



Structure of the Zooplankton Community in Sıddıklı Küçükboğaz Dam Lake, Türkiye: The Importance of Environmental Factors

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Received: 6 February 2021 / Accepted: 19 April 2023
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Abstract

The zooplankton fauna of Sıddıklı Küçükboğaz Dam Lake, located in Kırşehir city in Turkey, was researched as monthly between September 2015 and August 2016. A total of 24 major zooplankton species was determined. Zooplanktonic organisms were presented by three main groups: Rotifera (75%), Cladocera (21%) and Copepoda (4%). The minimum and maximum number of species were revealed in May (4 species) and April (12 species), respectively. Rotifera was the most abundant taxon dominated mainly by the species *Keratella cochlearis*, *Polyarthra dolichoptera*, *Asplanchna priodonta* and *Synchaeta pectinata*. *Brachionus*: *Trichocerca* quotient value of 1.00 was estimated. This result has clearly showed that the Sıddıklı Küçükboğaz Dam lake is oligotrophic. All species of Rotifera, Cladocera and Copepoda group are new records for this dam lake. The fundamental data of the Sıddıklı Küçükboğaz Dam Lake are provided, and the relationships between zooplankton and environmental parameters have researched in this study. Also, this study was supported by academic basics for monitoring a reservoir in Central Anatolia. Redundancy analysis (RDA) showed that all environmental indicators accounted for 34.1% total variance of zooplankton. Besides, RDA results demonstrated that zooplankton abundance is correlated with biological oxygen demand, water temperature, total suspended solid, ammonium and total ammonia nitrogen.

Keywords Zooplankton · Environmental factors · Dam lake · Redundancy analysis (RDA)

1 Introduction

The substance groups of zooplankton in freshwater ecosystems are Rotifera, Cladocera and Copepoda. (Segers 2004). Some lakes in Europe have shown clear changes in

zooplankton community structure and richness along a eutrophication gradient. The zooplankton biomass increased with total phosphorus for all major groups (Jeppesen et al. 2011). Large Lake Peipsi and the very eutrophic Lake Vörtsjärv have shown that both abundance and biomass of zooplankton increase with eutrophication (Haberman 1996, 1998). Zooplankton diversity, good

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indicator of the health of aquatic ecosystems, is generally high in shallow lakes (García et al. 2009). Variance in zooplankton abundance, species diversity or community composition can supply significant indication of environmental variance or disturbance (Bulut and Saler 2018). Since zooplankton feeds heavily on phytoplankton, these organisms also play an important role in controlling the phytoplankton population in the ecosystem (Güher and Demir 2018).

Crustacean zooplankton are sensitive to individual stressors (Wei et al. 2019). In many aquatic ecosystems of Turkey such as Çaygören reservoir (Çelik et al. 2019), Hasan Uğurlu and Suat Uğurlu Dam Lakes (Bozkurt and Akın 2012), Van Lake (Yıldız et al. 2010), Ladik Lake (Apaydın Yağcı et al. 2015), Abant Lake (Gürbüz et al. 2019), Kapıkaya reservoir (Bulut and Saler 2020), Demrek Dam Lake (Bozkurt and Kara 2020) and Uzungöl Lagoon (Özdemir et al. 2021), zooplankton species diversity were varied. It has been reported that this change is related to the structure of aquatic ecosystems and the change of trophic structure (Bozkurt and Akın 2012). Also, they may be recommended in assessing the quality of lake waters, though crustacean indices of trophic state of lakes seem to be less useful than other biological indices (Ejsmont-Karabin and Karabin 2013). Accordingly, ecologists and biologists stated to with the focus on taxonomy, ecology of zooplankton communities of inland water ecosystems and the relationships between environmental variables and zooplankton community structure in ponds or lakes (e.g. Cottenie 2001; Bozkurt and Akın 2012; Gündüz et al. 2013; Lehtovaara et al. 2014; Gökçe and Özhan Turhan 2014; Dai et al. 2014; Apaydın Yağcı et al. 2017; Bulut and Saler 2018; Li et al. 2019). Lakes that are strongly linked with other elements of biota are especially sensitive to environmental changes. The canonical correlation analysis indicated that numerous species have been indicative of changing environmental conditions (Adamczuk et al. 2015). Zooplanktonic organisms rather tolerant to different environmental conditions can be used for the biomonitoring of water ecosystems (Gökçe and Özhan Turhan 2014). On the other hand, it has been reported that Rotifera change is affected by the physical variable (pH, temperature, dissolved oxygen concentration, conductivity) and Crustacean change is related by the total phosphorus variable (Dorak et al. 2019). Previous studies have greatly helped us to understand some fishery research, assessment of toxic metals in sediments and water quality in this dam lake (Ünver 2011; Anonymous 2011; Yılmaz and Ünver 2014; Teber 2013; Akkan et al. 2018a, b). In this paper, zooplankton species that have never been studied in this dam reservoir are presented. The current study aimed to gauge the determine Rotifera, Cladocera and Copepoda species and their monthly variations. Furthermore, this study has

determined the relations between physicochemical factors with zooplankton and the trophic state of Sıddıklı Küçükboğaz Dam Lake.

2 Material and Methods

2.1 Site Description

Sıddıklı Dam Lake located near Sıddıklı Küçükboğaz Village, 40 km west of Kırşehir province, was built for irrigation. It has a surface area of 1.62 km² and an active water level of 25.3 hm³. Irrigation of 4945 ha of the agricultural area is done with this dam water.

2.2 Field Sampling and Sample Processing

Zooplankton samples were collected on a monthly bases between September 2015 and August 2016 from 2 different stations in Sıddıklı Küçükboğaz Dam Lake (Fig. 1). Zooplankton samples were taken horizontally using a plankton net having a mesh size of 55 µm (diameter = 57 cm), and they were fixed with formalin solution immediately after collection in 250-mL dark bottles. Species were examined under an Olympus model stereo, invert and binocular research microscopes, and the species were determined to the species level using the keys of Kiefer (1952, 1955), Dussart (1967, 1969), Koste (1978), Negrea (1983), Smirnov (1996), and Nogrady and Segers (2002). Trophic structures were examined in the identification of Rotifera species. Dissecting procedures were performed for the identification of Cladocera and Copepoda species. A zooplankton species checklist was controlled according to Ustaoglu (2004), Ustaoglu et al. (2012) and Ustaoglu (2015). Water quality values obtained by Akkan et al. (2018a) were used in this paper. The values of environmental parameters such as water temperature, conductivity, total dissolved solids, pH, salinity and dissolved oxygen were determined in an simultaneous study and described in Akkan et al. (2018a).

2.3 Data Analysis

Bray Curtis distance measurement was taken in the cluster analysis. Flexible beta was used to convert the data ($\beta = -0.25$). Statistical analysis was devised using PC-ORD 6.0 (Cune and Mefford 2011). Firstly, Kruskal–Wallis test was applied in order not to cause any confusion in the relation of both species (zooplankton) and stations with all independent variables. Secondly, the relationships between the previously discriminated groups (3 groups formed in clustering analysis) and environmental variables were examined. Kruskal–Wallis test was carried out using

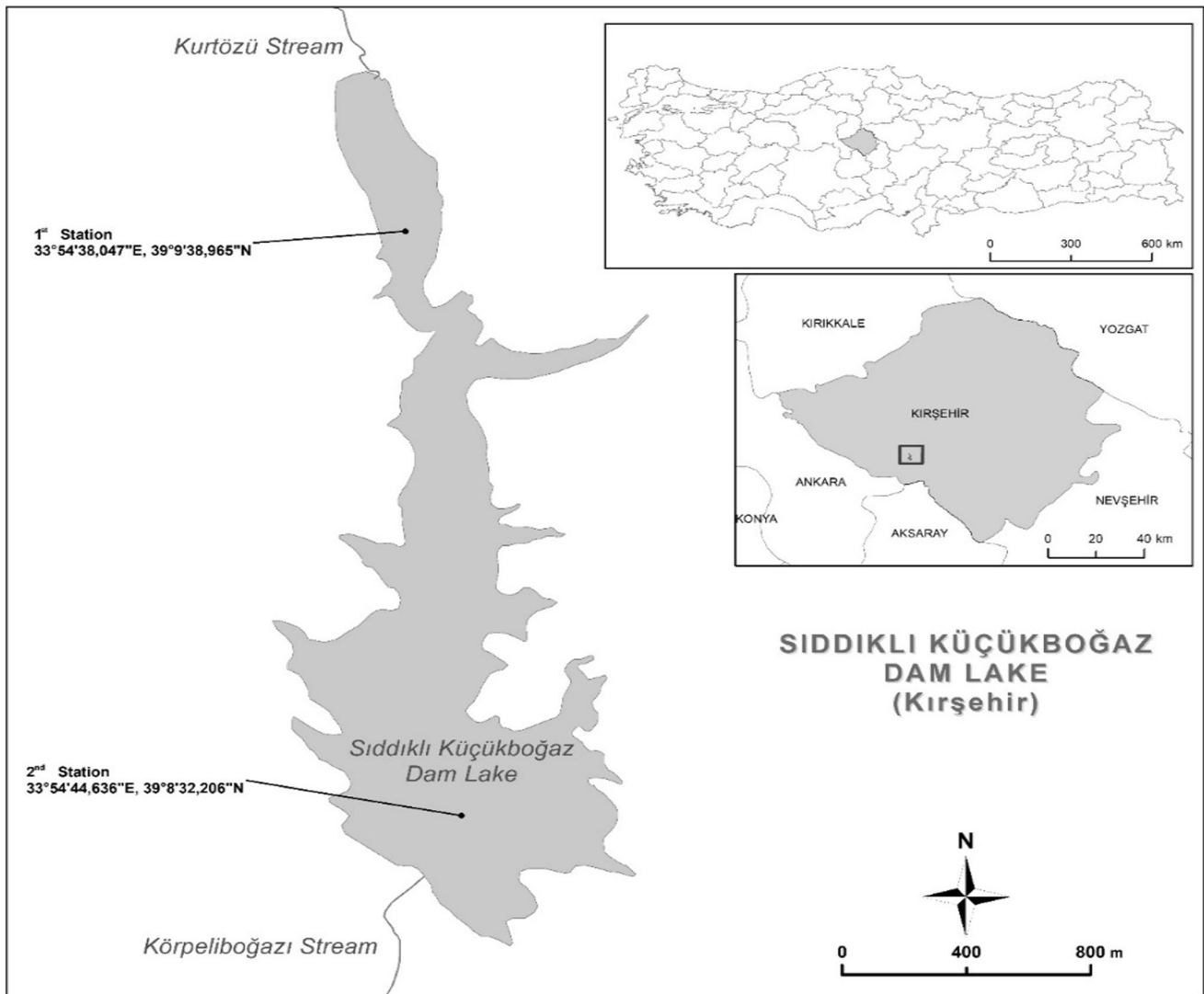


Fig. 1 Sampling stations and the study area

SPSS 20 software package. Statistically significant variables according to $p = 0.05$ were analyzed with stations and species by ordination methods. RDA was preferred in ordination methods. RDA and PC-ORD analysis were used to find a connection between water quality and zooplankton assemblages (Legendre and Legendre 1998). Discordance was observed in the distribution of station I in April. In this case, the station I in April was compared with all stations and months and was associated with Chi-square analysis (Özdamar 1997). Soyer's (1970) frequency index ($F\%$) was determined to define the frequency of species in the study area, and results were predicted as constant ($F \geq 50\%$), common ($50\% > F \geq 25\%$) or rare ($F < 25\%$).

This index (F) for special species was utilised using $F = m/M \times 100$, where m = the number of stations for the species and M = the number of two stations. QB/T (The *Brachionus:Trichocerca* quotient) was assessed to

calculate the trophic structure of the lake. Sládeček (1983) informed that a quotient of 1 indicated oligotrophic conditions, while a quotient between 1 and 2 corresponds to mesotrophic conditions and a ratio of > 2 was encountered in eutrophic lakes. Shannon's diversity index (H') was calculated for zooplankton data (Molles 2002), where H' : index of species diversity, P_i is the proportion by the number of zooplankton species i , s = number of species.

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

The Simpson's diversity index (D) was calculated using the following equation: where n_i = proportion of the i th taxon in the community. s = number of taxa; n = number of species (Simpson 1949).

$$D = - \frac{\sum_{i=1}^s n_i(n_i - 1)}{n(n - 1)}$$

In the water samples, firstly, the normality of the data was tested. Then, the variables showing normal distribution were analyzed by independent samples *t* test, whereas the variables showing abnormal distribution were analyzed by Mann–Whitney *U* test.

3 Results and Discussion

3.1 Water Quality Variables and Trophic Indicators

A summary of the physicochemical conditions at the study stations is presented in Table 1. Secchi disk reading varied from a maximum of 174.7 ± 15.3 cm at station I to a minimum of 152.7 ± 14.5 cm at station II, while the mean Secchi depth at all stations and months was 163.66 ± 10.54 cm (Table 1). Moreover, the difference between the stations was not statistically important ($p > 0.05$).

3.2 Zooplankton community

A total of 24 zooplankton species belonging to Rotifera, Cladocera and Copepoda were found in Siddikli Küçükboğaz Dam Lake (Table 2). The most dominant group was Rotifera (75%), followed by Cladocera (21%) and Copepoda (4%). The distribution of zooplankton groups by the station is shown in Fig. 2. According to frequency index values, 6 zooplankton species were divided as constant ($F \geq 50\%$), 5 zooplankton species were divided as common ($50\% > F \geq 25\%$), and 14 zooplankton species were divided as rare ($F < 25\%$). It was determined that *P. dolichoptera* species from Rotifera had the highest frequency value (91.66%) and this species was found in all the closest months. *B. longirostris* (83.33%) was followed by the Rotifera; *K. cochlearis* (79.16%), *A. priodonta* (66.66%), *S. pectinata* (66.66%) were by other common species (Table 2).

3.3 Statistical Analysis

The dendrogram obtained from Bray Curtis analysis was divided into three groups. In group 2, homogeneity was the highest in dendrogram. Group 1 in May, September and July; Group 2 in October June, August and April; and Group 3 showed similarity in the months representing the autumn and winter seasons. In Group 3, at Station 1, a situation was seen at the bottom of the dendrogram which disrupted the internal homogeneity of group 3 (Fig. 3). This

Table 1 The mean change in physicochemical parameters of Siddikli Dam Lake (Akkan et al. 2018a)

Physicochemical parameters	Stn 1 (Mean, SE)	Stn 2 (Mean, SE)
Water temperature (°C)	14.60 ± 2.278	14.16 ± 2.150
Conductivity (mS/cm)	0.770 ± 0.039	0.799 ± 0.038
pH	8.25 ± 0.080	8.16 ± 0.082
Dissolved oxygen (mg/L)	8.98 ± 0.780	9.37 ± 0.833
TDS (mg/L)	0.567 ± 0.053	0.585 ± 0.050
Salinity (ppt)	0.43 ± 0.043	0.44 ± 0.040
Turbidity (NTU)	13.70 ± 4.429	16.04 ± 5.326
Secchi disk (cm)	174.7 ± 15.3	152.7 ± 14.5
Nitrate (mg/L)	0.007 ± 0.001	0.013 ± 0.003
Nitrite (mg/L)	0.273 ± 0.039	0.433 ± 0.153
Sulphate (SO ₄ -mg/L)	63.00 ± 6.499	65.42 ± 5.220
Sulphite (SO ₃ -mg/L)	11.00 ± 1.022	10.25 ± 1.426
Silica (mg/L)	13.55 ± 5.370	15.36 ± 6.346
Alkalinity (mg/L)	15.45 ± 1.462	15.68 ± 1.380
Total Hardness (°F)	18.44 ± 1.302	17.78 ± 1.095
TSS (g/L)	1.04 ± 0.140	1.01 ± 0.146
TP (mg/L)	0.170 ± 0.044	0.234 ± 0.088
O-PO ₄ (mg/L)	0.752 ± 0.253	0.833 ± 0.244
TAN (mg/L)	0.685 ± 0.120	0.758 ± 0.099
NH ₃ (mg/L)	0.0037 ± 0.008	0.030 ± 0.005
NH ₄ (mg/L)	0.648 ± 0.119	0.728 ± 0.098
Na (mg/L)	13.20 ± 0.383	14.06 ± 0.423
K (mg/L)	5.65 ± 1.692	5.63 ± 1.848
BOD ₅ (mg/L)	3.38 ± 0.567	3.07 ± 0.543
CHLA (μ/L)	2.394 ± 0.248	2.234 ± 0.251

TSS total suspended solid, TDS total dissolved solid, TAN total ammonia nitrogen, CHLA chlorophyll-a

situation shows inconsistency between sample dispersion between April 1st station and April 2nd station. Therefore, April 1st station was compared with all stations and months and associated with Chi-square analysis. No significant similarities were found between stations and months ($p = 0.05$). Therefore, this can be explained by the fact that rare species are seen once at Station 1 in April.

In the clustering analysis, Kruskal–Wallis was performed by considering the three groups as dependent and correlating with the water quality parameters. According to Kruskal–Wallis analysis results, WT, BOD₅, TSS, Chlorophyll-a and NTU were statistically significant (Table 3). According to RDA, 1st axis explained 14.7% of total variance, 2nd axis explained 10.4%, 3rd axis explained 9.0% and these three axes explained 34.1% of total variance. Correlation coefficients between axes and zooplankton are given in Table 4 at the end of RDA.

Table 2 Distribution of zooplankton species in Lake Siddikli Küçükboğaz Dam Lake

Study period	Codes (RDA)	2015												2016												% f	
		Sep		Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		July		Aug			
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2		
<i>Rotifera</i>																											
<i>Ascomorpha saltans</i> Bartsch, 1870	Ascomorp	*					*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	16.66
<i>Asplanchna priodonta</i> Gosse, 1850	Asppir			*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	66.66
<i>Brachionus angularis</i> Gosse, 1851	Braang			*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	33.33
<i>Cephalodella gibba</i> (Ehrenberg, 1830)	Cepgib													*	*	*	*	*	*	*	*	*	*	*	*	8.33	
<i>Colurella adriatica</i> Ehrenberg, 1831	Colurelad									*											*					8.33	
<i>Euchlanis dilatata</i> Ehrenberg, 1832	Eucdilata					*										*										8.33	
<i>Filinia longiseta</i> (Ehrenberg, 1834)	Fillon					*				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	33.33	
<i>Hexarthra femica</i> (Levander, 1892)	Hexfen															*	*	*	*	*	*	*	*	*	*	16.66	
<i>Keratella cochlearis</i> (Gosse, 1851)	Kelcoc			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	79.16
<i>Lecane bulla</i> (Gosse, 1886)	Lecluna			*																						4.16	
<i>Lecane luna</i> (Müller, 1776)	Lecbul			*																						12.50	
<i>Lecane lunaris</i> (Ehrenberg, 1832)	Leclunaris					*					*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	33.33	
<i>Lepadella patella</i> (Müller, 1773)	Leppat													*	*	*	*	*	*	*	*	*	*	*	*	8.33	
<i>Lophocharis salpinia</i> (Ehrenberg, 1834)	Lopsal		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	20.83
<i>Notholca squamula</i> (Müller, 1786)	Notsqu			*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	50.00
<i>Polyarthra dolichoptera</i> Idelson, 1925	Poldol	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	91.66
<i>Synchaeta pectinata</i> Ehrenberg, 1832	Synpec	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	66.66
<i>Trichocerca similis</i> (Wierzeski, 1893)	Trisim																				*					8.33	
<i>Cladocera</i>																											
<i>Bosmina longirostris</i> (O.F.Müller 1785)	Boslon	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	83.33
<i>Ceriodaphnia quadrangula</i> (O.F.Müller 1785)	Ceriquad					*																				12.50	
<i>Chydorus sphaericus</i> (O.F.Müller 1776)	Chyspha																								*	4.16	
<i>Daphnia cucullata</i> (Sars 1862)	Dapcuc					*																				4.16	

Table 2 (continued)

Study period	2016												% f												
	2015						2016																		
	Sep		Oct		Nov		Dec		Jan		Feb			Mar		Apr		May		Jun		July		Aug	
Months	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Station/Species																									
<i>Disparalona rostrata</i> (Koch 1841)	*																								4.16
<i>Copepoda</i>																									
<i>Eucyclops serrulatus</i> (Fischer 1851)																									29.16
Copepodite																									45.83
Nauplii																									33.33

The values shown in bold show maximum dominance

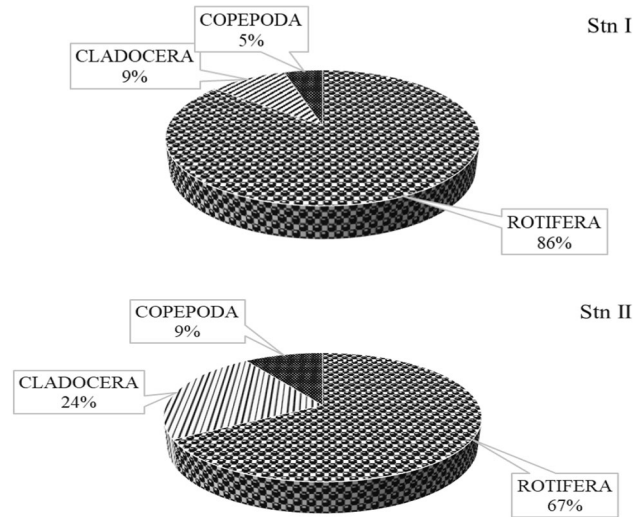


Fig. 2 Distribution of zooplankton groups according to stations in Siddikli Küçükboğaz Dam Lake

TSS and *L. salpina*, TAN and NH₄ with Nauplii, *N.* in the 2nd axis. In *squamula*, *B. angularis* and *F. longiseta* showed a positive relationship in the 1st axis. BOD₅ was positively correlated with *C. quadrangula*, whereas *L. lunaris*, *L. patella* and *C. gibba* species showed a negative relationship in terms of the correlation of physicochemical variables, in the 1st axis total suspended solids and water temperature negative correlation, while TAN and ammonium showed a positive correlation. Besides this, on the 2nd axis, water temperature and BOD₅ showed a positive correlation. The highest Pearson coefficient is the most related group (Table 5). All the variables (zooplankton and water quality) were given on the coordination chart in Figs. 4 and 5.

At the beginning of the analysis, the status of the groups determined on the dendrogram on the RDA coordination axes is given in Fig. 6. It has been seen that especially Group 3 is clearly separated from Group 1 and Group 2 in Fig. 6. In this section, April 1 was analyzed as a station in-group similarity. On the other hand, group 1 and group 2 are located on top of axis 1, and there is a gradual separation between these two groups. Hence, this status shows that species similarities between Group 1 and Group 2 may be more similar than Group 3.

The species diversity of zooplankton was determined by using diversity Shannon diversity and Simpson diversity index, and maximum values of 2.40 and 0.91 were recorded, respectively, in February and June. The minimum values of 1.39 and 0.75 were recorded, respectively, in September and May (Table 6).

It has been reported that the increase in zooplankton density is important in increasing the trophic level in lakes. Zooplanktonic organisms are used as indicators to

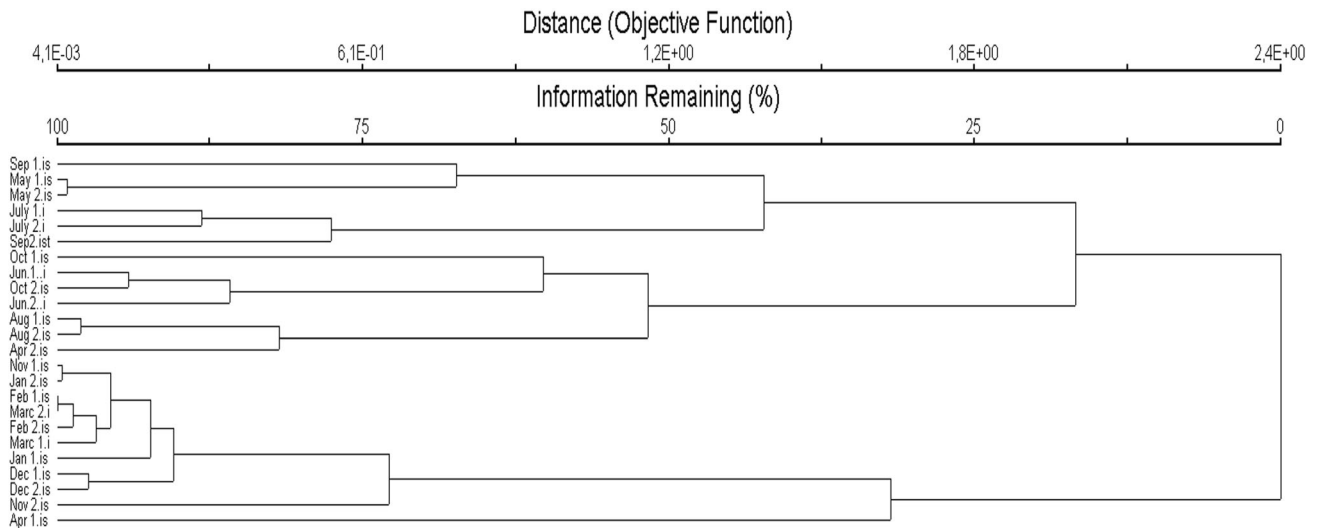


Fig. 3 Cluster analysis results of zooplankton for stations in Sıddıklı Küçükboğaz Dam Lake (1.is: 1. station; 2.ist: 2. station)

Table 3 Kruskal–Wallis result with zooplankton and related water quality parameters

Variables	Chi-square	p	Variables	Chi-square	p
WT	16.830	0.000	Silica	2.161	0.339
Time	2.720	0.257	Alkalinity	3.233	0.199
EC	2.777	0.250	Hardness	1.184	0.553
TDS	2.929	0.231	Phenol	1.577	0.455
Salinity	4.340	0.114	TSS	11.563	0.003
Satoxyge	0.68	0.738	TP	2.245	0.326
Oxygen	4.455	0.108	OPO4	1.417	0.492
pH	0.076	0.963	TAN	7.897	0.019
NTU	11.283	0.004	NH3	1.332	0.514
SD	0.195	0.907	NH4	8.912	0.012
NO ₂	4.849	0.089	NA	0.855	0.652
NO ₃	4.775	0.092	K	2.502	0.286
Sulpha	8.560	0.014	BOD ₅	15.766	0.000
Sulphite	2.764	0.251	CHLA	8.290	0.016

The values expressed in bold are statistically significant

WT: water temperature; Time: months; EC: conductivity; Oxygen: dissolved oxygen; Satoxyge: saturation of dissolved oxygen; SD: Secchi disk; NO₂: Nitrit; NO₃: Nitrat; Sulpha: Sulphate

determine the trophic levels of lakes (Canfield and Jones 1996; El-Bassat and Taylor 2007; Ahangar et al. 2012). Shannon diversity index was between 0.99 and 1.77 in the study conducted in Eğirdir Lake (Yağcı et al. 2014), between 0.36 and 2.26 in Kocaçay Delta (Tavşanoğlu and Emir Akbulut 2019), between 0.76 and 2.66 in Poyrazlar Lake, between 1.51 and 2.10 in Sorgun pond, between 1.43 and 2.35 in Çubuk II reservoir (Gürbüz et al. 2017), between 0.34 and 2.75 in Uzungöl Lagoon (Özdemir et al. 2021) in Turkey. In this study, Shannon diversity index was

Table 4 Pearson and Kendall Correlations with Ordination Axes

Species	Axis 1	Axis 2	Axis 3
Ascomorp	0.405	− 0.095	0.096
Asppir	0.102	− 0.082	− 0.568
Braang	0.770	− 0.298	0.112
Cepgib	− 0.489	− 0.670	0.064
Colurela	0.310	0.127	− 0.356
Eucdilal	− 0.402	− 0.296	0.323
Fillon	0.618	0.007	− 0.207
Hexfen	− 0.197	0.359	− 0.641
Kelcoc	0.220	− 0.364	0.066
Lecluna	− 0.360	0.400	0.436
Lecbul	− 0.141	0.332	0.614
Leclunar	− 0.490	− 0.508	− 0.096
Leppat	− 0.488	− 0.500	0.081
Lopsal	− 0.530	0.470	0.361
Notsqu	0.658	− 0.400	0.476
Poldol	0.488	0.500	− 0.081
Synpec	0.398	0.203	− 0.126
Trisim	− 0.279	0.237	− 0.396
Boslon	0.359	− 0.099	0.011
Ceriquad	− 0.044	0.527	− 0.345
Chyspha	− 0.318	− 0.387	− 0.081
Dapcuc	− 0.166	0.446	0.070
Disros	0.133	− 0.053	0.161
Eucyclop	− 0.217	− 0.106	− 0.572
Copepodi	− 0.131	0.200	0.124
Nauplii	0.728	− 0.129	− 0.136

Values expressed in bold have high correlation

found to be between 1.39 and 2.40. Values are compatible with other lakes in Turkey. Maximum diversity was observed in Uzungöl Lagoon in June. Similarly, the

Table 5 Pearson and Kendall Correlations with Ordination Axes between variables

Parameters	Cod	Axis I	Axis II	Axis III
Water temperature	WT	− 0.680	0.491	− 0.374
Turbidity	NTU	− 0.618	− 0.048	− 0.533
Sulphate	Sulpha	− 0.527	0.422	− 0.117
Total suspended solid	TSS	− 0.787	0.011	− 0.472
TAN	TAN	0.727	− 0.324	− 0.183
Ammonium	NH4	0.733	− 0.338	− 0.134
BOD ₅	BOI	− 0.631	0.643	− 0.028
Chlorophyll-a	CHLA	− 0.602	0.105	0.254

Values expressed in bold have high correlation

maximum diversity in Siddıklı Küçükboğaz Dam Lake was calculated in June. Simpson index, on the other hand, varied between 0.39 and 0.89 in Poyrazlar Lake, 0.57–0.85 in Sorgun pond and 0.63–0.86 in Çubuk II reservoir

(Gürbüz et al. 2017). Simpson index showed a similarity between 0.75 and 0.91 in Siddıklı Küçükboğaz Dam Lake.

The zooplankton fauna of Siddıklı Küçükboğaz Dam Lake consisted of 24 various species of zooplankton (Table 2). The recorded species were determined into 3 different groups as Rotifera (18 species), Cladocera (5 species) and Copepoda (1 species). Other researchers also observed Rotifera as the dominant group among zooplankton fauna of different dam lake ecosystems (Apaydın et al. 2013; İpek Alish and Saler 2016; Tuna and Ustaoglu 2016; Gürbüz et al. 2017; Bulut and Saler 2018). The highest number of species was observed in April (12), while the lowest number of species was observed in May (4) in all months and stations in this study.

The maximum number of zooplankton species (10) occurred at Station 1 in February, June and July. The zooplankton diversity was substantially decreased at Station 1 in May (4 species) (Table 2). *P.dolichoptera*, *S. pectinata* except for May and June, *K. cochlearis* except for September and May, and *B. longirostris* except for

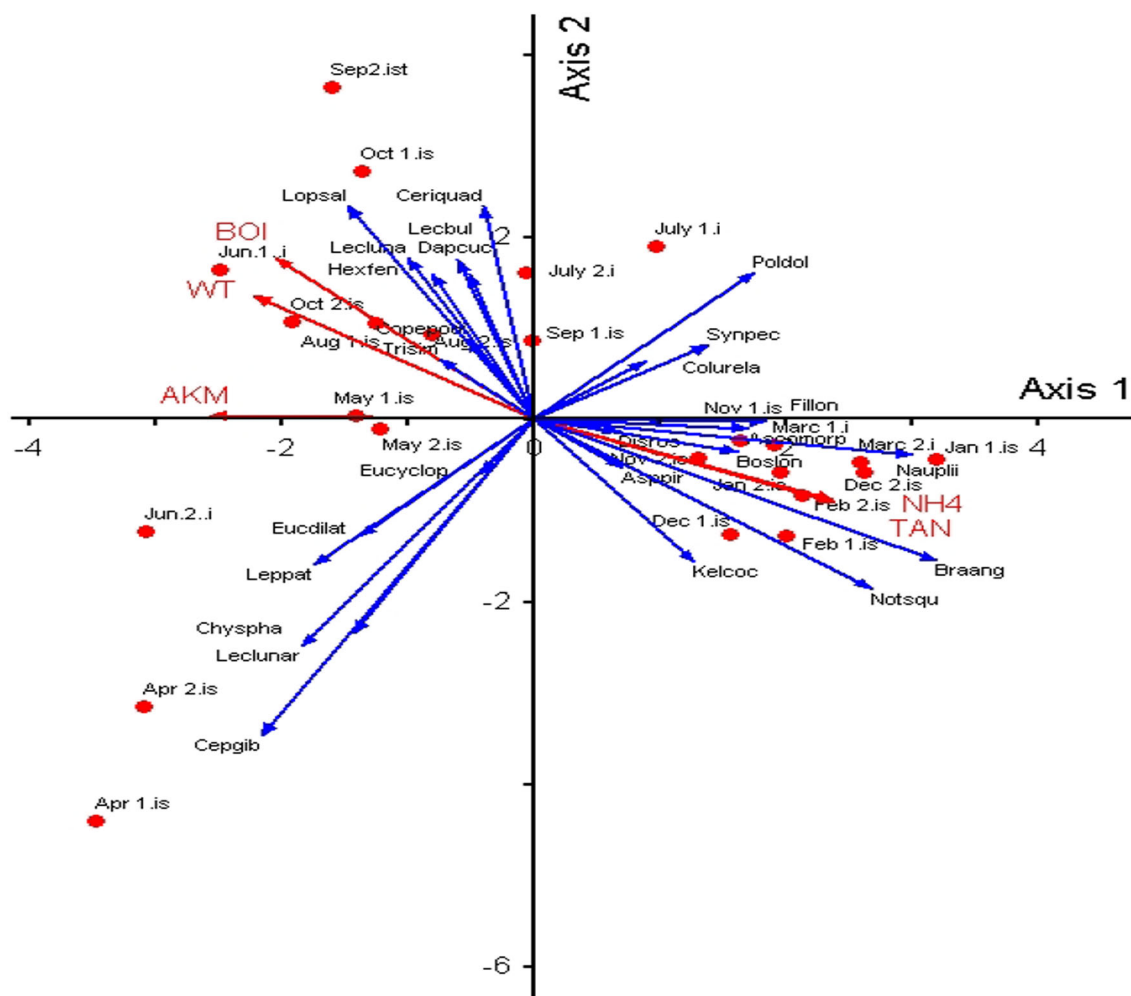


Fig. 4 RDA plot of zooplankton taxa and environmental variables (axis 1 and axis 2)

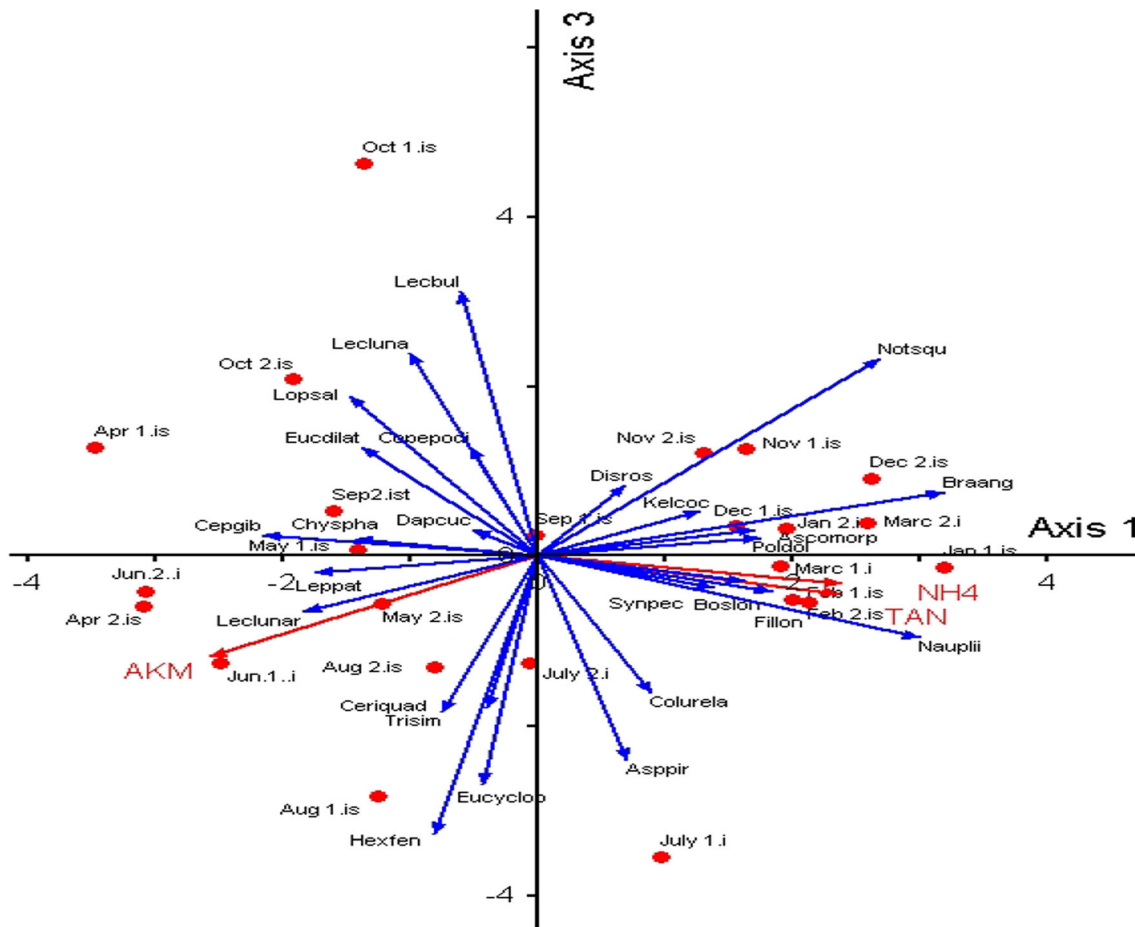


Fig. 5 RDA plot of zooplankton taxa and environmental variables (axis 1 and axis 3)

August were found in all months. *L. bulla*, *C. sphaericus* and *D. rostrata* were rare species with seen in only one month.

Zooplankton study was conducted in this study for the first time in the Siddıklı Küçükboğaz Dam Lake. It is reported that cyclopoid copepods best adapt to oligo-mesotrophic lakes (Maier 1996). Frutos et al. (2009) determined that *P. dolichoptera*, *Brachionus* spp, *K. cochlearis* and *Trichocerca* spp. were related to mesotrophic condition. *Polyarthra* is also considered to prefer mesosaprobic condition. Also, *F. longiseta* and *B. angularis* are recorded as a species preferring oligosaprobic or mesosaprobic condition (Skumaran and Das 2004). In this study, *B. angularis*, *F. longiseta*, *P. dolichoptera* zooplankton species were recorded, which were mostly indicators of mesotrophic water. According to the Q_{BIT} Rotifera index as expressed by Sládeček (1983), Gelingüllü Dam Lake a $Q_{BIT} = 1.00$ (Kaya and Altındağ 2007), Göksu Dam Lake with $Q_{BIT} = 1.00$ (Bekleyen 2003), Sazlıgöl with $Q_{BIT} = 1.00$ (Ustaoglu et al. 2004), Enne Dam Lake with $Q_{BIT} = 1.50$ (Apaydın Yağcı et al. 2013), Özlüce Dam Lake with a $Q_{BIT} = 1.00$ (İpek Alış and Saler 2016), Kemer Dam

Lake with a $Q_{BIT} = 1.00$ (Tuna and Ustaoglu 2016) and Kiğı Dam Lake with $Q_{BIT} = 1.00$ (Bulut 2018) have indicated to be oligotrophic-mesotrophic. In this research, the Q_{BIT} index was evaluated to be 1.0, and the results determined that the dam lake is at oligotrophic state. Numerous species of rotifers and crustaceans considered good indicators of the trophic level of inland waters were determined in the zooplankton community (Imoobe and Adeyinka 2009). In determining the trophic level of the inland waters, rotifer species are utilized as an indicator. According to the results of RDA study in Lake Valkea-Kotinen, it was stated that crustacean zooplankton was affected by water colour, alkalinity and total phosphorus (Lehtovaara et al. 2014). In Bosten Lake, Northwestern China, *B. longirostris* was found in places where the water temperature is low. Also, the results of the RDA in Bosten Lake, zooplankton community variation showed a significant association between water temperature, total nitrogen, pH and BOD_5 . In the study conducted in the Bosten Lake, temperature, nitrate and transparency were able to explain 31% of the zooplankton abundance variability (Dai et al. 2014). RDA showed that in the Dalyan Lagoon temperature, sulphate

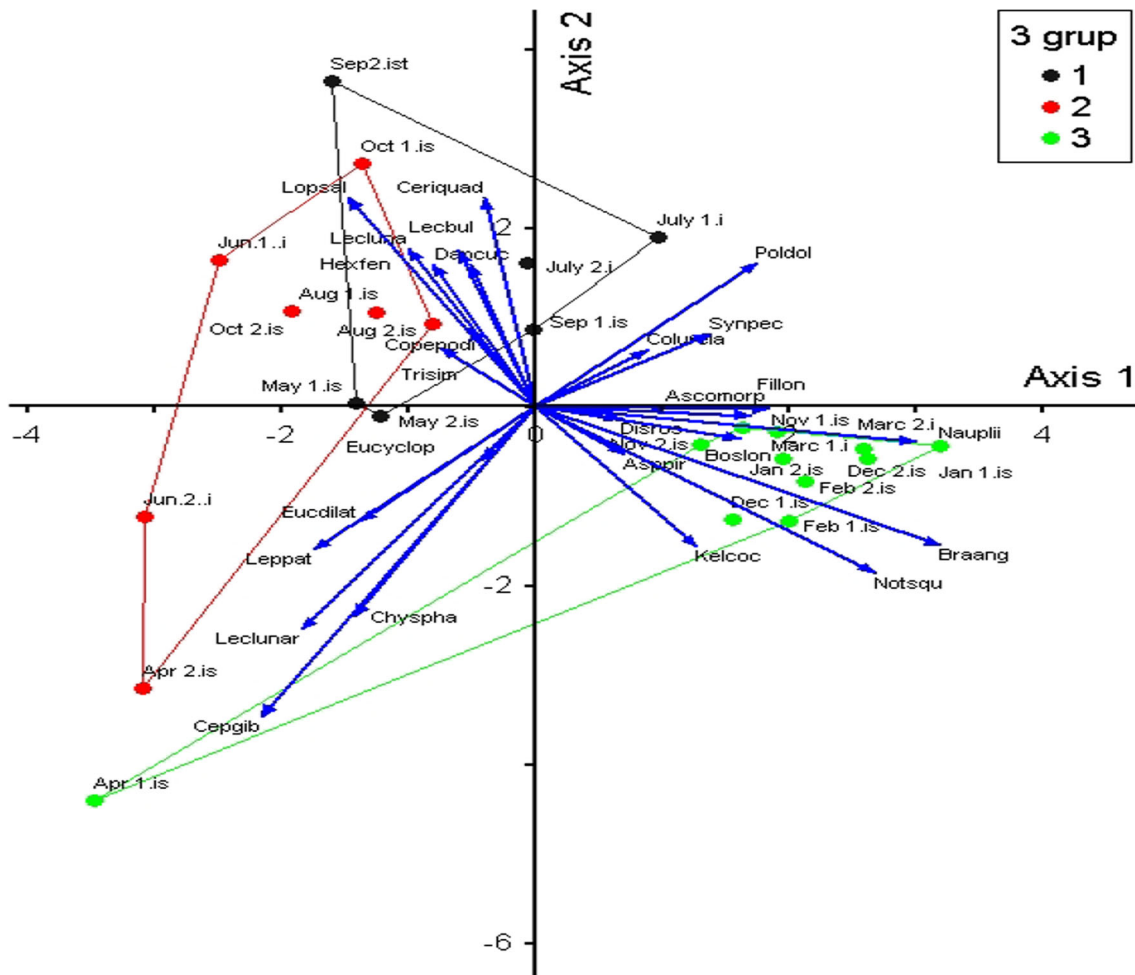


Fig. 6 Results of the redundancy analysis. For abbreviations of the environmental variables, see legend Tables 2 and 3

was the significant variables explaining the variation of species, while in Arapçiftliği Lagoon temperature, conductivity was the significant ones. These environmental variables explained a similar percentage for the Dalyan (54%) and Arap çiftliği (51%) lagoons (Akbulut and Tavşanoğlu 2018). RDA results explained 34.1% of the total variance in this study. In the Dalyan lagoon, *S. pectinata* was seen in places where the temperature was low which is similar to our results. According to RDA results (Fig. 3), we also found TAN, BOD₅, ammonium concentration significantly contributed to zooplankton variability in addition to water temperature. Li et al. (2019) proved that the variations of zooplankton showed a directional change in heavily polluted northern areas of Lake Taihu. Also, redundancy analysis demonstrated that environmental indicators together accounted for 50.1% variance of zooplankton, indicating that environmental variations affected significantly on the temporal dynamics of zooplankton communities. According to RDA, the long-term pattern in crustacean zooplankton was mainly

associated with abiotic factors like water colour, alkalinity and total phosphorus in small boreal lake (Lehtovaara et al. 2014). Also, the results of RDA, which were used to define the relationships between zooplankton and environmental variables, indicated that there were rotifers and crustaceans. *K. cochlearis*, *A. priodonta*, *F. longiseta* and *B. longirostris* occurrence was positively affected by conductivity and open water. *L. luna* was found to be attributed to the ponds with very good light conditions and high concentrations of total reactive phosphorus. Moreover, *B. angularis* and *T. similis* were positively associated with ammonium, chlorophyll-a and dissolved organic substances (Joniak and Kuczyńska-Kippen 2016). In addition, copepodite from the Copepoda group was significantly positively associated with TW, BOD₅ and TSS in this study, while nauplii were positively associated with TAN and NH₄. Similarly, copepodites and mature copepods were reported to be positively correlated with temperature ($r = 0.417$, $p = 0.001$) and dissolved oxygen ($r = 0.463$, $p = 0.0001$) in Lake Ohrid (Tasevska et al. 2017). The

Table 6 Variations in zooplankton diversity in Siddıklı Küçükboğaz Dam Lake

Months/stations	Shannon index	Simpson index
Sep 1.st	1.39	0.75
Oct 1.st	1.79	0.83
Nov 1.st	2.20	0.89
Dec 1.st	2.08	0.88
Jan 1.st	2.20	0.89
Feb 1.st	2.40	0.91
Marc 1.st	1.95	0.86
Apr 1.st	2.08	0.88
May 1.st	1.39	0.75
Jun 1.st	2.40	0.91
July 1.st	2.30	0.90
Aug 1.st	1.95	0.86
Sep 2.st	1.61	0.80
Oct 2.st	2.08	0.88
Nov 2.st	1.61	0.80
Dec 2.st	1.95	0.86
Jan 2.st	2.08	0.88
Feb 2.st	2.08	0.88
Marc 2.st	2.08	0.88
Apr 2.st	2.20	0.89
May 2.st	1.61	0.80
June 2.st	2.08	0.88
July 2.st	1.79	0.83
Aug 2.st	1.61	0.80

relationship between environmental parameters and zooplankton in Uzungöl Lagoon was evaluated by RDA (Özdemir et al. 2021), and *K.cochlearis* species showed a negative relationship with temperature. A similar relationship was observed in this study as well. In summary, water temperature (WT), total suspended solid (TAN) and NH_4 , BOD_5 , values were physicochemical parameters interacting with zooplankton community of Siddıklı Küçükboğaz Dam Lake. Also, these results proved that the variations of zooplankton showed a directional change in water quality of dam lake. For example, when our study results were evaluated, *B. angularis* (Braang) and *N. squamula* (Notsqu) species showed the highest positive correlation with NH_4 and TAN, and the highest negative correlation with BOD_5 and WT. Moreover, Kruskal–Wallis test analysis showed that there is a significant difference between zooplankton density in different stations, months and seasons (Özdemir et al. 2021). In another study, statistically, according to Kruskal–Wallis analysis, there were differences in total zooplankton and rotifer density between the studied stations, but on the contrary, there was no

significant between the main zooplankton groups and total zooplankton density between months (Dorak et al. 2019).

Walkusz et al. (2009) and Golmarvi et al. (2018) reported that cluster analysis revealed some differences among seasons in terms of zooplankton composition and abundance. Results of Kruskal–Wallis analysis showed that there was significant of zooplankton species between months and stations ($p < 0.05$). Cottenie et al. (2001) show that neighbouring and even interconnected ponds may differ substantially in their zooplankton community structure, and that these variations are strongly related to differences in trophic structure and biotic interactions.

The pH is important in the distribution of Rotifera, and it is reported that the alkaline limit is above $\text{pH} > 8$ and the acidic limit is below $\text{pH} < 5.5$ (Berzins and Pejler 1987). *S. pectinata*, *P. dolichoptera* and *K. cochlearis* species are found in waters above $\text{pH} > 8$, pH values in this study supported the literature. In a study conducted at the Maruf Dam, pH values varied between 7.71 and 8.98 (Mutlu et al. 2017). The normal pH range of water reservoirs is between 6.5 and 8.5 (Zhao et al. 2020). The pH values in this study varied between 8.16 and 8.25 and showed a uniform situation with the specified regions. In similar studies in Turkey, the geological structure is generally calcareous and the measured pH values show the slightly alkaline character of our lakes. Also, water temperature and dissolved oxygen are the most important physicochemical variables in the vital activities of aquatic organisms. It has been reported that conductivity increases with the increase in water temperature and dissolved oxygen (Yağcı et al. 2013). The concentration of dissolved oxygen in the water bodies varies depending on factors such as water temperature, flow rate, salt content, pollution status and biological events (Uncumusaoğlu and Mutlu 2021). In this study, oxygen values (DO) varied between 8.98 and 9.37. Healthy aquatic life is ensured in a water body with optimum DO values between 4 and 6 mg/L for good water quality (Avvannavarm and Shrihari 2008). The aquatic bodies of the studied reservoir were not characterized by variability because the difference between the two stations in all the analyzed physicochemical variables was not statistically significant. Thus, this situation showed that aquatic organisms were lacking ecosystem stress.

4 Conclusion

In this study, a total of 24 different species were recognized as new records for Siddıklı Küçükboğaz Dam Lake reservoir, including Rotifera, Cladosera and Copepoda, as there is no study on zooplankton in this dam lake. The results showed that *B. angularis*, *K. cochlearis*, *P. dolichoptera*, *C. quadrangula*, *B. longirostris*, *D. cucullata* and *C.*

sphaericus are the indicator species of Siddıklı Küçükboğaz Dam Lake. According to the preliminary results of water samples to environmental effects by Akkan et al (2018a, b) the nutrients, organic pollution and solid groups were the dominant determinants of water bodies in Siddıklı Küçükboğaz Dam Lake. In addition, the conclusion of this research suggests that *A. priodonta*, *H. fennica*, *K. cochlearis*, *L. bulla*, *D. cucullata* and *D. rostrata* have been less sensitive to environmental variables. Furthermore, the oligotrophic characteristic of the studied reservoir reflects the zooplankton species distribution given the habitat status. All species of zooplankton have contributed to the biodiversity of Siddıklı Küçükboğaz Dam Lake and Türkiye.

Author Contributions All authors have contributed equally in the planning, execution and analysis of this study.

Funding This research did not receive any specific funding.

Declarations

Conflict of interest The authors declare they have no conflicts of interest.

Human and Animal Rights The zooplankton is an invertebrate. According to the National Animal Experiments Ethics Committee legislation (<https://www.resmigazete.gov.tr/eskiler/2014/02/20140215-6.htm>) (as per article 4/d), Ethics Committee approval certificate is not required for invertebrates. Therefore, Ethics Committee Certificate was not received at the beginning of the study.

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