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Research Article

Seasonal Distribution of Phytoplankton in Orduzu Dam Lake (Malatya, Turkey)

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Abstract: The species composition and seasonal distribution of phytoplankton in Orduzu Dam Lake was studied for a year. Diatoms (*Bacillariophyta*) were most diverse, followed by green algae (*Chlorophyta*), blue-green algae (*Cyanophyta*), euglenoids (*Euglenophyta*) and dinoflagellates (*Dinophyta*). A total of 117 taxa were recorded and the phytoplankton of the lake contained a large number of detached benthic algae. Phytoplankton assemblages were dominated by diatoms in all the periods investigated and centric diatoms were the most abundant. Overall phytoplankton density was high during the spring and summer months and the highest phytoplankton density was observed in August. The abundance of phytoplankton was positively correlated with water temperature.

Key Words: Orduzu Dam Lake, Phytoplankton, Seasonal variations, Malatya, Turkey.

Orduzu Baraj Gölü (Malatya, Türkiye) Fitoplanktonunun Mevsimsel Değişimi

Özet: Bu çalışmada Orduzu Baraj Gölü fitoplanktonunun tür kompozisyonu ve mevsimsel değişimi bir yıl süreyle incelenmiştir. Fitoplankton içerisinde diyatomeler tür çeşitliliği bakımından en zengin grubu oluştururken onları *Chlorophyta*, *Cyanophyta*, *Euglenophyta* ve *Dinophyta* üyeleri izlemiştir. Fitoplanktonda toplam 117 taxa kaydedilmiştir. Diyatomeler araştırma süresince, fitoplanktonda baskın alg grubunu oluşturmuşlardır. Fitoplankton yoğunluğu ilkbahar ve yaz aylarında yüksek olurken maksimum fitoplankton yoğunluğu Ağustos ayında gözlenmiştir. Fitoplankton yoğunluğu su sıcaklığı ile pozitif bir korelasyon göstermiştir.

Anahtar Sözcükler: Orduzu Baraj Gölü, Fitoplankton, Mevsimsel değişim, Malatya, Türkiye

Introduction

Algae are the major primary producers in many aquatic systems and are an important food source for other organisms. They include planktonic and benthic forms. Species composition and the seasonal variations of planktonic and benthic forms in freshwaters are dependent on interactions between physical and chemical factors. A considerable amount of information has been gathered over the last 10 years on the ecology and distribution of algae in lakes and running waters in eastern Anatolia. The majority of these studies are concerned with seasonal variations of phytoplankton in natural lakes (Şen, 1988; Çetin, 2000) and reservoirs (Şen & Çetin, 1988; Çetin & Şen, 1998; Çetin & Yıldırım, 2000). Algae in running water have been studied less (Şen et al., 1999; Yavuz & Çetin, 2000).

There are no algological studies on Orduzu Dam Lake in the literature. The purpose of this study was to determine the species composition and seasonal variations of phytoplankton in Orduzu Dam Lake.

Study area

Orduzu Dam Lake was constructed for irrigation purposes in 1979 and is situated in the east of Turkey, 5 km from the city of Malatya (38°20´ E, 38°25´ N). The surface area, water capacity, average depth and altitude of the reservoir are 15 km^2, 1,600,000 m^3, 6 m and 950 m respectively. The lake has a narrow, elongated shape (Figure 1). It is shallow, with a maximum depth of 9 m, and it does not stratify. The climate of region is arid; the winters are cold and the summers hot and dry.

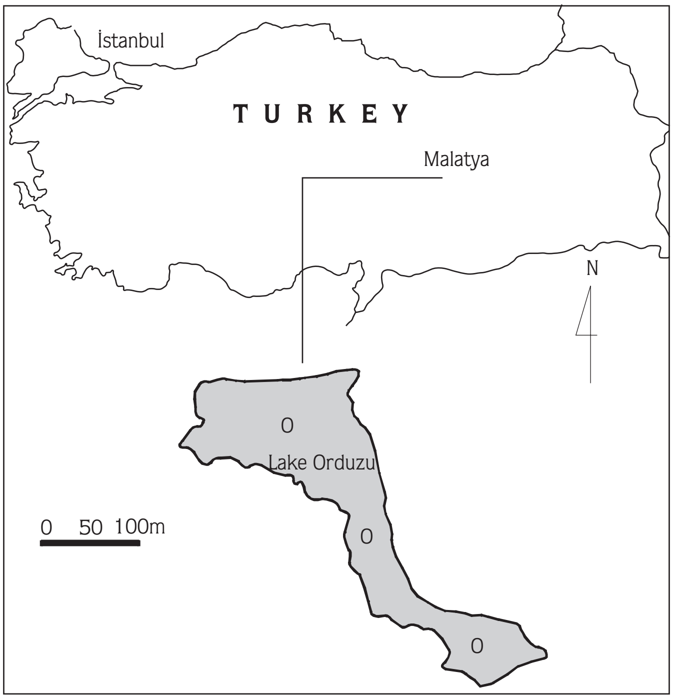

Figure 1. Map of Orduzu Dam Lake showing the position of sampling stations (o).

The location of Orduzu Dam Lake and the sampling stations are shown in Figure 1. Three sampling stations were chosen in the lake. The first station was on the north side of the lake (average depth of 3 m). The second sampling station was in the middle of the lake (average depth of 4 m), and the third was on the south side (average depth of 3 m).

Materials and Methods

Phytoplankton and water samples were taken from a 0-0.5 m water column monthly from the stations between April 1997 and May 1998 using a 1.5 l Nansen water sampler. Dissolved oxygen concentration and temperature were measured with a combined electrode (HACH oxygenmeter). Conductivity was measured through a conductivimeter (HACH 17250 model). pH was measured with a CyberScan (PD300 model) pH meter and transparency with a Secchi disc in situ. Total hardness, calcium, magnesium (by titration methods), nitrate-nitrogen (by brucinsulfate method), silica (by molybdosilicate method) and sulphate (by turbidimetric method) concentrations of the lake water were determined in the laboratory (APHA, 1985).

Phytoplankton individuals were counted using an inverted microscope (Lund et al., 1958). The phytoplankton density was estimated by counting all individuals. Single cells, colonies and filaments were all considered as individuals and the results are expressed as individuals ml^{-1} (ind. ml^{-1}). The phytoplankton was identified mainly using the works of Geitler (1925), Germain (1981), Patrick & Reimer (1966, 1975), Huber-Pestalozzi (1968), Prescott (1982), Ettl (1983) and Krammer & Lange-Bertalot (1986).

Results

Physical and chemical variables

The highest and lowest water temperatures in Orduzu Dam Lake were 23.5 °C and 4.8 °C in August and February, respectively. The annual cycle of water temperature at all stations showed a clear maximum in summer and a minimum in winter. Dissolved oxygen was 8.9-10.0 mg l^{-1}. Dissolved oxygen concentrations decreased in summer and increased in winter. The maximum conductivity (375 µs) was measured in July and minimum conductivity (200 µs) occurred in November (Table 1).

The lowest and highest light visibilities were 0.36 m and 1.46 m in April and August respectively. The lake was slightly basic and pH values varied between 7.5 and 8.3. The total hardness showed an irregular pattern, fluctuating between 143 and 180 mg l^{-1} $CaCO_3$. Seasonal fluctuations of nitrate-nitrogen were negligible in the lake. The maximum concentration of nitrate-nitrogen (0.023 mg l^{-1}) was determined in February and the minimum concentration (0.008 mg l^{-1}) was observed in July. Concentrations of sulphate were almost stable throughout the sampling period. The maximum (5.06 mg l^{-1}) and minimum (2.16 mg l^{-1}) values of sulphate were measured in August and September, respectively. Silica showed seasonal variations in Orduzu Dam Lake. The maximum concentration of silica (16.50 mg l^{-1}) was observed in February whilst the minimum value (5.65 mg l^{-1}) was recorded in October (Table 1).

Seasonal variations of phytoplankton

The total of 117 algal taxa belonging to *Bacillariophyta*, *Chlorophyta*, *Cyanophyta*, *Euglenophyta* and *Dinophyta* were identified in the phytoplankton. They are listed in Table 2. Diatoms were the most significant algae with respect to number of species and abundance in the phytoplankton, and centric diatoms were more conspicuous compared to pennate forms. *Cyclotella bodanica* Grun., *C. comta* (Ehrenb.) Kütz., *C. krammeri* Håk., *C. stelligera* Cleve & Grun., *C. ocellata* Pant., *Cymbella amphicephala* Naegeli ex Kütz., *Navicula veneta* Kütz. and *Fragilaria ulna* (Nitzsch) Lange-Bert. were the most dominant algae at all stations in the phytoplankton.

In general, the dynamics of algal numbers of all algal groups in the phytoplankton were quite similar (Figure 2). All algal groups started to increase in numbers in April and continued to increase slightly until the end of the summer. During this growth period the highest numbers of *Chlorophyta* were observed in May, whilst that of diatoms occurred in August. The numbers of individual of diatoms started to decrease after reaching their maximum and decreased regularly and continuously until the end of winter. By contrast, the number of individuals of other algal groups was either decreasing or low during autumn and winter. However, an exception was recorded in October when individual numbers of all algae excluding diatoms increased suddenly. *Dinophyta* and *Euglenophyta* were present from April to November but never exceeded 10 ind. ml^{-1} during the study. These algae were absent in winter.

In April, the phytoplankton was 358 ind. ml^{-1} and was dominated by diatoms (*Cyclotella bodanica*, *C. comta, C. krammeri, C. stelligera, C. ocellata, Achnanthes flexella* (Kütz.) Brunnth., *Cymbella affinis* Kütz., *Navicula veneta* and *Fragilaria ulna*).

Table 1. Variations in concentrations of some physical and chemical parameters in Orduzu Dam Lake water.

Sampling dates	Water temp., °C	pH	Dissolved O_2, (mgl^{-1})	Transparency (cm)	Total hardness $CaCO_3$(mgl^{-1})	Ca^{2+} (mgL^{-1})	Mg^{2+} (mgl^{-1})	Conductivity (µs)	Silica (mgl^{-1})	SO_4^{2-}(mgl^{-1})	NO_3-N (mgl^{-1})
Apr. 1997	10.90 ± 0.36	8.23 ± 0.15	9.71 ± 0.02	39.00 ± 2.64	161.00 ± 1.00	44.53 ± 0.61	12.06 ± 0.56	281.66 ± 2.88	11.93 ± 0.11	3.62 ± 0.60	0.050 ± 0.003
May 1997	14.93 ± 0.11	8.10 ± 0.10	9.41 ± 0.18	60.00 ± 2.64	154.00 ± 2.30	40.80 ± 0.80	12.79 ± 1.01	293.33 ± 2.88	15.50 ± 0.80	3.98 ± 0.15	0.017 ± 0.002
Jun. 1997	18.50 ± 0.50	7.96 ± 0.05	9.11 ± 0.12	101.00 ± 1.00	144.00 ± 1.00	39.46 ± 0.46	11.01 ± 0.50	276.66 ± 5.77	9.33 ± 0.35	3.40 ± 0.62	0.015 ± 0.005
Jul. 1997	20.06 ± 0.11	8.16 ± 0.05	9.06 ± 0.05	116.33 ± 4.04	179.00 ± 1.00	48.00 ± 0.40	14.33 ± 0.48	205.00 ± 5.00	7.10 ± 0.26	4.63 ± 0.57	0.017 ± 0.002
Aug. 1997	23.26 ± 0.25	7.96 ± 0.05	9.20 ± 0.00	144.33 ± 2.08	170.66 ± 1.15	46.66 ± 0.61	13.12 ± 0.24	321.66 ± 7.63	7.31 ± 0.40	5.06 ± 0.10	0.015 ± 0.005
Sep. 1997	23.00 ± 0,00	7.93 ± 0.11	9.01 ± 0.12	98.33 ± 0.57	147.33 ± 1.15	38.26 ± 1.00	12.63 ± 0.87	296.66 ± 2.88	6.01 ± 0.75	2.16 ± 0.07	0.015 ± 0.005
Oct. 1997	19.86 ± 0.23	8.03 ± 0.23	9.13 ± 0.05	75.33 ± 1.52	157.33 ± 1.15	41.33 ± 0.46	13.12 ± 0.00	360.00 ± 0.00	5.65 ± 0.21	3.03 ± 0.23	0.017 ± 0.002
Nov. 1997	11.90 ± 0.36	8.03 ± 0.15	9.30 ± 0.05	78.00 ± 1.00	161.33 ± 5.50	41.33 ± 1.40	13.87 ± 1.40	366.66 ± 7.63	8.18 ± 0.02	2.26 ± 0.12	0.015 ± 0.005
Dec. 1997	8.10 ± 0.17	7.83 ± 0.25	9.45 ± 0.13	80.33 ± 0.57	159.33 ± 1.15	40.66 ± 0.46	14.02 ± 0.30	366.66 ± 7.63	8.28 ± 0.02	2.23 ± 0.07	0.015 ± 0.000
Jan. 1998	5.06 ± 0.11	7.66 ± 0.20	9.90 ± 0.10	100.00 ± 1.00	154.33 ± 1.15	39.60 ± 0.69	13.44 ± 0.60	318.33 ± 2.88	14.33 ± 1.13	3.10 ± 0.25	0.017 ± 0.002
Feb. 1998	4.93 ± 0.11	8.13 ± 0.20	10.03 ± 0.05	75.66 ± 0.57	148.66 ± 1.52	38.13 ± 1.00	12.96 ± 0.27	303.33 ± 5.77	16.50 ± 0.50	2.15 ± 0.10	0.067 ± 0.007
Mar. 1998	6.96 ± 0.05	8.06 ± 0.11	9.96 ± 0.05	58.66 ± 1.52	163.66 ± 1.15	43.60 ± 1.44	13.28 ± 0.85	321.66 ± 2.88	14.25 ± 0,25	2.53 ± 0.02	0.013 ± 0.005

Table 2. Algal taxa recorded in the phytoplankton of Orduzu Dam Lake.

Bacillariophyta	*Gomphonema affine* Kütz.
Cyclotella bodanica Grun.	*G. dichotomum* S.Wunsam
C. comta (Ehrenb.) Kütz.	*G. subtile* Ehrenb.
C. krammeri Håk.	*Hannaea arcus* (Ehrenb.) in Patr. & Reimer
C. stelligera Cleve & Grun.	*Hantzschia amphioxys* (Ehrenb.) Grun.
C. ocellata Pant.	*H. amphioxys* var. *maior* Grun.
C. planctonica Brunnth.	*Navicula bacillum* Ehrenb.
Achnanthes delicatula Kütz.	*N. cari* Ehrenb.
A. flexella (Kütz.) Brunnth.	*N. cincta* (Ehrenb.) Ralfs in A.Pritch.
A. gibberula Grun in Cleve & Grun.	*N. cocconeiformis* Greg. ex Grevlle
A. minitussima Kütz.	*N.veneta* Kütz.
Amphora ovalis (Kütz.) Kütz.	*N. cuspidata* (Kütz.) Kütz.
A. veneta Kütz.	*N. cuspidata* var. *heribaudii* M.Peragallo in Hérib.
Asterionella formosa Hassall	*N. tripunctata* (O.F.Müll.) Bory
Caloneis alpestris (Grun.) Cleve	*N. neoventricosa* Hust.
C. ventricosa (Ehrenb.) F.Meister	*N. pupula* Kütz.
Cocconeis placentula Ehrenb.	*N. radiosa* Kütz.
Cymatopleura elliptica (Breb. ex Kütz.) W.Sm.	*N. reinhardtii* Grun. in Van Heurck
C. librile (Ehrenb.) Pant.	*N. rhyncocephala* Kütz.
Cymbella affinis Kütz.	*N. salinarum* Grun. in Cleve & Grun.
C. amphicephala Naegeli ex Kütz.	*N. veneta* Kütz.
C. aspera (Ehrenb.) H.Perag	*Neidium affine* (Ehrenb.) Pfitzer
C. cistula (Ehrenb.) Kirchner	*N. binodis* (Ehrenb.) Hust.
C. cistula var. *maculata* (Kütz.) Van Heurck	*N. dubium* (Ehrenb.) Cleve
C. cuspidata Kütz.	*N. iridis* (Ehrenb.) Cleve
C. helvetica Kütz.	*Nitzschia acicularis* (Kütz.)W.Sm.
C. obtusiuscula Kütz.	*N. amphibia* Grun.
C. parva (W.Sm.) Kirchner	*N. apiculata* (Gregory) Grun.
C. tumida (Breb. ex Kütz.) Grun in Van Heurck	*N. gracilis* Hantzsch
Denticula elegans Kütz.	*N. linearis* W.Sm.
D. tenue C. Agardh	*N. palea* (Kütz.) W.Sm.
Diatoma hyemale (Roth) Heib.	*N. sigmoidea* (Nitzsch) W.Sm.
D. vulgare Bory	*N. sinuata* (Thwaites ex W.Sm.) Grun. in Cleve & Grun.
Diploneis ovalis (Hilse) Cleve	*N. tryblionella* Hantzsch in Rabenh.
D. oblongella (Naegeli ex Kütz.) R. Ross	*Pinnularia acoricola* Hust.
Epithemia adnata (Kütz.) Rabenh.	*P. brebissonii* (Kütz.) Rabenh.
E. turgida (Ehrenb.) Kütz.	*P. mesolepta* (Ehrenb.)W.Sm.
Eunotia arcus Ehrenb.	*P. viridis* (Nitzsch) Ehrenb.
Fallacia pygmaea (Kütz.) Stickle & D.G.Mann	*Rhoichosphenia abbreviata* (C.Agardh) Lange-Bertalot
Fragilaria construens (Ehrenb.) Grun.	*Stauroneis anceps* Ehrenb.
F. construens var. *binodis* (Ehrenb.) Grun.	*S. phoenicenteron* (Nitzsch) Ehrenb.
F. ulna (Nitzsch) Lange-Bert.	*Surirella linearis* W.Sm.
Frustulia vulgaris (Thwaites) De Toni	*S. robusta* var. *splendida* (Ehrenb.)Van Heurck

Table 2. continued

Tabularia tabulata (C.Agardh) D.M.Williams & Round	*Tetraëdron minimum* (A.Braun) Hansg.
Chlorophyta	*Cyanophyta*
Eudorina elegans Ehrenb.	*Chroococcus turgidus* (Kütz.) Naegeli
Pandorina morum (Mull.) Bory	*Merismopedia elegans* A.Braun in Kütz.
Pediastrum boryanum (Turp.) Menegh.	*M. punctata* Meyen
P. duplex Meyen	*M. tenuissima* Lemmerm.
P. duplex var. *clathratum* (A.Braun) Lagerh.	*O. limosa* (Roth) C.A.Agardh ex Gomont
P. simplex Meyen	*O. princeps* Vaucher ex Gomont
Scenedesmus acuminatus (Lagerh.) Chodat	*O. rubescens* (de Candolle) ex Gomont
S. acutus Meyen ex Ralfs	*O. tenuis* C.A. Agardh ex Gomont
S. armatus Chodat	*O. tenuis* var. *natans* Gomont
S. intermedius Chodat	*Phormidium formosum* (Gomont) Anagn. et Komárek
S. longus Meyen	*Dinophyta*
S. obliquus (Turp.) Kütz.	*Ceratium hirundinella* (O.F.Müll.) Dujard.
S. protuberans F.E.Fritsch in M.F.Rich	*Peridinium cinctum* (O.F.Müll.) Ehrenb.
S. quadricauda (Turp.) Chodat	*Euglenophyta*
S. quadricauda var. *longispina* (Chod.) G.M.Smith	*Euglena viridis* Ehrenb.
S. quadricauda var. *maximus* West & West	*Phacus acuminatus* A.Stokes

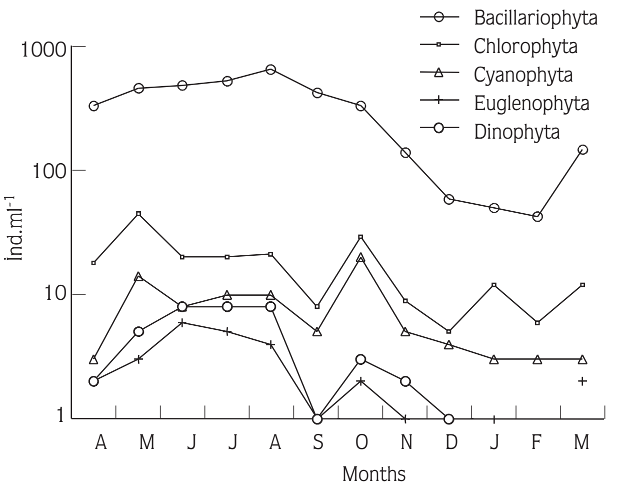

Figure 2. Seasonal variations in individual numbers of phytoplankton groups in Orduzu Dam Lake

Numbers of individuals in all algal groups started to increase in May and reached 519 ind. ml^{-1}. The dominant species were *Cyclotella comta, C. krammeri, C. stelligera, C. ocellata, Asterionella formosa* Hassal, *Cymbella affinis, Navicula veneta, N. tripunctata* (O.F.Müll.) Bory, *N. rhyncocephala* Kütz., *Pediastrum duplex* Meyen, *Tetraëdron minimum* (A.Braun) Hansg. and *Scenedesmus quadricauda* (Turp.) Chodat.

The highest summer number of individuals occurred in August (691 ind. ml^{-1}) and the proportions of the algal groups in the phytoplankton were as follows: *Bacillariophyta* (93.77%), *Chlorophyta* (3.03%), *Cyanophyta* (1.45%), *Dinophyta* (1.15%) and *Euglenophyta* (0.6%) (Figure 2). The phytoplankton was dominated by *Cyclotella comta, C. krammeri, C. ocellata, Achnanthes flexella, A. minutissima* Kütz., *Cymbella affinis, C. amphicephala, C. obtusiuscula* Kütz., *Navicula veneta, N. tripunctata, N. rhyncocephala, Nitzschia gracilis* Hantzsch, *Tetraëdron minimum* and *Ceratium hirundinella* (O.F.Müll.) Dujard. The numbers of individuals of centric diatoms were far higher than those of other algae. Diatoms were at their maximum in this month.

In September, the phytoplankton was dominated by *Bacillariophyta*, and centric diatoms were the most abundant (56%) once more. The phytoplankton composition in October was made up of *Bacillariophyta* (83.6%), *Chlorophyta* (7.49%), *Cyanophyta* (5.16%), *Dinophyta* (0.77%) and *Euglenophyta* (0.28%). The phytoplankton numbers in February were lowest (52 ind. ml^{-1}) at all sampling stations except for *Chlorophyta*. The phytoplankton increased (163 ind. ml^{-1}) in March again and *Bacillariophyta* (89.5%), *Chlorophyta* (7.36%), *Cyanophyta* (1.84%) and *Euglenophyta* (1.3%) were all present.

Discussion

The phytoplankton of Lake Orduzu was dominated by diatoms, whilst green algae, euglenoids, blue-green algae and dinoflagellates were less significant. The species composition of the phytoplankton of Lake Orduzu showed similarities to those of many lakes and reservoirs in Turkey (e.g., Aykulu et al., 1983; Şen, 1988; Çetin & Şen, 1998; Çetin, 2000; Çetin & Yıldırım, 2000; Yıldız, 1985).

Although pennate diatoms were represented by a higher number of taxa, they were much lower in numbers of individuals than were the centric forms in this lake. Although centric diatoms were poor in number of species they were much more abundant as individuals than were pennate forms and other algae. The dominance of centric diatoms, represented mainly by *Cyclotella krammeri, C. stelligera, C. ocellata* and *C. comta* in this study, has been previously documented by several authors in Turkish lakes (Çetin, 2000; Çetin & Yıldırım, 2000; Gönülol, 1985) and elsewhere (Round 1984; M'harzi et al., 1998; Piirsoo, 2001),

Centric diatoms are one of the best adapted algal groups to turbulent and turbid systems (Izaguirre et al., 2001), whereas pennate diatoms are regarded as benthic forms. However, plankton samples from shallow and turbulent water often contain benthic diatoms (mostly pennate forms), which are whirled up into the water as a result of water movement. It has been reported that pennate diatoms were richer in number of taxa than centric forms in the phytoplankton of many shallow Turkish lakes (Aykulu et al., 1983; Altuner, 1984; Gönülol, 1985).

The seasonal succession and species composition of the phytoplankton were similar at all the sampling stations during the study. The reasons for the similarities might be due to similar environmental conditions at the stations since physical and chemical properties at the different stations were quite similar.

The seasonal variations of phytoplankton are related to a variety of environmental factors in aquatic environments (Wu & Chou, 1998). Water temperature and transparency are among the most important physical factors affecting the distribution and seasonal variations of phytoplankton in lakes (Simon & Hildrev 1998; Mosisch et al., 1999). The effects of water temperature on phytoplankton have been examined in many freshwater ecosystems, and it was found that water temperature strongly regulates the seasonal variations of phytoplankton (Lund 1965; Richardson et al., 2000; Izaguirre et al., 2001). The increase in phytoplankton during the spring and summer months in Dam Lake Orduzu could also be a result of the increasing water temperature.

Light is a major resource for phytoplankton and has a complex pattern of spatial and temporal variability (Litchman, 2000). Suspended matter in lake water increases in autumn and spring, resulting in minimum transparency. During the summer the transparency was at its maximum level. There was also a significant correlation between the growth of phytoplankton and transparency in Orduzu Dam Lake since the largest populations of all algae occurred during the summer whilst indiviual numbers were low in winter.

No relation was observed between diatom growth and pH level since high and low individual numbers were observed at similar pH levels.

A notable relation was observed between diatom growth and silica concentrations in the present study. Silica concentrations decreased gradually during the vernal growth of diatoms and were recorded at their lowest when the vernal maximum ended. In fact, silica concentrations decreased during such growth periods and increased whilst individual numbers of diatoms were decreasing. This finding is in harmony with that of Pearsall (1930), who suggested that the fall in silica concentrations coincides with the diatom maxima.

The lake appeared to have moderately hard water. Calcium had no strong effects on the growth of any algal group since concentrations of calcium varied only between 38 and 48 mg l^{-1} during the study. A similar situation was also observed for magnesium since variations in its concentrations were negligible.

There appeared to be no correlation between the growth of algae and nitrate and sulphate since concentrations of these ions changed only slightly throughout the study.

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