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# A Study on the Seasonal Periodicity of Diatoms with Relation to Silica in the Phytoplankton of a Dam Lake in Turkey

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**Abstract:** In this study, diatoms occurring in the phytoplankton of Cip Dam Lake were investigated between September 1994 and 1995. Individual numbers of diatom taxa were obtained by counting 1 mL of phytoplankton sample and results were expressed as cells $mL^{-1}$. Water samples for chemical analyses were filtered immediately and concentrations of silica were determined spectrophotometrically. A total of 120 taxa were recorded; *Navicula* (24 taxa) and *Nitzschia* (19 taxa) were the genera represented by most species. Of all, *Achnanthes minutissima*, *Cyclotella meneghiniana*, *C. kutzingiana*, *C. ocellata*, *Fragilaria brevistriata* and *F. pinnata* were the most conspicuous diatoms with respect to both frequency of occurrence and number of individuals. Although, diatoms occurred in considerable numbers in almost every season their best growth was recorded in spring.

**Key words:** Diatoms, phytoplankton, concentration, compicuous, frequencu, spring

## INTRODUCTION

A considerable amount of information has been gathered since the beginning of this century on the ecology and distribution of algae in various waters of the world. Algal studies in Turkey are however, relatively new and most of these have been conducted on waters in the central and western parts of the country. So far, algae of freshwater bodies in eastern Turkey have been less studied. Elazig Province is an area of limnological interest in eastern Turkey with the existence of natural (Lake Hazar) and man made lakes (Keban, Karakoçan and Cip reservoirs). Cetin and Sen (1998) Sen and Topkaya, 1997) reported on planktonic algae of Keban Reservoir and their seasonal variations whilst limnological properties including trophic status, phytoplankton, phytobentos and nutrient loading of Lake Hazar were investigated by Sen (1988, 1995) and Sen *et al.* (1999). Cip reservoir is a slightly alkaline artifical lake situated 18 km from the city of Elazig (Fig. 1). The Dam was built for irrigation purposes and also for fish stocking. The surface area of the reservoir is 1.3 $km^2$ and its maximum depth is 22 m. Springs provide the major input of water to the reservoir. Water level of the reservoir decreases considerably during irrigation period. So far, there seems to be only one algal study carried out on Cip reservoir in which Sen and Cetin (1988) investigated the species composition and density of benthic diatoms of littoral region of the reservoir where they recorded 53 diatom taxa. The present study aimed to investigate diatom species occurring in the phytoplankton of the reservoir and their seasonal periodicity.

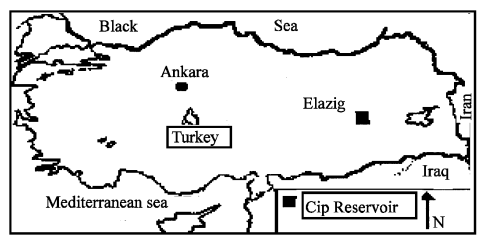


Fig. 1: Map of Turkey and location of Cip reservoir (■)

## MATERIALS AND METHODS

Five stations were chosen on the reservoir from which phytoplankton and water samples were taken at monthly intervals for a period of a year. Phytoplankton samples were collected using a plankton net and Nansen Water Bottle for qualitative and quantitative examination. The cell counts of diatom taxa were obtained after preservation of 1 mL of phytoplankton sample with Lugol's solution counting on an inverted microscope (Lund *et al*., 1958). The water temperature and pH of the surface water were measured directly by means of a

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thermometer and pH meter. Silica concentration of the surface lake water was determined through a spectrophotometric method (APHA, 1985) Fig. 1.

## RESULTS AND DISCUSSION

A total of 120 diatom taxa were recorded during the study that are listed in alphabetical orders with their distrubutions at stations in Table 1. It is apparent from the same tablet that 116 taxa belonged to the pennales whilst only 6 taxa was centric forms and *Navicula* (24 taxa) and species (Table 1). Seasonal fluctuations in cell numbers of dominant diatoms in Cip Reservoir were shown in figures with seasonal changes in concentrations of silica. Of all, *Achnanthes minutissima*, *Cyclotella meneghiniana*, *C. kutzingiana*, *C. ocellata*, *Fragilaria brevistriata* and *F. pinnata* were the most conspicuous diatoms with respect to both frequency of occurrence and number of individuals.

Although, diatoms occurred in considerable numbers in almost every season their best growth was recorded in spring. *Achnanthes minutissima*, *Cyclotella*

Table 1: Diatom taxa recorded in the phytoplankton of Cip reservoir and their distributions at stations

| | Stations | | | | |
|---|---|---|---|---|---|
| Diatom taxa | I | II | III | IV | V |
| **Centrales** | | | | | |
| *Cyclotella comta* (Ehr) Kutz | + | + | + | + | + |
| *Cyclotella kützingiana* Thwaites | + | + | + | + | + |
| *Cyclotella meneghiniana* Kutz | + | + | + | + | + |
| *Cyclotella ocellata* Pantocksek | + | + | + | + | + |
| *Thalasiosira weissflogii* Grun | - | + | - | - | - |
| **Pennales** | | | | | |
| *Achnanthes clevei* var. *rostrata* Hustedt | - | - | - | + | - |
| *Achnanthes exigua* Grun | - | + | + | + | - |
| *Achnanthes flexella* Kütz | - | + | - | + | - |
| *Achnanthes lanceolata* var. *rostrata* Hustedt | - | - | + | + | - |
| *Achnanthes minutissima* Kütz | + | + | + | + | + |
| *Achnanthes trigibba* Hustedt | + | + | + | + | + |
| *Amphora perpusilla* Grun | - | - | + | + | - |
| *Amphora ovalis* var. *affinis* Kuetz | + | + | + | + | - |
| *Caloneis alpestris* (Grun) Cleve | + | - | - | - | + |
| *Caloneis bacillaria* (Greg) Cleve | + | - | + | + | - |
| *Caloneis ventricosa* (Ehr.) Meister | + | - | - | - | - |
| *Cocconeis pediculus* (Ehr.) | + | + | + | + | + |
| *Cocconeis placentula* (Ehr.) | + | + | + | + | + |
| *Cocconeis placentula* var. *euglyta* (Ehr) Cleve | + | + | + | - | - |
| *Cocconeis placentula* var. *lineata* (Ehr) Cleve | - | + | - | - | - |
| *Cymatopleura elliptica* (Breb) W. Smith | - | + | - | - | - |
| *Cymatopleura solea* (Breb.) W. Smith | + | + | - | + | + |
| *Cymbella affinis* Kutz | + | + | + | + | + |
| *Cymbella cistula* (Hemprich) Grun | + | + | + | + | + |
| *Cymbella microcephala* Grun | + | + | + | + | + |
| *Cymbella minuta* var. *pseudogracilis* (Coln.) Reimer | + | - | - | - | - |
| *Cymbella obtusiuscula* (Kutz.) Grun | + | + | + | + | + |
| *Cymbella pusilla* Grun | + | - | + | - | - |
| *Cmybella prostrata* (Berkeley) Grun | - | + | - | - | - |
| *Cymbella prostrata* var. *auerswaldi* (Rabh) Reimer | - | - | + | + | - |
| *Cymbella tumidula* Grun | + | - | + | - | - |
| *Cymbella ventricosa* Kutz | + | + | + | - | + |
| *Diatoma elongatum* (Lynb.) Agardh | + | + | + | + | + |
| *Diatoma vulgare* Bory | - | + | - | - | - |
| *Epithemia adnata* var. *proboscidea* (Kutz) Patrick | - | - | - | + | - |
| *Epithemia turgida* (Ehr.) Kutz | - | - | + | - | - |
| *Epithemia zebra* var. *saxonica* (Kutz.) Grun | - | - | + | - | - |
| *Fragilaria bicapitata* A. Mayer | + | + | + | + | - |
| *Fragilaria brevistriata* Grun | + | + | + | + | + |
| *Fragilaria brevistriata* var. *inflata* (Pant.) Hustedt | - | - | - | - | + |
| *Fragilaria construens* (Ehr.) Grun | - | + | + | + | + |
| *Fragilaria crotonensis* Kitton | + | + | + | + | + |
| *Fragilaria intermedia* Grun | + | - | + | + | - |
| *Fragilaria pinnata* (Ehr.) | + | + | + | + | + |
| *Fragilaria pinnata* var. *lancettula* (Schum.) Hustedt | + | + | + | + | + |
| *Fragilaria sinuata* M. Perag | - | + | - | - | - |
| *Gomphoneis olivacea* (Lyngb.) Dawson | + | + | + | - | + |
| *Gomphonema angustatum* (Kutz.) Rabh | + | - | - | + | + |
| *Gomphonema angustatum* var. *producta* Grun | - | - | + | + | - |

Table 1: Continue

| | Stations | | | | |
|---|---|---|---|---|---|
| Diatom taxa | I | II | III | IV | V |
| *Gomphonema constrictum* (Ehr.) | - | + | + | - | + |
| *Meridion circulare* Agardh | - | + | + | - | - |
| *Navicula accomoda* Hustedt | - | + | + | + | + |
| *Navicula bicephala* Hustedt | - | + | - | - | + |
| *Navicula cari* var. *angusta* Grun | - | - | + | + | - |
| *Navicula cincta* (Ehr.) Kutz | + | + | + | - | - |
| *Navicula crucicula* (W. Smith) Donkin | + | - | + | - | + |
| *Navicula cryptocephala* Kutz | + | + | + | + | + |
| *Navicula cryptocephala* var. *exilis* Kutz | + | + | + | + | + |
| *Navicula cryptocephala* var. *veneta* (Kutz) Grun | + | + | + | + | + |
| *Navicula cuspidata* var. *ambigua* (Ehr) Cleve | - | - | + | - | - |
| *Navicula elmorei* Patr | - | - | - | + | - |
| *Navicula feuerborni* (Feuerb.) Hustedt | + | + | + | - | + |
| *Navicula halophila* var. *robusta* (Grun) Cleve | - | - | + | - | - |
| *Navicula heufleri* (Breb ex Grun) | + | + | - | - | + |
| *Navicula lacustris* Gregory | + | - | + | - | - |
| *Navicula lanceolata* (Agard) Kutz | + | + | - | - | - |
| *Navicula leteropunctata* Wallace | - | - | + | - | - |
| *Navicula laterostrata* Hustedt | + | - | - | - | - |
| *Navicula notha* Wallace | + | + | - | + | + |
| *Navicula pupula* var *capitata* Hustedt | + | - | - | - | - |
| *Navicula radiosa* Kutz | + | + | + | + | + |
| *Navicula radiosa* var. *tenella* (Breb) Grun | + | + | - | - | - |
| *Navicula tripunctata* (O.F. Muller) Bory | + | - | - | - | - |
| *Navicula subhamulata* Grun | + | - | - | - | - |
| *Navicula virudula* var. *rostellata* (Kutz.) Cleve | - | + | + | + | -. |
| *Neidium busilkatum* (Lagerst) Cleve | - | - | - | + | - |
| *Neidium iridis* (Ehr.) Cleve | - | + | - | - | - |
| *Nitzschia acicularis* W. Smith | + | + | - | + | - |
| *Nitzschia amphibia* Grun | + | + | + | + | + |
| *Nitzschia apiculata* (Gregory) Grun | + | + | + | + | + |
| *Nitzschia debilis* (Arnott) Grun | + | + | + | - | + |
| *Nitzschia denticula* var. *curta* Grun | - | - | + | - | - |
| *Nitzschia dissipata* Kutz) Grun | + | + | + | + | + |
| *Nitzschia hantzschiana* Rabh | - | + | + | + | + |
| *Nitzschia hungarica* Grun | + | + | - | + | - |
| *Nitzschia intermedia* Hantz | + | + | + | + | + |
| *Nitzschia linearis* W. Smith | + | + | + | + | + |
| *Nitzschia longissima* (Breb.) Ralf | + | - | - | - | - |
| *Nitzschia palea* (Kutz.) W. Smith | + | + | + | + | + |
| *Nitzschia romana* Grun. | + | - | + | + | - |
| *Nitzschia sigmoidea* (Ehr) W. Smith | - | - | - | - | + |
| *Nitzschia sinuata* v. *tabelleria* W. Smith | - | + | + | - | - |
| *Nitzschia tryblionella* Hantz | + | + | + | - | - |
| *Nitzschia tryblionella* v. *levidensis* (W. Smith) Grun | - | - | + | - | - |
| *Nitzschia umbonata* (Ehr) Lange-Bartalot | + | - | - | + | - |
| *Nitzschia vermicularis* (Kutz) Grun | + | - | + | + | - |
| *Opephora mertyi* Heribaud | + | - | + | + | - |
| *Pinnularia brebissonii* (Kutz) Rabh | - | + | - | + | - |
| *Pinnularia brebissoni* var. *diminuta* (Grun) Cleve | - | + | - | - | - |
| *Pinnularia globiceps* Gregory | - | - | - | + | - |
| *Rhoicosphenia curvata* (Kutz.) Grun | + | + | + | + | + |
| *Rhopalodia gibba* (Ehr.) O.F. Müller | - | - | - | - | + |
| *Stauroneis partabgarhensis* Ghandi | + | - | - | - | + |
| *Stauroneis phoenicenteron* (Ehr.) | - | + | + | - | - |
| *Surirella angusta* Kutz | + | - | - | - | - |
| *Surirella linearis* W. Smith | + | - | - | - | - |
| *Surirella ovata* Kutz | + | + | + | + | - |
| *Surirella ovata* v. *pinnata* W. Smith | + | - | + | - | - |
| *Surirella spiralis* Kutz | - | + | - | - | - |
| *Synedra acus* Kutz | + | + | + | + | + |
| *Synedra affinis* var. *faciculata* (Kutz) Grun | - | - | - | + | - |
| *Synedra amphicephala* Kutz | - | - | + | - | - |
| *Synedra parasitica* (W. Smith) Hustedt | + | - | - | - | - |
| *Synedra ulna* (Nitz.) Ehr. | + | + | + | + | + |
| *Synedra ulna* var. *amphirhyncus* (Ehr.) Kutz | + | - | - | - | - |
| *Synedra ulna* var. *biceps* (Kutz.) Kirch | + | - | + | - | + |

*Nitzschia* (19 taxa) were the genera represented by most *kutzingiana*, *Fragilari brevistriata* and *Cyclotella ocellata* were the most conspicuous diatoms with respect to frequency of occurrence and number of individuals at station I. *A. minutissima* and *C. kutzingiana* were present in the phytoplankton throughout the investigation (Fig. 2). However, total individual numbers of *C. kutzingiana* were higher in autumn and summer periods whilst best growth of *A. minutissima* occurred in late autumn-winter and summer. Two maxima were recorded for *A. minutissima* and summer maximum was larger than that of winter. Best growth of *C. ocellata* occurred in autumn and summer at station I; its summer growth was more noticable and lasted longer (Fig. 3). *F. brevistriata* occurred for a shorter time with much lesser cell numbers compare to other conspicuous diatoms recorded at this station (Fig. 3). It is noteworthy to mention that maximum of *C. ocellata* occurred in winter and lowest numbers and virtual absence of the diatom were recorded in spring at this station.

*F. brevistriata*, *F. pinnata*, *C. kutzingiana* and *C. ocellata* were most significant diatoms considering frequency of occurrence and numbers of individuals at station II (Fig. 4 and 5). *F. pinnata* and *F. brevistriata* did not show a regular growth pattern since their cell numbers increased or decreased irregularly during the study. Maximum numbers of individuals of *F. pinnata* and *F. brevistriata* were recorded in November and March respectively. Virtual absence of both diatoms coincided with summer (Fig. 4). It is worth to mention that centric diatoms *C. kutzingiana* and *C. ocellata* occurred almost in the same periods at station II (Fig. 5) with quite similar growth patterns. However, maxima of these diatoms were observed in different time of the year. *C. kutzingiana* reached its maximum in October whilst maximum individual numbers of *C. ocellata* was recorded in June. It was interesting that the absence of both diatoms was also observed in the same months (December and February).

*F. brevistriata*, *C. meneghiniana*, *C. kutzingiana* and *C. ocellata* were also most significant diatoms at station III as they were at station II. *C. ocellata* was observed in the phytoplankton for much longer period than *C. meneghiniana* (Fig. 6 and 7) which was absent continuously for 6 months in the first half of the year. Two growth periods may be mentioned for these diatoms; first period was from September to December and second one from April to August.

Maximum numbers of individuals of *C. meneghiniana* was recorded in December whilst maximum of *C. ocellata* occurred in July. *C. kutzingiana* and *F. brevistriata* were present on most occasions at station III (Fig. 7); the former diatom occurred with higher cells numbers. Maxima of *C. kützingiana* and *F. brevistriata* were observed in May and October, respectively (Fig. 7).

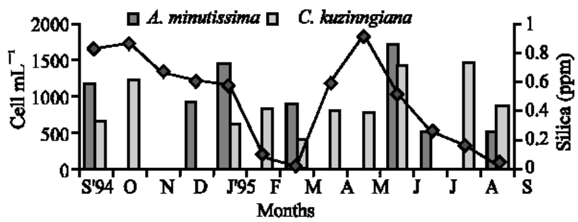


Fig. 2: Seasonal changes in cell numbers of *Achnanthes minutissima* and *Cyclotella kutzingiana* and seasonal changes in concentrations of silica at station I

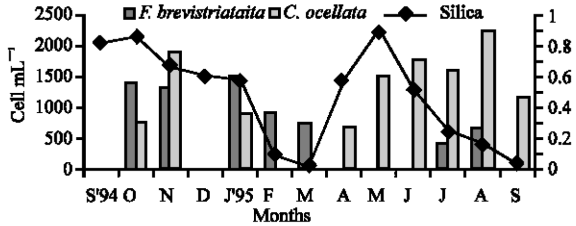


Fig. 3: Seasonal changes in cell numbers of *Fragilaria brevistriata* and *Cyclotella ocellata* and seasonal changes in concentrations of silica at station 1

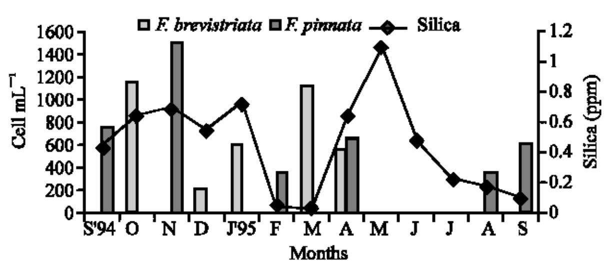


Fig. 4: Seasonal changes in cell numbers of *Fragilaria brevistriata* and *F. pinnata* and seasonal changes in concentrations of silica at station II

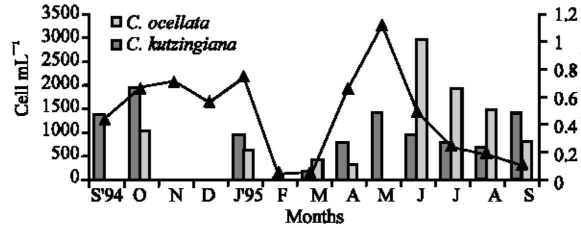


Fig. 5: Seasonal changes in cell numbers of *Cyclotella ocellata* and *Cyclotella kutzingiana* and seasonal changes in concentrations of silica at station II

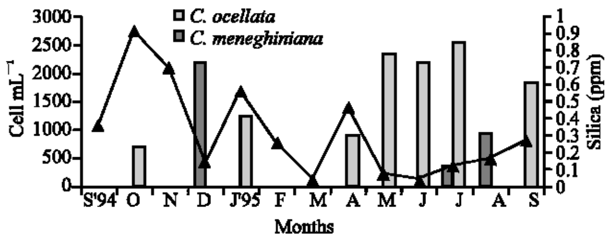


Fig. 6: Seasonal changes in cell numbers of *Cyclotella meneghiniana* and *Cyclotella ocellata* and seasonal changes in concentrations of silica at station III

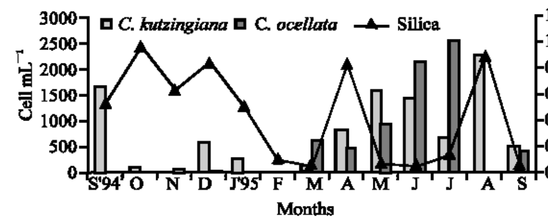


Fig. 8: Seasonal changes in cell numbers of *Cyclotella kutzingiana* and *Cyclotella ocellata* and seasonal changes in concentrations of silica at station IV

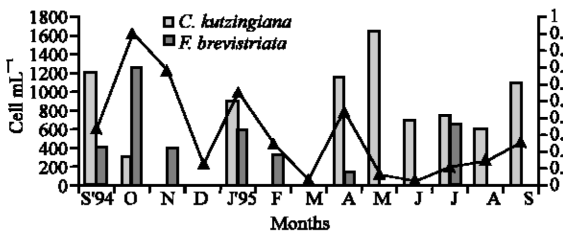


Fig. 7: Seasonal changes in cell numbers of *Cyclotella kutzingiana* and *Fragilaria brevistriata* and seasonal changes in concentrations of silica at station III

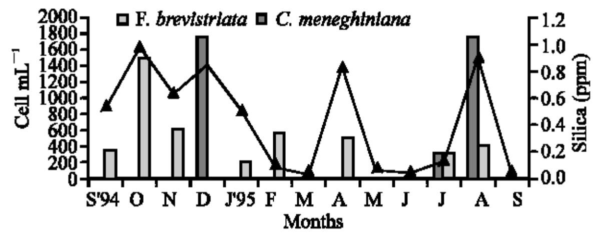


Fig. 9: Seasonal changes in cell numbers of *Cyclotella meneghiniana* and *Fragilaria brevistriata* and seasonal changes in concentrations of silica at station IV

It is important to mention that maximum of each diatom coincided with very low cell numbers or virtual absence of each other.

*F. brevistriata*, *C. meneghiniana*, *C. kutzingiana* and *C. ocellata* were most noticable at station IV as they were at stations II and III (Fig. 8 and 9). Growth patterns of *C. kutzingiana* and *C. ocellata* were almost similar. Actual growth period of these centrics started by early spring and lasted until the end of summer reaching their maxima in July and August (Fig. 8). A similar growth pattern was observed for *C. ocellata* at station III as well. Except one case (September, 1994), absence and low numbers of these diatoms were recorded in autumn and winter. *C. meneghiniana* appeared to have two short growth periods at station IV; one in autumn and the other in summer (Fig. 9). The size of the autumnal and summer maxima of the diatom were almost similar. *F. brevistriata* showed its best growth in October at station IV and individual numbers of the diatom were low for the most of the year (Fig. 8).

In contrast to other stations, *Fragilaria crotonensis* was one of the dominant diatoms together with *C. ocellata* and *C. kutzingiana* at station V (Fig. 10). *F. crotonensis* was observed in winter and summer periods and summer development of the diatom was more noticable than that observed in winter. It was interesting that summer maximum of *Fragilaria* sp. was larger than those of *Cyclotella* sp. at this station. *C. kutzingiana* was the most significant diatom at station V since it occurred with considerable numbers throughout this investigation. Two growth periods occurred for *C. kutzingiana* and its vernal development was better than that recorded in summer. Cip reservoir appeared to be a slightly alkaline artifical lake and pH level of surface water fluctuated irregularly throughout the study (Fig. 11).

The lowest pH (7.7) was measured in December and maximum level (8.8) in February and April. pH level was either increasing or was high for a long period between December and May. Surface water temperature of the reservoir started to increase in February and continued to increase regularly until July (Fig. 11) the lowest 3 surface water temperature (35° C) was recorded in December January and the maximum (26°C) in July. Water temperature started to decrease after September.

The diatoms were the most significant algal group with respect to both number of species and number of individuals in the phytoplankton of Cip reservoir. However, diatoms have often been reported as the dominant algae in the phytoplankton of many reservoirs in Turkey (Aykulu and Obaly, 1981; Gonlol, 1985; Yildiz 1985; Cetin and Sen, 1998). A total of 120 taxa were

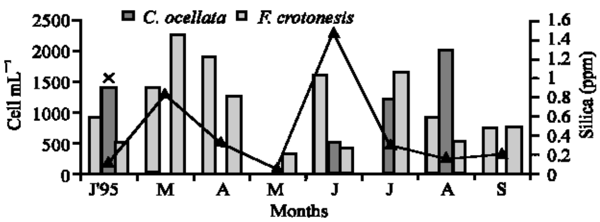


Fig. 10: Seasonal changes in cell numbers of *Cyclotella ocellata*, *Fragilaria crotonensis* and *Cyclotella kutzingiana* and seasonal changes in concentrations of silica at station V

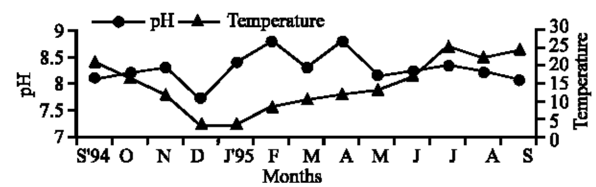


Fig. 11: Seasonal changes in pH level and surface water temperature

recorded throughout the study; 116 taxa belonged to the pennales whilst only 6 taxa was centric forms. Dominance of pennate species in the phytoplankton was also recorded in many reservoirs (Aykulu and Obaly, 1981; Yildiz, 1985; Cetin and Sen, 1998). In contrast, number of individuals of centric diatoms in Cip Reservoir were far higher compared to those of pennate forms. *Cyclotella* species are generally considered to be planktonic (Hutchinson, 1967) and *C. kützingiana* and *C. ocellata* were particularly conspicuous with their high cell numbers in the phytoplankton of Cip Reservior. Centric diatoms were also found to be more significant compare to pennate forms with respect to number of individuals in several reservoirs in Turkey (Aykulu and Obaly, 1981; Gonlol, 1985; Yildiz, 1985; Cetin and Sen, 1998). Occurrence of *Achnanthes*, *Cocconeis*, *Epithemia*, *Fragilaria*, *Gomphoneis*, *Rhoicosphenia*, *Rhopalodia*, *Opephora* sp. were characteristics in the phytoplankton whereas these diatoms were not observed previously in the phytobenthos of the same reservoir (Sen and Cetin, 1988).

By contrast, some species recorded previously in benthic alg communities (Sen and Cetin, 1988) were not present in the phytoplankton. This finding may show that species composition of algal flora of a water body may change in time. This especially holds true for reservoirs into which many algal species are carried by inflows. However, 17 diatom taxa were found to be common both in phytobenthos and phytoplankton. Considering that most of the species found both in phytoplankton and phytobenthos were known mainly to be benthic forms one may think that these diatoms may be thycoplanktonic and occasionally raise to the phytoplankton by water actions. Several species of *Achnanthes*, *Cocconeis* and *Fragilaria* were recorded in the phytoplankton in Cip Reservoir whilst no species belong to these genera were previously observed in the phytobenthos of the same reservoir (Sen and Cetin, 1988). These findings may indicate that species composition of phytoplankton varied to some extent from that of phytobenthos in the reservoir. *Cymbella* (10 taxa), *Navicula* (24 taxa), *Nitzschia* (19 taxa) and *Fragilaria* (9 taxa) were the richest genera in species numbers. Especially *Navicula* and *Nitzschia* were represented by more species than others.

This was also previously observed in the phytobenthos (Sen and Cetin, 1988). However, *Navicula* and *Nitzschia* were generally found to be represented by more species than any other diatom genera in many freshwater bodies (Altuner, 1984; Sen, 1988; Sen and Cetin, 1988; Cetin and Sen., 1998; Cetin *et al*., 2002) *Gyrosigma attenuation*, *Mastogloia smithii*, *Navicula oblanga*, *N. dicephala*, *N. placentula*, *N. reinhardtti*, *Nitzschia sigmoidea*, *N. denticula*, *Cymatopleura solea* and *C. elliptica* were reported to occur in alkaline lakes (Round, 1959). Some of these species were also recorded in Cip Reservoir that has also slightly alkaline water. Best growth of diatoms occurred in spring and to some extend in autum; spring growth was more striking. However vernal development of the diatoms is now well known (Hutchinson, 1967; Round, 1981). Of all, *Achnanthes minutissima*, *Cyclotella meneghiniana*, *C. kutzingiana*, *C. ocellata*, *Fragilaria brevistriata* and *F. pinnata* were the most conspicuous diatoms with respect to both frequency of occurrence and number of individuals.

Harrison and Hildrew (1998) reported that growth of algae was limited chiefly by physical factors such as light and temperature. The present study supported this finding since increasing and/or high water temperatures supported the growth of diatoms whilst low temperatures coincided with low diatom numbers. There was a good relation between pH and growth of diatoms since increasing or high pH levels generally supported their growth. In addition the lowest individual numbers were observed at the lowest pH levels in winter.

## CONCLUSION

In this study, silica concentrations generally decreased when individual numbers of diatoms were either increasing or were already high. This relation was particularly noticable for the growths of *C. kützingiana* at station III and for *F. crotonensis* at station V. This finding is in harmony with that of Pearsal (1930) who suggested that the fall in silica concentrations coincides with the diatom maxima. However, opposite situation was also observed in which both silica concentrations and individual numbers of diatom species decreased or increased simultaneously. This situation was particularly clear for the growths of *C. kutzingiana* at station II and for *C. meneghiniana* at station IV.

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