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Rotifera and Cladocera fauna of several lakes from the Central Anatolia, Marmara, and Western Black Sea regions of Turkey

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Abstract: In this study a total of 18 lakes from the Central Anatolia, Marmara, and Western Black Sea regions of Turkey were investigated along with their physicochemical parameters. Thirty-six species of Rotifera and 6 species of Cladocera were recorded. *Keratella tecta*, *K. cochlearis*, *Polyarthra dolichoptera*, and *P. vulgaris* were the most common Rotifera species and *Bosmina longirostris* was the most common Cladocera species among the sampling stations. The *Brachionus/Trichocerca* ($Q_{B/T}$) index was also calculated where applicable. The depth of the water bodies ranged between 2.5 and 62 m, Secchi depth between 0.1 and 6.2 m, water temperature between 19.1 and 29.1 °C, electrical conductivity between 89 and 1894 µS/cm, dissolved oxygen between 6.22 and 9.37 mg/L, and pH between 8.19 and 9.41. Total phosphorus ranged between 0.007 and 0.641 mg/L, total nitrogen between 0.57 and 7.85 mg/L, nitrate between 0.21 and 4.36 mg/L, and nitrite between 0.011 and 1.56 mg/L.

Key words: Inland waters, zooplankton, physicochemical parameters, nitrate, phosphorus

1. Introduction

The importance of zooplankton in the food chain of aquatic ecosystems has been well documented (Agasild and Noges, 2005; Medeiros and Arthington, 2008). Zooplankton has a special role as a food for fish larvae and aquatic invertebrates. Furthermore, the species composition and the abundance of zooplankton such as rotifers and cladocerans are excellent tools for interpreting the trophic level in a given water body, since they are very sensitive to environmental variables such as nutrient availability (Sladecek, 1983; Radwan, 1984; Snell and Janssen, 1995; Lougheed and Chaw-Fraser, 2002) and they can be observed in a wide range of water bodies.

In Turkey, the first studies on rotifers and cladocerans were carried out by Daday (1903) and Muckle (1951), respectively. Since then, 341 species of Rotifera (Ustaoğlu et al., 2012) and 93 species of Cladocera have been recorded (Gündüz, 1997; Yalım and Çıplak, 2005), and most of the studies on zooplankton deal with the seasonal dynamics of planktonic communities (Saygı et al., 2011; Gündüz et al., 2013). However, during the last decade, investigators focused on the planktonic fauna of Turkish inland water bodies (Altındağ et al., 2005; Ustaoğlu et al., 2005; Kaya and Altındağ, 2007; Altındağ et al., 2009; Bekleyen and İpek, 2010; Bozkurt and Göksu, 2010; Kaya and Altındağ, 2010). In this study, it was aimed to investigate the rotifer and cladoceran species of several lakes from the Central Anatolia, Marmara, and Western Black Sea regions of Turkey, along with their physicochemical parameters. Of the water bodies investigated, this is the first presentation on the zooplankton fauna of Lake Ilgın, Aşağıkuzfındık Dam Lake, Kızıldamalar Dam Lake, Boğazköy Dam Lake, Lake Taşkısığı, and Lake Poyrazlar to date.

2. Materials and methods

The zooplankton samples were collected vertically with a Hensen type plankton net (mesh size 55 µm, mouth diameter 25 cm, length 50 cm) from 18 different water bodies on June 2013. Sampling covered the entire water column, from the surface to the deepest part, and was repeated at 10-m intervals where applicable. The sampling stations and coordinates are shown in the Figure. The samples were fixed in 4% formaldehyde solution. Rotifera and Cladocera species were examined under binocular and inverted microscopes (Leica DM-LS Type 020-518-500). Identification of the rotifer species was performed according to Kolisko (1974), Koste (1978), and Segers (1995) and for cladocerans Smirnov (1974), Negrea (1983), and Margaritora (1983) were used. The *Brachionus/Trichocerca* ($Q_{B/T}$) index suggested by Sladecek (1983), which is used to interpret the trophic level of water bodies, was calculated where applicable.

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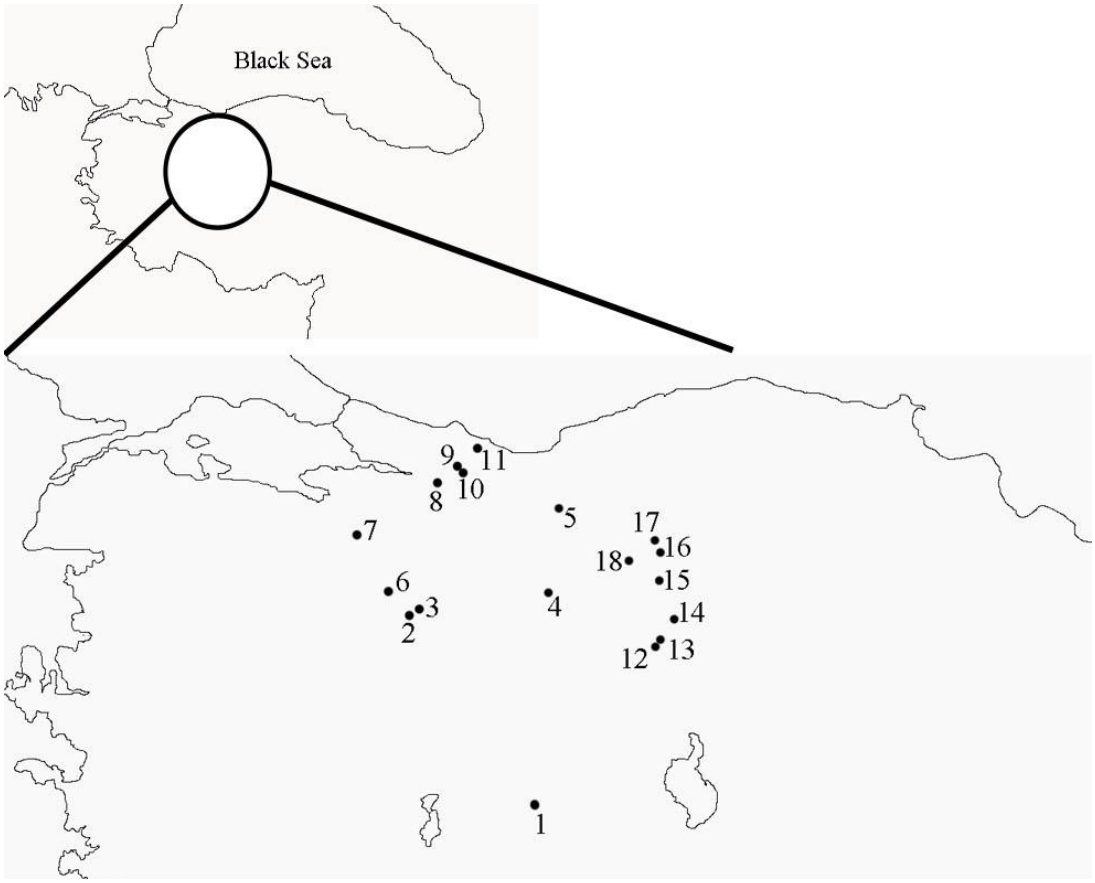

1. Lake Ilgın (38°20'57.49"N - 31°52'3.53"E)
2. Porsuk Dam Lake (39°37'55.53"N - 30°13'41.08"E)
3. Lake Musaözü (39°41'52.21"N - 30°19'7.14"E)
4. Sarıyar Dam Lake (40°1'51.53"N - 31°35'19.77"E)
5. Aşağıkuzfındık Dam Lake (40°41'59.88"N - 31°31'37.83"E)
6. Kızıldamalar Dam Lake (39°47'0.14"N - 29°57'43.26"E)
7. Boğazköy Dam Lake (40°10'22.53"N - 29°31'0.11"E)
8. Lake Sapanca (40°43'7.47"N - 30°13'32.98"E)
9. Lake Taşkısığı (40°52'17.30"N - 30°24'2.79"E)
10. Lake Poyrazlar (40°50'12.43"N - 30°28'10.49"E)
11. Lake Akgöl (41° 2'57.56"N - 30°33'54.02"E)
12. Lake Mogan (39°46'6.22"N - 32°47'30.16"E)
13. Lake Eymir (39°49'27.46"N - 32°49'27.59"E)
14. Çubuk Dam Lake (40° 0'10.82"N - 32°55'43.44"E)
15. Kurtboğazı Dam Lake (40°17'3.03"N - 32°42'26.01"E)
16. Akyar Dam Lake (40°30'23.14"N - 32°39'52.43"E)
17. Eğrekkaya Dam Lake (40°35'43.98"N - 32°34'46. 37"E)
18. Çamlıdere Dam Lake (40°24'1.16"N - 32°21'30.66"E)

Figure. Map showing sampling localities and coordinates.

Physicochemical parameters such as depth, Secchi depth, temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), total phosphorus (TP), total nitrogen (TN), nitrate (NO_3), and nitrite (NO_2) levels were also measured. Of these parameters, DO and temperature were measured with a YSI 51 B oxygen-meter, pH with a WTW 340-A/SET-1 pH-meter, EC with a WTW LF 92 conductometer, and light permeability with a Secchi disk. Water samples were taken from 0.5 m below the surface with a Nansen bottle and TP, TN, NO_3, and NO_2 levels were measured within a few hours after collection according to TS EN ISO 17294 (1–2), SM 4500 N, EPA Method 352.1 (EN ISO 10304-3), and SM 4500-NO_2, respectively.

3. Results

A total of 42 species belonging to Cladocera (6 species) and Rotifera (36 species) were detected in the water bodies investigated (Table 1). The species distribution in the sampling stations is also presented in Table 1. The most encountered rotifers were *Keratella tecta*, *K. cochlearis*, *Polyarthra dolichoptera*, and *P. vulgaris*, and *Bosmina longirostris* was the most common cladoceran among the stations. The species richness was highest in Lake Ilgın with 17 species and lowest in Lake Eymir with only 1 species (Table 1).

Table 1. List of zooplankton species and their distributions among stations.

Rotifera	Stations
Anureopsis fissa	3, 6, 7, 10, 11
Asplancha priodonta	4, 14, 15, 18
Brachionus angularis	1, 4, 6, 7, 12
B. calyciflorus	2, 12
B. diversicornis	2, 3, 4, 9, 11
B. forficula	1, 4, 9, 11
B. plicatilis	1
Cephalodella gibba	14
Colurella uncinata	3, 8, 12
Euchlanis dilatata	11
Filinia longiseta	1
Filinia terminalis	14, 18
Hexarthra mira	1
Kellicottia longispina	1
Keratella cochlearis	1, 5, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18
Keratella quadrata	12, 13
Keratella tecta	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 14, 15, 14
Lecane bulla	9, 12, 15
L. closterocerca	3, 9, 11, 12, 15
L. hamata	12
L. luna	2, 3, 6, 11, 12, 14
L. lunaris	3, 18
L. nana	9
L. ohioensis	3
Lepadella patella	11
L. quadricarinata	6, 12
Polyarthra dolichoptera	1, 3, 4, 5, 6, 7, 10, 11, 12, 14, 15, 18
P. major	1
P. remata	1, 4, 18
P. vulgaris	1, 6, 7, 10, 11, 12, 15, 16
Pompholyx sulcata	2, 3, 6, 7, 10
Synchaeta oblonga	18
Testudinella patina	12
Trichocerca rattus	2, 9
Trichocerca capucina	18
Trichocerca longiseta	1
Trichocerca similis	3, 14, 15, 16
Cladocera	
Bosmina longirostris	1, 2, 3, 4, 5, 6, 7, 8, 14, 18
Ceriodaphnia quadrangula	1, 14
Daphnia cucullata	2, 17
Moina brachiata	1, 14
Polyphemus pediculus	1
Simocephalus vetulus	15

The physicochemical parameters are summarized in Table 2. The depth of the water bodies ranged between 2.5 and 62 m, Secchi depth between 0.1 and 6.2 m, water temperature between 19.1 and 29.1 °C, EC between 89 and 1894 µS/cm, DO between 6.22 and 9.37 mg/L, and pH between 8.19 and 9.41. Total phosphorus was below the detection limits at station 8 and its range was between 0.007 and 0.641 mg/L; total nitrogen was below the detection limit at stations 5 and 9 and ranged between 0.57 and 7.85 mg/L; nitrate was below the detection limit at stations 1, 2, 3, 5, 10, and 15 and ranged between 0.21 and 4.36 mg/L; and nitrite was above the detection limit only at stations 1, 2, 4, and 7 and it ranged between 0.011 and 1.56 mg/L.

The *Brachionus*/*Trichocerca* ($Q_{B/T}$) index was only applicable for stations 1, 2, 3, and 9 and it ranged between 1 and 3; it was highest in Lake Ilgın and lowest in Lake Musaözü.

4. Discussion

In this study a total of 10 dam lakes and 8 natural lakes were sampled and a total of 42 zooplankton species were identified, with 36 rotifer species and 6 cladoceran species (Table 1). This is the first presentation of the zooplankton fauna of Lake Ilgın, Aşağıkuzfındık Dam Lake, Kızıldamalar Dam Lake, Boğazköy Dam Lake, Lake Taşkısığı, and Lake Poyrazlar. The most common rotifer species observed in this study, such as *Keratella quadrata*, *K. cochlearis*, *K. tecta*, *Polyarthra dolichoptera*, *P. vulgaris*, and *Trichocerca similis*, are cosmopolitan (Segers, 2007). However, species such as *Filinia longiseta* and *Lepadella patella*, which are also known to be also cosmopolites, were observed only at one station, which might be a result of unfavorable environmental conditions and/or overpredation by fish larvae and aquatic invertebrates in these water bodies (Murtaugh, 1989; Vadstein et al., 2012). The most common Cladocera species was *Bosmina longirostris*, which is a well-known indicator of eutrophication (Jaramillo and Pinto, 2010). *Polyphemus pediculus* and *Simocephalus vetulus* were observed only from one station, which could be the result of the seasonal dynamics of these cladoceran species.

The $Q_{B/T}$ index is calculated as the ratio of *Brachionus* to *Trichocerca*, and if the ratio is equal to 1, the lake is oligotrophic; if it is between 1 and 2, the lake is mesotrophic; and if it is >2, the lake is eutrophic (Sladecek, 1983). This index was applicable to Lake Ilgın, Lake Musaözü, Lake

Table 2. The physicochemical parameters of the sampling stations; Temperature (Temp), Secchi Depth, electrical conductivity (EC), dissolved oxygen (DO), pH, total phosphorus (TP), total nitrogen (TN), nitrate (NO_3) and nitrite (NO_2).

Stations		Depth (m)	Secchi depth (m)	Temp. (°C)	EC (µS/cm)	DO (mg/L)	pH	TP (mg/L)	TN (mg/L)	NO_3 (mg/L)	NO_2 (µg/L)
1	Lake Ilgın	3.4	0.4	21.7	383	7.4	8.29	0.036	1.57	<0.1	15
2	Porsuk Dam Lake	30	0.9	21.9	511	7.49	8.93	0.027	0.72	<0.1	11
3	Lake Musaözü	24	1.5	20.4	628	8.11	9.36	0.014	1.20	<0.1	<10
4	Sarıyar Dam Lake	2.5	0.1	24.3	1177	4.72	8.78	0.641	7.85	4.36	1560
5	Aşağıkuzfındık Dam Lake	31	1.6	19.1	795	7.26	8.91	0.021	<0.1	<0.1	<10
6	Kızıldamalar Dam Lake	26	0.5	20.0	326	7.61	9.41	0.054	0.84	0.45	<10
7	Boğazköy Dam Lake	12	0.3	25.0	594	6.50	9.15	0.054	1.85	2.35	31
8	Lake Sapanca	62	6.2	24.5	253	9.35	8.92	<0.005	1.96	0.44	<10
9	Lake Taşkısığı	4.7	0.6	26.1	540	7.82	8.87	0.021	<0.1	0.39	<10
10	Poyrazlar Lake	4.1	2.1	29.1	210	7.90	8.77	0.007	1.04	<0.1	<10
11	Lake Akgöl	3.4	0.8	25.0	1894	7.10	8.19	0.009	1.27	0.24	<10
12	Lake Mogan	3.5	1.5	23.3	746	6.5	8.61	0.089	0.61	0.29	<10
13	Lake Eymir	5.7	2.0	24.5	1689	6.22	8.64	0.085	1.32	0.38	<10
14	Çubuk Dam Lake	41	2.1	25.1	265	7.84	8.94	0.010	3.04	0.21	<10
15	Kurtboğazı Dam Lake	38	0.8	20.3	185	7.16	9.24	0.061	2.79	<0.1	<10
16	Akyar Dam Lake	24	1.6	20.8	89	8.71	8.96	0.034	0.71	0.28	<10
17	Eğrekkaya Dam Lake	29	1.1	23.1	139	9.37	9.20	0.059	0.57	2.52	<10
18	Çamlıdere Dam Lake	31	2.3	21.7	180	8.49	9.03	0.006	2.18	0.27	<10

Taşkısığı, and Porsuk Dam Lake. The highest value was calculated as 3 for Lake Ilgın, which indicates eutrophic conditions. This value was 2 for Porsuk Dam Lake and Lake Taşkısığı, and it was determined as 1 for Lake Musaözü.

Results of physicochemical parameters are summarized in Table 2. The lowest Secchi depth was observed in Sarıyar Dam Lake with a depth of 0.1 m. During the study, fish remains were observed on the shore, and there were visual signs of algal bloom. The DO level in the lake was below 5 mg/L and the nitrite level exceeded 1.56 mg/L, which also clearly indicated sewage discharge that could be the cause of fish deaths.

Secchi depths recorded in Lake Ilgın, Porsuk Dam Lake, Kızıldamalar Dam Lake, Boğazköy Dam Lake, Lake Taşkısığı, Lake Akgöl, and Kurtboğazı Dam Lake were in the range of 0.1 to 0.8 m. According to surface water quality management (SWQM) criteria (Orman ve Su İşleri Bakanlığı, 2012), Secchi depths below 1 m indicate eutrophic conditions. The water temperature was in the range of expected values for the season. EC values were higher than 1000 µS/cm in Sarıyar Dam Lake, Lake Eymir, and Lake Akgöl. The pH and DO levels were in the expected range and considered not to be limiting factors, except for Sarıyar Dam Lake, which had a DO level of 4.72 mg/L. Total phosphorus levels were highest in Sarıyar Dam Lake and were below the detection limit in Lake Sapanca. According to the SWQM criteria (Orman ve Su İşleri Bakanlığı, 2012), Sarıyar Dam Lake is hypertrophic with a TP level of 0.641 mg/L; Lake Sapanca, Poyrazlar Lake, Lake Akgöl, and Çamlıdere Dam Lake are oligotrophic; and the rest of the sampling stations are meso- to eutrophic. Although Lake Akgöl is facing problems due to eutrophication, low TP levels may indicate the deposition of phosphorus in the sediment, not in the water column (Moore et al., 1998). Total nitrogen levels were above 1.2 mg/L, which is also the limit for hypereutrophication according to the SWQM criteria (Orman ve Su İşleri Bakanlığı 2012), in Lake Ilgın, Lake Musaözü, Sarıyar Dam Lake, Boğazköy Dam Lake, Lake Sapanca, Lake Akgöl, Lake Eymir, Çubuk Dam Lake, Kurtboğazı Dam Lake, and Çamlıdere Dam Lake. These lakes are confronted with the adverse effects of the agricultural fields, settlement, and human practices.

Thus, activities such as unregulated use of fertilizers seem to be the main source of high nitrogen levels in those water bodies. Similar results were obtained for nitrate levels, which ranged between 0.21 and 4.36 mg/L, except for the ones that were below the detection limit. The nitrite level was above 10 µg/L in Lake Ilgın, Porsuk Dam Lake, and Boğazköy Dam Lake and was 1560 µg/L in Sarıyar Dam Lake, which may indicate possible sewage discharge.

A combination of physicochemical parameters such as light, temperature, DO, and available nutrients, along with both inter- and intraspecies interactions such as competition and predation, may affect the community structure and seasonal dynamics of zooplankton (Sladecek, 1983; Radwan, 1984; Lougheed and Chow-Fraser, 2005). Since zooplankton is a good indicator of these changes (Snell and Janssen, 1995; Araujo et al., 2008), it has an important role in biomonitoring of the deteriorating effects of human practices. Thus, historical data sets along with physicochemical parameters are essential to understand the actual effects over time in water bodies.

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