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Species composition and diversity of epipelic algae in Balikli Dam Reservoir, Turkey

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Abstract: *Between May and November 2006, the epipelic algal flora and its seasonal variations in the Balikli Dam Reservoir were investigated. A total of 55 species were identified, most of which belonged to the Bacillariophyta (31). Other taxonomic groups present were Chlorophyta (9), Cyanoprokaryota (8) and Euglenophyta (7). Navicula cryptocephala, N. veneta and Hannaea arcus were the most important species, regarding frequency of occurrence and relative abundance in the epipelic algal flora. While the highest density of epipelic community was found to be 28527 cells cm^{-2} in September, the lowest density was 24929 cells cm^{-2} in August. The highest Shannon-Weaver diversity index (H') in the epipelic flora was found to be 2.764 in August. Cluster analysis was applied to the epipelic algal community. In this study, ice, light, rainfall and water temperature were found to be the most important factors in regulating the growth of epipelic community in Balikli dam reservoir.*

Key words: *Epipelic algae, Species composition, Diversity, Cluster analysis, Balikli dam reservoir*
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Introduction

Benthic algae are regarded as an important component of lakes, as they make an important contribution to the biological diversity and productivity of the lakes (Moss, 1969). It has been recognized that seasonal changes, composition and production of benthic algae are affected by water chemistry and sediment structure (Round, 1984). Benthic algae, mostly autotrophic organisms, receive most of their nutrition from dissolved chemicals in water. Thus, many authors believe that they should be good indicators of the conditions prevailing in the aquatic environment (Round, 1984; Nather Khan, 1990), and algae are widely used as bioindicators to monitor eutrophication, pollution and water quality (Round, 1984; Nather Khan, 1990).

Although, factors that affect, seasonal variations and composition of phytoplankton have been subjected to several detailed investigations, there is little information on the ecology and composition of epipelic algae of high mountain lakes in Turkey (Sahin, 2000, 2001, 2002, 2004, 2005). This is mostly due to the remote location of many of these lakes and to logistical problems in reaching them.

The main aims of this study were to contribute to the documentation of the largely unknown epipelic algal flora of Turkey and to determine the community structure and seasonal variations of the epipelic in the Balikli Dam Reservoir.

Materials and Methods

Study area: The Balikli dam reservoir is located in Trabzon in the Eastern Black sea region of Turkey (Fig. 1). The Balikli Dam Reservoir was constructed in 1995 to avoid harmful floods. Its surface area is approximately 10 ha, the average depth is 11 m and the elevation of the lake is 1450 mean sea level. The reservoir is entirely surrounded by mountains and high plateaus; Karadag mountain and Karadag high plateau in the south, Tepeyurt and Ramazanyatak mountains in the south west, Arlik and Aykut high plateaus in the south east. The Balikli stream carries and discharges melted snow water to the reservoir from the surrounding mountains. Before the reservoir was put into operation, the area was woodland and pasture. The sediments of the reservoir may be organically polluted.

In order to examine the epipelic algal flora of Balikli Dam Reservoir, a station was chosen. Collections were made during snow-free period from May and November 2006. The samples were performed on a monthly basis from 20-30 cm depth and 50-100 cm offshore. The bottom of the station consists of muddy sediment. Vascular plants and stones were absent. The algal community was sampled by means of a glass tube 0.8 cm in diameter and 1 metre in length. The pipe was moved in a circular direction over the surface of sediment, releasing the tumb to take up sediment. Samples were transferred into plastic bottles and fixed with 5% formalin. Prior to counting the samples were homogenized at low speed until the sediment was througly mixed and was of uniform consistency. At least three water-mounted slides were examined for algae and living diatoms from every station to obtain an estimate of algal relative abundance (Round, 1953; Sladeckova, 1962). At least 300 algal cells were counted at 400 x magnification. Permanent slides for the identification of diatoms were prepared from the same sample after boiling in a 1:1 mixture of concentrated H_2SO_4 and HNO_3. The acid cleaned diatoms were mounted in Naphrax high refractive index medium (Round, 1953). Identifications were carried out at 400 x magnification.

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Taxonomic identifications were carried out according to Coesel (1982, 1983, 1985, 1991, 1997), Krammer and Lange-Bertalot (1986, 1988, 1991), Lenzenweger (1996, 1997, 1999), Patrick and Reimer (1966, 1975), Prescott (1973) and Wotowski and Hindák (2005).

At the time of sampling, water temperature and pH were measured using a mercury thermometer and WTW Digi 88 model pH meter, respectively. Dissolved oxygen concentration was measured according to the method of Winkler (Yaramaz, 1988).

To evaluate the richness and diversity of the epipelic community of Balikli Dam Reservoir, the Shannon-Weaver species diversity index (H) was used (Shannon and Weaver, 1949).

$$H = \sum_{i=1}^{S} Pi \log Pi$$

Where *s* is total number of species in the sample, and *Pi* is the proportion of number individuals in the i^{th} species to the total number of individuals.

The epipelic algal community data were analysed by cluster analysis (complete linkage method). This technique was applied to Bray-Curtis' dissimilarity matrices computed on abundance values. Square root transformation of the original data was applied to reduce the weight of the most abundant species. The cluster analysis was performed with Biodiversity professional 2.0.

Results and Discussion

Physical and chemical characteristics: The surface of the Balikli Dam Reservoir was frozen from January to April 2006. After the ice cover had disappeared, the reservoir water warmed up very quickly. In August, the surface water temperature rose to 21°C. The lowest water temperature (2.5°C) was recorded in November 2006. The concentrations of dissolved oxygen varied between 8.5-13.1 mg l^{-1}, being lower in summer than in spring and autumn. The pH value of the reservoir water varied between 6.5 and 7.9 (mean 7.2).

Epipelic algal flora: A total of 55 taxa have been identified in the epipelic community: 31 taxa belonged to the Bacillariophyta, 9 to the Chlorophyta, 8 to the Cyanoprokaryota and 7 to the Euglenophyta. The list of the identified species is given in Table 1. As expected, the Bacillariophyta was the dominant group in terms of species number and density, and comprised 56.36% of all recorded taxa. The Chlorophyta, Cyanoprokaryota and Euglenophyta represent 16.36, 14.54 and 12.72 of all recorded taxa, respectively. *Navicula cryptocephala*, *N. veneta* and *Hannaea arcus* were dominant during the study.

In late spring (May), after the ice had melted, the total cell number of epipelic algae was 25443 cells cm^{-2} in May (Fig. 2).

Fig. 1: Map of the study area Trabzon

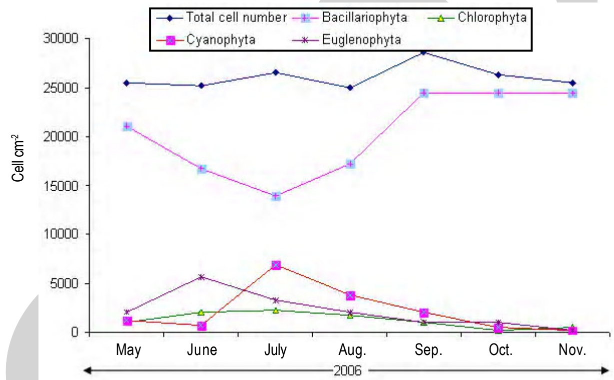

Fig. 2: Seasonal variations in the total cell number (cells cm^{-2}) of epipelic algae and comparison of epipelic composition

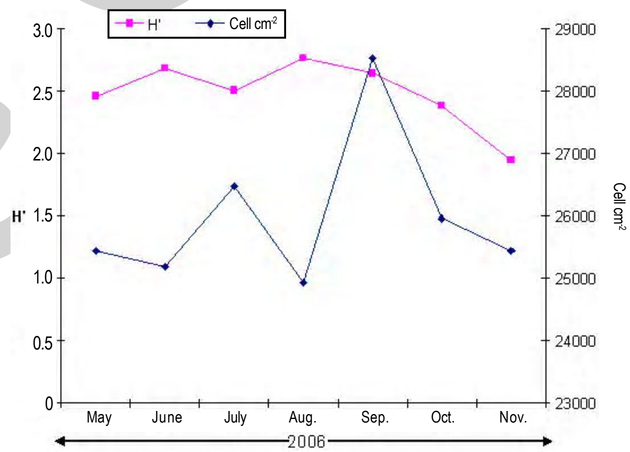

Fig. 3: The changes in the total cell number and species diversity of the epipelic algal community

Diatoms were dominant and constituted 82.82% of the epipelic algal community. The Euglenophyta and Cyanoprokaryota represented 8.08 and 5.05% of the epipelic algal conmmunity, respectively, whereas the Chlorophyta (4.04%) played an insignificant part in May. *Navicula cryptocephala* reached its greatest abundance (10794 cells cm^{-2}), constituted 42.42% of the total epipelic algal flora in May.

In the summer, there was a noticeable increase in the total cell numbers of the Cyanoprokaryota, Euglenophyta and Chlorophyta, while the total cell number of the Bacillariophyta decreased. The proportions of organisms belonging to the Bacillariophyta, Cyanoprokaryota, Euglenophyta and Chlorophyta were 52.42, 26.21, 12.62 and 8.73%, respectively. The total cell number of epipelic algae displayed its lowest value (24929 cells cm^{-2}) in August during the study period (Fig. 2). Most of the species in the epipelic community exhibited variation during summer period. *Navicula cryptocephala*, for example, reached its greatest abundance (6425 cells cm^{-2} in July). The same pattern was exhibited by *Anabaena affinis* (5654 cells cm^{-2} in July), *Euglena agilis* (3084 cells cm^{-2} in June) and *Micrasterias rotata* (2056 cells cm^{-2} in July). They constituted 42.42, 21.35, 12.24 and 7.76% of the total epipelic algal flora, respectively, in June and July.

In the autumn, the total cell numbers of the epipelic algae was observed its highest value (28527 cells cm^{-2}) in September during the study period. And then, it was gradually decreased in October and November (Fig. 2). The numbers of Bacillariophyta members excessively increased and reached its highest level. The proportions of organisms belonging to the Bacillariophyta, Cyanoprokaryota, Euglenophyta and Chlorophyta were 85.58, 7.20, 3.60 and 3.60%, respectively. During autumn period, dominant species were *Hannaea arcus* (9252 cells cm^{-2} in November), *Navicula veneta* (6682 cells cm^{-2} in October), *N. cryptocephala* (6425 cells cm^{-2} in October) and *Anabaena affinis* (1799 cells cm^{-2} in September). The members of the Chlorophyta and Euglenophyta were not important during the autumn period. Flamentous Chlorophyta were represented by several species, including *Ulothrix aequalis*, *Oedogonium* sp and *Spirogyra* sp, some of which were sterile and could not be identified. They were not common.

During the study period, the highest species diversity index was 2.764 in August, the lowest was 1.944 in November (Fig. 3).

The diagram obtained from cluster analysis (Fig. 4) showed that two different groups comprised in the epipelic samples. The first one is formed by spring and summer samples, characterized by a high development of *Navicula cryptocephala*, *Anabaena affinis*, *Euglena agilis* and *Trachelomonas hispida* var. *crenulatocollis*. The association between July and August samples are most significant. The second group includes spring and autumn samples and is characterized by the dominance of *Navicula cryptocephala*, *Hannaea arcus* and *Fragilaria ulna*. When the relative abundance of species in the samples was compared, the highest similarity was seen between July and August, according to the diagram obtained from cluster analysis (69%). The lowest similarity was seen between May and November (39%).

In the present study, all of the species found belong to 16 families. The best represented are *Naviculaceae*, *Nostocaceae*, *Euglenaceae* and *Desmidiaceae*. They comprise 34.55, 12.72, 12.72 and 9.09% of all receorded taxa, respectively. Diverse families are of great diagnostic importance in floristic analyses (Medvedeva,

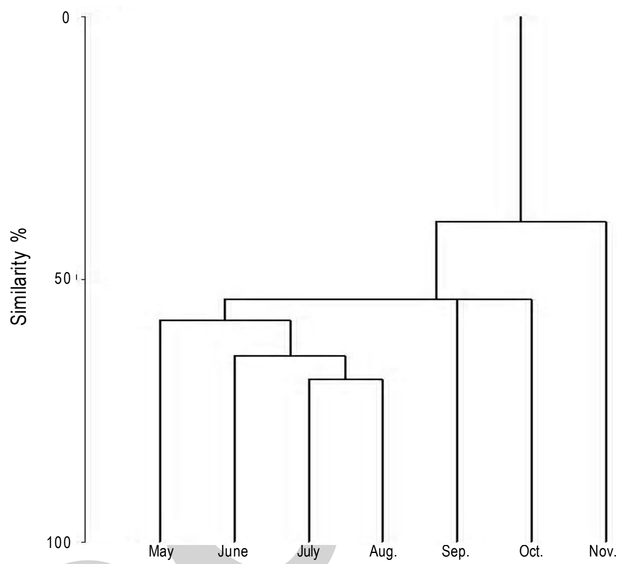

Fig. 4: Dendograms for hierarchical clustering of the months samples in the Baliki Dam Reservoir. The samples were clustered based on Bray-Curtis somilarity using the complete linkage method in the period 2006

2001). Also, *Achnanthaceae*, *Eunotiaceae*, *Fragilariaceae* and *Closteriaceae* are typical northern algal families (Medvedeva, 2001), and occupied 12.72% of the Balikli Dam Reservoir taxa belong to them.

In the Balikli Dam Reservoir, diatoms were dominant and constituted 55.36% of the total taxa. Moore (1974) and Round (1984) pointed out that diatoms are usually the most common element of epipelic communities. It is well know that diatoms are sensitive to a wide range of limnological and environmental variables, and that their community structure may quickly respond to changing physical, chemical and biological conditions in the environment (Mooser *et al*., 1996). They have been shown to be dominant in the epipelic algal flora of many reservoirs and lakes in Turkey (Gonulol, 1987; Gurbuz and Kivrak, 2003; Kivrak and Gurbuz, 2005; Sahin, 2004, 2005). *Navicula cryptocephala*, *N. veneta* and *Hannaea arcus* were the most abundant and common diatoms in the epipelic community. Nather Khan (1990) explained that the species of *Navicula* were common and abundant in both, organically enriched and non-enriched areas. Patrick and Reimer (1966, 1975) pointed out that *Hannaea arcus* was either acidophilic or indifferent, a reflection of the low alkalinity levels. Round (1960) reported that species of *Amphora*, *Cocconeis*, *Cymbella*, *Epithemia* and *Navicula* were common in calcareous and slightly alkaline waters. The present study supported this finding, since the results of chemical analyses of the Balikli Dam Reservoir water showed that it is slightly alkaline.

Lenzenweger (1996) has mentioned that alkalinity of water is one of the main factors affecting the occurrence of desmid species. Desmids prefer mainly acidic and pH-circumneutral waters. However, Feher (2003) reported that many desmid species were identified from alkaline lakes and wetlands in Southern Hungary. In

Table - 1: List of the epipelic algae identified from Balikli Dam Reservoir

Taxons	Species
Bacillariophyta	
Pennales	
Fragilariaceae	
	Diatoma vulgaris Bory
	Fragilaria ulna (Nitzsch) Lange-Bertalot
	Hannaea arcus (Ehrenberg) Patrick
	Meridion circulare (Greville) C.A. Agardh
Eunotiaceae	
	Eunotia pectinalis (Kutzing) Rabenhorst
Achnanthaceae	
	Cocconeis placentula Ehrenberg
Naviculaceae	
	Amphora ovalis (Kutzing) Kutzing
	Cymbella amphicephala Naegeli
	C. cymbiformis Agardh
	C. minuta Hilse
	Didymosphenia geminata (Lyngbye) M. Schmidt
	Diploneis elliptica (Kutzing) Cleve
	Frustulia vulgaris (Thwaites) De Toni
	Gomphonema olivaceum (Hornemann) Brebisson
	Navicula bacillum Ehrenberg
	N. cryptocephala Kutzing
	N. rhynchocephala Kutzing
	N. veneta Kutzing
	Pinnularia appendiculata (Agardh) Cleve
	P. borealis Ehrenberg
	P. gibba Ehrenberg
	P. interrupta W. Smith
	P. maior (Kutzing) Rabenhorst
	P. viridis (Nitzsch) Ehrenberg
	Stauroneis anceps Ehrenberg
Epithemiaceae	
	Epithemia sorex Kützing
	Bacillariaceae
	Hantzschia amphioxys (Ehrenberg) Grunow
Surirellaceae	
	Surirella angusta Kützing
	S. ovalis Brébisson
	S. tenera Gregory
	S. robusta Ehrenberg
Chlorophyta	
Chlorococcales	
Chlorococcaceae	
	Tetraedron duospinum Ackley
Ulotrichales	
Ulotrichaceae	
	Ulothrix aequalis Kutzing
Oedogoniales	
Oedogoniaceae	
	Oedogonium sp
Desmidiales	
Mesotaeniaceae	
	Netrium digitus (Breb.) Itzigs. et Rothe
Closteriaceae	
	Closterium striolatum Ehrenberg ex Ralfs
Desmidiaceae	
	Cosmarium leave Rabenhorst
	Micrasterias rotata (Greville) Ralfs ex Ralfs
	Staurastrum punctulatum (Breb.) Ralfs
Zygnematales	
Zygnemataceae	
	Spirogyra sp
Cyanoprokaryota	
Chroococcales	
Chroococcaceae	
	Merismopedia elegans A. Braun
Nostocales	
Nostocaceae	
	Anabaena affinis Lemmermann
	Oscillatoria amoena (Kutzing) Gomont
	O. curviceps C. A. Agardh ex Gomont
	O. formosa Bory ex Gomont
	O. limnetica Lemmermann
	O. minima Gicklhorn
	Spirulina nordstedtii Gomont
Euglenophyta	
Euglenales	
Euglenaceae	
	Euglena agilis Carter
	E. limnophila Lemmermann var. *limnophila*
	E. navicula Zakrys
	E. polymorpha Dangeard
	Phacus orbicularis Hubner var. *orbicularis* fo. *orbicularis*
	Trachelomonas abrupta var. *minor* Deflandre
	T. hispida var. *crenulatocollis* (Mask) Lemmermann

the Balikli Dam Reservoir, desmids were represented by 5 species and constituted 9.09% of the total taxa. Desmid species were also reported to be abundant and common in many alkaline dam reservoir and lakes in Turkey (Gurbuz and Kivrak, 2003; Kivrak and Gurbuz, 2005; Sahin, 1998).

Round (1984) notified that Cyanoprokaryota grow in eutrophic waters and on organically polluted sediment in summer and autumn. In addition, it has been suggested that *Oscillatoria* spp., which are indicators of pollution, are more prolific in polluted regions (Sen *et al*., 1990). Although, *Oscillatoria* was represented by 5 species and constituted 9.09% of the total taxa in our study area, they were not abundant and common during the study period.

Euglenophyta are know to be abundant in eutrophic waters and sediments polluted with organic matter (Round, 1984). In the Balikli dam reservoir, Euglenophyta, abundant and common in summer, were represented by 7 species and constituted 12.72% of the total taxa.

Muller (1994) reported that biomass and growth of algae were positively correlated with light intensity and water temperature. The growth of epipelic algae in the Balikli Dam Reservoir supported this finding, because the density of epipelic algae was low in late spring and late autumn, when water temperature is low. Higher temperatures supported their growth and the density of epipelic algae in the Balikli Dam Reservoir was at the highest level in September (Fig. 2). But, a decrease in the density of epipelic algae due to rainfall was observed in August (Fig. 2).

A number of previous reviews focused on phytoplankton diversity (Harris, 1986). In general, when using a diversity index such as Shannon-Weaver, phytoplankton diversity with a strong seasonal component (Margalef, 1958). However, little is known concerning the diversity of epipelic algae in lakes and dam reservoirs in Turkey (Sahin, 2004; Akar and Sahin, 2006). In the Balikli Dam Reservoir, it was observed that the seasonal changes in diversity showed an inverse pattern with species number (Fig. 3). This means that species evenness decreased with increasing size of the algal population. *Navicula cryptocephala*, for example, increased and occupied 30.63% of the total algal flora in September, when total cell number increased. The same trend was true in November, when *Hannaea arcus* occupied 36.36% of the algal flora (Fig. 3). The decrease in diversity index values during these months was probably caused by the high relative abundance of the dominant species. In August, when total species number was small, the dominant species (*Navicula cryptocephala*) occupied only 20.61% of total species number, and such a low relative abundance resulted in a high diversity index (Fig. 3). According to May (1975), the Shannon-Weaver diversity index is related to both the total number of species and their relative abundances, and can be designated as a positive function of total number of species.

The cluster analyses revealed that the Balikli Dam Reservoir tended to have similar epipelic composition in terms of relative abundances of species. However, the cluster showed that there is relative dissimilarity between sampling periods in the Balikli Dam Reservoir. Only a few months presented similarity <50%. The importance of seasonal influence on the epipelic community is confirmed when analyzing the groups formed in the cluster analysis.

In conclusion, the species found in the Balikli Dam Reservoir mainly reflect the trophic state of the reservoir, which is eutrophic, as can be seen from the existence of the species and their abundance.

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