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Seasonal Fluctuations in the Zooplankton Composition of a Eutrophic Lake: Lake Marmara (Manisa, Turkey)

Şükran YILDIZ[1], Ahmet ALTINDAĞ[2], Mehmet Borga ERGÖNÜL[2]

[1]Department of Biology, Faculty of Science and Arts, Celal Bayar University, Manisa - TURKEY

[2]Department of Biology, Faculty of Science, Ankara University, Tandoğan, Ankara - TURKEY

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Abstract: Seasonal fluctuations in the zooplankton fauna of Lake Marmara were studied between spring 2001 and winter 2002. In all, 41 species, consisting of 29 Rotifera (81.99%), 8 Cladocera (12.88%), and 4 Copepoda (5.13%), were recorded. The dominant species in the lake were *Keratella tecta* (Rotifera), *Bosmina longirostris* (Cladocera), and *Eucyclops serrulatus* (Copepoda). According to the $Q_{Brachionus/Trichocerca}$ index (6.08) used for the determination of trophic level, the lake was hypertrophic.

Key Words: Eutrophication, Lake Marmara, Rotifera, Turkey

Ötrofik Bir Göl Olan Marmara Gölü'nün (Manisa, Türkiye) Zooplankton Kompozisyonundaki Mevsimsel Değişimler

Özet: Marmara Gölü'nün zooplankton faunasındaki mevsimsel değişmeler 2001 Bahar ve 2002 Kış arasında incelendi. Toplam 41 zooplankton türü (29 Rotifera, % 81,99; 8 Cladocera, % 12,88; 4 Copepoda, % 5,13) tespit edildi. Göldeki dominant zooplankton türlerinin *Keratella tecta* (Rotifera), *Bosmina longirostris* (Cladocera) ve *Eucyclops serrulatus* (Copepoda) olduğu belirlendi. Trofik seviyenin belirlenmesinde kullanılan $Q_{Brachionus/Trichocerca}$ indeksine (6,08) göre, gölün hipertrofik olduğu tespit edildi.

Anahtar Sözcükler: Ötrofikasyon, Marmara Gölü, Rotifera, Türkiye

Introduction

The eutrophication process in shallow lakes can greatly change the community structure of aquatic organisms. Such change mainly starts with phytoplanktons, known as the first step in the food chain. It is known that eutrophication affects the specific composition of zooplankton through physical and chemical alterations of the environment (Tallberg et al., 1999), which may also change phytoplankton composition. Such changes may promote alterations in the quality and quantity of available food for the zooplankton population. The community structure of zooplanktons depends on the trophic status of the lake and individual species may reflect the level of eutrophication (Rogozin, 2000). In freshwater systems, total zooplankton abundance may increase with increasing eutrophication (Pace, 1986), and abundance and diversity of zooplanktons vary according to limnological features and trophic state (Jeppesen et al., 2002). Furthermore, Sendacz (1984) stated that the degree of eutrophication, particularly in temperate regions, is associated with the composition of the zooplankton community.

Lake Marmara has been the subject of many limnological surveys (Mann, 1940; Kiefer, 1952; Numann, 1958; Ustaoğlu, 1993). Previously, Ustaoğlu (1993) reported the lake's trophic status as eutrophic. He studied the zooplankton fauna of Lake Marmara between December 1984 and November 1985, from 10 different stations at monthly intervals. It is thought that the zooplankton structure of Lake Marmara has been changing since the 1990s. This study aimed to determine

*E-mail: altindag@science.ankara.edu.tr

the zooplankton structure of Lake Marmara, along with some physico-chemical parameters of the lake, and to compare the data to Ustaoğlu (1993).

Materials and Methods

Lake Marmara (lat 38º37'N, long 28º00'E) is an alluvial dam lake at an altitude of 75 m. Its maximum depth is 3.5 m and it covers an area of 45 km^2 (Ustaoğlu, 1993). It is fed by the Demirköprü Dam in the east and the Kum River to the northwest, and it regularly drains by means of a regulator in the south end into the Gediz River (Figure 1).

The zooplankton samples were collected with a standard plankton net (Hydrobios Kiel, 25 cm diameter and 55 µm mesh size) through vertical and horizontal hauls. Sampling was performed 4 times, in summer (July 2001), autumn (October 2001), winter (January 2002), and spring (April 2002), at 4 different stations (Figure 1). The samples were preserved in 4% formalin soon after collection. The samples were divided into sub-samples (1 cc) with a pipette and then were counted under a stereoscopic microscope, according to Botrell et al. (1976). Species were identified following Harding and Smith (1962), Dussart (1967), Kolisko (1974), Smirnov (1974), and Koste (1978).

Sladecek (1983) has suggested an index, Q, for the determination of the trophic level of a given lake. The Q index is calculated as the *Brachionus*:*Trichocerca* ratio ($Q_{B/T}$). He reported that if the ratio = 1, the lake is oligotrophic, if it is between 1 and 2, it is mesotrophic, and if it is > 2, the lake is eutrophic. This index was used for the present Lake Marmara study. Physico-chemical variables, such as depth, Secchi depth, temperature, salinity, electrical conductivity, turbidity, pH, and dissolved oxygen, were also measured. Of these, dissolved oxygen and temperature were measured with a YSI 51 B oxygen-meter, pH with a WTW 340-A/SET-1 pH-meter, electrical conductivity with a WTW LF 92 conductometer, and light permeability was measured with a Secchi disk 20 cm in diameter.

Results

In all, 41 species were found in the lake, including 29 Rotifera, 8 Cladocera, and 4 Copepoda (Appendix). Based on the number of species and biomass values (the number of individuals m^{-3}), rotifers were the dominant group in the lake (81.99%), followed by Cladocera (12.88%), and Copepoda (5.13%). The dominant Rotifera species was *Keratella* spp. (52.80%), followed by *Polyarthra* spp. (31.91%) and *Brachionus* spp. (7.22%). The dominant Cladocera species was *Bosmina longirostris* (62.02%), followed by *Daphnia* spp. (20.88%), *Diaphanosoma brachyurum* (11.75%), and *Moina branchiata* (4.39%). The dominant Copepoda species were cyclopoids

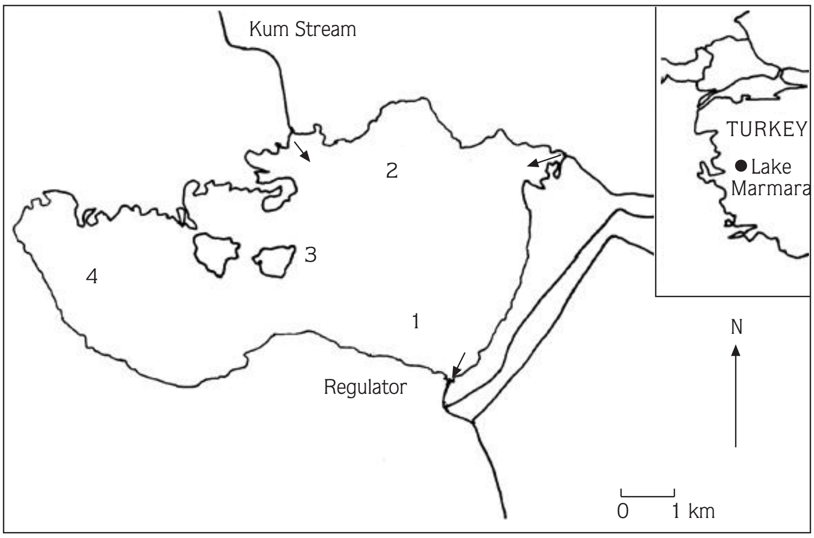

Figure 1. Lake Marmara and the 4 sampling stations used in this study. The arrows represent the outlets and inlets of the lake.

(83.26%), followed by calanoids (16.74%). Seasonal fluctuations in the zooplankton groups are shown in Figure 2. There was a marked decrease in total zooplankton biomass in summer and a sharp increase in autumn.

The $Q_{B/T}$ index for Lake Marmara was 6.8. The mean depth ranged between 1.1 and 5.9 m, and the average Secchi depth ranged between 25 and 518 cm. The mean depths for stations 1, 2, 3, and 4 were 1.5, 2.6, 4.7, 3.2 m, respectively. Seasonal fluctuations in the lake's physico-chemical variables are summarized in Table 1.

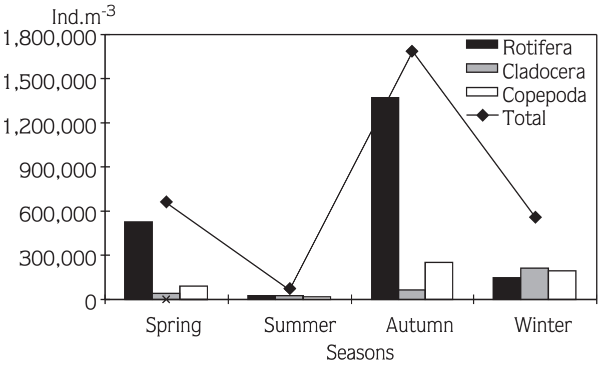

Figure 2. Seasonal distribution of zooplankton groups in Lake Marmara.

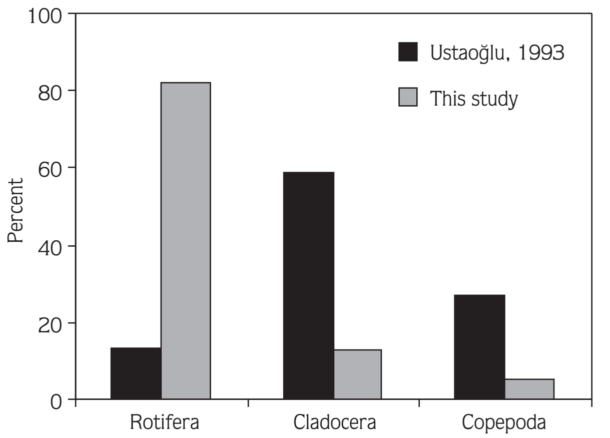

Figure 3. Comparison of zooplankton groups found by Ustaoğlu (1993) and the present study (percentages are given on the basis of total zooplankton biomass).

Discussion

Previously, Ustaoğlu (1993) reported the trophic status of Lake Marmara as eutrophic. The eutrophication process is associated with structural changes in the food web, and considerable alterations in fish, zooplankton, and macrophyte communities (Sas, 1989; Persson et al., 1991). The abundance and diversity of zooplanktons vary according to limnological features and the trophic state of freshwater bodies (Jeppesen et al., 2002), so that total zooplankton abundance may increase with increasing eutrophication. As shown in Figure 3 and Table 2, the data of the present study are quite different than Ustaoğlu's (1993) data. Our results clearly indicate a shift in the community structure of zooplanktons, which may be the result of the progression of eutrophication.

Rotifers are regarded as bioindicators of water quality (Sladecek, 1983; Saksena, 1987) and high rotifer density has been reported to be a characteristic of eutrophic lakes (Sendacz, 1984). The percentage of rotifers, which composed 13.31% of zooplankton between 1984 and 1985 (Ustaoğlu, 1993), has increased to 81.99%, demonstrating the progression of eutrophication. There is also a shift in the species composition of rotifers, which was represented by 18 species between 1984 and 1985, and numbered 29 species in this study (Table 2). Since

Table 1. Seasonal fluctuations in physico-chemical parameters.

Physico-chemical variables	Spring	Summer	Autumn	Winter	Mean values
Temperature (°C)	19.6	29.9	22.4	7.2	19.8
Salinity (‰)	14.1	18.5	17.9	9.8	15.0
Electrical conductivity (µs/cm)	477.5	611.4	650.1	852.4	647.9
Turbidity (mg/l)	310.5	381	453.8	337.5	370.7
pH	8.2	8.1	8.0	7.4	7.9
Dissolved oxygen (mg/l)	5.9	6.8	6.7	7.9	6.8

Table 2. Comparison of the dominant zooplankton species found by Ustaoğlu (1993) and the present study. Numbers of species indicate total number of species reported in each study.

	Rotifera	Cladocera	Copepoda
	18 species	10 species	4 species
Ustaoğlu (1993)	*Asplanchna priodonta* *Keratella quadrata* *Polyarthra major* *Testudinella patina* *Trichotria pocillum* *Hexarthra mira*	*Bosmina longirostris* *Daphnia longispina* *Daphnia magna* *Diaphanosoma brachyurum*	*Arctodiaptomus salinus* *Canthocamptus staphylinus* *Cyclops vicinus* *Eucyclops serrulatus*
	29 species	8 species	4 species
Present Study	*Polyarthra major* *Polyarthra vulgaris* *Keratella tecta* *Keratella tropica*	*Bosmina longirostris* *Chydorus sphaericus* *Daphnia longispina* *Daphnia magna* *Diaphanosoma brachyurum* *Moina branchiata*	*Acanthodiaptomus denticornis* *Arctodiaptomus salinus* *Eucyclops serrulatus* *Chanthocampus* sp.

rotifers are more sensitive to alterations in the quality of water (Gannon and Stremberger, 1978), they respond to environmental changes faster than cladocerans and copepods. The abundance of rotifers and their community characteristics are also used as effective indicators of environmental change, such as acidity, food level, and humidity (Attayde and Bozelli, 1998).

In the present study, such species as *Keratella quadrata, Mytilina ventralis*, *Monostyla quadridentata*, *Rotaria neptunia*, *Ceriodaphnia quadrangula*, *Scaphaloberis mucronata*, *Macrothrix laticornis*, and *Dunhevedia crossa*, which were reported by Ustaoğlu (1993), were not found. On the other hand, some species observed in this study (*Daphnia pulex* and *Moina branchiata*) were not found by Ustaoğlu (1993), although *M. branchiata* was reported by Mann (1940).

It is reported that calanoid copepods best adapt to oligotrophic lakes, and cyclopoid copepods best adapt to eutrophic lakes (Gannon and Stremberger, 1978). In addition to the high density of rotifers, a high density of cyclopoid copepods (83.26% of Copepoda) in the lake provides additional evidence of the progression of eutrophication. The dominant species of Cladocera was *B. longirostris* (62.02%, in cladocerans), which is also reported as an indicator of eutrophic lakes (Ryding and Rast, 1989).

According to the $Q_{B/T}$ index suggested by Sladecek (1983), the ratio for Lake Marmara was 6.08, which shows that the lake is hypertrophic. According to OECD's level of classification (Ryding and Rast, 1989), lakes with a mean Secchi depth < 1.5, 1.5-3.0, 3.0-6.0, and > 6.0 m are classified as hypertrophic, eutrophic, mesotrophic, and oligotrophic, respectively. The average Secchi depth in Lake Marmara was 1.53 m, which is in the eutrophic range.

Temperature and oxygen concentration are the key factors in restricting zooplankton occurrence. The water temperature of Lake Marmara varied between 7.2 and 29.9 °C, and dissolved oxygen concentration ranged between 5.9 and 7.9 mg/l. Physiological and population parameters are influenced by temperature, and the population development of rotifers is limited by the combined effect of oxygen concentration and temperature (Mikschi, 1989). pH is related to many other variables in freshwaters that are correlated with zooplankton distribution and it is known that rotifers exhibit a very wide range of pH and turbidity tolerance (Berzins and Pejler, 1987). Total dissolved salt and electrical conductivity (EC) are important factors affecting zooplankton distribution. The salinity and EC values in Lake Marmara ranged between 9.8% and 18.5% and 477.5 and 852.5 µs/cm, respectively.

In conclusion, the present data, compared to those reported by Ustaoğlu (1993), which were collected between 1984 and 1985, show that the species composition has changed. This may indicate that eutrophication in Lake Marmara has progressed towards a hypertrophic state within 12-13 years. In addition to the zooplankton density dominated by rotifers, the Secchi depth and $Q_{B/T}$ index provide evidence of the trophic status of the lake.

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Appendix

Rotifera

Anureopsis fissa Gosse, 1851
Ascomorpha ecaudis (Perty, 1850)
Asplanchna priodonta Gosse, 1850
Brachionus angularis (Gosse, 1851)
Brachionus urceolaris (O.F.Müller, 1773)
Brachionus calyciflorus Pallas, 1766
Brachionus quadridentatus Hermann, 1783
Euchlanis dilatata Ehrenberg, 1832
Conochilus unicornis Rousselet, 1892
Filinia limnetica (Zacharias, 1893)
Filinia longiseta (Ehrenberg, 1834)
Gastropus stylifer Imhof, 1891
Hexarthra mira (Hudson, 1871)
Keratella cochlearis (Gosse, 1851)
Keratella tecta (Gosse, 1851)
Keratella tropica (Apstein, 1907)
Lecane luna (O.F.Müller, 1776)
Lepadella ovalis (O.F.Müller, 1786)
Notholca squamula (O.F.Müller, 1786)
Philodina megalotrocha Ehrenberg, 1832
Pompholyx sulcata (Hudson, 1885)
Polyarthra vulgaris Carlin, 1943
Polyarthra major Burckhardt, 1900
Platiyas quadricornis (Ehrenberg, 1832)
Synchaeta pectinata Ehrenberg, 1832
Trichocerca stylata (Gosse, 1851)
Trichocerca elongata (Gosse, 1886)
Trichotria tecractis (Ehrenberg, 1830)
Testudinella patina (Hermann, 1783)

Cladocera

Alona guttata Sars, 1862
Chydorus sphaericus (O.F.Müller, 1776)
Daphnia longispina O.F.Müller, 1785
Daphnia pulex Leydig, 1860
Daphnia magna (Straus, 1820)
Diaphanosoma brachyurum (Lievin, 1848)
Bosmina longirostris (O.F.Müller, 1785)
Moina branchiata (Jurine, 1820)

Copepoda

Acanthodiaptomus denticornis (Wierzejski, 1887)
Arctodiaptomus salinus (Daday, 1885)
Eucyclops serrulatus (Fischer, 1853)
Canthocamptus sp. Westwood, 1836