TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2017) 41: 674-685
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doi:10.3906/zoo-1602-32

Distribution of rotifers of high mountain lakes in the Eastern Black Sea Range of Turkey

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Received: 16.02.2016 • **Accepted/Published Online:** 27.01.2017 • **Final Version:** 17.07.2017

Abstract: Six expeditions were conducted in 2005–2007 on the rotifer fauna of 59 high mountain lakes of the Eastern Black Sea Range. All of the lakes are located at altitudes between 2530 and 3370 m except Uzungöl (1100 m). A total of 63 rotifer taxa were identified. All of the taxa that were identified are new records for their localities except *Notholca squamula* and *Cephalodella gibba. Dissotrocha macrostyla*, *Hexarthra jenkinae*, *Lecane clara*, *Lecane kluchor*, *and Lecane latissima* are new records for the Turkish inland water fauna. The trophic classification based on the orthophosphate includes 22 lakes as ultraoligotrophic and 37 lakes as oligotrophic; by Secchi depth, 20 lakes are ultraoligotrophic, 12 lakes oligotrophic, and 27 lakes mesotrophic. Rotifer species richness showed a decrease with altitude (20 species in Lake Uzungöl with an altitude of 1100 m and 4 species in Lake Deniz with an altitude of 3370 m). We propose that 80% of the rotifer taxa were indicators of oligotrophic conditions and the remaining 20% were indicators of mesotrophic conditions.

Key words: Zooplankton, biodiversity, eutrophication, Kaçkar Mountain, glacial lakes

1. Introduction

Turkey is a natural museum, with a harmonious geography containing a wide variety of topographical structures. Glacial lakes, which exist in places close to summits of high mountain chains in this harmonious geographical structure, are important areas drawing the attention of scientists who are currently studying the bioecological diversity of the fauna and flora of these areas.

High mountain lakes and alpine lakes, which are difficult to access with little human activity in their catchment areas, are considered the least disturbed freshwater ecosystems in Europe (Galas, 2004).

Although situated far from local sources of pollution, these lakes are threatened by the deposition of atmospheric pollutants (acidity and air pollutants) and by climate change. The high mountain lakes are sensitive to these threats because of the poor buffering capacities of soil and rocks in the watershed for neutralizing acidic deposition (Mosello, 1986).

Although alpine lakes and mountain lakes have some similarities, there are differences between them. For instance, alpine lakes are located above the treeline at the top of the mountains. Mountain lakes are those located below the treeline (Sturm, 2007).

Five properties (uniform, remote, simple, extreme, and sensitive) make high mountain lakes ideal indicators of global climate changes. 1) Uniform: Depending on the elevation, we find alpine lakes at all latitudes; they are comparable worldwide and have many common characteristics. 2) Remote: Because of their distance from human settlements and activities, alpine lakes are only affected by global impacts, such as air pollution or climate change. 3) Simple: High mountain lakes are usually small, not very deep, species-poor, and characterized by a simple food web. 4) Extreme: Physicochemical conditions, such as temperature, UV radiation, ice cover, and nutrient status are usually more extreme than in lakes at lower elevations. 5) Sensitive: Because of extreme conditions and their immediate response to change, high mountain lakes are very much at risk from global impacts (Psenner, 2003).

Early studies on alpine lakes took far from an ecological and geographical approach and focused on taxonomy (Marchetto, 1998). Recent studies have focused particularly on the bioecology, acidification, and eutrophication processes of these lakes; the effects of global-scale climatic and meteorological changes; and the effects of a high level of UV light on the biota (Halac et al., 1997; Brancelj et al., 2000; Tolotti et al., 2006).

Only a few studies of high mountain lakes are available for Turkey. Among these, a pioneering study by Ustaoğlu et al. (2005) investigated the zooplankton fauna of some mountain lakes in the Taurus range; a second study by Ustaoğlu et al. (2008) investigated the limnology and fauna of glacial lakes and streams on Mount Uludağ in western

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Anatolia. Aygen et al. (2009) investigated zooplankton composition and abundance in Lake Eğrigöl in the Taurus Mountains.

More recently, Aygen et al. (2012) presented the results of their study on the biodiversity of Crustacea (Branchiopoda, Maxillopoda, and Ostracoda), and Yıldız et al. (2010, 2012) presented their results on littoral oligochaete (Lumbriculidae and Enchytraeidae) communities and distribution of aquatic oligochaetes in the high mountain lakes of the Eastern Black Sea Range of Turkey.

Rotifera is a group of primary freshwater invertebrates. Rotifers play a pivotal role in many freshwater ecosystems. They are ubiquitous, occurring in almost all types of freshwater habitats (Segers, 2008). Rotifer species richness shows a monotonic decrease with altitude, related to the interplay of habitat diversity, productivity, heat content, and human influence (Obertegger et al., 2010).

This study was conducted in order to obtain insight into the composition of the rotifer fauna of high mountain lakes in the Eastern Black Sea Range of Turkey.

2. Materials and methods

2.1. Study area

The Eastern Black Sea Mountains are a range rising along the Black Sea coast in northern Turkey. The highest peak is Kaçkar Mountain (3937 m), and the plateaus at about 3000 m a.s.l. are the highest part of the range. The mountains are glaciated and alpine in character, with steep rocky peaks and numerous lakes (Yıldız et al., 2012). Locality information for the 59 lakes in the 6 drainage basins of the studied project and the characteristics of the sampling sites on those lakes are presented in Figure 1 and Table 1.

When the altitudes of the lakes are taken into account, all the lakes are situated between 2530 and 3370 m except Uzungöl (1100 m). The lakes are small in size (areas of 0.03–8.9 ha) and mostly shallow (maximum depths of 0.5–49 m) (Sarı et al., 2015) (Table 1).

2.2. Environmental variables

Water samples were taken from the littoral zone of each lake. Five environmental variables, water temperature, dissolved oxygen, pH, electrical conductivity (EC), and Secchi depths, were measured in situ with a WTW pH meter (model 330), WTW oxygen meter (model 330), YSI SCT meter (model 30), and Secchi disk. Other variables (alkalinity, temporary hardness, total hardness, HCO^{3-}, Ca^{2+}, Mg^{2+}, NO_2^--N, NO_3^--N, NH_4^--N, PO_4^{3-}-P, SiO_2^-, and chlorophyll a) were measured in the laboratory following the standard methods of the APHA (1989).

2.3. Zooplankton collections and identification

In order to the study the rotifer fauna of 59 mountain lakes in the Eastern Black Sea range, 6 excursions were taken

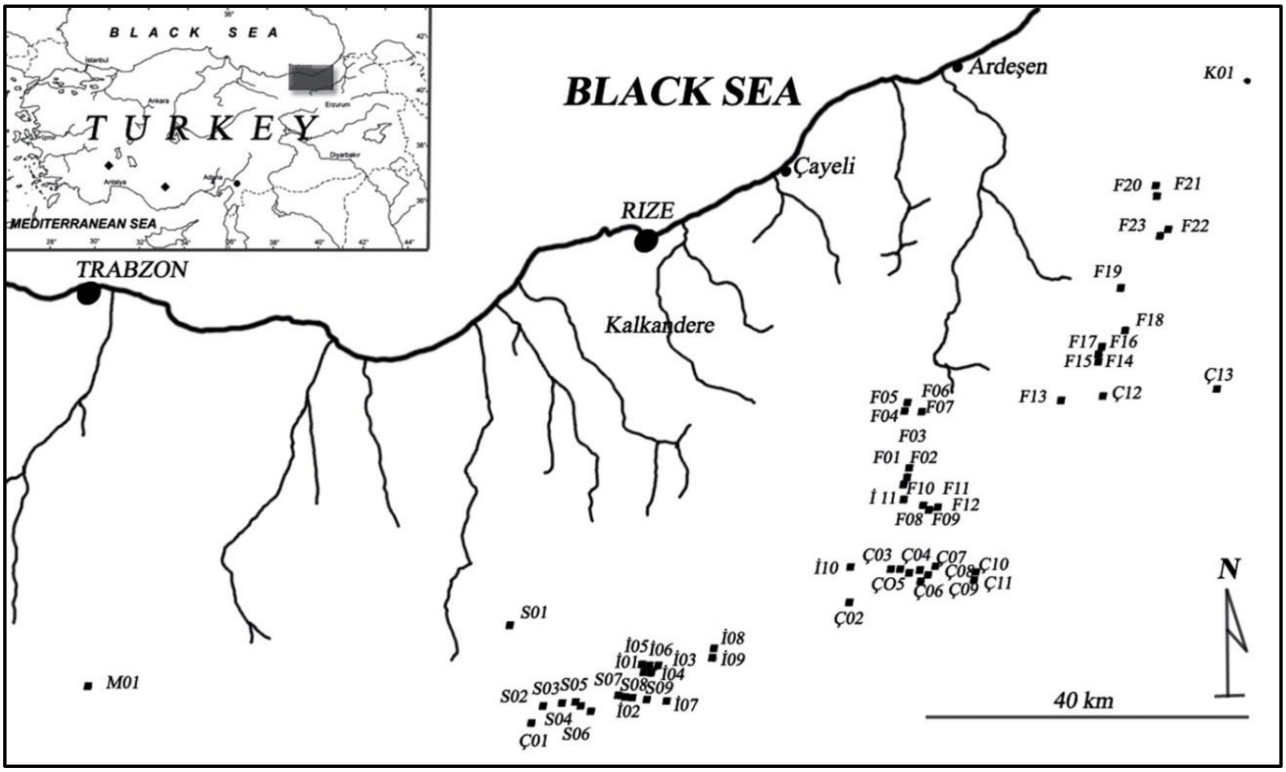

Figure 1. Map of 59 sampling stations associated with 6 drainage basins in the Eastern Black Sea Range in Turkey. Ç = Çoruh River Basin, F = Fırtına Stream Basin, İ = İyidere Stream Basin, K = Kabisra Stream Basin, S = Solaklı Stream Basin, M = Maçka Stream Basin.

Table 1. Investigated localities and sampling dates of high mountain lakes in the Eastern Black Sea Range of Turkey (A = Surface area, Z_m = Maximum depth).

Basin code	Sampling dates	Locality	Basin	Elevation (m)	A/Z_m (ha/m)	Coordinates
Ç01	30.07.2007	Lake Göloba (Göloba valley)	Çoruh River	2540	0.79/3.00	40°30′36″N 40°19′12″E
Ç02	19.08.2005	Lake Dağbaşı (Ovit valley)	Çoruh River	2710	2.63/2.90	40°37′02″N 40°46′47″E
Ç03	04.08.2006	Lake Batıaksu (Aksu valley)	Çoruh River	3050	2.55/7.50	40°39′13″N 40°50′39″E
Ç04	04.08.2006	Lake Kuzeyaksu (Aksu valley)	Çoruh River	3070	1.36/3.00	40°39′19″N 40°50′57″E
Ç05	04.08.2006	Lake Doğuaksu (Aksu valley)	Çoruh River	3120	1.44/20.00	40°39′09″N 40°51′06″E
Ç06	26.07.2007	Lake Ortagöl (Ovit Yedigöller – Küçükovit)	Çoruh River	2960	2.21/10.00	40°38′51″N 40°52′09″E
Ç07	19.08.2005	Lake Üstgöl (Mor yayla Yedigöller)	Çoruh River	3030	3.28/4.40	40°38′51″N 40°52′54″E
Ç08	06.07.2005 19.08.2005	Lake Adalıgöl (Mor yayla Yedigöller)	Çoruh River	3020	8.90/8.10	40°38′43″N 40°53′10″E
Ç09	06.07.2005 19.08.2005	Lake Ortagöl (Mor yayla Yedigöller)	Çoruh River	3010	0.36/4.10	40°38′53″N 40°53′18″E
Ç10	06.07.2005 19.08.2005	Lake Büyükgöl (Mor yayla Yedigöller)	Çoruh River	2980	4.11/0.96	40°38′45″N 40°53′36″E
Ç11	19.08.2005	Lake Altgöl (Mor yayla Yedigöller)	Çoruh River	2950	2.01/2.80	40°38′53″N 40°53′40″E
Ç12	23.08.2006	Lake Deniz (Bahral valley)	Çoruh River	3370	8.38/49.00	40°49′07″N 41°09′39″E
Ç13	24.08.2006	Lake Kartal (Bahral valley)	Çoruh River	2940	1.63/2.80	40°50′20″N 41°18′04″E
Ç14	24.08.2006	Lake Devise (Bahral valley)	Çoruh River	2935	0.11/1.00	40°50′22″N 41°18′12″E
F01	22.08.2005	Lake Keçi (Çermeş valley)	Fırtına Stream	3070	1.79/12.30	40°44′25″N 40°51′50″E
F02	22.08.2005	Lake Çermeş Karagöl (Çermeş valley)	Fırtına Stream	2990	4.60/32.70	40°44′37″N 40°52′04″E
F03	09.07.2005 22.08.2005	Lake Çermeş (Çermeş valley)	Fırtına Stream	2780	4.77/6.20	40°44′58″N 40°52′09″E
F04	25.08.2007	Lake Kayakaynak (Ambarlık valley)	Fırtına Stream	3080	1.02/1.00	40°49′17″N 40°52′43″E
F05	25.08.2007	Lake Büyük Balıklı (Ambarlık valley)	Fırtına Stream	2990	6.92/11.00	40°49′28″N 40°52′51″E
F06	01.08.2006	Lake Sırpal (Çahberik valley)	Fırtına Stream	2940	0.95/0.70	40°49′21″N 40°53′40″E
F07	01.08.2006	Lake Çahberik (Çahberik valley)	Fırtına Stream	2810	1.00/0.50	40°49′17″N 40°54′09″E
F08	08.07.2005 21.08.2005	Lake Atmeydan (Verçenik valley)	Fırtına Stream	2910	3.24/3.70	40°43′11″N 40°54′01″E
F09	08.07.2005 21.08.2005	Lake Kumlugöl (Verçenik valley)	Fırtına Stream	2860	0.49/0.80	40°43′22″N 40°54′17″E
F10	08.07.2005 21.08.2005	Lake İncegöl (Verçenik valley)	Fırtına Stream	2915	0.86/3.00	40°43′06″N 40°54′23″E
F11	21.08.2005	Lake Büyük Kapılı (Verçenik valley)	Fırtına Stream	3000	6.07/3.70	40°43′00″N 40°54′54″E
F12	21.08.2005	Lake Altkapılı (Verçenik valley)	Fırtına Stream	3000	1.46/3.50	40°43′11″N 40°54′57″E
F13	31.07.2006	Lake Kıblekaya (Apivanak valley)	Fırtına Stream	2870	0.56/3.20	40°49′24″N 41°06′06″E
F14	11.07.2005 24.08.2005	Lake Büyükdeniz (Kavron valley)	Fırtına Stream	2900	5.83/15.10	40°52′09″N 41°09′42″E
F15	24.08.2005	Lake Meterez (Kavron valley)	Fırtına Stream	2990	1.86/0.50	40°51′49″N 41°09′45″E

Table 1. (Continued).

Basin code	Sampling dates	Locality	Basin	Elevation (m)	A/Z_m (ha/m)	Coordinates
F16	11.07.2005 24.08.2005	Lake İsimsiz (Kavron valley)	Fırtına Stream	2890	0.56/3.10	40°52′28″N 41°09′46″E
F17	24.08.2005	Lake Karadeniz (Ceymakcur valley)	Fırtına Stream	2770	2.30/11.50	40°52′42″N 41°10′03″E
F18	29.07.2006	Lake Ceymakcur (Ceymakcur valley)	Fırtına Stream	2650	0.33/1.50	40°53′44″N 41°11′30″E
F19	30.07.2006	Lake Büyükgöl (Avusor valley)	Fırtına Stream	2670	2.43/10.20	40°56′13N 41°12′02″E
F20	22.08.2007	Lake Tobamızga (Tunca valley)	Fırtına Stream	2620	0.75/3.50	41°02′19″N 41°15′37″E
F21	22.08.2007	Lake Küçük Tobamızga (Tunca valley)	Fırtına Stream	2630	0.14/1.00	41°02′08″N 41°15′39″E
F22	23.08.2007	Lake Büyük Çiftegöl (Tunca valley)	Fırtına Stream	2600	2.27/6.50	40°59′24″N 41°15′41″E
F23	23.08.2007	Lake Küçük Çiftegöl (Tunca valley)	Fırtına Stream	2550	1.11/6.00	40°59′36″N 41°15′49″E
İ01	20.08.2006	Lake Dipsizgöl (Anzer valley)	İyidere	2670	0.93/2.00	40°33′28″N 40°28′25″E
İ02	25.07.2007	Lake Koyun (Anzer valley)	İyidere	3010	1.68/10.00	40°31′34″N 40°28′58″E
İ03	20.08.2006	Lake Küçükhatalan (Anzer valley)	İyidere	2800	0.24/0.80	40°33′16″N 40°29′22″E
İ04	20.08.2006	Lake Hatalan (Anzer valley	İyidere	2810	0.61/4.00	40°33′11″N 40°29′24″E
İ05	20.08.2006	Lake Küçüksivri (Anzer valley)	İyidere	2710	0.10/1.00	40°33′36″N 40°29′50″E
İ06	20.08.2006	Lake Sivrinin (Anzer valley)	İyidere	2700	0.42/1.50	40°33′39″N 40°29′52″E
İ07	02.08.2006	Lake Akçaağıl (Anzer valley)	İyidere	2940	0.59/2.50	40°31′19″N 40°30′40″E
İ08	21.08.2006	Lake Katreç (Arzayan valley)	İyidere	2700	1.73/6.50	40°34′06″N 40°34′51″E
İ09	21.08.2006	Lake Küçükkatreç (Arzayan valley)	İyidere	2690	0.03/1.00	40°34′13″N 40°34′58″E
İ10	03.08.2006	Lake Çitrik (Cimil valley)	İyidere	2850	2.80/14.00	40°39′31″N 40°46′59″E
İ11	03.08.2006	Lake Salar (Cimil valley)	İyidere	2820	3.20/2.50	40°43′28″N 40°52′09″E
K01	25.08.2006	Lake Arhavi Karagöl (Kabisra valley)	Kabisra Stream	2660	7.17/9.00	41°09′28″N 41°24′19″E
M01	26.08.2007	Lake Çakır (Altındere valley)	Maçka Stream	2530	5.46/10.00	40°34′34″N 39°41′26″E
S01	26.08.2006	Lake Uzungöl (Uzungöl valley)	Solaklı Stream	1100	8.50/6.90	40°37′14″N 40°17′44″E
S02	30.07.2007	Lake Kırklarcami (Uzungöl valley)	Solaklı Stream	2740	0.36/4.10	40°31′46″N 40°20′06″E
S03	29.07.2007	Lake Multat Karagöl (Uzungöl valley)	Solaklı Stream	2800	4.70/24.90	40°31′30″N 40°21′46″E
S04	27.07.2007	Lake Balık (Uzungöl valley)	Solaklı Stream	2570	4.26/4.50	40°31′54″N 40°23′01″E
S05	27.07.2007	Lake Aygır (Uzungöl valley)	Solaklı Stream	2710	4.08/13.00	40°31′39″N 40°23′28″E
S06	29.07.2007	Lake Sarıçiçek (Uzungöl valley)	Solaklı Stream	2890	1.46/5.20	40°31′15″N 40°24′21″E
S07	28.07.2007	Lake Büyükyayla Karagöl (Uzungöl valley)	Solaklı Stream	2930	2.13/16.50	40°31′41″N 40°27′03″E
S08	28.07.2007	Lake Pirömer (Uzungöl valley)	Solaklı Stream	2870	1.32/16.50	40°32′00″N 40°27′09″E
S09	28.07.2007	Lake Buz (Uzungöl valley)	Solaklı Stream	3040	1,98/13,80	40°31′58″N 40°27′36″E

in 2005–2007. Due to the high altitude, most of the sites studied are generally covered by snow and ice for 8–9 months of the year and ice-free periods occur only in the warm months of June–August.

Zooplankton samples were collected by horizontal and vertical hauls using a standard plankton net (mesh size of 55 µm) and were fixed in 4% formaldehyde. In addition, samples were taken from the littoral zone using a plankton hand net (mesh size of 55 µm).

For the taxonomical identification of the specimens, the keys of Ruttner-Kolisko (1974), Koste (1978), Collin (1961), Segers (1995), Nogrady et al. (1995), and Nogrady and Segers (2002) were used.

A clustering analysis of the unweighted pair-group method with arithmetic mean (UPGMA) was conducted using the MultiVariate Statistical Package (MVSP), version 3.1 (Kovach, 1998), in order to identify different taxonomic assemblages among the species at each sampling site.

3. Results

3.1. Environmental variables

Minimum and maximum values of the environmental variables of the studied lakes are shown in Table 2. In terms of water quality, all the lakes can be classified as first class in terms of their ammonium, nitrite, and nitrate nitrogen levels as well as the total phosphorus level. Similarly, the quality classes of the lakes ranged between I and III according to levels of dissolved oxygen. When the total nitrogen (TN) and total phosphorus (TP) are taken into consideration, all of the lakes show an oligotrophic character. The chlorophyll a concentrations of the lakes were generally low; this character also supports the above-mentioned results (Aygen et al., 2012).

The trophic classification of the lakes was obtained from the OECD model (Wollenweider and Kerekes, 1982) based on orthophosphate, Secchi depth, and chlorophyll a concentration (Tolotti et al., 2006). The

Table 2. Values of the environmental variables of high mountain lakes (n = 59).

Variables	Min.	Max.	Mean	SD
Maximum depth (m)	0.50	49.00	7.39	1.09
Surface area (ha)	0.03	8.90	2.46	0.29
Secchi depth (m)	0.50	13.00	4.44	3.29
Temperature (°C)	6.10	21.00	15.62	3.32
pH	6.75	9.82	8.03	0.77
Dissolved oxygen (mg/L)	5.30	9.40	6.91	0.94
DO saturation (%)	65.00	128.00	97.83	11.88
EC ($\mu S_{25°}$)	12.00	121.80	43.95	20.91
Alkalinity (mEq/L)	0.30	1.20	0.69	0.22
Temporary hardness (d°H)	0.80	3.40	1.94	0.62
HCO^{3-} (mg/L)	18.30	73.20	42.39	13.42
Total hardness (mg/L)	20.00	80.00	36.61	17.08
Ca^{2+} (mg/L)	8.00	32.10	14.66	6.84
Mg^{2+} (mg/L)	4.90	24.32	7.85	4.22
NO_2^--N (µg/L)	0.00	5.21	1.60	1.23
NO_3^--N (µg/L)	2.50	105.00	37.98	25.80
NH_4^--N (µg/L)	0.00	106.90	30.18	18.20
PO_4^{3-}-P (µg/L)	0.00	9.85	4.97	2.49
SiO_2^- (µg/L)	258.50	2516.30	1034.89	608.02
Chlorophyll a (µg/L)	0.00	2.32	0.13	0.44

trophic classification based on the orthophosphate includes 22 lakes as ultraoligotrophic and 37 lakes as oligotrophic (Table 3; Figure 2); by Secchi depth, 20 lakes are ultraoligotrophic, 12 lakes are oligotrophic, and 27 lakes are mesotrophic (Table 3; Figure 3).

3.2. Taxonomic structure

A total of 63 rotifer taxa (Philodinidae 1 taxa, Brachionidae 10 taxa, Euchlanidae 5 taxa, Mytilinidae 3 taxa, Trichotriidae 1 taxa, Lepadellidae 7 taxa, Lecanidae 11 taxa, Notommatidae 1 taxa, Trichocercidae 8 taxa, Synchaetidae 4 taxa, Asplanchnidae 2 taxa, Testudinellidae 2 taxa, Conochilidae 2 taxa, Hexarthridae 3 taxa, Filiniidae 2 taxa, Collothecidae 1 taxa) were identified. All of the taxa identified are new records for their localities except *Notholca squamula* and *Cephalodella gibba*, which were reported by Beladjal and Mertens (1997). Classifications of these taxa are as follows (Segers, 2007; Ustaoğlu et al., 2012; Ustaoğlu, 2015). Taxa printed in bold italics are recorded from Turkey for the first time.

Phylum: Rotifera
Classis: Eurotatoria
Subclassis: Bdelloidea
Ordo: Philodinida
Familia: Philodinidae
Dissotrocha macrostyla **(Ehrenberg, 1838)**
Subclassis: Monogononta
Superordo: Pseudotocha
Ordo: Ploimia
Familia: Brachionidae
Brachionus diversicornis (Daday, 1883)
Brachionus quadridentatus Hermann, 1783
Keratella cochlearis (Gosse, 1851)
Keratella quadrata (O.F.Müller, 1786)
Keratella tecta (Gosse, 1851)
Keratella tropica (Apstein, 1907)
Keratella valga (Ehrenberg, 1834)
Notholca acuminata (Ehrenberg, 1832)
Notholca salina Focke, 1961
Notholca squamula (Müller, 1786)
Familia: Euchlanidae
Euchlanis deflexa (Gosse, 1851)
*Euchlanis dilatata dilatata*Ehrenberg, 1832
Euchlanis dilatata lucksiana Hauer, 1930
Euchlanis incisa Carlin, 1939
Euchlanis lyra Hudson, 1886
Familia: Mytilinidae
Mytilina mucronata (Müller, 1773)
Mytilina ventralis brevispina (Ehrenberg, 1830)

Table 3. Trophic classification of the 59 lakes surveyed.

Variable	U-Oligotrophic	Oligotrophic	Mesotrophic
PO_4^{3-}-P	22 (37.29%)	37 (62.71%)	-
Chlorophyll a	59 (100.00%)	-	-
Secchi depth	20 (33.90%)	12 (20.34%)	27 (45.76%)

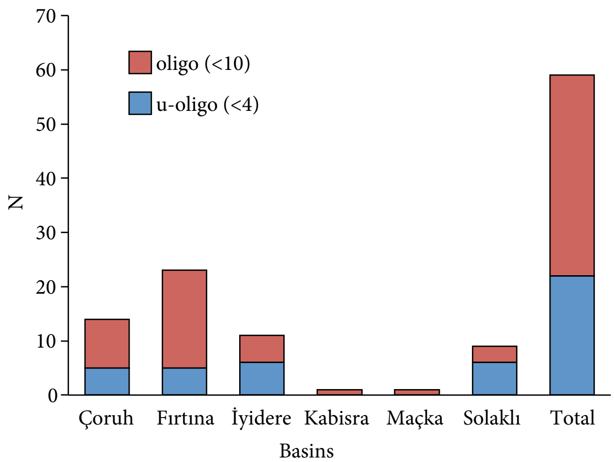

Figure 2. Trophic classes of the lakes based on orthophosphate (u-oligo = ultraoligotrophic; oligo = oligotrophic).

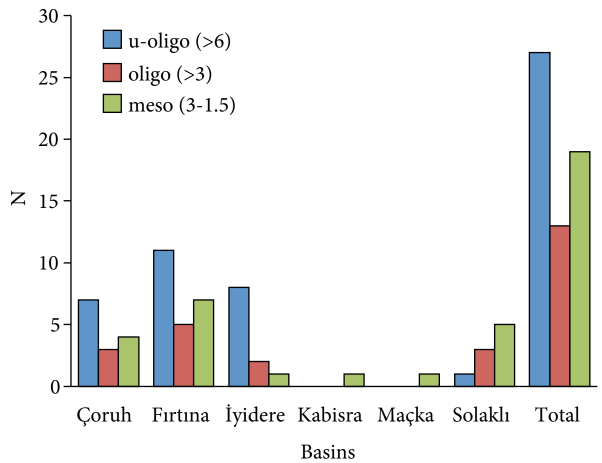

Figure 3. Trophic classes of the lakes based on Secchi depth (u-oligo = ultraoligotrophic; oligo = oligotrophic; meso = mesotrophic).

Mytilina ventralis ventralis (Ehrenberg, 1830)
Familia: Trichotriidae
Trichotria tetractis (Ehrenberg, 1830)
Familia: Lepadellidae
Colurella uncinata bicuspidata (Ehrenberg, 1832)
Lepadella acuminata (Ehrenberg, 1834)
Lepadella ovalis (Müller, 1786)
Lepadella patella (Müller, 1773)
Lepadella patella persimilis (de Ridder, 1961)
Lepadella quadricarinata (Stenroos, 1898)
Lepadella triptera (Ehrenberg, 1832)
Familia: Lecanidae
***Lecane clara* (Bryce, 1892)**
Lecane closterocerca (Schmarda, 1859)
Lecane flexilis (Gosse, 1886)
Lecane furcata (Murray, 1913)
Lecane hamata (Stokes, 1896)
***Lecane kluchor* Tarnogradski, 1930**
***Lecane latissima* Yamamoto, 1955**
Lecane luna (Müller, 1776)
Lecane lunaris (Ehrenberg, 1832)
Lecane quadridentata (Ehrenberg, 1832)
Lecane stichaea Harring, 1913
Familia: Notommatidae
Cephalodella gibba (Ehrenberg, 1838)
Familia: Trichocercidae
Trichocerca chattoni (De Beauchamp, 1907)
Trichocerca longiseta (Schrank, 1802)
Trichocerca myersi (Hauer, 1931)
Trichocerca porcellus (Gosse, 1851)
Trichocerca rattus (Müller, 1776)
Trichocerca similis (Wierzeski, 1893)
Trichocerca tenuior (Gosse, 1886)
Trichocerca vernalis (Hauer, 1936)
Familia: Synchaetidae
Polyarthra dolichoptera Idelson, 1925
Polyarthra remata Skorikov, 1896
Polyarthra vulgaris Carlin, 1943
Synchaeta pectinata Ehrenberg, 1832
Familia: Asplanchnidae
Asplanchna girodi de Guerne, 1888
Asplanchna priodonta Gosse, 1850
Superordo: Gnesiotrocha
Ordo: Flosculariacea
Familia: Testudinellidae
Testudinella mucronata (Gosse, 1886)
Testudinella patina (Hermann, 1783)
Familia: Conochilidae
Conochilus dossuarius (Hudson, 1885)
Conochilus unicornis Rousselet, 1892
Familia: Hexarthridae
Hexarthra cf. *bulgarica* (Wiszniewski, 1933)
Hexarthra fennica (Levander, 1892)
***Hexarthra jenkinae* (de Beauchamp, 1932)**
Familia: Filiniidae
Filinia longiseta (Ehrenberg, 1834)
Filinia terminalis (Plate, 1886)
Ordo: Collothecaceae
Familia: Collothecidae
Collotheca sp.

A list of the 63 rotifer taxa collected from the study area is given in Table 4. *Notholca squamula* (46 stations, 77.97%), *Keratella quadrata* (44 stations, 74.58%), *Lecane lunaris* (38 stations, 64.41%), *Euchlanis dilatata lucksiana* (29 stations, 49.15%), *Lepadella patella* (25 stations, 42.37%), and *Lecane flexilis* (18 stations, 30.51%) were the dominant species.

The rare taxa (*Asplanchna priodonta*, *Brachionus quadridentataus*, *Collotheca* sp., *Conochilus dossuaris*, *Dissotrocha macrostyla*, *Euchlanis deflexa*, *Euchlanis incisa*, *Euchlanis lyra*, *Hexarthra* cf. *bulgarica*, *Keratella valga*, *Lecane clara*, *Lecane hamata*, *Lecane kluchor*, *Lecane latissimi*, *Lecane quadridentata*, *Lecane stichaeta*, *Lepadella triptera*, *Mytilina ventralis brevispina*, *Testudinella mucronata*, *Testudinella patina*, *Trichocerca rattus*, *Trichocerca tenuior*, *Trichocerca vernalis*) were observed in only one station (lake) (1.69%) each (Table 4).

The highest number of taxa was found in the lakes in Fırtına Stream (39 taxa) and the lowest number of taxa in Lake Arhavi Karagöl (Kabisra Stream) (7 taxa) (Figure 4).

Based on the saprobic system (Sladecek, 1973), the rotifer taxa were evaluated as follows: 54% oligosaprobic (o), 26% oligosaprobic/beta-mesosaprobic (o-β), 16% beta-mesosaprobic (β), and 4% beta-mesosaprobic/oligosaprobic (β-o). We propose that 80% of the rotifer taxa were indicators of oligotrophic conditions and the remaining 20% were indicators of mesotrophic conditions (Figure 5).

When the dendrogram, which gives the similarities of the examined localities, was created, the stations named İ7 and F21 had obvious differences that caught our attention when they were compared with other stations. Moreover, a station named K1 closely shared features with those two stations. Concerning the variety of species, the most similar localities are the stations coded İ11 and İ3. Similar to those, the stations coded İ8 and F6 also have various similarities concerning the variety of species. In other localities, the rates of similarity are about 70% or lower (Figure 6).

When altitudes of the lakes that we studied and rotifer species diversity were compared, a decrease was not observed in species diversity as altitude increased (R^2 = 0.067) (20 species in Lake Uzungöl with an elevation of 1100 m and 4 species in Lake Deniz with an altitude of 3370 m) (Figure 7).

Table 4. Distribution of the rotifer taxa collected from 59 stations in high mountain lakes in the Eastern Black Sea Range of Turkey. Frequency is expressed as the percentage of lakes in which species occurred.

Taxa	Basins						Frequency %
	Çoruh (Ç1–Ç14)	Fırtına (F1–F23)	İyidere (İ1–İ11)	Kabisra (K1)	Maçka (M1)	Solaklı (S1–S9)	
Asplanchna girodi	2		1			1, 5	6.78
Asplanchna priodonta		8					1.69
Brachionus diversicornis		3, 8, 19	6	1			8.47
Brachionus quadridentatus	8						1.69
Cephalodella gibba	8	4, 5, 20, 21	4, 5			1, 3, 4, 6, 8, 9	22.03
Collotheca sp.						1	1.69
Colurella uncinata bicuspidata		5				1	3.39
Conochilus dossuarius		1					1.69
Conochilus unicornis	6, 8–11	5, 8, 20, 22, 23	2	1		1	22.03
Dissotrocha macrostyla		16					1.69
Euchlanis deflexa						1	1.69
Euchlanis dilatata dilatata	1, 3, 4	3, 6, 9, 10, 12, 16	6, 8–11		1		25.42
Euchlanis dilatata lucksiana	4–6, 9, 11, 13	3–5, 8–10, 14, 17, 20, 22, 23	1, 3–5, 11	1		1, 3–5, 7, 8	49.15
Euchlanis incisa	2						1.69
Euchlanis lyra						1	1.69
Filinia longiseta	1	13, 22			1	1, 2, 4, 6, 8, 9	16.95
Filinia terminalis	10	14, 16				1, 5, 6	10.17
Hexarthra cf. *bulgarica*		16					1.69
Hexarthra fennica	8, 9	8					5.08
Hexarthra jenkinae	12–14	4	4–6	1		1	15.25
Keratella cochlearis	5	5, 13, 22, 23					8.47
Keratella quadrata	1–3, 6–14	2–6, 8–15, 18–20, 22, 23	1–6, 8, 10, 11		1	1–9	74.58
Keratella tecta		23				3, 6	5.08
Keratella tropica		20				1, 3, 6, 9	8.47
Keratella valga	11						1.69
Lecane clara			5				1.69
Lecane closterocerca	2, 9	4, 5, 8, 14, 20	3, 11		1	1, 4–6, 9	25.42
Lecane flexilis	1–3, 13	1–3, 5, 12, 14, 20, 23	6		1	2, 3, 5, 8	30.51
Lecane furcata		4, 19, 20					5.08
Lecane hamata		20					1.69
Lecane kluchor			9				1.69
Lecane latissima		12					1.69
Lecane luna	1, 8, 11					7	6.78
Lecane lunaris	1–5, 7–11, 13	2–5, 8–10, 12, 15, 16, 20, 22, 23	1, 3, 5, 6, 9–11		1	1, 3–6, 9	64.41
Lecane quadridentata	8						1.69
Lecane stichaea				1			1.69
Lepadella acuminata	1, 4, 6, 11	1, 4, 16, 20, 23				1, 8	18.64
Lepadella ovalis		9, 20					3.39
Lepadella patella	3, 4, 8, 12	4, 5, 8, 14, 16, 19–21, 23	1, 3, 5–7, 9, 11		1	1, 2, 7, 9	42.37
Lepadella patella persimilis						4, 5	3.39
Lepadella quadricarinata		5				6	3.39
Lepadella triptera						2	1.69
Mytilina mucronata	10	5					3.39
Mytilina ventralis brevispina		5					1.69
Mytilina ventralis ventralis	8	6	1				5.08
Notholca acuminata	2–3, 8, 10	2, 3, 9, 11,15, 18, 19					18.64
Notholca salina	7, 8, 10	3, 10					8.47
Notholca squamula	2–6, 8, 11–13	1, 3–10,13–15, 17–19, 22, 23	1–6, 8–11		1	1–9	77.97
Polyarthra dolichoptera	1, 8–10	1, 9, 10, 14			1	1	16.95
Polyarthra remata						4, 9	3.39
Polyarthra vulgaris	9	18		1			5.08
Synchaeta pectinata	1	2, 3, 5, 15,18–20, 22, 23	1, 4		1	1, 2	25.42
Testudinella mucronata					1		1.69
Testudinella patina					1		1.69
Trichocerca chattoni						4, 5	3.39
Trichocerca longiseta	3, 11	4, 15	3, 4, 11	1		4, 6, 9	18.64
Trichocerca myersi			9		1		3.39
Trichocerca porcellus						4, 6	3.39
Trichocerca rattus					1		1.69
Trichocerca similis	8, 9						3.69
Trichocerca tenuior					1		1.69
Trichocerca vernalis			6				1.69
Trichotria tetractis	3	2, 5, 8, 20	1, 11				11.86
Total (63 taxa)	32	39	21	7	15	30	

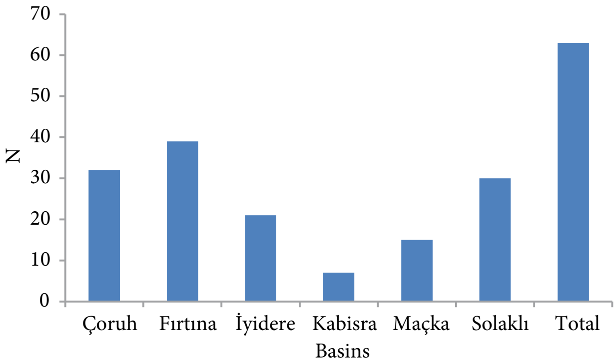

Figure 4. Taxa distributions of rotifers in the studied lakes.

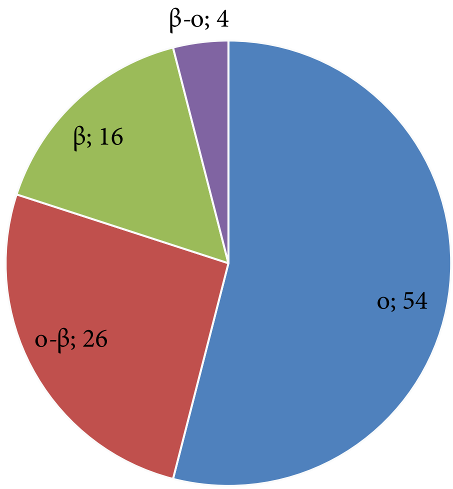

Figure 5. Percentage distributions of rotifers according to the saprobic system (o = oligosaprobic, o-β = oligosaprobic/beta-mesosaprobic, β = beta-mesosaprobic, β-o = beta-mesosaprobic/oligosaprobic).

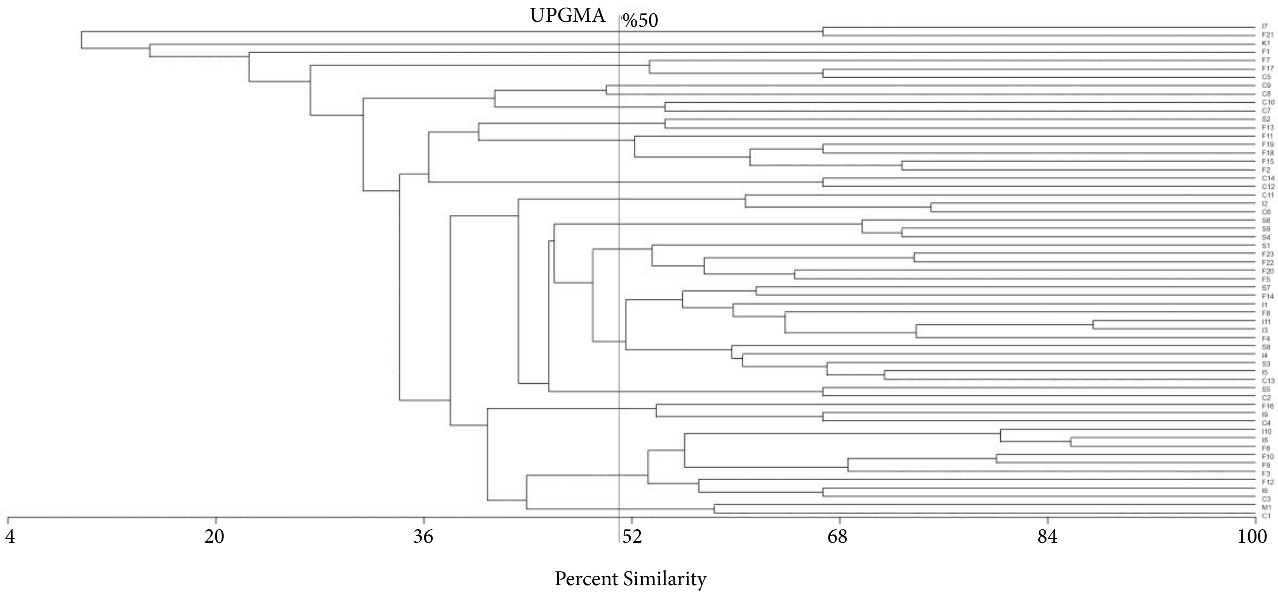

Figure 6. UPGMA dendrogram illustrating the relationship of rotifers in studied lakes.

4. Discussion

This study represents a pioneering contribution to the research of rotifer communities in the glacial lakes of Turkey. All the taxa identified are new records for their localities, except for *Notholca squamula* and *Cephalodella gibba*, which were reported by Beladjal and Mertens (1997). *Dissotrocha macrostyla*, *Hexarthra jenkinae*, *Lecane clara*, *Lecane kluchor*, and *Lecane latissima* are new records for the Turkish inland water fauna (Ustaoğlu et al., 2012; Ustaoğlu, 2015).

In regard to the studies of high mountain lakes in Turkey, 69 taxa of rotifers were reported among the zooplankton of 16 mountain lakes in the Taurus mountain range, the elevation of which ranges from 1500 to 2660 m (Ustaoğlu et al., 2005). Among them, the taxa *Brachionus quadridentatus*, *Keratella cochlearis*, *K. tecta*, *K. quadrata*, *Notholca squamula*, *Euchlanis dilatata*, *E. incisa*, *Mytilina ventralis*, *M. ventralis brevispina*, *Trichotria tetractis*, *Colurella uncinata*, *Lepadella patella*, *L. patella similis*, *Lecane flexilis*, *L. luna*, *L. lunaris*,

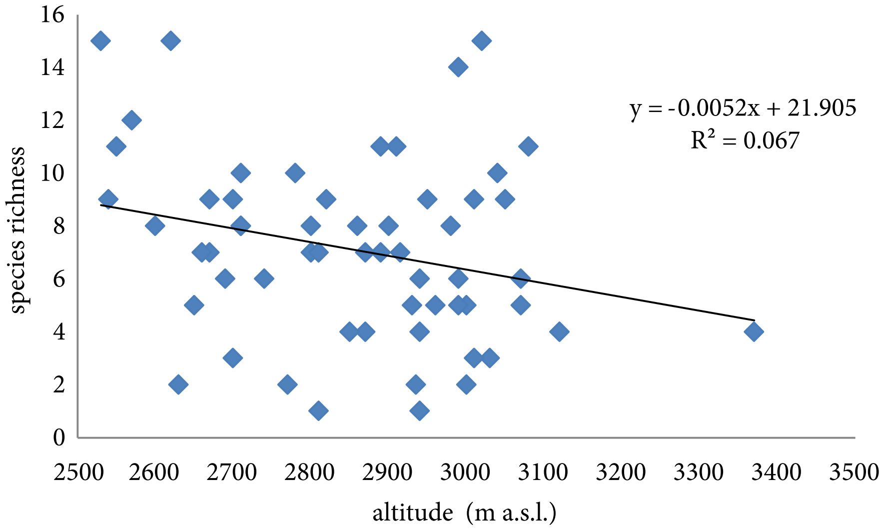

Figure 7. Rotifer species richness for different altitudinal distributions of lakes (n = 58) except Lake Uzungöl (1100 m a.s.l.).

L. quadrientata, *Cephalodella gibba*, *Trichocerca longiseta*, *T. rattus*, *T. similis*, *T. vernalis*, *Synchaeta pectinata*, *Asplanchna priodonta*, *A. girodi*, *Testudinella patina*, *Conochilus unicornis*, *Hexarthra fennica*, and *Filinia longiseta* were found in the present study.

Twenty-four taxa of rotifers were reported in the zooplankton of 5 glacial lakes on Mount Uludağ in Bursa [Kilimligöl (2330 m), Buzlugöl (2390 m), Karagöl (2270 m), Aynalıgöl (2310 m), and Heybeligöl (2410 m)] (Ustaoğlu et al., 2008). Of these taxa, *Keratella cochlearis*, *K. tecta*, *K. quadrata*, *Notholca squamula*, *Euchlanis dilatata lucksiana*, *Mytilina ventralis brevispina*, *Lepadella patella*, *Lecane flexilis*, *L. luna*, *L. furcata*, *L. lunaris*, *L. closterocerca*, *Cephalodella* sp., *Trichocerca longiseta*, *T. rattus*, *T. similis*, *Polyarthra dolichoptera*, and *Hexarthra bulgarica* showed distribution similarities with the present study.

Thirty taxa of rotifers were reported in the zooplankton of Lake Eğrigöl at 2000 m in the Middle Taurus Range (Aygen et al., 2009). Among them, the taxa *Brachionus quadridentatus*, *Keratella cochlearis*, *K. quadrata*, *Euchlanis deflexa*, *E. lyra*, *E. dilatata*, *E. dilatata lucksiana*, *Mytilina ventralis*, *M. ventralis brevispina*, *Trichotria tetractis*, *Colurella uncinata bicuspidata*, *Lepadella acuminata*, *L. ovalis*, *Lecane flexilis*, *L. closterocerca*, *L. luna*, *L. lunaris*, *Polyarthra dolichoptera*, *Asplanchna priodonta*, *Testudinella patina*, *Conochilus dossuarius*, and *Filinia terminalis* were also found in this study.

When the studies on alpine and subalpine lakes at different locations around the world are reviewed, it is observed that *Keratella quadrata*, *Polyarthra dolichoptera*, and *Brachionus angularis* were mentioned in a study of the alpine lakes of Portugal (Boavida and Gliwicz, 1996); *Hexarthra bulgarica*, *Keratella quadrata*, *Filinia maior*, *Polyarthra* sp., and *Ascomorpha* sp. were mentioned in a study of high mountain lakes in Khumbu Valley in the Nepalese Himalayas (Manca et al., 1998); and the taxa *Keratella hiemalis*, *Kellicottia longispina*, *Polyarthra* sp., and *Synchaeta* sp. were mentioned by McNaught et al. (1999). The taxa *Kellicottia* sp., *Conochilus unicornis*, *Keratella* spp., *K. quadrata*, and *Polyarthra* spp. were found by Knapp et al. (2001).

Of 31 taxa of rotifers reported from eastern Siberia (Bondarenko et al., 2002), *Cephalodella gibba*, *Polyarthra dolichoptera*, *Asplanchna priodonta*, *Lecane luna*, *L. lunaris*, *Trichotria tetractis*, *Mytilina mucronata*, *M. ventralis*, *Euchlanis dilatata*, *E. lyra*, *Keratella quadrata*, *Notholca acuminata*, *N. squamula*, *Conochilus unicornis*, *Filinia terminalis*, *Synchaeta* sp., and *Lepadella* sp. were common findings in our study.

The taxa *Keratella* sp., *Synchaeta* sp., *Polyarthra* sp., and *Notholca* sp. were reported in a study of benthic and pelagic food resources for zooplankton in shallow high-latitude lakes and ponds (Rautio and Vincent, 2006).

In a study of 70 lakes in the Italian and central Austrian Alps, a total of 51 taxa of rotifers were found, with the taxa *Ascomorpha ecaudis*, *Asplanchna priodonta*, *Euchlanis dilatata-parva*, *Filinia terminalis*, *Kellicottia longispina*, *Keratella hiemalis*, *Keratella tropica*, *Lecane mira*, *Lecane ungulate*, *Notholca squamula*, and *Polyarthra dolichoptera* being the dominant taxa (Tolotti et al., 2006).

Euchlanis dilatata was the most abundant species (81%) among the rotifer species detected in 37 lakes in the Sierra Nevada mountain range, whereas *Notholca squamula* was the most common (78%) species in the lakes that we studied. Typically known as a species of mountain lakes, *Hexarthra bulgarica* had the widest distribution (40%) in the Sierra Nevada mountain range, but it did not show a wide distribution in our lakes (2%) (Morales-Baquero, 1987).

In a study of 6 different types of substrate in the Alpine lakes of Austria (Jersabek, 1995), a total of 149 rotifer species were found; among these species, *Cephalodella gibba*, *Collotheca* sp., *Colurella uncinata bicuspidata*, *Euchlanis deflexa*, *E. dilatata*, *Keratella cochlearis*, *K. quadrata*, *K. valga*, *Notholca squamula*, *Lecane flexilis*, *L. luna*, *L. stichaea*, *L. kluchor*, *L. furcata*, *L. hamata*, *L. lunaris*, *Lepadella acuminata*, *L. ovalis*, *L. quadricarinata*, *L. triptera*, *Synchaeta pectinata*, *Trichocerca rattus*, and *Trichotria tetractis* were also found in the lakes that we studied.

In a study on the distribution in inland waters in Turkey of the taxa of rotifers found in the lakes studied (Ustaoğlu et al., 2012), it was observed that 74.55% of the taxa were cosmopolitan, 10.91% were widespread, and 14.54% were less commonly encountered taxa.

This study represents a pioneering contribution to the research of rotifer communities in the glacial lakes of Turkey. The present survey will be useful as a baseline for future studies and contributions to the knowledge of Turkey's biodiversity.

Acknowledgments

This project was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK, Project 104/Y/183). We are deeply grateful for that support. We would also like to thank Dr Süleyman Balık, Dr Cem Aygen, Dr Haşim Sömek, Dr Hasan M Sarı, Dr Murat Özbek, Dr Ali İlhan, Dr Esat T Topkara, Dr Özdemir Egemen, Dr. Aslı Başaran, and Mesut Kaptan for their invaluable support and help with technical issues.

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