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PROOF RESEARCH PAPER

Using Epilithic Algae Assemblages to Assess Water Quality in Lake Kovada and Kovada Channel (Turkey), and in Relation to Environmental Factors

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Abstract

In this study, distribution of epilithic algae assemblages in Lake Kovada and Kovada Channel, their relationships to environmental factors, and biological water quality were investigated. Epilithic algae and water samples were taken from four stations (one in the channel, others in the lake), between June 2012-May 2013 seasonally. Totally 51 taxa were observed belonging to the groups Bacillariophyta (37), Chlorophyta (8), Charophyta (4) and Cyanobacteria (2), respectively. The stations were clustered into main two groups based on UPGMA. The highest similarity value was determined between third and fourth station (94%). Saprobic Index (SI) was applied in order to determine biological water quality. Physicochemical parameters have been evaluated according to the Klee's method and Regulation on the Management of Surface Water Quality in Turkish (RMSWQ). According to the Klee's method, water quality was found unpolluted in Kovada Lake, and its channel while it was found as polluted based on RMSWQ. Biological water quality values indicated Lake Kovada as poorly polluted, but its channel as polluted. According to CCA, 84.6% of the variance was described by the first four axes of the relations of species and environmental variables (r=0.963), and pH, conductivity and Cl^- were found to be the most influential variables on distribution of dominant taxa.

Keywords: Lake Kovada, Saprobic Index, water quality, benthic algae, CCA.

Introduction

Freshwater systems are the most important natural resources for all living organisms. There are 1.4 billion km^3 water in the world and 3% of this value is freshwater systems. Nowadays water resources are polluted with various reasons as rapid population growth, unplanned urbanization, industrialization, and agricultural activities. (Kocataş, 2006; Cirik & Cirik, 2008). Contamination of water resources leads to irreversible problems (Atalık, 2006). Thus water pollution issue has an increasing importance in the world (Palmer, 1980; Gönülol & Obalı, 1986). Lakes comprise an important part of natural ecosystems with a lot of features, such as biological diversity, fishery, recreation, and hydrologic cycle. Above mentioned various negative influences cause to pollution in lakes (Kristensen & Hansen, 1994; Dodson, Arnott, & Cottingham, 2000).

Generally, planktonic primary production is investigated in order to determine the productivity of trophic levels in lakes. However, recent studies showed that primary production exists in both planktonic and benthic habitats. Benthic algae have significant effect to littoral zone and whole-lake in primary production (Vadeboncoeur, Peterson, Vander Zanden, & Kalff, 2008; Sadro, Melack, & MacIntyre, 2011; Althouse, Higgins, & Zanden, 2014). Water quality of freshwater systems should be designated according to physicochemical and biological data. Organisms are sensitive to fluctuations in their habitats. For this reason, physicochemical parameters are commented couple with biological approaches. Existence of some organisms or disappearance can show long-term changes in water quality, while chemical parameters reflect instantaneous water quality (Barlas, 1995; Kazancı, Girgin, Dügel & Oğuzkurt, 1997; Güler, 2003). Benthic diatoms are one of the most important organisms for determining water quality in freshwater systems (Garrido, Romo, & Villena, 2013). Several diatom-based indices were developed and these indices have been used in a number of countries (Whitton & Kelly, 1995; Kelly & Whitton, 1995; Lirika, Aleko, & Alqi, 2011; Bennion, Burgess, Juggins, Kelly, Reddihough, & Yallop, 2012; Lirika, Aleko, & Alqi, 2013). The Saprobic

Index was used for the first time in Turkey in order to assess the water quality of the Isparta Stream by the Kalyoncu and Barlas (1997). There are several studies about determine of water quality with Saprobi index in Turkey (Kalyoncu, Barlas, Ertan, & Gülboy, 2004; Kalyoncu 2006; Solak, Barinova, Ács, & Dayıoğlu, 2012; Kalyoncu & Şerbetçi, 2013). The aims of this study were to determine water quality based on benthic algae and physicochemical parameters, and to explain effects of some physicochemical variables on the dominant species occuring in Lake Kovada and its channel.

Materials and Methods

Study Area

Lake Kovada is one of the important surface waters of Turkey. The lake is located in the south of Eğirdir and the east of Isparta (Turkey). It forms natural extension of Lake Eğirdir. It was divided as a result in loading silty of narrow zone years ago, and actually has become a separate lake (Anonymus, 2016). The deepest point of Lake Kovada, a karst-tectonic lake, is about 7 m and the average width is about 2-3 km (Arslan & Şahin, 2006). The lake and its environment were declared as Natural Protected Area I in 1992. Kovada Channel, lenght 22 m, provides a link between Eğirdir and Lake Kovada. The water of Lake Eğirdir is transported by this channel to Lake Kovada (Figure 1).

Sampling Method

Physical and Chemical Sampling and Analysis

Water samples were taken from each stations seasonally (Jun 2012-May 2013), and analyzed within 24 hours after taken. Water temperature, pH, dissolved oxygen (DO) and conductivity were measured with YSI 550A meter, YSI EcoSense pH110A pH meter, YSI EcoSense EC300A conduvtivity meter, during sampling in the study area. Mg^{+2}, Ca^{+2}, Cl-, $NH4^{+}$-N, NO_2-N, NO_3-N, PO_4-P, ΣP, and total hardness determined in the laboratory according to Standard methods (Greenberg, Connors, Jenkins, & Franson, 2005). Physicochemical variables were evaluated according to Klee's method (Klee, 1991) and Regulation on the Management of Surface Water Quality in Turkish (Anonymus, 2012).

Epilithic Algae Sampling and Evaluation

Epilithic algae were taken from the four stations seasonally (between June 2012-May 2013). Samples of benthic algae were collected by brushing or scraping the upper surface of stones (cobbles or small boulders) obtained from the littoral zones of lake (Anonymous, 2014). The samples, fixed with 4% formaldehite. Samples were boiled with equal volume acid mixture (H_2SO_4:HNO_3) for identification of diatoms. The residue was washed vigorously with distilled and deionized water (DDW) to remove residual acid and then the diatom samples were fixed in Entella medium, at least 300 valves of epilithic diatom were counted (Round, 1953; Anonymous, 2014). Algae were identified under x100 Nikon microscope according to taxonomic keys (Pestalozzi, 1955; 1968; 1982; 1983; Prescott, 1973; 1978; Hustedt, 1985; Krammer & Lange-Bertaloth, 1986; 1988; 1991a,b; Bourrlly & Couté, 1991; Komárek, 2000; 2008; John, Whitton, & Brook, 2005). We use algaebase data base for algae list Guiry and Guiry (2016), and Gönülol (2016). Also, author names are given in abbreviated form according to Brummit and

Figure1. Study area and stations.

Powell (1992). Biological water quality was determined according to Saprobi index (Rott, Hofmann, Pall, Pfıster, & Pıpp, 1997; Vogel, 2004). Physicochemical water quality was evaluated according to the Klee's method (1991) and Regulation on the Management of Surface Water Quality in Turkish (RMSWQ) (Anonymous, 2012). Biodiversity was determined with Shannon-Wiener and Simpson diversity indices, and a clustering analysis of unweighted pair group mean averages (UPGMA) was applied to determine the similarities between four stations, based on algae taxa using MVSP 3.1 (Multi Variate Statistical Package) (Kovach, 2002). Relationship between biodiversity values and individual numbers was determined with Spearman's correlation analysis using SPSS (16.0) package program. Algae assemblages and their relation with environmental variables were determined by Canonical Correspondence Analysis (CCA) using CANOCO 4.5 package (Ter Braak & Šmilauer, 2002).

Results

During the study period, physicochemical values changed according to seasons and stations in Lake Kovada and its channel. The water temperature varied between 3.2 ^{0}C (in winter) and 23.7 ^{0}C (in summer). The maximum dissolved oxygen was evaluated in winter as 13.45 mg L^{-1} at station 4, and the minimum value 2.3 mg L^{-1} in autumn at station 1 (Kovada Channel). pH values were measured between the values 6.98 and 10.2 with minimum recorded in winter at station 4, and the maximum in autumn at station 2. The conductivity (25°) ranged between 304.2 µS/cm in autumn at station 1, and 226.6 µS/cm in summer at station 2. The NH_4-N, NO_3-N, NO_2-N, PO_4-P and ΣP mg L^{-1} values were measured in trace quantities generally. The maximum value evaluated for NH_4-N was 0.14 mg L^{-1} at station 4 in winter; for NO_2-N 0.046 mg L^{-1} at station 3 in winter; for NO_3-N 0.45 mg L^{-1} at station 2 in summer; for PO_4-P 1.27 mg L^{-1} and for ΣP 5.21 mg L^{-1} at station 1 in winter. The level of Cl^- ranged from 6.2 mg L^{-1} to 35.5 mg L^{-1} ; Ca from 17.64 mg L^{-1} to 38.49 mg L^{-1} , Mg from 8.74 mg L^{-1} to 32.07 mg L^{-1} , total hardness from 94.52 mg L^{-1} to 174.64 mg L^{-1} at all stations (Table 1). As a result of samplings, total of 51 taxa belong to Bacillariophyta (37), Chlorophyta (8), Charophyta (4), Cyanobacteria (2) were identified in study area (Table 2). Bacillariophyta comprised 72.3% of total taxa, *Cymbella* and *Navicula* (five species) represented the most species number. *Diatoma vulgaris*, *Encyonema minutum*, *Epithemia sorex*, *Ulnaria ulna* were observed constant in stations (Table 2). Dominant taxa changed according to seasons and stations. During this research *Epithemia sorex* Kütz., *Navicula capitatoradiata* H.

Table 1. Distributions of physichochemical variables according to stations in Lake Kovada and Kovada Channel

Physichochemical variables	St 1	St 2	St 3	St 4
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
	Min-Max	Min-Max	Min-Max	Min-Max
Temperature (oC)	13,80±7,87	15,15±8,60	15,42±8,11	14,10±7,40
	3,2-21,7	3,2-23,7	3,7-22,4	3,2-19,6
O2 (mg/l)	9,29±4,62	12,36±0,90	11,83±1,28	11,63±2,57
	2,9-12,96	11,22-13,4	9,95-12,85	7,8-13,45
pH	8,47±0,78	8,46±0,98	8,99±1,25	8,50±1,06
	7,36-9,16	7,18-9,4	7,28-10,21	6,98-9,4
Conductivity (µS/cm)	264,77±29,87	268,48±24,21	265,68±30,21	264,73±25,36
	231,4-298,8	251,3-304,2	226,6-291,5	244,5-301,2
Cl- (mg/l)	15,75±7,75	39,05±11,03	19,61±13,17	21,39±11,26
	6,20-24,85	10,65-35,5	17,64-38,49	24,60-32-08
NH4-N (mg/l)	0,067±0,01	0,12±0,04	0,07±0,05	0,06±0,04
	BDL*-0,11	0,025-0,13	BDL*-0,13	BDL*-0,14
NO2-N (mg/l)	0,0115±0,001	0,014±0,001	0,014±0,025	0,041±0,026
	BDL*-0,016	BDL*-0,015	BDL*-0,04	BDL*-0,06
NO3-N (mg/l)	BDL*	0,26±0,19	BDL*	BDL*
		0,05-0,45		
PO4 –P (mg/l)	0,46±0,70	BDL *	0,11±0,07	0,035±0,04
	BDL*-1,27		BDL *-0,16	BDL *-0,1
ΣP(mg/l)	2,04±2,32	1,64±0,54	0,42±0,26	0,32±0,16
	0,28-5,21	0,3-1,38	0,13-0,69	0,15-0,5
Ca (mg/l)	29,27±4,01	56,13±8,73	29,007±3,71	31,27±4,62
	24,06-33,68	17,64-38,49	24,6-32,08	27,27-35,28
Mg (mg/l)	21,14±4,44	34,98±6,49	21,38±5,32	23,81±7,54
	15,55-26,24	8,74-23,23	14,58-27,21	14,58-32,07
Total Hardn.	135,33±23,37	261,76±38,48	146,38±25,93	152,39±22,47
	113-167,25	94,52-170,44	118,76-174,64	118,76-165,80

Tablo 2. Species frequency (%) and distributions according to stations

	Sta 1	Sta 2	Sta 3	Sta 4
Bacillariophyta				
Bacillariophyceae				
Amphora ovalis (Kütz.) Kütz.	50	75	75	75
Cocconeis placentula Ehrenb.	50	50	25	50
Cocconeis placentula var. *euglypta* (Ehrenb.) Grunov	50	25	-	-
Cymatopleura elliptica (Bréb.) W. Sm.	25	-	25	25
Cymatopleura solea (Bréb.) W. Sm.	-	-	50	-
Cymbella affinis Kütz.	25	100	75	75
Cymbella aspera (Ehrenb.) Cleve	50	25	50	25
Cymbella cistula (Ehrenb.) O. Kirchn.	50	100	50	50
Cymbella helvetica Kütz.	25	25	75	25
Cymbella lanceolta (C. Agardh) C. Agardh	25	50	75	75
Diatoma tenuis C. Agardh	-	-	25	25
Diatoma vulgaris Bory	100	100	100	75
Diploneis ovalis (Hilse) Cleve	25	25	25	25
Encyonema leibleinii (C. Agardh) W. J. Silva *et al*.	25	50	-	-
Encyonema minutum (Hilse) D. G. Mann	100	75	100	100
Encyonema silesiacum (Bleisch) D. G. Mann	25	75	50	50
Epithemia adnata (Kütz.) Bréb.	50	50	50	75
Epithemia sorex Kütz.	50	100	75	100
Fragilaria acus (Kütz.) Lange-Bert.	25	25	-	-
Gomphonema acuminatum Ehrenb.	-	25	-	-
Gomphonema parvulum (Kütz.) Kütz.	25	75	50	50
Gomphonema truncatum Ehrenb.	25	50	-	25
Gyrosigma acuminatum (Kütz.) Rabenh.	25	-	-	-
Gyrosigma attenuatum (Kütz.) Rabenh.	50	25	25	25
Halamphora venata (Kütz.) Levkov	50	25	-	-
Navicula sp.	25	-	-	-
*Navicula capitato*radiata H. Germ.	50	75	75	75
Navicula cari Ehrenb.	75	75	75	100
Navicula cincta (Ehrenb.) Ralfs	25	25	-	-
Navicula radiosa Kütz.	25	75	25	75
Nitzcshia palea (Kütz.) W. Sm.	50	100	75	25
Nitzcshia sigmoidea (Nitzsch) W. Sm.	-	25	-	-
Rhoicosphenia abbreviata (C. Agardh) Lange-Bert.	50	25	50	75
Rhopalodia gibba (Ehrenberg) O. Müll.	-	50	75	75
Rhopalodia gibba var. minuta Kramm.	-	50	75	25
Ulnaria ulna (Nitzsch) Compére	100	100	100	75
Coscinodiscophyceae				
Melosira varians C. Agardh	-	50	25	-
Charophyta				
Conjugatophyceae				
Closterium sp.	-	-	25	-
Cosmarium obtusatum (Schmidle) Schmidle	25	25	-	-
Spirogyra sp.	25	-	-	0
Staurastrum sp.	-	25	-	0
Chlorophyta				
Chlorophyceae				
Acutodesmus acuminatus (Lagerh.) Tseranko	25	25	-	-
Desmodesmus communis (E.H. Hegew.) E.H. Hegew.	75	75	50	50
Monactinus simplex (Meyen) Corda	-	25	25	-
Monactinus simplex var. *echinulatum* (Wittr.) Pérez et. al.	-	25	-	-
Pseudopdiastrum boryanum (Turpin) E.H. Hegew.	25	50	25	25
Pseudopediastrum boryanum var. *longicorne* (Reinsch)	25	-	50	25
Scenedesmus obtusus Meyen	25	-	-	-
Stauridium tetras (Ehrenb.) E. H. Hegew.	50	-	25	50
Cyanobacteria (Cyanophyta)				
Cyanophyceae				
Merismopedia tenuissima Lemmerm.	-	25	25	25
Oscillatoria tenuis C Agarh ex Gomont		25		

Germ., *Nitzschia palea* (Kütz.) W.Sm., *Diatoma vulgaris* Bory, *Gomphonema parvulum* (Kütz.) Kütz., *Diatoma tenuis* C.Agardh were detected as dominant species of the study region (Figure 2).

According to Shannon Wiener (H') and Simpson (D) diversity indices, biological diversity values were determined in the channel and lake. The lowest diversity (H':2.4 and D: 0.75) was observed in winter season while the highest diversity (H':4.1 and D:0.93) was determined in summer season in the channel. Biological diversity values were not found seriously different among stations in the lake. However the highest biodiversity (H': 3.85 and D:0.89) was determined in the summer and the lowest biodiversity (H': 2.15 and D:0.57) was detected in the spring season in the lake (Table 3). Negative important correlation were found between biodiversity and individual numbers (r_S= -0.594 P<0.05 for Shannon Wiener; r_S=-0.545 P<0.05 for Simpson). Similarity between the stations was investigated by using Sorensen's similarity index, and the highest similarity was determined between stations 3 and 4 (94%) for dynamics of epilithic algae (Figure 3).

The water quality of Lake Kovada and Kovada Channel was found to be unpolluted (class I) based on Klee's (1991) method. According to Regulation on the Management of Surface Water Quality in Turkish station 3 and station 4 are polluted (class III) in all seasons while station 1 in spring and in autumn, station 2 in summer and in autumn. Saprobi Index values showed variation among the stations and seasons (Table 4). The water quality class of Kovada Channel was found to be moderate pollution in the autumn while slightly polluted in other seasons. Biological water quality of Lake Kovada was found slightly polluted (class I-II) in spring (in the stations 2 and 3), in winter (in the stations 2 and 4) and in autumn (station 4) seasons, while moderate polluted (class II) in summer (station 2), and autumn (stations 2 and 3). When the Saprobi Index values of the channel

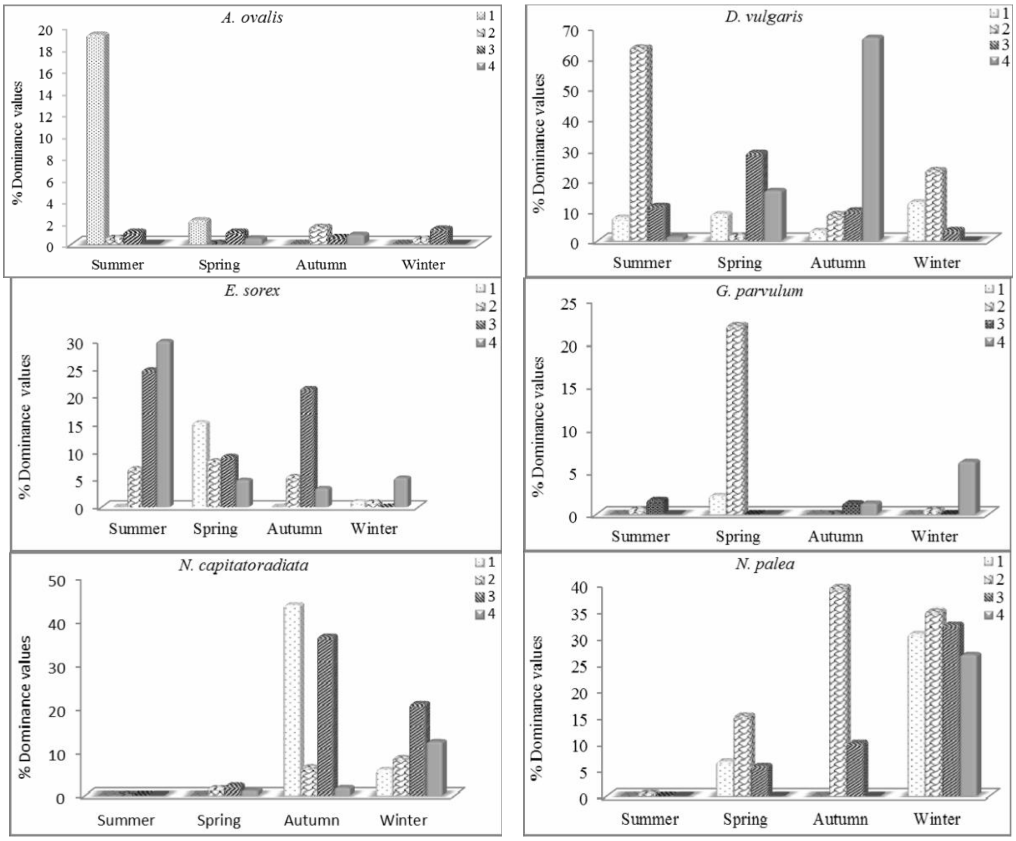

Figure 2. Distributions of some dominant taxa according to seasons.

Table 3. Shannon Wiener (H') and Simpson (D) Diversity Index values of the stations

	St 1		St 2		St 3		St 4	
Seasons	H'	D	H'	D	H'	D	H'	D
Summer	4,16	0,93	2,66	0,62	3,85	0,89	3,59	0,87
Autumn	2,68	0,76	3,45	0,81	2,97	0,80	2,51	0,62
Winter	2,45	0,75	2,87	0,82	2,51	0,78	3,06	0,84
Spring	4,07	0,92	3,52	0,88	2,15	0,57	2,23	0,63

increased, similarly an increase also detected in the lake (Figure 4).

The relationships between water temperature, pH, dissolved oxygen, nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), total phosphorus (TP), orthophosphate (PO_4-P), and the abundance of dominant species were explored using the statistical method of Canonical Correspondence Analysis (CCA). According to CCA, the first and second axis were explained %64.9 of total variance (Table 5). Dissolved oxygen, NO_3-N, total hardness, water temperature, pH, conductivity and Cl^- parameters positively correlated with first axis while PO_4-P and NH_4-N were negatively correlated. Distribution of *D. vulgare*, *E. adnata*, *E. sorex*, *R. abbreviata*, *C. cistula*, *S. quadricauda* and *R. gibba* were positively related with temperature, total hardness, dissolved oxygen, conductivity, pH, NO_3-N, Cl-. However NH_4-N and PO_4-P negative affected to distribution of these species. *C. cistula* and *R. abbreviata* were positively correlated with temperature and total hardness yet negatively correlated with PO_4-P and NH_4-N. Temperature was determined as the most effective factor for these taxa. *D. vulgare* was positively correlated with dissolved oxygen, temperature, total hardness and NO_3-N and the most effective parameters were dissolved oxygen and total hardness. *E. sorex* was positively affected with pH, furthermore *S. communis* closely related to this parameter. According to secondary axes, PO_4-P was positively related to distributions of *U. ulna*

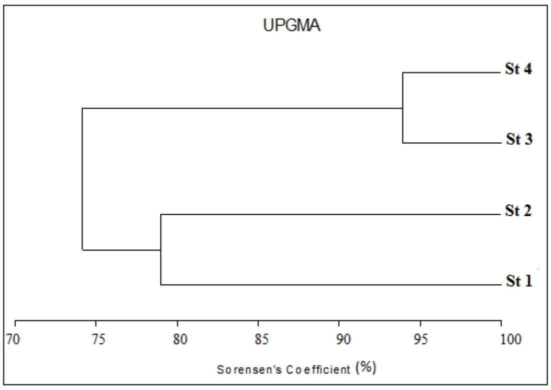

Figure 3. UPGMA dendrogram for four stations.

Tablo 4. Physicochemical and biological water quality classes according to seasons and stations

	St 1			St 2			St 3			St 4		
	SI	Kle e	WPC R	SI	Kle e	WPC R	SI	Kle e	WPC R	SI	Kle e	WPC R
Summer	I-II	I	II	II	I	III	I	I	III	I	I	III
Autumn	II	I-II	III	II	I	III	II	I	III	I-II	I	III
Winter	I-II	I-II	II	I-II	I	II	II	I	III	I-II	I	III
Spring	I-II	I	III	I-II	I	III	I-II	I	III	I	I	III
Mean	II	I	III	I-II	I	III	I-II	I	III	I	I	III

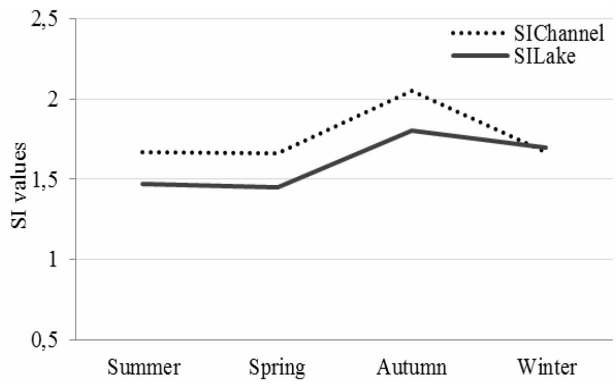

Figure 4. Saprobi Index values in Lake Kovada and its channel.

and *N. cari* whereas temperature, total hardness were negatively related to these taxa (Figure 5).

Discussion

In this study, water temperature ranged between 3.2 °C and 23.7 °C at the stations as mentioned above. Water temperature is one of the important parameters affecting distribution of organisms in aquatic ecosystems. Lake temperature changes according to lake surface area, depth, absorbed solar energy, and seasons (Tanyolaç, 2011; Egemen, 2000; Cirik & Cirik, 2008). Zeybek (2012) reported that water temperature showed an alteration seasonally in the Lake Kovada and its channel**.** The maximum pH value was 10.21 in autumn while the minimum was 6.98 in winter. In aquatic systems pH is closely associated with especially dissolved CO_2 level in water. pH of freshwater lakes is generally ranging between 6 and 9 (Tanyolaç, 2011; Wetzel & Likens, 2000). According to the pH values, Lake Kovada and its channel have alkaline characteristic. Similar results emphasized in other studies related to Lake Kovada **(**Gülle, 1999; Zeybek, Kalyoncu, & Ertan, 2013). The minimum dissolved oxygen value was determined in autumn while the maximum value was in winter. The maximum dissolved oxygen was measured as 13.45 mg L^{-1} at station 4, and the minimum value as 2.3 mg L^{-1} at station 1. Yüce and Ertan (2014) reported that value of dissolved oxygen was ranged from 1.8 to 25.7 mg/l in the channel while Zeybek *et al*. (2013) stated that the lowest dissolved oxygen was determined as 2.63 mg/l. The highest conductivity (304.2 µS/cm) was determined at station 2, in the connection area of the water of channel and lake, in autumn. Zeybek *et al*. (2013) reported that the highest conductivity was detected in Kovada Channel. Cl^- values were determined between 6.2 in autumn, and 35.5 mg/l in summer. The highest value was detected in the lake. Yüce (1999) mentioned that mean value of Cl^- was 22.69 mg/l in Lake Kovada. The NH_4-N, NO_3-N, NO_2-N, PO_4-P and ΣP mg L^{-1} values were measured trace quantities generally. PO_4-P and ΣP values increase in channel while the others in lake. Total phosphor determines productivity in aquatic systems (Wetzel, 2001). In water body 0,1 mg/l phosphor concentration is measure of water quality for eutrophication (Egemen, 2000). This result showed that the channel was affected by organic pollution. This situation probably arised from waste of cold storage depots and cultivated areas. A study related to determination of trophic status was informed that the channel was hypereutrophic according to total phosphor (Zeybek, Kalyoncu, & Ertan, 2012). In the clean waters NO_2-N is found in trace quantities or is absent while in polluted waters with organic matter reaches high concentrations (Girgin & Kazancı, 1994). The highest NO_2-N was determined between BDL-0.046 mg/l in winter. NO_3-N should

Table 5. The results of canonical correspondence analysis

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.249	0.097	0.065	0.041	0.693
Species-environment correlations :	0.955	0.988	0.953	0.963	
Cumulative percentage variance					
of species data :	35.9	50.0	59.4	65.4	
of species-environment relation:	46.7	64.9	77.2	84.6	
Sum of all eigenvalues			0.693		
Sum of all canonical eigenvalues			0.534		

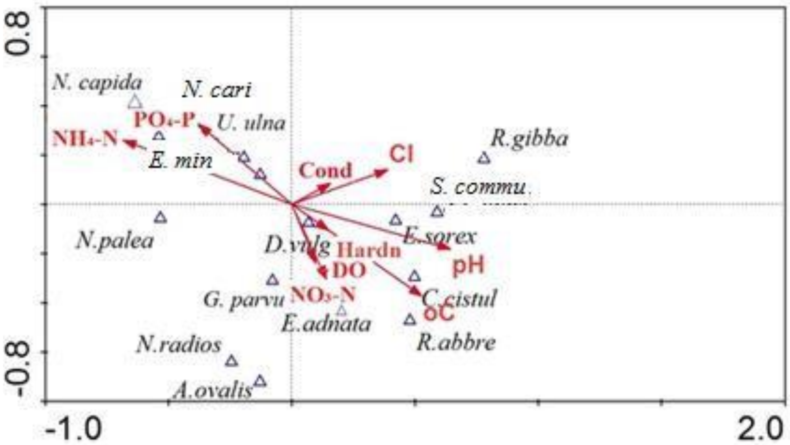

Figure 5. Ordination diagram of the CCA analysis.

be less from 1 mg/l (Anonymous, 1997). During the research period the highest NO_3-N was determined as 0.19 mg/l.

Bacillariophyta comprised the predominant group in the epilithic community. In the studies related to benthic algae in lakes similar results were notified (Şahin & Akar, 2005; Pala & Aker 2014; Yüce & Gönülol 2016). *Epithemia sorex* Kütz., *Navicula capitatoradiata* H. Germ., *Nitzschia palea* (Kütz.) W. Sm., *Diatoma vulgaris* Bory, *Gomphonema parvulum* (Kütz.) Kütz., *Diatoma tenuis* C.Agardh were determined as dominant taxa. Şahin (2002) reported that *C. minuta* (*E. minutum*) was the most common taxa in Yedigöller. In a study conducted in Palandöken Pond *Nizschia palea*, *Synedra ulna* (*U. ulna*), *Epithemia sorex*, *Cymbella minuta*, *Gomphonema parvulum* were report as dominant and constant taxa of epilithic flora (Gürbüz, 2000). Mean values of Shannon Wiener and Simpson diversity indices were lowest in winter. The highest epilithic algae density was determined in this season which was caused by the increase of *N. palea*. This taxa was dominant in all stations in winter season. Negative important correlation were found between biodiversity and individual numbers (r_S= -0.594 $P<0.05$ for Shannon Wiener; r_S=-0.545 $P<0.05$ for Simpson). When total cell number increase, caused by dominant taxa, diversity index values decrease (Coelho, Gamito, & Pe´rez-Ruzafa, 2007; Sevindik, Altunal, & Küçük, 2015). The highest diversity values (Shannon Wiener and Simpson diversity index) were found in station 1 (Kovada Channel). Zeybek *et al*. (2013) reported that the highest biodiversity values based on oligochaetes and chrinomids was determinated in also Kovada Channel. According to Sørensen's similarity index, the highest similarity was detected between station 3 and station 4 (%94), and the lowest similarity (0.73 %) between station 2 and station 4. According to Klee's method (1991), physicochemical water quality was determined unpolluted (class I) in Lake Kovada and its channel while according to Regulation on the Management of Surface Water Quality in Turkish polluted (class III). Biological water quality was found moderately polluted (class II) in Kovada Channel, and slightly polluted (class I-II) in Lake Kovada. In Lake Kovada and its channel Saprobi Index values increased in autumn.

In the CCA diagram *E. sorex* occurred near the pH vector. When pH values were high, individulas of this taxa were dominant. *E. adnata* positively correlated with the NO_3-N, dissolved oxygen, temperature, pH. Yüce and Gönülol (2016) reported that *E. adnata* become dominate taxa when pH values increased. *R. abbreviata* positively correlated with the total hardness and temperature, while showed negative correlation with PO4-P and NH4-N. Veraat, Romaní, Tornés and Sabater (2008) mentioned that nutrient enrichment caused increase of these taxa. *D. vulgare* occurred near the dissolved oxygen, temperature, total hardness and NO_3-N. *D. vulgare* was dominant in summer and autumn. It was reported that this species is able to grow fastly better light and nutrient conditios (Snoeijs, 1990). Dönmez and Maraşlıoğlu (2016) emphasized that temperature affected the seasonal variations and the density of epilithic diatoms. *U. ulna* and *N. capitatoradiata* positively correlated with PO_4-P and NH_4-N. Palmer (1969) reported that *Navicula* was tolerant to organic pollution and includes pollution-resistant diatom. *U. ulna* was the most tolerant taxa to organic matter concentration increase (Lange-Bertalot, 1979; Gómez, 1998). Consequently we can say that Kovada Channel and Lake Kovada were under the pollution effect, and especially Lake Kovada was negatively influenced from the pollution of the channel. As a result of CCA analysis, the distribution of the benthic algae were closely correlated particularly with variations in dissolved oxygen, total hardness, temperature, pH, NO_3-N, NH_4-N, and PO_4-P.

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