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An ecologic and taxonomic study on phytoplankton of a shallow lake, Turkey

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Abstract: *The middle Black sea region has quite large wetlands, including lakes, rivers, ponds, marshs and large reservoirs. Lake Cernek is one of the most valuable wetlands in Kizilirmak Delta. The lake and its environment have a high biodiversity due to species richness and natural habitats. Therefore, it has been recognized as a Ramsar site.The phytoplankton of lake Cernek consisted of 104 taxa belonging to Cyanobacteria, Bacillariophyta, Chlorophyta, Cryptophyta, Dinophyta, Euglenophyta and Xanthophyta divisions. Chlorophyta (46%) and Bacillariophyta (23%) members were dominant species. These were followed by Cyanobacteria (16%) and Euglenophyta (11%) members. Chlorella, Monoraphidium, Oocystis, Pediastrum and Scenedesmus from Chlorophyceae and also Anabaena, Chroococcus and Microcystis species from Cyanophyceae sometimes made water blooms. Blue green algae constituted algal communities in the surface of the lake in summer months. Algal community and its important species were grouped in terms of bray curtis similarity index, by taking into consideration the phytoplankton dynamics and months.*

Key words: *Lake, Phytoplankton, Wetland ecosystem, Eutrophication*

Introduction

Wetlands have quite large ecologic and economic functions. The Kizilirmak delta has great and important wetlands that have preserved its natural features in the middle Black sea region. More than 310 bird species or 75% of all known bird species in Turkey, use the delta for breeding, wintering and migration (Hustings and Dijk, 1993). For this reasons, the area was included into Europe's significant bird locations list by bird protection society "Bird Life International" (Grimmet and Jones, 1989). Some studies made in the delta report 10 species of mammals, 8 species of reptiles, 8 species of fishes and 18 species of invertebrates (Hustings and Dijk, 1993; Ozesmi and Karul, 1990).

The Kizilirmak Delta has a lot of lagoons named as the Bafra fish lakes including lake Liman, lake Cernek, lake Gici, lake Tatli, lake Balik and lake Uzun, starting from the north side. In the east region are found lake Karabogaz (Fig. 1). The lagoons are surrounded with marshes. Lake Cernek is an important ecosystem supporting local agriculture, tourism and fisheries in the region. The lake ecosystem is polluted due to many activities such as irrigation, sediment deposits and input of agricultural and domestic sewages causing a serious problem in its trophic state. The lagoon Cernek is shallow, 1-3 m depth and well mixed by wind without apparent stratification.

Some investigations were made in order to determine the ecosystem dynamics of these lakes (Gonulol and Comak, 1992; Gonulol and Comak, 1993). Within these researches, algae were reported to be very significant as they are first level in the food chain. They are primary producers for all living organisms found in the lakes. The first study about the algal flora of Bafra balik lakes (Balik lake, Uzun lake) was made by the researchers of the ministry of agriculture, forest and village affairs in 1983. In the subsequent years, the Bafra fish lakes (Lake Balik and Lake Uzun) (Gonulol and Comak, 1992a, b and 1993a, b) and lake Cernek (Isbakan *et al*., 1998; Isbakan Tas *et al*., 2002) were examined regarding floristic composition and seasonal variations. Gonulol (1993) reported 246 taxa of algae and 170 taxa of phytoplankton from Bafra fish lakes including Ballk lake and Uzun lake. In this study, the phytoplankton and seasonal dynamics were investigated.

Materials and Methods

The Cernek lake is located in the Kizilirmak delta (41°40'N and 35°46'E), in Northern Turkey. The other five lakes (Balik, Uzun, Liman Gici and Tatli) and some marshes with similar origin are scattered over the delta. Lake Cernek is in the boundary of Doganca town, which is a part of Bafra city in Samsun province. It is 20 km away from Bafra located on the east side of Kizilirmak river and Bafra city. The area of the lake, which is one of largest lakes in Bafra plain is 589 hectares. There are many drainage canals connected to the lake.

The area has a Mediterranean climate with warm and dry summers and tepid and wet winters. Mean annual temperature was 13.2 °C and the mean annual rainfall was 777.9 mm during the study period in the delta. The coldest months were January and February and the warmest months were July and August (Quezel *et al*., 1980; Kutbay and Kilinc, 1995). The climate diagram of the study area was given in Fig. 2.

The phytoplankton of lake Cernek was observed at monthly interval from three different stations between January

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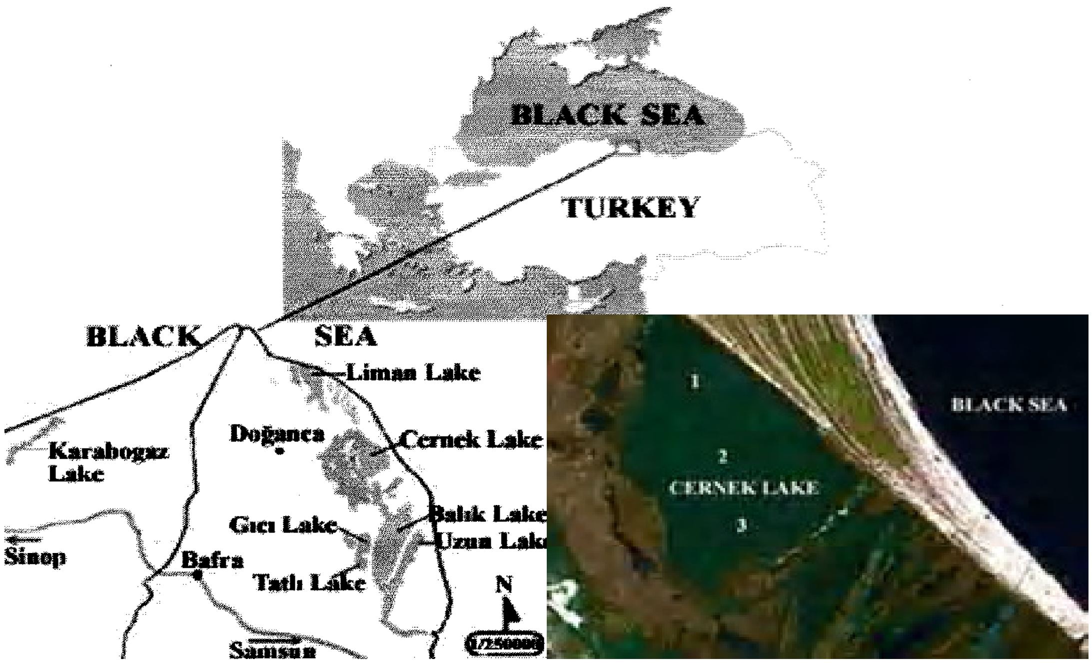

Fig. 1: Geographicic location of the Kizilirmak delta at the Black sea coast of Turkey and the satellite image of lake Cernek (1, 2 and 3 sampling stations)

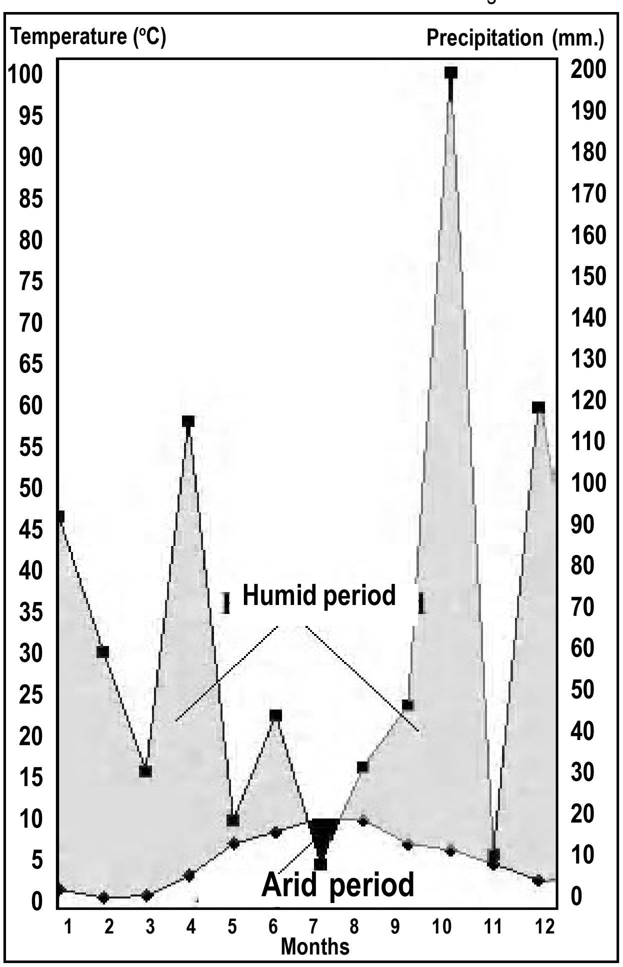

Fig. 2: Climate diagram of the study area (1996)

1996 and June 1997. The depth of the sample stations was nearly 1.5 meter. But, it was seen that the water level increased by 2-3 meters in winter. The bottom of the lake consists of grey colored mud, sand and rotten crops.

The water samples taken from surface (0-20 cm) and one meter depth were collected monthly from three stations with the help a two liter capacity hydrobios water sampler. The samples were carried to the research laboratory and were shaken to ensure the homogeneity of the organisms. They were fixed and preserved with 10% lugol solution. The algae were identified and counted in the counting tubes using an inverted microscope as described by Lund *et al*. (1958). In the evaluations, the average of three countings from each station was used. The remaining water samples were filtered using whatman GF/A glass fibre filter paper with a pore size of 55 µm and the residue on the filter paper was used to identify the algae except Bacillariophyta. The remaining two divisions were identified on permanent slides which had been prepared according to the method of Round (1953).

Taxonomic identifications were performed following Bourrelly (1968), Huber Pestalozzi (1969, 1972), Anagnostidis and Komarek (1988), Komarek and Anagnostidis (1986, 1989 and 1999), Komarek *et al*. (1998), Krammer and Lange Bertalot (1986, 1991a, b and 1999) and John *et al*. (2003). The species list of the three stations was prepared and the abundance of every species was accounted. The data was subjected to cluster analysis using Biodiversity professional 2 statistic program.

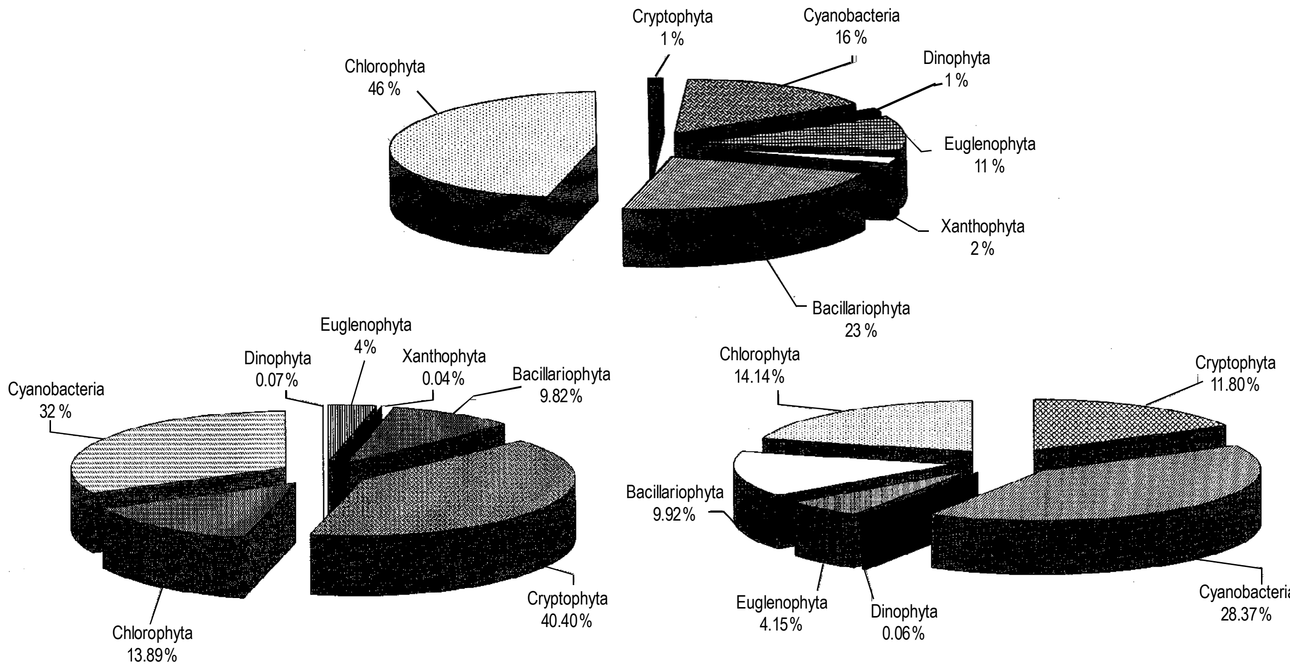

Fig. 3: Phytoplankton composition of lake Cernek (a), total phytoplankton density in the surface (b) and one meter (c)

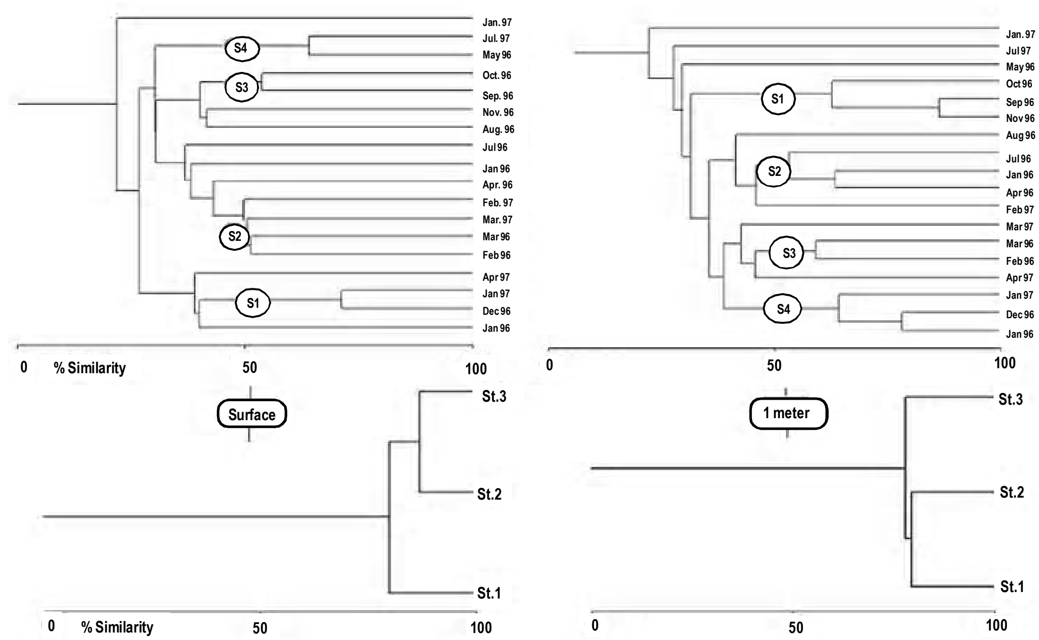

Fig. 4: Dendrograms for hierarchical clustering of the samples months and the stations in the Lake Cernek.

Results and Discussion

The phytoplankton consisted of total 104 taxa belonging to Cyanobacteria (17), Bacillariophyta (24), Chlorophyta (48), Cryptophyta (1), Dinophyta (1), Euglenophyta (11) and Xanthophyta (2) (Table 1). The dominant and subdominant phytoplankton species in different seasons were given in Table 2. According to the percentage distribution of species diversity, the highest rich algal group was Chlorophyta at 46%. In terms of the counting results, the total densities of Cyanobacteria and Chlorophyta were 32% and 40% in the surface water. In one meter depth, these values were 28% and 14% respectively (Fig. 3).

The diagram obtained from cluster analysis showed that four different groups comprised in the surface water samples at 50% hierarchical level (Fig. 4). The first important group within these was S1, characterized by the dominant of *Cryptomonas ovata*. S2 group was the second important group, characterized

Table - 1: List of recorded taxa

Cyanobacteria (Cyanophyta) (Blue green algae)
Anabaena catenula var. *affinis* (Lemmermann) Geitler
Anabaena spiroides Klebahn
Aphanizomenon aphanizomenoides (Forti) Hortobagyi *et* Komárek
Aphanocapsa biformis A. Braun in Rabenhorst
Chroococcus limneticus Lemmermann
Chroococcus minimus (Keissler) Lemmermann
Chroococcus minutus (Kutzing) Nageli
Lyngbya sp.
Merismopedia elagans A. Braun in Kutzing
Merismopedia tenuissima Lemmermann
Microcystis aeruginosa (Kutzing) Kutzing
Nodularia spumigena Mertens Bornet *et* Flahault
Oscillatoria tenuis (C. Agardh) Gomont
Phormidium mucicola Huber Pestalozzi *et* Naumann
Pseudanabaena limnetica (Lemmermann) Komarek
Snowella lacustris (Chodat) Komarek *et* Hindak
Spirulina major (Kutzing) Gomont

Bacillariophyta (Diatoms) (Golden brown algae)
Amphora ovalis Kutzing (Kutzing)
Chaetoseros sp.
Cocconeis placentula Ehrenberg
Cyclotella meneghiniana Kützing
Cyclotella ocellata Pantocsek
Cymbella affinis Kutzing
Cymbella prostrata (Berkeley) Cleve
Cymbella ventricosa C. Agardh
Diatoma vulgaris var. *vulgaris* Bory
Fragilaria fasciculata (Agardh) Lange-Bertalot
Fragilaria intermedia Grunow
Gomphonema olivaceum (Hornemann) Brébisson
Gomphonema ventricosum Gregory
Gyrosigma acuminatum (Kutzing) Rabenhorst
Melosira varians C. Agardh
Navicula cryptocephala Kutzing
Navicula rhyncocephala Kutzing
Navicula veneta Kutzing
Nitzschia acicularis (Kutzing) W. Smith
Nitzschia umbonata (Ehrenberg) Lange-Bertalot
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot
Stenopterobia sp.
Surirella ovata Kutzing
Surirella peisonis Pantocsek

Chlorophyta (Green algae)
Actinastrum hantzschii Lagerheim
Botryococcus braunii Kutzing
Chlamydomonas globosa J. Snow
Chlorella saccharophila (W. Kruger) Migula
C. ellipsoidea Gerneck *sensu* Shihira *et* Krauss]
Chlorella vulgaris M. Beijerinck
Cladophora glomerata (Linnaeus) Kutzing
Closterium acutum (Lyngbye) Brébisson
Coelastrum microporum Nageli in A. Braun
Cosmarium bioculatum Brebisson ex Ralfs in Ralfs
Cosmarium formosulum Hoff
Cosmarium meneghinii Brebisson in Ralfs
Cosmarium phaseolus Brebisson in Ralfs f. *minor* Boldt
Monoraphidium caribeum Hindak
Monoraphidium irregulare (G. M. Smith) Komarkova-Legnerova
Monoraphidium komarkovae Nygaard
Monoraphidium minutum (Nageli) Komarkova-Legnerova
Oedogonium sp.
Oocystis borgei J. Snow
Oocystis solitaria Wittrock in Wittrock and Nordstedt
Oocystis submarina Lagerheim
Pediastrum boryanum (Turpin) Meneghini
Pediastrum duplex Meyen
Pediastrum simplex Meyen
Pediastrum tetras (Ehrenberg) Ralfs
Pediastrum tetras var. *tetraedon* (Corda) Hansgirg
Phacotus lenticularis (Ehrenberg) F. Stein
Scenedesmus acuminatus (Lagerheim) Chodat
Scenedesmus communis E. H. Hegewald
Scenedesmus dimorphus (Turpin) Kutzing
Scenedesmus ecornis (Ehrenberg) Chodat
Scenedesmus intermedius Chodat
Scenedesmus magnus Meyen
Scenedesmus opoliensis P.G. Richter
Scenedesmus quadrispina Chodat
Schroederia indica Philipose
Schroederia setigera (Schroder) Lemmermann
Sphaerocystis schroeteri Chodat
Spirogyra grevilleana (Hassall) Kützing
Spirogyra rivularis (Hassall) Rabenhorst
Spirogyra varians (Hassall) Kützing
Spirogyra weberii Kutzing
Tetraedron minimum (A. Braun) Hansgirg
Tetraedron pentaedricum West *et* G. S. West
Tetrastmus komarekeii Hindák
Tetrastrum staurogeniaeforme (Schröder) Lemmermann
Ulothrix sp.
Zygnema sp.

Cryptophyta (Cryptomonads)
Cryptomonas ovata Ehrenberg

Dinophyta (Pyrrophyta) (Dinoflagellates)
Gymnodinium sp.

Euglenophyta (Euglenoids)
Euglena acus Ehrenberg
Euglena elastica Prescott
Euglena gracilis G. A. Klebs
Euglena minuta Prescott
Euglena polymorpha P.A. Dangeard
Lepocinclis acuta Prescott
Phacus acuminatus A. Stokes
Phacus nordstedtii Lemmermann
Phacus tortus (Lemmermann) Skvortsov
Trachelomonas hexangulata Svirenko
Trachelomonas volvocina Ehrenberg

Xanthophyta (Yellow green algae)
Characiopsis cylindrica (Lambert) Lemmermann
Goniochloris fallax Fott

by the increase of the green algae. In this month *Monoraphidium*, *Oocystis*, *Scenedesmus* and *Pediastrum* from Chlorophyta were dominant species. The S2 group was characterized by the increase of the green algae together with beginning of spring and end of winter. S3 group comprised with the decline of blue green algae, green algae and the increase of diatoms. *Cyclotella* and *Nitzschia* from the diatoms and also *Trachelomonas* from Euglenoids were prevalent species.

Once the diagram fround in one meter depth is examined, four groups are seen at 50% hierarchical level (Fig. 4). The first one (S1) was the most significant group and was characterized by high increase of *Monoraphidium irregulare*. In this group (containing winter samples), *C. ovata* also showed an increase. In the same group, some species such as *Crucigenia*, *Oocystis* and *Scenedesmus* were also found. The second significant group was S4 which contained only spring samples. This group was characterized by the dominant green algae. *Monoraphidium, Oocystis* and *Scenedesmus* species were water blooms. *Cocconeis*, *Navicula* and *Nitzschia* from diatoms and *Anabaena* from cyanophytes were prevalent species in the same group. The S2 group was characterized by the dominant diatoms and green algae. In this group, *Cyclotella*, *Monoraphidium* and *Scenedesmus* species showed increase. The S3 group contained only autumn samples. In this group, diatoms were dominant species. *Crucigenia, Monoraphidium, Pediastrum, Scenedesmus, Tedraedron* (Chlorophyta), *Cryptomonas* (Cryptophyta), *Chroococcus, Oscillatoria* (Cyanobacteria) and *Trachelomonas hexangulate* (Euglenophyta) were prevalent species in the same group.

When the relative abundance of species in the sample stations was compared, the highest similarity in the surface was seen between the first and second stations, according to the diagram obtained from cluster analysis (87%). In one meter depth, there was no important difference (77-79%) at all stations (Fig. 4).

The Kizilirmak delta is a biodiversity hotspot in the Black Sea region and Turkey. Because of enormous species diversity and natural habitats, the delta was included into important wetlands list in terms of international "Ramsar Site'. A lot of small local streams and channels are connected with the Kizilimak River and they feed the wetlands in the delta. With irrigation aim, the waters of the channels and streams are used by villagers. Drained waters return into the wetlands from agricultural lands, by taking silt, fertilizer and pesticides. The waters in the channels are high in nitrates (1.1-5.8 mgl^{-1} NO_3) and phosphorus (0.28-14.2 mgl^{-1} PO_4) (van Elswijk and Fedder, 1995). Badut channel has the high phosphorus (14.2 mgl^{-1}) and nitrate (3.72 mgl^{-1}) (van Elswijk and Fedder, 1995) concentration because it carries the sewage of Bafra into the wetlands. Which connected with lake Cernek. Therefore, the Cernek lake has high phosphorus and nitrogen concentrations. Channels to the north are high in sulphates (22.2-418.1 mgl^{-1} SO_4) (van Horssen *et al*., 1995). Hollis (1994) reported that the cumulative effect due to these destructive factors will upset the natural cycles of water fluctuations.

Several studies indicate the effects of environmental parameters on phytoplankton dynamics (Voros and Padisak, 1991; Moustaka Gouni and Nikolaidis, 1994; Tryphon and Moustaka Gouni, 1997). The influence of various factors on the seasonal appearance of phytoplankton differs significantly, with physical factors (temperature, water mixing underwater, light, climate) being the most important and chemical (nutrient level) as well as biotic factors (grazing and parasitism) being of lesser importance (Reynolds, 1984). Temperature and light among physical factors provided great advantage for phytoplankton in the Cernek lake. The water temperature of lake Cernek changed

Table - 2: Important phytoplankton species according to the counting results

Seasons	Dominant	Subdominant
Spring	*Cladophora glomerata* *Cyclotella ocellata* *Microcystis aeruginosa* *Monoraphidium* sp. *Nitzschia acicularis* *Oocystis borgei* *Pediastrum boryanum Phacotus lenticularis* *Scenedesmus* sp.	*Cocconeis placentula* *Cryptomonas ovata* *Euglena polymorpha* *Schroederia indica*
Summer	*Anabaena catenula* *Anabaena spiroides* *Microcystis aeruginosa* *Nodularia spumigena*	*Pseudanabaena limnetica*
Autumn	*Cyclotella ocellata* *Pseudanabaena limnetica*	*Trachelomonas hexangulata*
Winter	*Cryptomonas ovata* *Monoraphidium* sp. *Scenedesmus communis*	*Closterium acutum*

between 6-27 °C. Average water temperature was 15.6 °C during the sampling period.

In subtropical regions, different algal groups were seen as if they followed typical succession model (Reynolds, 1984; Lewis, 1986; Sommer, 1991). It is thought that these successions cause the variations related to the use of the light and temperatures. Once the temporal dynamic of the phytoplankton of lake Cernek was researched, 104 taxa belonging to Cyanophyta (Cyanobacteria), Bacillariophyta, Chlorophyta, Cryptophyta, Dinophyta, Euglenophyta and Xanthophyta divisions were determined. According to the number of species, Chlorophyta and Bacillariophyta type phytoplankton existed in lake Cernek. In some months, it was reported that Chlorophyta and Bacillariophyta divisions were dominant and they had Chlorococcales Pennales type phytoplankton (Isbakan Tas *et al*., 2002) as it was found in Balik and Uzun lakes in the delta (Gonulol 1987; Gonulol and Comak 1992a, b and 1993a, b). Lake Cernek had a typical phytoplankton population of eutrophic lakes. Chlorophyta, Dinophyta, Cryptophyta and Chrysophyta divisions include harmful water blooms (Paerl *et al*., 2001). Except Chrysophyta, other algae groups in some seasons made water blooms in the lake Cernek.

The phytoplankton of the lake was characterized by tremendous species diversity and numerical dominance of Chlorophyta, Bacillariophyta and Cyanobacteria. The seasonal succession of algae in lake Cernek was Chlorophyta and Diatoms in the spring, Chlorophyta in early summer, Cyanophytes in late summer and Diatoms in autumn and winter. Generally, it was a complicated succession, as it happens in many shallow lakes (Hutcinson, 1967). This succession dynamic have been also reported in shallow eutrophic lakes in Greek (Kagalou *et al*., 2001).

In the dendrogams obtained from cluster analysis, species making blooms encountered as dense composed groups. *Monoraphidium* sp., *Oocysis borgei*, *Pediastrum boryanum* and *Scenedesmus* sp. showed blooming sometimes. Round (1956) reported that some Chlorococcales members are quite abundant in the water zones showing transition from oligotrophic condition to eutrophic one. In terms of Hutchinson (1967), these species are dominant organisms in eutrophic waters. In lake Balik, lake Uzun (Gonulol and Comak, 1992a, b and 1993a, b), lake Cernek (Isbakan Tas *et al*., 2002) and lake Simenit (Ersanly and Gonulol, 2003) located in Samsun environment, green algae are dominant and are responsible for making blooms in some months. Also, *Chroococcus* sp. from blue green algae and *Euglena gracilis* from euglenoids were prevalent species in the lakes having eutrophic properties in particular. Prescott (1973) reported that Cyanobacteria members make blooms in the stagnant waters of Anatolia, Europe and North America. In the eutrophication of lake ecosystems, the blooming of Cyanobacteria is a frequent event (Moss *et al*., 1996). Blue-green algae are the most prevalent and dangerous for peoples (Chorus and Bartram, 1999) and limiting the convenient use of water (Pitois *et al*., 2001). Because of organic pollution, Euglenoids members were often found in lake Cernek. When the phytoplankton dynamics expressed to seasons were investigated, blue green algae were found to make blooms in summer and early autumn. *Cryptomonas ovata* from Cryptophyta made blooms in winter, early spring and summer months. In most of the researches made in Europe on lakes, it has been reported that *Cryptomonas* genus is the biomonitor of eutrophic lakes (Akbulut and Yildiz, 2001). In these months, blue-green algae and green algae made blooimngs in the phytoplankton. *Anabaena catenula, Mircocystis aeruginosa, Nodularia spumigena* and *Pseudoanabaena limnetica* species from these divisions were seen important increases in summer and late autumn. In the water basins with eutrophic characteristic, blue-green algae were reported to make blooms in the Black Sea Region in summer months (Gonulol and Comak, 1992a; Yazici and Gonulol, 1994; Isbakan Tas *et al*., 2002; Ersanli and Gonulol, 2003). *Phacus* and *Trachelomonas* from Euglenophyta were attracting attention organisms in spring months. It is reported that Euglenophyta members generally develop very well in waters which is rich regarding organic substances (Round, 1984).

The results obtained from cluster analysis and the counting methods supported to each other regarding phytoplankton biomass. There was no difference between the phytoplankton composition and the seasonal dynamics except for some months. When the diagram was examined, the dominant species comprised groups in cluster analysis. It was reported that these taxa composed groups in lakes with eutrophic characteristic (Hutchinson, 1967). Most of taxa determined inthe lake have a cosmopolitan characteristic. Also, blue-green and green algae make water blooms in summer months. As a consequence, Lake Cernek has a eutrophic lake.

The data obtained from this study indicated that the lake has a strong eutrophication potential owing to hypertrophic capacity. This was corresponded by the algal indicators and the phytoplankton composition. The phytoplankton biomass was related not only to the higher nutrient inputs, but also to the presence of submerged macrophytes, which compete with planktonic primary producers. Shallowness, temperature and primary production were main factors that affected the phytoplankton community found in Cernek lake.

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