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Research Article

A Study on the Past and Present Diatom Flora of Two Alkaline Lakes

Sabri KILINÇ, Erdal Rıdvan SIVACI
Cumhuriyet University, Science and Art Faculty, Department of Biology, 58140, Sivas - TURKEY

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Abstract: The diatom flora of Lakes Hafik and Tödürge was studied qualitatively. Each lake was sampled monthly during two periods. The first period was between April 1986 and June 1987 in Lake Hafik and between August 1990 and October 1990 in Lake Tödürge. The second period was between December 1999 and July 2000 in both lakes. A total of 94 diatom taxa belonging to 25 genera and 53 diatom taxa belonging to 21 genera were identified in Lakes Hafik and Tödürge respectively. *Cymbella* Agardh, *Navicula* Bory and *Nitzschia* Hassall appeared to have the richest genera in terms of number of species in both lakes. The comparison of diatom species showed that *Navicula cryptocephala* Kützing and *Nitzschia sublinearis* Hustedt replaced *Navicula radiosa* Kützing and *N. bicephala* Hustedt whereas *Cymbella prostrata* (Berkeley) Cleve showed a decreasing trend in Lake Hafik. Study of present samples of Lake Tödürge revealed that *Amphora* Ehrenberg decreased while *Cymbella ventricosa* Kützing and *Caloneis clevie* (Lagerstedt) Cleve increased noticeably. Although both lakes' water is alkaline, Hafik seemed to have acidophilic diatom assemblages, which were probably the result of excessive microbial activity occurring during the decomposition of algal mats after algal bloom took place repeatedly over four or five years. This led to a lowering of the pH at the sediment-water interface as a result of acidic fermentation products and led to the presence of acidophilic species.

Key Words: Lake Hafik, Lake Tödürge, Diatom

İki Alkalik Gölün Geçmiş ve Şimdiki Diyatome Flora'ları Üzerine Bir Çalışma

Özet: Hafik ve Tödürge Göllerinin diatom florası kalitatif olarak çalışılmıştır. Örnekler Hafik gölünden Nisan 1986-Haziran 1987 ve Aralık 1999-Temmuz 2000 tarihleri arasında toplanırken Tödürge gölünden Ağustos 1990-Ekim 1990 ve Aralık 1999-Temmuz 2000 tarihleri arasında toplanmıştır. Hafik ve Tödürge Göllerinde sırasıyla 25 genus'a ait 94 taxa ve 21 genus'a ait 53 taxa tespit edilmiştir. Her iki gölde de *Cymbella* Agardh, *Navicula* Bory and *Nitzschia* Hassall en zengin tür sayısına sahip görünmüşlerdir. Hafik gölünde diatom türlerinin karşılaştırılmaları sonucunda *Navicula cryptocephala* Kützing ve *Nitzschia sublinearis* Hustedt 'in *Navicula radiosa* Kützing ve *N. bicephala* Hustedt 'nın yerini aldığı ve *Cymbella prostrata* (Berkeley) Cleve 'nın azaldığını göstermiştir. Tödürge gölünün yeni örneklerinin çalışılması, *Amphora* Ehrenberg türleri azalırken *Cymbella ventricosa* Kützing ve *Caloneis clevei* (Lagerstedt) Cleve 'nin önemli miktarda arttığını ortaya koymuştur. Her ne kadar her iki gölün suyu alkalik özellikte ise de, Hafik gölünün asidofilik türlere sahip olduğu gözlenmiştir. Bu durum belki de 4-5 yıl tekrarlayan alg aşırı üremesi sonucunda oluşan alg tabakalarının çöktükten sonra parçalanmaları sonucu gerçekleşen aşırı mikrobiyal aktivite nedeniyle salınan asidik fermentasyon ürünlerinin sediment-su kontak noktasında pH'yı düşürmesinin bir sonucu olarak gerçekleşmiş ve asidik türlerin yerleşmesine neden olmuştur.

Anahtar Sözcükler: Hafik Gölü, Tödürge Gölü, Diyatome

Introduction

The first qualitative and quantitative studies on algae were carried out at Çubuk-1 Dam lake (Geldiay, 1949) and Lake Mogan (Tanyolaç and Karabatak, 1974) and have been accepted as pioneering studies in this area for Turkey.

These studies were followed by others which mainly focused on the algal flora and factors affecting them in mid - Anatolia (Obalı, 1984; Gönülol, 1984; Aykulu et al. 1983; Yıldız, 1986). In addition, a number of detailed studies have been carried out in the northern, western, and eastern parts of Turkey (Altuner, 1988; Yıldız, 1987; Şahin, 1998; Çetin and Şen, 1998).

Recently, algological studies have gained momentum in Turkey, but have not yet reached an acceptable level. Despite the fact that the Sivas region is one of the lake districts with numerous lakes and wetlands, it is not well known. Almost no work has been done on the algae of the region (Kılınç, 1998).

The aim of this study was to determine the epipelic diatom flora of Lakes Hafik and Tödürge, which have slightly different water and catchment characteristics. In addition recently taken samples were compared with samples taken ten years ago in order to see whether there were any changes in the diatom flora during this period of time.

Study Sites and Geological Composition

Lake Hafik is located at the bottom of a large U-shaped karstic subsidence on an east-west orientated gypsum plateau. The lake has a strip of 2-15-metre-wide macrophytic vegetation consisting of *Juncus* L. and *Phragmites* L. The general characteristics of the lake are given in Table 1. More details about the lake geology and its surrounding area are given elsewhere (Kılınç, 1998).

Table 1. General Characteristics of Lakes Hafik and Tödürge

	Hafik	Tödürge
Surface Area (km^2)	0.75	3.5
Mean Depth (m)	3	3
Max. Depth (m)	4	5.5
Altitude (m)	1290	1295

Lake Tödürge, 20 km away from Lake Hafik, is the biggest karstic subsidence lake in Turkey. This triangular lake is located south of the village of Demiryurt (Tödürge), by the mouth of Kızılırmak Canyon, and north of the Sivas-Erzincan highway. The lake is 1.5 km from the Kızılırmak and is bordered by an old alluvion of the Kızılırmak (Atiker, 1993; Gökçe and Ceyhan, 1998). The lake has an inflow that nearly dries out in late autumn, carrying more salty water into the lake from the east. There is an outflow from the lake carrying water to the Kızılırmak. The lake is mainly fed by rainfall and karstic groundwater (Değirmenci et al., 1995). Both the inflow and outflow areas have large marshlands that dry out during the summer and flood in late winter and spring. There is a small agricultural area on the north side of the lake. The average depth of Lake Tödürge is approximately 3-4 metres. It has been speculated that there is a 30-metre-deep hole on the west side of an island in the east of the lake, but we were not able to find it during our study. The general characteristics of the lake are given in Table 1. Lakes Hafik and Tödürge have an altitude of 1290 m and 1295 m respectively. The locations of the lakes are shown in the Figure.

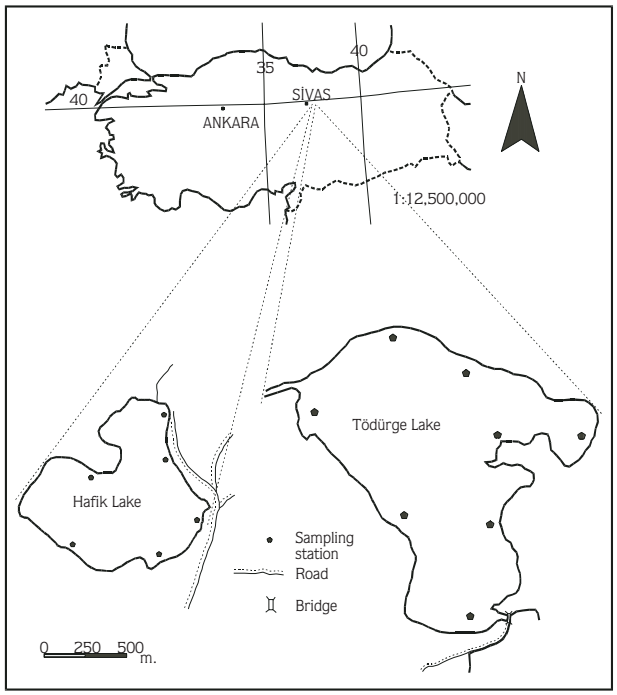

Figure. The Location of Lakes Hafik and Tödürge

Materials and Methods

Each lake was sampled monthly during two periods. The first period was between April 1986 and June 1987 in Lake Hafik and between August 1990 and October 1990 in Lake Tödürge. The second period was between December 1999 and July 2000 in both lakes. Sediment samples were collected from four stations from each lake by means of a glass pipe 11 mm in diameter and 1 metre in length. The pipe was lowered by hand to the surface of the sediment while one end was closed with the thumb. The pipe was then moved in a circular direction on the surface and the thumb was slightly loosened to suck the sediment into the pipe. The collected sediment samples were transferred into plastic bottles and taken to the laboratory for further examination. The sediment samples were put into petri dishes and allowed to settle

for four to six hours. The supernatant was removed from the petri dishes by micropipetting and cover glasses were placed over the sediments. After 24 hours the cover glasses were carefully taken and washed into beakers. Thereafter diatoms were prepared following standard techniques: carbonate dissolution by HCl followed by oxidation of organic matter using H_2O_2 and repeated washing of the resultant diatom frustule in demineralized water (Batterbee, 1986). Permanent slides were examined using an Olympus Vanox research microscope under 1600 X magnification. Relevant books and references were used in the identification of diatoms (Krammer and Lange-Bertalot, 1999 / 1-2; Krammer and Lange-Bertalot, 1991 / 1-2).

Results and Discussion

A total of 94 diatom taxa belonging to 25 genera and 53 diatom taxa belonging to 21 genera were identified in Lakes Hafik and Tödürge respectively. Although there was no difference in diatom species composition between the stations within each lake itself, some differences were observed between the lakes (Table 2). Members of the order Pennales were the dominant group while Centrales was represented by only *Cyclotella ocellata* Pantocsek and *Cyclotella meneghiniana* Kützing. *Cymbella, Navicula* and *Nitzschia* genera appeared to be the richest in terms of number of species with 16, 13, and 9 species respectively. The species *Amphora ovalis* Kützing, *Cocconeis placentula* Ehrenberg, *Cymbella prostrata* Berkeley and *Diatoma vulgare* Bory were found to occur frequently in both lakes. The same species were also frequently recorded in the sediments of Altınapa and Çubuk-I Dam lake (Yıldız, 1986; Gönülol, 1984).

Species belonging to *Navicula* and *Nitzschia* genera were noted as the dominant diatoms in studies carried out around the mid-Anatolian region (Obalı et al., 1989). *Gomphonema olivaceum* (Hornemann) Breèbisson and *G. ventricosum* Gregory are found in both littoral plankton and littoral epilithic flora and are real epilithic and epipelic diatoms. These species were identified in the sediments of Lakes Hafik and Tödürge. *Cymbella* and *Synedra* Ehrenberg genera members, which were frequently recorded in the two lakes, are distributed and accepted as true epilithic and epipelic diatoms (Margalef, 1960). *Cymbella, Gomphonema* Agardh and *Synedra* genera were also recorded in epiphytic and epilithic (Altuner,

Table 2. List of diatoms found in Lakes Hafik and Tödürge

Divisio: Bacillaiophyta	Hafik	Tödürge
Classis: *Centrobacillariophyceae*		
Cyclotelle meneghiniana Kuetz.	+	+
Cyclotella ocellata Pantocsek	+	+
Classis: *Pennatibacillariophyceae*		
Achnanthes deflexa Reimer	+	-
Achnanthes flexella (Kützing) Brun	+	-
Achnanthes lanceolata (Brèbisson) Grunow	+	-
Achnanthes minutissima Kützing	+	+
Amphora commutata Grunow	-	+
Amphora lineolata Ehrenberg	-	+
Amphora ovalis var. *pediculus* Kützing	+	+
Asterionella formosa Hassall	+	-
var. *gracillima* (Hantzsch) Grunow	+	-
Caloneis amphisbaena (Bory) Cleve	+	-
Caloneis clevei (Lagerstedt) Cleve	-	+
Caloneis limosa sensu Patrick	+	+
Caloneis silicula (Ehrenberg) Cleve	+	+
Cocconeis placentula Ehrenberg	+	+
Cymatopleura elliptica (Brèbisson) W. Smith	+	-
Cymatopleura solea (Brèbisson) W. Smith	+	-
Cymbella affinis Kützing	-	+
Cymbella cistula (Ehrenberg) Kirchner	+	+
var. *cistula* Brun	+	-
var. *gibbosa* Brun	+	-
Cymbella cymbiformis Agardh	+	-
Cymbella hauckii var. *hauckii* Van Heurck	+	-
Cymbella inaequalis (Ehrenberg) Rabenhorst	+	-
Cymbella laevis Naegeli Ex. Kützing	+	+
Cymbella minuta Hilse Ex. Rabenhorst	+	+
var. *pseudogracilis* (Cholnoky) Reimer	+	-
var. *silesiaca* (Bleisch Ex. Rabhorst) Reimer	+	-
Cymbella muelleri Hustedt	-	+
Cymbella prostrata (Berkeley) Cleve	+	+
Cymbella sinuata Gregori	-	+
Cymbella turgida (Georgi) Cleve	+	+
Cymbella turgidula Grunow	+	-
Cymbella ventricosa Kützing	+	+
Denticula elegans Kützing	+	-
Denticula lauta var. *lauta* J.W. Bail	+	-
Denticula tenuis Kützing	+	+
Denticula thermalis Kützing	+	-
Diatoma elogatum Agardh	+	-
Diatoma vulgare Bory var. *brevis* Grunow	+	+
Epithemia adnata (Kützing) Brebisson. var. *adnata*	+	-
Epithemia intermida Ficke	+	+
Epithemia sorex Kützing	+	-
Epithemia turgida (Ehrenberg) Kützing	+	+
Eunotia arcus Ehrenberg	+	+
Eunotia monodon Ehrenberg	+	-
Eunotia pectinalis (Kützing) Rabenhorst	+	-
Eunotia praerupta Ehrenberg var. *inflata* Grunow	+	-
Fragillaria constricta (Ehrenberg) Grunow	+	+
var. *subsalina* Hustedt	+	-

Table 2. Continue

Fragillaria crotenensis Kitton	+	-
Fragillaria pinnata Ehrenberg	+	+
var. *trigona* (Brun U. Heribaund) Hustedt	+	-
Fragillaria intermedia Grunow	-	+
Fragillaria virescens Ralfs	+	-
Frustulia rhomboides (Ehrenberg) De toni	+	-
Gomphonema olivaceum (Hornemann) Brèbisson	+	+
Gomphonema parvulum Kützing	+	+
Gomphonema truncatum Ehrenberg	+	-
var. *capitatum* (Ehrenberg) Patrick	+	-
Gomphonema tenellum Kützing var. *tenellum*	+	-
Gomphonema ventricosum Gregory	+	+
Gyrosigma acuminatum (Kützing) Rabenhorst	+	+
Hatzschia amphioxys (Ehrenberg) Grunow	+	+
Mastoglia elliptica Agardh	+	-
Navicula anglica Ralfs	-	+
Navicula arvensis Hustedt var. *arvensis*	+	-
Navicula bicephala Hustedt var. *bicephala*	+	-
Navicula cryptocephala Kützing	+	+
Navicula hungarica Grunow	-	+
Navicula integra (W. Smith) Ralfs	+	-
Navicula minima Grunow	+	-
Navicula pupula Kützing	+	+
Navicula radiosa Kützing	+	-
Navicula reinhardtii Grunow	+	-
Navicula spicula (Dickie) Cleve	+	-
Navicula tripunctata (O. F. Müller) Bory	+	-
Navicula virudula Kützing	+	+
Neidium dubium (Ehrenberg) Cleve	+	-
Nitzschia acuta Hantzsch	+	-
Nitzschia acicularis W. Smith	-	+
Nitzschia gandershemiensis Kraske	-	+
Nitzschia linearis W. Smith	-	+
Nitzschia palea (Kützing) W. Smith	+	+
Nitzschia recta Hantzsch	+	-
Nitzschia sigmoidea (Ehrenberg) W. Smith	-	+
Nitzschia spectabilis (Ehrenberg) Ralfs	+	-
Nitzschia sublinearis Hustedt	+	-
Nitzschia vermicularis (Kützing) Grunow	+	-
Pinnularia lata (Brèbisson) Smith	+	-
Pinnularia major (Kützing) Rabenhorst. var. *major*	+	-
Pinnularia viridis (Nitzsch) Ehrenberg	+	+
Staurneis anceps f. gracillis Rabenhorst	+	+
Staurneis nobilis Schumann var. *nobilis*	+	-
Surirella ovalis Brèbisson	+	-
Surirella ovata Kützing	+	+
Synedra actinastroides Lemmermann	+	-
Synedra affinis Kützing	+	-
var. *faciculata* (Kützing) Grunow	+	-
Synedra amphicephala Kützing	+	-
Synedra tenera W. Smith var. *tenera*	+	-
Synedra ulna Ehrenberg	+	+
var. *amphiryncus* (Ehrenberg) Grunow	+	+
var. *biceps* (Kützing) Kirchner	+	+
Tabellaria flocculosa var. *asterionelloides* Grunow	+	-
Tabellaria fenestrata (Lyngbye) Kützing	+	-

1984) and epipelic (Altuner and Aykulu, 1987) communities of Lake Tortum. It has been concluded that in samples taken from the shore, species of epiphytic and epilithic communities are commonly found in epipelic communities as a result of wave and water circulation, detaching them from their habitat and settling them on the sediments (Dere, 1989; Gönülol, 1985).

Furthermore, *Tabellaria fenestrata* (Lyngbye) Kützing has recently been re-named *Tabellaria flocculosa* var. *asterionelloides* Grunow; it was found in both plankton and on sediments. The appearance of the *Tabellaria* Ehrenberg population in the field is controlled by the availability of light, temperature and nutrients. It competes better against other species because of its adaptation of photosynthesis and growth in lower light intensities and higher temperatures and its comparatively lower loss rates (Dokulil and Kofler, 1994). *T. flocculosa* var. *asterionelloides* was found in Lake Hafik sediments but not in those of Lake Tödürge. The reason for this could be the salinity difference between the two lakes. The salinity of Lake Hafik was between 5.9 g l^{-1} and 8 g l^{-1}, whereas it was between 26.9 g l^{-1} and 34.2 g l^{-1} in Lake Tödürge. It has been documented that *T. flocculosa* var. *asterionelloides* can occur in a salinity range of 0.00-52.24 g. L^{-1} (Cumming et al., 1995). There may be other factors affecting the distribution and occurrence of this species in Lake Hafik and its absence in Lake Tödürge. Therefore, it can not be explained only by salinity, which is not a major primary factor affecting the distribution of this species. It has been shown that *T. flocculosa* var. *asterionelloides* growth optimally occurs between 18 and 21°C (Pientiz et al., 1995). The water temperature was over 17°C in Lake Hafik when *T. flocculosa* var. *asterionelloides* started to occur frequently in the samples, and thus one of the major factors controlling its abundance might have been temperature.

It has been stated that *Eunotia* Ehrenberg, *Frustulia* Agardh, *Pinnularia* Ehrenberg and *Neidium* Pfitzer are commonly found in oligotrophic lakes and are acidophilic (Round, 1960). Although the water characteristics of both lakes show alkaline conditions, the sediment diatom assemblages of Lake Hafik seemed to have species that are described as acidophilic with a pH preference of less than 7 (species list- Table 2). During the sampling in 2000, it was observed that Lake Hafik had algal blooms, mainly consisting of Chlorophyceae classis members (*Spirogyra* Link). After a short period of time, the algal

mat at the surface collapsed to the bottom and decomposition took place. Local residents pointed out that this has been happening for at least the last 4-5 years. Interstitial pH levels are lowered as a result of the release of acidic fermentation products by microbial activity (Marsden, 1989; Eckerrot and Pettersson, 1993). Excessive microbial activity, which occurred during the decomposition of algal mats after algal bloom took place repeatedly over four or five years, might well lower the pH at the sediment-water interface and lead to acidophilic species living in lake sediments despite the alkaline condition of the water.

When the present species composition was compared with that of the past, *Navicula cryptocephala* Kützing and *Nitzschia sublinearis* Hustedt replaced *Navicula radiosa* Kützing, and *N. bicephala* Hustedt in Lake Hafik. *C. prostrata* (Berkeley) Cleve seemed to have decreased in abundance; it was recorded frequently in samples taken in 1987. *Cymbella cymbiformis* Agardh showed no difference. The examination of samples taken from Lake Tödürge in 1990 revealed that *Amphora commutata* Grun., *Amphora ovalis* (Kütz) Kützing, *N. cryptocephala* and *C. cymbiformis* Agardh were the dominant species. However, the present samples showed that while the occurrence of *N. cryptocephala* and *C. cymbiformis* did not change, *Amphora* spp. were seen least frequently and *Cymbella ventricosa* Agardh and *Caloneis clevie* (Lagerstedt) Cleve increased noticeably.

The species replacing others in these lakes are found more in lakes that are naturally or artificially fertilized (Moss, 1980). However, these differences in species composition probably indicate that both systems are changing and giving warning signals that eutrophication is on the way, with the case of Lake Hafik being more serious. In the future it will be necessary to study these two lakes in more detail in order to produce solutions to prevent eutrophication from becoming more severe.

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