VARIATION OF ZOOPLANKTON IN THE HALBORI SPRINGS (TUNCELI, TURKEY)

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Abstract. This study examined certain water quality parameters and zooplankton fauna at two stations in Halbori Springs (Tunceli, Turkey), over a 12-month period from June 2022 to May 2023. The highest water temperature of 15.4°C was recorded at Station 2 in August, while the lowest water temperature of 5.0°C was recorded at Station 2 in January. The pH value of Halbori Springs ranged from 6.4 to 8.5. Dissolved oxygen varied between 8.1 and 11.9 mg/L during the study period. A total of 26 zooplankton species were identified in Halbori Springs. Nineteen of these species belong to Rotifera, five Cladocera and two Copepoda. According to the index analysis results of Station 1, the month with the highest species richness index, as measured by the Shannon Wiener H′ index, was October with a value of 1.97, while the lowest value was 0.45 in January. The highest value for the Margalef species diversity D index was 0.78 in October, and the lowest was 0.12 in January. According to the index analysis results of the station 2, the month with the highest species richness index, Shannon Wiener H', was September with a value of 1.68, while the lowest value was observed in January with 0.67. As for the Margalef species diversity index D, the highest value was recorded in September with 0.64, and the lowest value was observed in January with 0.12. In Halbori Springs, 1 species of Brachionus and 2 species of Trichocerca were found. The QB/T ratio was calculated to be 0.5, suggesting that the study area has oligotrophic characteristics.
Keywords: *Rotifera, Cladocera, Copepoda, Halbori Springs, Tunceli, Turkey*

Introduction

The increasing global population has led to the emergence of food problems and the recognition of the importance of protein in nutrition, directing all nations towards aquatic products, which are considered as major food stocks. Aquatic creatures living in freshwater and seas, especially fish, are seen as the world's most important food source in closing the animal protein gap. Turkey located between the continents of Europe, Asia, and Africa is rich in natural lakes, rivers, reservoirs, and ponds. There are over 120 natural lakes and 706 dam lakes in Turkey (DSI, 2015).

In recent years, some zooplankton species have been in decline or have disappeared due to factors such as eutrophication and overfishing, leading to changes in the food chain with an increase in different organisms; the quantity and quality of phytoplankton at the bottom of the chain and then zooplankton are affected. This situation is also having an impact on fisheries and fish (Bat et al., 2008).

Zooplankton, which is a large group of aquatic organisms and important for freshwater fisheries, has also been evaluated as a pollution indicator due to its sensitivity to environmental changes (Güher and Kırgız, 1992). The abundance and diversity of zooplankton provides information on the productivity of the aquatic environment as many aquatic organisms feed on zooplankton throughout their life

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stages. The short reproductive periods, rapid growth, and quick regeneration of Cladocera, rotifers and copepods make them important for fish larvae. Additionally, zooplankton play a crucial role in the aquatic environment and ecosystem as most of these creatures filter the water and quickly convert phytoplankton into animal protein. Some predators exist during the winter, but most do not (Cirik and Gökpınar, 1993).

While the majority of aquatic organisms consume zooplankton throughout their entire life cycle, others feed on zooplanktonic organisms during a specific part of their life cycle, in particular during the larval stage. This helps to explain the strong relationship between the diversity and abundance of zooplanktonic organisms and the productivity of the aquatic environment (Brun et al., 2019).

In addition, some zooplankton are important for the nutrition of juvenile fish and they are also crucial in determining pollution, eutrophication and water quality. Zooplankton’s significance is further strengthened by these factors (Berzins and Pejler, 1987; Mikschi, 1989; Güher and Kırgız, 1992).

The composition and abundance of zooplankton are related to water quality and can increase or decrease depending on the trophic levels of lakes (Canfield and Jones, 1996). Zooplankton in aquatic ecosystems form an important link in the food chain from primary to tertiary levels, leading to fishery production. Fish, crustaceans, molluscs and marine mammals are directly or indirectly dependent on zooplankton. Due to their abundance and intermediary role between phytoplankton and fish, they are considered the main index of the use of the aquatic habitat at the secondary trophic level. Herbivorous zooplankton are efficient grazers of phytoplankton and are referred to as living machines that convert plant material into animal tissue. Therefore, they play an important role as intermediaries in the transfer of nutrients/energy between the primary and tertiary trophic levels. Due to their short lifespans, drifting nature, high variety of groups/species, and varying tolerances to harsh conditions, they are used as indicator organisms for physical, chemical, and biological processes in aquatic ecosystems. They can be found at different depths in deeper waters and create a complex ecological system that deserves special attention (Gajbhiye, 2002).

The zooplankton fauna of the Halbori Springs, located within the borders of Tunceli Province in Turkey, has not been scientifically studied. Therefore, in order to provide data for future studies, an assessment of the current water quality and zooplankton status in the study area was carried out. The aim is to contribute to the determination of the pollution level of Halbori Springs by using some zooplankton species as indicators.

Materials and methods

Study area

Halbori Springs are located on the Munzur River in Turkey, approximately 20 km from the city center, on the Tunceli-Ovacık road. Halbori Springs is a popular recreational area with cold spring waters (URL-1, 2023). Zooplankton samples were collected at two stations on a monthly basis between June 2022 and May 2023 to determine the zooplankton of the Halbori Springs (*Fig. 1; Table 1*). Stations that were thought to best represent the characteristics of their area were selected. At each station, horizontal and vertical collections was done with a Hydrobios standard plankton net with a mesh size of 55 µ, and 5 samples were collected and preserved in 250 ml jars with 4% formaldehyde. The organisms were examined under a microscope and have been identified by their respective families, genera, and species.

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In the samples, a counting slide and a Leitz brand inverted microscope were used to indicate the number of zooplankton per unit volume. For counting, the jar was shaken slightly each time and 1 ml was taken with the help of a pipette, and zooplankton species were identified and counted. This process was repeated 10 times for each station. The number of organisms per cubic meter was calculated by proportioning the results first to the jar volume and then to the amount of water filtered through the plankton net.

The samples analyzed under an inverted microscope (GMBH D-6330 diavert inverted microscope, Earnst Leitz Ltd., Canada) and identified under a compound microscope (Nikon Eclipse E 100, Nikon Instruments Inc., Japan). Sources used for the diagnosis of the species include Edmondson (1959), Grasse (1965), Kolisko (1974), Koste (1978a, b), Segers et al. (1992), Flössner (1972), Negrea (1983), Einsle (1996), Karaytuğ (1999), Dussart and Defaye (2001). Temporary preparations were made for the immediate examination of zooplankton samples, and permanent preparations were made for later examination. Samples were taken from 2 stations to determine some physicochemical parameters of Halbori Springs. Temperature, pH and dissolved oxygen values at each sampling station were measured in the field during the study period. During the sampling, water temperature and dissolved oxygen were measured with Oxi 315i/SET brand and pH values were measured with Lamotte (pH5-WC) brand digital instruments.

Figure 1. *Halbori Springs (URL-2, 2023)*

Table 1. *The coordinates of Halbori Springs stations*

	1. Station	2. Station
Halbori Springs	39°10’39.86”N 39°27’40.83”E	39°10’10.38”N 39°27’41.15”E

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Rotifers are used as indicator species to reveal the trophic status. The QB/T index may be an important criterion for monitoring and managing the health of aquatic ecosystems. This index is formulated with (QB/T = number of Brachionus species / number of Trichocerca species). Q = 1.0 < is considered oligotrophic, Q = 1.0-2.0 is considered mesotrophic, Q = 2.0 > is considered eutrophic (Sladeck, 1983).

The Shannon Weiner diversity index was used for the understanding of the zooplankton species richness of Halbori Springs. The index value ranges from 0 to 5. When species are evenly distributed, the index shows high values. Conversely, if species are concentrated in a few families, the index shows low values. The Shannon-Weiner diversity index was calculated using the following formula (Washington, 1984).

$$H' = -\sum_{i=1}^{S} \mathrm{p_i} \ln \mathrm{p_i} \qquad \text{(Eq.1)}$$

H: Shannon diversity index, S: Total number of species in the community, pi: the ratio of the nth species to S, ln: natural logarithm.

Margalef species richness index was also used. Margalef “species richness index” was calculated by the following formula.

Margalef species richness index:

$$(D) = (S - 1) / \log N \qquad \text{(Eq.2)}$$

Q: number of species, N: total number of individuals.

Results

The surface water temperature of the Halbori Springs was measured and recorded in the field at regular intervals every month between June 2022 and May 2023. Starting from September, temperatures gradually decrease and reach their minimum value in January. The highest water temperature of 15.4°C was recorded in August at station 2, while the lowest water temperature of 5.0°C was recorded in January at station 2. The pH value was recorded between 6.4 and 8.5. The lowest pH value was measured at station 2 in July with 6.4 and the highest pH value was measured at station 1 in January with 8.5. During the study period, dissolved oxygen varied between 8.1 and 11.9 mg/L. The lowest amount of dissolved oxygen was measured as 8.5 mg/L at station 2 in August and the highest amount was measured as 11.9 mg/L at station 2 in January (*Fig. 2*).

The total number of individuals of zooplankton in Station 1 of Halbori Springs was calculated as 11,208 (individuals/m^3) at its highest in August and 1528 at its lowest in January. At Station 2, the highest number of individuals of zooplankton was calculated as 11,208 (individuals/m^3) in September, while the lowest was calculated as 2546 (individuals/m^3) in January. These data show that zooplankton populations show seasonal changes, reaching peaks in the summer and lowest levels in the winter. These differences may depend on various factors such as water temperature, amount of nutrients, amount of light and other environmental factors (*Tables 2–3*).

Differences in food sources between stations affect zooplankton density. Different food sources can have an impact on the diversity of zooplankton species and the growth rates of individuals. It is thought that the water flow and circulation between stations affects the transport rate and distribution of zooplankton and is the reason why the peak in zooplankton density is delayed in Station 2 compared to Station 1. *K. quadrata* and

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B. angularis from rotifera were recorded as dominant species in summer. *D. cucullata* from Cladocera was the dominant species in the summer season. Cyclopoid species were recorded as the dominant species in spring (*Tables 2–3*).

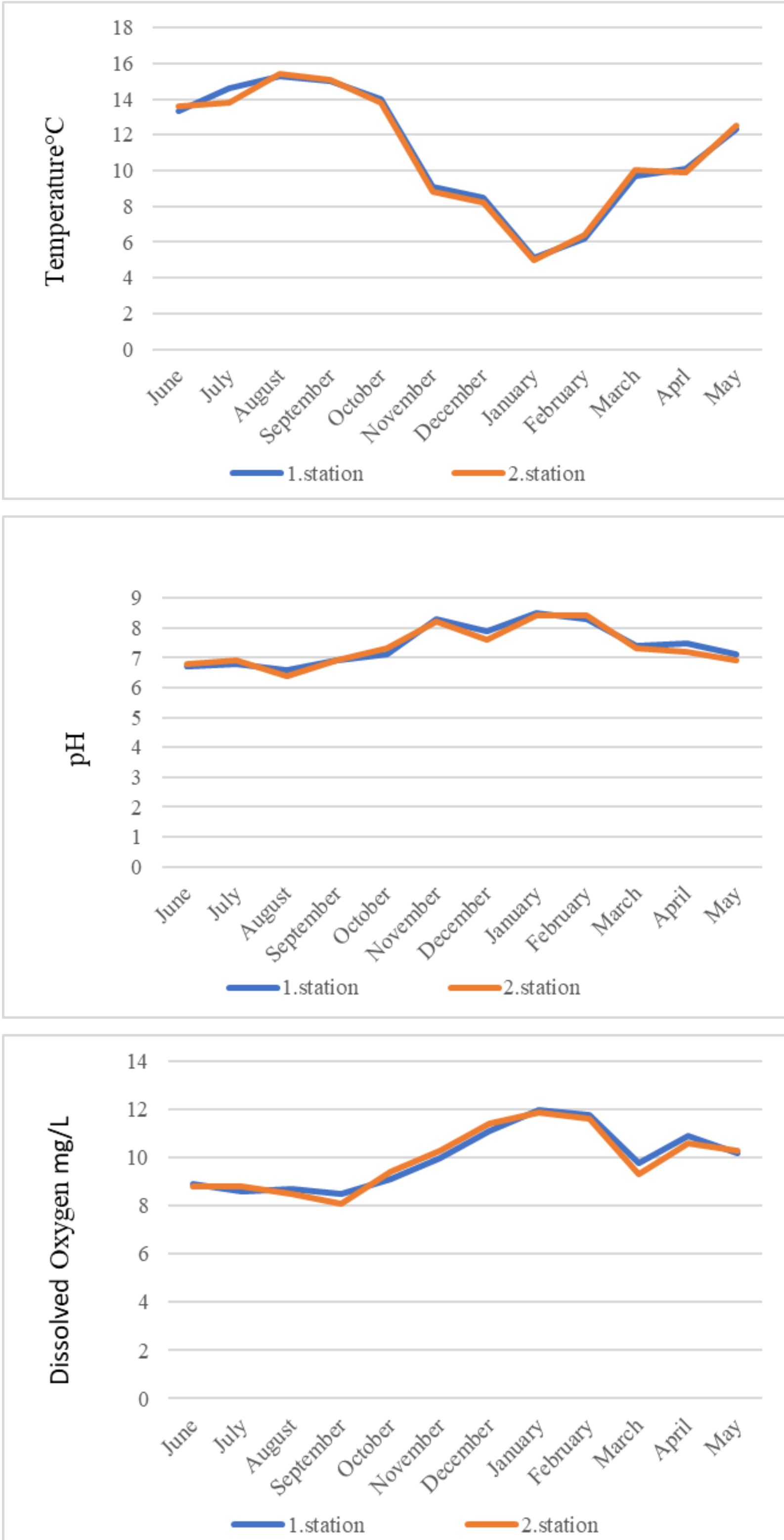

Figure 2. *Halbori Springs monthly temperature, pH, dissolved oxygen change*

Table 2. *Monthly distribution of number of zooplankton individuals detected at Halbori Springs, station 1 (individuals/m³)*

Species	Months											
	Jun.	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May**
Rotifera												
Ascomorpha saltans	509	509	-	-	1019	-	-	-	-	1019	509	1019
Brachionus angularis	509	509	1019	1019	1019	509	-	-	-	-	-	509
Cephalodella catellina	-	-	-	-	-	-	-	1019	-	-	-	-
C. forficula	509	-	-	-	-	-	-	-	-	-	-	-
Colurella colurus	-	-	509	-	509	-	-	-	-	-	-	-
Dicranophorus epicharis	-	-	-	1019	-	509	509	-	-	-	-	-
Euchlanis dilatata	2038	-	-	-	-	-	-	509	-	1019	-	-
Gastropus stylifer	-	-	1019	-	-	-	-	-	-	-	-	-
Keratella quadrata	1528	1019	3057	-	-	1019	-	-	-	509	-	509
Keratella tecta	-	-	-	-	1019	-	-	-	-	-	-	-
Notommata glyphura	-	-	509	-	-	-	-	-	-	-	-	-
Polyarthra dolichoptera	-	-	-	509	-	1528	-	-	-	1528	-	-
Synchaeta oblonga	-	-	-	-	-	-	-	-	1528	-	-	-
Synchaeta pectinata	-	-	509	-	-	+	-	-	-	-	1019	-
Trichocerca similis	-	509	-	-	-	-	-	-	-	-	509	509
Cladocera												
Bosmino longirostris	-	-	-	3566	509	509	-	-	-	1019	509	-
Chydorus sphaericus	-	-	-	1019	1019		509	-	509	-	-	-
Daphnia cucullata	-	-	4585	-	1528	-	-	-	-	-	-	1019
Copepoda												
Acanthopdiaptomus denticornis	-	509	-	1019	-	-	-	-	-	-	-	-
Cyclops vicinus	-	509	-	-	509	-	2038	-	-	1019	-	509
Total	**5093**	**3564**	**11207**	**8151**	**7131**	**4074**	**3056**	**1528**	**2037**	**6113**	**2546**	**4074**

Table 3. *Monthly distribution of number of zooplankton individuals detected at Halbori Springs, station 2 (individuals/m³)*

Species	Months											
	Jun.	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May**
Rotifera												
Brachionus angularis	509	509	1019	-	2038	1019	-	-	-	-	1019	1019
Cephalodella catellina	-	-	-	-	-	-	-	1528	1019	-	-	-
C. gibba	-	-	-	-	-	-	509	509	509	-	-	-
Colurella colurus	-	-	509	1019	-	-	-	-	-	-	-	509
Encentrum putorius	509	509	-	-	-	-	-	-	-	-	-	-
Gastropus stylifer	-	-	-	1019	-	-	-	-	-	-	-	-
Keratella quadrata	509	509	509	509	-	509	-	-	-	1019	-	1528
Keratella tecta	-	-	-	4585	1019	-	-	-	-	-	2038	-
Lecane nana	-	-	509	-	-	-	-	-	-	-	-	-
Polyarthra dolichoptera	1019	509	-	2038	-	3057	2547	-	-	-	-	-
Synchaeta oblonga	-	-	-	-	-	-	-	-	1019	-	-	-
Synchaeta pectinata	-	-	-	-	-	509	1019	-	-	-	2547	-
Trichocerca capucina	509	509	-	-	-	-	-	-	-	509	509	-
Cladocera												
Alona guttata	-	-	-	1019	1019	-	-	-	-	-	-	1019
Daphnia cucullata	1528	509	509	-	-	-	-	-	-	-	-	-
Pleuroxus aduncus	-	-	-	-	509	-	-	-	-	2038	1019	-
Copepoda												
Acanthopdiaptomus denticornis	-	-	1528	-	-	-	-	-	-	-	-	-
Cyclops vicinus	-	2038	-	1019	1019	-	-	509	-	509	-	509
Total	**4583**	**5093**	**4583**	**11208**	**5604**	**5094**	**4075**	**2546**	**2547**	**4075**	**7132**	**4584**

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According to the index analysis results of the station, the month with the highest richness index H’ of Shannon Wiener is October with a value of 1.97, while the lowest value is 0.45 in January. The month with the highest value of Margalef’s species diversity index D is October with a value of 0.78, and the lowest value is 0.12 in January. These two index results support each other (*Table 4*).

Table 4. *Total number of individuals (individuals/m^3), H’ (species diversity) and D (Margalef index) values of the organisms identified at station 1 in Halbori Springs*

	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May
Total number of individuals	5093	3564	11207	8151	7131	4074	3056	1528	2037	6113	2546	4074
H’	1.41	1.74	1.57	1.54	1.97	1.49	0.86	0.45	0.56	1.74	1.33	1.73
D	0.46	0.61	0.64	0.55	0.78	0.48	0.24	0.12	0.13	0.57	0.38	0.63

According to the index analysis results of the 2nd station, the highest value of Shannon Wiener H′ species richness index was determined as September with 1.68 and the lowest value was determined as January with 0.67. According to Margalef species diversity D index, the highest value was 0.64 in September and the lowest value was 0.12 in January. The results of these two indices support each other (*Table 5*; *Eqs. 1–2*).

Table 5. *Total number of individuals (individuals/m^3), H’ (species diversity) and D (Margalef index) values of the organisms identified at station 2 in Halbori Springs*

	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May
Total number of İndividuals	4583	5093	4583	11208	5604	5094	4075	2546	2547	4075	7132	4584
H’	1.66	1.60	1.67	1.68	1.51	1.08	0.90	0.67	1.05	1.21	1.47	1.52
D	0.60	0.58	0.59	0.64	0.46	0.35	0.24	0.12	0.25	0.36	0.45	0.47

When examining the seasonal variations in the number of species of Rotifera, Cladocera and Copepoda found at station 1 of Halbori Springs, it was determined that Rotifera had a higher number of species than the other two groups in all seasons. The highest number of species of Rotifera was observed in the summer season, while the highest number of species of Cladocera and Copepoda was observed in the autumn season (*Fig. 3*).

When comparing the seasonal variations in the number of species of Rotifera, Cladocera and Copepoda found at Station 2 of Halbori Springs, it was determined that Rotifera species were more abundant than the other two groups in all seasons. Cladocera species followed this group. Cladocera species followed this group (*Fig. 4*). Only in the autumn season was the Cladocera group not encountered.

Discussion

Temperature is crucial for both species diversity and zooplankton density in aquatic environments, just like it is for other organisms. It has a direct or indirect impact on plankton migrations (Herzig, 1987). In this study, we found that the water temperature in Halbori Springs varies according to the seasons. From September onwards, the

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temperature gradually decreases and reaches its minimum value in January. The highest water temperature of 15.4°C was recorded in August at station 2, while the lowest water temperature of 5.0°C was recorded in January at station 2. pH is an important factor that affects the life of zooplankton, and each organism has a certain pH tolerance range. The optimal pH value for zooplankton is known to be 8.5 (Berzins and Pejler, 1987). In this study, the pH value of Halbori Springs was recorded between 6.4 and 8.5. According to the findings, the pH values at both stations were found to be compatible with EPA (1979).

In aquatic environments, the amount of oxygen is lower compared to the air due to its low solubility in water. Knowing the amount of oxygen in water provides information about the quality of aquatic environments. The solubility of oxygen in water increases as the temperature decreases. In this study, the dissolved oxygen varied between 8.1 and 11.9 mg/L. The lowest concentration was measured at the second station in August, with a value of 8.5 mg/L, while the highest concentration was measured at the same station in January, with a value of 11.9 mg/L.

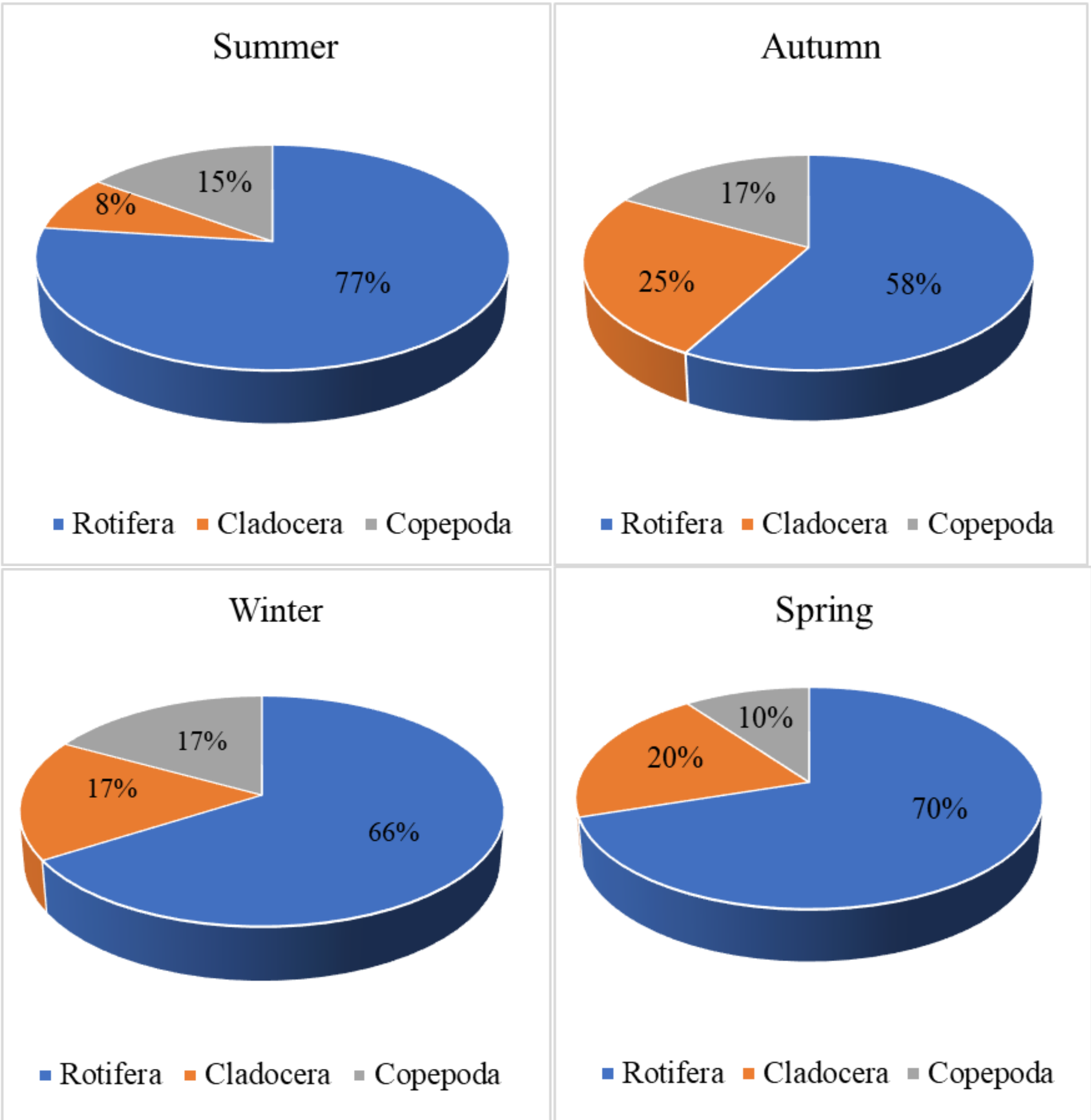

Figure 3. *The seasonal variation of zooplankton species at station 1*

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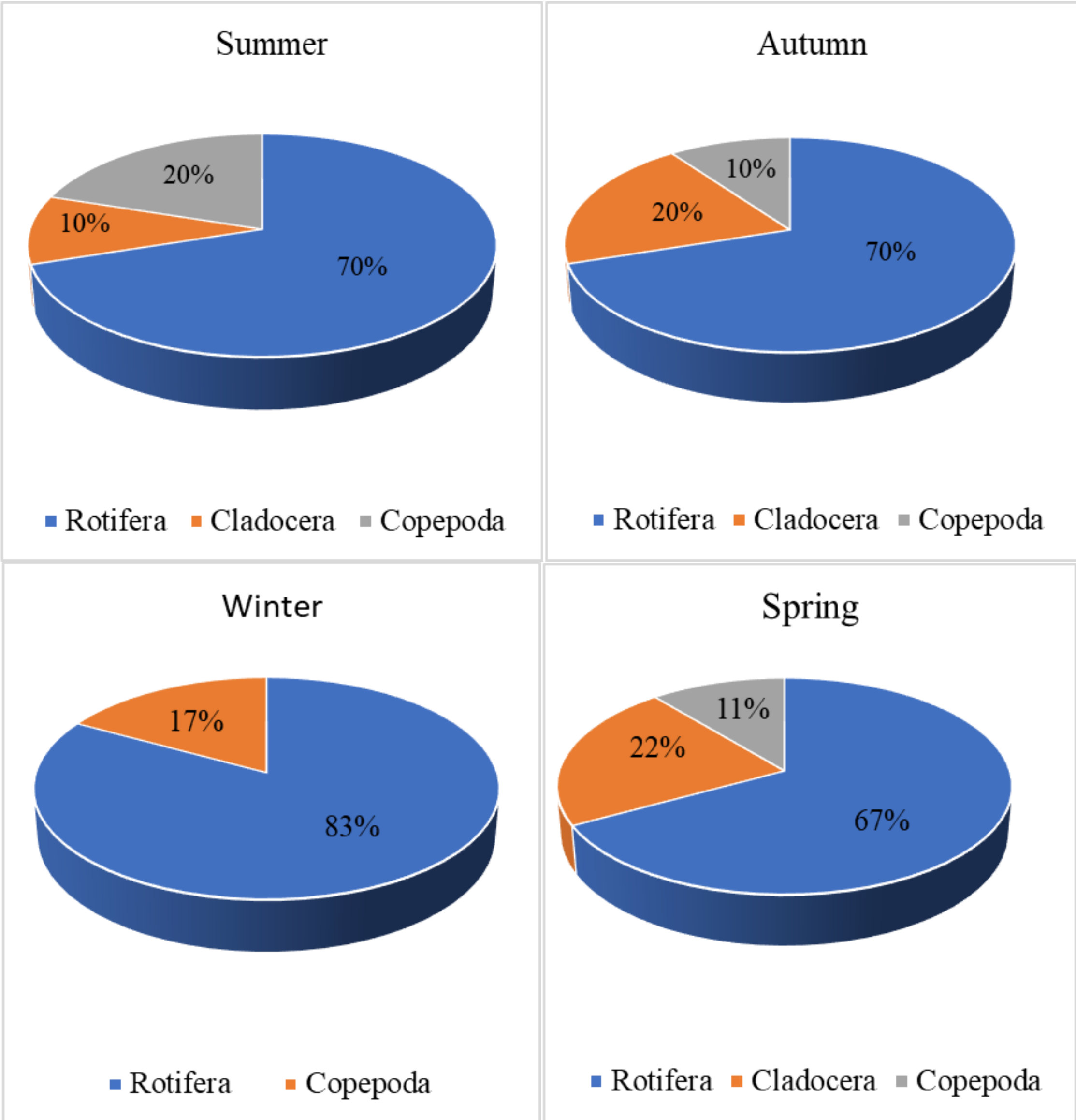

Figure 4. *The seasonal variation of zooplankton species at station 2*

A total of 26 zooplankton species were diagnosed in Halbori Springs when examining the diversity of the zooplankton groups identified in our study. Out of these, 19 species belonged to Rotifera, 5 to Cladocera and 2 to Copepoda. At the first station, the zooplankton of Halbori Springs includes Rotifera such as Ascomorpha saltans, *Brachionus angularis* and *Keratella quadr*ata, which are present for most months of the year, However *Cephalodella catellina*, *Cephalodella forfic*ula, *Gastropus stylifer*, *Keratella tecta*, *Notommata glyph*ura and *Synchaeta oblonga*, which are present for only one month of the year. The most abundant cladocerans are *Bosmina longi*rostris and *Chydorus sphae*ricus. The most commonly occurring copepod is Cyclops vicinus, which is present for most months of the year. At the second station, Halbori Springs Zooplankton is dominated by Rotifers such as *Brachionus angularis*, *Keratella quadrata*, and *Polyarthra dolichoptera*, while *Gastropus stylifer*, *Lecane nana*, and

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Synchaeta oblonga are only observed for one month of the year. Among Cladocerans, *Alona guttata* and *Daphnia cucullata* are the most abundant species. The most frequently observed Copepod is *Cyclops vicinus*, which is present for most of the year. When examining the seasonal variations in the number of species of Rotifera, Cladocera, and Copepoda found in Halbori Springs 1 and 2, it was determined that the Rotifera group was more abundant than the other two groups throughout all seasons.

In studies conducted in the same geographical region as Halbori Springs, including Peri, Pülümür, and Tahar Streams, Munzur River and Uzunçayır Dam Lake, Rotifera ranked first in the distribution of zooplankton species, followed by Cladocera and Copepoda groups. Similar results were obtained in Halbori Springs (Saler et al., 2011; Saler and Haykır, 2011; Öcalan and Saler, 2016; Saler, 2011; Bulut et al., 2021).

Rotifers are used as indicators to determine the trophic state. Indicator species of oligotrophic waters are Trichocerca species and are also used to determine trophic level. Zooplankton species such as Trichocerca are important indicator species that reflect certain conditions or characteristics in aquatic ecosystems. In particular, species that live in oligotrophic waters and are sensitive can provide information about the nutrient status of the water. The presence or abundance of certain zooplankton species, such as Trichocerca, can be used to determine the nutrient level of water, eutrophication levels or other environmental changes. Changes in the abundance of these species are used to monitor changes in water quality or the effects of environmental stress. Zooplankton play an important role in the food web and ecosystem dynamics in aquatic environments. Therefore, the abundance, diversity and distribution of zooplankton species are used to assess the health and trophic state of aquatic ecosystems and the effects of other environmental factors (Sladeck, 1983). The presence of Trichocerca species in Halbori Springs supports that this area may be oligotrophic. The rotifer trophic state index can be a useful tool for assessing the ecological quality of fresh water bodies in a temperate zone (Jurczak et al., 2019).

The index (QB/T = number of Brachionus species / number of Trichocerca species) is formulated to evaluate the trophic state. Q values of 1.0 < are considered oligotrophic, Q values of 1.0-2.0 are considered mesotrophic, and Q values of 2.0 > are considered eutrophic (Sladeck, 1983). In Halbori Springs, 1 species of Brachionus and 2 species of Trichocerca were found. The QB/T ratio was calculated to be 0.5, suggesting that the study area has oligotrophic characteristics.

Conclusion

In contrast to stagnant water bodies, fast-flowing waters may contain large numbers of rotifera but fewer cladocera and copepods (Shiel et al., 1982). The physical conditions of lotic ecosystems are not suitable for the growth and development of zooplankton compared to lentic ecosystems. Zooplankton strives to maintain its current situation and is carried against the current (Richardson, 1992; Walks and Cry, 2004; Chang et al., 2008). The high number of rotifer taxa in this study is parallel to this finding. Zooplankton plays an important role in food web and ecosystem dynamics in aquatic environments. Therefore, the abundance, diversity, and distribution of zooplankton species are used to assess the health, trophic state, and effects of other environmental factors of aquatic ecosystems (Sladeck, 1983). The presence of Trichocerca species in Halbori Springs supports that this area may be oligotrophic.

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