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Seasonal exploration of water quality and bioindicators of an agricultural irrigation and drinking water reservoir: Armağan Dam Lake, Kırklareli, Türkiye

by

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Abstract

This study aims to examine the water quality and dynamics of bioindicators (phytoplankton, zooplankton, and benthic macroinvertebrates) in the Armağan Dam Lake, a major freshwater reservoir that serves the drinking, domestic, irrigation, and industrial water needs of Turkey's Thrace region. To achieve this, water and sediment samples were collected seasonally from three stations over 1 year. Results show that the water quality generally remains within acceptable limits, as defined by the World Health Organization (WHO) and the Surface Water Quality Management Regulation (SWQMR) standards for dam water. Regarding irrigation suitability, the sodium absorption rate (SAR) and magnesium rate (MgR) indices indicate that the lake is appropriate for irrigation. However, the Kelly index (KI) values are only marginally suitable, and the %Na Index suggests that it is unsuitable for irrigation. The Heavy Metal Pollution Index (HPI) indicates that the lake is free from heavy metal pollution (maximum of 98.72) and is safe for drinking. Based on the Metal Index (MI), Class II results were observed in autumn, while Class I results appeared in the other seasons. The Shannon–Wiener diversity index displayed low values (maximum H' = 1.354) for the aquatic groups. Overall, the water quality parameters and biodiversity data suggest that the lake exhibits oligotrophic characteristics.

Key words: dam lake, benthic macroinvertebrates, bioindicators, phytoplankton, water quality, zooplankton

1. Introduction

The global human population is steadily rising, intensifying the demand for water across industrial, agricultural, and domestic sectors. Despite the fixed quantity of freshwater resources worldwide, climate change, primarily driven by accelerating global warming, continues to reduce available water and degrade water quality. In response to growing water needs, dam lakes have been constructed as freshwater reservoirs. Like elsewhere in the world, Türkiye has numerous dam lakes serving various purposes, including drinking water supply, irrigation, industrial usage, and flood control. Consequently, the sustainability of these reservoirs is becoming increasingly critical.

Similar to other aquatic ecosystems, dam lakes possess dynamic structures and trophic networks initiated by primary producers. Phytoplankton, which are primary producers, support zooplankton populations, which in turn serve as prey for invertebrate aquatic organisms. Together, these communities maintain the ecological balance of freshwater systems (Chi et al., 2023). Hence, sustaining a dam lake depends not only on quantity and quality of water but also on its biological diversity.

This study examines the water quality of Armağan Dam Lake, located in Türkiye's Thrace Region, through seasonal monitoring, while also assessing the sustainable use of key aquatic organism groups. Although the Thrace region comprises a small portion of the country's land area, it stands out as one of Türkiye's leading agricultural zones in terms of productivity and yield per unit area, hosting 11 dam lakes (Tokatlı, 2020). Armağan Dam Lake serves as an essential resource for irrigation and drinking water and supports local fisheries, with species such as carp and gray mullet contributing to regional livelihoods. While several studies have examined water quality in other dam lakes across the Thrace region (Güher et al., 2022; Tokatlı, 2019, 2020, 2021, 2022; Tokatlı et al., 2017), no prior research has comprehensively analyzed both water quality and biodiversity within Armağan Dam Lake. Accordingly, this study conducted seasonal monitoring over 1 year and performed statistical evaluations on the collected data.

2. Materials and methods

2.1. Study area

Armağan Dam Lake was established in 1986 on the Kocadere Stream, 26 km north of Kırklareli city center (Fig. 1). The dam lake has a lake area of 3 km^2, stores volume of approximately 52 hm^3, and provides irrigation services to 5.623 ha. In this study, three stations that best represent the dam lake were selected (Station 1: the deepest point of the lake, Station 2: the middle of the lake, Station 3: the shallowest point of the lake; Fig. 1), and water samples were taken from these selected stations seasonally (spring summer, autumn, and winter). Additionally, phytoplankton, zooplankton, and benthic macroinvertebrate samples were collected

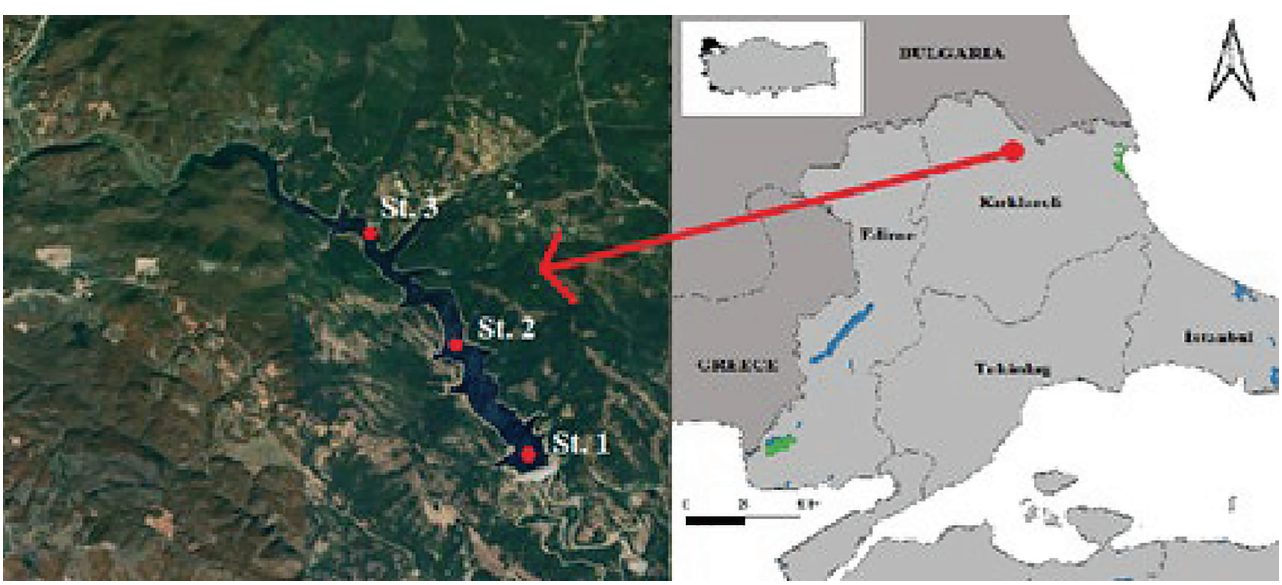

Figure 1

The sampling stations.

simultaneously with water sampling at the stations. At the field area, temperature, pH, conductivity, salinity, total dissolved solids (TDS), and dissolved oxygen (DO) values were measured in the lake water using the ORION STAR S/N 610541(Thermo Scientific Orion Star A214) brand multiparameter device. The light permeability was determined with a Secchi disk (20 cm × 20 cm) at each station.

2.2. Physical and chemical features

To measure the concentrations of chlorophyll-*a*, nutrient salts (nitrite nitrogen, nitrate nitrogen, phosphate, and sulfate), ions (fluoride, chloride, chlorate, chlorite, bromide, and bromate), and elements (B, Al, Cr, Mn, Co, Fe, Ni, Cu, Zn, As, Se, Cd, Ag, Pb, Na, Mg, K, and Ca) in the water from the three stations, water samples were taken with a Ruttner water collecting bottle (1.5 L capacity) seasonally for a year. The water samples were collected in light-proof glass bottles and transported to the laboratories of Trakya University Technology Research Development Application and Research Center (TÜTAGEM) for analysis. The ion and element analyses of the water taken from each station and each sampling period were measured in three repetitions in an Agilent Technologies (Tokyo, Japan) 7700 XX ICP-MS system according to EPA 200.8, and the average values were obtained (U.S. EPA, 1994). Water samples of 1 L were taken for chlorophyll-*a* determination and were filtered through a Whatman CF/C filter paper. The filter paper was dissolved in ethanol. The prepared sample was read in quartz glass cell cuvettes (1 cm) for spectrophotometric measurement. Chlorophyll-*a* was calculated using Nusch's method on a Shimadzu U.V. 1240 model UV-Vis spectrophotometer (Shimadzu Corporation) (Nusch, 1980).

2.3. Zooplanktonic organisms

For qualitative sampling, a simple plankton mesh net (25 cm mouth diameter, 75 cm length, and 25-μm spacing), for quantitative sampling (up to the surface from the bottom), a Hensen-type plankton net (mesh size 55 μm, mouth diameter 15 cm, and length 75 cm) were used. The collected materials were put into 250 mL plastic bottles containing 4% formaldehyde, labeled, and brought to the laboratory. Edmondson's (1959) method was used to count zooplankton samples. For this purpose, plankton samples in 250 mL plastic bottles were shaken well to make them homogeneous. Five milliliters of the sample was taken with a 10 mL pipette and was placed in the counting container. All organisms were counted under an inverted microscope. This process was repeated three times to determine the average number of individuals in 5 mL. The literature used for the zooplanktonic samples at the species level was Flössner (1972), Herzig (1987), Ejsmont-Karabin et al. (2004), Dussart and Defaye (2002, 2006), Segers (2008), and Błędzki and Rybak (2016).

2.4. Phytoplanktonic organisms

Water samples were collected using a 2 L Nansen water sampler from the surface, 3 m, 5 m, 10 m, and 20 m depths at Stations 1 and 2, and from the surface, 3 m, 5 m, and 10 m depths at Station 3. The samples were transported to the laboratory in light-proof glass bottles. Plankton samples were also taken horizontally from each station using a plankton scoop with a mouth diameter of 25 cm and a pore size of 55 μm. The samples were first agitated, poured into 50-mL graduated cylinders, and allowed to settle for at least 24 hr. At the end of the settling period, 45 mL of water was aspirated from each graduated cylinder. The remaining 5 mL of water was poured into a small glass vial for microscopic analysis. The counts were made for the water in the counting tubes using an Zeiss Axio Observer 5 inverted microscope following standard protocols as described by Utermöhl (1958). Phytoplankton samples were identified with a light microscope, and their photographs were taken. The literature used for the phytoplanktonic samples at the species level was Anagnostidis & Komárek (1988), Hartley (1996), Krammer (2003), John et al. (2003), and Tsarenko et al. (2006).

2.5. Benthic macroinvertebrates

Sediment samples taken using Van Veen Bager with an area of 260 cm^2 twice at each station were passed through a series of sieves with different mesh sizes (1.19, 0.595, and 0.297 mm, respectively). The material remaining on the sieve was fixed in 250 cc plastic containers containing 70% alcohol and brought to the laboratory. In addition to qualitatively determining the benthic macroinvertebrate fauna, mud samples were taken from random areas with hand-mud scoops and passed through sieves, and the resulting benthic material was fixed in 250 cc plastic containers containing 70% alcohol and brought to the laboratory. The samples were examined under a binocular microscope. The literature used for the macrozoobenthic samples at the species level was Soós (1968), Brinkhurst (1971), Pinder and Reiss (1983), Milligian (1997), Epler (2001), Schmelz and Collado (2010), Picazo et al. (2010), and Hacet et al. (2010).

2.6. Statistical analyses

The Shannon–Wiener diversity index was used to assess species diversity; the Bray–Curtis similarity index was used to compare sampling stations and seasons regarding physicochemical properties and the dynamics of zooplankton, phytoplankton, and benthic macroinvertebrates; canonical correlation analysis (CCA) was used to examine the correlation between zooplankton, phytoplankton, and benthic macroinvertebrates (most abundant species included in the CCA analyses for each group) and environmental factors. Heavy Metal Pollution Index (HPI; Mohan et al., 1996) and Metal Index (MI; Tamasi & Cini, 2004) were used to assess the impact of metal element pollution. To determine if the Armağan Dam Lake water is suitable for irrigation, the average concentrations of K, Mg, Na, and Ca over four seasons were analyzed. These averages were used to evaluate the lake's suitability for irrigation based on sodium percentage (%Na), sodium absorption rate (SAR), magnesium rate (MgR), and Kelly index (KI) (Balamurugan et al., 2020; Madhav et al., 2018). Additionally, water suitability for drinking was assessed according to World Health Organization (WHO) standards (WHO, 2024), and water quality was classified according to the Surface Water Quality Management Regulation (SWQMR) standards (SWQMR 2015).

3. Results and discussion

3.1. Physical and chemical variables

The analysis results of the water samples were averaged by station, and the values were evaluated according to water quality classes as outlined in the SWQMR (Turkish Regulations, 2015), as shown in Table 1. The values of pH (7.98), DO (8.18 mg · L^{-1}), conductivity (379.55 µS · cm^{-1}), TDSs (187 mg · L^{-1}), and water temperature (19°C) were found to be in Class I water quality; the salinity values were at permissible freshwater values (0.2‰–0.29‰) (Table 1). The nutrient salts, nitrate (0.95 mg · L^{-1}) and sulfate (7.01 mg · L^{-1}), were found to be in Class I water quality. However, nitrite (0.07 mg · L^{-1}) was in Class III water quality, and phosphate (0.33 mg · L^{-1}) was in Class II water quality (Table 1). All of the values belonging to the elements were recorded in Class I water quality values (B: 5.1 µg · L^{-1}; Al: 5 µg · L^{-1}; Cr: 0.1 µg · L^{-1}; Mn: 0.9 µg · L^{-1}; Fe: 3.9 µg · L^{-1}; Co: 0.04 µg · L^{-1}; Ni: 1 µg · L^{-1}; Cu: 1.5 µg · L^{-1}; Zn: 7.6 µg · L^{-1}; As: 1.3 µg · L^{-1}; Cd: 0.1 µg · L^{-1}; Se: 0.5 µg · L^{-1}; Pb: 0.9 µg · L^{-1}) (Table 1). The average chlorophyll-*a* value of the dam lake during the sampling period was measured as 2.23 µg · L^{-1}. Chlorophyll-*a* concentration is a parameter in classifying lakes according to their trophic level (Dillon & Rigler, 1974). According to the values of chlorophyll-*a* and light transparency (466.25 cm), Armağan Dam Lake was found to be a dam lake with an oligotrophic character (Turkish Regulations, 2015). The analysis results of the water samples were averaged by station, and the values were evaluated by the drinking water standards outlined by the WHO, as shown in Table 1. According to WHO standards, the values of physico-chemical variables were at the desirable levels for drinking water standards (WHO, 2024).

According to the suitability of irrigation water, the SAR and the MgR indices showed that Armağan Dam Lake was suitable for irrigation. However, the KI values were marginally suitable, and the %Na Index was unfit for irrigation (Table 1) (Balamurugan et al., 2020; Madhav et al., 2018). According to the WHO, the permissible 'K' value in drinking water is 12 mg · L^{-1} (Table 1) (WHO, 2024). According to the results of this study, the value exceeded the permissible limit (18.88 mg · L^{-1}) (Table 1). In this context, the fact that it is not suitable for irrigation according to the %Na Index result suggests that it may be due to the 'K' value used in the index calculation.

The results of HPI showed that the water of the Armağan Dam Lake is safe for drinking and is not polluted with determined elements (Table 2). According to the MI, the dam water is at Class I (very pure) values in terms of heavy metals. However, in autumn, the water is at Class II (pure) level (Table 3).

The Bray–Curtis Similarity index results showed >80% similarity degree among the stations according to physicochemical features (Fig. 2). Accordingly, while Stations 2 and 3 were a cluster, Station 1 constituted the second cluster (Fig. 2). The reason for the difference is that Station 1 differs from the others because it accumulates behind the dam embankment.

When studies on other dam lakes in the Thrace region are examined, the Armağan Dam Lake has cleaner water quality than the others. Tokatlı et al. (2017) studied at Sultanköy, Altınyazı, Süloğlu, and Kadıköy dams on physicochemical variables, and all the investigated reservoirs have Classes I–II. Class water quality in terms of electrical conductivity (EC), TDS, nitrate, sulfate, phosphate, and chemical oxygen demand (COD) parameters; Sultanköy, Altınyazı, and Kadıköy Dam Lakes have III. Class water quality in terms of nitrite parameter; Süloğlu and Sultanköy Dam Lakes have IV. Class water quality in terms of pH parameter; and Altınyazı and Kadıköy Dam Lakes have IV. Class water quality in terms of total organic carbon parameter (Tokatlı et al., 2017). Tokatlı (2020) determined the element pollution of Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanbey, and Süloğlu

Table 1

The seasonal average values of physical and chemical variables measured at the stations, SWQMR water quality classes, WHO permissible limits, and irrigation water suitability

Parameter	St. 1	St. 2	St. 3	Average	Water quality class (SWQMR)	Permissible limit (WHO)
pH	7.83	8.07	8.05	7.98	I	8.2–8.8
DO/mg · L^{-1}	8.2	8.27	8.08	8.18	I	-
Conductivity/µS · cm^{-1}	509.25	314.73	314.68	379.55	I	400 µS · cm^{-1}
Salinity/‰	0.29	0.2	0.2	0.23	-	-
TDS/mg · L^{-1}	251.38	153.73	155.88	187	I	1000 mg · L^{-1}
T_{water}/°C	18.88	18.83	19.3	19	I	-
Light transparency/cm	446.25	542.5	410	466.25	-	-
Chlorophyll-*a*/µg · L^{-1}	2.46	2.44	1.79	2.23	-	-
Fluoride/mg · L^{-1}	0.16	0.08	0.11	0.12	I	0.5 mg · L^{-1}
Chloride/mg · L^{-1}	17.93	4.01	4.02	8.65	-	700 mg · L^{-1}
Nitrite/mg · L^{-1}	0.1	0.06	0.06	0.07	III	3 mg · L^{-1}
Nitrate/mg · L^{-1}	1.25	0.84	0.75	0.95	I	50 mg · L^{-1}
Sulfate/mg · L^{-1}	5.34	7.82	7.87	7.01	I	250 mg · L^{-1}
Phosphate/mg · L^{-1}	0	0.76	0.24	0.33	II	-
Element	St. 1	St. 2	St. 3	Average	Water quality class (SWQMR)	Permissible limit (WHO)
B/µg · L^{-1}	11.61	1.98	1.83	5.1	I	2.4 mg · L^{-1}
Al/µg · L^{-1}	5	3	8	5	I	0.1 mg · L^{-1}
Cr/µg · L^{-1}	0.25	0.04	0.02	0.1	I	0.05 mg · L^{-1}
Mn/µg · L^{-1}	0.97	1.07	0.55	0.9	I	0.05 mg · L^{-1}
Fe/µg · L^{-1}	4.72	2.28	4.65	3.9	I	0.1 mg · L^{-1}
Co/µg · L^{-1}	0.06	0.04	0.03	0.04	I	-
Ni/µg · L^{-1}	1.75	0.73	0.62	1	I	0.07 mg · L^{-1}
Cu/µg · L^{-1}	2.38	1.14	0.87	1.5	I	2 mg · L^{-1}
Zn/µg · L^{-1}	17.25	2.87	2.73	7.6	I	3 mg · L^{-1}
As/µg · L^{-1}	1.27	1.35	1.32	1.3	I	0.01 mg · L^{-1}
Se/µg · L^{-1}	0.47	0.56	0.4	0.5	I	0.04 mg · L^{-1}
Cd/µg · L^{-1}	0.28	0.02	0.01	0.1	I	0.003 mg · L^{-1}
Ag/µg · L^{-1}	0.07	0.02	0.01	0.03	-	-
Pb/µg · L^{-1}	1.11	0.82	0.68	0.9	I	0.01 mg · L^{-1}
Na/mg · L^{-1}	6.84	5.79	5.85	6.16	-	250 mg · L^{-1}
Mg/mg · L^{-1}	13.56	14.35	14.24	14.05	-	50 mg · L^{-1}
K/mg · L^{-1}	52.31	1.35	2.97	18.88	-	12 mg · L^{-1}
Ca/mg · L^{-1}	19.07	20.09	19.13	19.43	-	75 mg · L^{-1}
Irrigation Water Indexes	St. 1	St. 2	St. 3	Average	Suitability for irrigation	
SAR	3.46	4.17	4.09	3.88	Excellent	
KI	1.75	2.18	2.09	1.99	Marginally suitable	
MgR	45.83	45.6	44.6	45.45	Suitable	
%Na	77.6	571.3	293.63	103.3	Unfit	

DO, dissolved oxygen; KI, Kelly index; MgR, magnesium rate; SAR, sodium absorption rate; SWQMR, Surface Water Quality Management Regulation; TDS, total dissolved solids; WHO, World Health Organization.

dams. As a result of the study, the 'Se' limit of the dams exceeds the acceptable limit (Tokatlı, 2020). Tokatlı (2021) studied irrigation water quality in Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanbey, and Süloğlu dams, and the investigated reservoirs were found to be suitable for use as irrigation water, in general.

3.2. Organisms

3.2.1. Zooplankton

A total of 51 zooplankton species were recorded (12 from *Cladocera*, 9 from *Copepoda*, and 30 from *Rotifera*), and 20 024 individuals · m^{-3} zooplanktonic organisms were found on average per year in the dam lake. In the seasonal distribution of zooplanktonic organism groups, the highest number of organisms was found in the spring season (34 183 individuals · m^{-3}), followed by summer (32 484 individuals · m^{-3}), autumn (10 722 individuals · m^{-3}), and winter (2707 individuals · m^{-3}) seasons (Table 4). *Cladocera* and *Rotifera* were most abundant in spring (*Cladocera* 2548 individuals · m^{-3}, *Rotifera* 30 414 individuals · m^{-3}, respectively), and *Copepoda* was abundant in summer (5149 individuals · m^{-3}) (Table 4). In freshwater habitats, nutrient salts increase with the warming of the weather in spring, and there is an increase in phytoplanktonic organisms. Accordingly, there is an increase in the number of zooplanktonic organisms that use phytoplanktonic organisms as food (Mikschi, 1989). However, in Armağan Dam Lake, although the values were close to each other, the highest number of organisms was

Table 2

The HPI results according to seasons

	Wi × Qi			
Element	**Spring**	**Summer**	**Autumn**	**Winter**
As	0.47108	0.44218	0.38367	0.4405
Cu	0.00225	0.0023	0.00208	0.0023
Zn	0.0003	0.0003	0.0003	0.0003
Cd	30	30	29.5	26.42
Ni	0.57143	0.57143	0.47952	0.54771
Pb	0	0.021	2.70333	0.52067
HPI (Σ Wi × Qi)	92.68	92.65	98.72	83.38

HPI >100 = It shows that the water is polluted with heavy metals.
HPI <100 = It shows that the water is safe for drinking and is not polluted with heavy metals.
HPI, Heavy Metal Pollution Index.

Table 3

The MI results according to seasons

	MI			
Element	**Spring**	**Summer**	**Autumn**	**Winter**
As	0.01157	0.02313	0.04653	0.0238
Cu	0.00077	0	0.00311	0
Zn	0.00044	0	0.0016	0
Cd	0	0	0.01667	0.11933
Ni	0	0	0.16083	0.0415
Pb	0	0.0021	0.27033	0.05207
ΣMI	0.01277	0.02523	0.49907	0.2367

MI <0.3 Class I (very pure).
MI = 0.3–1 Class II (pure).
MI = 1–2 Class III (slightly affected).
MI = 2–4 Class IV (moderately affected).
MI = 4–6 Class V (strongly affected).
MI >6 Class VI (seriously affected).
MI, Metal Index.

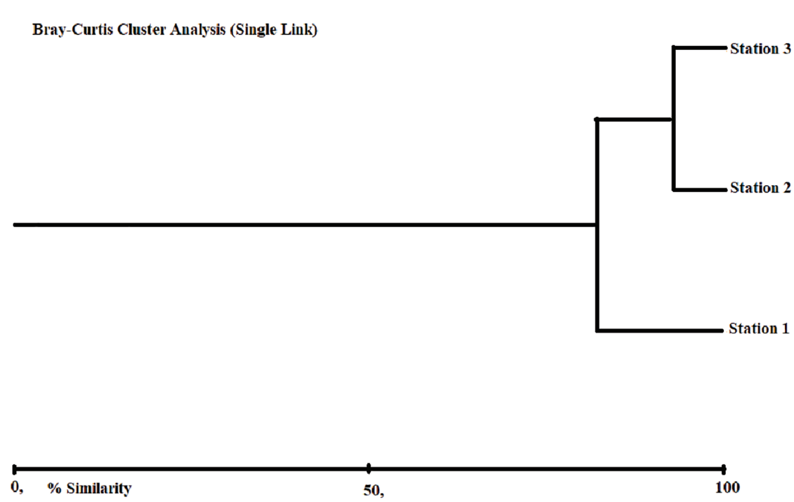

Figure 2

The similarity dendrogram of the stations according to physicochemical features.

Table 4

The distribution of zooplanktonic organisms in the Armağan Dam Lake according to the seasons (individuals · m^{-3})

	Autumn	Winter	Spring	Summer
Cladocera				
Diaphanosoma brachyurum (Liévin, 1848)	0	0	0	318
Daphnia pulex (Leydig, 1860)	0	0	0	1752
Daphnia cucullata (G. O. Sars, 1862)	0	0	0	425
Daphnia longispina (O. F. Müller, 1876)	106	0	0	637
Ceriodaphnia quadrangula (O. F. Müller, 1785)	318	0	0	796
Bosmina longirostris (O. F. Müller, 1785)	1274	531	2389	584
Pleuroxus aduncus (Jurine, 1820)	0	265	0	212
Chydorus sphaericus (O. F. Müller, 1776) (cins isminin önünde nokta işareti olmamalı)	425	0	106	106
Alona guttata (Sars, 1862)	0	0	0	106
Alona quadrangularis (O. F. Müller, 1785)	0	53	53	372
Total *Cladocera*	**2123**	**849**	**2548**	**5308**
Copepoda				
Eudiaptomus vulgaris (Schmeil, 1898)	0	0	0	159
Arctodiaptomus wierzejskii (Richard, 1888)	0	0	0	106
Eucyclops (E.) serrulatus (Fischer, 1851)	0	0	0	106
Cyclops abyssorum (G. O. Sars, 1863)	159	0	0	159
Cyclops vicinus (Uljanin, 1875)	53	0	159	372
Acanthocyclops robustus (G. O. Sars, 1863)	0	0	53	372
Megacyclops viridis (Jurine, 1820)	0	0	0	159
Onychocamptus mohammed (Blanchard, Rıchard, 1891)	0	0	0	106
Nauplius	425	159	902	1911
Cyclopoid copepodit	265	212	106	1115
Calanoid copepodit	53	0	0	584
Total *Copepoda*	**955**	**372**	**1221**	**5149**
Rotifera				
Anuraeopsis navicula (Rousselet, 1911)	0	0	0	53
Brachionus angularis (Gosse, 1851)	0	0	0	212
Brachionus quadridentatus (Hermann, 1783)	0	53	0	212
Brachionus diversicornis (Daday, 1883)	0	0	0	265
Kellicottia longispina (Kellicott, 1879)	4565	1274	0	3609
Keratella cochlearis (Gosse, 1851)	478	0	3981	4459
Keratella quadrata (Müller, 1786)	0	0	4618	2866
Keratella tecta (Gosse, 1851)	478	0	1168	106
Keratella tropica (Apstein, 1907)	0	0	2017	0
Colurella uncinata (Müller, 1773)	53	0	53	53
Polyarthra vulgaris (Carlin, 1943)	0	0	1911	902
Polyarthra remata (Skorikov, 1896)	0	0	0	53
Polyarthra euryptera (Wierzejski, 1891)	478	0	0	0
Synchaeta oblonga (Ehrenberg, 1832)	0	0	159	159
Synchaeta pectinata (Ehrenberg, 1832)	106	0	0	53
Asplanchna priodonta (Gosse, 1850)	1062	106	2601	2176

(*Continued*)

Table 4

Continued

	Autumn	Winter	Spring	Summer
Mytilina mucronata (Müller, 1773)	0	0	53	106
Lecane luna (Müller, 1776)	0	0	212	106
Lecane bulla (Gosse, 1886)	0	0	0	53
Ascomorpha ovalis (Bengendahl, 1892)	159	53	0	637
Ascomorpha ecuadis (Petry, 1850)	159	0	212	53
Gastropus minor (Rousselet, 1892)	0	0	106	106
Epiphanes macroura (Barrois & Daday, 1894)	0	0	106	0
Trichocerca capucina (Wierjeski & Zacharias, 1893)	0	0	1911	53
Trichocerca cylindrica (Imhof, 1891)	53	0	6104	478
Trichocerca elongata (Gosse, 1886)	53	0	1592	106
Trichocerca bicristata (Gosse, 1887)	0	0	0	1062
Trichocerca longiseta (Schrank, 1802)	0	0	1592	796
Hexarthra mira (Hudson, 1871)	0	0	0	265
Filinia longiseta (Ehrenberg, 1834)	0	0	2017	3025
Total *Rotifera*	**7643**	**1486**	**30 414**	**22 028**
TOTAL	**10 722**	**2707**	**34 183**	**32 484**

observed during the summer and autumn seasons, likely due to the delayed warming of the weather. No significant numerical difference was detected between the distributions of zooplanktonic organisms at the stations. We believe that the distribution of zooplankton has similar characteristics since both the water and the surroundings of the dam lake are poor in terms of plant vegetation.

Zooplanktonic organisms play an indicator role in determining water quality, eutrophication, and water pollution levels (Saksena, 1987; Sládeček, 1983). *Rotifera* species are generally more abundant in eutrophic lakes, while *Copepoda* species are more abundant in oligotrophic lakes (Herzig, 1987). *Brachionus* and *Trichocerca* genera belonging to *Rotifera* are used as indicators for determining the trophic status of a lake (Q = B/T; *Brachionus* species number/*Trichocerca* species number). According to this index, Q = 1 < oligotroph, Q = 1–2 mesotroph, Q = 2> eutroph (Sládeček, 1983). In the current study, three species belonging to the *Brachionus* genus, namely *B. angularis*, *B. diversicornis*, and *B. quadridentatus*; and five species belonging to the *Trichocerca* genus, namely *T. capucina*, *T. cylindrica*, *T. elongata*, *T. bicristata*, and *T. longiseta* were determined. According to the Q = B/T ratio (*Rotifera* index = 0.6), Armağan Dam Lake shows oligotrophic character.

In the CCA, the eigenvalues of the first two axes were calculated as 0.3793 and 0.1968, respectively. In the analysis, the two axes explain 97.95% of the variance of the species, 64.48% (Axis 1) and 33.47% (Axis 2) (Fig. 3). According to CCA, the distribution of *Asplanchna priodonta*, *Keratella cochlearis*, and *Filinia longiseta* was affected by Se, Al, Cu, Mn, As, Ni, Pb, Co, Cd, K, Cr, Fe, salinity, nitrite, nitrate, phosphate, fluoride, and DO; the distribution of *Keratella tecta*, *T. cylindrica*, and *Bosmina longirostris* was affected by Ca, pH, Zn, and B; the distribution of *Kellicottia longispina* was affected by sulfate, temperature, chloride, TDS, and secchi; the distribution of *Daphnia pulex*, *Ceriodaphnia quadrangula*, *Cyclops abyssorum*, and *Cyclops vicinus* was affected Na, Mg, and EC (Fig. 3).

3.2.2. Phytoplankton

A total of 58 phytoplankton species were recorded (37 from Bacillariophyta, 2 from Charophyta, 5 from Chlorophyta, 6 from Cyanobacteria, 3 from Heterokontophyta, and 5 from Miozoa), and 9276 individuals · mL^{-1} phytoplanktonic organisms were found on average per year in the dam lake. The highest number of organisms was found in Station 1 (10 563 org. · mL^{-1}), followed by Station 2 (10 035 org. · mL^{-1}) and Station 3 (7231 org. · mL^{-1}) (Table 5). According to the seasonal distribution of phytoplanktonic organism groups, the highest number of organisms was found in spring (11 655 org. · mL^{-1}), followed by summer (11 503 org. · mL^{-1}) and autumn (10 702 org. · mL^{-1}). The lowest number of organisms was found in the lake phytoplankton during winter months (3245 org. ·

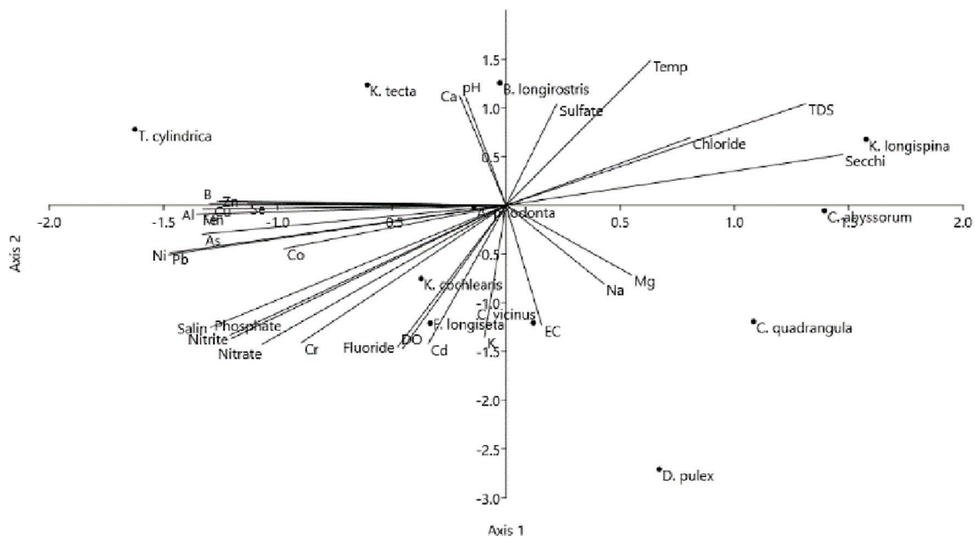

Figure 3

CCA between physicochemical variables and zooplankton taxa. CCA, canonical correlation analysis.

Table 5

The distribution of phytoplanktonic organisms in the Armağan Dam Lake according to the stations (individuals · mL^{-1})

	Station 1	Station 2	Station 3
Kingdom Eubacteria			
Phylum Cyanobacteria			
Anabaena sp.	131	157	142
Aphanocapsa sp.	10	3	14
Leptolyngbya sp.	13	13	6
Merismopedia tenuissima	26	21	0
Oscillatoria sp.	44	60	38
Planktothrix sp.	325	227	172
Kingdom Chromista			
Phylum Bacillariophyta			
Acanthoceras zachariasii	44	60	45
Achnanthes lanceolata	33	34	10
Achnanthidium exiguum	32	39	19
Amphora sp.	14	23	18
Asterionella formosa	632	701	341
Aulacoseira granulata	1097	897	694
Brachysira brebissonii	8	10	3
Cocconeis placentula	11	13	44
Cocconeis scutellum	15	10	23
Cyclotella meneghiniana	71	23	0
Cymbella cymbiformis	4	0	0
Cymbella cistula	12	15	15
Diatoma moniliformis	23	10	0

Table 5

Continued

	Station 1	Station 2	Station 3
Diploneis coffaeiformis.	0	8	7
Diploneis smithii	0	6	0
Epithemia sorex	8	0	14
Fragilaria capucina	142	132	98
Fragilaria crotonensis	279	190	153
Gomphonema angustatum	3	1	10
Gomphonema olivaceum	1	1	11
Gyrosigma acuminatum	90	98	42
Hannaea arcus	12	4	8
Hantzschia amphioxy	2	11	0
Mastogloia lanceolata	1	1	3
Melosira varians	0	17	13
Meridion circulare	53	59	0
Navicula cincta	8	21	0
Navicula radiosa	3	4	0
Nitzschia acicularis	458	420	347
Nitzschia dissipata	49	45	29
Nitzschia gracilis	34	39	45
Nitzschia sp.	10	7	0
Rhopalodia gibba	11	10	7
Tabellaria fenestrata	7	6	3
Ulnaria capitata	448	304	224
Ulnaria acus	39	25	4
Urosolenia eriensis	48	29	8

(*Continued*)

Table 5

Continued

	Station 1	Station 2	Station 3
Kingdom Chromista			
Phylum Miozoa			
Ceratium hirundinella	4033	4076	2675
Peridinium cinctum	463	337	297
Peridinium quinquecorne	233	93	93
Peridiniopsis quadridens	54	62	46
Protoperidinium bipes	113	128	83
Kingdom Chromista			
Phylum Heterokontophyta			
Dinobryon bavaricum	69	25	19
Dinobryon divergens	871	1082	1082
Dinobryon sertularia	286	191	172
Kingdom Plantae			
Phylum Chlorophyta			
Desmodesmus serratus	10	10	4
Monactinus simplex	18	1	8
Scenedesmus acunae	5	13	22
Scenedesmus obliquus	2	0	1
Scenedesmus opolinensis	3	4	2
Kingdom Plantae			
Phylum Charophyta			
Mougeotia abnormis	108	186	81
Mougeotia genuflexa	50	75	34
Total	**10 563**	**10 035**	**7231**

mL^{-1}). In freshwater habitats, with the warming of the weather in spring and the increase in nutrient salts, an increase in phytoplanktonic organisms occurs first. Accordingly, an increase is also seen in the number of zooplanktonic organisms that use phytoplanktonic organisms as food. However, in Armağan Dam Lake, the values are close to each other, and the highest number of organisms was found in spring and summer seasons. Relatively high species and organism numbers were also reached in the autumn season.

In the CCA, the eigenvalues of the first two axes were calculated as 0.019 and 0.014, respectively. In the analysis, the two axes explain 91.76% of the variance of the species, 53.47% (Axis 1) and 38.29% (Axis 2) (Fig. 4). According to CCA, the distribution of *Anabaena* sp. and *Planktothrix* sp. was affected by nitrite; the distribution of *Ceratium hirundinella* and *Fragilaria crotonensis* was affected by chloride, sulfate, TDS, temperature, pH, Al, Cu, Mn, Ni, Pb, Fe, and B; the distribution of *Asterionella formosa* and *Dinobryon divergens* was affected by Co and As; and the distribution of *Aulacoseira granulata* and *Nitzschia accularis* was affected by fluoride, nitrate, phosphate, K, DO, salinity, EC, Cd, Cr, secchi, Na, and Mg (Fig. 4).

3.2.3. Benthic macroinvertebrates

A total of 34 benthic macroinvertebrate species were recorded, and 1205 individuals · m^{-2} benthic macroinvertebrates were found on average per year in the dam lake. In the seasonal distribution of benthic macroinvertebrate groups, the highest

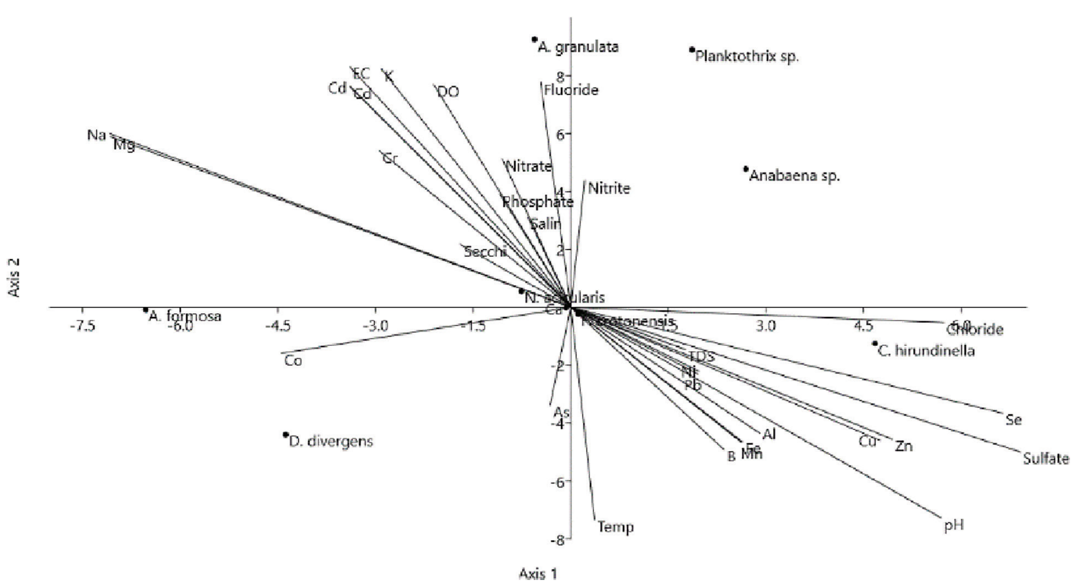

Figure 4

CCA between physicochemical variables and phytoplankton taxa. CCA, canonical correlation analysis.

Table 6

The distribution of benthic macroinvertebrates in the Armağan Dam Lake according to the seasons (individuals · m^{-2})

Taxa	Spring	Summer	Autumn	Winter
Cnidaria				
Hydra sp.	7	0	0	0
Nematoda	0	0	0	37
Mollusca				
Dreissena polymorpha	59	215	22	0
Physella acuta	0	30	0	0
Oligochaeta				
Limnodrilus hoffmeisteri	0	1000	156	474
Potamothrix hammoniensis	296	348	178	0
Stylaria lacustris	0	133	0	0
Hirudinea				
Glossiphoniidae	7	15	0	0
Ephemeroptera				
Baetis sp. 1	44	133	0	0
Baetis sp. 2	22	74	0	0
Odonata				
Orthetrum sp.	0	7	0	0
Coenagrionidae	0	7	0	0
Coleoptera (Larva)	0	67	0	0
Ceratopogonoidae	0	67	0	0
Chironomidae				
Halocladius millenarius	0	0	15	0
Psectrocladius limbatellus	0	7	7	22
Psectrocladius sordidellus	0	0	0	15
Orthocladius thienemanni	0	0	0	22
Ablabesmyia monilis	0	59	0	0
Ablabesmyia phatta	0	37	7	0
Procladius sp.	0	44	0	0
Tanypus kraatzi	30	0	0	0
Tanypus punctipennis	0	437	0	0
Chironomus tentans	0	0	7	0
Endochironomus albipennis	0	0	15	0
Endochironomus dissidens	15	0	0	0
Polypedilum nubeculosum	22	96	0	0
Cladotanytarsus mancus	0	141	0	0
Micropsectra curvicornis	15	22	0	0
Micropsectra notescens	22	15	0	0
Rheotanytarsus sp.	0	37	0	0
Rheotanytarsus exiquus	0	111	0	0
Tanytarsus gregarius	30	67	22	0
Virgatanytarsus arduennensis	15	59	0	7
TOTAL	**584**	**3228**	**429**	**577**

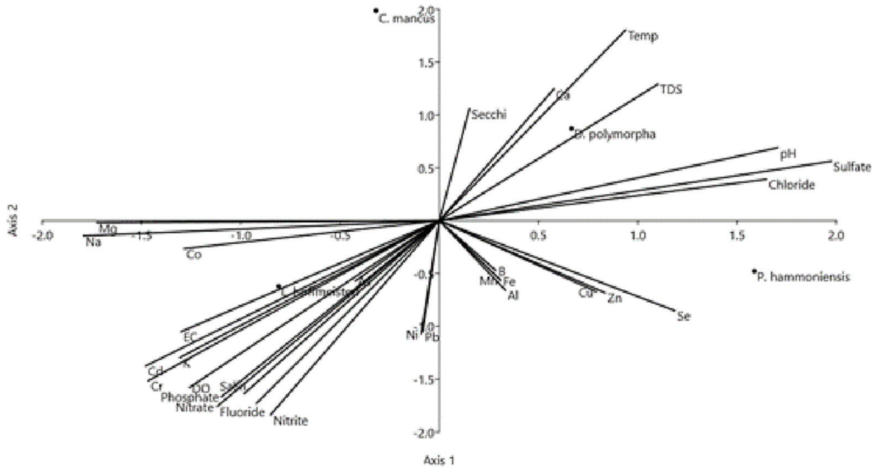

Figure 5

CCA between physicochemical variables and benthic macroinvertebrate taxa. CCA, canonical correlation analysis.

number of organisms was found in the summer season (3228 individuals · m^{-2}), followed by spring (584 individuals · m^{-2}), winter (577 individuals · m^{-2}), and autumn (429 individuals · m^{-2}) seasons (Table 6). *Limnodrilus hoffmeisteri* from the Oligochaeta group is an indicator species frequently found in polluted habitats and has the highest number of individuals among all taxa, with an average of 407 individuals · m^{-2} (Table 6). It is also reported that individuals of *Tanypus punctipennis* from the Chironomidae group are defined as pollution indicators (Epler, 2001), and this species was recorded as the highest number of Chironomidae taxa with an average of 109 individuals · m^{-2} (Table 6). This suggests that there may be a pollution load in the lake.

In the CCA, the eigenvalues of the first two axes were calculated as 0.3388 and 0.1093, respectively. In the analysis, the two axes explain 99.79% of the variance of the species, 75.44% (Axis 1) and 24.35% (Axis 2) (Fig. 5). According to CCA, the distribution of *Dreissena polymorpha* was affected by secchi, temperature, TDS, pH, sulfate, chloride, and Ca; the distribution of *Potamothrix hammoniensis* was affected by Se, Zn, Cu, B, Fe, Al, and Mn; the distribution of *L. hoffmeisteri* was affected by salinity, DO, EC, nitrite, nitrate, phosphate, fluoride, Mg, Na, Co, As, Ni, Pb, Ca, K, and Cr; and environmental variables do not affect the distribution of *C. mancus* (Fig. 5).

The species composition and numerical abundance of organisms showed that Armağan Dam Lake has an oligotrophic character. The Shannon–Wiener diversity index values supported it and were low for zooplankton, phytoplankton, and benthic macroinvertebrates (minimum H′ = 0.811; maximum H′ = 1.354) (Fig. 6).

According to the Bray–Curtis analysis index, the dynamism of zooplankton, phytoplankton, and benthic macroinvertebrates showed similarity in spring and autumn seasons (Fig. 7).

4. Conclusions

In this study, a year-long monitoring program was implemented to evaluate the seasonal dynamics of water quality and biodiversity in Armağan Dam Lake—a vital freshwater reservoir located in Türkiye's Thrace region, irrigating 5562.3 ha of agricultural land, and supplying drinking water to surrounding communities. Water analyses revealed that the lake generally meets Class I water quality standards, as defined by both the SWQMR and the WHO. Although the lake poses no significant risk for irrigation use, future monitoring efforts should pay particular attention to potassium ('K') concentrations within the water. Biodiversity assessments were carried out by collecting phytoplankton and zooplankton samples from the water column and benthic macroinvertebrates from the sediment. According to the HPI and the MI, the lake water was found to be clean with minimal elemental accumulation. Quantitative analysis across all three aquatic organism groups revealed the presence of bioindicator species that signal pollution; however, biological index values were generally low. Collectively, the results indicate that Armağan Dam Lake exhibits the characteristics of an oligotrophic ecosystem. Given the increasing pressures on global water resources caused by population growth and climate change, continuous monitoring of freshwater reserves like this one is essential. This study presents 1 year of biological

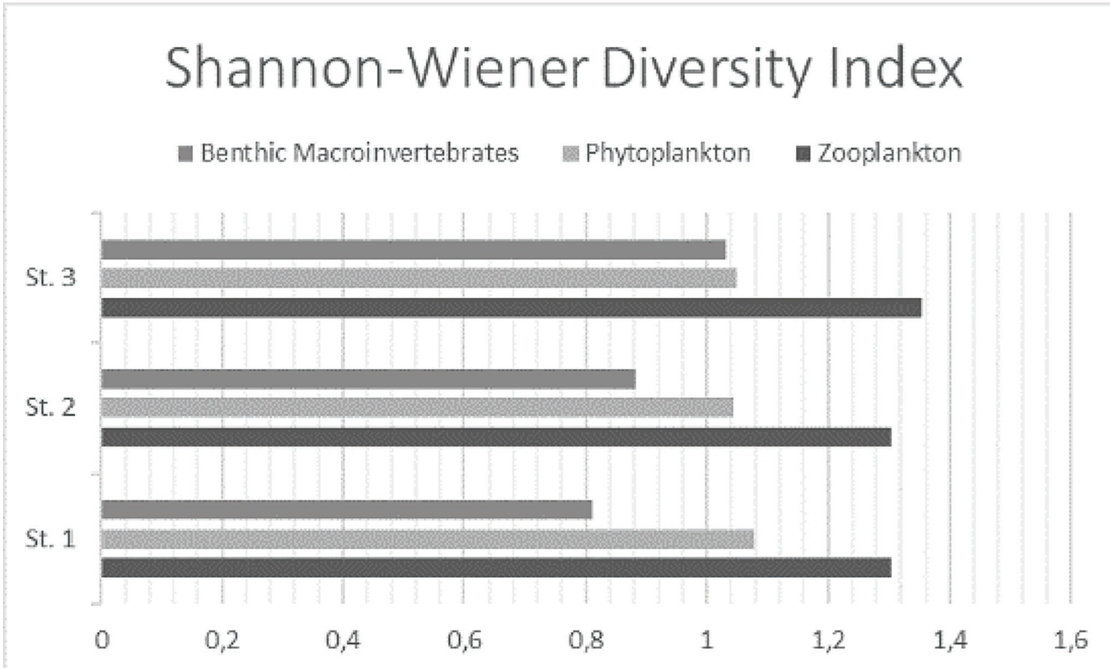

Figure 6

The Shannon–Wiener diversity index distributions of zooplankton, phytoplankton, and benthic macroinvertebrate taxa according to the sampling stations.

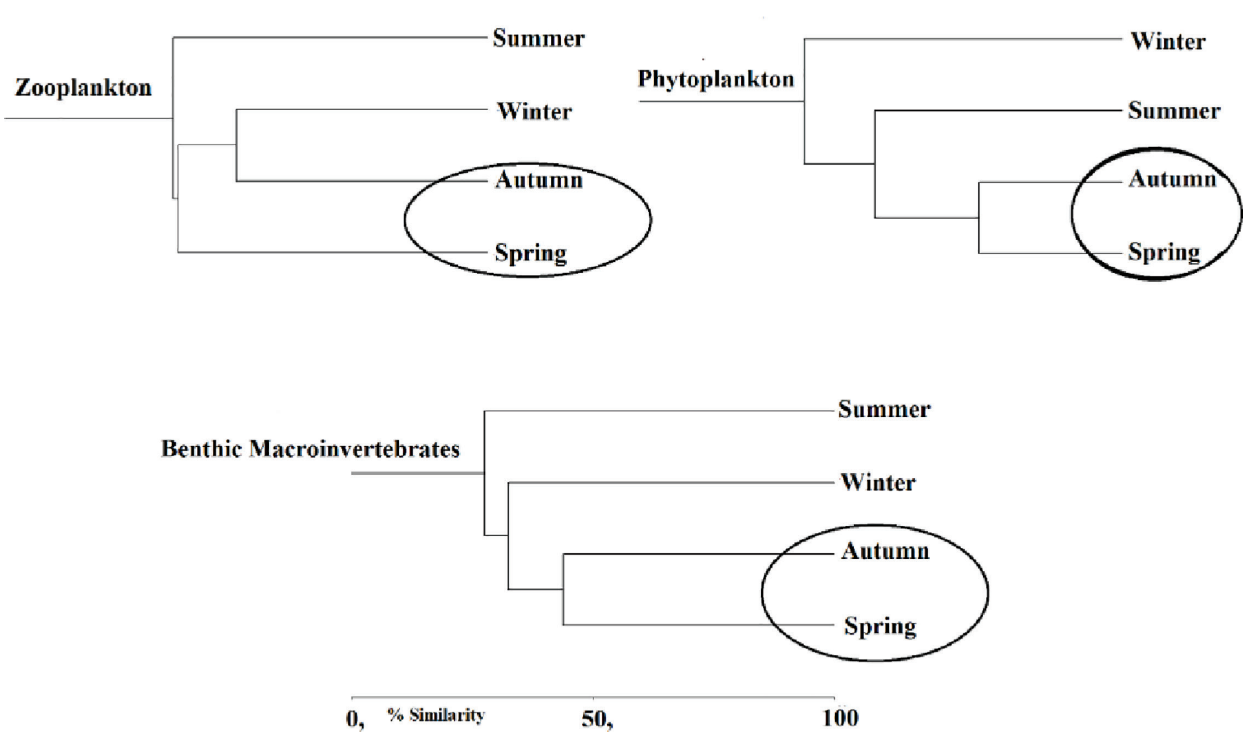

Figure 7

The similarity dendrogram of the seasons according to distributions of zooplankton, phytoplankton, and benthic macroinvertebrate taxa.

monitoring data for Armağan Dam Lake, contributing important insights into its sustainable management. We believe that such periodic monitoring plays a critical role in preserving the ecological integrity of Armağan Dam Lake, which appears to be cleaner than other regional dam lakes. Looking ahead, regular assessments should be conducted to determine the lake's trophic status, track shifts in phytoplankton community composition, and identify toxin-producing Cyanobacteria species. As protective measures, we recommend systematic water sampling to regulate nutrient salt inputs and ongoing physical and chemical surveillance of the tributaries that feed the lake.

Acknowledgment

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