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The Effects of Certain Physical and Chemical Variables on the Succession of the Phytoplankton in the Shallow Cagis Pond (Balıkesir, Turkey)

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Abstract
The effects of certain physical and chemical variables on the phytoplankton succession in the shallow Çağış Pond (Balıkesir, Turkey) were investigated between August 2006 and July 2008. Samples were taken monthly from one sampling station. A total of 93 taxa belonging to 7 divisions were identified, including Chlorophyta (39 taxa), Heterokontophyta (30 taxa), Cyanobacteria (17 taxa), Euglenophyta (2 taxa), Dinophyta (2 taxa), Charophyta (2 taxa) and Cryptophyta (1 taxa). *Cyclotella meneghiniana*, *Microcystis aeruginosa*, *Microcystis protocystis*, *Arthrospira platensis*, and *Micractinium pusillum* dominated the phytoplankton at least for one season. A Canonical Correspondence Analysis (CCA) showed that water temperature, transparency, conductivity, and total dissolved solids had significant effects on the distribution and abundance of the dominant phytoplankton taxa.
Keywords: Abundance, Canonical Correspondence Analysis (CCA), Physical and Chemical Parameters, Phytoplankton, and Pond

Sığ Çağış Göleti (Balıkesir, Türkiye) Fitoplankton Süksesyonu Üzerine Bazı Fiziksel ve Kimyasal Değişkenlerin Etkisi

Özet
Sığ bir gölette (Çağış Göleti, Balıkesir, Türkiye), fitoplanktonun tür kompozisyonu ve yoğunluğu üzerine bazı temel fiziksel ve kimyasal parametrelerin etkisini belirlemek amacıyla Ağustos–2006 ile Temmuz–2008 tarihleri arasında örnekleme yapılmıştır. Çalışma süresi boyunca Chlorophyta'ya ait 39, Heterokontophyta'ya ait 30, Cyanobacteria'ya ait 17, Dinophyta'ya ait 2, Euglenophyta'ya ait 2, Charophyta'ya ait 2 ve Cryptophyta'ya ait 1 olmak üzere toplam 93 takson tespit edilmiştir. *Cyclotella meneghiniana*, *Microcystis aeruginosa*, *Microcystis protocystis*, *Arthrospira platensis* ve *Micractinium pusillum* hücre yoğunluğu yönünden fitoplanktonda önemli olmuşlardır. Kanonik Uyum Analizi (CCA) baskın türlerin dağılımını ve yoğunluğunu etkileyen en önemli parametrelerin su sıcaklığı, suyun ışık geçirgenliği, elektriksel iletkenlik ve toplam çözünmüş madde olduğunu göstermiştir.
Anahtar Kelimeler: Fitoplankton, Fiziksel ve Kimyasal Parametreler, Gölet, Hücre yoğunluğu, Kanonik Uyum Analizi (CCA)

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INTRODUCTION

Small, shallow ponds exist in a variety of shapes, depths, and sizes world-wide. They include seasonal, temporary, or permanent water bodies. They are exposed to environmental conditions that affect their trophic status and the biota (Fairchild et al. 2005, Peretyatko et al. 2007, Soininen et al. 2007). Especially, for algae there is a strong relationship between species number and habitat diversity. Shallow lakes and ponds have a large number of ecological niches that cause high species diversity (Reynolds 1984, Wetzel 2001, Duelli and Obrist 2003). Species diversity within a community arises from very different factors such as soil erosion, changes in water level, nutrient concentrations, or density of herbivores (Wetzel 2001).

Phytoplankton populations in shallow ponds usually exist in a horizontal band near the surface. This band where the dense phytoplankton growth occurs contains depths between 5-8 cm and 45-50 cm. The depth of this band depends on a variety of factors such as the presence of appropriate nutrients, light transmittance and the turbidity of the water (Messyasz and Jurgonska 2003). Shallow ponds are

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continuously mixed, which permits the algae to remain in suspension and exposes them to light, promoting their growth (Messyasz et al. 2005).

High concentrations of cyanobacteria, chlorophytes, cryptophytes, and diatoms are frequently associated with the eutrophic condition in ponds (Oladipo and Williams 2003, Harsha and Malammanavar 2004, Peretyatko et al. 2007). Fairchild et al. (2005), in a study of 13 eutrophic ponds, reported that the phytoplankton biomass was directly correlated with the total phosphorus and negatively correlated with the Secchi depth disk. Mcmaster et al. (2005) associated phytoplankton abundance and composition with total phosphorus, total nitrogen, and conductivity in Alpine ponds, while Oladipo and Williams (2003) reported a positive correlation between the pH and total phytoplankton in their study of fish ponds.

The goal of this study was to investigate the effects of some basic physical and chemical variables on the species diversity and the abundance of phytoplankton in a shallow recreation pond (Çağış Pond) to determine how the dynamics of these parameters were related to the distribution and cell abundance of phytoplankton species using Canonical Correspondence Analysis (CCA).

MATERIALS AND METHODS

Çağış Pond is located at 39º31'12"N; 28º00'45"E, 17 km southeast of Balıkesir, Turkey (Fig. 1) and is fed by the Çağış Stream. It has a maximum depth of 2.5 m, a mean depth of 1 m and a surface area of 3 km^2. It was also seen that there is not a very dense development of macrophytes at the edges of the pond.

Sampling was carried out monthly at one station from about 10 cm below the surface between August 2006 and July 2008. In the field, phytoplankton samples were placed in 250 mL dark bottles and fixed with Lugol's solution. In the laboratory, the fixed samples were firstly agitated, then poured into 50 mL graduated cylinders and were allowed to settle for 24 h. At the end of the settling period, 45 mL of water was aspirated from each graduated cylinder, and the remaining 5 mL of water was poured into a small glass vial for microscopic analysis. Enumeration and identification of phytoplankton were performed using a Palmer–Maloney counting cell and a compound microscope equipped with water immersion lenses and a phase-contrast attachment according to the Utermöhl sedimentation method (Utermöhl 1958).

Diatoms were also analyzed using permanent preparations where the samples were digested with acid (Hasle 1978, APHA 1995). The phytoplankton species were identified according to Huber–Pestalozzi (1950, 1961, 1962, 1969, 1982, and 1983), Round et al. (1990), Kramer and Lange-Bertalot (1986, 1991), Sims (1996), John et al. (2003) and Komarek and Anagnostidis (2008). Taxonomy of algae was controlled for current accepted status of the species (Guiry and Guiry 2014).

Conductivity, total chlorophyll, total dissolved solid (TDS), pH, oxidation-reduction potential (ORP), and water temperature were measured using an YSI 6600 multi probe. The water transparency was measured regularly on each sampling date using a Secchi disk. Concentrations of orthophosphate (PO_4^{3-}) and nitrate (NO_3^-) were determined spectrophotometrically according to standard methods (APHA 1995).

The species diversity of phytoplankton was calculated with the Shannon-Weaver species diversity index using a Biodiversity program (McAleese et al. 1997). Data was log-transformed before the statistical analysis to obtain normal distribution. Canonical correspondence analysis (ter Braak and Smilauer 1997) was used to investigate the relationship between the conductivity, total chlorophyll, total dissolved solid (TDS), pH, oxidation-reduction potential (ORP), water temperature, Secchi disk, orthophosphate, nitrate, and the monthly abundance of dominant phytoplankton.

RESULTS

During the sampling period the following was found: the conductivity ranged from 0.25 mS/cm to 1.35 mS/cm, total chlorophyll ranged from 17 μg/L to 109.2 μg/L, total dissolved solids ranged from 0.2 g/L to 0.88 g/L, pH ranged from 9.02 to 10.78, oxidation-reduction potential ranged from 0.3 mV to 139.3 mV, water temperature ranged from 12°C to 25.87°C, the Secchi disk ranged from 0.03 m to 0.85 m, orthophosphate ranged from 0.22 mg/L to 0.69 mg/L, and the nitrate ranged from 4 mg/L to 6.8 mg/L, respectively (Fig. 2).

A total of 93 phytoplanktonic taxa were identified (Table 1). Chlorophyta comprised 43% (43 taxa) of the total taxa. The remaining divisions

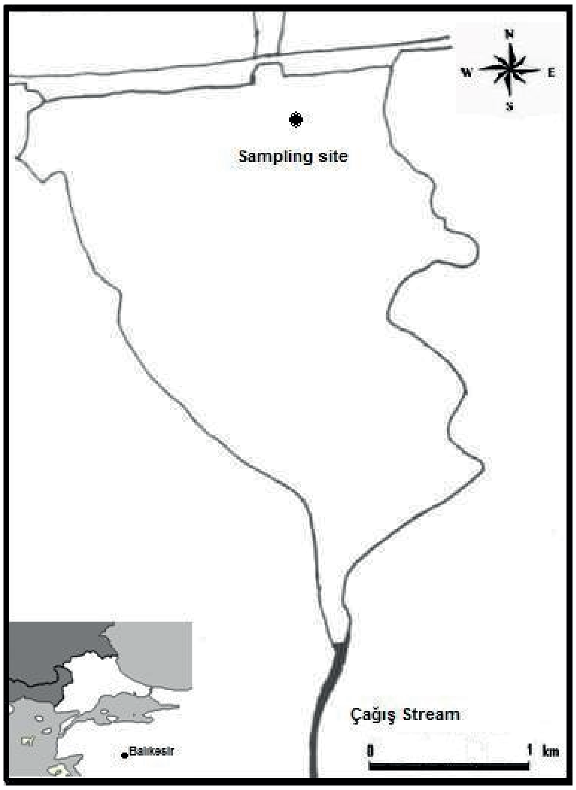

Fig. 1. The map of the Çagis Pond and the location of the sampling station.

were as follows: Heterokontophyta 32% (30 taxa), Cyanobacteria 18% (17 taxa), Dinophyta 2% (2 taxa), Euglenophyta 2% (2 taxa), Charophyta 2% (2 taxa), and Cryptophyta 1% (1 taxa) (Fig. 3). The highest number of species was recorded in July 2008 with 33 taxa while the lowest species richness was found in February 2008 with 2 taxa.

Cyanobacteria overwhelmingly dominated the phytoplankton (about 848 cell/L, 80%) in summer and fall in both years. The abundance of Heterokontophyta increased in the winter of 2007 where Chlorophyta and Heterokontophyta increased in the winter and spring of 2008 (Fig. 4).

Cyclotella meneghiniana constituted 51.8% (about 130 cell/L) of the total phytoplankton abundance in the winter, 29% in the spring (about 55 cell/L), 15.5% (about 66 cell/L) in the summer, and 18.2% (about 75 cell/L) in the fall where *Micractinium pusillum* contributed 30.2% in the winter (about 25 cell/L) and 21.3% (about 20 cell/L) in the spring. *Microcystis aeruginosa* contributed 41% (about 489 cell/L) of the total phytoplankton abundance in the summer and 8% (about 30 cell/L) in the fall where *Microcystis protocystis* contributed 8% (about 30 cell/L) in the summer and 24% (about 109 cell/L) in the fall and *Arthrospira platensis* contributed 8.2% (about 32 cell/L) in the fall and 15.6% (about 16 cell/L) in the spring. Furthermore *Geitlerinema lemmermannii* contributed 13.6% (about 20 cell/L) of the total phytoplankton abundance in the spring, *Oscillatoria subbrevis* contributed 18.8% (about 78 cell/L) in the fall, and *Anathece clathrata* contributed 11.5% (about 60 cell/L) in the summer.

The Shannon-Weaver species diversity index value was 0.13 in March 2007 indicating the dominance of *C. menenghiniana* (94% of the total abundance), the index value was 0.129 in May 2007 indicating the dominance of *A. platensis* (95% of the total abundance), and was 0.007 in February 2008 indicating the dominance of *M. pusillum* (98% of the total abundance) respectively. Index values reached near 1 in September 2006, July 2007, and June 2008 (Table 2).

The four axis of the CCA explained 92.5% of the total variance in the dominant species environmental relationship. Of the total variance 27.5% was explained by the first axis, 26% explained by the second axis, 19.9% explained by the third axis, and 19.1% explained by the fourth axis. *G. lemmermannii* and *M. pusillum* were correlated with the Secchi disk depth, *O. subbrevis* was correlated with the oxidation-reduction potential, *M. aeruginosa* and *A. clathrata* were correlated with the water temperature and total chlorophyll, *M. protocystis* was correlated with the conductivity and total dissolved solids, and *A. platensis* was correlated with the nitrate concentration in the CCA diagram (Fig. 5).

DISCUSSION

A total of 93 taxa were identified during the study. There was a large contribution of Chlorococcales, belonging to Chlorophyta, to the species richness. Round (1956) indicated that some Chlorococcales species were more abundant in eutrophic water bodies. It is remarkable that the species number decreased to 2 and the Shannon species diversity index values dropped to 0.007 during the dominance of *M. pusillum* in February 2008. *M. pusillum* is usually dominant in shallow, nutrient rich systems (Reynolds et al. 2002). Similarly *A. platensis* contributed 95% of the total phytoplankton abundance and the Shannon species index value was 0.129 in May 2007. High temperature values were recorded during the dominance of this species.

Spirulina and *Arthrospira* species exist in shallow

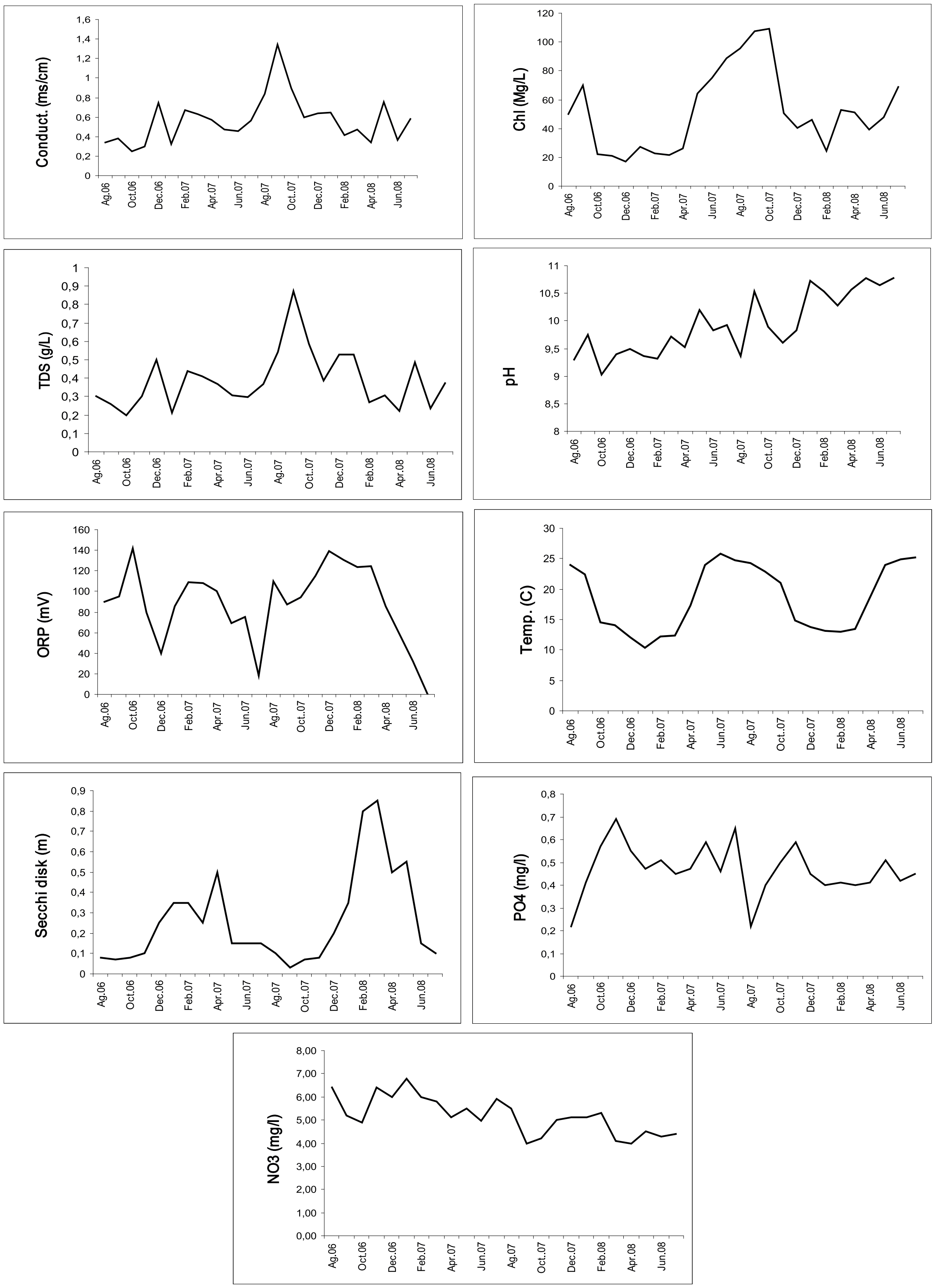

Fig. 2. Conductivity, Total chlorophyll (Chl), Total dissolved solids (TDS), pH, Oxidation-reduction potential (ORP), Temperature, Secchi disk depth, Orthophosphate (PO_4^{3-}), and Nitrate (NO_3^-) values of the pond.

lakes during warm periods of the year (Reynolds 2000). The low index values during the period of dominance of this species showed that the system was under stress. Soylu et al. (2011) in a similar

Table 1. List of phytoplankton in the Cagis Pond.

HETEROKONTOPHYTA
BACILLARIOPHYCEAE
Achnantes sp.
Amphora eximia J.R.Carter
Aulocoseira sp.
A. granulata (Ehrenberg) Simonsen
Craticula cuspidata (Kutzing) D.G.Mann
C. halophila (Grunow) D.G.Mann
Cyclotella meneghiniana Kützing
Cymatopleura solea (Brébisson) W.Smith
Cymbella sp.
C. cistula (Ehrenberg) O.Kirchner
Encyonema minutum (Hilse) D.G.Mann
Fragilaria sp.
F. capucina Desmazières
F. nanana Lange-Bertalot
Gomphonema gracile Ehrenberg emend van Heurck
G. olivaceum (Hornemann) Brébisson
G. parvulum (Kützing) Kützing
Halamphora montana (Krasske) Levkov
Hantzschia amphioxys (Ehrenberg) Grunow
Melosira lineata (Dillwyn) C.Agardh
Neidium productum (W.Smith) Cleve
Nitzschia acicularis (Kützing) W.Smith
N. amphibia Grunow
N. palea (Kützing) W.Smith
N. recta Hantzsch ex Rabenhorst
Pinnularia microstauron (Ehrenberg) Cleve
Surirella brebissonii var. *kuetzingii* Krammer & Lange-Bertalot
Tryblionella calida (Grunow) D.G.Mann
Ulnaria acus (Kützing) M.Aboal
U. ulna (Nitzsch) P.Compère
CHLOROPHYTA
CHLOROPHYCEAE
Actinastrum fluviatile (J.L.B.Schröder) Fott
A. hantzschii Lagerheim
A. hantzschii var. *subtile* J.Woloszynska
Acutodesmus acuminatus (Lagerheim) Tsarenko
A. dimorphus (Turpin) Tsarenko
Ankistrodesmus falcatus (Corda) Ralfs
A gracilis (Reinsch) Korshikov
Coelastrella oocystiformis (J.W.G.Lund) E.Hegewald & N.Hanagata
Coelastrum astroideum De Notaris
Chlamydomonas sp.
C. leiostraca (Strehlow) H.Ettl
C. depressa Skuja
Desmodesmus protuberans (F.E.Fritsch & M.F.Rich) E.Hegewald
D. magnus (Meyen) P.Tsarenko
D. opoliensis var. *mononensis* (Chodat) E.Hegewald
D. communis (E.Hegewald) E.Hegewald
Ettlia pseudoalveolaris (T.R.Deason & H.C.Bold) J.Komárek
Franceia ovalis (Francé) Lemmermann
Golenkiniopsis solitaria (Korshikov) Korshikov
Korshikoviella limnetica (Lemmermann) P.C.Silva
Lagerheimia ciliata (Lagerheim) Chodat
Micractinium pusillum Fresenius
Monoraphidium contortum (Thuret) Komárková-Legnerová
M. minutum (Nägeli) Komárková-Legnerová
Mucidosphaerium pulchellum (H.C.Wood) C.Bock, Proschold & Krienitz
Oocystis borgei J.W.Snow
Pediastrum duplex var. *rugulosum* Raciborski
Pseudopediastrum boryanum (Turpin) E.Hegewald
Scenedesmus obliquus (Turpin) Kützing
S. longispina R.Chodat
Schroederia setigera (Schröder) Lemmermann
Sphaerocystis planctonica (Korshikov) Bourrelly
Tetraedron minimum (A.Braun) Hansgirg
T. muticum (A.Braun) Hansgirg
Tetrastrum glabrum (Y.V.Roll) Ahlstrom & Tiffany
T. staurogeniiforme (Schröder) Lemmermann
Treubaria triappendiculata C.Bernard
Tetrabaena socialis (Dujardin) H.Nozaki & M.Itoh
Volvox sp.
CHAROPHYTA
CONJUGATOPHYCEAE
Closterium acutum var. *linea* (Perty) West & G.S.West
C. nordstedtii var. *polystichum* (Nygaard) Ruzicka
Limnothrix planctonica (Woloszynska) Meffert
Merismopedia minima Beck
M. tenuissima Lemmermann
Microcystis aeruginosa (Kützing) Kützing
M. protocystis Crow
Oscillatoria subbrevis Schmidle
Phormidium formosum (Bory de Saint-Vincent ex Gomont) Anagnostidis & Komárek
Pseudanabaena limnetica (Lemmermann) Komárek
Raphidiopsis mediterranea Skuja
Spirulina laxissima G.S.West
S. subtilissima Kützing ex Gomont
EUGLENOPHYTA
EUGLENOPHYCEAE
Euglena acus var. *detonii* (Van Oye) Huber-Pest
Euglenaria clavata (Skuja) Karnkowska & E.W.Linton
CRYPTOPHYTA
CRYPTOPHYCEAE
Cryptomonas nordstedtii (Hansgirg) Senn
DINOPHYTA
DINOPHYCEAE
Gymnodinium sp.
Peridiniopsis polonica (Woloszynska) Bourrelly
CYANOBACTERIA
CYANOPHYCEAE
Anabaenopsis ballygungii (Banerji) Komárek & Anagnostidis
Anathece clathrata (W.West & G.S.West) Komárek, Kastovsky & Jezberová
Arthrospira platensis Gomont
Geitlerinema lemmermannii (Woloszynska) Anagnostidis
Jaaginema homogeneum (Frémy) Anagnostidis & Komárek
Limnococcus limneticus (Lemmer.)Komárko.,Jezber.,Komár.&Zapo.

Table 2. The Shannon diversity index results for the phytoplankton in the pond.

Months	Agu.06	Sep.06	Oct.06	Nov.06	Dec.06	Jan. 07	Feb.07	Mar.07	Apr.07	May.07	Jun. 7	Jul.07
Shannon Diversity	0,59	0,85	0,58	0,24	0,56	0,35	0,28	0,13	0,32	0,129	0,54	0,72
Months	Agu.07	Sep.07	Oct.07	Nov.07	Dec.07	Jan.08	Feb.08	Mar.08	Apr.08	May.08	Jun.08	Jul.08
Shannon Diversity	0,29	0,22	0,5	0,44	0,25	0,29	0,007	0,47	0,6	0,53	0,9	0,59

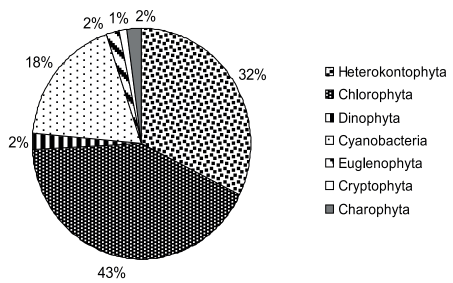

Fig. 3. The phytoplankton composition of the pond.

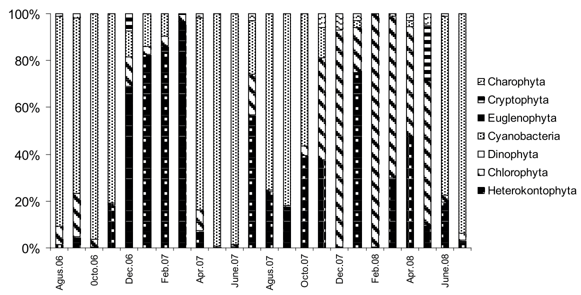

Fig. 4. Relative frequency (%) of each phytoplankton taxonomical group according to the cell abundance during the study period.

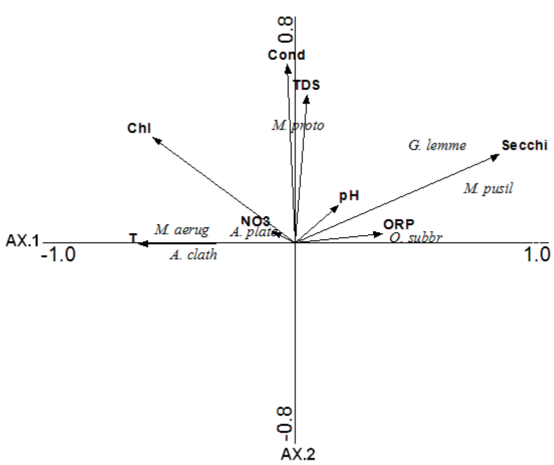

Fig. 5. The ordination diagrams of Canonical Correspondence Analysis (T: Temperature, Chl: Total chlorophyll, Cond: Conductivity, TDS: Total dissolved solid, Secchi: Secchi disk depth, ORP: Oxidation reduction potential, *A. clath*: *A. clathrata*, *M. aerug*: *M. aeruginosa*, *A. plate*: *A. platensis*, *M. proto*: *M. protocystis*, *G. lemme*: *G. lemmermannii*, *M. pusil*: *M. pusillum*, and *O. subbr*: *O. subbrevis*)

study on Liman Lake (Bafra, Samsun), found that the system was under stress during the low diversity index values. Besides these periods, *M. pusillum* reached high population densities in winter and *A. platensis* was highly abundant during the spring.

In the pond, the Secchi disk depth and oxidation-reduction potential were high whereas, the total chlorophyll concentration, total dissolved solids, and conductivity were low in the winter and *C. meneghiniana* was dominant in that period. Furthermore, the Shannon species index value was 0.13 in March 2007 when *C. menenghiniana* was dominant. Phlips et al. (1997) state that phytoplankton may contain high biovolumes of small centric diatoms during the winter. The small dimensions of these species provide them high efficiency of using low light in the water column. The Secchi disk depth was not high in the winter (maximum 0.85 m) when *C. meneghiniana* prevailed. The Cyclotella species has been commonly found in other eutrophic waters in Turkey (Akbay et al. 1999, Kıvrak and Gürbüz 2010, Fakıoğlu and Demir 2011).

The Secchi disk depth and oxidation-reduction potential values were low, whereas, the total chlorophyll, total dissolved solids, and conductivity values were high in the summer and fall. The high concentration of total chlorophyll in summer and fall indicates the high abundance of phytoplankton. This is also the reason of low Secchi disk depths during the summer and fall. *M. aeruginosa* and *M. protocystis* were dominant species and made surface aggregation in summer. Late summer and fall are the proper periods for the growth of *Microcystis* in Turkey (Cirik and Cirik 1989, Aykulu et al. 1999). *Microcystis* species are adapted to high light penetration in shallow and eutrophic ponds where high temperature, low conductivity, high turbidity, and weak water discharge have been observed (Reynolds et al. 2002). These algae control their position in the water column with their gas vesicles (Ibelings et al. 1991). They go down by releasing gas or go up by storing gas in their vesicles (Brookes and Ganf 2001). These species need stagnant water for forming dense colonies near the surface (Zohary and Breen 1989, Reynolds 1980). This study revealed that *M. protocystis* had close relationships with the total chlorophyll, conductivity, and total dissolved solids.

A. clathrata was another remarkable species in the summer and correlated with the water temperature and total chlorophyll concentrations. A. clathrata thrive well in nutrient rich shallow lakes and ponds all over the world (John et al. 2003).

The filamentous blue-green algae, *G. lemmermannii* was abundant in the spring and *O. subbrevis* was abundant in the fall. The non N_2 fixing blue-green algae, especially those that belong to the Oscillatoriaceae family usually are a nuisance in shallow eutrophic waters (Berger 1989, van Duin et al. 1995, Scheffer 2004). It is reported that these algae commonly exist in nutrient rich, continuously mixing, generally shallow, temperate lakes, and are resistant to low light conditions (Reynolds 1993, van Duin et al. 1995, Reynolds et al. 2002).

Members of Oscillatoriaceae may reach a high biomass in eutrophic water but they don't achieve a dense abundance in surface waters. This is attributed to their ability to maintain high growth rates at low light conditions (van Liere and Mur 1979, Loeb and Rueter 1981). It is probable that they dominate phytoplankton in the spring and fall when there is wind induced mixing in the shallow waters. Furthermore, a low Secchi disk depth and high nutrient concentration favor their development.

In conclusion, the CCA showed that the dominance of certain species was closely related to water temperature, transparency, conductivity, and total dissolved solids. The low water transparency and high nutrient and total chlorophyll concentrations indicated that the system was eutrophic. The dominance of Cyanobacteria in the fall and summer, a high abundance of Heterokontophyta in the winter, and the co-dominance of Chlorophyta and Heterokontophyta are characteristic to eutrophic water bodies. Furthermore, the extremely low Shannon-Weaver species diversity value, especially during the summer, indicates that the system is under stress.

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