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Evaluation of vertical and horizontal changes in community structure of zooplankton in a deep dam lake

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Abstract: The purpose of this study was to describe the horizontal and vertical distributions of the zooplankton community structure in Karakaya Dam Lake. Rotifers were numerically dominant (81.89%) in the community during the study period; they were followed by Copepoda (10.32%) and Cladocera (7.79%). In the metalimnetic maximum oxygen zone between 5 and 10 m, cladocerans made up 70.1% of the total number of zooplankton in June and 27.3% of the total number of zooplankton in November. Oxygen values decreased at 10 and 15 m in September and November. While the abundance of rotifers and cladocerans decreased as well, cyclopoids increased (60% of total zooplankton at 10 m). Nitrogen and soluble reactive phosphate were at low concentrations. Relationships among zooplankton, abundance, and environmental factors were analyzed using the unweighted pair-group method using arithmetic averages (UPGMA) and canonical correspondence analysis (CCA). UPGMA cluster analysis was used to illustrate unimodal species distribution by classification into 2 groups. Eigenvalues of axes clarified 42.7% of the cumulative variance in species data and 62.9% of the relationship between species and environmental data in the CCA. Many zooplankton species, rather tolerant to different environmental conditions, are good indicators for water quality and can be used for the biomonitoring of water ecosystems.

Key words: Canonic ordination, spatial distribution, population dynamics, water quality, Karakaya Dam Lake, upper Euphrates River

1. Introduction

In freshwater ecosystems, the community structure of zooplankton is especially affected by climatic, physical, and chemical characteristics; geographical factors; and inter- and intraspecific competition (Gulati and DeMott, 1997; Masson et al., 2001; Hobæk et al., 2002; Persson et al., 2007). Zooplankton species are commonly utilized as bioindicators for environmental changes since they respond quickly to environmental pollution as a whole community (Whitman et al., 2004; Altindag et al., 2009; Kaya et al., 2010; Sellami et al., 2010). Zooplankton as indicators of ecological circumstances have importance due to their position in the food web; they reflect the top-down regulators (fish), bottom-up factors (phytoplankton), and benthic status, and thus they supply information about the relative importance of top-down and bottom-up control and their effects on water transparency (Zhao et al., 2008; Jeppesen et al., 2011).

In stratified waters, different water masses are interrupted along with their contact surfaces due to changes in physical parameters. These clines are often determined by steep gradients of temperature and chemical composition and can put significant restrictions on the distribution and dispersion of zooplankton species (Armengol et al., 1998; Liu and Hu, 2001; Andersen et al., 2004; Bottger-Schnack, 1996; Badosa et al., 2007). Consequently, vertical distribution of zooplankton species depends on their ecophysiological tolerances and the availability of food supplies.

The purpose of this study is to describe horizontal and vertical distributions of the zooplankton species in Karakaya Dam Lake, located on the upper Euphrates River, and to investigate the relationships of the plankton species with major physical and chemical parameters. The main objectives of this study were 1) to determine the temporal and spatial community structure of zooplankton groups, 2) to identify the most significant environmental variables affecting seasonal dynamics of zooplankton species in the study area, and 3) to use data obtained from this study as a monitoring tool to improve water quality in future studies.

In order to achieve these purposes, this study assesses species-specific vertical distribution figures of zooplankton and relates them to the physicochemical environment. Investigations on the structure of the zooplankton community and abundance of organisms, associated with analyses on chemical and physical parameters of the water,

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are important in collecting data on the species diversity of a water body and its underlying dynamics.

One of the aims of water quality monitoring and management is to define the physical, chemical, and biological characteristics of natural waters. Water quality monitoring is used to determine 2 important features. These features are actual physical and chemical characteristics of water for a period of time, and changes in the properties of water over the course of time for multiple monitoring cases. Properties of water such as temperature, pH, dissolved oxygen, and the concentration of nitrates and phosphates are important indicators of the water quality. The results of the comparison made between water quality and zooplankton community structure in this study may be used for long-term sustainable water resource monitoring and management. Our biological assessment data are important for measuring the attainment of water quality standards to protect the basin of Karakaya Dam Lake in the future.

2. Material and methods

2.1. Field sampling and laboratory analyses

The Euphrates River, which is one of the most important rivers in the world, is a transboundary river rising in the eastern part of Anatolia and flowing into the Persian Gulf. Karakaya Dam Lake, situated on the upper Euphrates River, is the study area. Sampling was carried out between October 2005 and November 2006, until the second hydrological cycle in the dam lake (sampling could not be done in January, August, and October). Sampling points were selected in Karakaya Dam Lake; 2 stations were located in the northern section of the dam lake (stations 5 and 6), 2 stations were located in the center of the lake near settlements (stations 1 and 4), and the other 2 stations (stations 2 and 3) were located in the eastern part of the study area (Figure 1). Station 1 had a very shallow depth of about 5 m. On the other hand, stations 3, 5, and 6 each had a depth of nearly 46 m.

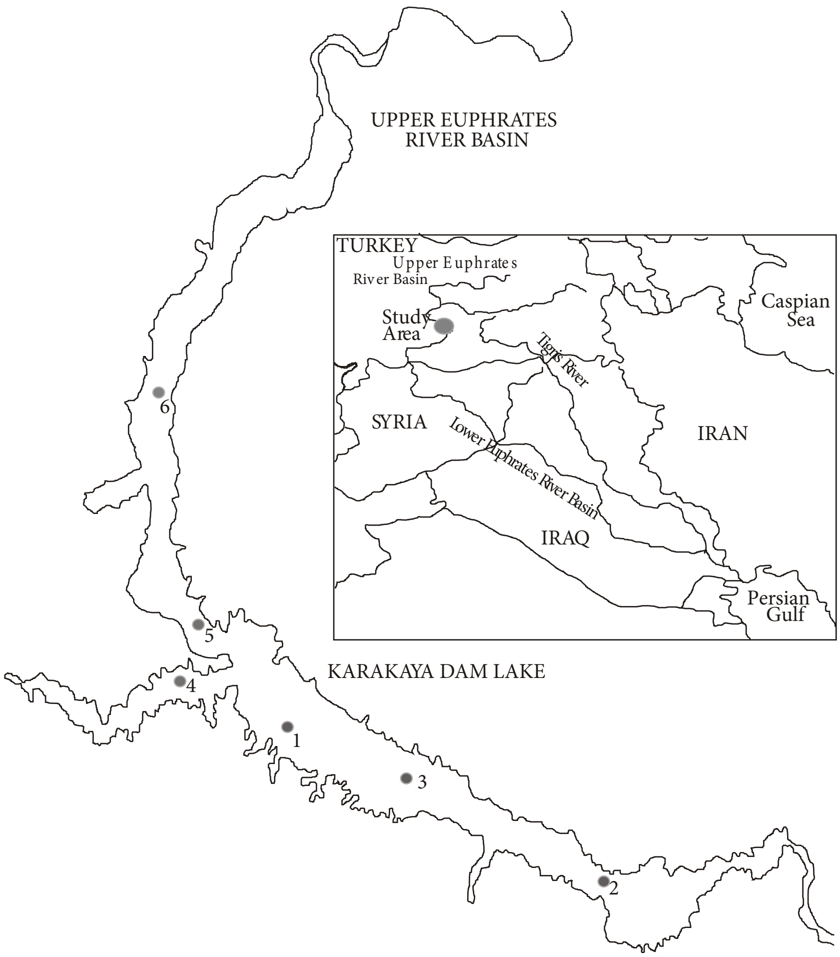

Figure 1. Map of Karakaya Dam Lake on the Euphrates River in eastern Anatolia. Sampling stations surveyed in this study are indicated.

In order to conduct chemical analysis, water samples were obtained from mixed water collected at 5-m intervals in the water column using a Ruttner water sampler (Hydro-Bios, 2 L). Dissolved oxygen (DO; YSI-55), specific electrical conductivity (EC_{25}; YSI-30), and pH (YSI-60) were determined in situ. Secchi transparency was measured using a standard Secchi disk (Hydro-Bios). Ammonium (NH_4-N), nitrite (NO_2-N), nitrate (NO_3-N), and soluble reactive phosphate (SRP) were analyzed from water samples filtered in the lab using Whatman GF/C glass-fiber filters. All of these parameters were measured according to DEV standard methods (Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung). SRP was measured using the ammonium molybdate spectrophotometric method (DIN 38 405-D11-1). We used the indophenol blue method (DIN 38 406-E5-1) to measure NH_4-N concentrations. NO_2-N and NO_3-N were measured in accordance with sulfanilamide and N-(1-naphthyl)-ethylenediamine methods (DIN 38 405-D10 and DIN 38 405-D9-2, respectively). Magnesium and calcium concentrations were analyzed for water hardness according to titration methods (Merck, 1974).

While vertical zooplankton samples were collected at 5-m intervals in the water column between April and November (during the circulation period of spring to autumn), samples of horizontal subsurface zooplankton were taken monthly from the study area (between October 2005 and November 2006). Samples were collected during the daytime between 1000 and 1500 hours (Guevara et al., 2009). Subsurface zooplankton samples were captured by filtering 100 L of subsurface water through a 55-µm pore-size Hydro-Bios plankton net. Vertical samples were taken using a clear Ruttner water sampler (Hydro-Bios 2 L, 0.5 m long), which was suspended vertically (Armengol et al., 1998). Zooplankton was concentrated by filtering the samples through a plankton net and preserved in 4% formalin. Two replicate samples were collected from each 5-m interval in the depth between the surface and 20 m in all stations. Each zooplankton sample was counted in sedimentation chambers (Hydro-Bios) (Paterson, 1993). An inverted microscope (Leica DM) with 100× and 200× magnification was used to count, and the zooplankton taxa were identified at species level as far as possible (Armengol et al., 1998). Species control was made in accordance with Ustaoğlu (2004) and was taken into account for the following calculations and data analysis.

2.2. Data analyses

For each zooplankton sample (rotifers, cladocerans, and copepods), the following community parameters were calculated: the Shannon–Weaver diversity index (H′) and species density (ind m^{-3}). These results were tested by the unweighted pair-group method using arithmetic averages (UPGMA). UPGMA analysis was classified into sampling points that were similar due to zooplankton composition. A canonical correspondence analysis (CCA) was carried out to analyze the relationships between the zooplankton composition and environmental variables. CCA is a modification of correspondence analysis that selects a linear combination of environmental variables to maximize the distribution of species scores. It is an efficient ordination technique because living organisms often show unimodal responses to environmental gradients (ter Braak, 1989; Jongman et al., 1995). All statistical analyses were done with $\log_{10}(x + 1)$ transformed variables in order to improve linearity, as well as normality and homogeneity of variances (Legendre and Gallagher, 2001). NTSYS 2.0 and CANOCO 4.5 software programs were used to conduct statistical analyses.

3. Results and discussion

3.1. Nutrient composition and dynamics

Water quality of the area was evaluated according to results of physical and chemical analysis conducted during the study period. NO_3-N, NO_2-N, NH_4-N, and SRP, which have a restrictive effect on aquatic organisms and are the main nutrient salts, were determined as water quality criteria (Whitman et al., 2004; Mageed and Heikal, 2006; Wu and Feng, 2012). Table 1 illustrates the average values of physicochemical parameters for environments where zooplankton were present.

The Karakaya Dam Lake ecosystem generally reveals Secchi disk measurements that vary based on periods with rain and mixture (at a 45-m depth in station 3, Secchi disk depth was measured as 3.09 m in March and 5.8 m in November). Maximum Secchi disk depth was measured as 7.4 m and 6.4 m (in stations 5 and 3). pH value, which is close to neutral in the winter season, was found to be at a high level of alkalinity in the dam lake. The Secchi disk depth was 3.6 m and epilimnion temperature was 21–20.2 °C (1 m and 5 m, station 2) in October. Accordingly, pH was 10.63–9.30 at the same layers. In May and June, pH was recorded above 9.

Dissolved oxygen amount was high in every season. The oxygen concentrations in the surface layers were high (12.31 mg L^{-1} DO) and decreased rapidly at the bottom, reaching extremely low values of DO as anoxic levels (2.68 and 1.31 mg L^{-1}) in station 4 in July and September. In October, in station 3, epilimnetic DO of 7.67 mg L^{-1} showed a metalimnetic decrease to 4.38–5.1 mg L^{-1} (10 m–15 m). In December, bottom DO concentration displayed a slight increase to 7.15 mg L^{-1} (at 25 m). In a similar way, the metalimnetic minimum oxygen zone (10 m and 15 m) decreased (5.29–4.89 mg L^{-1}) in station 2 in December. Metalimnetic DO values significantly decreased in July and were measured to be 7.38–7.92 mg L^{-1} at the epilimnion, while DO was 4.1 mg L^{-1} at 10 m

Table 1. Environmental parameters (mean ± SD (min–max) values) in the 6 sampling stations in Karakaya Dam Lake between October 2005 and November 2006.

Stations		Secchi (m)	Temp. (°C)	DO (mg L^{-1})	pH	EC_{25} (µS cm^{-1})	Salinity (ppt)	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NH_4-N (mg L^{-1})	SRP (µg L^{-1})	SO_4 (mg L^{-1})
st1	Mean ± SD	1.275 ± 0.716	16.160 ± 6.071	9.891 ± 2.239	8.230 ± 0.702	455.132 ± 69.834	0.230 ± 0.040	0.054 ± 0.083	0.026 ± 0.039	0.334 ± 0.350	0.315 ± 0.314	0.809 ± 1.767
	(min–max)	(0.5–2.7)	(8.8–26.2)	(6.89–14.09)	(7.1–9.3)	(371.8–610.4)	(0.2–0.3)	(0–0.261)	(0–0.131)	(0–1.211)	(0–1.131)	(0.038–5.318)
st2	Mean ± SD	3.523 ± 1.704	14.439 ± 5.685	7.923 ± 2.021	8.371 ± 0.636	413.762 ± 39.513	0.2 ± 0.0001	0.068 ± 0.191	0.003 ± 0.004	0.010 ± 0.015	0.110 ± 0.247	1.109 ± 1.819
	(min–max)	(1.0–6.3)	(7.0–30.8)	(4.10–13.42)	(7.44–10.63)	(336.6–477.8)	(0.2–0.2)	(0–1.660)	(0–0.017)	(0–0.070)	(0–1.962)	(0.027–6.125)
st3	Mean ± SD	3.527 ± 1.847	13.86 ± 5.354	8.129 ± 1.917	8.299 ± 0.540	414.071 ± 39.721	0.199 ± 0.009	0.040 ± 0.080	0.002 ± 0.003	0.026 ± 0.089	0.020 ± 0.069	0.086 ± 0.178
	(min–max)	(0.9–6.4)	(7.0–30.4)	(3.9–14.2)	(7.4–9.5)	(340.5–535.857)	(0.1–0.2)	(0–0.320)	(0–0.016)	(0–0.504)	(0–0.391)	(0–948)
st4	Mean ± SD	2.982 ± 1.980	16.126 ± 6.345	8.701 ± 2.473	8.324 ± 0.535	451.661 ± 46.788	0.202 ± 0.013	0.053 ± 0.088	0.006 ± 0.013	0.049 ± 0.176	0.083 ± 0.186	1.887 ± 2.884
	(min–max)	(0.9–8.0)	(8.7–32.3)	(1.31–14.23)	(7.6–9.4)	(371.9–602.5)	(0.–0.3)	(0–0.334)	(0–0.086)	(0–1.286)	(0–1.009)	(0.037–8.370)
st5	Mean ± SD	3.675 ± 2.127	13.884 ± 5.646	8.419 ± 1.830	8.243 ± 0.528	416.159 ± 38.298	0.2 ± 0.0001	0.022 ± 0.039	0.006 ± 0.020	0.008 ± 0.013	0.072 ± 0.230	0.787 ± 1.718
	(min–max)	(1–7.4)	(7–29.7)	(4.85–13.24)	(7.4–9.3)	(351.6–531.069)	(0.2–0.2)	(0–0.187)	(0–0.139)	(0–0.073)	(0–1.347)	(0.027–7.435)
st6	Mean ± SD	3.56 ± 1.881	14.069 ± 5.845	8.468 ± 1.590	8.293 ± 0.518	407.485 ± 31.766	0.2 ± 0.0001	0.022 ± 0.050	0.004 ± 0.004	0.005 ± 0.007	0.071 ± 0.169	0.824 ± 1.651
	(min–max)	(1.3–6.3)	(7.6–30.3)	(5.76–12.46)	(7.7–9.4)	(45.9–467.145)	(0.2–0.2)	(0–0.248)	(0–0.020)	(0–0.029)	(0–0.765)	(0.026–6.195)

in station 2. A similar situation was observed in station 3; subsurface DO concentration was 8.6 mg L^{-1}, while it decreased to 3.9 mg L^{-1} DO at 10 m (Figure 2). EC_{25} values increased due to this declining profile.

When evaluating the amounts of nitrogen such as NO_3, NO_2, NH_4, and SRP, it was seen that they were at low concentrations. The highest values were measured to be SRP at 1.962 µg L^{-1} (station 2) in November and SRP at 1.313 µg L^{-1} (station 5) in July. During other periods, these nutrients were at very low concentrations. Although NO_3-N values were low in general, it was 1.660 mg L^{-1} (station 2) in November. The amount of NO_2-N was lower. NH_4-N was 1.286 mg L^{-1} and 1.211 mg L^{-1} in November at stations 4 and 1, respectively, which are high values for this ecosystem.

3.2. Zooplankton community structure and composition

A total of 20 taxa were determined in all zooplankton samples, with rotifers being the most represented phyla with 14 taxa. Only 6 other taxa were encountered in the study area: 5 cladocerans and 1 copepods (Table 2).

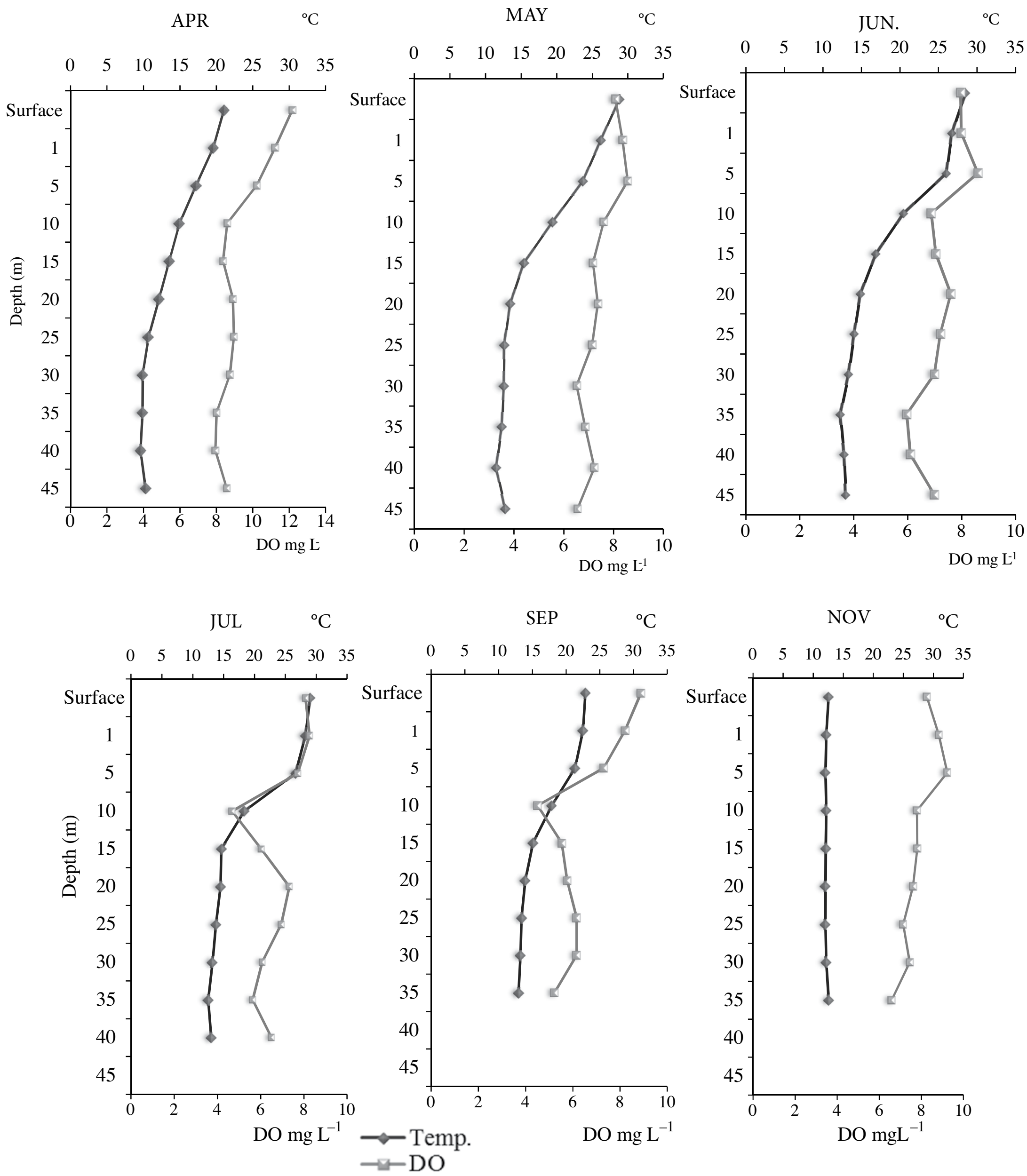

Figure 2. Vertical profiles (every 5 m of depth) of temperature (°C) and dissolved oxygen (mg L^{-1}) in the study area. Illustrations were formed for the vertical zooplankton sampling period.

Table 2. Vertical distribution (every 5 m of depth) of presence of zooplankton taxa in the sampling stations during the study period.

Taxa	st1		st2					st3					st4					st5					st6				
	Surf.	5 m	Surf.	5 m	10 m	15 m	20 m	Surf.	5 m	10 m	15 m	20 m	Surf.	5 m	10 m	15 m	20 m	Surf.	5 m	10 m	15 m	20 m	Surf.	5 m	10 m	15 m	20 m
Keratella cochlearis	+		+	+	+	+		+	+	+	+		+	+	+			+	+	+	+	+	+	+	+	+	
K. quadrata	+		+		+	+		+	+	+			+	+	+			+		+	+	+	+	+	+		
K. tropica	+		+					+					+					+					+				
Kellicottia longispina	+		+	+	+	+		+						+	+			+									
Polyarthra vulgaris	+		+	+	+			+	+	+			+	+	+			+	+		+		+	+	+		
P. dolichoptera	+		+					+	+				+					+					+				
Synchaeta oblonga			+					+					+					+					+				
Asplanchna priodonta	+		+	+	+			+	+	+	+	+	+	+	+			+	+	+			+	+			
A. brightwelli	+		+					+	+				+		+			+					+				
Lepadella patella	+												+														
L. rhomboides	+		+																								
Lecane quadridentata	+		+										+					+					+				
Filinia longiseta	+				+								+														
Habrotrocha sp.				+											+												
Daphnia cucullata			+	+	+	+		+	+	+	+		+	+	+			+	+	+	+	+	+	+	+	+	
D. longispina																		+					+				
Bosminia longirostris	+		+	+	+			+	+	+	+		+	+	+			+	+	+			+	+	+	+	
Chydorus sphaericus													+														
Coronatella rectangula													+														
Cyclops sp.	+				+	+		+		+	+	+	+	+	+			+	+	+	+	+	+	+	+		
Nauplius	+		+	+	+	+		+	+		+		+		+			+	+	+	+	+	+	+	+		

Rotifers were the most important component of the total zooplankton abundance, comprising 81.89% of total individuals in zooplankton samples; they were followed by copepods (10.32%) and then cladocerans (7.79%). Among the rotifers, the most abundant taxa were *Keratella cochlearis* (20,240 ind m^{-3}), *Asplanchna priodonta* (15,360 ind m^{-3}) and *Polyarthra vulgaris* (14,640 ind m^{-3}). *K. cochlearis* is a cosmopolitan species found within wide temperature ranges. Although *K. cochlearis* was denser than the other species in the study area, it was also recorded in very low densities during the summer season. *A. priodonta* and *P. vulgaris* were observed to be denser during spring and autumn periods. Among the cladocerans, *Bosminia longirostis* (3440 ind m^{-3}) and *Daphnia cucullata* (2080 ind m^{-3}) were recorded as the most abundant taxa compared to the other cladocerans. On the other hand, *Lepadella rhomboides* (160 ind m^{-3}) and *Lepadella patella* (80 ind m^{-3}) among the rotifer species and *Daphnia longispina* (160 ind m^{-3}) and *Chydorus sphaericus* (160 ind m^{-3}) among the cladoceran species were recorded in very low densities.

Tropical and temperate limnological comparative studies indicated that whereas oligotrophic habitats are dominated by copepods, more eutrophic habitats are dominated by rotifers and cladocerans. The dominance of small rotifers and cladocerans in eutrophic ecosystems is thought to be directly associated with their ability to effectively avoid typically abundant cyanobacteria and feed on smaller algal particles (Paranaguá et al., 2005). These conditions could be related to the higher abundance of rotifers (comprising 81.89% of all samples) in the Karakaya Dam Lake, where small algae are abundant (Gokce and Ozhan, 2011).

3.3. Vertical distribution of zooplankton abundance

The vertical distribution of zooplankton species abundances in relation to environmental conditions is an important aspect of the structure and function of freshwater plankton communities. According to Guevara et al. (2009), most of the zooplankton community was recorded in the euphotic layer in the study area. Cyclopoids were commonly more abundant at greater depths than cladocerans. In general, as seen in Figures 2 and 3, the lake had a metalimnetic maximum oxygen curve in May, June, and November. During this period, cladocerans, uncommon in the epilimnion, were observed at 5 m and 10 m. In the metalimnetic zone between 5 and 10 m, cladocerans were 70.1% of the total number of zooplankton in June and 27.3% of the total number of zooplankton in November. *D. cucullata* was the dominant species at these layers.

Decreasing oxygen values were observed at 10 and 15 m in September and November. Abundance of rotifers and cladocerans decreased, while the number of cyclopoids increased (60% of total zooplankton at 10 m). The dominant rotifer *K. cochlearis* was densely found at 5 m and 10 m in April and May, while it was found at 5 m in July. Another dominant species, *P. vulgaris*, demonstrated similar behavior.

The hypolimnion, where light and oxygen are reduced, can produce a refuge for zooplankton due to nonexistent or significantly lower predation (Armengol et al., 1998; Auel and Verheye, 2007). *D. cucullata* made up 50% of the total zooplankton at 20 m in April while *K. cochlearis*, *K. quadrata*, and *Cyclops* sp. and its nauplius larvae constituted the other part of the zooplankton total. According to Hutchinson (1967), *A. priodonta* was clearly more dispersed in the epilimnetic layers down to 15 m than in the deeper water in later spring. In May, *A. priodonta* was encountered at 20 m (Table 2; Figure 3).

Nitrogen and phosphate had higher concentrations in stations 1 and 4 compared to the other stations (Table 1). These concentrations affected zooplankton diversity (Figure 4). Shannon–Weaver diversity analysis was applied to zooplankton by taxa. Stations 1 and 4, which contained higher nitrogen and phosphorus salts, had the highest diversity (mean H′ = 1.647 and H′ = 1.574, respectively), while station 3 had the lowest diversity of species (mean H′ = 0.939, Figure 4). March, April, and November were recorded as the highest in terms of diversity; maximum diversity (H′ = 2.276) was observed in station 4 in November. Control factors such as DO, nutrient concentrations, and temperature were effective on species diversity. The results of CCA correlation between nutrients and zooplankton data supported this finding (Table 3).

According to the distribution of zooplankton species in the study area, sampling points were classified into 2 main groups in accordance with UPGMA cluster analysis (Figure 5). In the dendrogram, the first group was similar to each other in station 1 and station 4 sampling points. Nutrient concentration and zooplankton abundance resulted in this situation. According to their coefficient of similarity, the second group was divided into 2 subclusters. Stations 2, 3, and 5 were included in the first subcluster; stations 5 and 2 were more similar in comparison with each other. Station 6 was placed in the second subcluster.

In the pelagic zone of a stratified water body, the upper warm epilimnion supports a high density of food for zooplankton. Furthermore, temperature and food in the epilimnion are useful for the zooplankton in this region, but the highest fish predation is seen at this layer, as well. Trade-offs exist between feeding and predator avoidance (Burns and Mitchell, 1980; Masson et al., 2001; Andersen et al., 2004; Ignoffo et al., 2005). The composition and dynamics of the zooplankton community are affected by interspecies competition and selective predation pressures. Top-down pressure by planktivorous fish can reduce the

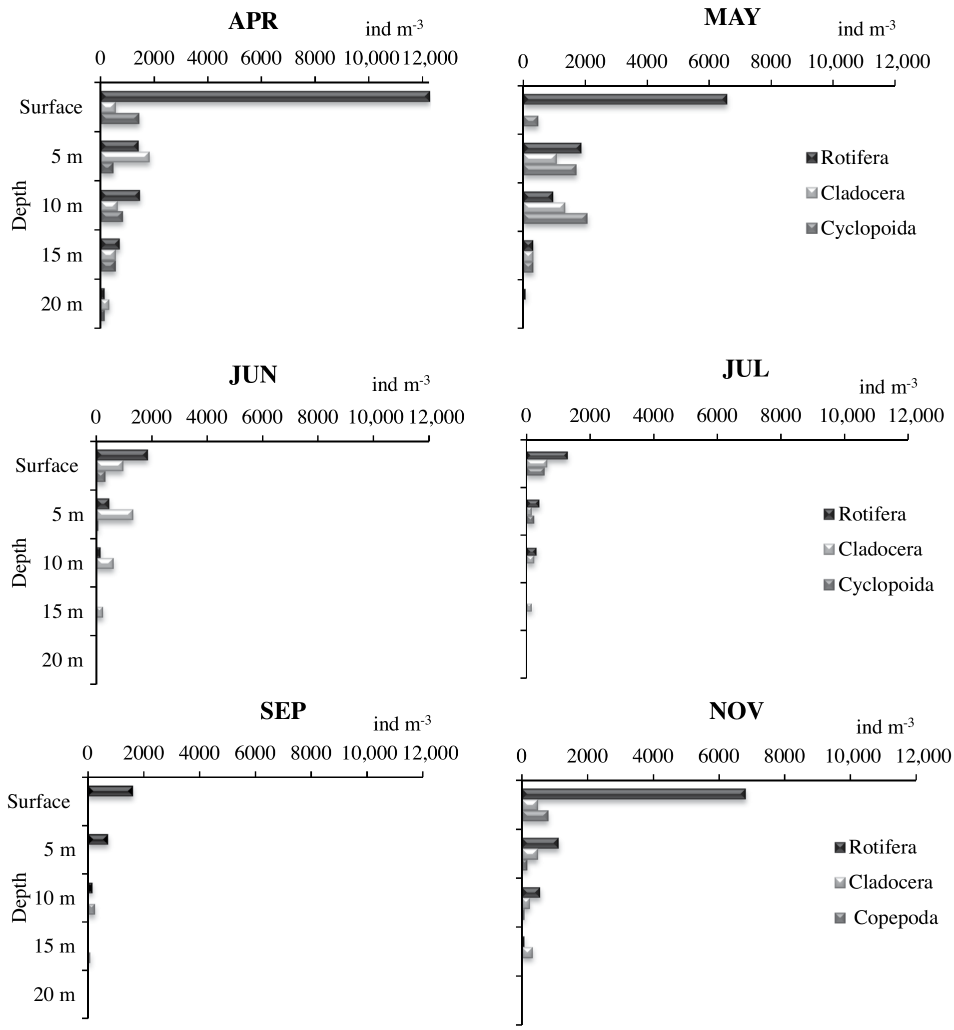

Figure 3. Vertical distribution of zooplankton in the lake. Total density (ind m^{-3}) of main zooplankton groups was demonstrated at different depths by horizontal bars.

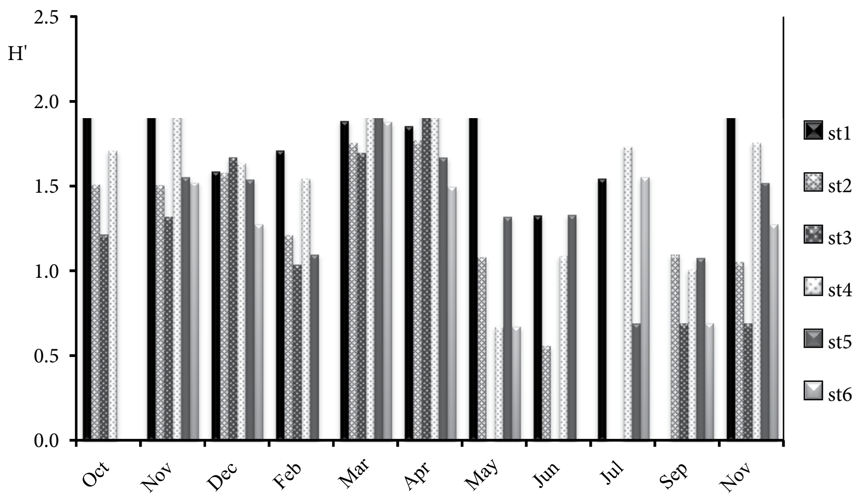

Figure 4. The Shannon–Weaver species diversity index (H′) based on numbers of individuals during the study period.

Table 3. Interset correlation of zooplankton variables with axes. Significant correlations are bolded.

	Axis 1 (λ_1 = 0.60)	Axis 2 (λ_2 = 0.28)	Axis 3 (λ_3 = 0.27)	Axis 4 (λ_4 = 0.15)
Secchi	–0.875	–0.482	0.019	0.040
Temp	**0.883**	–0.004	–0.245	0.022
DO	0.780	0.527	–0.297	0.105
EC_{25}	**0.944**	–0.075	–0.262	0.059
SO_4	0.358	–0.318	–0.326	0.332
pH	–0.275	–0.452	0.332	–0.294
Salinity	0.756	0.644	0.052	0.003
NO_3-N	0.542	–0.163	0.577	–0.196
NO_2-N	**0.797**	0.570	–0.027	0.149
NH_4-N	**0.813**	0.556	0.062	–0.029
SRP	0.715	0.651	0.174	0.178

population of large cladocerans (Masson et al., 2001; Morozov et al., 2007; Eggermont and Martens, 2011).

3.4. Environment and zooplankton relationships

Species composition may therefore be a more informative indicator for environment in comparison with any given set of measured environmental variables. The aim of canonical ordination is to detect the main pattern in the relationship between the species and the observed environment (Jongman et al., 1995).

The CCA was significant (P = 0.006, Monte Carlo). Eigenvalues of axes explained 42.7% of the cumulative variance in species data and 62.9% of the relationship between species and environmental data (Table 3). The CCA illustrated a very high correlation between temperature and EC_{25}; DO and salinity, NO_2-N, NH_4-N, and SRP; salinity and NO_2-N, NH_4-N, and SRP; and NO_2-N and NH_4-N and SRP. The correlation between the other variables was high and moderate (Table 4).

Environmental arrows indicate their relative importance to each axis. NH_4-N, NO_2-N, DO, salinity, and SRP were more correlated with the first axis (Table 3) and together separated in the CCA triplot. Stations 1

Table 4. Correlation among environmental and nominal variables used in canonical correspondence analysis. Significant correlations are bolded.

	Secchi	Temp	DO	EC_{25}	SO_4	pH	Salinity	NO_3-N	NO_2-N	NH_4-N	SRP
Secchi	1										
Temp	–0.765	1									
DO	–0.941	0.712	1								
EC_{25}	–0.789	**0.970**	0.759	1							
SO_4	–0.136	0.703	0.153	0.599	1						
pH	0.471	–0.039	–0.671	–0.202	0.378	1					
Salinity	–0.973	0.609	**0.927**	0.633	–0.028	–0.559	1				
NO_3-N	–0.379	0.556	0.078	0.460	0.407	0.576	0.275	1			
NO_2-N	–0.970	0.659	**0.961**	0.703	0.066	–0.623	**0.982**	0.223	1		
NH_4-N	–0.983	0.636	**0.925**	0.680	–0.032	–0.560	**0.993**	0.304	**0.980**	1	
SRP	–0.927	0.612	**0.861**	0.601	0.093	–0.445	**0.963**	0.379	**0.956**	**0.940**	1

and 4 separated from the other stations in the UPGMA dendrogram (Figure 5). Furthermore, stations 1 and 4, containing higher nutrient salts, had the highest diversity (Figure 4). According to UPGMA, station 1 and *Habrotrocha* sp. and *Filinia longiseta* were differently located in the CCA diagram, and similar behavior was seen for station 4 (Figure 6).

The other stations were contrarily positioned in the triplot, and station 6 was independently located in the CCA triplot as in the UPGMA dendrogram. Most species were located centrally and strongly with correlated nutrients. On the other hand, *D. longispina*, *Lecane quadridentata*, *Keratella tropica*, *Asplancha brightwelli*, and *K. cochlearis* were situated conversely; moreover, *D. longispina* and *L. quadridentata* with very low densities were further separated than the other species. *Polyarthra dolichoptera* and *C. sphaericus* had a high correlation with NO_3-N, and *Coronatella rectangula* had a high correlation with temperature. *F. longiseta* and *Habrotrocha* sp. were clustered more specifically with DO, salinity, and NO_2-N, NH_4-N, and SRP.

Consequently, habitat heterogeneity and changing habitat structure in lakes and rivers play a key role in controlling the abundance, distribution, and diversity of zooplankton. Heterogeneity in the water column can be represented by vertical gradients in temperature, light, and nutrients. Obviously, environmental gradients should favor the distribution of nutrient concentration, prey, and predators in specified layers. Our results demonstrated that the seasonal dynamics of zooplankton are affected by a combination of abiotic and biotic factors in the study area on the upper Euphrates River. Comparing the upstream region and downstream stations of the lake, this study shows that vertical distributions of the dominant zooplankton are similar, but differences are evident among species. However, these results need to be confirmed by a long-term investigation.

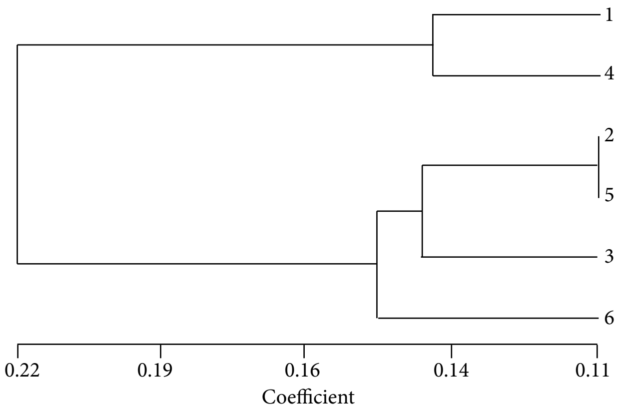

Figure 5. Tree diagram resulting from average linkage clustering using UPGMA method on the zooplankton community data reported during study period.

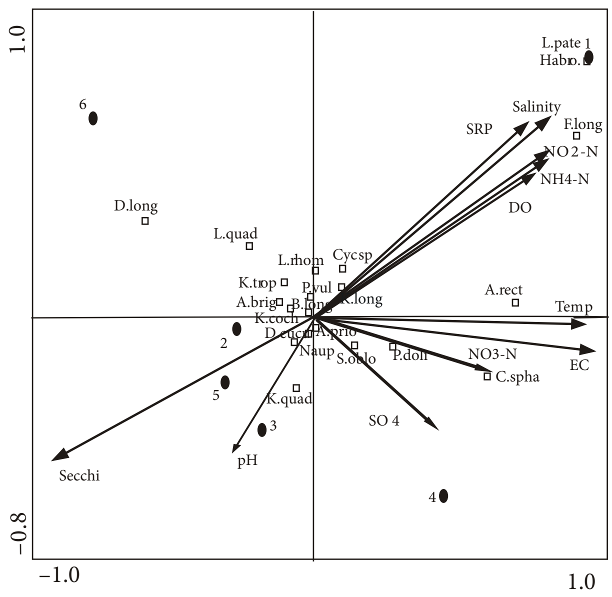

Figure 6. CCA triplots for zooplankton abundance and environmental variables (variables are represented by arrows. Species are depicted by points; the numbers indicate sampling stations). Abbreviations: *K.coch*: *K. cochlearis*; *K.quad*: *K. quadrata*; *K.trop*: *K. tropica*; *K.long*: *K. longispina*; *P.vulg*: *P. vulgaris*; *P.doli*: *P. dolichoptera*; *S.oblo*: *S. oblonga*; *A.prio*: *A. priodonta*; *A.brig*: *A. brightwelli*; *L.pate*: *L. patella*; *L.rhom*: *L. rhomboides*; *L.quad*: *L. quadridentata*; *Habro.*: *Habrotrocha* sp.; *F.long*: *F. longiseta*; *D.cucu*: *D. cucullata*; *D.long*: *D. longispina*; *B.long*: *B. longirostris*; *C.spha*: *C. sphaericus*; *C.rect*: *C. rectangula*; *Cyc* sp: *Cyclops* sp.; Naup: nauplius.

Zooplankton species abundance was at low levels, possibly due to the presence of planktivorous fish in the study area. Moreover, a major portion of the zooplanktonic community appears to consist of very common species. The freshwater zooplankton occupy an important and strategic position within the trophic web of a lake ecosystem and are sensitive to anthropogenic impacts (Jeppesen et al., 2011). Understanding the relationship between the zooplankton community and its spatial and temporal distribution is important for the comprehension of trophic interactions within a reservoir. As trophodynamic relationships in pelagic systems depend on spatial overlap of predators and prey, it is essential to understand the mechanisms that lead to different vertical distributions (Morozov et al., 2007; Zhao et al., 2008).

Additionally, increasing climatic change affects top-down regulation by fish and may interact with productivity in determining the zooplankton standing biomass and community composition (Jeppesen et al., 2011). Hence, the food web dynamics are associated with climatic characters. Therefore, their potential value as indicators of alteration in the water quality of the study area situated on the upper Euphrates River needs to be assessed. Furthermore, there is an increasing demand for water management monitoring programs for bioindicators of water quality. Continuous monitoring of water properties and biota in the lake should be performed to follow the changes in the ecosystem.

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