Study on epilithic diatoms in the Balikli Tohma Creek (Darende/Malatya in Turkey)

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Introduction

Water, being the source of life, contains many life forms. The number and diversity of algae, which constitutes the first link of the food chain, affect all living things within the aquatic environment including fish. With its streams and lakes that cover an area of approximately 10000 km^2, Turkey has very important internal water resources. About 135 of the wetlands within the borders of Turkey have international importance. Twelve of those have been declared as Ramsar areas (Anonymous, 2009).

The structure of diatom communities has been directly linked to the physical and chemical state of water. Therefore, diatoms are used in water quality calculations and comparisons among rivers that have different morpho-dynamics (Allan, 1995). The Water Framework Directive has established diatom communities as an indicator for stream systems besides the physico-chemical parameters (APHA, 1985). The inert algal species that typically cover stones and hard rocks, and exist in mucilaginous and filiform masses constitute the epilithic flora. There have been many studies in Turkey on epilithic and epiphytic diatoms. Some of those studies have been on rivers whereas some have been on creeks that periodically dry up or freeze (Altuner and Gurbuz, 1988; Dere and Sivaci, 1995; Yildiz and Atici, 1996; Pala and Caglar, 2006; Pala and Caglar, 2008; Cicek and Ertan, 2015).

The algal studies in the streams of Eastern Anatolia Region are quite limited (Pala and Caglar, 2008; Kivrak and Gurbuz, 2010; Fakioglu *et al*., 2012). This study aims to examine the diatoms and certain water quality parameters in Balikli Tohma Creek.

Furthermore, this study is significant in presenting initial data regarding the creek.

Materials and methods

Water samples were taken from three stations from Balikli Tohma Creek in Darende, Malatya Province in Turkey. A general view of the stations chosen from Balikli Tohma Creek is presented (Fig. 1).

The coordinates of the stations are given below;

Station 1: 38°31'23.82" N and 38°07'12.93"E

Station 2: 38°31'17.10" N and 38°07'23.43"E

Station 3: 38°31'08.72"N and 38°07'25.293"E

Sorensen Similarity Index was used to express the percentage of similarity among the three samples. This index was calculated using the following formula:

$Q/S = 2j/a+b$

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 to both samples (Kazanci and Dugel, 2000).

Diatoms were identified in a Nikon microscope after permanent slides were prepared with Entellan following the procedures of boiling the water samples, which were first settled by dripping lugol solution, with nitric acid and sulphuric acid of same volumes and washing away the acid. Relevant sources (Husdeth, 1932; Patrick and Reimer, 1966; Bourelly, 1968; Patrick and Reimer, 1975; Germain, 1981) were used for the identification of the diatom species.

Results and discussion

In order to determine certain physical and chemical qualities of Balikli Tohma Creek, the temperature, pH, dissolved oxygen and hardness values of the surface water in all three stations were measured once a month from April 2015 to November 2015 and the results are given in Table 1.

All three stations of Balikli Tohma Creek have first class water quality according to the inland water resources criteria (Uslu and Turkman, 1987). According to the directive regarding waters intended for human consumption, pH values should be within 6.5–9.5 (Anonymous, 2005). For Balikli Tohma Creek, the pH values of the three stations were within 8.0–8.6. The pH was within the range of first class water quality levels according to the Water Pollution Control Directive, quality criteria for inland water resources (Anonymous, 2004).

Figure 1: A general view of the stations chosen from Balikli Tohma Creek (URL).

Table 1: Monthly temperature, dissolved oxygen, pH and total hardness value variations recorded at the 1st, 2nd and 3rd stations in Balikli Tohma Creek (Average: Avg. Standard deviation: ±SD).

	April	May	June	July	August	September	October	November	Mean	±SD
Temperature										
1st station	9	10	11	13	14	13	13	12	11.875	1.72
2nd station	8	10	12	13	13	12	10	11	11.125	1.64
3rd station	8	13	16	15	16	14	13	14	13.625	2.55
Oxygen										
1st station	9.9	9.7	9.7	9.5	9.6	9.8	9.8	9.9	9.737	0.140
2nd station	9.8	9.7	9.7	9.6	9.5	9.3	9.4	9.7	9.587	0.172
3rd station	8.6	8.4	8.0	7.9	7.6	7.4	7.6	7.0	7.812	0.524
pH										
1st station	8.1	8.0	8.1	8.2	8.4	8.4	8.3	8.2	8.212	0.145
2nd station	8.2	8.3	8.1	8.5	8.3	8.2	8.1	8.1	8.225	0.138
3rd station	8.5	8.3	8.2	8.5	8.6	8.1	8.4	8.2	8.35	0.177
T. hardness										
1st station	110	117	120	116	118	90	91	100	107.75	12.360
2nd station	109	110	110	117	119	92	94	98	106.12	10.246
3rd station	112	119	120	116	122	101	111	116	114.62	6.674

USEPA (1986) classified water in terms of degree of hardness stated based on which water with 0–75 mg/L degree of hardness classifies as soft, with 75–150 mg/L degree of hardness as slightly hard, with 150–300 mg/L degree of hardness as hard and with 300 mg/L and higher degree of hardness as very

hard. According to this classification, it is determined that Balikli Tohma Creek has slightly hard water quality.

In total, 40 taxa of diatoms were identified in the samples taken from the first station in Balikli Tohma Creek. The diatom taxa that were represented with the highest number of species in this station were *Cymbella* (6 taxa), *Gomphonema* (5 taxa), *Navicula* (5 taxa) and *Nitzschia* (5 taxa). The number of species of other diatoms ranged between one and 3 (Table 2). On the other hand, the diatom species that were recorded with the highest number of individuals in the first station during the study were *Navicula tripunctata, Navicula radiosa, Encyonema minutum, Gomphonema parvulum* and *Gomphonema olivaceum.* The total recorded number of individuals of these diatom species was over 200.

Taking Table 2 into consideration, the fact that some species were present in the environment and some were not, or that the frequency of appearance of some species and the number of their individuals were higher than other species' make us think that those diatoms must have made better use of the surrounding conditions than other diatoms. In other words, this situation may be taken as an indicator showing that the adaptability of these species to different habitats is better than that of other species.

In water samples taken from the second station in Balikli Tohma Creek, 23 taxa of diatoms were identified in total which were *Cymbella* (3 taxa), *Cymbopleura* (1 taxon), *Diatoma* (1 taxon), *Encyonema* (2 taxa), *Encyonopsis* (1 taxon), *Fragilaria* (1 taxon), *Gomphonema* (3 taxa), *Halamphora* (1 taxon), *Mayamaea* (1 taxon), *Navicula* (3 taxa), *Nitzschia* (2 taxa), *Surirella* (1 taxon), *Tabellaria* (1 taxon) and *Ulnaria* (1 taxon) (Table 2). The diatom species that were recorded with the highest number of individuals in the second station during the study, on the other hand, were *Navicularadiosa, Naviculatripunctata, Gomphonema olivaceum* and *Encyonema minitum.* The total number of individuals of these diatom species varied between 167 and 186 cells/mL.

Taking Table 2 into consideration, the fact that certain species were found in the first station but not in the second and third stations can be linked to the fact that the rocks collected from the second and 3rd stations were in the flow direction of the creek. Diatoms might have therefore not held on to them.

In water samples collected from the third station in Balıklı Tohma Creek, 23 taxa of diatoms were identified in total which were *Amphora* (1 taxon) *Cymbella* (4 taxa), *Cymbopleura* (1 taxon), *Diatoma* (1 taxon), *Encyonema* (2 taxa), *Encyonopsis* (1 taxon), *Fragilaria* (1 taxon), *Gomphonema* (3 taxa), *Halamphora* (1 taxon), *Navicula* (3 taxa), *Nitzschia* (2 taxa), *Surirella* (1 taxon), *Tabellaria* (1 taxon) and *Ulnaria* (1 taxon) (Table 2).

Table 2: Monthly variations in the individual numbers of diatom species in all stations in Balikli Tohma Creek from April 2015 to November 2015.

Taxa	April	May	June	July	August	September	October	November
1st Station								
Amphora ovalis (Kütz.) Kütz.	20	25	30	25	18	13	11	9
Cymbella affinis Kütz.	26	30	41	34	22	16	9	0
*Cymbella cistula (Ehr.)*O. Kirchner	14	17	25	17	13	11	0	0
Cymbella cymbiformis C. Agardh	19	19	19	15	11	9	9	5
Cymbella helvetica Kütz.	28	35	47	31	25	17	7	4
Cymbella mesiana Cholnoky	9	11	18	14	10	7	0	0
Cymbella turgidula Grun.	26	31	31	26	20	16	8	5
Cymbopleura amphicephala (Naegeli) Krammer	23	33	48	33	21	14	6	0
*Diatoma anceps (Ehr.)*Kirchner	17	19	26	17	13	9	0	0
Diatomatenuis C. Agardh	13	15	18	13	9	6	0	0
Diatoma vulgaris Bory	24	26	34	29	24	19	13	0
Encyonema minutum (Hilse) D.G. Mann	35	40	44	35	26	18	12	7
Encyonema prostratum (Berkeley) Kütz.	21	29	37	24	19	15	6	0
Encyonopsis microcephala (Grun.) Krammer	30	38	49	31	24	13	5	0
Fragilaria acus(Kütz.) Lange-Bertalot	8	11	18	15	11	7	0	0
Fragilaria famelica(Kütz.) Lange-Bertalot	12	14	19	14	11	8	0	0
Fragilariformabicapitata D.M. Williams and Round	0	9	15	12	9	5	0	0
Gomphonema affine Kütz.	14	18	21	13	9	8	0	0
Gomphonema angustatum (Kütz.) Rabenhorst	29	34	40	26	20	15	11	9
Gomphonema longiceps	17	19	23	14	7	4	0	0
Gomphonema olivaceum (Hornemann)	32	38	48	32	24	15	10	6
Gomphonema parvulum(Kütz.) Kütz.	30	44	48	30	23	16	12	5
Halamphora veneta (Kütz.) Levkov	24	24	33	20	22	17	13	5
Mayamaeaatomus (Kütz.) Lange Bertalot	17	21	30	19	16	10	5	0
Navicula cincta (Ehr.) Ralfs	19	24	36	17	15	11	9	4
Navicula gregaria Donkin	14	19	24	15	12	8	0	0
Navicula radiosa Kütz.	25	45	51	35	27	18	13	9
*Navicula tripunctata (*O.F. Müller*)* Bory	34	41	50	31	25	20	16	9
Navicula veneta Kütz.	13	19	22	17	10	5	0	0
Nitzschia constricta (Gregory) Grun.	19	21	28	22	18	13	9	5
Nitzschia hybrida Grunow	15	15	21	14	11	7	0	0
Nitzschia palea (Kütz.) W. Smith	23	29	38	31	27	23	14	9
Nitzschia thermalis (Ehr.) Auerswold	11	14	26	21	17	11	5	0
Nitzschia vitrea G. Norman	13	17	19	16	11	9	0	0
Surirella angusta Kütz.	16	23	27	0	13	7	0	0
Surirella minuta Brebisson	21	0	34	0	28	24	16	7

Table 2 (continued):

Taxa	April	May	June	July	August	September	October	November
Surirella ovalis Brebisson	0	11	17	20	15	11	5	0
Tabellaria flocculosa (Roth) Kütz.	0	19	22	20	27	21	17	14
*Tabularia fasciculata (*C. Agardh*)* D.M. Williams and Round	0	7	10	16	13	9	6	0
Ulnaria ulna (Nitzsch.) Ehr.	0	23	26	31	26	22	14	7
2nd Station								
Cymbella affinisKütz.	22	26	37	28	17	12	5	0
Cymbella cymbiformis C. Agardh	15	15	18	10	8	5	5	
Cymbella helvetica Kütz.	25	32	36	24	22	14	6	0
Cymbella turgidula Grun.	24	29	29	22	17	12	5	0
Cymbopleura amphicephala (Naegeli) Krammer	17	31	34	25	15	10	3	0
Diatoma vulgaris Bory	21	20	26	23	18	16	8	0
Encyonema minutum (Hilse) D.G. Mann	29	37	40	22	15	13	8	3
Encyonema prostratum (Berkeley)Kütz.	13	21	32	20	14	9	0	0
Encyonopsis microcephala (Grun.) Krammer	26	31	34	26	20	9	0	0
Fragilaria famelica (Kütz.) Lange-Bertalot	16	16	13	10	7	5	0	0
Gomphonema angustatum (Kütz.) Rabenhorst	26	30	37	21	14	10	4	0
Gomphonema olivaceum (Hornemann) Brebisson	28	35	41	28	18	11	7	3
Gomphonema parvulum (Kütz.) Kütz.	25	36	44	30	18	13	6	0
Halamphora veneta (Kütz.) Levkov	15	22	27	20	16	14	9	4
Mayamaeaatomus (Kütz.) Lange Bertalot	10	16	24	19	12	9	0	0
Navicula cincta (Ehr.) Ralfs	13	21	32	17	10	7	5	0
Navicula radiosa Kütz.	19	36	45	31	23	16	10	6
*Navicula tripunctata (*O.F. Müller*)* Bory	30	34	40	27	19	15	12	7
*Nitzschia constricta (*Gregory*) Grun.*	12	17	24	19	16	9	4	2
Nitzschia palea(Kütz.) W. Smith	19	22	34	29	21	16	7	4
Surirella minuta Brebbisson	15	0	25	0	21	15	9	4
Tabellaria flocculosa(Roth) Kütz.	0	14	17	18	25	18	15	3
Ulnaria ulna (Nitzsch.) Ehr.	0	20	24	23	23	19	11	0
3rd Station								
Amphora ovalis (Kütz.) Kütz.	14	17	21	19	15	10	8	0
Cymbella affinis Kütz.	19	21	25	21	13	10	0	0
Cymbella cymbiformis C. Agardh	10	10	10	7	5	3	3	0
Cymbella helvetica Kütz.	19	28	30	16	12	9	0	0
Cymbella turgidula Grun.	21	24	24	15	10	8	3	0
Cymbopleura amphicephala (Naegeli) Krammer	14	26	27	17	12	6	0	0

Table 2 (continued):

Taxa	April	May	June	July	August	September	October	November
Diatoma vulgaris Bory	19	17	24	19	14	11	7	0
Encyonema minutum(Hilse) D.G. Mann	26	32	34	17	11	9	5	0
Encyonema prostratum(Berkeley)Kütz.	11	18	26	18	11	6	0	0
Encyonopsis microcephala (Grun.) Krammer	22	26	31	14	9	3	0	0
Gomphonema angustatum (Kütz.) Rabenhorst	22	26	29	16	12	6	0	0
Gomphonema olivaceum (Hornemann) Brebisson	25	29	37	20	16	8	4	0
Gomphonema parvulum (Kütz.) Kütz.	23	30	40	24	13	7	0	0
Halamphora veneta (Kütz.) Levkov	10	16	20	16	13	11	6	0
Navicula cincta (Ehr.) Ralfs	9	14	24	13	9	4	0	0
Navicula radiosa Kütz.	14	30	37	24	17	12	8	0
*Navicula tripunctata (*O.F. Müller*)* Bory	28	26	35	20	12	7	9	3
*Nitzschia constricta (*Gregory*) Grun.*	10	13	18	10	7	5	0	0
Nitzschia palea (Kütz.) W. Smith	15	19	30	26	17	14	0	0
Surirella minuta Brebisson	13	0	22	0	16	12	6	0
Tabellaria flocculosa (Roth) Kütz.	0	10	13	0	14	10	8	3
Ulnaria ulna (Nitzsch.) Ehr.	0	17	19	17	16	13	7	0

The diatom species that were recorded with the highest number of individuals in the third station during the study, on the other hand, were *Navicula radiosa*, *Navicula tripunctata*, *Gomphonema olivaceum*, *Gomphonema parvulum* and *Encyonema minitum*. The total number of individuals of these diatom species varied between 134 and 142 cells/mL.

According to the Sorenson Similarity Index, the similarity index between the first and second stations was 66.66; between the first and third stations, it was 67.74 and between the second and third stations, it was 97.67.

Taking Table 2 into consideration, the fact that the most significant species in terms of frequency of appearance and number of individuals were pretty much the same ones in all three stations can be a sign showing that those diatom species make better use of their surrounding conditions than other diatom species.

According to the results of physical and chemical examinations of water, Balikli Tohma Creek has first class water quality.

Cox (1984) stated that light is the most important factor in the seasonal distribution of diatoms and Round (1973) stated that among phytoplankton, diatom growth is good during early spring and summer. Epilithic diatoms were recorded more during the spring and summer months compared to the autumn months in Balikli Tohma Creek, as well.

Lund (1965) wrote that temperature and light have important effects on the growth of algae. This was found in Balikli Tohma Creek, as well, that there was a striking relationship between the water temperatures of all the stations and the growth of diatoms in them.

In this study conducted on Balikli Tohma Creek, 40 species of epilithic diatoms were recorded in total, all of which belong to the order pennales. Obali (1984) and Kairesalo and Koskimes (1985) suggest that the members of the order pennales are not real planktonic species and state that the pennate diatoms are more likely to be found in abundance among phytoplankton during times when lakes and streams are rough. Round (1981) suggests that pennate diatoms are essentially benthic forms, and that they rise to become phytoplankton through water mixtures. This finding supports the findings of Balikli Tohma Creek. It has been stated that the species of *Cymbella, Diatoma, Navicula* and *Nitzschia* are among the most encountered species in Turkey's inland waters and that *Nitzschia* is the richest species in nutrient rich waters (Cetin, 2011; Solak, 2011; Tokatli and Dayioglu, 2011).

In the study conducted by Fakioglu *et al.* (2012) in Pulur Creek, which is one of the important tributaries that drains into Karasu River, it was pointed out that the relative density of *Diatoma vulgaris* (40.67%) constitutes almost half of all species and *Navicula cryptocephala* (13.23%), *Cymbella affinis* (7.27%), *Aulacoseria granulata* (7.13%), *Nitzschia sigmoidea* (6.30%) and *Gomphonema olivaceum* (5.62%) come after this species, respectively. In Balikli Tohma Creek, as well, the most important diatoms in terms of frequency of appearance and number of individuals were *Cymbella, Gomphonema, Navicula, Nitzschia, Encyonema* and *Diatoma.* Due to the fact that diatoms are the dominant species among epilithic algae, other algae were dismissed in this study conducted on Balikli Tohma Creek. This finding is also supported by the studies of other researchers (Yildiz, 1987; Altuner and Gurbuz, 1989; Gonulol and Arslan, 1992; Pala and Caglar, 2008).

In the study Altuner and Gurbuz conducted on the epipelic algal flora of Karasu (Euphrates) River, *Navicula cryptocephala, Cymbella affinis, Cymbella ventricosa, Amphora ovalis, Nitzschia palea* and *Synedra ulna* were observed as the dominant species. The dominant species among the epilithic diatoms of Balikli Tohma Creek were *Navicula tripunctata, Navicula radiosa, Encyonema minitum* and *Gomphonema olivaceum.*

Chessman (1986) stated that *Navicula* and *Nitzschia* species are cosmopolitan. The fact that *Navicula* and *Nitzschia* were found in various studies in Turkey (Yildiz, 1987; Altuner and Gurbuz, 1989; Sahin, 1998; Pala and Caglar, 2006; Pala and Caglar, 2008) supports this idea. These species

were also encountered in all of the stations in the Balikli Tohma Creek.

In conclusion, the epilithic diatoms of Balikli Tohma Creek were examined in this study and it was found that the number of species at the first station was higher than the number of species at the second and third stations. This was because the rocks collected from the second and third stations were in the water flow direction. There was not much difference between the second and third stations in terms of species numbers. This study reveals the first data regarding Balikli Tohma Creek. It is very important to present the ecological characteristics of our country's water resources, and to develop monitoring programs for their sustainable use by researching water resources in different regions.

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