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Research Article

Seasonal Variation of Phytoplankton and Value of Chlorophyll *a* in the Sarıyar Dam Reservoir (Ankara, Turkey)

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Abstract: The phytoplanktonic algae were determined in samples taken from 7 different locations at the Sarıyar Dam Reservoir (SDR) from March 1996 to June 1997. The seasonal variation of phytoplankton and their chlorophyll a were determined and contents were discussed in relation to the physical and chemical parameters of the water. The divisions *Bacillariophyta* and Chlorophyta were dominant; however, *Cyclotella*, *Navicula*, *Nitzschia* and *Synedra* of *Bacillariophyta*, and *Chlorella* and *Scenedesmus* of *Chlorophyta* were abundant. Chlorophyll *a* reached its maximum levels during June and September 1996 and May 1997, corresponding to the maximum values of orthophosphate, sulphate, calcium and temperature in the lake.

Key Words: Phytoplankton, Algae, Sarıyar Dam Reservoir, Seasonal variation, Chlorophyll *a*

Sarıyar Barajı (Ankara/TÜRKİYE) Fitoplanktonunun Mevsimsel Değişimi ve Klorofil-a Değerleri

Özet: Sarıyar Baraj Gölü fitoplanktonik algleri Mart 1996- Haziran 1997 tarihleri arasında belirlenen yedi istasyondan alınan örneklerde incelenmiştir. Fitoplanktonun mevsimsel değişimi ve klorofil- a miktarı belirlenerek suyun fiziksel ve kimyasal verileriyle ilişkilendirilmiştir. *Bacillariophyta* ve Cholorophyta divizyoları baskın organizmalardır. *Bacillariophyta* dan *Cyclotella*, *Navicula*, *Nitzschia* ve *Synedra*, *Chlorophyta* dan da *Chlorella* ve *Scenedesmus* üyeleri yaygın durumdalardır. Klorofil-a değerleri Haziran, Eylül 1996 ve Mayıs 1997 de maksimum seviyeye ulaşmıştır. Aynı dönemlerde gölde fosfat, sülfat, kalsiyum ve sıcaklıkta en üst seviyelerde kaydedilmiştir.

Anahtar Sözcükler: Fitoplankton, Algae, Sarıyar Baraj Gölü, Mevsimsel değişim, Klorofil-a

Introduction

The Sarıyar Dam Reservoir (SDR), in Central Anatolia, lies at an altitude of 475 m, and is located at 40° 03´ 00´´ N latitudes and between 30° 45' 36'' and 31° 45´ 40´´ E longtitudes, 180 km north-west of Ankara (Figure 1). The reservoir was constructed for the purpose of hydroelectric power generation. It is 10^6 m high, with a maximum depth of 90 m, and has average water volume of 1.9×10^6 m^3. The dam has an approximate surface area of 84 km^2. The nearest populated areas are the villages of Davutoğlan and Sarıyar, with a total population of 6610.

The SDR is fed by the Sakarya River, and Ankara, Porsuk, Kirmir, Gürleyik and Aladağ streams. Gürleyik stream is dry in autumn while Aladağ stream is perennial. Kirmir stream, with pure water at source, becomes polluted when it passes through the town of Güdül, resulting in 4^{th} quality water at its discharge in the SDR. Porsuk stream is polluted with heavy metals from the Eskişehir industrial zone. The dam reservoir is surrounded by diverse volcanic rocks, along with brown soils, characteristic of central Anatolia (Erentoz & Pamir, 1975).

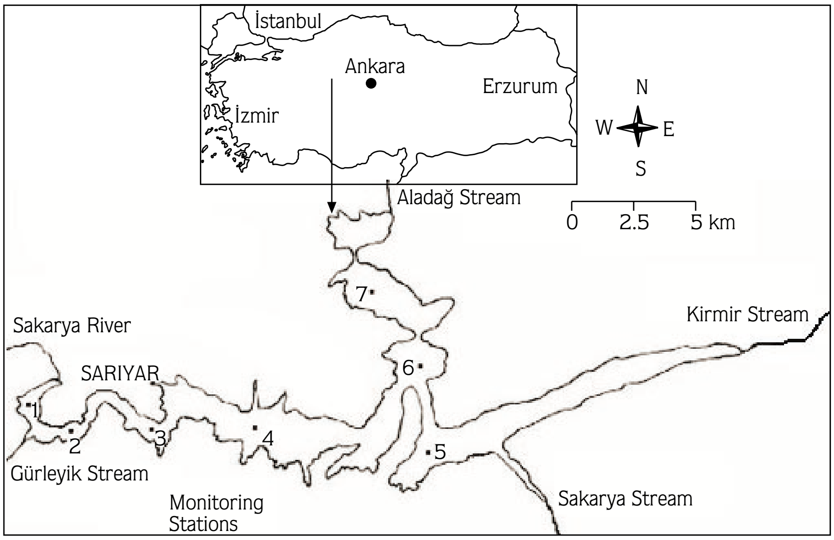

Figure 1. Location of stations in the SDR.

The surroundings of the SDR have a meagre flora. However, the southern side of the reservoir, has rich plantations of pine (*Pinus nigra* Arn.), juniper (*Juniperus excelsa* Bieb.), oak (*Quercus pubescens* Wild.), thicket (*Paliurus spina-christi* Miller, *Berberis crataegina* DC.), poplar (*Populus tremula* L.), willow (*Salix* sp.) etc. along the stream banks.

The area is a bird paradise and attracts migrating birds (*Ciconia ciconia* L., *Ciconia nigra* L., *Egretta alba* L., *Ardea cinera* L., *Ardea purpurea* L., *Alcedo atthis* L., and *Phalacrocorax pygmeus* Pallas) every year. Most of the birds remigrate. Other birds live in trees and thickets, which are widespread in this area. In addition, the area is abundant with water frogs (*Rana ridibunda* Pallas) and water snakes (*Natrix natrix* Laurenti).

Algae in lakes, ponds, dams, reservoirs and rivers are of multiple importance; they are oxygen producers, indicators of water quality and constitute the basic productivity chain. Moreover, they are used for obtaining single cell proteins, and are of medicinal and cosmetic importance.

Materials and Methods

In order to examine the algae of the SDR, samples were taken once a month from 7 stations from March 1996 to June 1997. The stations were situated close to different water sources that feed the dam. Phytoplankton of the SDR were collected using a plankton net (mesh width 55 µm) (Round, 1973). The net was moved slowly and horizontally and pulled 100 m (2-3 min) from the boat. The samples were put into 250-500 cc plastic jars and were brought to the laboratory for analyses after preservation with 4%-6% formaldehyde, alcohol and glycerol (Hecky & Kling, 1987).

At the same time, the levels of nitrate, phosphate, electrical conductivity, turbidity and pH were also measured. The water analyses were performed at the Soil and Fertiliser Research Centre of the General Directorate of Rural Services.

The temperature, salt and dissolved oxygen values of the lake were determined by oxygenmeter (OXI-96) at different depths, and visibility was determined by a limnological Secchi disc with a diameter of 20 cm. A Zenway 6105 UV/VIS spectrophotometer was used to determine chlorophyll a, according to Youngman (1978). Temporary and permanent slides were made for the identification of phytoplanktonic species. Sampling in December 1996 and February 1997 was not performed, because the weather conditions were not suitable. An average value was used for all properties.

Results and Discussion

Environmental condition

The maximum surface water temperature was 31 °C, in July-August 1996. The lowest temperature was recorded in January 1997, as 4 °C (Figure 2).

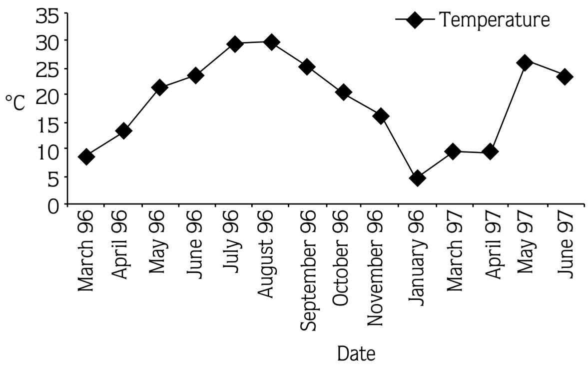

Figure 2. Seasonal variation of temperature in the SDR.

Maximum dissolved O_2 was recorded in January 1997, as 15.3 mg/l. The lowest value was recorded in September, as 6 mg/l (Figure 3).

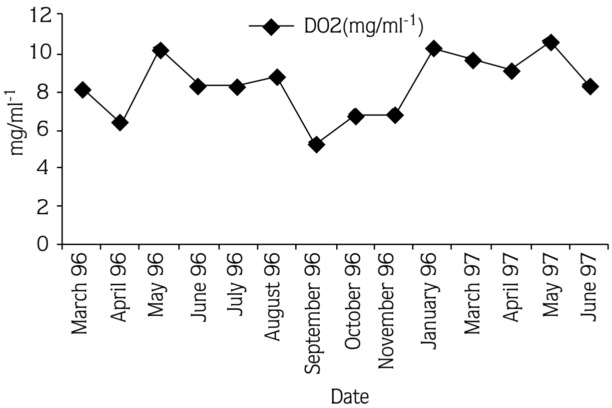

Figure 3. Seasonal variation of dissolved O2 in the SDR.

pH varied from 7.4 to 10.0 (Figure 4).

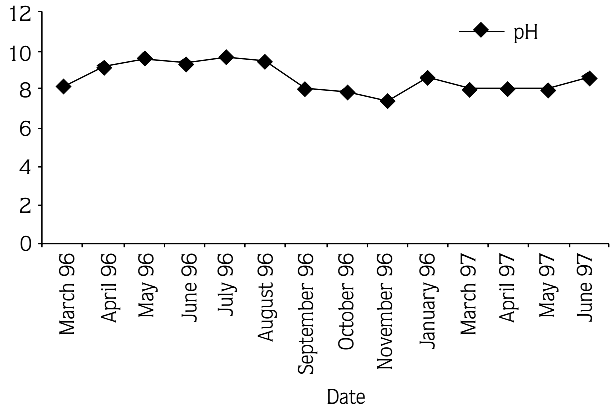

Figure 4. Seasonal variation of pH in the SDR.

Secchi depth ranged from 4.2 to 0.62 m, depending on the concentration of chlorophyll a and other factors (Figure 5).

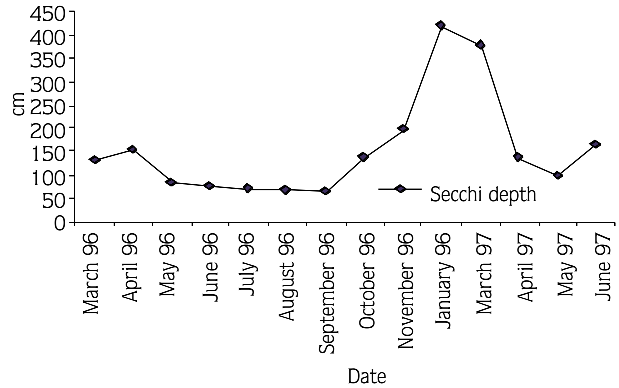

Figure 5. Seasonal variation of Secchi depth in the SDR.

The lowest electrical conductivity (EC) was 475 µmhos/cm, during May 1996, and the highest was 890 µmhos/cm, during November 1996 (Figure 6).

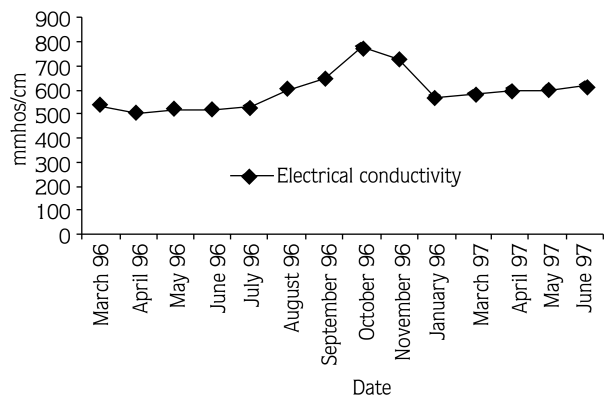

Figure 6. Seasonal variation of electrical conductivity in the SDR.

The amounts of ammonium (NH^{4+}), nitrite (NO_2^-) and nitrate (NO_3^-) were 0.01-1.42, 0.02-0.96 and 0.03-0.94 µmol/l, respectively (Figure 7).

Maximum chlorophyll a concentration was recorded during July 1996, as 84.5 µg l^{-1}, (Figure 8).

The results (Table 1) showed that the SDR had major algae species belonging to the classes *Cyanophyta*, Pyrrhophyta, Euglenophyta, Xanthophyta, Chrysophyta, Rhodophyta, *Chlorophyta* and *Bacillariophyta* (Krammer, 1991a, 1991b, 1999a, 1999b).

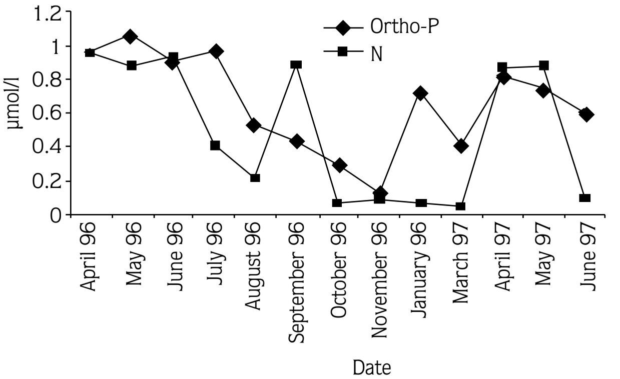

Figure 7. Seasonal variation of ortho-P and N values in the SDR.

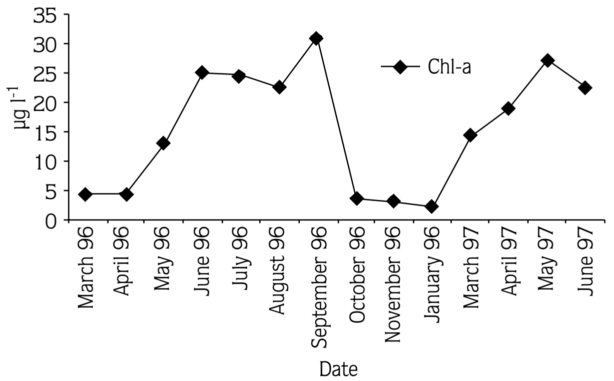

Figure 8. Seasonal variation of chlorophyll a in the SDR.

The chlorophyll a concentrations in September 1996 and May 1997 indicate that the algae reached their maximum biomass at about 25 °C. The algal biomass decreased at 31 °C in July-August 1996, showing that a temperature higher than 25 °C was not optimal for algal growth, in agreement with Reynolds (1993).

In July 1996, the abundance of the species of *Navicula*, *Synedra* and *Microcystis* was very evident. In August 1996, there was also an increase in the numbers of cells of *Synedra* and *Navicula*. An increase was also evident for species belonging to *Bacillariophyta*, *Cyanophyta* and *Scenedesmus* (*Chlorophyta*) in September 1996 and May 1997. At the lowest temperature, 4 °C in January 1997, *Nitzschia*, *Synedra*, Phormidium, *Chlorella* and *Scenedesmus* species were detected (Figure 9).

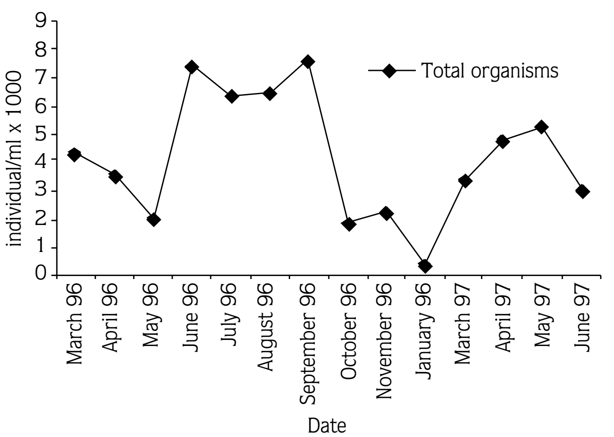

Figure 9. Seasonal variation total organisms (individual/ml) (x1000) in the SDR.

In August 1996, the diatom genera *Synedra*, *Navicula*, *Fragilaria* and *Cyclotella* were predominant compared to *Chlorella*, *Oocystis, Anabaena, Microcystis, Nostoc, Phormidium* and *Spirulina*. Horizontal variations were observed.

Especially in autumn, H_2S was formed as a result of high activity of sulphur bacteria (*Thiobacillus*, *Desulfovibrio* etc.) and accompanied by high mortality of lake fish (data not shown). At this time, an increase in the members of *Anabaena*, *Chorooccoccus* and *Scenedesmus* was also observed. *Bacillariophyta* and *Chlorophyta* members were very abundant in samples taken for quantification (Figure 10).

At pH 8-10, the CO_2 used in the photosynthesis of algae passes easily through the cellular membrane by diffusion, and the photosynthetic rate is high (Bozniak & Kennedy, 1968). The SDR is lightly alkaline, with a pH varying from 7.4 to 10.0 (Figure 7). Our results are in agreement with Reynolds (1993), who found that some diatoms such as *Synedra*, *Fragilaria*, *Nitzschia*, *Amphora* and *Cyclotella* are widespread in alkaline freshwaters.

The reduced number of *Cyanophyta* compared to *Chlorophyta* and *Bacillariophyta* may be attributed to the lack of a concentration of nitrogen complexes (Uslu & Türkman, 1987). *Cyanophyta* can fix N_2, and so they do not need NO_3 or NH_4 at all. Phosphorus, necessary for the growth of algae, controls the primary productivity in water. The amount of total phosphorus was found to be 90-150 µg/l in eutrophic lakes (Uslu & Türkman, 1987).

In the SDR, all of the genera belonging to *Chlorophyta*, *Bacillariophyta*, *Cyanophyta*, Euglenophyta, *Pyrrophyta*, Rhodophyta, Chrysophyta, and Xanthopyta

Table 1. The list of phytoplanktonic organisms in the SDR.

Cyanophyta	**Chlorophyta**	**Bacillariophyta**
Anabaena affinis	*Actinastrum gracillimum*	*Achnanthes linearis*
Anabaena flos-aquae	*Actinastrum hantzschii*	*Amphora ovalis*
Aphanizomenon flos-aquae	*Actinotaenium cucurbita*	*Amphora pediculus*
Chroococcus limneticus	*Ankistrodesmus falcatus*	*Anomoeoneis sphaerophora*
Chroococcus minutus	*Ankyra judayi*	*Asterionella formosa*
Chroococcus turgidus	*Aphanochaeta vermiculoides*	*Caloneis silicula*
Cylindrospermum minimum	*Chlamydomonas globosa*	*Cocconeis pediculus*
Cylindrospermum stagnale	*Chlamydomonas snowiae*	*Cocconeis placentula*
Gloeothece rupestris	*Chlorella vulgaris*	*Cyclotella meneghiniana*
Gloeotrichia pisum	*Chlorolobion braunii*	*Cyclotella ocellata*
Gomphosphaeria aponina	*Closteriopsis longissima*	*Cymatopleura elliptica*
Lyngbya lagerheimii	*Closterium aciculare*	*Cymatopleura solea*
Lyngbya versicolor	*Closterium dianaea*	*Cymbella affinis*
Merismopedia elegans	*Closterium kuetzingii*	*Cymbella amphicephala*
Merismopedia punctata	*Closterium setaceum*	*Cymbella helvetica*
Microcystis aeruginosa	*Coelastrum microsporum*	*Denticula elegans*
Microcystis incerta	*Coelastrum sphaericum*	*Diatoma elongatum*
Nostoc commune	*Cosmarium botrytis*	*Diatoma vulgaris*
Nostoc pruniforme	*Cosmarium granatum*	*Diploneis elliptica*
Oscillatoria amoena	*Cosmarium monomazum*	*Diploneis ovalis*
Oscillatoria bornetii	*Cosmarium obtusatum*	*Epithemia argus*
Oscillatoria splendida	*Dimorphococcus lunatus.*	*Epithemia zebra*
Oscillatoria tenuis	*Franceia amphitricha*	*Fragilaria dilatata*
Phormidium ambiguum	*Mougeotia viridis*	*Fragilaria pinnata*
Phormidium mucicola	*Oocystis borgei*	*Fragilaria ulna*
Rhabdogloea hungarica	*Oocystis elliptica*	*Fragilaria ulna var. acus*
Spirulina laxa	*Oocystis eremosphaeria*	*Gomphonema lanceolatum*
Spirulina major	*Oocystis parva*	*Gomphonema olivaceum*
Spirulina princeps	*Oocystis solitaria*	*Gyrosigma acuminatum*
	Pandorina morum	*Gyrosigma attenuatum*
Pyrrophyta	*Pediastrum boryanum*	*Hantzschia amphioxys*
Cystodinium cornifax	*Pediastrum dublex*	*Melosira granulata*
Gymnodinium fuscum	*Scenedesmus acuminatus*	*Meridion circulare*
Peridinium cinctum	*Scenedesmus arcuatus*	*Navicula cryptocephala*
	Scenedesmus bicaudatus	*Navicula cuspidata*
Euglenophyta	*Scenedesmus communis*	*Navicula lanceolata*
Euglena acus	*Scenedesmus obliquus*	*Navicula pupula*
Lepocinclis playfairiana	*Scenedesmus spinosus*	*Navicula radiosa*
Trachelomonas armata	*Schizochlamys gelatinosa*	*Navicula tripunctata*
Trachelomonas lacustris	*Selenastrum gracile*	*Neidium dubium*
	Sphaerocystis schroeteteri	*Nitzschia hungarica*
Xanthophyta	*Staurastrum cyclacantum*	*Nitzschia linearis*
Ophioctium sp.	*Staurastrum gracile*	*Nitzschia palea*
	Stigeoclonium attennuatum	*Nitzschia vermicularis*
Chrysophyta	*Tetraedron minimum*	*Pinnularia microstauron var. brebissonii*
Dinobriyon sertularia	*Tetrastrum triangulare*	*Pinnularia viridis*
Paraphysomonas vestita	*Traubaria setigera*	*Rhopalodia gibba*
		Surirella caproni
Rhodophyta		*Surirella ovata*
Lemanea fucina		*Tryblionella acuta*

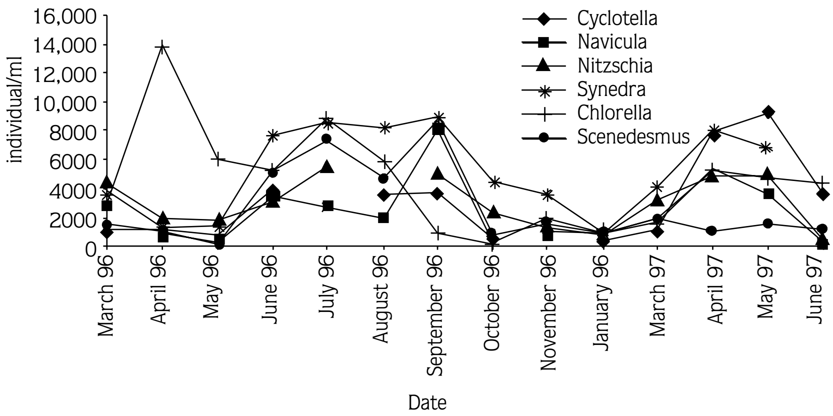

Figure 10. Seasonal variation of some abundant genera (individual/ml) in the SDR.

showed sharp developments in the presence of Ca^{2+}, Mg^{3+}, SO_4^{2-}, K^+ and Na^+ salts. However, their numbers were affected by increases or decreases in the salt concentration.

Seasonal succession and distribution of surface phytoplankton

The total biomass and seasonal distribution of phytoplankton in the SDR are under the control of physical and chemical changes in the streams that flow into the lake, in line with Gilbert (1989), who found that streams are the corridor of mixed habitats and affect the seasonal distributions of phytoplankton in large quantities, which also affects the other steps of the food chain. Our results support this study.

In March 1996, many *Bacillariophyta* members (Table 1), like *Nitzschia*, *Navicula*, *Synedra*, *Gomphonema* and *Cymbella; Chlorophyta* members, like *Scenedesmus, Oocystis* and *Chloeralla*; and *Cyanophyta* members, such as *Anabaena, Chroococcus, Nostoc* and *Spirulina*, were found at all stations. Furthermore, *Oscillatoria* and *Microcystis* species of *Cyanophyta*; *Surirella, Cymatopleura* and *Rhoicosphaenia* species of *Bacillariophyta*; *Cosmarium* and *Ankistrodesmus* species of *Chlorophyta*; and *Gymnodinium* of Pyrrophyta were very rare.

In April 1996, species belonging to the genera *Asterionella*, *Navicula*, *Nitzschia*, *Synedra*, *Cyclotella*, *Oocystis* and *Euglena* were very common, and species of the genera *Anomoeoneis, Surirella, Epithemia, Rhopalodia, Cocconeis, Anabaena, Spirulina* and *Microcystis* were rare compared to the other genera. In April 1996, especially *Peridinium* multiplies and changes the colour of the water to light red in a straight line.

In May 1996, species belonging to *Navicula*, *Nitzschia*, *Oocystis, Cymbella* and *Cocconeis* were very widespread.

In June 1996, species belonging to Asterionella, Pinnularia, *Navicula*, Peridinium, *Synedra* and *Gomphonema* were very common. However, species belonging to *Oedogonium* diminished and constituted a rare genus together with *Merismopedia* and *Spirulina*. *Cyanophyta* reached its maximum value during this month.

Navicula was the dominant organism at almost every station during July 1996. *Synedra*, *Microcystis* and *Nitzschia* were observed as subdominant organisms.

There was a noticeable increase in the number of members of *Bacillariophyta*. In contrast, species of the genera *Cylindrospermum, Phormidium, Spirulina, Gymnodinium, Euglena* and *Anabaena* were very rare. In August 1996, there was a considerable decrease (2384 individuals/ml) especially in the total organism number of the genus *Synedra*. Moreover, an increase was observed in *Cyclotella*, a centric diatom. *Cocconeis, Pinnularia, Surirella, Achnanthes, Cymatopleura, Microcystis, Nostoc, Lyngbya* and *Peridinium* were low in number.

In September 1996, an increase in the number of total organisms was observed. *Synedra* and *Cyclotella* increased to 8625 and 1712 individuals/ml, respectively, and became the most abundant organisms. *Nitzschia*, *Navicula* and *Scenedesmus* species were increased in number compared to the previous month. The number of species belonging to *Mastoglia, Melosira*, *Chlorella*, *Oocystis, Merismopedia, Treubaria, Anabaena* and *Microcystis* also increased but not as much as the members of *Bacillariophyta*. Species belonging to other divisions were not found during September.

In October 1996, with a considerable drop in temperature, some species disappeared but *Synedra* did not. *Synedra*, thought to be affected by temperature, did not disappear but decreased to 800 individual/ml. On the other hand, *Nitzschia* and *Surirella* constituted the subdominant organisms. Species belonging to the genera *Peridinium, Euglena, Phormidium, Aphanizomenon, Chroococcus, Scenedesmus* and *Franceia* were very abundant. During the same period, *Cocconeis, Cymatopleura, Chlorella, Sphaerocystis, Lepocincilis*, and *Ophioctium* were very rare. *Nitzschia* (480 individual/ml) was found at the lowest value during this month. Although there was a decrease in the number of species, an increase in the diversity of species was very evident in general.

In December 1996, organisms except *Bacillariophyta* were found to be dominant in the SDR. *Chlorella* (260 individual/ml), *Scenedesmus* (352 individual/ml), *Microcystis* (290 individual/ml), *Ankistrodesmus* (296 individual/ml), *Schizoclamys* (206 individual/ml) and *Oocystis* (276 individual/ml) constituted the dominant groups. *Bacillariophyta* was less common. Abundancy was observed only in *Synedra*. It was determined that environmental conditions including temperature during this month were detrimental to *Bacillariophyta*, but conducive to *Chlorophyta*.

Between December 1996 and February 1997, sampling could not be carried out because of heavy snowfall, resulting in freezing of the lake's surface.

The work done during January 1997 revealed the presence of *Chlorella* as a dominant organism, in addition to *Synedra*, *Nitzschia* and *Microcystis*. However, the number of total organisms at all stations was very low. Species of the genera *Cyclotella*, *Franceia* and *Anabaena* were also observed but in low numbers. During this period, it was the first time that members of Rhodophyta were observed in very low numbers.

During March 1997, an increase was observed once again in the number of members of *Bacillariophyta* at all stations and they became abundant. *Nitzschia* and *Synedra* (in particular) were the dominant organisms. Organisms of other divisions were present in low numbers.

Cyclotella and *Synedra* were very widespread during April 1997. An increase in *Phormidium* of *Cyanophyta*, with numerical values of 900 individual/ml, was determined. *Cyclotella*, *Synedra* and *Chlorella* played an important role in the distribution of phytoplankton with values of 1184, 1280 and 880 individual/ml, respectively. An increase in the number of total organisms corresponding to a decrease in the number of *Tetrastrum, Actinastrum* and *Oocystis* was also detected.

Cyclotella with 1696 individual/ml, *Nitzschia* with 896 individual/ml, *Chlorella* and *Ankistrodesmus* with 880 individual/ml were the abundant organisms during May 1997. No significant difference in the numbers of total determined algae was found during this month compared to the previous month. During June 1997, *Chlorochromonas* (3469 individual/ml) multiplied significantly and caused an algae explosion on the surface of the dam reservoir at the 4^{th} station. On the other hand, *Cyclotella*, *Navicula*, *Coelastrum* and *Spirulina* became the dominant organisms at the other stations. In this period, an increase was observed in the values of phosphate and nitrogen, which then caused a numerical increase in *Chlorochromonas minuta*.

The algae were found to reproduce less and their biological mass was found to decrease because of less sunlight and low temperature. With the increments in temperature and day length, phytoplankton started to multiply (Figure 5), and resulted in an algal explosion at the end of spring and early autumn. Water circulation supported this situation. Changes in climatic condition were accompanied by a decrease in the number of organisms and chlorophyll a values. Similar peaks were observed in the temperate zone lakes of the Northern hemisphere (Hutchinson, 1967).

Cyclotella species (centric diatoms) are predominant and widespread in the lakes around Ankara (Aykulu & Obalı, 1981; Aykulu et al., 1983), and eutrophic Mogan Lake (Obalı, 1984), and Karamık Lake (Gönülol & Obalı, 1986). In contrast, pennate diatoms were dominant in the SDR.

In terms of species diversity, *Chlorophyta*, most common in the Manisa-Marmara Lake (Cirik, 1982, 1983, 1984), were also dominant in the SDR. Observations on the algal flora of Hazar Lake (East Anatolia) strongly demonstrate the predominance of diatoms in littoral plankton (Şen, 1988), and the transition of the lake from an oligotrophic to a mesotrophic state. Being slightly alkaline, the SDR and Hazar Lake have similar types of algae. In contrast, Akbay et al. (1999) found that phytoplankton of Keban Dam Reservoir were dominated by *Bacillariophyta*, closely followed by *Chlorophyta* and *Cyanophyta*. The seasonal distribution of algae and their biomass results are in good correlation with the results obtained from the SDR.

Data for chlorophyll a and algae in Abbot's and Priddy lakes, in the United Kingdom (Moss, 1998) showed the presence of *Chlamydomonas* during January-March; *Asterionella*, *Synedra* and *Ankistrodesmus* during March-June; *Pandorina* during June-August; *Cyclotella* during August-September; and *Stephanodiscus* during October-December in Abbot's lake, which is similar to the SDR. During the study period, the genera Cycotella, *Navicula*, *Nitzschia*, *Synedra*, *Chlorella* and *Scenedesmus* were observed at all stations and designated as dominant organisms. The increases and decreases in the amount of chlorphyll a are affected by increases in the number of these species (Figure 10).

The genera of secondary importance were *Fragilaria, Gomphonema, Oocystis, Anabaena* and *Spirulina*. These genera were not generally observed during summer. They were followed by species belonging to *Cocconeis* and *Euglena*.

In this work, the (chlorophyll *a*) measurements indicate that the SDR is becoming mesotrophic. It is therefore urgently needed to protect this dam reservoir. The Sakarya river, with organically polluted arms (Atıcı, 1997); Kirmir stream, polluted with 4th quality water from urbanisation (Kazancı et al., 1997); and Porsuk stream, carrying heavy metal pollution from the Eskişehir industrial zone (Yücel et al., 1995) to the Sakarya River (discharging into the SDR), should be refined. Otherwise, the pollution of this reservoir will cause irreversible economic, ecological and biological losses.

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