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Spatial and Temporal Changes of Planktonic Microcrustaceans (Cladocera, Copepoda) and their Relationship with Physicochemical Parameters in Kırklareli Reservoir (Kırklareli-Türkiye)

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ABSTRACT

The present study focused on monthly densities and abundances of planktonic microcrustaceans (Cladocera and Copepeda) in Kırklareli reservoir, as well as their relationship with some physicochemical parameters at three stations for the period from May 2018 to April 2019. In the present study, a total of 26 planktonic microcrustaceans species, 14 from Cladocera and 12 from Copepoda were identified. The mean annual microcrustacean abundance recorded during the study was 24076 ind/m^3, 67% of which was Cladocera (16054 ± 12414 ind/m^3) and 33% was Copepoda (8022 ± 5564 ind/m^3). The maximum abundance of planktonic microcrustaceans were found in September (51521 ind/m^3) and the minimum was found in January (2919 ind/m^3). The most common species in the reservoir were *Bosmina longirostris, Daphnia pulex, Daphnia cucullata, Daphnia galeata, Daphnia longispina* and *Diaphanosoma brachyurum* from Cladocera and *Cyclops abyssorum, Cyclops vicinus, Eudiaptomus vulgaris* and *Arctodiaptomus wierzejskii* from Copepoda. The environmental parameter values measured in the reservoir were acceptable to support aquatic life, especially the zooplankton community. The total density and abundance of zooplanktonic microcrustaceans showed positive correlation with the water temperature and Chlorophyll-a. According to these results, we concluded that Kırklareli reservoir has a mesotrophic character in terms of the microcrustacean fauna and the physicochemical parameters.

Keywords: Cladocera, Copepoda, diversity, water quality, reservoir

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Kırklareli Baraj Gölü'nde (Kırklareli-Türkiye) Planktonik Mikrocrustacea'ın (Cladocera, Copepoda) Mevsimsel değişimi ve Fizikokimyasal Parametrelerle İlişkisi

Öz: Bu çalışma, Kırklareli baraj Gölü'nde planktonik mikrocrustacea (Cladocera, Copepoda) faunasının mevsimsel değişimi ve bazı fizikokimyasal parametrelerle ilişkilerini belirlemek amacıyla Mayıs 2018-Nisan 2019 tarihleri arasında üç farklı istasyonda yapılmıştır. Cladocera'dan 14 ve Copepoda'dan 12 olmak üzere 26 tür tespit edilmiştir. Çalışma sırasında yıllık ortalama 24076 birey/m^3 mikrocrustacea bulunurken, bunun % 67 Cladocera (16054 ± 12414 birey/m^3) ve % 33 Copepoda (8022 ± 5564 birey/m^3) bireylerinden oluştuğu tespit edilmiştir. Planktonik mikrocrustacea maksimum bolluğu Eylül (51521 birey/m^3) ve minimum (2919 birey/m^3) Ocak ayında bulunmuştur. Rezervuardaki en yaygın türler Cladocera'dan *Bosmina longirostris, Daphnia pulex, Daphnia cucullata, Daphnia galeata, Daphnia longispina, Diaphanosoma brachyurum* ile Copepoda'dan *Cyclops abyssorum, Cyclops vicinus, Eudiaptomus vulgaris, Arctodiaptomus wierzejskii*'dir. Rezervuarda ölçülen çevresel parametreler başta zooplankton topluluğu olmak üzere sucul yaşamı desteklemek için kabul edilebilir değerler arasında tespit edilmiştir. Toplam mikrocrustacea yoğunluğu, su sıcaklığı ve Chlorophyll-*a* ile pozitif korelasyon göstermiştir. Bu sonuçlara göre Kırklareli rezervuarının mikrocrustacea faunası ve fizikokimyasal parametreler açısından mezotrofik bir karaktere sahip olduğu sonucuna varılmıştır.

Anahtar kelimeler: *:* Cladocera, Copepoda, çeşitlilik, su kalitesi, baraj gölü

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Introduction

The zooplanktonic organisms, which play a role in the transformation of plant based foods into animal proteins in freshwater ecosystems, are the food source of many living things and are among the important energy dynamics of aquatic ecosystems. These organisms occupy an intermediate position in the food web and are among the important zooplankton groups that mediate the transition of energy from low to high trophic levels (Sharma et al. 2010). The freshwater zooplankton comprises Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda. Cladocera and Copepoda are planktonic microcrustaceans that are widely distributed in freshwaters. They are crucial groups among zooplankton and form the most useful and nutritive group of crustaceans for higher members in the food chain such as fishes. Cladocera are known as filter feeders as they filter the water to trap the organisms in it. Cladocera are highly sensitive against even low concentrations of pollutants (Murugan et al. 1998). Copepoda provide an important food source for fish and are influenced by negative environmental factors in water bodies. In addition, these organisms play a role in preventing pollution by controlling the phytoplankton population due to grazing pressure on phytoplankton (Trivedi et al. 2003).

The variability in the distribution of zooplankton in freshwater ecosystems is affected by abiotic and biotic parameters or by a combination of both (Beyst et al. 2001; Escribano and Hidalgo 2000). Although zooplankton exists under a wide range of environmental conditions, yet many species are limited by temperature, dissolved oxygen, salinity and other physicochemical factors. To conserve freshwater ecosystems from further deterioration there is a need for regular monitoring. A comprehensive biomonitoring process involves both physicochemical and biological approaches and gives the exact status of the aquatic ecosystem. Biomonitoring of water bodies also helps to understand the composition of biota and its dynamics. Zooplankton has been recently used as an indicator to observe and understand changes in the ecosystem (Li et al. 2000). For this reason, studies on Cladocera and Copepoda, which are an important component of the aquatic ecosystem, are extremely important.

A number of studies have been carried out to examine the distribution and diversity of microcrustaceans (Cladocera and Copepoda) in the inland waters of Türkiye (Ustaoğlu 2015; Güher 2014). However, studies on reservoirs are limited (Saler and Alış 2014; Ulgu and Bozkurt 2015; Güher and Çolak 2015; Güher 2019; Dorak et al. 2019; Dorak 2019; Bozkurt and Kara 2020; and Güher and Öterler 2021). Also, the distribution and diversity of planktonic microcrustaceans (Cladocera and Copepoda) of Kırklareli Reservoir have not been studied so far. Therefore, the aim of this paper is to investigate the influence of physicochemical parameters of water of Kırklareli Reservoir on species composition, relative abundance and seasonal dynamics of the planktonic microcrustaceans (Cladocera and Copepoda).

Materials and Methods

Study Area

Kırklareli Reservoir was built between the years 1985-1995 for irrigation and flood control on Şeytandere stream. The reservoir which supplies freshwater to the province of Kırklareli for drinking and domestic usages is located between 41°44'08.6"N and 27°16'59.0"E coordinates. The volume of the reservoir is about 112 hm^3 and the surface area is 6 km^2. Although the reservoir is fed mainly by the Ana stream and Büyük stream, it is also fed by other creeks in the basin and by rainfall (Figure 1). The reservoir is subjected to temporal fluctuations in water volume with high water volume in the rainy season and less water in the dry season due to high evaporation. The microcrustaceans and water samples were collected monthly from May 2018 to April 2019 at three stations representing the lake's ecological characters. The first sampling station is located in the middle of the reservoir (41°44'53,8"N 27°17'02,6"E), the second sampling station is located in the western part of the reservoir where Ana stream feeds the reservoir (41°45'54,9"N 27°16'41,6"E) and the third sampling station is located in the eastern branch of the reservoir where Büyük stream feeds the reservoir (41°45'41,9"N 27°18'30,3"E) (Figure 1).

Sampling

The planktonic microcrustaceans and water samples were taken at monthly intervals from May 2018 to April 2019 in three stations in the reservoir (Figure 1). The planktonic microcrustaceans and water samples were carried out at monthly intervals from May 2018 to April 2019 in three stations in the reservoir (Figure 1). Due to unfavourable weather conditions, no sampling could be performed in March 2019. Planktonic microcrustacean samples were collected with a Hensen type plankton net (mesh size 55 μ, mouth diameter 15 cm, length 75 cm) vertically up to the surface from the bottom point (10 m deeply) and horizontally. Plankton samples taken from the reservoir were immediately preserved in 4 % formaldehyde in the field and then brought to the laboratory for further analyses. In the laboratory, samples were identified at the species level according to Dussart (1967, 1969), Flössner (1972), Smirnov (1974), Kiefer (1978), Margaritora (1983), Korinek (1987), Apostolov and Marinov (1988), Dussart and Defaye (2002, 2006) and Bledzki and Raybok (2016). The counting of the samples was made according to Edmondson (1959) using an Olympus inverted microscope. Densities were presented as the number of individuals per cubic meter (ind/m^3).

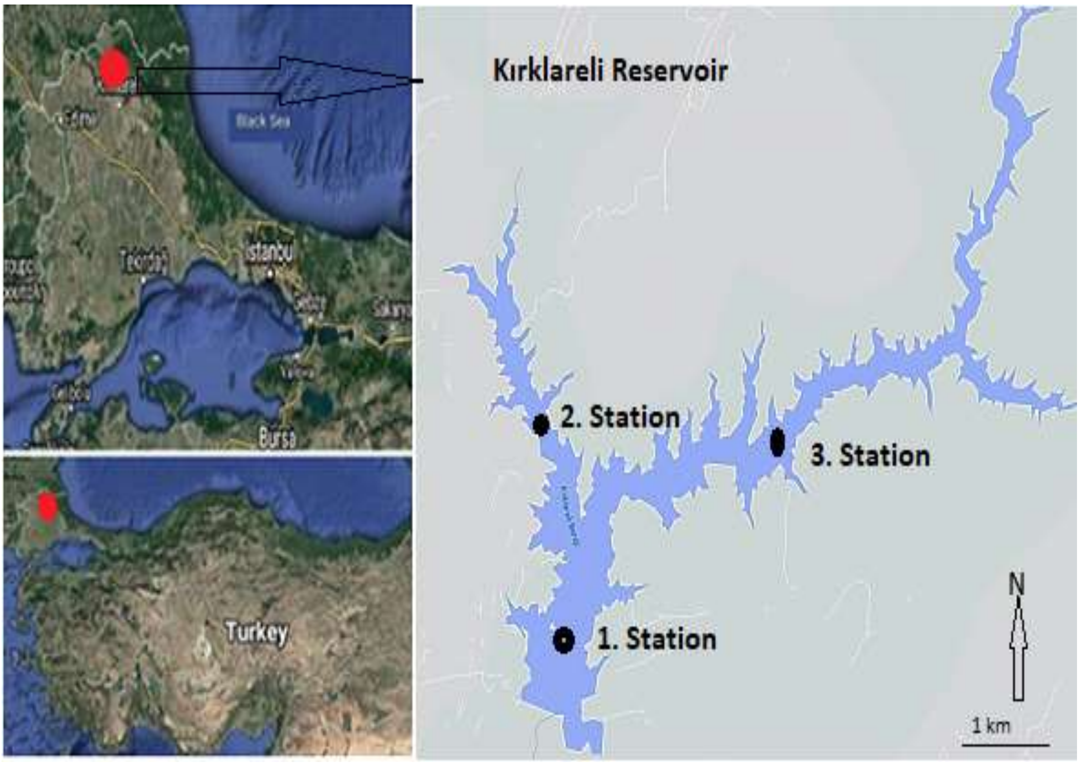

Figure 1. Location of Kırklareli Reservoir and the sampling stations

The water samples were taken with Ruttner water sampling bottles from about 15 to 20 cm below the water surface. Some physicochemical parameters, such as Water temperature (WT), Dissolved oxygen (DO), pH and Conductivity (EC) were measured on site simultaneously by using Orion Star S/N 610541 water analyser. The light permeability (LP) of the reservoir was measured using a Secchi disk. Nitrate nitrogen (NO_3-N), Nitrite nitrogen (NO_2-N) Phosphate (PO_4^-P), Sulphate (SO_4^{2-}), Calcium (Ca_2^+) and Magnesium (Mg_2^+) were measured at the Trakya University Technology Research Development Application and Research Centre. The analyses were performed by Metrohm Ion Chromatography System and the Agilent Technologies 7700 ICP-MS System (EPA 2001), immediately after the sample collection.

Statistical Analyses

Shannon-Weaver index, Margalef diversity and Simpson's diversity indexes were used to determine the species diversity and the species richness of planktonic microcrustaceans in the reservoir (Shannon and Weaver 1949, Margalef 1958). Bray-Curtis similarity index was used to examine the similarities of the sampling based on the months and the seasons according to diversity and abundance of Cladocera and Copepoda species (Jaccard 1912). Spearman's correlation was used to determine the relationship of Cladocera and Copepoda groups with each other and with environmental parameters (Krebs 1999). In addition, the statistical association between Cladocera and Copepoda assemblage structure and environmental variables were quantified with the canonical correspondence analysis (CCA) by the Past Version3.14 (Hammer et al. 2001).

Results

Physicochemical Variables

The measured environmental parameters and their minimum, maximum and average values are given in Table 1. Variations in these environmental parameters according to the sampling stations and months are given in Figure 2. The WT ranged between the lowest value of 6.00 ℃ obtained during the winter season in January and the highest of 27.00 ℃ obtained during the summer season in July (average 16.50 ± 7.66 ℃). The summer season temperature was significantly higher ($p< 0.05$) than the winter season temperature. DO fluctuated between the lowest monthly mean of 7.43 mg/L obtained in September in winter season and the highest monthly mean of 13.75 mg/L recorded in April in the spring season. The monthly average of the DO values measured in the reservoir was 9.71 ± 1.83 mg/L. Light permeability was highest at 336.67 cm obtained in November in the autumn season and lowest at 66.67 cm in January in the winter season (average 198.33 ± 73.5 cm). Significantly higher transparency ($p<0.05$) was obtained in the autumn season. The pH value of the reservoir was moderately alkaline varying from 8.15 to 9.45. The lowest pH was obtained in December, while the highest was obtained in April (average 8.64 ± 0.49). The monthly mean variations in conductivity were similar. The monthly average of EC values measured in the reservoir was 248.17 ± 30.10 µScm/L. The NO_2-N concentration in the reservoir was found below the limit of detection in June, while it was highest in May with 0.05 mg/L (average 0.02 ± 0.02 mg/L). The highest concentration of NO_3-N recorded was 2.13 mg/L in February in the winter seasons, while the lowest was obtained as 0.04 mg/L in September in the autumn seasons. The monthly average of NO_3-N values measured in the reservoir was 0.73 ± 0.71 mg/L. The PO_4-P concentration in the reservoir was found below the limit of detection in April June, July, September and October, while it was highest in May, respectively 0.78 mg/L (average 0.11 ± 0.23 mg/L). The maximum value of sulphate was recorded in December and the minimum in January. The mean value of SO_4^{2-} in the reservoir was 10.12 ± 0.25 mg/L. The maximum Mg_2^+ value was detected as 12.30 mg/L in October in the autumn season and the minimum as 1.90 mg/L in January in the winter season (average 8.19 ± 3.87 mg/L). The maximum Ca^{2+} concentration was measured as 22.31mg/L in November and the minimum as 3.04 mg/L in January (average 13.66 ± 6.60 mg/L). The highest and the lowest chlorophyll-*a* values were recorded 13.09 µg/L in September in the summer and the autumn season and 2.31µg/L in February in the winter season, respectively. The mean chlorophyll-*a* in the reservoir was 5.96 ± 3.49 µg/L (Figure 2 and Table 1).

Table 1. The measured physicochemical parameters in the reservoir and their minimum, maximum and average ± stdev values (*below limit of detection)

	Abbreviation	**Min.**	**Max.**	**Average ± stdev**
Water temperature (°C)	WT	6.00	27.00	16.50 ± 7.66
Dissolved oxygen (mg/L)	DO	7.43	13.75	9.71 ± 1.83
Light permeability (cm)	LP	66.67	336.67	198.33 ± 73.53
pH	pH	8.15	9.45	8.64 ± 0.49
Conductivity (µS cm/L)	EC	213.33	322.37	248.17 ± 30.10
Nitrite nitrogen (mg/L)	NO_2-N	*	0.05	0.02 ± 0.02
Nitrate nitrogen (mg/L)	NO_3-N	0.04	2.13	0.73 ± 0.71
Phosphate (mg/L)	PO_4-P	*	0.78	0.11 ± 0.23
Sulphate (mg/L)	SO_4^{2-}	9.71	10.57	10.12 ± 0.25
Calcium (mg/L)	Ca^{2+}	3.04	22.31	13.66 ± 6.60
Magnesium (mg/L)	Mg^{2+}	1.90	12.30	8.19 ± 3.87
Chlorophyll-a (µg/L)	Chl-*a*	2.31	13.09	5.96 ± 3.49

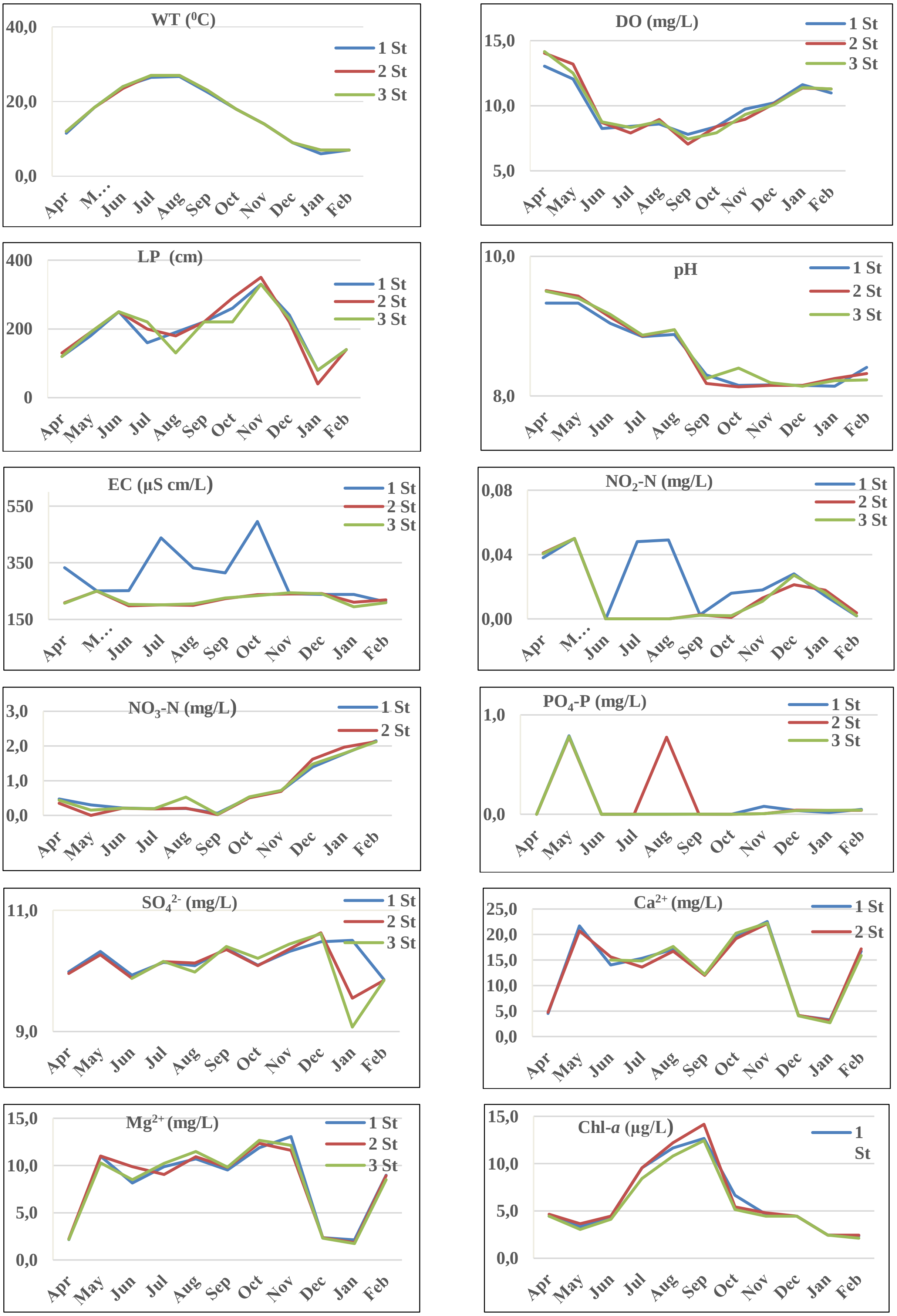

Figure 2. Variations of the physicochemical parameters according to the sampling stations and months in the reservoir

The results of the cluster analysis showed that the stations were very similar in terms of environmental parameters (91.0 % to 98.5 % similarity) (Figure 3).

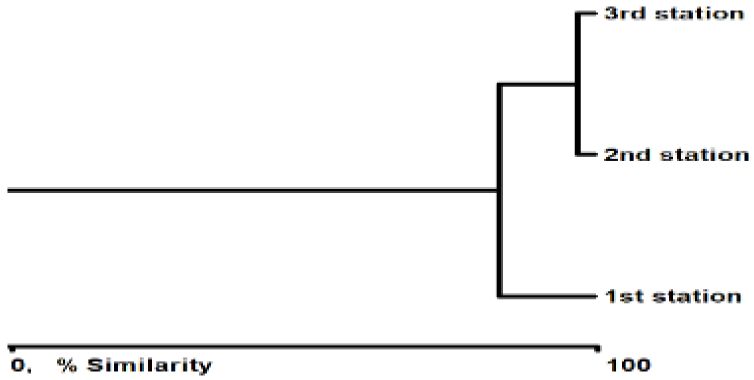

Figure 3. Cluster analysis showing the similarity index of the physicochemical parameters according to the sampling stations

Community Structure Of Planktonic Microcrustaceans

A total of 26 planktonic microcrustaceans species, 14 from Cladocera and 12 from Copepoda were identified, from 3 stations in Kırklareli Reservoir. Cyclopoid copepodites, Calanoid copepodites, and Nauplius were also observed (Table 2).

Table 2. Cladocera and Copepoda species in Kırklareli Reservoir and the average values of their annual numbers per m^3

CLADOCERA	**Average ± stdev**	**%**
Diaphanosoma brachyurum (Liévin,1848)	2477 ± 3907	15.4
Daphnia pulex Leydig, 1860	281 ± 308	1.8
Daphnia cucullata Sars, 1862	1062 ± 1299	6.6
Daphnia galeata Sars, 1863	850 ± 2283	5.3
Daphnia hyalina Leydig 1860	1070 ± 2817	6.7
Daphnia longispina (O.F.Müller, 1876)	1471 ±1917	9.2
Ceriodaphnia quadrangula (O.F.Müller, 1785)	1102 ± 2096	6.9
Bosmina longirostris (O.F.Müller, 1785)	6796 ±6375	42.3
Pleuroxus aduncus (Jurine, 1820)	8 ± 25	0.1
Chydorus ovalis Kurz, 1875	40 ± 87	0.3
Chydorus sphaericus (O.F.Müller, 1776)	712 ± 1502	4.4
Alona guttata Sars, 1862	8 ± 25	0.1
Leptodora kindtii (Focke, 1844)	88 ±119	0.6
Cercopagis pengoi (Ostroumov, 1892)	88 ± 280	0.6
Total	16054 ± 12414	100
COPEPODA		
Eudiaptomus vulgaris (Schmeil, 1898)	97 ± 122	1.2
Arctodiaptomus wierzejskii (Richard, 1888)	48 ± 69	0.6
Macrocyclops albidus (Jurine, 1820)	8 ± 25	0.1
Cyclops abyssorum G.O.Sars, 1863	249 ± 328	3.1
Cyclops strenuus Fischer, 1851	16 ± 51	0.2
Cyclops vicinus Uljanin, 1875	185 ± 265	2.3
Acanthocyclops robustus (G.O.Sars, 1863)	88 ± 203	1.1
Mesocyclops leuckarti (Claus, 1857)	64 ± 126	0.8
Megacyclops viridis (Jurine, 1820	88 ± 156	1.1
Thermocyclops crassus (Fischer, 1853)	56 ± 94	0.7
Canthocamptus microstaphylinus Wolf, 1905	40 ± 127	0.5
Canthocamptus staphylinus (Jurine, 1820)	24 ± 55	0.3
Nauplius	3788 ± 2532	47.2
Cyclopoid copepodit	2252 ± 2317	28.1
Calanoid copepodit	1017 ± 845	12.7
Total	8022 ± 5564	100

The seasonal species richness of planktonic microcrustaceans was listed from the highest to the lowest as; summer (11 Cladocera, 10 Copepoda species), autumn (13 Cladocera, 8 Copepoda species), spring (9 Cladocera, 4 Copepoda species) and winter (4 Cladocera, 4 Copepoda species). According to the stations, the highest species number was found in the 1st station (13 Cladocera, 11 Copepoda species) followed by the 2nd (13 Cladocera, 9 Copepoda species) and the 3rd stations (11 Cladocera, 10 Copepoda species). The maximum species diversity was recorded as, 10 species from Cladocera in August and in October and 8 species from Copepoda in July, while the least diversity was found as 1 species from Cladocera in February and 1 species from Copepoda in December and February.

The most common species in the reservoir was *Bosmina longirostris* from Cladocera and was found in all sampling months. *Daphnia pulex*, *D. cucullata D. galeata* and *D. longispina* were sampled for seven months and *Diaphanosoma brachyurum* was sampled for six months and *Chydorus sphaericus*, *Daphnia hyalina* and *Leptodora kindtii* were sampled for five months. The most common species from Copepoda were *Cyclops abyssorum* and *C. vicinus* found during six months and *Eudiaptomus vulgaris* and *Arctodiaptomus wierzejskii* found during five months. Also, Cyclopoid copepodites, Calanoid copepodites and Nauplius from Copepoda were found in all sampling months. *Pleuroxus aduncus, Alona guttata* and *Cercopagis pengoi* from Cladocera and *Macrocyclops albidus, Cyclops strenuus* and *Canthocamptus microstaphylinus* from Copepoda were sampled only in one month during the study.

According to the Shannon Diversity Index, while species richness was at its maximum (0.82) in September it was found in the lowest value (0.555) in June. According to the Simpsons Diversity Index, while species richness was at its maximum in August (6.969), its lowest value (2.362) was found in April. According to the Margalef Index, while species richness was at its maximum in October (8.081), its lowest value (5.942) was found in September ($p>0.005$) (Table 3).

Table 3. Species diversity and species richness values of microcrustacean groups according to the sampling months

Index	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Shannon J'	0.571	0.641	**0.555**	0.727	0.777	**0.82**	0.73	0.798	0.734	0.726	0.679
Simpsons Diversity (1/D)	**2.362**	4.283	2.686	5.969	**6.969**	6.209	6.466	5.352	3.238	3.269	2.609
Margaleff M Base 10,	6.829	6.595	6.119	6.057	6.261	**5.942**	**8.081**	6.796	7.966	5.999	7.178

As a result of the quantitative evaluation of plankton samples, the annual average value of planktonic microcrustaceans in the reservoir was found as 24076 ind/m^3. The annual average values according to the groups were 16054 ± 12414 ind/m^3 for Cladocera and 8022 ± 5564 ind/m^3 for Copepoda. In other words, the planktonic microcrustaceans in the Kırklareli Reservoir consists of 67 % Cladocera and 33 % Copepoda. However, a large part of Copepoda consists of larval individuals such as Nauplius or copepodite stage (12 % adult individuals, 88 % larval individuals) (Table 2). When the results were evaluated in terms of sampling months, the maximum abundance of planktonic microcrustaceans were found in September (51521 ind/m^3) followed by October (46502 ind/m^3) and July (41976 ind/m^3) and the minimum was found in January (2919 ind/m^3) followed by February (7962 ind/m^3) (Figure 4). According to the results of cluster analysis, January-December (80 %), February-April-May (69 %) and July-August (63 %) were the most similar to each other while the least similar months were June-July (17 %), July-November and July-December-January (7 %) (Figure 5). In other words, spring was very similar to the summer season (60 % similarity) and autumn was very similar to the summer season (72 % similarity) (Figure 6).

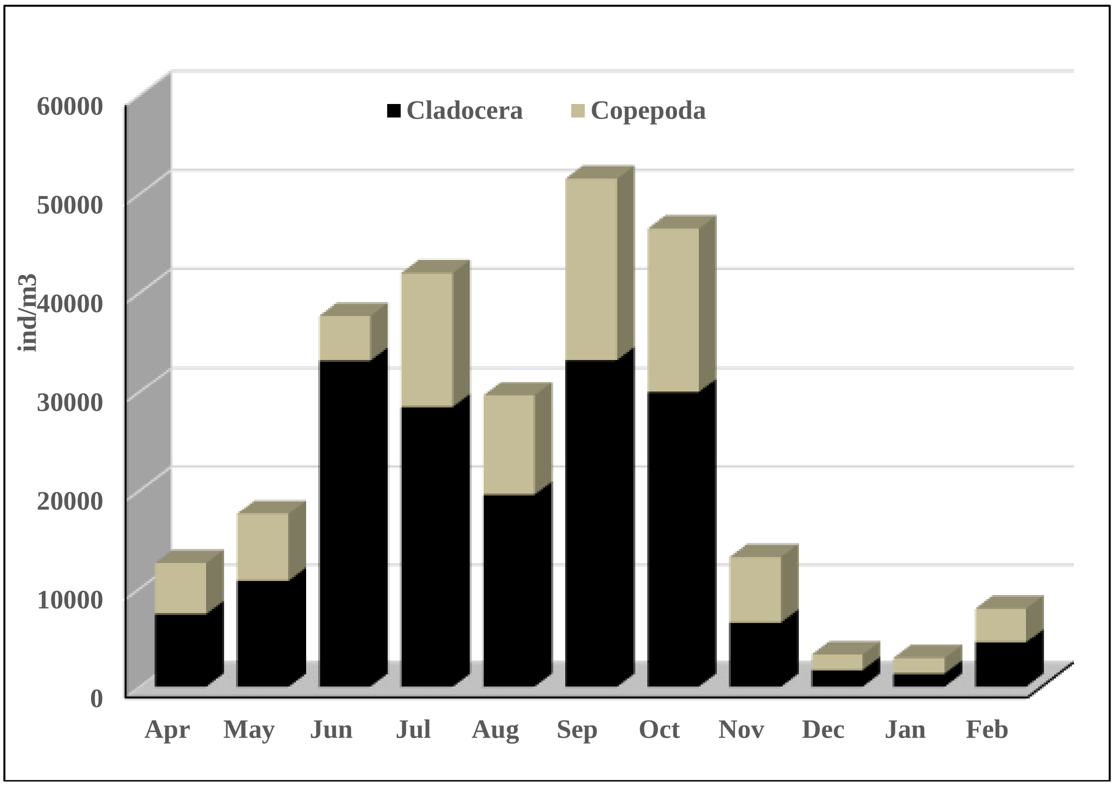

Figure 4. The abundance of planktonic microcrustacean in Kırklareli Reservoir according to the sampling months

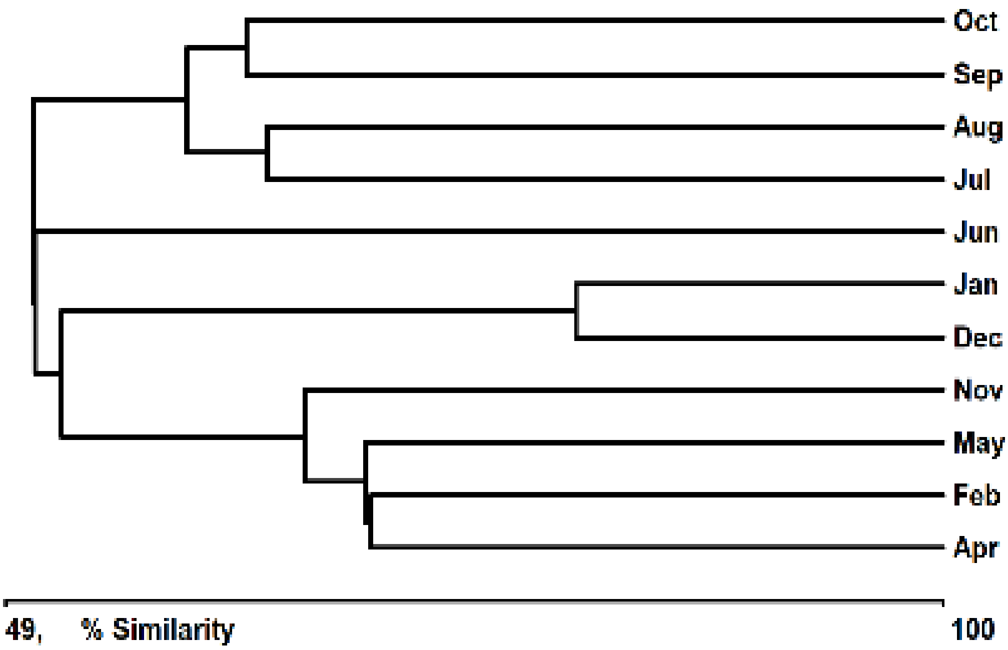

Figure 5. Cluster analysis showing the similarity index of planktonic microcrustaceans according to the sampling months

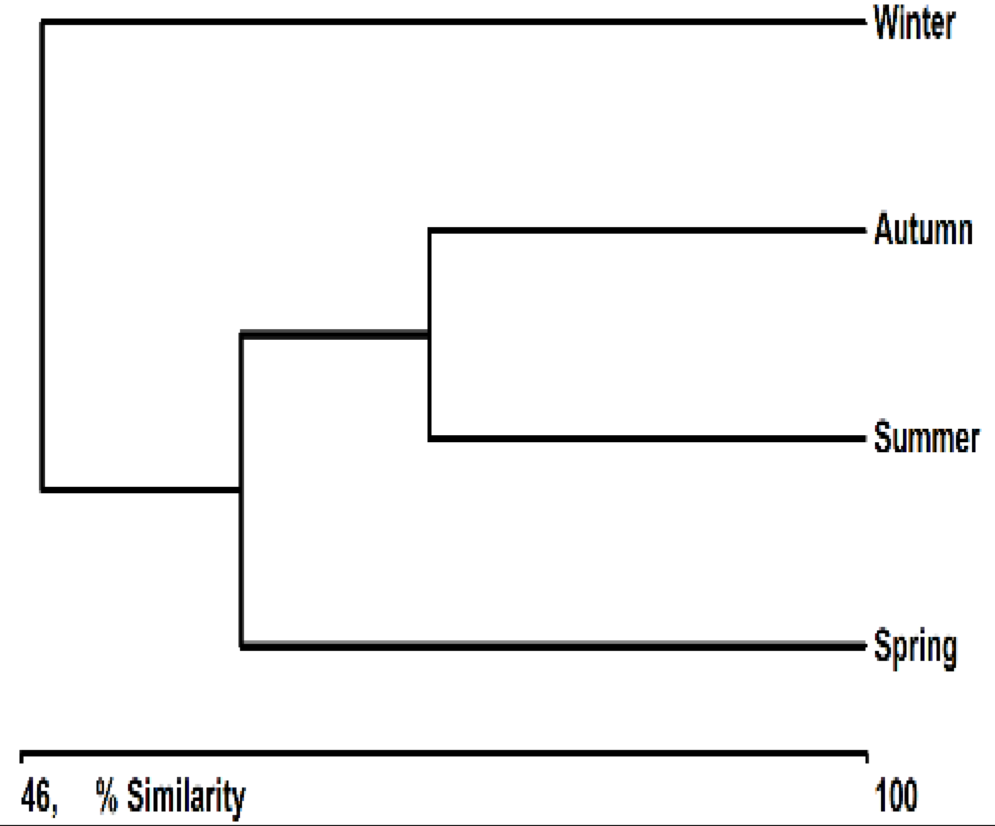

Figure 6. Cluster analysis showing the similarity index of planktonic microcrustaceans according to the sampling seasons

The Spearman's correlation was used to determine the relationship of Cladocera and Copepoda groups with environmental parameters. There was a positive correlation between Cladocera with WT (r= 0.809) ($p< 0.01$), EC (r=0.636) ($p< 0.05$) and Chl-*a* (r=0.636) ($p< 0.05$), while there was a negative correlation with DO (r=0.736) ($p< 0.01$) and NO_3-N (r=0.800) ($p< 0.01$). Also, there was a positive correlation between Copepoda with WT (r=0.711) ($p< 0.05$), EC (r=0.875), Mg_2^+ (r=0.738) and Chl-*a* (r=0.806) and Cladocera (r=0.797) ($p< 0.01$), while there was a negative correlation with DO (r=0.656) and NO_3-N (r=0.715) ($p< 0.05$). There was a positive correlation between WT with Chl-*a*, NO_3-N with DO, Mg^{2+} with LP, Chl-*a* with EC and Ca^{2+} with Mg^{2+}, while there is a negative correlation between WT with DO and NO_3-N (Table 4).

Table 4. The relationship between microcrustacean groups and environmental parameters in Kırklareli Reservoir as revealed by the Spearman's correlation analysis (Cop: Copepoda, Clad: Cladocera).

	WT	DO	LP	pH	EC	NO_2N	NO_3N	PO_4^-P	Ca	Mg	Chl-*a*	Clad	Cop
WT	1												
DO	**-.655***	1											
LP	.327	-.582	1										
pH	.436	.236	-.391	1									
EC	.582	-.464	.309	.191	1								
NO_2N	-.165	**.651***	-.413	.202	.156	1							
NO_3N	**-.818****	.436	-.182	-.536	**-.664***	.000	1						
PO_4^-P	-.248	.515	-.334	-.029	-.410	.433	.267	1					
Ca	.336	-.118	.482	.136	.255	-.128	-.173	.257	1				
Mg	.536	-.500	**.645***	-.055	.573	-.220	-.364	.019	**.855****	1			
Chl-*a*	**.673***	**-.709***	.364	-.027	**.718***	-.138	-.564	-.420	.118	.545	1		
Clad	**.809****	**-736****	.427	.391	**.636***	-.486	**-.800****	-.543	.273	.527	**.636***	1	
Cop	**.711***	**-.656***	.333	.210	**.875****	-.193	**-.715***	-.349	.433	**.738****	**.806****	**.797****	1

**.Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The Canonical Correspondence Analysis (CCA) was used to determine the relationship of Cladocera and Copepoda species with environmental parameters. The eigenvalues of the first two axes were calculated as 0.052 and 0.026, respectively. In the analysis, the two axes explain 100% of the variance of the species, 66.11% (Axis 1) and 33.89% (Axis 2). The distributions of *Canthocamptus staphylinus*, *Thermocyclops crassus*, *Macrocyclops albidus*, *Acanthocyclops robustus*, and *Mesocyclops leuckarti* from Copepoda and *Daphnia hyalina* from Cladocera were affected by DO and NO_3-N. Environmental parameters did not affect the distributions of *Cyclops vicinus* and *Arctodiaptomus wierzejiskii* from Copepoda and *Daphnia pulex, Cercopagis pengoi* and *Pleuroxus aduncus* from Cladocera. These species were found to have the highest ecological tolerance. While WT, SO_4^{2-}, Ca_2^+, Mg_2^+, LP, PO_4-P and pH are effective in the distribution of *Daphnia cucullata, Bosmina longirostris,* and *Chydorus ovalis* from Cladocera and *Megacyclops viridis* and *Eudiaptomus vulgaris* from Copepoda. EC and NO_2-N parameters are effective in the distribution of *Daphnia galeata* and *Chydorus sphaericus* from Cladocera and *Cyclops strenuous, Canthocamptus microstaphylinus* and Calanoid copepodit from Copepoda. (Figure 7).

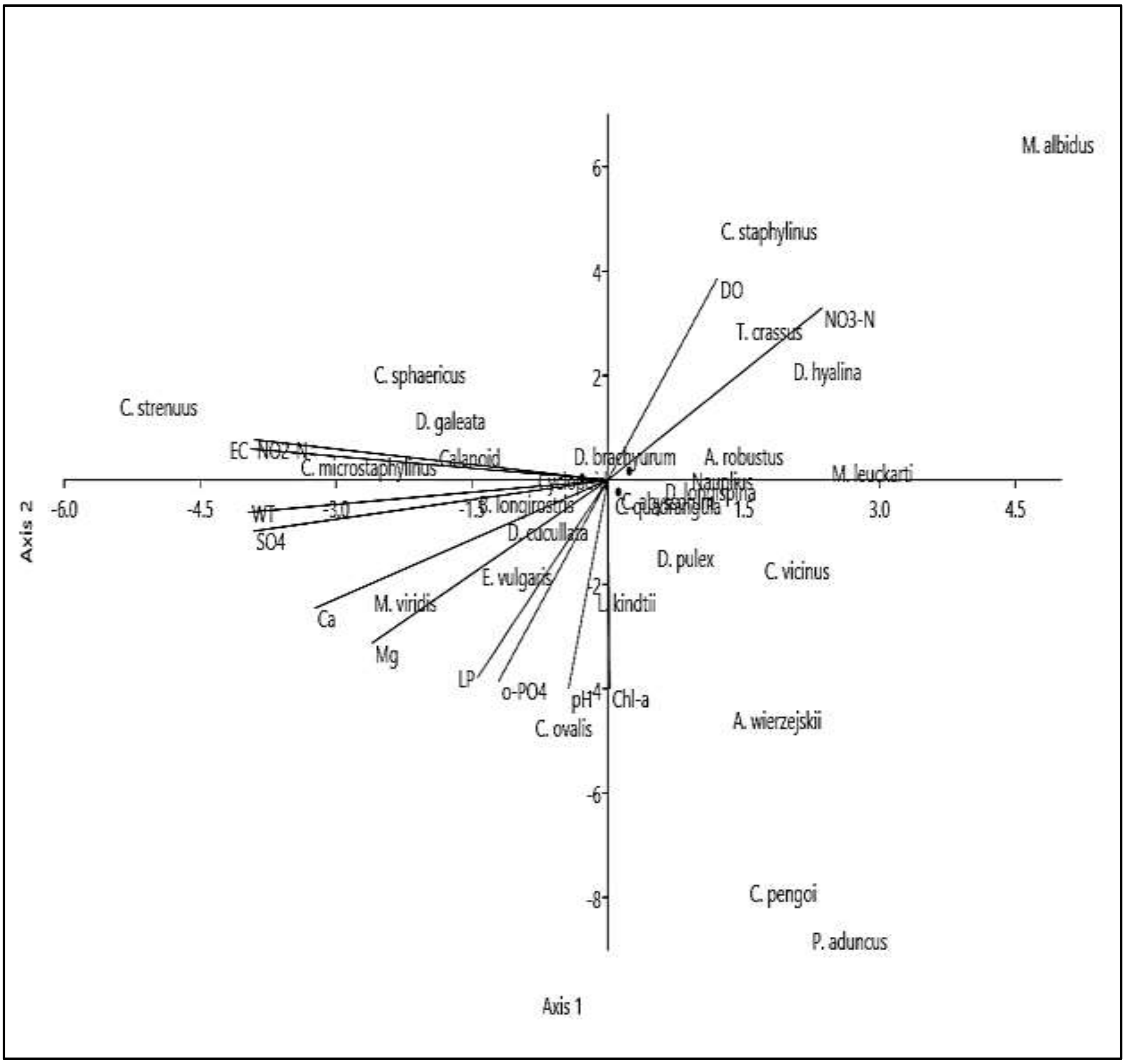

Figure 7. Water quality data of Kırklareli Reservoir and diagram of Canonical Correspondence Analysis (CCA) of zooplankton species density

Discussion

In the present study, which was performed for one-year period in Kırklareli reservoir, a total of 26 species have been identified as 14 species belonging to Cladocera and 12 species to Copepoda. The most common species in the reservoir were *D. brachyurum, B. longirostris, D. pulex, D. cucullata D. galeata* and *D. longispina* from Cladocera and *C. abyssorum, C. vicinus, E. vulgaris* and *A. wierzejskii* from Copepoda. Most of the zooplankton species found in the present study are reported to be widespread in freshwater ecosystems of all sizes in different geographic regions (Güher 2014, Ustaoğlu 2015). This is due to the fact that these species are able to adapt to very different ecological conditions and have a cosmopolitan distribution. The annual mean zooplankton abundance recorded during the study were 24076 ind/m^3, and 67% of it was Cladocera (16054 ± 12414 ind/m^3) and 33% was Copepoda (8022 ± 5564 ind/m^3) (Table 2). Considering the geographical region where Türkiye is located, zooplankton organisms are expected to increase twice in spring and autumn during the year. But, in Kırklareli reservoir, while Cladocera reaches its maximum in the summer and Copepoda in the autumn, Cladocera and Copepoda become minimum in the winter season. As one can see from the results of Bray-Curtis similarity index, according to the diversity and abundance of zooplankton species, similarities of months are associated with seasons. When the present results are compared with the studies carried out in the reservoirs in the same area, the abundances of Cladocera and Copepoda are relatively low (Güher and Çolak 2015, Güher 2019, Güher and Öterler 2021). The relatively low abundances of Cladocera and Copepoda were as a result of the hydrodynamics of the reservoir such as the low water volume, short residence time, relative old age of the reservoir and its morphometry.

Simpsons diversity index results showed that species richness of zooplankton is higher during the summer months. The increase in the temperature and the increase in aquatic macrophytes forming very specific habitats within the water body support species richness. The Shannon diversity index revealed no significant differences in species diversity of zooplankton by months. Species diversity and species richness increase and decrease in the same months and are affected by similar conditions (Table 4).

The correlations of Cladocera and Copepoda with nitrate and phosphate may not necessarily be a direct consequence of the zooplankton utilizing the nutrients, but could be attributed to the dependence of the phytoplankton (which serves as food for the zooplankton) on these nutrients. The positive correlation of zooplankton with transparency was as a result of the transparency of the water which supports zooplankton growth and abundance. The correlation with Chl-*a* depends on the use of phytoplankton as food by Cladocera and Copepoda.

The water temperature was recorded in its lowest value in winter and in the highest in the summer seasons. Similarly, the abundance of planktonic microcrustaceans was recorded in its lowest in the winter and in its highest in late summer and early autumn seasons. The zooplankton growth and abundance in the reservoir showed a positive correlation with WT, because WT is the most important factor affecting the amount of nutrients and life in freshwater (Geller and Müller 1981). pH is one of the important factors affecting the living life in water. Many species of fish and aquatic organisms develop well in waters with a pH range of 6.5 - 8.5 (Arrignon 1976; Dauba 1981). In this study, the average pH value was found to be 8,64 ± 0,49 and the reservoir water was graded as alkaline water (Table 1). Mean dissolved oxygen concentrations above 5 mg/L (Karpowicz and Ejsmont-Karabin 2017) and the electrical conductivity values around 250-500 μS/cm were reported to be the acceptable (Yücel 1990). Accordingly, the values recorded in the reservoir were among the acceptable values to support aquatic life, especially the zooplankton community.

According to the results of CCA analysis, high correlations (for CCA axis 1: 0.052, for CCA axis 2: 0.026) between Cladocera and Copepoda species and the environmental variables shows that, WT, SO_4^{2-}, Ca_2^+, Mg_2^+, LP, PO_4-P and pH are the significant factors determining the distribution of zooplankton organisms. CCA analysis showed that *D. hyalina, D. cucullata, B. longirostris, C. ovalis* from Cladocera and *C. staphylinus, T. crassus, M. albidus, A. robustus, M. leuckarti, M. viridis and E. vulgaris* from Copepoda are affected by similar environmental conditions.

Zooplanktonic organisms play an important role as indicators in determining water quality, eutrophication and water pollution level. Cladocera and Cyclopoid Copepods are particularly well adapted to eutrophic conditions (Gannon and Stremberger 1978). *C. sphaericus* (712 ± 1502 ind/m^3; 4.4 %), *B. longirostris* (6796 ±6375 ind/m^3; 42.3%) and *C. vicinus* (185 ± 265 ind/m^3; 2.3%) in Kırklareli reservoir are known as typical indicators of eutrophic lakes (Ryding and Rast 1989, Makarewicz 1993). Also, Yağcı (2016) reported that *C. quadrangula, B. longirostris, C. sphaericus, D. longispina* and *Cyclops strenuus paternonis* are mesotrophic-eutrophic indicators. In the present study, although *D. brachyurum, B. longirostris, D.*

pulex, D. cucullata, D. galeata and *D. longispina* from Cladocera and *C. vicinus, E. vulgaris* and *A. wierzejski* from Copepoda are the most common species in Kırklareli reservoir, the abundances of these species were very low. This shows that the reservoir has mesotrophic characteristics.

In conclusion, a total of 26 species from planktonic microcrustaceans (14 Cladocera and 12 Copepoda) were found in Kırklareli reservoir. As a result of quantitative evaluation of the samples, 67 % of the total microcrustaceans were Cladocera (16054 ± 12414 ind/m^3) and 33 % were Copepoda (8022 ± 5564 ind/m^3). When the mean values of each environmental factor measured in the reservoir were evaluated according to Water Pollution Control Regulations (Anonymous 2015), it can be concluded that they are within the normal ranges. When we examined the species identified in the reservoir, the distribution of the individuals that make up the microcrustaceans fauna and physicochemical parameters as a whole, it has been concluded that Kırklareli reservoir posesses mesotrophic characteristics in terms of zooplankton.

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