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The diatoms of Asartepe Dam Lake (Ankara), with environmental and some physicochemical properties

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Abstract: The shoreline benthic diatoms of Asartepe Dam Lake were identified from different habitats (epipelic, epiphytic, and epilithic) at 7 sampling stations between April 2003 and June 2004. In the investigation, a total of 93 taxa were identified. Of those, *Cymbella affinis* Kütz., *Navicula radiosa* Kütz., *Ulnaria ulna* (Nitzsch) Compère, *Pinnularia borealis* Ehrenb., *Amphora ovalis* (Kütz.) Kütz., *Cyclotella ocellata* Pant. and *Nitzschia dissipata* (Kütz.) Grunow were observed and abundant at all stations. Some physical and chemical water quality parameters were measured and correlated with biological parameters.

Key words: Asartepe Dam Lake, algae, diatoms, biological parameters

Bazı fiziksel, kimyasal ve çevresel özellikleri ile Asartepe Baraj Gölü (Ankara) diyatomeleri

Özet: Bu çalışmada, Asartepe Barajı kıyı bölgesi bentik diyatomeleri; Nisan 2003-Haziran 2004 tarihleri arasında, belirlenen 7 örnek alma istasyonunda, farklı habitatlardan (epipelik, epifitik ve epilitik) alınan örneklerde incelenmiştir. Araştırma sırasında toplam 93 takson tespit edilmiştir. *Cymbella affinis* Kütz., *Navicula radiosa* Kütz., *Ulnaria ulna* (Nitzsch) Compère, *Pinnularia borealis* Ehrenb., *Amphora ovalis* (Kütz.) Kütz., *Cyclotella ocellata* Pant. ve *Nitzschia dissipata* (Kütz.) Grunow bütün istasyonlarda gözlenmiş diyatome türleridir. Biyolojik parametreler ile suyun fiziksel ve kimyasal özellikleri ilişkilendirilmiştir.

Anahtar sözcükler: Asartepe Baraj Gölü, algler, diyatomeler, biyolojik özellikler

Introduction

Diatoms are considerably important biological organisms because they are one of the sources of oxygen, like other algal divisions, and the first ring of food chains in aquatic systems. A complete picture of the lake ecosystem is necessary to understand the mechanisms regulating the nutrient content and biomass of benthic algae, because they can be

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dominant primary producers and are an important food resource (Wetzel, 1996). In addition, algae are used in textiles, paper, construction, cosmetics, fertiliser, food, and medical industries, and to produce single cell protein in biotechnology (Round, 1973). Some indicator algal species are also important criteria for determining water pollution. Waste waters come from domestic and industrial sources, consisting of organic and inorganic compounds (Atıcı, 1997; Karacaoğlu et al., 2004). Diatoms have been used in a number of countries as indicators of water pollution (Ács et al., 2004, 2006; Gosselain et al., 2005). The natural structure of water pollution is such that a useful water source is destroyed by any harmful chemical or physical factor. Similar studies were completed in the middle Anatolian region of Turkey (Obalı & Atıcı, 1997).

The benthic algae, except Bacillariophyta, of Asartepe Dam Lake were previously determined (Atıcı & Çalışkan, 2007), and the publication of these research results should support that study.

Study Area

Asartepe Dam was built on İlhan Stream, a tributary of Kirmir Stream. It is 825 m above sea level (Figure 1). It has a surface area of 177 ha. The maximum depth is 36 m and the maximum water capacity is 20×10^6 m^3. The structure of the bottom is thick, with a brown colour. Nevertheless, salt is widespread in the soil and the bottom deposits are extensively salty. Vein gypsum is found on the hilltop of the study area. This salt raises the salinity of the lake water. Cereal grains, sugar beets, tomatoes, peppers, chickpeas, and lentils are grown in the area. In addition to *Populus* sp. and *Salix* sp., some fruit trees are found near the lake.

A terrestrial climate type is dominant in the area. Winter is cold and rainy, and summer is hot and dry. There is a difference in the temperatures of nights and daytime. The average annual temperature is 11.7 °C in Ankara (MGM, 2004).

Materials and methods

Monthly samples of planktonic, epipelic, epiphytic and epilithic diatoms (Table 1) from 7 stations were taken at Asartepe Dam Lake between April 2003 and July 2004. Sampling stations were chosen near different sources of waters. Epipelic samples were taken over the sediment with a glass tube, 0.8 cm in diameter and 100-150 cm in length. Epiphytic samples were collected from stems and leaves of plants (*Populus* sp., *Ranunculus* sp.), *Salix* roots, and algae in

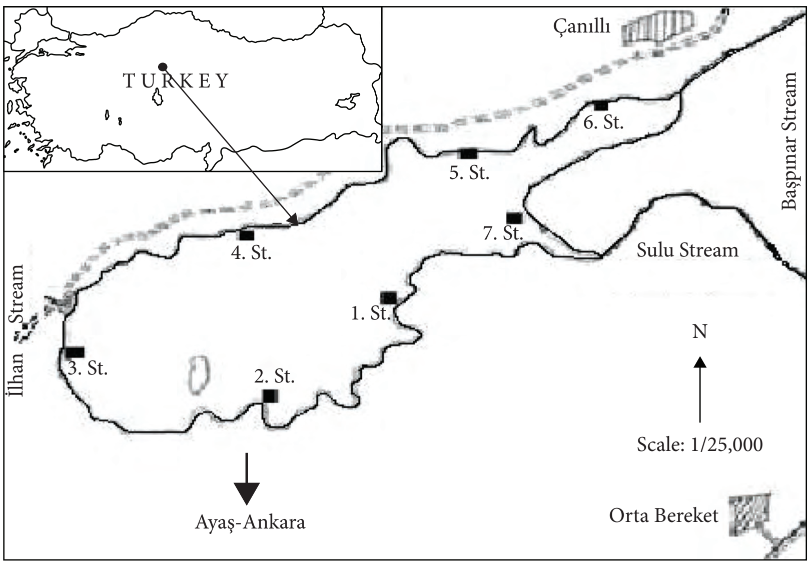

Figure 1. Asartepe Dam Lake and sampling stations.

Table 1. Diatoms of Asartepe Dam Lake.

Taxa	**Habitats Pl: Planktonic, Ep: Epipelic, Ef: Epiphytic, El: Epilithic**			
Bacilariophyta	**Pl**	**Ep**	**Ef**	**El**
Amphipleura pellucida (Kütz.) Kütz.	+	-	-	+
Amphora brebissonii Perag.	-	-	+	-
Amphora ovalis (Kütz.) Kütz.	-	-	+	+
Bacillaria paxillifer (O.F.Müll.) Hendey	-	-	-	+
Caloneis amphisbaena (Bory) Cleve	-	-	+	-
Caloneis silicula silicula (Ehrenb.) Cleve var. *ventricosa* (Ehrenb.) Cleve	-	-	+	+
Caloneis trinodis (Cleve) F.Meister	-	-	+	+
Chamaepinnularia amphiborealis Lange-Bert. & Werum	-	+	-	-
Cocconeis communis Heiberg var. *placentula* (Ehrenb.) Kirchn.	-	+	-	+
Craticula halophila (Grunow in Van Heurck) D.G.Mann	-	-	+	-
Cyclotella meneghiniana Kütz.	-	+	+	+
Cyclotella ocellata Pant.	-	-	+	+
Cymatopleura elliptica (Bréb.) W.Sm.	+	+	+	-
Cymatopleura solea (Bréb.) W.Sm.	+	+	-	+
Cymbella affinis Kütz.	-	-	+	+
Cymbella amphicephala Näegeli	-	+	-	-
Cymbella austriaca Grunow var. *ventricosa* Cleve-Euler	-	+	-	+
Cymbella cistula (Hemprich & Ehrenb.) Kirchn.	-	+	+	+
Cymbella cymbiformis C.Agardh var. *nonpunctata* Fontell	-	-	+	+
Cymbella helvetica Kütz.	+	+	+	-
Cymbella minutissima Hust.	-	+	+	+
Cymbella silesiacum (Bleisch) D.G.Mann	+	-	+	+
Cymbella turgidula Grunow	+	+	+	+
Detonula pumila (Castrac.) Gran	-	-	+	+
Diatoma elongatum (Lyngb.) C.Agardh var. *actinastroides* Krieg.	-	-	+	-
Diatoma moniliformis Kütz.	-	+	+	+
Diatoma vulgare Bory var. *tenuis* (C.Agardh) Kütz.	-	+	+	+
Diatoma vulgaris Bory	+	+	-	+
Diploneis boldtiana Cleve var. *ovalis* Playfair	-	-	+	+
Diploneis puella (Schum.) Cleve	-	+	+	-
Entomoneis ornata (Bailey) Patrick	-	+	+	-
Epithemia smithii Carruth.	-	+	+	+
Eunotia bilunaris (Ehrenb.) Schaarschm.	-	-	-	+
Eunotia faba (Ehrenb.) Grunow	-	-	+	-
Eunotia lunaris (Ehrenb.) Grunow var. *emarginatovalida* W.West	+	-	+	+
Fragilaria californica Grunow var. *intermedia* Perag.	+	+	+	+
Fragilaria capucina Desm. var. *vaucheriae* (Kütz.) Lange-Bert.	-	-	+	+
Fragilaria crotonensis Kitton	-	-	+	-
Frustulia pararhomboides Lange-Bert.	-	+	+	+
Gomphonema acuminatum Ehrenb.	+	+	-	+
Gomphonema clavatum Ehrenb.	-	-	+	+
Gomphonema olivaceum (Hornem.) Bréb.	+	-	-	+
Gomphonema vibrio Ehrenb. var. *subventricosa* Van Heurck	-	+	+	+
Gyrosigma acuminatum (Kütz.) Rabenh.	+	+	+	+
Gyrosigma peisonis (Grunow) Hust.	-	-	+	+
Hantzschia amphioxys (Ehrenb.) Grunow	-	-	+	-
Karayevia clevei (Grunow in Cleve & Grunow) Round & Bukht.	-	+	-	+

Table 1. (Continued).

Taxa	**Habitats Pl: Planktonic, Ep: Epipelic, Ef: Epiphytic, El: Epilithic**			
Bacilariophyta	**Pl**	**Ep**	**Ef**	**El**
Mastoglia smithii Thwaites ex W.Sm.	-	+	+	+
Melosira varians C.Agardh	-	+	+	+
Meridion circulare (Grev.) C.Agardh	+	+	-	+
Navicula accomoda Hust.	-	-	+	+
Navicula acus Cleve var. *minuta* Cleve-Euler	-	+	+	+
Navicula appendiculata appendiculata (C.Agardh) Cleve var. *lanceolata* Grunow	-	+	+	+
Navicula bicuspidata Cleve & Grunow	+	+	+	+
Navicula cryptocephala Kütz. var. *rhynchocephala* Grunow	-	-	+	+
Navicula gregaria Donkin	-	+	+	+
Navicula hemiviridula Perag.	-	+	+	+
Navicula menisculus Schum. var. *meniscus* (Schum.) Hust.	+	+	-	+
Navicula radiosa Kütz.	-	-	+	+
Navicula reichardtiana Lange-Bert.	+	+	+	-
Navicula splendicula VanLand.	-	+	+	+
Neidium dubium (Ehrenb.) Cleve	+	+	+	+
Neidium iridis (Ehrenb.) Cleve	-	-	+	+
Nitzschia amphibia Grunow var. *intermedia* A.Mayer	-	-	+	-
Nitzschia dissipata (Kütz.) Grunow	-	+	+	+
Nitzschia distans var. *subsigmoidea* Grunow	-	+	+	+
Nitzschia draveillensis Coste & Ricard	+	+	-	+
Nitzschia fonticola (Grunow) Grunow	-	-	+	+
Nitzschia rostellata Hust.	-	-	+	+
Pinnularia leptosoma (Grunow) Cleve	-	+	+	+
Pinnularia borealis Ehrenb.	-	-	+	+
Pinnularia interruptiformis Krammer	+	+	+	+
Pinnularia microstauron (Ehrenb.) Cleve	-	-	+	-
Pinnularia subviridis A.Cleve	-	+	+	+
Pinnularia tabellaria (C.Agardh) Lange-Bert.	-	+	+	+
Rhoicosphenia abbreviata (C.Agardh) Lange-Bert.	+	+	-	+
Rhopalodia gibba (Ehrenb.) O.F.Müll.	-	+	+	+
Stauroneis phoenicenteron (Nitzsch) Ehrenb.	+	+	+	+
Stauroneis pseudosmithii Van de Vijver & Lange-Bert.	-	-	+	+
Stauroneis pygmaea Krieg.	-	-	+	-
Stephanodiscus astraea (Kütz.) Grunow	-	+	+	+
Stephanodiscus astrea var. *matrensis* Pant.	-	+	+	+
Surirella angusta Kütz.	+	+	-	+
Surirella biseriata Bréb. var. *robusta f. armata* Mong.	-	-	+	+
Surirella elegans Ehrenb.	+	-	+	+
Surirella ovalis Bréb.	-	-	+	-
Tabellaria flocculosa (Roth) Kütz.	-	-	+	+
*Ulnaria acus (*Kütz.) Aboal	-	-	+	+
Ulnaria biceps (Kütz.) Compère	-	+	+	+
Ulnaria capitata (Ehrenb. 1836) Compère 2001	-	-	+	+
Ulnaria delicatissima (W.Smith) Aboal & P.C.Silva var. *angustissima* (Grunow) M.Aboul & P.C.Silva	-	+	-	+
Ulnaria ulna (Nitzsch) Compère	-	+	+	+
Urosolenia eriensis (H.L.Sm.) Round & R.M.Crawford	+	-	+	-

water (*Spirogyra* sp., *Chara* sp.). Epilithic samples were taken over stones and pebbles in the water. Planktonic samples were taken by plankton net and were put into 500 cc samples; those samples were then brought to the laboratory and were mixed with 1 L of alcohol, 1 L of glycerine, and 1 L of formaldehyde (37%) (Hecky & Kling, 1987). Temporary preparations of diatoms were prepared with Canada balsam (Round, 1953).

Planktonic, epipelic, epiphytic, and epilithic samples were studied in order to find relationships among the physical and chemical structures of the lake and the diatoms. Some chemical and physical analyses, such as temperature, DO, pH, electrical conductivity (EC), and salinity, were measured directly with YSI multiparameter probes as determined by APHA (1989) in the Government Water Organisation Laboratory (Table 2).

A Thoma microscope slide was used for counting organisms. Numerical values of different diatom groups were determined. Counting sections were available below 1/10 mm, according to the surfaces that contacted the slides. Counting was done in a small square with a volume of 10^{-4} mL, and the average from 64 small squares was taken (Lund, 1958).

Results

Biological Parameters

In the qualitative and quantitative study of Asartepe Dam Lake, 93 diatom species were identified. Of those, 11 belonged to *Navicula*, 9 to *Cymbella*, 6 to *Pinnularia,* 6 to *Nitzschia*, and 5 to *Ulnaria*. Taxa written in necessary sources were used for identification (Krammer & Lange-Bertalot, 1986, 1991a, 1991b, 1999; Hartley, 1996; John et al., 2003; Guiry & Guiry, 2009). Table 1 is given according to the http://www.algaebase.org system, in alphabetic order.

Physicochemical Parameters

The annual average values of seasonal changes in the physicochemical features of Asartepe Dam Lake are given in Table 2.

Table 2. Some physical and chemical features of Asartepe Dam Lake.

	April 2003	**May 2003**	**June 2003**	**July 2003**	**August 2003**	**September 2003**	**October 2003**	**November 2003**	**December 2003**	**February 2004**	**March 2004**	**April 2004**	**May 2004**	**June 2004**
Temperature (°C)	7	14	19	22	24.5	18	15	7.5	3.5	2	4	8	16	21
pH	8.32	8.35	8.10	8.60	8.58	8.50	7.59	6.46	8.19	6.06	8.47	8.64	8.60	8.20
EC (µmhos/cm)	395	372	380	386	397	420	433	404	402	402	390	385	396	400
O_2 (mg/L)	6.0	7.2	7.4	8.6	11.4	-	-	-	10.4	9.5	-	11.2	8.2	12.6
Na (mg/L)	0.69	0.69	0.42	0.44	0.44	0.69	0.65	0.65	0.73	0.65	0.65	0.60	0.40	0.40
K (mg/L)	0.21	0.09	0.09	0.06	0.06	0.06	0.06	0.05	0.05	0.02	0.01	0.05	0.07	0.06
Ca+Mg (mg/L)	3.89	3.40	4.00	3.70	3.50	3.79	3.82	3.99	4.18	3.90	3.94	3.72	3.45	3.62
CO_3 (mg/L)	0.32	0.32	0.32	0.60	0.82	1.04	0.28	0.01	0.20	0.01	0.46	0.68	0.65	0.65
HCO_3(mg/L)	3.43	4.00	3.20	3.60	2.70	2.75	3.52	4.01	4.07	2.50	3.41	3.11	3.65	3.52
Cl (mg/L)	0.36	0.36	0.50	0.56	0.41	0.38	0.48	0.43	0.40	0.37	0.38	0.30	0.45	0.50
SO_4 (mg/L)	0.68	0.30	0.78	0.30	0.31	0.36	0.24	0.25	0.29	1.70	0.34	0.28	0.36	0.46
% Na	14.4	15.5	16.2	16.2	16.2	15.2	14.3	13.8	14.7	14.2	14.1	13.7	14.4	15.2
SAR	0.49	0.54	0.56	0.56	0.52	0.50	0.47	0.46	0.50	0.47	0.46	0.44	0.52	0.52
Hardness (F.S°)	19.5	19.5	19.2	19.1	19.1	19.1	19.1	19.9	20.9	19.5	19.7	18.6	17.5	17.2
Total salt (ppm)	260	257	256	255	258	260	269	277	292	292	259	259	245	240
NH_3 (mg/L)	0.11	0.02	0.15	-	0.06	-	0.17	-	0.31	0.21	-	-	0.01	0.15

(-) Not measured (some technical problems occurred)

Discussion

In this study, a total of 93 diatom species were identified. Of those, 11 species belonged to *Navicula*, 9 to *Cymbella*, 6 to *Pinnularia,* 6 to *Nitzschia*, and 5 to *Ulnaria*, with those 37 species representing 39.78% of the total species found.

Seasonal variations influenced physical and chemical factors in the lake, and water flow can especially influence the diatom population density and thus the food chain.

Cymbella affinis, *Navicula radiosa*, *Ulnaria ulna*, *Nitzschia dissipata*, *Pinnularia borealis*, and *Stauroneis pygmaea* were the dominant organisms in May 2003. The total number of organisms increased on 18 April and 18 May 2004.

The species diversity of *Diatoma*, *Gomphonema*, and *Surirella* was low, but abundance was high. Generally, members of *Amphora* and *Cyclotella* were widespread in all months during the study period. Species of *Ulnaria* were low in Asartepe Dam Lake.

Sunlight, temperature, salinity, and physicochemical characteristics have a great influence on diatoms. They all have a maximum density in spring and autumn. Temperature influences biological, chemical, and physical activities in the water. Thus, oxygen consumption increases. The oxygen level is related to temperature, salinity, current, photosynthetic activities (algae and macrophytes), and atmospheric pressure in natural waters. Water temperature ranged between 2 and 24.5 °C in Asartepe Dam Lake (Figure 2). Water temperature increases in spring months, then decreases in winter months, depending on changes in the air temperature (Atıcı, 2003).

Oxygen solubility differs based on the rate on photosynthesis and the level of nutrients in the aquatic environment. The oxygen levels of Asartepe Dam Lake varied during the research period; the maximum was 12.6 mg/L and the minimum was 6.0 mg/L. Solubility of oxygen decreases in water when temperature increases (Wetzel, 1983). Generally, the concentration of oxygen is 10 mg/L in natural oligotrophic water (20 °C) (DSİ, 1998).

The pH varied between 6.06 and 8.64 in Asartepe Dam Lake. A pH of 8.64 was measured in April 2004. The ions carried by spring rains were the cause of that increase. pH values range between 6 and 9 in natural lakes and streams (Tanyolaç, 2000). Temperature and conductivity, which were measured in Asartepe Dam Lake, were related. Conductivity also increases with the temperature of the water. The conductivity was 105-500 µmhos/cm (DSİ, 1989).

Furthermore, particularly Cl^- and Na^+ determine conductivity. These and some other minerals are important sources of salinity. The total salt level was 240-292 ppm in Asartepe Dam Lake. Generally, the salinity value increases with evaporation in shallow lakes (John et al., 2003; Kolaylı & Şahin, 2009). The diversity of all algae decreased in December 2003 and February 2004 due to an increase of salinity. High levels of salinity restrict diatom diversity (Nagasathya & Thajuddin, 2008). The source of nitrogen

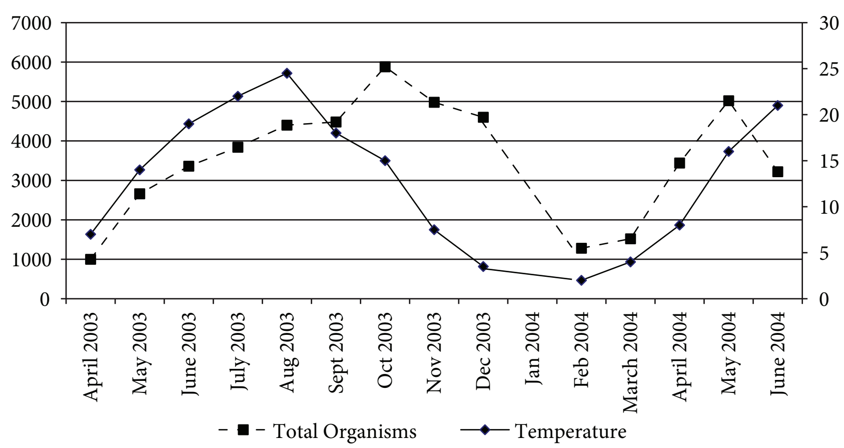

Figure 2. Seasonal variation in temperature and total organisms in Asartepe Dam Lake.

compounds was atmospheric nitrogen and agricultural activity, such as domestic and industrial wastes in the lake water. The source of ammonia was the waste from fish and other organisms.

Ca^{++} and Mg^{++} have vital importance in plants, which photosynthesise in the aquatic environment. Mg^{++} is in the structure of chlorophyll. The concentration of Mg^{++} has a great effect on algae growing in lakes. As a result, the trophic level is influenced (Wetzel, 1983). The concentration of Ca^{++} increases with rain in winter. Life became active with the increase in the temperature of the water and environment after April 2003, and consumption of Ca^{++} began in the lake. Therefore, a decrease of values of Ca^{++} was observed.

Alkalinity, which shows that the water is gaining proton capacity, is formed by the reaction of CO_2 and water, producing H_2CO_3 and the disintegration of structure. These ions adjust the pH of the water and control the acidity (Hecky & Kling, 1987). The values of HCO_3 were 2.50-4.07 mg/L and the values of CO_3 were 0.01-1.04 mg/L.

Precipitation waters arrive at the lake in short spans of time, because the plant cover is limited. Due to a pasture, organic material is also mixed with the lake water. These mixtures have an influence on the chemistry of the lake water, and this then affects the turbidity.

Some groups (such as the pennate diatoms *Cymbella*, *Amphora*, and *Nitzschia*, and the centric *Cyclotella*) were found to be abundant; they are tolerant to the environmental and other factors in Asartepe Dam Lake.

Conclusion

Diatoms are abundant and diverse in Turkish freshwaters. They form an important component of many benthic algal communities in streams and standing waters, but are generally less common in the phytoplankton. Diatoms are excellent ecological indicator species because their remains are preserved in many sedimentary environments. More research is needed to analyse the causes of the observed enormous variation in the nutrient status and biomass of benthic algae in lakes.

The physicochemical parameters were evaluated and connected with diatoms. Asartepe Dam Lake is in a transition period to eutrophic from mesotrophic. It is an important freshwater source for Ankara, but the usage of the water endangers human health because of the overgrowth of algae.

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