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RESEARCH PAPER

Diversity and Ecology of Benthic Diatoms in Karagöl Lake in Karagöl-Sahara National Park (Şavşat, Artvin, Turkey)

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Abstract

The main goal of this study is to determine the composition, diversity and ecology of benthic diatoms in Karagöl Lake in Karagöl-Sahara National Park. Monthly sampling (from sediments, stones and aquatic plants in littoral zone of the lake) taken in three consecutive years revealed 57 diatom taxa with *Gomphonema* and *Pinnularia* being the most abundant species while other genera are represented with three or fewer species. *Lindavia ocellata* was the most dominant taxon in the samplings examined throughout the whole study. The values of diversity and evenness indices are high during the spring and early summer. Based on cluster analysis for monthly samples of epipelic diatom, there are two different groups at the lowest similarity level. The associations between August 2010 and September 2010 months are the most significant with 86.02%. The organism number of epipelic diatoms showed positive correlation ($P<0.01$) with dissolved oxygen, while negative correlation ($P<0.05$) with temperature. Detailed floristic and ecological examination of the benthic diatom communities has not been carried out before this study in this lake. Therefore, this study is the first to our knowledge towards revealing aquatic benthic diatom biodiversity of Karagöl-Sahara National Park and provides basis for future investigations.

Keywords: Diatoms, diversity, ecology, Karagöl lake, Turkey.

Introduction

Diatoms, microscopic single-celled algae distributed broadly in salt water and freshwater, are characterized by having a silica cell wall and as tolerant species against ecological changes (Sládeček, 1986; Round *et al*.,, 1990). At the same time, diatoms are responsible for a major part of the biomass produced by algae in aquatic environments (Poulíčková *et al*., 2004). Their widely presence in almost all aquatic environments and shorter life cycles compared to macrophyte, fish and other macroinvertebrates make diatoms useful indicators for monitoring water quality (Van De Vijver *et al*., 2003; Stevenson *et al*., 2010; Bennion *et al*., 2010). Moreover, specific diatom communities can help us deduce more about the history, present and future of any lake that bears them (Meriläinen *et al*., 1982) Therefore, new studies are important to better understand these diatom communities and their interaction with the ever-changing environment.

There have been studies regarding diatom diversity and distribution in alpine and subalpine lakes in the Eastern Black Sea Region of Turkey (Şahin, 1998, 2000, 2001; Şahin and Akar, 2005; Akar and Şahin, 2006; Kolaylı and Şahin, 2008; Şahin *et al*., 2010). However there was no study of Karagöl Lake so far. Here we investigated the composition of diatoms in this lake and also reported parameters about the seasonal changes that occurs in diatom communities. This investigation focuses on benthic diatom communities of the Karagöl Lake and their relationship with environmental variables. In addition, this study provides one more step towards identifying the diversity of freshwater algal flora in Turkey.

Materials and Methods

In 1994, Karagöl-Sahara was included in the list of national parks of Turkey by the Ministry of Forestry. The total protected area of Karagöl-Sahara National Park is 3304 ha. It is located in the Şavşat district of Artvin in the Eastern Black Sea region. It consists of two main parts, namely Karagöl and Sahara plateaus (Anonymous, 2007). According to Davis (1965) and Zohary (1973), the national park is within Colchic sector belonging to the Euro Siberian floristic area of the Holarctic region. Karagöl-Sahara National Park has very rich invaluable flora and fauna (Anonymous, 2002; Eminağaoğlu and Anşin, 2004;

Eminağaoğlu *et al*., 2007; Sert *et al*., 2013) and plays an important role in biodiversity conservation in Turkey. Moreover, it is regarded as one of the world's 200 priority ecological regions in terms of biogeographic characteristics (WWF/IUCN, 1994).

Karagöl Lake is positioned at longitudes of 42°29' E and latitudes of 41°18' N at altitude of 1630 m a.s.l on the north of Şavşat (Figure 1). Sampling was done monthly from October 2008 to September 2010, except in January, February, December 2009 and January, February 2010 due to inaccessibility of the lake via transportation. Diatom samples were taken from different habitats: sediments (epipelic), stones (epilithic) and aquatic plants (epiphytic). A total amount of 112 samples from the epipelic (17), epilithic (38) and epiphytic (57) habitats were examined. Epipelic samples were taken by means of a glass pipe at station II (Figure 1). Epilithic samples were scraped from the stone surfaces with a scalpel blade and brush at stations I and II, while the epiphytic was taken from aquatic plants Equisetum ramosissimum Desf., Polygonum amphibium L. and Myriophyllum spicatum L. at all stations. Samples were fixed with formaldehyde to a final concentration of 4%. In order to remove organic matter, samples were treated with H_2SO_4 and HNO_3, and then washed several times with distilled water. Afterwards, the samples were air dried on cover glasses and mounted in Entellan. In order to estimate abundance, at least 300 diatom cells were counted at 400× magnification (Round, 1953; Sládečková, 1962). Light microscope observations and photographs were made using a Leica DM 2500 microscope with a camera (Leica DFC 290) attached. In the field, water temperature, pH, electrical conductivity and dissolved oxygen were measured with a Orion4Star and YSI 55 portable measuring instruments at each sampling station. Analyses of other hydrochemical parameters (Ca++, SiO_2, PO_43-_P, NO_2–N, NO_3–N, NH_4^+–N and $CaCO_3$) were carried out using with WTW S12 Model photometer. For algal identification, the following books were used: Krammer and Lang-Bertalot (1986, 1988, 1991a,b). Taxonomy of diatoms was controlled based on Guiry and Guiry (2016) and Gönülol (2016) websites. Calculation of Shannon's diversity and evenness index were determined with using epipelic diatom data. Shannon's diversity index (H') was calculated as follows (Shannon and Weaver, 1949):

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. Evenness (E) gives information about the quantitative distribution of the species in communities. Values of evenness are between 0 and 1. If it is closer to 1, similarity is great. Evenness was calculated as follows: E=(H')/H'max

Where H'max is the possible maximum diversity.

Data of the epipelic diatom community were analyzed based on Bray-Curtis cluster analysis (complete linkage method). Analysis of cluster and correlation was carried out BioDiversity Professional 2.0 package and PASW Statiscs 18 programs, respectively.

Results and Discussion

Physico-chemical Analysis

The detailed results of the physico-chemical properties of the water in this lake have been published before (Akar and Şahin, 2014). According to that study the water temperature gradient was between 1.1-25.4°C. Dissolved oxygen concentrations ranged from 6.58 mg/L to 12.42 mg/L. Values of the pH varied from slightly acidic (6.87) to alkaline (9.22) and mean value of pH was 7.79 (slightly alikaline). Conductivity level had small variations (57.70-140.20 µS/cm). In general, the amount of nutrients (SiO_2, PO43-_P, NO_2–N, NO_3–N, NH_4^+–N) was lowest and balanced.

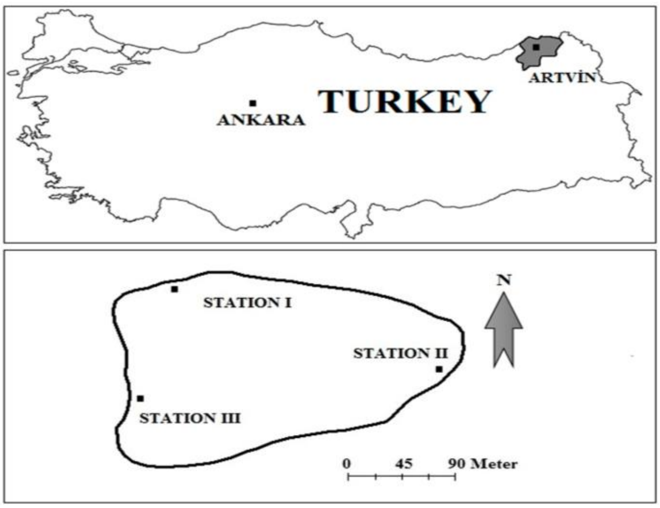

Figure 1. Map of the Karagöl Lake.

Diatom Taxa Composition

There are 57 Bacillariophyta taxa in Karagöl Lake. The floristic list of the determined diatoms in Karagöl Lake is given in Table 1. Photographs of some taxa are shown in Figure 2, Figure 3, Figure 4. Abbreviation of author names is according to Brummit and Powell (1992).

The diatom taxa composition listed for the lake is consistent with that recorded for mountain lakes. In this study, the recorded diatom taxa are generally common taxa and are similar to the diatom communities in alpine and subalpine lakes in the Eastern Black Sea Region of Turkey (Şahin, 1998, 2000, 2001; Şahin and Akar, 2005; Akar and Şahin, 2006; Kolaylı and Şahin, 2008; Şahin *et al*., 2010). There are different diatom taxa representing trophic levels and specific aquatic environments. According to Wojtal *et al.,* (2005) existence of various diatom taxa could indicate evidence of a wide range of environmental possibilities for their development in studied area. Nagy (2011) pointed out that diatoms tend to prefer cold water. In our study, the epipelic diatom taxa reached the highest value in December 2008 (49601 org/cm2) and November 2009 (54741 org/cm2) (Figure 5). The lowest values (9252 org/cm2) were observed in May 2009 and 9509 org/cm2 with in June 2010 (Figure 5). Also, the total epipelic diatoms showed positive correlation ($P<0.01$) with dissolved oxygen, while negative correlation ($P<0.05$) with temperature (Table 2).

The genus Gomphonema had the highest number of taxa (6 taxa) followed by the genus Pinnularia (4 taxa). Other genera were represented with 3 or fewer taxa. Gomphonema species were present in all habitats throughout investigation but could not reach high values. Gomphonema parvulum reached striking values in the epiphytic communities (Table 3). Round (1993) reported that this species has a wide distribution and is not present in extremely polluted environments, which indicates the cleanliness of the lake studied.

The most dominant taxon was Lindavia ocellata. It was present in all epipelic samples during the study period. L. ocellata reached its peak (37779 org/cm2) in November 2009 and represented 69% of the epipelic diatoms (Figure 5). Ecological data about L. ocellata are controversial in the literature. This taxon has been identified from different trophic levels, ultra-oligotrophic, oligotrophic, oligo-mesotrophic and meso-eutrophic (Cremer and Wagner, 2003). In addition, Krammer and Lange-Bertalot (1991a) and Medvedeva *et al*., (2009) announced that this taxon is ubiquitous. Our findings showed that the water of Karagöl Lake is slightly alkaline and has mesotrophic character. Also, a positive correlation ($P<0.05$) was detected between L. ocellata with dissolved oxygen (Table 2).

Fragilaria construens and Staurosira venter have been present continuously in the epipelic community during the study period and reached significant values (2056 org/cm2) in November 2008 and July 2009 and (7196 org/cm2) in August 2009, respectively (Figure 5). Van Dam *et al*., (1994) reported that both taxa are alkaliphilous (pH>7), occur in freshwater and brackish waters, oxygen requirements continuously high (about 100% saturation), β-mesosaprobous, meso-eutraphentic and never, or only very rarely, occurring outside water bodies. In addition, they are nitrogen-autotrophic taxa; F. construens tolerates very small concentrations of organically bound nitrogen, while S. venter tolerating elevated concentrations of organically bound nitrogen. Water of the lake is slightly alkaline and has mesotrophic character. In addition, F. construens was showed negative correlation ($P<0.05$) with conductivity and TDS. Also, there is a positive correlation ($P<0.05$) between S. venter and pH (Table 2). Besides these dominant species, Epithemia sorex have been occurred whole study period in the epipelic.

Also, Encyonema minutum, Fragilaria capucina, Ulnaria delicatissima, Rhopalodia gibba, Nitzschia gracilis and Navicula viridula were important in terms of frequency and abundance. F. capucina and U. delicatissima occurred generally spring months in the epipelic flora. King *et al*. (2006) pointed out especially long and thin forms of Fragilaria genera are common spring and autumn months. In addition to E. minutum, F. capucina, U. delicatissima were common and abundant taxa lake outlets in the Swiss Alps (Robinson *et al*., 2010).

The diatom communities were very similar at all stations. In general, the most abundant diatom taxa were common at all stations (Table 3). L. ocellata also has been the most dominant species in epilithic and epiphytic diatom communities. However, it was followed Encyonema minutum and Epithemia sorex (Table 3).

Cymbella aspera, Craticula cuspidata, Fragilariforma constricta, Gomphonema olivaceum, Caloneis ventricosa, Diatoma mesodon, Diploneis elliptica, Neidium dubium, Placoneis gastrum, Stauroneis anceps and Surirella spiralis were rarely available in the diatom communities and not reached significant numbers during all sampling period. They are probably not ecologically significant for Karagöl Lake, but they are important for floristic studies. This structure of the diatom community assemblages in Karagöl Lake is consistent with the findings in the related literature; for example, it is reported that specific species dominated the diatom communities frequently and large number of rare species occurs occasionally (Chatháin and Harrington, 2008).

The values of diversity and evenness indices are generally high during the spring and early summer (Figure 6). In June 2009, the members of the Bacillariophyta had high diversity indices (2.954) because of high evenness (0.907). In this month, the dominant species (S. venter) occupied 18.75% of the total organism number of diatoms. The low relative

Table 1. The list of the diatoms in Karagöl Lake

Taxa		Epipelic	Epilithic	Epiphytic
Division	BACILLARIOPHYTA			
Class	Coscinodiscophyceae			
Order	Aulacoseirales			
Family	Aulacoseiraceae			
	Aulacoseira sp.		+	
Order	Coscinodiscales			
Family	Coscinodiscaceae			
	Lindavia ocellata (Pantocsek) Nakov et al	+	+	+
Class	Bacillariophyceae			
Order	Tabellariales			
Family	Tabellariaceae			
	Asterionella formosa Hassall	+	+	+
	Diatoma mesodon (Ehrenb.) Kütz.	+	+	+
	Meridion circulare (Grev.) C.Agardh		+	+
	Tabellaria fenestrata (Lyngbye) Kütz.	+	+	
Order	Fragilariales			
Family	Fragilariacea			
	Fragilaria capucina Desm.	+	+	+
	F. construens (Ehrenb.) Grunow	+	+	+
	Fragilariforma constricta (Ehrenb.) Williams & Round		+	+
	Staurosira venter (Ehrenb.) Cleve & Möller	+	+	+
Order	Licmophorales			
Family	Ulnariaceae			
	Ulnaria capitata (Ehrenb.) Compère		+	+
	U. delicatissima (W.Smith) Aboal & Silva	+	+	+
	U. ulna (Nitzsch) Compère	+	+	+
Order	Cocconeidales			
Family	Achnanthidiaceae			
	Achnanthidium exiguum (Grunow) Czarnecki	+		
	Planothidium lanceolatum (Bréb. ex Kütz.) Lange-Bert.	+	+	+
Family	Cocconeidaceae			
	Cocconeis placentula Ehrenb.	+	+	+
Order	Thalassiophysales			
Family	Catenulaceae			
	Amphora ovalis (Kütz.) Kütz.	+	+	+
	Amphora sp.	+		
Order	Cymbellales			
Family	Cymbellaceae			
	Cymbella affinis Kütz.	+	+	+
	C. aspera (Ehrenb.) Cleve	+	+	+
	C. cymbiformis C. Agardh	+	+	+
Family	Gomphonemataceae			
	Encyonema minutum (Hilse) Mann	+	+	+
	Gomphonema acuminatum Ehrenb.	+	+	+
	G. angustatum (Kütz.) Rabenh.	+	+	+
	G. gracile Ehrenb.	+	+	+
	G.olivaceum (Horn.) Bréb.			+
	G. parvulum (Kütz.) Kütz.	+	+	+
	G. truncatum Ehrenb.	+	+	+
	Placoneis gastrum (Ehrenb.) Mereschk.		+	+
Family	Rhoicospheniaceae			
	Rhoicosphenia abbreviata (C.Agardh) Lange-Bert.		+	+
Order	Naviculales			
Family	Amphipleuraceae			
	Amphipleura pellucida (Kütz.) Kütz.	+	+	+
Family	Diploneidaceae			
	Diploneis elliptica (Kütz.) Cleve	+	+	+
Family	Naviculaceae			
	Caloneis ventricosa (Ehrenb.) Meister	+	+	
	Gyrosigma scalproides (Rabenh.) Cleve	+	+	+
	Navicula radiosa Kütz.	+	+	+
	N. rhynchocephala Kütz.	+	+	+
	N. viridula (Kütz.) Ehrenb.	+		
Family	*Neidiaceae*			
	Neidium ampliatum (Ehrenb.) Krammer		+	+
	N. dubium (Ehrenb.) Cleve		+	+
Family	*Pinnulariaceae*			
	Pinnularia borealis Ehrenb.	+		+
	P. interrupta W. Smith.	+	+	+
	P. major (Kütz.) Rabenh.		+	+
	P. viridis (Nitzsch) Ehrenb.	+	+	+

Table 1. Continued

Taxa		Epipelic	Epilithic	Epiphytic
Family	Sellaphoraceae			
	Sellaphora pupula (Kütz.) Mereschk.	+	+	+
Family	Stauroneidaceae			
	Craticula cuspidata (Kütz.) Mann		+	+
	Stauroneis anceps Ehrenb.			+
Order	Surirellales			
Family	Surirellaceae			
	Cymatopleura solea (Bréb.) W. Smith	+	+	
	Surirella angusta Kütz.	+	+	+
	S. spiralis Kütz.	+		+
	S. splendida (Ehrenb.) Kütz.			+
Order	Rhopalodiales			
Family	Rhopalodiaceae			
	Epithemia adnata (Kütz.) Bréb.	+	+	+
	E. sorex Kütz.	+	+	+
	E. turgida (Ehrenb.) Kütz.	+	+	+
	Rhopalodia gibba (Ehrenb.) Otto Müller	+	+	+
Order	Bacillariales			
Family	Bacillariaceae			
	Hantzschia amphioxys (Ehrenb.) Grunow	+	+	+
	Nitzschia gracilis Hantzsch	+		
	N. nana Grunow	+		

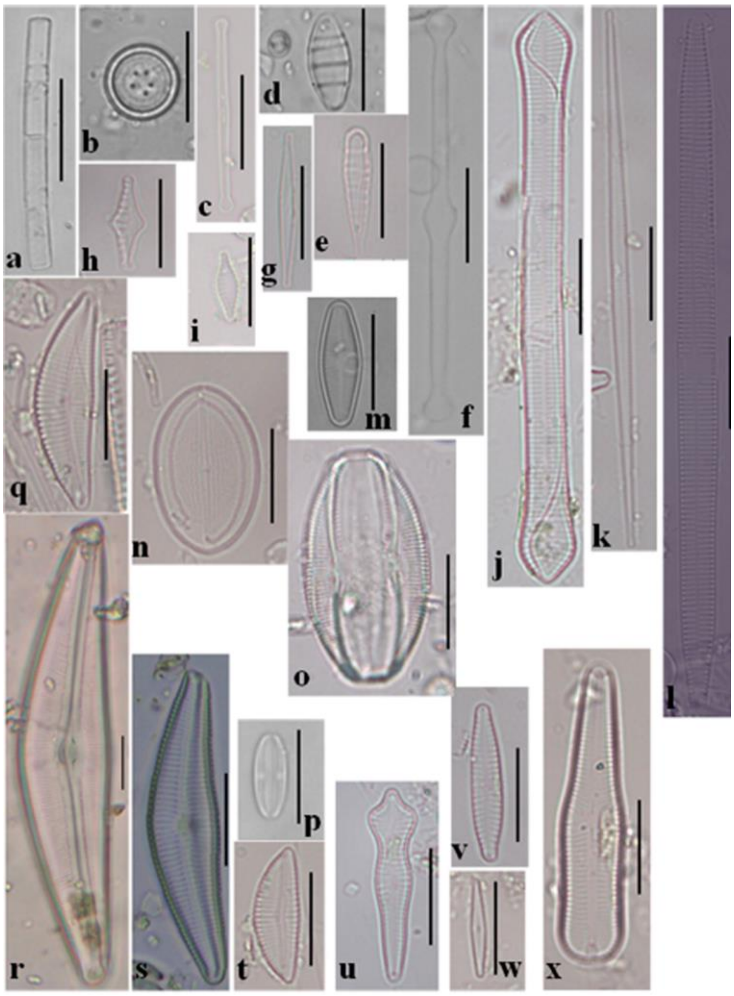

Figure 2. a. *Aulacoseira* sp., b. *Lindavia ocellata*, c. *Asterionella formosa*, d. *Diatoma mesodon*, e. *Meridion circulare*, f. *Tabellaria fenestrate*, g. *Fragilaria capucina*, h. *Fragilaria construens*, i. *Staurosira venter*, j. *Ulnaria capitata*, k. *Ulnaria delicatissima*, l. *Ulnaria ulna*, m. *Planothidium lanceolatum*, n. *Cocconeis placentula*, o. *Amphora ovalis*, p. *Amphora* sp., q. *Cymbella affinis*, r. *Cymbella aspera*, s. *Cymbella cymbiformis*, t. *Encyonema minutum*, u. *Gomphonema acuminatum*, v. *Gomphonema angustatum*, w. *Gomphonema parvulum*, x. *Gomphonema truncatum*, (Scale bar = 20 μm).

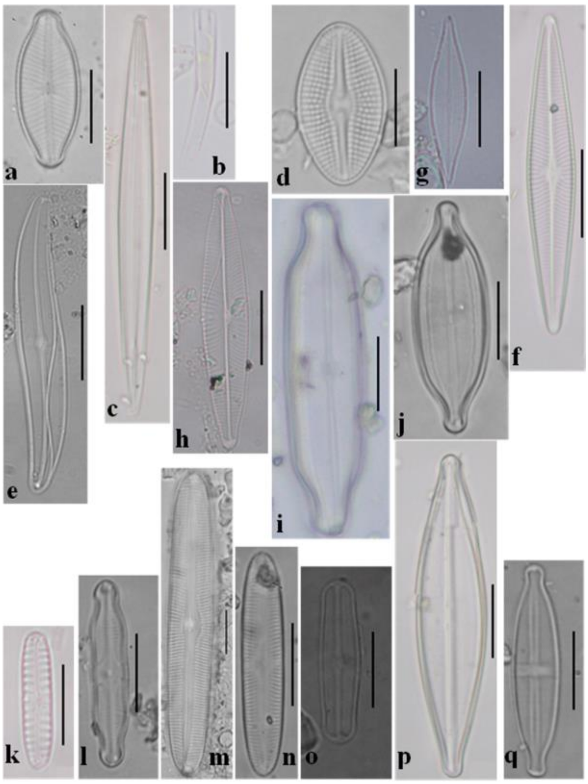

Figure 3. a. *Placoneis gastrum*, b. *Rhoicosphenia abbreviate*, c. *Amphipleura pellucida*, d. *Diploneis elliptica*, e. *Gyrosigma scalproides*, f. *Navicula radiosa*, g. *Navicula rhynchocephala*, h. *Navicula viridula*, i. *Neidium ampliatum*, j. *Neidium dubium*, k. *Pinnularia borealis*, l. *Pinnularia interrupta*, m. *Pinnularia major*, n. *Pinnularia viridis*, o. *Sellaphora pupula*, p. *Craticula cuspidata*, q. *Stauroneis anceps*, (Scale bar = 20 μm).

Figure 4. a. *Cymatopleura solea*, b. *Surirella angusta*, c. *Surirella spiralis*, d. *Surirella splendida*, e. *Epithemia adnata*, f. *Epithemia sorex*, g. *Epithemia turgida*, h. *Rhopalodia gibba*, i. *Hantzschia amphioxys*, j. *Nitzschia gracilis*, k. *Nitzschia nana*, (Scale bar = 20 μm).

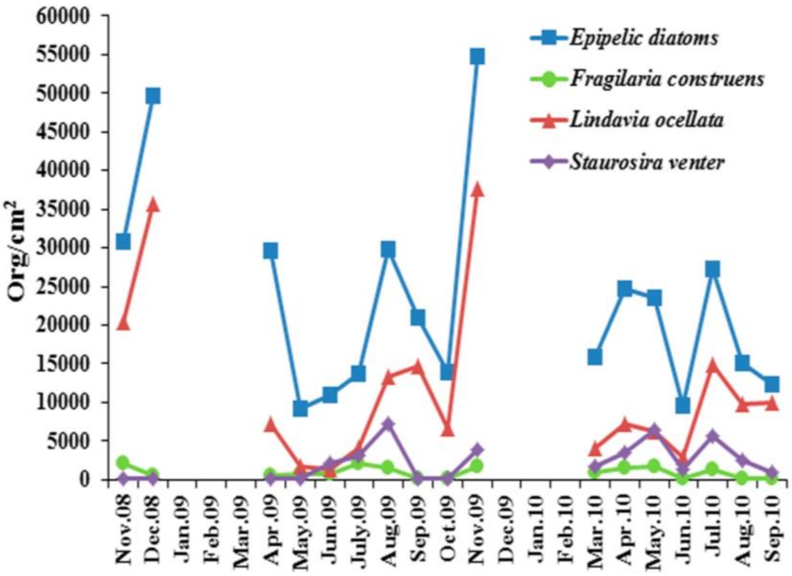

Figure 5. Seasonal variations of total epipelic diatoms and dominant taxa.

Table 2. Correlations among physical and chemical variables of water, epipelic diatoms and dominant taxa

	Temperature	Dissolved Oxy.	pH	Elec. Cond.	TDS	Tot. Hard.($CaCO_3$)	NH_4^+-N	NO_3^--N	NO_2^-- N	PO_4^{3+}- P	SiO_2	Ca^{2+}
Epipelic Diatoms	-.582*	.619**	.074	-.155	-171	.375	.276	.116	-.137	.214	.033	.391
Fragilaria construens	-.078	.045	.236	-.510*	-.542*	-.031	-.207	.266	-.215	.415	.122	-.036
Lindavia ocellata	-.461	.523*	.006	-.180	-.192	.367	.294	.196	.154	.302	-.199	.380
Staurosira venter	.380	-.397	.539*	.029	.008	-.315	-.302	-.169	-.310	-.194	-.137	-.309

* P<0.05; ** P<0.01

Table 3. Mean relative abundance values (≥5.00) of diatom taxa in epilithic and epiphytic communities for the stations

	Epilithic (%)		Epiphytic (%)		
Taxa	Station I	Station II	Station I	Station II	Station III
Cocconeis placentula	1.32	1.58	5.26	5.47	3.95
Encyonema minutum	10.21	10.26	9.32	15.05	12.16
Epithemia sorex	18.05	17.53	12.37	16.74	13.47
Fragilaria construens	6.74	2.68	4.06	2.37	1.68
Gomphonema parvulum	1.37	1.37	5.16	4.26	8.68
Lindavia ocellata	39.37	37.74	33.00	31.63	36.74
Staurosira venter	3.84	2.37	5.00	1.74	0.79
Ulnaria delicattissima	4.37	5.58	3.26	1.58	2.53

abundance of dominant species was caused high diversity index value. When L. ocellata was constituted 81.25% of the total organism number of diatoms in September 2010, diversity index and evenness values decreased (0.779 and 0.400, respectively). The lowest diversity index in this month was probably caused by the high relative abundance of the dominant species (Figure 6).

Based on cluster analysis, there are two different groups at the lowest similarity level (Figure 7). While the first group is formed by autumn, spring and summer months that had total organism number varied from 9252 org/cm2 (May 2009) to 30840 (November 2008), second group includes December 2008 and November 2009 months that characterized the highest total organism number (49601 org/cm2 and 54741 org/cm2, respectively). In the first group, L. ocellata, F. construens, S. venter and U. delicatissima are very important species. The other group includes is characterized by the dominance of

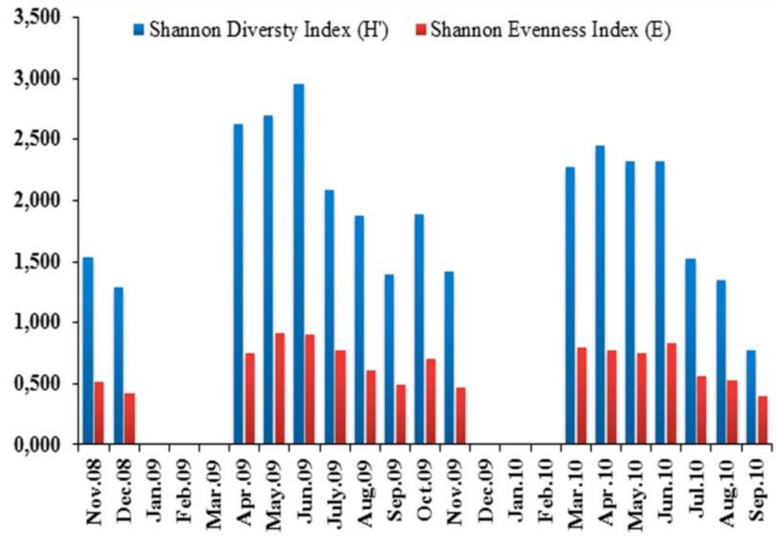

Figure 6. Shannon diversity and evenness index during study period in the Karagöl Lake (There were no sampling for January-March 2009 and December 2009 to February 2010).

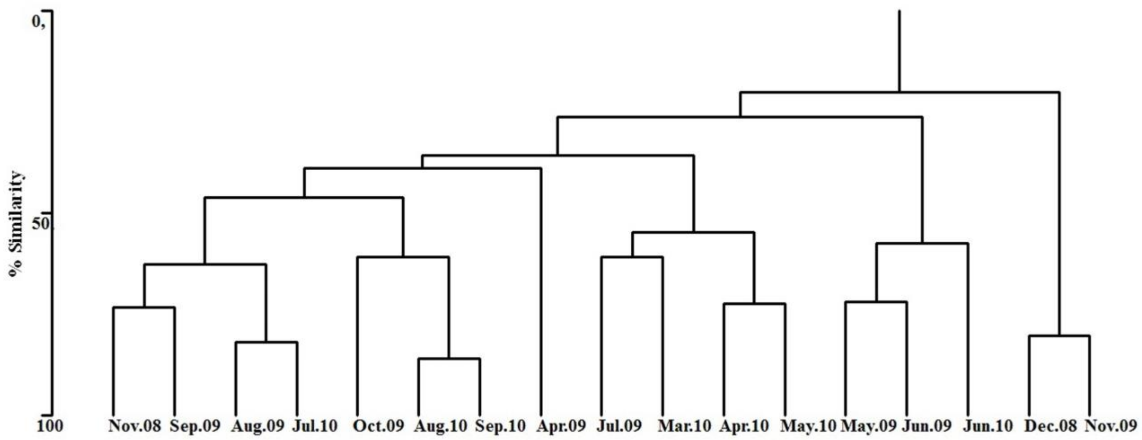

Figure 7. Cluster analysis for monthly samples of epipelic diatom in Karagol Lake based on the Bray-Curtis similarity index.

L. ocellata. The highest similarity was seen between August 2010 and September 2010, with 86.02%.

In conclusion this article provides a baseline for aquatic biodiversity of Karagöl-Sahara National Park and future investigation. Reported values here can supplement future studies in terms of possible future changes in diatom communities that may be analyzed in this specific lake. Especially global warming may cause temperature changes all over the world, which may give rise to changes in diatom populations.

References

Akar, B. and Şahin, B. 2006. Benthic algal flora of Karanlık Lake and diversity of epipelic algae. Fresenius Environmental Bulletin, 15: 48-54.

Akar, B. and Şahin, B. 2014. New desmid records of Karagöl Lake in Karagöl-Sahara National Park (Şavşat-Artvin/Turkey). Turkish Journal of Fisheries and Aquatic Sciences 14(1): 269-274. doi: 10.4194/1303-2712-v14_1_29

Anonymous, 2002. Karadeniz Teknik Üniversitesi inceleme raporu, Orman Bakanlığı Doğu KaradenizBölge Müdürlüğü Artvin Milli Parklar ve Av-Yaban Hayatı Başmühendisliği, Artvin.

Anonymous, 2007. Karagöl-Sahara Milli Parkı 1/25.000 ölçekli uzun devreli gelişme planı. Ankara: Çevre ve Orman Bakanlığı, Doğa Koruma ve Milli Parklar Genel Müdürlüğü.

Bennion, H., Sayer, C.D., Tibby, J. and Carrick, H.J. 2010. Diatoms as indicators of environmental change in shallow lakes. In Smol, J.P. and Stoermer, E.F. (eds), The Diatoms: Applications for the Environmental and Earth Sciences, 2nd ed. Cambridge University Press, Cambridge, 152-173. doi: 10.1017/CBO9780511763175.009

Brummit, R.K. and Powell, C.E. (editors). 1992. Authors of plant names. Royal Botanic Gardens Kew, UK 732 pp.

Chatháin, B.N. and Harrington, T.J. 2008. Benthic Diatoms of The River Deel: Diversity and Community Structure. Biology and Environment: Proceedings of the Royal Irish Academy, 108B: 29-42. doi:10.3318/BIOE.2008.108.1.29

Cremer, H. and Wagner, B. 2003. The diatom flora in the ultra-oligotrophic Lake El'gygytgyn, Chukotka. Polar Biology, 26: 105-114. doi: 10.1007/s00300-002-0445-0

Davis, P.H. 1965. Flora of Turkey and the East Aegean Islands, Vol 10. Edinburg University Press, Edinburg, UK, 590 pp.

Eminağaoğlu, Ö. and Anşin, R. 2004. Flora of the Karagöl-Sahara National Park (Artvin) and its environs. Turkish Journal of Botany, 28: 557-590.

Eminağaoğlu, Ö., Anşin, R. and Kutbay, H.G. 2007. Forest vegetation of Karagöl-Sahara National Park Artvin-Turkey. Turkish Journal of Botany, 31: 421-449.

Gönülol, A. 2016. Turkishalgae electronic publication, Samsun, Turkey. http://turkiyealgleri.omu.edu.tr; searched on 14 July 2016.

Guiry, M.D. and Guiry, G.M. 2016. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 14 July 2016.

King, L., Clarke, G., Bennion, H., Kelly, M., and Yallop, M. 2006. Recommendations for sampling littoral diatoms in lakes for ecological status assessments. Journal of Applied Phycology, 18(1): 15-25.

Kolaylı, S. and Şahin, B. 2008. Seasonal variations of benthic diatoms with relation to physical and chemical variables in Karagöl Lake (Borçka-Artvin, Turkey). Fresenius Environmental Bulletin, 17: 956-961.

Krammer, K. and Lange-Bertalot, H. 1986. Susswasserflora von Mitteleuropa, Bacillariophyceae, Band 2/1, 1. Teil: Naviculaceae. 1 st ed, Gustav Fischer Verlag, Stuttgart, (D), 876 pp.

Krammer, K. and Lange-Bertalot, H. 1988. Susswasserflora von Mitteleuropa, Bacillariophyceae, Band 2/2, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. 1 st ed, Gustav Fischer Verlag, Stuttgart, (D) 596 pp.

Krammer, K. and Lange-Bertalot, H. 1991a. Susswasserflora von Mitteleuropa, Bacillariophyceae, Band 2/3, 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. 1 st ed, Gustav Fischer Verlag Stuttgart, (D) 576 pp.

Krammer, K. and Lange-Bertalot, H. 1991b. Susswasserflora von Mitteleuropa, Bacillariophyceae, Band 2/4, 4. Teil: Achnanthaceae, Kritische Ergänzungen zu Navicula (Lineolatae) und Gomphonema Gesamtliteraturverzeichnis. 1 st ed. Gustav Fischer Verlag, Stuttgart, (D) 437 pp.

Medvedeva, L.A., Nikulina, T.V. and Genkal, S.I. 2009. Centric diatoms (Coscinodiscophyceae) of fresh and brackish water bodies of the southern part of the Russian Far East. Oceanological and Hydrobiological Studies, 38(2): 139-164. doi: 10.2478/v10009-009-0018-4

Meriläinen, J., Huttunen, P.and Pirttiala, K. 1982. The effect of land use on the diatom communities in lakes. Hydrobiologia, 86(1): 99-103. doi:*10.1007*/*BF00005794*

Nagy, S. S. 2011. Collecting, Cleaning, Mounting, and Photographing Diatoms. In Seckbach, J. and Kociolek (eds.) In The Diatom World, Springer, Netherlands, 1-18.

Poulíčková, A., Duchoslav, M. and Dokulil, M. 2004. Littoral diatom assemblages as indicators of lake trophic status: A case study from perialpine lakes in Austria. European Journal of Phycology, 39: 143–152. doi:10.1080/0967026042000201876

Robinson, C.T., Kawecka, B., Füreder, L. and Peter, A. 2010. Biodiversity of flora and fauna in Alpine waters. In: Bundi U, (ed): In The Handbook of Environmental Chemistry. Alpine Waters: Springer, Berlin Heidelberg, 193-223. doi: 10.1007/978-3-540-88275-6_10

Round, F.E. 1953. An investigation of two benthic algal communities in Malharm, Tarn, Yorkshire. Journal Ecology, 41: 174-197. doi: 10.2307/2257108

Round, F.E. 1993. A review and methods for the use of epilithic diatoms for detecting and monitoring changes in river water quality. 1 st ed., HMSO Publisher, London, UK, 65 pp.

Round, F.E., Crawford, R.M. and Mann, D.G. 1990. The diatoms: Biology and morphology of the genera. Cambridge University Press, Cambridge, UK, 747 pp.

Sert, O., Şabanoğlu, B. and Fırat, S. 2013. A study on determination of insect fauna of Karagöl Sahara Natural Park (Artvin, Turkey). Hacettepe Journal Biology and Chemistry, 41: 225-234.

Shannon, C.E. and Weaver, W. 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana, 125 pp.

Sládeček, V. 1986. Diatoms as indicators of organic pollution. Acta hydrochimica et hydrobiologica, 14(5): 555-566. doi: 10.1002/aheh.19860140519

Sládečková, A. 1962. Limnological investigation methods for the periphyton ("Aufwuchs") community. Botanical Review, 28: 286-350, doi: 10.1007/BF02860817

Stevenson, R.J., Pan, Y. and Van Dam, H. 2010. Assessing environmental conditions in rivers and streams with diatoms. In Smol, J.P. and Stoermer, E.F. (eds), The Diatoms: Applications for the Environmental and Earth Sciences, 2nd ed. Cambridge University Press, Cambridge, 57-85. doi: 10.1017/CBO9780511763175.005

Şahin, B. 1998. A study on the benthic algae of Uzungöl (Trabzon). Turkish Journal of Botany, 22: 171-189.

Şahin, B. 2000. Algal flora of Lakes Aygır and Balıklı (Trabzon, Turkey). Turkish Journal of Botany, 24: 35-45.

Şahin, B. 2001. Epipelic and epilithic algae of Dağbaşı Lake (Rize, Turkey). Turkish Journal of Botany, 25: 187-194.

Şahin, B. and Akar, B. 2005. Epipelic and epilithic algae of Küçükgöl lake (Gümüşhane-Turkey). Turkish Journal of Biology, 29(1): 57-63.

Şahin, B., Akar, B., and Bahçeci, İ. 2010. Species composition and diversity of epipelic algae in Balık Lake (Şavşat-Artvin, Turkey). Turkish Journal of Botany, 34(5): 441-448. doi: 10.3906/bot-0912-290

Van Dam, H., Mertens, A. and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from The Netherlands. *Netherlands Journal of Aquatic Ecology*, 28, 117–133. doi: 10.1007/BF02334251

Van De Vijver, B., Van Kerckvoorde, A. and Beyens, L. 2003. Freshwater and terrestrial moss diatom assemblages of the Cambridge Bay area, Victoria Island (Nunavut, Canada). Nova Hedwigia, 76(1-2): 225-243. doi: 10.1127/0029-5035/2003/0076-0225

Wojtal A., Wilk-Woźniak, E. and Bucka, H. 2005. Diatoms (Bacillariophyceae) of the transitory zone of Wolnica Bay (Dobczyce dam reservoir) and Zakliczanka stream (Southern Poland). Algological Studies, 115:

1-35. doi: 10.1127/1864-1318/2005/0115-0001

WWF/IUCN, 1994. Centers of plant diversity. A guide and strategy for their conservation. Vol. 1. Europe, Africa, South West Asia and the Middle East. Cambridge, UK: IUCN Publications Unit.

Zohary, M. 1973. Geobotanical foundations of the Middle East, Vol 2. 1 st ed. Gustav Fischer Verlag, Amsterdam, NL 739 pp.