZYONU	48
6 INTRODUCTION.....	49
7 RESULTS	50
7.1 Composition of Diatom (Bacillariophyta) of Lake Gököy.....	50
7.2 Bacillariophyta.....	50
7.2.1 Centrales	50
7.2.2 Pennales	53
8 DISCUSSION	75
Part C	78
ABSTRACT.....	78
PHYTOPLANKTON (EXCEPT BACILLARIOPHYTA) COMPOSITION OF	
LAKE ABANT (BOLU).....	78
ÖZET	78

ABANT GÖLÜ (BOLU) FİTOPLANKTON (BACILLARIOPHYTA HARİÇ)	
KOMPOSİZYONU	78
9 INTRODUCTION.....	79
10 RESULTS	80
10.1 Phytoplankton composition of Lake Abant	80
10.2 Description of some phytoplankton taxa	80
10.2.1 Cyanoprokaryota (Blue-green algae)	80
10.2.2 Euglenophyta.....	86
10.2.3 Cryptophyta.....	91
10.2.4 Pyrrophyta (Dinoflagellates)	92
10.2.5 Chrysophyta (Golden Algae)	97
10.2.6 Xanthophyta (Yellow-Green Algae).....	98
10.2.7 Prasinophyta	99
10.2.8 Chlorophyta (Green algae)	99
11 DISCUSSION	124
Part D	127
ABSTRACT	127
PHYTOPLANKTON (EXCEPT BACILLARIOOPHYTA) COMPOSITION OF	
LAKE GÖLKÖY (BOLU).....	127
ÖZET	127
GÖLKÖY GÖLÜ (BOLU) FİTOPLANKTON	127
(BACILLARIOPHYTA HARİÇ) KOMPOSİZYONU.....	127
12 INTRODUCTION.....	128
13 RESULTS	129
13.1 Phytoplankton composition of Lake Gököy.....	129
13.1.1 Cyanoprokaryota.....	129
13.1.2 Euglenophyta.....	133

13.1.3	Cryptophyta.....	138
13.1.4	Pymophyta.....	141
13.1.5	Chrysophyta (Golden Algae).....	143
13.1.6	Xanthophyta (Yellow-Green Algae).....	145
13.1.7	Prasinophyta.....	146
13.1.8	Chlorophyta (Green algae).....	146
14	DISCUSSION.....	170
Part E		174
PHYTOPLANKTON COMPOSITION OF LAKE ABANT AND GÖLKÖY (BOLU).....		174
CHAPTER II.....		194
ECOLOGY OF PHYTOPLANKTON.....		194
Part A		194
ABSTRACT.....		194
PLANKTONIC DIATOM COMPOSITION AND ITS RELATIONSHIP TO PHYSICO-CHEMICAL FACTORS IN LAKE ABANT (BOLU).....		194
ÖZET.....		195
15	INTRODUCTION.....	196
16	RESULTS AND DISCUSSION.....	198
16.1	Physical and chemical variables.....	198
16.2	Diatom density of Lake Abant.....	210
16.3	Net-Diatom Composition of Lake Abant.....	213
16.4	Effect of environmental factors on distribution of diatom composition.....	214
17	CONCLUSION.....	223
Part B		225
ABSTRACT.....		225
BACILLARIOPHYTA COMPOSITION AND ITS RELATIONSHIP TO.....		225
ENVIRONMENTAL VARIABLES IN LAKE GÖLKÖY (BOLU).....		225

ÖZET	226
GÖLKÖY GÖLÜ (BOLU) BACILLARIOPHYTA KOMPOSİZYONU VE.....	226
ÇEVRESEL DEĞİŞKENLER İLE İLİŞKİSİ	226
18 INTRODUCTION.....	227
19 RESULTS AND DISCUSSION	228
19.1 Physical and chemical variables	228
19.2 Diatom density of Lake Gököy	241
19.3 Net-Diatom Composition.....	244
19.4 Relationship between diatom and environmental factors	245
20 CONCLUSION.....	255
Part C	257
ABSTRACT	257
PHYTOPLANKTON (EXCEPT BACILLARIOPHYTA) COMPOSITION AND ITS RELATIONSHIP TO ENVIRONMENTAL FACTORS	257
IN LAKE ABANT (BOLU).....	257
ÖZET	258
ABANT GÖLÜ (BOLU) FİTOPLANKTON (BACILLARIOPHYTA HARİÇ) TOPLULUGU VE ÇEVRESEL FAKTORLER İLE İLİŞKİSİ	258
21 INTRODUCTION.....	259
22 RESULTS AND DISCUSSION	260
22.1 Physical and chemical variables	260
22.2 Phytoplankton (except Bacillariophyta) density.....	265
22.3 Net-Phytoplankton Composition.....	270
22.4 Phytoplankton-environment relation with CCA.....	272
23 CONCLUSION.....	282
Part D	284
ABSTRACT	284

PHYTOPLANKTON (EXCEPT BACILLARIOPHYTA) COMPOSITION AND ITS RELATIONSHIP TO PHYSICO-CHEMICAL FACTORS IN LAKE GÖLKÖY (BOLU).....	284
ÖZET	285
GÖLKÖY GÖLÜ (BOLU) FİTOPLANKTON (BACILLARIOPHYTA HARİÇ) KOMPOSİZYONU VE FİZİKO-KİMYASAL FAKTÖRLER İLE İLİŞKİSİ	285
24 INTRODUCTION.....	286
25 RESULTS AND DISCUSSION	287
25.1 Physical and chemical variables	287
25.2 Phytoplankton (except Bacillariophyceae) abundance	295
25.3 Net-Phytoplankton (except Bacillariophyceae) Composition.....	299
25.4 Phytoplankton-environmental factors relationship with CCA	301
26 CONCLUSION.....	310
CHAPTER III.....	312
WATER QUALITY	312
Part A	312
ABSTRACT	312
WATER QUALITY OF LAKE ABANT (BOLU).....	312
ÖZET	312
ABANT GÖLÜ'NÜN (BOLU) SU KALİTESİ.....	312
27 INTRODUCTION.....	313
28 RESULTS AND DISCUSSION	315
28.1 Phytoplankton biomass of Lake Abant.....	325
29 CONCLUSION.....	329
Part B	330
ABSTRACT	330
WATER QUALITY OF LAKE GÖLKÖY (BOLU).....	330
ÖZET	330

GÖLKÖY GÖLÜ'NÜN SU KALİTESİ	330
30 INTRODUCTION.....	331
31 RESULTS AND DISCUSSION	333
31.1 Phytoplankton biomass of Lake Gököy.....	341
32 CONCLUSION.....	346
33 GENERAL CONCLUSION.....	348
34 REFERENCES	352
PHOTOGRAPHES.....	391
CURRICULUM VITAE.....	393

LIST OF FIGURES

Figure 1. Schematic map of study area.....	8
Chapter I (Lake Abant)	
Figure 1. 1. Five sampling stations are shown in Lake Abant.....	18
Figure 1. 2. a, b) <i>Aulacoseria granulata</i> , c) <i>Cyclotella bodanica</i> , d) <i>C. meneghiniana</i> , e, f) <i>C. ocellata</i> , g) <i>C. praeternisa</i> , h) <i>Melosira lineata</i>	21
Figure 1. 3. a) <i>Diatoma tenuis</i> , b) <i>Diatoma vulgaris</i> , c) <i>Fragilaria capucina</i> , d) <i>F. capucina</i> var. <i>mesolepta</i> , e) <i>F. crotonensis</i> , f) <i>F. dilata</i> , g) <i>F. pinnata</i> , h) <i>Meridion circulare</i> , i) <i>Tetracyclus rubestris</i>	23
Figure 1. 4. a) <i>Cocconeis pediculus</i> , b) <i>C. placentula</i> var. <i>lineata</i> , c) <i>Eunotia bilunaris</i>	27
Figure 1. 5. a) <i>Amphora ovalis</i> , b) <i>Cymbella affinis</i> , c) <i>C. amphicephala</i> , d) <i>C. aspera</i> , e) <i>C. cistula</i> , f) <i>C. ehrenbergi</i> , g) <i>C. helvetica</i> , h) <i>C. leptoceros</i>	29
Figure 1. 6. a) <i>Diploneis elliptica</i> b-c) <i>G. acuminatum</i> , d) <i>G. augur</i> , e) <i>G. hebridense</i> , f) <i>Gyrosigma attenuatum</i> , g) <i>Mastogloia smithii</i> , h) <i>Navicula gastrum</i> , i) <i>N. radiosa</i> , j) <i>N. trivialis</i> , k) <i>Nedium dubium</i>	33
Figure 1. 7. a-b) <i>Pinnularia microstauron</i> , c) <i>Hantzschia amphioxys</i> , d) <i>Campylodiscus hibernicus</i> , e) <i>C. noricus</i> , f) <i>Cymatopleura elliptica</i> , g) <i>C. solea</i> var. <i>apiculata</i> h) <i>Surirella spiralis</i>	38
Chapter I (Lake Gököy)	
Figure 2. 1. Map of Lake Gököy and location of the sampling stations.....	50
Figure 2. 2. a) <i>Aulacoseria granulata</i> , b-c) <i>Cyclotella ocellata</i> , d) <i>C. praeternisa</i> , e) <i>Melosira varians</i>	52
Figure 2. 3. a) <i>Diatoma tenuis</i> , b) <i>Fragilaria biceps</i> , c) <i>F. capucina</i> , d) <i>F. dilata</i> , e) <i>F. pinnata</i> , f) <i>F. ulna</i> , g) <i>Meridion circulare</i>	54

Figure 2. 4. a) <i>Amphora ovalis</i> , b) <i>Anomoeoneis sphaerophora</i> , c) <i>Cymbella affinis</i> , d, e) <i>C. aspera</i> , f, g) <i>C. cistula</i> , h) <i>C. subcuspidata</i>	59

Figure 2. 5. a) <i>Diploneis pseudovalis</i> b-d) <i>Navicula cuspidata</i> , e) <i>N. nivalis</i> f) <i>N. trivialis</i>	65

Figure 2. 6. a) <i>Pinnularia interrupta</i> , b) <i>P. maior</i> , c, d) <i>Stauroneis phoenicenteron</i> , e) <i>Nitzschia tryblionella</i> , f) <i>Epithemia adnata</i> , g) <i>Rhopalodia gibba</i> , h) <i>Cymatopleura solea</i>	68

Chapter I (Lake Abant)

Figure 3. 1. a) <i>Chroococcus turgidus</i> , b) <i>Microcystis aeruginosa</i> , c) <i>Oscillatoria limosa</i> , d) <i>O. sancta</i> , e) <i>Spirulina maior</i> , f) <i>Anabaena bergei</i> , g) <i>A. planctonica</i> , h) <i>Cylindrospermum minutissimum</i> , i) <i>Trachelomonas volvocina</i>	83

Figure 3. 2. a) <i>Campylomonas rostratiformis</i> , b) <i>Cryptomonas marsoni</i> , c) <i>C. ovata</i> , d) <i>Ceratium cornutum</i> , e) <i>Peridiniopsis thompsonii</i> , f) <i>Peridinium willei</i>	94

Figure 3. 3. a) <i>Dinobryon bavaricum</i> , b) <i>D. divergens</i> , c) <i>D. sertularia</i> , d) <i>D. sociale</i> var. <i>americanum</i>	96

Figure 3. 4. a) <i>Eudorina elegans</i> , b) <i>Pandorina morum</i> , c) <i>Ankistrodesmus falcatus</i> , d) <i>A. spiralis</i> , e) <i>Botryococcus braunii</i> , f) <i>Elakototrix gelatinosa</i> , g) <i>Monoraphidium arcuatum</i>	100

Figure 3. 5. a) <i>Oocystis parva</i> , b) <i>O. tainoensis</i> , c) <i>Pediastrum boryanum</i> , d) <i>P. tetras</i> , e) <i>Scenedesmus communis</i> , f) <i>S. obliquus</i> , g) <i>Tetrastrum komarekii</i> , h) <i>Pseudosphaerocystis lacustris</i>	107

Figure 3. 6. a) <i>Closterium parvulum</i> , b) <i>Cosmarium botrytis</i> , c) <i>C. contractum</i> var. <i>ellipsoideum</i> , d) <i>Gonatozygon brebissoni</i>	116

Figure 3. 7. a) <i>Mougeotia boodlei</i> , b) <i>M. nummuloides</i> , c) <i>M. scalaris</i> , d) <i>Spirogyra fluvialis</i> , e-f) <i>S. longata</i> , h-i) <i>S. weberi</i>	121

Chapter I (Lake Gölköy)

Figure 4. 1. a) <i>Microcystis aeruginosa</i> , b) <i>Scenedesmus lacustris</i> , c) <i>Oscillatoria formosa</i> , d) <i>O. limosa</i> , e) <i>O. princeps</i> , f) <i>Spirulina maior</i> , g) <i>Anabaena crassa</i>	130
Figure 4. 2. a) <i>Euglena acus</i> , b) <i>E. chlamydomorpha</i> , c) <i>E. oblonga</i> , d) <i>E. viridis</i> , e) <i>Lepocinclis ovum</i> , f) <i>Phacus curvicauda</i> , g) <i>Trachelomonas hispida</i> , h) <i>T. volvocina</i>	134
Figure 4. 3. a, b) <i>Campylomonas rostratiformis</i> , c) <i>Cryptomonas marssonii</i> , d-f) <i>C. ovata</i> , g) <i>Plagioselmis nannoplantonica</i> , h) <i>Ceratium furcoides</i> , i) <i>C. hirundinella</i> , j) <i>Peridinium willei</i>	140
Figure 4. 4. a.) <i>Dinobryon bavaricum</i> , b) <i>D. sertularia</i> , c) <i>D. sociale</i> var. <i>americanum</i> d) <i>D. sociale</i> var. <i>stipitatum</i> , e) <i>Uroglena volvox</i> , f) <i>Tetraselmis cordiformis</i>	144
Figure 4. 5. a) <i>Eudorina elegans</i> , b) <i>Gonium pectorale</i> , c-e) <i>Volvox globator</i> , f) <i>V. polychlamys</i>	149
Figure 4. 6. a) <i>Oocystis marssonii</i> , b-d) <i>Pediastrum boryanum</i> , e) <i>P. integrum</i> , f) <i>Scenedesmus acutus</i> var. <i>globosus</i> , g) <i>S. arcuatus</i>	157
Figure 4. 7. a) <i>Cosmarium botrytis</i> , b) <i>C. subcrenatum</i> , c) <i>Gonatozygon monotaenium</i>	163
Figure 4. 8. a) <i>Mougeotia quadrangulata</i> , b) <i>M. scalaris</i> , c-d) <i>Spirogyra longata</i> , e) <i>S. setiformis</i> , f-g) <i>S. weberi</i>	167
Chapter II (Lake Abant)	
Figure 6. 1. Isopleths of temperature in Lake Abant.....	200
Figure 6. 2. Isopleths of dissolved oxygen in Lake Abant.....	201
Figure 6. 3. Temporal variation of dissolved oxygen, water and air temperature in Lake Abant.	202
Figure 6. 4. Total abundance of diatom composition in Lake Abant.....	212

Figure 6. 5. Ordination diagram of Canonical correspondence analysis (CCA) with diatom in Lake Abant.	215
Figure 6. 6. UPGMA dendrogram shows sampling months in Lake Abant.	221
Chapter II (Lake Gök�y)	
Figure 7. 1. Isopleths of temperature in Lake G�k�y.	229
Figure 7. 2. Isopleths of dissolved oxygen in Lake G�k�y.	231
Figure 7. 3. Temporal variations of dissolved oxygen, water and air temperature recorded in Lake G�k�y.	232
Figure 7. 4. Total abundance of diatom composition in Lake G�k�y.	243
Figure 7. 5. Canonical correspondence analysis (CCA) ordination with diatom in Lake G�k�y.	247
Figure 7. 6. UPGMA dendrogram shows sampling months in Lake G�k�y.	253
Chapter II (Lake Abant)	
Figure 8. 1. Temporal variation of dissolved oxygen, water temperature, chlorophyll-a in Lake Abant.	260
Figure 8. 2. Abundance of phytoplankton taxa and genera with number of species were recorded in Lake Abant.	265
Figure 8. 3. Total abundance of phytoplankton composition in Lake Abant.	266
Figure 8. 4. Detrended Correspondence Analysis (DCA) in Lake Abant.	273
Figure 8. 5. Canonical correspondence analysis (CCA) ordination shows net-phytoplankton taxa in Lake Abant.	275
Figure 8. 6 UPGMA dendrogram shows sampling months in Lake Abant.	280
Chapter II (Lake G�k�y)	
Figure 9. 1. Temporal variation of dissolved oxygen, water temperature, chlorophyll-a in Lake G�k�y.	287

Figure 9. 2. Abundance of phytoplankton taxa and genera with number of species were recorded in Lake Gök��y.....	295
Figure 9. 3. Canonical correspondence analysis ordination shows net-phytoplankton taxa in Lake G����y	303
Figure 9. 4. UPGMA dendrogram shows sampling months in Lake G����y.....	308
Chapter III (Lake Abant)	
Figure 10. 1. Temporal variations in Carlson’s TSI values in Lake Abant.....	316
Figure 10. 2. Temporal variations in OECD’s TSI values in Lake Abant.....	317
Figure 10. 3. Colonies of total coliform bacteria, and colonies of <i>Escherichia coli</i>	324
Figure 10. 4. Temporal variations of diatoms’ biomass in Lake Abant.	326
Figure 10. 5. Temporal variations of biomass during two years.....	327
Chapter III (Lake G����y)	
Figure 11. 1. Temporal variations in Carlson’s TSI values in Lake G����y.....	334
Figure 11. 2. Temporal variations in OECD’s TSI values in Lake G����y.	335
Figure 11. 3. Temporal variations of dominant genera’ biomass in Lake G����y...	343
Figure 11. 4. Percentage biomass of phyla in Lake G����y.....	344
Figure 11. 5. Temporal variations of biomass of phyla in Lake G����y.....	345

LIST OF TABLES

Chapter I

Table 5. 1. Jaccard's and Sorenson similarity indexes of phytoplankton phylum between Lake Abant and Gök��y.....	175

Table 5. 2. Net-Phytoplankton taxa observed in Lake Abant and G����y.....	177

Chapter II

Table 6. 1. Physico-chemical variables in Lake Abant	206

Table 6. 2. Correlation matrix with diatoms in Lake Abant.....	209

Table 6. 3. Abundance of diatom genera in Lake Abant.....	211

Table 6. 4. Main results of CCA with using Monte Carlo permutation test for 123 diatom species.....	216

Table 6. 5. Results of CCA show the critical values of both F and p.....	217

Chapter II

Table 7. 1. Physico-chemical variables in Lake G����y	237

Table 7. 2. Correlation matrix with diatoms in Lake G����y.....	240

Table 7. 3. Abundance of diatom genera in Lake G����y.....	242

Table 7. 4. Main results of DCA with 119 diatom species in Lake G����y.....	246

Table 7. 5. Main results of canonical correspondence analysis (CCA) with using Monte Carlo permutation test for 119 diatom species.....	248

Table 7. 6. Results of CCA ordination with environmental variables in Lake G����y.....	249

Chapter II

Table 8. 1. Correlation matrix with phytoplankton species in Lake Abant.....	264

Table 8. 2. Abundance of phytoplankton genera were recorded in Lake Abant	268
Table 8. 3. Main results of DCA with 162 phytoplankton species given values.....	274
Table 8. 4. Main results of CCA with using Monte Carlo permutation test for 162 net-phytoplankton species	276
Table 8. 5. Results of CCA ordination with environmental variables	277
Chapter II	
Table 9. 1. Mean values of environmental changes found seasonally from Lake Gölköy.....	289
Table 9. 2. Correlation matrix with phytoplankton species in Lake Gölköy.....	294
Table 9. 3. Abundance of phytoplankton genera were recorded in Lake Gölköy	297
Table 9. 4. Main results of DCA with 152 phytoplankton species in Lake Gölköy.....	302
Table 9. 5. Main results of CCA with using Monte Carlo permutation test for 152 net-phytoplankton species.	304
Table 9. 6. Results of CCA ordination with environmental variables in Lake Gölköy.....	305
Chapter III	
Table 10. 1. Carlson (1977) classified TSI into numerical scales.	315
Table 10. 2. Temporal variation in Carlson's TSI values in Lake Abant.....	319
Table 10. 3. Temporal variation in OECD's TSI values in Lake Abant.	321
Table 10. 4 1. Temporal variation saprobic status for BOD ₅ in Lake Abant.....	323
Chapter III	
Table 11. 1. Carlson (1977) classified TSI into numerical scales.	334

Table 11. 2. Temporal variation in mean TSI values from Carlson's equation in Lake Gök�y	336
Table 11. 3. Temporal variation of OECD's TSI in Lake G���y	338
Table 11. 4. Temporal variation saprobic status for BOD ₅ in Lake G���y	340

LIST OF APPENDIX

Appendix A. Total of 123 net-diatom species in Lake Abant.	366
Appendix B: Total of 119 net-diatom species in Lake Gök�y	372
Appendix C. Total of 162 net-phytoplankton species in Lake Abant.	377
Appendix D. Total of 152 net-phytoplankton species in Lake G���y	384

LIST OF PHOTOGRAPHES

Photograph 1. Littoral 1 sampling station in Lake Abant.....	391
Photograph 2. Littoral 2 sampling station in Lake Abant.....	391
Photograph 3. Littoral 1 sampling station in Lake Abant.....	391
Photograph 4. Littoral 1 sampling station in Lake Gököy.	392
Photograph 5. Littoral 2 sampling station in Lake Gököy.	392
Photograph 6. Littoral 1 sampling station in Lake Gököy.	392

1 INTRODUCTION

Phytoplankton is defined as free-floating unicells and colonies that grow photoautotrophically with chlorophyll pigments that enable them to fix solar energy by means of photosynthesis, converting carbon into an energy form, which is transferable to other part of aquatic food web in aquatic environment. Phytoplankton is crucial important organisms in ecosystems with playing a key role in primary production and global element cycles of the Earth (Graham and Wilcox, 2000; Danilov and Ekelund, 2001; John et al., 2002).

Different cell size and shape of phytoplankton play important role to identify them. The shapes of algae vary in form from unicellular, through colonial, filamentous, siphonaceous, to the complex parenchymatous thalli. (Round, 1973; Werh and Sheath, 2003). Phytoplankton covers a vast range of sizes and forms, both as single cells and as colonies. Phytoplankton can be separated on the basis of cell size into macroplankton ($>500\text{ }\mu\text{m}$), micro-phytoplankton ($200\text{-}20\text{ }\mu\text{m}$), nanophytoplankton ($20\text{-}2\text{ }\mu\text{m}$), and picophytoplankton ($2\text{-}0.2\text{ }\mu\text{m}$) (Wetzel, 1975; Horne and Goldman, 1994; Graham and Wilcox, 2000). Humans can only see the individual of phytoplankton with aid of a microscope, but large populations can give waters green or other type colors. Color variations reflect differences in the types and amount of blue-green, red, orange, and golden accessory pigments accompanying the green of chlorophyll (Graham and Wilcox 2000; John et al., 2002).

Lakes have different structure as shoreline, basin, and depth etc. Regions within lakes exhibit physical and chemical differences that affect algal community. The open water region of lakes is called as pelagic (limnetic) zone, whereas close to shore is littoral zone, where greatest exchange between nutrient-rich sediments and the

water occurs. The littoral zone is not also colonized by submerged and emerged flowering plants, but also some macroalgae (e.g. *Chara*, *Nitella*) and nonflowering plants (mosses, liverworts) (Wehr and Sheath, 2003). Lake Abant has generally constant water level, whereas the water level of Gököy Dam decreases during summer for irrigating agriculture areas. Therefore, Lake Gököy has changeable littoral zone that can affect algae composition and biomass.

Vertical zones also develop in temperate regions. In early spring, most temperate lakes are well mixed, with similar temperature and chemical condition from top to bottom. As temperatures increase, upper mixed waters become thermally isolated from the colder bottom part water, a process which is called as stratification (Boney, 1975; Graham and Wilcox, 2000). Gököy Dam and Lake Abant, which have different altitude from the sea level, show their water stratifications and mixing.

Phytoplankton composition is not only affected by lake structure and water level, but also stimulated or inhibited by environmental requirements. Phytoplankton relies on two important environmental factors such as light and nutrients for their growth. These nutrients include carbon, nitrogen, phosphorus, silica, and trace metals such as iron, and a few vitamins (Smith 1980; Horne and Goldman 1994).

The availability of sunlight as the source of radiant energy is an important requirement for primary production. Growth of algae and photosynthesis rates are directly related to quantitative light intensity. Illumination is not only depend on sun's position with latitude, season, time of day and on the cloudy cover, but also compound of water such as organisms and other suspended particles (Boney, 1975; Wetzel, 1975).

In north temperate regions the daily illumination reaches a maximum intensity in May and June, falling to approximately one-ninth of this summer level during December and January (Graham and Wilcox, 2000). Temperature has two aspects; direct effects such as temperature tolerance of organisms in relation to conditions in nature and the decreased solubility of oxygen in water with rise in temperature, and the indirect effects arising from temperature changes in the water column (Wetzel, 1975). The important indirect effect of temperature on the phytoplankton organisms are to be seen in the thermal stratification of water in lakes. This stratification that is accompanied by formation of thermocline, occur most often in summer (Werh and Sheath, 2003).

Dynamic of phytoplankton are primarily correlated with spatial and temporal fluxes of major nutrient ions such as N, P, and Si (Horne and Goldman, 1994; Graham and Wilcox, 2000; John et al., 2002).

Nitrogen is an important requirement for the growth of phytoplankton. Nitrogen has several forms such as nitrite, nitrate, ammonia, and ammonium. Utilization of nitrate by the phytoplankton involves its conversion ultimately to ammonia before assimilation into cell material (Boney, 1975; Horne and Goldman, 1994).

Phosphorus in the natural waters occurs as solution in both inorganic and organic forms. Orthophosphates general appear to be main sources for phytoplankton in lakes. Phytoplankton organisms are able to accumulate phosphate reserves when nutrient levels are high. This metabolism is called as luxury consumption and to utilize these reserves during periods of low phosphate concentration in the natural waters (Hutchinson, 1967; Wetzel 1975; Horne and Goldman, 1994).

Silicate is an important element for diatoms to use their cell wall silicification. Generally diatoms prefer soluble orthosilicate (SiO_3^{2-}) as the principal source of element (Boney, 1975; Horne and Goldman, 1994).

Phytoplankton generally is slightly heavier than water and tends to sink deep down to the aquatic systems. They move by swimming or changing their density. Thus the sinking of phytoplankton due to gravity is very slow compared to the descent of a small stone. Sinking is slowed down by viscous drag on cell walls and reversed by upward turbulent mixing water. It is known that phytoplankton have individual cells and colonies, which may possess flagella, and be motile or lack flagella and be non-motile (Horne and Goldman, 1994; Graham and Wilcox, 2000).

Many factors contribute to phytoplankton diversity and production, including temporal and spatial variations in nutrient supply, grazing, temperature, and parasitism. It is known that algae respond to this constant rearrangement of the physical and chemical structure of their environment with characteristic population fluctuations. In general, there are three obvious features of the seasonal cycle: the large spring diatom bloom, the smaller irregular summer peaks of various flagellates, and the large fallal bloom of diatoms, blue-green algae, and dinoflagellates (Horne and Goldman, 1994; Graham and Wilcox, 2000; Wehr and Sheath, 2003). There is an interaction between organisms and their environments. Ecological studies are important to understand temporal and spatial changes around the organisms and their distributions in aquatic ecosystems.

Although limnological studies had been started ca six decades ago (Geldiay, 1949; Tanyolaç & Karabatak, 1974) the pioneer algological study was carried out by Aykulu & Obalı, (1981) in Turkish inland waters. After study in Kurtboğazi Reservoir, which was carried out by Aykulu & Obalı (1981), several algological

studies (Cirik-Altındağ, 1982; Gönüloğlu, 1985; Altuner, 1988) have gained momentum in Turkey; however have not yet reached an acceptable grade. Many studies on the algal composition and factors affecting them in mid-Anatolia had been completed (Aykulu et al., 1983; Obalı, 1984; Gönüloğlu, 1984; Yıldız, 1986; Akbulut and Yıldız, 2002; Atıcı and Obalı, 2002; Akbulut, 2003). In addition, a number of detailed studies have been carried out in northern, western, and eastern parts of Turkey (Yıldız, 1987; Altuner, 1988; Gönüloğlu and Obalı, 1998; Gürbüz and Altuner, 2000; Kılınç and Sıvacı, 2001; Albay and Akçaalan, 2003; Şahin, 2003; Çetin and Şen, 2004). In the western many algological studies have been carried out on the sea, streams and lakes (Ertan and Morkoyunlu 1998; Dere et al. 2002). Some of these studies are only taxonomic level; however, some studies are ecological studies.

Although increasing attention has been given to algological studies in Turkey, there are sites that have not yet been investigated. One of these areas is Lake Gököy (Bolu) which is 10 km east of Bolu, was built in a wetland area in 1970 to provide water for irrigation and other agricultural uses and for commercial fishing. The lake has natural beauties which are surrounded with pine and fir trees. That particular study constitutes the first record of genus from Turkey. It is stated that the trophy of this lake is going to eutrophication (Külköylüoğlu, 2005). In near future, the water of lake is thought to use drinking water for the city of Bolu. Therefore, limnological studies on the lake are crucially important. On the other hands, Lake Abant (Bolu), which is located at about 30 km southwest of Bolu, is a natural lake. The lake is of a land-slide origin (Akşiray, 1959; Erinç et al., 1961; Bottema et al., 1993-94) after series of tectonic activities. This lake has natural beauties surrounded by pine and fir trees, for which tourism activity is increasing every season to make picnic, camping, fishing etc. Obalı and her colleagues (2002) carried out an algological study on the

lake, but this study included only taxonomy of algae for 10 months. Abant area as a nature park has several endemics species of plants and animals. Therefore, this lake has to be studied from the limnological perspective for a long time. Findings gained from the present study on phytoplankton will provide information on the characteristics of this unique aquatic environment. The knowledge on the ecology of phytoplankton and physico-chemical variations of the lakes is important to give information about future of these aquatic ecosystems, whether any protection is necessary.

The purposes of this study are (1) to define taxonomy of phytoplankton composition, (2) to investigate the relationship between phytoplankton and changes on physico-chemical variables of their habitats, (3) to understand both ecological and biological assemblages, composition, abundance, and species richness of both lakes, and (4) to evaluate water quality of both lakes.

2 MATERIALS AND METHODS

2.1 Site Description

Lake Abant (31°, 16' 735 E, 40°, 36' 713 N) (Figure 1), which is about 30 km southwest of Bolu city, is a natural lake. This lake has natural beauties surrounded by pine and fir trees. The lake is situated at about 1340 m above the sea level and has a surface area of 125 ha (Akşiray, 1959; Erinç et al., 1961; Bottema et al., 1993-94). The lake is known with its natural beauties surrounded by a rich flora and fauna. Therefore, it is one of the well known visiting sites in Turkey.

Lake Gököy (31°, 31' E, 40°, 42' N, 730 asl) (Figure 1), which is 10 km east of Bolu, was originally built on a wetland area early 1970s where water was aimed to deposited for both irrigation of agricultural uses and commercial fishing. The lake has natural beauties which is surrounded with oak and pine which a lot of tourists come every season to make picnic, camping, fishing etc. The lake receives two major inflows from Abant creek in the northeast and Mudurnu creek in the southwest of the lake. Both creeks carry nutrient rich water from chicken farms, agricultural areas, and villages. The lake area fluctuates between 150 ha to 180 ha in average with a maximum depth of 18 m. During summer and fall season, the lake water level drops down to about 6-8 m (Çelekli, in press).

2.2 Sampling and Methods

Samples were collected monthly from three littoral and two vertical stations of the lake between June 2003 and June 2005. Vertical samplings were made with a Zodiac boat when samples from open water (0.3, 4, 7, and 10 m) were collected with a 2.5 L of Van Dorn bottle from different depths. Several samples taking with Van Dorn bottle were concentrated by plankton net for net-diatom identification.

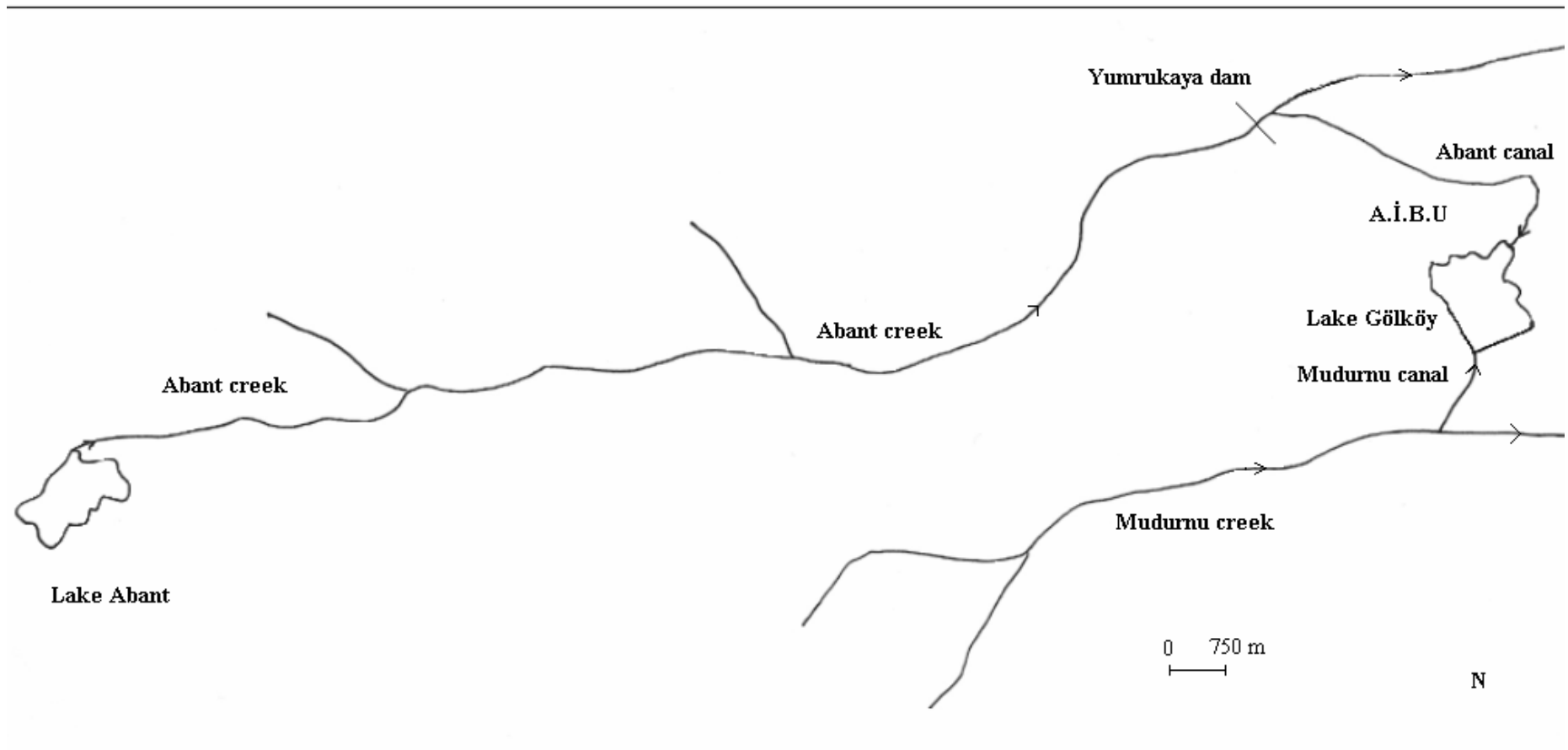


Figure 1. Schematic map of study area.

Samples were not taken from lake in some winter months such as February, March 2004 and January-March 2005 due to ice cover. Only littoral sampling was done in January 2004. The geographical data (elevation, latitude and longitude) were recorded with a geographical positioning system (45 XL model GPS). We obtained atmospheric temperature and rainfall values from Bolu Meteorological Station.

Five environmental variables (e.g. water temperature, percent oxygen saturation, dissolved oxygen, electrical conductivity, and salinity) were measured *in situ* by using YSI-85 model oxygen-temperature meter, and pH and redox potential (Eh) were determined using Hanna model HI-98150 pH/ORP meter. Eh values are calculated based on Standard Hydrogen Electrode (SHE) in millivolt (mV).

Light attenuation was measured using secchi disc (20 cm diameter limnological disc). It is known that the mean secchi depth at which it disappears and reappears on being raised can be taken as a measure of the transparency of the water (Wetzel and Likens, 1991).

2.3 Chemical and Physical Variables

Collected water samples as 250 ml stored in coolers with ice packs were used to measure chemical analysis and turbidity. Standard methods (APHA AWWA, 1989) were used to determine chemical variables. As soon as the sampling waters which were taken from lake, went to laboratory to chemical analysis. Water was filtered through a 0.8 μ m pore size membrane (Whatman GF filter). Filtered water was used for chemical analysis. Alkalinity, chloride, calcium, and magnesium were determined using titrable method. Nitrate-nitrogen, nitrite-nitrogen, ammonium-nitrogen, ortho-phosphate and sulphate were measured by spectrophotometer according to Standard methods (APHA AWWA, 1989).

Collected water samples were waited for 5 days in incubator at 20 °C in dark to determine Biological oxygen demand (BOD₅) (Wetzel and Likens, 1994). Turbidity of water was measured with turbidity meter as Nephelometric Turbidity Unit (NTU) (Wetzel and Likens, 1991).

2.4 Chlorophyll-a Concentration

Chlorophyll-a concentrations were determined by spectrophotometer after extraction in 90 % methanol according to the method described by Youngman (1978). To determine chlorophyll-a concentration, water samples were filtered through a cellulose acetate membrane filter (0.45 µm). The pressure of filtration should not exceed 0.3 atm, to minimize damage to delicate organisms (Wetzel and Likens, 1991). The amount of sample required will vary according to the concentration of phytoplankton. Generally 0.4-1.0 litre water was filtered through the filter. Amount of sample filtration was adjusted according to seasonal changes. Filtration should be done as rapidly as possible, avoiding exposure to bright light or high temperature. After the filtration was completed, acetate filter is put the small glass covered bottle containing 14 ml 90 % methanol. The parafilm was used for covering glass bottle to prevent evaporation methanol. These glass bottles containing acetate filter and methanol were put in hot water bath adjusting 70 °C for 10 minutes. Thereafter, bottles were waited in the dark condition for 5 minutes. Thereafter acetate filter in the bottle was mashed with glass baget. Methanol contained chlorophyll pigment was taken centrifuge tube and make centrifuge at 5000 rpm for 5 minutes to separate pigment from other solid particles. Blank tube was prepared with methanol to zero spectrophotometer. These solutions, which were extracted with 90 % methanol, were measured by spectrophotometer at different wavelengths

(750 (for presence of turbidity), 665 nm) (Youngman 1978). The absorbance of solution were smaller than 0.02 at 750 nm wavelength

Youngman formula (1978) is

$$Chla \cdot (\mu g / l) = \frac{[(13.6) \cdot (A) \cdot (v)]}{[(d) \cdot (V)]}$$

Where;

A: the absorption value.

v = volume of extract in ml.

V = volume of water filtered in liters.

d: length of light path through cuvette or cell in cm.

k = absorption coefficient of chlorophyll-a, = 13.6

2.5 Water Quality Analysis

Trophic State Indices (TSI) were calculated based on Secchi depth (TSI_{SD}), total phosphate (TSI_{TP}), and chlorophyll a (TSI_{CHO}) levels, following Carlson (1977) and Vollenweider and Kerekes (1982). Saprobic water quality classes were determined by using BOD₅ ranks according to Hamm 1969 (in Rott et al., 2003). The volumes of phytoplankton cells were calculated to determine phytoplankton biomass following their geometric shapes (Rott, 1981; Hillebrand et al., 1999; Sun and Liu, 2003).

Microbiological samples as 100 ml were taken from all littoral stations of both lakes for determining the number of coliform bacteria colony. These samples were kept under cool condition (+4 °C). Coliform bacteria were inoculated on the EMB agar using dilution method (Jay, 1992; Madigan et al., 1997). After inoculation, coliform bacteria were incubated at 37 °C for 48 hours. After then the colonies of bacteria were counted.

2.6 Sampling Preservation

Phytoplankton species should be examined while alive, particularly delicate species of flagellated algae, whenever possible. Algae may be maintained for several hours without appreciable deterioration when kept in cold during transportation to laboratory. Usually, preservation is necessary for longer storage periods. A better preservative is lugol's solution, added to samples to yield a 1 % final concentration (1:100). After lugol's solution was added to the sample, the cells of sample begin to absorb iodine from lugol's solution (Wetzel and Likens, 1991). During the study, acetic lugol solution with adding glycerol 2-3 % of final solution was used to preserve phytoplankton samples and stored 4-5 °C. Sample collections were normally finished as possible as in little time. Add 10 drops lugol's iodine to each 200 ml sample. Samples preserved in lugol's fixative were sensitive to light and do not have a long shelf life.

Acid lugol's solution; dissolved 100 g KI in 1 L of distilled water, and dissolved 50 g iodine (crystalline) in 100 ml glacial acetic acid, then mixed these two solutions. Removed any precipitates. Store in the dark (Thronsdon, 1978).

2.7 Phytoplankton density net-plankton analysis

Collected water samples stored in coolers with ice packs were used to count and identify phytoplankton. Water samples (250 ml) for phytoplankton counting were taken directly from littoral stations and via Van Dorn Bottle from vertical sampling stations into polyethylene bottles. Samples for identification and counting were preserved with acetic lugol-glycerol solution in different polyethylene bottles. Sub-samples (30-90 ml) were permitted to settle for 24-48 hours in counting chamber and then enumerated at magnification of 400x (3 replicate) for each samples using

inverted microscope technique (Utermöhl, 1958). At least 300-500 cells of the most abundant species were counted per samples.

2.8 Net-plankton identification

Net-plankton samples as 250 ml were collected with plankton net (45 µm-mesh sizes and 20 cm diameter) to identification of phytoplankton. After concentrated samples were brought to laboratory, temporary and permanent slides of phytoplankton were made for species identification under the light microscope at 400X, 800X, and 1000X magnification. The shapes of some phytoplankton were photographed with the attachment of BX 51 Olympus microscope camera. The cell size and shape, number and type of chloroplast and pyrenoid, pigmentations, structure of cell wall, zygospores size and shapes, and conjugation type (for Zygnematales) were generally used during the classification of taxa.

Permenant microscope slide from the concentrated samples were prepared to identify diatom taxa. Organic constituents of diatom were removed from the debris to observe the details and ornamentations of the valves. Diatom samples were boiled in a mixture of concentrated hydrochloric acid and potassium permanganate. The diatomaceous remains were then washed in distilled water until the valves were acid-free (Simonsen, 1974). The shapes of some phytoplankton were photographed with the attachment of BX 51 Olympus microscope camera. The shapes of some diatoms were photographed with the attachment of BX 51 Olympus microscope camera. The cell size and shape, and ornamentation on cell wall (raphe, spin, number of costae and striae per 10 µm in valves) were generally used during identification of taxa.

Identification of phytoplankton from net samples were based on the taxonomic keys of Patrick and Reimer (1966, 1975), Prescott (1982), Ettl, (1983), Huper-Pestalozzi (1983), Popovsky and Pfiester (1990), Round et al. (1990), Krammer and

Lange-Bertalot (1991 a, b), Komarek and Anagnostidis (1998), Krammer and Lange-Bertalot (1999 a, b), Graham and Wilcox (2000), John et al. (2002), and Wehr and Sheath (2003). Additionally, some other sources were also used for classification of phytoplankton (Geitler, 1930-1932; Bourrelly, 1972). Algaebase (2006) data list was also used to check taxonomy of algae.

2.9 Statistical Methods

The relationship between the environmental variables and phytoplankton were evaluated by means of stepwise multiple regression analysis. Jacard and Sorenson's Similarity index were used to compare net-plankton algal floras between two lakes and consecutive sample dates (Magurran, 1988). Physico-chemical variables among the sampling stations were compared using Analysis of Variance (ANOVA) (Zar 1999). Regression analysis was used to evaluate relationship between correlated variables (Zar, 1999). Spearman Correlation was used to test correlation among environmental variables. A cluster analysis of unweighted pair group mean averages (UPGMA) was applied to discern different sampling month based on occurrences of taxonomic assemblages among the species. All statistical analyses were conducted using the Multi-Variate Statistical Package (MVSP) program version 3.1 (Kovach, 1998). Detrended correspondence analysis (DCA) was used to determine gradient length of diatom composition, which is unimodal response before performing CCA (Leps and Smilauer 2003). Canonical Correspondence Analysis (CCA) was used to determine the relationships between diatom composition and physico-chemical environmental variables. All environmental variables were log-transformed ($\log(x+1)$), except for pH; in order to reduce the skewness during CCA application (ter Braak and Smilauer 1998). In our CCA, we only included taxa encountered two or more times so as to reduce multicollinearity (ter Braak, 1986, 1995). Net-diatom

composition with binary data (presence/absence) was used in this analysis. Only species weight range with a percentage of 2 % was selected in CCA diagram. Together of taxa was prevented in CCA ordination. Environmental data was performed with forward selection with Monte Carlo permutation. The program CANOCO was used for all the ordination analyses (ter Braak and Smilauer 1998; Leps and Smilauer 2003).

CHAPTER I

TAXONOMY OF BACILLARIOPHYCEAE

Part A

ABSTRACT

NET PLANKTONIC DIATOM (BACILLARIOPHYTA) COMPOSITION OF LAKE ABANT (BOLU)

The diatom flora of Lake Abant was studied monthly for two years (June 2003-June 2005) from 3 littoral and 2 vertical stations. A total of 123 diatom taxa were identified. Some species (*Asterionella formosa* Hassall, *Cymbella silesiaca* Bleisch, *C. cistula* Kirchner, *Fragilaria biceps* (Kützing) Lange-Bertalot, *F. dilata* (Brebisson) Lange-Bertalot, *Navicula radiosa* Kützing, and *Rhopalodia gibba* Müller) showed frequent occurrence in each month at all stations. Numbers of diatoms were increased in certain months of fall season such as November (83 taxa), December (68 taxa) 2003 and August (65 taxa), September (76 taxa) 2004.

Key Words: Lake Abant, Diatom, Taxonomy

ÖZET

ABANT GÖLÜ NET PLANKTONİK DİYATOME (BACILLARIOPHYTA) KOMPOZİSYONU

Abant Gölü diyatome florası üç kıyısız ve iki vertikal istasyonda aylık olarak iki yıl boyunca (Haziran 2003-Haziran 2005) çalışılmıştır. Toplam 123 diyatome taksonu tanımlanılmıştır. Bazı türler (*Asterionella formosa* Hassall, *Cymbella silesiaca* Bleisch, *C. cistula* Kirchner, *Fragilaria biceps* (Kützing) Lange-Bertalot, *F. dilata* (Brebisson) Lange-Bertalot, *Navicula radiosa* Kützing ve *Rhopalodia gibba* Müller) bütün istasyonlarda her ay sıklıkla görülmüştür. Diyatome tür sayısı Kasım (83 takson) ve Aralık (68 takson) 2003, Ağustos (65 takson) ve Eylül (76 takson) 2004 sonbahar mevsiminin bazı aylarında artmıştır.

Anahtar Kelimeler: Abant Gölü, Diyatome, Taksonomi

3 INTRODUCTION

Diatoms are distributed to variety of environments from freshwater to marine water in all over the world, where environmental conditions in some of the major factors (e.g., light, temperature, and chemical components) are suitable (Hutchinson, 1967). Diatoms are unicellular algae, whose cell walls are composed of silicon dioxide. The diatoms valves are highly ornamented, reflecting taxonomic diversity. These structures are found in both living and fossil forms, reflecting the effects of different environmental conditions. Therefore, they can not only provide important knowledge on the reconstruction of the past history of an area (Patrick and Reimer, 1966; Round, 1981; Wehr and Sheath, 2003) but also provide useful tool to determine current status of habitats as well.

In recent years, studies concerning freshwater diatoms in Turkey gained momentum; however, they have not reached to an acceptable level. Numbers of studies have been carried out in Turkey such as in northern parts (Gönülol and Obalı, 1998; Şahin, 2003), in eastern parts (Çetin and Şen, 1998; Akbay et al., 1999; Kılınç and Sıvacı, 2001), and in the parts of the mid-Anatolia (Elmacı and Obalı, 1998; Akbulut, 2003). Additionally, several investigations on the diversity of phytoplankton were done in different aquatic bodies in western (Aysel et al., 2002; Dere et al., 2002) and in South-western Anatolia (Ertan and Morkoyunlu, 1998). From the previous studies, which have great contribution to the understanding of the floral richness of Turkey, one can interpret that the species richness of Turkey is much higher than estimated before. Therefore, the aim of this study was to determine the diatom composition in Lake Abant (Bolu) to contribute the knowledge of algal flora of Turkey.

4 RESULTS

4.1 Composition of Diatom (Bacillariophyta)

A total of 123 diatoms taxa, belonging to four genera and 11 taxa of Centrales, and 29 genera and 112 taxa of the order Pennales, respectively. Lake Abant (Figure 1. 1) had high diatom diversity during two study years. Descriptive information about each diatom collected includes size range, costae and striae counts for specimens. Measurements from taxonomic books are given in brackets. All measurements were done as micrometer (μm) unless otherwise indicated.

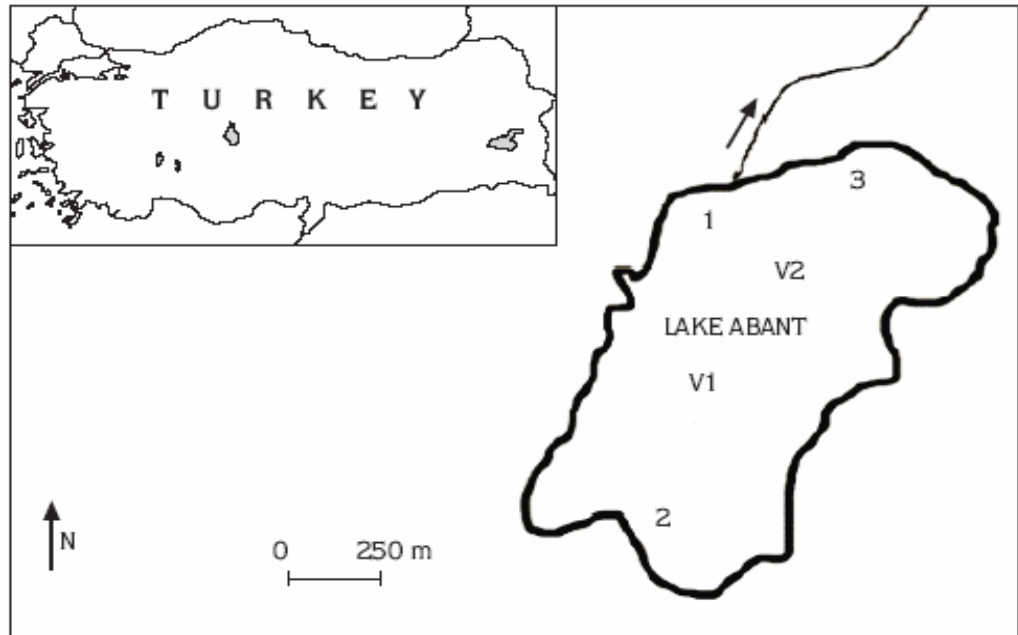


Figure 1. 1. Five sampling stations (two verticals (V1, V2) and three littoral (1-3) are shown in Lake Abant.

4.2 Bacillariophyta

4.2.1 Centrales

Thalassiosiraceae Hasle 1973

Aulacoseira Thwaites 1848

A. granulata (Ehrenberg) Simonsen 1979 (Figure 1. 2. a-b).

Valves 12.5-16 μm (5-24 μm) in length and 7-10 μm (4-30 μm) in diameter, 6 (5-9) puncta 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 16: 1, 2; 17: 1-10; 18: 1-14).

A. islandica (O. Müller) Simonsen 1979.

Valves 15-20 μm (4-21 μm) in length and 7-9 μm (3-28 μm) in diameter, 11-12 (12-18) puncta 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 22:1-12).

Cyclotella (Kützing) Brebisson 1838.

C. bodanica Grunow 1878 (Figure 1. 2. c).

Valves 21-57.5 μm (20-80 μm) in diameter, valves is discoid-shaped (Krammer and Lange-Bertalot, 1991 a, Figure 53: 1-6; 54: 1-4b; 55: 1-7b; 56: 3a-5; 57: 1-5; 58: 1-6; 61: 1-5b).

C. meneghiniana Kützing 1844 (Figure 1. 2. d).

Valves 17.5 μm (10-20 μm) in diameter, valve circular (Krammer and Lange-Bertalot, 1991 a, Figure 44: 1-10).

C. ocellata Pantocsek 1901 (Figure 1. 2. e-f).

Valves 15 μm (6-25 μm) in diameter, the outer of valves is slightly flat circular (Krammer and Lange-Bertalot, 1991 a, Figure 50: 1-11, 13, 14; 51: 1-5).

C. praetermissa Lund 1951 (Figure 1. 2. g).

Valves 15-17.5 μm (8-25 μm) in diameter, valves is discoid-shaped, 12-14 (13-19) striae in 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 60: 7-10).

Ellerbeckia Crawford 1988.

E. arenaria Crawd 1988.

Valves 57.5 μm (38-135 μm) in diameter and 10-12 μm (10-15 μm) in length (Krammer and Lange-Bertalot, 1991 a, Figure 3: 6; 14:1-5; 15:1-5).

Stephanodiscus Ehrenberg 1846

S. alpinus Husted 1942

Valves 14-16 μm (10-32 μm) in diameter, valves is discoid-shaped, 17-18 (18-29) areola in 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 72: 3a-4).

Melosiraceae Kützing 1844

Melosira Agardh 1827

M. dickiei (Thwaites) Kützing 1849.

Valves 8.5 μm (7-10 μm) in length and 11 μm (10-20 μm) in diameter (Krammer and Lange-Bertalot, 1991 a, Figure 9: 1-13).

M. lineata Agardh 1824 (Figure 1. 2. h).

Valves 20 μm (13-23 μm) in length and 25 μm (6-40 μm) in diameter (Krammer and Lange-Bertalot, 1991 a, Figure 7: 1-9).

M. varians Agardh 1827

Valves 12-13 μm (4-14 μm) in length and 10 μm (8-35 μm) in diameter (Krammer and Lange-Bertalot, 1991 a, Figure 3: 8; 4: 1-8).

4.2.2 Pennales

Araphidineae

Fragilariceae Hustedt 1930

Asterionella Hassall 1850

A. formosa Hassall 1850.

Valves 85-115 μm (30-160 μm) in length and 2.5-4.75 μm (1.3-6 μm) in width, 23-26 (24-28) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 103: 1-9; 104: 9, 10).

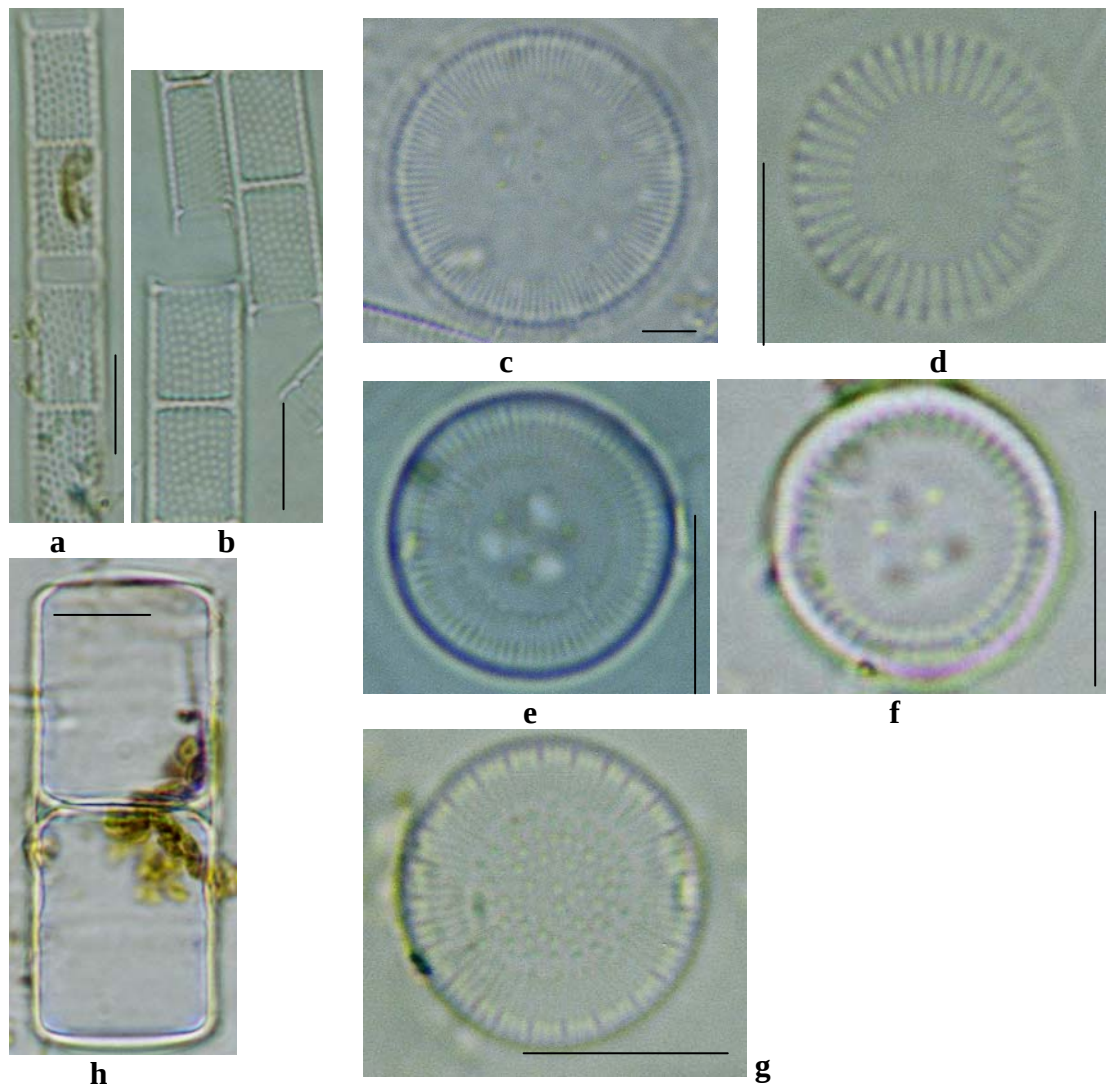


Figure 1. 1. a, b) *Aulacoseria granulata*, c) *Cyclotella bodanica*, d) *C. meneghiniana*, e, f) *C. ocellata*, g) *C. praetermissa*, h) *Melosira lineata* (Scale 10 μm).

Diatoma Borry 1824

D. tenuis Agardh 1812 (Figure 1. 3. a).

Valves 27-74 μm (22-120 μm) in length and 3-4 μm (2-5 μm) in width, 7-8 (6-10) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 96: 1-9, 10).

D. vulgaris Borry 1824 (Figure 1. 3. b).

Valves 32-45 μm (8-75 μm) in length and 12.5-15 μm (7-18 μm) in width, 8 (5-12) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 91: 2, 3; 93: 1-12; 94: 1-13; 95: 1-7; 97: 3-5).

Fragilaria Lyngbye 1819

F. biceps (Kützing) Lange-Bertalot 1991

Valves 292.5-370 μm (160-750 μm) in length and 8 μm (7-10 μm) in width, 7-10 (7-9) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 121: 1-5).

F. brevistriata Grunow 1885.

Valves 12 μm (5-42 μm) in length and 4 μm (3-7 μm) in width, 13 (12-17) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 130. 9-16; 131: 7).

F. capucina Desmazieres 1925 (Figure 1. 3. c).

Valves 25 μm (10-100 μm) in length and 3.75-4.4 μm (2-6.5 μm) in width, 9-11 (9-22) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 108: 1-8).

F. capucina Desmazieres **var. mesolepta** (Rabenhorst) Rabenhorst 1864, (Figure 1. 3. d).

Valves 26 μm (10-100 μm) in length and 4 μm (2-6.5 μm) in width, 12-16 (9-22) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 110: 14-21, 23, 24).

F. capucina Desmazieres **var. vaucheriae** (Kützing) Lange-Bertalot 1980.

Valves 24 μm in length and 4 μm (4-5 μm) in width, 9-10 (9-14) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 108: 10-15).

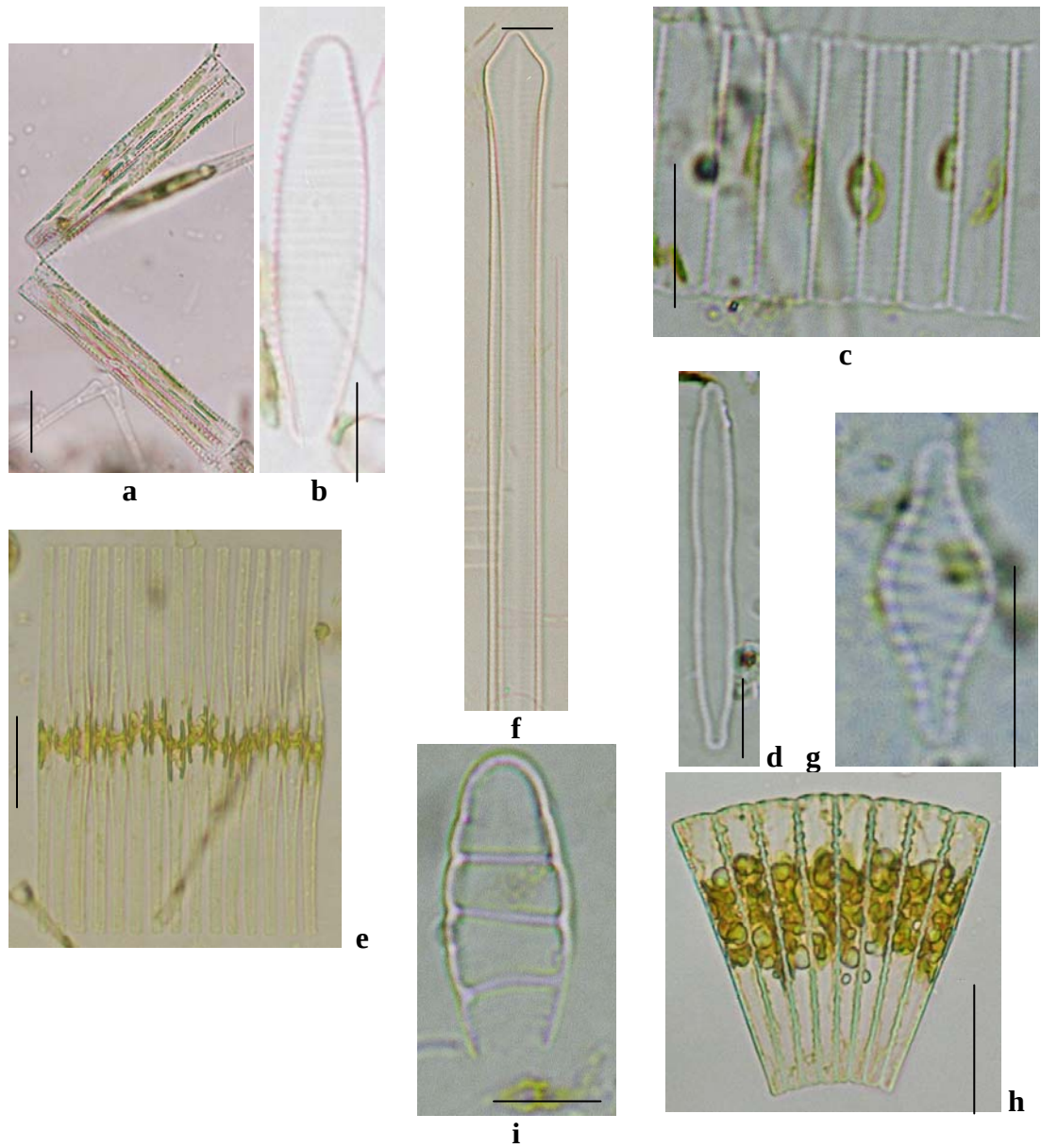


Figure 1. a) *Diatoma tenuis*, b) *Diatoma vulgaris*, c) *Fragilaria capucina*, d) *F. capucina* var. *mesolepta*, e) *F. crotonensis*, f) *F. dilata*, g) *F. pinnata*, h) *Meridion cirquulare*, i) *Tetracyclus rubestris* (Scale 10 μm).

F. construens (Ehrenberg) Grunow 1862.

Valves 17-18 μm (4-35 μm) in length and 4-5 μm (2-12 μm) in width, 13-15 (12-20) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 132: 1- 34; 129: 21-27; 131: 5).

F. crotonensis Kitton 1869 (Figure 1. 3. e).

Valves 31-59 μm (40-170 μm) in length and 3-4 μm (2-5 μm) in width, 16 (15-18) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 116: 1-4).

F. dilata (Brebisson) Lange-Bertalot 1986 (Figure 1. 3. f).

Valves 124-375 μm (120-500 μm) in length and 7.5-8.5 μm (7-10 μm) in width, 7 (6-11) striae 10 μm (Krammer and Lange-Bertalot, 1991 a,, Figure 123: 1-3).

F. lapponica Grunow 1881.

Valves 17-21 μm (10-40 μm) in length and 3.5-4.5 μm (3-6 μm) in width, 7-8 (6-10) striae 10 μm (Krammer and Lange-Bertalot, 1991 a,, Figure 134: 1-8).

F. pinnata Ehrenberg 1843 (Figure 1. 3. g).

Valves 15 μm (3-60 μm) in length and 7 μm (2-8 μm) in width, 7-9 (5-12) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 112: 15, 16; 117: 3; 131: 3, 4).

***Fragilaria* sp.**

Valves 13 μm in length and 3.7-4 μm in width, 15-17 striae 10 μm .

F. ulna (Nitzsch) Lange-Bertalot 1980.

Valves 98-475 μm (27-600 μm) in length and 3-7.5 μm (1.5-9 μm) in width, 8-9 (7-15) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 119-122).

F. ulna (Nitzsch) Lange-Bertalot **var. *danica*** (Kützing) Lange-Bertalot 1980.

Valves 178-210 μm in length and 3.5-4.75 μm in width, 11-12 striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 122: 9).

F. ulna (Nitzsch) Lange-Bertalot **var. *acus*** (Kützing) Lange-Bertalot 1980.

Valves 185-235 μm in length and 3-4 μm in width, 11 striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 122: 9).

F. virescens Ralfs 1843.

Valves 15-23 μm (10-120 μm) in length and 7-8 μm (6-10 μm) in width, 14-15 (13-19) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 119-122).

Meridion Agardh 1824

M. circulare (Greville) C. A. Agardh 1831 (Figure 1. 3 .h).

Valves 32 μm (10-82 μm) in length and 5 μm (4-8 μm) in width, 3 (2-5) costae in 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 100: 1-3; 101:1-14; 102: 1-3).

Tetracyclus Ralfs 1843

T. rupestris (Braun) Grunow 1881 (Figure 1. 3. i).

Valves 23 μm (4-30 μm) in length and 9 μm (3-12 μm) in width, 3 (3-5) costae in 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 89: 8-20).

Raphidineae

Achnanthaceae Kützing 1844

Achnanthes Bory 1822

A. minutissima* var. *minutissima Kützing 1833.

Valves 8-13 μm (5-25 μm) in length and 3-3.5 μm (2.5-4 μm) in width, 24-26 (20-30) striae in 10 μm , (Krammer and Lange-Bertalot, 1991 a, Figure 32: 1-24; 35: 1, 2).

Cocconeis Ehrenberg 1838

C. fluviatilis Wallace.

Valves 17-18 μm (15-34 μm) in length and 9-11 μm (9-19 μm) in width, 15 (16) striae 10 μm in axial area, 11-12 (12) striae 10 μm in margins of valves (Patrick and Reimer, 1966, Figure 15: 11-12).

C. pediculus Ehrenberg 1838 (Figure 1. 4. a).

Valves 17-23 μm (12-54 μm) in length and 15-18 μm (7-37 μm) in width, 18-20 (16-24) striae 10 μm and 21 (18-23) puncta 10 μm (Krammer and Lange-Bertalot, 1991 b, Figure 55: 1-8).

C. placentula Ehrenberg 1838.

Valves 33-37 μm (7.5-98 μm) in length and 17-24 μm (8-40 μm) in width, 16-18 (14-23) striae 10 μm and 17 (15-20) puncta 10 μm (Krammer and Lange-Bertalot, 1991 b, Figure 49: 1-4; 50: 1, 2, 5; 51: 1-9; 52: 1-13; 53: 1-19; 54: 1-12).

C. placentula Ehrenberg **var. *euglypta*** Grunow 1884

Valves 27 μm (10-46 μm) in length and 23-26 μm in width, 19-20 (19-22) striae 10 μm (Krammer and Lange-Bertalot, 1991 b, Figure 49: 3; 50: 1; 53: 1-19).

C. placentula Ehrenberg **var. *lineata*** Grunow 1884 (Figure 1. 4. b).

Valves 28 μm (10-80 μm) in length and 16 μm in width, 18-20 (18-23) striae 10 μm (Krammer and Lange-Bertalot, 1991 b, Figure 49: 1; 50: 1-13).

C. rugosa Sovereing 1960.

Valves 33-37 μm (18-63 μm) in length and 23-26 μm (12-52 μm) in width, 14-15 (14-16) striae 10 μm and 16 (15-20) puncta 10 μm (Patrick and Reimer, 1966, Figure 15: 13-14).

Eunotiaceae Kützing 1844

Eunotia Ehrenberg 1837

E. bilunaris (Ehrenberg) Mills 1934 (Figure 1. 4. c)

Valves 91-110 μm (10-150 μm) in length and 4 μm (1.9-6 μm) in width, 19-24 (11-28) striae in 10 μm , (Krammer and Lange-Bertalot, 1991 a, Figure 137; 138: 10-24).

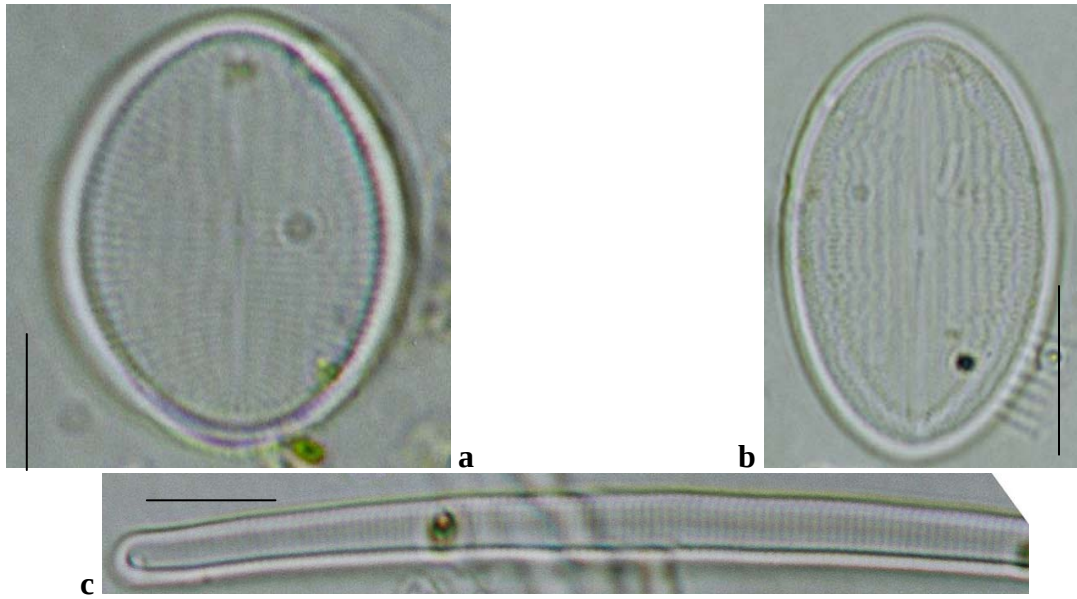


Figure 1. 1. a) *Cocconeis pediculus*, b) *C. placentula* var. *lineata*, c) *Eunotia bilunaris* (Scale 10 μm).

E. paralella Ehrenberg 1843.

Valves 51-123 μm (30-200 μm) in length and 7-11 μm (5-15 μm) in width, 9-10 (8-16) striae in 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 152: 1-7).

Naviculaceae Kützing 1844

Amphora Ehrenberg in Kützing 1844

A. aequalis Krammer 1980.

Valves 21-25 μm (18-37 μm) in length and 4.5-5 μm (4.7-5.5 μm) in width, 15 (15-17) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 150: 18-22; 13:6; 18:2).

A. ovalis (Kützing) Kützing 1844 (Figure 1. 5. a)

Valves 31-42 μm (30-105 μm) in length and 18-21 μm (17-50 μm) in width, 11-12 (10-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 149: 1, 2; 2: 7-9; 7: 7, 8).

Caloneis Cleve 1894

C. alpestris (Grunow) Cleve 1894.

Valves 47-58 μm (45-92 μm) in length and 7-12 μm (6-15 μm) in width, 19-22 (19-24) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 170: 3-7).

C. silicula (Ehrenberg) Cleve 1894.

Valves 45 μm (13-120 μm) in length and 8.7-9 μm (5-20 μm) in width, 16-17 (15-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 172: 1-13; 7: 6; 9: 3).

Cymbella Agardh 1830

C. affinis Kützing 1844 (Figure 1. 5. b).

Valves 47-54 μm (20-70 μm) in length and 8-11 μm (7-16 μm) in width, 8-10 (9-11) mid-dorsal and end 12-13 (12-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 125: 1-22; 10: 1).

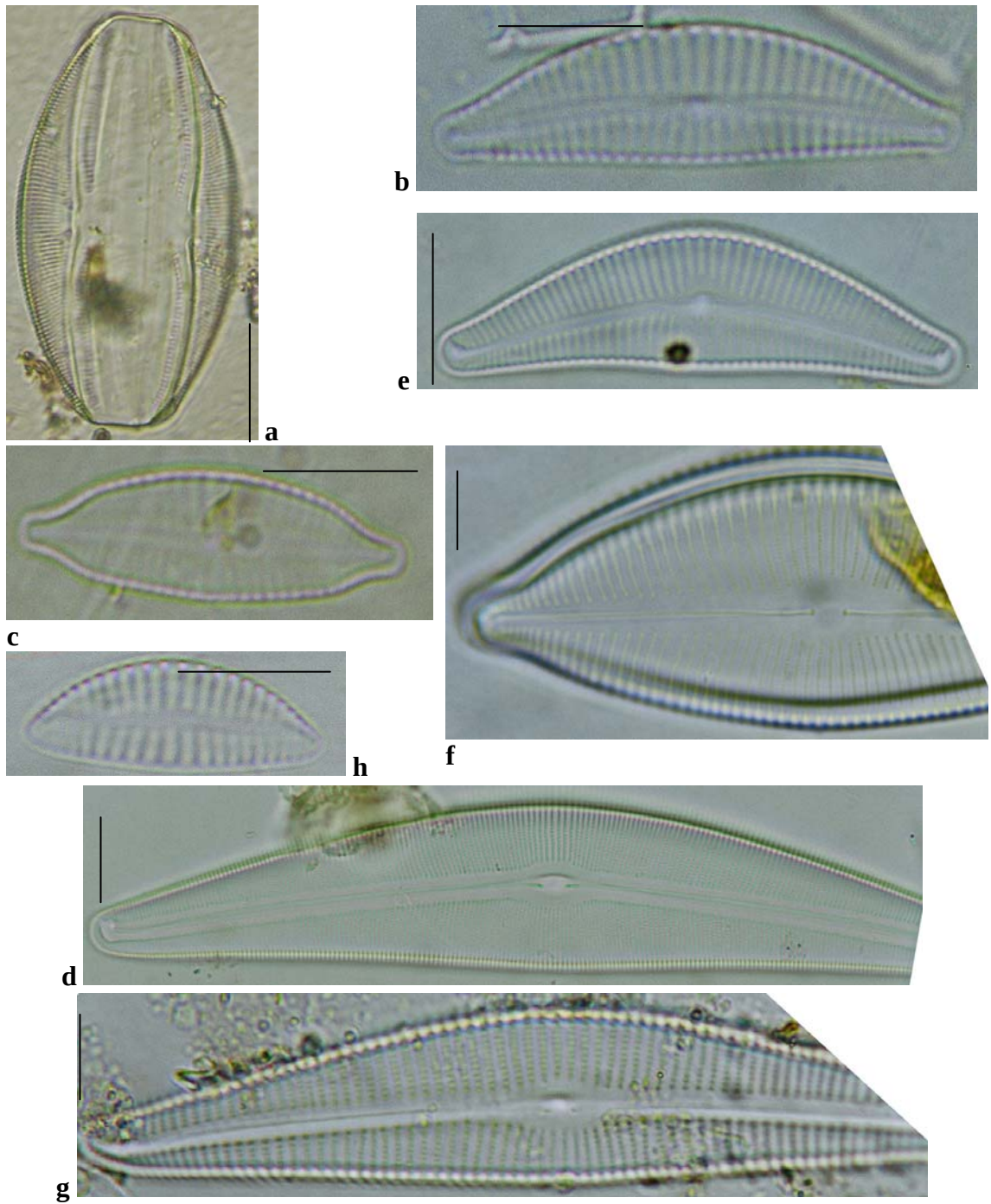


Figure 1. 1. a) *Amphora ovalis*, b) *Cymbella affinis*, c) *C. amphicephala*, d) *C. aspera*, e) *C. cistula*, f) *C. ehrenbergi*, g) *C. helvetica*, h) *C. leptoceros* (Scale 10 μm).

C. amphicephala Naegeli 1849 (Figure 1. 5. c).

Valves 26-28 μm (16-40 μm) in length and 8-9 μm (6-9 μm) in width, 13 (12-15) mid-dorsal and end 19 (17-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 142: 3-21).

C. aspera (Ehrenberg) Peragallo 1849 (Figure 1. 5. d).

Valves 94-135 μm (70-265 μm) in length and 21-25 μm (20-48 μm) in width, 8-9 (7-10) mid-dorsal and end 11 (11-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 131: 1; 7: 1; 8: 2; 11: 5).

C. cistula (Ehrenberg) Kirchner 1878 (Figure 1. 5. e).

Valves 62-100 μm (35-120 μm) in length and 15-17.5 μm (13-25 μm) in width, 8-9 (7-10) mid-dorsal and end 12 (12-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 127: 8-11; 128. 1-6; 10: 5).

C. cuspidata Kützing 1844.

Valves 33-42 μm (28-66 μm) in length and 13-17 μm (14-20 μm) in width, 10-11 (8-12) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 146: 1-4).

C. cymbiformis Agardh 1830.

Valves 33-38 μm (25-95 μm) in length and 13-14 μm (8-15 μm) in width, 9 (8-10) mid-dorsal and end 11 (11-15) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 129: 2-9; 5: 5; 12: 5).

C. ehrenbergii Kützing 1844 (Figure 1. 5. f)

Valves 100-112 μm (50-225 μm) in length and 33.5-36 μm (19-50 μm) in width, 6 (6-9) mid-dorsal and end 10 (10-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 144. 1-6; 8, 4).

C. gracilis (Ehrenberg) Kützing 1844.

Valves 23-28 μm (22-57 μm) in length and 5-6.5 μm (4.5-9 μm) in width, 10-11 (9-14) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 120: 1-16; 12: 3 b; 13: 3).

C. helvetica Kützing 1844 (Figure 1. 5. g).

Valves 70-107 μm (22-170 μm) in length and 11-20 μm (8-27 μm) in width, 9 (8-12) mid-dorsal and end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 132: 2-4; 133: 1-8).

C. leptoceros (Ehrenberg) Kützing 1844 (Figure 1. 5. h).

Valves 17-25 μm (15-60 μm) in length and 8-11 μm (7-13 μm) in width, 9-11 (9-13) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 143: 1-13).

C. lanceolata (Ehrenberg) Kirchner 1878.

Valves 67-97 μm (60-220 μm) in length and 19-23 μm (18-32 μm) in width, 9 (9-10) mid-dorsal and 13-14 (13-16) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 124: 1-8).

C. minuta Hilse ex Rabenhorst 1862.

Valves 17-23 μm (7-32 μm) in length and 4-6.5 μm (3.9-7 μm) in width 11-13 (10.5-15) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999.a, Figure 119: 1-13; 16: 4).

C. proxima Reimer 1975.

Valves 41-68 μm (38-128 μm) in length and 19-24 μm (14-26 μm) in width, 8-9 (7-10) mid-dorsal and 9 (7-14) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 128: 9; 129: 1).

C. silesiaca Bleisch 1864.

Valves 18-23 μm (15-46 μm) in length and 8.5-11 μm (6.5-14.2 μm) in width, 11-12 (10.5-15) mid-dorsal and 15 (14-20) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 117: 1-24).

C. schimanskii Krammer 1982.

Valves 153-162 μm (145-175 μm) in length and 31-32 μm (29-35 μm) in width, 8 (7-8) mid-dorsal and 9-10 (10-11) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 132: 1).

Diploneis Ehrenberg 1844

D. elliptica (Kützing) Cleve 1891 (Figure 1. 6. a).

Valves 34 μm (20-130 μm) in length and 16.5 μm (10-60 μm) in width, 11 (8-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 108: 1-6).

D. pseudovalis Hustedt 1930.

Valves 19-22 μm (16-31 μm) in length and 10-12 μm (9-14 μm) in width, 11 (8-12) striae 10 μm , and 19 (18-22) puncta 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 108: 11-13).

D. puella (Schumann) Cleve 1894.

Valves 15-16 μm (13-25 μm) in length and 8-11 μm (8-14 μm) in width, 13 (13-18) striae 10 μm , and 17 (16-20) puncta 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 109: 15, 16).

Gomphonema Ehrenberg 1832

G. acuminatum Ehrenberg 1832 (Figure 1. 6. b-c).

Valves 30-58 μm (20-120 μm) in length and 5-12.5 μm (5-17 μm) in width, 12 (8-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 160: 1-12).

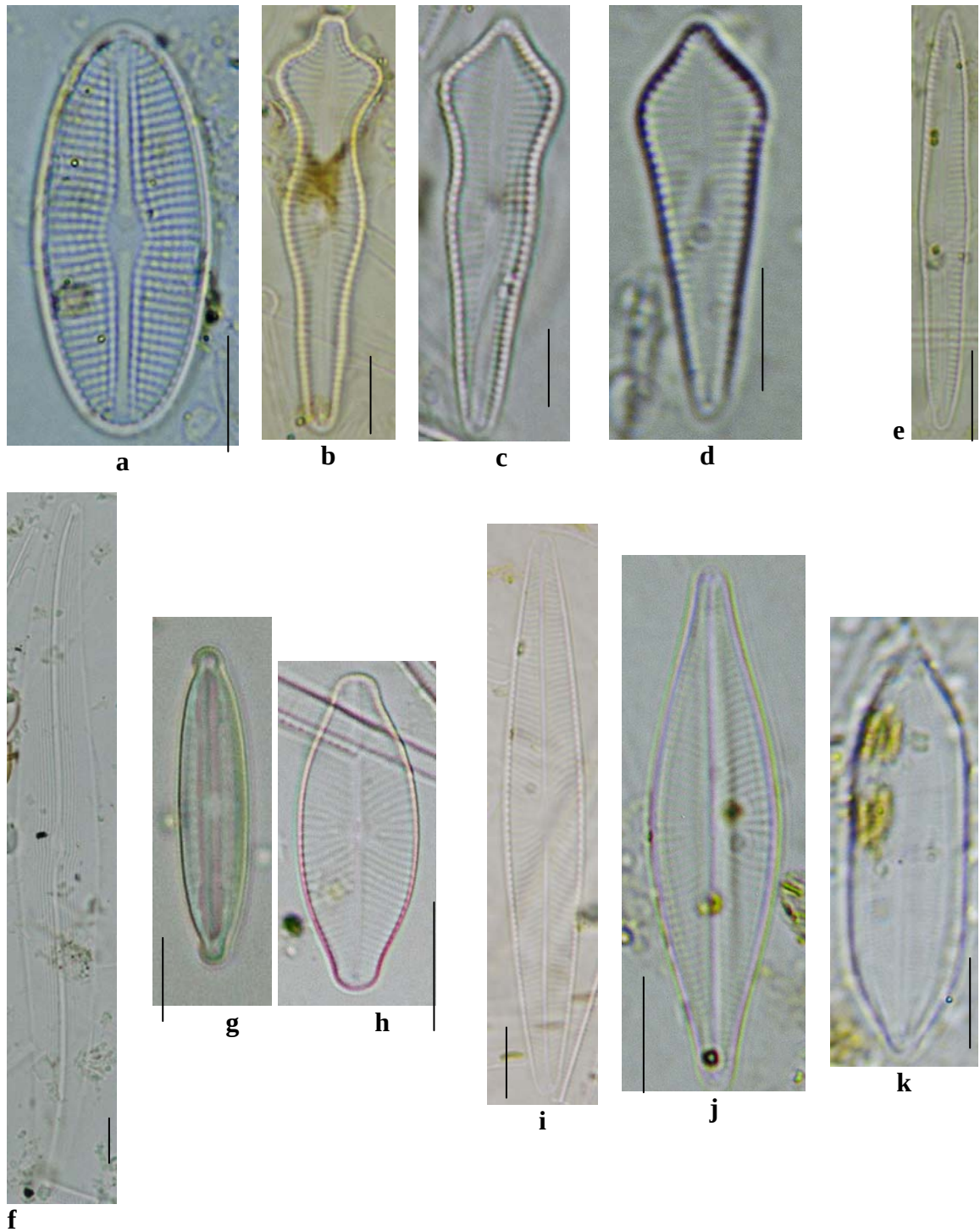


Figure 1. a) *Diploneis elliptica* b-c) *G. acuminatum*, d) *G. augur*, e) *G. hebridense*, f) *Gyrosigma attenuatum*, g) *Mastogloia smithii*, h) *Navicula gastrum*, i) *N. radiosa*, j) *N. trivialis*, k) *Nedium dubium* (Scale 10 μm).

G. angustum Agardh 1831.

Valves 65 µm (12-130 µm) in length and 7 µm (3-12 µm) in width, 7-8 striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 155: 1-21).

G. augur Ehrenberg 1840 (Figure 1. 6. d).

Valves 32 µm (17-130 µm) in length and 8-11 µm (8-20 µm) in width, 8 (7-15) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 157: 1-8; 158: 1-6).

G. clavatum Ehrenberg 1832.

Valves 23-27 µm (20-95 µm) in length and 7-11 µm (6-14 µm) in width, 11-12 (9-15) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 163: 1-12).

G. gracile Ehrenberg 1838.

Valves 37-45 µm (20-100 µm) in length and 4.5-6 µm (4-8 µm) in width, 8-9 (4-11) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 156: 1-11; 154: 26, 27).

G. hebridense Ehrenberg 1832 (Figure 1. 6. e).

Valves 39-48 µm (30-60 µm) in length and 5-7 µm (4-8 µm) in width, 11-12 (10-14) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 156: 12-14).

G. olivaceum (Hornemann) Brebisson 1838.

Valves 18 µm (8-45 µm) in length and 4.5 µm (3.5-13 µm) in width, 10 (9-16) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 165: 1-18).

G. parvulum (Kützing) Kützing 1849.

Valves 16-24 µm (10-36 µm) in length and 4-7 µm (4-8 µm) in width, 8-12 (7-20) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 154: 1-25).

G. subtile Ehrenberg 1843.

Valves 27-32 µm (24-50 µm) in length and 4-6.5 µm (3.5-8 µm) in width, 12 (10-14) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 162: 10-13).

G. truncatum Ehrenberg 1832.

Valves 18-29 μm (13-75 μm) in length and 8-13 μm (7-17 μm) in width, 10 (9-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 159: 11-18).

Gyrosigma Hassall 1843

G. acuminatum (Kützing) Rabenhorst 1853.

Valves 78-148 μm (60-180 μm) in length and 12-16 μm (11-18 μm) in width, 17-18 (16-22) median striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 114: 4, 8).

G. attenuatum (Kützing) Rabenhorst 1853 (Figure 1. 6. f).

Valves 215-260 μm (150-240 μm) in length and 25 μm (23-26 μm) in width, 13-14 (14-16) median striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 114: 5, 7, 9; 4: 5, 6; 15: 3; 16: 2, 6).

Mastogloia Thwaites 1856

M. elliptica (Agardh) Cleve 1893.

Valves 37-48 μm (20-80 μm) in length and 11-14 μm (9-18 μm) in width, 16 (15-18) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 201: 10-14; 202: 1, 2; 20: 1).

M. smithii Thwaites 1856 (Figure 1. 6. g).

Valves 31-42 μm (20-60 μm) in length and 8-10 μm (8-14 μm) in width, 17 (15-20) mid striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 201: 1,6).

Navicula Borry 1822

N. cryptocephala Kützing 1844.

Valves 24-29 μm (20-40 μm) in length and 5-6 μm (5-7 μm) in width, 15-16 (14-17) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 31: 8-14).

N. cuspidata (Kützing) Kützing 1844.

Valves 43-74 μm (30-150 μm) in length and 25-31 μm (13-44 μm) in width, 12 (11-19) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 43: 1-8).

N. gastrum (Ehrenberg) Kützing 1844 (Figure 1. 6. h).

Valves 22-31 μm (20-60 μm) in length and 12-14 μm (10-20 μm) in width, 11 (8-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 49: 4-9).

N. radiosa Kützing 1844 (Figure 1. 6. i).

Valves 72-100 μm (40-120 μm) in length and 11-12 μm (7.5-15 μm) in width, 10-11 (10-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 29: 1-4).

N. reinhardtii (Grunow) Grunow 1877

Valves 47-58 μm (35-70 μm) in length and 14-16 μm (11-18 μm) in width, 8-9 (7-9) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 40: 1, 2).

N. rhynchocephala Kützing 1844.

Valves 46-61 μm (35-80 μm) in length and 11-13 μm (9-14 μm) in width, 10-11 (7-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 30: 5-8; 31: 1, 2).

N. trivialis Lange-Bertalot 1980 (Figure 1. 6. j).

Valves 40-48.5 μm (25-65 μm) in length and 10-12 μm (8-12.5 μm) in width, 11-12 (11-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 35: 1-4).

Nedium Pfitzer 1871

N. dubium (Ehrenberg) Cleve 1894 (Figure 1. 6. k).

Valves 38 μm (30-58 μm) in length and 10 μm (10-16 μm) in width, 18 (16-24) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 99: 1-7).

Pinnularia Ehrenberg 1843

P. divergens Smith 1853.

Valves 84-137 μm (50-160 μm) in length and 17-28 μm (13-30 μm) in width, 9-10 (8-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 179: 3-8).

P. gibba Ehrenberg 1841.

Valves 63-98 μm (50-140 μm) in length and 8-11 μm (7-13 μm) in width, 9-11 (9-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 99: 1-7).

P. interrupta Smith 1853

Valves 48 μm (26-80 μm) in length and 10 μm (6.7-16 μm) in width, 11 (9-15) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 99: 1-7).

P. legumen (Ehrenberg) Ehrenberg 1843.

Valves 72-97 μm (60-130 μm) in length and 17-21 μm (15-23 μm) in width, 8-10 (8-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 184: 1-4).

P. maior (Kützing) Rabenhorst 1853.

Valves 156-245 μm (140-340 μm) in length and 28-37 μm (25-42 μm) in width, 5-6 (5-7) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 196: 1-4; 7: 3-4; 13: 7).

P. microstauron (Ehrenberg) Cleve 1891 (Figure 1. 7. a-b).

Valves 42 μm (20-90 μm) in length and 10 μm (7-11 μm) in width, 10-12 (10-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 191. 7-9).

P. rubestris (Ehrenberg) Smith 1856.

Valves 48-63 μm (40-75 μm) in length and 8-10 μm (7-11 μm) in width, 8-9 (7-11) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 181: 4-10; 18: 4).

P. viridis (Nitzsch) Ehrenberg 1843.

Valves 69-156 μm (50-170 μm) in length and 12-23 μm (10-30 μm) in width, 7-9 (6-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 194: 1-4; 195: 1-6; 2: 4-6).

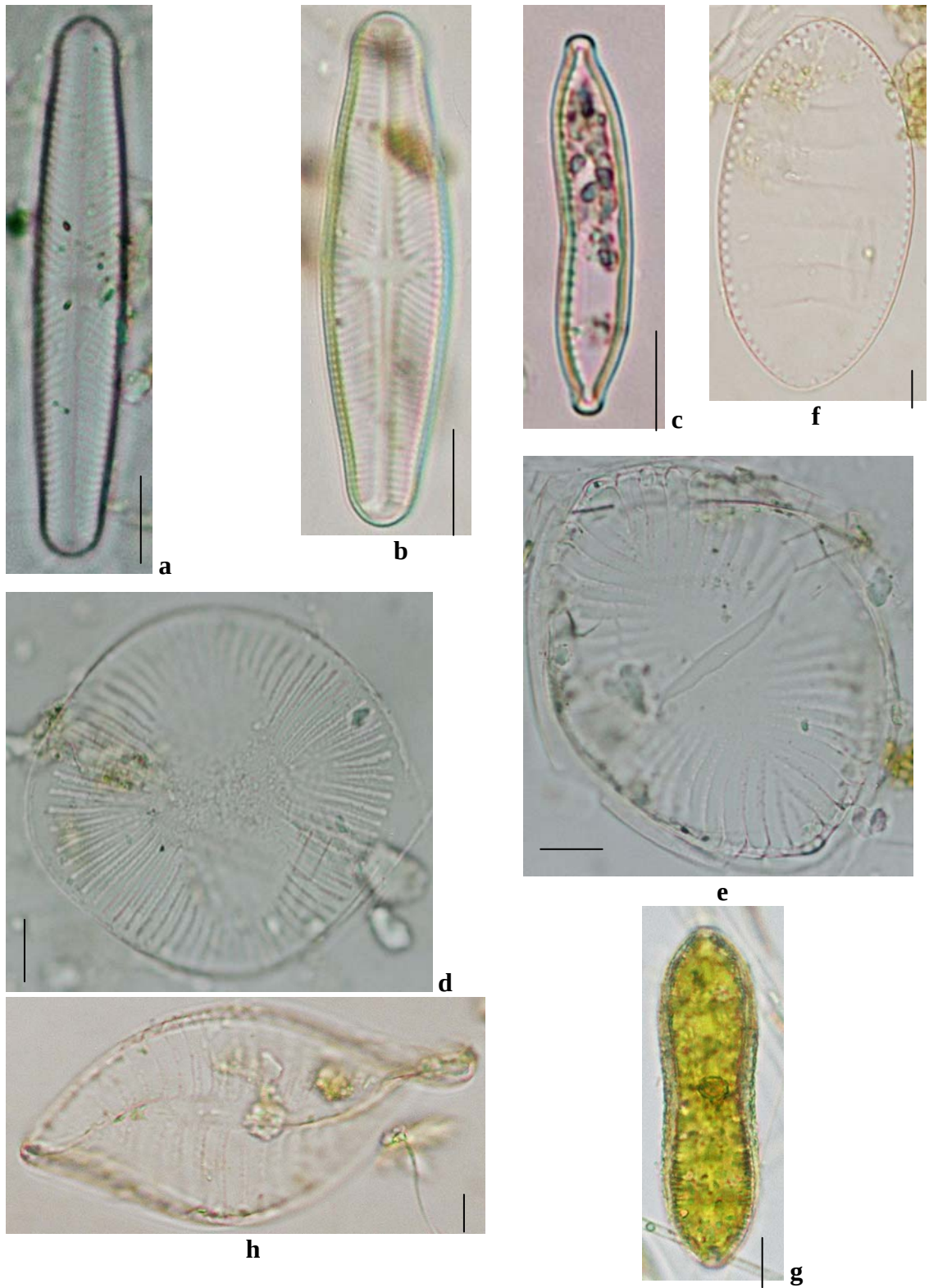


Figure 1. 1. a-b) *Pinnularia microstauron*, c) *Hantzschia amphioxys*, d) *Campylodiscus hibernicus*, e) *C. noricus*, f) *Cymatopleura elliptica*, g) *C. solea* var. *apiculata* h) *Surirella spiralis* (Scale 10 μm).

Rhoicophenia Grunow 1860.

R. abbreviata (Agardh) Lange-Bertalot 1980b.

Valves 22.5 µm (10-75 µm) in length and 7.6 µm (3-8 µm) in width, 16 (15-20) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 91: 20-28).

Stauroneis Ehrenberg 1843

S. anceps Ehrenberg 1843.

Valves 38-98 µm (20-130 µm) in length and 8-16 µm (6-18 µm) in width, 22-24 (20-33) striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 87: 3-9; 88: 1-4).

S. phoenicenteron Ehrenberg 1843

Valves 198-227 µm (70-360 µm) in length and 39-54 µm (16-53 µm) in width, 12 (12-20) mid-dorsal striae 10 µm (Krammer and Lange-Bertalot, 1999 a, Figure 6: 7-8; 8: 3; 15: 2; 18:1-3).

Bacillariaceae Ehrenberg 1840

Hantzschia Grunow 1877

H. amphioxys (Ehrenberg) Grunow 1880 (Figure 1. 7. c).

Valves 49-76 µm (20-300 µm) in length and 7-21 µm (5-25 µm) in width, 11-15 (11-28) striae 10 µm, 8 (4-11) fibula 10 µm (Krammer and Lange-Bertalot, 1999 b, Figure 88: 1-7).

Nitzschia Hassall 1845

N. angustata (Smith) Grunow 1880.

Valves 47-94 µm (20-180 µm) in length and 6.5-9 µm (4-12 µm) in width, 12 (11-18) striae 10 µm (Krammer and Lange-Bertalot, 1999 b, Figure 36: 1-5).

N. palea (Kützing) Smith 1856.

Valves 21-37 µm (15-70 µm) in length and 3-4 µm (2.5-5 µm) in width, 27-29 (28-40) striae 10 µm (Krammer and Lange-Bertalot, 1999 b, Figure 59: 1-24; 60: 1-7).

N. recta Hantzsch 1861.

Valves 49-112 μm (35-130 μm) in length and 4-7 μm (3.5-8 μm) in width, 29 (28-32) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 12: 1-11).

N. sigma (Kützing) Smith 1853.

Valves 57-189 μm (35-1000 μm) in length and 8-23 μm (4-26 μm) in width, 16-18 (15-38) striae 10 μm , 4-6 (3-12) fibula 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 23: 1-9).

N. sigmoidea (Nitzsch) Smith 1853.

Valves 245 μm (90-500 μm) in length and 10 μm (8-15 μm) in width, 23 (21-27) striae 10 μm , 5 (5-7) fibula 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 4: 1, 2; 5: 1-5).

N. vermicularis (Kützing) Hantzsch 1860.

Valves 87-156 μm (75-250 μm) in length and 4-6.5 μm (3.5-7 μm) in width, 29-32 (30-40) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 4: 4, 5; 7: 1-7; 8: 1, 2).

N. wuellerstorffii Lange-Bertalot 1987.

Valves 161-214 μm (140-250 μm) in length and 8 μm (8-8.5 μm) in width, 30 (30-31.5) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 4: 3; 6: 1-6).

Epithemiaceae Karsten 1928

Denticula Kützing 1844

D. elegans Kützing 1844

Valves 24-28 μm (15-45 μm) in length and 4-6 μm (4-8 μm) in width, 16 (15-18) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 94: 1, 2; 96: 10-33; 97: 1-5).

Epithemia Brebisson 1844

E. argus (Ehrenberg) Kützing 1844.

Valves 27-39 μm (20-130 μm) in length and 6-9 μm (4-18 μm) in width, 9-11 (8-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 102: 1-9; 103: 1-5).

E. adnata (Kützinger) Brebisson 1838.

Valves 57.5-117.5 μm (15-150 μm) in length and 7.5-14 μm (7-14 μm) in width, 9-11 (11-14) striae 10 μm , 48 (20-80) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 107: 1-11; 108: 1-3).

E. goeppertiana Hilse 1860.

Valves 43-76 μm (40-120 μm) in length and 13-15 μm (12-18 μm) in width, 10 (10-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 103: 6-9).

E. sorex Kützinger 1844.

Valves 27,5-31 μm (8-70 μm) in length and 7,5-16 μm (6,5-16 μm) in width, 11 (10-15) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 106. 1-14).

E. turgida (Ehrenberg) Kützinger 1844

Valves 170 μm (45-200 μm) in length and 20 μm (13-35 μm) in width, 7 (7-9) striae 10 μm , 35 (30-50) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 108: 4-8; 109: 1-7).

Rhopalodia Müller 1895

R. gibba Müller 1895.

Valves 92.5-245 μm (22-300 μm) in length and 25 μm (18-30 μm) in width, 54 (50-80) fibula 100 μm , and 12 (12-17) inter fibula 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 110: 1; 111: 1-13; 111A: 1-7).

Surirellaceae Kützinger 1844

Campylodiscus Ehrenberg 1840

C. hibernicus Ehrenberg 1845 (Figure 1 7. d).

Valves 55-57 μm (25-150 μm) in diameter, 12 (10-20) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 175: 5; 179: 1-4; 180: 1-7; 181: 1-3)

C. noricus Ehrenberg 1840 (Figure 1. 7. e).

Valves 62-113 μm (60-150 μm) in diameter, 23-25 (20-30) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 182: 1-5)

Cymatopleura Smith 1851

C. elliptica Smith 1851 (Figure 1. 7. f).

Valves 82.5-90 μm (60-280 μm) in length and 42.5-47.5 μm (30-90 μm) in width, 4 (2.5-6) fibula 10 μm , 15-17 (15-20) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 119: 1-4; 120: 1-6; 121: 1-3; 122: 3).

C. solea Smith 1851

Valves 87 μm (30-300 μm) in length and 22.5 μm (10-45 μm) in width, 6 (6-9) fibula 10 μm , 26-28 (25-32) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 116:1- 4; 117: 1-5; 118: 1-8; 122: 4).

C. solea W. Smith **var. *apiculata*** Ralfs 1861 (Figure 1. 7. g).

Valves 67.5 μm in length and 16 μm in width, 5-6 fibula 10 μm , 23-27 (25-32) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 118: 2, 4-8).

Stenopterobia Brebisson 1878

S. curvula (Smith) Krammer 1987.

Valves 110 μm (70-280 μm) in length and 6.5 μm (6-9 μm) in width, 34 (30-60) fibula 100 μm , 22 (22-24) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 170: 1, 2; 171: 5-9; 172: 1-3).

Surirella Turpin 1828

S. angusta Kützing 1844.

Valves 21-41 μm (18-70 μm) in length and 7-13 μm (6-15 μm) in width, 1:3-1:4 (1:3-1:5) length:width ratio, 21-24 (20-28) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 133: 6-13; 134: 1, 6-10).

S. biseriata Brebisson 1836.

Valves 87-317 μm (80-400 μm) in length and 33-79 μm (30-90 μm) in width, 14 (10-20) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 141: 1-3; 142: 1-5; 143: 1-9; 144: 1-3; 145: 1).

S. ovalis Brebisson 1838.

Valves 27-53 μm (16-120 μm) in length and 15-36 μm (12-45 μm) in width, 1:1.5-1:3 (1:3-1:1) length: width ratio, 17 (16-19) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 125: 1-7; 126: 1).

S. robusta Ehrenberg 1841.

Valves 178-359 μm (150-400 μm) in length and 67-114 μm (50-150 μm) in width, 7-8 (7-12) canal 100 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 156: 1-5; 157: 1-4).

S. spiralis Kützing 1844 (Figure 1. 7. h).

Valves 91-126 μm (40-220 μm) in length and 58-64 μm (50-80 μm) in width, 24-25 (25) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 168: 1-7).

S. subsalsa Smith 1853.

Valves 17-24 μm (15-48 μm) in length and 9-11 μm (8-16 μm) in width, 10-11 (10-13) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 128: 1-10).

***Surirella* sp.**

Valves 37-52 μm in length and 16-24 μm in width, 15-17 striae 10 μm .

5 DISCUSSION

During the present study, a total of 123 diatom taxa were identified from Lake Abant. Eleven taxa with five genera in Centrales, and 112 taxa with 29 genera in the order Pennales were described. The diatom composition of the lake was especially dominated with Naviculaceae at about 45 % of abundance, including 55 taxa in 12 genera. In a recent study continued about ten months in Lake Abant, Obalı and colleagues (2002) reported 83 algae taxa, of which only 34 belonged to Bacillariophyceae. In contrast, our study continued for two years reports much higher numbers of diatom species than this one. Such difference is possibly because of different sampling time and different numbers of stations sampled. These differences affected the results. Indeed, these authors reported some genera in lower taxa such as 5, 4, and 3 taxa belonging to *Navicula*, *Cymbella*, and *Gomphonema*, respectively. In the present study, however, *Navicula* had 7 taxa, *Cymbella* 14, and *Gomphonema* included 10 taxa. Besides, *Fragilaria* and *Pinnularia* had also 15 and 9 taxa. In the average, 53 taxa occurred per month during our study. Numbers of species were increased in some months (e.g., November (83 taxa), December (68 taxa)) from 2003 to (e.g., August (65 taxa), September (76 taxa)) the second year 2004. In addition, the lowest number of species was detected in September 2003 with 33 taxa. These results clearly show the importance of long-term monthly (or even weekly) sampling.

Most of the members of Bacillariophyceae collected from Lake Abant have wide distribution that they were already reported in those of earlier studies from different parts of Turkey (Gönüloğlu et al., 1996). For example, some species including *Asterionella formosa*, *Cymbella silesiaca*, *C. cistula*, *Fragilaria biceps*, *F. dilata*, *Navicula radiosa*, and *Rhopalodia gibba* were reported in almost each month from

each station. These diatoms are already known to be commonly distributed in different part of Turkey. However, some species such as *Cyclotella praetermisa*, *Stephanodiscus alpinus*, *Tetracyclus rupestris*, *Navicula gastrum*, and *Cymatopleura solea* var. *apiculata* found in Lake Abant were rarely distributed in aquatic ecosystem of Turkey (Gönülol et al., 1996). One of the critical similarities among the previous reports and the results of the present study is that most of the diatoms described are known to prefer nutrient rich environments (Patrick and Reimer, 1966, 1975; Krammer and Lange-Bertalot, 1991 a, b, 1999 a, b). This may suggest changes in water quality of Lake Abant.

A. formosa, which was the most common diatom in Lake Abant during spring season (especially in April 2004 and 2005) has been reported as dominant species in mesotrophic lakes even in eutrophic lakes (Nygaard, 1949; Round, 1981). This species is not only commonly distributed in European lakes, but also generally found in almost all types of water bodies such as lakes, marshes, and ponds (Çetin and Şen, 1998; Gönülol and Obalı, 1998; Obalı et al., 2002; Akbulut, 2003). As Horne and Goldman (1994) and Wetzel (1975) already reported that *Asterionella* is common diatom in spring bloom of temperate lakes through out the world. Besides, in a current study, Çelekli and Külköylüoğlu (2006) stated that *A. formosa* was dominant from April to May 2004 when phosphate concentrations of the spring water were also maximized in a karstic spring called Akkaya Spring (Bolu, Turkey). Similarly, Hutchinson (1967) stated that in productive lakes, *Melosira* can be abundant species in winter, and following *Asterionella*, reached to a high level during spring season. In our study, *Aulacoseria granulata* was commonly encountered except a few months of summer season. The genus, *Fragilaria* was consisted 15 taxa. Some of them such as *Fragilaria biceps*, *F. dilata*, and *F. pinnata* were identified in almost each month

from each station. These taxa were followed by *F. crotonensis* which was observed sometimes in some months of fall season. Many species of *A. formosa*, and as well as *F. crotonensis* and *Melosira granulata* were characterized as eutrophic diatom plankton. Considering that these taxa have wide ranges of tolerance to environmental changes, they can also be found from oligotrophic to eutrophic conditions (Hutchinson, 1967; Wetzel, 1975; Round, 1981).

Many member of *Fragilaria* (the most common genus in the present study) were distributed in all sampling stations during the study period. Many species of this genus were commonly found in different parts of Turkey (Gönülol et al., 1996). Similar to *Asterionella* species, many species of *Fragilaria* also prefer nutrient rich environment, so that they can be found especially in meso-eutrophic characteristics of water (Hutchinson, 1967; Round, 1981). Obalı and colleagues (2002) underlined that some species identified previously from Lake Abant with mesotrophic characteristics were indicator species of polluted water. This finding was also supported in the present study.

Some species of *Navicula* such as *N. radiosa* and *N. trivialis* were also reported from different lakes with special ecological characteristic in Turkey (Gönülol et al., 1996). Similarly, these taxa were commonly found in Lake Abant. *Navicula cryptocephala* and *Fragilaria ulna*, which were moderately found in Lake Abant, are known to have a broad distribution in Turkey (Gönülol et al., 1996) and European (Kitner and Poulickova, 2003).

The genus *Gomphonema* was represented with 10 taxa in Lake Abant, among which *G. acuminatun*, *G. truncatum*, and *G. gracile* were common species in almost all stations. Patrick and Reimer (1975) stated that *G. acuminatun* and *G. truncatum* were found from oligotrophic to mesotrophic waters. The two genera *Gomphonema*

and *Nitzschia* distributed commonly in temperate lakes have wide tolerances to organic pollution (Round, 1981). *Nitzschia* with seven taxa consists of an important part of diatom composition of Lake Abant. Some species such as *N. sigmoidae* and *N. vermicularis* were identified in the some months. Round (1981) reported that members of this genus generally prefer rich organic environment and high alkalinity waters. Overall, results of this study indicate that there are some kinds of changes in water quality of Lake Abant that was reflected from the diatom composition during our study.

Part B

ABSTRACT

NET DIATOM (BACILLARIOPHYTA) COMPOSITION OF LAKE GÖLKÖY (BOLU)

The diatom composition of Lake Gököy was studied monthly during two years (June 2003-June 2005) from 3 littoral and 2 vertical stations in Lake Gököy (Bolu-Turkey). A total of 119 diatom taxa were identified, most of them belong to Naviculaceae (48.7 %) Kützing, Fragilariceae (16.8 %) Hustedt, Surirellaceae (11.8 %) Kützing, and Bacillariaceae (6.7 %) Ehrenberg, where many species (*Asterionella formosa* Hassall, *Aulacoseria granulata* (Ehrenberg) Simonsen, *Cyclotella praetermis* Lund, *Cymbella cistula* Kirchner, *Fragilaria biceps* (Kützing) Lange-Bertalot, *F. crotonensis* Kitton, *F. dilata* (Brebisson) Lange-Bertalot, *Navicula radiosa* Kützing, and *Nitzschia sigmoidae* (Nitzsch) Smith) were found each month from all stations. Species richness was especially high in the fall (November-December 2003 and September-October 2004) during study periods.

Key words: Lake Gököy, Diatom, Taxonomy, Species diversity

ÖZET

GÖLKÖY GÖLÜ NET DİYATOME (BACILLARIOPHYTA) KOMPOSİZYONU

Gököy Gölü diyatome kompozisyonu üç kıyısız ve iki vertikal istasyonda aylık olarak iki yıl boyunca (Haziran 2003-Haziran 2005) çalışılmıştır. Naviculaceae (% 48,7) Kützing, Fragilariceae (% 16,8) Hustedt, Surirellaceae (% 11,8) Kützing, ve Bacillariaceae (% 6,7) sınıflarına ait toplam 119 diyatomenin tanımlandığı yerde birçok tür (*Asterionella formosa* Hassall, *Aulacoseria granulata* (Ehrenberg) Simonsen, *Cyclotella praetermis* Lund, *Cymbella cistula* Kirchner, *Fragilaria biceps* (Kützing) Lange-Bertalot, *F. crotonensis* Kitton, *F. dilata* (Brebisson) Lange-Bertalot, *Navicula radiosa* Kützing, ve *Nitzschia sigmoidae* (Nitzsch) Smith) bütün istasyonlardan her ay bütün istasyonlarda bulunmuştur. Çalışma süresince, tür zenginliği özellikle sonbahar aylarında (Kasım-Aralık 2003 ve Eylül-Ekim 2004) artmıştır.

Anahtar Kelimeler: Gököy Gölü, Diatom, Taksonomi, Tür Çeşitliği

6 INTRODUCTION

In the region of Bolu, a few earlier studies focused on some of the certain groups of animals such as ostracods (Klkylođlu and Dgel, 2004; Klkylođlu, 2005), orthopters (nal, 1997), and plants (Davis et al. 1988) although the area is known with its variety of different habitats. All these studies increased our understanding on the species diversity of the area, but little attention has been given to phytoplankton, especially diatoms. Previous studies on this taxonomic group were done in some of the certain areas including Lake Abant (Obalı et al., 2002; elekli and Klkylođlu (in press)), Lake Yedigller (Atıcı and Obalı 2002), Lake Yeniađa (Kılın 2003) and Akkaya Spring (elekli and Klkylođlu (2006)). Until the present study, nothing was known about the diatoms of Lake Glky, which is one of the largest dam lakes in the city Bolu. The present study aimed to investigate diatom species composition and their seasonal occurrences in Lake Glky during two years.

7 RESULTS

7.1 Composition of Diatom (Bacillariophyta) of Lake Gök  y

A total of 119 diatoms taxa were identified, belonging to 4 genus and 10 taxa and 29 genus and 109 taxa Centrales and Pennales orders respectively. Lake G  lk  y (Figure 2.1) had high diatom diversity during two study years.

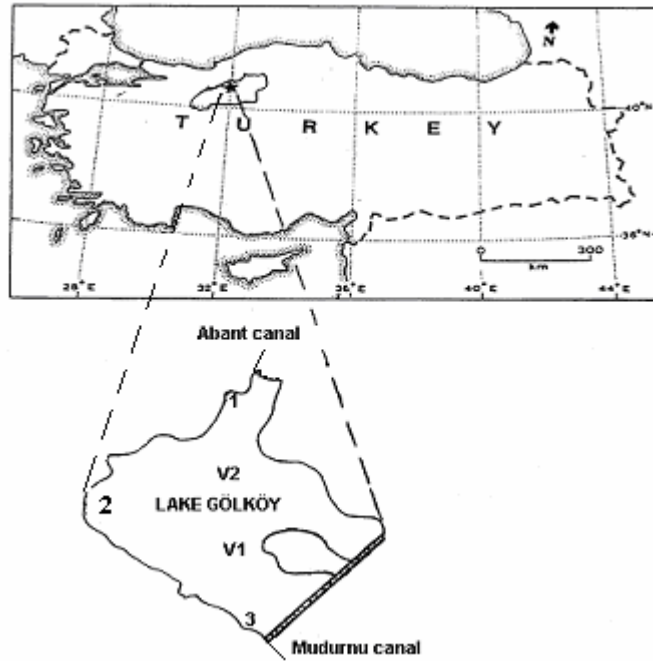


Figure 2. 1. Map of Lake G  lk  y and location of the sampling stations.

7.2 Bacillariophyta

7.2.1 Centrales

Thalassiosiraceae Hasle 1973

Aulacoseria Thwaites 1848

A. granulata (Ehrenberg) Simonsen 1979, (Figure 2. 2. a).

Valves 11-16 μm (5-24 μm) in length and 7-12 μm (4-30 μm) in diameter, 5-6 (5-9) puncta 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 16: 1, 2; 17: 1-10; 18: 1-14).

A. islandica (O. M  ller) Simonsen 1979.

Valves 15-20 μm (4-21 μm) in length and 7-10 μm (3-28 μm) in diameter, 11-12 (12-18) puncta 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 22: 1-12).

Cyclotella (Kützing) Brebisson 1838.

C. bodanica Grunow 1878

Valves 21-62 μm (20-80 μm) in diameter, valves is discoid-shaped (Krammer and Lange-Bertalot, 1991 a, Figure 53: 1-6; 54: 1-4b; 55: 1-7b; 56: 3a-5; 57: 1-5; 58: 1-6; 61: 1-5b).

C. meneghiniana Kützing 1844

Valves 17-19 μm (10-20 μm) in diameter, valve circular (Krammer and Lange-Bertalot, 1991 a, Figure 44: 1-10).

C. ocellata Pantocsek 1901, (Figure 2. 2. b).

Valves 14-17 μm (6-25 μm) in diameter, the outer of valves is slightly flat circular (Krammer and Lange-Bertalot, 1991 a, Figure 50: 1-11, 13, 14; 51: 1-5).

C. praeternisa Lund 1951, (Figure 2. 2. c).

Valves 16-20 μm (8-25 μm) in diameter, valves is discoid-shaped, 12-13 (13-19) striae in 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 60: 7-10).

Stephanodiscus Ehrenberg 1846

***Stephanodiscus* sp.**

Valves 11-14 μm in diameter, valves is discoid-shaped, 14-16 areole in 10 μm .

Melosiraceae Kützing 1844

Melosira Agardh 1827

M. dickiei (Thwaites) Kützing 1849.

Valves 8.5-9 μm (7-10 μm) in length and 11-12 μm (10-20 μm) in diameter (Krammer and Lange-Bertalot, 1991 a, Figure 9: 1-13).

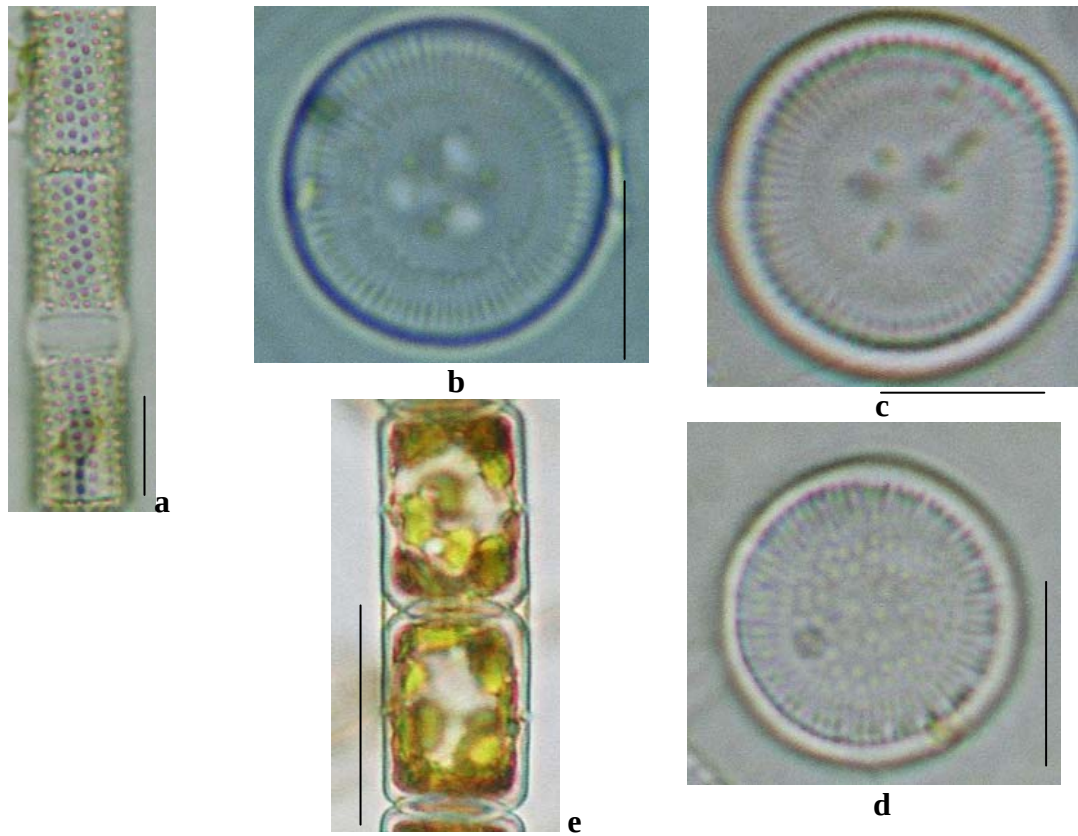


Figure 2. 1. a) *Aulacoseria granulata*, b-c) *Cyclotella ocellata*, d) *C. praetermisa*, e) *Melosira varians* (Scale 10 μm).

M. lineata Agardh 1824

Valves 19-22 μm (13-23 μm) in length and 24-26 μm (6-40 μm) in diameter (Krammer and Lange-Bertalot, 1991 a, Figure 7: 1-9).

M. varians Agardh 1827

Valves 11-13 μm (4-14 μm) in length and 10-12 μm (8-35 μm) in diameter (Krammer and Lange-Bertalot, 1991 a, Figure 3: 8; 4: 1-8).

7.2.2 Pennales

Araphidineae

Fragilariceae Hustedt 1930

Asterionella Hassall 1850

A. formosa Hassall 1850

Valves 74-119 μm (30-160 μm) in length and 2.5-5 μm (1.3-6 μm) in width, 23-25 (24-28) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 103: 1-9; 104: 9, 10).

Diatoma Borry 1824

D. anceps Agardh 1812

Valves 21-35 μm (12-85 μm) in length and 5-6 μm (4-7 μm) in width, 17-18 (18-20) striae 10 μm (Krammer and Lange-Bertalot, 1991a Figure 102: 4-10).

D. tenuis Agardh 1812, (Figure 2. 3. a).

Valves 28-81 μm (22-120 μm) in length and 3-4 μm (2-5 μm) in width, 7-8 (6-10) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 96: 1-9, 10).

D. vulgaris Borry 1824

Valves 30-57 μm (8-75 μm) in length and 12.5-16 μm (7-18 μm) in width, 8 (5-12) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 91: 2, 3; 93: 1-12; 94: 1-13; 95: 1-7; 97: 3-5).

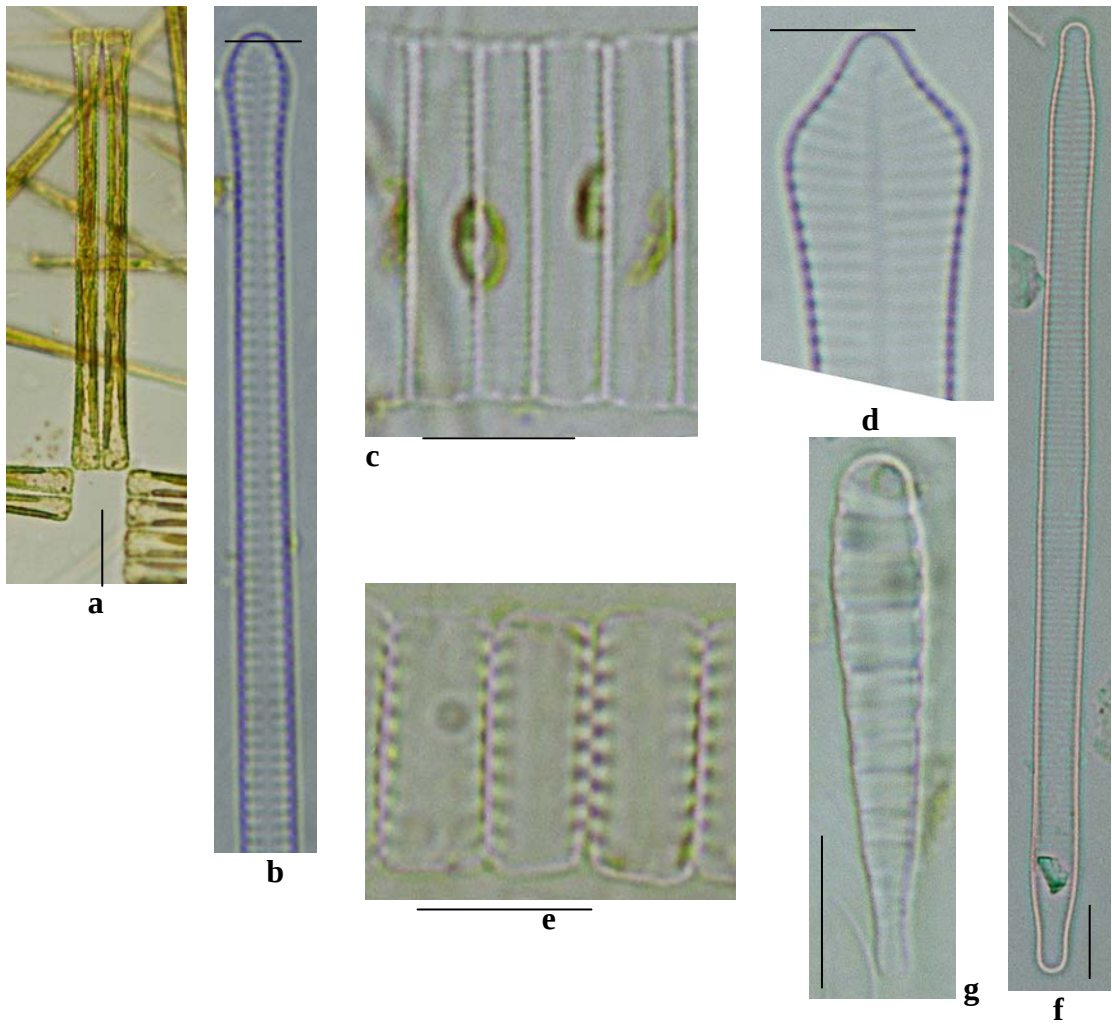


Figure 2. 1. a) *Diatoma tenuis*, b) *Fragilaria biceps*, c) *F. capucina*, d) *F. dilata*, e) *F. pinnata*, f) *F. ulna*, g) *Meridion cirquulare* (Scale 10 μm).

Fragilaria Lyngbye 1819

F. biceps (Kützing) Lange-Bertalot 1991, (Figure 2. 3. b)

Valves 287-382 μm (160-750 μm) in length and 8-9 μm (7-10 μm) in width, 7-10 (7-9) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 121: 1-5).

F. capucina Desmazières 1925, (Figure 2. 3. c)

Valves 25-32 μm (10-100 μm) in length and 3.75-4 μm (2-6.5 μm) in width, 9-11 (9-22) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 108: 1-8).

F. capucina Desmazières **var. mesolepta** (Rabenhorst) Rabenhorst 1864

Valves 22-33 μm (10-100 μm) in length and 4-4.5 μm (2-6.5 μm) in width, 12-15 (9-22) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 110: 14-21, 23, 24).

F. capucina Desmazières **var. vaucheriae** (Kützing) Lange-Bertalot 1980.

Valves 25-28 μm in length and 4 μm (4-5 μm) in width, 9-10 (9-14) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 108: 10-15).

F. construens (Ehrenberg) Grunow 1862.

Valves 17-19 μm (4-35 μm) in length and 4-5 μm (2-12 μm) in width, 13-14 (12-20) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 132: 1-34; 129: 21-27; 131: 5, 6).

F. crotonensis Kitton 1869

Valves 31-84 μm (40-170 μm) in length and 3-4 μm (2-5 μm) in width, 16 (15-18) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 116: 1-4).

F. dilata (Brebisson) Lange-Bertalot 1986, (Figure 2. 3. d)

Valves 124-383 μm (120-500 μm) in length and 7.5-9 μm (7-10 μm) in width, 7 (6-11) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 123: 1-3).

F. lapponica Grunow 1881.

Valves 17-21 μm (10-40 μm) in length and 3.5-5 μm (3-6 μm) in width, 7-8 (6-10) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 134: 1-8).

Fragilaria leptostauron Husted **var. *martyi*** Lange-Bertalot 1991.

Valves 17-31 μm (15-36 μm) in length and 12-15 μm (10-23 μm) in width, 7-8 (5-11) striae 10 μm (Krammer and Lange-Bertalot, 1991a Figure 133: 28-31).

F. pinnata Ehrenberg 1843, (Figure 2. 3. e)

Valves 15-17 μm (3-60 μm) in length and 5-7 μm (2-8 μm) in width, 7-9 (5-12) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 112: 15, 16; 117: 3; 131: 3, 4).

F. ulna (Nitzsch) Lange-Bertalot 1980, (Figure 2. 3. f)

Valves 93-487 μm (27-600 μm) in length and 3-7.5 μm (1.5-9 μm) in width, 8-9 (7-15) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 119-122).

F. ulna (Nitzsch) Lange-Bertalot **var. *danica*** (Kützing) Lange-Bertalot 1980.

Valves 168-232 μm in length and 3.5-4.75 μm in width, 11-12 striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 122: 9).

F. ulna (Nitzsch) Lange-Bertalot **var. *acus*** (Kützing) Lange-Bertalot 1980.

Valves 185-232 μm in length and 3-4 μm in width, 11 striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 122: 9).

F. virescens Ralfs 1843.

Valves 15-32 μm (10-120 μm) in length and 7-8 μm (6-10 μm) in width, 14-15 (13-19) striae 10 μm (Krammer and Lange-Bertalot, 1991 a, Figure 119-122).

Meridion Agardh 1824

M. circulare (Greville) C. A. Agardh 1831, (Figure 2. 3. g)

Valves 27-35 μm (10-82 μm) in length and 5 μm (4-8 μm) in width, 3 (2-5) costae in 10 μm , (Krammer and Lange-Bertalot, 1991 a, Figure 100: 1-3; 101:1-14; 102: 1-3).

Tetracyclus Ralfs 1843

T. rupestris (Braun) Grunow 1881

Valves 23-25 μm (4-30 μm) in length and 9-10 μm (3-12 μm) in width, 3 (3-5) costae in 10 μm , (Krammer and Lange-Bertalot, 1991 a, Figure 89: 8-20).

Raphidineae

Achnanthaceae Kützing 1844

Achnanthes Bory 1822

A. minutissima* var. *minutissima Kützing 1833

Valves 8-13 μm (5-25 μm) in length and 3-3.5 μm (2.5-4 μm) in width, 24-26 (20-30) striae in 10 μm , (Krammer and Lange-Bertalot, 1991 a, Figure 32: 1-24; 35: 1, 2).

Cocconeis Ehrenberg 1838

C. pediculus Ehrenberg 1838

Valves 17-29 μm (12-54 μm) in length and 15-18 μm (7-37 μm) in width, 18-20 (16-24) striae 10 μm and 21 (18-23) puncta 10 μm (Krammer and Lange-Bertalot, 1991 b,, Figure 55: 1-8).

C. placentula Ehrenberg 1838

Valves 33-46 μm (7.5-98 μm) in length and 18-34 μm (8-40 μm) in width, 16-18 (14-23) striae 10 μm and 17 (15-20) puncta 10 μm (Krammer and Lange-Bertalot, 1991 b,, Figure 49: 1-4; 50: 1, 2, 5; 51: 1-9; 52: 1-13; 53: 1-19; 54: 1-12).

C. placentula* Ehrenberg var. *lineata Grunow 1884

Valves 28-49 μm (10-80 μm) in length and 16-17 μm in width, 18-20 (18-23) striae 10 μm (Krammer and Lange-Bertalot, 1991 b, Figure 49: 1; 50: 1-13).

C. rugosa Sovereing 1960

Valves 33-38 μm (18-63 μm) in length and 23-25 μm (12-52 μm) in width, 14-15 (14-16) striae 10 μm and 16 (15-20) puncta 10 μm (Patrick and Reimer, 1966, Figure 15: 13-14).

Eunotiaceae Kützing 1844

Eunotia Ehrenberg 1837

E. bilunaris (Ehrenberg) Mills 1934

Valves 91-119 μm (10-150 μm) in length and 4 μm (1.9-6 μm) in width, 19-24 (11-28) striae in 10 μm , (Krammer and Lange-Bertalot, 1991 a, Figure 137; 138: 10-24).

Naviculaceae Kützing 1844

Amphora Ehrenberg in Kützing 1844

A. aequalis Krammer 1980.

Valves 21-29 μm (18-37 μm) in length and 4.5-5 μm (4.7-5.5 μm) in width, 15 (15-17) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 150: 18-22; 13:6; 18: 2).

A. ovalis (Kützing) Kützing 1844, (Figure 2. 4. a).

Valves 29-48 μm (30-105 μm) in length and 18-21 μm (17-50 μm) in width, 11-12 (10-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 149: 1, 2; 2: 7-9; 7: 7, 8).

Anomoeoneis Pfitzer 1871.

A. sphaerohora (Ehrenberg) Pfitzer 1871 (Figure 2. 4. b).

Valves 58-106 μm (25-200 μm) in length and 49-54 μm (12-60 μm) in width, 14-17 (13-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 92: 1-6; 93: 1-3).

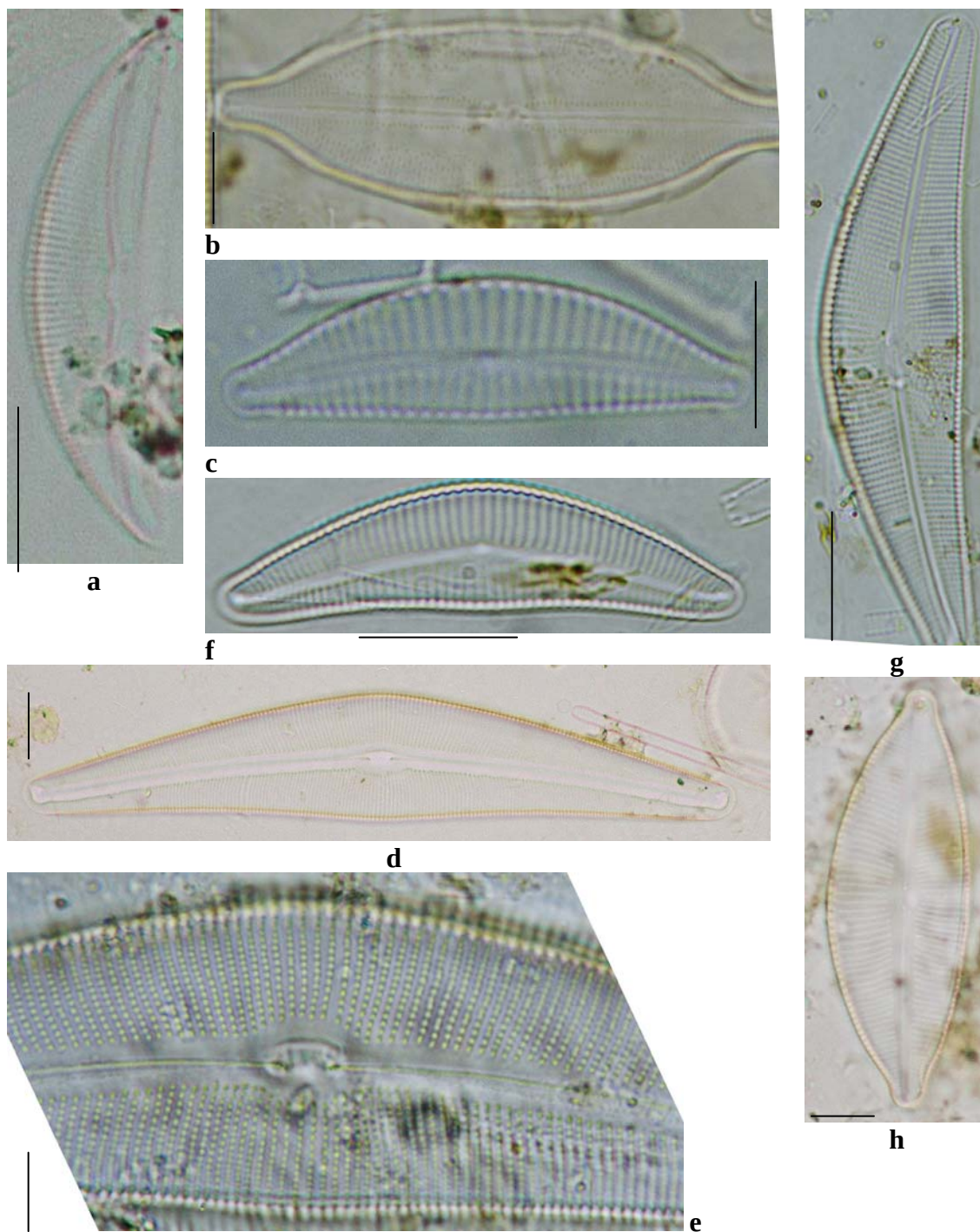


Figure 2. 1. a) *Amphora ovalis*, b) *Anomoeoneis sphaerophora*, c) *Cymbella affinis*, d, e) *C. aspera*, f-g) *C. cistula*, h) *C. subcuspidata* (Scale 10 μm).

Caloneis Cleve 1894

C. silicula (Ehrenberg) Cleve 1894.

Valves 45-49 μm (13-120 μm) in length and 8.7-9 μm (5-20 μm) in width, 16-17 (15-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 172: 1-13; 7: 6; 9: 3).

Cymbella Agardh 1830

C. affinis Kützing 1844, (Figure 2. 4. c).

Valves 47-58 μm (20-70 μm) in length and 8-11 μm (7-16 μm) in width, 8-10 (9-11) mid-dorsal and end 12-13 (12-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 125: 1-22; 10: 1).

C. amphicephala Naegeli 1849

Valves 22-29 μm (16-40 μm) in length and 8-9 μm (6-9 μm) in width, 13 (12-15) mid-dorsal and end 19 (17-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 142: 3-21).

C. aspera (Ehrenberg) Peragallo 1849, (Figure 2. 4. d, e)

Valves 91-175 μm (70-265 μm) in length and 21-31 μm (20-48 μm) in width, 8-9 (7-10) mid-dorsal and end 11 (11-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 131: 1; 7: 1; 8: 2; 11: 5).

C. cistula (Ehrenberg) Kirchner 1878, (Figure 2. 4. f, g)

Valves 62-108 μm (35-120 μm) in length and 15-17.5 μm (13-25 μm) in width, 8-9 (7-10) mid-dorsal and end 12 (12-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 127: 8-11; 128. 1-6; 10: 5).

C. cuspidata Kützing 1844

Valves 33-51 μm (28-66 μm) in length and 13-17 μm (14-20 μm) in width, 10-11 (8-12) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 146: 1-4).

C. subcuspidata Krammer 1982, (Figure 2. 4. h)

Valves 62-87 μm (54-100 μm) in length and 21-24 μm (19-31 μm) in width, 8-9 (8-11) mid-dorsal striae 10 μm , 14-15 (15) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 146: 6, 7; 15: 1).

C. cymbiformis Agardh 1830

Valves 33-41 μm (25-95 μm) in length and 13-14 μm (8-15 μm) in width, 9 (8-10) mid-dorsal and end 11 (11-15) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 129: 2-9; 5: 5; 12: 5).

C. ehrenbergii Kützing 1844

Valves 97-123 μm (50-225 μm) in length and 33.5-38 μm (19-50 μm) in width, 6 (6-9) mid-dorsal and end 10 (10-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 144. 1-6).

C. gracilis (Ehrenberg) Kützing 1844

Valves 23-28 μm (22-57 μm) in length and 5-6.5 μm (4,5-9 μm) in width, 10-11 (9-14) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 120: 1-16; 12: 3b; 13: 3).

C. helvetica Kützing 1844

Valves 70-117 μm (22-170 μm) in length and 11-23 μm (8-27 μm) in width, 9 (8-12) mid-dorsal and end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 132: 2-4; 133: 1-8).

C. leptoceros (Ehrenberg) Kützing 1844

Valves 17-35 μm (15-60 μm) in length and 8-12 μm (7-13 μm) in width, 9-11 (9-13) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 143: 1-13).

C. lanceolata (Ehrenberg) Kirchner 1878

Valves 67-97 μm (60-220 μm) in length and 19-21 μm (18-32 μm) in width, 9 (9-10) mid-dorsal and 13-14 (13-16) end striae 10 μm (Krammer and Lange-Bertalot, 1999a, Figure 124: 1-8).

C. minuta Hilse ex Rabenhorst 1862

Valves 17-21 μm (7-32 μm) in length and 4-6.5 μm (3.9-7 μm) in width 11-13 (10.5-15) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999.a, Figure 119: 1-13; 16: 4).

C. proxima Reimer 1975

Valves 41-81 μm (38-128 μm) in length and 19-24 μm (14-26 μm) in width, 8-9 (7-10) mid-dorsal and 9 (7-14) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 128: 9; 129: 1).

C. silesiaca Bleisch 1864

Valves 17-23 μm (15-46 μm) in length and 8.5-11 μm (6.5-14.2 μm) in width, 11-12 (10.5-15) mid-dorsal and 15 (14-20) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 117: 1-24).

C. schimanskii Krammer 1982

Valves 152-162 μm (145-175 μm) in length and 31-32 μm (29-35 μm) in width, 8 (7-8) mid-dorsal and 9-10 (10-11) end striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 132: 1).

Didymosphaenia Schmidt nom. cons.

D. geminata Schmidt 1899

Valves 67-76 μm (60-140 μm) in length and 26-35 μm (25-43 μm) in width, 8-9 (8-10) striae (Krammer and Lange-Bertalot, 1999a, Figure 166: 15).

Diploneis Ehrenberg 1844

D. elliptica (Kützing) Cleve 1891

Valves 34-37 μm (20-130 μm) in length and 16.5 μm (10-60 μm) in width, 11 (8-14) striae 10 μm , and 12 (12-14) alveolus 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 108: 1-6).

D. pseudovalis Hustedt 1930 (Figure 2. 5. a).

Valves 19-24 μm (16-31 μm) in length and 10-12 μm (9-14 μm) in width, 11 (8-12) striae 10 μm , and 19 (18-22) puncta 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 108: 11-13).

D. puella (Schumann) Cleve 1894

Valves 15-18 μm (13-25 μm) in length and 8-11 μm (8-14 μm) in width, 13 (13-18) striae 10 μm , and 17 (16-20) puncta 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 109: 15, 16).

Gomphonema Ehrenberg 1832

G. acuminatum Ehrenberg 1832

Valves 30-75 μm (20-120 μm) in length and 5-12.5 μm (5-17 μm) in width, 12 (8-13) striae 10 μm (Krammer & Lange-Bertalot, 1999 a, Figure 160: 1-12).

G. angustum Agardh 1831

Valves 65-68 μm (12-130 μm) in length and 7 μm (3-12 μm) in width, 7-8 striae 10 μm (Krammer & Lange-Bertalot, 1999 a, Figure 155: 1-21).

G. augur Ehrenberg 1840

Valves 32-41 μm (17-130 μm) in length and 8-11 μm (8-20 μm) in width, 8 (7-15) striae 10 μm (Krammer & Lange-Bertalot, 1999 a, Figure 157: 1-8; 158: 1-6).

G. gracile Ehrenberg 1838

Valves 37-48 μm (20-100 μm) in length and 4.5-7 μm (4-8 μm) in width, 8-9 (4-11) striae 10 μm (Krammer & Lange-Bertalot, 1999 a, Figure 156: 1-11; 154: 26, 27).

G. olivaceum (Hornemann) Brebisson 1838

Valves 18-19 μm (8-45 μm) in length and 4.5 μm (3.5-13 μm) in width, 10 (9-16) striae 10 μm (Krammer & Lange-Bertalot, 1999 a, Figure 165: 1-18).

G. parvulum (Kützing) Kützing 1849

Valves 16-24 μm (10-36 μm) in length and 4-7 μm (4-8 μm) in width, 8-12 (7-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 154: 1-25).

G. subtile Ehrenberg 1843

Valves 27-32 μm (24-50 μm) in length and 4-6.5 μm (3.5-8 μm) in width, 12 (10-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 162: 10-13).

G. truncatum Ehrenberg 1832

Valves 18-29 μm (13-75 μm) in length and 8-13 μm (7-17 μm) in width, 10 (9-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 159: 11-18).

Gyrosigma Hassall 1843

G. acuminatum (Kützing) Rabenhorst 1853

Valves 78-158 μm (60-180 μm) in length and 12-15 μm (11-18 μm) in width, 17-18 (16-22) median striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 114: 4, 8).

G. attenuatum (Kützing) Rabenhorst 1853

Valves 218-248 μm (150-240 μm) in length and 25 μm (23-26 μm) in width, 13-14 (14-16) median striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 114: 5, 7, 9; 4: 5, 6; 15: 3; 16: 2, 6).

Navicula Borry 1822

N. clementis Kützing 1844

Valves 27-35 μm (15-50 μm) in length and 11-13 μm (7-15 μm) in width, 8-9 (8-15) striae 10 μm (Krammer and Lange-Bertalot, 1999a, Figure 47: 1-9; 53: 3).

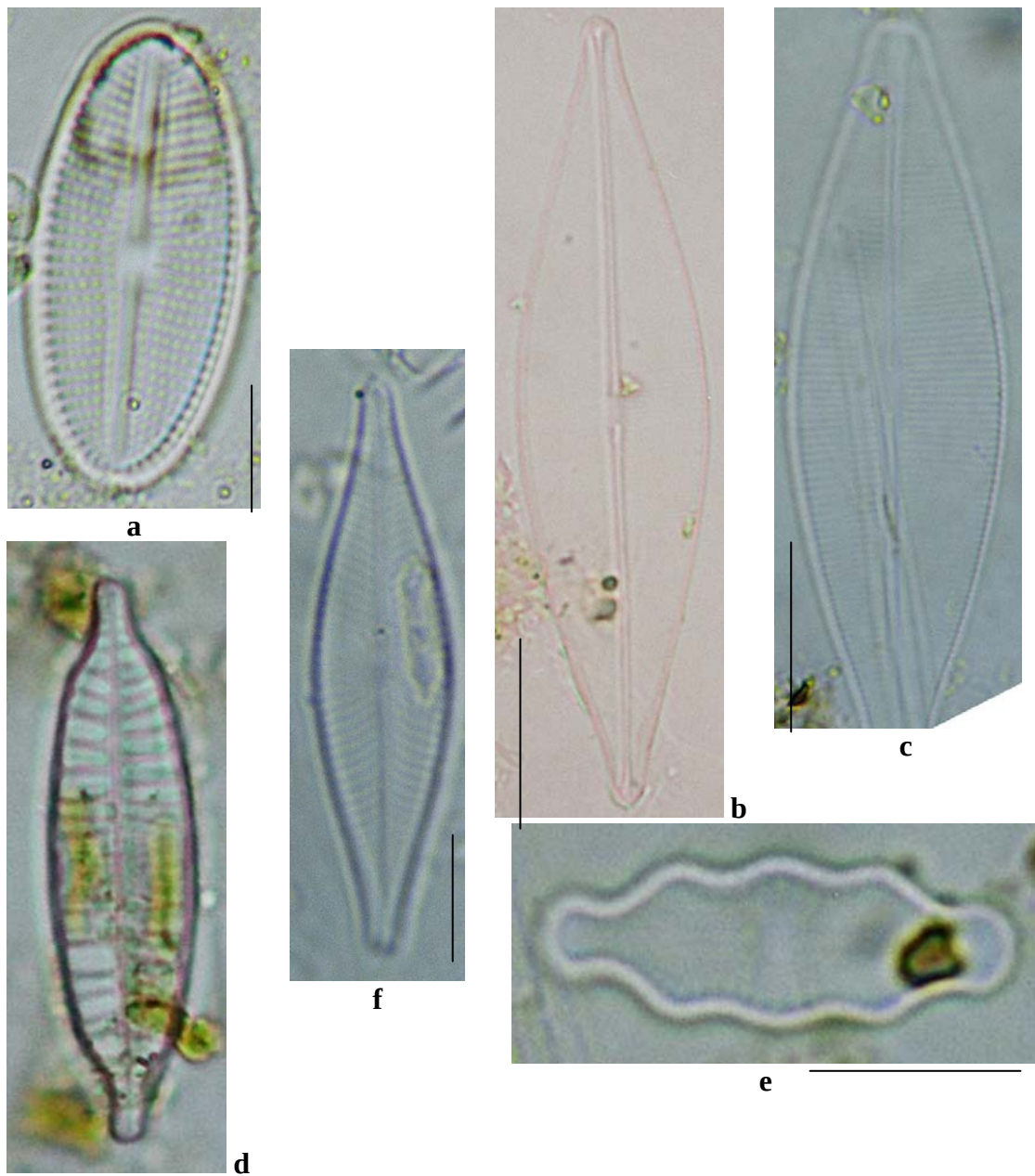


Figure 2. 1. a) *Diploneis pseudovalis* b-d) *Navicula cuspidata*, e) *N. nivalis* f) *N. trivialis* (Scale 10 μ m).

N. cryptocephala Kützing 1844

Valves 24-29 μm (20-40 μm) in length and 5-6 μm (5-7 μm) in width, 15-16 (14-17) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 31: 8-14).

N. cuspidata (Kützing) Kützing 1844, (Figure 2. 5. b-d)

Valves 32-85 μm (30-150 μm) in length and 17-33 μm (13-44 μm) in width, 12 (11-19) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 43: 1-8).

N. menisculus Schumann 1867

Valves 17-25 μm (15-50 μm) in length and 8-9 μm (7,5-12 μm) in width, 7-8 (8-12) striae 10 μm (Krammer and Lange-Bertalot, 1999a, Figure 32: 16-25).

N. nivalis Ehrenberg 1854, (Figure 2. 5. e).

Valves 13-28 μm (12-42 μm) in length and 6-9 μm (5,5-13 μm) in width, 18 (17-24) striae 10 μm (Krammer and Lange-Bertalot, 1999a, Figure 61: 17-20).

N. radiosa Kützing 1844

Valves 72-112 μm (40-120 μm) in length and 11-12 μm (7.5-15 μm) in width, 10-11 (10-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 29: 1-4).

N. reinhardtii (Grunow) Grunow 1877

Valves 47-68 μm (35-70 μm) in length and 14-16 μm (11-18 μm) in width, 8-9 (7-9) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 40: 1, 2).

N. rhynchocephala Kützing 1844

Valves 46-61 μm (35-80 μm) in length and 11-13 μm (9-14 μm) in width, 10-11 (7-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 30: 5-8; 31: 1, 2).

N. trivialis Lange-Bertalot 1980, (Figure 2. 5. f)

Valves 37-58 μm (25-65 μm) in length and 10-12 μm (8-12.5 μm) in width, 11-12 (11-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 35: 1-4).

Nedium Pfitzer 1871

N. dubium (Ehrenberg) Cleve 1894

Valves 38 μm (30-58 μm) in length and 10 μm (10-16 μm) in width, 18 (16-24) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 99: 1-7).

N. iridis (Ehrenberg) Cleve 1894

Valves 84-112 μm (37-300 μm) in length and 18-24 μm (15-40 μm) in width, 13-14 (12-18) striae 10 μm , 13 (12-18) puncta 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 104: 1-4; 105: 1).

Pinnularia Ehrenberg 1843

P. divergens Smith 1853

Valves 84-137 μm (50-160 μm) in length and 17-28 μm (13-30 μm) in width, 9-10 (8-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 179: 3-8).

P. gibba Ehrenberg 1841

Valves 63-98 μm (50-140 μm) in length and 8-11 μm (7-13 μm) in width, 9-11 (9-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 99: 1-7).

P. interrupta Smith 1853, (Figure 2. 6. a)

Valves 37-52 μm (26-80 μm) in length and 10-12 μm (6.7-16 μm) in width, 11 (9-15) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 99: 1-7).

P. maior (Kützing) Rabenhorst 1853, (Figure 2. 6. b)

Valves 146-249 μm (140-340 μm) in length and 28-36 μm (25-42 μm) in width, 5-6 (5-7) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 196: 1-4; 7: 3-4; 13: 7).

P. microstauron (Ehrenberg) Cleve 1891

Valves 42 μm (20-90 μm) in length and 10 μm (7-11 μm) in width, 10-12 (10-13) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 191. 7-9).

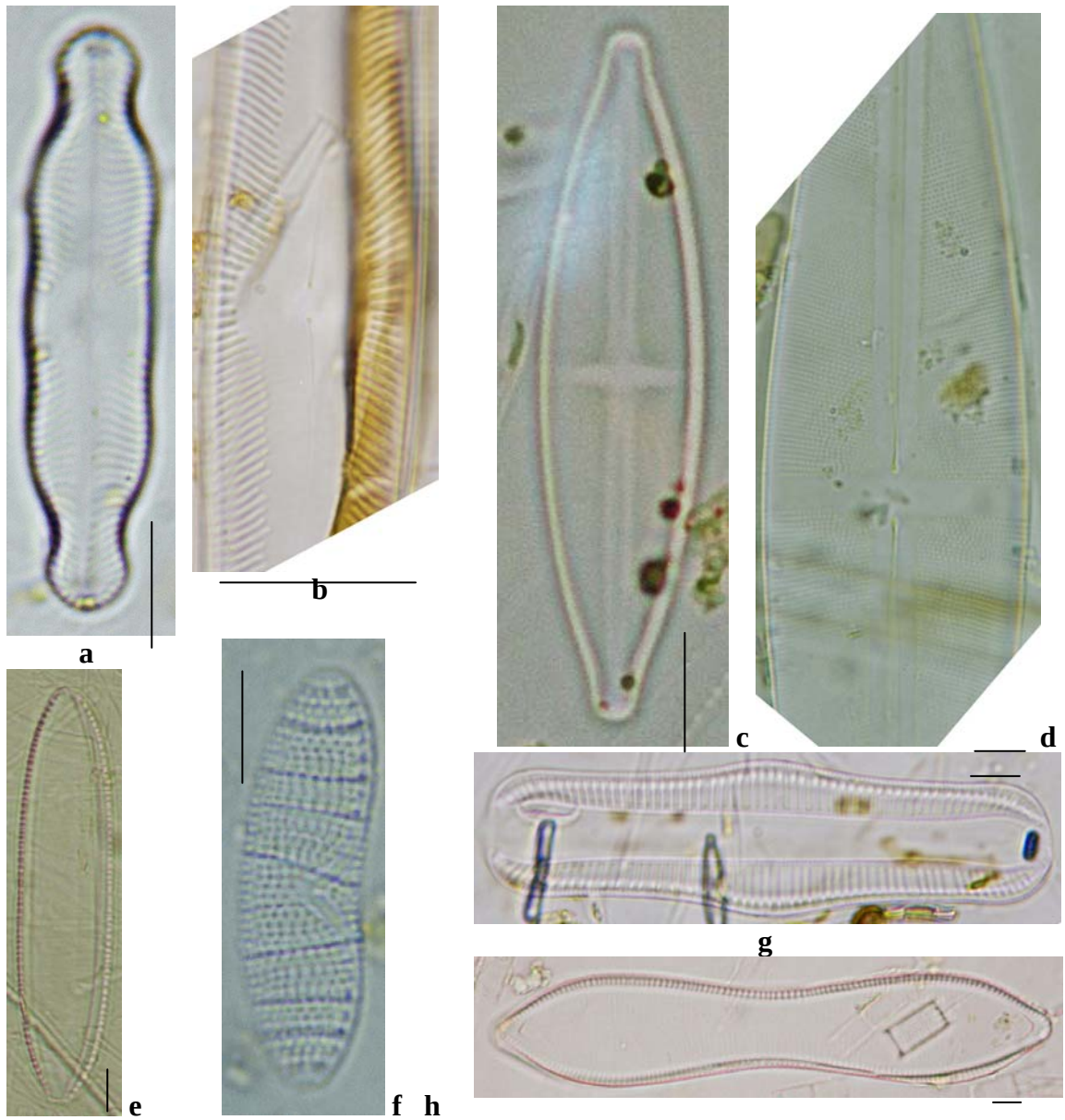


Figure 2. 1. a) *Pinnularia interrupta*, b) *P. maior*, c, d) *Stauroneis phoenicenteron*, e) *Nitzschia tryblionella*, f) *Epithemia adnata*, g) *Rhopalodia gibba*, h) *Cymatopleura solea* (Scale 10 μm).

P. nobilis (Ehrenberg) Ehrenberg 1843

Valves 227-279 μm (200-350 μm) in length and 37-43 μm (34-50 μm) in width, 4-5 (4-6) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 198. 2, 3).

P. streptoraphe Cleve 1891

Valves 91-119 μm (85-260 μm) in length and 17-21 μm (15-35 μm) in width, 5 (5-7) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 191. 1-3).

P. viridis (Nitzsch) Ehrenberg 1843

Valves 69-146 μm (50-170 μm) in length and 12-23 μm (10-30 μm) in width, 7-9 (6-12) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 194: 1-4; 195: 1-6; 2: 4-6).

Rhoicophenia Grunow 1860

R. abbreviata (C. Agardh) Lange-Bertalot 1980b

Valves 22.5 μm (10-75 μm) in length and 7.6 μm (3-8 μm) in width, 16 (15-20) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 91: 20-28).

Stauroneis Ehrenberg 1843

S. anceps Ehrenberg 1843.

Valves 38-98 μm (20-130 μm) in length and 8-16 μm (6-18 μm) in width, 22-24 (20-33) striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 87: 3-9; 88: 1-4).

S. phoenicenteron Ehrenberg 1843, (Figure 2. 6. c, d)

Valves 194-237 μm (70-360 μm) in length and 39-51 μm (16-53 μm) in width, 12 (12-20) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 6: 7-8; 8: 3; 15: 2; 18:1-3).

S. producta Grunow 1880

Valves 32-37 μm (30-50 μm) in length and 8-9 μm (8-11 μm) in width, 23-24 (22-28) mid-dorsal striae 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 89: 1-7).

Bacillariaceae Ehrenberg 1840

Hantzschia Grunow 1877

H. amphioxys (Ehrenberg) Grunow 1880

Valves 49-76 μm (20-300 μm) in length and 7-21 μm (5-25 μm) in width, 11-15 (11-28) striae 10 μm , 8-9 (4-11) fibula 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 88: 1-7).

Nitzschia Hassall 1845

N. linearis Smith 1853

Valves 78-132 μm (34-228 μm) in length and 4-6 μm (2.5-7.5 μm) in width, 28-30 (28-41) striae 10 μm , 10-11 (8-17) fibula 10 μm (Krammer and Lange-Bertalot, 1999a, Figure 55: 1-10).

N. lorenziana Grunow 1880

Valves 78-149 μm (37-190 μm) in length and 4-6 μm (3-7 μm) in width, 14-15 (13-19) striae 10 μm , 7 (6-10) fibula 10 μm (Krammer and Lange-Bertalot, 1999 a, Figure 86: 6-10).

N. palea (Kützing) Smith 1856

Valves 21-47 μm (15-70 μm) in length and 3-4 μm (2.5-5 μm) in width, 27-29 (28-40) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 59: 1-24; 60: 1-7).

N. sigma (Kützing) Smith 1853

Valves 57-209 μm (35-1000 μm) in length and 8-23 μm (4-26 μm) in width, 16-18 (15-38) striae 10 μm , 4-6 (3-12) fibula 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 23: 1-9).

N. sigmoidea (Nitzsch) Smith 1853

Valves 215-248 μm (90-500 μm) in length and 10-13 μm (8-15 μm) in width, 23 (21-27) striae 10 μm , 5 (5-7) fibula 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 4: 1, 2; 5: 1-5).

N. tryblionella Hantzsch 1860, (Figure 2. 6. e)

Valves 88-109 μm (50-180 μm) in length and 19-27 μm (16-35 μm) in width, 32-33 (30-35) striae 10 μm , 7 (5-9) fibula 10 μm (Krammer and Lange-Bertalot, 1999a, Figure 27: 1-4).

N. vermicularis (Kützing) Hantzsch 1860

Valves 87-186 μm (75-250 μm) in length and 4-6.5 μm (3.5-7 μm) in width, 29-32 (30-40) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 4: 4, 5; 7: 1-7; 8: 1, 2).

Epithemiaceae Karsten 1928

Epithemia Brebisson 1844

E. adnata (Kützing) Brebisson 1838, (Figure 2. 6. f).

Valves 57-127 μm (15-150 μm) in length and 7.5-13 μm (7-14 μm) in width, 9-11 (11-14) striae 10 μm , 48 (20-80) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 107: 1-11; 108: 1-3).

E. argus (Ehrenberg) Kützing 1844.

Valves 27-39 μm (20-130 μm) in length and 6-9 μm (4-18 μm) in width, 9-11 (8-14) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 102: 1-9; 103: 1-5).

E. sorex Kützing 1844.

Valves 27,5-31 μm (8-70 μm) in length and 7,5-16 μm (6,5-16 μm) in width, 11 (10-15) striae 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 106. 1-14).

Rhopalodia Müller 1895

R. gibba Müller 1895, (Figure 2. 6. g).

Valves 92.5-245 μm (22-300 μm) in length and 25 μm (18-30 μm) in width, 54 (50-80) fibula 100 μm , 3 (2-4) alveolus 10 μm , and 12 (12-17) inter fibula 10 μm (Krammer and Lange-Bertalot, 1999 b, Figure 110: 1; 111: 1-13; 111A: 1-7).

Surirellaceae Kützing 1844

Campylodiscus Ehrenberg 1840

C. hibernicus Ehrenberg 1845

Valves 55-57 μm (25-150 μm) in diameter, 12 (10-20) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 175: 5; 179: 1-4; 180: 1-7; 181: 1-3)

C. noricus Ehrenberg 1840

Valves 62-113 μm (60-150 μm) in diameter, 23-25 (20-30) fibula 100 μm (Krammer and Lange-Bertalot, 1999 b, Figure 182: 1-5)

Cymatopleura Smith 1851

C. elliptica Smith 1851

Valves 82.5-97 μm (60-280 μm) in length and 42.5-47.5 μm (30-90 μm) in width, 4 (2.5-6) fibula 10 μm , 15-17 (15-20) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 119: 1-4; 120: 1-6; 121: 1-3; 122: 3).

C. solea Smith 1851, (Figure 2. 6. h).

Valves 76-118 μm (30-300 μm) in length and 22.5-31 μm (10-45 μm) in width, 6 (6-9) fibula 10 μm , 26-28 (25-32) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 116:1- 4; 117: 1-5; 118: 1-8; 122: 4).

C. solea Smith **var. *apiculata*** Ralfs 1861

Valves 67-75 μm in length and 16-17 μm in width, 5-6 fibula 10 μm , 23-27 (25-32) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 118: 2, 4-8).

Stenopterobia Brebisson 1878

S. curvula (Smith) Krammer 1987.

Valves 110 µm (70-280 µm) in length and 6.5-7 µm (6-9 µm) in width, 34 (30-60) fibula 100 µm, 22 (22-24) striae 10 µm, (Krammer and Lange-Bertalot, 1999 b, Figure 170: 1, 2; 171: 5-9; 172: 1-3).

Surirella Turpin 1828

S. angusta Kützing 1844.

Valves 21-41 µm (18-70 µm) in length and 7-13 µm (6-15 µm) in width, 1:3-1:4 (1:3-1:5) length:width ratio, 21-24 (20-28) striae 10 µm, (Krammer and Lange-Bertalot, 1999 b, Figure 133: 6-13; 134: 1, 6-10).

S. biseriata Brebisson 1836.

Valves 87-327 µm (80-400 µm) in length and 33-79 µm (30-90 µm) in width, 14 (10-20) striae 10 µm, (Krammer and Lange-Bertalot, 1999 b, Figure 141: 1-3; 142: 1-5; 143: 1-9; 144: 1-3; 145: 1).

S. brebissonii Krammer and Lange-Bertalot 1987.

Valves 29-43 µm (8-70 µm) in length and 16-23 µm (8-30 µm) in width, 1.8:1-1.9:1 (1:1-2.4:1) length:width ratio, 17-18 (16-20) striae 10 µm, 37 (35-70) fibula 10 µm (Krammer and Lange-Bertalot, 1999b, Figure 123: 4, 5; 126: 2-11; 127: 1-13).

S. elegans ehrenberg 1843.

Valves 187-315 µm (110-400 µm) in length and 59-74 µm (35-90 µm) in width, 16-17 (12-21) canal 100 µm (Krammer and Lange-Bertalot, 1999b, Figure 160: 5; 161: 1, 2; 162: 1-7; 163: 1-4).

S. minuta Brebisson 1849.

Valves 13-21 µm (9-47 µm) in length and 9-10 µm (9-11 µm) in width, 22-23 (21-29) striae 10 µm, 64-68 (60-80) fibula 100 µm (Krammer and Lange-Bertalot, 1999 b, Figure 127: 14; 134: 2, 11, 12; 135: 1-14).

S. ovalis Brebisson 1838.

Valves 27-53 μm (16-120 μm) in length and 15-36 μm (12-45 μm) in width, 1:1.5-1:3 (1:3-1:1) length: width ratio, 17 (16-19) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 125: 1-7; 126: 1).

S. robusta Ehrenberg 1841.

Valves 178-359 μm (150-400 μm) in length and 67-114 μm (50-150 μm) in width, 7-8 (7-12) canal 100 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 156: 1-5; 157: 1-4).

S. subsalsa Smith 1853.

Valves 17-24 μm (15-48 μm) in length and 9-11 μm (8-16 μm) in width, 10-11 (10-13) striae 10 μm , (Krammer and Lange-Bertalot, 1999 b, Figure 128: 1-10).

8 DISCUSSION

During the present study, a total of 119 diatom taxa were identified from Lake Gök  y (Figure 2. 1). Ten taxa in four genera of Centrales, and 109 taxa with 29 genera in the order Pennales were described. The diatom composition of the lake was especially dominated with Naviculaceae at about 48.7 % of density, including 58 taxa in 13 genera. This family is followed by Fragilariaceae at 16.8 % of abundance with 20 taxa in 5 genera. Additionally, some genera showed high abundance with 16, 14, 9, and 8 taxa for *Cymbella*, *Fragilaria*, *Navicula*, and *Pinnularia*, respectively. In comparison, diatom composition of Lake G  lk  y showed similarity to the Lake Abant (Bolu), a natural lake in similar size (  lekli and K  lk  yl  o  lu, in press). Although structural and geographical differences occur in two lakes, such similarity may depend on the indirect connection between them. This is because the water released from Lake Abant travels to Yumrukaya Reedbeds, and then it is transferred to Lake G  lk  y by concrete canals due to agricultural purposes. This may eventually brings many diatoms from Lake Abant to Lake G  lk  y.

In the average, 45 taxa occurred per month during our study. Numbers of species were increased in some months (e.g., November (68 taxa), December (62 taxa)) from the year 2003 to September (55 taxa) and October (58 taxa) 2004. The lowest number of species was detected in June 2003 with 21 taxa.

Most of the members of Bacillariophyceae collected from Lake G  lk  y have a wide distribution as reported in Lake Abant and in a karstic Akkaya spring (  lekli and K  lk  yl  o  lu, 2006), and in different parts of Turkey (G  n  lol et al., 1996). For example, during our study, some species found in almost each month from each station (e.g., *Asterionella formosa*, *Aulacoseria granulata*, *Cyclotella praetermis*,

Cymbella cistula, *Fragilaria bicep*, *F. crotonensis*, *F. dilata*, *Navicula radiosa*, *N. trivialis* and *Nitzschia sigmoidae*) were already reported commonly from different aquatic bodies in Turkey (Gönülol et al., 1996). One of the critical similarities among the previous reports and the results of the present study is that most of the diatoms described are known to prefer nutrient rich environments (Patrick and Reimer 1966, 1975; Round, 1981). This may suggest changes in water quality of Lake Gökçöy where two creeks (Abant and Mudurnu creeks) apparently carry nutrient enriched water from chicken farms, industries, and domestic sources. Such effects of point and non-point sources were already underlined to affect the occurrence of other taxonomic groups. For example, Kulköylüoğlu (2005) stated that among 17 ostracod taxa reported from the lake, almost all were cosmopolitan, and the four most frequently occurred species consisted of about 70% of the total abundance. Such increase in the numbers of cosmopolitan species and decrease in the specialist species is called ‘Pseudorichness’ (Kulköylüoğlu, 2004). Mesotrophic characteristic *A. formosa* (Nygaard, 1949; Round, 1981) was found each month in all sampling stations.

In a current study, Kulköylüoğlu (2005) stated that Lake Gökçöy is of mesotrophic characteristic. The most common two diatoms (*Asterionella. formosa* and *A. granulata*) in Lake Gökçöy during fall and spring seasons have been reported as dominant species in mesotrophic lakes and in eutrophic lakes as well (Round, 1981). Indeed, in productive lakes, *Aulacoseria* can be abundant species in winter, and following *Asterionella* can reach to a high level during spring season (Hutchinson, 1967). Similarly, *A. granulata* was co-dominant diatom especially fall and winter season and *A. formosa* was very common in spring season in our study

Cymbella has the most diversity, including 16 species. Most of them have wide distribution in thought out Turkey (Gönülol et al. 1996; Akbulut, 2003). Second, high composition genus, *Fragilaria* was consisted 14 taxa, some of them such as *F. biceps*, *F. capucina*, *F. crotonensis* and *F. dilata* were commonly distributed for almost each sampling station during study period. Many species of this genus were commonly found in different habitats of Turkey (Gönülol et al., 1996), also prefer nutrient rich environment, so that they can be found especially in meso-eutrophic characteristics of water (Hutchinson, 1967; Wetzel, 1975; Round, 1981).

Nitzschia included 7 species, two of them; *N. sigmoidae* and *N. vermicularis* were common in almost each month from each station. Round (1981) reported that in temperate lakes, *Nitzschia* can be dominant plankton when lake water is comprised with rich organic nutrients. Similarly, as mentioned above, major sources of polluted water are both Abant and Mudurnu creeks in Lake Gököy; this can explain the common occurrence of these species.

Some species such as *Didymosphaenia geminata* and *Cymatopleura solea var apiculata* were rarely distributed in this lake. Krammer and Lange-Bertalot (1999 a) stated that *D. geminata* was generally found in oligotrophic water. Both species are not commonly distributed in Turkey (Gönülol et al. 1996).

Overall, results of this taxonomic study showed that the diatom composition of Lake Gököy support the idea of pseudorichness due to increasing numbers of cosmopolitans. On of the possible reasons of such effect is due to changes in physicochemical structure of the lake water. When the lake is considered to be a potential drinking water reservoir for Bolu in future, such changes are critical.

Part C

ABSTRACT

PHYTOPLANKTON (EXCEPT BACILLARIOPHYTA) COMPOSITION OF LAKE ABANT (BOLU)

A total of 162 non-diatom phytoplankton species collected monthly from 3 littoral and 2 pelagic 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 in about each month, but others had unique seasonality. Phytoplankton composition of this lake was especially dominated with Chlorophyta at about 58.6 % of abundance.

Keywords: Phytoplankton, Taxonomy, Lake Abant, Bolu

ÖZET

ABANT GÖLÜ (BOLU) FİTOPLANKTON (BACILLARIOPHYTA HARİÇ) KOMPOSİZYONU

Haziran 2003 ve Haziran 2005 yılları arasında üç kıyısal ve iki pelajik istasyondan olmak üzere aylık olarak toplam 162 fitoplankton türü Abant Gölü'nden (Bolu) tanımlanmıştır. *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 zenginlikle bu gölün fitoplankton kompozisyonunda baskın halde bulunmuştur.

Anahtar Kelimeler: Fitoplankton, Taksonomi, Abant Gölü, Bolu

9 INTRODUCTION

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

Although studies of biodiversity of phytoplankton have been conducted in some parts of Turkey for over a few decades (e.g., Altuner, (1988); Akbay et al., (1999); Aysel et al., (2002); Kılınç, (2003); Maraşlıoğlu et al., (2005)), but a few earlier works focused on some particular sites in Bolu. For example; studies include Obalı et al., (2002) in Lake Abant; Atıcı and Obalı, (2002) in Lake Yedigöller; Kılınç, (2003) in Lake Yeniçağa; Atıcı et al., (2005) in Lake Abant; Çelekli and Külköylüoğlu, (2006) in Akkaya Spring. All these studies increased our understanding on the algae species diversity in Bolu region, but little attention has been given to phytoplankton species. However, the area is known with its potentially high species diversity. Thus, the aim of the present study was to investigate non-diatom phytoplankton species composition and their seasonal occurrences in Lake Abant to contribute the knowledge of algal flora of Turkey.

10 RESULTS

10.1 Phytoplankton composition of Lake Abant

During the study period, we identified total of 162 taxa in 69 different genera, 39 of which includes a dominant group Chlorophyta (Table 5. 2). Among the species, some (e.g., *Trachelomonas volvocina*, *Cryptomonas ovata*, and *Ceratium hirundinella*) were observed in almost all sampling times, while others had unique phenology. Below, photographs of species, which are representing taxonomic groups, given in Figure 2, 3, 4, 5, 6, 7, and 8. These taxa were described below, and other species are showed in Table 1.

10.2 Description of some phytoplankton taxa

10.2.1 Cyanoprokaryota (Blue-green algae)

Chroococcales

***Aphanocapsa* Nageli 1849**

***A. litoralis* Hansgirg 1892.**

Subspherical colon 24-33 μm (up to 60 μm), subspherical-shaped cells 3-3.5 μm (3-5 μm) in diameter (John et al., 2002, 1. C).

***Aphanothece* Nageli 1849.**

***A. clathrata* West 1906**

Colonies 37-58 μm (up to 400 μm), rod-shaped cells 2.75-3.5 μm (2.5-4.5 μm) in length and 1-1.5 μm (0.4-2 μm) in width (John et al., 2002, 1. E, F).

***Chroococcus* Nageli 1849.**

***C. turgidus* (Kützing) Nageli 1849 (Figure 3. 1. a).**

Microscopic colony 2-8 (2-32) cell inclosed by sheath, spherical and hemispherical cell 29-34 (6-45) μm in dimension, tychoplankter, seldom found (common in many lakes and bogs) (Prescot, 1982, 100: 19; Komarek and Anagnostidis, 1998, 407; John et al., 2002, 3: A, B; Wehr and Sheath, 2003, 14: g, h).

Coelosphaerium Naegeli 1849.

C. kuetzingianum Naegeli 1849.

Spherical colony 41-62 (up to 100) μm in diameter, cup, and heart-shaped spherical or subspherical cell 2-3 (2-4) μm in dimension (John et al., 2002, 5: B).

Merismopedia Meyen 1839.

M. tenuissima Lemmermann 1898.

Rectangular colonies, 15-17 (16-18) μm in broad, contain closely aggregated groups of colonies. Spherical-hemispherical cells 0.7-1.5 (0.4-1.6) μm in dimension (Prescott, 1982, 100: 17; John et al., 2002).

Microcystis Kützing 1833 ex Lemmermann 1907 nom. cons.

M. aeruginosa (Kützing) Kützing 1846 (Figure 3. 1. b).

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 fall and mid summer (fresh to moderately brackish water, blooms in mid to late summer) (Prescott, 1982, 102: 1-4; Komarek and Anagnostidis, 1998, 304; John et al., 2002, 3: K-L).

Snowella Elenkin 1938.

S. lacustris (Chodat) Komarek et Hindak 1988.

Spherical colonies, 43-61 (up to 80) μm in diameter, ellipsoidal cells 2-3x2-2.5 (1.5-3.5x1.5-4) μm in dimension (John et al., 2002, 4: D-E).

Oscillatoriales

Oscillatoria (Vaucher) Gomont 1892.

O. formosa (Bory) Gomont 1892

Straight, tapering at ends filament and end cell blunt with adjacent granules, calyptra absent cells 3-5 (2.5-5) μm in length and 3.75-5 (4-6) μm in width (John et al., 2002, 11: D).

O. limosa (Agard) Gomont 1892 (Figure 3. 1. c).

Straight or less straight, rounded ends 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, especially found fall and summer season (slightly brackish nutrient-rich water plankton or attached, tychoplankton) (Prescott, 1982, 109, 17; John et al., 2002, 11: G, H; Wehr and Sheath, 2003, 16: a).

O. princeps (Vaucher) Gomont 1892

Mostly straight, abruptly bent at apex trichome and end cell flatly rounded without adjacent granules, cells 4.5-6 (3.5-7) μm in length and 17-25 (16-60) μm in width (Prescott, 1982, Pl. 110, 1; John et al., 2002).

O. sancta (Kützinger) Gomont 1892 (Figure 3. 1. d).

Straight, abruptly bent 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 and Sheath, 2003, 16 e).

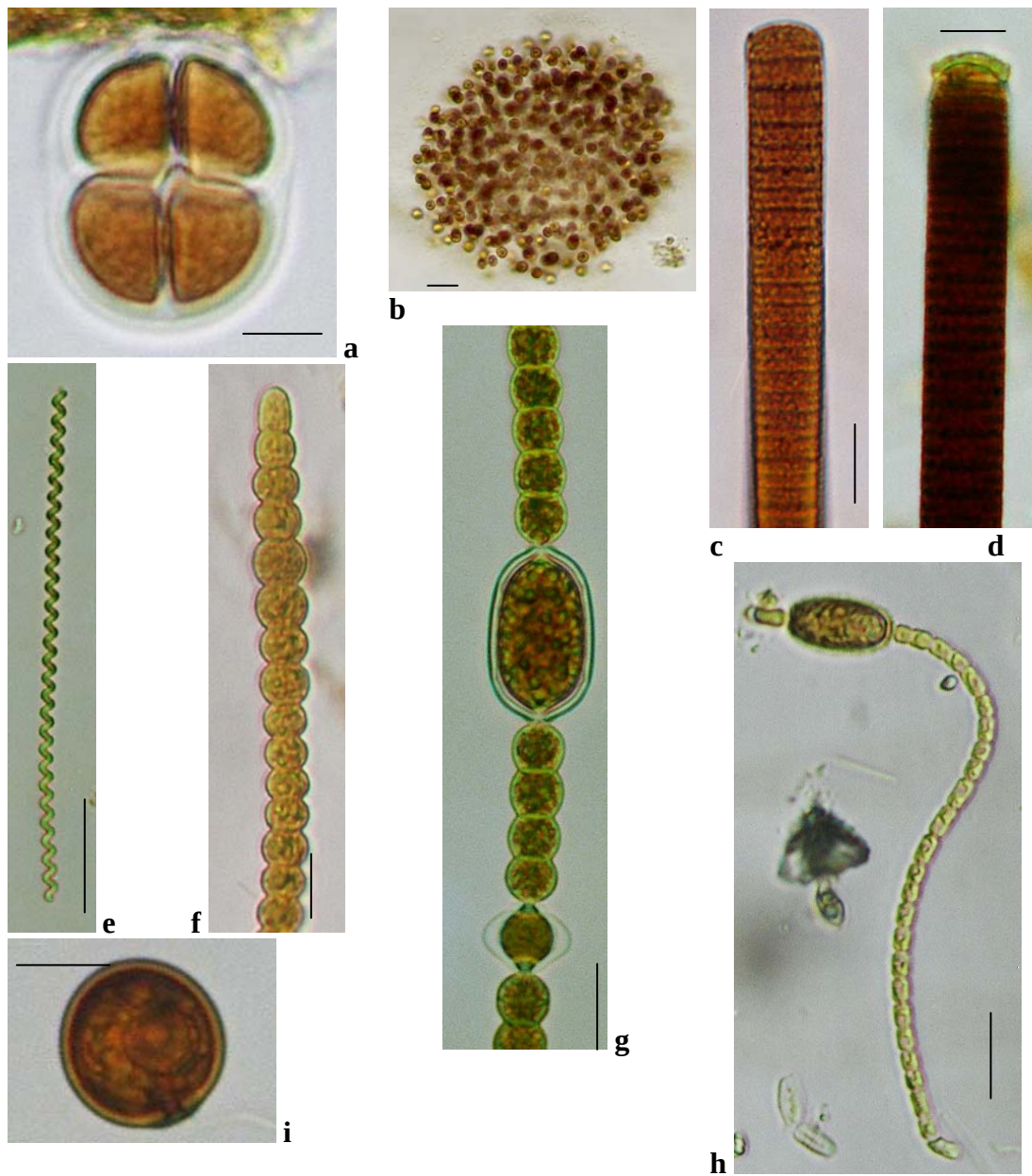


Figure 3. 1. a) *Chroococcus turgidus*, b) *Microcystis aeruginosa*, c) *Oscillatoria limosa*, d) *O. sancta*, e) *Spirulina maior*, f) *Anabaena bergei*, g) *A. planctonica*, h) *Cylindrospermum minutissimum*, i) *Trachelomonas volvocina* (scale 10 μm).

O. tenuis Schmidle 1901

Straight or less straight end not attenuated at the apex trichome and end cell more or less hemispherical with adjacent granules and thickened outer membrane, cells 2.5-3 μm (2.5-5 μm) in length and 5-6.5 (4-10) μm in width (Prescott, 1982, Pl. 110, 8, 9, 14: 0; John et al., 2002, 11: K)

Phormidium (Kützing) Gomont 1892.

***Phormidium* sp.**

Slightly attenuated at towards ends, parallel trichomes and end cell rounded, calyptra absent, cells 4-5 μm in wide and 5-7 μm in long.

Pseudoanabaena Lauterborn 1914-17

***Pseudoanabaena* sp.**

Single, not attenuated at towards ends trichome and cells 2-2.5 μm in long and 12-1.5 μm in wide.

Spirulina (Turpin) Gomont 1892

S. maior (Kützing) Gomont 1892 (Figure 3. 1. e).

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

S. subsalsa (Oersted 1842) Gomont 1892.

Generally closely spiralled trichome 0.9-1.4 (1-3) μm in diameter, helix 3.5-4 (3-8) μm in wide, tightly coiled, so no distance between turns (Prescott, 1982, Pl. 108, 14; John et al., 2002, 13: C-E).

Nostocales

Anabaena (Bory) Bornet 1886.

A. bergii (Kützinger) Bornet 1886 (Figure 3. 1. f).

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

A. crassa (Lemmermann) Komárková-Legnerová and Cronberg 1992.

Under the name of *Anabaena spiroides* var. *crassa* Lemmermann 1898, John and colleagues (2002) described the species as trichome single, helical consist of spherical-shaped cells 11.5-12 (6.5-15) μm in wide, 10-11 (5-12) μm in long, heterocyst 12.5-13.5 (13-25) μm in wide, 13-14 (13-33) μm in long (John et al., 2002, 15:I, Algaebase, 2006)

A. planctonica Brunnthaler 1903 (Figure 3. 1. g).

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

A. smithii (Komárek) Watanabe

Straight trichomes and ellipsoidal cells 9-12 (9-15) μm in wide, 7-8 (6-12) μm in long, spherical heterocyst 14-15 (10-14) μm in wide, 12-13 (10-14) μm in long, and subspherical akinete distans from the heterocyst 12-14 (10-20) μm in wide, 15-18 (15-30) μm in long (John et al., 2002, 15: C)

***Anabaena* sp.**

Straight trichomes and ellipsoidal cells 1-2 μm in wide, 1.5-2.5 in long, spherical heterocyst 1.5-2 μm in diameter.

Calothrix (Agardh 1824) Bornet et Flahault 1886.

C. stagnalis Gomont 1895.

Filaments in usually stellate small group and trichome gradually tapering from head to end like hair. Filaments are 8-9 (8-12) μm in wide. Cells 6-8 (6-9) μm in wide and generally shorter than wide of cells. Heterocyst 10 (10.8) μm in diameter and cylindrical akinets 10-10.5 (10-11) μm in wide, 26-27 (26-40) μm in long (Prescott, 1982, Pl. 132, 7; John et al., 2002, 16: D)

Cylindrospermum (Kützting 1843) Bornet et Flahault 1886.

C. minutissimum Collins 1896 (Figure 3. 1. h).

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

10.2.2 Euglenophyta

Single cell flagellates, free swimming, generally green, rarely masked by red orange pigments, storage material paramylon.

Euglenales

Euglena Ehrenberg 1833.

E. acus Ehrenberg 1830.

Cells 7.5-10 (7-28.3) μm in wide, 54-82 (52-311) μm in long, needle and elongate spindle-shaped cell, anterior end narrowed truncate, posterior end tapering to a point, chloroplast numerous, disc like without pyrenoids (John et al., 2002, 34: A).

E. agilis Carter 1856

Cells 13-15 (4-15) μm in wide, 39-46 (13-60) μm in long, anterior end bluntly rounded, posterior end rounded, chloroplast 2 (2-3), elongated near the side cell with pyrenoids (John et al., 2002, 35: G, H).

E. contabrica Pringsheim 1953.

Cells 21-23 (20-25) μm in wide, 55-58 (54-62) μm in long, cylindrical in middle part, of cell, anterior end narrowed, posterior end rounded, chloroplast numerous, band like, and very long flagellum (John et al., 2002, 37: E-F)

E. deses Ehrenberg **fo** ***klebsii*** (Lemmermann) Popova 1966.

Cells are 10-12 (5-15) μm in wide, 55-61 (45-130) μm in long. Cells have anterior end slightly narrowed, posterior end narrowed to short rounded tail, disc-shaped numerous chloroplast without pyrenoids, and very long flagellum (John et al., 2002, 37: L-M)

E. granulata (Klebs) Schmitz 1884.

Cells are 17-19 (11-28) μm in wide, 53-59 (50-115) μm in long. Spindle-shaped cells have conical anterior end rounded, posterior end tapering to point, plate-shaped numerous chloroplast with pyrenoid, and very long flagella (John et al., 2002, 36, A)

E. obtusa Schmitz 1884.

Cells are 17-18 (16-24) μm in wide, 93-101 (90-124) μm in long. Cells have both ends rounded, discs and plate-shaped numerous chloroplast with pyrenoid (John et al., 2002, 36, G)

E. proxima Dangeard 1901.

Cells 14-17 (13-25) μm in wide, 53-62 (52-80) μm in long, spindle-shaped cell, anterior end tapering truncate, posterior end tapering to a short point, chloroplast disc-shaped, numerous without pyrenoids, and long flagellum (John et al., 2002, 35: B)

E. sanguinea Ehrenberg 1830.

Cells 23-26 (22-44) μm in wide, 95-123 (90-150) μm in long, spindle-shaped cell, anterior end tapering rounded, posterior end gradually tapering to a point, chloroplast numerous with pyrenoids, and long flagellum (John et al., 2002, 36: J)

Lepocinclis Perty 1852.

L. fusiformis (Carter) Lemmermann 1901.

Cells 17-19 (15-32.5) μm in wide, 35-37 (15-42.5) μm in long, lemon-shaped cell, anterior end conically tapering, posterior end gradually narrowing to short tail piece, disc-shaped chloroplast numerous, and flagellum (John et al., 2002, 38: I)

L. ovum (Ehrenberg) Lemmermann 1901.

Cells 21-22 (13-25) μm in wide, 28-29 (20-43.3) μm in long, broadly ovate cell, anterior end rounded, posterior end a short blunt tail piece 6-6.4 (6-7) μm in long, flagellum (John et al., 2002, 38: B, C)

L. playfairiana Deflandre 1932.

Cells 20-23 (19-26) μm in wide, 35-44 (32-53) μm in long, broadly spindle-shaped cells, anterior end slightly narrowing, posterior end tapering to tail piece 7-8 (7-12) μm in long, disc-shaped chloroplast numerous, and flagellum (John et al., 2002, 38: B-C)

L. steinii Lemmermann 1901.

Cells 8-9 (8-15) μm in wide, 22-26 (21-33) μm in long, spindle-shaped cells, anterior end slightly narrowing truncate, posterior end tapering to sharp tail piece, chloroplast numerous, and long flagellum (John et al., 2002, 38: F)

Phacus Dujardin 1841.

P. caudatus Hübner 1886.

Cells 18-21 (16-27) μm in wide, 35-43 (31-50) μm in long, pear-shaped to ovate cell, anterior end rounded, posterior end tapering to a short tail 6-6.5 (5-11) μm , chloroplast disc-shaped, numerous without pyrenoids (John et al., 2002, 40: B).

P. pseudonordstedtii Pochmann 1941.

Cells 12-14 (10-16) μm in wide, 35-37 (31-42) μm in long, ovoid cells, anterior end rounded, posterior end narrowing to a long sharp tail-piece, disc-shaped chloroplast numerous, long flagellum (John et al., 2002, 40: J).

P. striatus (Drezepolski) France 1893.

Cells 8-10 (8.5-19) μm in wide, 20-21 (19-25) μm in long, pear-shaped cells, anterior end rounded, posterior end narrowing to a long sharp tail-piece, disc-shaped chloroplast numerous, flagellum (John et al., 2002, 38: Y).

Trachelomonas Ehrenberg 1833.

T. acanthostoma Stokes 1887.

Cells 17-19 (15-36) μm in wide, 18-22 (18-42) μm in long, ovoid, spherical cells, densely punctate cell walls with surrounded by 1 or 2 rows of short spines (John et al., 2002, 43: H).

T. armata Stein 1878.

Cells 30-31 (29-32) μm in wide, 29-38 (28-45) μm in long, generally ovoid cell, apical pore 7-8 (6-8) μm , long spines 3-7.5 (3-10) μm in long, posterior end rounded, flagellum twice length of cell (John et al., 2002, 42: M).

T. granulosa Playfair 1915..

Cells 18-19 (17-22) μm in wide, 22-23 (22-26) μm in long, spherical cells covered granules, posterior end rounded, apical pore without collar (John et al., 2002, 42: R).

T. planctonica Svirenko 1914.

Cells 17-18 (16-22) μm in wide, 19-25 (18-32) μm in long, generally ovoid, ellipsoid cells, apical pore with collar 3-4 (3.4-5.4) μm in wide, 2-3 (2-5) μm in long, posterior end rounded, (John et al., 2002, 42: W).

T. pulchella Drezepolski 1925.

Cells 15-16 (15-17) μm in wide, 18-19 (18-21) μm in long, ellipsoid cells, surrounded granules, apical pore without a collar, posterior end rounded (John et al., 2002, 42: J).

T. volvocina Ehrenberg 1833 (Figure 3. 1. i).

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

10.2.3 Cryptophyta

Campylomonas Hill 1991.

C. reflexa Hill 1991.

Sigmoid-shaped cells 12.5-15 (10-30) μm in wide, 19-50 (15-60) μm in long, cells are slightly contorted, anterior end slightly tapering, characteristic curved posterior end wide rounded, flagella unequal, chloroplast 2 at the lateral site of cell without pyrenoid, nucleus in the posterior and center of cell (Wehr and Sheath, 2003, 5A, 7C, D).

C. rostratiformis Hill 1991 (Figure 3. 2. a).

Cells 17.5-28 (16-40) μm in wide, 46-52 (45-80) μm in long, cells are slightly recurved at posterior end wide rounded, anterior end rostrate, flagella unequal, chloroplast 2 with numerous pyrenoids, nucleus in about center of cell, slightly curved furrow towards the left, and rarely monitoring especially spring months (Wehr and Sheath, 2003, 5:B, 7:B).

Cryptomonas Ehrenberg 1838.

C. marssonii Skuja 1948 (Figure 3. 2. b).

Cells 8-10 (8-14) μm in wide, 17-21 (16-33) μm in 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 site of cell without pyrenoid, nucleus in the posterior and center of cell, sometimes observed in Lake Abant, found almost each season (found as plankter in lakes and ponds, and not commonly distributed) (John et al., 2002, 45: E).

C. ovata Ehrenberg 1838 (Figure 3. 2. c).

Cells 7.5-16 (5-20) μm in wide, 15-30 (14-80) μm in long, cell with moderate degree of lateral push, anterior end slightly acute, dorsal protuberance rounded, posterior end rounded, contractile vacuole at cell dorsal anterior, flagella generally equal and shorter than cell, chloroplast 2 at the lateral site of cell without pyrenoid, nucleus in the posterior, commonly distributed and founded about all season, however especially second years of this study (euplankter in lakes and ponds, probably cosmopolitan) (Prescott 1982, 95: 40; John et al., 2002, 45: B).

C. platyuris Skuja 1948.

Cells 9-11 (9-14) μm in wide, 32-38 (31-50) μm in long, anterior end slightly tapering, posterior end wide rounded, flagella unequal, chloroplast 2 at the lateral site of cell without pyrenoid, nucleus in the posterior and center of cell (John et al., 2002, 45: F).

Plagioselmis Hill 1990

P. nannoplanctica (Skuja) G. Novarino 2002

Cells 4-5 (3.5-5.5) μm in wide, 7.5-11 (8-12) μm in long, anterior end slightly tapering, slightly curved at posterior end, flagella unequal, chloroplast with a pyrenoid, nucleus in the posterior and center of cell (Algabase).

10.2.4 Pyrrophyta (Dinoflagellates)

Single celled, having two flagella (transverse and encircling cell), cell wall firm or fromed of regular arranged polygonal plates.

Gonyaulacales

Ceratium Schrank 1793.

C. coralinianum (Bailey) Jorgensen 1911.

Cells 75-87 (73-105) μm in wide, 131-178 (125-213) μm in long, spindle-shaped cell, epitheca wide above cingulum, narrowing usually right side, apical horn curved, hypotheca broad below the cingulum with long central horn and short right horn (John et al., 2002, 49: D).

C. cornutum (Ehrenberg) Claparede 1858 (Figure 3. 2. d).

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

C. furcoides (Lavender) Langhans 1925.

Cells 31-42 (28-56) μm in wide, 137-186 (123-222) μm in long, spindle-shaped cell, epitheca narrow with a horn, broad and short hypotheca separated into two horns (short lateral and long central) (John et al., 2002, 49: B. C).

C. hirundinella (Müller) Dujardin 1841.

Cells 37-46 (28-55) μm in wide, 97-194 (40-450) μm in long, broadly spindle-shaped cell, epitheca narrow with a apical horn, hypotheca broad below the cingulum with extending into 2 or 3 apical horns (lateral horns shorter than central) (John et al., 2002, 49: E).

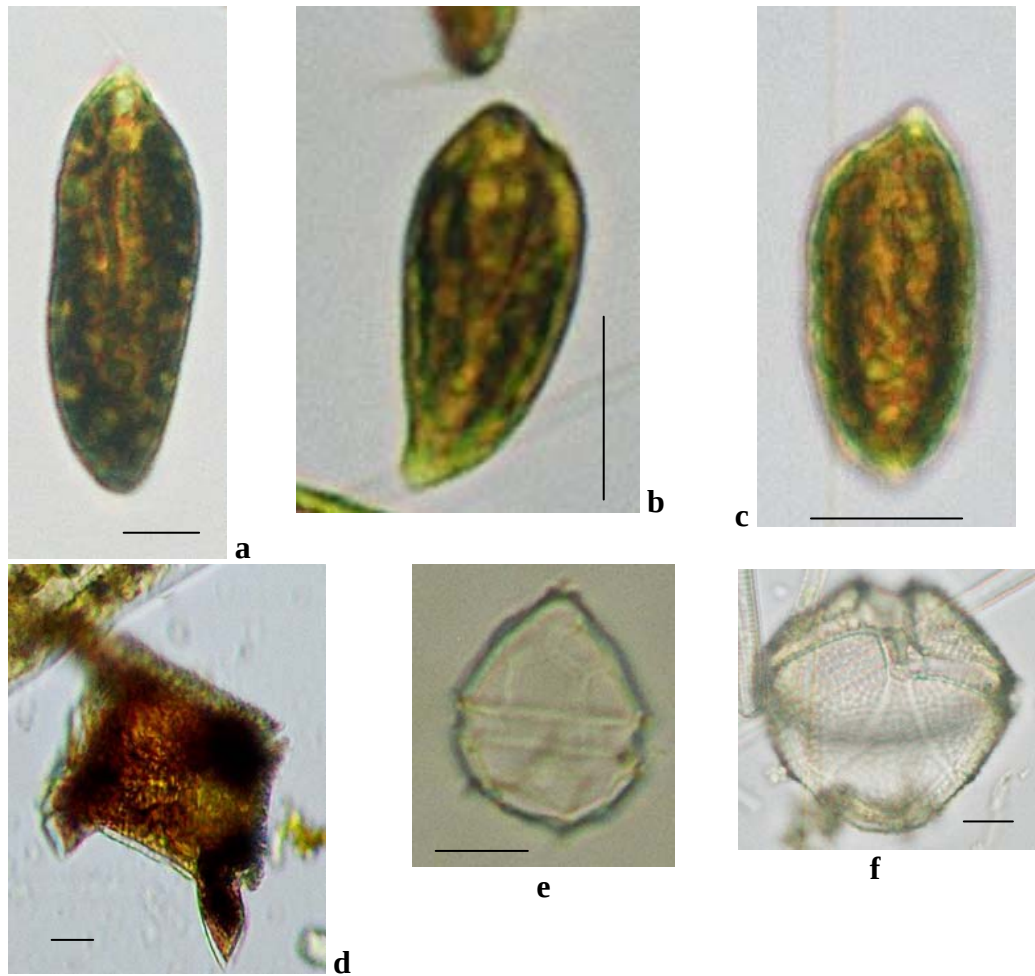


Figure 3. 1. a) *Campylomonas rostratiformis*, b) *Cryptomonas marsoni*, c) *C. ovata*, d) *Ceratium cornutum*, e) *Peridiniopsis thompsonii*, f) *Peridinium willei* (scale 10 μm).

Gymnodiniales

Gymnodinium Stein 1878.

G. cnecoides T. Harris 1940.

Cells 9-10 (8-18) μm in wide, 9-12 (9-23) μm in long, cell ovoid with rounded, equal size epicone and hypocone, both hemispherical and wide cingulum, ribbon-like chloroplast 1 or 2, nucleus in the anterior site (Popovsky and Pfiester, 1990, 80: a-h; John et al., 2002, 46: E).

Peridinales

Peridiniopsis Lemmermann 1904.

P. thompsonii (Thompson) Bourrelly 1968 (Figure 3. 2. e).

Ovoid cells 18-20 (18.5) μm in wide, 31-33 (31-38) μm in 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 (Popovsky and Pfiester, 1990, 209: a-d; John et al., 2002, 50: G).

Peridinium Ehrenberg 1832

P. cinctum (Müller) Ehrenberg 1838.

Cells 47-69 (35-73) μm in wide, 43-65 (40-78) μm in 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, 51: J).

P. willei Huitfeldt-Kaas 1900 (Figure 3. 2. f).

Cells 48-67 (36-80) μm in wide, 45-63 (38-78) μm in 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).

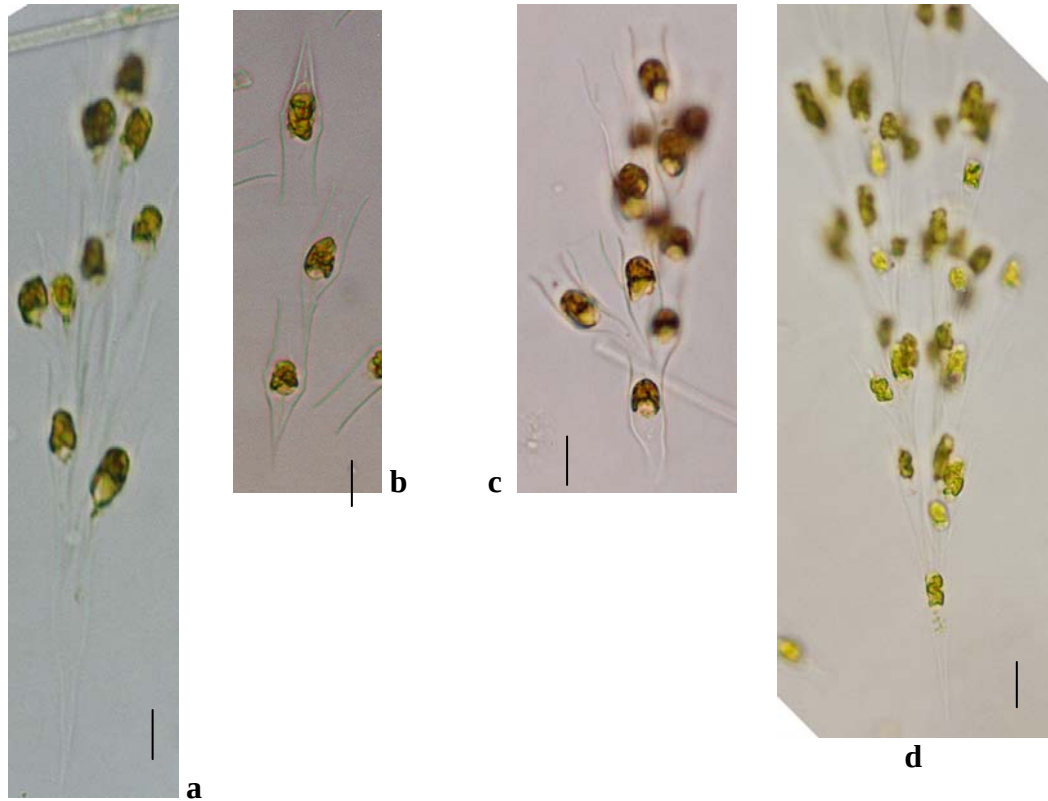


Figure 3. 1. a) *Dinobryon bavaricum*, b) *D. divergens*, c) *D. sertularia*, d) *D. sociale* var. *americanum* (scale 10 μm).

10.2.5 Chrysophyta (Golden Algae)

Chromulinales

Dinobryon Ehrenberg 1834.

D. bavaricum Imhof 1890 (Figure 3. 3. a).

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

D. divergens Imhof 1887 (Figure 3. 3. b).

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

D. sertularia Ehrenberg 1838 (Figure 3. 3. c).

Prolonged lorica 10-12 (10-14) μm in wide, 32-37 (30-40) μm in long, oblique basal colonies, lorica lying divergens 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 1838

Lorica 7.5-8.5 (8-10) μm in wide, 34-44 (30-70) μm in long, cone-shaped lorica lying erect in the colonies, posterior tapering to a blunt point (Prescott, 1982, 98: 13; John et al., 2002)

D. sociale Ehrenberg **var. *americanum*** Bachmann 1911 (Figure 3. 3. d).

Lorica 8-8.5 (8-10) μm in wide, 35-46 (30-70) μm in 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

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

Synurophyceae

Synurales

Synura Ehrenberg 1835.

S. petersenii Korshikov 1929.

Colonies spherical, ovoid cells without spines base, cells 7-9 μm in wide, 17-29 μm in long, chloroplast parietal unequal two flagella (John et al., 2002, 55: B)

10.2.6 Xanthophyta (Yellow-Green Algae)

Mischococcales

Ophiocytium Nageli 1849.

O. capitatum Wolle 1887.

Arcuate cylindrical cells 5-6 (5-10) μm in wide, 18-25 (up to 150) μm in long, both end of cells with a short, disc-shaped chloroplast numerous (John et al., 2002, 70: E).

10.2.7 Prasinophyta

Dunalliellales

Tetraselmis F. Stein 1878.

T. cordiformis (Carter) Stein 1878

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

10.2.8 Chlorophyta (Green algae)

Volvocales

Chlamydomonas Ehrenberg 1833.

C. globosa Snow 1902.

Spherical cells 6-7.5 (5-8) μm in diameter, papilla absent, cup-shaped chloroplast basally thickened with basal pyrenoid and equal two flagella (Ettl, 1983, 189: John et al., 2002, 77: E)

C. leptobasis Skuja 1956.

Spherical or ellipsodisc cells 10-15 (9-17) μm in long, 7.5-9 (5-13) μm in wide, papilla present, peripheral chloroplast basally thickened with basal ellipsodisc pyrenoid and equal two flagella (Ettl, 1983, 260)

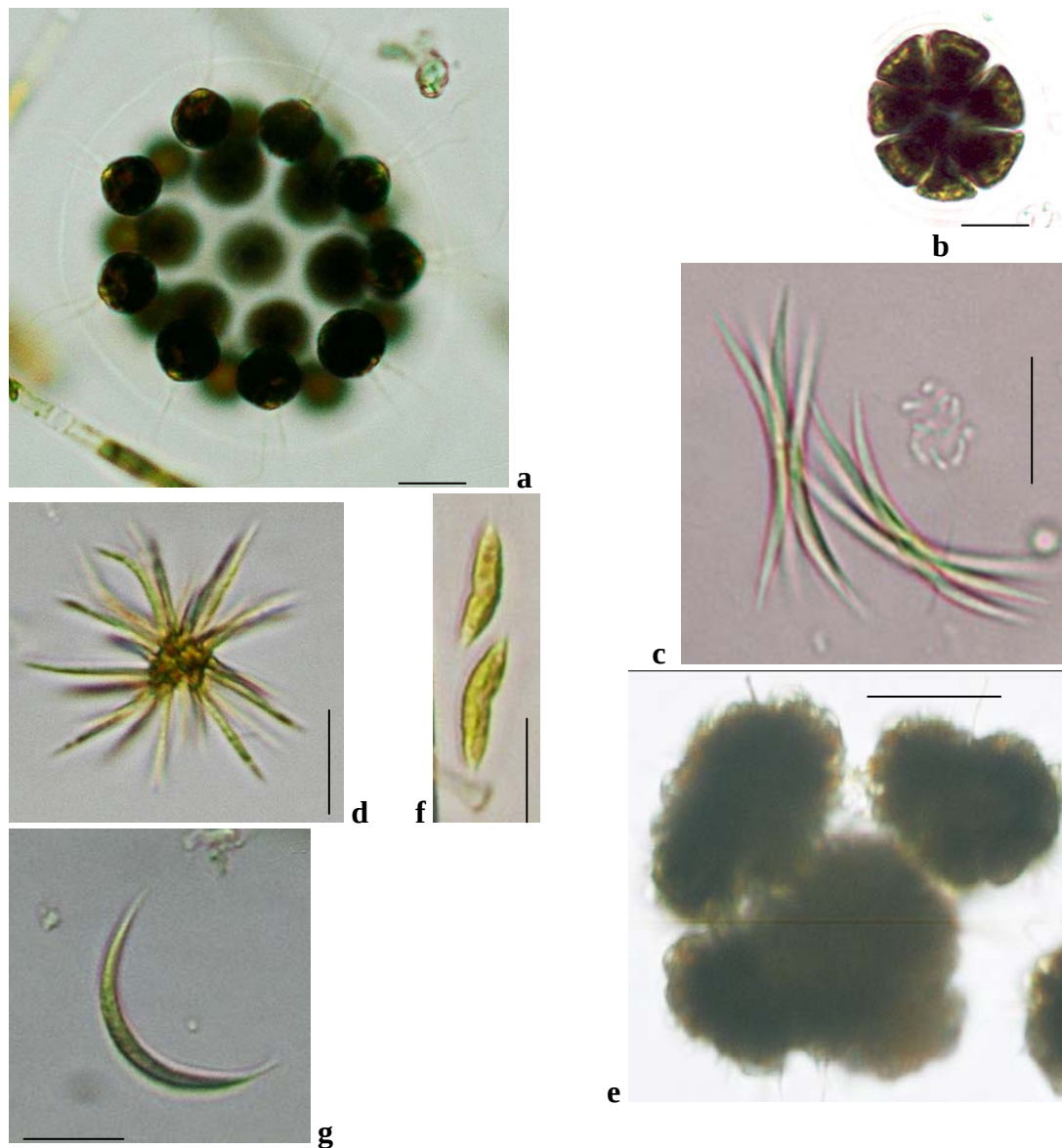


Figure 3. 1. a) *Eudorina elegans*, b) *Pandorina morum*, c) *Ankistrodesmus falcatus*, d) *A. spiralis*, e) *Botryococcus braunii*, f) *Elakototrix gelatinosa*, g) *Monoraphidium arcuatum* (scale 10 μm).

C. passiva Skuja 1956.

Spherical cells 12-15 (12-19) μm in long, 9-10 (9-15) μm in wide, colony 64-78 (60-200) μm papilla absent, cup-shaped chloroplast basally thickened with basal pyrenoid and equal two flagella (Ettl, 1983, 307).

Eudorina Ehrenberg 1830.

E. elegans Ehrenberg 1831 (Figure 3. 4. a).

Elipsoidal or spherical coenobium 62.5-73 (60-200) μm in diameter, consist of 16-32 (4-64) celled: spherical cells 12.5-15 (12-24) μm in diameter, cup-shaped chloroplast with pyrenoids, monitored during seven different months (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 (Müller) Bory 1824 (Figure 3. 4. b).

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

Polytoma Ehrenberg 1838.

P. cylindraceum Pascher 1927.

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

Sphaerellopsis Korshikov 1925.

S. spiralis Belcher *et* Swale 1963.

Obovoid cells with thin envelope 6-7.5 (6-8.5) μm in wide, 11-12 (11-15) μm in long, chloroplast parietal with basal pyrenoid (John et al., 2002, 78: T)

Chlorococcales

Ankistrodesmus Corda 1838.

A. falcatus (Corda) Ralfs 1848 (Figure 3. 4. c).

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

A. fusiformis Corda ex Korshikov 1953.

Clustered colonies consist of 2-4 (1-32) cells, needle-like: narrowly spindle-shape cells 1.5-2 (1-4.3) μm in wide, 24-31 (19-57) μm in long (John et al., 2002, 97: N).

A. spiralis (Turner) Lemmermann 1908 (Figure 3. 4. d).

Spirally twisted 4-8 (2-16) cells in colonies, twisted at centre, narrowing to ends, spindle-shape cells 1.5-2 (1-4.3) μm in wide, 26-37 (20-68) μm in 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 3. 4. e).

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

Characium Braun 1849.

C. ornithocephalum Braun 1855.

Semicircular cells 7.5-10 (3.8-16) μm in wide, 26-28 (12-50) μm in long, konveks in midlle of cells, chloroplast with an ellipsodisc pyrenoid (Huber-Pestalozzi, 1983, 59: 8)

Chondrosphaera Skuja 1964.

C. lapponica Skuja 1964.

Ellipsodisc colonies include 4-8 (2-50) cells, and 42-58 (up to 200) μm in diameter, spherical cells 10-11 (8-12) μm in diameter, chloroplast with ellipsodisc pyrenoids (Huber-Pestalozzi, 1983, 155: 2)

Crucigeniella Morren 1830.

C. rectangularis (Nageli) Komarek 1974.

Rhomboidal coenobium 8-12 (7-14) μm in wide, 10-14 (8-20) μm in long: consist of 16 (16 or more) cells, ovoid cells 4-6x5-7(3-7x4-10) μm in dimension, parietal chloroplast with pyrenoid (John et al., 2002, 84: F).

Elakatothrix Wille 1898.

E. gelatinosa Wille 1898 (Figure 3. 4. f).

Colonies of cells in a mucilaginous envelope: narrowly spindle-shaped cylindrical cells 3-3.2 (3-4) μm in wide, 14-21 (12-26) μm in long, tapering to sharply pointed

ends, and parietal chloroplast with pyrenoid (Bourrelly, 1972, 40:7; John et al., 2002, 114: K).

Eremosphaera de Bary 1858.

E. viridis de Bary 1858.

Spherical cells 48-67 (30-200) μm in diameter, cell wall smooth, disc-shaped chloroplast numerous with small pyrenoids (John et al., 2002, 87: B).

Geminella Turpin 1823

***Geminella* sp.**

Cells, 5-7 μm in wide, 7.5-10 μm in length, separated cells in pairs with mucilaginous sheath 9-12 μm in wide, chloroplast with pyrenoid. Occasionally distributed in Lake Abant.

Golenkinia Chodat 1894.

G. radiata Chodat emend. Korshikov 1953.

Cells 14-17 (6.4-21) μm in diameter, cells spherical, smooth wall with spines 19-21 (21-65) μm in long, more than 20 per cell, chloroplast with pyrenoid (John et al., 2002, 88: H).

Kirchneriella Schmidle 1893.

K. obesa (West) Schmidle 1893.

Cells 2.5-3.5 (2-16) μm in wide, 7-10 (6-16) μm in long, cells circular, tapering to bluntly pointed apices, chloroplast with pyrenoids (John et al., 2002, 98: J).

Korshikoviella Silva 1959.

K. limnetica (Lemmermann) Silva 1959.

Cells 6-8 (3-15) μm in in wide, 31-58(25-200) μm in long, cells cylindrical to spindle-shaped, curved, and tapering at ends, chloroplast each segment with pyrenoid (Huber Pestalozzi, 1983, 71: 3).

K. michailovskoensis (Elenkin) Silva 1959

Cells 6-9 (5-23) μm in in wide, 32-51 (30-140) μm in long, cells cylindrical to spindle-shaped, curved, tapering at ends (John et al., 2002, 90: F).

Monoraphidium Komarkova-Legnerova 1969.

M. arcuatum (Korshikov) Hindak 1970 (Figure 3. 4. g).

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

Nephrocytium Nageli 1849.

N. agardhianum Nageli 1849.

Coenobia contain 4 or 8 (4 or 8) cells, spirally or irregularly arranged cells in asymmetrically ovoid musilaj sheath 37-45 (30-125) μm , kidney-shaped with rounded apices cells 5-8 (4-10) μm in wide, 12-18 (10-25) μm in long (Prescott, 1983, 54: 15, 16: John et al., 2002, 83: B).

N. limneticum (Smith) Smith 1933.

Coenobia contain 4 or 8 (4 or 8) cells, spirally or irregularly arranged cells in asymmetrically ovoid musilaj sheath 43-61 (40-90) μm , kidney-shaped with rounded apices cells 4-7 (2-12) μm in wide, 10-15 (8-18) μm in long (Prescott, 1983, 157: 3).

Oocystis Braun 1855.

O. apiculata West 1893.

Coenobia contain 2-4 (2, 4) cells, oblong spindle-shaped with rounded apices cells 5.5-7.5 (5-15) μm in wide, 12-15 μm (11-25 μm) in long, chloroplast 1 (1 or 2) with pyrenoid (John et al., 2002, 92: A).

O. borgei Snow 1903.

Cells solitary or coenobia contain 2-4 (2, 4 or 8) cells, ellipsoid with rounded apices cells without polar wall tickening 7-9 (6-20) μm in wide, 10-15 (9-20) μm in long, chloroplast 1-2 (1-4) with pyrenoid (John et al., 2002, 92: C).

O. marssonii Lemmermann 1898.

Cells solitary or 2-4 (2, 4 or 8) celled coenobia, broadly spindle-shaped with narrowed apices cells with polar wall tickening 5-8 (4-14.4) μm in wide, 7.5-12.5 μm (6.4-20.8 μm) in long, grooved chloroplast 2-4 (2-8) with pyrenoid in each groove (John et al., 2002, 92: F).

O. parva West and West 1898 (Figure 3. 5. a).

Cells solitary or 2-4 (2, 4 or 8) celled packed in coenobia, ellipsoidal, broadly spindle-shaped with rounded apices cells with polar wall tickening 4-7 (1.5-10) μm in wide, 7-10 (3.2-17) μm in 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. pusilla Hansgirg 1890.

Coenobia 2-8 (2, 4 or 8), ellipsoidal rounded cells 4-6 (3-7.5) μm in wide, 6-8 (6-12) μm in long, chloroplast 2 (2-3) without pyrenoid (John et al., 2002, 92: K).

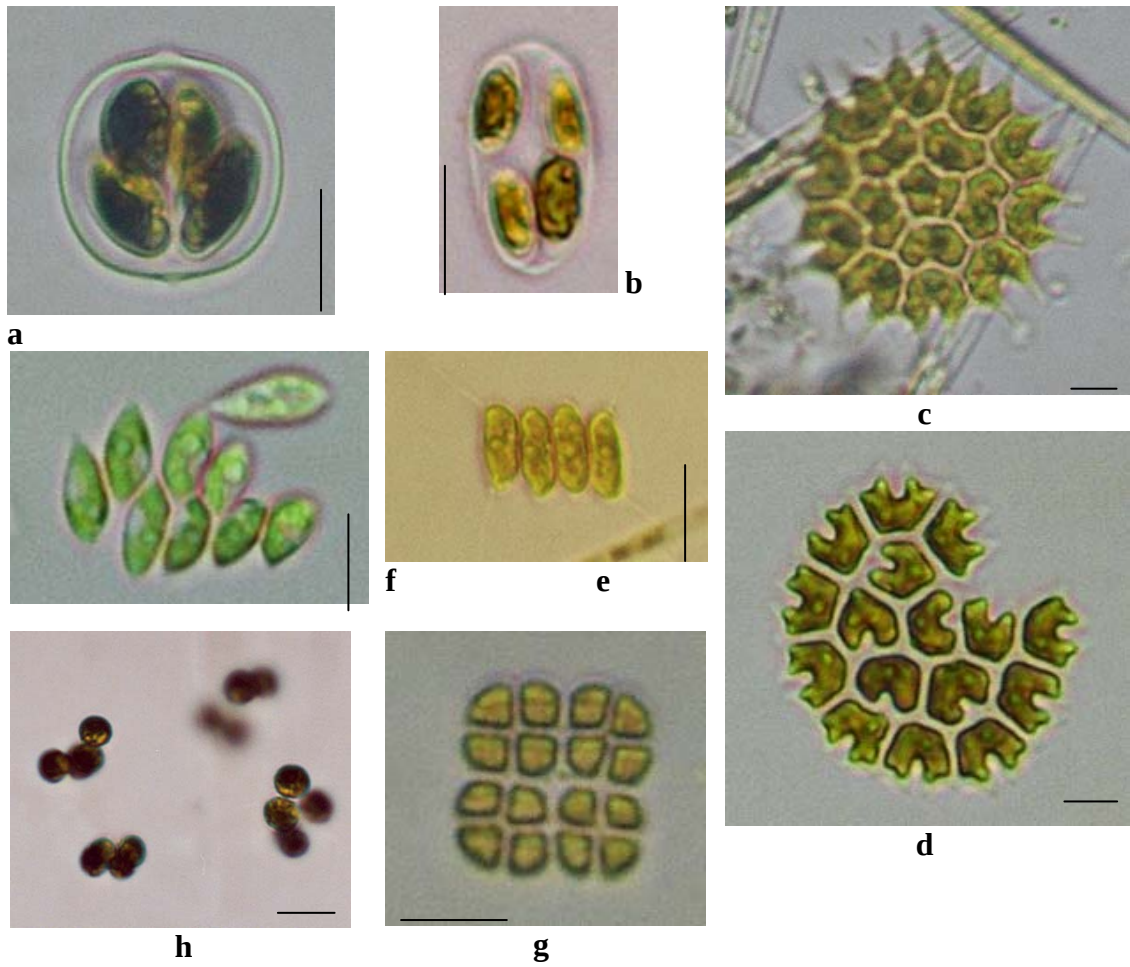


Figure 3. 1. a) *Oocystis parva*, b) *O. tainoensis*, c) *Pediastrum boryanum*, d) *P. tetras*, e) *Scenedesmus communis*, f) *S. obliquus*, g) *Tetrastrum komarekii*, h) *Pseudosphaerocystis lacustris* (scale 10 μm).

O. tainoensis Kommarek 1983 (Figure 3. 5. b).

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

***Oocytis* sp.**

Coenobia 2 celled in mother cell, 9-12x 14-21 μm in dimension with polar wall thickened, ellipsoidal cells 3.75-5 μm in wide, 6-9 μm in long, chloroplast 1-2 with pyrenoid.

Pediastrum Meyen 1829.

P. boryanum (Turpin) Meneghini 1840 (Figure 3. 5. c).

Coenobia 29-84 (16-208) μm in diameter, consist of 16-64 polygonal cells, marginal cells 7-9x9-11 (5-40x5-31) μm in dimension, inner cells 6-8x6-8.5 (5-26x4-27) μm in dimension, intercellular spaces absent, chloroplast with a pyrenoid for each cell, and rarely observed (common, eu-and tychoplanktonic in lakes) (Prescott, 1982, 47: 9, 48: 1, 3; Huber Pestalozzi, 1983, 87:1; John et al. 2002: 93: C).

P. boryanum (Turpin) Meneghini **var. *cornutum*** (Raciborski) Sulek 1969.

Coenobia 30-98 (20-118) μm in wide, projections lying marginal cells, 5-15x5-13 (4.5-27x4-24) μm in dimension, polygonal inner cells 5-13 (5-26) μm in wide, 6-16 (5,7-27) μm in long (John et al., 2002, 93: D, F).

P. boryanum (Turpin) Meneghini **var. *longicorne*** Reinsch 1867.

Coenobia 37-84 (30-150) μm in wide, projections lying marginal cells, 9-18x6-14 (8.1-41x4-35) μm in dimension, polygonal without intercellular spaces inner cells 5-15x4-12 (5-27x4-22.5) μm in dimension (John et al., 2002, 93: E).

P. dublex Meyen 1829.

Coenobia 41-77 (28-212) μm in wide, projections lying marginal cells, 8-15x7-13 (7-28x6-28) μm in dimension, polygonal without intercellular spaces inner cells 5-13x4-12 (4-26x4-30) μm in dimension (John et al., 2002, 93: I).

P. integrum Nageli 1849.

Coenobia consist of 8-32 (4, 8, 16, 32 or 128) cells, 41-84 (up to 125) μm short projections lying cells, 7.5-12.5 (up to 38) μm in dimension, cells irregularly arranged, chloroplast with a pyrenoid for each cell (Huber Pestalozzi, 1983).

P. tetras (Ehrenberg) Ralfs 1844 (Figure 3. 5. d).

Coenobia contain 4-8 (4, 8, 16 or 32) cells, 16-37 (15-74) μm in wide, marginal cells, 8-14x9-13 (4-18x5-18) μm in dimension, laterally united to apex, apex divided two lobes, inner cells 8-10x8-10 (4-14x5-16) μm in dimension without intercellular spaces, and seldom distributed during study period (generally distributed, eu- and tychoplanktonic in lakes) (Prescott, 1982, 50: 3, 6; Huber Pestalozzi, 1983, 91: 5; John et al., 2002, 93: N).

Quadricoccus Fott 1948.

Q. verrucosus Fott 1948.

Oval cells 4-5 (4) μm in wide, 8-9 (8-9) μm in long with rounded end of cells, smooth wall, parietal chloroplast with pyrenoid (John et al., 2002, 84: I).

Radiococcus Schmidle 1902.

R. planktonicus Lund 1956.

Colonies 48-67 (up to 250) μm contain 2-4 (2-8) cells groups, spherical cells 5-6 (4-7) μm in diameter (John et al., 2002, 86: I).

Scenedesmus Meyen 1829.

S. arcuatus (Lemmermann) Lemmermann 1899.

Coenobia consist of 8 (4, 8 or 16) cells in two rows, broadly rounded, slightly curved cells, 4,5 μm (2-9,5 μm) in wide, 10,5 μm (7-18 μm) in long (John et al., 2002, 97: C).

S. bicaudatus Dedusenko 1925.

Coenobia contain 2-4 (2, 4 or 8) tightly packed, linearly arranged cells, broadly rounded, ovoid cylindrical cells, 4-5 (2-5.4) μm in wide, 9-12 (7.8-14.5) μm in long (Huber Pestalozzi 1983, 240: 5: John et al., 2002, 94: M).

S. communis Hegewald 1977 (Figure 3. 5. e).

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

S. dimorphus (Turpin) Kützing 1833.

Coenobia contain 4 (2, 4 or 8) linearly arranged cells, tapering to apices, spindle-shaped cells, 4.5-6 (2-14) μm in wide, 9-16 (5-27) μm in long (Huber Pestalozzi 1983, 228: 3: John et al., 2002, 96: M)

S. ellipticus Corda 1835.

Cells 2, 4, and 16 (2, 4 or 8 rarely 16 or 32) single linearly arranged in coenobia, broadly rounded apices, ovoid-cylindrical cells, 5-6.5 (2-9) μm in wide, 9-15 (3,5-23) μm in long (John et al., 2002, 97: B)

S. obliquus (Turpin) Kützing 1833 (Figure 3. 5. f).

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 in wide, 10-16 (4-25 μm) μm in long, and seldom monitoring, cultured in laboratory (cosmopolitan) (Huber-Pestalozzi 1983, 227:3; John et al., 2002, 96: O).

S. subspicatus Chodat 1926.

Cells 4 (2, 4 or 8) linearly or alternately arranged in coenobia, acute apices, spindle-shaped cells, 2.5 (2.4-7) μm in wide, 10-11 (5-12) μm in long, large spin on each apex and small spines lateral of marginal cells (Huber Pestallozi 1983, 237: 8: John et al., 2002, 96: D).

Schroederia Lemmermann 1898.

S. robusta Korshikov 1953.

Cells 5-7 (3-8) μm in wide, 37.5-64 (30-140) μm in long, cells, S-shaped or straight spindle-shaped, narrowing ends with spine 20-24 (20-33) μm in long, chloroplast with 2-5 (1-5) pyrenoids (John et al., 2002, 90: G).

Sorastrum Kützing 1845.

S. americanum (Bohlin) Schmidle 1900.

Kidney cells 8-15 (4.8-20 μm) μm in wide, about equal in length and widedity, cells, heart-shaped, apical side with 2 (1-4) spines, parietal chloroplast with pyrenoid (John et al., 2002, 94: A).

Sphaerocystis Chodat 1897.

S. planctonica (Korshikov) Bourrelly 1966.

Colonies contain 16-32 (4, 8, 16 or 32) cells 38-56 (35-150) μm in diameter, cells 6-8 (4-9) μm in diameter, spherical cells regularly arranged in musilaj envelope, sporangia 11-12 (up to 12,5 μm) μm in diameter (John et al., 2002, 99: A).

Tetrachlorella Korshikov 1939.

T. alternans (G. Smith) Korshikov 1939.

Cells 6-8 (4-9) μm in diameter, spherical cells regularly arranged in musilaj envelope, sporangia 11-12 (up to 12.5 μm) μm in diameter (John et al., 2002, 99: A).

Tetrastrum Chodat 1895.

T. komarekii Hindak 1977 (Figure 3. 5. g).

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

Thorakochloris Pasher 1932.

T. nygardii Komarek 1979.

Colonies contain 16-32 (4-64) cells 31-48 (up to 150) μm in diameter, cells 3.7-6 (3-8) μm in diameter, spherical cells regularly arranged in musilaj envelope, sporangia 2-4 (2-4) cells group, chloroplast with a pyrenoid (Huber Pestalozzi 1983, 118: 3).

Tetrasporales

Pseudosphaerocystis Worocnichin 1931.

P. lacustris (Lemmermann) Novakova 1965 (Figure 3. 5. h).

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

Oedogoniales

Bulbochaete Agardh 1817.

***Bulbochaete* sp.**

Cells, 10-15 μm in wide, 15-20 μm in length, a long haired ellipsoidal oogonia 20-23 μm in wide, 28-32 μm in long, oospore superior division suffultory cell.

Zygnematales

Zygnemataceae

Closterium Nizsch 1848.

C. aciculare West 1860.

Cells, 5.5-7.5 (5-8) μm in wide, 367-489 (350-560) μm in length, apices 1-2 (1.5-2) μm in wide, straight long cell, tapering towards to slightly curved ends, chloroplast occupying one-third of cell with 8-14 (6-20) pyrenoid (John et al., 2002, 129: I).

C. calosporum Wittrock 1869.

Cells, 8-10 (8-12) μm in wide, 86-94 (80-100) μm in length, apices 2 (1.5-2.5) μm in wide, straight long cell, tapering towards to slightly curved ends, chloroplast with 4-5 (3-5) pyrenoids for each ridges, smooth cell wall (John et al., 2002).

C. incurvum Brebisson 1856.

Strongly curved cells, 8-11 (6-12) μm in wide, 47-65 (40-80) μm in length, apices 1-2 (1-2) μm in wide, straight long cell, tapering towards to slightly curved ends,

chloroplasts 3 (3) ridges with 2-3 (1-3) pyrenoids for each ones, smooth cell wall, small terminal vacuole (John et al., 2002, 129: P).

C. littorale F. Gay 1884.

Cells, 17-19 (15-20) μm in wide, 132-169 (120-200) μm in length, apices 3-4 (3-5) μm in wide, straight long cell, tapering towards to slightly curved ends, chloroplasts 3-4 (3-5) longitudinal ridges with 2-3 (2-5) pyrenoids, spherical terminal vacuole (John et al., 2002, 130: D).

C. moniliferum (Bory) Ehrenberg ex Ralfs 1848

Cells, 36-46 (35-55) μm in wide, 213-289 (200-350) μm in length, apices 8-9 (8-10) μm in wide, straight long cell, tapering towards to slightly curved ends, chloroplasts 3-4 (3-6) longitudinal ridges with 3-6 (2-10) pyrenoids, spherical terminal vacuole (John et al., 2002, 130: A).

C. parvulum Nageli 1849 (Figure 3. 6. a).

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

C. venus Kützinger ex Ralfs 1848.

Strongly curved cells, 7-9 (7-10) μm in wide, 62-71 (55-80) μm in length, rounded apices 2-2.5 (1.5-2.5) μm in wide, cell tapering towards to slightly ends, chloroplast with 1 (1-2) longitudinal ridges and 1-2 (1-2) pyrenoids, terminal vacuole (John et al., 2002, 129: O).

Cosmarium Corda 1848.

C. bioculatum Brebisson 1848.

Cells, 22,5 µm (8-27 µm) in wide, 25 µm (9-29 µm) in length, deep sinus, narrow towards inside, oblong with rounded lateral margin, smooth cell wall with puncta (John et al., 2002, 132: K).

C. botrytis Meneghini 1848 (Figure 3. 6. b).

Cells, 57,8-62,5 µm (51-85 µm) in wide, 87,5 µm (60-111 µm) in length, 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** West *et* West 1902 (Figure 3. 6. c).

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

C. crenatum Ralfs 1848

Cells, 22.5-25 (15-38) µm in wide, 29-34 (22-43) µm in length, shallow sinus, pyramidal-quadrangle semicells, cell wall with granules, lateral margin 3 (3) crenates and angular base 4 (4) crenates (John et al., 2002, 135: M).

C. depressum (Nageli) Lundell **var. planctonicum** Reverdin 132: S.

Cells are characterized with being surrounded by gelatinous sheath, 17-23 (16-30) µm in wide, 19-26 (18-28) µm in length (John et al., 2002, 132: S).

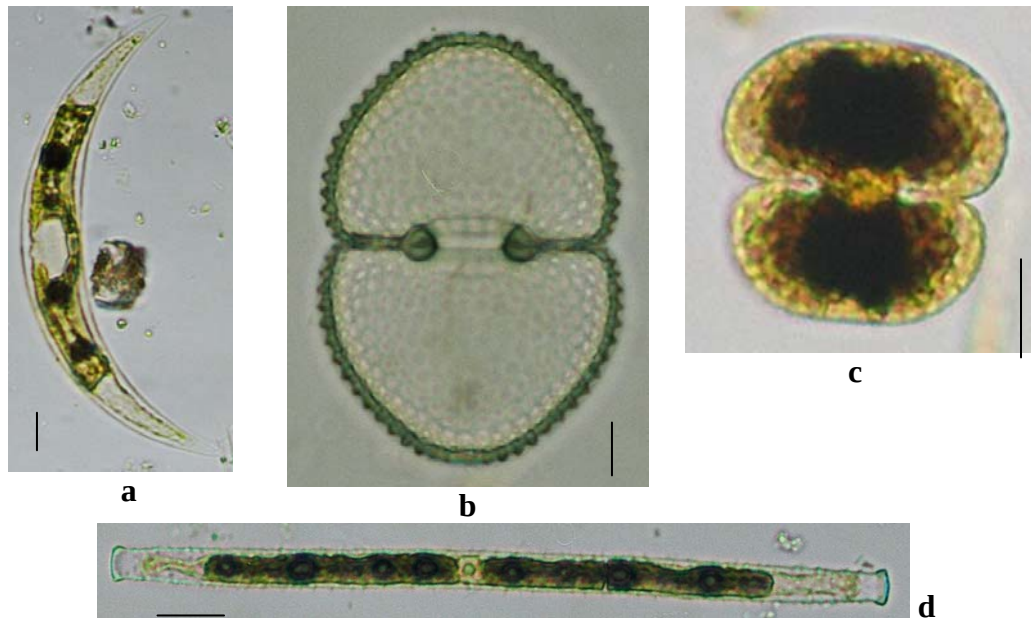


Figure 3. 1. a) *Closterium parvulum*, b) *Cosmarium botrytis*, c) *C. contractum* var. *ellipsoideum*, d) *Gonatozygon brebissoni* (scale 10 μm).

C. granatum Brebisson 1848

Subrhomboidal cells, 15-21 μm (15-38 μm) in wide, 25-34 (22-47) μm in length, narrow sinus, pyramidal-quadrate semicells, smooth cell wall (John et al., 2002, 135: V).

C. meneghinii Rabenhorst 1868.

Cells, 11-15 (9.5-17) μm in wide, 13-18 (12.5-24) μm in length, deep sinus, semicells with rounded angles, truncate-pyramidal at apex (John et al., 2002, 133: R).

C. pygmaeum Archer 1864.

Cells, 8-10 (8-16) μm in wide, 8-11 (8-15) μm in length, deep sinus, semicells rounded rectangular (John et al., 2002, 133: P).

C. venustum (Brebisson) Archer 1861.

Cells, 18-24 (17-38) μm in wide, 27-35 (25-48) μm in length, narrow sinus, semicells truncate, 3 (3) undulations at lateral margins (John et al., 2002, 133: H).

Gonatozygon Barry 1858.

G. brebissonii Barry 1858 (Figure 3. 6. d).

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

G. monotaenium de Bray 1856.

Cylindrical cells, 8-10 (8-12.5) μm in wide, 94-178 (90-300) μm in length, truncate apices, ribbon-like chloroplast with 8-16 (6-16) series pyrenoids (John et al., 2002, 128: M).

Staurostrum (Meyen) Ralfs 1848.

S. armigerum Brebisson **fo. *furcigerum*** (Ralfs) Teiling 1957

Cells, 48-59 (45-68) μm in wide, 37-45 (35-48) μm in length, lateral margins elongate, narrow sinus to inside and opening widely, isthmus 14-16 (13-18) μm in wide, elliptical semicells with lateral margins extended laterally with ending 2 (2-3) short spines (John et al., 2002, 138: P).

S. gracile Ralfs 1848.

Cells, 24-25 (23-27) μm in wide, 32-34 (30-36) μm in length, lateral margins elongate, U-shaped sinus, isthmus 8-9 (8-10) μm in wide, apex convex, converting processs tapering to 4 (4) small spins (John et al., 2002, 139: N).

S. lunatum Ralfs 1848.

Cells, 36-39 (35-43) μm in wide, 36-38 (35-39) μm in length, acute sinus opening widely to outside, isthmus 10-12 (10-13) μm in wide (John et al., 2002, 138: O).

Mougeotia Agardh 1824.

M. boodlei (West) Collins 1921 (Figure 3. 7. a)

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

M. capucina (Bory) Agardh 1824.

Cells, 15-18 (14-21) μm in wide, 74-112 (70-340) μm in length, axile ribbon-shaped 1 or 2 chloroplast filling one-third to half of cell length with a series of 4-12 (4-16) pyrenoids, irregularly quadrangular (John et al., 2002, 121: C).

M. nummuloides (Hassall) De Toni 1889 (Figure 3. 7. b)

Cells, 8-12 (8-16) μm in wide, 42-68 (32-160) μm in length, chloroplast with a median series of 4-6 (2-6) pyrenoids, spherical (John et al., 2002, 120: F).

M. parvula Hassall 1843.

Cells, 7-12 (6-13) μm in wide, 37-74 (30-140) μm in length, chloroplast filling about 2-3 (two-thirds) of cell with a median series of 4-6 (4-8) pyrenoids, spherical (John et al., 2002, 119: G).

M. quadrangulata Hassall 1843

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

M. scalaris Hassall 1842 (Figure 3. 7. c)

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

Spirogyra Link 1820.

S. fluviatilis Hilse 1863 (Figure 3. 7. d)

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

S. communis (Hassall) Kützing 1849.

Cells, 20-24 (18-26) μm in wide, 38-47 (35-90) μm in length with end walls plane, single chloroplast with making 2-3 (1.5-4) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal, smooth zygospore 21-23 (19-26) μm in wide, 37-45 (36-78) μm in length (John et al., 2002, 122: H).

S. jugalis (Dillwyn) Kützing 1845.

Cells, 78-97 (75-103) μm in wide, 94-128 (80-300) μm in length with end walls plane, 3 (3-4) chloroplast with making 2.5-3.5 (2-5) turns of cell (John et al., 2002, 122: D).

S. longata (Vaucher) Kützing 1843 (Figure 3. 7. e-f)

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

S. majusculas Kützing 1849.

Cells, 54-65 (50-80 μm) μm in wide, 95-146 (80-500 μm) μm in length with end walls plane, 3-5 (3-10) chloroplast with making 1-3 (1-3) turns of cell, conjugation tubes occurred from both gametangia, lens-shaped smooth zygospore 58-60 (57-62) μm in wide, 46-53 (45-60) μm in length (John et al., 2002, 124: E).

S. mirabilis (Hassall) Kützing 1849.

Cells, 24-28 (23-29) μm in wide, 76-97 (70-200) μm in length with end walls plane, single chloroplast with making 4-6 (4-7) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospore 24-26 (23-29) μm in wide, 51-64 (50-83) μm in length (John et al., 2002, 122: F).

S. pratensis Transeau 1914.

Cells, 17-19 (17-20) μm in wide, 84-96 (80-240) μm in length with end walls plane, single chloroplast with making 2-4 (1-8) turns of cell (Prescott 1982, 75: 4-6).

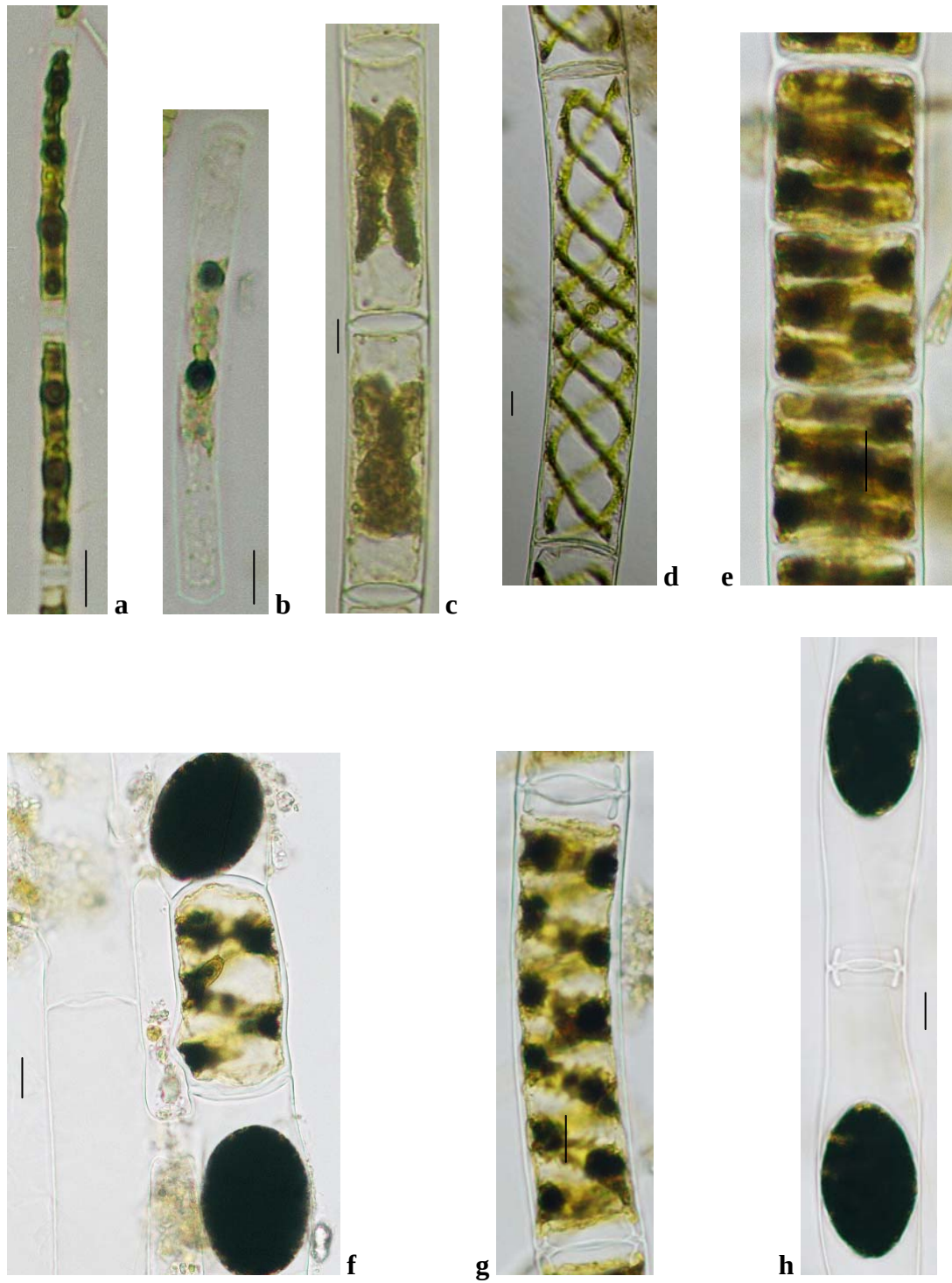


Figure 3. 1. a) *Mougeotia boodlei*, b) *M. nummuloides*, c) *M. scalaris*, d) *Spirogyra fluviatilis*, e-f) *S. longata*, g-h) *S. weberi* (scale 10 μm).

S. rivularis (Hassall) Rabenhorst 1868.

Cells, 32-38 (30-41) μm in wide, 104-178 (100-400) μm in length with end walls plane, 2-3 (2- 3) chloroplast with making 2.5-3 (2.5-3.5) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospore 33-37 (32-42) μm in wide, 64-72 (60-100) μm in length (John et al., 2002, 124: D).

S. setiformis (Roth) Kützing 1845.

Cells, 98-112 (90-115) μm in wide, 116-194 (100-225) μm in length with end walls plane, 4 (4) chloroplast with making 1-3.5 (0.5-4) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospore 88-95 (85-100) μm in wide, 118-133 (115-160) μm in length (John et al., 2002, 125: C).

S. submargaritata Godward 1956.

Cells, 85-90 (70-100) μm in wide, 157-175 (100-192) μm in length with end walls plane, 9 (8-10) chloroplast with making 0.5-1 (0.5-1) turns of cell (John et al., 2002, 125: E).

S. tenuissima (Hassall) Kützing 1849.

Cells, 9-12 (8-13) μm in wide, 43-68 (40-250) μm in length with end walls replicate, single chloroplast with making 3-5 (3-6) turns of cell (John et al., 2002, 126: C).

S. weberi Kützing 1843 (Figure 3. 7. g-h)

Cells, 21-28 (19-30) μm in wide, 97-159 (80-480) μm in length with end walls replicate, single chloroplast with making 3-5 (3-6.5) turns of cell, conjugation tubes occurred from both gametangia, ovoid smooth zygospore 26-29 (25-36) μm in wide, 34-46 (32-67) μm in length (John et al., 2002, 122: E).

Zygnema Agardh 1824

Z. conspicuum (Hassall) Transeau 1934 (Figure 3. 7. i)

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

11 DISCUSSION

Total of 162 non-diatom phytoplankton taxa identified from Lake Abant were belonged to Chlorophyta (58.6 %), Cyanoprokaryota (14.2 %), Euglanophyta (13 %), Pyrrophyta (5 %), Chrysophyta (4.3 %), Cryptophyta (3.7 %), Xanthophyta (0.6 %), and Prasinophyta (0.6 %). Chlorophyta, which is consisting of 95 species, is the most abundant phylum with about 58.6 % of the total species. The species richness of this phylum was increased especially in fall season of the year 2003-2004 and late summer of 2004 during the study period. Second dominant phylum was Cyanoprokaryota with 23 species belonging to 14 genera. Species number of blue-green algae was found relatively high in the fall of 2003-2004 and the late summer months of the year 2004. In January 2004, member of Cyanoprokaryota was not detected in all sampling stations. In a recent study continued about ten months in Lake Abant, Obalı and colleagues (2002) reported 83 algae taxa, of which only 49 belonged to non-diatom phytoplankton. The authors reported five phyla belonging to Chlorophyta (53 %), Cyanoprokaryota (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 recent study. Such difference between these two studies is possibly because of different sampling time and different numbers of stations sampled.

During this study, total phytoplankton species are belonged 69 genera, most of them are found in Chlorophyta with 39 genera at 56.5 % level. Finding some species (e.g., *Trachelomonas volvocina*, *Cryptomonas ovata*, and *Ceratium hirundinella*) in almost all year around during the study period may suggest a wide range of tolerance

level 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, it is called as *Scenedesmus ellipticus*) (John et al., 2002), *O. borgei*, and *Merismopedia tenuissima* were commonly found in their study. However, these taxa were not widespread in the present study. Additionally, Huber-Pestalozzi (1983) regarded that *S. bijuga* can be accepted as *Scenedesmus linearis*, but later on John and his colleagues (2002) argued against that both species share common structure and ecological features, so that they used as *Scenedesmus ellipticus*. In our case, therefore, following John et al. (2002), we preferred to use both species as *S. ellipticus*, which was almost widespread in Lake Abant throughout study period. Identified most taxa in this study are commonly distributed in different parts of Turkey (Gönülol et al. 1996).

In the average, 45 taxa occurred per month during our study. The highest numbers of taxa (75 taxa) was found in August of 2004. Numbers of species were increased especially in late summer and months of fall seasons (e.g., September (64 taxa), November (59 taxa)) from 2003 to (e.g., August (74 taxa), September (61 taxa), October (57 taxa)) the second year 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 with 12, 8, 7, 7, and 6 taxa, respectively. The type of 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 environmental condition of Lake Abant.

Gönülol and his colleagues (1996) reported total of 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 characterized by tremendous non-diatom phytoplankton species, comprised 23.4 % of total number of non-diatom freshwater algae of Turkey. Earlier limnological studies in different water bodies supported the finding of present study such as 96 taxa in Lake Ladik (Maraşlıoğlu et al., 2005), 59 taxa in Lake Yeniçağa (Kılınç, 2003), 42 taxa in Keban Dam Reservoir (Akbay et al., 1999) as non-diatom algae in Turkey, and 84 taxa for three lakes (Kalchev et al., 2000) in Bulgaria, 62 species for both Lake Abbadia and Como (Buzzi, 2002) in Italy, and 50 taxa for Banglang Reservoir (Ariyadej et al., 2004) in Thailand were identified (given taxa are non-diatom phytoplankton).

Total numbers of species in each phylum were changed from first to second years of study period. Numbers of total taxa for all phyla was increased second year comparing to first year. Especially, species richness of three phyla (Cyanoprokaryota, Euglenophyta, Cryptophyta) were increased twice in the second year than the first. The other phyla were higher only one time more in second year than the first year. It is known that blue-green algae, euglenoids, and cryptomonads prefer nutrient rich water (John et al., 2002; Wehr and Sheat, 2002). Increasing numbers of species in these phyla suggests possible nutrients input changing the water chemistry of Lake Abant. During two years of this study, determining the taxonomic composition of phytoplankton assemblages is important to have an understanding on ecological conditions of Lake Abant. However, such view requires detailed information in other groups based on knowledge on long-term monthly (or even weekly) biomonitoring studies.

Part D

ABSTRACT

PHYTOPLANKTON (EXCEPT BACILLARIOOPHYTA) COMPOSITION OF LAKE GÖLKÖY (BOLU)

The non-diatom phytoplankton composition of Lake Gök  y was studied monthly during two years (June 2003-June 2005) from 3 littoral and 2 vertical stations. Identified total of 152 taxa belong 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 %). *Spirogyra* and *Scenedesmus* were the most species richness genera with 13 and 10 taxa, respectively. Some species (e.g. *Anabaena crassa* (Lemmermann) Kom  rkov  -Legnerov   and Cronberg, *Gonium pectorale* M  ller, and *Provasoliella ovata* (Jacobsen) Loeblich) have been only found in Lake G  lk  y comparing to algological studies in Bolu region up to now.

Keywords: Phytoplankton, Taxonomy, Lake G  lk  y, Bolu

  ZET

G  LK  Y G  L   (BOLU) F  TOPLANKTON (BACILLARIOPHYTA HAR   ) KOMPOS  ZYONU

G  lk  y G  l   diyatome olmayan fitoplankton kompozisyonu     kıyısal ve iki vertikal istasyonda aylık olarak iki yıl boyunca (Haziran 2003-Haziran 2005)   alışılmıştır. Toplam tanımlanan 152 takson 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) filumlarına aittir. *Spirogyra* ve *Scenedesmus* sırasıyla 13 ve 10 taksa ile en fazla t  r zenginliđi olan cinslerdir. Şimdiye kadar Bolu b  lgesinde yapıłana algolojik   alışmalarla kıyaslanıldığında, bazı t  rler (  rneđim, *Anabaena crassa* (Lemmermann) Kom  rkov  -Legnerov   and Cronberg, *Gonium pectorale* M  ller, ve *Provasoliella ovata* (Jacobsen) Loeblich) sadece G  lk  y G  l  nde bulunmuştur.

Anahtar Kelimeler: Fitoplankton, Taksonomi, G  lk  y G  l  , Bolu

12 INTRODUCTION

The pioneer limnological studies were carried by (Geldiay, 1949) in Çubuk-1 Reservoir, (Tanyolaç and Karabatak, 1974) in Lake Mogan, and (Aykulu and Obalı, 1981) in Kurtboğazı Reservoir. After study in Kurtboğazı Reservoir, algological studies have gained momentum in Turkey; however have not yet reached an acceptable grade. In Bolu region, a few earlier algological studies in different ecosystems such as in lakes (Obalı et al., 2002; Kılınç, 2003; Atıcı et al., 2005; Çelekli and Kulköylüoğlu, in press), in reservoir (Çelekli and Kulköylüoğlu, in press), and in karstic spring (Çelekli and Kulköylüoğlu, 2006) were carried out, however many different aquatic habitats are not studied for limnological researches. Until the present study, nothing was known about the non diatomous phytoplankton of Lake Gököy, which is one of the largest dam lakes in the city Bolu. The present study aimed to investigate net non-diatom phytoplankton species composition and their seasonal occurrences in Lake Gököy during two years.

13 RESULTS

13.1 Phytoplankton composition of Lake Gölköy

In the whole study period identified a total of 152 taxa, so belonged; 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 %). A total 65 genera were founded in this lake during two years.

13.1.1 Cyanoprokaryota

Chroococcales

Chroococcus Nageli 1849.

C. turgidus (Kützing) Nageli 1849

Microscopic colony 2-8 (2-32) cell, spherical and hemispherical cell 29-34 (6-45) µm in dimension (John et al., 2002, 3: A, B).

Merismopedia Meyen 1839.

M. tenuissima Lemmermann 1898.

Rectangular colonies, 15-17 (16-18) µm in broad, contain closely aggregated groups of colonies. Spherical-hemispherical cells 0.7-1.5 (0.4-1.6) µm in dimension (Prescott, 1982, 100: 17; John et al., 2002).

Microcystis Kützing 1833 ex Lemmermann 1907 nom. cons.

M. aeruginosa (Kützing) Kützing 1846 (Figure 4. 1. a).

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

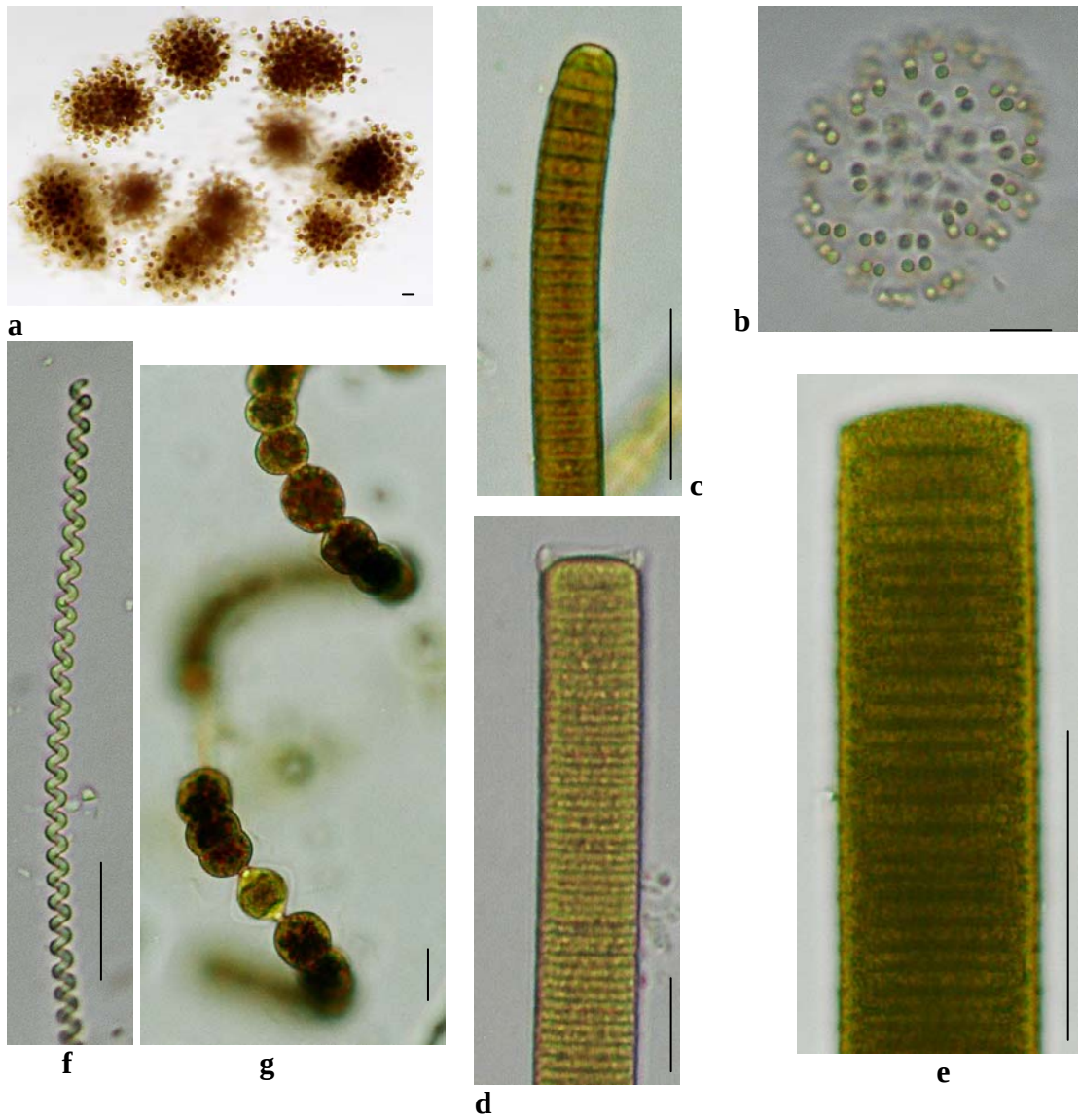


Figure 4. 1. a) *Microcystis aeruginosa*, b) *Snowella lacustris*, c) *Oscillatoria formosa*, d) *O. limosa*, e) *O. princeps*, f) *Spirulina maior*, g) *Anabaena crassa* (scale 10 μm).

Snowella Elenkin 1938.

S. lacustris (Chodat) Komarek et Hindak 1988 (Figure 4. 1. b).

Spherical colonies, 41-56 (up to 80) μm in diameter, ellipsoidal cells 2-3x2-2.5 (1.5-3.5x1.5-4) μm in dimension (John et al., 2002, 4: D-E).

Oscillatoriales

Oscillatoria (Vaucher) Gomont 1892.

O. formosa (Bory) Gomont 1892 (Figure 4. 1. c).

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

O. limosa (Agard) Gomont 1892 (Figure 4. 1. d).

Straight or less straight, rounded ends trichome and end cell rounded with slightly thickened membrane, cells 3.5-4.5 (2.5-5) μm in length and 10.5-12.5 (11-22) μm in width (Prescott 1982, Pl. 109: 17; John et al., 2002, 11: G, H).

O. minima Gicklhorn 1921

Spirally twisted trichome, end cell not tapering without calyptra, cells 5-5.5 (5-6) μm in length and 2-2.5 (2) μm in width (Prescott 1982, Pl. 107: 24).

O. princeps (Vaucher) Gomont 1892 (Figure 4. 1. e).

Mostly straight, abruptly bent at apex trichome and end cell flatly rounded without adjacent granules, cells 4.5-6.5 (3.5-7) μm in length and 16-24 (16-60) μm in width (Prescott 1982, Pl. 110: 1; John et al., 2002).

O. rubescens (de Candolle 1825) Gomont 1892

Mostly straight richome and end cell rounded and tapering at ends, cells 5-6.5 (5-8) μm in wide and 2.5-3 (2-4) μm in long, cross wall is granular, slightly capitate present at end of cells (Prescott 1982, Pl. 110, 8, 9, 14; John et al., 2002).

O. sancta (Kützing) Gomont 1892

Straight, abruptly bent 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, Pl. 110, 4; John et al., 2002, 11: L).

O. subbveris Schmidle 1901

Straight solitary trichomes not attenuated at apex, apical cell rounded- without calyptra, cells 5 (5-6) μm in length and 2 (1-2) μm in width (Prescott 1982, Pl. 107: 23; John et al., 2002, 11: M-N).

O. tenuis Schmidle 1901

Straight or less straight end not attenuated at the apex trichome and end cell more or less hemispherical with adjacent ganules and thickened outer membrane, cells 2.5-3 μm (2.5-5 μm) in length and 5-6.5 (4-10) μm in width (Prescott 1982, Pl. 110, 8, 9, 14: 0John et al., 2002, 11: K)

Phormidium (Kützing) Gomont 1892.

***Phormidium* sp.**

Slightly attenuated toward ends trichomes and end cell rounded, calyptra absent, cells 3-4 μm in wide and 5-6 μm in long.

Spirulina (Turpin) Gomont 1892

S. maior (Kützing) Gomont 1892 (Figure 4. 1. f).

Loosely spiraled trichome 0.9-1.4 (1-2) μm in diameter, helix 3.5 (2.5-4) μm in wide, distance between regular spirals 3.5-5 (2.7-5) μm in wide (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 4. 1. g).

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

***Anabaena* sp.**

Straight trichomes and ellipsoidal cells 1-2 μm in wide, 1.5-2.5 in long, spherical heterocyst 1.5-2 μm in diameter.

13.1.2 Euglenophyta

Euglenales

Euglena Ehrenberg 1833.

E. acus Ehrenberg 1830 (Figure 4. 2. a).

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

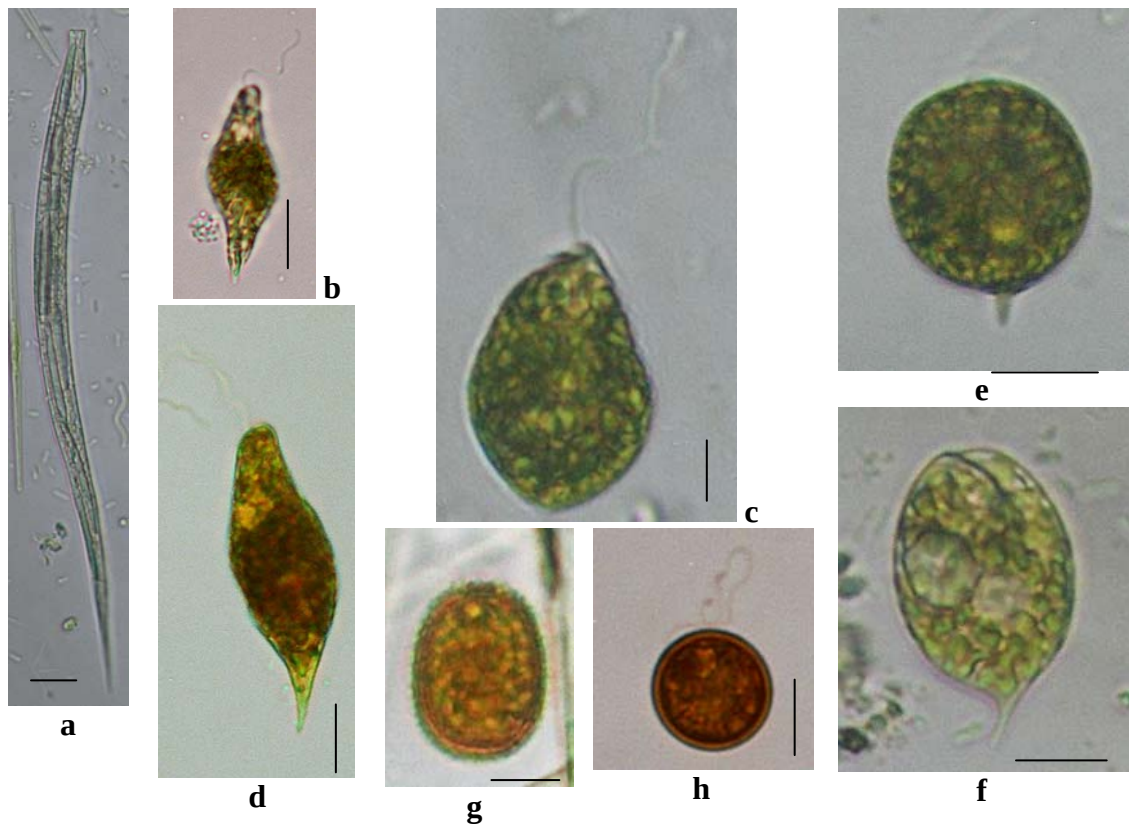


Figure 4. 1. a) *Euglena acus*, b) *E. chlamydophora*, c) *E. oblonga*, d) *E. viridis*, e) *Lepocinclis ovum*, f) *Phacus curvicauda*, g) *Trachelomonas hispida*, h) *T. volvocina* (Scale 10 μm).

E. agilis Carter 1856

Cells 13-15 (4-15) μm in wide, 39-46 (13-60) μm in long, anterior end bluntly rounded, posterior end rounded, chloroplast 2 (2-3), elongated near the side cell with pyrenoids (John et al., 2002, 35: G, H).

E. chlamydophora Mainx 1927 (Figure 4. 2. b).

Cells 10-12.5 (9-20) μm in wide, 36-43 (32.2-54) μm in long, spindle-shaped cell, rounded anterior end narrowed, posterior end tapering to a point, disc-shaped chloroplast numerous without pyrenoid, and long flagellum (John et al., 2002, 35: I-J)

E. geniculata (Schmitz) Dujardin 1841

Spindle shaped cells 10-12 (9.5-22) μm in wide, 55-63 (50-85) μm in long, anterior end rounded, posterior end narrowed to sharp rounded tail, star-shaped 2 chloroplast with pyrenoid, nucleus between chloroplasts, and long flagellum (John et al., 2002, 37: C)

E. gracilis Klebs 1883.

Cells 9-13 (6-22) μm in wide, 54-61 (31-70) μm in long, spindle-shaped cells, anterior end rounded, posterior end tapering to a blunt point, 8-9 (7-14) disc-shaped chloroplast with pyrenoid, and long flagellum (John et al., 2002, 36, F)

E. limnophila Lemmermann 1898 **var. *swirenkoi*** (Anoldi) Popova 1955.

Spindle-shaped cells 8-9 (7.5-12) μm in wide, 42-45 (24-48) μm in long, anterior end truncate, posterior end tapering to a sharp tail point, discs-shaped numerous chloroplast with pyrenoid, and small flagellum (John et al., 2002, 34, D-E).

E. oblonga F. Schmitz 1884 (Figure 4. 2. c).

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

E. viridis Ehrenberg 1830 (Figure 4. 2. d).

Spindle-shaped slightly twisted cells 13.5-15 (9-22) μm in wide, 36-46 (30-89) μm in 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 4. 2. e).

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

L. playfairiana Deflandre 1932.

Cells 20-23 (19-26) μm in wide, 35-44 (32-53) μm in long, broadly spindle-shaped cells, anterior end slightly narrowing, posterior end tapering to tail piece 7-8 (7-12) μm in long, disc-shaped chloroplast numerous, and flagellum (John et al., 2002, 38: B-C)

L. steinii Lemmermann 1901.

Cells 8-9 (8-15) μm in wide, 22-26 (21-33) μm in long, spindle-shaped cells, anterior end slightly narrowing truncate, posterior end tapering to sharp tail piece, chloroplast numerous, and long flagellum (John et al., 2002, 38: F)

Phacus Dujardin 1841.

P. caudatus Hübner 1886.

Cells 18-21 (16-27) μm in wide, 35-43 (31-50) μm in long, pear-shaped to ovate cell, anterior end rounded, and posterior end tapering to a short tail 6-6.5 (5-11) μm , chloroplast disc-shaped, numerous without pyrenoids (John et al., 2002, 40: B).

P. curvicauda Svirenko 1915 (Figure 4. 2. f).

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

P. haemeli P. Allorge *et* Lefevre 1930.

Ovoid cells 13-16 (12-20) μm in wide, 26-30 (25-37) μm in long, narrowing anterior end rounded, and posterior end tapering to a sharp tail-piece, disc-shaped numerous chloroplast, long flagellum (John et al., 2002, 39: A)

P. pseudonordstedtii Pochmann 1941.

Cells 12-14 (10-16) μm in wide, 35-37 (31-42) μm in long, ovoid cells, anterior end rounded, posterior end narrowing to a long sharp tail-piece, disc-shaped chloroplast numerous, long flagellum (John et al., 2002, 40: J).

Trachelomonas Ehrenberg 1833.

T. armata Stein 1878.

Cells 30-31 (29-32) μm in wide, 29-38 (28-45) μm in long, generally ovoid cell, apical pore 7-8 (6-8) μm , long spines 3-7.5 (3-10) μm in long, posterior end rounded, flagellum twice length of cell (John et al., 2002, 42: M).

T. dubia (Svirenko) Deflandre 1926.

Cells 12-13 (11-15) μm in wide, 22-23 (21-28) μm in long, ellipsoidal cells, smooth cell wall, apical pore with cylindrical collar 2-3 (2.5-4) μm in wide, 2-3 (2.3-5) μm in high, posterior end rounded, ver long flagellum, 7-8 (7-10) chloroplasts, pyrenoid absent (John et al., 2002, 42: Y).

T. hispida (Perty) Stein emend. Deflandre 1926 (Figure 4. 2. g).

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

T. volvocina Ehrenberg 1833 (Figure 4 3. h).

Cells 15-19 (12.5-32) μm in diameter, spherical cells, smooth apical pore without a collar, and flagellum 2-3 time of cell (John et al., 2002, 43: A).

13.1.3 Cryptophyta

Campylomonas Hill 1991.

C. reflexa Hill 1991.

Sigmoid-shaped cells 12.5-15 (10-30) μm in wide, 19-50 (15-60) μm in long, cells are slightly contorted, anterior end slightly tapering, characteristic curved posterior end wide rounded, flagella unequal, chloroplast 2 at the lateral site of cell without pyrenoid, nucleus in the posterior and center of cell (Wehr and Sheath, 2003, 5 A, 7C, D).

C. rostratiformis Hill 1991 (Figure 4. 3. a).

Cells 17.5-27 (16-40) μm in wide, 44-56 (45-80) μm in long, cells are slightly recurved at posterior end wide rounded, anterior end rostrate, flagella unequal,

chloroplast 2 with numerous pyrenoids, nucleus in about center of cell, slightly curved furrow towards the left (Wehr and Sheath, 2003, 5B, 7B).

Cryptomonas Ehrenberg 1838.

C. marssonii Skuja 1948 (Figure 4. 3. b).

Cells 8-11 (8-14) μm in wide, 17-24 (16-33) μm in 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 site of cell without pyrenoid, nucleus in the posterior and center of cell (John et al., 2002, 45: E).

C. ovata Ehrenberg 1838 (Figure 4. 3. d-f).

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

C. platyuris Skuja 1948.

Cells 9-11 (9-14) μm in wide, 32-38 (31-50) μm in long, anterior end slightly tapering, posterior end wide rounded, flagella unequal, chloroplast 2 at the lateral site of cell without pyrenoid, nucleus in the posterior and center of cell (John et al., 2002, 45: F).

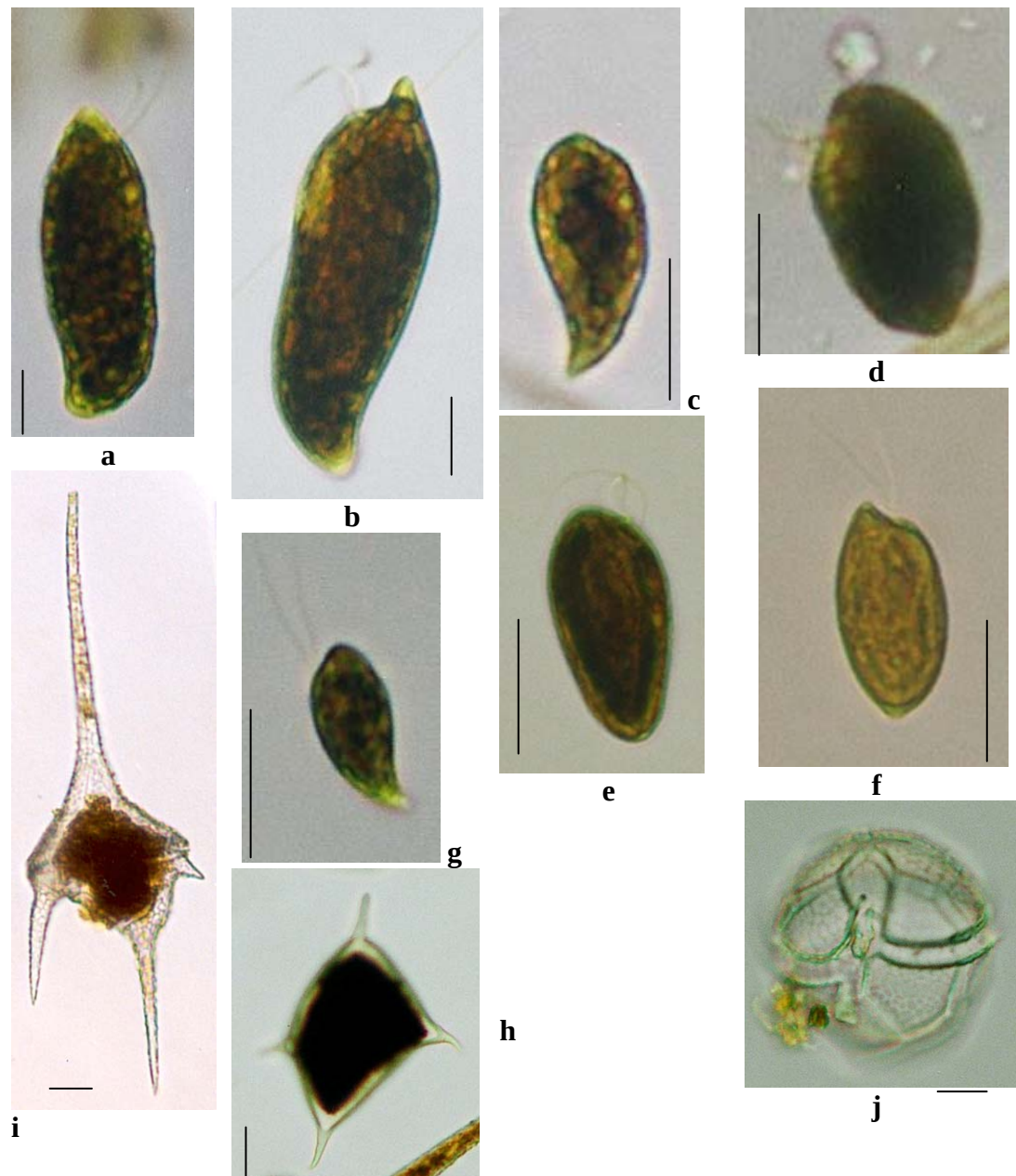


Figure 4. 1. a, b) *Campylomonas rostratiformis*, c) *Cryptomonas marssoni*, d-f) *C. ovata*, g) *Plagioselmis nannoplanctonica*, h) *Ceratium furcoides*, i) *C. hirundinella*, j) *Peridinium willei* (scale 10 μm).

Plagioselmis Hill 1990

P. nannoplanctonica (Skuja), Novarino, Lucas and Morrall 1994 (Figure 4. 3. g).

(*Rhodomonas minuta* var. *nannoplanctica* Skuja 1948).

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

13.1.4 Pyrrophyta

Gonyaulacales

Ceratium Schrank 1793.

C. coralinianum (Bailey) Jorgensen 1911.

Cells 75-87 (73-105) μm in wide, 131-178 (125-213) μm in long, spindle-shaped cell, epitheca wide above cingulum, narrowing usually right side, apical horn curved, hypotheca broad below the cingulum with long central horn and short right horn (John et al., 2002, 49: D).

C. cornutum (Ehrenberg) Claparede 1858

Cells 50-65 (48-75) μm in wide, 102-128 (97-150) μm in long, spindle-shaped cell, narrowing epitheca wide above cingulum, apical horn slightly curved, hypotheca broad below the cingulum with extending into 2 horns (lateral horn shorter than central) (John et al., 2002, 49: A).

C. furcoides (Lavender) Langhans 1925 (Figure 4. 3. h).

Cells 31-41 (28-56) μm in wide, 131-178 (123-222) μm in long, spindle-shaped cell, epitheca narrow with a horn, broad and short hypotheca separated into two horns (short lateral and long central) (John et al., 2002, 49: B. C).

C. hirundinella (Müller) Dujardin 1841 (Figure 4. 3. i).

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

Gymnodiniales

Gymnodinium Stein 1878.

G. cnecoides T. Harris 1940.

Cells 9-10 (8-18) μm in wide, 9-12 (9-23) μm in long, cell ovoid with rounded, equal size epicone and hypocone, both hemispherical and wide cingulum, ribbon-like chloroplast 1 or 2, nucleus in the anterior site (Popovsky and Pfiester, 1990, 80: a-h; John et al., 2002, 46: E).

Peridinales

Peridiniopsis Lemmermann 1904.

P. thompsonii (Thompson) Bourrelly 1968

Ovoid cells 18-21 (18.5) μm in wide, 30-34 (31-38) μm in 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 (Popovsky and Pfiester, 1990, 209: a-d; John et al., 2002, 50: G).

Peridinium Ehrenberg 1832

P. cinctum (Müller) Ehrenberg 1838.

Cells 47-69 (35-73) μm in wide, 43-65 (40-78) μm in 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, 51: J).

P. willei Huitfeldt-Kaas 1900 (Figure 4. 3. j)

Cells 48-67 (36-80) μm in wide, 45-63 (38-78) μm in 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).

13.1.5 Chrysophyta (Golden Algae)

Chromulinales

Dinobryon Ehrenberg 1834.

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

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

D. divergens Imhof 1887

Fusiformed lorica 7.5 (7-8) μm in wide, 37-43 (35-50) μm in long, anterior cylindrical and slightly tapering, posterior tapering to a sharply point, lorica lying divergens in the colonies (Prescott 1982, 98: 7).

D. sertularia Ehrenberg 1838 (Figure 4. 4. b).

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

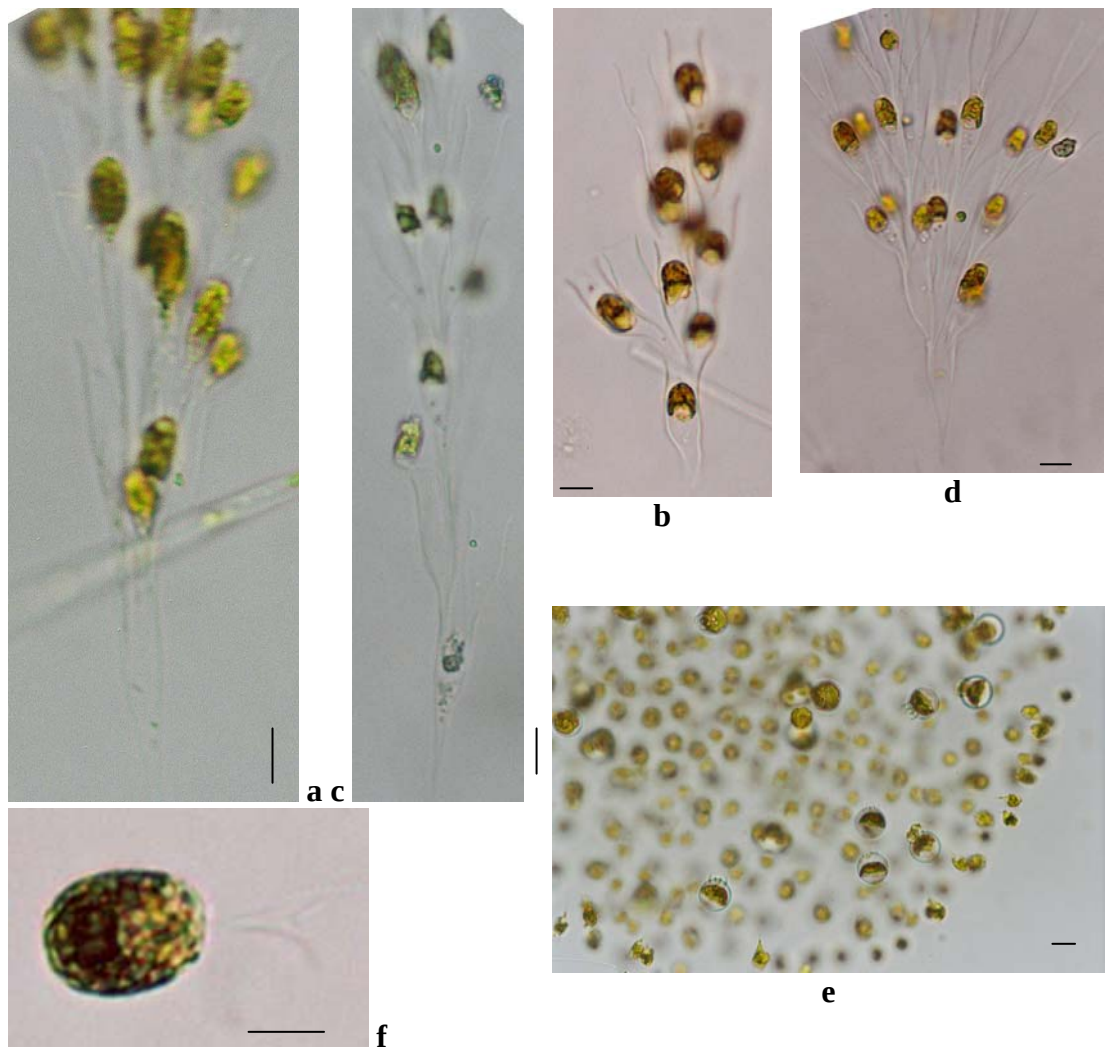


Figure 4. 1. a.) *Dinobryon bavaricum*, b) *D. sertularia*, c) *D. sociale* var. *americanum* d) *D. sociale* var. *stipitatum*, e) *Uroglena volvox*, f) *Tetraselmis cordiformis* (scale 10 μ m).

D. sociale Ehrenberg 1838

Lorica 7.5-8.5 (8-10) μm in wide, 34-44 (30-70) μm in long, cone-shaped lorica lying erect in the colonies, posterior tapering to a blunt point (Prescott, 1982, 98: 13; John et al., 2002)

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

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

D. sociale Ehrenberg **var. *stipitatum*** (Stein) Lemmermann 1903 (Figure 4. 4. d).

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

Uroglena Ehrenberg 1834.

U. volvox Ehrenberg 1834 (Figure 4. 4. e).

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

13.1.6 Xanthophyta (Yellow-Green Algae)

Mischococcales

Ophiocytium Nageli 1849.

O. capitatum Wolle 1887.

Arcuate cylindrical cells 5-6 (5-10) μm in wide, 18-25 (up to 150) μm in long, both end of cells with a short, disc-shaped chloroplast numerous (John et al., 2002, 70: E).

13.1.7 Prasinophyta

Prasinophyceae

Tetraselmis F. Stein 1878.

T. cordiformis (Carter) Stein 1878 (Figure 4. 4. f).

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

13.1.8 Chlorophyta (Green algae)

Cells have nucleus and organelles such as chloroplast (different shape), light to dark grass green pigmentation, only few taxa red, orange or yellow-orange pigmentation due to presence of masking pigments (e.g. *Haematococcus*, *Dunaliella*, and *Botryococcus*) and different cell shape and size.

Volvocales

Carteria Diesing 1866 emend. France 1893.

C. klebsii (Dangeard) France emend. Troitzkaya 1921.

Ellipsoidal cells 7.5-10 (6-17) μm in wide, 10-15 (8-35) μm in long, papilla present, cup-shaped chloroplast basally thickened with basal large pyrenoid and equal a pairs flagella from anterior part (Ettl, 1983, 854; John et al., 2002, 80: H)

Chlamydomonas Ehrenberg 1833.

C. globosa Snow 1902.

Spherical cells 6-7.5 (5-8) μm in diameter, papilla absent, cup-shaped chloroplast basally thickened with basal pyrenoid and equal two flagella (Ettl, 1983, 189: John et al., 2002, 77: E)

C. leptobasis Skuja 1956.

Spherical or ellipsodisc cells 10-15 (9-17) μm in long, 7.5-9 (5-13) μm in wide, papilla present, peripheral chloroplast basally thickened with basal ellipsodisc pyrenoid and equal two flagella (Ettl, 1983, 260)

C. passiva Skuja 1956.

Spherical cells 12-15 (12-19) μm in long, 9-10 (9-15) μm in wide, colony 64-78 (60-200) μm papilla absent, cup-shaped chloroplast basally thickened with basal pyrenoid and equal two flagella (Ettl, 1983, 307).

***Chlamydomonas* sp.**

Spherical or ellipsodisc cells 5-7.5 μm in long, 4-6 μm in wide, papilla absent, peripheral chloroplast basally thickened with basal ellipsodisc pyrenoid and equal two flagella.

Sphaerellopsis Korrschikoff 1925

***Sphaerellopsis* sp.**

Ellipsoidal, egg shaped cells are 7-9 μm in wide, 9-11 μm in wide, have broad envelope, cup-shaped chloroplast with basal pyrenoid. Occasionally found in sampling stations (cosmopolitan, from nutrient poor to dystrophic water (John et al., 2002)).

Eudorina Ehrenberg 1830.

E. elegans Ehrenberg 1831 (Figure 4. 5. a).

Ellipsoidal or spherical coenobium 62.5-75 (60-200) μm in diameter, consist of 16-33 (4-64) celled: spherical cells 12.5-15.5 (12-24) μm in diameter, cup-shaped chloroplast with pyrenoids (Ettl, 1983, 1108; John et al., 2002, 81: G).

Gonium Müller 1773.

G. pectorale Müller 1773 (Figure 4.5. b).

Coenobia 62.5-75 (70-100) μm in wide, consist of 16 (16) cells, 12 (12) cells arranged peripheral site, other center of coenobium, pear-shaped cells 12.5-14 (up to 18) μm in wide, 15-15.5 (15-20) μm in long, chloroplast cup-shaped (Prescott 1982, 1: 21; John et al., 2002, 81; G).

Hyaliella Pascher 1931.

H. polytomoides Pascher 1931.

Ovate or egg-shaped cells 14-17 (12-20) μm in long, 9-11 μm in wide, papilla absent, chloroplast numerous, and equal two flagella (Ettl, 1983, 165)

Monomastix Scherffel 1912.

M. opisthostigma Scherffel 1912.

Cylindrical cells 15-17.5 (14-21) μm in long, 6-7 (5.5-10) μm in wide, colony 64-78 (60-200) μm papilla absent, chloroplast lying both laterals with pyrenoid and a flagellum apical site (Ettl, 1983, 69).

Pandorina Bory 1824.

P. morum (Müller) Bory 1824

Subspherical coenobium 24-37.5 (20-60) μm in wide, consist of 8-16 (8-16) cells, pear-shaped cells 8-10 (8-17) μm in long, chloroplast with basal pyrenoid (Bourrelly, 1972, 7: 2; Ettl, 1983, 1104; John et al., 2002, 81: E).

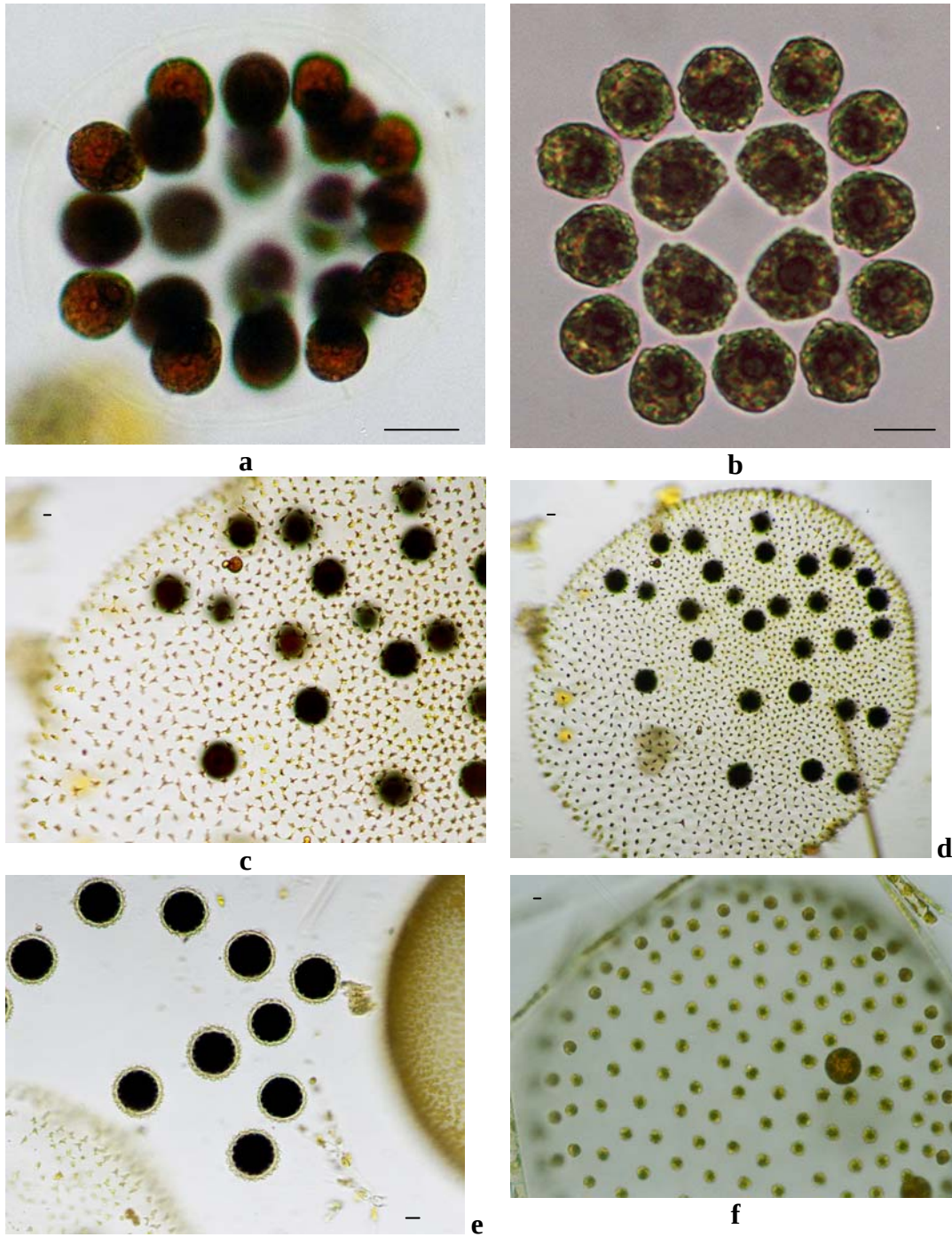


Figure 4. 1. a) *Eudorina elegans*, b) *Gonium pectorale*, c-e) *Volvox globator*, f) *V. polychlamys* (scale 10 μm).

Pleodorina Shaw 1894.

P. californica Shaw 1894.

Spherical coenobia 84-115 (up to 200) μm in diameter, consist of spherical cells 13-14 (13-27) μm in diameter, cup-shaped chloroplast with pyrenoid (Ettl, 1983, 1114).

Polytoma Ehrenberg 1838.

P. cylindraceum Pasher 1927.

Cylindrical cells 15-22 (16-30) μm in long, 7-9 (up to 10) μm in wide, papilla present, numerous chloroplast, and a pairs flagella, two vacuol apical site (Ettl, 1983, 967).

Provasoliella Loeblich 1967.

P. ovata (Jacobsen) Loeblich 1967.

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

Volvox (Linne) Ehrenberg 1830.

V. aureus Ehrenberg 1832.

Elipsoidal or spherical coenobia 412-446 (170-850) μm in diameter, consist of numerous spherical cells 5-6 (5-9) μm in diameter, each cells interconnected with protoplasmic structures, parietal chloroplast with pyrenoid, zygote with smooth cell wall, 45-50 (60) μm in diameter (Ettl, 1983, 1118; John et al., 2002, 81: H).

V. globator Linnaeus 1758 (Figure 4. 5. c-e).

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

V. polychlamys Korschikoff 1939 (Figure 4. 5. f).

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

Tetrasporales Lemmermann

Pseudosphaerocystis Woronichin 1931.

P. lacustris (Lemmermann) Novakovas 1965.

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

Chlorococcales

Ankistrodesmus Corda 1838.

A. falcatus (Corda) Ralfs 1848

Clustered colonies consist of 2-8 (2-8) cells, needle-like: narrowly spindle-shape cells 1.5-2 (1-7) μm in wide, 25-37.5 (20-165) μm in long, a parietal type chloroplast (Prescott, 1982, 56: 5, 6; John et al., 2002, 97: J).

A. fusiformis Corda ex Korshikov 1953.

Clustered colonies consist of 2-4 (1-32) cells, needle-like: narrowly spindle-shape cells 1.5-2 (1-4.3) μm in wide, 24-31 (19-57) μm in long (John et al., 2002, 97: N).

A. spiralis (Turner) Lemmermann 1908 (Figure 4. 6. e).

Spirally twisted 4-8 (2-16) cells in colonies, twisted at centre, narrowing to ends, spindle-shape cells 1.5-2 (1-4.3) μm in wide, 26-37 (20-68) μm in long, a parietal type chloroplast without pyrenoid (Prescott, 1982, 56: 11, 12; John et al., 2002, 97: M).

Ankyra Fott 1957.

A. judayi (Smith) Fott 1957.

Spindle-shaped cells 5-7.5 (2-9) μm in wide, 47-61 (30-100) μm in long, cell slightly curved at ends, apical gradually tapering to long spin, basal end long spind separated bifid extention, a parietal type chloroplast with pyrenoid (Huber Pestalozzi 1983, 70: 1; John et al., 2002, 90: A).

A. lanceolata (G. Smith) Fott 1957.

Cyindrical cells 3.75-5.5 (2.5-8) μm in wide, 64-78 (30-130) μm in long, cell slightly curved at ends, apical gradually tapering to long spin, basal end long spind separated bifid parallel extention, a parietal type chloroplast with pyrenoid (Huber Pestalozzi 1983, 70: 2).

Botryococcus Kützing 1849.

B. braunii Kützing 1849 (Figure 5. f).

Ellipsoid or oval irregularly embedded cells in periphery 3-5 (2.5-9) μm in wide, 6-8.5 (5.7-12) μm in long, chloroplast with a pyrenoid (John et al., 2002, 85: H).

Characium A. Braun 1849.

C. ensiformis A. Braun 1855.

Semicircular cells 7.5-10 (3.8-16) μm in wide, 26-28 (12-50) μm in long, konveks in middle of cells, chloroplast with an ellipsodisc pyrenoid (Huber-Pestalozzi 1983, 59: 8)

Elakatothrix Wille 1898.

E. gelatinosa Wille 1898 (Figure 4. 6. g).

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

Geminella Turpin 1823

***Geminella* sp.**

Cells, 5-7 μm in wide, 7.5-10 μm in length, separated cells in pairs with mucilaginous sheath 9-12 μm in wide, chloroplast with pyrenoid. Seldom distributed in Lake Gölköy.

Golenkinia Chodat 1894.

G. paucispina West et West 1902.

Cells 14-17 (5.5-19) μm in diameter, cells spherical, smooth wall with spines 10-13 (8-16) μm in long, more than 20 per cell, chloroplast with pyrenoid (John et al., 2002, 88: G).

Golenkiniopsis Korsikov 1953.

G. solitaria Korsikov 1953.

Cells 7.5-8 (7-11) μm in diameter, cells spherical, smooth wall with spines 17-19 (15-45) μm in long, more than 8 per cell, chloroplast with pyrenoid (Huber Pestalozzi 1983, 99: 3).

Kirchneriella Schmidle 1893.

K. obesa (West) Schmidle 1893.

Cells 2.5-3.5 (2-16) μm in in wide, 7-10 (6-16) μm in long, cells circular, tapering to bluntly pointed ages, chloroplast with pyrenoids (Bourrelly 1972, 28: 1; John et al., 2002, 98: J).

Korshikoviella Silva 1959.

K. limnetica (Lemmermann) Silva 1959.

Cells 6-8 (3-15) μm in in wide, 31-58 (25-200) μm in long, cells cylindrical to spindle-shaped, curved, and tapering at ends, chloroplast each segment with pyrenoid (Huber Pestalozzi 1983, 71: 3).

K. michailovskoensis (Elenkin) Silva 1959

Cells 6-9 (5-23) μm in in wide, 32-51 (30-140) μm in long, cells cylindrical to spindle-shaped, curved, tapering at ends (John et al., 2002, 90: F).

Micractinium Fresenius 1858.

M. crassisetum Hortob. 1973.

Spherical cells 5-7 (5-8) μm in diameter, needle-like setae 1.5-2 (1.5-2.6) μm in wide, 27-30 (24.7-37) μm in long, colonies include tetrahedral cell group, parietal chloroplast with pyrenoid (Huber Pestalozzi 1983, 98: 2).

Monoraphidium Komarkova-Legnerova 1969.

M. arcuatum (Korshikov) Hindak 1970

Arched cells 2-2.5 (0.8-4.5) μm in in wide, 21-23 (18-90) μm in long, cells spindle-shaped, gradually narrowing to pointed apices (John et al., 2002, 90: I).

M. irregulare (Smith) Komarkova-Legnerova 1969.

Arched cells 1-2 (1.3-5) μm in in wide, 43-57 (40-150) μm in long, cells spindle-shaped, gradually narrowing to pointed each ends, slightly S-shaped, parietal chloroplast (John et al., 2002, 90: L).

Nephrocytium Nageli 1849.

N. agardhianum Nageli 1849.

Coenobia contain 4 or 8 (4 or 8) cells, spirally or irregularly arranged cells in asymmetrically ovoid musilaj sheath 37-45 (30-125) μm , kidney-shaped with rounded apices cells 5-8 (4-10) μm in wide, ,12-18 (10-25) μm in long (Prescott, 1983, 54: 15, 16: John et al., 2002, 83: B).

Oocystis Braun 1855.

O. apiculata West 1893.

Coenobia contain 2-4 (2, 4) cells, oblong spindle-shaped with rounded apices cells 5.5-7.5 (5-15) μm in wide, 12-15 μm (11-25 μm) in long, chloroplast 1 (1 or 2) with pyrenoid (John et al., 2002, 92: A).

O. borgei Snow 1903.

Cells solitary or coenobia contain 2-4 (2, 4 or 8) cells, ellipsoid with rounded apices cells without polar wall tickening 7-9 (6-20) μm in wide, 10-15 (9-20) μm in long, chloroplast 1-2 (1-4) with pyrenoid (John et al., 2002, 92: C).

O. marssonii Lemmermann 1898 (Figure 4. 6. a).

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 in wide, 7.5-13 μm (6.4-20.8 μm) in long, grooved chloroplast 2-4 (2-8) with pyrenoid in each groove (John et al., 2002, 92: F).

O. parva West 1898.

Cells solitary or 2-4 (2, 4 or 8) celled packed in coenobia, ellipsoidal, broadly spindle-shaped with rounded apices cells with polar wall thickening 4-7 (1.5-10) μm in wide, 7-10 (3.2-17) μm in long, chloroplast with pyrenoid (John et al., 2002, 92: J).

Pediastrum Meyen 1829.

P. boryanum (Turpin) Meneghini 1840 (Figure 4. 6. b-d).

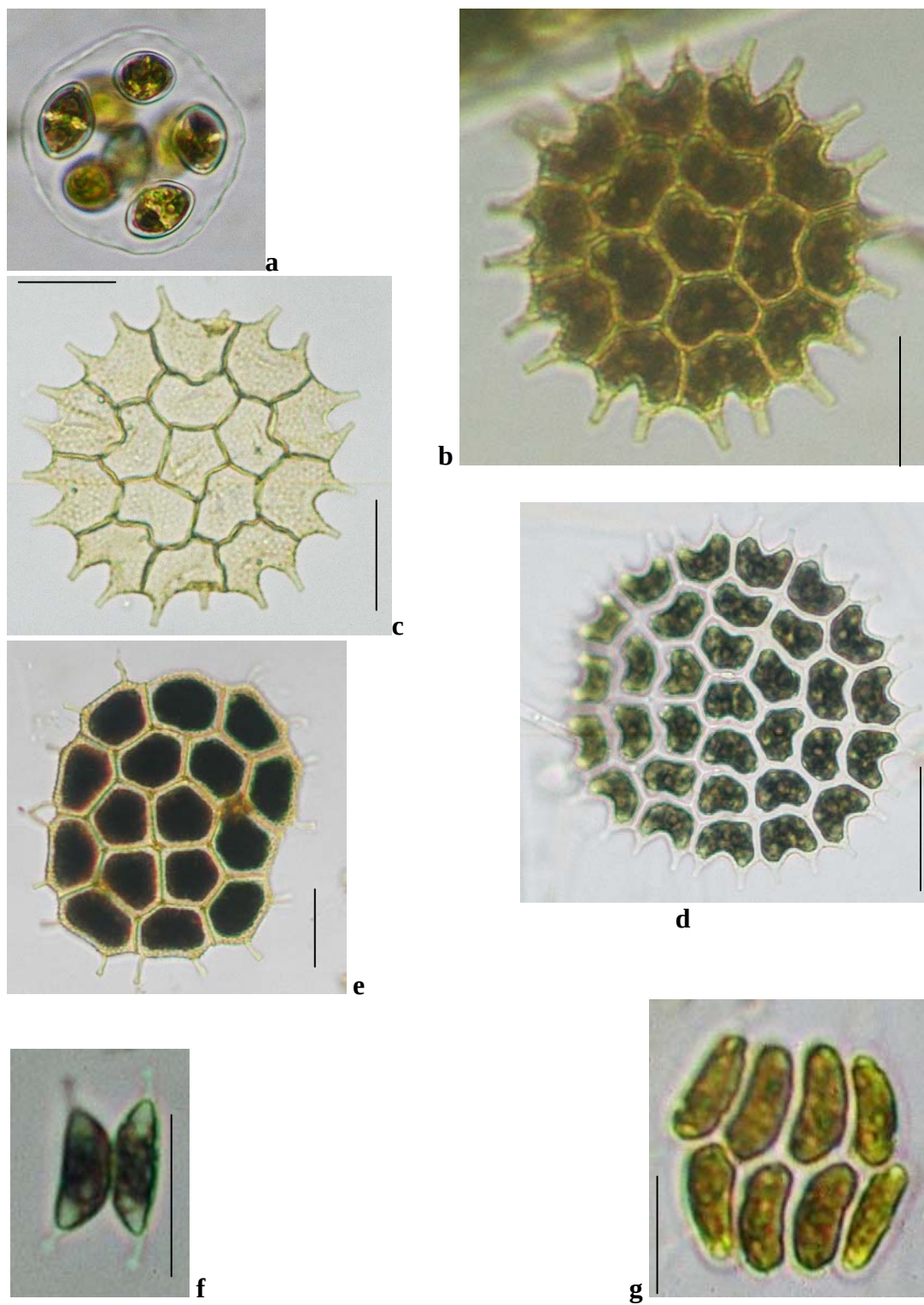
Coenobia 29-88 (16-208) μm in diameter, consist of 16-64 polygonal cells, marginal cells 7-9.5x9-11.5 (5-40x5-31) μm in dimension, inner cells 6-8.5x6-8.5 (5-26x4-27) μm in dimension, intercellular spaces absent, chloroplast with a pyrenoid for each cell (Huber Pestalozzi 1983, 87: 1; John et al. 2002: 93: C).

P. boryanum (Turpin) Meneghini **var. *cornutum*** (Raciborski) Sulek 1969.

Coenobia 30-98 (20-118) μm in wide, projections lying marginal cells, 5-15x5-13 (4.5-27x4-24) μm in dimension, polygonal inner cells 5-13 (5-26) μm in wide, 6-16 (5,7-27) μm in long (John et al., 2002, 93: D, F).

P. boryanum (Turpin) Meneghini **var. *longicorne*** Reinsch 1867.

Coenobia 37-84 (30-150) μm in wide, projections lying marginal cells, 9-18x6-14 (8.1-41x4-35) μm in dimension, polygonal without intercellular spaces inner cells 5-15x4-12 (5-27x4-22.5) μm in dimension (John et al., 2002, 93: E).



P. integrum Nageli 1849 (Figure 4. 6. e).

Coenobia consist of 8-32 (4, 8, 16, 32 or 128) cells, 41-84 (up to 125) μm short projections lying cells, 7.5-12.5 (up to 38) μm in dimension, cells irregularly arranged, chloroplast with a pyrenoid for each cell (Huber Pestalozzi 1983).

P. tetras (Ehrenberg) Ralfs 1844.

Coenobia contain 4-8 (4, 8, 16 or 32) cells, 16-37 (15-74) μm in wide, marginal cells, 8-14x9-13 (4-18x5-18) μm in dimension, laterally united to apex, apex divided two lobes, inner cells 8-10x8-10 (4-14x5-16) μm in dimension without intercellular spaces (Huber Pestalozzi 1983, 91: 5: John et al., 2002, 93: N).

Radiococcus Schmidle 1902.

R. planktonicus Lund 1956.

Colonies 48-67 (up to 250) μm contain 2-4 (2-8) cells groups, spherical cells 5-6 (4-7) μm in diameter (John et al., 2002, 86: I).

Scenedesmus Meyen 1829.

S. acutus Meyen 1829 **var. *globosus*** Hortobagyi 1959 (Figure 4. 6. f).

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

S. arcuatus (Lemmermann) Lemmermann 1899 (Figure 4. 6. g).

Coenobia consist of 8 (4, 8 or 16) cells in two rows, broadly rounded, slightly curved cells, 4,5 μm (2-9,5 μm) in wide, 10,5 μm (7-18 μm) in long (John et al., 2002, 97: C).

S. bicaudatus Dedusenko 1925.

Coenobia contain 2-4 (2, 4 or 8) tightly packed, linearly arranged cells, broadly rounded, ovoid cylindrical cells, 4-5 (2-5.4) μm in wide, 9-12 (7.8-14.5) μm in long (Huber Pestallozi 1983, 240: 5: John et al., 2002, 94: M).

S. brevispina (Smith) Chodat 1926.

Coenobia contain 4 (2-8) linearly arranged cells, apices setae 1-1.5 (0.6-2), ovoid-cylindrical cells, 5-7 (3-8) μm in wide, 10-12 (9-21) μm in long (Huber Pestallozi 1983, 237: 5)

S. communis Hegewald 1977.

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

S. dimorphus (Turpin) Kützing 1833.

Coenobia contain 4 (2, 4 or 8) linearly arranged cells, tapering to apices, spindle-shaped cells, 4.5-6 (2-14) μm in wide, 9-16 (5-27) μm in long (Huber Pestallozi 1983, 228: 3: John et al., 2002, 96: M)

S. ellipticus Corda 1835.

Cells 2, 4, and 16 (2, 4 or 8 rarely 16 or 32) single linearly arranged in coenobia, broadly rounded apices, ovoid-cylindrical cells, 5-6.5 (2-9) μm in wide, 9-15 (3.5-23) μm in long (John et al., 2002, 97: B)

S. falcatus Chodat 1894.

Cells 4 (2, 4 or 8) single linearly arranged in coenobia, spindle-shaped cells, 5-6.5 (3.4-9) μm in wide, 17.5-20 (18-35.5) μm in long (John et al., 2002, 97: B)

S. obliquus (Turpin) Kützing 1833

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 in wide, 10-16 (4-25) μm in long (John et al., 2002, 96: O).

***Scenedesmus opoliensis* Richter var. *monoensis* Chodat 1926**

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

***S. subspicatus* Chodat 1926.**

Cells 4 (2, 4 or 8) linearly or alternately arranged in coenobia, acute apices, spindle-shaped cells, 2.5 (2.4-7) μm in wide, 10-11 (5-12) μm in long, marginal cells curved crescent-shaped and tapering to acute apices (Huber Pestalozzi 1983, 237: 8: John et al., 2002, 96: N).

***Schroederia* Lemmermann 1898.**

***S. robusta* Korshikov 1953.**

Cells 5-7 (3-8) μm in wide, 37.5-64 (30-140) μm in long, cells, S-shaped or straight spindle-shaped, narrowing ends with spine 20-24 (20-33) μm in long, chloroplast with 2-5 (1-5) pyrenoids (John et al., 2002, 90: G).

***Sphaerocystis* Chodat 1897.**

***S. planctonica* (Korshikov) Bourrelly 1966.**

Colonies contain 16-32 (4, 8, 16 or 32) cells 38-56 (35-150) μm in diameter, cells 6-8 (4-9) μm in diameter, spherical cells regularly arranged in musilaj envelope, sporangia 11-12 (up to 12,5 μm) μm in diameter (John et al., 2002, 99: A).

***Tetrachlorella* Korshikov 1939.**

***T. alternans* (Smith) Korshikov 1939.**

Cells 6-8 (4-9) μm in diameter, spherical cells regularly arranged in musilaj envelope, sporangia 11-12 (up to 12.5 μm) μm in diameter (John et al., 2002, 99: A).

Tetrastrum Chodat 1895.

T. komarekii Hindak 1977.

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

Oedogoniales

Bulbochaete Agardh 1817.

***Bulbochaete* sp.**

Cells, 12-15 μm in wide, 18-23 μm in length, a long haired ellipsoidal oogonia 19-24 μm in wide, 25-32 μm in long, oospore superior division suffultory cell.

Zygnematales

Zygnemataceae

Closterium Nizsch 1848.

C. aciculare West 1860.

Cells, 5.5-7.5 (5-8) μm in wide, 367-489 (350-560) μm in length, apices 1-2 (1.5-2) μm in wide, straight long cell, tapering towards to slightly curved ends, chloroplast occupying one-third of cell with 8-14 (6-20) pyrenoid (John et al., 2002, 129: I).

C. gracile Brebisson ex Ralfs 1848.

Cells, 5-5.5 (4-6) μm in wide, 112-185 (100-350) μm in length, apices 2 (2.5-3.5) μm in wide, straight long cell, tapering towards to slightly curved ends, chloroplast with 4-5 (4-7) pyrenoids, smooth cell wall (John et al., 2002, 130: G).

Cosmarium Corda 1848.

C. bioculatum Brebisson 1848.

Cells, 22.5 μm (8-27 μm) in wide, 25 μm (9-29 μm) in length, deep sinus, narrow towards inside, oblong with rounded lateral margin, smooth cell wall with puncta (John et al., 2002, 132: K).

C. botrytis Meneghini 1848 (Figure 4. 7. a).

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

C. granatum Brebisson 1848

Subrhomboidal cells, 15-21 μm (15-38 μm) in wide, 25-34 (22-47) μm in length, narrow sinus, pyramidal-quadrangle semicells, smooth cell wall (John et al., 2002, 135: V).

C. impressulum Elfving 1881.

Cells, 14-16 (13-27) μm in wide, 21-27 (18-37) μm in length, deep sinus, ellipsoidal semicells, on each lateral margin 2 (2) equal crenations, on each apex 2 (2) undulations (John et al., 2002, 133: S).

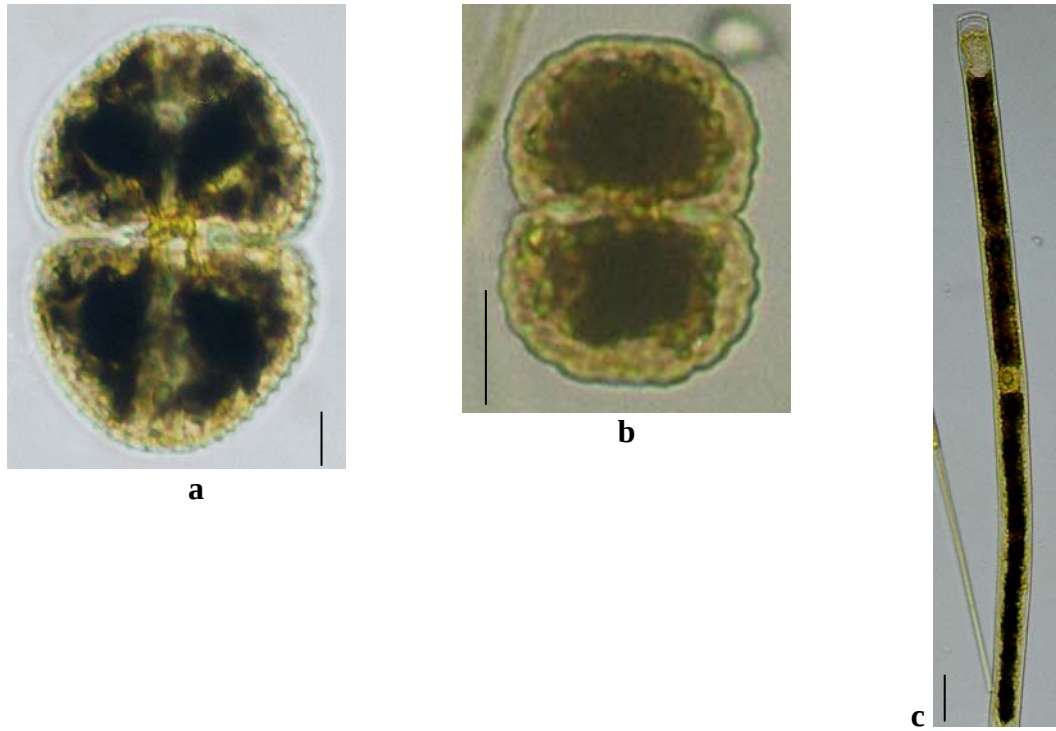


Figure 4. 1. a) *Cosmarium botrytis*, b) *C. subcrenatum*, c) *Gonatozygon monotaenium* (scale 10 µm).

C. laeve Rabenhorst 1868.

Cells, 16-21 (11-26) μm in wide, 17-25 (14-36) μm in length, deep sinus, and semicells rounded oblong elliptical (John et al., 2002, 133: V).

C. subcrenatum Hantzsch 1861 (Figure 4. 7. b).

Cells, 20-27 (18-34) μm in wide, 28-32 (21-38) μm in length, 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 (John et al., 2002, 135: A).

C. venustum (Brebisson) Archer 1861.

Cells, 18-24 (17-38) μm in wide, 27-35 (25-48) μm in length, narrow sinus, semicells truncate, 3 (3) undulations at lateral margins (John et al., 2002, 133: H).

Gonatozygon Barry 1858.

G. brebissonii Barry 1858

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

G. monotaenium de Bray 1856 (Figure 4. 7. c).

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

Staurostrum (Meyen) Ralfs 1848.

S. armigerum Brebisson **fo. *furcigerum*** (Ralfs) Teiling 1957

Cells, 48-59 (45-68) μm in wide, 37-45 (35-48) μm in length, lateral margins elongate, narrow sinus to inside and opening widely, isthmus 14-16 (13-18) μm in

wide, elliptical semicells with lateral margins extended laterally with ending 2 (2-3) short spines (John et al., 2002, 138: P).

S. lunatum Ralfs 1848.

Cells, 36-39 (35-43) μm in wide, 36-38 (35-39) μm in length, acute sinus opening widely to outside, isthmus 10-12 (10-13) μm in wide (John et al., 2002, 138: O).

Mougeotia Agardh 1824.

M. boodlei (West) Collins 1921

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

M. capucina (Bory) Agardh 1824.

Cells, 15-18 (14-21) μm in wide, 74-112 (70-340) μm in length, axile ribbon-shaped 1 or 2 chloroplast filling one-third to half of cell length with a series of 4-12 (4-16) pyrenoids, irregularly quadrangular (John et al., 2002, 121: C).

M. parvula Hassall 1843.

Cells, 7-12 (6-13) μm in wide, 37-74 (30-140) μm in length, chloroplast filling about 2-3 (two-thirds) of cell with a median series of 4-6 (4-8) pyrenoids, spherical (John et al., 2002, 119: G).

M. quadrangulata Hassall 1843 (Figure 4. 8. a)

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

M. scalaris Hassall 1842 (Figure 4. 8. b)

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

Spirogyra Link 1820.

S. communis (Hassall) Kützing 1849.

Cells, 20-24 (18-26) μm in wide, 38-47 (35-90) μm in length with end walls plane, single chloroplast with making 2-3 (1.5-4) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal, smooth zygospore 21-23 (19-26) μm in wide, 37-45 (36-78) μm in length (John et al., 2002, 122: H).

S. dubia Kützing 1855.

Cells, 42-47 (40-50) μm in wide, 78-145 (60-250) μm in length with end walls plane, 2 (2-3) chloroplast with making 3-3.5 (2-8.5) turns of cell (John et al., 2002, 124: A).

S. fluviatilis Hilse 1863

Cells, 36-40 (30-45) μm in wide, 82-112 (70-240) μm in length with end walls plane, 3 (3-4) chloroplast with making 2-3 (1.5-3.5) turns of cell (John et al., 2002, 124: B).

S. longata (Vaucher) Kützing 1843 (Figure 4. 8. c-d)

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

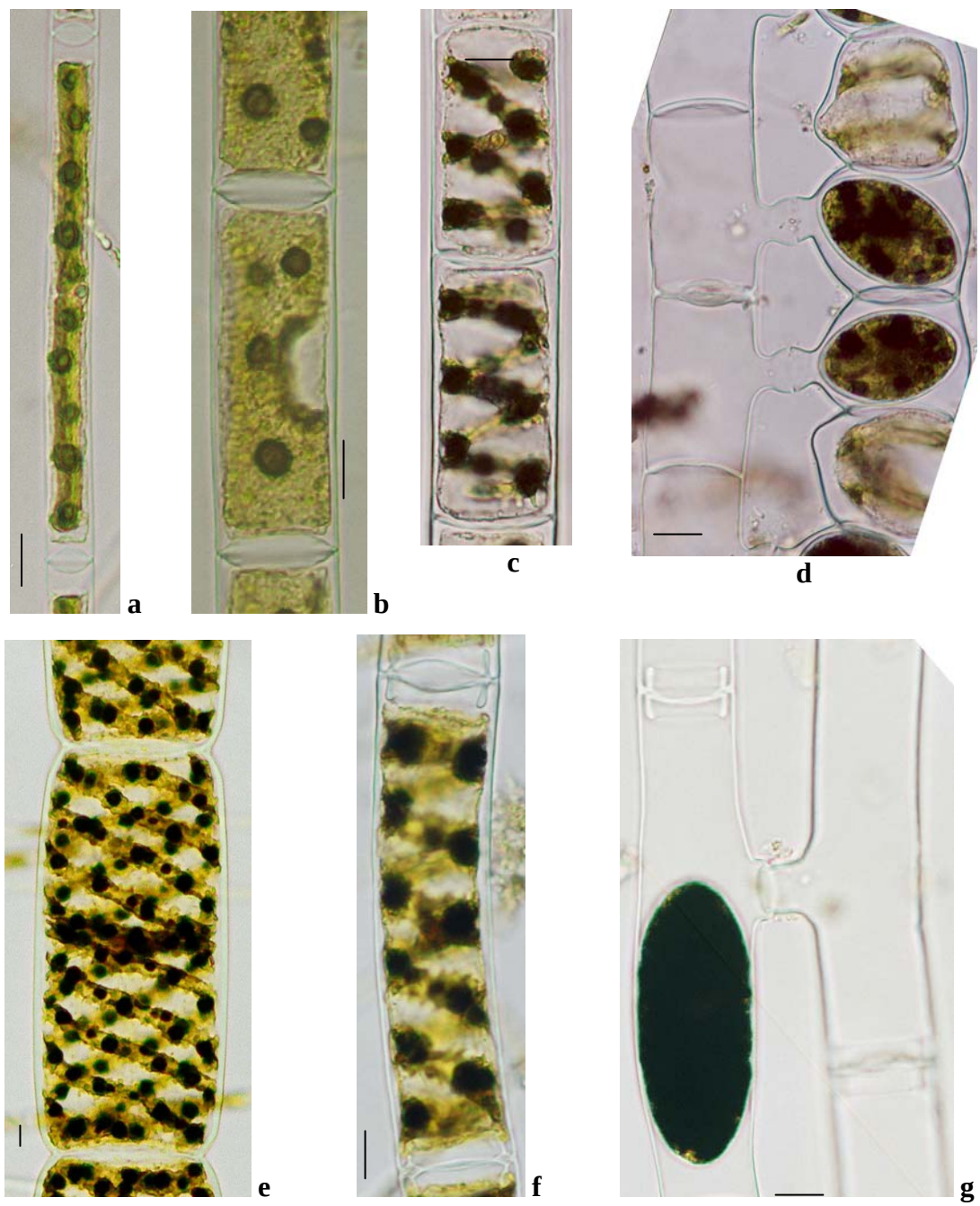


Figure 4. 1. a) *Mougeotia quadrangulata*, b) *M. scalaris*, c-d) *Spirogyra longata*, e) *S. setiformis*, f-g) *S. weberi* (scale 10 μm).

S. majusculas Kützing 1849.

Cells, 54-65 (50-80 μm) μm in wide, 95-146 (80-500 μm) μm in length with end walls plane, 3-5 (3-10) chloroplast with making 1-3 (1-3) turns of cell, conjugation tubes occurred from both gametangia, lens-shaped smooth zygospor 58-60 (57-62) μm in wide, 46-53 (45-60) μm in length (John et al., 2002, 124: E).

S. mirabilis (Hassall) Kützing 1849.

Cells, 24-28 (23-29) μm in wide, 76-97 (70-200) μm in length with end walls plane, single chloroplast with making 4-6 (4-7) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospor 24-26 (23-29) μm in wide, 51-64 (50-83) μm in length (John et al., 2002, 122: F).

S. porticalis (Müller) Cleve 1868.

Cells, 43-50 (40-50) μm in wide, 72-132 (66-200) μm in length with end walls plane, single chloroplast with making 2-4 (3-5) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal zygospor 42-47x50-64 (38-50x50-83) μm in dimension (John et al., 2002, 123: A).

S. pratensis Transeau 1914.

Cells, 17-19 (17-20) μm in wide, 84-96 (80-240) μm in length with end walls plane, single chloroplast with making 2-4 (1-8) turns of cell (Prescott 1982, 75: 4-6).

S. rivularis (Hassall) Rabenhorst 1868.

Cells, 32-38 (30-41) μm in wide, 104-178 (100-400) μm in length with end walls plane, 2-3 (2- 3) chloroplast with making 2.5-3 (2.5-3.5) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospor 33-37 (32-42) μm in wide, 64-72 (60-100) μm in length (John et al., 2002, 124: D).

S. setiformis (Roth) Kützing 1845 (Figure 4. 8. e).

Cells, 91-112 (90-115) μm in wide, 116-164 (100-225) μm in length with end walls plane, 4 (4) chloroplast with making 1-3.5 (0.5-4) turns of cell, conjugation tubes occurred from both gametangia, ellipsoidal smooth zygospores 87-96 (85-100) μm in wide, 118-132 (115-160) μm in length (John et al., 2002, 125: C).

S. subechinata Godward 1956.

Cells, 85-93 (80-100) μm in wide, 91-146 (60-200) μm in length with end walls plane, 7-8 (7-8) chloroplast with making 1-2 (1) turns of cell (John et al., 2002, 125: D).

S. tenuissima (Hassall) Kützing 1849.

Cells, 9-12 (8-13) μm in wide, 43-68 (40-250) μm in length with end walls replicate, single chloroplast with making 3-5 (3-6) turns of cell (John et al., 2002, 126: C).

S. weberi Kützing 1843 (Figure 4. 8. f-g)

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

Zygnema Agardh 1824.

Z. conspicuum (Hassall) Transeau 1934

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

14 DISCUSSION

During the present study, Lake Gök  y non-diatom phytoplankton was characterized with tremendous species diversity of a total of 152 taxa. Chlorophyta was the most species richness phylum with 95 species concerning 42 genera. The green algae contain a great number of morphologically diverse organisms. Species numbers of green phytoplankton were increased especially fall season 2003-2004 and late summer 2004 during the study period, however the members of Chlorophyceae were increased in 2004 comparing 2003. The highest species richness was recorded as 29 taxa in September 2004. Some species such as *Spirogyra mirabilis*, *Pandorina morum*, *Eudorina elegans* were commonly distributed in Lake G  lk  y during present study period. *S. mirabilis* was generally recorded summer and early fall seasons, while *P. morum* and *E. elegans* was showed frequent occurrence in about each months of spring and fall seasons. Input lake water via two canals contains high organic materials increased in both seasons. (Figure 1) Both taxa have wide tolerance range and widespread in different aquatic habitats in Turkey (G  n  l   et al., 1996) and in British Isles (John et al., 2002). It is known that *E. elegans* was founded in more eutrophic lakes (Hutchinson, 1967), and prefer nutrient enrichment usually observed in spring or fall seasons. Additionally, members of Volvocales and Chlorococcales are frequently facultative heterotrophic in culture, and require inorganic nutrient levels. *Scenedesmus* has been grown medium containing glucose in dark condition. So, members of this class have wide tolerance to organic pollution which supported occurrence of some green taxa.

Second dominant phylum is Euglenophyta with 19 species belonging to 4 genera. Species numbers of euglenophytes were found highly fall season 2003 and reach

maximum level in July 2004. *Trachelomonas volvocina* was the most common taxa, and almost founded in each month at sampling stations. Hutchinson (1967) point out that *T. volvocina* is widespread in open water of lakes. This taxon was commonly detected in different aquatic ecosystem in Turkey (Gönülol et al., 1996). Euglena is most abundant genus with 8 species in this phylum. It is known that this genus prefer organic rich water (Wetzel, 1975; John et al., 2002; Zimba et al., 2004).

Cyanoprokaryota following Euglenophyta consist of 16 species in 8 genera. The most species richness was recorded in August 2003, and number of blue green algae was usually increased in late summer and early fall seasons. *Oscillatoria* is common genus with 8 species, and *O. formosa* and *O. limosa* were frequently distributed almost in sampling months. Both species prefer slightly brackish nutrient rich water (John et al., 2002).

Pyrrophyta, Chrysophyta, and Cryptophyta have medium species richness with 8, 7, 6 taxa respectively in present study. Pyrrophyta was mostly founded in spring, early summer, and fall seasons 2004, and *Ceratium hirundinella* and *Peridinium willei* were widespread taxa during study time. Species richness of Chrysophyta was increased especially in April, May 2004, and April 2005. *Dinobryon divergens* was commonly distributed about each month in all sampling stations. This species is widely distributed from moderately to very nutrient rich water (John et al., 2002). Cryptophyta was not detected in September and November 2003. *Cryptomonas ovata* and *Plagioselmis nanoplanktonica*, which were most abundant species, commonly distributed in sampling months of 2004, 2005. The lowest distributed phylum was Xanthophyta with a species in now study. Most of non-diatom flora which are cosmopolite have wide tolerance range and prefer nutrient rich water. Species composition of present, which mostly prefers nutrient rich water type, increased

second year comparing to 2003 in Lake Gölköy. However, it is difficult to have any idea about of lake trophic status, only using to species composition. On the other hand, results of current studies concerning on ostracods fauna (Külköylüoğlu, 2005) and on diatom flora (Çelekli, in press) in Lake Gölköy supported consequence of this study. Külköylüoğlu (2005) denoted that this lake showed mesotrophic status. Many factors can affect Lake Gölköy water which is considered to be a potential drinking water reservoir for Bolu in future.

In recent studies, Aysel and his colleagues (2002) signified that 20 freshwater taxa were new records in Lake Kazan (İzmir, Turkey). A few new records taxa such as *Ankistrodesmus spiralis* and *Mougeotia capucina* were also identified Lake Gölköy. *A. spiralis* was rarely distributed, while *M. capucina* was sometimes detected in Lake Gölköy.

The highest mean number of total species was detected in summer season, while the lowest species richness was founded in winter season. Spring and fall seasons have similar number of species during study period.

In Bolu region, a few limnological studies have been carried out in different aquatic habitats. Lake Gölköy has enormous algae diversity (total 271 taxa) with 152 non-diatom phytoplankton and 119 diatom taxa (Çelekli, (in press)). Algae of Lake Abant was studied from flora of benthic and planktonic. Obalı and her colleagues (2002) reported 83 algae taxa, of which only 49 belonged to non-diatom phytoplankton in Lake Abant. Atıcı and Obalı (2002) expressed that 43 and 29 non-diatom algae were identified in Lake Abant and Lake Yedigöller, respectively. Çelekli and Külköylüoğlu (in press) argued that tremendous non-diatom phytoplankton species as 162 phytoplankton was identified in Lake Abant. Benthic algal flora of Lake Abant was founded as 69 non-diatom taxa (Atıcı et al., 2005). Two algological

studies (Kılınç, 2003; Saygı-Başbuğ and Demirkalp, 2004) were carried out between October 1997 and August 1999 in Lake Yeniçağa, which included 59 and 18 non-diatom algae taxa respectively was eutrophic characteristic. Çelekli and Külköylüoğlu (2006) point out that Akkaya spring which included 24 non-diatom taxa, is a karstic spring. Some taxa (e.g. *Gonium pectorale*, *Provasoliella ovata*, and *Anabaena crassa*) have been only found in Lake Gök  y comparing to above studies up to now. Many factors such as two creeks carry different water input this lake, fluctuation water of lake for irrigation, trophic status, area can affect phytoplankton diversity in Lake G    y. Above all studies were carried out in natural lakes and spring; however present study was made Lake G    y which is a reservoir. These algological studies have important contribution to algae flora of this area. These results clearly show the importance of long-term monthly (or even weekly) sampling.

Part E

PHYTOPLANKTON COMPOSITION OF LAKE ABANT AND GÖLKÖY (BOLU)

A total of 285 net phytoplankton taxa belonging to 103 genera (Table 5. 2) and 271 net phytoplankton species belonging to 98 genera were identified in Lake Abant and Gököy respectively. In Lake Abant, Bacillariophyta which was dominant phylum with 43.2 % of the total species is consisting of 123 diatom taxa in 34 genera. This group was followed by Chlorophyta (33.3 %), Cyanoprokaryota (8.1 %), Euglenophyta (7.4 %), Pyrrophyta (2.8 %), Chrysophyta (2.5 %), Cryptophyta (2.1 %), Xanthophyta (0.4 %), and Prasinophyta (0.4 %). Chlorophyta, which is consisting of 95 species, is the most abundant phylum with about 58.6 % of the total species. Similarly, in Lake Gököy, dominant phylum is Bacillariophyta with 43.9 % of total species, consisting of 119 diatom taxa in 33 genera. Other phylum putting in similar order to in Lake Abant; Chlorophyta (34.7 %), Euglenophyta (7 %), Cyanoprokaryota (5.9 %), Pyrrophyta (3 %), Chrysophyta (2.6 %), Cryptophyta (2.2 %), Xanthophyta (0.4 %), and Prasinophyta (0.4 %). The percentages of phyla were similar for both lakes; however, not only species richness of Cyanoprokaryota and Euglenophyta was higher in Lake Abant than in Lake Gököy, but also total numbers of taxa and genera were excess in Lake Abant.

Total number of phytoplankton taxa from both these lakes is identified as 363 species. Many algae (209 taxa) were found in both lakes, while numbers of exclusive species are 76 and 62 taxa for Lake Abant and Gököy respectively. Both lakes were characterized with tremendous species diversity. Species assemblages were quantified with the Jaccard and Sorenson similarity indexes (Magurran, 1988).

Calculations were based on presence/absence of a species in these indexes. Jaccard formula is;

$$JI = j / (a + b - j) \text{ (Magurr)}$$

Where j; the number of species present in both sites (lakes)

a; the number of species present in site a (Lake Abant)

b; the number of species present in site b (Lake Gök  y)

Sorenson formula is;

$$Cs = 2j / (a + b)$$

Abbreviations of Sorenson formula are similar to the Jaccard formula.

Table 5. 1. There are showed Jaccard and Sorenson similarity indexes of phytoplankton phylum between Lake Abant and G  lk  y.

	Jaccard Index	Sorenson Index
Bacillariophyta	70.4	82.6
Cyanoprokaryota	50	66.7
Euglenophyta	29	45
Cryptophyta	100	100
Pyrrophyta	100	100
Chrysophyta	75	85.7
Xanthophyta	100	100
Prasinophyta	100	100
Chlorophyta	52.8	69.2
Total System	60.2	75.2

Phytoplankton composition in Lake Abant and Gök y is showed high similarity according to values of Jaccard and Sorenson similarity index. During two years, similarity in phytoplankton composition between both lakes is varied from 29 % to 100 %. Species assemblages of four phyla were same in both lakes, so 100 % similarity is founded. The high difference is calculated in Cyanoprokaryota.

In diatom composition, some species such as *Asterionella formosa* Hassall, *Cymbella cistula* Kirchner, *Fragilaria biceps* (K tzing) Lange-Bertalot, *F. dilata* (Brebisson) Lange-Bertalot, *Navicula radiosa* K tzing showed frequent occurrence in each month for each stations for both lakes. *Cymbella silesiaca* Bleisch, and *Rhopalodia gibba* M ller were common in Lake Abant, while *Aulacoseria granulata* (Ehrenberg) Simonsen, *Cyclotella praetermis* Lund, *Fragilaria crotonensis* Kitton, and *Nitzschia sigmoidae* (Nitzsch) Smith were found each month from all stations in Lake G lk y. In Lake Abant, some genera such as *Fragilaria*, *Cymbella*, and *Gomphonema* appeared to be the richness in term of species with 15, 14, and 10 taxa respectively, while high species richness was recorded from Lake G lk y with 16, 14, and 9 taxa for *Cymbella*, *Fragilaria*, and *Navicula* respectively.

Species composition is similar between these lakes; however natural Lake Abant has about stable depth, high latitude with cooler water. Reservoir Lake G lk y has low latitude, changeable depth (irrigation), warm water. A cause of most taxa was distributed in both lakes, because Abant creek from output of Lake Abant connects these lakes waters. Many factors such as physical and chemical variables, geomorphologic structure can affect phytoplankton diversity in these lakes.

Table 5. 2. Net-Phytoplankton taxa observed in Lake Abant and Gök  y from June 2003 to June 2005.

	Lake	
	Abant	G��k��y
BACILLARIOPHYTA		
Centrales		
Thalassiosiraceae		
<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen 1979	+	+
<i>A. islandica</i> (M��ller) Simonsen 1979	+	+
<i>Cyclotella bodanica</i> Grunow 1878	+	+
<i>C. meneghiniana</i> K��tzing 1844	+	+
<i>C. ocellata</i> Pantocsek 1901	+	+
<i>C. praetermisa</i> Lund 1951	+	+
<i>Elleerbeckia arenaria</i> Crowd 1988	+	
<i>Stephanodiscus alpinus</i> Husted 1942	+	
<i>Stephanodiscus</i> sp.		+
Melosiraceae		
<i>Melosira dickei</i> (Thwaites) K��tzing 1849	+	+
<i>M. lineata</i> Agardh 1824	+	+
<i>M. varians</i> Agardh 1827	+	+
Pennales		
Araphidineae		
Fragilariceae		
<i>Asterionella formosa</i> Hassall 1850	+	+
<i>Diatoma anceps</i> Agardh 1812		+

(Table 5. 2 continued).

Abant Gölköy

<i>Diatoma tenuis</i> Agardh 1812	+	+
<i>D. vulgaris</i> Borry 1824	+	+
<i>Fragilaria biceps</i> (Kützing) Lange-Bertalot 1991	+	+
<i>F. brevistriata</i> Grunow 1885	+	
<i>F. capucina</i> Desmazieres 1925	+	+
<i>F. capucina</i> var. <i>mesolepta</i> (Rabenhorst) Rabenhorst 1864	+	+
<i>F. capucina</i> var. <i>vaucheriae</i> (Kützing) Lange-Bertalot 1980	+	+
<i>F. construens</i> (Ehrenberg) Grunow 1862	+	+
<i>F. crotonensis</i> Kitton 1869	+	+
<i>F. dilata</i> (Brebisson) Lange-Bertalot 1986	+	+
<i>F. leptostauron</i> Husted var. <i>martyi</i> Lange-Bertalot 1991		+
<i>F. lapponica</i> Grunow 1881	+	+
<i>F. pinnata</i> Ehrenberg 1843	+	+
<i>Fragilaria</i> sp.	+	
<i>F. ulna</i> (Nitzsch) Lange-Bertalot 1980	+	+
<i>F. ulna</i> var. <i>danica</i> (Kützing) Lange-Bertalot 1980	+	+
<i>F. ulna</i> var. <i>acus</i> (Kützing) Lange-Bertalot 1980	+	+
<i>F. virescens</i> Ralfs 1843	+	+
<i>Meridion circulare</i> (Greville) Agardh 1831	+	+
<i>Tetracyclus rupestris</i> (Braun) Grunow 1881	+	+

(Table 5. 2 continued).

Abant Gök y

Raphidineae		
Achnanthaceae		
<i>Achnanthes minutissima</i> K�tzing 1833	+	+
<i>Cocconeis fluviatis</i> Wallace 1960	+	
<i>C. pediculus</i> Ehrenberg 1838	+	+
<i>C. placentula</i> Ehrenberg 1838	+	+
<i>C. placentula</i> var. <i>euglypta</i> Grunow 1884	+	
<i>C. placentula</i> var. <i>lineata</i> Grunow 1884	+	+
<i>C. rugosa</i> Sovereing 1960	+	
Eunotiaceae		
<i>Eunotia bilunaris</i> (Ehrenberg) Mills 1934	+	+
<i>E. parallella</i> Ehrenberg 1843	+	
Naviculaceae		
<i>Amphora aequalis</i> Krammer 1980	+	+
<i>A. ovalis</i> (K�tzing) K�tzing 1844	+	+
<i>A. pediculus</i> (K�tzing) Grunow 1880		+
<i>Anomoneis sphaerophora</i> (Ehrenberg) Pfitzer 1871		+
<i>Caloneis alpestris</i> (Grunow) Cleve 1894	+	
<i>C. silicula</i> (Ehrenberg) Cleve 1894	+	+
<i>Cymbella affinis</i> K�tzing 1844	+	+
<i>C. amphicephala</i> Naegeli 1849	+	+
<i>C. aspera</i> (Ehrenberg) Peragallo 1849	+	+
<i>C. cistula</i> (Ehrenberg) Kirchner 1878	+	+

(Table 5. 2 continued).

Abant Gölköy

<i>C. cuspidata</i> Kützing 1844	+	+
<i>C. cymbiformis</i> Agardh 1830	+	+
<i>C. ehrenbergii</i> Kützing 1844	+	+
<i>C. gracilis</i> (Ehrenberg) Kützing 1844	+	+
<i>C. helvetica</i> Kützing 1844	+	+
<i>C. lanceolata</i> (Ehrenberg) Kirchner 1878	+	+
<i>C. leptoceros</i> (Ehrenberg) Kützing 1844	+	+
<i>C. minuta</i> Hilse ex Rabenhorst 1862	+	+
<i>C. proxima</i> Reimer 1975	+	+
<i>C. schimanskii</i> Krammer 1982	+	+
<i>C. silesiaca</i> Bleisch 1864	+	+
<i>C. subcuspidata</i> Krammer 1982		+
<i>Didymosphaenia geminata</i> Schmidt 1899		+
<i>Diploneis elliptica</i> (Kützing) Cleve 1891	+	+
<i>D. pseudovalis</i> Hustedt 1930	+	+
<i>D. puella</i> (Schumann) Cleve 1894	+	+
<i>Gomphonema acuminatum</i> Ehrenberg 1832	+	+
<i>G. angustum</i> Agardh 1831	+	+
<i>G. augur</i> Ehrenberg 1840	+	+
<i>G. clavatum</i> Ehrenberg 1832	+	
<i>G. gracile</i> Ehrenberg 1838	+	+
<i>G. hebridense</i> Ehrenberg 1832	+	
<i>G. olivaceum</i> (Hornemann) Brebisson 1838	+	+

(Table 5. 2 continued).

Abant Gökçöy

<i>G. parvulum</i> (Kützing) Kützing 1849	+	+
<i>G. subtile</i> Ehrenberg 1843	+	+
<i>G. truncatum</i> Ehrenberg 1832	+	+
<i>Gyrosigma acuminatum</i> (Kützing) Rabenhorst 1853	+	+
<i>G. attenuatum</i> (Kützing) Rabenhorst 1853	+	+
<i>Mastogloia elliptica</i> (Agardh) Cleve 1893	+	
<i>M. smithii</i> Thwaites 1856	+	
<i>Navicula clementis</i> Grunow 1882		+
<i>N. cryptocephala</i> Kützing 1844	+	+
<i>N. cuspidata</i> (Kützing) Kützing 1844	+	+
<i>N. gastrum</i> (Ehrenberg) Kützing 1844	+	
<i>N. menisculus</i> Schumann 1867		+
<i>N. nivalis</i> Ehrenberg 1853		+
<i>N. radiosa</i> Kützing 1844	+	+
<i>N. reinhardtii</i> (Grunow) Grunow 1877	+	+
<i>N. rhynchocephala</i> Kützing 1844	+	+
<i>N. trivialis</i> Lange-Bertalot 1980	+	+
<i>Nedium dubium</i> (Ehrenberg) Cleve 1894	+	+
<i>N. iridis</i> (Ehrenberg) Cleve 1894		+
<i>Pinnularia divergens</i> Smith 1853	+	
<i>P. gibba</i> Ehrenberg 1841	+	+
<i>P. interrupta</i> Smith 1853	+	+
<i>P. legumen</i> (Ehrenberg) Ehrenberg 1843	+	

(Table 5. 2 continued).

Abant Gölköy

<i>Pinnularia maior</i> (Kützing) Rabenhorst 1853	+	+
<i>P. microstauron</i> (Ehrenberg) Cleve 1891	+	+
<i>P. nobilis</i> (Ehrenberg) Ehrenberg 1843		+
<i>P. rupestris</i> (Ehrenberg) Smith 1856	+	
<i>P. streptoraphe</i> Cleve 1891		+
<i>P. viridis</i> (Nitzsch) Ehrenberg 1843	+	+
<i>Rhoicosphenia abbreviata</i> (Agardh) Lange-Bertalot 1980 b	+	+
<i>Stauroneis anceps</i> Ehrenberg 1843	+	+
<i>S. phoenicenteron</i> Ehrenberg 1843	+	+
<i>S. producta</i> Grunow 1880		+
Bacillariaceae		
<i>Hantzschia amphyoxys</i> (Ehrenberg) Grunow 1880	+	+
<i>Nitzschia angustata</i> (Smith) Grunow 1880	+	
<i>N. linearis</i> Smith 1853		+
<i>N. lorenziana</i> Grunow 1880		+
<i>N. palea</i> (Kützing) Smith 1856	+	+
<i>N. recta</i> Hantzsch 1861	+	
<i>N. sigma</i> (Kützing) Smith 1853	+	+
<i>N. sigmoidea</i> (Nitzsch) Smith 1853	+	+
<i>N. tryblionella</i> Hantzsch 1860		+
<i>N. vermicularis</i> (Kützing) Hantzsch 1860	+	+
<i>N. wuellerstorffii</i> Lange-Bertalot 1987	+	
Epithemiaceae		
<i>Denticula elegans</i> Kützing 1844	+	

(Table 5. 2 continued).

Abant Gökölü

<i>Epithemia adnata</i> (Kützing) Brebisson 1838	+	+
<i>E. argus</i> (Ehrenberg) Kützing 1844	+	+
<i>E. goeppertiana</i> Hilse 1860	+	
<i>E. sorex</i> Kützing 1844	+	+
<i>E. turgida</i> (Ehrenberg) Kützing 1844	+	
<i>Rhopalodia gibba</i> Müller 1895	+	+
Surirellaceae		
<i>Campylodiscus noricus</i> Ehrenberg 1840	+	+
<i>C. hibernicus</i> Ehrenberg 1845	+	+
<i>Cymatopleura elliptica</i> Smith 1851	+	+
<i>C. solea</i> Smith 1851	+	+
<i>C. solea</i> var. <i>apiculata</i> Ralfs 1861	+	+
<i>Stenopterobia curvula</i> (Smith) Krammer 1987	+	+
<i>Surirella angusta</i> Kützing 1844	+	+
<i>S. biseriata</i> Brebisson 1836	+	+
<i>S. brebissoni</i> Krammer and Lange-Bertalot 1987		+
<i>S. elegans</i> Ehrenberg 1843.		+
<i>S. minuta</i> Brebisson 1849		+
<i>S. ovalis</i> Brebisson 1838	+	+
<i>S. robusta</i> Ehrenberg 1841	+	+
<i>S. spiralis</i> Kützing 1844	+	
<i>Surirella</i> sp.	+	
<i>S. subsalsa</i> Smith 1853	+	+
<i>S. spiralis</i> Kützing 1844		+

(Table 5. 2 continued with non-diatom phytoplankton taxa).

	Lake	
	Abant	Gölköy
CYANOPROKARYOTA		
Chroococcales		
<i>Aphanocapsa litoralis</i> Hansgirg 1892	+	
<i>A. clathrata</i> West 1906	+	
<i>Chroococcus turgidus</i> (Kützing) Nageli 1849	+	
<i>Coelosphaerium kuetzingianum</i> Naegeli 1849	+	
<i>Merismopedia tenuissima</i> Lemmermann 1898	+	+
<i>Microcystis aeruginosa</i> (Kützing) Kützing 1846	+	+
<i>Snowella lacustris</i> (Chodat) Komarek et Hindak 1988	+	+
Oscillatoriales		
<i>Oscillatoria formosa</i> (Bory) Gomont 1892	+	+
<i>O. limosa</i> (Agard) Gomont 1892	+	+
<i>O. minima</i> Gicklhorn 1921		+
<i>O. princeps</i> (Vaucher) Gomont 1892	+	+
<i>O. rubescens</i> (de Candolle) Gomont 1892		+
<i>O. sancta</i> (Kützing) Gomont 1892	+	+
<i>O. subbveris</i> Schmidle 1901		+
<i>O. tenuis</i> Schmidle 1901	+	+
<i>Phormidium</i> sp.	+	+
<i>Pseudoanabaena</i> sp.	+	
<i>Spirulina maior</i> (Kützing) Gomont 1892	+	+
<i>S. subsalsa</i> (Oersted 1842) Gomont 1892	+	

(Table 5. 2 continued).

Abant Gölköy

Nostocales		
<i>Anabaena bergei</i> (Kützing) Bornet 1886	+	
<i>A. crassa</i> Lemmarmann 1896	+	+
<i>A. planctonica</i> Brunnthaler 1903	+	
<i>A. smithii</i> (Komárek) Watanabe	+	
<i>Anabaena</i> sp.	+	+
<i>Calothrix stagnalis</i> Gomont 1895	+	
<i>Cylindrospermum minutissimum</i> Collins 1896	+	
EUGLENOPHYTA		
Euglenales		
<i>Euglena acus</i> Ehrenberg 1830	+	+
<i>E. agilis</i> Carter 1856	+	+
<i>E. chlamydophora</i> Mainx 1927		+
<i>E. contabrica</i> Pringsheim 1953	+	
<i>E. deses</i> fo. <i>klebsii</i> (Lemmermann) Popova 1966	+	
<i>E. geniculata</i> (Schmitz) Dujardin 1841		+
<i>E. gracilis</i> Klebs 1883		+
<i>E. granulata</i> (Klebs) Schmitz 1884	+	
<i>E. limnophila</i> Lemmermann var. <i>swirenkoi</i> (Anoldi) Popova 1955		+
<i>E. oblonga</i> Schmitz 1884		+
<i>E. obtusa</i> Schmitz 1884	+	
<i>E. proxima</i> Dangeard 1901	+	
<i>E. sanguinea</i> Ehrenberg 1830	+	

(Table 5. 2 continued).

Abant Gölköy

<i>E. viridis</i> Ehrenberg 1830		+
<i>Lepocinclis fusiformis</i> (Carter) Lemmermann 1901	+	
<i>L. ovum</i> (Ehrenberg) Lemmermann 1901	+	+
<i>L. playfairiana</i> Deflandre 1932	+	+
<i>L. steinii</i> Lemmermann 1901	+	+
<i>Phacus caudatus</i> Hübner 1886	+	+
<i>P. curvicauda</i> Svirenko 1915		+
<i>P. haemeliai</i> Allorge et Lefevre 1930		+
<i>P. pseudonordstedtii</i> Pochmann 1941	+	+
<i>P. striatus</i> (Drezepolski) France 1893	+	
<i>Trachelomonas acanthostoma</i> Stokes 1887	+	
<i>T. armata</i> Stein 1878	+	+
<i>T. dubia</i> (Svirenko) Deflandre 1926		+
<i>T. granulosa</i> Playfair 1915	+	
<i>T. hispida</i> (Perty) Stein emend. Deflandre 1926		+
<i>T. planctonica</i> Svirenko 1914	+	
<i>T. pulchella</i> Drezepolski 1925	+	
<i>T. volvocina</i> Ehrenberg 1833	+	+
CRYPTOPHYTA		
Cryptomonadales		
<i>Campylomonas reflexa</i> Hill 1991	+	+
<i>C. rostratiformis</i> Hill 1991	+	+
<i>Cryptomonas marssonii</i> Skuja 1948	+	+

(Table 5. 2 continued).

Abant Gölköy

<i>C. ovata</i> Ehrenberg 1838	+	+
<i>C. platyuris</i> Skuja 1948	+	+
<i>Plagioselmis nannoplanctica</i> (Skuja) Novarino	+	+
PYRROPHYTA		
Gonyaulacales		
<i>Ceratium coralinianum</i> (Bailey) Jorgensen 1911	+	+
<i>C. cornutum</i> (Ehrenberg) Claparede 1858	+	+
<i>C. furcoides</i> (Lavender) Langhans 1925	+	+
<i>C. hirundinella</i> (Müller) Dujardin 1841	+	+
Gymnodiniales		
<i>Gymnodinium cnecoides</i> Harris 1940	+	+
Peridinales		
<i>Peridiniopsis thompsonii</i> (Thompson) Bourrelly 1968	+	+
<i>Peridinium cinctum</i> (Müller) Ehrenberg 1838	+	+
<i>P. willei</i> Huitfeldt-Kaas 1900	+	+
CHRYSOPHYTA		
Chromulinales		
<i>Dinobryon bavaricum</i> Imhof 1890	+	+
<i>D. divergens</i> Imhof 1887	+	+
<i>D. sertularia</i> Ehrenberg 1838	+	+
<i>D. sociale</i> Ehrenberg 1838	+	+
<i>D. sociale</i> var. <i>americanum</i> (Brunnthaler) Bachmann 1911	+	+
<i>D. sociale</i> var. <i>spitatum</i> (Stein) Lemmermann 1903		+

(Table 5. 2 continued).

Abant Gölköy

Uroglena volvox Ehrenberg 1834

+ +

Synurales

Synura petersenii Korshikov 1929

+

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

+ +

Chlamydomonas sp.

+

Eudorina elegans Ehrenberg 1831

+ +

Gonium pectorale Müller 1773

+

Hyaliella polytomoides Pascher 1931

+

Monomastix opisthostigma Scherffel 1912

+

Pandorina morum (Müller) Bory 1824

+ +

(Table 5. 2 continued).

Abant Gökçöy

<i>Pleodorina californica</i> Shaw 1894		+
<i>Polytoma cylindraceum</i>	+	+
<i>Provasoliella ovata</i> (Jacobsen) Loeblich 1967		+
<i>Sphaerellopsis</i> sp.		+
<i>Sphaerellopsis spiralis</i> Belcher et Swale 1963	+	
<i>Volvox aureus</i> Ehrenberg 1832		+
<i>V. globator</i> Linnaeus 1758		+
<i>V. polychlamys</i> Korschikoff 1939		+
Tetrasporales		
<i>Pseudosphaerocystis lacustris</i> (Lemmermann) Novakova 1965	+	+
Chlorococcales		
<i>Ankistrodesmus falcatus</i> (Corda) Ralfs 1848	+	+
<i>A. fusiformis</i> Corda ex Korshikov 1953	+	+
<i>A. spiralis</i> (Turner) Lemmermann 1908	+	+
<i>Ankyra judayi</i> (Smith) Fott 1957		+
<i>A. lanceolata</i> (Smith) Fott 1957		+
<i>Botryococcus braunii</i> Kützing 1849	+	+
<i>Characium ensiformis</i> Braun 1855		+
<i>C. ornithocephalum</i> Braun 1855	+	
<i>Chonrosphaera lapponica</i> Skuja 1964	+	
<i>Crucigeniella rectangularis</i> (Nageli) Komarek 1974	+	
<i>Elakatothrix gelatinosa</i> Wille 1898	+	+
<i>Eremosphaera viridis</i> de Bary 1858	+	

(Table 5. 2 continued).

Abant Gölköy

<i>Geminella</i> sp.	+	+
<i>Golenkinia paucispina</i> West et West 1902		+
<i>Golenkiniopsis solitaria</i> Korsikov 1953		+
<i>Golenkinia radiata</i> Chodat 1894 emend. Korshikov 1953	+	
<i>Kirchneriella obesa</i> (West) Schmidle 1893	+	+
<i>Korshikoviella limnetica</i> (Lemmermann) Silva 1959	+	+
<i>K. michailovskoensis</i> (Elenkin) Silva 1959	+	+
<i>Micractinium crassisetum</i> Hortob. 1973		+
<i>Monoraphidium arcuatum</i> (Korshikov) Hindak 1970	+	+
<i>M. irregulare</i> (Smith) Komarkova-Legnerova 1969		+
<i>Nephrocytium agardhianum</i> Nageli 1849	+	+
<i>N. limneticum</i> (Smith) Smith 1933	+	
<i>Oocystis apiculata</i> West 1893	+	+
<i>O. borgei</i> Snow 1903	+	+
<i>O. marssonii</i> Lemmermann 1898	+	+
<i>O. parva</i> West and West 1898	+	+
<i>O. pusilla</i> Hansgirg 1890	+	
<i>O. tainoensis</i> Kommarek 1983	+	
<i>Oocystis</i> sp.	+	
<i>Pediastrum boryanum</i> (Turpin) Meneghini 1840	+	+
<i>P. boryanum</i> var. <i>cornutum</i> (Raciborski) Sulek 1969	+	+
<i>P. boryanum</i> var. <i>longicorne</i> Reinsch 1867	+	+
<i>P. dublex</i> Meyen 1829	+	

(Table 5. 2 continued).

Abant Gölköy

<i>P. integrum</i> Nageli 1849	+	+
<i>P. tetras</i> (Ehrenberg) Ralfs 1844	+	+
<i>Polytoma cylindraceum</i> Pascher 1927	+	+
<i>Quadricoccus verrucosus</i> Fott 1948	+	
<i>Radiococcus planktonicus</i> Lund 1956	+	+
<i>Scenedesmus arcuatus</i> (Lemmermann) Lemmermann 1899	+	+
<i>S. bicaudatus</i> Dedusenko 1925	+	+
<i>S. brevispina</i> (Smith) Chodat 1926		+
<i>S. communis</i> Hegewald 1977	+	+
<i>S. dimorphus</i> (Turpin) Kützing 1833	+	+
<i>S. ellipticus</i> Corda 1835	+	+
<i>S. falcatus</i> Chodat 1894		+
<i>S. obliquus</i> (Turpin) Kützing 1833	+	+
<i>S. opoliensis</i> Richter var. <i>monoensis</i> Chodat 1926		+
<i>S. subspicatus</i> Chodat 1926	+	+
<i>Schroederia robusta</i> Korshikov 1953	+	+
<i>Sorastrum americanum</i> (Bohlin) Schmidle 1900	+	
<i>Sphaerocystis planctonica</i> (Korshikov) Bourrelly 1966	+	+
<i>Tetrachlorella alternans</i> (Smith) Korshikov 1939	+	+
<i>Tetrastrum komarekii</i> Hindak 1977	+	+
<i>Thorakochloris nygardii</i> Komarek 1979	+	
<i>Trochiscia hystrix</i> (Reinsch) Hansg. 1888	+	

(Table 5. 2 continued).

Abant Gököy

Oedogoniales		
<i>Bulbochaete</i> sp.	+	+
Zygnematales		
Zygnemataceae		
<i>Closterium aciculare</i> West 1860	+	+
<i>C. calosporum</i> Wittrock 1869	+	
<i>C. gracile</i> Brebisson ex Ralfs 1848		+
<i>C. incurvum</i> Brebisson 1856	+	
<i>C. littorale</i> F. Gay 1884	+	
<i>C. moniliferum</i> (Bory) Ehrenberg ex Ralfs 1848	+	+
<i>C. parvulum</i> Nageli 1849	+	
<i>C. venus</i> Kützing ex Ralfs 1848	+	
<i>Cosmarium bioculatum</i> Brebisson 1848	+	+
<i>C. botrytis</i> Meneghini 1848	+	+
<i>C. contractum</i> var. <i>ellipsoideum</i> (Elfving) West et West 1902	+	
<i>C. crenatum</i> Ralfs 1848	+	
<i>C. depressum</i> var. <i>planctonicum</i> Reverdin 1919	+	
<i>C. granatum</i> Brebisson 1848	+	+
<i>C. impressulum</i> Elfving 1881		+
<i>C. laeve</i> Rabenhorst 1868		+
<i>C. meneghinii</i> Rabenhorst 1868	+	
<i>C. pygmaeum</i> Archer 1864	+	
<i>C. subcrenatum</i> Hantzsch 1861		+
<i>C. venustum</i> (Brebisson) W. Archer 1861	+	+

(Table 5. 2 continued).

Abant Gölköy

<i>Gonatozygon brebissonii</i> Barry 1858	+	+
<i>G. monotaenium</i> de Bray 1856	+	+
<i>Mougeotia boodlei</i> (West) Collins 1921	+	+
<i>M. capucina</i> (Bory) Agardh 1824	+	+
<i>M. nummuloides</i> (Hassall) De Toni 1889	+	
<i>M. parvula</i> Hassall 1843	+	+
<i>M. quadrangulata</i> Hassall 1843	+	+
<i>M. scalaris</i> Hassall 1842	+	+
<i>Spirogyra communis</i> (Hassall) Kützing 1849	+	+
<i>S. fluviatilis</i> Hilse 1863	+	+
<i>S. dubia</i> Kützing 1855		+
<i>S. jugalis</i> (Dillwyn) Kützing 1845	+	
<i>S. longata</i> (Vaucher) Kützing 1843	+	+
<i>S. majusculas</i> Kützing 1849	+	+
<i>S. mirabilis</i> (Hassall) Kützing 1849	+	+
<i>S. porticalis</i> (Müller) Cleve 1868		+
<i>S. pratensis</i> Transeau 1914	+	+
<i>S. rivularis</i> (Hassall) Rabenhorst 1868	+	+
<i>S. setiformis</i> (Roth) Kützing 1845	+	+
<i>S. subechinata</i> Godward 1956		+
<i>S. submargaritata</i> Godward 1956	+	
<i>S. tenuissima</i> (Hassall) Kützing 1849	+	+
<i>S. weberi</i> Kützing 1843	+	+
<i>Staurastum armigerum</i> fo. <i>furcigerum</i> (Ralfs) Teiling 1957	+	+
<i>S. gracile</i> Ralfs 1848	+	
<i>S. lunatum</i> Ralfs 1848	+	+
<i>Zygnema conspicuum</i> (Hassall) Transeau 1934	+	+

CHAPTER II

ECOLOGY OF PHYTOPLANKTON

Part A

ABSTRACT

PLANKTONIC DIATOM COMPOSITION AND ITS RELATIONSHIP TO PHYSICO-CHEMICAL FACTORS IN LAKE ABANT (BOLU)

Diatom assemblages and their relationship to environmental variables were studied monthly in Lake Abant from June 2003 to June 2005. Physico-chemical variables (e.g., temperature, pH, dissolve oxygen, nitrate, alkalinity), chlorophyll-a, were measured and diatom species were identified. Diatom abundance was increased in fall and spring months. *Asterionella formosa* and a few other species belonging to *Fragilaria* had important contribution in both spring and fall peaks of diatoms composition. Lake water is mixed completely during early months of winter and spring and dimictic characteristic. According to Canonical correspondence analysis (CCA) with forward selection of Monte Carlo permutation test, five environmental variables (temperature, turbidity, conductivity, alkalinity, and silica) showed a significant ($p < 0.01$) influence on the species distribution. Based on their seasonal occurrence, most of the species found closer to the center of CCA diagram have cosmopolitan characteristics. Overall, the first two axes of CCA explained 84.7 % of the relationship between species composition and environmental variables.

Keywords: Diatoms, Ecology, CCA, Phenology, Lake Abant, Bolu

ÖZET

ABANT GÖLÜ (BOLU) PLANKTONİK DİYATOME KOMPOSİZYONU VE FİZİKO-KİMYASAL FAKTÖRLER İLE İLİŞKİSİ

Abant Gölü'nde diyatome topluluğu ve çevresel değişkenler ile ilişkisi aylık olarak Haziran 2003'ten Haziran 2005'e kadar çalışılmıştır. Fiziko-kimyasal değişkenler (örneğin; sıcaklık, pH, çözünmüş oksijen, nitrat, alkalinite), klorofil a ölçülmüş ve diyatome türleri teşhis edilmiştir. Diyatome zenginliği sonbahar ve ilkbahara aylarında artmıştır. *Asterionella formosa* ve *Fragilaria*'ya ait bazı türler ilkbahar özellikle sonbahar diyatome kompozisyon piklerinde önemli katkıya sahiptir. Göl suyu kışın ve ilkbaharın ilk aylarında tamamen karışmış olup dimiktik yapıdadır. İleri seleksiyon yapılan Monte Carlo permütasyon testi ile Canonical correspondence (CCA) analizine göre, türlerin dağılımında beş çevresel değişken (sıcaklık, bulanıklık, konduktivite, alkalinite ve silika) türlerin dağılımında önemli bir etki ($p<0,01$) sahip olduğunu göstermiştir. Mevsimsel oluşumlarına dayanarak CCA diyagramının merkezine yakın bölgede bulunan türlerin çoğu kosmoplitan karakteristiğe sahiptirler. Genel olarak, tür kompozisyonu ile çevresel değişkenler arasındaki ilişkinin % 84,7'sini CCA analizinin ilk iki eksenini açıklamaktadır.

Anahtar Kelimeler: Diyatome; Ekoloji; Fenoloji; Abant Gölü; Bolu; CCA

15 INTRODUCTION

Phytoplankton, especially diatoms is commonly used to understand trophic status of ecological habitats. Different environmental factors such as pH, light, temperature, and chemical component can affect the assemblages of diatom (Patrick and Reimer, 1966; Round, 1981; Stoermer and Smol, 1999). Besides their importance as the primary producers in food webs and ensuring ecological balance, species of phytoplankton can be useful indicators of water quality (Kitner and Poulickova, 2003; Denys, 2004; Rey et al., 2004). For example, although diatoms are widely distributed group most species occur only in habitats with specific physical, chemical, and biological characteristics. Therefore, diatoms are considered as an effective bio-indicators, because they (i) occur in all types of aquatic ecosystems, (ii) show a broad range of tolerance to environmental variables (Round et al., 1990), (iii) have the shortest generation times of all biological indicators (Rott, 1991), they reproduce and respond rapidly to environmental changes, (iv) are sensitive to change in nutrient values (Pan et al., 1996), (v) diatoms include diverse group (high species richness), so considered as ecological information. This situation are important in multivariate analysis, (vi) they are primarily photoautotrophic organisms and directly affected by changes in nutrient and light availability (Dixit et al., 1992), (vii) some members of this group are slowly immigrate, and some others found on substrata are affected changes in physical-chemical variables, and (viii) the taxonomy of diatoms is generally well-documented (Kramer and Lange-Bertalot, 1991 a, b-1999 a, b). In addition to these, diatoms are useful tools for bio-monitoring studies.

There are few studies on their ecology and seasonal occurrences in Turkey, although diatoms are of useful organisms in many ways. Previously, limnological

studies have gained momentum in Turkey in the last decades. Some of the earlier studies, for example, have been carried out in Northern (Gönülol and Obalı, 1998; Şahin, 2003; Maraşlıoğlu et al. 2005), in Western parts (Karacaoğlu et al., 2004; Albay et al., 2003), in Southern parts (Polat and Işık, 2002; Naz and Türkmen, 2005), and Eastern parts of Turkey (Akbay et al., 1999).

Comparing to the studies on different taxonomic groups of aquatic organisms (e.g., ostracods (Külköylüoğlu, 2003, 2004, and 2005), relatively few studies on phytoplankton are found in the Bolu region, (Obalı et al., 2002; Kılınç 2003; Çelekli and Külköylüoğlu, 2006). All these studies increased our understanding on the species diversity of the area, but little attention has been given to phytoplankton, especially diatoms in water bodies of Bolu. Therefore, the aim of this study was to determine the relationships among diatom composition, their seasonal occurrence, and environmental factors in Lake Abant (Bolu), and contribute to the knowledge of algal flora of Turkey.

16 RESULTS AND DISCUSSION

16.1 Physical and chemical variables

During the study period, Lake Abant showed a dimictic characteristic. The variation of water temperature from each meter of vertical stations in Lake Abant indicated an overturn period monthly during each year. Values of two vertical measurements for each meter were superimposed in Figure 6. 1. Accordingly, thermal stratification was observed in the both of vertical stations from June 2003 to November 2003 and again occurrence of stratification from June 2004 to November 2004 (Figure 6. 1). That is, the occurrence of thermal stratification begun in late spring, became stable during summer, and toward to homogenization in late fall season (Figure 6. 1). Complete homogenization in this lake water took place from November to May for both years. The highest water temperature recorded at lake surface was 20.9 °C in August 2004. Depth of epilimnion layer was about 9 m in 2003, while it was 11 m in the second year (Figure 6. 1). This difference may have possibly caused by different sampling time and air temperature, as well.

Depth of epilimnion layer was about 9 m in 2003, while in second year, was to be 11 m (Figure 6. 1). This difference is likelihood affected by different sampling time and air temperature. Overall, results show that this lake water was mixed and thermal stratification about same date in Figure 6. 1. Lake Gököy showed a water homogenization (see Figure 7. 1), however mixed water continued longer time comparing in Lake Abant. These water circulations in spring and fall seasons were found in Lake Garda (Salmaso, 2002), in Lake Como (Buzzi, 2002).

Mean values of dissolved oxygen (DO) from both vertical sites showed a variation in Lake Abant during present study. Both the highest DO (14.67 mg/l) at surface of vertical station 1 and monthly mean DO (12.85 mg/l) concentrations were recorded in May 2005. On the other hand, the lowest DO and mean level were measured as 5.52 mg/l in August 2003 and total mean DO concentration was recorded as 8.57 mg/l (Table 6. 1). About same DO value (8.84 mg/l) was recorded in a shallow polymictic Lake Rodo in Uruguay (Kruk et al., 2002), however this lake had a broader range of DO comparing in Lake Abant. In this month, high DO level was supported by high abundance of phytoplankton with high nutrient, light intensity, and temperature. At the lake surface, photosynthesis rate was increased as high level with suitable condition. High Nutrient from releasing sediments of lake due to mixing water column that supported increasing in abundance of phytoplankton. Low DO concentrations recorded in hypolimnion during occurrence of thermal stratification. About anoxic conditions (<1 mg/l) were found at bottom of lake during summer and fall seasons for both years. When mean value was taken monthly, slight anoxic conditions (<2 mg/l) were detected in the bottom in summer and fall seasons (Figure 6. 2). DO levels were uniformly distributed from top to bottom of this lake, when thermal homogenization completed during late fall, early winter (Figure 6. 2).

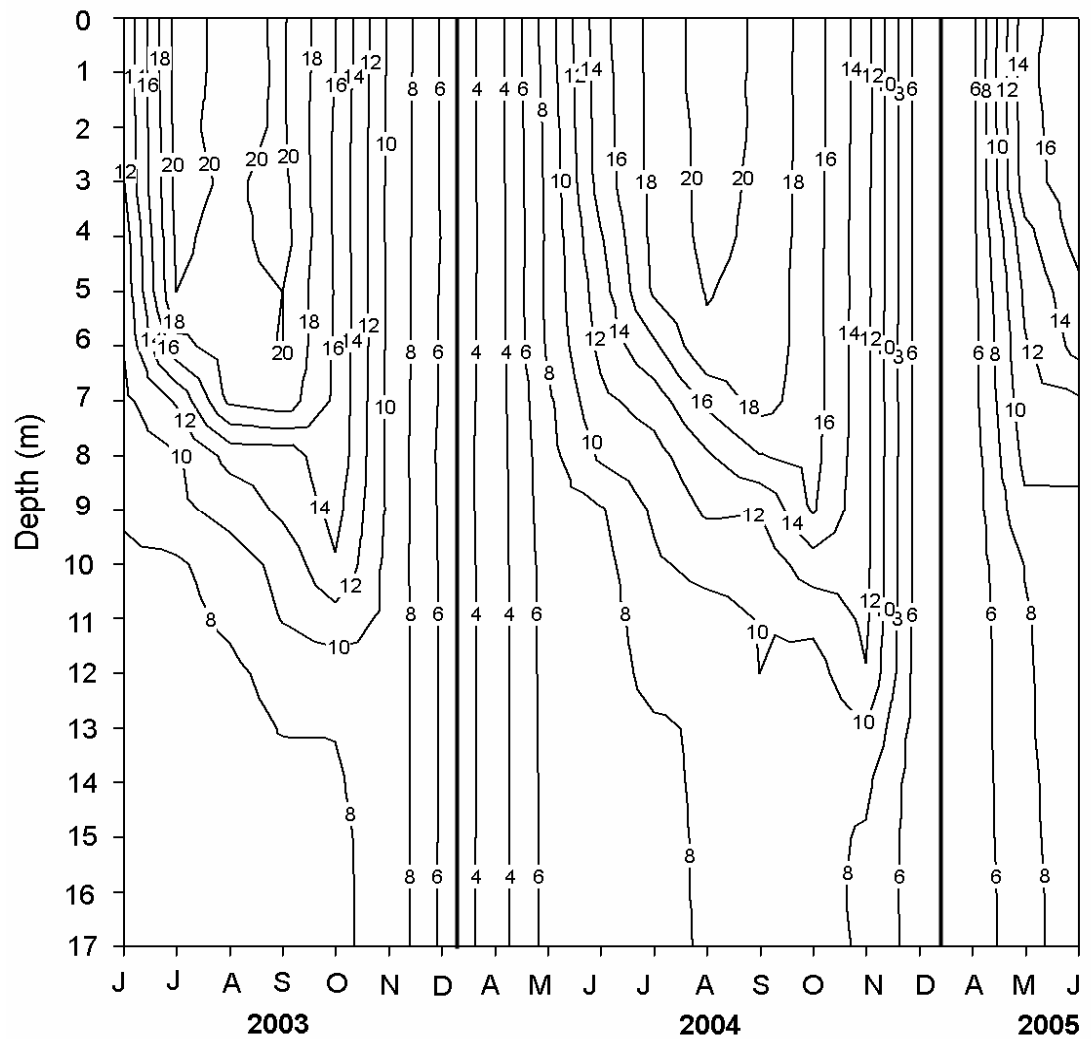


Figure 6. 1. Isopleths of temperature monthly with superimposed seasonal variation of vertical station at Lake Abant. Abbreviations indicate the code of each month (e.g., June (J) and August (A), respectively for each year). Vertical data were not included from January to February for both years due to ice cover.

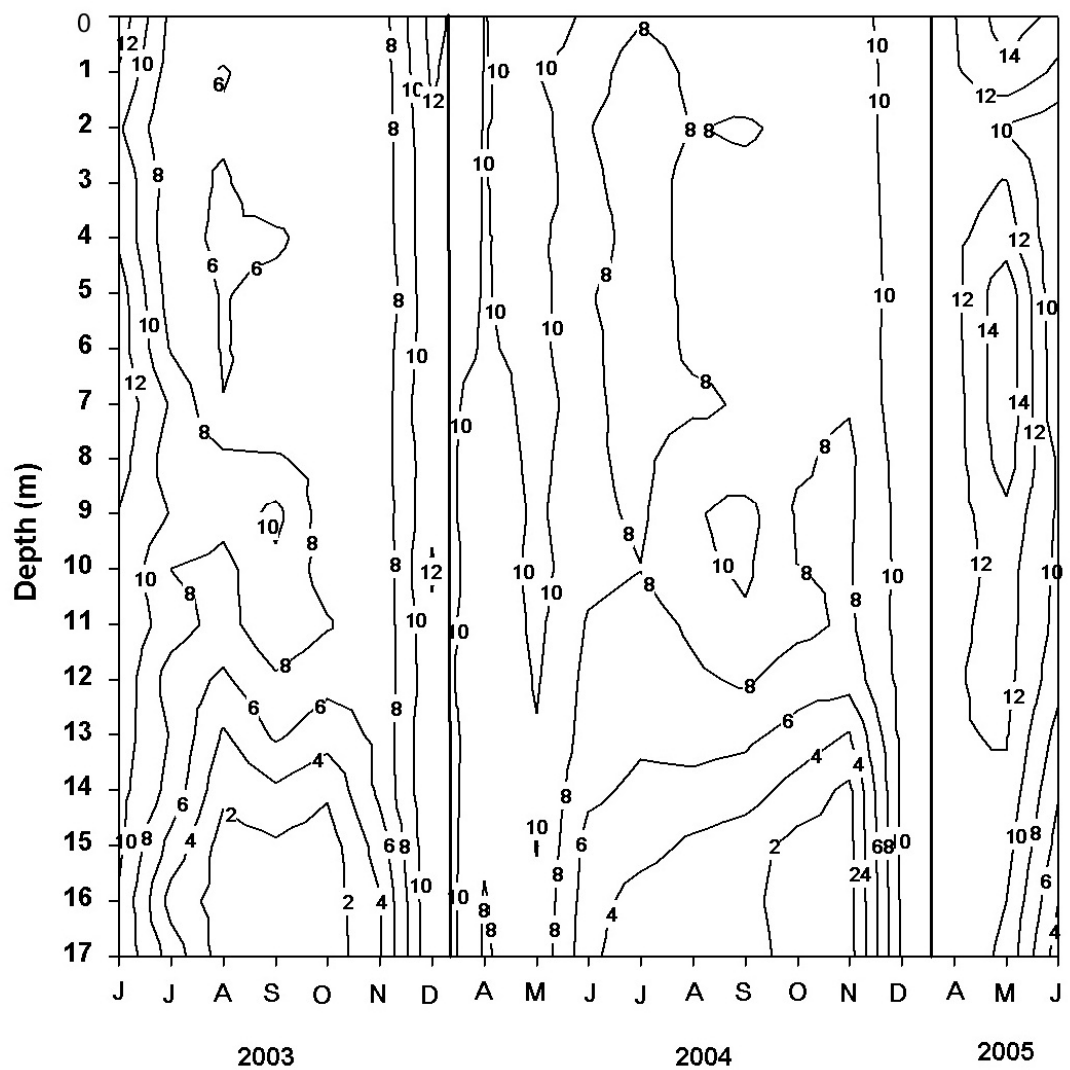


Figure 6. 2. Isopleths of dissolved oxygen (DO) monthly with superimposed seasonal variation of vertical station at Lake Abant. Abbreviations indicate in Figure 6. 1. Vertical data were not included from January to February for both years due to ice cover.

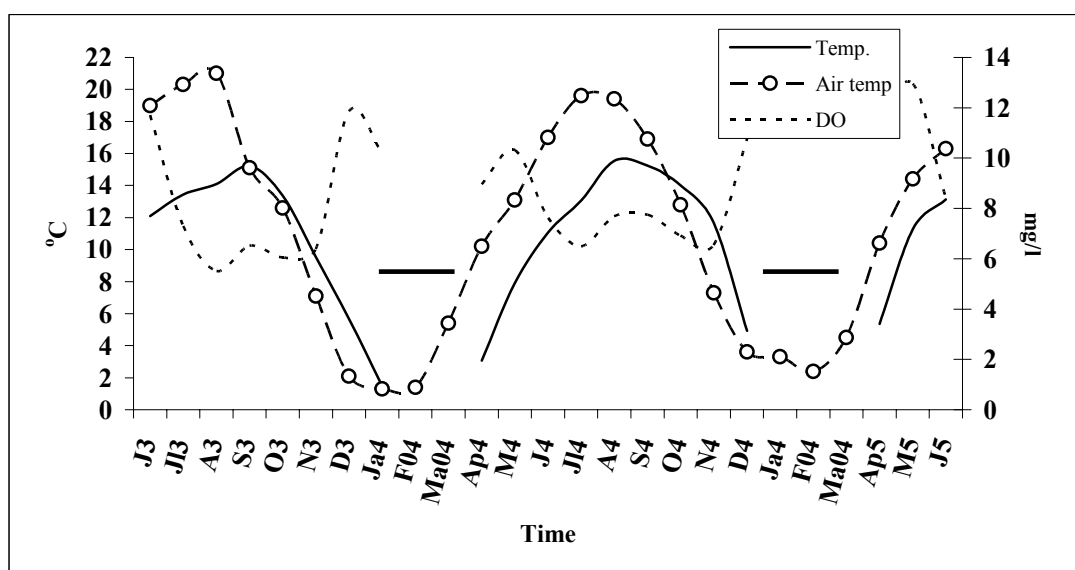


Figure 6. 3. Temporal variation of dissolved oxygen (DO), water and air temperature. Mean value of variables monthly from each sampling stations are taken. (—) shows ice cover. Abbreviations are given in Figure 6. 1 and Table 6. 2. Only littoral sampling was done in January 2004.

Temporal variation of DO, water and air temperatures are given in Figure 6. 4. Air temperature was varied from 1.3°C in January 2004 to 20.3°C in July 2003 when minimum (1.47°C) and maximum (15.54°C) water temperature values were found in January 2004 and August 2004, respectively. Indeed, Spearman correlation displayed a significant ($p < 0.001$) relationship between water and air temperatures. In the meantime, as expected, there was a negative correlation ($p < 0.05$) between dissolved oxygen and water temperature (Table 2). Consequences of such relationship possible caused by a low ratio of high photosynthetic rate and respiration rate. In fact that, first small peak was showed during fall 2003, when abundance of diatom composition was high (Figure 6. 4). Similarly, DO concentration and water temperature were increased in October 2004 when a sharp increase was observed in diatom composition along with the other photosynthetic organisms (e.g., non-diatom phytoplankton, macrophytes, and aquatic plants). Table 6. 2 shows the mean values

of environmental variables calculated and superimposed for each month. As seen from the table, physico-chemical variables were varied from littoral to vertical sampling stations along study time.

Lake Abant has circumneutral or slightly basic water (Table 6. 2) because of changes in pH. For example, mean pH values were recorded as 7.22 in November 2004 and 8.24 in July 2003. This is an expected reason of increasing photosynthesis rate with high nutrient concentration, temperature and light intensity. The lowest pH level (7.1) recorded in the anoxic water layer near the lake sediment still shows alkaline characteristic of the water.

With regard to nutrient concentrations, nitrite ($\text{NO}_2\text{-N}$) and ammonium ($\text{NH}_4\text{-N}$) measurements showed high values in fall season. The highest nitrite concentration (0.139 mg/l) was detected at littoral station 1 (L-1) in November 2004, when its average was also the highest (0.052 mg/l) in October 2004. Nitrite level was usually decreased at the lake surface, while its high concentration was recorded at the bottom of Lake Abant near the sediment with anoxic condition. At the lake surface, most of nitrite values changed to nitrate due to high DO level.

Nitrate ($\text{NO}_3\text{-N}$) value was ranged from 0.202 mg/l in August 2004 to 0.047 mg/l in October 2004. Mean value of nitrate was found as 0.080 mg/l in result of study. Similar value was already recorded in Piburger See (Austria), which is meromictic lake and situated at 913 m a.s.l (Tolotti and Thies, 2002). High nitrate concentration from Piburger See was recorded in late winter. However, in the present study, high value of nitrate was detected in late summer and not measured in late winter due to ice cover. In late summer, natural and unnatural nutrient input might be affective. During thermal stratification, high nitrate concentration was usually detected at the lake surface, while low level was measured at bottom part of Lake Abant with anoxic

condition. This can be explained as consequence of increasing microbial reduction processes which decreased $\text{NO}_3\text{-N}$ value in near the sediment part. Conversely, nitrite was recorded high level.

Average of silica (Si) concentration was ranged from 0.218 mg/l in June 2004 to 0.105 mg/l in August 2004. Similarly, Salmaso (2002) measured Si value in relatively deep and large Lake Garda (Italy). This nutrient showed clearly a decrease during stable thermal layer in summer months (Figure 6. 1). The intense assimilation of centric diatoms at epilimnion layer can affect the depletion of Si in summer season. Result of Pigurger See (Tolotti and Thies, 2002) supported research in Lake Abant. High values of silica were usually recorded at the bottom of lake near the sediment during thermal stratification, while it decreased at epilimnion layer during thermal stratification. It is possibly due to the affect of sinking of non-living diatom and accumulation of Si with degradation processes of diatom. Depletion of silica at epilimnion layer in summer season can be a consequence of intense assimilation by centric diatoms. Depth of epilimnion layer increased towards to the bottom parts, when air temperature was decreased during fall season. Silica level was increased in fall and spring seasons with mixing lake water.

Mean phosphate (PO_4) concentration fluctuated between 0,006 and 0,017 mg/l in August 2004 and April and June 2005, respectively, and especially increased in spring season months. During thermal stratification (Figure 6. 1) in summer season, low phosphate values were found at epilimnion layer. In this layer, high assimilation rate of flagellated phytoplankton can probably affect on depletion of phosphate with suitable luminance and water temperature. Indeed, during this study, high phosphate concentrations in deep water were likely consequence of decomposition processes with non-living organisms sinking to sedimentation. However, the maximum

phosphate level was recorded as 0.024 mg/l at 10 m of vertical 1 sampling station in June 2004. Its situation can be affected by water wave and at this depth, low assimilation rate due to low light intensity.

Mean electrical conductivity (EC) values fluctuated from 208.23, to 205.49 $\mu\text{S cm}^{-1}$ in November, and December 2004, respectively to 243.96 $\mu\text{S cm}^{-1}$ in July 2003 during research months. Mean low levels of conductivity were usually recorded late-summer, fall, and winter seasons, while its high concentrations were detected in spring season during the present study. Rainfall, air temperature, and nutrient input are possible factors for conductivity variations. The higher conductivity values recorded in deeper parts of the lake during stratification periods are probably due to ion release from sediments.

Redox potential (Eh) value fluctuated monthly from 194 mV in June 2005 to 149.1 mV in July 2003. Eh value was decreased in summer and increased in spring season. During research, high Eh levels were measured while EC were recorded low values. Eh is found by measuring amount of oxidizing and reducing materials. So, this factor especially related with pH, DO, and nutrient concentrations. This relationship between Eh and pH is clearly showed in Eh-pH diagram (O'Neil, 1993). Indeed, significant correlations were recorded among these variables by using Spearman correlation (Table 6. 2).

Biological oxygen demand (BOD_5) levels were usually increased in spring and early summer seasons and decreased again in the following summer season. With melting snow and increasing water temperature, not only photosynthesis rate is increased with suitable conditions, but also, grazing and decomposition rate is highly increased due to high decomposer-preys, and suitable temperature (Hinder et al., 1999).

Table 6. 1. The mean, minimum and maximum values of physico-chemical variables measured combined from all stations (n = 780 bits of data) in Lake Abant.

		Min.	Max.	Mean
Temperature water	°C	1.47	15.54	10.43
Temperature air	°C	1.3	20.3	11.06
Annual Precipitation	mm	1.6	96	45.54
Dissolved Oxygen	mg/l	5.52	12.95	8.57
Saturation	%	55.68	120.04	77.05
Conductivity	$\mu\text{S cm}^{-1}$	205.49	243.96	219.41
Redox potential	mV	149.1	194.0	173.9
pH		7.22	8.24	7.76
Turbidity	NTU	0.19	13.90	3.67
Chlorophyll-a	$\mu\text{g/l}$	1.05	4.65	2.77
Secchi Depth	m	2.65	6.74	4.85
BOD	mg/l	2.5	8.8	4.9
Nitrite	mg/l	0.001	0.052	0.017
Nitrate	mg/l	0.047	0.202	0.080
Phosphate	mg/l	0.006	0.017	0.013
Ammonium	mg/l	0.061	0.326	0.155
Silica	mg/l	0.105	0.218	0.186
Alkalinity	mg/l	0.080	3.350	1.611
Sulfate	mg/l	2.39	79.36	18.75
Chloride	mg/l	1.25	33.86	10.24
Calcium	mg/l	32.68	67.83	51.17
Magnesium	mg/l	12.470	57.600	26.440
Salinity	ppt	0.1	0.1	0.1

The lowest Secchi depth (2.7 m) was recorded in June 2004, while the highest transparency was observed in August 2004 with 6.74 m. In spring season, phytoplankton composition especially diatom assemblages showed an important increase along with high nutrient concentrations. As mentioned above, maximum phosphate concentration was measured in spring season, where factors such as a complete water homogenization, high diatom abundance, and soil erosion might have caused an increase of water turbidity (Hinder et al., 1999). Eventually, such factors can affect the water transparency. Secchi depth was increased in summer season during thermal stratification.

All physico-chemical variables in sampling stations for each month were tested by one-way ANOVA. Among the stations sampled monthly, there was no significant difference ($p>0.05$) the physico-chemical variables in sampling stations during study period. This result may give that lake water was distributed as about homogeny for each sampling month.

Results of the correlations among some of the selected variables are given in Table 6. 2. Redox potential is positively correlated to ammonium ($p<0.01$) and DO ($p<0.005$), while it was negatively correlated to pH ($p<0.01$) and calcium ($p<0.05$). Similar result was found in CCA ordination diagram (Figure 6 6). It is known that a negative relationship between Eh and pH is present in aquatic ecosystems and this relationship clearly shows in Eh-pH diagram (O'Neill, 1993). Temperature was negatively related to DO ($p<0.05$), but this correlation was positive with Secchi Depth ($p<0.01$). Secchi depth was increased in summer season due to thermal stratification. Flagellated organisms cause depletion of nutrient and a clear layer occurred in epilimnion layer. Number of diatom taxa is positively correlated to both magnesium ($p<0.01$) and turbidity ($p<0.05$), while it was negatively correlated to

electrical conductivity (EC) ($p < 0.05$). Both abundance and species richness of diatom was decreased especially at epilimnion layer in summer season, when stable thermal stratification occurred with high transparency. Similarly, diatom composition was increased in fall season with high nutrient concentration and turbidity level. Alkalinity is correlated with pH ($p < 0.05$), and some chemical variables such as Ca ($p < 0.01$), Cl ($p < 0.01$), and SO_4 ($p < 0.05$), while it was negatively correlated to SD, NO_2 , and Mg^{2+} at $p < 0.05$ level. Alkalinity is consisting of OH^- , CO_3^{2-} , and HCO_3^- . Therefore, these chemicals reflect pH level and other chemicals, as well. Not only these chemicals affected by pH values, but also NH_4 was negatively correlated ($p < 0.05$) with pH (Table 6. 2). Therefore, physical-chemical variables not only influence organisms' composition, but also affected their geochemical cycles.

Table 6. 2. Correlation matrix for monthly averages of environmental variables and number of diatom species (Spp) from Lake Abant. Abbreviations showed as; Temp, temperature; DO, dissolved oxygen; Eh, redox potential, EC, conductivity; Chlo, chlorophyll a; BOD, biological oxygen demand; Turbi, turbidity; SD, Secchi depth; PO₄, phosphate, NO₂, nitrite; NO₃, nitrate; NH₄, ammonium; SO₄, sulphate; Ca, calcium; Mg, magnesium; Cl, chloride; Alkali, alkalinity; Si, silica; Spp, number of species. * Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

	Temp	DO	pH	Eh	EC	Chlo	BOD	Turbi	SD	PO ₄	NO ₂	NO ₃	NH ₄	SO ₄	Ca	Mg	Cl	Alkali	Si	Spp
Temp	1.00																			
DO	-.559*	1.00																		
pH	.296	-.457*	1.00																	
Eh	-.332	.496*	-.958**	1.00																
EC	.084	.126	.032	.024	1.00															
Chlo	-.287	.352	-.018	-.059	.257	1.00														
BOD	-.383	.865**	-.317	.368	.135	.296	1.00													
Turbi	-.232	.068	-.355	.359	-.242	-.047	.092	1.00												
SD	.674**	-.384	.330	-.405	-.374	-.396	-.246	-.168	1.00											
PO₄	-.071	.024	-.382	.356	.065	-.015	.026	.206	-.171	1.00										
NO₂	.297	-.356	-.147	.006	-.347	-.194	-.129	.432	.243	.532*	1.00									
NO₃	.140	-.420	.378	-.427	-.259	-.091	-.755**	-.434	.056	-.168	-.133	1.00								
NH₄	.432	-.043	-.639*	.650**	.118	-.375	.196	.389	.341	.336	.514*	-.643*	1.00							
SO₄	.121	-.305	.253	-.165	.420	-.213	-.178	-.073	-.445	-.068	.240	.210	-.033	1.00						
Ca	.064	-.178	.840**	-.705*	.199	-.075	-.267	-.498	-.306	-.434	-.235	.541	-.680*	.847**	1.00					
Mg	.250	-.571	.250	-.679	-.679	-.321	-.929**	.500	.786*	-.107	.536	.786*	-.321	-.036	.099	1.00				
Cl	-.090	-.292	.323	-.380	.134	.191	-.301	.042	-.555*	-.182	-.099	.497	-.415	.582*	.740**	.179	1.00			
Alkali	-.175	-.068	.519*	-.366	.303	.139	-.184	-.292	-.533*	-.423	-.524*	.381	-.512	.578*	.815**	-.453	.793**	1.00		
Si	-.333	-.127	-.152	.200	.224	.576	.152	.115	-.564	.333	.139	-.309	.103	.430	.113	-.643	.358	.300	1.00	
Spp	-.044	.192	-.158	.187	-.453*	.055	.090	.499*	-.058	.084	.339	.546	-.175	-.132	.141	.929**	.081	-.114	-.620	1.00

16.2 Diatom density of Lake Abant

Thirty-four diatom taxa belonging to 19 genera were recorded in Lake Abant. Abundance of genera fluctuated from 4.9 cell/ml to 18657.9 cell/ml. The lowest percentage of genera composition was *Surirella* with 0.01 %, while *Fragilaria* was the most abundant genus with 46.39 % (Table 6. 3). The most abundant was *Asterionella formosa*, which was the most common diatom with 11754.2 total cell/ml in Lake Abant during spring season (especially in April 2004 and 2005) has been reported as dominant species in mesotrophic lakes even in eutrophic lakes (Nygaard, 1949; Round, 1981). As Horne and Goldman (1994) and Wetzel (1975) reported that *Asterionella* is common diatom in spring bloom of temperate lakes through out the world. The members of *Fragilaria* showed high abundance in spring and fall seasons, while high abundances of *Cyclotella* were recorded during summer seasons and decreased in fall season. Additionally, *A. formosa*, *Fragilaria capucina*, and *F. crotonensis* were also counted for almost each month in all stations. Horne and Goldman (1994) reported that *A. formosa* and *Fragilaria* are holoplankton algae that are always present in plankton. On the other hand, *Aulacoseria* which was usually counted in fall seasons, are meroplankton diatom that are found in plankton due to their life cycle in dormant form in lake sediments (Horne and Goldman, 1994). Similarly, Hutchinson (1967) stated that in productive lakes, *Melosira* can be abundant species in winter, and following *Asterionella*, reached to a high level during spring season. *A. formosa* showed high abundance in spring season, when nutrient concentrations were high levels. Earlier studies supported this result. Çelekli and Külköylüoğlu (2006) stated that *A. formosa* was dominant from April to May 2004 when phosphate concentrations were also maximized in a karstic spring called Akkaya Spring (Bolu). Similar results are found in three Dinaric karstic lakes

(Jasprica and Hafner 2005), in Lake Solumsjö of Sweden (Danilov and Ekelund, 2001).

Table 6. 3. Abundance of diatom genera in Lake Abant during 20 months.

Genera	Total %
<i>Fragilaria</i>	46.39
<i>Asterionella</i>	29.22
<i>Cyclotella</i>	19.75
<i>Cymbella</i>	0.89
<i>Gomphonema</i>	0.86
<i>Meridion</i>	0.50
<i>Navicula</i>	0.45
<i>Aulacoseria</i>	0.43
<i>Epithemia</i>	0.43
<i>Amphora</i>	0.17
<i>Nitzschia</i>	0.08
<i>Cocconeis</i>	0.61
<i>Achnanthes</i>	0.06
<i>Diatoma</i>	0.06
<i>Pinnularia</i>	0.05
<i>Diploneis</i>	0.02
<i>Gyrosigma</i>	0.02
<i>Hantzshia</i>	0.01
<i>Surirella</i>	0.01

This species is not only commonly distributed in European lakes (John et al., 2002), but also generally found in almost all types of water bodies such as lakes,

marshes, and ponds in Turkey (Çetin and Şen, 2004; Gönülol and Obalı, 1998; Obalı et al., 2002; Akbulut, 2003).

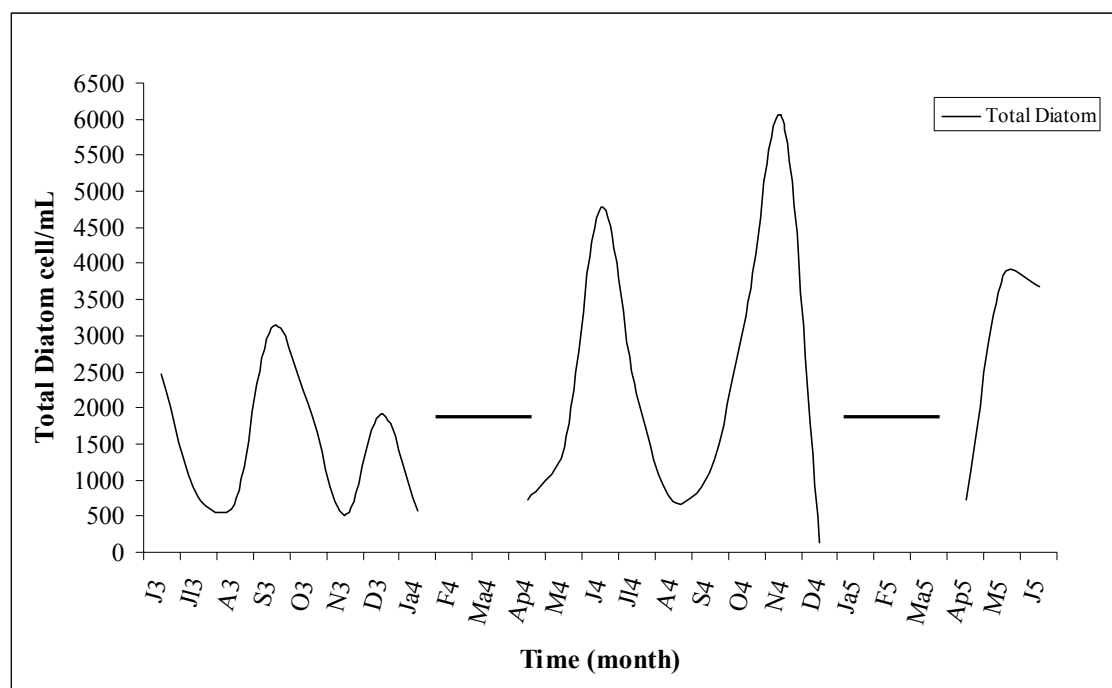


Figure 6. 4. Total abundance of diatom composition in Lake Abant during two years. Abbreviations indicate the code of each month (e.g., June 2003 (J03) and July 2004 (Jl04) etc.). (—) ice cover.

Total numbers of diatom individuals were increased especially in fall, late spring and early summer months. Diatom abundance showed seasonal variations and caused five peaks in fall and spring seasons (Figure 6. 4). The maximum diatom density (6003 cell/ml) was recorded in November 2004, while the lowest abundance (124 cell/ml) was recorded in December 2004 (Figure 6. 4). In the first and second peaks of Figure 6. 4, 3095.9 and 1926.4 cell/ml was counted that most of them belonging to *Asterionella. formosa* as 2457 and 1679 cell/ml in September and December 2003, respectively. *Fragilaria* was the most abundance genus in third and fourth peaks during spring and fall 2004, however *A. formosa* was usually dominant species in spring peak population due to its luxury consumption for major growth-limiting

nutrients (especially phosphorus) and potential competition over other diatoms such as *Fragilaria*, *Asterionella* can reduce low level phosphate concentrations in lakes (Horne and Goldman, 1994). However, in fall season *Fragilaria crotonensis* was common diatom and had great contribution to fallal total diatom peak (Figure 6. 4). The most abundant species such as *Asterionella formosa*, *F. crotonensis*, and *Cyclotella praefermissa* apparently had great contribution to these peaks. Abundance of *Cyclotella* increased in summer season 2004 and late spring 2005. Previous studies such as Buzzi (2002) in Lake Como, in Akkaya Spring stated that *A. formosa* has resulting of water column stabilization and exhaustion of silica are important factors for decline of total diatom number, especially large diatom taxa. It is known that many diatoms have advantages in competing for nutrients at lower temperature, and conversely they are less abundant in warm water (Hutchinson, 1967; Horne and Goldman, 1994; Graham and Wilcox, 2000).

16.3 Net-Diatom Composition of Lake Abant

A total of 123 diatom taxa from Lake Abant belonging to 33 net-phytoplankton genera were identified from June 2003 to June 2005. These genera are belonging to four genera of Centrales, and 29 genera of the order Pennales, respectively. Naviculaceae is the most species richness in diatom composition of the lake with 45 % of abundance, including 55 taxa in 12 genera. Gönülol and colleagues (1996) studied a check-list of the freshwater of Turkey based on literature. They reported that a total of 601 diatoms taxa were recorded from different aquatic habitats in Turkey. So, diatom composition of Lake Abant included about 20.5 % of total diatom species in Turkey. Indeed, this ratio may be decreased, because some studies have been carried out and have contribution to increase diatom composition of Turkey since 1996.

In the present study, *Fragilaria*, *Cymbella*, *Gomphonema*, *Pinnularia*, and *Navicula* had high species number with 15, 14, 10, 9, and 7 taxa, respectively. Some species including *Asterionella formosa*, *Cyclotella leptoceros*, *Cymbella cistula*, *Fragilaria biceps*, *F. dilata*, *Navicula radiosa*, and *Rhopalodia gibba* were recorded in almost each month from each station. These diatoms are already known to be commonly distributed in different part of Turkey. However, some species such as *C. praetermissa*, *Stephanodiscus alpinus*, *Tetracyclus rupestris*, *Navicula gastrum*, and *Cymatopleura solea* var. *apiculata* found in Lake Abant were rarely distributed in aquatic ecosystem of Turkey (Gönülol et al., 1996).

16.4 Effect of environmental factors on distribution of diatom composition

Diatom composition was apparently affected by environmental variables during this work. The linear or no-linear (unimodal) response models of diatom to environmental axes can be examined before performing CCA (ter Braak, 1988). DCA ordination was used to show good dispersion of diatom species on the axes. DCA result provides the gradient length for species data. The unimodal response of diatom taxa to environmental variables is found with gradient length as 3.176. After that CCA analysis was used to explain relationship between diatom abundance and environmental variables during study time. In this analysis, 123 net-diatom taxa and 18 physico-chemical variables were applied to CCA analysis. Total of 18 environmental variables selected were tested by Monte Carlo permutation test (499 unrestricted permutations) after unimodal response of the results of CCA with 123 species and selected 11 environmental variables are shown in Figure 6. 5.

Canonical correspondence analysis (CCA) ordination shows 123 diatom taxa (2%) and forward selected environmental variables (arrows) during 20 months (triangular). Sampling size (N) is 220. Species codes (numbers) are shown in Appendix A.

The forward selection with Monte Carlo permutation test (499 unrestricted permutations) showed that both axes were highly significant ($p=0.002$). In CCA ordination, axis 1 ($\lambda_1=0.109$) and axis 2 ($\lambda_2=0.087$) with their ratio 1.3 explained 4.3 % of cumulative variance in species data (Table 6. 4).

Table 6. 4. Main results of canonical correspondence analysis (CCA) with using Monte Carlo permutation test for 123 diatom species.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.109	0.087	0.082	0.061	4.591
Species-environment correlations	0.846	0.757	0.786	0.682	
Cumulative percentage variance					
of species data	2.4	4.3	6.1	7.4	
of species-environment relation	20.8	37.6	53.3	65.0	
Sum of all eigenvalues					4.591
Sum of all canonical eigenvalues					0.522
P-value = 0.0020	F-ratio = 2.334				

The relationship between diatom composition and environmental factors were high as 0.846 and 0.757 for axis 1 and 2, respectively (Table 6. 4). Earlier studies were reported that high relationship were found between diatom community and environmental variables as 0.89 for axis 1 in many lakes of Tasmanian (Vyverman et al., 1996), 0.96 for axis 1 in Spanish salt lakes (Reed, 1998), 0.95 for axis 1 in 18 sites of lowland river in Portugal (de Almeida and Gil, 2001), and 0.96 for axis one in 49 lakes and Yangtze River in China (Yang et al., 2005). These results pointed that diatom composition can directly be reflected with the environmental factors.

Therefore, diatom taxa can be used to understand about water quality. Temperature, turbidity, EC, and silica concentration are the most significant ($p < 0.01$) factors on distributions and occurrences of diatom composition. The significant level of temperature and turbidity on distribution of diatom composition was explained as 95 % and 88 % respectively.

Table 6. 5. Results of CCA show the critical values of both F and p. Total of 220 bits of data is used in this analysis.

Environtal Variables	Explained %	p	F
Temperature	95	0.002	5.273
Turbidity	88	0.002	3,866
EC	81	0.002	3,336
Silica	72	0.002	3.276
Alkalinity	68	0.002	3.065
NH ₄	48	0.004	1.948

In CCA ordination, arrow of temperature is closely related summer month such as July 2003, 2004 and August 2003, 2004 (the highest temperature), while dissolved oxygen is found opposite to temperature in cold months such as November, December 2003 and January 2004 (the lowest temperature recorded). This negative relationship is already given in Table 6. 3 with Spearman correlation. Similarly, arrows of pH and alkalinity are lied in the opposite side with arrows of Eh, while a close relationship is presented between NH₄ and Eh (Figure 6. 5). Nutrients, which were abundantly found in fall and spring seasons were also related to the abundance of diatom composition as shown (Figure 6. 5). Nutrient concentration was increased in spring and fall seasons. For example, high levels of silica factor can affect diatom abundance in spring and fall. It is known that diatom frustules consist of silica

(Horne and Goldman, 1994). Arrow of chlorophyll-a is closer to pH factor. It is explained a consequence of increasing photosynthesis rate with high chlorophyll levels and can change pH values in Lake Abant.

In CCA ordination, arrows of temperature, electrical conductivity (EC), chlorophyll-a, and pH were closely related summer month for both years, while turbidity, Eh, DO, and nutrients were related fall and spring months. CCA analyses suggested that the majority of diatom species have substantial tolerance to different environmental variables. Indeed, most of them were emerged close to the center of the CCA diagram. This is probably due to the cosmopolitan characteristics of these species which are known to tolerate large ranges of fluctuations in different water bodies. Indeed, holoplankton diatoms such as *Asterionella formosa*, *Fragilaria biceps*, *F. capucina*, *F. dilata*, *C. leptoceros*, *N. radiosa*, *R. gibba*, which were commonly distributed about each sampling month, were found closer to CCA ordination. Among which, *A. formosa* was closely related phosphate and ammonium concentrations in fall season and especially in April 2005 (Figure 6. 5). Similar result was also documented in a karstic spring (Akkaya spring) by Çelekli and Külköylüoğlu (2006).

Cyclotella meneghinia which was recorded especially in fall months such as November and December 2003 with high nutrient levels, was found closer especially arrow of DO and phosphate in November 2003 on CCA ordination. In this month, high nutrient values, DO turbidity, pH and low Secchi depth were recorded in Lake Abant. This species is mainly found in eutrophic and hyper-eutrophic lakes (Yang et al., 2005).

Aulacoseria granulata was usually recorded in fall season month of 2003 and 2004. In CCA ordination, this species was found closely related fall season's of all months

of the year 2004. As explained in physical and chemical part, the maximum values of most nutrients were measured in this season. Horne and Goldmann (1994) stated that a meroplankton genus *Aulacoseria* (old name called *Melosira*) is most abundant from October to early spring, sinking to sediment of lakes during thermal stratification, and survive under anoxic condition for two years. *Aulacoseria granulata* was distributed in eutrophic water type (Hutchinson 1967; Wetzel 1975; Round 1981). Yang and colleagues (2005) pointed out that *A. granulata* was dominant species in mesotrophic and meso-eutrophic situations and accompanied by *Gyrosigma acuminatum*. However, *G. acuminatum* was located closer to September-October months of the year 2003 around the center of CCA ordination diagram. In fall 2003, most physical and chemical variables except pH values were about similar in fall 2004. High value of pH was recorded in fall season of 2003. Considering that this species was found closer to arrow of pH may imply its relationship to the changes in pH values .

A few species of *Gomphonema* (e.g., *G. olivaceum*, *G. clavatum*) were found closer to the arrows of alkalinity, pH and chlorophyll-a and species of *Cymbella minuta*, and *C. schimanskii* in fall season 2003, while *G. subtile*, *G. parvulum* with *Cymbella proxima* and *C. lanceolata* were near the calcium and silica arrows in fall 2004 (Figure 6. 5). Potapova and Charles (2003) reported that species of both genera are alkaliphilous and calciphilous species. However, members of *Gomphonema* and *Cymbella* in Lake Abant are not same taxa in US river.

Eunotia bilunaris was usually reported in 2004. This species was related low pH level in rivers (Potapova and Charles 2003). However, in Lake Abant, this taxon was not opposite of pH arrow. Considered three dimensions of CCA ordination, this species may be found distant from pH arrow.

A few species of *Navicula* such as *N. radiosa*, *N. trivialis* were found near the center of CCA. These species are commonly distributed in different aquatic habitats of Turkey (Gönülol et al., 1996). *Navicula cryptocephala*, which was occasionally found in sampling stations during early fall months, was closely placed near the ammonium, phosphate and turbidity arrows in fall and early winter seasons, especially December 2004 in CCA (Figure 6. 5). This species was not recorded in earlier study (Obalı et al., 2002) in Lake Abant.

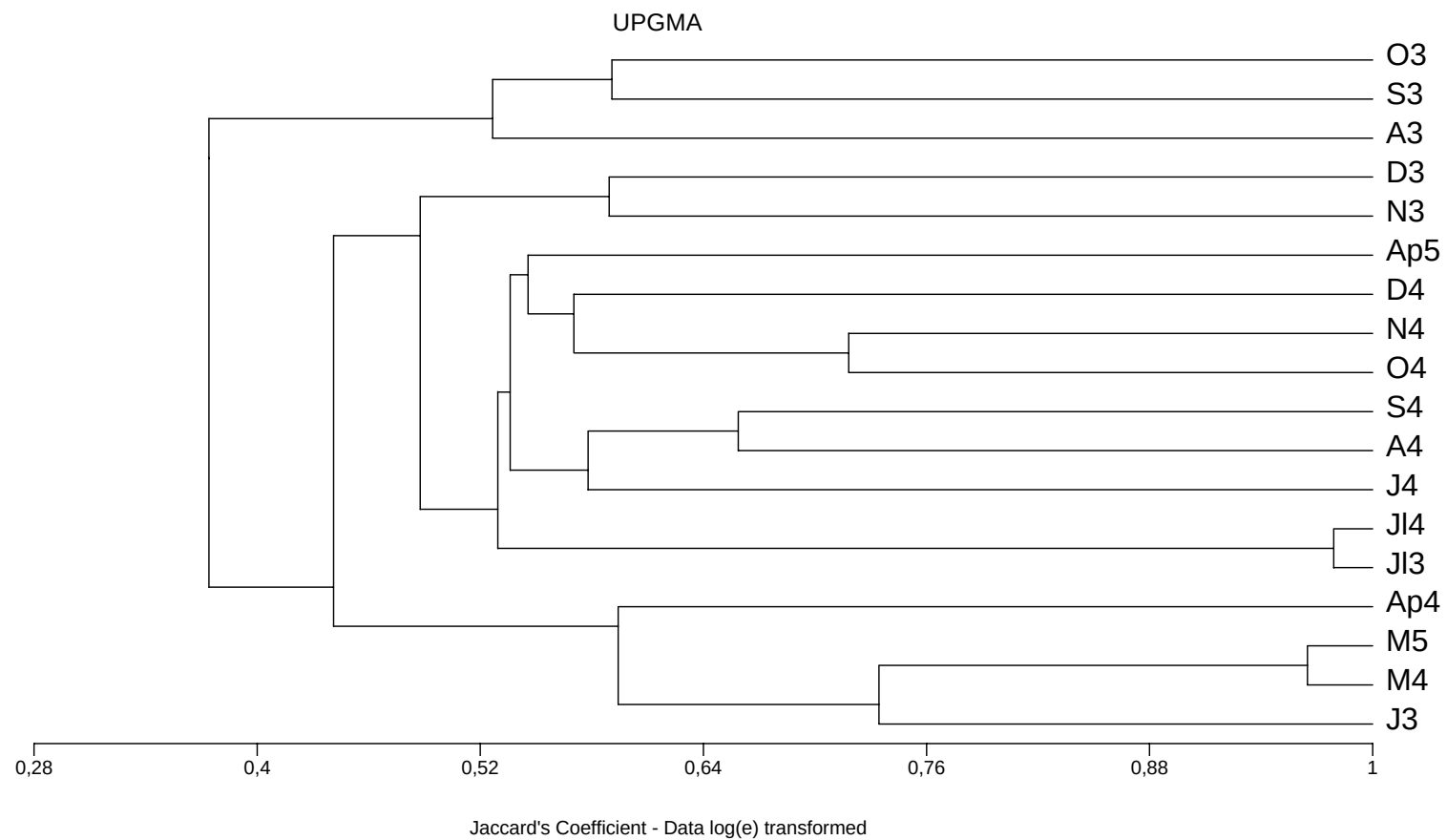


Figure 6. 6. UPGMA dendrogram shows sampling monhts. Abbreviation is given in Figure 6. 4.

In Lake Abant, the dendrogram of UPGMA includes sampling months based on binary data (presence/absence) of diatoms (Figure 6. 6). Occurrence of diatom taxa were changed monthly and affected environmental variables during the present study. Accordingly, UPGMA shows six groups based on closely relationships among sampling months (Figure 6. 6). In this dendrogram, the first group included late summer and early fall season's months, while late fall and early winter months were clustered in second group in Lake Abant. Mainly, sampling months of fall and summer 2004 were grouped in third and fourth cluster respectively. The fifth group was consisting of early summer months, while the last cluster included mainly spring months. Clustering sampling months in UPGMA dendrogram (Figure 6.6) were similarly found in CCA ordination (Figure 6. 5).

Diatom composition was changed seasonally during study time. Some taxa such as *Asterionella formosa* and *Fragilaria capucina* were commonly found from all sampling stations in Lake Abant. On the other hand, some diatom species such as *Cyclotella meneghinia*, *Diploneis elliptica*, *Melosira varians* were observed in some months. Thus, UPGMA dendrogram (Figure 6. 6) suggests that months with common species were found closer to each other. These outcomes of UPGMA are mainly supported by the results of CCA ordination (Figure 6. 5).

17 CONCLUSION

In the present study, the seasonal development of diatom community seem to be strictly associated with the temporal variation of environmental factors. Physical and chemical variables changed seasonally. In general, high nutrient concentrations were recorded in both spring and fall seasons. Lake Abant water mixed from early winter to late spring and thermal stratification occurred during summer season. This indicates a dimictic characteristic.

Diatom abundance fluctuated during study time and maximum levels were recorded in spring and fall seasons. A few member of *Fragilaria* and *Cyclotella* and *Asterionella formosa*, have great contribution to high diatom abundances, in which *A. formosa* and some *Fragilaria* species were commonly found in spring and fall seasons while *Cyclotella* taxa were high level in summer season. During the study, Lake Abant showed highly diverse diatom species with total 123 diatom taxa. Among which, *A. formosa*, *Cymbella leptoceros*, *C. cistula*, *Fragilaria biceps*, *F. dilata*, *Navicula radiosa*, and *Rhopalodia gibba* were commonly recorded in almost each month from each station.

CCA analysis explained as the first axis of CCA explained 84.6 % of the relationship between environmental variables and diatom composition. According to analysis, all physico-chemical factor were significantly ($p < 0.05$) important on distribution of diatom taxa. Among which, both temperature and turbidity were most important two variables ($p = 0.002$) on the occurrence of diatom species. Most cosmopolitan diatom taxa, which were found closer to center of CCA ordination, have a broad tolerance ranges to environmental changes. Therefore, the results

demonstrated that diatom composition is distributed continuously along with the gradient changes in environmental factors.

Ecological data with organisms composition especially diatom community are useful for understanding purpose of water quality changes. These present study findings have contribute essential phytoplankton and physical and chemical information that should aid in evaluating the state of Lake Abant in future.

Part B

ABSTRACT

BACILLARIOPHYTA COMPOSITION AND ITS RELATIONSHIP TO ENVIRONMENTAL VARIABLES IN LAKE GÖLKÖY (BOLU)

Diatom composition and their relationship to environmental variables were studied monthly in Lake Gököy from June 2003 to June 2005. Diatom abundance was increased in fall and spring months. *Asterionella formosa*, *Aulacoseria granulata*, and some taxa belonging to *Fragilaria* had important contribution in both spring and fall peaks of diatoms composition. Lake water is mixed completely during fall, winter, and spring months showing monomictic characteristic. According to Canonical correspondence analysis (CCA) with forward selection of Monte Carlo permutation test, almost all environmental variables (e.g., silica, pH, nitrate, temperature, calcium, and alkalinity) showed a significant ($p < 0.01$) influence on the species occurrence. Based on their seasonal occurrence, most of the species found closer to the center of CCA diagram have cosmopolitan characteristics. Overall, the first two axes of CCA explained 88.1 % of the relationship between species composition and environmental variables.

Keywords: Diatoms; Ecology; CCA; Phenology; Lake Gököy; Bolu

ÖZET

GÖLKÖY GÖLÜ (BOLU) BACILLARIOPHYTA KOMPOSİZYONU VE ÇEVRESEL DEĞİŞKENLER İLE İLİŞKİSİ

Gölköy Gölü'nde diyatome topluluğu ve çevresel değişkenler ile ilişkisi aylık olarak Haziran 2003'ten Haziran 2005'e kadar çalışılmıştır. Diyatome zenginliği sonbahar ve ilkbahar aylarında artmıştır. *Asterionella formosa*, *Aulacoseria granulata*, ve *Fragilaria*'ya ait bazı türler; ilkbahar özellikle sonbahar diyatome kompozisyon piklerinde önemli katkıya sahiptir. Göl suları sonbahar, kış ve ilkbahar süresince karışmış ve monomiktik karakteristik göstermiştir. Monte Carlo permütasyon testinin ileri seleksiyon ile Canonical correspondence (CCA) analizine göre, türlerin dağılımında hemen hemen bütün çevresel değişken (örneğin; silika, pH, nitrate, sıcaklık, kalsiyum ve alkalinite) türlerin oluşumlarında önemli bir etki ($p<0,01$) sahip olduğunu görülmüştür. Mevsimsel oluşumlarına dayanarak CCA diyagramının merkezine yakın bölgede bulunan türlerin çoğu kosmoplitan karakteristiğe sahiptirler. Genel olarak, tür kompozisyonu ile çevresel değişkenler arasındaki ilişkinin % 88,1'sini CCA analizinin ilk iki eksenini açıklamaktadır.

Anahtar Kelimeler: Diyatome, Ekoloji, CCA, Fenoloji, Gölköy Gölü, Bolu

18 INTRODUCTION

Diatoms are distributed to variety of environments from freshwater to marine water in all over the world, where environmental conditions in some of the major factors (e.g., light, temperature, and chemical components) are suitable (Hutchinson, 1967; Round, 1981; Stoermer and Smol, 1999). Besides their importance as the primary producers in food webs and ensuring ecological balance, species of phytoplankton can be useful indicators of water quality (Kitner and Poulickova, 2003; Denys, 2004; Rey et al., 2004). For example, although diatoms are widely distributed group most species occur only in habitats with specific physical, chemical, and biological characteristics.

Although diatoms are of useful organisms in many ways, there are few studies on their ecology and seasonal occurrences in Turkey. Previously, limnological studies have gained momentum in Turkey in the last decades but more studies are still needed. Relatively few studies on phytoplankton, which are found in the Bolu region, included in Lake Abant (Obalı et al., 2002; Atıcı and Obalı, 2002; Çelekli and Külköylüoğlu, in press); in Lake Gököy (Çelekli, in press); in Lake Yeniçağa (Kılınç, 2003; Saygı-Başbuğ and Demirkalp, 2004); in Akkaya Spring (Çelekli and Külköylüoğlu, 2006). All these studies increased our understanding on the species diversity of the area, but little attention has been given to phytoplankton, especially diatoms in the lakes of Bolu. Therefore, the aim of this study was to determine the relationships among diatom composition, their seasonal occurrence, and environmental factors in Lake Gököy (Bolu), and contribute to the knowledge of algal flora of Turkey.

19 RESULTS AND DISCUSSION

19.1 Physical and chemical variables

The variation of water temperature from each meter of vertical stations in Lake Gök  y indicated an overturn period monthly during each year. Superimposed values of two vertical measurements for each meter show in Figure 7. 1. At early month of present research, thermal stratification was detected. Accordingly, thermal stratification was observed in the both of vertical stations from June 2003 to August 2003 and again occurrence of stratification from June 2004 to August 2004 (Figure 7. 1). That is, the occurrence of thermal stratification begun in late spring, became stable during early summer, and toward to homogenization in late summer season (Figure 7. 1). Complete homogenization in this lake water took place from August to May for both years. The highest water temperature recorded at Littoral station 1 (L-1) with 26.3   C in August 2003 and at Vertical 2 sampling station as 23.7   C in August 2003. Epilimnion layer was about 9-11 m during present research (Figure 7. 1). Lake water except 3 months showed a complete homogenization. Overall, results show that this lake water was mixed and thermal stratification about same date. During study, Lake G  lk  y showed a monomictic characteristic and given in Figure 7.1. These water circulations in spring and fall seasons were in Lake Como (Buzzi, 2002), however Lake G  lk  y water had longer homogenization period than in Lake Como. In Lake G  lk  y, water temperature showed seasonal variation as 9.95   C in spring, 19.1   C in summer, 17.43   C in fall, and 6   C in winter season.

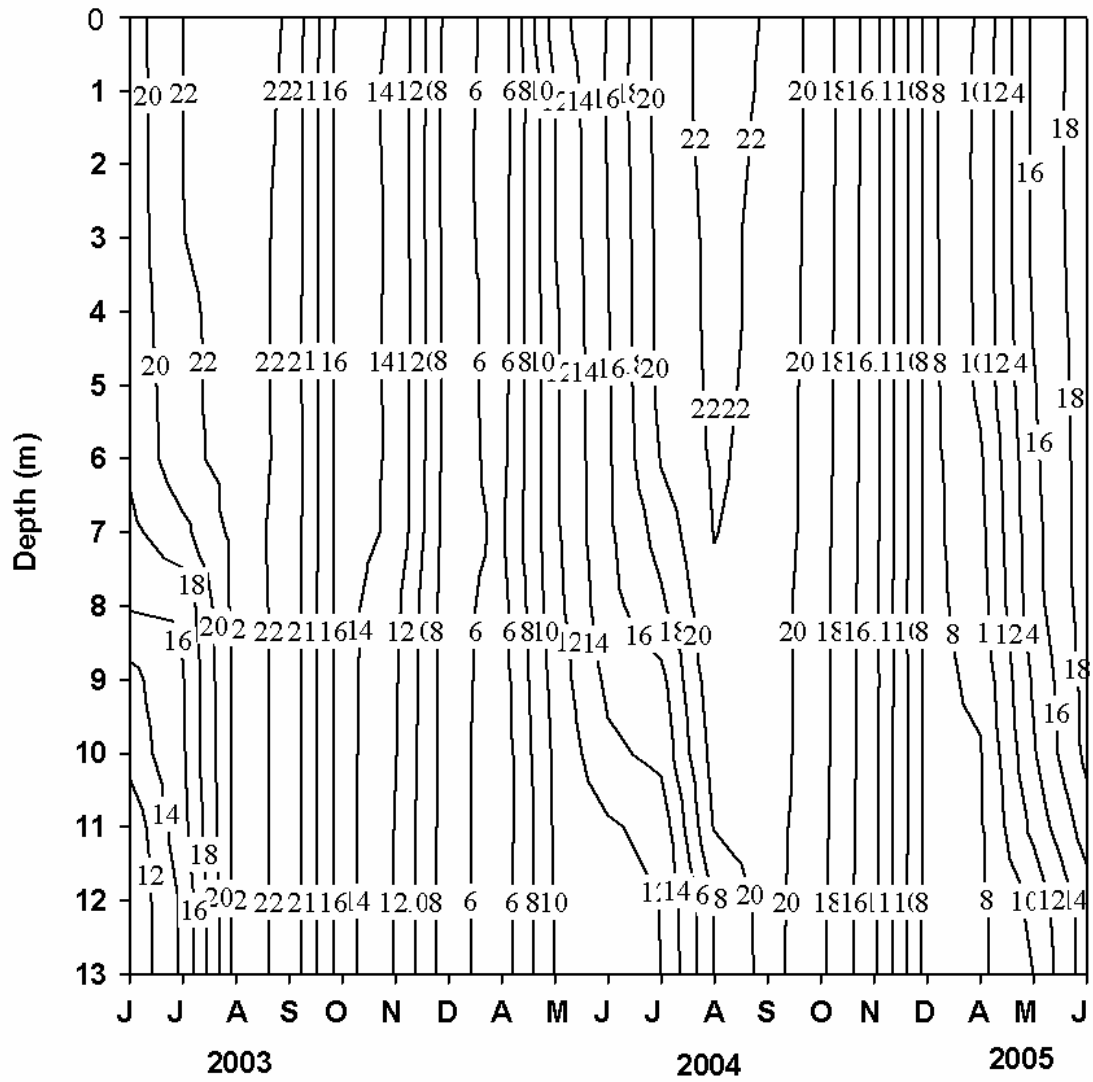


Figure 7. 1. Isopleths of temperature monthly with superimposed seasonal variation of vertical station at Lake Gölköy. Abbreviations indicate the code of each month (e.g., June (J) and August (A), respectively for each year). January-February 2004 and 2005 were not including vertical data due to ice cover at littoral site.

In Lake Gölköy, mean values of dissolved oxygen (DO) from both vertical sites showed a variation in during this study. The highest DO was measured at surface of vertical 1 station as 16.48 mg/l in May 2005 while, high mean DO concentrations were recorded with 12.54 mg/l in December 2004. On the other hand, low mean DO value opposite of water temperature was detected as 5.30 mg/l in August 2003. During thermal stratification, and about anoxic condition (<2 mg/l) was found at the bottom of Lake Gölköy in August 2004 (Figure 7. 2). Usually, lower DO levels were recorded in bottom of this lake during present research. In this month, changed DO levels were affected by high assimilation and aerobic decomposition. At lake surface, high abundance of phytoplankton with high nutrient, light intensity, and temperature supported increasing DO level with high photosynthesis rate, while decomposition process can cause depletion of DO in the bottom of the lake. During thermal stratification, low DO values in hypolimnion layer decreased mean DO values due to anoxic condition and high water temperature. With complete water homogenization nutrient concentrations that supported abundance of phytoplankton, were increased from releasing sediment of lake due to mixing water column and input to lake with anthropogenic and natural factors.

In Lake Gölköy, DO concentrations were changed seasonally with 11.50 mg/l in spring, 7.09 mg/l in summer, 7.81 mg/l in fall and 10.95 mg/l in winter season. These DO variations are consequence of changing water temperature, and photosynthesis: respiration ratio.

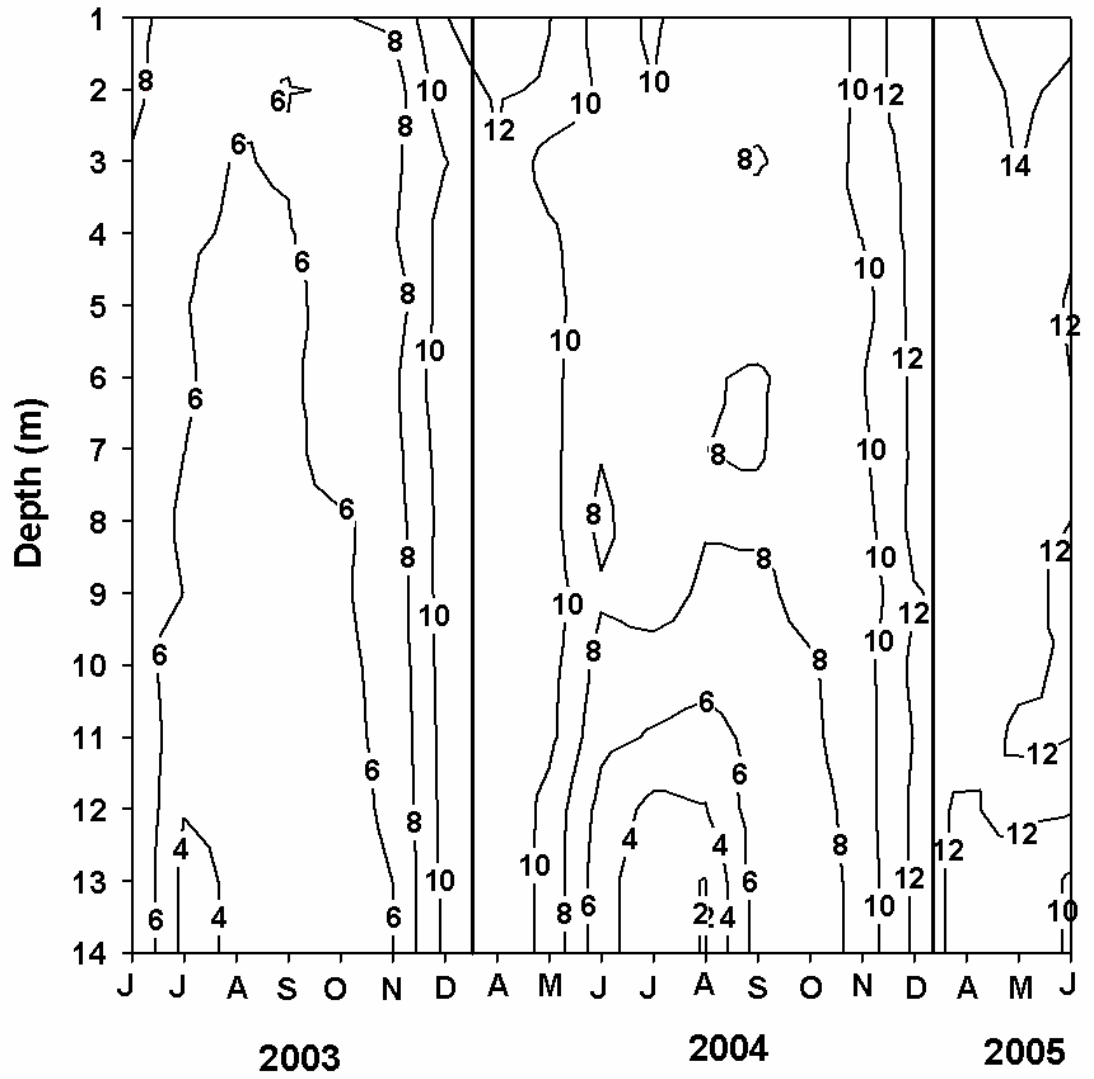


Figure 7. 2. Isopleths of dissolved oxygen (DO) monthly with superimposed seasonal variation of vertical station at Lake Gök  y. Abbreviations indicate in Figure 7 1. January-February 2004 and 2005 were not including vertical data due to ice cover at littoral site.

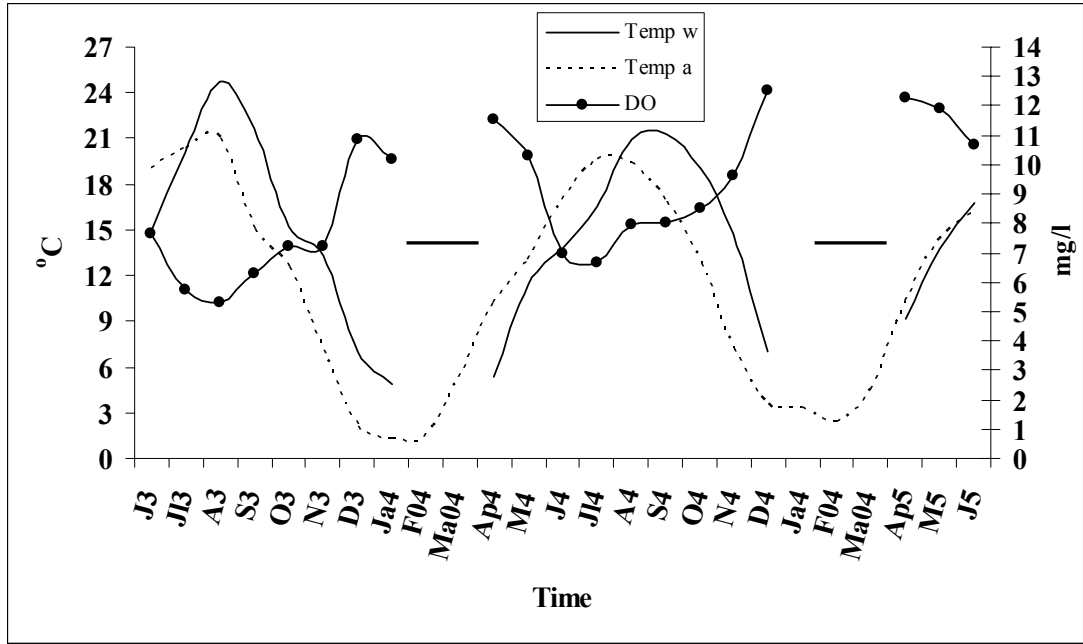


Figure 7. 3. Temporal variations of dissolved oxygen (DO), water and air temperature recorded. Mean value of variables monthly from each sampling stations are taken. (—) ice cover. Abbreviations are given in Figure 7. 1 and Table 7. 2. Only littoral sampling was done in January 2004.

Temporal variation of DO, water and air temperatures showed in Figure 7. 3. Water temperature, which changed parallel to variation of air temperature, fluctuated from 4.93 °C in January 2004 to 24.75 °C in August 2003 during present study time. Lake Gölköy showed similar variation temperature values of water and air (Külköylüoğlu, 2005), however, water temperature had broader range comparing in present study. It is consequence of different sampling time and stations. Recent study included only littoral sampling and water temperature recorded also in all winter months. In present study, Spearman correlation displayed a significant ($p < 0.001$) relationship between water and air temperatures. In the meantime, as expected, there was a negative correlation ($p < 0.01$) between dissolved oxygen and water temperature (Table 7. 2). There is not only water temperature affected DO level, but also assimilation:

respiration ratio influence DO concentration. DO value showed an increase in spring and fall season. Total high diatom abundance (Figure 7. 4) supported seasonally increasing DO levels during study time. On the other hand, high DO level record in December 2003, when total diatom abundance was found very low level. In this month, especially low water temperature can affect DO value, and at the same time, other photosynthetic organisms (e.g., non-diatom phytoplankton, macrophytes, and aquatic plants) can influence level of this variable. In recent study (Külköylüoğlu, 2005), similar mean temperature degree was found, although, lower and higher water temperature stated in recent study comparing present study values. Different sampling time and sampling station can affect these results, because nine sampling stations were selected from only littoral region. Likelihood, it can affect water temperature and other environmental variables. Indeed mean DO and saturation values were record higher in recent study than in present study, however lower EC and salinity were detected in recent study.

Table 7. 2 shows the mean values of environmental variables calculated and superimposed for each month. As seen from the table, environmental changes were varied from littoral to vertical sampling stations along study time.

Lake Gököy has slightly basic water (mean pH 8.0) (Table 7. 2). Külköylüoğlu (2005) studied about ostracods in Lake Gököy from 2000 to 2001, and lake mean pH value was reported as 8.1. This is showed that mean pH level had not changed for 5 years; however this pH level was detected in the last years of present research. Similar result was detected in Lake Abant, and Yedigöller (Atıcı and Obalı, 2002). pH values were fluctuated from 7.31 in July 2005 and 8.59 in October 2003 in present study. This is an expected reason of increasing photosynthesis rate with high nutrient concentration, temperature and light intensity. Partly, diatom abundance can

affect this variation. The lowest pH level (7.01) recorded in the anoxic water layer near the lake sediment in July 2003, shows a circumneutral characteristics of the water. This is consequence of decompose process during thermal stratification.

With regard to nutrient concentrations, nitrite ($\text{NO}_2\text{-N}$) showed high values in fall season and decreased in late spring and summer months. After water homogenization occurred, maximum nitrite concentration record as 0.046 mg/l in September 2004. Later, value of nitrite showed a decreased in October and increasing in November with changing abundance of phytoplankton. Indeed, peaks of diatom abundance, which found in October for both years and sharply decreased its abundances in November for both years.

Nitrate ($\text{NO}_3\text{-N}$) value ranged between 0.014 mg/l in July 2004 and 0.192 mg/l in May 2004. Mean value of nitrate was found as 0.070 mg/l in result of study. Tolotti and Thies (2002) stated that Piburger See (Austria) showed similar mean nitrate, and high nitrate concentration (189 $\mu\text{g/l}$) recorded at lake surface in late winter. In Lake Gölköy, the highest nitrate level as 0.232 mg/l detected at Vertical 1-10 m (V1-10 m) sampling station in May 2004. In this month, the highest nitrate concentration supported to record the highest total diatom abundance in Lake Gölköy during this study. On the other hand, high value of nitrate was not measured in late winter due to ice cover in the present study. Not only melting snow and high rainfall carried material input to Lake Gölköy, but also both canals carried nutrient rich water especially in spring month. These factors highly affected nitrate and nutrient concentrations. Loading high organic material was transformed to inorganic nutrient with decomposer process. During thermal stratification, low nitrate concentration was recorded at bottom part of Lake Gölköy with anoxic condition. This can be explained as consequence of increasing microbial reduction processes which

decreased $\text{NO}_3\text{-N}$ value in near the sediment part. Conversely, nitrite was recorded high level at near sediment lake.

Ammonium ($\text{NH}_4\text{-N}$) was fluctuated from 0.271 mg/l in August 2004 to 0.052 mg/l in April 2004 during present study. The highest ammonium concentration, which showed inverse pattern in comparison to nitrate recorded as 0.705 mg/l near the sediment of vertical 2 sampling station. Mean ammonium value was found as 0.12 mg/l in Lake Gököy. Horne and Goldman (1994) reported that Lake Cayuga, which included 100-300 $\mu\text{g/l}$ ammonium, eutrophic and monomictic characteristic. The value of these variables can be affected by pH levels. In near lake sediment low pH value recorded due to high decomposer process. Indeed, significant ($p < 0.05$) negative relationship between ammonium and pH showed in Table 7. 2 with Spearman correlation. According to distribution of NO_3 , NO_2 , and NH_4 (Horne and Goldman, 1994), Lake Gököy showed eutrophic trophic status.

Silica (Si) concentration was ranged from 0.268 mg/l in July 2004 to 0.126 mg/l in November 2004. Decreased silica value is likely the consequence of an intense assimilation of diatoms. Usually, high values of silica were recorded at the bottom of lake near the sediment during thermal stratification, while it decreased at epilimnion layer during thermal stratification. It is possibly due to the affect of sinking of non-living diatom, chrysophytes and accumulation of Si with degradation processes.

Phosphate (PO_4) concentration fluctuated between 0.010 and 0.022 mg/l in May 2004 and April-June 2005 respectively (Table 7. 1). High phosphate concentration usually recorded in spring months. Similar phosphate level was already recorded in Lake Garda in 1999 (Salmaso, 2002). During thermal stratification (Figure 7. 1) in summer season, low phosphate values were found at epilimnion layer in Lake Gököy. In this layer, high assimilation rate of flagellated phytoplankton can

probably have intense affect on depletion of phosphate with suitable luminance and water temperature. Indeed, during this study, high phosphate concentrations in deep water were detected and likely consequence of decomposition processes with non-living organisms sinking to sedimentation.

Mean electrical conductivity (EC) values fluctuated from 420.6, to 296.0 $\mu\text{S cm}^{-1}$ in May 2005, and September 2004, respectively during research months (Table 7. 1). Mean low levels of conductivity were usually recorded late-summer, fall, and winter seasons, while its high concentrations were detected in spring season during the present study. Rainfall, air temperature, and nutrient input are possible factors for conductivity variations.

Redox potential (Eh) value fluctuated monthly from 186.85 mV in July 2005 to 124.88 mV in October 2003. Eh value was usually decreased in summer and increased in spring season. Eh is found by measuring amount of oxidizing and reducing materials. So, this factor especially related with pH, DO, and nutrient concentrations. O'Neil (1993) stated that negative relationship between Eh and pH is clearly showed in Eh-pH diagram. In Lake Gököy, highly significant ($p < 0.01$) correlations were recorded between pH and Eh in Table 7 2 by using Spearman correlation.

Biological oxygen demand (BOD_5) levels were usually increased in spring and fall seasons and decreased again in the following summer season. This factor is not only affected by high photosynthesis rate with suitable conditions, but also high respiration and decomposition rate can affect BOD_5 value.

Table 7. 1. The mean, minimum and maximum values of physico-chemical variables measured combined from all stations (n = 780 bits of data) in Lake Gök  y.

		Min.	Max.	Mean
Temperature water	�C	4.93	24.75	14.58
Temperature air	�C	1.3	20.3	11.06
Annual Precipitation	mm	1.6	96	45.54
Dissolved Oxygen	mg/l	5.30	12.54	8.87
Saturation	%	49.10	116.87	88.68
Conductivity	$\mu\text{S cm}^{-1}$	296.00	420.61	336.96
Redox potential	mV	124.84	186.85	159.66
pH		7.31	8.59	8.00
Turbidity	NTU	1.01	5.59	3.28
Chlorophyll-a	$\mu\text{g/l}$	3.21	10.77	6.49
Secchi Depth	m	1.35	7.10	3.28
BOD ₅	mg/l	1.90	9.26	5.39
Nitrite	mg/l	0.010	0.046	0.026
Nitrate	mg/l	0.014	0.192	0.070
Phosphate	mg/l	0.010	0.022	0.014
Ammonium	mg/l	0.052	0.271	0.125
Silica	mg/l	0.126	0.268	0.184
Alkalinity	eq/l	1.00	4.14	2.61
Sulfate	mg/l	11.92	44.94	29.48
Chloride	mg/l	1.87	35.17	14.68
Calcium	mg/l	40.08	76.20	53.48
Magnesium	mg/l	14.59	48.12	28.03
Salinity	ppt	0.2	0.2	0.2

During present study, BOD₅ ranged from 9.26 mg/l in June 2005, to 1.90 mg/l in August 2003 (Table 7. 1). According to mean BOD₅ value, Lake Gök y had beta to alpha-mesosaprobic status (Ham, 1969 in Rott et al., 2003).

Secchi Depth (SD) ranged as 1.35 in September 2003 and 7.10 m in August 2004 (Table 7. 1). Yan and colleagues (2004) reported similar SD values from Lake Qiandaohu that begins to occurrence of eutrophication in 1998. In fall season, phytoplankton composition especially diatom assemblages showed an important increase along with high nutrient concentrations. As mentioned above, maximum nutrient concentrations were measured in fall and spring season, where factors such as a complete water homogenization, high diatom abundance, and soil erosion might have caused an increase of water turbidity. Eventually, such factors can affect the water transparency. Secchi depth was increased in summer season due to clear epilimnion layer during thermal stratification.

All physico-chemical variables in sampling stations for each month were tested by one-way ANOVA. Among the stations sampled monthly, there was no significant difference ($p>0.05$) in the physico-chemical variables during study period. This result may give that lake water was distributed as about homogeny for each sampling month.

Results of Spearman correlations among some of the selected variables are given in Table 7. 2. Eh showed significantly positive correlation to some environmental variables such as ammonium ($p<0.01$), phosphate ($p<0.01$), magnesium ($p<0.01$), silica ($p<0.01$), nitrate ($p<0.05$), DO ($p<0.05$), turbidity ($p<0.05$), and while it was significant negatively correlated to pH ($p<0.01$) (Table 7. 2). Indeed, similar result was clearly found in CCA ordination diagram (Figure 7. 5). It is known that a

negative relationship between Eh and pH is present in aquatic ecosystems and this relationship clearly shows in Eh-pH diagram (O'Neill, 1993).

Significant negative relationship between temperature and some physico-chemical variables such as DO ($p<0.01$), EC ($p<0.05$), CI ($p<0.05$), alkalinity ($p<0.05$) was found in Lake Gök  y (Table 7. 2). Number of diatom taxa is positively correlated to both nitrite and chloride with ($p<0.05$) and showed a negative correlation to water temperature. However it is not significant correlation. In Lake G    y' ecosystem physical-chemical variables, which are close correlated, not only influence organisms' composition, but also affected their geochemical cycles.

Table 7. 2. Correlation matrix for monthly averages of environmental variables and number of diatom species (Spp) from Lake Gökçöy. Abbreviations are given in Table 6. 2. * Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

	Temp	DO	pH	Eh	EC	Chlo	BOD	Turbi	SD	NO ₂	NO ₃	PO ₄	NH ₄	SO ₄	Cl ⁻	Ca ²⁺	Alkali	Mg ²⁺	Si	Spp
Temp.	1.00																			
DO	-.678**	1.00																		
pH	-.034	-.417	1.00																	
Eh	-.069	.472*	-.931**	1.00																
EC	-.493*	.173	.235	-.159	1.00															
Chlo	-.009	-.233	.007	.068	-.371	1.00														
BOD	-.511*	.904**	-.417	.499*	.214	-.317	1.00													
Turbi	.080	.098	-.338	.474*	-.442	.538*	.140	1.00												
SD	.256	-.017	-.192	.072	-.044	-.294	.180	-.250	1.00											
NO₂	-.216	.273	-.230	.147	-.395	.313	.193	.163	.105	1.00										
NO₃	-.204	.626**	-.551*	.538*	-.234	.051	.537*	.276	.080	.461*	1.00									
PO₄	-.202	.359	-.577**	.589**	-.115	.176	.412	.177	.025	.565**	.576**	1.00								
NH₄	-.241	.341	-.531*	.564**	-.024	-.118	.391	.068	.317	.263	.315	.558*	1.00							
SO₄	-.112	.265	-.480*	.414	-.139	.086	.250	-.017	.309	.388	.595**	.689**	.763**	1.00						
Cl⁻	-.494*	.352	-.182	.226	.117	.194	.279	-.183	.139	.389	.427	.621**	.563**	.762**	1.00					
Ca²⁺	-.091	.231	-.413	.399	-.162	.143	.249	.151	.208	.388	.744**	.590**	.525*	.790**	.669**	1.00				
Alkali	-.546*	.299	-.173	.159	.178	.047	.201	-.151	-.054	.288	.359	.479*	.601**	.703**	.773**	.610**	1.00			
Mg²⁺	.039	.524*	-.743**	.688**	-.439	.004	.459*	.376	.078	.473*	.665**	.459*	.172	.199	-.057	.216	-.162	1.00		
Si	.205	.297	-.652**	.631**	-.436	-.004	.391	.300	.486*	.288	.500*	.488*	.459*	.489*	.242	.449*	.044	.621**	1.00	
Spp	-.228	.084	-.087	.074	-.222	.206	.000	-.217	.045	.530*	.116	.390	.255	.336	.520*	.229	.407	.192	.269	1.00

19.2 Diatom density of Lake Gölköy

Thirty-nine diatom taxa belonging to 26 genera were recorded in Lake Gölköy. During the present study, *Rhoicosphaena* was the lowest abundant genera with 3cell/ml, while *Asterionella* was the most abundant genera with 40.3 % of total abundance as 63794.3 cell/ml in Lake Gölköy. Total diatom abundance showed two important peaks as 23936.0 and 32120.7 cell/ml in fall and spring seasons, respectively. The most abundant species was *Asterionella formosa*, which was also the most common diatom in Lake Gölköy during spring season (especially in May and June 2004), had great contribution to total abundance peaks in fall season 2003 and especially in spring 2004. In earlier studies (e.g., Nygaard, 1949; Round, 1981), this species was reported dominant one in mesotrophic lakes even in eutrophic lakes. Wetzel (1975) and later Horne and Goldman (1994) pointed out that *Asterionella* was common diatom in spring bloom of temperate lakes through out the world. In Lake Gölköy, this species was followed by members of *Fragilaria* such as *F. capucina*, and *F. crotonensis* that showed high abundance in spring and fall seasons. *A. formosa*, *F. capucina*, and *F. crotonensis* were also counted for almost each month. Horne and Goldman (1994) reported that *A. formosa* and *Fragilaria* are holoplankton algae that are always present in plankton.

As explained above, the highest phosphate concentration usually recorded in spring months especially May 2004. *A. formosa* showed high abundance in spring season month especially in May and June 2004, when phosphate concentrations were high levels. Earlier studies supported result of present study. Çelekli and Külköylüoğlu (2006) stated that *A. formosa* was dominant from April to May 2004 when phosphate

concentrations were also maximized in a karstic spring called Akkaya Spring (Bolu). Similar results are found in three Dinaric karstic lakes (Jasprica and Hafner, 2005).

Table 7. 3. Abundance of diatom genera in Lake Gök  y during 20 months.

Genera	Total number	Genera	Total number
<i>Asterionella</i>	63794.3	<i>Cocconeis</i>	184,3
<i>Fragilaria</i>	63402.6	<i>Caloneis</i>	106.7
<i>Aulacoseria</i>	19100.3	<i>Meridion</i>	84.6
<i>Cyclotella</i>	4442.9	<i>Gyrosigma</i>	47.2
<i>Diatoma</i>	2584.7	<i>Cymatopleura</i>	36.7
<i>Cymbella</i>	1203.6	<i>Epithemia</i>	30.8
<i>Navicula</i>	1009.3	<i>Pinnularia</i>	26
<i>Stephanodiscus</i>	654	<i>Denticula</i>	7.4
<i>Nitzschia</i>	508.8	<i>Stauroneis</i>	7.4
<i>Amphora</i>	431.3	<i>Diploneis</i>	7
<i>Gomphonema</i>	323.5	<i>Stephanopterobia</i>	5
<i>Achnanthes</i>	299.7	<i>Surirella</i>	3.6
<i>Hantzshia</i>	207.2	<i>Rhoicosphaena</i>	3

Total diatom abundance showed seasonal variations and caused 2 high and one small of 3 peaks in fall and spring seasons (Figure 7. 4). The highest total diatom abundance (32280.0 cell/ml) was recorded in June 2004, while the lowest density with 629 cell/ml was recorded in January 2004 (Figure 7. 4).

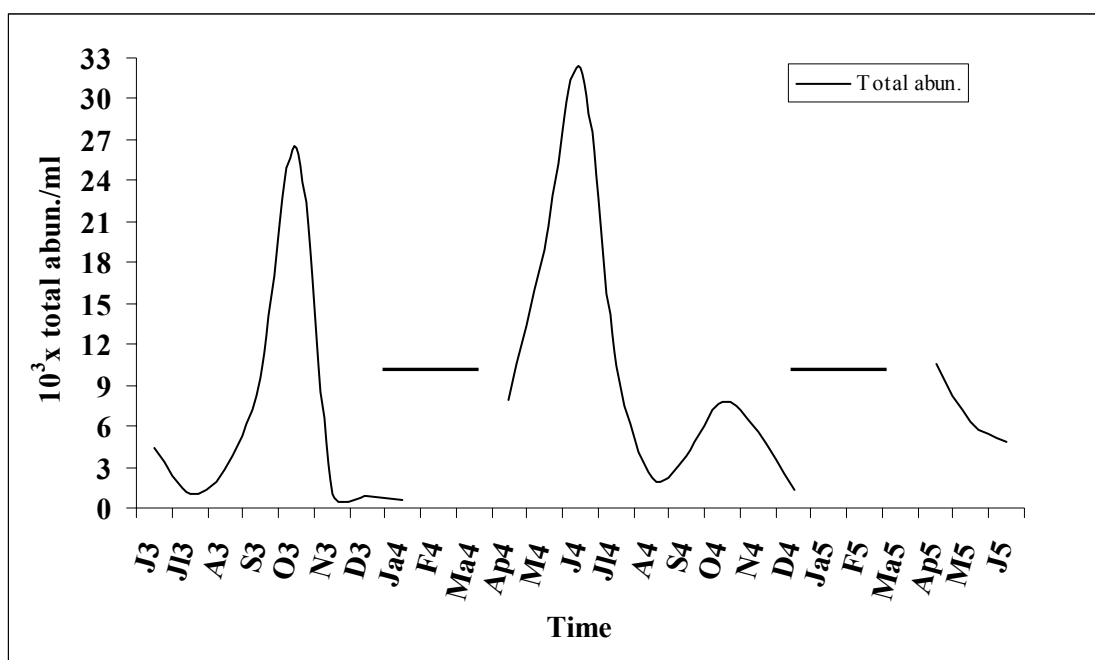


Figure 7. 4. Total abundance of diatom composition in Lake Gökçöy during two years. Abbreviations indicate the code of each month (e.g., June 2003 (J3) and July 2004 (Jl4) etc.). (—) ice cover.

Thermal stratification was followed by the first abundance in October 2003. *Asterionella formosa*, and *Aulacoseria granulata* had great contribution to this peak in fall 2003, followed by members of *Fragilaria* and *Cyclotella*. *A. formosa* showed an important decreasing in its total abundant, when total density sharply decreased in November 2003. On the other hand, density of *Aulacoseria* not decreased and also increased in a few sampling stations during late fall and early winter seasons. *Aulacoseria* which was usually counted in fall, winter and spring seasons and has high abundant in fall season, are meroplankton diatom that are found in plankton due to their life cycle in dormant form in lake sediments (Horne and Goldman, 1994). Similarly, Hutchinson (1967) stated that in productive lakes, *Melosira* (called *Aulacoseria*) can be abundant species in winter, and following *Asterionella*, reached to a high level during spring season. Second diatom density was the most abundant peak in spring 2004. *Cyclotella praetermissa* commonly counted late spring, summer

and early fall season. Members of *Fragilaria* and especially *A. formosa* had enormous contribution in this peak during spring season 2004. Similarly, third taxa (*A. formosa*, *A. granulata*, and a few members of *Fragilaria*) were detected in small third peak in fall 2004.

These species are not only commonly distributed in European lakes (John et al., 2002), but also generally found in almost all types of water bodies such as lakes, marshes, and ponds in Turkey (Gönülol et al., 1996; Obalı et al., 2002; Akbulut, 2003; Çetin and Şen, 2004).

19.3 Net-Diatom Composition

A total of 119 diatom taxa from Lake Gököy belonging to 33 net-phytoplankton genera were identified from June 2003 to June 2005. *Cymbella*, *Fragilaria*, *Navicula*, and *Pinnularia* showed high species number with 16, 14, 9, and 8 taxa, respectively. In comparison, diatom composition of Lake Gököy showed similarity to the Lake Abant (Bolu), a natural lake in similar size (Çelekli and Külköylüoğlu, in press). Although structural and geographical differences occur in two lakes, such similarity may depend on the indirect connection between them. This is because the water released from Lake Abant travels to Yumrukaya Reedbeds, and then it is transferred to Lake Gököy by concrete canals due to agricultural purposes (see Figure 1). This may eventually brings many diatoms from Lake Abant to Lake Gököy.

Lake Gököy had high species diversity, included 19.8 % of total diatom species from different aquatic habitats in Turkey. In their check-list of freshwater algae in Turkey until 1996, Gönülol and his colleagues (1996) reported that a total of 601 diatoms taxa were recorded from literature in Turkey. After such important studies, many algological studies have been carried out from different parts of Turkey.

Accordingly, diatom species ratio for Lake Gök  y may be decreased in Turkey due to increase algological studies from unstudied in aquatic parts of Turkey.

In the present study, some species found in almost each month from each station (e.g., *Asterionella formosa*, *Aulacoseria granulata*, *Cyclotella praetermis*, *Cymbella cistula*, *Fragilaria. bicep*, *F. crotonensis*, *F. dilata*, *Navicula radiosa*, *N. trivialis* and *Nitzchia sigmoidae*) were already reported commonly from different aquatic bodies in Turkey (G  n  l  l et al., 1996). Some species such as *Cymbella schimanskii*, *Didymosphaenia geminata*, *Gomphonema olivaceum* found in Lake G  lk  y were rarely distributed in aquatic ecosystem of Turkey (G  n  l  l et al., 1996).

19.4 Relationship between diatom and environmental factors

In Lake G  lk  y, diatoms composition was affected by means of different environmental factors. Detrended correspondence analysis (DCA) was used to determine the gradient length of the diatom composition and linear or no-linear (unimodal) response model of diatom to environmental axes can be examined before performing CCA. DCA ordination was used to show good dispersion of diatom species on the axes.

The unimodal response of diatom taxa to environmental variables was found with gradient length as 2.78 (Table 7. 4). The first axis of DCA showed about 73.7 % of correlation to environmental data with a low cumulative percentage variance of species data. DCA ordination diagram explained 5.6 % of cumulative variance in species data when axis 1 ($\lambda_1=0.300$) and axis 2 ($\lambda_2= 0.188$) with the ratio of 1.60 was found (Table 7. 4). This result showed that unimodal perform was reasonably well established (Leps and Smilauer, 2003).

Table 7. 4. Main results of DCA with 119 diatom species given values in Lake Gölköy.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.300	0.188	0.163	0.124	5.364
Lengths of gradient	2.783	2.638	2.743	2.141	
Species-environment correlation	0.737	0.668	0.666	0.610	
Cumulative percentage variance					
of species data	5.6	9.1	12.1	14.5	
of species-environment relation	11.1	18.0	0.0	0.0	
Sum of all eigenvalues					5.364
Sum of all canonical eigenvalues					1.073

Relationship between diatom composition and environmental variables was explored by using CCA analysis in present study. In this analysis, 119 net-diatom taxa and 18 physical-chemical variables are applied to CCA analysis. After unimodal response of the results of CCA with 119 species and selected 11 environmental variables are shown in Figure 7. 5.

The forward selection with Monte Carlo permutation test (499 unrestricted permutations) showed that both axes were highly significant ($p= 0.002$). In CCA ordination, axis 1 ($\lambda_1=0.200$) and axis 2 ($\lambda_2= 0.159$) with their ratio 1.3 explained 3.7 % of cumulative variance in species data (Table 7. 5).

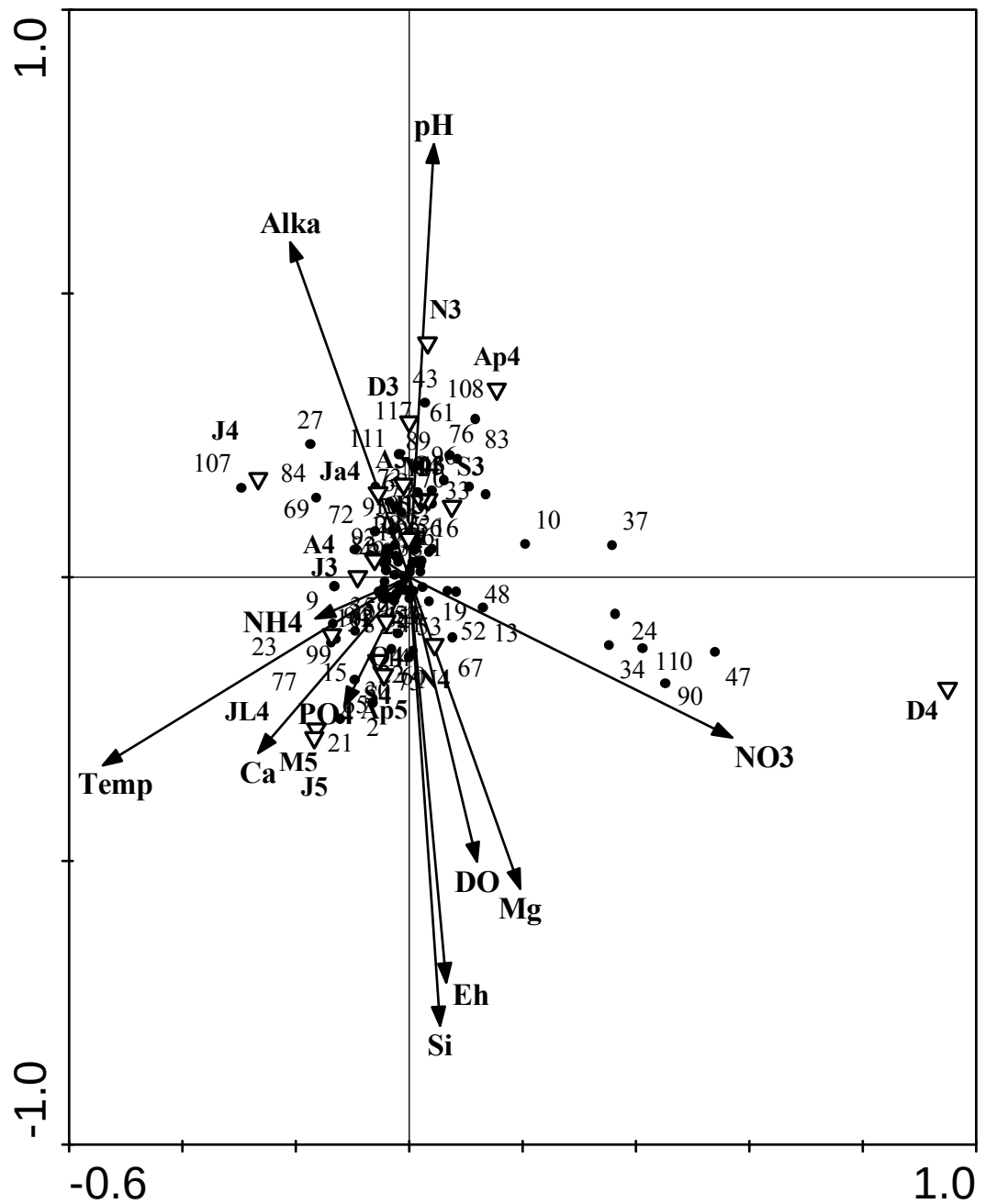


Figure 7. 5. Canonical correspondence analysis (CCA) ordination shows 119 diatom taxa (2%) and forward selected environmental variables (arrows) during 20 months (triangular). Sampling size (N) is 220. Species codes (numbers) are shown in Appendix B. Abbreviations are given in Figure 7. 4.

Table 7. 5. Main results of canonical correspondence analysis (CCA) with using Monte Carlo permutation test for 119 diatom species.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.200	0.159	0.110	0.100	5.364
Species-environment correlations	0.852	0.881	0.828	0.843	
Cumulative percentage variance					
of species data	3.7	6.7	8.7	10.6	
of species-environment relation	18.6	33.5	43.7	53.0	
Sum of all eigenvalues					5.364
Sum of all canonical eigenvalues					1.073
P-value = 0.0020 F-ratio = 7.014					

The relationship between diatom composition and environmental factors were high; 0.852 and 0.881 for axis 1 and 2, respectively (Table 7. 4). Earlier studies were reported that high relationship were found between diatom community and environmental variables as 0.89 for axis 1 in many lakes of Tasmanian (Vyverman et al., 1996), 0.96 for axis 1 in Spanish salt lakes (Reed, 1998), 0.95 for axis 1 in 18 sites of lowland river in Portugal (de Almedida and Gil, 2001), and 0.96 for axis one in 49 lakes and Yangtze River in China (Yang et al., 2005). These result of researches show that diatom composition is directly reflected with its environmental factors. Diatom composition-environmental data were significantly ($p < 0.01$) correlated in CCA ordination during two study years.

Table 7. 6. Results of CCA ordination test along with forward selection of Monte Carlo permutation test shows forward selected environmental variables during 20 months. Total of 220 bits of data is used in this analysis.

Environmental Variables	Explained %	p	F
Silica	114	0.002	4.338
pH	109	0.002	4.136
NO ₃	102	0.002	3.887
Temperature	100	0.002	3.783
Ca ²⁺	99	0.002	3.745
Alkalinity	98	0.002	3.734
Eh	96	0.002	3.657
NH ₄	90	0.002	3.403
Mg	86	0.002	3.256
DO	83	0.002	3.156
SO ₄	76	0.002	2.869

In CCA, silica, pH, NO₃, temperature are the most significant ($p < 0.01$) factors on distributions and occurrences of diatom composition. The significant level of variables on distribution of diatom composition was explained about very high levels. According to Monte Carlo permutation test, all physical and chemical variables except EC and NO₂ were most significant ($p = 0.002$) factors on influence diatom composition in Lake Gök  y during two years. Silica which was one of the most important variables, closely related arrows of Eh, magnesium, NO₃ and lied opposite arrow of pH (Figure 7. 5). Indeed, these significant negative and positive relationships with using Spearman correlation among above variables are given in Table 7. 2. In CCA ordination, arrows of nutrients were closer to fall months 2004 and spring months 2005. The first CCA axis corresponded positively to NO₃ and

negatively temperature, calcium and alkalinity. The second CCA axis was highly correlated pH-alkalinity and negatively nutrients, temperature, and Eh (Figure 7. 5).

The effect of silica factor showed in fall and spring season months. In these seasons, diatom abundance was increased to high level. It is known that diatom frustules consist of silica. CCA analyses suggested that the majority of diatom species have substantial tolerance to different environmental variables. Indeed, most of them were emerged close to the center of the CCA diagram. This is probably due to the cosmopolitan characteristics of these species; all are known to tolerate large ranges in water qualities. Months of present research except December 2004, were found closely related in CCA ordination (Figure 7. 5). This close relationship can be caused to increase occurrence of cosmopolitan taxa. Indeed, some diatoms species such as *Asterionella formosa*, *Amphora ovalis*, *Aulacoseria granulata*, *Cymbella cistula*, *Cymatopleura solea*, *Fragilaria biceps* *F. capucina*, *F. crotonensis*, *F. dilata*, *Navicula trivialis*, *Nitzchia sigmoidae*, which were commonly distributed about each sampling month, were found closer to CCA ordination. Most of them are found closer to center of CCA ordination, suggested broad tolerance to environmental factors, and have well computer comparing some other algae in a few seasons (Round, 1981; Horne and Goldman, 1994; Stomer and Smol, 1999; Jasprica and Hafner, 2005). *A. formosa* was closely related arrows of nutrients especially, phosphate, silica and ammonium concentrations, in fall season and especially in May and April 2005 in CCA ordination (Figure 7. 5). Similar result was found in Akkaya spring (Çelekli and Kùlköylüoğlu, 2006). On the other hand, a few species such as *Didymosphaenia geminata*, *Gomphonema subtile*, *Navicula menisculus*, and *Nedium iris* found in Lake Gùlköy are rarely distributed in aquatic habitats of Turkey (Gönùlol et al., 1996).

In this ordination, *Surirella angusta*, *S. robusta*, *Nitzchia linearis*, *Cymatopleura solea* were found closer arrows of alkalinity and pH and fall-early winter 2003 and winter-spring 2004. Similarly, these taxa were closely distributed to alkalinity from Portugal in CCA ordination (de Almeida and Gil, 2001). Round (1981) reported that *Surirella* and *Gomphonema* prefer cooler water in the temperal lakes. Conversely, *Meridion circularia*, *F. crotonensis*, *F. capucina* var. *vaucheria*, a few taxa of *Cymbella*, *Pinnularia* and *Nitzchia* were distributed negative part of second axis and related nutrients in spring and fall months. Some taxa such as *M. circularia*, *F. crotonensis* were distributed low acidic waters, and most of them prefer high organic water (de Almeida and Gil, 2001). Indeed, in spring and fall seasons, both canal carried high nutrient rich water into Lake Gököy. Additionally, most of them are mesotrophic and eutrophic characteristic taxa and have broad tolerance to environmental changes (Round, 1981; Wetzel, 1975; Jasprica and Hafner, 2005).

Cyclotella meneghinia was commonly recorded especially fall and summer months except a few months of spring and closely found in September 2003 during present study. This species was present closer to CCA ordination (Figure 7. 5). Hutchinson (1967) stated that *C. meneghinia* was distributed optimally in September. *C. meneghinia* can be used as indicators of oligo-mesotrophic reservoir (Ariyadej et al., 2004; Jasprica and Hafner, 2005). However, this species can also be found in eutrophic and hyper-eutrophic lakes (Yang et al., 2005). Indeed, according to Carlson Trophic State, Lake Gököy showed meso-eutrophic for chlorophyll-a and eutrophic for Secchi depth state in September 2003. This may suggest changes in water quality of Lake Gököy where two creeks (Abant and Mudurnu creeks) apparently carry nutrient enriched water from chicken farms, industries, and domestic sources. Such

effects of point and non-point sources were already underlined to affect the occurrence of other taxonomic groups.

Aulacoseria granulata was recorded in months of present research. This species was found center of CCA ordination and similarly distributed in Lake Gök  y. Horne and Goldmann (1994) stated that *Aulacoseria* which is meroplankton, was usually most abundant genus from October to early spring, where the members of the genus sink to sediment of lakes during thermal stratification, and survive under anoxic condition for two years. *A. granulata* was distributed in eutrophic water type (Hutchinson 1967; Wetzel 1975; Round 1981). Yang and colleagues (2005) already pointed out that *A. granulata* was dominant species in mesotrophic and meso-eutrophic status, supporting previous reports.

Most of diatom taxa found in Lake G  lk  y, which are not only distributed in different parts of Turkey (G  n  l  l et al., 1996), but also are widespread in different parts of the world (Patrick and Reimer 1966, 1975; Round 1981; Krammer and Lange-Bertalot, 1991 a,b; 1999 a,b; Wehr and Sheath, 2003, Jasprica and Hafner, 2005; Abrantes et al., 2006). It is showed that diatom compositions including mainly cosmopolitan taxa have broad tolerance ranges to environmental variables. Additionally, it gives important information about to understand Lake G  lk  y water quality.

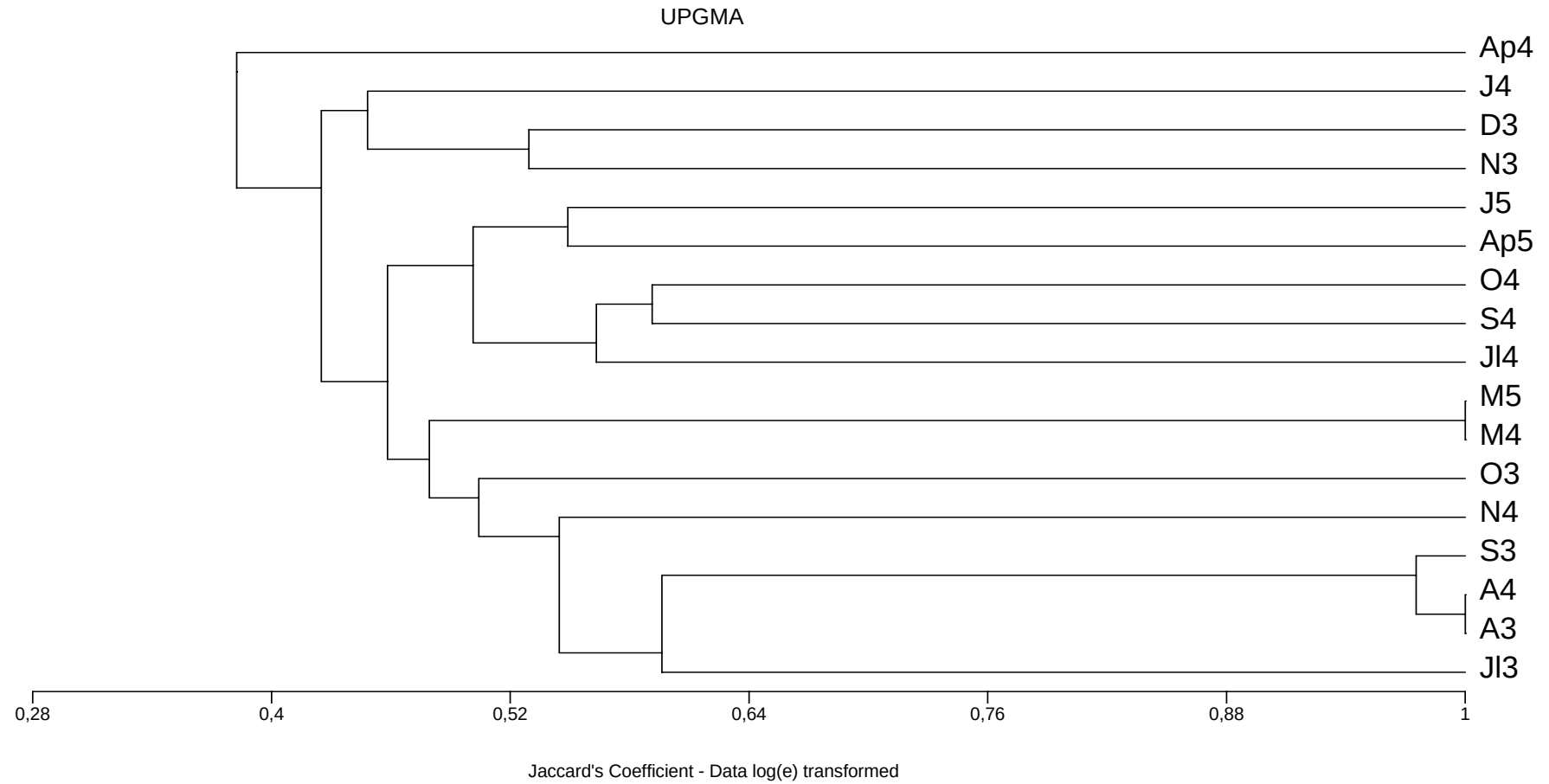


Figure 7. 6. UPGMA dendrogram shows sampling months in Lake Gököy. Abbreviation is given in Figure 7. 4.

During present study, the dendrogram of UPGMA showed five groups in Lake Gök  y, based on occurrence of diatom taxa.   lekli (in press) denoted that some species (e.g., *A. formosa*, *A. granulata*, *Cyclotella praetermis*, *Cymbella cistula*, *F. bicep*, *F. crotonensis*, *F. dilata*, *N. radiosa*, and *Nitzchia sigmoidae*) were already reported commonly in Lake G  lk  y, while some species such as *Cymbella schimanskii*, *Didymosphaenia geminata*, *Gomphonema olivaceum* found in Lake G  lk  y were rarely distributed in his study. The occurrences of diatom taxa affected clustering of sampling months by using UPGMA. The first group consist of three months, two of them related fall 2003 (Figure 7. 6). In this group diatom taxa close related arrow of pH and cooler water. *Surirella robusta* and *Diploneis pseudovalis* prefer cool water temperature (Round, 1981). Indeed, result of CCA supported outcome of UPGMA. The second group included April and June 2005. In this term, nutrient concentrations were recorded high level. Both months were found near nutrient concentrations such as phosphate, calcium, and silica in CCA (Figure 7. 5). Third group related except July 2004, fall 2004. Group 2 and group 3 can be together in UPGMA dendrogram as sampling months of both group were together and related nutrient factors in CCA ordination. Fourthly group included May 2004 and 2005. Indeed, 37 diatom taxa were identified in both months during present study. The last group included six month related summer and fall seasons. Cosmopolitan diatom taxa, which were recorded in these months, found closer to CCA ordination.

20 CONCLUSION

In the present study, the seasonal development of diatom composition was strictly affected by temporal variation of environmental factors. Lake Gölköy showed temperate lake type. Generally, high nutrient concentrations were recorded both of spring and fall seasons. Lake Gölköy has long water mixed period from September to May and thermal stratification occurred between June and August during two years of the present study. So, this suggests that the lake is of monomictic characteristic.

Diatom abundance fluctuated during study time and maximum levels were recorded in spring and fall seasons. *Asterionella formosa*, *Aulacoseria granulata* a few member of *Fragilaria* and *Cyclotella* have great contribution to high diatom abundances. During this study, Lake Gölköy has high diverse diatom species with total 119 diatom taxa. *A. formosa*, *Amphora ovalis*, *A. granulata*, *Cymbella cistula*, *Cymatopleura solea*, *Fragilaria biceps* *F. capucina*, *F. crotonensis*, *F. dilata*, *Navicula trivialis*, *Nitzchia sigmoidae*, were commonly recorded in almost each month from each station and found closer to center of CCA ordination.

CCA analysis explained ca. 88.1 % of the relationship between environmental variables and diatom composition. Hence, most physico-chemical factors were significantly ($p < 0.01$) important on the distribution of diatom taxa. Silica and pH were the most important two variables ($p = 0.002$) on the occurrence of diatom species. Most cosmopolitan diatom taxa, which were also located closer to center of CCA ordination diagram, have a broad tolerance to environmental factors. Such similar results were already underlined for cosmopolitan ostracods, different taxonomic group found in Lake Gölköy (Külköyköylüoğlu, 2005).

Present study results demonstrated that diatom composition is distributed continuously along gradients of environmental factors. Therefore, ecological and species composition information especially indicators organisms are important for understanding purpose of water quality assessment. These findings have an important contribution to the knowledge on phytoplankton ecology along with physical and chemical information that should aid in evaluating the state of Lake Gölköy in future. This study is the first study on diatom composition of Lake Gölköy. Therefore, results gained from this one can also be used to compare future water conditions of the lake.

Part C

ABSTRACT

PHYTOPLANKTON (EXCEPT BACILLARIOPHYTA) COMPOSITION AND ITS RELATIONSHIP TO ENVIRONMENTAL FACTORS IN LAKE ABANT (BOLU)

Phytoplankton community and their relationship to environmental variables (e.g., temperature, pH, dissolve oxygen, nitrate, and alkalinity) were studied monthly in Lake Abant from June 2003 to June 2005. Phytoplankton abundance increased in spring and early summer months. Some species belonging to *Dinobryon*, *Trachelomonas*, and *Scenedesmus* had important contribution to the phytoplankton composition in spring peaks. Some net-species (e.g., *Trachelomonas volvocina*, *Cryptomonas ovata*, and *Ceratium hirundinella*) encountered in almost all year around may suggest a wide range of tolerance levels to the changes in ecological conditions in the lake. In Bolu area, *Polytoma cylindraceum* firstly recorded in Lake Abant. According to Canonical correspondence analysis (CCA) with forward selection of Monte Carlo permutation test, all environmental variables (e.g., dissolved oxygen, conductivity, nitrite, temperature, alkalinity, and calcium) showed a significant ($p=0.002$) influence on the species distribution. Based on their seasonal occurrence, most of the species found closer to the center of CCA diagram seems to have cosmopolitan characteristics with wide bio-geographical distribution. Overall, the first axis of CCA explained 90.5 % of the relationship between species composition and environmental variables.

Keywords: Phytoplankton; Ecology; CCA; Phenology; Lake Abant; Bolu

ÖZET

ABANT GÖLÜ (BOLU) FİTOPLANKTON (BACILLARIOPHYTA HARİÇ) TOPLULUĞU VE ÇEVRESEL FAKTÖRLER İLE İLİŞKİSİ

Abant Gölü'nde fitoplankton topluluğu ve çevresel değişkenler (örneğin; sıcaklık, pH, çözülmüş oksijen, nitrat, alkalinite) ile ilişkisi aylık olarak Haziran 2003'ten Haziran 2005'e kadar çalışılmıştır. Fitoplankton zenginliği ilkbahara ve ilk yaz aylarında artmıştır. *Dinobryon*, *Trachelomonas* ve *Scenedesmus* cinslerine ait bazı türler ilkbahar piklerindeki fitoplankton kompozisyonunda önemli katkıya sahiptir. Göldeki koşullara karşı geniş bir toleransı olabilecek bazı net türler (örneğin, *Trachelomonas volvocina*, *Cryptomonas ovata* ve *Ceratium hirundinella* çalışma periyodu boyunca hemen hemen bütün yıl süresince görülmüştür. Bolu bölgesinde *Polytoma cylindraceum* ilk kez Abant Gölü'nde kaydedilmiştir. Monthe Carlo permütasyon testi ile Canonical correspondence (CCA) analizine göre, türlerin dağılımında bütün çevresel değişken (örneğin, çözülmüş oksijen, konduktivite, nitrit, sıcaklık, alkalinite ve kalsiyum) türlerin dağılımında önemli bir etki ($p=0,002$) sahip olduğunu göstermiştir. Mevsimsel oluşumlarına dayanarak CCA diyagramının merkezine yakın bölgede bulunan türlerin geniş biyo-jeolojik dağılımı ile çoğu kosmopolitan karakteristiğe sahiptirler. Genel olarak, tür kompozisyonu ile çevresel değişkenler arasındaki ilişkinin % 90,5'sini CCA analizinin ilk eksenini açıklamaktadır.

Anahtar Kelimeler: Fitoplankton, Ekoloji, CCA, Fenoloji, Abant Gölü, Bolu

21 INTRODUCTION

Phytoplankton, which show variety of cell organizations in water bodies, are affected by environmental factors (John et al., 2002; Ariyadej et al., 2004; Forsström et al., 2005). Besides, they are indispensable in ecosystems with their importance as the primary producers in food webs ensuring ecological balance, phytoplankton can be useful tool for understanding water quality (Graham and Wilcox, 2000; Rakocovic-Nedovic and Hollert, 2005; Abrantes et al., 2006).

Studies concerning phytoplankton algae for water quality monitoring have shown that changes in composition reflect not only variation in water quality, but also changes in physical and chemical variables and biotic interactions. This implies the importance of biomonitoring type of studies in a variety of aquatic ecosystems. There are few studies on their ecology and seasonal occurrences of phytoplankton in Turkey. Concerning Bolu region, there are relatively few studies on phytoplankton (Obalı et al., 2002; Kılınç 2003; Atıcı et al., 2005; Çelekli and Kulköylüoğlu, 2006). These earlier works have made great contribution to not only evaluating and understanding the limnological conditions in different aquatic habitats, but also determining biodiversity of phytoplankton in Turkey. Although little attention has been given to phytoplankton species in Bolu region, the area is known with its potentially high species diversity, at least in different taxonomic groups (İkinci, 2000; Kulköylüoğlu 2003; Ünal, 2003) Therefore, the objective of this study was to analyze the relationships among phytoplankton composition, their seasonal occurrence, and environmental changes in Lake Abant (Bolu).

22 RESULTS AND DISCUSSION

22.1 Physical and chemical variables

Environmental variables were fluctuated seasonally in Lake Abant during two years. Temporal variation of dissolved oxygen (DO), water temperature and chlorophyll-a value are given in Figure 8.1. Water temperature values were ranged from minimum (1.47°C) to maximum (15.54°C) in January 2004 and August 2004, respectively, while mean values of DO were varied from 5.52 mg/l in August 2003 to 12.95 mg/l in May 2005, during present study.

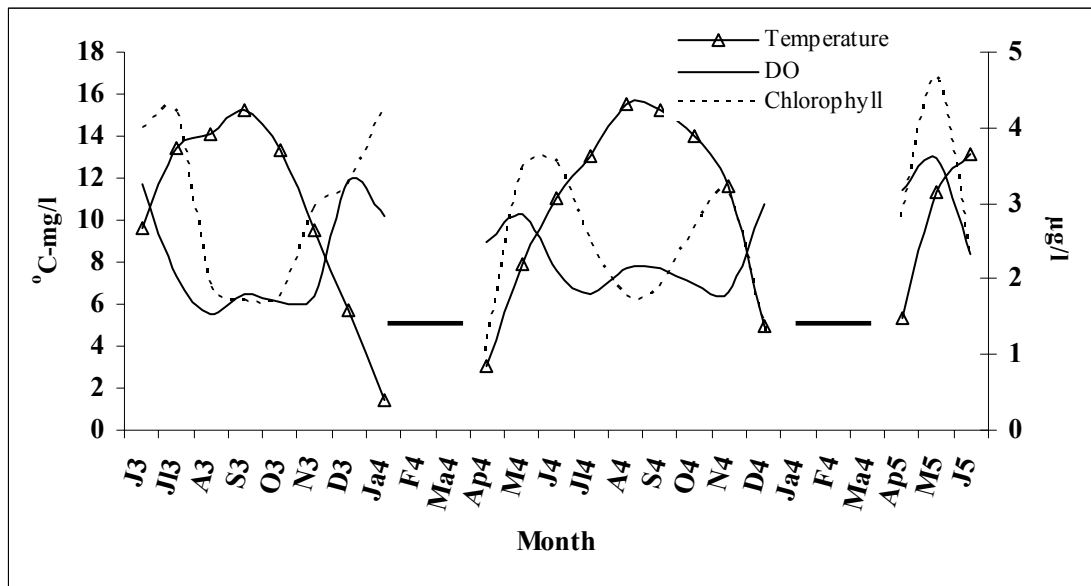


Figure 8. 1. Temporal variation of dissolved oxygen (DO), water temperature, chlorophyll-a. Mean value of variables monthly from each sampling stations are taken. (—); ice cover. Abbreviations indicate the code of each month (e.g., June (J) and August (A), respectively for each year). January-February 2004 and 2005 were not including in to the vertical data due to ice cover. Only littoral sampling was done in January 2004.

Figure 8. 1 shows a negative relationship between water temperature and dissolved oxygen that the same expected result was observed in Spearman correlation ($p < 0.01$) where a negative relationship was also seen between water and air temperatures (Table 8. 1). In the meantime, as expected, a negative correlation between DO and water temperature is showed in Table 7. 2 in part of diatoms ecology in Lake Abant. Annual mean of high chlorophyll-a concentration reached to 3.76 $\mu\text{g/l}$ at Littoral 1 (L-1) sampling station followed by Vertical II at 10 m depth (V2-10 m) station as 3.27 $\mu\text{g/l}$. There was not significant difference ($p > 0.05$) for the annual mean chlorophyll-a value among sampling stations. Phytoplankton chlorophyll-a levels were changed between 1.05 $\mu\text{g/l}$ in April 2004 and 4.55 $\mu\text{g/l}$ in May 2005. High chlorophyll-a values were usually recorded in spring and fall seasons, while this variable showed low levels in summer season. It is a consequence of increasing abundance of phytoplankton especially diatom abundance with high nutrient concentrations in fall and spring seasons (see Figure 6. 4I). Other non-diatom phytoplankton abundance was increased especially in spring season (Figure 8. 2). Increased DO levels can be related to high photosynthetic rate with increasing phytoplankton abundance. In Figure 8. 1, changing in DO levels is shown with similar variation of chlorophyll-a values. However, there was no significant correlation between DO and amount of chlorophyll-a in Lake Abant during two years (Table 8 1).

Chemical component was increased in spring and fall seasons, while it was decreased in summer season with stable thermal stratification in Lake Abant. For example, phosphate (P-PO_4) concentration fluctuated between minimum level in August 2004 and maximum value in spring months such as April, May 2005. There was a negative correlation between water temperature and phosphate values,

however, this correlation is not significant level ($p>0.05$). Indeed, high nutrient concentrations supported maximum total abundance, chlorophyll-a and DO values in May 2005. On the other hand, during thermal stratification (see Figure 6. 1) in summer season, low phosphate values were found at epilimnion layer. In this layer, high assimilation rate of flagellated phytoplankton can probably have intense affect on depletion of phosphate with suitable light intensity and water temperature. Additionally, during this study, high phosphate concentrations in deep water were likely the consequence of decomposition processes, with non-living organisms, and loading organic materials sinking to lake sedimentation (Horne and Goldman, 1994). Decomposition process can affect biological oxygen demand (BOD_5) levels, which usually increased in spring and early summer seasons and decreased again in the following summer season. With melting snow increased organic loading into lake and increasing water temperature, not only photosynthesis rate in suitable conditions can affect this variables changes, but also, BOD_5 concentrations are influenced by grazing and aerobic decomposition rate due to high decomposer-preys rate, and suitable temperature and DO levels. This nutrient cycle is important in phytoplankton seasonal succession (Kalchev et al., 2000; Forsström et al., 2005; Abrantes et al., 2006). In summer season, low BOD level at epilimnion layer was affected by low aerobic decomposer process rate with low organic material due to thermal stratification. So, turbidity was recorded as minimum level and clear zone showed in this layer. Indeed, the lowest Secchi depth (2.7 m) was recorded in June 2004, while the highest transparency was observed in August 2004 with 6.74 m. Rott and colleagues (2003) stated that BOD_5 which showed a relationship with diatom abundance, are used to understanding saprobic water quality of water bodies. Indeed, high BOD_5 values were recorded in spring season, when diatom abundance showed

high level in Lake Abant, where phytoplankton composition especially diatom assemblages showed an important increase along with high nutrient concentrations in spring season. As mentioned above, maximum phosphate concentration was measured in spring season, where factors such as a complete water homogenization, high phytoplankton abundance, and soil erosion might have caused an increase of water turbidity. Eventually, such factors can affect the water transparency. Secchi depth was increased in summer season during thermal stratification (Hinder et al., 1999).

According to Spearman correlation, most of physico-chemical variables showed significant correlations (Table 8. 1). There was present significant correlation ($p<0.05$) between Si and rainfall. Value of silica was increased in spring and fall seasons, and supported abundance of diatom showed peaks. Number of phytoplankton species was a) positively correlated to water temperature ($p<0.001$), magnesium ($p<0.05$) and Secchi depth (SD) ($p<0.05$), while it was b) negatively correlated to DO ($p<0.05$), electrical conductivity (EC) ($p<0.05$), chlorophyll-a ($p<0.05$), and BOD ($p<0.05$). Earlier study by Jamu and colleagues (1999) in ponds reported significant relationship between SD and chlorophyll. Water temperature had important influence on the number of phytoplankton taxa seasonally. The lowest number species was recorded as 22 taxa in January 2004. Mean species richness was increased in water with high temperature, while abundance of phytoplankton showed an important decreasing in summer season. Abundance and species richness of phytoplankton are clearly given in Figure 8. 2. There was a negative relationship between abundance and richness of phytoplankton due to a few species increased its individuals number and to be dominant taxa.

Table 8. 1. Correlation matrix for monthly averages of environmental variables and number of phytoplankton species (Spp) from Lake Abant. Abbreviations are given in Table 6. 2. (*) Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

	Temp	DO	pH	Eh	EC	Chlo	BOD ₅	Turb	SD	PO ₄	NO ₂	NO ₃	NH ₄	SO ₄	Ca	Mg	Cl	Alk	Si	Spp
Temp	1.00																			
DO	-.559*	1.00																		
pH	.296	-.457*	1.00																	
Eh	-.332	.496*	-.958**	1.00																
EC	.084	.126	.032	.024	1.00															
Chlo	-.287	.352	-.018	-.059	.257	1.00														
BOD₅	-.383	.865**	-.317	.368	.135	.296	1.00													
Turbi	-.232	.068	-.355	.359	-.242	-.047	.092	1.00												
SD	.674**	-.384	.330	-.405	-.374	-.396	-.246	-.168	1.00											
PO₄	-.071	.024	-.382	.356	.065	-.015	.026	.206	-.171	1.00										
NO₂	.297	-.356	-.147	.006	-.347	-.194	-.129	.432	.243	.532*	1.00									
NO₃	.140	-.420	.378	-.427	-.259	-.091	-.755**	-.434	.056	-.168	-.133	1.00								
NH₄	.432	-.043	-.639*	.650**	.118	-.375	.196	.389	.341	.336	.514*	-.643*	1.00							
SO₄	.121	-.305	.253	-.165	.420	-.213	-.178	-.073	-.445	-.068	.240	.210	-.033	1.00						
Ca	.064	-.178	.840**	-.705*	.199	-.075	-.267	-.498	-.306	-.434	-.235	.541	-.680*	.847**	1.00					
Mg	.250	-.571	.250	-.679	-.679	-.321	-.929**	.500	.786*	-.107	.536	.786*	-.321	-.036	.099	1.00				
Cl	-.090	-.292	.323	-.380	.134	.191	-.301	.042	-.555*	-.182	-.099	.497	-.415	.582*	.740**	.179	1.00			
Alkali	-.175	-.068	.519*	-.366	.303	.139	-.184	-.292	-.533*	-.423	-.524*	.381	-.512	.578*	.815**	-.453	.793**	1.00		
Si	-.333	-.127	-.152	.200	.224	.576	.152	.115	-.564	.333	.139	-.309	.103	.430	.113	-.643	.358	.300	1.00	
Spp	.606**	-.535*	.228	-.251	-.555*	-.472*	-.559*	.062	.571*	-.200	.265	.448	-.021	.037	.182	.857*	.055	-.045	-.515	1.00

22.2 Phytoplankton (except Bacillariophyta) density

Sixty-six phytoplankton species belonging to 46 genera were recorded in Lake Abant. Total abundance of genera fluctuated from 1.07 colony/ml of *Sorastrum americanum* to 42769.5 cell/ml of *Dinobryon* taxa. Accordingly, *Dinobryon* was the most abundant genus in Lake Abant during study period.

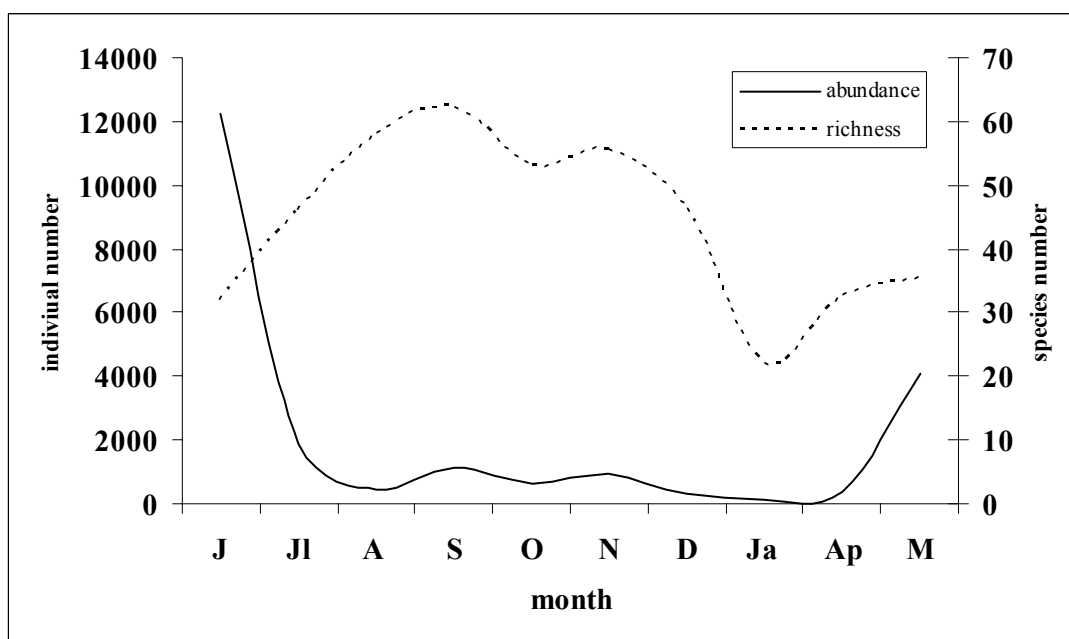


Figure 8. 2. Abundance of phytoplankton taxa and genera with number of species were recorded in Lake Abant. Abbreviations are given in Figure 8. 1. Superimposed data for each month are taken. Data was not included between February to March 2004 and 2005 due to ice cover.

In June, total abundance of phytoplankton showed maximum level and then it decreased due to increasing water temperature and decreasing nutrient concentration with thermal stratification (Figure 8. 2). Individual's number of species slowly increased during fall season and again a decreasing in total abundance of phytoplankton was found during winter months. After that phytoplankton abundance began to increase in April, after snow melting, water temperature increased, and

nutrient value showed high concentration. Members of Chrysophyta had great contribution to increasing total abundance in spring season due to silica value. Member of this group consist of siliceous cyst (Hutchinson, 1967; Horne and Goldman, 1994).

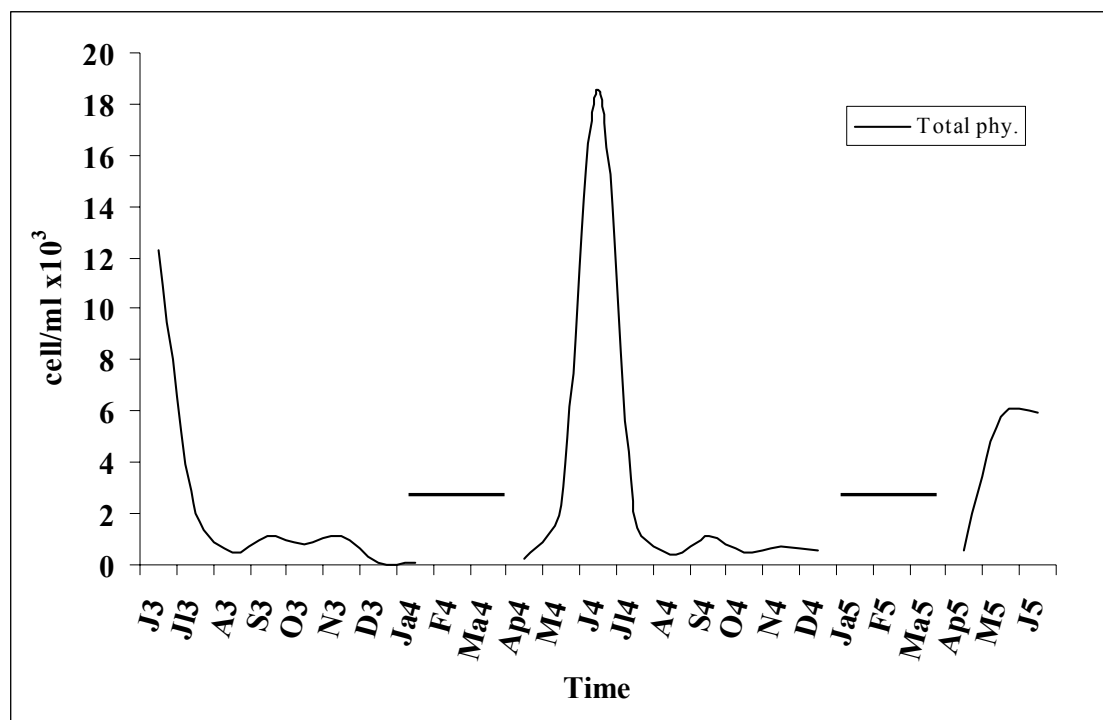


Figure 8. 3. Total abundance of phytoplankton composition was detected from Lake Abant during two years. Abbreviations are given in Figure 8. 1. (—) ice cover.

Total abundance of phytoplankton (except diatoms) is given in Figure 8. 3. During present study, three peaks of phytoplankton were found and data was not including in February, March 2004 and January-March 2005 because of ice cover. The highest peak of abundance (18.52×10^3 cu/ml) was recorded in spring season especially in June 2004 (Figure 8. 3). A few species belonging to *Dinobryon* have the greatest contribution to total abundance in Lake Abant (Figure 8. 3, Table 8. 2). These high phytoplankton abundances in spring seasons sharply decreased from July to August for both years. It is possibly the outcome of stable thermal stratification occurrence. Lake Abant water was completely mixed in November (see Figure 6. 1), although,

total abundance not showed any increase. It is consequence of not only affected by decreasing water temperature, but also too low light intensity.

Microcystis aeruginosa was usually counted only in June and November 2003, and June and July 2004, during which the species seems to prefer nutrient rich water as indicated earlier from eutrophic lakes (Hutchinson, 1967; Wetzel, 1975; Abrantes et al., 2006). In Bolu region, this taxon was recorded from eutrophic Lake Yeniçağa (Kılınç, 2003; Saygı-Başbuğ, 2004), in Lake Abant (Atıcı and Obalı, 2002; Obalı et al., 2002), in Lake Gököy and not detected in karstic Akkaya Spring (Çelekli and Kulköylüoğlu, 2006).

Members of *Ankistrodesmus*, which were commonly distributed each month in the lake, had high abundance in fall season. John and colleagues (2002) pointed out that species of *Ankistrodesmus* such as *A. falcatus* are cosmopolitan, widely distributed, and have a broad tolerance range to environmental changes, usually preferring high nutrient water. In recent studies in Bolu region, the species was not recorded in phytoplankton community from this lake (Atıcı and Obalı, 2002; Obalı et al., 2002). It may be affected a series of reasons such as changing water quality, different sampling time and stations. *A. falcatus* species in Bolu area is not only found in Lake Abant, but also it is distributed in Lake Gököy, in Lake Yeniçağa (Kılınç, 2003).

Total abundance of species and genera are given with their organization types in Table 8. 2. *Dinobryon*, which was the most abundant genera with 42769.48 cu/ml, was followed by *Trachelomonas* with 2802.58 cu/ml. *Dinobryon divergens* was the most abundant species among the other members of this genus. This species is of a widespread distribution reported from moderately to very nutrient rich lakes (John et al., 2002).

Table 8. 2. Abundance of phytoplankton genera were recorded in Lake Abant during 20 months. Abbreviations indicate the code of organism's type (counting unit includes; c; cell, co; colony, and f; filament). Phytoplankton abundances were determined according to these types of organisms.

Taxon	Total number	counting unit
<i>Dinobryon</i>	42769.48	c
<i>Trachelomonas</i>	2802.58	c
<i>Scenedesmus</i>	1885.18	c
<i>Chlamydomonas</i>	1831.78	c
<i>Cryptomonas</i>	1081.64	c
<i>Plageaselmis nannoplanctonica</i>	791.48	c
<i>Oocystis</i>	698.95	c
<i>Peridinium willei</i>	572.46	c
<i>Pseudosphaerocystis lacustris</i>	549.63	c
<i>Tetrastrum komarekii</i>	465.69	c
<i>Ankistrodesmus</i>	406.01	c
<i>Snowella lacustris</i>	345.55	co
<i>Golenkina radiata</i>	308.98	c
<i>Elakototrix gelatinosa</i>	248.64	c
<i>Anabaena</i>	245.00	c
<i>Gymnodium cnecoides</i>	156.85	c
<i>Tetraselmis cordiformis</i>	134.29	c
<i>Eudorina elegans</i>	126.00	c
<i>Staurastum armigerum</i>	99.83	c
<i>Oscillatoria</i>	87.29	f
<i>Mougeotia</i>	79.17	c
<i>Pandorina morum</i>	73.00	c
<i>Nephrocytium agardhianum</i>	72.00	c
<i>Radiococcus planktonicus</i>	68.48	c
<i>Uroglena volvox</i>	58.57	co
<i>Ceratium</i>	56.41	c

Table 8. 2 (continued).

Taxon	Total number	counting unit
<i>Botryococcus braunii</i>	55.59	co
<i>Zygnema conspicuum</i>	55.31	c
<i>Synura peterseni</i>	43.49	co
<i>Peridiniopsis thompsonii</i>	40.74	c
<i>Spirogyra</i>	35.54	c
<i>Kirchneriella obesa</i>	34.07	c
<i>Cosmarium</i>	32.40	c
<i>Pediastrum</i>	29.00	c
<i>Geminella</i> sp.	26.25	c
<i>Euglena</i>	23.76	c
<i>Korshikoviella michailovskoensis</i>	20.33	c
<i>Bulbothece</i> sp	14.73	c
<i>Microcystis aeruginosa</i>	10.34	co
<i>Phacus</i>	10.31	c
<i>Chondrosphaera lapponica</i>	7.54	c
<i>Closterium aciculare</i>	7.39	c
<i>Merismopedia tenuissima</i>	6.31	co
<i>Pseudoanabaena</i> sp.	1.47	f
<i>Sorastrum americanum</i>	1.07	co
<i>Spirulina maior</i>	0.96	f

On other hand, *Trachelomonas volvocina* was commonly counted in abundance of phytoplankton. Similarly, this species is stated as cosmopolitan, widely distributed in lakes, ditches, peat bogs and waste water, and indicators of heavily polluted water (John et al., 2002). The species is also known with its widespread distribution in different water bodies of Europe (Kalchev et al., 2000; Danilov and Ekelund, 2001; John et al., 2002; Pongswat et al, 2004), and in Turkey (Gönülol et al., 1996; Kılınç, 2003; Maraşlıoğlu et al., 2005). Another highly abundant genus was *Scenedesmus*,

which was commonly recorded each month during the present study, especially showed high abundance in fall season. A few species of this genus such as *S. communis*, and *S. ellipticus* had great contribution to the total abundance of *Scenedesmus*. John and colleagues (2002) stated that both taxa are cosmopolitan and prefer moderately polluted water. Indeed, both taxa showed high abundance with increasing nutrient concentrations in fall season during this study.

As stated above most phytoplankton taxa are not only commonly distributed in European lakes (John et al., 2002), but also generally found in almost all types of water bodies such as lakes, marshes, and ponds in Turkey (Gönülol and Obalı, 1998; Obalı et al., 2002).

22.3 Net-Phytoplankton Composition

In the whole study period we identify a total of 162 taxa, belonging to 69 genera, most of which are concerned in Chlorophyta with 39 genera found between June 2003 and June 2005. This group is followed by Cyanoprokaryota with 23 taxa and 8.1 % of total non-diatom phytoplankton. Increasing percentages of blue green algae can give important information about of water quality. During the present study, blue green algae mostly distributed in late summer and fall seasons, while they were not recorded in January 2004. Abrantes and colleagues (2006) studied in Lake Vela, a polymictic, shallow eutrophic lake in Portugal. In their study, Cyanoprokaryota were recorded as dominant group in longer (spring-summer) period of time. Other following group Euglanophyta was distributed in late summer and fall seasons. Most members of Cyanoprokaryota and Euglanophyta were recorded fall seasons in this lake, where they well survive in nutrient rich waters (John et al., 2002; Ariyadej et al., 2004; Abrantes et al., 2006). These reports correspond with the findings of present study.

Some species such as *Trachelomonas volvocina*, *Cryptomonas ovata*, and *Ceratium hirundinella*, which showed frequent occurrence in about each month in Lake Abant, may suggest a wide range of tolerance level to the conditions (Danilov and Ekelund, 2001). Identified most taxa in this study are commonly distributed in different parts of Turkey (Gönülol et al. 1996). In general, these taxa usually prefer moderately nutrient rich waters (John et al., 2002). Hutchinson (1967) reported that most members of *Ceratium* are mesotrophic dinoflagellate plankton, while *Peridinium willei*, *P. cinctum* was eutrophic dinoflagellate in lakes. Actually, *C. hirundinella* was commonly distributed, and recorded almost about each sampling month, while *P. willei* was found sometimes in sampling stations during study. In one of the earlier study in Lake Abant, *T. volvocina* (see Figure 3. 1 i) and *C. hirundinella* were recorded each month, while algae flora were not include *Peridinium willei* (Obalı et al., 2002). Regularly found species *Staurastrum polymorphum* (but now it is called *S. gracile*) (Obalı et al., 2002) were not frequently detected in our study. This species was usually recorded in fall season in Lake Abant. John and colleagues (2002) pointed out that *S. gracile* is commonly distributed and found in moderately nutrient rich ponds and lakes. In the present study, many taxa (e.g., species of *Anabaena*, *Closterium*, *Euglena*, *Microcystis*, *Oscillatoria*, *Trachelomonas*, *Eudorina*, *Pandorina*, *Pediastrum* etc.) apparently tend to prefer from moderately to high nutrient rich waters: however, some species such as *Staurastrum armigerum* fo. *furcigerum*, *Cosmarium bioculatum*, and *C. meneghinii* can usually be found in oligotrophic lakes. Among the species, for example, *Anabaena*, *Closterium*, *Oscillatoria*, *Trachelomonas*, *Eudorina*, and *Pandorina* were recorded in a shallow eutrophic (Lake Yeniçağa, Bolu) (Kılınç, 2003; Saygı-Başbuğ and Demirkalp, 2004). With the present study, phytoplankton compositions have

great contribution to algae flora of Lake Abant due to high number of algae taxa. Several other net-phytoplankton taxa (e.g., *Chlamydomonas passiva*, *Cosmarium botrytis*, *Nephrocytium limneticum*, *Oocystis marssonii*, *Polytoma cylindraceum* etc.) were to be added to the algae flora of Lake Abant. *P. cylindraceum* firstly recorded Lake Gök  y and later in Lake Abant in Bolu area.

22.4 Phytoplankton-environment relation with CCA

During present study, net phytoplankton composition was apparently affected by environmental factors. Detrended correspondence analysis (DCA) was used to determine the gradient length of the phytoplankton community. The linear or non-linear (unimodel) response model of phytoplankton to environmental axes can be examined before performing CCA (ter Braak 1995; Leps and Smilauer 2003). DCA ordination showed good dispersion of phytoplankton species on the axes (Figure 8 4). DCA results provide high gradient length as 6.31 for 162 phytoplankton species data. In DCA ordination, $\lambda_1=0.456$ for axis 1 and $\lambda_2= 0.299$ for axis 2 with their ratio 1.53 explained 4.2 % of cumulative variance in species data (Table 8. 4). Almost all the gradient length for all axes was found with a high level but low variance of species data. These results showed that phytoplankton composition unimodal perform to environmental variables during present study (Leps and Smilauer, 2003).

Table 8. 3. Main results of DCA with 162 phytoplankton species given values.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.456	0.299	0.262	0.241	10.819
Lengths of gradient	6.311	3.334	2.968	4.148	
Species-environment correlations	0.821	0.645	0.707	0.513	
Cumulative percentage variance					
of species data	4.2	7.0	9.4	11.6	
of species-environment relation	13.6	20.0	0.0	0.0	
Sum of all eigenvalues					10.819
Sum of all canonical eigenvalues					1.994

The convince length of gradient in DCA result (Table 8. 3) serves as a lead for CCA (Leps and Smilauer, 2003). CCA analysis was used to explain relationship between diatom abundance and environmental variables. In this analysis, 162 net-phytoplankton species and 18 physical-chemical variables are used (Figure 8. 5).

In the present study, Monte Carlo permutation test with unconstrained permutations was used to test if there is no effect of the environmental variables on phytoplankton species. Result of forward selection with Monte Carlo permutation test (499 unrestricted permutations) showed that both first two axes were highly significant ($p=0.002$).

Table 8. 4. Main results of canonical correspondence analysis (CCA) with using Monte Carlo permutation test for 162 net-phytoplankton species.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.328	0.215	0.186	0.150	10.819
Species-environment correlations	0.905	0.868	0.852	0.779	
Cumulative percentage variance					
of species data	3.0	5.0	6.7	8.1	
of species-environment relation:	16.5	27.3	36.6	44.1	
Sum of all eigenvalues					10.819
Sum of all canonical eigenvalues					1.994
Test of significance of first canonical axis: eigenvalue =	0.328				
P-value = 0.0020	F-ratio = 5.821				

Results of CCA showed that the first and second axes are very well correlated. Both axes of CCA explained as 90.5 % and 86.8 % the relationship between environmental data with very low cumulative percentage variance of species. Correlations for other axes are again important levels with low variances (Table 8. 4). Earlier studies were reported that high relationship was found between phytoplankton community and environmental variables as 0.96 for axis 1 in Spanish salt lakes (Reed, 1998), 0.95 for axis 1 in 18 sites of lowland river in Portugal (de Almeida and Gil, 2001), 0.96 for axis one in 49 lakes and Yangtze River in China (Yang et al., 2005), 0.954 for axis 1 in Lake Vela in Portugal (Abrantes et al., 2006) and 0.97 for axis 1 in Akkaya spring in Turkey (Çelekli and Külköylüoğlu, 2006). These high correlations suggest how phytoplankton taxa are directly affected by environmental variables; therefore, algae are very important for understanding, controlling, and management water quality of different aquatic habitats.

Selected 18 environmental variables were tested by Monte Carlo permutation test (499 unrestricted permutations) to determine if environmental influence on species distribution is significant or not. Results of this test showed that phytoplankton composition is directly reflected with its environmental factors. All physical and chemical variables significantly ($p=0.002$) affected distribution of phytoplankton taxa. Additionally, factors such as Mg^{2+} , DO, EC, NO_2 , alkalinity, and Eh are the most significant ($p<0.01$) factors on the distributions and occurrences of phytoplankton composition. The high significant value of factors on distribution of phytoplankton taxa was explained very high levels (Table 8. 5).

Table 8. 5. Results of CCA ordination test along with forward selection of Monte Carlo permutation test shows forward selected environmental variables during 20 months. Total of 220 bits of data is used in this analysis.

Environmental Variables	Explained %	p	F
Mg^{2+}	228	0.002	4.374
DO	194	0.002	3.697
EC	191	0.002	3.654
NO_2	178	0.002	3.395
Alkalinity	172	0.002	3.288
Eh	172	0.002	3.270
pH	161	0.002	3.076
Ca^{2+}	157	0.002	2.983
Temperature	154	0.002	2.922
Silica	139	0.002	2.633
NH_4	116	0.002	2.197
Turbidity	98	0.002	1.857
PO_4	89	0.002	1.678

In CCA ordination, arrow of DO is closely related spring and early summer month especially May 2005 (the highest DO value), while temperature arrow is opposite of DO in July 2003 and August 2004, which is found almost in the center of CCA

ordination. It is possibly a consequence of usually increasing in values of physical and chemical variables (e.g., detected the highest level of temperature, NO₃, and alkalinity). Similarly, arrow of pH was related the first year months especially July 2003 (the highest pH) of present study. Negative relationship between pH and Eh is clearly showed in Figure 8. 5 (O'Neil, 1993). Nitrite arrow was closely related fall months of 2004 (the highest level NO₂ in October 2004). Arrows of nutrients were close to spring, early summer and fall seasons. Frequently distributed taxa such as *Trachelomonas volvocina*, *Ceratium hirundinella*, and *Cryptomonas ovata* which were found closer to center of CCA ordination (Figure 8. 5), seem to prefer moderately nutrient rich water in different aquatic habitats (Horne and Goldman, 1994; Gönülol et al., 1996; John et al., 2002; Wehr and Sheath, 2003). Other species of *Ceratium* such as *C. cornutum* and *C. furcoides* were closely related to arrow of nitrite nearby the fall season of 2004, accompanied by *Cyanoprokaryota* (e.g., *Anabaena planctonica*, *Chroococcus turgidus*, and *Phormidium* sp.), *Chlorophyta* (e.g., *Ankistrodesmus spiralis*, *Pediastrum dublex*, *Peridinium cinctum*, *Cosmarium botrytis*, and a few species of *Mougeotia* (closer center of CCA ordination)). John and colleagues (2002) reported that *C. furcoides* prefers moderately nutrient rich lakes; *C. cornutum* is found in low temperature with adequate nutrition, while others prefer usually nutrient rich waters, and cosmopolitan taxa. On the other hand, a few blue green algae such as *Spirulina subsalsa*, *Pseudoanabeana* sp. were detected in 2003, again fall season. The members of Cryptophyta were together in a group, related arrows of nutrients and distributed both fall and spring seasons. *C. ovata* was commonly distributed in this group, close related arrow of NH₄. Chrysophyta species such as *Dinobryon sertularia*, *Uroglena volvox*, and *Synura peterseni* were commonly found in spring 2004, and usually closer to Si arrow. It is known that this

group include silica cyst. However, *Dinobryon divergens* was distributed opposite of silica arrow in closer to September 2003. *Dinobryon sertularia* was accompanied by high nutrient requirement taxa in spring and early summer seasons. Some species of genera (e.g., *Scenedesmus*, *Spirogyra*, *Cryptomonas*, and *Dinobryon*) occurred together in groups. *Stauastrum armigerum* fo. *furcigerum*, which was found in the reverse side of nutrient arrow, is known to be widely distributed from nutrient poor to moderately nutrient rich waters. Result of CCA showed that environmental variables especially DO, EC and NO₂ played important role on the distribution of phytoplankton species.

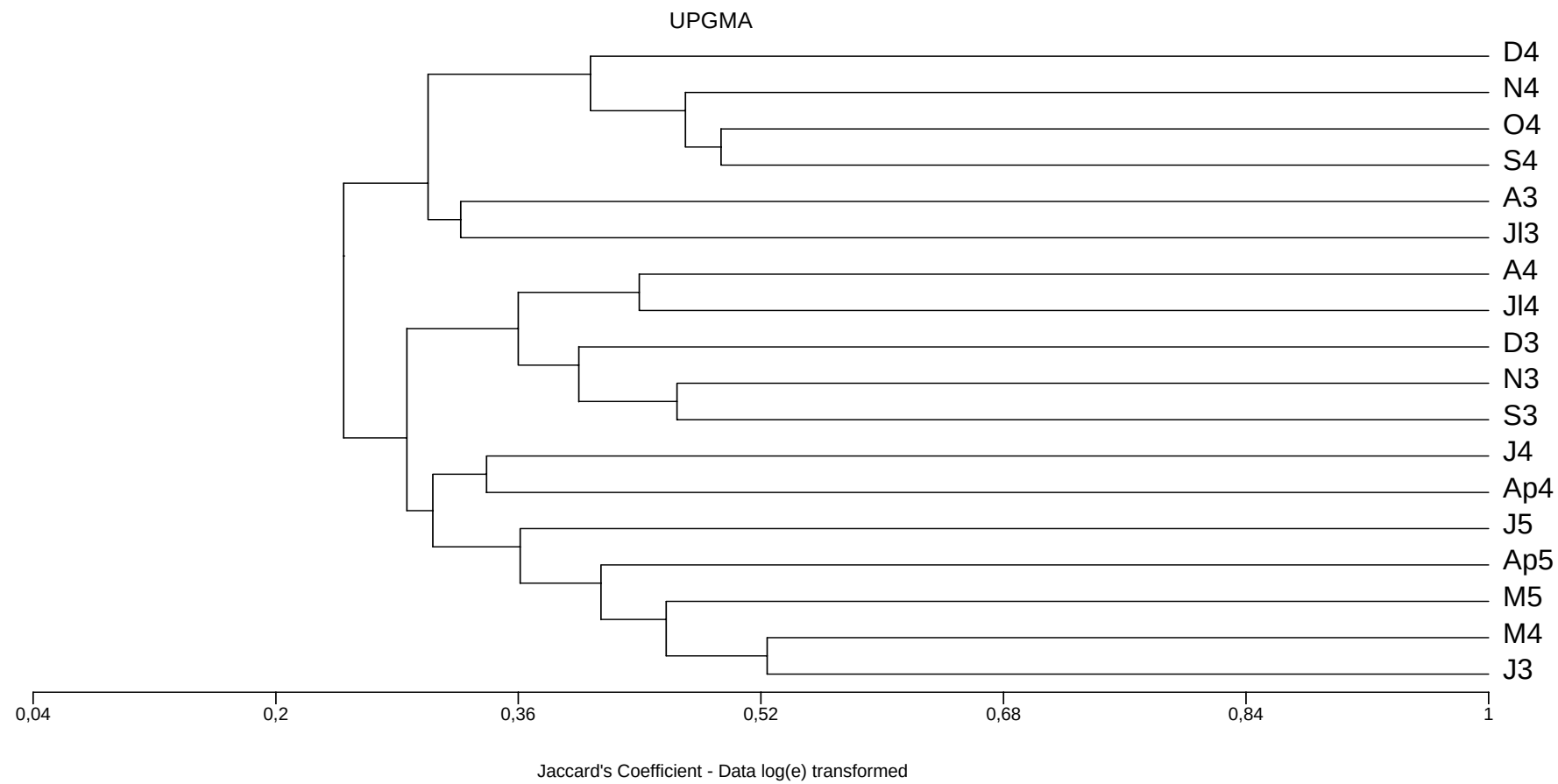


Figure 8. 6 UPGMA dendrogram shows sampling months in Lake Abant. Abbreviation is given in Figure 8. 1.

During present study, UPGMA dendrogram revealed clear five distinct groups among sampling months based on phytoplankton (except Bacillariophyceae) phenology (Figure 8. 6). In Lake Abant, some phytoplankton taxa (e.g., *T. volvocina*, *C. ovata*, and *C. hirundinella*), which showed frequent occurrence in about each month, may suggest a wide range of tolerance level to the conditions (Danilov and Ekelund, 2001), while some species such as *Anabaena crassa*, *Euglena granulata*, *Closterium littorale*, and *Pediastrum boryanum* were rarely recorded during present study. Occurrence of phytoplankton affected by environmental variables cause clustering of sampling months with using UPGMA. The first group consist of four months, three of them related fall 2004 and other is December 2004 (Figure 8. 6). Result of CCA (Figure 8. 5) supported this together of months in a group. CCA was not only showed this group, but also revealed relationship between this group's months and nitrite. Usually, some phytoplankton taxa (e.g., *C. hirundinella*, *C. furcoides*, and a few species of *Spirogyra*), which prefer moderately nutrient enriched water bodies (John et al., 2002), were closer the arrow of NO₂ in CCA ordination (Figure 8. 5). The second and third groups included summer months. Similarly, this result was supported by outcome of CCA. Fourth group was similar group one, included fall and early winter months 2003 (Figure 8. 6). CCA ordination showed that this group was closely related arrow of pH. The last group included seven months, related spring and early summer seasons. Cosmopolitan phytoplankton taxa, which were recorded in these months. The last group which clearly showed in CCA ordination (Figure 8. 5), was closely related arrows of DO and nutrients and EC.

23 CONCLUSION

In the present study, phytoplankton composition including 162 taxa was shown to be closely associated with the temporal variation of environmental variables. Lake Abant water showed dimictic characteristic with annual one thermal stratification during summer season. Both thermal stratification and completely homogenization of lake water can influence nutrient concentrations and distribution, and occurrence of phytoplankton composition, as well. In spring and fall seasons, high nutrient concentrations recorded and have great contribution on the abundance of phytoplankton.

Total phytoplankton abundance showed seasonal variation, and the highest number recorded in spring seasons of both years. *Dinobryon* was the most abundance genera in this lake. Lake Abant had high diverse phytoplankton taxa with a total of 162 net phytoplankton species described during present study time. Cyanoprokaryota recorded as second dominant group in phytoplankton composition. *Trachelomonas volvocina*, *Cryptomonas ovata*, and *Ceratium hirundinella*, which showed frequent occurrence in about each month in Lake Abant, may suggest a wide range of tolerance to nutrient concentrations.

Phytoplankton composition showed a high gradient length with 82.1 % of environmental-species correlation for axis one in DCA analysis. The relationship between environmental variables and phytoplankton composition explained as 90.5 % with relatively low species variance for axis one in CCA analysis. According to CCA diagram, almost all physico-chemical factors (especially, DO, EC, and NO₂ were the most influential factors) were significantly ($p < 0.01$) important on distribution of phytoplankton taxa. Distribution of phytoplankton composition

showed seasonality in CCA ordination diagram. Results of the present study clearly demonstrated that phytoplankton composition was distributed continuously along gradients of environmental factors. Finding of CCA clearly supported result of UPGMA.

Phytoplankton species were directly affected by changing environmental factors. This view is an important tool for biomonitoring studies especially for understanding the state of Lake Abant in future. Therefore, ecological data with organisms composition especially phytoplankton composition for long time sampling are useful for understanding water quality assessment. The findings of the present study have, therefore, an important contribution to not only the current physical and chemical conditions of the lake, but also the future conditions as well.

Part D

ABSTRACT

PHYTOPLANKTON (EXCEPT BACILLARIOPHYTA) COMPOSITION AND ITS RELATIONSHIP TO PHYSICO-CHEMICAL FACTORS IN LAKE GÖLKÖY (BOLU)

Phytoplankton composition and their relationship to environmental variables were studied monthly in Lake Gököy from June 2003 to June 2005. Phytoplankton abundance was increased in late spring, early summer and the fall. Some net species (e.g., *Cryptomonas ovata*, *Dinobryon divergens*, *Oscillatoria limosa*, *Pandorina morum*, *Peridinium willei* and *Ceratium hirundinella*) were commonly recorded almost all year around during our study. Water of Lake Gököy showed completely homogenization from the fall to the spring and thermal stratification took place in the summer. Most of the environmental variables (e.g., calcium, chloride, magnesium, sulphate, and pH) played significant ($p=0.002$) role on the species distribution in Monte Carlo permutation test. Many phytoplankton taxa found closer to the center of CCA ordination have cosmopolitan characteristics. Overall, the first axis of CCA explained 88.6 % of the relationship between species composition and environmental variables.

Keywords: Phytoplankton; Ecology; CCA; Phenology; Lake Gököy; Bolu

ÖZET

GÖLKÖY GÖLÜ (BOLU) FİTOPLANKTON (BACILLARIOPHYTA HARİÇ) KOMPOSİZYONU VE FİZİKO-KİMYASAL FAKTÖRLER İLE İLİŞKİSİ

Gölköy Gölü'nde fitoplankton kompozisyonu ve çevresel değişkenler ile ilişkisi aylık olarak Haziran 2003'ten Haziran 2005'e kadar çalışılmıştır. Fitoplankton zenginliği ilkbahar sonunda, yaz başında ve sonbaharda artmıştır. Bu göldeki bazı net türler (örneğin, *Cryptomonas ovata*, *Dinobryon divergens*, *Oscillatoria limosa*, *Pandorina morum*, *Peridinium willei* ve *Ceratium hirundinella*) yaklaşık olarak bütün yıl süresince kaydedilmiştir. Gölköy Gölü suyu sonbahardan ilkbahara kadar tamamen karışım göstermiş ve sıcaklık tabakalaşması yazın olmuştur. Monte Carlo permütasyon testinde, çevresel değişkenlerin çoğu (örn., kalsiyum, klor, magnezyum, sülfat ve pH) türlerin dağılımı üzerine önemli bir role ($p=0.002$) oynamıştır. CCA diyagramının merkezine yakın bölgede bulunan türlerin çoğu kosmoplitan karakteristiğe sahiptirler. Genel olarak, tür kompozisyonu ile çevresel değişkenler arasındaki ilişkinin % 88,6'sını CCA analizinin ilk eksenini açıklamaktadır.

Anahtar Kelimeler: Diyatome, Ekoloji, CCA, Fenoloji, Gölköy Gölü, Bolu

24 INTRODUCTION

Phytoplankton dynamics in a variety of freshwater ecosystems are affected by complex interactions among phytoplankton, zooplankton and other processes in food web, as well as variety of environmental factors (Graham and Wilcox, 2000; Buzzi, 2002; Wehr and Sheath 2003; Pongswat et al. 2004). Besides, they are indispensable in ecosystems with their importance as the primary producers in food webs, and can be useful for understanding water quality (Wetzel 1975; Rakocovic-Nedovic and Hollert, 2005; Abrantes et al., 2006).

In Turkey, pioneering limnological studies were carried out by (Geldiay, 1949) in Çubuk-1 Reservoir, (Tanyolaç and Karabatak, 1974) in Lake Mogan, and (Aykulu and Obalı, 1981) in Kurtboğazı Reservoir. Limnological studies concerning algae have gained momentum with these researches in Turkey; however, they are not yet reached to an acceptable level. Bolu area has many different aquatic habitats such as lakes, reservoirs, ponds, creeks, and springs. However, relatively few studies on phytoplankton have been carried out for the last four years in the area including Lake Abant (Obalı et al., 2002; Çelekli and Külköylüoğlu, 2006), Lake Gököy (Çelekli, in press), Lake Yeniçağa (Kılınç, 2003; Saygı-Başbuğ and Demirkalp, 2004), and Akkaya Spring (Çelekli and Külköylüoğlu, 2006). Furthermore, many different aquatic habitats are still awaiting future studies. For example, until the present study, nothing was known about the non diatom phytoplankton of Lake Gököy, which is one of the largest reservoir lakes in the city of Bolu. Hence, the present study aimed to investigate net phytoplankton (except diatoms) species composition and their seasonal occurrences along with ecological characteristics in Lake Gököy during two years.

25 RESULTS AND DISCUSSION

25.1 Physical and chemical variables

Environmental variables were fluctuated seasonally in Lake Gök  y during two years; however, there was no significant difference ($p>0.05$) among physical and chemical changes in seasons. Information and explanations about physical and chemical variables are already given in Part B of Chapter II.

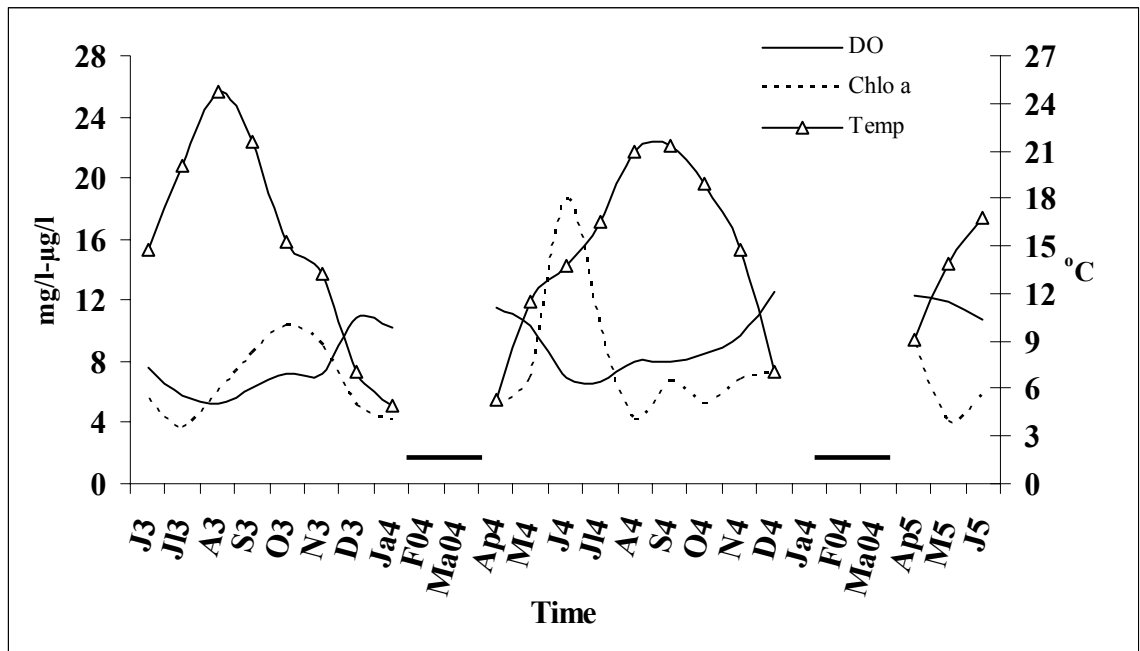


Figure 9. 1. Temporal variation of dissolved oxygen (DO), water temperature, chlorophyll-a. Mean value of variables monthly from each sampling stations are taken. (—) ice cover. Abbreviations indicate the code of each month (e.g., June (J) and August (A), respectively for each year). January-February 2004 and 2005 were not including vertical data due to ice cover. Only littoral sampling was done in January 2004.

Temporal variation of dissolved oxygen (DO), water temperature and chlorophyll-a values are given in Figure 9.1. Water temperature values, which were positively affected by air temperature fluctuations, were ranged between 4.93   C January 2004

and 24.75 °C in August 2004. On the contrary, DO concentrations were varied from 5.30 mg/l in summer 2003 to 12.54 mg/l in spring 2005 during study period (Figure 9. 1). Likely, Lake Vela in Portugal showed about similar variation of DO (Abrantes et al., 2006); however, it had higher temperature levels comparing in Lake Gök  y. Oxygen depletions were recorded in July 2003 and 2004, and August 2004 in Lake G  lk  y, while in Lake Vela, it occurred in May, and responded to large fish kill. On the other hand, fish kill was not detected in Lake G  lk  y. In the spring of the year 2004, DO concentration increased, when water temperature showed an increasing in Lake G  lk  y. Usually, there is a reverse relationship between these two variables, but in this case, it is a consequence of high assimilation rate with phytoplankton especially diatoms organisms. Indeed, phytoplankton abundance (Figure 9. 2) especially diatom abundance (see Figure 7. 2) showed counting peaks with high density. During present research, high chlorophyll-a concentrations were recorded in fall and spring seasons. This is probably due to increasing abundance of phytoplankton especially diatom abundance with high nutrient concentrations in fall and spring seasons. Chlorophyll-a concentration was ranged from 3.21 µg/l and 10.77 µg/l in June 2003 and June 2004 in Lake G  lk  y, respectively (see Table 7. 1). Similar changes in chlorophyll-a levels were recorded in Lake Qiandaohu (China) where eutrophication began similarly (Yan et al., 2004). In present study, usually low chlorophyll-a values were detected in winter and late summer months. Spearman correlation showed that negative relationship among these variables, but it is not significant level (Table 9. 2).

Table 9. 1. Mean values of environmental changes found seasonally from Lake Gölköy.

Variables	Unit	Spring	Summer	Fall	Winter
Temperature water	°C	9,95	18,75	17,53	6,00
Temperature air	°C	12,05	19,19	11,97	2,075
Precipitation	mm	51,40	30,12	35,83	51,45
Dissolved Oxygen	mg/l	11,50	7,09	7,81	10,95
Saturation	%	92,38	79,88	81,04	88,65
Conductivity	$\mu\text{S cm}^{-1}$	368.70	335.67	312.35	355.64
Redox potential (SHE)	mV	164.25	157,83	154,22	165.08
pH		7,97	8,01	8,07	7,96
Turbidity	NTU	3,26	2,72	3,86	3,13
Chlorophyll-a	$\mu\text{g/l}$	6,16	5,89	7,77	5,18
Secchi Depth	m	2,49	4,86	2,47	3,13
BOD	mg/l	7,19	4,43	4,60	5,59
Nitrite	mg/l	0,017	0,016	0,045	0,015
Nitrate	mg/l	0,092	0,028	0,017	0,139
Phosphate	mg/l	0,015	0,140	0,013	0,012
Ammonium	mg/l	0,082	0,200	0,096	0,126
Silica	mg/l				
Alkalinity	eq/l	2,43	3,20	1,93	2,93
Sulfate	mg/l	25,66	38,77	31,89	23,53
Chloride	mg/l	19,20	17,14	11,50	8,39
Calcium	mg/l	55,41	59,10	48,16	40,08
Magnesium	mg/l	20,57	14,59	35,74	33,82
Salinity	ppt	0,20	0,20	0,20	0,20

Environmental variables changed seasonally during present study (Table 9. 1). Environmental variables were superimposed to find their seasonal levels. There are not significant differences ($p>0.05$) in changing physico-chemicals among the seasons studied. Especially chemical component of Lake Gök y showed about similar values during study seasons.

In Table 9. 1, water temperature values, which fluctuated from 6.0  C to 18.75  C in winter to summer seasons respectively, were affected by air temperature changes. On the contrary, DO concentrations showed the highest value in spring season. In this season, phytoplankton especially diatom succession occurred and showed high abundances during study time. Conductivity and redox potential values were changed seasonally, showing high levels in cold seasons such as spring and winter seasons. Indeed, Spearman correlation provided a negative correlation between conductivity and water temperature, and similarly, between redox potential and water temperature; however, these correlations were not significant (Table 9. 2). Turbidity was slightly fluctuated in seasons and high levels record in fall season.

During the study period, Lake G   y had slightly alkaline water from season to season (Table 9. 1). Mean values of turbidity were not significantly different ($p>0.05$) in seasons. Lake water completely mixed in September month during the present study. Water homogenization supported to increase total phytoplankton abundance with suitable conditions. Consequently, high abundance of phytoplankton and particles in lake water can affect lake turbidity. Indeed, the highest chlorophyll-a value was found similarly in fall season. Thus, it causes to increase the water turbidity in lake. In spring season, phytoplankton composition especially diatom assemblages showed an important increase along with high nutrient concentrations. As showed in Table 9 1, maximum phosphate concentration was measured in spring

season, where factors such as a complete water homogenization, high phytoplankton abundance, and soil erosion might have caused an increase of water turbidity. Eventually, such factors can affect the water transparency, so that the lowest Secchi depth (SD) was recorded in spring season, and similarly in Lake Como, it showed the lowest levels of transparency in this season (Buzzi, 2002). Secchi depth was increased in summer season during thermal stratification. In summer season, turbidity variable showed a low value due to clear epilimnion with thermal stratification (see Figure 7. 1). Indeed, the highest Secchi depth detected in summer season because of thermal stratification. In epilimnion zone, phytoplankton especially flagellated algae reduce nutrient concentrations which limited phytoplankton abundance. Therefore, detected low turbidity level at clear epilimnion layer cause high SD value. Indeed, Spearman correlation showed negative correlation between SD and turbidity (Table 9. 2); however, this negative correlation is not significant.

Chemical components varied from season to season (Table 9. 1). Nitrate concentration ranged from 0.017 mg/l in fall to 0.139 mg/l in winter season. During summer and fall seasons, it was even lower than 0.028 mg/l in Lake Gököl. This finding supports the results of earlier studies; for instance, high nitrate value was recorded in Lake Piburger See (Tolotti and Thies, 2002), or minimum concentration of nitrate was detected in September in Lake Como (Buzzi, 2002). Likely, in Lake Gököl, it is a consequence of high DO rate with oxidation and reduction processes. Indeed, there are significant positive correlations between nitrate and DO, and Eh values in Spearman correlation (Table 9. 2). Phosphate concentration showed slightly changings in season (Table 9. 1). For example, high phosphate level was recorded at bottom of Lake Gököl. This is probably because of releasing some amount of

phosphate from lake sediment when pH changes. However, the level is still lowest in a eutrophic water of Lake Yeniçağa (Saygı-Başbuğ and Demirkalp, 2004).

Chemical component was increased in spring and fall seasons, while they were decreased in summer season with stable thermal stratification in Lake Gökçöy. For example, phosphate (PO_4) concentration fluctuated between minimum level in August 2004 and maximum value in spring months such as April, May 2005. There is a negative correlation between water temperature and phosphate value, but this correlation is not significant ($p>0.05$). Indeed, high nutrient concentrations supported maximum total abundance, chlorophyll-a and DO values in May 2005. On the other hand, during thermal stratification (see Figure 7. 1) in summer months, low phosphate values were found at epilimnion layer. In this layer, high assimilation rate of flagellated phytoplankton which was counted high levels in Lake Abant can probably have intense affect on depletion of phosphate with suitable light intensity and water temperature. Additionally, during this study, high phosphate concentrations in deep water were likely consequence of decomposition processes, with non-living organisms, and loading organic materials sinking to lake sedimentation. Biological oxygen demand (BOD_5) had high concentration in spring season and low value in summer. Decomposition process can affect biological oxygen demand levels, which usually increased in spring and early summer seasons and decreased in the following summer season. With snow melting, lake had high loading organic materials, were digested by many decomposer organisms. In decomposition process, these organisms, especially aerobic bacteria were required to much concentration of DO to convert organic materials to inorganic nutrients with heating water temperature. Result of this process causes to increase phytoplankton abundance with increasing nutrient values. High abundances of photosynthetic

organisms supported to record high level DO concentration in lake water. In summer season, low BOD₅ level at especially epilimnion layer was affected by low aerobic decomposer process rate with presence of low organic material due to thermal stratification. Indeed, significant positive relationship ($p<0.001$) between BOD₅ and DO, and negative relationship between BOD₅ and temperature are given in Spearman correlation (Table 9 2).

Spearman correlation showed significant positive and negative correlations among variables in Lake Gök  y (Table 9. 2). Number of phytoplankton species were correlated positively with temperature ($p<0.05$), silica ($p<0.001$), and calcium ($p<0.05$), but negatively correlated to conductivity ($p<0.05$). The lowest species richness recorded in winter months, while in late summer and fall season number of phytoplankton species showed an increasing in this lake. Not only temperature was important factor on number of phytoplankton, but also nutrient concentrations and light intensity were effective variables on the phytoplankton composition. Silica concentration can stimulate phytoplankton communities especially members of Chrysophyceae whose body structure depends on silica (Horne and Goldman, 1994).

Environmental variables slightly changed from season to season (Table 9. 1) due to long term water homogenization in Lake G  lk  y. Generally, high nutrient concentrations were recorded in spring and fall seasons. Two canals into this lake carry out high nutrient materials in both seasons. Accumulation of nutrient likelihood prevented by out two canals from near lake bottom for irrigation during summer season.

Table 9. 2. Correlation matrix for monthly averages of environmental variables and number of phytoplankton species (Spp) from Lake Gökölü. Abbreviations are given in Table 6. 2. * Correlation is significant at the 0.05 level (2-tailed), and ** Correlation is significant at the 0.01 level (2-tailed).

	Temp	DO	pH	Eh	EC	Chlo	BOD ₅	Turbi	SD	NO ₂	NO ₃	PO ₄	NH ₄	SO ₄	Cl ⁻	Ca ²⁺	Alkali	Mg ²⁺	Si	Spp
Temp	1.00																			
DO	-.678**	1.00																		
pH	-.034	-.417	1.00																	
Eh	-.069	.472*	-.931**	1.00																
EC	-.493*	.173	.235	-.159	1.00															
Chlo	-.009	-.233	.007	.068	-.371	1.00														
BOD₅	-.511*	.904**	-.417	.499*	.214	-.317	1.00													
Turbi	.080	.098	-.338	.474*	-.442	.538*	.140	1.00												
SD	.256	-.017	-.192	.072	-.044	-.294	.180	-.250	1.00											
NO₂	-.216	.273	-.230	.147	-.395	.313	.193	.163	.105	1.00										
NO₃	-.204	.626**	-.551*	.538*	-.234	.051	.537*	.276	.080	.461*	1.00									
PO₄	-.202	.359	-.577**	.589**	-.115	.176	.412	.177	.025	.565**	.576**	1.00								
NH₄	-.241	.341	-.531*	.564**	-.024	-.118	.391	.068	.317	.263	.315	.558*	1.00							
SO₄	-.112	.265	-.480*	.414	-.139	.086	.250	-.017	.309	.388	.595**	.689**	.763**	1.00						
Cl⁻	-.494*	.352	-.182	.226	.117	.194	.279	-.183	.139	.389	.427	.621**	.563**	.762**	1.00					
Ca²⁺	-.091	.231	-.413	.399	-.162	.143	.249	.151	.208	.388	.744**	.590**	.525*	.790**	.669**	1.00				
Alkali	-.546*	.299	-.173	.159	.178	.047	.201	-.151	-.054	.288	.359	.479*	.601**	.703**	.773**	.610**	1.00			
Mg²⁺	.039	.524*	-.743**	.688**	-.439	.004	.459*	.376	.078	.473*	.665**	.459*	.172	.199	-.057	.216	-.162	1.00		
Si	.205	.297	-.652**	.631**	-.436	-.004	.391	.300	.486*	.288	.500*	.488*	.459*	.489*	.242	.449*	.044	.621**	1.00	
Spp	.476*	-.089	-.338	.279	-.445*	.150	.039	.120	.224	.177	.328	.333	.100	.345	.128	.461*	-.033	.283	.596**	1.00

25.2 Phytoplankton (except Bacillariophyceae) abundance

Fifth-nine phytoplankton species belonging to 43 genera were recorded in Lake Gök  y. Total abundance fluctuated from $0.3 \cdot 10^3$ cu/ml to $18.2 \cdot 10^3$ cu/ml in June 2003 and July 2004 for respectively. Lake Garda showed similar phytoplankton density as minimum and maximum levels (Salmaso, 2002). Chlorophyll-a concentration showed significant correlation with phytoplankton densities (Figure 9. 2). However in fall season 2003 and early summer 2004, amount of chlorophyll-a increased and low non-diatom phytoplankton abundance recorded in Lake G  lk  y. On the other hand, in October 2003 and June 2004, Lake G  lk  y showed high abundance of diatom as density peaks (see, Figure 7. 3), and reflected high chlorophyll-a values recorded positively correlated as peak in same months (Figure 9. 2).

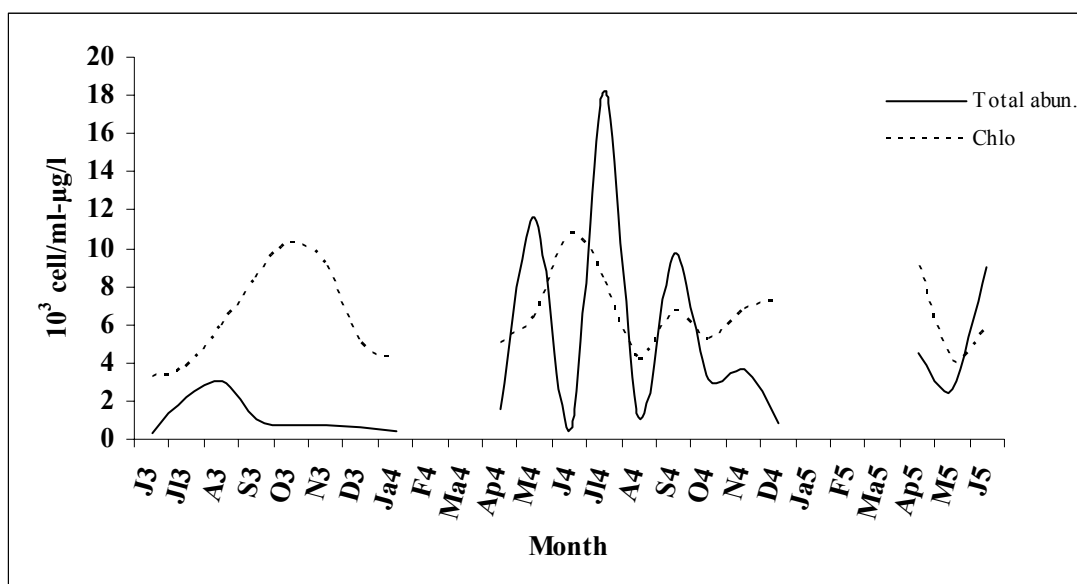


Figure 9. 2. Abundance of phytoplankton taxa and genera with number of species were recorded in Lake G  lk  y during 25 months. Abbreviations are given in Figure 9. 1. Superimposed numbers for each month are taken in the figure. Data was not included between January to March due to ice cover.

Dinobryon was the most abundance genus in Lake Gölköy from June 2003 to June 2005. Similar result recorded in Lake Abant. Density of phytoplankton showed high levels in spring, early summer and fall seasons (Figure 9. 2). Some members of genera such as *Dinobryon divergens*, *D. sertularia*, *Eudorina elegans*, *Tetrachlorella alternans*, *Tetraselmis cordiformis* had great contribution to total density of phytoplankton in Lake Gölköy (Table 9. 3). John and colleagues (2002) stated that above taxa found in Lake Gölköy prefer moderately or nutrient rich water bodies. *E. elegans* showed high abundance in late spring, early summer, and fall seasons when nutrient concentrations increased in Lake Gölköy, and similar *T. cordiformis* found in especially spring and early summer seasons. On the other hand, member of *Dinobryon* usually recorded in Lake Gölköy, but its high abundance found in late spring, early summer and early fall seasons (Figure 9. 2, Table 9. 3). High abundant organisms supported to total phytoplankton density. In late spring (May 2004), mid summer (July 2004), and fall (September 2004) seasons showed high density peaks in this lake (Figure9. 2). Members of Chrysophyta had great contribution to increasing total abundance in spring season due to silica value. Member of this group consist of siliceous cyst (Hutchinson, 1967). In Lake Abant, *Dinobryon* had the most abundant genus and found especially spring season.

Microcystis aeruginosa only recorded in June 2004, prefer nutrient rich water and found in eutrophic lakes (Hutchinson, 1967; Wetzel, 1975). This species frequently found as dominant organism in eutrophic lakes such as in Lake Yenicağa (Saygı-Başbuğ and Demirkalp, 2004), and in Lake Vela in Portugal (Abrantes et al., 2006). At the same time, *M. aeruginosa* was counted in more sampling months in Lake Abant comparing to Lake Gölköy.

Table 9. 3. Abundance of phytoplankton genera were recorded in Lake Gök  y during two years. Abbreviations indicate counting unit (c; cell, co; colony, and f; filament). Phytoplankton abundances were determined according to these types of organisms.

	Total number	type
<i>Dinobryon</i>	36155.1	c
<i>Eudorina</i>	6853.3	c
<i>Tetrachlorella</i>	4811.7	c
<i>Tetraselmis</i>	4637.9	c
<i>Mougeotia</i>	4286.8	c
<i>Cryptomonas</i>	3781.8	c
<i>Chlamydomonas</i>	3631.6	c
<i>Spirogyra</i>	2775.2	c
<i>Plageaselmis</i>	1657.5	c
<i>Peridiopsis</i>	1326.6	c
<i>Scenedesmus</i>	1245.5	c
<i>Trachelomonas</i>	1148.3	c
<i>Oscillatoria</i>	883.6	f
<i>Golenkinia</i>	880.2	c
<i>Gymnodim cenocoides</i>	572.7	c
<i>Peridinium</i>	426	c
<i>Tetrastrum</i>	317	c
<i>Pandorina morum</i>	294.8	c
<i>Ceratium</i>	206.6	c
<i>Elakotothrix</i>	132.8	c

Table 9. 3 (continued).

<i>Ankistrodesmus</i>	126.3	c
<i>Phacus</i>	116.5	c
<i>Pseudospharocystis</i>	116.5	c
<i>Oocystis</i>	107	c
<i>Euglena</i>	102.5	c
<i>Pediastrum</i>	101	c
<i>Carteria</i>	87.6	c
<i>Kirchnella robusta</i>	61.2	c
<i>Gonium pectorale</i>	40.2	c
<i>Closterium</i>	37.1	c
<i>Snowella</i>	34	co
<i>Korshikoviella</i>	32	c
<i>Microcystis</i>	26.5	co
<i>Spirulina</i>	24.1	f
<i>Anabaena</i>	10	f
<i>Zygnema</i>	10	c
<i>Gonatozygon</i>	8.1	c
<i>Cosmarium</i>	4.8	c
<i>Volvox</i>	4.4	co
<i>Stauastrum</i>	2.8	c
<i>Monoraphidium</i>	2.5	c
<i>Uroglenia</i>	1.6	co
<i>Bothryococcus</i>	1.5	co

Members of *Ankistrodesmus*, which commonly distributed each month in Lake Gök  y, had low abundance in spring and early summer seasons. Similarly, this species had lower density in Lake G  lk  y than in Lake Abant. John and colleagues (2002) point out that *Ankistrodesmus* taxa such as *A. falcatus* are cosmopolitan, widely distributed, have a broad tolerance range to environmental changes, and prefer high nutrient water.

In Lake G  lk  y, above explained most phytoplankton taxa, which have broad tolerance to changing environmental variables, are not only commonly distributed in European lakes (John et al., 2002; Abrantes et al., 2006), but also generally found in almost all types of water bodies such as lakes, marshes, and ponds in Turkey (G  n  l  l and Obalı, 1998; Obalı et al., 2002; Saygı-Başbuğ and Demirkalp, 2004).

25.3 Net-Phytoplankton (except Bacillariophyceae) Composition

In present study period, a total of 152 taxa identified, and belonged to eight phyla. Phytoplankton composition related 65 genera; most of them are concerning Chlorophyta with 42 genera recorded between June 2003 and June 2005. This group is followed by Euglenophyta with 19 taxa belonging to four genera and 7.0 % of total non-diatom phytoplankton. Increasing percentages of euglenoids algae in algae composition can give information about of water quality. John and colleagues (2002) point out that many members of Euglenophyta usually found in organic mater rich water. During present study, members of this group were commonly distributed in July 2004, while they were not recorded in December 2004. *Trachelomonas volvocina* was the most common species in this group, showed frequent occurrence in about each month in Lake G  lk  y, may suggest a wide range of tolerance level to the conditions. *T. volvocina* was showed as indicator of mildly to heavily polluted water (John et al., 2002), on the other hand, Danilov and Ekelund (2001) reported

that *T. volvocina* occasionally found near sediment in oligotrophic lakes. Indeed, this species, which widespread on earth; and not only found different water bodies; in eutrophic Lake Yeniçağa (Kılınç, 2003; Saygı-Başbuğ, 2004), in Lake Ladik (Maraşlıoğlu et al., 2005), in Lake Abant (Obalı et al., 2002), in other lakes and reservoirs of Turkey (Gönülol et al., 1996), but also distributed in lakes of Sweden (Danilov and Ekelund, 2001), in Lake Rama IX and reservoir of Thailand (Pongswat et al., 2004), and in many different aquatic habitats in British Isles (John et al., 2002). Euglanophyta prefer nutrient rich water were recorded in many researches (John et al., 2002; Ariyadej et al., 2004; Abrantes et al., 2006). Cyanoprokaryota was third common group, mostly distributed in late summer and fall seasons in Lake Gököy. *Oscillatoria limosa* was the most common species during present study. Abrantes and colleagues (2006) studied in Lake Vela a polymictic, shallow eutrophic lake. In their study, Cyanoprokaryota were recorded as dominant group longer time (spring-summer) period.

Some species such as *Cryptomonas ovata*, *D. divergens*, *O. limosa*, *P. morum*, *Peridinium willei* and *C. hirundinella*, which showed frequent occurrence in about each month in Lake Gököy, may suggest a wide range of tolerance level to the conditions (John et al., 2002). Most of them prefer nutrient rich water bodies (Wehr and Sheath, 2003). Hutchinson (1967) reported that *C. ovata*, *Dinobryon divergens*, *P. morum*, *P. willei* and *C. hirundinella* were as eurytopic species. On the other hand, *D. divergens* that showed oligotrophic indicator species (Hutchinson, 1967), was recorded moderately to very nutrient rich ponds and lakes (John et al., 2002). Identified most taxa in this study are commonly distributed in different parts of Turkey (Gönülol et al. 1996). These taxa which widely distributed in different trophic status aquatic habitats usually prefer moderately nutrient rich water (John et

al., 2002). In present study, finding many taxa (e.g., species of *Anabaena*, *Euglena*, *Microcystis*, *Oscillatoria*, *Trachelomonas*, *Eudorina*, *Pandorina*, *Pediastrum*, *Volvox* etc) prefer from moderately to high nutrient rich water, however, some rarely found species such as *S. armigerum* fo. *furcigerum*, and *Cosmarium bioculatum* usually found in oligotrophic lakes. Some of them such as *Anabaena*, *Closterium*, *Oscillatoria*, *Trachelomonas*, *Eudorina*, *Pandorina*, and *Volvox* were recorded in eutrophic, shallow Lake Yeniçağa in Bolu region (Kılınç, 2003; Saygı-Başbuğ and Demirkalp, 2004). With present study, phytoplankton compositions have firstly introduced algae flora of Lake Gököy.

25.4 Phytoplankton-environmental factors relationship with CCA

During present study, net phytoplankton composition which was distributed along changing environmental variables. Detrended correspondence analysis (DCA) was used to determine the gradient length of the phytoplankton community to show linear or no-linear (unimodel) response model of phytoplankton to environmental axes can be examined before performing CCA (Leps and Smilauer 2003). DCA ordination showed good dispersion of phytoplankton species on the axes. DCA result provides very high gradient length as 3.48 for 152 phytoplankton species data. In DCA ordination, $\lambda_1=0.516$ for axis 1 and $\lambda_2= 0.386$ for axis 2 with their ratio 1.34 explained 4.6 % of cumulative variance in species data (Table 9 4). In DCA, gradient lengths for all axes were found high level with low variance of species data. These results showed that unimodal perform should perform reasonably well (Leps and Smilauer, 2003). DCA showed that the first both axes are correlated with environmental data with 78.4 %, and the correlations for other axes are important levels (Table 9. 4).

Table 9. 4. Main results of DCA with 152 phytoplankton species are from Lake Gölköy.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.516	0.386	0.330	0.285	11.206
Lengths of gradient	3.483	4.357	3.722	3.784	
Species-environment correlations	0.458	0.784	0.690	0.631	
Cumulative percentage variance					
of species data	4,6	8.1	11.0	13.5	
of species-environment relation	2,7	14.5	0.0	0.0	
Sum of all eigenvalues					11.206
Sum of all canonical eigenvalues					1.980

The length of gradient length from DCA (Table 9. 4) serves as a lead for CCA (ter Braak, 1995; Leps and Smilauer, 2003). After that CCA analysis was used to explain relationship between phytoplankton composition and environmental variables during study time. This analysis includes 152 phytoplankton taxa and 18 environmental data from Lake Gölköy during 20 sampling months. Length of arrow showed influence of environmental variables on occurrence and distribution of phytoplankton taxa.

In present study, Monte Carlo permutation test with unconstrained permutations was used to test if there is no effect of the environmental variables on phytoplankton species. Result of forward selection with Monte Carlo permutation test (499 unrestricted permutations) showed that both axes were highly significant ($p=0.002$).

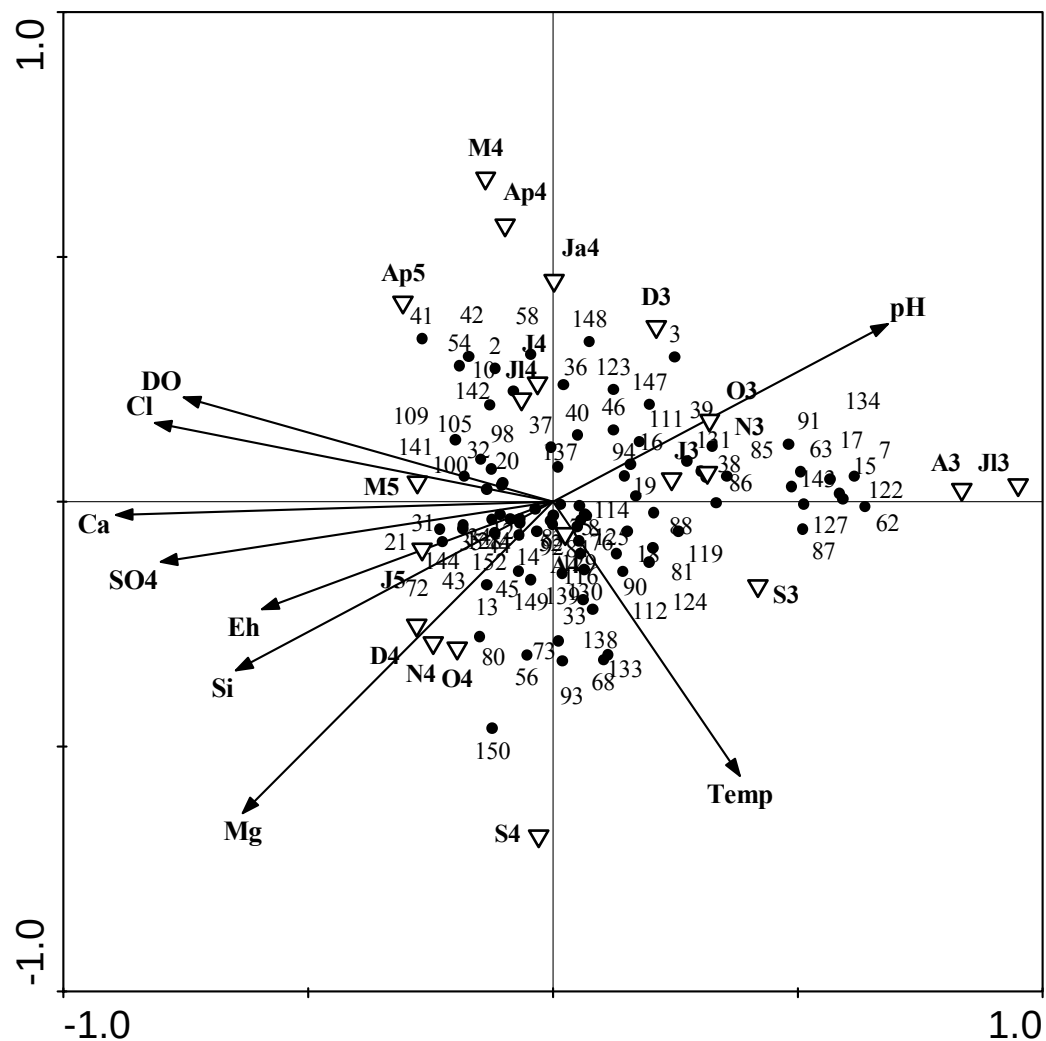


Figure 9. 3. Canonical correspondence analysis (CCA) ordination shows 152 net-phytoplankton taxa (2 %) and forward selected environmental variables (arrows) during 20 months (triangular). Sampling size (N) is 220. Species codes (numbers) are shown in Appendix D. Abbreviations are given in Figure 9. 1.

In CCA ordination, $\lambda_1=0.311$ for axis 1 and ($\lambda_2= 0.225$ for axis 2 with their ratio 1.38 explained 2.8 % of cumulative variance in species data (Table 9. 5). Result of CCA showed similar ratio to outcome of DCA from Table 9. 4. This similarity is explained that explanatory environmental variables can clearly affected distribution of phytoplankton taxa (Leps and Smilauer, 2003).

Table 9. 5. Main results of canonical correspondence analysis (CCA) with using Monte Carlo permutation test for 152 net-phytoplankton species.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.311	0.225	0.209	0.149	11.206
Species-environment correlations	0.886	0.872	0.809	0.818	
Cumulative percentage variance					
of species data	2.8	4.8	6.7	8.0	
of species-environment relation:	17.7	30.6	42.5	51.0	
Sum of all eigenvalues					11.206
Sum of all canonical eigenvalues					1.755
Test of significance of first canonical axis: eigenvalue = 0.311					
P-value = 0.0020 F-ratio = 4.997					

CCA showed that the first both axes are very well correlated with environmental data with 88.6 % and 87.2 % with very low cumulative percentage variance of species for respectively, and the correlations for other axes are important levels as >80 % (Table 9. 5). Findings from CCA showed that phytoplankton were highly sensitive changes environmental factors, and correlated changes in physico-chemical factors. High relationship between phytoplankton community and environmental variables from earlier studies which supported outcome of present research, reported that as 0.96 for axis 1 in Spanish salt lakes (Reed, 1998), 0.97 for axis 1 in Akkaya spring in Turkey (Çelekli and Kulköylüoğlu, 2006), and 0.95.4 for axis 1 in Lake Vela in Portugal (Abrantes et al., 2006). This high relation showed that how phytoplankton taxa directly affected by environmental variables; therefore, algae are very important to understanding, controlling, and management water quality of different aquatic habitats.

Selected 18 environmental variables were tested by Monte Carlo permutation test (499 unrestricted permutations) to determine if environmental influence on species distribution is significant or not. This test showed that phytoplankton composition is directly reflected with its environmental factors. All physical and chemical variables significantly (except NO₂, EC and NH₄) (p= 0.002) affected distribution of phytoplankton taxa. Ca²⁺, Cl⁻, Mg²⁺, SO₄, pH, and DO were the most significant (p<0.01) factors on distributions and occurrences of phytoplankton composition. The high significant value of factors on distribution of phytoplankton taxa was explained very high levels (Table 9. 5).

Table 9. 6. Results of CCA ordination test along with forward selection of Monte Carlo permutation test shows forward selected environmental variables during 20 months. Total of 220 bits of data is used in this analysis.

Environmental Variables	Explained %	p	F
Ca ²⁺	268	0.002	4.601
Cl ⁻	239	0.002	4.098
Mg ²⁺	238	0.002	4.085
SO ₄	237	0.002	4.070
pH	221	0.002	3.785
DO	219	0.002	3.754
Silica	199	0.002	3.394
Eh	189	0.002	3.221
Temperature	182	0.002	3.106
Alkalinity	137	0.002	2.334

In CCA ordination, axis 1 showed positive correlation pH and temperature, while other variables such as nutrients, DO, and Eh were negatively correlated. Spring

months 2004 were positively correlated axis 2 and fall 2004 showed a negative correlation. In this analysis, arrow of Mg^{2+} is closely related fall month 2004, high value magnesium recorded in this season. On the other hand, DO and Ca^{2+} are related to May 2005 in this ordination. There is present of close relationship between pH and November, October 2003 in present study. Indeed, the highest pH recorded in these months.

Some members of Chlorophyta (e.g., *Chlamydomonas* sp., *C. globosa*, *Scenedesmus arcuatus*, *Pediastrum boryanum* var. *cornutum*, *Spirogyra porticatis*, *S. setiformis*), Chrysophyta (*Dinobryon sertularia*, *D. sociale*) were found to relate pH factor (Figure 9. 3). Some species such as *Cryptomonas ovata*, *Dinobryon divergens*, *O. limosa*, *Pandorina morum*, *Peridinium willei* and *Ceratium hirundinella* which showed commonly occurrence in about each month in Lake Gölköy, found closer to center of CCA ordination (Figure 9. 3). John and colleagues reported that these taxa had a wide range of tolerance level to the conditions. Most of them prefer nutrient rich water bodies (Wehr and Sheath, 2003). Additionally, *C. ovata*, *D. divergens*, *P. morum*, *P. willei* and *C. hirundinella* were found in eutrophic lakes and ponds (Hutchinson, 1967). On the other hand, *D. divergens* that showed oligotrophic indicator species (Hutchinson, 1967), was recorded moderately to very nutrient rich ponds and lakes (John et al., 2002). These species not only commonly distributed in different water bodies of Turkey (Gönülol et al., 1996; Kılınç, 2003), but also found in different aquatic habitats in parts of earth (Horne and Goldman, 1994; John et al., 2002; Wehr and Sheath, 2003; Danilov and Ekelund, 2001).

In CCA, Cyanoprokaryota (e.g., *M. aeruginosa*, *Oscillatoria tenuis*, and *Spirulina maior*), Chlorophyta (*Scenedesmus bicaudatus*, *Spirogyra rivularis*, and *Oocystis parva*) and a Cryptophyta (*Cryptomonas platyuris*) showed closely relation with

temperature factor in Lake Gölköy. These taxa were commonly occurred in late summer and early fall seasons. Similarly, some members of these groups were found near arrow of temperature in CCA (see Figure 9. 3).

Phytoplankton composition showed low correlation to spring months 2004, while fall 2004 and summer 2004, 2005 can influence occurrence and distribution of phytoplankton in CCA ordination. In diatom ecology, environmental factors can affect diatom composition in all months of except December 2004 of study time (see Figure 7. 5).

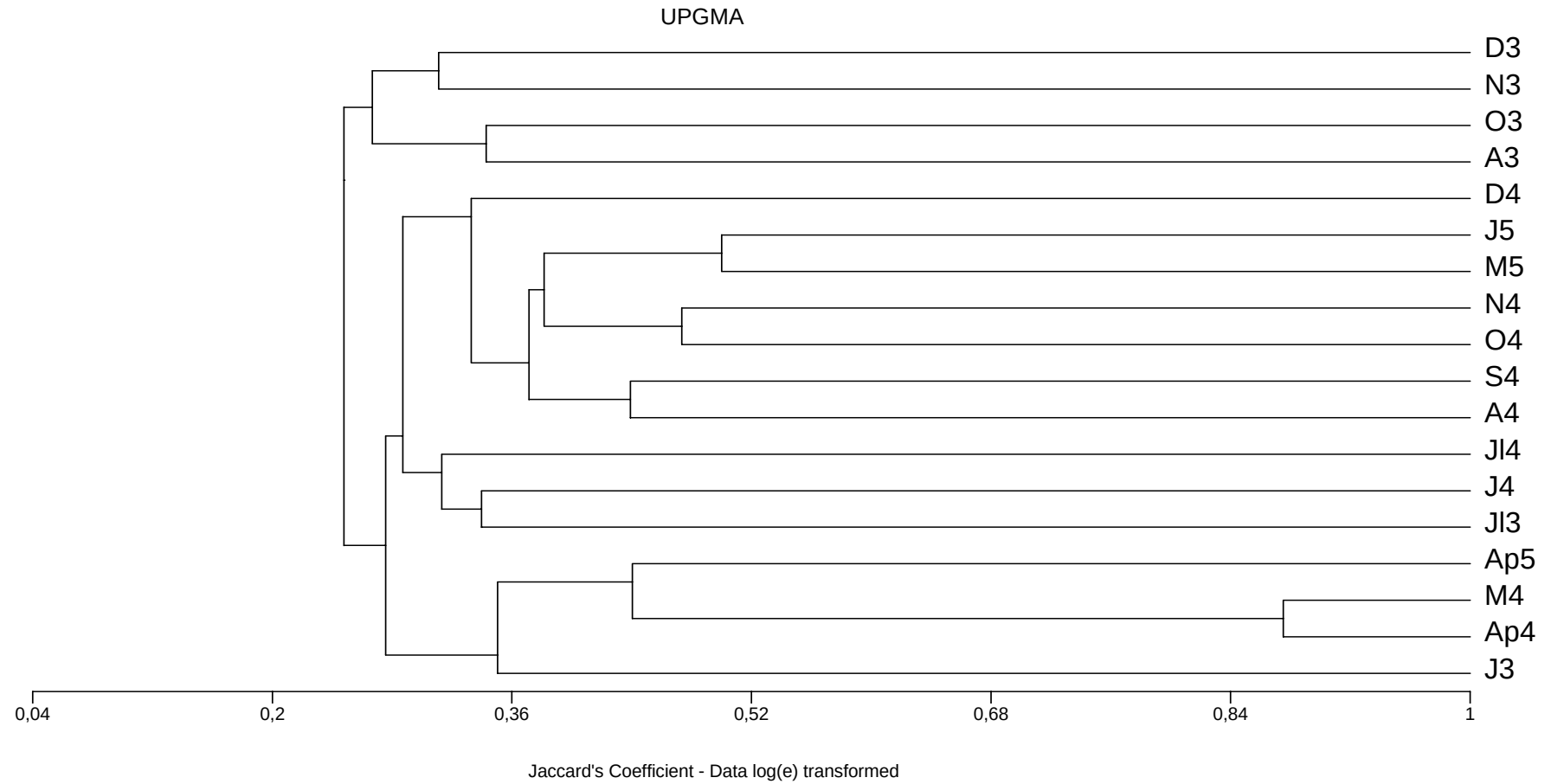


Figure 9. 4. UPGMA dendrogram shows sampling months in Lake Gök  y. Abbreviation is given in Figure 9. 2.

In Lake Gölköy, UPGMA dendrogram showed four groups among sampling months based on phytoplankton (except Bacillariophyceae) phenology (Figure 9. 4). Some species (e.g., *C. ovata*, *D. divergens*, *O. limosa*, *P. morum*, *P. willei* and *C. hirundinella*), which showed frequent occurrence in about each month in Lake Gölköy, may suggest a wide range of tolerance level to the conditions (John et al., 2002), while some species such as *Cosmarium granatum*, *Euglena oblonga*, *Trachelomonas hispida* and *Spirogyra tenuissima* were rarely recorded from sampling months during present study. Environmental variables affected occurrence of phytoplankton in sampling months clustered by using UPGMA (Figure 9. 4). The first group consists of four months, three of them related fall 2003 and other is August 2003. This group related pH was clearly showed in CCA ordination (Figure 9. 3). Similarly, sampling months of fall 2003 in Lake Abant was close related arrow of pH in CCA ordination (Figure 8. 5). The second groups included seven months except May 2005 were belonged to summer and fall seasons. Similarly, this result was supported by outcome of CCA. Additionally, CCA showed that months of this group not only related nutrient factors such as magnesium, silica, sulphate and calcium, but also included cosmopolitan phytoplankton taxa (e.g., *Trachelomonas armata*, *Volvox globator*, *Oocystis marssonii*, and a few members of *Euglena*). These taxa prefer nutrient enriched water bodies (John et al., 2002). Indeed, result of CCA supported finding of UPGMA in Lake Gölköy. The third group included only summer months, while the last group consist of spring and early summer seasons. Especially, the last group was similarly found in CCA ordination. In the spring, member of Chrysophyta such as *D. divergens* had great contribution to total phytoplankton abundance. Wetzel (1975) stated that Chrysophyta showed seasonality and had high abundance in spring season.

26 CONCLUSION

In this research, phytoplankton dynamic is strictly affected with the temporal variation of environmental variables. Total phytoplankton abundance showed seasonally variation, and the highest values recorded in late spring, early summer and fall seasons. High diverse phytoplankton taxa recorded with 152 net phytoplankton species in Lake Gökçöy. Some species such as *Cryptomonas ovata*, *Dinobryon divergens*, *Oscillatoria limosa*, *Pandorina morum*, *Peridinium willei* and *Ceratium hirundinella* which were frequently found in about each month in this lake, may suggest a wide range of tolerance level to the conditions.

Result of DCA showed a high gradient length with 82.1 % of environmental-species correlation for axis one. Similarly, relationship between environmental variables and phytoplankton composition explained as 88.6 % for axis 1 with low species variance for axis one in CCA ordination. Monte Carlo permutation test showed that physical and chemical changes had significant effect ($p < 0.01$) on distribution phytoplankton in Lake Gökçöy. Many taxa found closer to center of CCA ordination and were recorded already in nutrient rich water bodies. Lake Gökçöy had long water mixed period from fall season to end of spring season in present study, while thermal stratification had take place for 3 months in summer season. Both thermal stratification and completely homogenization importantly influenced nutrient concentrations and distribution, occurrence of phytoplankton composition. Chemical component of this lake showed not significant differences ($p > 0.05$) in sampling seasons, However high nutrient concentrations recorded in spring and fall seasons, and have great contribution on abundance of phytoplankton. Not significant

differences chemical variables in seasons are consequence of long water homogenization time.

Phytoplankton species were directly affected by changing environmental factors. Ecological and biological data for long term are extremely important to understand the state of habitats in past and future. These present study findings have contribution essential phytoplankton and environmental information that should aid in evaluating the state of Lake Gök  y in future and other limnological researches.

CHAPTER III WATER QUALITY

Part A

ABSTRACT

WATER QUALITY OF LAKE ABANT (BOLU)

Phytoplankton biomass, chlorophyll-a, Secchi depth, phosphate level, BOD₅, and total coliform bacteria were studied monthly in Lake Abant during two years (June 2003-June 2005). Phytoplankton density and biomass increased in spring, early summer, and fall seasons. Chrysophyta had the greatest contribution to total biomass, while Bacillariophyta was the most abundant phylum in Lake Abant. Flagellated Chrysophyceae showed high density in late spring and in early summer. According to Carlson's Trophic State Indices and OECD trophic classifications for using Secchi depth, total phosphorous, and chlorophyll-a, Lake Abant showed mainly mesotrophic status in present study. Additionally, BOD₅ concentration showed beta mesosaprobic status in this lake.

Keywords: Water quality, Biomass, Lake Abant, TSI, Bolu

ÖZET

ABANT GÖLÜ'NÜN (BOLU) SU KALİTESİ

Abant Gölü'nde fitoplankton biyomas, klorofil a, Secchi derinliği, fosfat düzeyi, BOD₅, ve toplam koliform bakteri aylık olarak iki yıl süresince (Haziran 2003-Hazirana 2005) çalışılmıştır. Fitoplankton biyomas ve yoğunluğu ilkbahar, erken yaz ve sonbahar mevsimlerinde artmıştır. Abant Gölü'nde, Bacillariophyta en fazla filum iken, Chrysophyta toplam biyomas üzerine en büyük katkıya sahip olmuştur. Kamçılı Chrysophyceae ilkbaharın sonunda ve yaz başında fazla bir yoğunluk göstermiştir. Bu çalışmada, Secchi derinliği, toplam fosfat ve klorofil kullanıldığı Carlson's Trophic State Indices and OECD trofik sınıflandırmasına göre Abant Gölü genel olarak mesotrophic yapı göstermiştir. Ek olarak, BOD₅ konsantrasyonu bu gölün beta mesosaprobic statüde olduğunu göstermiştir.

Anahtar Kelimeler: Su kalitesi, Biyomas, Abant Gölü, TSI, Bolu

27 INTRODUCTION

Phytoplankton as the primary producers in trophic cascades of lakes, especially diatoms can be a good indicator of trophic stages (Graham and Wilcox, 2000; John et al., 2002; Stoermer and Smol, 1999). This suggests that such a community is sensitive to environmental changes, and are used to evaluated water quality (Kitner and Poulickova, 2003; Rakocovic-Nedovic and Hollert, 2005).

The trophic state of lakes is indicative of their biological productivity, that is, the amount of living organisms supported within environmental variables, primarily in the form of algae (Randolph and Wilh, 1984; Denys, 2004). Earlier studies (Carlson, 1977) and organization (Vollenwider and Kerekes, 1982) suggested criteria on which the trophic status of water bodies, usually assessed as: a) nutrient supply, b) water transparency, b) biomass, taxonomic composition and diversity of phytoplankton. Biomass of phytoplankton which is affected by nutrients especially phosphorus in lakes, indicates trophic status. Changes in phytoplankton community can be useful as an evaluation tool because of their rapid response to environmental factors. Nitrogen and phosphorus are essential nutrients. Excessive phosphorus can lead to over-enrichment with algae and aquatic weeds and depletion of dissolved oxygen as the excess plant and animal matter decay (Horne and Goldman, 1994; Rakocovic-Nedovic and Hollert, 2005). In large quantities of nutrients, which can encourage the growth of nuisance aquatic plants such as algal blooms, most often come from agricultural runoff and urban wastewater, and can also come from geothermal inputs and deep springs that leach phosphorus from the rock geology.

In earlier studies concerning water quality followed a few variables such as total phosphate, total nitrate, chlorophyll, Secchi dept, biological oxygen demand, and

bacteria in aquatic bodies (Pepe et al., 2001; Rott et al., 2003; Rakocevic-Nedovic and Hollert, 2005).

In Turkey, a few studies concerning water quality carried out (Albay and Akçaalan, 2003 a, b; Girgin et al., 2004; Karafistan and Arık-Çolakoğlu, 2005), in Bolu area (Saygı-Başbuğ and Demirkalb, 2004). Until the present study, there has been no study concerning water quality of Lake Abant. The objective of the present study was to determine values of chlorophyll-a, phosphorus, water transparency and used to these variables to estimate trophic state index values for Lake Abant.

28 RESULTS AND DISCUSSION

During present study, chlorophyll-a concentration was ranged between 1.05 µg/l and 4.65 µg/l in April 2004 and May 2005 respectively. Secchi disc depth fluctuated seasonally from low level in spring to high value in late summer and early fall seasons. Spearman correlation showed significant ($p<0.05$) correlations among Secchi dept, chlorophyll and phosphate levels.

After values of these variables values converted to TSI levels in each sampling month according to Carlson (1977) equations. TSI variations of these variables were showed in Figure 10. 1. TSI_{TP} ranged from 32.10 in August 2004 to 45.05 both in April and May 2005. On the other hand, TSI_{SD} changed between 32.47 and 45.94 in September and June 2004 for respectively in Lake Abant (Figure 10. 1). In May 2005, recorded high phosphate levels supported densities of diatoms such as *Asterionella formosa*, *Fragilaria capucina*, and flagellated chrysophytes such as *Dinobryon divergens* in Lake Gököy. Çelekli and Külköylüoğlu (2006) reported that *A. formosa* showed high density in Akkaya Spring, when phosphate concentration was maximum value. In Lake Abant, chlorophyll-a had the highest TSI_{Cho} as 45.87 in May 2005 during present study. Carlson's TSI numerical scales are given in Table 10. 1. Trophic status of Lake Abant were determined monthly according to finding TSI levels based on values of chlorophyll-a, total phoshate, and Secchi depth.

Table 10. 1. Carlson (1977) classified TSI into numerical scales.

<u>Classes</u>	<u>TSI</u>
Oligotrophic	0-40
Mesotrophic	40-50
<u>Eutrophic</u>	<u>>50</u>

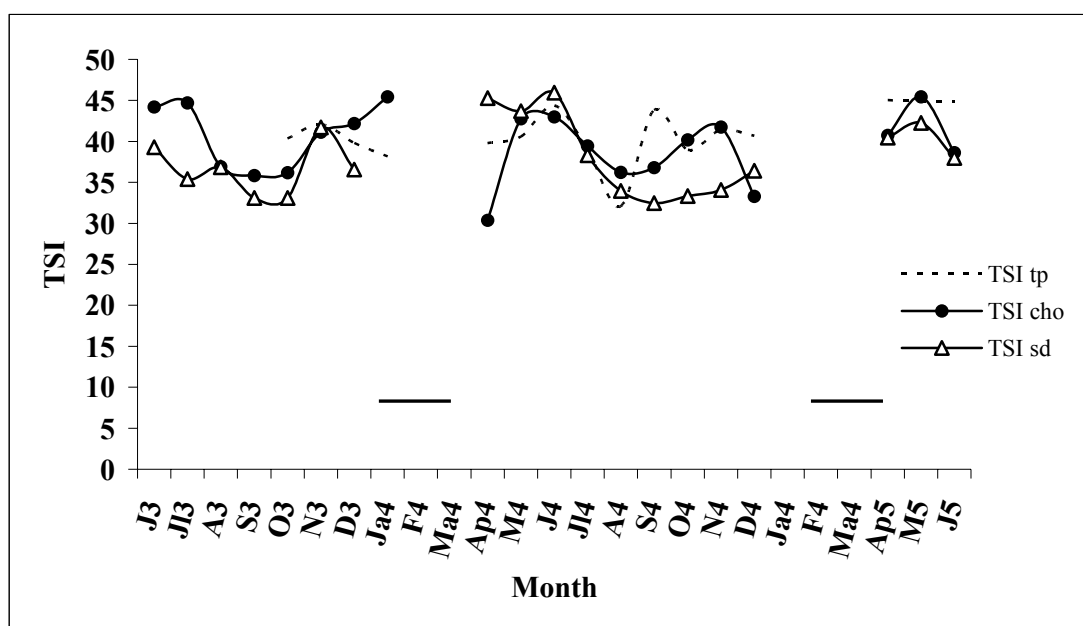


Figure 10. 1. Temporal variations in TSI values of Secchi depth, total phosphorous, and chlorophyll-a. These values were superimposed monthly from all sampling stations. Abbreviations indicate the code of each month (e.g., June 2003 (J3) and August (A3)), code of trophics state (TSI_{TP} , TSI_{CHO} , and TSI_{SD} related Trophic State Indices for Total Phosphorous, Chlorophyll-a, and Secchi Depth for respectively). (—) showed ice cover.

Variations in TSI_{SD} are consequence of changing water turbidity with thermal stratification and water homogenization in Lake Abant. This variable had low levels (Figure 10. 1) in summer season due to clear epilimnion layer with thermal stratification. High abundance of phytoplankton recorded in late spring month (see Figure 6. 4). Therefore, increased water turbidity with high phytoplankton abundance and other water particles showed very high water transparency in this lake.

High level TSI_{TP} in the spring supported phytoplankton abundance, and Lake Abant showed high TSI_{CHO} and low TSI_{SD} . These interconnected variables were parallel TSI variation in this lake (Figure 10. 1). Indeed, there is significant ($p < 0.01$) correlation among them during present study.

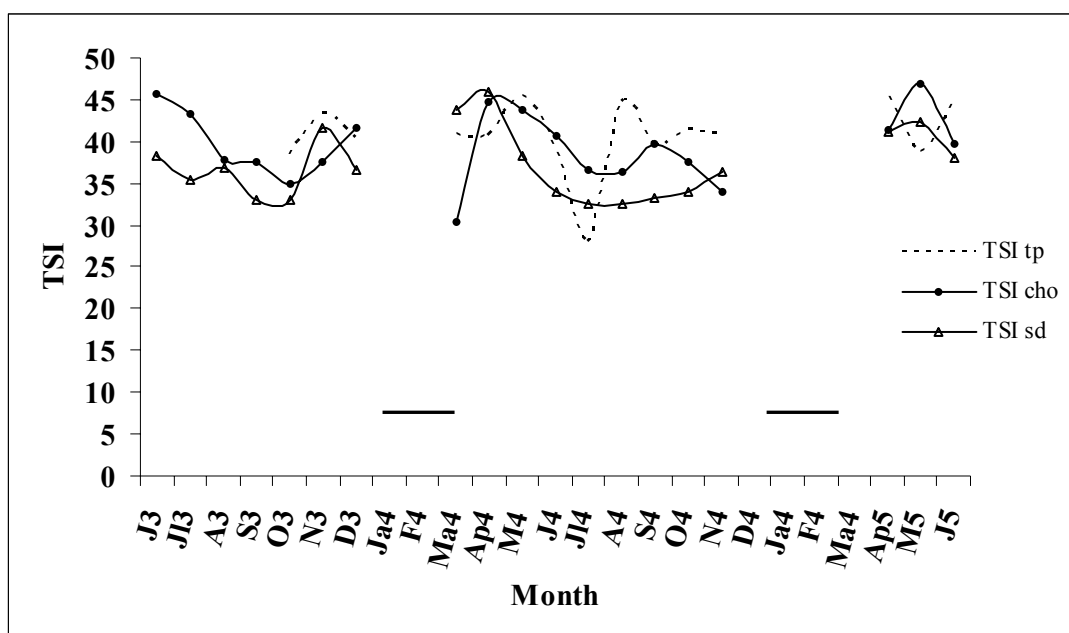


Figure 10. 2. Temporal variations in TSI values of Secchi depth, total phosphorous, and chlorophyll-a. These variables' values were superimposed monthly form only vertical sampling stations. Abbreviations are given in Figure 10. 1. (—) ice cover.

TSI values of these variables from vertical stations fluctuated temporary in Lake Abant (Figure 10. 2). In vertical station, TSI level showed slight variation comparing all sampling stations. Indeed, there is not significant difference ($p>0.05$) between both two TSI values. Additionally, physico-chemical variables were not significantly different ($p>0.05$) among sampling stations in Lake Abant. Thus, this may be a consequence of a uniform distribution of lake water for each sampling month during study period.

Lake Abant for TSI_{TP} usually showed oligo-mesotrophic and mesotrophic stages during present study (Table 10. 2), however oligotrophic state recorded in August 2004 during thermal stratification (see Figure 6. 1). It is likelihood consequence of a depletion of phosphate concentration with assimilation of flagellated phytoplankton in epilimnion layer. According to TSI_{Cho} values, three trophic states found in this lake water during sampling time (Table 10. 2). Lake Abant was oligotrophic during

thermal stratifications. Low available phosphate concentrations were important for chlorophyll-a levels in this time.

Usually high phosphate concentration supported chlorophyll level; however, low chlorophyll-a value recorded with high phosphate level in April 2004 caused to show oligotrophic status of this lake. In the same month, melting ice cover was newly completed and water temperature recorded as 3.07 °C in Lake Abant. It is known that not only nutrient concentration supported phytoplankton abundance, but also suitable water temperature, light intensity and other factors are required in water bodies (Horne and Goldman, 1994). During present study, phosphorous was to be limiting factor algal productivity in summer season.

Water quality of Lake Abant was also evaluated according to Vollenwider and Kerekes (1982) criteria based on chlorophyll-a, Secchi depth, and phosphorous levels. Vollenwider and Kerekes (1982) generated numerical range of these variables. Temporal variation in TSI of this lake is shown in Table 10. 3.

Results of Vollenwider and Kerekes (OECD)'s trophic classification for phosphorous and chlorophyll-a were similar to the output of Carlson's TSI index, while trophic state of Secchi depth showed higher status in OECD than in Carlson's TSI. For example, in OECD criteria, Secchi depth indicated eutrophic state in both April and June 2004 (Table 10. 3), while Lake Abant had mesotrophic for Carlson's TSI_{SD} (Table 10. 2). Carlson's (1977) TSI are determined for Florida lakes; however, European lakes were assessed by OECD (1982) and found its criteria for water quality. Two different regions have different evolutionary and geomorphologic structure.

Table 10. 2. Temporal variation in TSI values for total phosphorous, chlorophyll-a, and Secchi depth are in Lake Abant. Abbreviations indicate code of trophics state (e.g., O; Oligotrophic, OM; Oligo-Mesotrophic status), and others are given in Figure 10. 1.

	TSI_{TP}	TSI_{Cho}	TSI_{SDD}
J3		M	OM
Jl3		M	O
A3		OM	OM
S3		O	O
O3	M	O	O
N3	M	M	M
D3	M	M	OM
Ja4	OM	M	
Ap4	M	O	M
M4	M	M	M
J4	M	M	M
Jl4	OM	M	OM
A4	O	O	O
S4	M	O	O
O4	OM	M	O
N4	M	M	O
D4	M	O	O
Ap5	M	M	M
M5	M	M	M
J5	M	OM	OM

Carlson's stated a few equation relating Secchi depth and chlorophyll-a as follows;
 $\ln SD = 2.04 - 0.68 \ln(Cho)$ (n=147, r=0.93).

A similar relationship found for Lake Abant is;

$$\ln SD = 1.87 - 0.57 \ln(Cho) \quad (n=40, r = 0.31, p<0.001)$$

and calculated relationship between TP and chlorophyll-a is;

$$\log TP = 1.87 - 0.57 \log(Cho) \quad (n= 212, r = 0.49, p<0.001).$$

Similar negative relationships between SD and chlorophyll-a for Lake Skadar is;

$$\ln SD = 0.58 - 0.4 \ln(Cho) \quad (n=70, r = 0.6, p=0.002) \text{ (Rakocevic-Nedovic and Hollert, 2003)}.$$

During this study, there was sufficient amount of total nitrogen to support phytoplankton abundance, while phosphate concentrations were likelihood limited phytoplankton densities. N: P ratios except in January 2004 were usually detected higher level than 10:1 and the highest ratio recorded as 57:1 in August 2004 in Lake Abant. Chiaudani and Vighi (1974) showed that nitrogen was limiting factor, when N:P ratio is less than 5:1, while phosphorous is the limiting nutrient on algae density at this ratio greater than 10:1. Crossetti and colleagues (2005) stated that phosphate was limiting factor on phytoplankton composition, when N:P ratio was higher than 16 in their experiment condition.

There is not only the three factors (chlorophyll-a, Secchi depth and phosphorous) but also others such as number of total bacteria and BOD₅ influence the water quality of the lake.

Table 10. 3. Temporal variation in TSI values for total phosphorous, chlorophyll-a, and Secchi depth are in Lake Abant, according to Vollenwider and Kerekes (1982). Abbreviations are given in Figure 10. 1.

	TSI_{TP}	TSI_{Cho}	TSI_{SDD}
J3		M	M
Jl3		M	M
A3		O	M
S3		O	O
O3	M	O	O
N3	M	M	M
D3	M	M	M
Ja4	M	M	
Ap4	M	O	E
M4	M	M	ME
J4	M	M	E
Jl4	M	M	M
A4	O	O	M
S4	M	O	O
O4	M	M	O
N4	M	M	M
D4	M	O	M
Ap5	M	M	M
M5	M	M	M
J5	M	OM	M

Considering that point, total coliform bacteria in Lake Abant were counted between 3×10^2 and 4×10^4 cfu/ml during this study. Fall season had the highest number of total coliform bacteria (Figure 10. 3), followed in spring season during the present study. Additionally, *Escherichia coli* were (Figure 10. 3) found in this lake, usually counted

in fall season between 46 and 148 cfu/ml. These high amounts of bacteria are possibly the reason of high organic material inflow from sewage. Consequently, the values suggest that Lake Abant is not convenient for swimming due to high coliform bacteria. According Environmental Protection Agency (EPA) criteria, water bodies which include 100 cfu/l, are not suitable for swimming. These results showed that somehow organic material is loaded from anthropogenic sources into the lake, to which a close touch may cause deathly results.

Biological oxygen demand ranged 2.54 to 8.81 mg/l in Lake Abant during present study. Saprobic water quality classes were determined by using BOD₅ ranks according to Hamm 1969 (in Rott et al., 2003). Lake Abant showed usually beta to alpha mesosaprobic water status (Table 10. 4). During summer season, beta saprobic water class recorded due to thermal stratification.

According BOD₅ rank, higher water trophic status found in this lake, comparing to Carlson's TSI value. There is not only total coliform bacteria affected BOD levels, but also other decomposer organisms such as other bacteria, fungi played important role to change in this variables. Additionally, both BOD₅ and saturation of DO were used to understand water quality (van Dam et al., 1994, in Denys, 2004). According to both variables, Lake Abant usually showed beta and alpha mesosaprobic water class. These results commonly support saprobic water class of BOD ranks.

Table 10. 4 1. Temporal variation saprobic status for BOD₅, according to Hamm (1969) (in Rott et al., 2003). Abbreviations are given in Figure 10. 1.

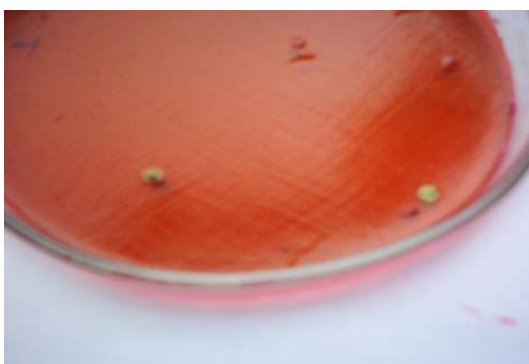
Saprobic water quality class	
J3	beta to alpha mesosaprobic
JI3	beta to alpha mesosaprobic
A3	beta mesosaprobic
S3	beta mesosaprobic
O3	beta mesosaprobic
N3	beta mesosaprobic
D3	beta to alpha mesosaprobic
Ja4	beta to alpha mesosaprobic
Ap4	beta to alpha mesosaprobic
M4	beta to alpha mesosaprobic
J4	beta mesosaprobic
JI4	beta mesosaprobic
A4	beta mesosaprobic
S4	beta to alpha mesosaprobic
O4	beta to alpha mesosaprobic
N4	beta mesosaprobic
D4	beta to alpha mesosaprobic
Ap5	beta to alpha mesosaprobic
M5	Alpha mesosaprobic
J5	beta to alpha mesosaprobic



a



b



c



d

Figure 10. 1. a-b) Colonies of total coliform bacteria, and c-d) colonies of *Escherichia coli*.

28.1 Phytoplankton biomass of Lake Abant

Sixth-six phytoplankton species belonging to 46 genera were recorded in Lake Abant. Bacillariophyta was the most abundant phylum with 41.9 % of total phytoplankton abundance, while the lowest group was Prasinophyta with 0.14 % in this lake. Phytoplankton densities were changed seasonally and high levels were recorded in fall and spring seasons in Lake Abant. Density of Bacillariophyta showed seasonal variation in the lake (see Figure 6. 4). During present study, biovolume and biomass of diatom taxa fluctuated monthly. Mean biovolume value was used in the present study. *Asterionella formosa* had 511 μm^3 mean biovolume in Lake Abant. Similar biovolumes for *A. formosa* were found between 500 and 650 μm^3 in eutrophic Faaker See (Austria) (Rott, 1981), and between 350-750 μm^3 in eutrophic Lake Mjøsa (Norway) (Rott, 1981). In Lake Abant, biomass of diatom had similar changes in seasonal to diatom abundance. Total diatom biomass increased in fall and spring seasons, and the highest level was 3.28 mg/l in June 2004 (Figure 10. 4). In Lake Abant, *Fragilaria*, *Cylotella*, *Cymbella*, and *Asterionella* had great contributions to total diatom biomass with 8.23, 8.05, 7.34, and 6.17 mg/l, respectively in Lake Abant. During the summer, biomasses of genera decreased. For example, *A. formosa* showed usually high biomass in spring and early summer season, while high biomass of *Fragilaria crotonensis* recorded in fall season in the lake. *Cyclotella* showed high biomass value in summer season. Results of the present study supported earlier findings in Lake Como (Italy) (Buzzi, 2002).

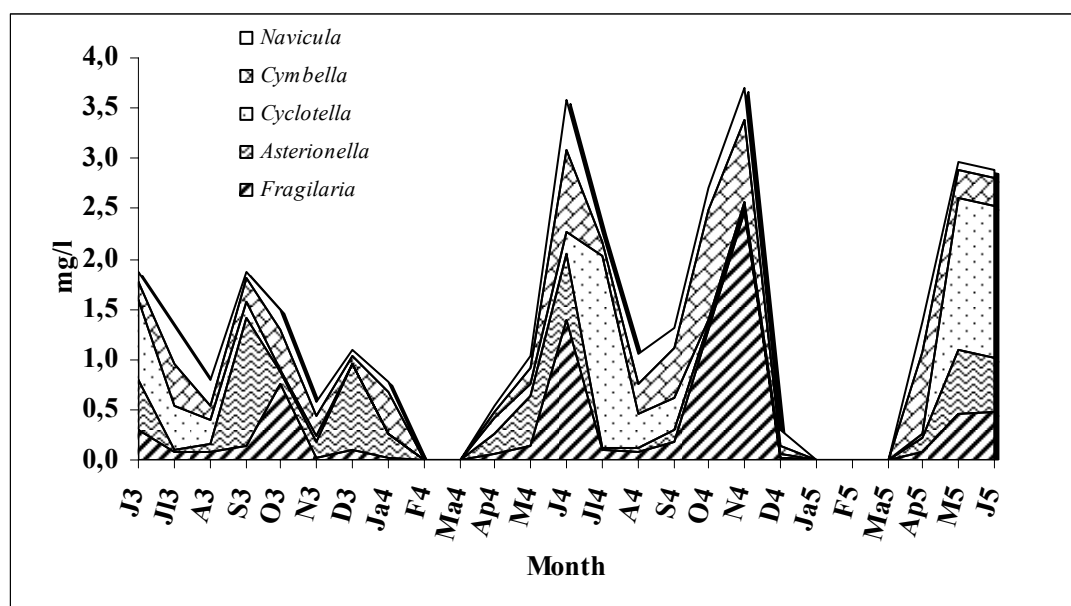


Figure 10. 3. Temporal variations of diatoms' biomass in Lake Abant. Abbreviations are given in Figure 10. 1.

Bacillariophyta was the most abundant group in phytoplankton densities; however it was the second high biomass levels with only 14.84 mg/l of total biomass. During the present study, Chrysophyta had the most biomass level, while Chlorophyta showed the lowest biomass value in Lake Abant (Figure 10. 5). In Lake Abant Chrysophyceae usually reached absolute high abundance and biomass in June 2004. Member of *Dinobryon* especially *D. divergens* had great contribution to their high density. This phylum similarly found as the highest abundance in May in Lake Piburger See (Austria) (Tolotti and Thies, 2002). Similarly, *Dinobryon* increased their abundance in Linsley pond in June (Hutchinson, 1967). In June 2004, the lowest total coliform bacteria recorded from Lake Abant. It can be a consequence of high density of *Dinobryon* in the lake. They are to be potentially mixotrophic, showing facultative feeding on bacteria (Isaksson, 1998, in Pugnetti and Bettinetti, 1999). In summer season, low biomass level recorded due to thermal stratification during present study.

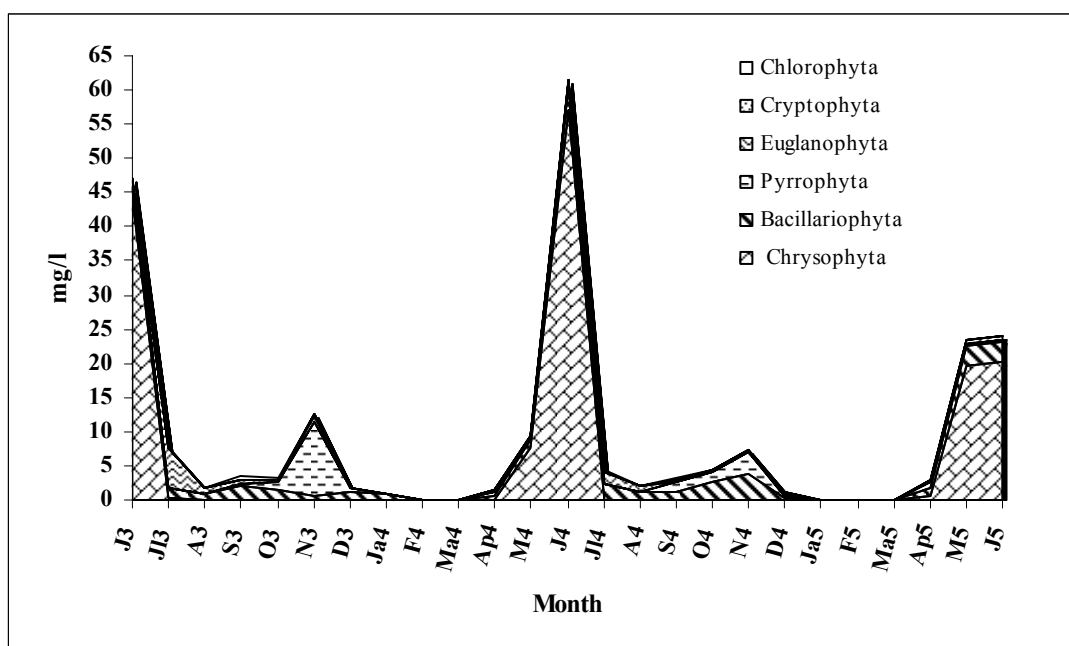


Figure 10. 4. Temporal variations of biomass during two years. Abbreviations are given in Figure 10 1.

Bacillariophyceae biomass was followed Pyrrophyta in Lake Abant. This group showed high biomass concentrations especially in fall season. *Peridinium willei* had the most common species in this group. Hutchinson (1967) stated that *P. willei* was found in oligotrophic, mesotrophic and eutrophic lakes.

Euglenophyta increased their biomass in late summer and fall seasons during present study. *Trachelomonas* had great contribution to this total biomass of this phylum. This group was abundant, when organic materials were reached to high levels (Ariyadej et al., 2004; Abrantes et al., 2006). A commonly distributed genera, *Trachelomonas*, prefers organically rich water bodies (Hutchinson, 1967; John et al., 2002). Cryptophyta also had important contribution to phytoplankton biomass level in Lake Abant. This phylum had high biomass values in fall season especially in November during the present study. *Cryptomonas ovata* was one of the most common species in this lake that the species was also reported with its wide distribution in variety of water bodies (Gönülol et al., 1996; John et al., 2002).

Similarly, *Trachelomonas volvocina* (see Figure 3. 1. i), *C. ovata*, *A. formosa* and *F. crotonensis*, which were already mentioned in Part A and B of Chapter II, showed frequent occurrence in about each month in Lake Abant. This may suggest a wide range of tolerance levels to the environmental conditions. These taxa in a recent study were also recorded in Lake Abant (Obalı et al., 2002).

29 CONCLUSION

During present study, trophic state of Lake Abant was evaluated by using several factors. At first, according to Carlson's TSI index used for Secchi depth, chlorophyll-a, total phosphate, Lake Abant showed mainly mesotrophic status, however, in a few months, oligotrophic and oligo-mesotrophic state were found in this lake especially based on TSI_{SD}. Additionally, same variables were applied with the criteria of OECD (1982). Results of this trophic classification usually supported output of Carlson's TSI.

Water quality of Lake Abant is not only evaluated by using amount of chlorophyll-a, Secchi depth and phosphorous, but also number of total bacteria, BOD₅ and other factors as well. Maximum total coliform bacteria were recorded as 4×10^4 cfu/ml in this lake in fall and spring seasons during present study. Additionally, *Escherichia coli* found in fall season between 46 and 148 cfu/ml suggests that swimming activities should not be performed in the lake. Saprobic water quality classes were determined by using BOD₅ ranks. High BOD₅ values recorded during present study. According BOD₅ rank, higher water trophic status found in this lake, comparing to Carlson's TSI value.

In Lake Abant, biovolume and biomass values showed variation during study time. Bacillariophyta was the most abundant phylum; however Chrysophyta was dominant group in total phytoplankton biomass. Total biomass showed an increase in fall and spring seasons and a decrease in summer season.

Part B

ABSTRACT

WATER QUALITY OF LAKE GÖLKÖY (BOLU)

Trophic State of Lake Gök  y was studied monthly from June 2003 to June 2005. Phytoplankton density and biomass increased in spring, early summer, and fall seasons. Chlorophyta, Bacillariophyta, and Chrysophyta were great contributions to total phytoplankton biomass of the lake. The highest total biomass value was recorded in May 2004, when nutrient concentrations were maximum levels. According to Carlson's Trophic State Indices and OECD trophic classifications based on three factors (Secchi depth, total phosphorous, and chlorophyll-a), Lake G  lk  y showed mainly meso-eutrophic status during the present study. These results were also supported by finding high levels of Total coliform bacteria.

Keywords: Trophic State, Biomass, Lake G  lk  y, Bolu

  ZET

G  LK  Y G  L  'N  N SU KAL  TES  

G  lk  y G  l  'n  n trofik durumu Haziran 2003 yılından Haziran 2005'e kadar aylık olarak   alıřılmıştır. Fitoplankton yoęunluęu ve biyoması ilkbahar, erken yaz ve sonbahar mevsiminde artmıştır. Chlorophyta, Bacillariophyta ve Chrysophyta g  l  n toplam fitoplankton biyomasına b  y  k katkıları olmuřtur. En fazla toplam biyomas besin tuzlarının maksimum olduęu Mayıs 2004'de kaydedilmiştir. Bu   alıřma s  resince,     fakt  re dayanılan (Secchi derinlięi, toplam fosfat ve klorofil a) Carlson trofik durum ve OECD trofik sınıflamaya g  re, G  lk  y G  l   genellikle meso-  trofik yapı g  stermiştir. Bu sonu  lar, bulunan y  ksek d  zeydeki toplam koliform bakteri sayısı da desteklemektedir.

Anahtar Kelimeler: Trofik Durum, Biyomas, G  lk  y G  l  , Bolu

30 INTRODUCTION

Freshwater quality which is affected by several types of both biotic and abiotic factors, can be reduced due to excessive input of inorganic and organic materials (Pepe et al., 2001; Rakocevic-Nedovic and Hollert, 2005). Environmental variables and biological organisms (e.g., phytoplankton and macrophytes) as the primary producers in trophic cascades of lakes are used to assess water quality (Graham and Wilcox, 2000; Widinski et al., 2001; John et al., 2002).

The trophic state of lakes is indicative of their biological productivity, that is, the amount of living organisms supported within environmental variables, primarily in the form of algae (Randolph and Wilh, 1984; Denys, 2004). Hence, some biotic (i.e. biomass, taxonomic composition and diversity of phytoplankton) and abiotic factors (i.e. nutrient supply, water transparency) were commonly used in different water bodies (Carlson, 1977; Vollenwider and Kerekes, 1982). Phytoplankton compositions are useful tool in understanding water quality, because of their rapid response to the changes in different environmental conditions. Phytoplankton communities are directly affected by chemical components; for instance, phosphorus is an essential element for all organisms and is found naturally (and limited) in water bodies. Excessive phosphorus can lead to over-enrichment with algae and aquatic weeds and depletion of dissolved oxygen as the excess plant and animal matter decay. Phytoplankton are indispensable in ecosystems with their importance as in food webs, ensuring ecological balance and phytoplankton as useful tools for assessing water qualities (Graham and Wilcox, 2000; Abrantes et al., 2006).

Water quality studies concerning phytoplankton were increased in different countries including Sweden (Danilov and Ekelund, 1999), Germany (Seele et al.,

2000; Rakocevic-Nedovic and Hollert, 2005), Austria (Rott et al., 2003), and Italy (Pepe et al., 2001; Salmaso, 2002), although trophic state studies were few in water bodies of Turkey (Albay and Akçaalan, 2003; Saygı-Başbuğ and Demirkalp, 2004; Kazancı et al., 2004). Such studies on phytoplankton algae for water quality monitoring have shown that changes in composition reflect not only variation in water qualities, but also changes in physical and chemical variables and biotic interactions. Therefore, biomonitoring studies are important in aquatic ecosystem to understanding condition of aquatic bodies. The objective of this study was to analyze water quality based on the relationship between phytoplankton composition and environmental changes in Lake Gököy (Bolu).

31 RESULTS AND DISCUSSION

In Lake Gök  y, water quality study based on Secchi depth, phosphate, and chlorophyll-a concentrations recorded monthly during two years were converted to determine trophic levels based on Carlson trophic state (1977). Accordingly, trophic status of Lake G  lk  y changed from moderately productive mesotrophic lake to high productive eutrophic lake conditions. Three interrelated water quality variables (Secchi disc depth (SD), chlorophyll-a (Cho) and total phosphorous measurement (TP)) were used as proposed by Carlson's (1977) TSI to understand water status.

To determine Carlson's TSI;

- TP, $TSI = 10(6 - \ln[48/TP]/\ln[2])$
- SD, $TSI = 10(6 - \ln[SD]/\ln[2])$
- Cho, $TSI = 10(6 - (2.04 - 0.68\ln[Cho]/\ln[2]))$

During the present study, chlorophyll-a concentration was fluctuated between 3.21 $\mu\text{g/l}$ and 10.77 $\mu\text{g/l}$ in June 2003 and 2004, respectively. This corresponds with the water transparency that is one of the major diagnostic tools used in the analysis of eutrophication. . Secchi disc depth changed seasonally from 1.35 m in September 2003 to 7.10 m in August 2004. In summer season, high Secchi depth recorded in Lake G  lk  y with clear epilimnion layer due to thermal stratification. Water homogenization and thermal stratification were importantly affected variations of water transparency.

Secchi depth, chlorophyll and phosphorous values converted to TSI levels by using Carlson (1977) TSI numerical scale in each sampling month, variations of TSI were showed in Figure 11. 1. TSI_{TP} ranged from 36.48 in August to 46.84 in October

2004, and TSI_{SD} changed between 37.60 and 55.67 in June 2005 and September 2003 for respectively in Lake Gököy (Figure 11. 1). On the other hand, chlorophyll-a changed from 42.01 to 54.75 in June 2003 and 2004 for respectively. Carlson's TSI numerical scales are given in Table 11. 1.

Table 11. 1. Carlson (1977) classified TSI into numerical scales.

Classes	TSI
Oligotrophic	0-40
Mesotrophic	40-50
Eutrophic	>50

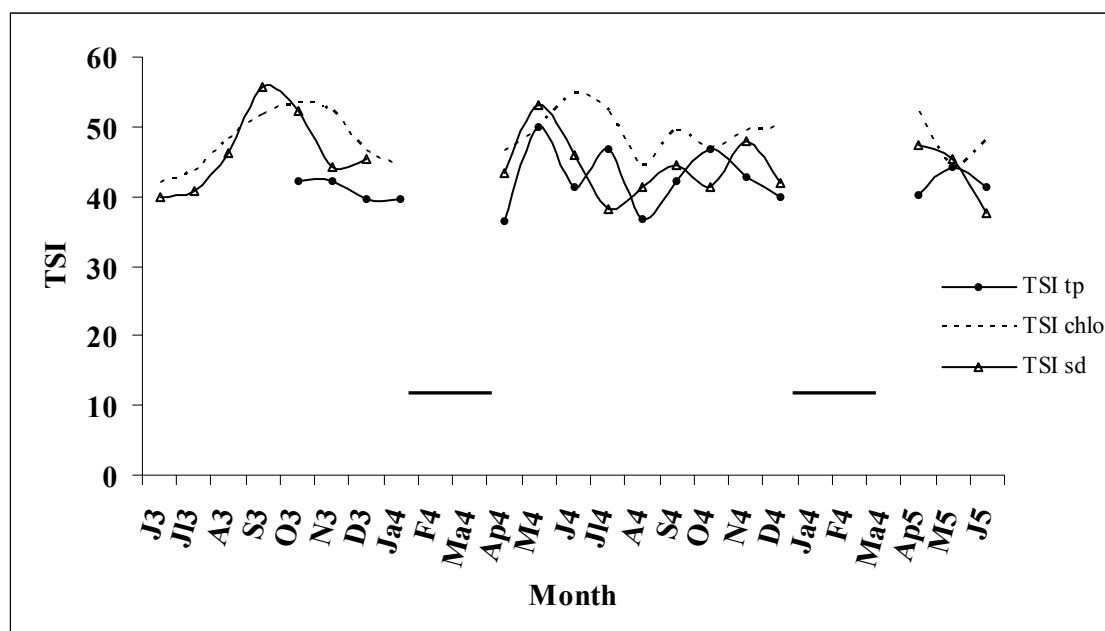


Figure 11. 1. Temporal variations in TSI values of Secchi depth, total phosphorous, and chlorophyll-a. These variables' values were superimposed monthly from all sampling stations. Abbreviations indicate the code of each month (e.g., June 2003 (J3) and August (A3)), code of trophics state (e.g., TSI_{TP} , TSI_{Chlo} , and TSI_{SD} related Trophic State Indices for Total Phosphorous, Chlorophyll a, and Secchi Depth for respectively). — ice cover

TSI values of these variables from vertical stations showed seasonally variations in Lake Gököy (Figure 11. 2). In vertical station, TSI level showed slightly variation comparing in all sampling stations. Indeed, there is not significant difference

($p>0.05$) between both two TSI values. It is out put of great contribution of littoral stations on phosphate and chlorophyll value. Indeed, low TSI_{Chl} recorded in August 2003 during thermal stratification. These conditions showed that Lake Gök  y water about uniformly distributed for each sampling month during study time.

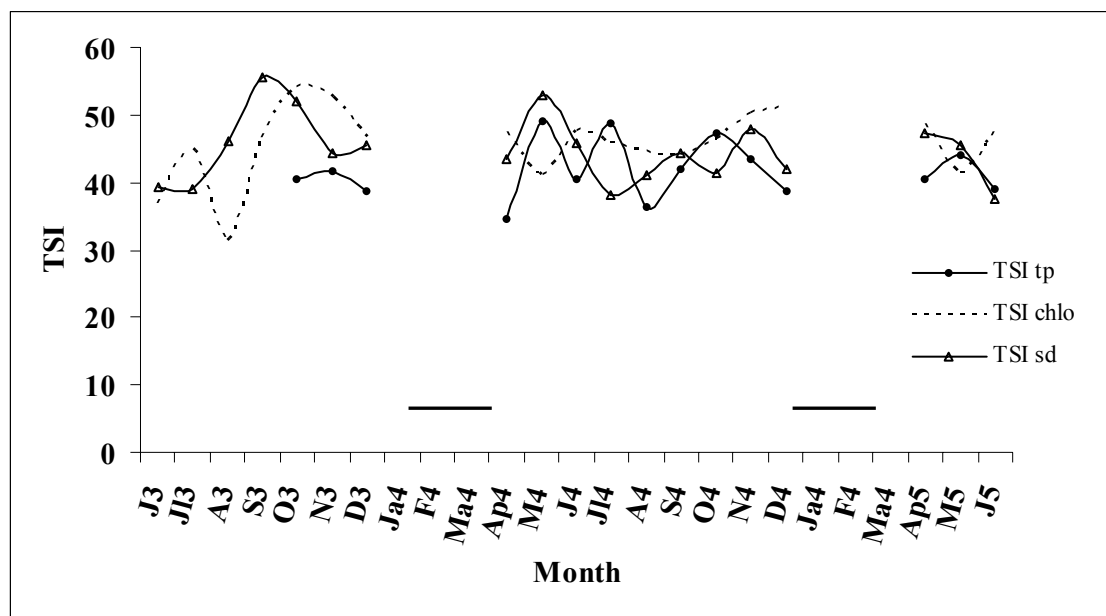


Figure 11. 2. Temporal variations in TSI values of Secchi depth, total phosphorous, and chlorophyll-a. These variables' values were superimposed monthly form all sampling stations. Abbreviations are given in Figure 11. 1. — ice cover.

During present study, trophic status of Lake G  lk  y changed seasonally (Table 11. 2). According to TSI_{TP} , this lake, which usually showed mesotrophic, had oligotrophic sate in April and August 2004, while in May 2004, eutrophic condition was recorded. Low TSI_{TP} in the summer is likelihood consequence of depletion of phosphate concentration with assimilation of flagellated phytoplankton in epilimnion layer. In spring seasons was not only water homogenization affected to record high phosphate concentrations, but also nutrient rich water carried Abant and Mudurnu creeks influence this variables in Lake G  lk  y.

Table 11. 2. Monthly variation in TSI values for total phosphorous, chlorophyll-a, and Secchi depth are in Lake Gölköy. Abbreviations indicate code of trophics state (e.g., O; Oligotrphic, OM; Oligo-Mesotrophic), and others are given in Figure 11. 1.

	TSI_{TP}	TSI_{Cho}	TSI_{SDD}
J3		M	M
Jl3		M	M
A3		ME	M
S3		E	E
O3	M	E	E
N3	M	E	M
D3	M	M	M
Ja4	M	M	
Ap4	O	M	M
M4	E	E	E
J4	M	E	M
Jl4	M	E	OM
A4	O	ME	M
S4	M	E	M
O4	M	ME	M
N4	M	E	ME
D4	M	E	M
Ap5	M	E	ME
M5	M	ME	M
J5	M	ME	OM

In Lake Gölköy, TSI_{Cho} status fluctuated from mesotrophic to eutrophic structure. It is consequence of a few important factors; a) short term thermal stratification in

summer, b) long term water homogenization and c) high organic loading into Lake Gök  y. Thermal stratification cause decrease chlorophyll concentration due to low available nutrients for phytoplankton. Similar result was recorded from Italy lakes such as in Lake Iseo (Garibaldi et al., 2003), in Lake Garda (Salmaso, 2002). It known that nutrient concentration suitable water temperature, light intensity and other factors supported phytoplankton abundance in water bodies (Horne and Goldman, 1994).

TSI_{SD} ranged from oligo-mesotrophic to eutrophic status in Lake G  lk  y during two years (Table 11. 2). This trophic state usually had values between TSI_{TP} and TSI_{Cho} levels. Lake G  lk  y was eutrophic status in September-October 2003 and May 2004 according to TSI values of SD. In these months, high available nutrients due to water homogenization supported phytoplankton composition in Lake G  lk  y. Therefore, high water turbidity caused to record low SD levels due to high phytoplankton and other water particles concentrations. High total biovolume detected in Lake Como in late spring and fall seasons, when SD decreased low level (Buzzi, 2002). Three TSI variables stated that this lake was eutrophic status in May 2004.

OECD (1982) generated numerical range criteria based on chlorophyll-a, Secchi disk, and phosphorous levels to evaluate water quality. Lake G  lk  y showed meso-eutrophic status (Table 11. 3), according to criteria of OECD (1982). Temporal variation in these variables of this lake showed in Table 3. In Lake G  lk  y, Total phosphate value stated mesotrophic condition, while meso-eutrophic to eutrophic status occurred by levels of chlorophyll-a and Secchi depth during present study time (Table 11. 3). Results of OECD's trophic class values supported Carlson's TSI levels based on same variables.

Table 11. 3. Temporal variation in values of total phosphorous, chlorophyll-a, and Secchi depth are in Lake Gölköy, according to Vollenwider and Kerekes (1982). Abbreviations are given in Figure 11. 1 and Table 11. 2.

	TSI_{TP}	TSI_{Cho}	TSI_{SDD}
J3		M	M
Jl3		M	M
A3		ME	E
S3		E	E
O3	M	E	E
N3	M	E	EM
D3	M	M	E
Ja4	M	M	
Ap4	OM	M	M
M4	EM	M	E
J4	M	E	E
Jl4	M	E	M
A4	OM	M	O
S4	M	M	EM
O4	M	M	M
N4	M	M	E
D4	M	M	M
Ap5	M	E	E
M5	M	M	E
J5	M	M	M

Carlson's stated a few equation relating Secchi depth and chlorophyll-a is as follows;

$$\ln SD = 2.04 - 0.68 \ln(Cho) \quad (n=147, r=0.93).$$

A similar relationship found for Lake Gököl is;

$$\ln SD = 2.25 - 0.64 \ln(Cho) \quad (n=40, r = 0.48, p<0.001)$$

Similar equation concerning regression of SD and chlorophyll found in Lake Abant .

Additionally, negative relationships between SD and chlorophyll-a for Lake Skadar is;

$$\ln SD = 0.58 - 0.4 \ln(Cho) \quad (n=70, r = 0.6, p=0.002) \quad (\text{Rakocevic-Nedovic and Hollert, 2003}), \text{ and for Lake Apopka is given as;}$$

$$\log(SD) = 0.377 - 0.525 \log(Cho) \quad (\text{Bachmann et al., 2001}).$$

In Lake Gököl, relationship between TP and chlorophyll a was evaluated and found its equation as;

$$\log TP = 0.72 - 0.48 \log(Cho) \quad (n= 212, r = 0.62, p<0.001).$$

During this study, total nitrogen supported phytoplankton abundance due to high N: P ratio, while phosphate concentrations except in July 2004 were limited phytoplankton densities. This ratios except in July 2004 were usually detected higher level than 10:1 and the highest ratio recorded was 33.9:1 in August 2004 in Lake Gököl. Chiaudani and Vighi (1974) showed that nitrogen is limiting factor, when N:P ratio is less than 5:1, while phosphorous is the limiting nutrient on algae density at this ratio greater than 10:1. On the other hand, phosphate played a limiting factor, when N:P rate was higher than 16:1 (Crossetti and Bicudo, 2005).

Table 11. 4. Temporal variation saprobic status for BOD₅, according to Hamm (1969 in Rott et al., 2003). Abbreviations are given in Figure 11. 1 and Table 11. 2.

Saprobic water quality class	
J3	beta to alpha mesosaprobic
Jl3	beta mesosaprobic
A3	oligo to beta mesosaprobic
S3	beta mesosaprobic
O3	beta mesosaprobic
N3	beta mesosaprobic
D3	beta to alpha mesosaprobic
Ja4	beta to alpha mesosaprobic
Ap4	alpha mesosaprobic
M4	beta to alpha mesosaprobic
J4	beta mesosaprobic
Jl4	beta to alpha mesosaprobic
A4	beta to alpha mesosaprobic
S4	beta to alpha mesosaprobic
O4	alpha mesosaprobic
N4	beta to alpha mesosaprobic
D4	alpha mesosaprobic
Ap5	alpha mesosaprobic
M5	alpha mesosaprobic
J5	alpha mesosaprobic

Number of total bacteria and BOD₅ are important factors influence water status. Total coliform bacteria (see Figure 10. 3) ranged between $1,3 \times 10^2$ and $2,5 \times 10^4$ cfu/ml

in Lake Gölköy. *Escherichia coli* (see Figure 10. 3) recorded in this lake, fluctuated between 10 and 192 cfu/ml in fall and late spring seasons. The highest number of total coliform bacteria in fall season and followed in the spring during present study. It is consequence of loading organic materials via both creeks during fall and spring seasons. Low coliform bacteria recorded in winter and early spring seasons. Lake Gölköy water is not convinced to swim due to high coliform bacteria.

Biological oxygen demand showed high concentrations in spring 2005 during present study. This variables were converted saprobic water quality classes by using BOD₅ ranks according to Hamm (1969, in Rott et al., 2003). According to BOD₅ levels, Lake Gölköy showed usually beta to alpha mesosaprobic water status (Table 11. 4). Only, oligo to beta mesosaprobic class recorded in August 2003, while alpha mesosaprobic values detected during spring 2005. In August 2003, the highest water temperature and the lowest DO concentration recorded in Lake Gölköy. Phytoplankton densities were found lower levels in spring 2005, comparing in spring 2004, while total coliform bacteria showed higher level than in spring 2004.

31.1 Phytoplankton biomass of Lake Gölköy

Ninety eight phytoplankton species belonging to 69 genera were recorded in Lake Gölköy during present study. Phytoplankton abundance was changed seasonally and high densities were recorded in fall and spring seasons in this lake. Bacillariophyta was the most abundant phylum with 64.2 % of total phytoplankton abundance during present study. Diatom and non diatom densities were affected changes of environmental variables in Lake Gölköy (see Figure 7. 4, and Figure 9. 2).

In the present study, mean biovolume values were used to calculation of biomass levels. Some genera such as *Spirogyra*, *Dinobryon*, *Asterionella*, and *Fragilaria* had great contribution to total phytoplankton biomass in Lake Gölköy (Figure 11. 3). In

spring 2004, *Spirogyra* and *Dinobryon* were especially responsible to increase phytoplankton biomass in Lake Gölköy. In phytoplankton composition, *Dinobryon divergens* have gained competition for uptake nutrients in May 2004. Similarly, this taxon in Lake Como (Italy) had the highest abundance in May (Tolotti and Thies, 2002). In this month, the highest phosphate concentration recorded in Lake Gölköy. Hutchinson (1967) reported that *Dinobryon* had maximum level until nutrient was decreased critical value. Indeed, *Dinobryon* in Lake Gölköy biomass was declined with decreasing phosphate concentration in June 2004. In July 2004, *Dinobryon* showed important increase in their biomass, when phosphate value was again increased in the lake. On the other hand, *Asterionella formosa* showed high biomass values in June 2004, when *Dinobryon* and other phytoplankton decreased in Lake Gölköy (Figure 11. 3). It is consequence of competition among phytoplankton genera at low phosphate levels. Wetzel (1975) stated that *A. formosa* has broad phosphate concentration range and minimum phosphate requirement is lower than 0.2 µg/l.

Fragilaria and *Cymbella* in total diatom biomass usually had high biomass values in late spring and early summer (Figure 11. 3). Both genera were counted almost each month during present study. High biomass of *Cymbella* was detected as 8.8 mg/l in June 2003.

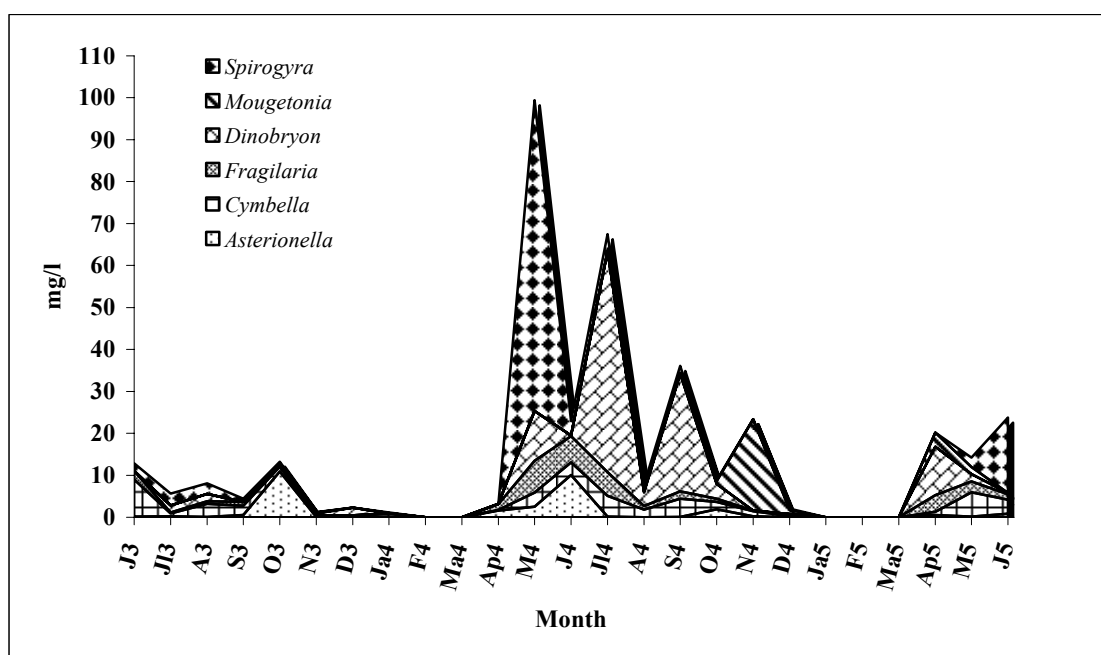


Figure 11. 3. Temporal variations of dominant genera' biomass in Lake G  lk  y. Abbreviations are given in Figure 11. 1.

Total phytoplankton biomass ranged from 2.0 mg/l in January 2004 to 110.3 mg/l in May 2004 in Lake G  lk  y during present study. Some phyla especially Chlorophyta, Bacillariophyta, and Chrysophyta had great contributions to total phytoplankton biomass with 34.6 %, 29.5 %, and 27.2 % respectively (Figure 11. 4). Similar results were found in Piburger See (Austria) (Tolotti and Thies, 2002); however, lower total phytoplankton biomass recorded in the study of Tolotti and her colleague (2002). In Lake G  lk  y, Euglenophyta had the lowest biomass percentage that is probably because this group included only the biomass of *Trachelomonas volvocina* with high abundance, while biomass of other taxa were not counted due to their low abundance in Lake G  lk  y. *Trachelomonas volvocina* stated as cosmopolitan is widely distributed in lakes, ditches, peat bogs and waste water, and indicators of heavily polluted water (John et al., 2002; Ariyadej et al., 2004). At the same time, this species was found eutrophic and bottom of oligotrophic temperate lakes in Sweden (Danilov and Ekelund, 2001), and in Lake Yeni  a  a (Kılın  , 2003).

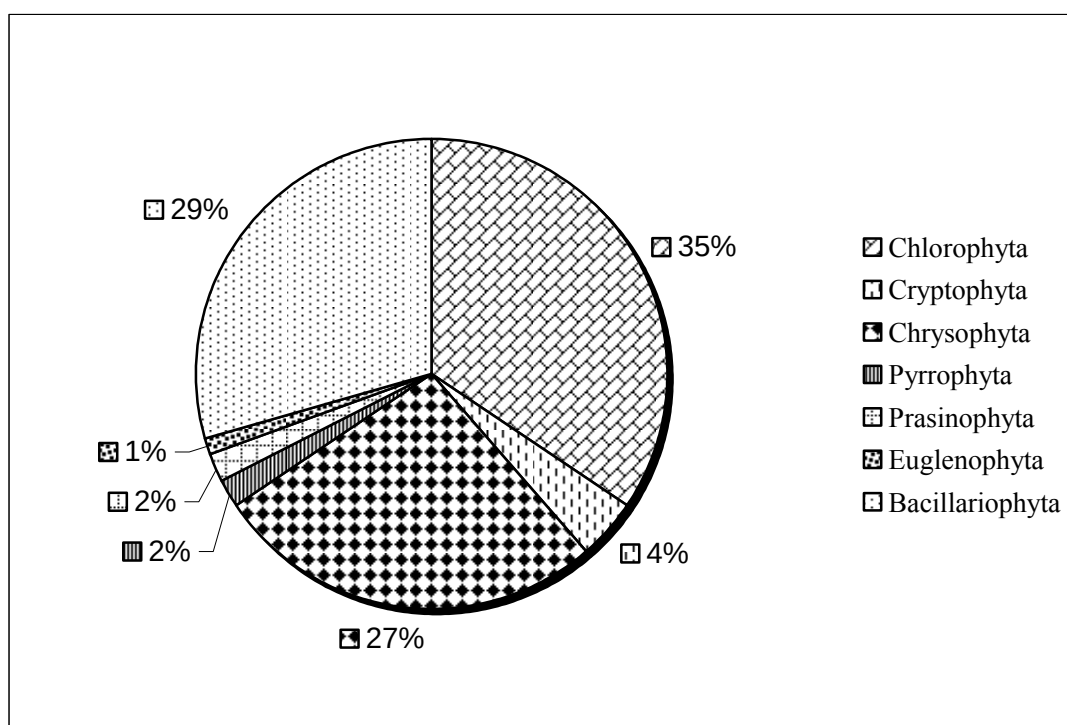


Figure 11. 4. Percentage biomass of phyla in Lake Gökçöy.

Cryptophyta and Prasinophyta had a small contribution to total phytoplankton biomass with 4 and 2 %, respectively (Figure 11. 4). Only, abundance and biovolume of *Tetraselmis cordiformis* were used to determine biomass of Prasinophyta, Cryptophyta included *Cryptomonas ovata* and *Plagioselmis nanoplanctonica* in Lake Gökçöy. Bacillariophyta was the most abundant phylum with 64.2 % of total phytoplankton abundance; however it is the second dominant group with 29.5 % rate of total phytoplankton biomass. It is consequence of their low biovolumes. These three phyla were responsible for biomass peaks in May, July, and September 2004 (Figure 11. 5). Total phytoplankton biomass ranged between 2.0 mg/l and 110.3 mg/l in January and May 2004 respectively. In May, recorded high phytoplankton biomass is consequence of available nutrient (e.g., recorded maximum phosphate, nitrate, chloride, sulphate) in Lake Gökçöy.

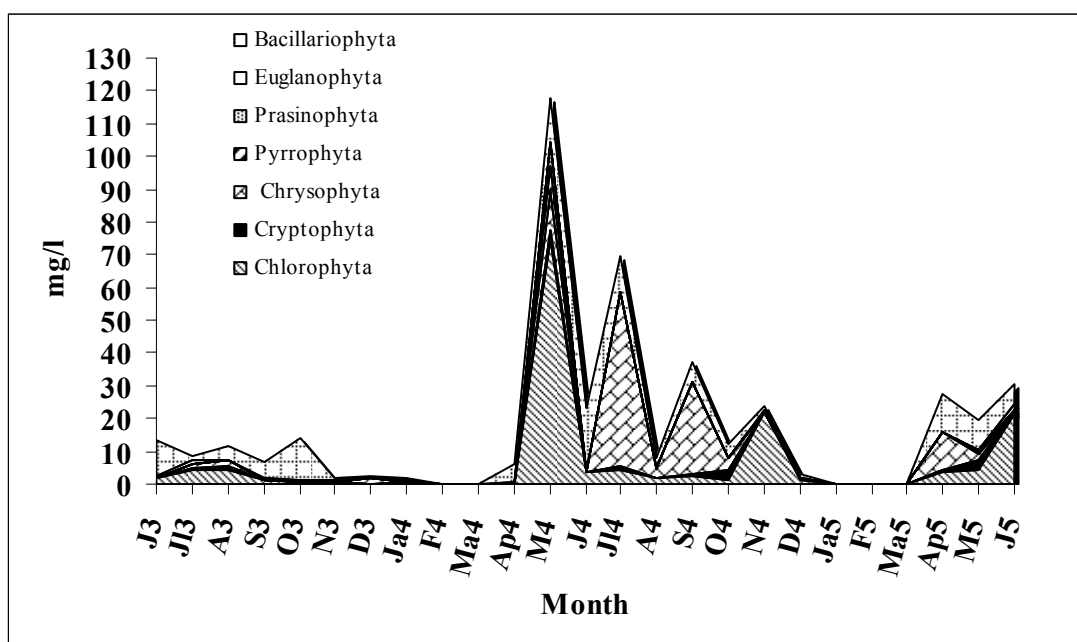


Figure 11. 5. Temporal variations of biomass of phyla in Lake Gököl. Abbreviations are given in Figure 11. 1.

In summer season, low phytoplankton biomass recorded during present study. Biomass level was sharply decreased in August 2004. Flagellated algae usually counted in epilimnion layer. For example, *Eudorina elegans* was found in summer and fall season. John and colleagues (2002) reported that *E. elegans* prefer nutrient enrichment water and common in spring and fall seasons. Low nutrient concentrations were affected phytoplankton abundance due to thermal stratification in Lake Gököl.

32 CONCLUSION

In the present study, Lake Gök  y showed temporal variations of Secchi depth, chlorophyll, phosphate, BOD₅ and coliform bacteria. Water quality was evaluated according to several criteria. TSI_{SD}, TSI_{Cho}, and TSI_{TP} had similar levels in Lake G  lk  y during study time. According to Carlson (1977) TSI values based on Secchi depth, phosphate and chlorophyll, Lake G  lk  y showed meso to eutrophic status. Additionally, output of these variables applied OECD (1982) criteria supported result of Carlson's TSI form this lake. N:P ratio played important role on phytoplankton composition. Phosphate was found as a limiting factor in lake water on phytoplankton dynamic, according to high N:P ratio. High number of total coliform and *E. coli* bacteria recorded in Lake G  lk  y. Colony number of bacteria showed that lake water was not suitable for swim.

Not only nutrient rich water preferred taxa found in Lake G  lk  y, but also high biomass levels were recorded. Chlorophyta, Bacillariophyta, and Chrysophyta were mainly responsible for total phytoplankton biomass during the present study. The highest biomass concentration recorded in May 2004, when nutrient concentrations were maximum levels.

All used variables showed that Lake G  lk  y was high productive lake and was to be eutrophic status. Phytoplankton composition, biodiversity, odor and other problems will be occurred, unless loading organic materials in Lake G  lk  y are prevented. Thus, the results of this study strongly suggest that water quality of Lake G  lk  y has been deteriorating by means of outside loading. Considering the importance of the lake for drinking purposes in near future, these results should be

taken seriously. A few criteria such as diatom, macrophyte index, and other trophic indexes are studied to evaluate the lake water quality.

33 GENERAL CONCLUSION

During the study, total number of phytoplankton taxa from both lakes is identified as 363 taxa. Many algae (209 taxa) were found in both lakes, while numbers of exclusive species are 76 and 62 taxa for Lake Abant and Gök  y, respectively. A total of 285 net phytoplankton taxa belonging to 103 genera and 271 net phytoplankton species belonging to 98 genera were identified in Lake Abant and G  lk  y, respectively (Table 5. 2). Both lakes were characterized with tremendous species diversity. Bacillariophyta was dominant phylum followed by Chlorophyta in both lakes during study period. Phytoplankton composition in both lakes showed high similarities according to values of Jaccard's and Sorenson similarity indices. Accordingly, similarity of phytoplankton composition between both lakes was varied from 29 % to 100 %. Euglenophyta showed the lowest similarity in lakes. It was consequence of different content of habitats and temperature levels. Many organic materials were carried into Lake G  lk  y via Abant and Mudurnu creeks. In diatom composition, some species such as *Asterionella formosa*, *Cymbella cistula*, *Fragilaria biceps*, *F. dilata*, *Navicula radiosa* showed frequent occurrence in each month for each stations for both lakes. *Cymbella silesiaca*, and *Rhopalodia gibba* were common in Lake Abant, while *Aulacoseria granulata*, *Cyclotella praetermis*, *Fragilaria crotonensis*, and *Nitzschia sigmoidae* were found each month from all stations in Lake G  lk  y. In non-diatom phytoplankton composition, *Trachelomonas volvocina*, *Cryptomonas ovata*, and *Ceratium hirundinella* were observed commonly in both lakes. *Polytoma cylindraceum* recorded from Lake G  lk  y was a first report for the Bolu region. Additionally, some other species (e.g. *Gonium pectorale*, *Provasoliella ovata*, and *Anabaena crassa*) were only found in Lake G  lk  y for the

area. Mainly, nutrient enriched water bodies preferred by phytoplankton species were higher in Lake Gök  y comparing to Lake Abant during present study. Species composition was similar between these lakes; however, Lake Abant showed almost about stable depth at high latitude with cooler water than Lake G  lk  y. In contrast, as a reservoir, Lake G  lk  y showed changeable depth due to agricultural activities at low latitude, with relatively warm water. Such differences were possibly the reasons of species diversity. However, several other factors such as physical and chemical variables, geomorphologic structure can affect phytoplankton diversity in these lakes.

Environmental variables were fluctuated seasonally in both lakes during two years. Lake G  lk  y had warmer water temperature than in Lake Abant. Thermal stratification occurred in summer in two lakes; however, stratification in Lake Abant had longer time comparing to in Lake G  lk  y. Additionally, Lake Abant was mainly covered with ice during winter, while ice-cover was only seen in the littoral site of Lake G  lk  y. Lake Abant had lower chlorophyll-a concentration and higher Secchi depth comparing in Lake G  lk  y. Lake G  lk  y usually had higher chemical component than Lake Abant.

In present study, diatom density showed seasonality and high abundance were usually recorded in late spring, early summer and fall seasons in both lakes. However, higher diatom abundance was recorded in Lake G  lk  y comparing to Lake Abant. In the both lakes, *Asterionella formosa*, *Fragilaria crotonensis* and *F. capucina* had great contribution to total diatom abundance. Total abundance of phytoplankton (except diatoms) especially increased in early summer during the study. In Lake Abant, the highest phytoplankton density was recorded in June 2004, while maximum phytoplankton level was found in July 2004 in Lake G  lk  y. *Dinobryon divergens* was the most abundant species in both lakes.

The relationship between phytoplankton composition and environmental factors was clearly explained by using CCA. Monte Carlo permutation test showed that environmental variables played significant ($p=0.002$) role on the distribution of phytoplankton in both lakes during present study. In both lakes, diatom-environment relation was not only high level, but also high relation found between non diatom Phytoplankton and physico-chemical variables. In Lake Abant, temperature, turbidity, conductivity, and alkalinity were mostly affected on diatom composition, while in Lake Gök  y, silica, pH, nitrate, temperature, and calcium were the most important factors on distribution of diatom taxa. Non diatom phytoplankton taxa were especially affected by magnesium, DO, conductivity, nitrite, and alkalinity in Lake Abant, while in Lake G  lk  y, calcium, chloride, magnesium, sulphate, and pH were the most important variables on occurrence of phytoplankton taxa. Monte Carlo permutation test showed that environmental variables played significant ($p=0.002$) role on the distribution of phytoplankton in both lakes during present study. Commonly detected phytoplankton taxa, which were found closer to center of CCA ordination in both lakes, may suggest a wide range of tolerance to nutrient concentrations.

Results of present study showed that Lake Abant had mesotrophic state, while Lake G  lk  y had threshold from mesotrophic to eutrophic status. Additionally, Lake G  lk  y had higher BOD₅, total coliform bacteria and *Escherichia coli* than in Lake Abant. At same time, higher biomass level was recorded in Lake G  lk  y comparing to in Lake Abant during present study.

Phytoplankton species were directly affected by changing environmental factors. Ecological and biological data for long term are extremely important to understand the state of habitats in past and future. These present study findings have contribution

essential phytoplankton and environmental information that should aid in evaluating the state of both lakes in future and other limnological researches.

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Appendix A. Total of 123 net-diatom species with number codes found during 20 months of sampling.

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- 1 *Achnanthes minutissima* Kützing 1833
 - 2 *Amphora aequalis* Krammer 1980
 - 3 *A. ovalis* (Kützing) Kützing 1844
 - 4 *Asterionella formosa* Hassall 1850
 - 5 *Aulacoseira granulata* (Ehrenberg) Simonsen 1979
 - 6 *A. islandica* (Müller) Simonsen 1979
 - 8 *Caloneis silicula* (Ehrenberg) Cleve 1894
 - 7 *C. alpestris* (Grunow) Cleve 1894
 - 10 *Campylodiscus noricus* Ehrenberg 1840
 - 9 *C. hibernicus* Ehrenberg 1845
 - 11 *Cocconeis fluviatis* Wallace 1960
 - 12 *C. pediculus* Ehrenberg 1838
 - 13 *C. placentula* Ehrenberg 1838
 - 14 *C. placentula* var. *euglypta* Grunow 1884
 - 15 *C. placentula* var. *lineata* Grunow 1884
 - 16 *C. rugosa* Sovereing 1960
 - 17 *Cyclotella bodanica* Grunow 1878
 - 18 *C. meneghiniana* Kützing 1844
 - 19 *C. ocellata* Pantocsek 1901
 - 20 *C. praetermissa* Lund 1951
 - 21 *Cymatopleura elliptica* Smith 1851
 - 22 *C. solea* Smith 1851
 - 23 *C. solea* var. *apiculata* Ralfs 1861
-

Appendix A (continued).

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- 24 *Cymbella affinis* Kützing 1844
 - 25 *C. amphicephala* Naegeli 1849
 - 26 *C. aspera* (Ehrenberg) Peragallo 1849
 - 27 *C. cistula*(Ehrenberg) Kirchner 1878
 - 28 *C. cuspidata* Kützing 1844
 - 29 *C. cymbiformis* Agardh 1830
 - 30 *C. ehrenbergii* Kützing 1844
 - 31 *C. gracilis* (Ehrenberg) Kützing 1844
 - 32 *C. helvetica* Kützing 1844
 - 33 *C. lanceolata* (Ehrenberg) Kirchner 1878
 - 34 *C. leptoceros* (Ehrenberg) Kützing 1844
 - 35 *C. minuta* Hilse ex Rabenhorst 1862
 - 36 *C. proxima* Reimer 1975
 - 38 *C. silesiaca* Bleisch 1864
 - 37 *C. schimanskii* Kramer 1982
 - 39 *Denticula elegans* Kützing 1844
 - 40 *Diatoma vulgaris* Borry 1824
 - 41 *D. tenuis* Agardh 1812
 - 42 *Diploneis elliptica* (Kützing) Cleve 1891
 - 43 *D. pseudovalis* Hustedt 1930
 - 44 *D. puella* (Schumann) Cleve 1894
 - 45 *Elleerbeckia arenaria* Crawd 1988
 - 46 *Epithemia argus* (Ehrenberg) Kützing 1844
 - 47 *E. adnata* (Kützing) Brebisson 1838
-

Appendix A (continued).

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- 48 *E. goeppertiana* Hilse 1860
 - 49 *E. sorex* Kützing 1844
 - 50 *E. turgida* (Ehrenberg) Kützing 1844
 - 51 *Eunotia bilunaris* (Ehrenberg) Mills 1934
 - 52 *E. parallella* Ehrenberg 1843
 - 53 *Fragilaria biceps* (Kützing) Lange-Bertalot 1991
 - 54 *F. brevistriata* Grunow 1885
 - 55 *F. capucina* Desmazieres 1925
 - 56 *F. capucina* var. *mesolepta* (Rabenhorst) Rabenhorst 1864
 - 57 *F. capucina* var. *vaucheriae* (Kützing) Lange-Bertalot 1980
 - 58 *F. construens* (Ehrenberg) Grunow 1862
 - 59 *F. crotonensis* Kitton 1869
 - 60 *F. dilata* (Brebisson) Lange-Bertalot 1986
 - 61 *F. lapponica* Grunow 1881
 - 62 *F. pinnata* Ehrenberg 1843
 - 63 *Fragilaria* sp.
 - 64 *F. ulna* (Nitzsch) Lange-Bertalot 1980
 - 65 *F. ulna* var. *danica*(Kützing) Lange-Bertalot 1980
 - 66 *F. ulna* var. *acus* (Kützing) Lange-Bertalot 1980
 - 67 *F. virescens* Ralfs 1843
 - 68 *Gomphonema acuminatum* Ehrenberg 1832
 - 69 *G. angustum* Agardh 1831
 - 70 *G. augur* Ehrenberg 1840
 - 71 *G. clavatum* Ehrenberg 1832
-

Appendix A (continued).

- 72 *G. hebridense* Ehrenberg 1832
 - 73 *G. gracile* Ehrenberg 1838
 - 74 *G. olivaceum* (Hornemann) Brebisson 1838
 - 75 *G. parvulum* (Kützing) Kützing 1849
 - 76 *G. subtile* Ehrenberg 1843
 - 77 *G. truncatum* Ehrenberg 1832
 - 78 *Gyrosigma acuminatum* (Kützing) Rabenhorst 1853
 - 79 *G. attenuatum* (Kützing) Rabenhorst 1853
 - 80 *Hantzschia amphyoxys* (Ehrenberg) Grunow 1880
 - 81 *Mastogloia elliptica* (Agardh) Cleve 1893
 - 82 *M. smithii* Thwaites 1856
 - 83 *Meridion circulare* (Greville) Agardh 1831
 - 84 *Melosira dickei* (Thwaites) Kützing 1849
 - 85 *M. lineata* Agardh 1824
 - 86 *M. varians* Agardh 1827
 - 87 *Navicula cryptocephala* Kützing 1844
 - 88 *N. cuspidata* (Kützing) Kützing 1844
 - 89 *N. gastrum* (Ehrenberg) Kützing 1844
 - 90 *N. trivialis* Lange-Bertalot 1980
 - 91 *N. radiosa* Kützing 1844
 - 92 *N. reinhardtii* (Grunow) Grunow 1877
 - 93 *N. rhynchocephala* Kützing 1844
 - 94 *Nedium dubium* (Ehrenberg) Cleve 1894
 - 95 *Nitzschia angustata* (Smith) Grunow 1880
-

Appendix A (continued).

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- 96 *N. palea* (Kützing) Smith 1856
 - 97 *N. recta* Hantzsch 1861
 - 98 *N. sigmoidea* (Nitzsch) Smith 1853
 - 99 *N. sigma* (Kützing) Smith 1853
 - 100 *N. vermicularis* (Kützing) Hantzsch 1860
 - 101 *N. wuellerstorffii* Lange-Bertalot 1987
 - 102 *Pinnularia divergens* Smith 1853
 - 103 *P. gibba* Ehrenberg 1841
 - 104 *P. interrupta* Smith 1853
 - 105 *P. legumen* (Ehrenberg) Ehrenberg 1843
 - 106 *P. maior* (Kützing) Rabenhorst 1853
 - 107 *P. microstauron* (Ehrenberg) Cleve 1891
 - 108 *P. rupestris* (Ehrenberg) Smith 1856
 - 109 *P. viridis* (Nitzsch) Ehrenberg 1843
 - 110 *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot 1980 b
 - 111 *Rhopalodia gibba* Müller 1895
 - 112 *Stauroneis anceps* Ehrenberg 1843
 - 113 *S. phoenicenteron* Ehrenberg 1843
 - 114 *Stenopterobia curvula* (Smith) Krammer 1987
 - 115 *Stephanodiscus alpinus* Husted 1942
 - 116 *Surirella angusta* Kützing 1844
 - 117 *S. biseriata* Brebisson 1836
 - 118 *S. ovalis* Brebisson 1838
 - 119 *S. robusta* Ehrenberg 1841
-

Appendix A (continued).

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120	<i>S. spiralis</i> Kützing 1844
121	<i>S. subsalsa</i> Smith 1853
122	<i>Surirella</i> sp.
123	<i>Tetracylus rupestris</i> (Braun) Grunow 1881
-

Appendix B: Total of 119 net-diatom species with number codes found during 20 months of sampling.

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- 1 *Achnanthes minutissima* Kützing 1833
 - 2 *Amphora aequalis* Krammer 1980
 - 3 *A. ovalis* (Kützing) Kützing 1844
 - 4 *A. pediculus* (Kützing) Grunow 1880
 - 5 *Anomoneis sphaerophora* (Ehrenberg) Pfitzer 1871
 - 6 *Asterionella formosa* Hassall 1850
 - 8 *Aulacoseira granulata* (Ehrenberg) Simonsen 1979
 - 7 *A. islandica* (Müller) Simonsen 1979
 - 10 *Caloneis silicula* (Ehrenberg) Cleve 1894
 - 9 *C. hibernicus* Ehrenberg 1845
 - 11 *Campylodiscus noricus* Ehrenberg 1840
 - 12 *Cocconeis pediculus* Ehrenberg 1838
 - 13 *C. placentula* Ehrenberg 1838
 - 14 *C. placentula* var. *lineata* Grunow 1884
 - 15 *Cyclotella bodanica* Grunow 1878
 - 16 *C. meneghiniana* Kützing 1844
 - 17 *C. ocellata* Pantocsek 1901
 - 18 *C. praetermissa* Lund 1951
 - 19 *Cymatopleura elliptica* Smith 1851
 - 20 *C. solea* Smith 1851
 - 21 *C. solea* var. *apiculata* Ralfs 1861
 - 22 *Cymbella affinis* Kützing 1844
 - 23 *C. amphicephala* Naegeli 1849
-

Appendix B (continued).

- 24 *C. aspera* (Ehrenberg) Peragallo 1849
 - 25 *C. cistula* (Ehrenberg) Kirchner 1878
 - 26 *C. cuspidata* Kützing 1844
 - 27 *C. cymbiformis* Agardh 1830
 - 28 *C. ehrenbergii* Kützing 1844
 - 29 *C. gracilis* (Ehrenberg) Kützing 1844
 - 30 *C. helvetica* Kützing 1844
 - 31 *C. lanceolata* (Ehrenberg) Kirchner 1878
 - 32 *C. leptoceros* (Ehrenberg) Kützing 1844
 - 33 *C. minuta* Hilse ex Rabenhorst 1862
 - 34 *C. proxima* Reimer 1975
 - 35 *C. schimanskii* Kramer 1982
 - 36 *C. silesiaca* Bleisch 1864
 - 38 *C. subcuspidata* Krammer 1982
 - 37 *Diatoma anceps* Agardh 1812
 - 39 *D. vulgaris* Borry 1824
 - 40 *D. tenuis* Agardh 1812
 - 41 *Didymosphaenia geminata* Schmidt 1899
 - 42 *Diploneis elliptica* (Kützing) Cleve 1891
 - 43 *D. pseudovalis* Hustedt 1930
 - 44 *D. puella* (Schumann) Cleve 1894
 - 45 *Epithemia adnata* (Kützing) Brebisson 1838
 - 46 *E. argus* (Ehrenberg) Kützing 1844
 - 47 *E. sorex* Kützing 1844
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Appendix B (continued).

- 48 *Eunotia bilunaris* (Ehrenberg) Mills 1934
 - 49 *Fragilaria biceps* (Kützing) Lange-Bertalot 1991
 - 50 *F. capucina* Desmazieres 1925
 - 51 *F. capucina* var. *mesolepta* (Rabenhorst) Rabenhorst 1864
 - 52 *F. capucina* var. *vaucheriae* (Kützing) Lange-Bertalot 1980
 - 53 *F. construens* (Ehrenberg) Grunow 1862
 - 54 *F. crotonensis* Kitton 1869
 - 55 *F. dilata* (Brebisson) Lange-Bertalot 1986
 - 56 *F. lapponica* Grunow 1881
 - 57 *F. leptostauron* Husted var *martyi* Lange-Bertalot 1991
 - 58 *F. pinnata* Ehrenberg 1843
 - 59 *F. ulna* (Nitzsch) Lange-Bertalot 1980
 - 60 *F. ulna* var. *danica* (Kützing) Lange-Bertalot 1980
 - 61 *F. ulna* var. *acus* (Kützing) Lange-Bertalot 1980
 - 62 *F. virescens* Ralfs 1843
 - 63 *Gomphonema acuminatum* Ehrenberg 1832
 - 64 *G. angustum* Agardh 1831
 - 65 *G. augur* Ehrenberg 1840
 - 66 *G. gracile* Ehrenberg 1838
 - 67 *G. olivaceum* (Hornemann) Brebisson 1838
 - 68 *G. parvulum* (Kützing) Kützing 1849
 - 69 *G. subtile* Ehrenberg 1843
 - 70 *G. truncatum* Ehrenberg 1832
 - 71 *Gyrosigma acuminatum* (Kützing) Rabenhorst 1853
-

Appendix B (continued).

- 72 *G. attenuatum* (Kützing) Rabenhorst 1853
 - 73 *Hantzschia amphioxys* (Ehrenberg) Grunow 1880
 - 74 *Melosira dickei* (Thwaites) Kützing 1849
 - 75 *M. lineata* Agardh 1824
 - 76 *M. varians* Agardh 1827
 - 77 *Meridion circulare* (Greville) Agardh 1831
 - 78 *Navicula clementis* Grunow 1882
 - 79 *N. cryptocephala* Kützing 1844
 - 80 *N. cuspidata* (Kützing) Kützing 1844
 - 81 *N. menisculus* Schumann 1867
 - 82 *N. nivalis* Ehrenberg 1853
 - 83 *N. radiosa* Kützing 1844
 - 84 *N. reinhardtii* (Grunow) Grunow 1877
 - 85 *N. rhynchocephala* Kützing 1844
 - 86 *N. trivialis* Lange-Bertalot 1980
 - 87 *Nedium dubium* (Ehrenberg) Cleve 1894
 - 88 *N. iridis* (Ehrenberg) Cleve 1894
 - 89 *Nitzschia linearis* Smith 1853
 - 90 *N. lorenziana* Grunow 1880
 - 91 *N. palea* (Kützing) Smith 1856
 - 92 *N. sigma* (Kützing) Smith 1853
 - 93 *N. sigmoidea* (Nitzsch) Smith 1853
 - 94 *N. tryblionella* Hantzsch 1860
 - 95 *N. vermicularis* (Kützing) Hantzsch 1860
-

Appendix B (continued).

- 96 *Pinnularia divergens* Smith 1853
 - 97 *P. gibba* Ehrenberg 1841
 - 98 *P. interrupta* Smith 1853
 - 99 *P. maior* (Kützing) Rabenhorst 1853
 - 100 *P. microstauron* (Ehrenberg) Cleve 1891
 - 101 *P. nobilis* (Ehrenberg) Ehrenberg 1843
 - 102 *P. streptoraphe* Cleve 1891
 - 103 *P. viridis* (Nitzsch) Ehrenberg 1843
 - 104 *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot 1980 b
 - 105 *Rhopalodia gibba* Müller 1895
 - 106 *Stauroneis anceps* Ehrenberg 1843
 - 107 *S. phoenicenteron* Ehrenberg 1843
 - 108 *S. producta* Grunow 1880
 - 109 *Stephanodiscus* sp.
 - 110 *Stenopterobia curvula* (Smith) Krammer 1987
 - 111 *Surirella angusta* Kützing 1844
 - 112 *S. biseriata* Brebisson 1836
 - 113 *S. brebissoni* Kramer and Lange-Bertalot 1987
 - 114 *S. elegans* Ehrenberg 1843
 - 115 *S. minuta* Brebisson 1849
 - 116 *S. ovalis* Brebisson 1838
 - 117 *S. robusta* Ehrenberg 1841
 - 118 *S. subsalsa* Smith 1853
 - 119 *Tetracylus rupestris* (Braun) Grunow 1881
-

Appendix C. Total of 162 net-phytoplankton species with number codes found during 20 months of sampling.

-
- 1 *Anabaena bergei* (Kützing) Bornet 1886
 - 2 *A. crassa* Lemmarmann 1896
 - 3 *Anabaena* sp.
 - 4 *A. planctonica* Brunnthaler 1903
 - 5 *A. smithii* (Komárek) Watanabe
 - 6 *Ankistrodesmus falcatus* (Corda) Ralfs 1848
 - 7 *A. fusiformis* Corda ex Korshikov 1953
 - 8 *A. spiralis* (Turner) Lemmermann 1908
 - 9 *Aphanocapsa litoralis* Hansgirg 1892
 - 10 *Aphanothece clathrata* West 1906
 - 11 *Botryococcus braunii* Kützing 1849
 - 12 *Bulbochaete* sp.
 - 13 *Calothrix stagnalis* Gomont 1895
 - 14 *Campylomonas reflexa* Hill 1991
 - 15 *C. rostratiformis* Hill 1991
 - 16 *Ceratium coralinianum* (Bailey) Jorgensen 1911
 - 17 *C. cornutum* (Ehrenberg) Claparede 1858
 - 18 *C. furcoides* (Lavender) Langhans 1925
 - 19 *C. hirundinella* (Müller) Dujardin 1841
 - 20 *Characium ornithocephalum* Braun 1855
 - 21 *Chlamydomonas globosa* Snow 1902
 - 22 *C. leptobasis* Skuja 1956
 - 23 *C. passiva* Skuja 1956
-

Appendix C (continued).

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- 24 *Chonrosphaera lapponica* Skuja 1964
 - 25 *Chroococcus turgidus* (Kützing) Nageli 1849
 - 26 *Closterium aciculare* West 1860
 - 27 *C. calosporum* Wittrock 1869
 - 28 *C. incurvum* Brebisson 1856
 - 29 *C. littorale* F. Gay 1884
 - 30 *C. moniliferum* (Bory) Ehrenberg ex Ralfs 1848
 - 31 *C. parvulum* Nageli 1849
 - 32 *C. venus* Kützing ex Ralfs 1848
 - 33 *Coelosphaerium kuetzingianum* Naegeli 1849
 - 34 *Cosmarium bioculatum* Brebisson 1848
 - 35 *C. botrytis* Meneghini 1848
 - 36 *C. contractum* var. *ellipsoideum* (Elfving) West *et* West 1902
 - 37 *C. crenatum* Ralfs 1848
 - 38 *C. depressum* var. *planctonicum* Reverdin 1919
 - 39 *C. granatum* Brebisson 1848
 - 40 *C. meneghinii* Rabenhorst 1868
 - 41 *C. pygmaeum* Archer 1864
 - 42 *C. venustum* (Brebisson) W. Archer 1861
 - 43 *Crucigeniella rectangularis* (Nageli) Komarek 1974
 - 44 *Cryptomonas marssonii* Skuja 1948
 - 45 *C. ovata* Ehrenberg 1838
 - 46 *C. platyuris* Skuja 1948
 - 47 *Cylindrospermum minutissimum* Collins 1896
-

Appendix C (continued).

48	<i>Dinobryon bavaricum</i> Imhof 1890
49	<i>D. divergens</i> Imhof 1887
50	<i>D. sertularia</i> Ehrenberg 1838
51	<i>D. sociale</i> Ehrenberg 1838
52	<i>D. sociale</i> var. <i>americanum</i> (Brunnthaler) Bachmann 1911
53	<i>Elakatothrix gelatinosa</i> Wille 1898
54	<i>Eremosphaera viridis</i> de Bary 1858
55	<i>Eudorina elegans</i> Ehrenberg 1831
56	<i>Euglena acus</i> Ehrenberg 1830
57	<i>E. agilis</i> Carter 1856
58	<i>E. contabrica</i> Pringsheim 1953
59	<i>E. deses</i> fo. <i>klebsii</i> (Lemmermann) Popova 1966
60	<i>E. granulata</i> (Klebs) Schmitz 1884
61	<i>E. obtusa</i> Schmitz 1884
62	<i>E. proxima</i> Dangeard 1901
63	<i>E. sanguinea</i> Ehrenberg 1830
64	<i>Geminella</i> sp.
65	<i>Golenkinia paucispina</i> Chodat 1894 emend. Korshikov 1953
66	<i>Gonatozygon brebissonii</i> Barry 1858
67	<i>G. monotaenium</i> de Bray 1856
68	<i>Gymnodinium cnecoides</i> Harris 1940
69	<i>Kirchneriella obesa</i> (West) Schmidle 1893
70	<i>Korshikoviella limnetica</i> (Lemmermann) Silva 1959
71	<i>K. michailovskoensis</i> (Elenkin) Silva 1959

Appendix C (continued).

72	<i>Lepocinclis fusiformis</i> (Carter) Lemmermann 1901
73	<i>L. ovum</i> (Ehrenberg) Lemmermann 1901
74	<i>L. playfairiana</i> Deflandre 1932
75	<i>L. steinii</i> Lemmermann 1901
76	<i>Merismopedia tenuissima</i> Lemmermann 1898
77	<i>Microcystis aeruginosa</i> (Kützing) Kützing 1846
78	<i>Monoraphidium arcuatum</i> (Korshikov) Hindak 1970
79	<i>Mougeotia boodlei</i> (West) Collins 1921
80	<i>M. capucina</i> (Bory) Agardh 1824
81	<i>M. nummuloides</i> (Hassall) De Toni 1889
82	<i>M. parvula</i> Hassall 1843
83	<i>M. quadrangulata</i> Hassall 1843
84	<i>M. scalaris</i> Hassall 1842
85	<i>Nephrocytium agardhianum</i> Nageli 1849
86	<i>N. limneticum</i> (Smith) Smith 1933
87	<i>Oocystis apiculata</i> West 1893
88	<i>O. tainoensis</i> Kommarek 1983
89	<i>O. borgei</i> Snow 1903
90	<i>O. marssonii</i> Lemmermann 1898
91	<i>O. parva</i> West & West 1898
92	<i>O. pusilla</i> Hansgirg 1890
93	<i>Oocystis</i> sp.
94	<i>Ophiocytium capitatum</i> Wolle 1887
95	<i>Oscillatoria formosa</i> (Bory) Gomont 1892

Appendix C (continued).

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96	<i>O. limosa</i> (Agard) Gomont 1892
97	<i>O. princeps</i> (Vaucher) Gomont 1892
98	<i>O. sancta</i> (Kützing) Gomont 1892
99	<i>O. tenuis</i> Schmidle 1901
100	<i>Pandorina morum</i> (Müller) Bory 1824
101	<i>Pediastrum boryanum</i> (Turpin) Meneghini 1840
102	<i>P. boryanum</i> var. <i>cornutum</i> (Raciborski) Sulek 1969
103	<i>P. boryanum</i> var. <i>longicorne</i> Reinsch 1867
104	<i>P. dublex</i> Meyen 1829
105	<i>P. integrum</i> Nageli 1849
106	<i>P. tetras</i> (Ehrenberg) Ralfs 1844
107	<i>Peridiniopsis thompsonii</i> (Thompson) Bourrelly 1968
108	<i>Peridinium cinctum</i> (Müller) Ehrenberg 1838
109	<i>P. willei</i> Huitfeldt-Kaas 1900
110	<i>Phacus caudatus</i> Hübner 1886
111	<i>P. pseudonordstedtii</i> Pochmann 1941
112	<i>P. striatus</i> (Drezepolski) France 1893
113	<i>Phormidium</i> sp.
114	<i>Plagioselmis nannoplanctica</i> (Skuja) Novarino
115	<i>Polytoma cylindraceum</i> Pascher 1927
116	<i>Pseudoanabaena</i> sp.
117	<i>Pseudosphaerocystis lacustris</i> (Lemmermann) Novakova 1965
118	<i>Quadricoccus verrucosus</i> Fott 1948
119	<i>Radiococcus planktonicus</i> Lund 1956
-

Appendix C (continued).

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120	<i>Scenedesmus arcuatus</i> (Lemmermann) Lemmermann 1899
121	<i>S. bicaudatus</i> Dedusenko 1925
122	<i>S. communis</i> Hegewald 1977
123	<i>S. dimorphus</i> (Turpin) Kützing 1833
124	<i>S. ellipticus</i> Corda 1835
125	<i>S. obliquus</i> (Turpin) Kützing 1833
126	<i>S. subspicatus</i> Chodat 1926
127	<i>Schroederia robusta</i> Korshikov 1953
128	<i>Snowella lacustris</i> (Chodat) Komarek <i>et</i> Hindak 1988
129	<i>Sorastrum americanum</i> (Bohlin) Schmidle 1900
130	<i>Sphaerellopsis spiralis</i> J. Belcher <i>et</i> Swale 1963
131	<i>Sphaerocystis planctonica</i> (Korshikov) Bourrelly 1966
132	<i>Spirogyra fluviatilis</i> Hilse 1863
133	<i>S. communis</i> (Hassall) Kützing 1849
134	<i>S. jugalis</i> (Dillwyn) Kützing 1845
135	<i>S. longata</i> (Vaucher) Kützing 1843
136	<i>S. majusculas</i> Kützing 1849
137	<i>S. mirabilis</i> (Hassall) Kützing 1849
138	<i>S. pratensis</i> Transeau 1914
139	<i>S. rivularis</i> (Hassall) Rabenhorst 1868
140	<i>S. setiformis</i> (Roth) Kützing 1845
141	<i>S. submargaritata</i> Godward 1956
142	<i>S. tenuissima</i> (Hassall) Kützing 1849
143	<i>S. weberi</i> Kützing 1843
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Appendix C (continued).

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144	<i>Spirulina maior</i> (Kützing) Gomont 1892
145	<i>S. subsalsa</i> (Oersted 1842) Gomont 1892
146	<i>Staurastrum gracile</i> Ralfs 1848
147	<i>S. lunatum</i> Ralfs 1848
148	<i>S. armigerum</i> fo. <i>furcigerum</i> (Ralfs) Teiling 1957
149	<i>Synura petersenii</i> Korshikov 1929
150	<i>Tetrachlorella alternans</i> (Smith) Korshikov 1939
151	<i>Tetraselmis cordiformis</i> (Carter) Stein 1878
152	<i>Tetrastrum komarekii</i> Hindak 1977
153	<i>Thorakochloris nygardii</i> Komarek 1979
154	<i>Trachelomonas acanthostoma</i> Stokes 1887
155	<i>T. armata</i> Stein 1878
156	<i>T. granulosa</i> Playfair 1915
157	<i>T. planctonica</i> Svirenko 1914
158	<i>T. pulchella</i> Drezepolski 1925
159	<i>T. volvocina</i> Ehrenberg 1833
160	<i>Trochiscia hystrix</i> (Reinsch) Hansg. 1888
161	<i>Uroglena volvox</i> Ehrenberg 1834
162	<i>Zygnema conspicuum</i> (Hassall) Transeau 1934
-

Appendix D. Total of 152 net-phytoplankton species with number codes found during 20 months of sampling.

- 1 *Anabaena crassa* (Lemmermann) Komárková-Legnerová & Cronberg 1992
 - 2 *Anabaena* sp.
 - 3 *Ankistrodesmus falcatus* (Corda) Ralfs 1848
 - 4 *A. fusiformis* Corda ex Korshikov 1953
 - 5 *A. spiralis* (Turner) Lemmermann 1908
 - 6 *Ankyra judayi* (Smith) Fott 1957
 - 7 *A. lanceolata* (Smith) Fott 1957
 - 8 *Botryococcus braunii* Kützing 1849
 - 9 *Bulbochaete* sp.
 - 10 *Carteria klebsii* (Dangeard) France emend. Troitzkaya 1921
 - 11 *Ceratium coralinianum* (Bailey) Jorgensen 1911
 - 12 *C. cornutum* (Ehrenberg) Claparede 1858
 - 13 *C. furcoides* (Lavender) Langhans 1925
 - 14 *C. hirundinella* (Müller) Dujardin 1841
 - 15 *Characium ensiformis* Braun 1855
 - 16 *Chlamydomonas globosa* Snow 1902
 - 17 *C. leptobasis* Skuja 1956
 - 18 *C. passiva* Skuja 1956
 - 19 *Chlamydomonas* sp.
 - 20 *Chroococcus turgidus* (Kützing) Nageli 1849
 - 21 *Closterium aciculare* West 1860
 - 22 *C. gracile* Brebisson ex Ralfs 1848
 - 23 *C. moniliferum* (Bory) Ehrenberg ex Ralfs 1848
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Appendix D (continued).

- 24 *Cosmarium bioculatum* Brebisson 1848
 - 25 *C. botrytis* Meneghini 1848
 - 26 *C. granatum* Brebisson 1848
 - 27 *C. impressulum* Elfving 1881
 - 28 *C. laeve* Rabenhorst 1868
 - 29 *C. subcrenatum* Hantzsch 1861
 - 30 *C. venustum* (Brebisson) Archer 1861
 - 31 *Cryptomonas marssonii* Skuja 1948
 - 32 *C. ovata* Ehrenberg 1838
 - 33 *C. platyuris* Skuja 1948
 - 34 *Campylomonas reflexa* Hill 1991
 - 35 *C. rostratiformis* Hill 1991
 - 36 *Dinobryon bavaricum* Imhof 1890
 - 37 *D. divergens* Imhof 1887
 - 38 *D. sertularia* Ehrenberg 1838
 - 39 *D. sociale* Ehrenberg 1838
 - 40 *D. sociale* var. *americanum* (Brunnthaler) Bachmann 1911
 - 41 *D. sociale* var. *spitatum* (Stein) Lemmermann 1903
 - 42 *Elakatothrix gelatinosa* Wille 1898
 - 43 *Eudorina elegans* Ehrenberg 1831
 - 44 *Euglena acus* Ehrenberg 1830
 - 45 *E. agilis* Carter 1856
 - 46 *E. chlamydophora* Mainx 1927
 - 47 *E. geniculata* (Schmitz) Dujardin 1841
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Appendix D (continued).

- 49 *E. limnophila* Lemmermann var. *swirenkoi* (Anoldi) Popova 1955
 - 50 *E. oblonga* Schmitz 1884
 - 51 *E. viridis* Ehrenberg 1830
 - 52 *Geminella* sp.
 - 53 *Golenkiniopsis solitaria* Korsikov 1953
 - 54 *Golenkinia paucispina* West et West 1902
 - 55 *Gonatozygon brebissonii* Barry 1858
 - 56 *G. monotaenium* de Bray 1856
 - 57 *Gonium pectorale* Müller 1773
 - 58 *Gymnodinium cnecoides* Harris 1940
 - 59 *Hyaliella polytomoides* Pascher 1931
 - 60 *Kirchneriella obesa* (West) Schmidle 1893
 - 61 *Korshikoviella limnetica* (Lemmermann) Silva 1959
 - 62 *K. michailovskoensis* (Elenkin) Silva 1959
 - 63 *Lepocinclis ovum* (Ehrenberg) Lemmermann 1901
 - 64 *L. playfairiana* Deflandre 1932
 - 65 *L. steinii* Lemmermann 1901
 - 66 *Merismopedia tenuissima* Lemmermann 1898
 - 67 *Micractinium crassisetum* Hortob. 1973
 - 68 *Microcystis aeruginosa* (Kützing) Kützing 1846
 - 69 *Monomastix opisthostigma* Scherffel 1912
 - 70 *Monoraphidium arcuatum* (Korshikov) Hindak 1970
 - 71 *M. irregulare* (Smith) Komarkova-Legnerova 1969
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Appendix D (continued).

- 72 *Mougeotia boodlei* (West) Collins 1921
 - 73 *M. capucina* (Bory) Agardh 1824
 - 74 *M. parvula* Hassall 1843
 - 75 *M. quadrangulata* Hassall 1843
 - 76 *M. scalaris* Hassall 1842
 - 77 *Nephrocytium agardhianum* Nageli 1849
 - 78 *Oocystis apiculata* West 1893
 - 79 *O. borgei* Snow 1903
 - 80 *O. marssonii* Lemmermann 1898
 - 81 *O. parva* West and West 1898
 - 82 *Ophiocytium capitatum* Wolle 1887
 - 83 *Oscillatoria formosa* (Bory) Gomont 1892
 - 84 *O. limosa* (Agard) Gomont 1892
 - 85 *O. minima* Gicklhorn 1921
 - 86 *O. princeps* (Vaucher) Gomont 1892
 - 87 *O. rubescens* (de Candolle) Gomont 1892
 - 88 *O. sancta* (Kützing) Gomont 1892
 - 89 *O. subbveris* Schmidle 1901
 - 90 *O. tenuis* Schmidle 1901
 - 91 *O. terebiformis* (Agardh) Gomont 1892
 - 92 *Pandorina morum* (Müller) Bory 1824
 - 93 *Pediastrum boryanum* (Turpin) Meneghini 1840
 - 94 *P. boryanum* var. *cornutum* (Raciborski) Sulek 1969
 - 95 *P. boryanum* var. *longicorne* Reinsch 1867
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Appendix D (continued).

- 96 *P. integrum* Nageli 1849
 - 97 *P. tetras* (Ehrenberg) Ralfs 1844
 - 98 *Peridiniopsis thompsonii* (Thompson) Bourrelly 1968
 - 99 *Peridinium cinctum* (Müller) Ehrenberg 1838
 - 100 *P. willei* Huitfeldt-Kaas 1900
 - 101 *Phacus caudatus* Hübner 1886
 - 102 *P. curvicauda* Svirenko 1915
 - 103 *P. haemeli* Allorge et Lefevre 1930
 - 104 *P. pseudonordstedtii* Pochmann 1941
 - 105 *Plagioselmis nannoplantica* (Skuja) Novarino
 - 106 *Pleodorina californica* Shaw 1894
 - 107 *Polytoma cylindraceum* Pascher 1927
 - 108 *Provasoliella ovata* (Jacobsen) Loeblich 1967
 - 109 *Pseudosphaerocystis lacustris* (Lemmermann) Novakova 1965
 - 110 *Radiococcus planktonicus* Lund 1956
 - 111 *S. arcuatus* (Lemmermann) Lemmermann 1899
 - 112 *S. bicaudatus* Dedusenko 1925
 - 113 *S. brevispina* (Smith) Chodat 1926
 - 114 *S. communis* Hegewald 1977
 - 115 *S. dimorphus* (Turpin) Kützing 1833
 - 116 *S. ellipticus* Corda 1835
 - 117 *S. falcatus* Chodat 1894
 - 118 *S. obliquus* (Turpin) Kützing 1833
 - 119 *S. opoliensis* Richter var. *mononensis* Chodat 1926
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Appendix D (continued).

- 120 *S. subspicatus* Chodat 1926
 - 121 *Schroederia robusta* Korshikov 1953
 - 122 *Snowella lacustris* (Chodat) Komarek *et* Hindak 1988
 - 123 *Sphaerellopsis* sp.
 - 124 *Sphaerocystis planctonica* (Korshikov) Burrelly 1966
 - 125 *Spirogyra communis* (Hassall) Kützing 1849
 - 126 *S. dubia* Kützing 1855
 - 127 *S. fluviatilis* Hilse 1863
 - 128 *S. longata* (Vaucher) Kützing 1843
 - 129 *S. majusculas* Kützing 1849
 - 130 *S. mirabilis* (Hassall) Kützing 1849
 - 131 *S. porticalis* (Müller) Cleve 1868
 - 132 *S. pratensis* Transeau 1914
 - 133 *S. rivularis* (Hassall) Rabenhorst 1868
 - 134 *S. setiformis* (Roth) Kützing 1845
 - 135 *S. subechinata* Godward 1956
 - 136 *S. tenuissima* (Hassall) Kützing 1849
 - 137 *S. weberi* Kützing 1843
 - 138 *Spirulina maior* (Kützing) Gomont 1892
 - 139 *Staurastrum lunatum* Ralfs 1848
 - 140 *S. armigerum* fo. *furcigerum* (Ralfs) Teiling 1957
 - 141 *Tetrachlorella alternans* (Smith) Korshikov 1939
 - 142 *Tetraselmis cordiformis* (Carter) Stein 1878
 - 143 *Tetrastrum komarekii* Hindak 1977
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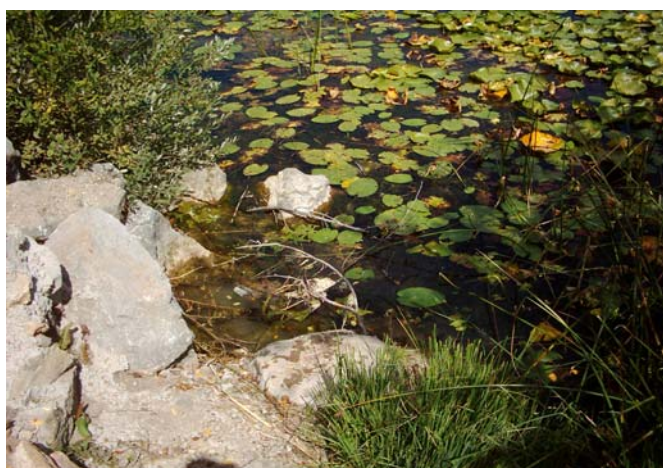
Appendix D (continued).

- 144 *Trachelomonas armata* Stein 1878
- 145 *T. dubia* (Svirenko) Deflandre 1926
- 146 *T. hispida* (Perty) Stein emend. Deflandre 1926
- 147 *T. volvocina* Ehrenberg 1833
- 148 *Uroglena volvox* Ehrenberg 1834
- 149 *Volvox aureus* Ehrenberg 1832
- 150 *V. globator* Linnaeus 1758
- 151 *V. polychlamys* Korschikoff 1939
- 152 *Zygnema conspicuum* (Hassall) Transeau 1934
-

PHOTOGRAPHS



Photograph 1. Littoral 1 sampling station in Lake Abant.



Photograph 2. Littoral 2 sampling station in Lake Abant.



Photograph 3. Littoral 1 sampling station in Lake Abant.



Photograph 1. Littoral 1 sampling station in Lake Gölköy.



Photograph 2. Littoral 2 sampling station in Lake Gölköy.



Photograph 3. Littoral 1 sampling station in Lake Gölköy.

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Presentations

- ÇELEKLİ, A., 2001. The Effect of pH and Salt Concentrations on Growth and β -carotene Accumulation by *Dunaliella salina*. 1th International Algae Technology Symposium, 24-26 October, İZMİR, TURKEY (oral presentation).
- ÇELEKLİ, A., and KÜLKÖYLÜOĞLU, O. 2004. Comparative Analysis of Seasonal Water Quality Changes and Algae Potential Between Lake Abant And Lake Gölköy (Bolu, TURKEY). I. National Limnology Workshop. 17-19 May 2004, Sapanca-Adapazarı, Turkey (oral presentation).
- ÇELEKLİ A. 2004. Changing of Algae potential and Water Quality in Lake Abant. V. National Ecology and Environment Congress. 5-8 October 2004, BOLU (oral presentation).
- ÇELEKLİ, A., 2005. The Effect of Salt and Nitrogen Concentrations, and light intensity on Growth and β -carotene Accumulation by *Dunaliella salina*.

14th National Biotechnology Congress. 29 August-September 2005, Eskişehir (oral presentation).

- **ÇELEKLİ A.**, Balcı M, and Deveci A., 2005. Effect of pH on growth and chlorophyll a, protein accumulation by a new isolate of *Scenedesmus obliquus* from Lake Gölçük (Bolu). 14th National Biotechnology Congress. 29 August-September 2005, Eskişehir (poster session).
- **ÇELEKLİ, A.**, and KÜLKÖYLÜOĞLU, O. 2005. On the Relationship between Ecology and Phytoplankton Composition in a Karstic Spring (Akkaya, Bolu). 14th Workshop of The International Association of Phytoplankton Taxonomy and Ecology (IAP) September 4-11, 2005, Sapanca, Turkey (poster session).
- **ÇELEKLİ, A.**, and KÜLKÖYLÜOĞLU O., 2006. Phytoplankton (except Bacillariophyceae) Community and its Relationship to Environmental Factors in Lake Abant (Bolu). IV Balkan Botanical Congress, Sofia / Bulgaria / 20 – 26 June 2006 (oral presentation).
- **ÇELEKLİ, A.**, and BALCI, M., 2006. Effects of pH, Nitrate, and Phosphate Concentrations on Growth, Production of Protein, Chlorophyll-a, and Biomass of *Scenedesmus obliquus* species. IV Balkan Botanical Congress, Sofia / Bulgaria / 20 – 26 June 2006 (oral presentation).

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- **ÇELEKLİ, A.** and Dönmez, G. 2006. Effect of pH, light intensity, salt and nitrogen concentrations on growth and β -carotene accumulation by a new isolate of *Dunaliella* sp. World Journal of Microbiology & Biotechnology, 22(2):183-189.
- **ÇELEKLİ, A.**, and KÜLKÖYLÜOĞLU, O. (2006). On The Relationship between Ecology and Phytoplankton Composition in a Karstic Spring (Çepni, Bolu). Ecological Indicators. DOI: 10.1016/j.ecolind.
- **ÇELEKLİ, A.**, and KÜLKÖYLÜOĞLU, O. (2006). Net Planktonic Diatom (Bacillariophyceae) Composition of Lake Abant (Bolu). Turkish J. Botany
- **ÇELEKLİ, A.**, (in press). Net Diatom (Bacillariophyceae) Flora of Lake Gölköy (Bolu). Turkish J. Botany.

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- **ÇELEKLİ, A.,** ALBAY, M., and DÜGEL, M. (in review). Phytoplankton (Exclusive of the Diatoms) Flora of Lake Gök  y (Bolu). Turkish J. Botany.

Projects:

- Comparative Analyses of Seasonal Water Quality Changes and Algae Potential between Lake Abant and Lake G  lk  y. T  B  TAK TBAG (2281) 103T028 Nolu Proje. Yardımcı Arařtırmacı (2003-2005).
- Isolation and Characterization of Cellulolytic Enzymatic Complex of Anaerobic Fungi for Extending the Shelf life of Bread, Turkish Scientific and Technical Reseach Council (TUB  TAK)-TBAG-U-73 (103 T 084)- Republic of Macedonia Ministry of Science and Education Joint Project. Yardımcı Arařtırmacı (2003-)
-   evresel Fakt  rlerin S  nnet G  l   (Bolu, T  rkiye) Ostracoda (Crustacea) Fauanası   zerine Mevsimsel Etkileri. 104Y222 no'lu TUB  TAK projesi.Yardımcı Arařtırmacı (2005-).
- Bolu İli B  y  ksu Deresi'nin   evre Kalitesinin Biyolojik ve Fiziko-Kimyasal Y  ntemlerle Belirlenmesi. 104Y165 no'lu TUB  TAK projesi, Yardımcı Arařtırmacı. (2005-)

Shcolarship/Fellowship:

- Bilim Adamı Yetiřtirme Grubu (BAYG) shcolarship for MSc, 1999-2001.
- Bilim Adamı Yetiřtirme Grubu (BAYG) shcolarship for Ph.D, 2003-2006

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