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Research Article

Zooplankton Biodiversity in Reservoirs of Different Geographical Regions of Turkey: Composition and Distribution Related with Some Environmental Conditions

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ABSTRACT

The zooplankton fauna and the relationship with their environmental variables were investigated on the epilimnion layer of the seven reservoirs (Demirdöven, Devegeçidi, Menzelet, Sır, Ömerli, Porsuk, Tahtalı) of different regions (Marmara, Aegean, Mediterranean, Central Anatolia, Eastern Anatolia, Southeastern Anatolia) throughout the summer months (2015) in Turkey. According to the trophic conditions reservoirs varied between oligo- and eutrophic status. Chlorophyll*a* concentration, measured for the estimation of primary production, was determined considerably high along the investigation period. A total of 62 zooplankton species were identified with the contribution of 44 rotifers, nine cladocerans and nine copepods. Except one reservoir, all of the others were dominated by rotifera group, and also in each study site dominant taxa were changed at species level. On the other hand common dominant taxa for all reservoirs was the rotifer *Polyarthra vulgaris* Carlin, 1943 with 95 % frequency. In terms of zooplankton species, most of the studied reservoirs showed less than 50% similarities, due to their different limnological conditions and different geographic locations. Reservoirs in high trophic conditions in the present study were represented by low species diversity. Water quality in the reservoirs with respect to biological data were determined as ß-mesosaprobic. The using limnological and biological indices to determine water quality were consistent. Densities of main zooplankton groups, and also frequent species of the reservoirs correlated with epilimnion layer depths and total phoshorus concentrations significantly. On the other hand rotifera variation was affected mainly by physical variables (pH, temperature, dissolved oxygen concentration, conductivity), and crustacean variations were related with total phoshorus. The comperative assessment between limnological variables and zooplankton community in this reservoirs was studied for the first time.

Keywords: Turkey, trophic state, limnological conditions, rotifera, biological indices

INTRODUCTION

Rapid population growth and development of the industry cause the need for freshwater to increase in Turkey as well as around the world. Therefore, many of reservoirs were built for drinking water supply, irrigation, flood control, and energy generation in Turkey since the 1930s. But, nowadays as a result of the urbanization and industrialization, reservoirs faced with the eutrophication hazard. Also, persistence of the eutrophic conditions causes loss of biodiversity, and may destroy the balance of the food chain from the bottom to the top (Brito et al., 2011). For this reason, limnological and biological variables should be investigated and followed for assessment, and obtained data should be used to improve the water conditions of reservoirs.

Biotic and abiotic factors of the reservoirs might alter the zooplankton species diversity, density, biomass, and spatio-temporal distribution. Life cycles of zooplankton are between days to weeks (Brock et al., 2005). Due to feeding and reproduction form alterations among the groups (Hutchinson, 1967), they show varied reactions to the abiotic conditions. Also, zooplankton groups, especially rotifers, respond quickly to these alterations, and consequently they are known as biologic indicators to estimate the water quality in the freshwater ecosystems (Sladecek, 1983; Herzig, 1987; Saksena, 1987; Hanazato, 2001; Pereira et al, 2002). Quick response of rotifers to the alterations in their environment results from their small-sizes, permeable integument (Arora and Mehra, 2003), rapid reproductive rates, and also ability to generate dense populations (Pace, 1986). Because of the rotifer density variation informs about eutrophication, they are used as trophic state indicators (Chen et al., 2012).

This present investigation was designed to determine the zooplankton community structure of seven reservoirs (Demirdöven, Devegeçidi, Menzelet, Sır, Ömerli, Porsuk, Tahtalı) from different river basins of Turkey and analyzed the relationship between zooplankton assemblages and various limnological variables for the first time.

MATERIALS AND METHODS

In the present study, a total of seven reservoirs (Devegeçidi, Demirdöven, Menzelet, Sır, Ömerli, Porsuk, Tahtalı) from different six regions from Turkey were investigated (Figure 1). General features of each reservoir was given in Table 1.

The study was carried out in the summer months (June, July, August) in 2015, simultaneously, in each reservoir. Samples were

Figure 1. Sampling locations. (I: Demirdöven, II: Devegeçidi, III: Menzelet, IV: Sır, V: Ömerli, VI: Porsuk, VII: Tahtalı)

Table 1. General features of studied reservoirs.

Dam Lake	Demirdöven	Devegeçidi	Menzelet	Sır	Ömerli	Porsuk	Tahtalı
Site	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Coordinates	40° 02′ 22.56″ N 41° 44′ 11.4″ E	38° 03′ 24.67″ N 39° 59′ 09.55″ E	37° 42′ 10.66″ N 36° 53′ 45.18″ E	37° 35′ 40.37″ N 36° 45′ 29.06″ E	41° 05′ 09.37″ N 29° 24′ 33.92″ E	39° 38′ 07.17″ N 30° 13′ 10.34″ E	37° 42′ 10.66″ N 36° 53′ 45.18″ E
Geographical Region	Eastern Anatolia	Southeastern Anatolia	Mediterranean	Mediterranean	Marmara	Central Anatolia	Aegean
Locality	Erzurum	Diyarbakır	Kahramanmaraş	Kahramanmaraş	İstanbul	Eskişehir	İzmir
Basin	Aras	Dicle-Fırat	Ceyhan	Ceyhan	Marmara	Sakarya	Küçük Menderes
River	Tımar creek	Devegeçidi creek	Ceyhan river	Ceyhan river	Riva stream	Porsuk creek	Tahtalı creek
Building date	1986-1996	2009-2010	1980-1989	1987-1991	1968-1973	1966-1972	1986-1999
Building purpose	Irrigation	Irrigation	Energy-Flood control	Energy	Drinking water	Irrigation, Flood control, Drinking water	Irrigation, Drinking water
Altitude	1788 m	747 m	621 m	1281 m	83 m	887 m	52 m
Volume	34,25 hm^3	202,32 hm^3	1.950 hm^3	1.120 hm^3	386,5 hm^3	431 hm^3	306,65 hm^3
Catchment area	1.45 km^2	32.14 km^2	42 km^2	47.50 km^2	23.10 km^2	23.40 km^2	23.52 km^2
Max. Depth/ Epilimnion depth (ave±stdev)	30 m/ 2 m±1.5	17 m/ 2 m±2.3	30 m/ 9 m±2.3	30 m/ 14 m± 4.2	20 m/ 6 m± 1.5	35 m/ 8 m±1.2	20 m/ 10 m±1.7

collected from the surface to the bottom of the epilimnion layer at the deepest point of the reservoirs (Table 1).

Some physicochemical variables [water temperature (T), dissolved oxygen concentration (DO), pH, electrical conductivity (EC)] were measured using by multiparameter (YSI 6820) with one meter intervals along the epilimnion layer, and water transparency was determined using by Secchi disk, *in situ*. The water samples for nutrient analysis [total nitrogen (TN), total phosphorus (TP)] and also Chlorophyll*a* (Chl*a*) concentration (as the primary production=phytoplankton biomass) were taken with 5 L Van-Dorn bottle from the surface, middle and bottom at the epilimnion layer, and they were mixed to obtain a composite sample. Nutrient analysis were performed according to APHA, AWWA,WEF (1989), and Chl*a* concentration was determined according to Nusch (1980). All variables were measured in triplicate.

Zooplankton was sampled with a closing net (55 µm mesh size, 0.6 m diameter opening, 1 m length) vertically from to the end of the epilimnion layer to the surface, and fixed with 4% formaldehyde solution. Zooplankton species were determined using a binocular microscope. The identification of the zooplankton species was performed according to the relevant taxonomic keys (Dussart, 1969; Koste, 1978; Margaritora, 1983). Enumeration, measurement, and also biomass calculations of the zooplankton species were performed according to EPA Standard Operating Procedure LG403 (U.S. Environmental Protection Agency, 2010). The body length of 20 randomly chosen individuals were measured via by camera attachment to use for the biomass calculation.

Trophic status of the reservoirs were determined according to Carlson's Trophic State Index (TSI) (Carlson, 1977). Species richness (*R*) of zooplankton was given as the total number of species. Shannon-Wiener diversity index (*H'*) (Shannon and Weaner, 1949), and Pielou evenness (*J*) (Pielou, 1966) indices for zooplankton were computed monthly. Saprobic index (S) was calculated according to the formula developed by Pantle and Buck (1955), and individual valence of each rotifer species were determined with reference to Sladecek (1983). To determine the Quotient of Community similarity degree for each pair of sites by using the zooplankton species Sørensen Similarity Index (QS) (Sørensen, 1948) was performed, and also a cluster analysis depending on determined species were used to compare the zooplankton compositions between studied sites (Bray and Curtis, 1957). Because of the data showed not normal distribution considering to the Shapiro-Wilk test, non-parametric tests (Spearman, Kruskal-Wallis) were selected. Non-parametric Kruskal-Wallis test was performed to determine differences of physicochemical variables and Chl*a* concentration, between study sites. To determine the correlation between biological (zooplankton and Chl*a*) and environmental data Spearman's rho was used. To investigate correlations between biological (zooplankton abundance and Chl*a* concentration) and physicochemical variables (Table 2) linear model of Redundancy Analysis (RDA) was employed via CANOCO 4.5 computer program (ter Braak and Šmilauer 2002). Monte Carlo permutation test (999 unrestricted permutations) was used to test the importance of correlation between biotic and abiotic variables.

RESULTS AND DISCUSSION

Different geographic regions and morphometric features (Table 1) of the investigated reservoirs were concluded in variations of main physical and chemical variables, with some exceptions. Water temperature, conductivity, nutrients, transparency and epilimnion layer depth showed significant differences between studied reservoirs (Table 1). Water temperature showed regional differences in summer months, and also conductivity variation showed similar patterns with water temperature. Nutrient concentrations were considerably high in every site (Table 1). Transparency of the sites were low, generally, due to summer months high primary production as given Chl*a* concentration in each reservoir. Epilimnion layer were differed based on the vertical water temperature variations of each reservoir (Table 1). Trophic state index (Carlson, 1977) of the studied reservoirs were ranged from 38 to 62 (Table 2), that means they changed between oligotrophic and eutrophic conditions. Components of CTSI [TSI (SD), TSI (CHL), TSI (TP)] were correlated each other significanlty. The negative correlation between transparency (Secchi depth) and Chl*a* (r=-0.606, p=0.004, N=21) was the indicator, that transparency of the reservoirs not depends on the phytoplankton abundance only.

Table 2. Summer variation of some physcicochemical variables and Chl*a* concentration (mean±stdev)

Site	T (°C)	DO (mg L^{-1})	pH	EC (mS cm^{-1})	TN(mg L^{-1})	TP (µg L^{-1})	Trans. (m)	Epilimniyon (m)	Chl*a* (µg L^{-1})	CTSI
I	17.3±3.6	7.3±0.7	8.0±0.6	80.1±17.4	1.4±0.1	29.7±5.7	1.0±0.1	2.0±1.5	6.9±1.6	57 (eutrophic)
II	27.1±1.6	6.9±2.1	7.9±0.7	323±9.0	2.3±0.7	28.7±7.4	2.0±0.4	2.0±2.3	9.3±6.5	54 (eutrophic)
III	25.4±1.8	8.7±0.6	8.7±0.8	323±14.8	1.7±0.2	7.2±4.7	4.0±1.4	9.0±2.3	2.7±1.5	38 (oligotrophic)
IV	24.2±0.9	6.7±2.7	8.0±0.7	464.4±84.7	1.8±0.3	12.5±5.8	2.0±1.2	14.0±4.2	10.1±5.8	48 (mesotrophic)
V	26.2±2.4	8.6±2.0	8.5±0.3	320.4±11.6	1.8±0.2	15.0±4.9	2.0±0.13	6.0±1.5	11.1±6.5	49 (mesotrophic)
VI	23.0±2.0	9.3±4.3	8.8±0.2	457±20.1	3.1±1.5	108.7±108.2	1.0±0.4	8.0±1.2	11.2±11.6	62 (eutrophic)
VII	26.9±1.5	7.9±1.8	8.5±0.2	381±13.5	1.9±0.2	11.1±1.9	4.0±1.0	10.0±1.7	4.5±2.8	42(mesotrophic)
Kruskal-Wallis (by sites) df=6; N=21										
$\chi 2$	13.749	5.818	7.948	17.541	12.658	17.075	14.684	17.557	11.833	
P	0.033	0.444	0.242	0.007	0.049	0.009	0.023	0.005	0.066	

Table 3. Summer zooplankton variation of the studied reservoirs.

	I			II			III			IV			V			VI			VII		
Copepoda	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**
Acanthodiaptomus denticornis (Wierzejski, 1887)								*		+		+				*	*	*		+	
Acanthocyclops venustus Normann & Scott, 1906																+	+	+			
Acanthocyclops viridis (Jurine, 1820)										+	+					+	+				
Cyclops abyssorum Sars, 1863	+		+																		
Cyclops vicinus (Sars, 1863)				+																	
Eudiaptomus vulgaris (Schmeil, 1896)	+	+	+																		
Metacyclops stammeri Kiefer, 1938	+						+	*		*						*	+				
Thermocyclops crassus (Fischer, 1853)													+	*							
Thermocyclops dybowskii (Lande, 1890)										+	+	+									
Cladocera																					
Alona quadrangularis (Müller, 1776)																			*		
Bosmina longirostris (Müller, 1785)				*	*	+	+			+	+	*	+	+	+	+	+	+	+	+	*
Ceriodaphnia puchella Sars, 1862																			*	+	+
Ceriodaphnia quadrangula (Müller, 1785)							+	*	*	+	+	+				+					
Daphnia cucullata Sars, 1862	+	+	+	+			+			+	*					+	+		*		
Diaphanosoma brachyurum (Lievin, 1848)			*	+		+	*	+	+		+	+		+	+		+	+		*	+
Disparalona rostrata (Koch, 1841)	*																				
Leptodora kindtii (Focke, 1844)				+																	
Moina micrura Kurz, 1874				+		*															
Rotifera																					
Adineta vaga (Davis, 1873)																					+
Anuraeopsis fissa (Gosse, 1851)													+	+	+						
Ascomorpha coelata De Beuchamp, 1932						+															
Ascomorpha ecaudis Perty, 1850																	+	+	+	+	+
Ascomorpha ovalis (Bergendahl, 1892)				*											+						
Ascomorpha saltans Bartsch,1870								*	+	+	+	+									
Asplanchna priodonta Gosse, 1850		*	+		+	+	+	+	+	+	+	+	+	+	+	+	*	+			
Asplanchna sieboldi (Leydig, 1854)														+	+						
Brachionus angularis Gosse, 1851				*	+	+								+				+		*	
Brachionus calyciflorus Pallas, 1766						*					*			+				*			
Brachionus caudatus (Barrois & Daday, 1894)					+	+															
Brachionus diversicornis (Daday, 1883)					*	+									*						
Brachionus falcatus Zacharias, 1898					+	+															+
Brachionus diversicornis (Daday, 1883)					*	+									*						
Brachionus urceolaris Müller, 1773								*													+
Cephalodella gibba (Ehrenberg, 1830)					*																
Colurella colurus (Ehrenberg, 1830)												*									
Conochilus dossuarius Hudson, 1885																					+
Conochilus unicornis Rousselet, 1892		+				+	+				+	+			+						
Epiphanes macrourus (Barrois & Daday, 1894)					+	+													+		
Filinia limnetica (Zacharis, 1893)														+	+						
Filinia longiseta (Ehrenberg, 1834)					+	+															
Filinia opoliensis (Zacharias, 1898)					+																
Filinia terminalis (Plate, 1886)					+	+									*						
Hexarthra intermedia (Wiszniewski, 1929)					+	+															
Hexarthra mira (Hudson, 1871)														*	+			+	*		+
Kelicottia longispina (Kellicott, 1879)	+	+	+				*			*											
Keratella cochlearis (Gosse, 1851)				+	+	+	+	*		+	+	+	+	+	+	+	+	+			*
Keratella quadrata (Müller, 1786)	+	+	*							*			+			+	+	+			
Keratella tropica (Apstein, 1907)						*															
Keratella valga (Ehrenberg, 1834)											+	+									
Lecane lunaris (Ehrenberg, 1832)													*				+				

Table 3. Summer zooplankton variation of the studied reservoirs. (continued)

	I			II			III			IV			V			VI			VII		
Rotifera	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**	**J**	**J**	**A**
Polyarthra dolichoptera Idelson, 1925				+	+	+								+	+	+	+	+			
Polyarthra vulgaris Carlin, 1943	+	*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pompholyx complanata Gosse,1851				+	+																
Pompholyx sulcata Hudson, 1885													+	+	+	+	+	+			
Rotaria rotatoria (Pallas, 1776)															+						
Synchaeta oblonga Ehrenberg, 1832				*	*	+	+	+	+	+	+	+	+	+		*	*	+			
Synchaeta pectinata Ehrenberg, 1832																			+	+	
Synchaeta stylata Wierzejsk, 1893															+						
Trichocerca capucina (Wierzejski & Zacharias, 1893)									+		+			+	+			+			
Trichocerca cylindirica (Imhof, 1891)					+	+								+	+						
Trichocerca pusilla (Jennings, 1903)										+	+	+	+	+	+		*	+	+		
Trichocerca ruttneri Donner, 1953						+								+	+						
Trichocerca similis (Wierzejski, 1893)						+	+	+	+			+	+	+	+				+	+	+

*: only once

Table 4. Sørensen's similarity coefficient index.

Site	I	II	III	IV	V	VI	VII
I	1	0.18	0.48	0.31	0.24	0.34	0.09
II		1	0.46	0.37	0.41	0.39	0.30
III			1	0.80	0.47	0.61	0.30
IV				1	0.48	0.59	0.39
V					1	0.58	0.31
VI						1	0.35
VII							1

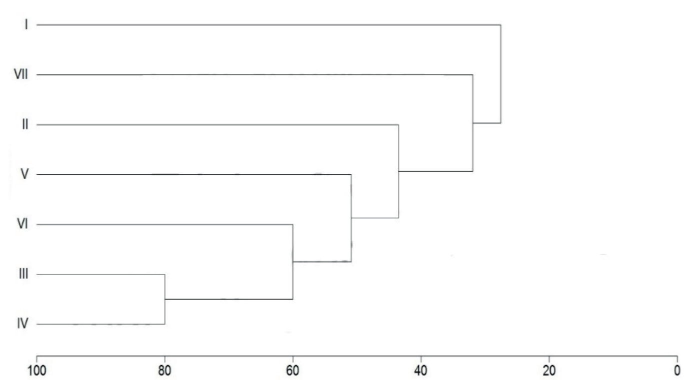

Figure 2. Dendrogram based on differences in zooplankton diversity between the studied reservoirs.

Also the positive significant correlation between TSICHL and TSITP (r=0.492, p=0.023, N=21) showed that in the studied reservoirs phosphorus may be limiting factor (Gołdyn et al., 2003). The water quality and ecological conditions of the studied reservoirs affected by their intended use (drinking water, energy, flood control and irrigation). Due to some of the studied reservoirs are drinking water resources, meso- and eutrophic quality of the waters may resulted as a drinking water quality problem (Palmstrom et al., 1988; Smith et al., 2002; Davies et al., 2004).

A total of 63 zooplankton taxa were identified (Table 3). Rotifers were dominant as numerically with 44 species. Crustaceans were represented by nine cladocerans and nine copepods throughout the sampling period (Table 3). The similarity of seven reservoirs from different regions was shown in Table 4. In terms of zooplankton species, site III and site IV showed highest incidence of similarity (0.80) (Table 4), due to their location in the same region (Table 1). On the other hand, according to the Sørensen's index, based on the common species of the sites (Table 3), zooplankton taxa of site IV were more similar with site III, IV and V (0.61, 0.59, 0.58, respectively) (Table 4). Also, similar results were verified by cluster analysis (Figure 2). Similarities or dissimilarities between the reservoirs were shaped by different abiotic conditions of the sites in different regions (Figure 2).

Species richness (R), as the total number of zooplankton species, changed between 9 (site I) - 26 (site II) species (Table 5). Shannon diversity index (*H'*) was determined between 1.59 (site III)- 2.29 (site V), and Pielou Evenness index (*J*) was ranged from 0.55 to 0.75 (Table 5). According to the description of Mason (1983) trophic state of aquatic environments evaluated between 1-3, therefore in terms of diversity index studied sites found as meso- and eutrophic status. The diversity results of the studied site showed similarity with TSI (Carlson, 1977). In the present study, species diversity of the sites, with high trophic conditions, found in low val-

Table 5. Index results of the studied reservoirs.

Site	Species richness (*R*)	Diversity index (*H'*)	Evenness index (*J*)	Saprobic index (*QS*)
I	9	1.66	0.75	1.52 (oligosaprobic)
II	26	2.16	0.66	1.64 (ß-mesosaprobic)
III	13	1.59	0.62	1.67 (ß-mesosaprobic)
IV	17	1.95	0.69	1.57 (ß-mesosaprobic)
V	25	2.29	0.71	1.63 (ß-mesosaprobic)
VI	20	1.65	0.55	1.58 (ß-mesosaprobic)
VII	15	1.68	0.62	1.59 (ß-mesosaprobic)

ues (Reed, 1978). Meso- and eutrophic reservoirs (Table 2) in the present investigation represented by low species diversity and on the contrary they had high densities than other sites (Figure 3A) (Reed, 1978). The high abundances of limited number of zooplankton species in the eutrophic sites caused unbalanced environments (*J*, Table 5). The saprobic index of the studied reservoirs varied from 1.52 (site I) to 1.67 (site III) and these values attributed to the ß-mesosaprobic, except site I (Table 5). Saprobic values showed the high organic matter decomposition levels in the reservoirs (Nandini et al., 2016). Most of the identified rotifer species in the study (24 of total 44 rotifer species) are known as eutrophication indicators due to their saprobic degrees (beta-mesosaprobic and alpha-mesosaprobic) (Sladecek, 1983).

In freshwater ecosystems rotifers dominate the zooplankton fauna (Saksena, 1987), and are also used as the biological indicators to determine the trophic status of the environment (Sladecek, 1983; Saksena, 1987). In this way, not only qualitative features but also quantitative characteristics (density) of the rotifers are important to evaluate the water quality, that high rotifer abundances expresses eutrophication (Sendacz, 1984). Most of the studied reservoirs, except site I where the copepods represented 48.2% of total zooplankton abundance, were dominated by rotifers in terms of relative abundance (ind/L) (Figure 3A).

Total zooplankton abundance (ind/L) varied between 132±21 ind/L (site VII) and 3258±718 ind/L (site II) (Table 6). Statistically total zooplankton and total rotifer abundance showed differences between study sites (Kruskal-Wallis; $H_{(6,N=21)}$=15.706, p=0.015; $H_{(6,N=21)}$=14.874, p=0.021, respectively), on the contrary no significant monthly differences were found between density of main zooplankton groups and total zooplankton (Kruskal-Wallis; H, df:2, P>0.05, N=21).

Seven of the identified taxa during the study showed ≥ 50 frequency (% F), they were *Polyarthra vulgaris* (Carlin) (95% F), nauplii (76% F), *Asplanchna priodonta Gosse* (67% F), *Keratella cochlearis* Gosse (62% F), *Bosmina longirostris* (Müller) (57% F), *Diaphanosoma brachyurum* (Lievin) (52% F), and *Trichocerca similis* (Wierzejski) (52% F), respectively. On the other hand, dominant taxa varied temper to reservoirs (Table 6). According to the frequency and dominance results rotifer *P. vulgaris* determined as the common dominant species all of the sites.

Main zooplankton groups [(copepoda: r=0.591, p=0.010, N=21);

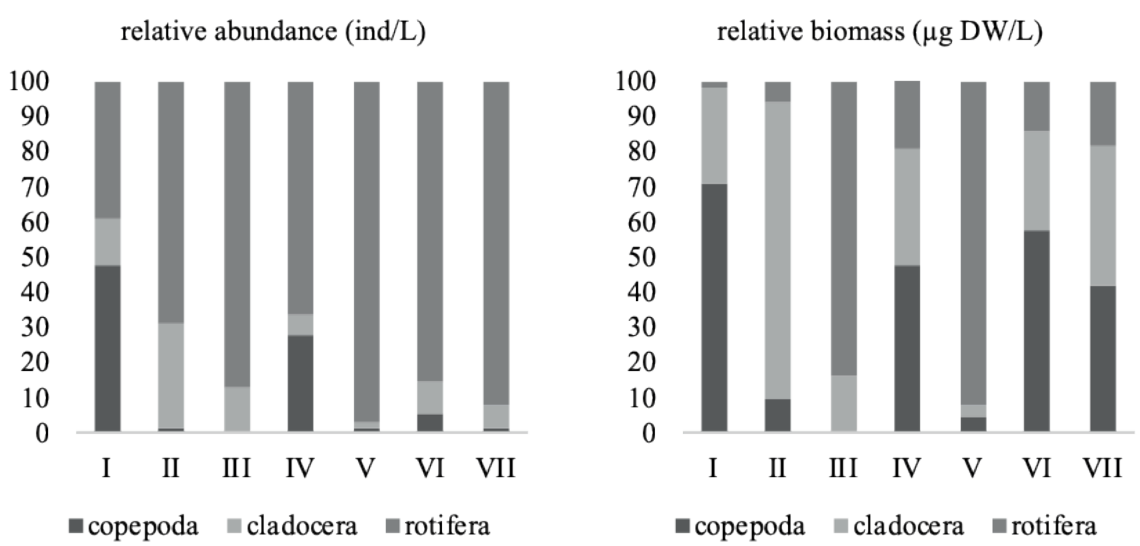

Figure 3. A- Relative abundance (ind/L) and B- Relative biomass (µg DW/L) variation of main zooplankton groups.

Table 6. Length and weight variations of dominant zooplankton taxa (N% ≥10 of total zooplankton abundance) of the reservoirs.

				Length (µm)		Weight (µg DW)		Total zooplankton abundance	Total zooplankton biomass
Site	**N**		**Relative abundance (%N) in related reservoir**	**min-max**	**ave±stdev**	**min-max**	**ave±stdev**	**(ind/L) total±stdev in related reservoir**	**(µg DW/L) total±stdev in related reservoir**
I	37	Nauplii**	29	132.9-261.7	190.5±38.6	0.1-0.5	0.3±0.1	339±76	723±56
	29	*K.quadrata*	19	109.0-147.4	131.9±8.1	0.03-0.1	0.1±0.01		
	24	*P.vulgaris*/**	16	108.0-178.4	153.5±18.8	0.04-0.2	0.1±0.04		
	47	*D.cucullata*	13	553.7-1519.1	885.7±235.4	0.8-16.9	4.1±3.6		
	25	*E.vulgaris*	11	901.7-157.7	1138.6±189.7	6.1-23.0	10.9±4.3		
II	60	*D.cucullata*	29	414.0-964.7	629.6±149.3	0.4-4.4	1.4±1.0	3258±718	1625±876
	71	*P.dolichoptera*	17.2	51.7-124.0	88.5±20.5	0.004-0.1	0.02±0.002		
	39	*P.vulgaris**	15.5	87.4-181.1	126.9±25.9	0.02-0.2	0.06±0.04		
	51	*K.cochlearis***	14.6	65.8-118.7	81.2±11.9	0.001-0.003	0.001±0.0001		
III	88	*P.vulgaris**	47.5	78.7-163.4	109.6±16.1	0.02-0.13	0.04±0.02	144±40	147±59
	93	*S.oblonga*	18.8	73.6-214.5	154.6±30.6	0.004-0.1	0.04±0.02		
	67	*T.similis***	11.4	114.3-166.5	139.2±9.9	0.08-0.24	0.14±0.03		
	77	*D.brachyurum***	10.1	347.1-988.8	620.4±130.5	0.4-3.7	1.4±0.6		
IV	58	*P.vulgaris*/**	36.8	86.2-173.1	139.5±25	0.02-0.16	0.09±0.04	163±14	50±9
	60	Nauplii**	22.9	90.3-313.7	139.9±36.5	0.1-0.6	0.1±0.01		
V	71	*K.cochlearis***	22.1	68.5-132.9	95.1±19.6	0.001-0.005	0.002±0.001	1828±410	172±75
	29	*P.dolichoptera*	21.4	59.0-89.2	70.8±7.2	0.01-0.02	0.01±0.004		
	33	*P.vulgaris*/**	12.5	63.6-162.7	105.5±22.2	0.01-0.1	0.04±0.03		
	26	*T.cylindirica*	11.6	108.6-261.9	212.2±33.3	0.1-0.9	0.5±0.2		
VI	98	*K.cochlearis***	39.97	66.6-122.4	90.4±13.9	0.0006-0.004	0.002±0.0007	1407±243	199±64
	31	*P.sulcata*	25.53	102.3-186.9	139.8±23.7	0.03-0.2	0.09±0.04		
	52	*P.vulgaris*/**	10.74	68.6-114.6	93.2±11.0	0.005-0.02	0.01±0.004		
VII	69	*P.vulgaris*/**	41.68	60.6-147.0	93±20.5	0.007-0.1	0.03±0.02	132±21	24±9
	54	*A.ecaudis*	24.58	65.0-147.0	90.3±19.7	0.003-0.1	0.02±0.002		
	40	*T.similis***	10.61	129.1-162.7	139.7±8.4	0.11-0.22	0.14±0.03		

*common species for all sites; ** frequent species ≥50%F

(cladocera: R=0.604, p=0.005, N=21); (rotifera: r=0.495, p=0.023, N=21)], and also total zooplankton (r=0.590, p =0.005, N=21) densities were correlated posivitely TP concentration. Moreover total zooplankton abundance showed positive significant correlation with Chla concentration (r=0.520, p =0.016, N=21).

The density of copepoda (r=-0.485, p =0.010, N=21), cladocera (r=-0.481, p=0.032, N=21), rotifera (r=-0.441, p =0.046, N=21), and also total zooplankton abundance (r=-0.588, p =0.005, N=21) correlated negatively with increasing epilimnion layer depth. The common dominant species of the study sites *P.vulgaris* density correlated negatively (r=0.445, p=0.009, N=21) with epilimnion layer depth like total rotifer abundance. Phytoplankton growth rates may decrease through the depletion of phosphorus stock levels in the epilimnion, that may resulted as the lack of food for zooplankton (Arhonditsis et al., 2004). This case was supported by the negative correlation between Chla concentration as phytoplankton biomass, and epilimnion layer depth (r=-0.304, p=0.018, N=21).

Total zooplankton biomass (µg DW/L) ranged between 24±9 µg DW/L (site VII) and 1625±876 µg DW/L (site II). Cladoceran and total zooplankton biomasses between sites showed significant differences (Kruskal-Wallis; $H_{(6,N=21)}$=7.584, p=0.004; $H_{(6,N=21)}$=10.009 p=0.006, respectively). Average individual length (µm) and weight (µg DW) values of the dominant species were given in Table 6. The highest biomass in site II related with the dominance of big-sized cladoceran *D. cucullata* in June (943 ind/L). Relative biomass dominance of the main zooplankton groups varied for each site, that although rotifers were the predominant group along the study period, because of their small sized bodies they could not have a high contribution to the total zooplankton biomass, generally (Figure 3B).

Zooplankton fauna of Devegeçidi (site II) (Bekleyen, 2001; Bekleyen, 2006), Porsuk (site VI) (Apaydın Yağcı et al., 2013), and Tahtalı (site VII) (Özdemir Mis et al., 2009) reservoirs were investigated, previously. Zooplankton fauna of site II, VI and VII showed similarities with the previous studies, but the identified taxa in the pres-

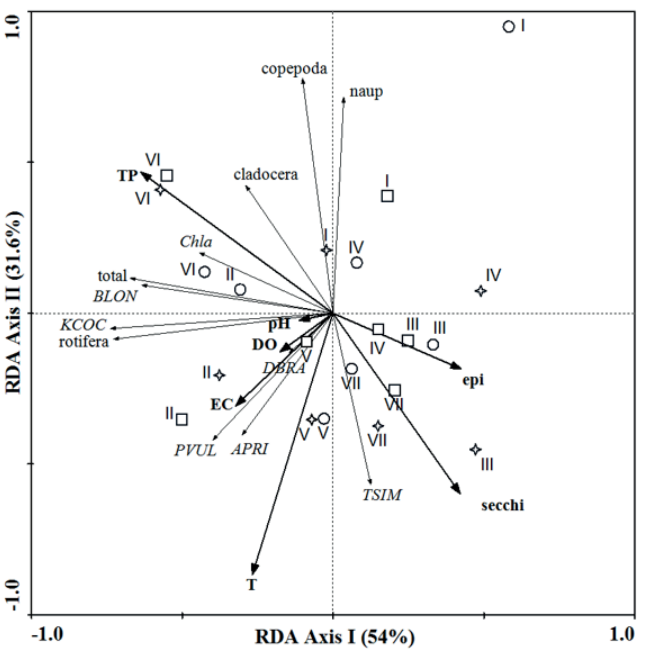

Figure 4. RDA ordination plot. (Roman numerals (I-VII) explained the reservoirs codes; PVUL: *P. vulgaris*, APRI: *A. priodonta*, KCOC: *K. cochlearis*, BLON: *B. longirostris*, DBRA: *D. brachyurum*, TSIM: *T. similis*, naup: nauplii; circle: June, square: July; star: August).

ent study were fewer than the former. This is probably related to the sampling procedures and times, and also may be affected by the trophic and environmental conditions changing in time. Because of the lack of available data on the trophic conditions of the previous studied sites, it is not possible to compare before and after. Zooplankton variation of the other reservoirs, and the relationship between zooplankton fauna and their environmental conditions in all reservoirs were investigated for the first time in the present study.

In the redundancy analysis (RDA) Chl*a*, total zooplankton, main zooplankton groups, and most frequent taxa abundances were used as biological data (Figure 4). Furthermore, after the control of environmental variables with regard to the Variance Inflation Factor (VIF<10) (ter Braak and Šmilauer 1998), and a stepwise forward selection (FS), total nitrogen (TN) (VIF>10) was removed from the data set, thereby eight limnological variables were used in the multiple comparison (Figure 4). According to the RDA analysis first two axes explained 85.6% of total variation. First axis was in a relation with largely epilimnion layer depth (0.3225) and pH (-0.0850), whereas second axis correlated with TP (0.3916) and pH (-0.0202), mainly. The sampling times of each reservoir were grouped in itself, generally (Figure 4). The reservoirs (site I, II, IV) identified as eutrophic according to the TSI, showed significanly correlation with TP, whereas oligo- and mesotrophic sites related mainly water temperature, epilimnion layer depth and transparency (Secchi disk depth) (Figure 4). Eutrophic conditions were related with high nutrients, that eutrophic sites represented by high zooplankton abundance (Table 6). Relatively higher transparency, compared to the other sites, in the oligotrophic site III resulted in low zooplankton abundance. The negative correlation between total zooplankton abundance (both at group and species level) and epilimnion layer depth may seen in RDA graph (Figure 4). Because TP is the nutritional source for the primary producers, total zooplankton density (both at group and species level) was related with TP indirectly and also significantly, as seen on the multiple comparison (Figure 4). An other evidence, that support this relevance, was the positive correlation between Chl*a* and TP concentration (r=0.505, p=0.020, N=21). According to the ordination plot rotifer taxa were related with pH, DO, EC, and T, mainly (Figure 4), because they are not selective on food quality, and they are also consumers of detritus and bacteria (Ruttner-Kolisko, 1974; Conde-Porcuna et al., 2002). The common dominant species of the reservoirs *P. vulgaris*, and most frequent species of the study showed similar behaviors as in the groups they belonging to.

High rotifer abundance (Almeida et al. 2009; Lodi et al., 2011; Špoljar, 2013) in eutrophic waters attributed to the avaliable food (phytoplankton, bacteria, and especially detritus) for rotifers and also their short generation times (Sed'a and Devetter, 2000; Nogueira, 2001, Gazonato Neto et al., 2014, Haberman and Haldna, 2014). When all data and statistical results of the present study are evaluated, the dominance of rotifers in both density and diversity are related with trophic status of the studied reservoirs. The siginifant correlation between total rotifer abundance and total phosphorus (TP) (r= 0.495, p=0.023, N=21) (Stemberger, 1995) of investigated sites is the evidence that trophic conditions of the water affected their composition and dynamics relatively (Arora and Mehra, 2003). An other probability, that may clarify the dominance of rotifers, was the pH values of the studied reservoirs. Rotifer species of eutrophic waters prefers pH≥7 (Berzins and Pejler, 1987) similar in the present study. pH levels shows increasing in nutrient-rich waters with dense photosynthetic activity resulting from algal growth, accordingly most of the rotifer species may find optimum conditions for their development. Also in the studied reservoirs cyanobacterial blooms occured in the summer months (Köker et al., 2017). It is known that these blooms provide an opportunity to reconstitute the zooplankton population from big-bodied to the small sized species (Gilbert, 1996). This information was supported by the results of the present study. The small-sized evasive rotifer *P. vulgaris* was determined as the common dominant and most frequent (95% F) species in the reservoirs during the study period.

In conclusion, both the laboratory data and the statistical results verified each other. Physicochemical and biological data showed that water bodies are under pollution pressure. The statistical results of the present study stated the possibility the usefullness of the zooplankton groups, especially rotifers, as a good ecological indicators (Montagud et al., 2019). Also, when considering their intended use, especially as drinking water, trophic conditions and biological patterns of the reservoirs must be controlled and followed for safe use.

Conflict of Interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

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