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## The seasonal succession of diatoms in phytoplankton of a soda lake (Lake Hazar, Turkey)

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**Abstract:** Some physicochemical variables and climatic effects on the succession of a diatom community in the plankton of the pelagic zone of Lake Hazar, an alkaline soda lake, were investigated. Monthly diatom samples were collected from the surface water at western, central, and eastern pelagic areas of the ellipsoid-shaped lake using a plankton net from November 2004 to October 2005. When high temperature and pH levels prevailed in May and September, *Epithemia*, *Rhopalodia*, *Cocconeis*, and *Cyclotella* were dominant. *Cymbella* was dominant in early spring and late autumn, but was not significantly correlated with temperature or pH. The species of *Gomphonema*, *Fragilaria*, *Navicula*, and *Nitzschia* were dominant at low temperature and pH levels in winter. However, the diatom community of the surface phytoplankton in the lake comprised largely cosmopolitan and nonplanktonic species of *Cocconeis*, *Cyclotella*, *Cymbella*, *Epithemia*, *Fragilaria*, *Gomphonema*, and *Rhopalodia* detached from benthic habitats of littoral zone by wind-driven currents.

**Key words:** Diatom, succession, water quality, soda lake

### Introduction

Soda lakes as extreme ecosystems represent the most stable natural alkaline environments. They are characterised by high concentrations of sodium carbonate. The presence of carbonate provides the buffering capacity of the lake waters (Ulukanlı & Dıđrak, 2002). Soda lakes show large salinity and pH ranges and the pH may rise to high values, especially in closed lakes. The formation of high alkalinity in soda lake environments requires a combination of geographical, topographical, and climatic conditions (Reimer et al., 2009).

The oligotrophic Lake Hazar is the second largest natural lake in Eastern Anatolia (Şen et al., 2003).

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The algal flora of Lake Hazar mainly comprises *Bacillariophyta*, *Chlorophyta*, *Cyanophyta*, *Dinophyta*, and *Euglenophyta*. Lake Hazar, with a high pH value and carbonate content, is characterised by the dominance of pennate diatoms in the phytoplankton and phytobenthos (Şen et al., 1995).

Diatoms, besides being important components of primer productivity, are valuable indicators of environmental conditions because they respond directly and sensitively to many physical, chemical, and biological changes in aquatic ecosystems. Diatoms have proven to be extremely powerful tools with which to explore and interpret many ecological conditions (Round et al., 1990; Stoermer & Smol, 1999; Reynolds, 2006).

This study aims to reveal the environmental factors leading to the diversity and dominance of diatoms in phytoplankton and the influences on the succession of planktonic diatoms in surface water of the pelagic zone of Lake Hazar.

## Material and methods

### Study site

The oligotrophic Lake Hazar is the second largest natural lake in Eastern Anatolia. Lake Hazar, formed by faulting of the Eastern Anatolia Fault, is a tectonic lake located at 38°31'N, 39°25'E. The lake, with a parallelogram or elliptical shape, has a surface area of 80 km<sup>2</sup> and a basin area of 403 km<sup>2</sup> at an altitude of 1238 m. Since there is no exact bathymetrical measurement of the lake, previous studies have reported various maximum depths ranging between 80 and 300 m (Şen et al., 2003). The lake is monomictic, with the incomplete mixing in spring and the complete mixing between autumn and early winter. It is stratified from June to September, forming a thermocline between 10 and 20 m (unpublished data).

### Sampling and analysis

Surface water samples for analysis of physicochemical variables were taken monthly from November of 2004 to October of 2005. The minimum depth of the sampling stations was 10 m, which was the pelagic zone during the study period. Diatom samples were qualitatively collected along about 1 km of trawling

with a boat using a plankton net with a pore size of 55 µm (Figure 1). Water samples for diatom counting were placed in 250-mL bottles and fixed with Lugol's solution.

Temperature, pH, and conductivity were measured using a YSI 63 model instrument in situ. Total alkalinity, bicarbonate, and carbonate were determined with amperometric titration (Radtke et al., 1998). Nitrate nitrogen, total nitrogen, soluble reactive phosphorus, total phosphorus, and silica were determined with automatic methods using a Lachat Instrument QuickChem 8000 flow injection analyser. Chlorophyll *a* was determined with a Thermo Helios-α spectrophotometer after acetone extraction (APHA et al., 1995).

Permanent slides were prepared after boiling with acidic solution and mounting with Entellan medium (Wetzel & Likens, 1991; APHA et al., 1995). Diatoms were identified under 1000× magnification on an Olympus CX41 research microscope according to the methods of Patrick and Reimer (1966, 1975), Hustedt (1985), and Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b).

### Data evaluation

Normality of data was checked by the Shapiro–Wilk test. The differences of variables with normal distribution among the sampling depths were tested using the signed rank test (Wilcoxon) for nonnormal distribution. The Wilcoxon test did not detect significant differences between the regions

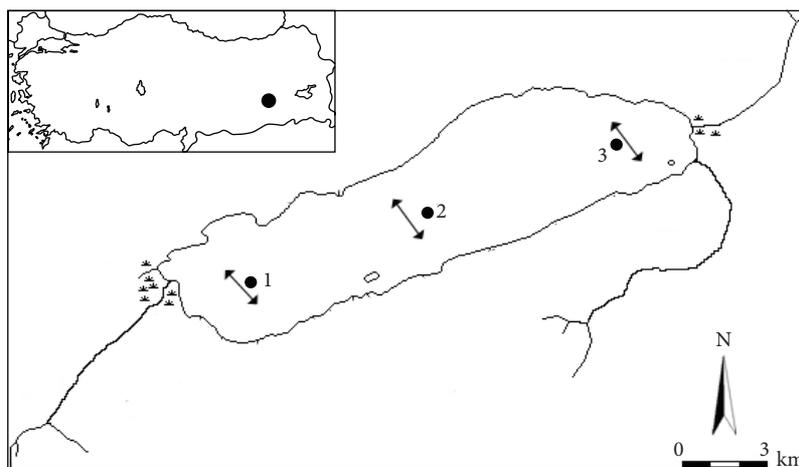


Figure 1. Lake Hazar and sampling sites in the pelagic zone of the lake.

in terms of relative abundances of species and physicochemical variables ( $P > 0.05$ ). Therefore, the data were evaluated calculating the mean values of relative abundances and physicochemical variables.

We resorted to multivariate analysis to determine the relationships between phytoplankton composition and physicochemical environmental variables. In the first step of the analysis, an unconstrained ordination was calculated to select linear or unimodal methods in detrended correspondence analysis (DCA). Species data were transformed logarithmically ( $\log(a \times y + b)$ ). In DCA with detrending by segments and Hill's scaling, the length of the longest axis provided an estimate of the beta diversity in the data set. Because DCA showed short gradient lengths ( $<0.95$  standard deviation), a linear model was appropriate for our data (ter Braak, 1995; Lepš & Šmilauer, 2003). Principal component analysis (PCA) was then used for scaling in interspecies relations and dividing species scores by the standard deviation. Logarithmically transformed species data were centred (ter Braak, 1995; ter Braak & Verdonschot, 1995; Lepš & Šmilauer, 2003). Multivariate analysis and triplot loading were performed using CANOCO 4.5.

## Results and discussion

The surface water temperature of the pelagic zone of Lake Hazar was measured between 4.7 and 29.4 °C during the study period. The mean pH value was  $9.1 \pm 0.2$ , being consistent with high alkalinity and high bicarbonate and carbonate concentrations. High conductivity can be attributed to high dissolved solids content, including mainly bicarbonate, carbonate, and calcium. The mean concentrations of total nitrogen in the surface water of the pelagic zone changed between 0.525 and 0.570 mg N/L while total phosphorus changed between 0.020 and 0.027 mg P/L. Mean chlorophyll *a* concentrations at the sites changed between 1.2 and 1.4 µg/L with a maximum concentration of 2.2 µg/L (Table 1). Although there appeared to be some differences among the sampling sites in terms of physicochemical variables, variance analysis did not detect statistically significant differences ( $P > 0.05$ ). Based on the trophic status classification (OECD, 1982), the surface water of the pelagic zone of Lake Hazar exhibited oligotrophic

characteristics in terms of total nitrogen and mean and maximum chlorophyll *a* concentrations, but it was mesotrophic in total phosphorus. Overall, the main physicochemical characteristics suggest that Lake Hazar is an oligotrophic, hard-water, and alkaline soda lake with regard to the surface water of the pelagic zone.

In the study period, there were 50 taxa belonging to genera *Achnanthes*, *Amphora*, *Caloneis*, *Cocconeis*, *Cyclotella*, *Cymatopleura*, *Cymbella*, *Diatoma*, *Epithemia*, *Fragilaria*, *Gomphonema*, *Navicula*, *Nitzschia*, *Pinnularia*, *Rhoicosphenia*, *Rhopalodia*, and *Surirella* (Table 2).

The number of species observed was minimum (17 taxa) in August and maximum (43 taxa) in March. The number of species was low between May and October. It showed an increasing trend between January and April, when low temperature conditions prevailed (Figure 2).

In winter (January, February, and March), *Gomphonema clavatum* was dominant (19%, 16%, and 22%, respectively). *Fragilaria capucina* var. *rumpens*, *Gomphonema olivaceum*, and *Cymbella helvetica* were subdominant species in the same period. The dominant species of spring (March and April) was *Cymbella affinis* (16% and 20%, respectively), followed by *Gomphonema clavatum*, *Gomphonema olivaceum*, *Cymbella cymbiformis*, and *Cymbella leptoceros*. The relative abundance of *Epithemia turgida* (32%) and *Rhopalodia gibba* (12%) increased in the late spring (May) when thermal stratification formed (Figure 3).

The dominance of *Cyclotella meneghiniana* (32%, 24%, and 15%, respectively) and *Cocconeis placentula* (5%, 22%, and 29%, respectively) was observed during summer (June, July, and August) when *Cocconeis placentula* var. *lineata*, *Epithemia turgida*, and *Rhopalodia gibba* were subdominant. Again, *Cymbella affinis* was found to be dominant (21%) in September, and it became the major component of the diatom community in phytoplankton (40%) in October. *Cocconeis placentula* was the dominant taxon in August and subdominant in September. The relative abundances of *Gomphonema clavatum* and *Gomphonema olivaceum* showed an increasing tendency in October. There was a marked increase of *Gomphonema clavatum* in November (Figure 3).

Table 1. The mean concentration and standard deviation (minimum–maximum) of variables of surface water in the pelagic zone of Lake Hazar during the study period.

| Variables   | Site 1                         | Site 2                         | Site 3                         |
|---|--------------------------------|--------------------------------|--------------------------------|
| Temperature (°C)  | 14.0 ± 8.9<br>(4.7–29.4)       | 13.2 ± 8.5<br>(5.1–28.6)       | 13.5 ± 8.8<br>(5.2–28.8)       |
| pH  | 9.1 ± 0.2<br>(8.5–9.2)         | 9.1 ± 0.2<br>(8.6–9.4)         | 9.1 ± 0.2<br>(8.7–9.3)         |
| Conductivity (µS/cm)  | 2249 ± 129<br>(2001–2510)      | 2235 ± 127<br>(1920–2469)      | 2244 ± 142<br>(1953–2490)      |
| Alkalinity (mg CaCO <sub>3</sub> /L)                                | 466 ± 56<br>(369–640)          | 467 ± 70<br>(344–656)          | 455 ± 42<br>(328–574)          |
| Bicarbonate (mg HCO <sub>3</sub> <sup>-</sup> /L)                   | 303 ± 33<br>(212–400)          | 292 ± 77<br>(200–435)          | 298 ± 61<br>(208–405)          |
| Carbonate (mg CO <sub>3</sub> <sup>-2</sup> /L)                     | 97 ± 9<br>(83–136)             | 97 ± 8<br>(84–120)             | 99 ± 10<br>(86–127)            |
| Calcium (mg Ca <sup>2+</sup> /L)                                    | 99.8 ± 5.7<br>(72.9–105.2)     | 100.9 ± 3.9<br>(89.9–107.9)    | 103.2 ± 6.0<br>(92.8–121.5)    |
| Magnesium (mg Mg <sup>2+</sup> /L)                                  | 10.1 ± 5.0<br>(5.2–24.0)       | 8.5 ± 1.9<br>(6.4–12.0)        | 8.9 ± 2.5<br>(6.4–14.4)        |
| Nitrate (mg NO <sub>3</sub> <sup>-</sup> -N/L)                      | 0.368 ± 0.137<br>(0.100–0.847) | 0.409 ± 0.191<br>(0.100–1.020) | 0.371 ± 0.239<br>(0.100–1.280) |
| Total nitrogen (mg N/L)   | 0.525 ± 0.170<br>(0.160–1.126) | 0.570 ± 0.236<br>(0.180–1.326) | 0.552 ± 0.284<br>(0.190–1.643) |
| Soluble reactive phosphorus (µg PO <sub>4</sub> <sup>-3</sup> -P/L) | 13.9 ± 7.7<br>(8.7–50.0)       | 19.4 ± 6.8<br>(10.0–67.5)      | 15.0 ± 6.5<br>(8.7–40.0)       |
| Total phosphorus (µg P/L)   | 20.0 ± 12.5<br>(12.3–62.5)     | 26.9 ± 9.3<br>(12.5–92.8)      | 21.5 ± 10.9<br>(12.9–65.0)     |
| Silica (mg SiO <sub>2</sub> /L)                                     | 3.3 ± 0.6<br>(2.1–5.2)         | 2.8 ± 0.8<br>(1.7–4.7)         | 2.8 ± 0.6<br>(1.8–4.5)         |
| Chlorophyll <i>a</i> (µg/L)   | 1.2 ± 0.1<br>(0.7–2.0)         | 1.2 ± 0.2<br>(0.4–2.0)         | 1.4 ± 0.3<br>(0.6–2.2)         |

The species of *Cocconeis*, *Cyclotella*, *Cymbella*, *Epithemia*, *Fragilaria*, *Gomphonema*, and *Rhopalodia* almost completely represented the diatom community in phytoplankton from the lake surface during the study period (total relative abundance: 83%–98%). Moreover, these genera showed a clear seasonal succession tendency. There was a periodicity that emerged in the dominance of *Gomphonema* and *Fragilaria* in winter, *Cymbella* in early spring and autumn, *Epithemia* and *Rhopalodia* in late spring, and *Cyclotella* and *Cocconeis* in summer (Figure 4).

PCA revealed 2 main directions of variation, with axis 1 explaining 55.6% of the total variance and axis 2 explaining an additional 14.0% (Figure 5). The inter-set correlations of species and environmental data showed that the strongest direction of variation

(axis 1) was primarily a gradient of species succession together with temperature, carbonate, conductivity, pH, silica, alkalinity, and species number. The second gradient (axis 2) was mainly characterised by the correlations of soluble reactive phosphorus and silica together with some species. *Epithemia* and *Rhopalodia*, dominant in late spring, and *Cocconeis* and *Cyclotella*, dominant in high temperature conditions, were placed on the right side of the graph near May, June, July, August, and September. *Cymbella*, dominant in early spring and late autumn, was not significantly correlated with temperature. The species of *Gomphonema*, *Fragilaria*, *Navicula*, and *Nitzschia*, dominant in the period of low temperature, were placed on the left side of the graph near December and January (Figure 5).

Table 2. The list of diatom species in the phytoplankton of the pelagic zone of Lake Hazar.

| Taxa  | Taxa   |
|---|--|
| <i>Achnanthes delicatula</i> (Kützing) Grunow                           | <i>Fragilaria capucina</i> var. <i>vaucheriae</i> (Kützing) Lange-Bertalot       |
| <i>Amphora ovalis</i> Kützing   | <i>Fragilaria crotonensis</i> Kitton   |
| <i>Caloneis obtusa</i> (W.Smith) Cleve                                  | <i>Fragilaria fasciculata</i> (C.Agardh) Lange-Bertalot                          |
| <i>Cocconeis placentula</i> Ehrenberg                                   | <i>Fragilaria ulna</i> (Nitzsch) Lange-Bertalot                                  |
| <i>Cocconeis placentula</i> var. <i>lineata</i> (Ehrenberg) Van Heurck  | <i>Fragilaria ulna</i> var. <i>acus</i> (Kützing) Lange-Bertalot                 |
| <i>Cyclotella meneghiniana</i> Kützing                                  | <i>Fragilaria virescens</i> Ralfs  |
| <i>Cymatopleura solea</i> (Brebisson) W.Smith                           | <i>Gomphonema angustatum</i> (Kützing) Rabenhorst                                |
| <i>Cymbella affinis</i> Kützing   | <i>Gomphonema clavatum</i> Ehrenberg   |
| <i>Cymbella cymbiformis</i> C.Agardh                                    | <i>Gomphonema constrictum</i> Ehrenberg  |
| <i>Cymbella ehrenbergii</i> Kützing                                     | <i>Gomphonema olivaceum</i> (Hornemann) Brebisson                                |
| <i>Cymbella helvetica</i> Kützing                                       | <i>Gomphonema parvulum</i> Kützing   |
| <i>Cymbella lata</i> Grunow   | <i>Navicula exigua</i> (Gregory) Grunow  |
| <i>Cymbella leptoceros</i> (Ehrenberg) Kützing                          | <i>Navicula menisculus</i> var. <i>upsaliensis</i> Grunow                        |
| <i>Cymbella tumidula</i> Grunow   | <i>Navicula phyllepta</i> Kützing  |
| <i>Cymbella turgidula</i> Grunow  | <i>Navicula reinhardtii</i> Grunow   |
| <i>Diatoma vulgare</i> Bory   | <i>Navicula tripunctata</i> (O.F.Müller) Bory                                    |
| <i>Epithemia adnata</i> (Kützing) Brebisson                             | <i>Navicula viridula</i> Kützing   |
| <i>Epithemia argus</i> (Ehrenberg) Kützing                              | <i>Nitzschia hantzschiana</i> Rabenhorst   |
| <i>Epithemia sores</i> Kützing  | <i>Nitzschia sigmoidae</i> (Nitzsch) W. Smith                                    |
| <i>Epithemia sores</i> var. <i>gracilis</i> Hustedt                     | <i>Pinnularia viridis</i> (Nitzsch) Ehrenberg                                    |
| <i>Epithemia turgida</i> (Ehrenberg) Kützing                            | <i>Rhoicosphenia abbreviata</i> (C.Agardh) Lange-Bertalot                        |
| <i>Epithemia turgida</i> var. <i>granulata</i> (Ehrenberg) Brun         | <i>Rhopalodia gibba</i> (Ehrenberg) O.F.Müller                                   |
| <i>Fragilaria brevistriata</i> Grunow                                   | <i>Rhopalodia gibba</i> var. <i>parallela</i> (Grunow) H.Peragello & M.Peragallo |
| <i>Fragilaria brevistriata</i> var. <i>pusilla</i> Grunow               | <i>Surirella ovalis</i> Brebisson  |
| <i>Fragilaria capucina</i> var. <i>rumpens</i> (Kützing) Lange-Bertalot | <i>Surirella turgida</i> W.Smith   |

The pH value of Lake Hazar was always highly alkaline (8.7 to 9.2), and thus most species had to be alkaliphilic. The influence of pH was characterised with the same directions of *Epithemia* and *Rhopalodia*, predominantly alkaliphilic, and with the opposite direction of *Gomphonema*, which is more acidophilic (Stoermer & Smol, 1999). The preference for high electrolyte content of *Epithemia* and *Rhopalodia* (Krammer & Lange-Bertalot, 1988) was clearly reflected in the graph with placement in the same position and direction as conductivity. Moreover, *Epithemia* and *Rhopalodia*, which are found in oligotrophic hard waters (Kramer and Lange-Bertalot, 1988), showed relatively significant

correlations with carbonate. *Cymbella*, distributed in surface waters with different electrolyte contents (Kramer & Lange-Bertalot, 1986), did not show any significant relations with pH and conductivity (Figure 5).

Despite these approaches aiming to explain the succession patterns of diatoms in plankton, most of the species discussed, except for *C. meneghiniana*, are benthic algae that are primarily epilithic and epiphytic forms. Some of them can tolerate depth variations (eurytopic) and can be planktonic (Servant-Vildary & Roux, 1990), but there are no euplanktonic species. Carrick et al. (1993) showed that wind turbulence increases the spatial differentiation in phytoplankton.

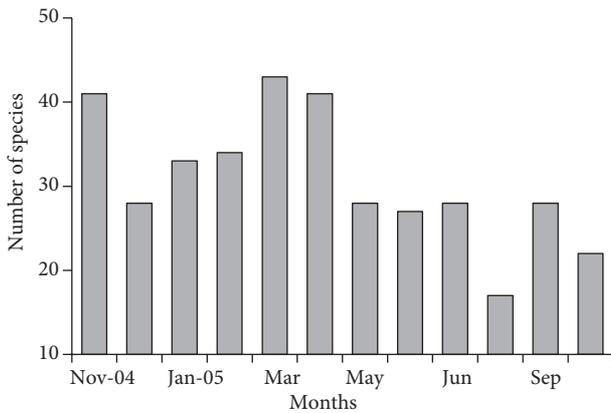


Figure 2. Monthly changes of the species number.

Indeed, many studies have verified that wind-induced currents can cause considerable heterogeneity in the horizontal distribution of phytoplankton cells (Carrick et al., 1993; Verhagen, 1994; Webster & Hutchinson, 1994). In mildly saline (total salts of 500–2000 mg/L) lakes, algal flora is fairly rich and composed of a variety of diatoms (e.g., species of

*Amphora*, *Cyclotella*, *Epithemia*, *Fragilaria*, *Navicula*, *Nitzschia*, and *Rhopalodia*), especially if nitrogen and phosphorus are high (Wehr & Sheath, 2003).

The tychoplanktonic species, especially in *Cocconeis*, *Cymbella*, *Fragilaria*, *Gomphonema*, and *Epithemia*, have been found to be important components of the phytoplankton communities of various lakes (Elmacı & Obalı, 1998; Kılınç, 1998; Akbulut & Yıldız, 2002; Karacaoğlu et al., 2004; Atıcı & Obalı, 2006; Çelekli & Köylüoğlu, 2006; Yılmaz, 2007; Atıcı & Obalı, 2010) and streams (Pala & Çağlar, 2008; Barinova et al., 2011; Solak et al., 2011). The genera *Cymbella* and *Gomphonema*, representing highly abundant taxa of diatoms in the phytoplankton of Lake Hazar, have been reported as common species in the benthos and plankton of surface waters in the same region (Çetin & Şen, 1998; Çetin & Yavuz, 2001; Yıldırım et al., 2003; Alp & Sen, 2010). These genera are generally dominant in the littoral phytoplankton and benthic habitats of Lake Hazar (Şen et al., 1995).

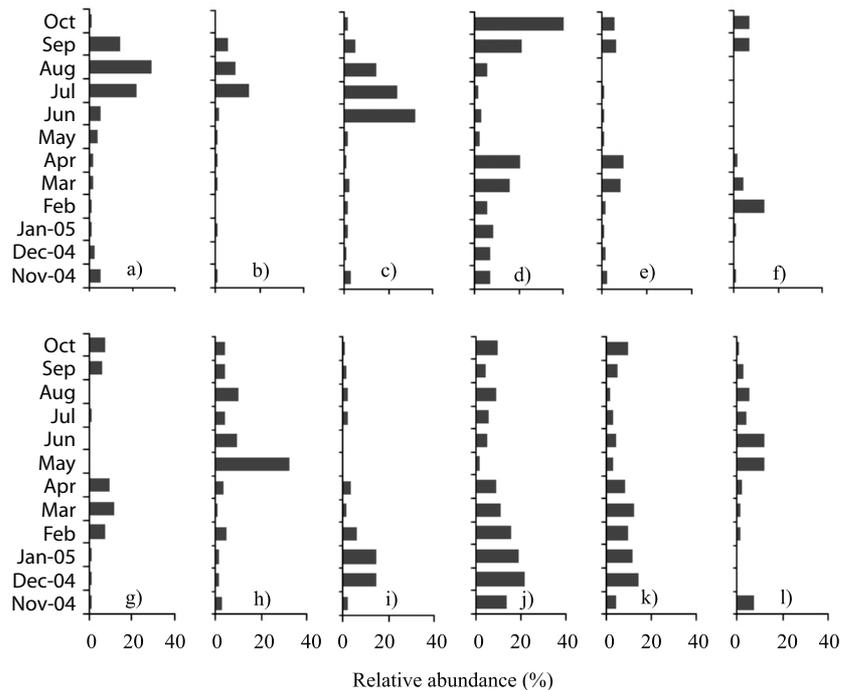


Figure 3. The changes of relative abundances of dominant diatom species: a) *Cocconeis placentula*, b) *Cocconeis placentula* var. *lineata*, c) *Cyclotella meneghiniana*, d) *Cymbella affinis*, e) *Cymbella cymbiformis*, f) *Cymbella helvetica*, g) *Cymbella leptoceros*, h) *Epithemia turgida*, i) *Fragilaria capucina* var. *rumpens*, j) *Gomphonema clavatum*, k) *Gomphonema olivaceum*, l) *Rhopalodia gibba*.



- Atıcı T & Obalı O (2010). The diatoms of Asartepe Dam Lake (Ankara), with environmental and some physicochemical properties. *Turkish Journal of Botany* 34: 541–548.
- Barinova S, Kukhaleishvili L, Nevo E & Janelidze Z (2011). Diversity and ecology of algae in the Algeti National Park as a part of the Georgian system of protected areas. *Turkish Journal Botany* 35: 729–774.
- Carrick HJ, Aldridge FJ & Schelske CL (1993). Wind influences phytoplankton biomass and composition in a shallow, productive lake. *Limnology and Oceanography* 38: 1179–1192.
- Çelekli A & Köylüoğlu O (2006). Net planktonic diatom (Bacillariophyceae) composition of Lake Abant (Bolu). *Turkish Journal of Botany* 30: 331–347.
- Çetin AK & Şen B (1998). Diatoms (Bacillariophyta) in the phytoplankton of Keban Reservoir and their seasonal variations. *Turkish Journal of Botany* 22: 25–33.
- Çetin AK & Yavuz OG (2001). Epipellic, epilithic and epiphytic algae flora of Cip Stream (Elazığ/Turkey). *Science and Engineering Journal of Firat University* 13: 9–14.
- Elmacı A & Obalı O (1998). The algal flora of the littoral region in Lake Akşehir. *Turkish Journal of Biology* 22: 81–98.
- Hustedt F (1985). *The Pennate Diatoms*. Koenigstein: Koeltz Scientific Books.
- Hutchinson GE (1967). *A Treatise on Limnology: Vol. 2, Introduction to Lake Biology and the Limnoplankton*. New York: Wiley.
- Karacaoğlu D, Dere Ş & Dalkıran N (2004). A taxonomic study on the phytoplankton of Lake Uluabat (Bursa). *Turkish Journal of Botany* 28: 473–485.
- Kılınc S (1998). A study in the seasonal variation of phytoplankton in Hafik Lake (Sivas, Turkey). *Turkish Journal of Botany* 22: 35–41.
- Krammer K & Lange-Bertalot N (1986). *Subwasserflora von Mitteleuropa. Bacillariophyceae 1. Tiel: Naviculaceae*. Stuttgart: Gustav Fischer Verlag.
- Krammer K & Lange-Bertalot N (1988). *Subwasserflora von Mitteleuropa. Bacillariophyceae 2. Tiel: Bacillariaceae, Epithemiceae, Surirellaceae*. Stuttgart: Gustav Fischer Verlag.
- Krammer K & Lange-Bertalot N (1991a). *Subwasserflora von Mitteleuropa. Bacillariophyceae 3. Tiel: Centrales, Fragiliariaceae, Eunotiaceae*. Stuttgart: Gustav Fischer Verlag.
- Krammer K & Lange-Bertalot N (1991b). *Subwasserflora von Mitteleuropa. Bacillariophyceae 4. Tiel: Achmanthaceae*. Stuttgart: Gustav Fischer Verlag.
- Lepš J & Šmilauer P (2003). *Multivariate Analysis of Ecological Data Using CANOCO*. New York: Cambridge University Press.
- Lund JWG, Kipling C & Le Cren ED (1958). The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. *Hydrobiologia* 11: 143–171.
- OECD (1982). *Eutrophication of Waters. Monitoring, Assessment and Control. OECD Cooperative Programme on Monitoring of Inland Waters (Eutrophication Control)*. Environment Directorate, Paris: OECD.
- Pala G & Çağlar M (2008). Epilithic diatoms in Peri Stream (Tunceli/Turkey) and their seasonal variations. *Science and Engineering Journal of Firat University* 20: 557–562.
- Patrick R & Reimer CW (1966). *The Diatoms of the United States, Exclusive of Alaska and Hawaii, Monograph No: 13*. Philadelphia: Academy of Natural Sciences.
- Patrick R & Reimer CW (1975). *The Diatoms of the United States. Vol. 2, Part 1. Monograph No. 13*. Philadelphia: Academy of Natural Sciences.
- Radtke DB, Wilde FD, Davis JV & Popowski TJ (1998). Alkalinity and acid neutralizing capacity. In: Wilde FD & Radtke DB (eds.) *National Field Manual for the Collection of Water Quality Data, U.S. Geological Survey TWRI Book 9*, pp. ALK1–ALK33. USGS Office of Water Quality: Reston, Virginia.
- Reimer A, Landmann G & Kempe S (2009). Lake Van, Eastern Anatolia, hydrochemistry and history. *Aquatic Geochemistry* 15: 195–222.
- Reynolds CS (2006). *The Ecology of Phytoplankton*. New York: Cambridge University Press.
- Round FE (1981). *The Ecology of Algae*. New York: Cambridge University Press.
- Round FE, Crawford RM & Mann DG (1990). *Diatoms: Biology and Morphology of the Genera*. Cambridge: Cambridge University Press.
- Şen B, Alp MT & Koçer MAT (2003). Lake Hazar. In: *22nd National Symposium on Aquaculture and Fisheries*, pp. 87–97. Elazığ.
- Şen B, Topkaya B & Nacar V (1995). Algae and trophic status of Lake Hazar. In: *1st Symposium on Lake Hazar and Its Environment*, pp. 149–153. Elazığ: Çağ Ofset.
- Servant-Vildary S & Roux M (1990). Multivariate analysis of diatoms and water chemistry in Bolivian saline lakes. *Hydrobiologia* 197: 261–290.
- Solak CN, Barinova S, Ács É & Dayioğlu H (2012). Diversity and ecology of diatoms from Felent creek (Sakarya river basin), Turkey. *Turkish Journal Botany* 36: 191–203.
- Stoermer EF & Smol JP (1999). *The Diatoms: Applications for the Environmental and Earth Sciences*. New York: Cambridge University Press.
- ter Braak CJF (1995). Ordination. In: Jongman RHG, ter Braak CJF & van Tongeren OFR (eds.) *Data Analysis in Community and Landscape Ecology*, pp. 91–173. Cambridge: Cambridge University Press.
- ter Braak CJF & Verdonschot PFM (1995). Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences* 57: 255–264.

The seasonal succession of diatoms in phytoplankton of a soda lake (Lake Hazar, Turkey)

- Ulukanlı Z & Dıđrak M (2002). Alkaliphilic micro-organisms and habitats. *Turkish Journal of Biology* 26: 181–191.
- Verhagen JHG (1994). Modeling phytoplankton patchiness under the influence of wind-driven currents in lakes. *Limnology and Oceanography* 39: 1551–1565.
- Webster IT & Hutchinson PA (1994). Effect of wind on the distribution of phytoplankton cells in lakes revisited. *Limnology and Oceanography* 39: 365–373.
- Wehr JD & Sheath RG (2003). *Freshwater Algae of North America: Ecology and Classification*. San Diego, California: Academic Press.
- Wetzel RG & Likens GE (1991). *Limnological Analyses*. New York: Springer-Verlag.
- Yıldırım V, Şen B, Çetin AK & Alp MT (2003). Epipellic algal flora of Kürk Stream discharging into Lake Hazar (Elazığ/Turkey). *Science and Engineering Journal of Fırat University* 15: 329–336.
- Yılmaz N (2007). A taxonomic study on the phytoplanktonic algal flora on the littoral region in the west part of Lake Sapanca. *İstanbul University Journal of Fisheries* 23: 47–57.