The zooplankton composition of Lake Ladik (Samsun, Turkey)

Meral APAYDIN YAĞCI1,*, Savaş YILMAZ2, Okan YAZICIOĞLU3, Nazmi POLAT2
1Fisheries Research Station, Eğirdir, Isparta, Turkey
2Department of Biology, Faculty of Arts and Sciences, Ondokuz Mayıs University, Kurupelit, Samsun, Turkey
3Organic Farming Program, Botanic and Animal Production Department, Technical Vocational Schools of Higher Education, Ahi Evran University, Kırşehir, Turkey

Abstract: The zooplankton composition of Lake Ladik, located in Samsun Province in northern Turkey, was investigated monthly between November 2009 and October 2010. Some physicochemical parameters such as temperature of surface water, pH, dissolved oxygen, salinity, conductivity, and total dissolved solids were also evaluated. A total of 29 zooplankton species were identified. These species were represented by three main groups: Rotifera (59%), Cladocera (24%), and Copepoda (17%). The maximum and minimum numbers of species were found in July and October, respectively. Bosmina longirostris, Keratella quadrata, Asplanchna priodonta, Cyclops abyssorum, Polyarthra dolichoptera, Brachionus calyciflorus, Keratella cochlearis, Brachionus angularis, and Chydorus sphaericus were the dominant species of the lake. According to the Brachionus:Trichocerca quotient (QB/T), the trophic level of the lake is eutrophic.

Key words: Lake Ladik, Cladocera, Copepoda, Rotifera, zooplankton, eutrophic, Turkey

1. Introduction
Zooplankton plays an important role in aquatic ecosystems (Baloch et al., 2005). Zooplankton species have been used as an indicator of the trophic states of lakes (El-Bassat and Taylor, 2007; Ahangar et al., 2012) because of their sensitivity to any ecological change in water bodies (Güher et al., 2011). Additionally, Saksena (1987) reported that zooplankton should be considered as an indicator of water quality. Baloch and Suzuki (2009) concluded that Cladocera and Rotifera dominate eutrophic lakes, whereas Copepoda dominates oligotrophic lakes.

Many studies on zooplankton communities of inland water bodies have been carried out in Turkey (e.g., Gündüz 1991a, 1991b; Emir Akbulut, 2000; Yiğit and Altındağ, 2005; Bekleyen and Taş, 2008; Özdemir Mis and Ustaoğlu, 2009; Güle et al., 2010; Saler, 2011; Bozkurt and Akın, 2012a; Ustaoğlu et al., 2012a; Gündüz et al., 2013; Apaydın Yaşcı, 2013).

The phytoplankton of Lake Ladik was investigated by Maraşlıoğlu et al. (2005). The zooplankton species of Lake Ladik were investigated by Bulut and Saler (2013). However, the annual zooplankton composition and species indices of this lake have not been studied before. The aim of this work was to determine the recent zooplankton composition and its annual variations, and to describe the trophic level of the lake.

* Correspondence: meralyagci@gmail.com

Received: 31.12.2013 • Accepted/Published Online: 16.12.2014 • Printed: 30.07.2015

2. Materials and methods
The study area (40°50′N to 41°00′N, 35°40′E to 36°05′E) is located within the borders of the Ladik district of Samsun Province in the central Black Sea region of Turkey. The lake has an elevation of 867 m a.s.l. and a depth of 2.5–6.0 m, and it is approximately 5 km long and 2 km wide. Lake Ladik has a drainage area of 141.40 km². The lake is fed by small streams coming from Akdağ Mountain. Tersakan Stream, an outlet stream helping to control the water levels of the lake, runs into the Yeşilirmak River (Ügurlu et al., 2009). It has been classified as a eutrophic lake (Maraşlıoğlu, 2001) and is a natural protected area due to its floating islands (Bulut, 2012).

Zooplankton and water samplings were carried out monthly between November 2009 and October 2010 at 3 stations in Lake Ladik (Figure 1). The average depth was ~2 m at Station 1 and Station 3, and 4 m at Station 2. Zooplankton samples were collected horizontally using a plankton net having a mesh size of 55 µm (diameter = 57 cm), and they were fixed with lugol solution immediately after collection in 250-mL dark bottles. Species were examined under a binocular microscope and the species were identified to the species level using the keys of Kiefer (1952, 1955), Dussart (1967, 1969), Koste (1978), Negrea (1983), Smirnov (1996), and Nogrady and Segers (2002). A zooplankton species checklist was prepared.
Physicochemical parameters such as conductivity, total dissolved solids (TDS), pH, salinity, dissolved oxygen, and water temperature were measured from surface water using a portable Hach Lange model HQ40d. Data were tested for normality using the Shapiro–Wilk test, which rejects the normal distribution hypothesis with small P-values (<0.05). Because data were not normally distributed, logarithmic transformation (log [n + 1]) was applied to the data for cluster analysis (Koçer and Şen, 2014). Using squared Euclidean distances as a measure of similarity, hierarchical agglomerative cluster analysis was performed on the transformed data set by means of Ward’s method. The linkage distance is reported as $D_{\text{link}} / D_{\text{max}}$, which represents the quotient between the linkage distance for a particular case divided by the maximal distance, multiplied by 100 as a way to standardize the linkage distance represented on the y-axis (Simeonov et al., 2003; Sinha et al., 2009). Statistical analysis was performed using JMP 7 (SAS Institute Inc.) and STATISTICA 8 (StatSoft Inc.). Soyer’s (1970) frequency index (F %) was used to define the frequency of species in the research area and results were estimated as constant (F ≥ 50%), common (50% > F ≥ 25%), or rare (F < 25%). This index (F) for special species was evaluated using $F = m / M \times 100$, where m is the number of stations for the species and M is the number of all stations.

The Brachionus:Trichocerca quotient ($Q_{\text{BT}}$) was calculated to assess the trophic structure of the lake. Sládeček (1983) reported that a quotient of 1 indicates oligotrophic conditions, while a quotient between 1 and 2 corresponds to mesotrophic conditions and a ratio of >2 is encountered in eutrophic lakes.

### 3. Results

The monthly values of some physicochemical parameters from Lake Ladik between November 2009 and October 2010 are given in Figure 2. The water temperature varied between 3.8 °C (January) and 25.2 °C (July). Values of pH ranged from 8.00 in November to 9.06 in February. The dissolved-oxygen concentration changed from 7.12 mg/L in May to 12.15 mg/L in February. The minimum and maximum salinity was measured as 0.09‰ and 0.14‰, respectively. The highest conductivity value was 300.00 µs/cm in June, while the lowest value was 227.43 µs/cm in September. The TDS values were noted between 96.30 and 147.40 mg/L.

A total of 29 zooplankton species belonging to Rotifera, Cladocera, and Copepoda were identified in Lake Ladik (Table). The most dominant group was Rotifera (59%), followed by Cladocera (24%) and Copepoda (17%). The distribution of zooplankton groups by station is presented in Figure 3. *Cyclops abyssorum*, *Bosmina longirostris*, *Polyarthra dolichoptera*, *Asplanchna priodonta*, and *Keratella quadrata* were observed in all months. The highest number of zooplankton taxa (19) occurred at Station 3 in July. The zooplankton diversity was substantially reduced at Station 2 in October. Cluster analysis of species abundances at the 3 stations revealed temporal heterogeneity, and it resulted in a dendrogram (Figure 4) grouping the sampling stations into 4 main
Priodonta was followed by the Rotifera (91.18%), A. K. quadrata and this species was found most frequently in all months. Determined to have the highest frequency value (94.12%), B. longirostris common (50% > F ≥ 25%), and 11 species were classified marked temporal variation, cluster analysis also showed no clear spatial variation of species abundance despite a data between August and October. Although there was while Cluster 4 consisted of late summer and early autumn data from all 3 sampling stations, while Cluster 2 included Cluster 1 consisted exclusively of November and May data between December and March. Of 29 species identified in Lake Ladik, 17 taxa belonged to Rotifera, and the family Brachionidae had the highest number of species. The genus Brachionus was represented by 5 species including B. angularis, B. quadridentatus, B. urceolaris, B. diversicornis, and B. calyciflorus. Seven species of Cladocera were observed during the study. The majority of these species were members of the family Daphniidae. Five copepods were determined, most of them belonging to the family Cyclopoidae (Table). In this study, a total of 13 species were the same as reported by Bulut and Saler (2013): from the rotifers, B. angularis, B. urceolaris, K. coehlearis, K. quadrata, Synchaeta pectinata, P. dolichoptera, A. priodonta, and Hexarthra mira; from the cladocerans, B. longirostris and C. sphaericus; and from the copepods, Eudiaptomus gracilis, Cyclops vicinus, and Nitokra hibernica. However, 9 species determined by Bulut and Saler (2013) were not found in this study. B. calyciflorus, B. diversicornis, B. quadridentatus, Notholca acuminata, Ascomorpha saltants, Asplanchna girodi, Filinia terminalis, and Trichocerca similis from Rotifera; Daphnia cucullata, Ceriodaphnia quadrangula, Simocephalus vetulus, Moina brachiata, and Coronatella rectangula from Cladocera; and C. abyssorum and Thermocyclops crassus from Copepoda are new records for Lake Ladik.

4. Discussion

Of 29 species identified in Lake Ladik, 17 taxa belonged to Rotifera, and the family Brachionidae had the highest number of species. The genus Brachionus was represented by 5 species including B. angularis, B. quadridentatus, B. urceolaris, B. diversicornis, and B. calyciflorus. Seven species of Cladocera were observed during the study. The majority of these species were members of the family Daphniidae. Five copepods were determined, most of them belonging to the family Cyclopoidae (Table). In this study, a total of 13 species were the same as reported by Bulut and Saler (2013): from the rotifers, B. angularis, B. urceolaris, K. coehlearis, K. quadrata, Synchaeta pectinata, P. dolichoptera, A. priodonta, and Hexarthra mira; from the cladocerans, B. longirostris and C. sphaericus; and from the copepods, Eudiaptomus gracilis, Cyclops vicinus, and Nitokra hibernica. However, 9 species determined by Bulut and Saler (2013) were not found in this study. B. calyciflorus, B. diversicornis, B. quadridentatus, Notholca acuminata, Ascomorpha saltants, Asplanchna girodi, Filinia terminalis, and Trichocerca similis from Rotifera; Daphnia cucullata, Ceriodaphnia quadrangula, Simocephalus vetulus, Moina brachiata, and Coronatella rectangula from Cladocera; and C. abyssorum and Thermocyclops crassus from Copepoda are new records for Lake Ladik.
Table. Distribution of zooplankton species found in Lake Ladik according to month and station.

<table>
<thead>
<tr>
<th>Station/Species</th>
<th>2009</th>
<th>2010</th>
<th>% f</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov</td>
<td>Dec</td>
<td>Jan</td>
</tr>
<tr>
<td><strong>ROTHIFERA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachionus angularis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Brachionus calyciflorus</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brachionus urceolaris</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brachionus quadridentatus</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Keratella cochlearis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Keratella quadrata</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Keratella sp.</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Notholca acuminata</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Trichocerca similis</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ascomorpha saltants</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Synchaeta pectinata</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Polyaerthra dolichoptera</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Asplanchna girodi</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Asplanchna priodonta</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hexarthra mira</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Filinia terminalis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>CLADOCERA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daphnia cucullata</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Simocereus vetulus</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ceriodaphnia quadrangula</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Moina brachiata</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bosmina longirostris</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Chydorus sphaericus</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Coronatella rectangula</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>COPEPODA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eudiaptomus gracilis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cyclops abyssorum</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cyclops vicinus</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thermocyclops ornatus</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitokra hibernica</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Zooplankton samples could not be taken at the 2nd and 3rd stations in September.
Figure 3. Distribution of zooplankton groups in Lake Ladik during the research period.

Figure 4. Cluster analysis results of zooplankton for stations in Lake Ladik.
Rotifera was the dominant group in the lakes and some lagoons of past studies (Emir, 1990; Bekleyn and Taş, 2008; Bozkurt and Akin, 2012a; Ustaoğlu et al., 2012a; Gündüz et al., 2013). Gündüz et al. (2013) reported similar observations from Lake Karabogaz in the Kızılirmak Delta.

The number of zooplankton species of Lake Ladik is very low when compared to other inland bodies of water: e.g., Lake Černek, 31 species (Bekleyn and Taş, 2008); Karaman Stream, 37 species (Altndağ et al., 2009); Lake Gölcük, 33 species (Özdemir Mis and Ustaoğlu, 2009); Hasan Uğurlu and Suat Uğurlu Dam Lakes, 42 species (Bozkurt and Akin, 2012a); Lake Karaboğaz, 63 species (Gündüz et al., 2013); and Lake Karataş, 42 species (Apaydın Y ağcı, 2013). These studies showed that the number of zooplankton species varied among the natural and dam lakes and rivers. These variations were due to the trophic status of the water, ecological structures of the aquatic systems (Bozkurt and Akin, 2012a), water, and hot climate zones. For example, Gündüz et al. (2013) declared that the number of species also changed at stations with different salinity levels.

Maraslioglu et al. (2005) stated that Lake Ladik is moderately eutrophic in terms of phytoplankton. In the present work, the Q_{B/T} ratio was calculated to be 5.0, and this result showed that the lake is at a eutrophic level. Additionally, zooplankton species (e.g., B. calyciflorus, B. angularis, K. quadrata, K. cochlearis, B. longirostris, C. vicinus, and T. crassus) that are indicators of eutrophic conditions were also found. The presence of B. calyciflorus clearly indicates increased organic matter in this water body. Moreover, Altndağ et al. (2009) reported that cyclopoid Copepoda and Cladocera species dominated in eutrophic waters. Gutiérrez-Aguirre and Suárez-Morales (2000) associated Thermocyclops crassus with eutrophic waters. Duchovnay et al. (1992) associated this species with meso- or eutrophic environments. Imoobe and Adeyinka (2009) determined that Brachionus and Keratella were indicators of eutrophication. The dominance of Rotifera in eutrophic systems (e.g., K. cochlearis, K. quadrata, and B. angularis) has been documented by several authors (Baiao and Boavida, 2005; Baloch et al., 2005; Geng et al., 2005). In this study, 12 zooplankton species were determined, which were mostly indicators of mesotrophic-eutrophic water (Table).

E. gracilis, the most widely distributed calanoid copepod species in Europe, has been determined in higher numbers in eutrophic lakes (Bozkurt and Akin, 2012a). Bozkurt and Akin (2012b) reported the first record of E. gracilis from the Yeşilrmak River and Hasan Uğurlu and Suat Uğurlu Dam Lakes in the Black Sea region of Turkey. They stated that E. gracilis was determined at pH 6.95–8.84. In this research, E. gracilis was observed at pH 8.00–9.06, which is consistent with the pH levels in other studies.

Walkusz et al. (2009) reported that cluster analysis revealed some differences among seasons in terms of zooplankton composition and abundance. Altndağ et al. (2009) performed cluster analysis to determine the similarity level of zooplankton composition among 4 stations in Karaman Stream; they observed the highest similarity between Stations 1 and 4 at 68%. In this study, the cluster analyses revealed some differences between summer/autumn and winter/spring in terms of zooplankton composition and abundances. Such differences may be associated with water temperatures (Figure 2). In addition, the zooplankton species P. dolichoptera, A. priodonta, D. cucullata, B. longirostris, C. sphaericus, and C. abyssorum were similar with regard to their abundances between May and November at Stations 1, 2, and 3. Stations and months have similarities in zooplankton species composition. Cluster analysis showed that the growth pattern of zooplanktonic species in Lake Ladik was similar in summer and autumn months, as suggested by Walkusz et al. (2009).

In Lake Ladik, the maximum numbers of zooplankton species were obtained in June and July, while the minimum was seen in March. Hammer (1986) reported that T. crassus was found in marginally saline to fresh water. Despite the low density of T. crassus during the study period, it was common in June and July. Bërzińs and Pejler (1989) reported that B. calyciflorus was related with temperature; this species was determined at temperatures above 20 °C. B. calyciflorus is a species that is tolerant to dissolved oxygen and pH levels of 7–9 (Güher et al., 2011); the species can also be found throughout the year in this lake. Myers (1931) reported that Brachionus, Asplanchna, and Filinia are present in alkaline water conditions. B. angularis and B. calyciflorus are recorded as species preferring alkaline waters (Sládeček, 1983; Sukumaran and Das, 2004). According to the pH values, this lake is alkaline. The alkalinity of Lake Ladik was found to be within the limit values for freshwater biota. P. dolichoptera is found in aquatic systems with rich dissolved-oxygen concentrations (Baiao and Boavida, 2005). In this study, the dissolved-oxygen value was highest in February. Bozkurt and Akin (2012a) reported that Notholca squamula was found in fresh water and saltwater. Consequently, this work will be useful as a reference for subsequent studies in Lake Ladik and contributes to the known zooplankton biodiversity of inland waters in Turkey.

Acknowledgment

We would like to thank Dr MA Turan Koçer for his helpful suggestions and statistical approaches.
References


Marasgçoğlu F (2001). An investigation on phytoplankton and algae of coast of Lake Ladik (Ladik-Samsun-Turkey). MSc, Ondokuz Mayıs University, Samsun, Turkey.


