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Research Article

A Preliminary Study on Using Rotifera Fauna to Determine The Trophic Level of The Büyükçekmece Reservoir (İstanbul, Turkey)

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ABSTRACT

In this study, the abundance of rotifera fauna, in the Büyükçekmece Reservoir (İstanbul) and some physicochemical features of the reservoir, were investigated between May 2009 and February 2010. In terms of physicochemical conditions, the trophic state of the reservoir was determined as eutrophic (CTSI= 57.8). A total of 33 rotifera species were identified. *Keratella cochlearis* represented 40.62% of the total annual rotifera present, and was predominant. It was followed by *Polyarthra vulgaris* (10.14%), *Synchaeta oblonga* (9.06%), *Brachionus urceolaris* (5.58%), *Pompholyx sulcata* (5.21%) and *Epiphanes macroura* (%4.86), respectively. The contribution of the other rotifer species to the annual presence of rotifera was determined as being 24.52%. The dominance of these species was attributed to the eutrophic state of the reservoir, because *K. cochlearis*, *P. vulgaris, B. urceolaris* and *P. sulcata* are known as eutrophication indicator species, due to their saprobic valences. Also, the trophic state of the reservoir was found to be eutrophic according to the $Q_{B/T}$ index (= 3). According to the present data about rotifera species, and the abundance of them, the Büyükçekmece Reservoir was specified as eutrophic. However it is necessary to follow the conditions with periodic monitoring to observe the alterations in the Büyükçekmece Reservoir, in this respect the results of the present study would constitute an important baseline for subsequent studies.

Keywords: Zooplankton, indicator species, seasonal distribution, water quality, eutrophication

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INTRODUCTION

Rapid population growth and the development of industry has caused an increase in the need for drinkable tap water. However, usable water resources in Turkey are limited as well as around the world. Therefore, many reservoirs have been built for the supply of drinking water, irrigation, flood control, and energy generation in Turkey since the 1930s. Due to reservoirs being affected both by water level changes, sediment transport, the introduction of non-native species, and urbanization and industrialization, they are under the threat of eutrophication. Eutrophication causes a loss of biodiversity, and for this reason may destroy the balance of the food chain in aquatic systems (Brito et al., 2011). For this reason, the environmental conditions of reservoirs may affect diversity, density, biomass, and the spatiotemporal distribution of the zooplankton.

Zooplankton play a critical role in food and energy cycles in aquatic environments. Zooplankton groups grazing on phytoplankton, bacteria and detritus are significant protein sources for fish larvae, fish and aquatic invertebrates. The life cycles of zooplankton range from days to weeks (Brock et al., 2005). The feeding and reproduction forms of zooplankton vary among the groups (Hutchinson, 1967). Therefore their reactions to environmental conditions are different. Due to their quick responses to environmental alterations, zooplanktonic organisms, especially rotifers, are used as biological indicators (Ramadan et al. 1963; Gannon and Stemberger 1978; Sladecek 1983; Herzig, 1987; Saksena, 1987; Green 1993; Hanazato, 2001; Pereira et al., 2002; Jeppesen et al. 2011). Rotifers are small and have permeable integument (Arora and Mehra, 2003). They are able to reproduce in a short time (Snell and Janssen 1995), to give a quick response to the alterations in water quality by altering their species composition and abundance (Maley et al., 1988), and also to generate dense populations (Pace, 1986). Due to the above mentioned features, rotifers constitute the subject of this study.

This study focuses on rotifer taxa and their densities, which are a good biological indicator for determining water quality, and also aims to determine some limnological properties of the Büyükçekmece Reservoir. Another objective of the study is to compare the results with the previous study on biotic and abiotic variables of the reservoir performed by Aktan et al. (2006). Thus it is possible to evaluate the conditions of the reservoir and whether it has changed or not. To date, 417 rotifer species have been identified in Turkish freshwater resources (Ustaoğlu, 2015). The results of this study will also contribute to the knowledge of the inland water zooplankton diversity in Turkey. Also the data obtained will give insight to other planned studies.

MATERIAL AND METHODS

The Büyükçekmece Reservoir, which is located in the north west of Turkey and 50 km from the city centre of İstanbul (Soyer, 2003), was chosen as the study area. The Büyükçekmece Reservoir, which was constructed on a lake located at the mouth of the Karasu Stream, drains into the Sea of Marmara. As a result of the construction of the 11.4 m dam wall by the State Water System Services Department of Turkey (DSI) in the years 1983-1988 between the Sea of Marmara and the lake, the Büyükçekmece Reservoir lost its lagoon characteristic and it became a freshwater lake (Özuluğ, 1999). The lake meets the drinking and tap water requirements of İstanbul with 70 hm^3 water per year (Aktan et al., 2006).

The total water basin area of the Büyükçekmece Reservoir is 622 km^2 which has a 28.5 km^2-surface area, is 10 km long and 2.5 km wide (Soyer, 2003). The maximum depth of the lake is 7.15 m (Meriç, 1992). The main stream of this lake is the Karasu Stream which is located to the north of the lake. It has many tributaries such as Delice, Karamurad, Tavşan, Ayva, Akalan, Kestanelik and Öncürlü. The Keşliçiftiği (located on the west side of the lake) and Çekmece (located on the east side of the lake) Streams are also other sources (Özuluğ, 1999).

This study was conducted at 3 stations, which were selected as being representative of the Büyükçekmece Reservoir. The first station was selected from the area that is the most distant from the point that the Karasu Stream (the main source of the lake) flows into the lake (41.09095°N, 28.536003°E). The second station was selected from the middle of the lake (41.069596°N, 28.552753°E) and the third one was selected from the south side of the lake which is the closest part to the sea (41.047893°N, 28.569603°E) (Figure 1). The measured average depths of St. 1 and St. 2 were 3 m, and St. 3 was 5 m.

Figure 1. The Büyükçekmece Reservoir and sampling sites.

The sampling was conducted in May (2009), August (2009), November (2009) and February (2010) which were selected as being representative of each season. Dissolved oxygen (DO), water temperature, pH, electrical conductivity (EC) and salinity were measured *in situ* by a Hach Lange HQ 40d Multi-parameter instrument in order to determine the general limnological conditions of the reservoir. The water transparency of the reservoir was determined *in situ* using a Secchi disk. The trophic status of the lake was determined according to Carlson (1977), Chlorophyll *a* was determined according to Nusch (1980), and also total phosphorus was determined according to APHA AWWA WEF (1989). A non-parametric Kruskal-Wallis test was performed to determine the seasonal and spatial variations of the measured limnological variables.

Zooplankton was sampled with a closing net (55 µm mesh size, 9 cm diameter opening, 1 m length) vertically from the bottom to the surface and fixed with a 4% formaldehyde solution. The identification and classification of Rotifera species was performed on the isolated trophi of each individual according to the relevant taxonomic keys: Ruttner-Kolisko (1974), Pontin (1978), Koste (1978), Herzig (1987) and Sharma (1983). Species richness (S) of Rotifera was given as the total number of species at each station and season. The Relative abundance of Rotifera was calculated as individuals per litre (ind. L^{-1}). The individuals which have ≥ 5% proportion in total rotifera presence were considered as being dominant taxa. In order to determine the Rotifera trophic level of the reservoir the $Q_{Brachionus/Trichocerca}$ index was applied (Sladecek, 1983). The $Q_{B/T}$ index shows the rate of the number of *Brachionus* to the number of *Trichocerca*. The Q index is evaluated in three groups for the lake's trophic state, that Q=1 means oligotrophy, Q = 1.0-2.0 means mesotrophy, and Q>2 means eutrophy.

RESULTS AND DISCUSSION

The seasonal values of some of the main limnological parameters for each station, which were measured *in situ* in this study in the Büyükçekmece Reservoir, are shown in Table 1.

Table 1. Some limnological features of Büyükçekmece Reservoir

	Spring 2009			Summer 2009			Autumn 2009			Winter 2010		
	1st st.	2nd st.	3rd st.	1st st.	2nd st.	3rd st.	1st st.	2nd st.	3rd st.	1st st.	2nd st.	3rd st.
Temperature (°C)	17.1	15.2	14.9	25.9	25.5	25.1	18.6	18.1	17.1	6.6	6.2	5.5
DO (mg L^{-1})	10.48	11.59	11.25	7.66	7.20	8.26	8.19	9.32	9.83	9.57	9.63	10.57
pH	8.10	8.11	8.19	8.23	8.26	8.32	7.99	7.93	7.87	7.90	7.98	8.01
Salinity (ppt)	0.21	0.21	0.30	0.20	0.21	0.23	0.19	0.20	0.22	0.18	0.31	0.24
EC (25°C-µScm^{-1})	388.6	451.2	489.5	543.6	547.2	591.9	446.6	448.0	478.6	370.0	408.3	514.0
Secchi disk depth(m)	0.52	0.61	1.01	0.68	0.62	1.45	0.49	0.53	0.83	0.45	0.56	1.56
TP (µg L^{-1})	44.00	22.25	27.5	85.70	35.17	29.33	46.33	118.3	48.33	111.3	88.75	31.67
Chlorophyll a (µg L^{-1})	11.8	9.5	6.5	14.8	5.0	5.2	3.0	4.0	1.8	3.3	2.2	2.0

The annual average of the lake temperature was 16.3 ± 7.3°C and the temperature showed seasonal differences. The dissolved oxygen concentration (DO) reached its peak level due to the increase in water temperature and primary production in spring. The annual mean of the DO was measured as 9.5 ± 1.4 mg L^{-1}. The lake showed alkaline characteristics during the study period, and the mean pH was 8.1 ± 0.1. The annual mean salinity concentration, which had a freshwater characteristic after the dam construction, was 0.23 ± 0.04 ppt. The maximum conductivity values were measured in the summer period and the mean conductivity was 473.1 ± 67.6 µS cm^{-1}, annually. The annual average of the transparency (Secchi depth) was 0.8 ± 0.4 m in this shallow lake. Higher transparency values were detected in the areas that were closer to the seaside and deeper than the other stations (5 m). The annual average of the total phosphorus (TP) concentration was 54.81 µg L^{-1}. Higher Chlorophyll *a* (Chl *a*) concentration was found in the spring and summer periods where primary production increased with increasing temperatures. The annual average of Chlorophyll *a* was calculated as 5.76 µg L^{-1} (Table 1).

Table 2. Variance analysis results of the limnological variables of the Büyükçekmece Reservoir (Kruskal Wallis; p < 0.05).

Variable	By seasons	By stations
	Kruskal Wallis (p < 0.05)	
Water temperature (°C)	H = 10.202	H = 0.782
	p = 0.017	p = 0.677
DO (mg L^{-1})	H = 8.641	H = 1.654
	p = 0.034	p = 0.437
pH	H = 9.462	H = 0.154
	p = 0.024	p = 0.926
Salinity (ppt)	H = 1.605	H = 6.430
	p = 0.658	p = 0.140
EC (25 °C-µS cm^{-1})	H = 6.385	H = 3.500
	p = 0.094	p = 0.174
Transparency (m)	H = 1.667	H = 8.000
	p = 0.644	**p = 0.018**
Total Phosphorus (µg L^{-1})	H = 5.205	H = 2.577
	p = 0.157	p = 0.276
Chlorophyll a (µg L^{-1})	H = 8.436	H = 1.385
	p = 0.038	p = 0.500

Significant seasonal variations were observed between water temperature, dissolved oxygen, pH and Chlorophyll *a* concentration ($p< 0.05$). Significant spatial variations were determined for transparency values ($p< 0.05$) (Table 2).

The trophic status of the Büyükçekmece Reservoir was determined according to Carlson's Trophic State Index (1977) based on the Secchi disk depth (m), total phosphorus (µg L^{-1}) and the Chlorophyll *a* concentration (µg L^{-1}) values. The trophic status of the reservoir was determined as CTSI = 57.8 according to TSI(SD) = 63.7; TSI(TP) = 61.9 and TSI(CHL) = 47.8 values which were calculated based on annual averages.

Changes in the water level in the reservoirs, brought on by changes in the evaporation and precipitation amounts depending on seasonal conditions as well as the purpose and amount of water usage, are one of the most important factors in the role of aquatic organisms and biodiversity. The Büyükçekmece Reservoir is a very shallow reservoir and its deepest level was found to be 7.15 m in 1992 (Meriç, 1992), 6.9 m in 2006 (Aktan et al., 2006) and 5 m in this study. According to the Surface Water Quality Management Regulations it is reported that transparency <1.5 m indicates eutrophic conditions (Ministry of Forestry and Water Management, 2012). The average annual transparency (0.78 m) found in this study indicated eutrophic conditions. This decrease in transparency can be explained by the decrease in water depth of the reservoir over time due to its natural water usage conditions and seasonal increases in primary production. In this study, the Büyükçekmece Reservoir which was reported as being oligotrophic by Aktan et al. (2006) was found to be eutrophic (CTSI = 57.8).

A total of 33 rotifer species were identified, belonging to 17 families that were collected seasonally from 3 stations in Büyükçekmece Reservoir (Table 3). The distribution of the species by stations and seasons are given in Table 4.

When Rotifera fauna was evaluated in terms of the seasonal species richness, it was listed from the highest to lowest as: summer (32 species), autumn (22 species), spring (18 species) and winter (14 species) (Table 4). When the species richness was evaluated based on the stations, the highest species number was found in

Table 3. The taxonomic distribution of identified rotifers in the Büyükçekmece Resevoir.

Familya	Tür
Brachionidae Ehrenberg. 1838	*Anuraeopsis fissa* Gosse. 1851
	Brachionus angularis Gosse. 1851
	B. budapestinensis Daday. 1885
	B. calyciflorus Pallas. 1766
	B. diversicornis (Daday. 1883)
	B. quadridentatus Hermann. 1783
	B. urceolaris (O.F.Müller. 1773)
	Keratella cochlearis (Gosse. 1851)
	K. quadrata (O.F.Müller. 1786)
Ascomorpha Perty. 1850	*Ascomorpha ecaudis* (Petry. 1850)
	A. saltans Bartsch.1870
Asplanchnidae Eckstein. 1883	*Asplanchna priodonta* Gosse. 1850
	A. sieboldi (Leydig.1854)
Lepadellidae Harring. 1913	*C. colurus* (Ehrenberg.1830)
Conochilidae Harring. 1913	*Conochilus unicornis* Rousselet. 1892
Dicranophoridae Harring. 1913	*Dicranophorus grandis* (Ehrenberg.1832)
Epiphanidae Harring. 1913	*Epiphanes macroura* (Barrois & Daday.1894)
Euchlanidae Ehrenberg. 1838	*Euchlanis dilatata* Ehrenberg.1832
Filiniidae Harring & Myers. 1926	*Filinia longiseta* (Ehrenberg.1834)
Gastropodidae Harring. 1913	*Gastropus stylifer* Imhof. 1891
Lecanidae Remane. 1933	*Lecane stichaea* Harring.1913
Notommatidae Hudson & Gosse. 1886	*Notommata copeus* Ehrenberg.1834
Philodinidae Ehrenberg. 1838	*Philodina gregaria* Murray. 1910
Synchaetidae Hudson & Gosse. 1886	*Polyarthra dolichoptera* Idelson.1925
	P. vulgaris Carlin.1943
	Synchaeta litoralis Rousselet.1902
	S. oblonga Ehrenberg.1831
	S. pectinata Ehrenberg. 1832
Testudinellidae Harring. 1913	*Pompholyx sulcata* (Hudson.1885)
	Testudinella patina (Hermann.1783)
Trichocercidae Harring. 1913	*Trichocerca cylindirica* (Imhof.1891)
	T. (Diurella) porcellus (Gosse.1886)
Trichotriidae Harring. 1913	*Trichotria tetractis* (Ehrenberg.1830)

the 3rd station (30 species) followed by the 2nd station (27 species) and the 1st station, respectively (Table 4).

In this study, the annual total number of the rotifer was found as 2855 ind. L^{-1}. The abundance determined in summer period contributed to 62% of the average annual abundance and followed by spring (20%), autumn (11%) and winter (7%) (Figure 2).

The highest rotifer abundance were found in the 1st station (1245 ind.L^{-1}) followed by the 3rd station (838 ind.L^{-1}) and the 2nd station (772 ind.L^{-1}) (Figure 3).

The average 40.62% of the total annual rotifera abundance was composed of *Keratella cochlearis* in Büyükçekmece Reservoir followed by *Polyarthra vulgaris* (10.14%), *Synchaeta oblonga* (9.06%), *Brachionus urceolaris* (5.58%), *Pompholyx sulcata* (5.21%) and *Epiphanes macroura* (4.86%). The abundance of the rest of the identified species was less than 3% individually and 24.52% in total (Figure 4).

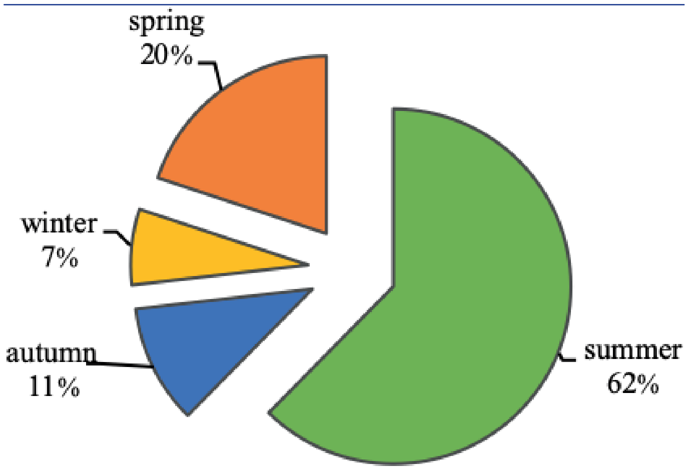

Figure 2. The seasonal distribution of rotifers.

Table 4. The spatiotemporal variation of rotifers in the Büyükçekmece Reservoir (sp: spring, su: summer, au: autumn, wi: winter).

	1st station				2nd station				3rd station			
	sp.	su.	au.	win.	sp.	su.	au.	win.	sp.	su.	au.	win.
Anuraeopsis fissa						+						
Ascomorpha ecaudis		+				+	+					
A. saltans			+			+	+				+	
Asplanchna priodonta		+		+	+	+	+	+		+		
A. sieboldi		+				+	+			+		+
Brachionus angularis	+	+					+					
B. budapestinensis	+	+	+			+	+			+	+	
B. calyciflorus	+	+			+	+	+		+	+	+	
B. diversicornis		+		+					+	+		+
B. quadridentatus		+				+				+		
B. urceolaris		+	+			+		+		+		
Colurella colurus			+		+	+	+			+	+	
Conochilus unicornis						+				+		
Dicranophorus grandis										+	+	
Epiphanes macroura		+	+	+	+	+	+	+	+	+	+	+
Euchlanis dilatata										+		
Filinia longiseta		+		+		+				+	+	+
Gastropus stylifer		+				+				+	+	+
Keratella cochlearis	+	+	+	+	+	+	+	+	+	+	+	+
K. quadrata	+	+			+	+			+	+		
Lecane stichaea										+		
Notommata copeus							+				+	
Philodina gregaria		+			+	+				+		
Polyarthra dolicoptera		+			+	+	+			+	+	
P. vulgaris	+	+	+		+	+	+	+	+	+	+	+
Pompholyx sulcata		+		+	+	+		+	+	+		+
Synchaeta littoralis			+		+	+	+	+			+	+
S. oblonga	+	+	+	+	+	+	+	+	+	+	+	+
S. pectinata		+	+	+		+	+	+		+	+	+
Testudinella patina		+		+	+	+		+			+	+
Trichocerca cylindrica		+	+			+	+		+	+	+	
T. porcellus	+	+								+		
Trichotria tetractis										+		
S	8	23	11	9	13	25	17	10	9	26	17	12

Table 5. The spatiotemporal distribution of dominant taxa (individual L^{-1}) (sp: spring, su: summer, au: autumn, wi: winter).

	1st station				2nd station				3rd station			
	sp.	su.	au.	wi.	sp.	su.	au.	wi.	sp.	su.	au.	wi.
B. urceolaris	-	99	3	-	-	33	-	3	-	21	-	-
E. macroura	-	15	2	16	1	43	2	10	2	3	30	17
K. cochlearis	429	311	9	3	24	125	4	1	5	238	6	1
P. vulgaris	5	56	2	-	20	72	12	3	1	111	6	1
P. sulcata	-	101	-	2	2	32	-	2	4	4	-	2
S. oblonga	1	2	44	2	2	5	44	70	4	18	55	13
Others	28	91	15	9	35	186	26	15	4	213	49	30
Total	463	675	75	32	84	496	88	104	20	608	146	64

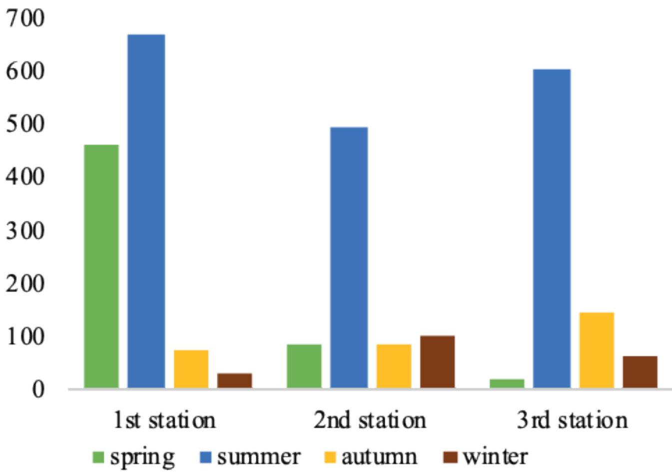

Figure 3. The spatiotemporal distribution of rotifers (ind. L^{-1}) (sp: spring, su: summer, au: autumn, wi: winter).

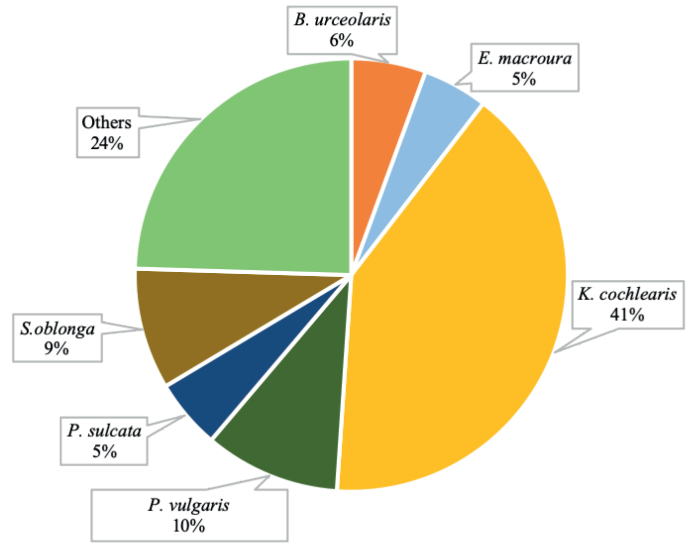

Figure 4. The annual distribution of dominant taxa (N%).

K. cochlearis, determined as the predominant species, was found at each station and in each season and the highest abundance values were detected in the 1st station, in spring (429 ind. L^{-1}) (Table 5). Moreover the species which had the relatively highest abundance were found as follows in the Rotifera community: *P. vulgaris* had the highest abundance in the 3rd station in the summer (111 individuals L^{-1}), *S. oblonga* in 2nd station in the winter (70 ind. L^{-1}), *B. urceolaris* and *P. sulcata* in the 1st station in the summer (99 ind. L^{-1} and 101 ind. L^{-1}, respectively) and *E. macroura* in the 2nd station in the summer (43 ind. L^{-1}) (Table 5).

The contribution of *K. cochlearis* which was one of the predominant species in the abundance of rotifera in the Büyükçekmece Reservoir throughout the year was 60.6%, 20.0% and 29.9% at the 1st, 2nd and 3rd stations respectively (Figure 5a). The contribution of *P. vulgaris* to the total abundance of rotifera was found to be 5% 13.9% and 14.3% at the 1st, 2nd and 3rd stations respectively. Whereas, the abundance of *S. oblonga* was found to be 3.9% (1st station), 15.7% (2nd station) and 10.7% (3rd station), *B. urceolaris* was found 8.2% (1st station), 4.6% (2nd station) and 3.5% (3rd station) throughout the year (Figure 5a). The contribution of *E. macroura* to the rotifer abundance was 2.6% (1st station), 7.3 (2nd station) and 6.1% (3rd station), while *P. sulcata* was found 8.3% (1st station), 4.6% (2nd station) and 1.2% (3rd station) throughout the year (Figure 5a). These spatial differences of the dominant spe-

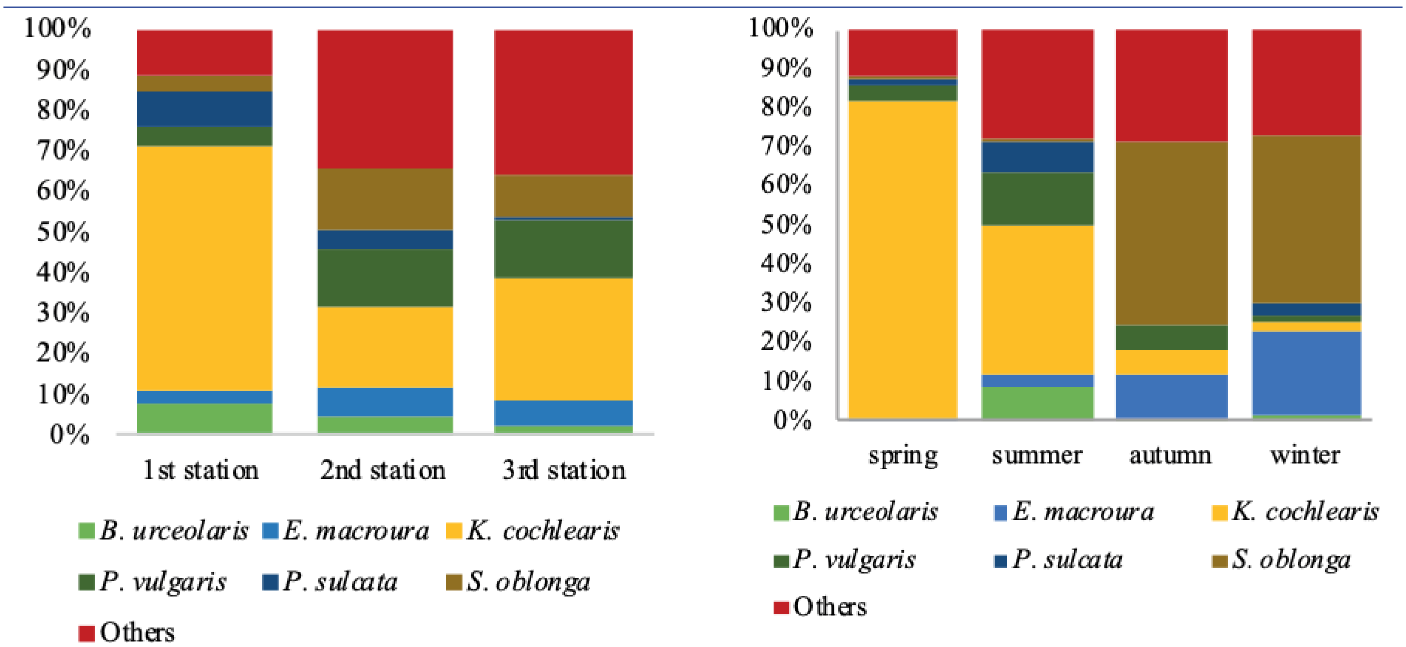

Figure 5. The spatial (a) and seasonal (b) distribution of rotifers in Büyükçekmece Reservoir.

cies may result from the distance to the streams' flow into the reservoir and the different depths of the stations.

Whereas the dominant rotifer species in the summer and the spring periods was determined as *K. cochlearis* (37.9% and 80.9% respectively), *S. oblonga* was the most abundant of the rotifer species in the autumn and the winter (46.1% and 42.9%) (Figure 5b). While *P. vulgaris* (13.5%), *B. urceolaris* (8.6%), *P. sulcata* (7.7%) species contributed to the greatest share in the summer period *E. macroura* (20.2%) has the greatest contribution in winter in which these species were considered the predominant species (Figure 5b).

The variance analysis (Table 2) indicated a significant difference in the spring season. This situation can be explained by the high total of phosphorous levels detected in the autumn and the winter used by primary producers in spring, which resulted in an increase in Chlorophyll *a* concentration (Table 1). Moreover, an increase in the algal population contributed to an increase in dissolved oxygen levels (Table 1). As a result of the seasonal differences of these parameters in the reservoir, rotifer taxa reached a higher level of abundance in the spring and the summer periods than that of the autumn and the winter periods due to algal growth and an increase in water temperature (Table 5).

Although 50 reservoirs are there in Marmara Region, the zooplankton fauna was studied on only five (Kızıldamalar, Boğazköy, Süloğlu, Ömerli, Büyükçekmece) of them. The results of the Büyükçekmece and other reservoirs were evaluated together for a regional comparison.

The transparency was reported as ≤ 0.5 m both for Kızıldamalar (depth: 26 m) and Boğazköy Reservoirs (depth: 12 m). During the study period the water temperature was determined at higher levels in the Boğazköy Reservoir (25 °C). Whereas the dissolved oxygen concentration was measured as 7.61 mg L^{-1} for the Kızıldamalar Reservoir and 6.5 mg L^{-1} for the Boğazköy Reservoir. pH levels were in the alkaline range for both of them and electrical conductivity levels were 326 µS cm^{-1} and 594 µS cm^{-1} for the Kızıldamalar and the Boğazköy Reservoirs respectively. The total phosphorous concentration was reported as 54 µg L^{-1} for both reservoirs (Ergönül et al., 2016). It was concluded that the reservoirs showed eutrophic characteristics (Ergönül et al., 2016). Whereas 8 rotifer species were determined in Kızıldamalar Reservoir, 7 species were detected in the Boğazköy Reservoir. The shared species between Kızıldamalar, Boğazköy and Büyükçekmece Reservoirs were *A. fissa*, *B. angularis, P. dolichoptera, P. vulgaris* and *P. sulcata*. Additionally, *K. cochlearis* was found both in the Boğazköy and the Büyükçekmece Reservoirs. The Limnological conditions of Kızıldamalar and Boğazköy Reservoirs were quite similar to the conditions determined in the present study (Table 2). It has been concluded that the shared rotifer species in these reservoirs are tolerant to the current trophic conditions.

The physicochemical characterization of the Süloğlu Reservoir was not specified in a faunistic study carried out in March 2013 – February 2014 (Güher and Çolak, 2015). 32 rotifer species were identified in this study in which rotifer fauna was dominated by indicators of eutrophic water and the reservoir showed oligo-mesotrophic characteristics. 15 rotifer species namely *A. fissa, A. priodonta, A. sieboldi, B. angularis, B. budapestinensis, B. urceolaris, E. dilatata, K. cochlearis, K. quadrata, P. vulgaris, P. sulcata, S. pectinata, S. oblonga, T. patina* and *T.cylindirica* were found in both the Büyükçekmece and the Süloğlu Reservoirs. Although the dominant species differed according to the reservoirs eutrophication indicator taxon were detected in both of them.

The drinking water for the İstanbul Province in the Marmara Region is supplied by the Büyükçekmece, Ömerli, Darlık, Elmalı, Alibey, Terkos reservoirs and the Istranca streams (Pabuçdere, Kazandere, Sultanbahçedere, Büyükdere, Kuzuludere Dams, Elmalıdere Regulator, Düzdere Pond). Among these reservoirs only the Büyükçekmece Reservoir is a natural water basin. Although limnological research was carried out for most of these reservoirs, the studies on the zooplankton fauna were only conducted for the Ömerli Reservoir (Kaplan, 1989; Altınyurt, 2006; Tarkan, 2010; Dorak et al., 2019) and the Büyükçekmece Reservoir (Aktan et al., 2006).

In a study carried out at the Ömerli Reservoir in 2006 it was shown that the water temperature was 7–25°C, conductivity was 135–343 µS cm^{-1}, pH was 6.78–9.35 and the chlorophyll *a* concentration was 42-54 µg L^{-1} (Altınyurt, 2006). Altınyurt (2006) reported that the conditions which were classified as eutrophic (Tüfekçi et al., 2003) were better when compared with the previous results. In another study carried out at the same reservoir in 2010 the results also showed eutrophic characteristics (Tarkan, 2010). However, in a recent study conducted in 2019 the physicochemical characteristics of the Ömerli Reservoir were as follows; the average temperature: 26.2 °C, dissolved oxygen: 8.6 mg L^{-1}, pH: 8.5, conductivity: 320.4 µS cm^{-1}, transparency: 2 m, total phosphorous: 15.0 µg L^{-1} and chlorophyll *a* concentration: 11.1 µg L^{-1} and it was concluded that reservoir was in mesotrophic conditions (Dorak et al., 2019). 14 rotifer species found in this study were also detected at the Ömerli Reservoir namely *A. fissa, A. priodonta, A. sieboldi, B. angularis, B. calyciflorus, C. unicornis, K. cochlearis, K. quadrata, P. dolichoptera, P. vulgaris, P. sulcata, R. rotatoria, S. oblonga* and *T. cylindirica*. These species show reactions to the changes in water quality (Gannon and Stemberger, 1978; Sharma 1983; Sladecek, 1983; Saksena 1987).

The 33 species detected at the Büyükçekmece Reservoir (Table 3) are on the list of Turkish rotifer fauna (Ustaoğlu et al., 2012) and considered to be a common species in the world (Segers, 2007). 56 rotifer species were identified in a study carried out by Aktan et al. (2006) in Büyükçekmece Reservoir (June 2004 – June 2005). These species were similar to the species found in this study.

The species detected in this study *A. fissa, B. angularis, B. calyciflorus, K. cochlearis, K. quadrata, E. dilatata, T. cylindrica, T. porcellus, P. vulgaris, S. pectinata, S. oblonga* and *P. sulcata* are known as indicators of eutrophication (Ruttner-Kolisko, 1974; Koste, 1978; Saksena, 1987; Michaloudi, 1997). During the sampling period the share of each species was < 3% except *P. vulgaris, S. oblonga* and *P. sulcata*. Besides, the eutrophication indicator species *K. cochlearis, P. vulgaris* and *S. oblonga* dominated the community. Although *S. pectinata, P. dolichoptera* and *A. priodonta* which were identified as the dominant species for oligotrophic conditions (Ruttner-Kolisko, 1974) were found in almost each sampling period and stations and they had minor share in the rotifera community in the Büyükçekmece Reservoir.

K. cochlearis, which represented 40.62% of the total annual rotifer abundance in the Büyükçekmece Reservoir, is a biological indicator. It is eurythermal (Bath and Kaur, 1998) and tolerant to pollution and the accumulation of organic matter (Hulyal and Kaliwal, 2008). It also prefers alkaline waters (Siegfried et al., 1989; Mulani et al., 2009) and spreads worldwide (Pennak, 1978). The other dominant species *P. vulgaris* (10.14%) is a eutrophication indicator (Ruttner-Kolisko, 1974; Koste, 1978; Saksena, 1987; Michaloudi, 1997), and is eurythermal (Berzins and Pejler, 1989a) like *K.cochlearis*. These two dominant species are perennial (Kolisko, 1974), and also they can tolerate a wide range of oxygen concentrations (Berzins and Pejler, 1989b). Due to these specifications *K. cochlearis* and *P. vulgaris* were found in almost all of the reservoirs in the Marmara Region. Also, these species were found in many reservoirs from different geographical regions and lakes in Turkey (Kaya and Altındağ, 2007; Ustaoğlu et al., 2012; Apaydın Yağcı, 2014; Saler and Alış, 2014; Apaydın Yağcı et al., 2015; Ergönül et al., 2016; Dorak et al., 2017; Dorak, 2019; Dorak et al., 2019).

An index ($Q_{B/T}$), which is calculated by the ratio of the number of species belonging to the Brachionus genus to the number of species belonging to the Trichocerca genus, is used to interpret the trophic level of the reservoir (Sladecek, 1983). According to the index if the $Q_{B/T}$ ratio = 1 the reservoir is considered as oligotrophic if the ratio is in the range of 1-2 the reservoir is mesotrophic and if the ratio is > 2 the reservoir is considered as eutrophic. In this study, it was found that 6 species belonged to the *Brachionus* genus and 2 species belonged to the *Trichocerca* genus, and the $Q_{B/T}$ was calculated to be 3. In this study the contribution of *Trichocerca* species (*T. cylindirica* and *T. porcellus*) to the annual total presence of rotifer, was determined as 3.07%. The contribution of *Brachionus* species (*B. angularis, B. budapestinensis, B. calyciflorus, B. diversicornis, B. quadridentatus, B. urceolaris*) to the total amount of rotifera was determined as 7.98% during the year in which 5.58% belonged to *B. urceolaris*. It is known that the *Brachionus* species are less affected by algal blooms than other microcrustaceans (Ismail and Adnan, 2016) and the high abundance of these species is a good biological indicator for eutrophic waters (Attayde and Bozelli, 1998). Moreover they can tolerate pollution (Sladecek, 1983; Hra, 2011). *Brachionus* species were detected in each sampling period and station in the Büyükçekmece Reservoir. Also, they reached their highest abundance in the summer, when the total phosphorus and Chlorophyll *a* (as a primary production) concentrations were higher. The diversity, density and temporal distribution of rotifers was supported by the eutrophic state of the reservoir, and showed the strong relationship between water quality and rotifers.

CONCLUSION

Overall the trophic level of the Büyükçekmece Reservoir in terms of rotifer fauna should be evaluated considering the richness of species and the abundance of detected species (Bays and Crisman, 1983; Harman et al., 1995; González et al., 2011). According to the prevalence and dominance of the eutrophication indicator *K. cochlearis,* the species richness of *Brachionus* and the $Q_{B/T}$ index it was obvious that the trophic status of Büyükçekmece Reservoir was eutrophic. Moreover, CTSI values also supported the rotifer fauna results and indicated the eutrophication. The rapid change in the trophic level of the reservoir, which is described as oligotrophic in 2006 by Aktan et al., suggests that an action plan should be established in the Büyükçekmece Reservoir in terms of the water quality and biodiversity.

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REFERENCES

Aktan, Y., Aykulu, G., Albay, M., Okgerman, H., Akçaalan, R., Gürevin, C. & Dorak, Z. (2006). Büyükçekmece Gölü'nde aşırı artış gösteren fitoplankterlerin gelişimini kontrol eden faktörlerin araştırılması. Tübitak Projesi 2006; ÇAYDAG-103Y127, 112s.

Altınyurt, S. (2006). Ömerli Baraj Gölünde Zooplanktonların Mevsimsel Değişiminin Saptanması, Yüksek Lisans Tezi, Marmara Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.

Apaydın Yağcı, M. (2014). Seasonal Variations in Zooplankton Species of Lake Gölhisar, a Shallow Lake in Burdur, Turkey. *Pakistan Journal of Zoology*, *46*(4), 927–932.

Apaydın Yağcı, M., Yılmaz, S., Yazıcıoğlu, O., & Polat, N. (2015). The zooplankton composition of Lake Ladik (Samsun, Turkey). *Turkish Journal of Zoology, 39*, 652–659. [CrossRef]

APHA APHA-AWWA WPCF (1989). *Standard methods for the examination of water and wastewater*. 17th ed., Washington DC., 1391 p.

Arora, J., & Mehra, N.K. (2003). Seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamun (Delhi), India. *Hydrobiologia, 491*, 101–109. [CrossRef]

Attayde, J.L., & Bozelli, R.L. (1998). Assessing the indicator properties of zooplankton assemblages to disturbance gradients by canonical correspondence analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, *55* (8), 1789–1797. [CrossRef]

Bays, J.S., & Crisman, T.L. (1983). Zooplankton and trophic state relationships in Florida lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, *40*, 1813–1819. [CrossRef]

Bath, K.S., & Kaur, H. (1998). Seasonal distribution and population dynamics and rotifers in Harike reservoir (Punjab-India). *Journal of Environment and Pollution, 5*(4), 249–252.

Berzins, B., & Pejler, B. (1989a). Rotifer occurrence in relation to temperature. *Hydrobiologia, 175,* 223–231. [CrossRef]

Berzins, B., & Pejler, B., (1989b). Rotifer occurrence in relation to oxygen content. *Hydrobiologia, 183,* 165–172. [CrossRef]

Brito, S.L., Maia-Barbosa, P.M., & Pinto-Coelho, R.M. (2011). Zooplankton as an indicator of trophic conditions in two large reservoirs in Brazil. *Lakes & Reservoirs: Research and Management*, *16,* 253–264. [CrossRef]

Brock, M.A., Nielsen, D.L., & Crossle, K. (2005). Changes in biotic communities developing from freshwater wetland sediments under experimental salinity and water regimes. *Freshwater Biology*, *50,* 1376–1390. [CrossRef]

Carlson, R.E. (1977). A Trophic State Index for Lakes. *Limnology and Oceanography, 22* (2), 361–369. [CrossRef]

Dorak, Z., Köker, L., Sağlam, O., Akçaalan, R., & Albay, M. (2017). Determination of zooplankton community structure, biomass and trophic state of a shallow turbid lake. *Fresenius Environmental Bulletin*, *26* (1a), 834–845.

Dorak, Z. (2019). Indicator zooplankton species and ecological requirements of zooplankton communities in man-made reservoirs. *Fresenius Environmental Bulletin*, *28* (3), 2185–2198.

Dorak, Z., Köker, L., Gaygusuz, Ö., Gürevin, C., Akçaalan, R., & Albay, M. (2019). Zooplankton biodiversity in reservoirs of different geographical regions of Turkey: composition and distribution related with some environmental conditions. *Aquatic Sciences and Engineering, 34*(1), 29–38. [CrossRef]

Ergönül, M.B., Erdoğan, S., Altındağ, A., & Atasağun, S. (2016). Rotifera and Cladocera fauna of several lakes from Central Anatolia, Marmara, and Western Black Sea regions of Turkey. *Turkish Journal of Zoology*, *40*, 141–146. [CrossRef]

Gannon, J.E. & Stemberger, R.S. (1978). Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Transactions of the American Microscopical Society*, *97*, 1635. [CrossRef]

González, E., Matos, M., Peñaherrera, C., & Merayo, S. (2011). *Zooplankton Abundance, Biomass and Trophic State in Some Venezuelan Reservoirs*. Dr. Islam Atazadeh, editor. Biomass and Remote Sensing of Biomass. InTech pp. 57–74.

Green, J. (1993). Diversity and dominance in planktonic rotifers. *Hydrobiologia*, 255/256 (Dev. Hydrobiol. 83), 345–352. [CrossRef]

Güher, H. (2000). A Faunistic study on the freshwater Cladocera (Crustacea) species in Turkish Thrace (Edirne, Tekirdağ, Kırklareli). *Turkish Journal of Zoology, 24*, 237–243.

Güher, H. & Çolak, Ş. (2015). Süloğlu Baraj Gölü'nün (Edirne) zooplankton (Rotifera, Cladocera, Copepoda) faunası ve mevsimsel değişimi. *Trakya Üniversitesi Fen Bilimleri Dergisi*, *16*(1), 17–24.

Hanazato, T. (2001). Pesticide effects on freshwater zooplankton: an ecological perspective. -*Environmental Pollution*, *112,* 1–10. [CrossRef]

Harman, C.D., Bayne, D.R., & West, M.S. (1995). Zooplankton trophic state relationships in four Alabama–Georgia reservoirs. *Lake and Reservoir Management*, 11, 299–309. [CrossRef]

Herzig, A. (1987). The analysis of planktonic rotifer populations: A plea for long-term investigations. *Hydrobiologia, 147*, 163–180. [CrossRef]

Hra, M. (2011). Seasonal and spatial distribution of *Brachionus* (Pallas, 1966; Eurotatoria: Monogonanta: Brachionidae), a bioindicator of eutrophication in lake El-Manzalah, Egypt. *Biology and Medicine*, *3*(2), Special Issue, 60–69.

Hulyal, S.B., & Kaliwal, B.B. (2008). Water quality assessment of Almatti Reservoir of Bijapur (Karnataka State, India) with special reference to zooplankton. *Environmental Monitoring and Assessment*, *139*, 299–306. [CrossRef]

Hutchinson, G.E. (1967). *A Treatise on Limnology*. II. Introduction to Lake Biology and the Limnoplankton. Wiley, New York.

Ismail, A.H., & Adnan, A.A.M. (2016). Zooplankton Composition and Abundance as Indicators of Eutrophication in Two Small Man-made Lakes. *Tropical Life Sciences Research*, *27*(1), 31–38. [CrossRef]

Jeppesen, E., Nõges, P., Davidson, T.A., Haberman, J., Nõges, T., Blank, K., Lauridsen, T.L., Søndergaard, M., Sayer, C., Laugaste, R., Johansson, L.S., Bjerring, R., & Amsinck, S.L. (2011). Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). *Hydrobiologia, 676*, 279–297. [CrossRef]

Kaplan, H. (1989). Ömerli Baraj Gölü Zooplankton Gruplarının Mevsimsel Dağılımı, Yüksek Lisans Tezi, İstanbul Üniversitesi, Fen Bilimleri Enstitüsü.

Kaya, M., & Altındağ, A. (2007). Zooplankton Fauna and Seasonal Changes of Gelingüllü Dam Lake (Yozgat, Turkey). *Turkish Journal of Zoology*, *31*, 347–351.

Kolisko, W.R. (1974). *Planktonic Rotifers Biology and Taxonomy Biological Station*. Lunz of The Austrian Academy of Science, Stuttgart.

Koste, W. (1978). *Die Radertiere Mitteleuropas*. Ein Bestimmungswerk, Begründet Von Max Voigt. Überordnung Monogononta. 2 Auflage Neubearbeitet Von II. Tafelband. Berlin Stutgart, 234pp.

Maley, D.F., Chang, P.S.S., & Schindler, D.W. (1988). Decline of zooplankton populations following eutrophication of Lake 227, Experimental Lakes Area, Ontario – 1969-1974. Canadian technical report of fisheries and aquatic sciences, 1619, 29 pp.

Michaloudi, E. (1997). Composition, Abundance and Biomass of the Zooplanktonic Organisms In Lake Micri Prespa (Macedonia, Greece). Doctoral dissertation, Aristotle University, Thessaloniki 199 pp.

Meriç, N. (1992). Büyükçekmece Baraj Gölü Balıkları. Fırat Üniv. XI. Ulusal Biyoloji Kongresi, Elazığ.167–174.

Mulani, S.K., Mule, M.B., & Patil, S.U. (2009). Studies on water quality and zooplankton community of the Panchganga river in Kolhapur city. *Journal of Environmental Biology, 30*(3), 455–459.

Nush, E.A. (1980). Comparison of different methods for chlorophyll and phaeopigment determination. *Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie, 14*, 14–36.

Ministry of Forestry and Water Management (2012). Yüzeysel Su Kalitesi Yönetimi Yönetmeliği. Ankara, Turkey: Resmi Gazete 28483.

Özuluğ, M. (1999). A taxonomic study on the fish in the basin of Büyükçekmece Dam Lake. *Turkish Journal of Zoology, 23*, 439–451.

Pace, M.L. (1986). An empirical analysis of zooplankton community size structure across lake trophic gradients. *Limnology and Oceanography*, *31*(1), 45–55.

Pennak, R.W. (1978). *Freshwater invertebrates of the United States*.2nd ed. New York: John Wiley & Sons.

Pereira, R., Soares, A.M., Ribeiro, R., & Goçalves, F. (2002). Assessing the trophic state of Linhos lake: a first step towards ecological rehabilitation. *Journal of Environmental Management*, *64*, 285–297. [CrossRef]

Pontin, R.M. (1978). *A Key to the Freshwater planktonic and Semi-Planktonic Rotifera of the British Isles*. Freshwater Biological Association Scientific Publication, No: 38.

Ramadan, F.M., Klimowicz, H., & Swelim, A.A. (1963). The pollutional effect of industrial waste on rotifers. *Polish Archives Hydrobiology*, *11*, 97–108.

Ruttner-Kolisko, A. (1974). *Plankton Rotifers Biology and Taxonomy*. Stutgart: Biological Station Lunz of the Austrian Academy of Science.146pp.

Saler, S., & Alış, N. (2014). Zooplankton of Hancağız Dam Lake (Gaziantep–Turkey). *Journal of Survey in Fisheries Sciences*, *1*(1), 36-45. [CrossRef]

Saksena, N.D. (1987). Rotifer as indicators of water qality. *Acta Hydrocim Hydrobiologia*, *15*, 481–485. [CrossRef]

Segers, H. (2007). Annotated checklist of the rotifers (phylum Rotifera) with notes on nomenclature, taxonomy and distribution. *Zootaxa*, *1564*, 1–104. [CrossRef]

Siegfried, C.A., Bloomfield, J.A., & Sutherland, J.W. (1989). Planktonic rotifer community structure in Adirondack, New York, U.S.A. lakes in relation to acidity, trophic status and related water quality characteristics. *Hydrobiologia, 175*, 33–48. [CrossRef]

Sharma, B.K. (1983). The Indian species of the genus *Branchionus* (Eurotatoria: Monogononta: Brachionida), *Hydrobiologia*, *104*, 31–39. [CrossRef]

Sladecek, V. (1983). Rotifers as indicators of water quality. *Hydrobiologia*, *100*, 169–201. [CrossRef]

Snell, T.W., & Janssen, C.R. (1995). Rotifers in ecotoxicology: a review. *Hydrobiologia*, *313/314,* 231–247. [CrossRef]

Soyer, E. (2003). Büyükçekmece Su Kaynağının Ozonlama Sonucu Bromat Oluşturma Potansiyelinin Araştırılması, Yüksek Lisans Tezi, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul.

Tarkan, A.S. (2010). Effects of streams on drinkable water reservoir: an assessment of water quality, physical habitat and some biological features of the streams. *Journal of FisheriesSciences.com*, *4*(1), 8–19. [CrossRef]

Tüfekçi, V., Morkoç, E., Tüfekçi, H., Tolun, L., Telli Karakoç, F., Karakas, D., Olgun, A., & Aydöner, C. (2003). Ömerli Baraj Gölündeki Toksik Fitoplankton Türlerinin Tespiti ve Su Kalitesinin İyilestirilmesine Yönelik Çözüm Önerilerinin Belirlenmesi Projesi, Yer ve Deniz Bilimleri Arastırma Enstitüsü, TÜBİTAK-MAM, Gebze, Kocaeli.

Ustaoğlu, M.R., Altındağ, A., Kaya, M., Akbulut, N., Bozkurt, A., Özdemir Mis, D., Atasagun, S., Erdoğan, S., Bekleyen, A., Saler, S., & Okgerman, H.C. (2012). A Checklist of Turkish Rotifers. *Turkish Journal of Zoology, 36*(5), 607–622. [CrossRef]

Ustaoğlu, M.R. (2015). An Updated Zooplankton Biodiversity of Turkish Inland Waters. *Journal of Limnology and Freshwater Fisheries Research, 1*(3), 151–159. [CrossRef]