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EVALUATIONS OF EPILITHIC DIATOMS AND BIOTIC INDEX IN SAKARYA RIVER, TURKEY

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Abstract

Diversity and ecology in the diatoms of Sakarya River were investigated between October 2009 - September 2010. As a result, *Navicula radiosa* Kütz was the dominant taxa at the first and fourth stations. *Gomphonema olivaceum* (Horrn.) Brébisson, *Craticula cuspidata* (Kütz.) D.G. Mann, *Rhoicosphaenia abbreviata* (C. Agardh) Lange-Bertalot, and *Nitzschia recta* Hantzsch ex Rabenhorst taxa were found to be widespread throughout the research. Significant correlation was identified between SI and DI-CH and between TI and DI-CH in the epilithic diatoms. The minimum correlation was identified between SI and TI. Based on the assessments, according to SI, the fourth station was classified as II-III quality class, or critically polluted. Other stations were classified as II quality class, or moderately polluted. According to TI, the first station was determined to be II-III (mesotroph-eutroph) quality class. Second, third and fourth stations were found to be III (polytroph) quality class. According to DI-CH, the fourth station was classified as quality class IV (moderately polluted), while the first, second and third stations were determined as III (less polluted) quality class.

The environmental variables on the RDA diagram were selected ($p<0.05$) according to Monte Carlo permutation test. The first and second axis explained 89% of variation of the species in the correspondence analysis. Additionally, the first and second axis explained relationship between species and environmental variables at the rate of 34.6% and 61.1%. The RDA axes scores allow us to distinguish 5 diatom species assemblages with a total of 25 species.

Key words: River, Epilithic, RDA, Swiss Diatom Index (DI-CH), Trophic Index (TI) and Saprobic Index.

Introduction

The Sakarya River is one of the most important water sources in Turkey. The river is subject to chemical and biological pollution because it is deeply inland, there is over-population and there are many industrial activities. Furthermore, domestic waste, abattoirs and agricultural activities are further sources of pollution in the the region. There are several studies related to water quality and the sources of pollution of the Sakarya River (Atici, 1997; Sengorur & Isa 2001; Celik & Pulatsu 2003; Ozel *et al*., 2004; Balcioğlu & Ozturk 2009; Solak *et al*., 2012).

Diatoms are a key component of aquatic ecosystems. They respond directly and rapidly to many environmental parameters such as geology, current velocity and nutrients. Diatoms, which can be found in every surface water at any time, are an important part of water quality monitoring organisms. They have been used in a number of countries as indicators of water pollution (Kelly & Whitton, 1995; Stevenson & Pan, 1999; Kalyoncu *et al*., 2009; Solak, 2011; Tokatli *et al*., 2012; Atici & Yildiz 2012). At the same time, diatom community structure along environmental and spatial gradients were investigated in a lot of research (Soininen & Weckström, 2009; Wang *et al*., 2012; Ryves *et al*., 2003; Vilbaste *et al*., 2000; Poulickova *et al*., 2004)

The aim of this study was to evaluate the diatom composition of Sakarya River with diatom indices (Swiss Diatom Index (DI-CH), Trophic Index (TI) and Saprobic Index (SI)). In addition to, Redundancy Analysis (RDA) with variation was employed to examine the spatial structure of diatom communities.

Materials and Methods

The total length of Sakarya River together with its branches, which rise from near the Çifteler District of Eskişehir, is 824 km. The length of the river within the boundary of Adapazari Province is 159.5 km and it passes through four km. east of downtown Adapazari. Sakarya River, after taking the Mudurnu Stream and Çark water, which drains the excess water of Sapanca Lake, flows into the Black Sea from Karasu District Center (Atici & Yildiz, 2012). In order to study the diatoms of Sakarya River, four stations were chosen. The locations of the stations are given in Figure 1. The first station is the part of Sakarya River passing underneath the Ferizli Bridge. Water is quite turbid and medium-flowing, and the ground is muddy with both large and small stones. There is no real aquatic plant life in this part of the river. At the second station, which is in the Liman Dere region of the river, the water is turbid and the flow rate of the river is slower than at the first station, and the ground is muddy. This station is quite rocky and no aquatic plant life exists. The third station is in the Tuzla region and the water is turbid as in the first and second stations. Flow rate is quite slow, and the ground structure is miry. Stone characteristics are similar to the second station, and no aquatic plant life exists. There are residential areas around this station. The fourth station is in the Karasu Yenimahalle region of Sakarya River. The river flows into the Black Sea approximately 300m after this point. In this station some, fish restaurants and fishing boats exist. The water is quite turbid and calm, the ground is rather muddy, and there are some large and small stones on the shore. There is no real aquatic plant life, as is the case at the other stations (Fig. 1).

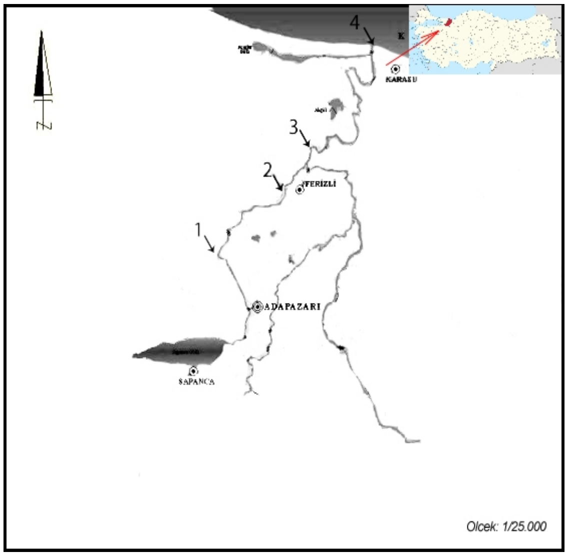

Fig. 1. Study area.

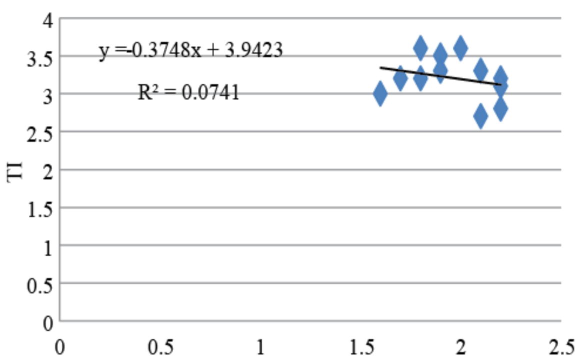

Fig. 2. The relationship between TI and SI indices.

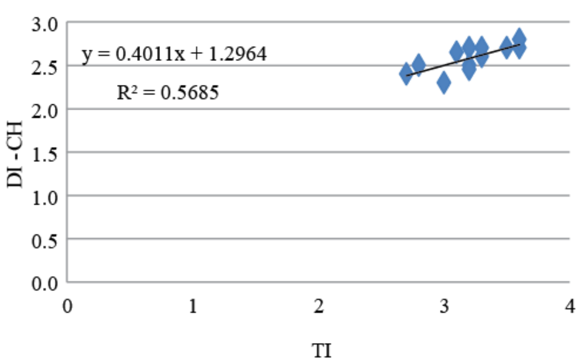

Fig. 3. The relationship between DI-CH and TI indices.

Seasonal samples of epilithic diatoms from four stations were taken at Sakarya River between October 2009 and September 2010. The diatoms were sampled by scraping the 25 cm^2 upper surface of the epilithon with a stiff toothbrush and collected in 250 ml sample bottles. The composition and relative abundance of diatoms was identified at 1000x magnification from acid-cleaned sub-samples, counted separately. Cleaned frustules were mounted on permanent slides using Naphrax resin. Diatoms were identified from the literature (Patrick & Reimer 1966, 1975; Findlay & Kling 1979; Krammer & Lange- Bertalot 1991a-b; Round *et al*., 1990, Anonymous I, 2014). The scientific names of diatoms were checked with the AlgaeBase website Guiry & Guiry, 2016). Saprobic Index (SI) according to Rott *et al*.,1997, Swiss Diatom Index (DI-CH) according to Buwal, 2002, Tropic Index (TI) according to Vogel, 2004 were evaluated. The correlation analysis was done according to Pearson and statistical analyses were carried out on Statistical Package for the Social Sciences (Anonymus II, 2004).

In addition to, the nature of variability of epilithic diatome assemblages was analyzed by using Detrended Correspondence Analysis (DCA). DCA indicated that the diatom specis assemblages showed linear variation within the Down Sakarya River. The relationship between epilithic diatome species and environmental variables was investigated with a direct analysis (Redundancy Analysis, RDA). The detection of significant ($p<0.05$) ecological variables was done by Monte Carlo permutation test (499 permutations) with automatic forward selection (Ter Braak & Barendregt, 1986). The Bray-Curtis Similarity Index and MDS were computed on the species abundancy to determine the similarity between stations and to analyze the spatial distribution pattern by using log (x+1) transformed data (Clarke & Warwick 2001).

Results

A total of 25 epilithic taxa belonging to Bacillariophyta were determined. A higher abundance of epilithic diatoms was recorded at the first and fourth in comparison to the other stations. Throughout the study, *Navicula radiosa* Kütz was dominant at stations one and four (Table 1).

Significant correlation was identified between SI and DI-CH and between TI and DI-CH in the epilithic flora (Figs. 2-3). The minimum correlation was identified between SI and TI. Sakarya River contains different water quality regions but according to SI, the fourth station was classified as II-III quality class, or critically polluted. Other stations were classified as II quality class, or moderately polluted. According to TI, the fourth station was determined to be III quality (polytroph) class. First, second and third stations were found to be within the II-III (mesotroph-eutroph) quality class. According to DI-CH, the fourth station was classified as quality class IV (moderately polluted), first, second and third stations were determined to be III (less polluted) quality class in the epilithic.

In the ordination based on the RDA (Fig. 4), the length and direction of the variable arrows indicate their importance and their approximate correlation to the ordination axis, respectively. The location of species scores relative to the arrows indicates the environmental preferences of each species. The environmental variables on the RDA diagram were selected ($p<0.05$) according to Monte Carlo permutation test. The difference in diatom composition among substrates was found to be significant in the Monte Carlo permutation test ($p<0.05$) The sampling seasons were used as nominal variables in the RDA analysis. The first and second axis explained 89% of variation of the species in the correspondence analysis. Additionally, the first and second axis explained relationship between species and environmental variables at the rate of 34.6% and 61.1%. The RDA axes scores allow us to distinguish 5 diatome species assemblages with a total of of 25 species.

Table 1. The percentage of epilithic diatoms in the Down Sakarya River.

Taxa	1.Station %	2.Station %	3.Station %	4.Station %
*Amphora ovalis (*Kütz.) Kütz.	-	-	8.3	-
Cocconeis pediculus Ehr.	16.6	25	8.3	8.3
Craticula cuspidata (Kutzing) D.G.Mann	16.6	25	50	50
Cymatopleura solea (Breb.) W. Smith	-	8.3	16.6	-
Encyonema minutum (Hilse) D.G.Mann	8.3	-	16.6	8.3
Gomphonema angustatum (Kütz.) Rabh.	25	16.6	16.6	16.6
Gomphonema olivaceum (Horn.) Brébisson	25	16.6	41.6	50
Hantzschia amphioxys (Ehr.) Grun	-	-	-	33.3
Melosira varians C.Agardh	8.3	8.3	16.6	16.6
Navicula cari Ehr.	-	-	8.3	16.6
Navicula radiosa Kütz.	66.6	50	50	66.6
Navicula rhynchocephala Kütz.	8.3	8.3	16.6	16.6
Navicula tripunctata (O.F.Müller) Bory	-	-	8.3	*
Neidium dubium (Ehr.) Cleve	8.3	-	-	-
Nitzschia acicularis (Kütz.) W.Smith	-	8.3	-	-
Nitzschia filiformis (W. Smith) Van Heurck	16.6	-	8.3	8.3
Nitzschia recta Hantzsch ex Rabh.	25	8.3	25	50
Nitzschia sublinearis Hustedt	25	16.6	8.3	16.6
Pinnularia major (Kütz.) Rabh.	16.6	-	-	16.6
Pinnularia microstauron (Ehr.) Cleve	8.3	8.3	8.3	16.6
Rhoicosphaenia abbreviata (C. Agardh) Lange-Bertalot	33.3	16.6	33.3	50
Surirella ovalis Brebisson	33.3	33.3	33.3	41.6
Tryblionella acuta (Cleve) D.G.Mann	-	-	8.3	-
Ulnaria delicatissima (W.Smith) Aboal & Silva	8.3	16.6	-	16.6
Ulnaria ulna (Nitzsch) Compère	16.6	16.6	25	33.3

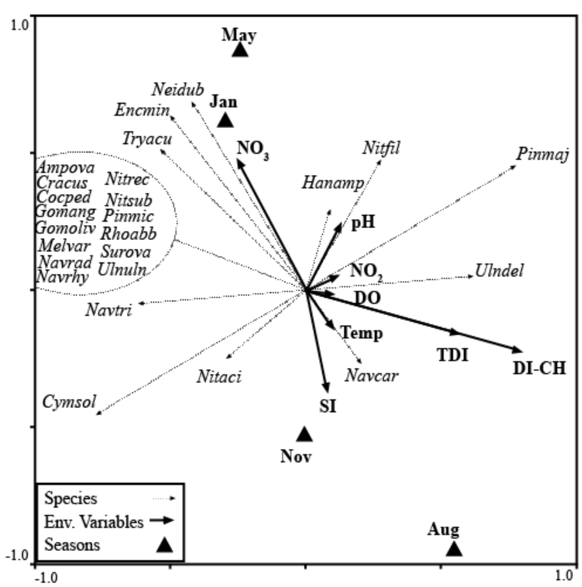

Fig. 4. The environmental variables on the RDA diagram. Epilithic samples with species indicated by arrows: Navrhy, *Navicula rhynchocephala;* Cracus, *Craticula cuspidata;* Gomoliv, *Gomphonema olivaceum*; Gomang, *Gomphonema angustatum;* Melvar, *Melosira varians;* Ampova, *Amphora ovalis;* Cocped, *Cocconeis pediculus;* Navrad, *Navicula radiosa;* Ulnuln, *Ulnaria ulna;* Surova, *Surirella ovalis;* Rhoabb, *Rhoicosphaenia abbreviata;* Nitrec, *Nitzschia recta;* Nitsub, *Nitzschia sublinearis;* Pinmic, *Pinnularia microstauron;* Cymsol, *Cymatopleura solea;* Navtri, *Navicula tripunctata;* Nitaci, *Nitzschia acicularis;* Navcar, *Navicula cari;* Hanamp, *Hantzschia amphioxys;* Nitfil, *Nitzschia filiformis;* Unldel, *Ulnaria delicatissima*; Pinmaj, *Pinnularia majör;* Tryacu, *Tryblionella acuta;* Encmin, *Encyonema minutum;* Neidub, *Neidium dubium.*

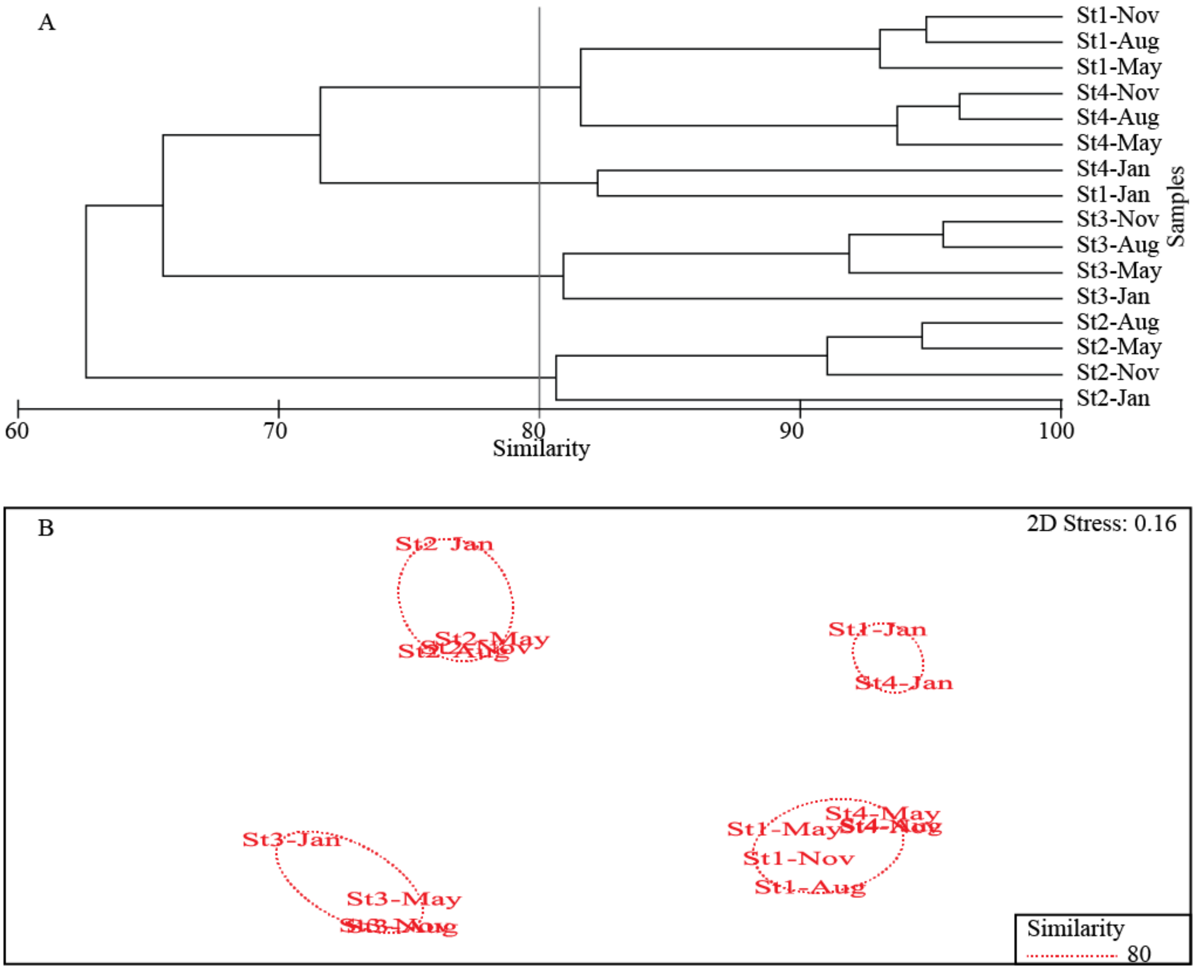

Fig. 5. Dendrogram for clustering of the sampling station with seasons during the study period in Sakarya River according to the species abundancy data based on Bray–Curtis similarities (a) and MDS ordination (b).

According to Figure 5, it was determined that St1-Jan and St4-Jan came together and formed a group and the fourth and last group was only composed of the samples of station 2.

Discussion

A total of 25 epilithic belonging to Bacillariophyta were determined. A higher abundance of epilithic diatoms was recorded at the first and fourth stations compared to the other stations. Throughout the study, *Navicula radiosa* was dominant at the first and fourth stations. These taxa, according to Saprobic Index (Austria) and Saprobicity (Netherlands) are tolerant of moderate to heavy organic pollution and β-mesosaprobous. In the research, *Gomphonema olivaceum, Craticula cuspidata, Rhoicosphaenia abbreviata* and *Nitzschia recta* were widespread and observed frequently. Three hundred species were detected in a similar study done at that part of Sakarya River where the Beş Köprü Village Region and Ankara Creek are mixed into the river, and flow into Sariyar Dam after curling (Gönülol *et al.,* 1996). In our study, a total of 25 species was determined. It is thought that sampling at different locations of the river, the flow rate, physical and chemical parameters and variability of the habitats could have an effect on this qualitative difference. Bacillariophyta members detected in Sakarya River were also encountered in the studies carried out on the lentic and lotic aquatic ecosystems of our country (Gürbüz & Kivrak, 2002; Aysel, 2005; Gönülol, 2016). The classifications (Diatom based indices; TI, DI-CH and SI) in this study according to diatoms correspond to the classifications of other research (Kalyoncu *et al*., 2009; Tokatli, 2012). In this research, significant correlation was identified between SI and DI-CH and between TI and DI-CH in the epilithic diatoms. The minimum correlation was identified between SI and TI.

Sakarya River contains different water quality regions and according to SI, the fourth station was classified as II-III (Beta-alfa-mesosaprob) quality class, or critically polluted. Other stations were classified as II quality class, or moderately polluted. According to TI, the fourth station was determined to be III (polytroph) quality class. First, second and third stations were found within the II-III (Beta-alfa-mesosaprob) quality class. According to DI-CH, the fourth station was classified as quality class IV (moderately polluted), First, second and third stations were determined to be III quality (less polluted) class in the epilithic. The structure of benthic diatom communities in Sakarya River is a function of geographical and anthropogenic factors. Anthropogenic activities, fish restaurants and fishing boats also played an important role in determining benthic diatom communities in the study. Overall, while the first, second and third stations indicated similar values to each other, it was detected that the fourth station had a significantly contaminated water quality. The reason for the fourth station to have such a negative quality seems to depend on the fact that there are seafood (fish) restaurants and fishing boats in the area and that the area is open to public usage, which causes contamination by organic materials. It has been determined in studies conducted in Turkey that most of the diatom indices effectively represent the quality changes in rivers (Gürbüz & Kivrak, 2002; Kalyoncu *et al.,* 2009; Solak, 2011).

According to this research distribution of *Navicula rhynchocephala, Craticula cuspidata, Gomphonema olivaceum, G. angustatum, Melosira varians, Amphora ovalis, Cocconeis pediculus, Navicula radiosa, Ulnaria ulna, Surirella ovalis, Rhoicosphaenia abbreviata, Nitzschia recta, N. sublinearis* and *Pinnularia microstauron* species have all environmental variables have powerfull impact and concluded that these variable are not responsible for his distrubition. In the RDA analysis, water temperature and SI associated with the August period *Navicula cari* showed a strong positive correlation with the current water temperature. Water temperature and nutrients (TN and TP) were the most critical factors driving phytoplankton community shift in the abundance and biomass data. However, biogeographic distribution of diatom species had the strongest relationship with surface temperature (Esper *et al*., 2010). Temperature, which manages the seasonal changes of benthic algae, the thermal stratification, and the mixing of the water column, seems to be one of the principal controlling mechanisms of the periodicity of diatom species in phytoplankton (Koçer & Şen, 2012). Similar results were also identified in this study.

In our research, the dissolved oxygen and NO_2 values were determined to have a strong impact on *Hantzschia amphioxys* and *Nitzschia filiformis*. In the study carried out on the epilihtic algae of Köprüçay River, it was stated that dissolved oxygen was an important factor which affected the development of aquatic biota and the chemical variables of BOD, electrical conductivity, ammonium nitrogen, orthophosphate and nitrate nitrogen also had a high impact on algae diversity (Çiçek & Ertan, 2012). Our findings were determined to have similar results with the diatom studies performed (Sengorur & Isa, 2001; Ryves *et al*., 2003; Aysel, 2005; Esper *et al*., 2010; Gönülol, 2016). In general, the assessments based on diatoms were found to be useful for the evaluation of specific trophic situations and variations along the shores of rivers (point-pollution sources). According to Bray–Curtis similarities and MDS ordination, it was determined that St1-Jan and St4-Jan came together and formed a group and the fourth and last group was only composed of the samples of station 2. This situation is thought to be due to the number species in the station being fewer than in the other stations, current velocity and the physical and chemical structure of it.

In the study carried out in Sakarya River, a correlation was found between the epilithic algae diversity and the physicochemical properties and it was determined that as well as water pollution, the physical properties of the river might also have an important impact on biodiversity. At the same time, long-term monitoring studies are clearly required to better understand the succession and productivity of epilitic diatoms in the river.

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