Seasonal variations in the epilithic diatoms of Koçan Falls (Erzincan, Turkey)

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Abstract

The present study explores some physical and chemical parameters in the epilithic diatoms in the water samples obtained from two stations in Koçan Falls, Erzincan from March to November 2014. Over the course of the study, 19 taxa of epilithic diatoms were recorded. Diatom genera which had the highest number of species in the study period were *Cymbella* (4 species), *Navicula* (4 species), and *Cyclotella* (3 species), while the most significant diatoms in terms of prevalence and the size of their populations were found to be *Cyclotella* spp., *Gomphonema* spp., *Navicula* spp., and *Nitzschia* spp. Over the course of the study, diatoms exhibited the highest level of growth in spring and summer, when there was more light and temperatures were higher. Considering the presence of diatoms within epilithic algae communities in all seasons, it appears that diatoms are cosmopolitan and can be among the algae that are commonly found at all types of substrata. The data obtained from the epilithic diatoms of Koçan Falls were analyzed according to Shannon-Weaver Diversity Index and Sorensen Similarity Index.

Keywords: Koçan falls, Diatom, Epilithic, Shannon Weaver, Sorensen Index.

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Introduction

Water, the principal source the life, hosts a plethora of living things. The number and variety of algae, the first link in the food chain, affect all living things in the aquatic environment, including the fish. Algae, the key members of phytoplankton and phytobenthos, which are the primary producers of surface water sources, play a major role in the biological productivity of water through both oxygen production by photosynthesis and the organic substances they synthesize. Besides, the degrees of adaptation that different alga species show in response to differing water quality and changes in water quality are crucial in alga ecology. It is important to know the changes that algae go through over time both for sustaining the quality of water and ensuring that the humankind can continue making use of them. The number and variety of algae and other organisms may vary constantly depending on the environmental conditions. Thus, knowing how the algae change over time is important to maintain water quality and to reap their benefits (Palmer, 1980).

Among the algae, diatoms play a key role in ecosystems. The valves of the single-cell diatoms formed from silica are very strong, compared to the skeletons of other living things. When the life cycles of diatoms end, these shells made up of silicium precipitate and are converted to diatomaceous earth. This earth, also called kieselgur, is obtained from the bottom of dried lakes and from the bottom of seas. When fossil fuels are examined, it is seen that these living things date back to the Jurassic. Diatoms have about 200 genera and about 100.000 species spread around the world. Thus, diatoms can be found in seas, fresh waters, earth, and even moist areas. The fact that diatom populations are much larger than the populations of other living things is very significant with regard to oceans, as the diatoms serve as the main producers of oceans. Diatoms produce their own food, and the pigment fucoxanthin that they have is highly important in food production.

Making efficient use of water products, which constitute a valuable source, but are underutilized in Turkey, will contribute substantially to the country’s economy. In fact, algae are employed in a vast array of fields from medicine, biotechnology, and cosmetics to food and fertilizer industries, as well as in obtaining single-cell proteins and identifying water contamination.

It is known that there has been an increase in the number of studies about inland waters in Turkey. The growing awareness of the importance of algae in standing and running waters has led to an increase in the number of studies about these organisms. The number of studies about rivers in our country is quite high. In one of these studies where Altuner and Gürbüz (1989) examined the phytoplankton communities in Karasu (Euphrates) River, the authors stated that *Bacillariophyta* was dominant in the phytoplankton, while *Chlorophyta*, *Cyanophyta* and *Euglenophyta* were occasionally encountered.

In a study titled the Diatoms of Kızılırmak (Red River), Yıldız (1991) noted that of the 122 species identified, 21 belonged to *Navicula* genius, 19 to *Nitzschia*, 7 to *Surirella*, 6 to *Gomphonema*, and 6 to *Pinnularia*, and that these species belonging to the concerned genera constituted 58% of the total number of species. .

Exploring the epipelic algal flora in Karasu (Euphrates) River, Altuner and Gürbüz (1991) found that *Bacillariophyta* was dominant in comparison to other algae.

In their study about the Çubuk Creak diatoms, Yıldız and Özkıran (1994) identified a total of 111 taxa.

Ertan and Morkoyunlu (1998) who studied the algal flora of Aksu Stream identified 73 species belonging to *Chlorophyta*, *Cyanophyta*, and *Euglenophyta*. The authors showed that *Bacillariophyta* was dominant with regard to the variety of species in the concerned flora.

In his study titled the benthic algal flora of Sera Stream, Şahin (1998) detected a total of 58 taxa involving *Bacillariophyta* (32), *Chlorophyta* (15), *Cyanophyta* (8) and *Euglenophyta* (3).

Çetin and Yavuz (2001) who studied the epipelic, epilithic, and epiphytic algal flora in Cip Creak (Elazığ-Turkey) identified 84 taxa belonging to *Bacillariophyta*, *Chlorophyta*, *Cyanophyta* and *Euglenophyta*. They discovered that the diatoms were dominant in the examined habitats.

In their study titled Epilithic Diatoms and Seasonal Variations on Peri Creak (Tunceli / Turkey), Pala and Çağlar (2008) recorded a total of 36 species of diatoms and found that majority of these belonged to *Gomphonema* (6 species), *Fragilaria* (5 species) and *Cymbella* (4 species) genera.

The studies cited above demonstrate that the dominant organisms in the fresh water habitats are diatoms.

In order to increase the utility of rivers, it is critical to identify the development of alga assemblages and the physical, chemical and biological factors affecting them. Accordingly, this study carried out at Koçan Falls investigated epilithic diatoms in benthic algae populations in consideration of certain physical and chemical factors. Identification of epilithic diatoms will also contribute to the compilation of a list of species in Koçan Falls.

Materials and Methods

Koçan Falls is located on the upper side of Embiyabey and Koçan districts of the Kemaliye county of Erzincan City. The falls rise as high as 150 m, particularly in spring. After turning into a small pond, the falls begin to flow. Although the intention was to collect water samples from the falls over the 12 months of the year, sampling was impossible during the winter months, when the falls froze.

In the present research, samples were collected from two stations at Koçan Falls at regular intervals from March 2014 to November 2014 for the purposes of identifying the epilithic

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algae. The first station was the rocky area 3 km from the location where the falls started descending and the second station was the rocks which were 500 m farther away from the first station.

Temperature and pH values were measured in the field using an Electromag brand pH meter, electrical conductivity (E.C. µmhos cm^{-1}) using a YSI model 33 S-C-T meter, and dissolved oxygen in the field using a YSI model 51B type oxygen meter.

The portable field devices mentioned above were calibrated before going out to the field using fixed solutions.

The stations do not suffer from any contamination and the water looks very clear and clean.

Epilithic samples in both stations were collected by scraping from the surface of the mucilaginous large rocks using a brush and were placed in sterile containers after being washed in sterile water.

After their continuous preparations were made, the diatoms were identified and counted under a Nikon microscope. The counts in continuous preparations were based on relative density and the results were presented as organism %.

Relative density (Rd) = $N_A/N \times 100$

N_A= the total number of the individuals of A species

N= the number of individuals of all species (Kocataş, 1999).

Shannon-Weaver Diversity Index was used to determine how rich Koçan Falls is in terms of species. It is observed that when there is a balanced distribution of species, the index gives higher values, and when the species are concentrated in a few families, the index values are lower. Shannon Weaver Index values were calculated using the Formula below (Shannon and Weaver, 1949).

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

H: Shannon diversity index

S: Total number of species in the community

pi: The rate of n species to S

In: Logarithm

Sorenson Similarity Index was employed to express the similarity % between two samples. This index was calculated according to the formula below.

Q/S = 2j/a+b

Q/S: Index

a: Total number of species in the first sample

b: Total number of species in the second sample

j: Number of species common in both samples (Kazancı and Dügel, 2000).

Relevant sources were used to identify the species of the diatoms (Hustedt, 1932; Prescott, 1961; Bourelly, 1968; Bourelly, 1972; Germain, 1981)

Results

Temperature, pH, dissolved oxygen and electrical conductivity values of the surface water in both stations at Koçan Falls were measured once a month from March to November 2014 with a view to determining certain physical and chemical characteristics of the falls and the results are presented in Table 1.

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The temperature of the lake water varies depending on the geographic location of the lake, its depth, surface area, the amount of dissolved substances in it, and the energy of sun it absorbs (Goldman and Horne, 1983).

Over the course of the study, the highest water temperature in the first station was found in July (19.3^{o}C) and the lowest water temperature (12.0^{o}C) was recorded in March, while the highest temperature was found in September (24.4^{o}C) and the lowest in March (14.0^{o}C) in the second station (Table 1). Although the water temperature at the location where the falls normally start flowing is about 3-4^{o}C, since the stations where the samples were taken are 3 km far from that location, the water temperature was found higher both because the water was warmed by sun and was stagnant. There was no thermal contamination regarding temperature, which varied seasonally. The water quality of the falls in consideration of mean water temperature is first grade (18.02^{o}C) (Anonim, 2004). The highest oxygen (9.6 mgO_2/L) was measured in March and April and the lowest oxygen (8.3 mgO_2/L) in August in the first station, while the highest oxygen (9.5 mgO_2/L) was measured in April and the lowest oxygen (8.1 mgO_2/L) in August in the second station (Table 1). The values of dissolved oxygen at Koçan Falls ranged between 8.1 and 9.6 mg/L. According to water contamination regulations, waters with dissolved oxygen levels above 8 mg/L are considered to have first grade quality and even the lowest dissolved oxygen value at the falls was measured to be higher than the concerned value (Anonim, 2004). The highest pH in the first station (8.4) was recorded in June and July and the lowest pH (8.0) in March, in contrast to the second station where the highest pH (8.5) was recorded in November, and the highest (8.0) in June. Pertinent to the regulations governing the water intended for human consumption, the pH value of such water must be between 6.5 and 9.5 (Anonim, 2004). The pH values of both stations in Koçan Falls range between 6 and 9. Accordingly, the water at Koçan Falls take places between grade II and grade III water quality with regard to the water contamination regulations about the quality criteria for inland waters.

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Table 1: Seasonal changes in temperature, dissolved oxygen, and pH values recorded at stations I and II of Koçan Falls (Standard deviation is expressed as ±ss; Standard error was expressed as ±sh.).

Temp.	**March**	**April**	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Nov.**
Stat. I	12.0	12.8	14.0	15.7	19.3	19.0	19.0	19.0	17.0
Stat. II	14.0	15.0	17.2	20.2	23.0	23.6	24.4	20.0	19.2
Mean	13.0	13.9	15.6	17.9	21.1	21.3	21.7	19.5	18.1
±ss	1.41	1.55	2.26	3.18	2.61	3.25	3.81	0.70	1.55
±sh	1.0	1.1	1.6	2.25	1.85	2.3	2.7	0.5	1.1
Oxygen									
Stat. I	9.6	9.6	9.5	9.3	8.5	8.3	9	8.8	8.9
Stat. II	9.3	9.5.	9	8.9	8.5	8.1	8.6	8.9	8.9
Mean	9.45	9.55	9.25	9.1	8.5	8.2	8.8	8.85	8.9
±ss	0.21	0.07	0.35	0.28	0	0.14	0.28	0.07	0
±sh	0.15	0.05	0.25	0.2	0	0.1	0.2	0.05	0
pH									
Stat. I	8.0	8.1	8.2	8.4	8.4	8.0	8.3	8.2	8.3
Stat. II	8.2	8.4	8.3	8	8.7	8.2	8.2	8.2	8.5
Mean	8.1	8.25	8.25	8.2	8.55	8.1	8.25	8.2	8.4
±ss	0.14	0.21	0.07	0.28	0.21	0.4	0.07	0	0.14
±sh	0.10	0.15	0.05	0.20	0.15	0.1	0.05	0	0.10

A total of 19 diatom taxa were recorded in the samples taken from the two stations chosen on Koçan Falls. A total of sixteen taxa, including *Cyclotella* (3 species), *Amphora* (1 species), *Cymbella* (3 species), *Gomphonema* (2 species), *Navicula* (4 species), *Nitzschia* (1 species), *Surirella* (1 species), and *Ulnaria* (1 species) were identified in the first station, and a total of 17 taxa including *Cyclotella* (3 species), *Amphora* (1 species), *Cymbella* (4 species), *Diatoma* (1 species), *Gomphonema* (2 species), *Navicula* (3 species), *Nitzschia* (2 species), and *Ulnaria* (1 species) were identified in the second station (Table 2).

In consideration of Table 2, the fact that some species were present while others were absent in the medium or that the prevalence and the number of individual members of certain species were higher than those of others suggests that the concerned diatoms make better use of environmental conditions than others. In other words, this can be considered an indicator of these species' better adaptation to different living conditions. When the similarity of taxa at the two stations was compared, the similarity rate was found 84.84% according to Sorenson Similarity Index (Table 2). The most remarkable diatoms in terms of their prevalence and relative density were *Cyclotella ocellata*, *Navicula cincta* and *Gomphonema olivaceum* in the first station (Figs. 1, 2 and 3).

The highest relative density of *C. ocellata* (8.45%) was found in April and the lowest density (4.18%) in July, while *Gomphonema olivaceum* had the highest relative density (11.70%) in November and the lowest relative density (2.64%) in May in the first station. *Navicula cincta* had the highest relative density (11.98%) in May and the lowest relative density (6.27%) in July Fig. 4).

Even though the relative densities of some diatoms in certain months were found high, these densities could not be shown in a table as their prevalence was irregular.

The major species with regard to their prevalence and relative density in the second station were *Cymbella affinis*, *Navicula radiosa* and *Navicula tripunctata*. *Cymbella affinis* displayed the highest relative density (7.63%) in March and the lowest relative density (3.43%) in August. *Navicula radiosa* had the highest relative density (8.39%) in the warmer month of July and the lowest relative density (5.06%) in April. Similar to *N. radiosa*, *Navicula tripunctata* had the highest relative density (9.44%) in July and the lowest relative density (5.34%) in March (Fig. 5).

Another species which was noteworthy in terms of its prevalence in this station was *Nitzschia amphibia*. The relative density of this diatom in June (9.62%) was the highest relative density found in all diatoms, and the relative density of *Ulnaria ulna* in the same month (1.88%) was the lowest relative density found.

Figs 6, 7 and 8 show the photographs of *Navicula radiosa*, *Cymbella affinis* and *Navicula tripunctata*, which are significant species with regard to their relative densities and prevalence in station II.

The results of Shannon-Weaver Index analysis carried out in the stations at Koçan Falls reveal that the variety of species was the highest in September (H’=3.87) and the lowest in May (H’=2.56) at station I. Station II, on the other hand, had the highest species variety in March (H’=3.36) and the lowest in November (H’=2.80) (Table 3).

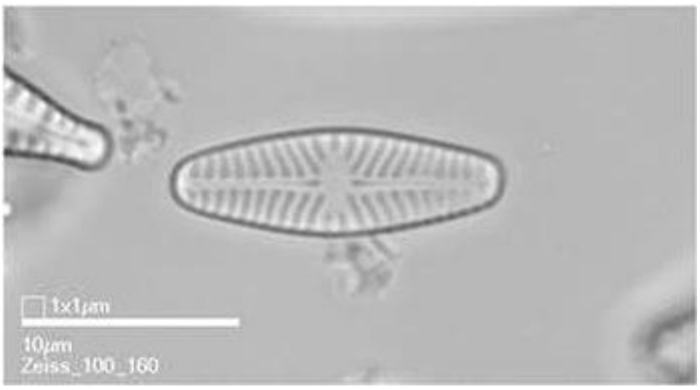

Figure 1: *Navicula cincta* (Ehr.) Ralfs (URL, 1).

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Table 2: Epilithic diatom taxa recorded in stations I and II at Koçan Falls (Erzincan).

Species	I.Station	II:Station
Cyclotella comta (Ehr.)Kütz.	+	+
C. meneghiniana Kütz.	+	+
C. ocellata Pantocksek	+	+
Amphora ovalis Kütz.	+	+
Cymbella cistula (Hemp.)O. Kircher	+	+
C. affinis Kütz.	-	+
C. parva (W Smith) Cleve	+	+
C. prostrata (Berkeley)Cleve	+	+
Diatoma vulgare Bory de Saint-Vincent	-	+
Gomphonema gracile Ehr.	+	+
G. olivaceum (Hornemann) Breb.	+	+
Navicula cincta (Ehr.) Ralfs	+	+
N. radiosa Kütz.	+	+
N. salinarum Grun.	+	-
N. tripunctata (O.F.Müller) Bory.	+	+
Nitzschia amphibia Grun.	-	+
N. linearis (Agardh) W. Smith	+	+
Surirella ovalis Breb.	+	-
Ulnaria ulna (Nitzsch.) P. Compere	+	+

+: present -: absence

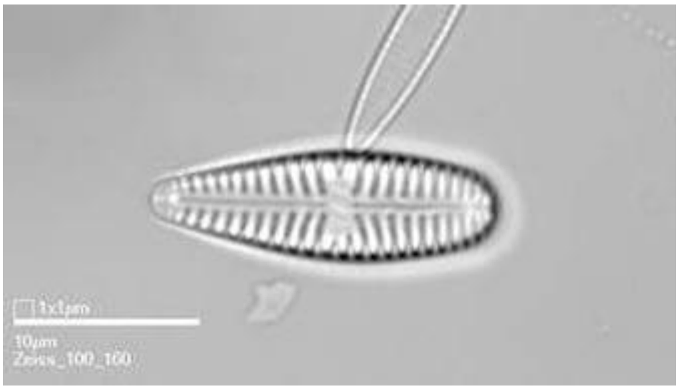

Figure 2: *Gomphonema olivaceum* (Hornemann) Breb (URL, 1).

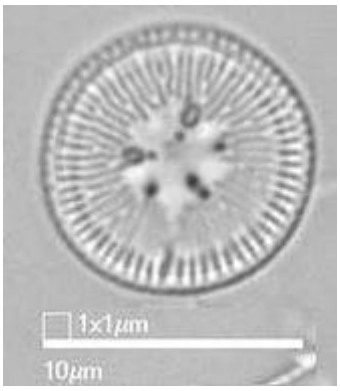

Figure 3: *Cyclotella ocellata* Pantocksek (URL, 1).

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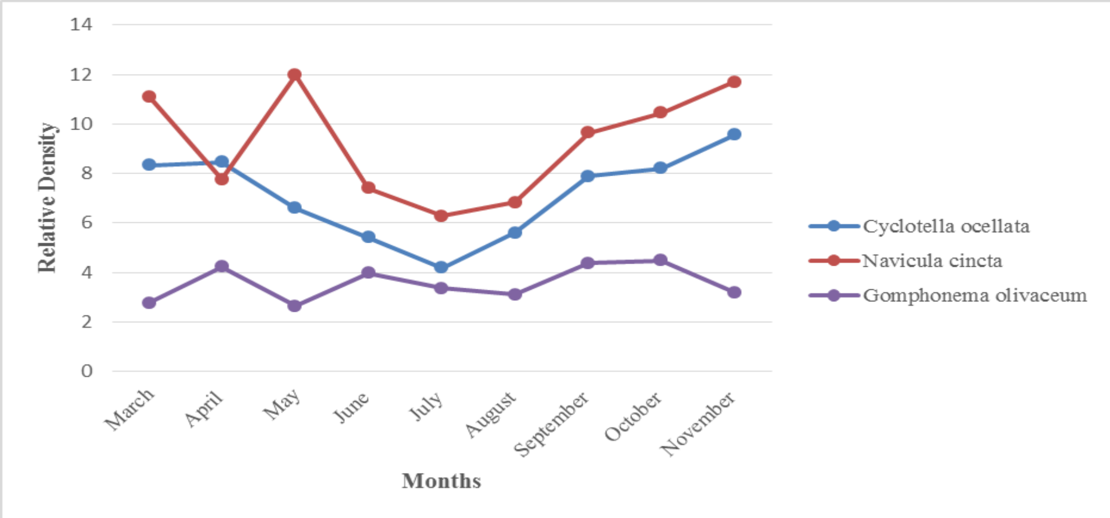

Figure 4: Seasonal varations in the relative densities of *Cyclotella ocellata*, *Navicula cincta* and *Gomphonema olivaceum* taxa in the first station.

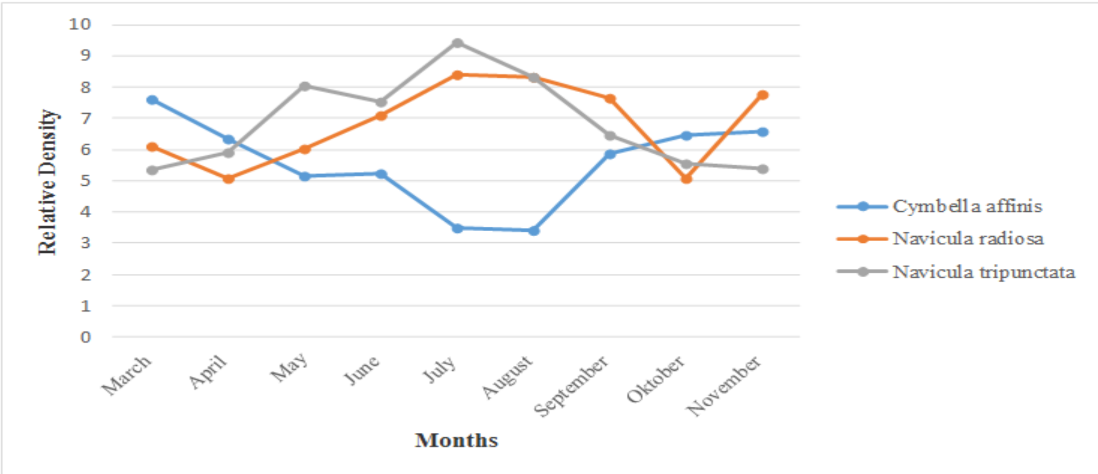

Figure 5: Seasonal variations in the relative densities of *Cymbella affinis*, *Navicula radiosa*, and *Navicula tripunctata* taxa in the second station.

Figure 6: *Navicula radiosa* Kütz (URL, 1).

Figure 7: ***Cymbella affinis*** **Kütz (URL, 1).**

Figure 8: ***Navicula tripuntata*** **(O.F.Müller) Bory. (URL, 1).**

Table 3: Shannon-Weaver Index calculated according to stations at Kocan Fall (Pi*Ln (Pi).

Months	Station I Pi*Ln(Pi)	Station II Pi*Ln(Pi)
March	2,56	3,36
April	2,72	2,92
May	3,82	2,91
June	2,89	2,89
July	2,86	2,87
August	2,82	2,86
September	3,87	2,79
October	2,72	2,81
November	2,66	2,80

Discussion and Conclusion

In the study period, a total of 19 taxa of epilithic diatoms were identified Koçan Falls. Since diatoms prevailed over other algae in terms of the number of individuals and prevalence, other algae were ignored.

Similarly, in the study they conducted on the epipelic algal flora on the Karasu (Euphrates) River, Altuner and Gurbuz (1991) found that the diatoms were the dominant group. In the group, the dominant taxa were established to be *Navicula cryptocephala*, *Cymbella affinis*, *Cymbella ventricosa*, *Amphora ovalis*, *Nitzschia palea*, and *Synedra ulna*. The diatoms which were significant in terms of their prevalence and individual numbers in the epilithic diatom flora of Koçan Falls (Erzincan) were *Cymbella affinis*, *Cyclotella ocellata*, *Navicula* *cincta*, *Navicula radiosa*, *Navicula tripunctata* and *Gomphonema olivaceum*. None of the taxa, except *Cymbella affinis*, were similar between these two studies.

Gonulol and Araslan (1992) who examined the algal flora of the Samsun-Incesu creek established that the dominant species among the epilithic algae were *Cocconeis*, *Cymbella* and *Gomphonema*. In our study, although *Cocconeis* genus was not seen, *Cymbella* and *Gomphonema* genera were found to be among the dominant species.

In a study including the alga populations in Altınapa Dam Lake and Meram Creek, Yıldız (1987) established that diatoms were more prevalent and dominant than other algae in both waters and that the dominant species among the epiphytic and epilithic diatoms in the Altınapa Dam Lake were *Synedra delicatissima*, *Navicula cryptocephala*, *Nitzschia palea*, *Cymbella microcephala*, *Cymbella amphicephala*, *Gomphonema olivaceum* and *Navicula cryptocephala*. These results are not similar to ours in terms of taxa, with the exception of *Gomphonema olivaceum*.

Studying the diatom flora on Aras River, Altuner (1988) identified *Achnanthes affinis*, *Fragilaria capucina*, *Gomphonema olivaceum*, *Navicula cryptocephala* var. *veneta*, *Nitzschia intermedia*, *N. subcapitellata* and *Surirella ovata* as the most common diatoms.

In their study titled "Epilithic Diatoms in Peri Stream (Tunceli) and Their Seasonal Variations", Pala and Çağlar (2008) recorded a total of 36 taxa of diatoms: *Gomphonema*, *Fragilaria*, *Cymbella* were the diatom genera represented by the highest number of species, while *Cymbella* spp., *Gomphonema* spp. and *Fragilaria* spp. constituted the most significant diatoms with regard to their prevalence and population size. In our study, the diatom genera with the highest representation were *Cymbella* spp., *Navicula* spp., and *Cyclotella* spp., whereas *Navicula* spp., *Nitzschia* spp. and *Gomphonema* spp. were the important diatoms in terms of their prevalence and population size.

In their study, Round (1957) and Butcher (1946) describe many of the algae to be species favoring alkaline waters. *Cocconeis placentula*, *Cymbella ventricosa*, *Gomphonema parvulum* ve *Gomphonema olivaceum*, in particular, were found to be the dominant organisms in alkaline waters. At Koçan Falls, however, only *Gomphonema olivaceum*, out of these algae, were found, while other diatoms were not.

Koçan Şelalesi' nin epilitik diyatomeleri içerisinde kaydedilen *Cymbella* spp., *Navicula* spp. ve *Ulnaria* spp., genelde iç suların tipik bentik türleri olarak rapor edilmişlerdir (Hutchinson, 1967).

Cymbella spp., *Navicula* spp. and *Ulnaria* spp., which were among the epilithic diatoms of Koçan Falls, were reported to be the typical benthic species of inner waters (Hutchinson, 1967).

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The increase in the number of diatoms particularly during summer in station II of Koçan Falls demonstrates that benthic algae can tolerate high temperatures and intense light of summer months very well and this high tolerance has already been shown in previous studies (Stanley and Daly, 1976).

Chessman (1986) noted that *Navicula* and *Nitzschia* were cosmopolitan taxa. His result is further supported by the presence of *Navicula* and *Nitzschia* species in both stations in our study.

Some diatoms identified in Koçan Falls (*Nitzschia amphibia*, *Ulnaria ulna*, *C. prostrata*) were not significant in terms of their prevalence among the epilithic alga populations, but attracted attention with the relative densities they showed in certain months. This result demonstrates that there might be a succession among diatoms when the conditions allow.

In consideration of the constant presence of diatoms among epilithic alga populations, it can be concluded that diatoms are cosmopolitan algae that can be found in all substrata.

According to the results of Shannon-Weaver index analysis, the month with the highest variety of species was September (H'=3.87) and the month with the lowest level of variety was May (H'=2.56) in station I. In the second station, March (H'=3.36) was the month with the highest species variety and November (H'=2,80) was the month with the lowest variety. That the highest number of taxa was recorded in September in station I and in March in station II is a result lending support to the Shannon-Weaver index.

Results of Sorenson Similarity Index revealed 84.84% similarity between stations I and II. This result is also supported by Table 2, where it is seen that both stations have the same 14 diatom species.

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