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Trophic State Assessment of Brackish Bafa Lake (Turkey) Based on Community Structure of Zooplankton

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ABSTRACT

Zooplankton abundance and composition are one of the most important factors which affect the food web in aquatic ecosystems. The purpose of this study was to determine the water quality of Bafa Lake in Turkey, based on zooplankton communities. As the study case, Bafa Lake is one of the biggest lake in Turkey, and the lake is quite rich in terms of biodiversity. Bafa Lake is the under effects of domestic, agricultural and industrial wastes that accumulate and cause the deterioration of ecology in the lake by Büyük Menderes River. With this purpose, 8 sampling sites were determined and zooplankton samples were collected monthly for two years. TSI_{NRot} index and various versions of diversity indices were used to determine the water quality and ecological status of Bafa Lake. To determine similarities between the stations, the stations were clustered by using UPGMA based on zooplankton fauna. By applying Pearson Correlation, correlations between the indices based on zooplankton fauna were assessed. With the identification of collected zooplankton, a total of 73 taxa which belong to groups of Rotifera, Cladocera, Copepoda, and Meroplankton were detected. As a result of similarity analysis, most similarity values were obtained between stations 1, 2 and 8, respectively. According to TSI_{NRot} index, Bafa Lake has got a *eutrophic* ecological state while according to all versions of diversity indices, Bafa Lake has got the *α-β mesosaprobic* ecological state.

Keywords: Bafa Lake, Zooplankton, Water Quality, Trophic State Index, Diversity Indices

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Acı Su Özelliğindeki Bafa Gölü'nün Zooplankton Topluluk Yapısına Göre Trofik Durumunun Belirlenmesi

Öz: Zooplankton miktarı ve dağılımı sucul ekosistemlerde besin ağını etkileyen en önemli faktörlerden biridir. Bu çalışmanın amacı, Türkiye'deki Bafa Gölü'nün su kalitesini zooplankton topluluklarını baz alarak belirlemektir. Çalışma alanı olarak Bafa Gölü, Türkiye'nin en büyük göllerinden biri olmakla birlikte göl biyolojik çeşitlilik açısından oldukça zengindir. Bafa Gölü, Büyük Menderes Nehri tarafından taşınarak gölde ekolojinin bozulmasına neden olan evsel, tarımsal ve endüstriyel atıkların etkisi altındadır. Bu amaçla 8 örnekleme alanı belirlenmiş ve zooplankton örnekleri iki yıl boyunca aylık olarak toplanmıştır. Bafa Gölü'nün su kalitesini ve ekolojik durumunu belirlemek için TSI_{NRot} indeksi ve çeşitlilik indekslerinin çeşitli versiyonları kullanılmıştır. İstasyonlar arasındaki benzerlikleri belirlemek için, istasyonlar zooplankton faunası temelli UPGMA kullanılarak kümelendirilmiştir. Pearson Korelasyonu uygulanarak, zooplankton faunasına dayalı indeksler arasındaki korelasyonlar değerlendirilmiştir. Toplanan zooplanktonik organizmaların tanımlanmasıyla Rotifera, Cladocera, Copepoda ve Meroplankton gruplarına ait toplam 73 takson tespit edilmiştir. Benzerlik analizi sonucunda, en yüksek benzerlik değerleri sırasıyla 1., 2. ve 8. istasyonları arasında elde edilmiştir. TSI_{NRot} indeksine göre, Bafa Gölü *ötrofik* ekolojik duruma sahipken, çeşitlilik indekslerinin tüm versiyonlarına göre, Bafa Gölü *α-β mezosaprobik* ekolojik duruma sahiptir.

Anahtar kelimeler: Bafa Gölü, Zooplankton, Su Kalitesi, Trofik Durum İndeksi, Çeşitlilik İndeksleri

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Introduction

Increasing pollution pressure and the diversity of pollution factors cause a rapid decline in surface water quality all around the world. With the increasing human needs, the distorted distribution of the population around the world has been the main

driver of deterioration in the quality of existing water bodies. The cumulative effect of all these factors is more severe in freshwater ecosystems. Therefore, the demand for biomonitoring research based on biometric approach has been increasing in recent years. At this point, the Water Framework Directive (WFD) is a very important legal regulation in terms of determining the quality of water resources and developing methodology. According to WFD, European Union (EU) countries classified the ecological status of surface waters based on benthic macroinvertebrates, fish, macrophytes, and phytoplankton. Although zooplankton fauna do not include as a biological quality element, it is an important element of the aquatic food web (Ejsmont-Karabin 2012; Davidson et al. 2011; Jeppesen et al. 2011; Caroni and Irvine 2010).

In aquatic ecosystems, defining the factors that detect zooplankton abundance and composition, provides information about plankton dynamics, and increase effective water management and biodiversity conservation (Zhao et al. 2017). On the other hand, according to Lampert and Sommer (2001), the changes in primary production, eutrophication, and abundance of the planktivorous fish community affect the zooplankton composition. Zooplankton diversity, biomass, and density are the most important ecological parameters to determine phytoplankton and fish relationship. Climatic conditions, vegetation cover, and physical-chemical parameters have an important influence on zooplankton distribution (Sharmila-Sree and Shameem 2017).

In terms of ecological diversity, Bafa Lake has 237 genera, 325 species, 22 subspecies, and 7 varieties belonging to 80 families and also 16 endemic species. At the same time, Bafa Lake includes breeding and nursery area on the coast and islands for about approximately 300.000 birds, 20 fish species. In the Bafa Lake basin, agricultural, industrial and domestic wastes cause the pollution pressure on the lake. However, the Büyük Menderes River causes another big pollution pressure on the lake which transports all the pollutants along the riverbed. Many researchers such as Mermer (1989), Balık and Ustaoğlu (1989), Balık et al. (1992) and Balık (1995), Sarı et al. (1999) reported that increased salinity levels caused the decreased water quality, and extinct a few endemic species such as *Acanthobrama mirabilis, Cyprinus carpio, Chondrostoma nasus*, *Barbus capito pectoralis*, *Silurus glanis* in the Bafa Lake.

In this research, we've determined the water quality of Bafa Lake using the zooplankton fauna data set. For this reason, the Rotifer-based Trophic State Index (TSI_{NRot}) and diversity indices were used to assess the ecological status of Bafa Lake. Moreover, to determine similarities between the stations and differences between the TSI_{NRot} and diversity indices, Pearson correlation and Unweighted Pair Group Method with Arithmetic Mean (*UPGMA*) clustering were used.

Materials and Methods

Study Area

Bafa Lake is a shallow freshwater lake in the southeastern part of the Büyük Menderes River delta, inside the Menteşe Mountains. Bafa Lake is the third largest (65 km^2) lake located in the west of Turkey, characterized by a high trophy (Figure 1). Bafa Lake is 2 meters high from the sea and the deepest part is 21 meters. The lake long axis is 16 km and the widest part of the lake is 6 km. The Büyük Menderes River and groundwaters are the main water sources of Bafa Lake. It is located in the provincial territory of Aydin and Mugla. The lake, which was a part of the Aegean Sea in ancient times, remained inside the coast for miles along with the alluviums carried by Büyük Menderes. Today it is approximately 17 km from the area where the Büyük Menderes River flows into the Aegean Sea. Büyük Menderes used to float in the Gulf of Latmos. The historical city of Herakleia or Herakleia Latmos, which today has ruins on the shore of the lake, was also located on the east coast of this gulf. With the accumulation of alluviums carried by the river, the Gulf of Latmos first became a salt lake. As the level rises with excess water collected behind the natural embankment, it expanded its area by covering the shallow Çerçen Bay in the north. It poured its excess water into the Büyük Menderes River with western-end vetch and slowly turned into a freshwater lake. The shores of the lake are jagged like the shores of the Aegean Sea. There are many small islands in Bafa Lake, which is a natural embankment lake. There are well-maintained olive trees on the shore of the lake.

Zooplankton samples were collected from 8 different stations on monthly periods for two years. The study was carried out between July 2015 and June 2017, over the two years. Stations were determined based on the hatchery facilities around the lake, settlements, and the points where the Büyük Menderes River flows into the lake.

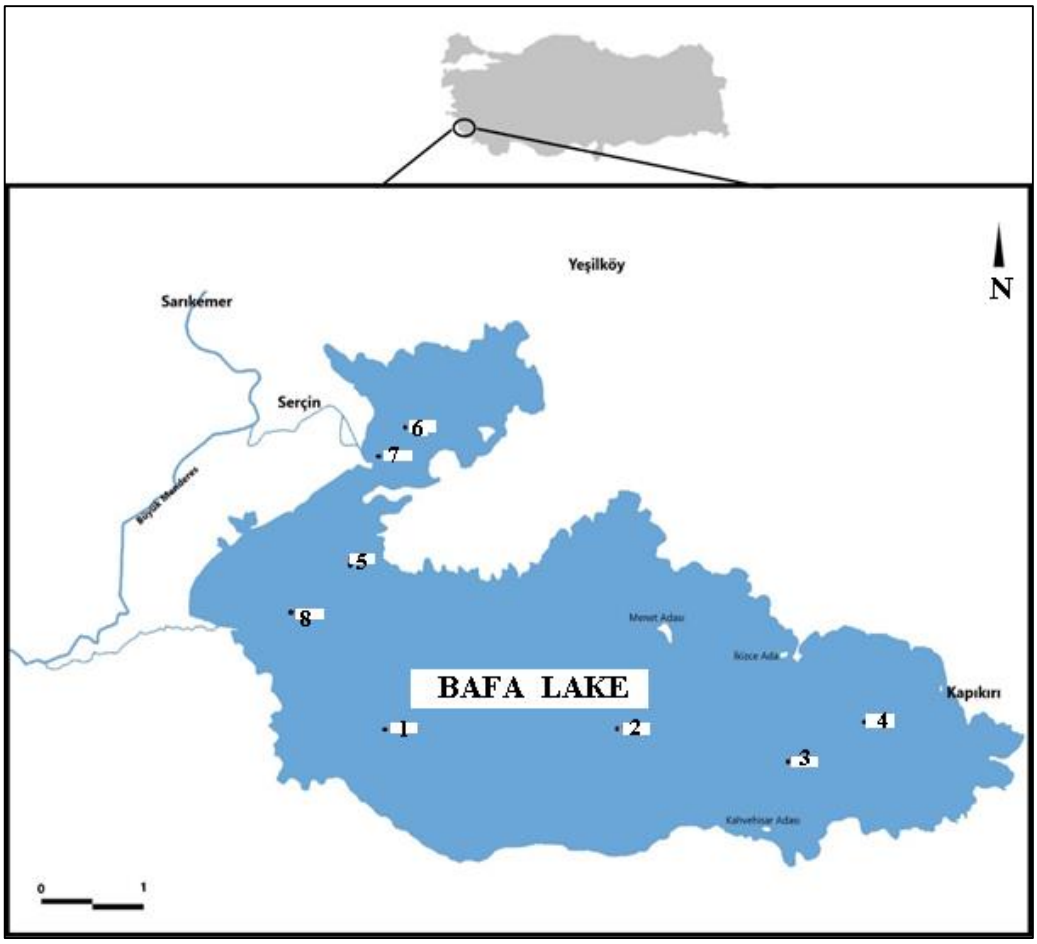

Figure 1. Distribution of stations in Bafa Lake.

Sample Collection

Zooplankton samples were collected every month from 8 sampling sites selected on Bafa Lake between July 2015 and June 2017. Hensen-type plankton net with 110 µm mesh size was used for zooplankton sampling. Due to the depth of the sampling stations were different, three repetitions were taken for each station with vertical shooting from different depths. Repeated samples taken from the same station were fixed with a 4-5% formaldehyde solution in different sample containers and 0.5 mL of 1% Lugol solution was added to facilitate the counting of transparent samples (Wetzel and Likens 2000). Qualitative and quantitative analyses of zooplankton were carried out with Stereo and binocular microscopes and other auxiliary materials. Zooplankton species were identified according to Edmondson (1959a, 1959b), Kolisko (1974), Koste (1978a, 1978b), Harding, and Smith (1974), Needham and Needham (1966). Samples preserved in 50 mL conical bottom Falcon tubes were partially diluted or condensed based on the estimated sample density. Counts with 1 mL volume of Sedgewick-Rafter counting cells were performed with counts having an organism density of at least 100 organisms. Copepods and Cladoceras were counted at x4, rotifers were counted at x10 magnification. The abundance (density) value of the count results is calculated as individual/L, but the results are expressed as individual/m^3 to give the decimal parts as integers.

Analytical Procedures

In this study, various versions of diversity indices and the trophic biotic index were used to determine species diversity and water quality ratio. The Shannon Weaver Diversity Index (*SWDI*), Margalef Diversity Index (*MDI*), Simpson's Diversity Index (*SDI*), Menhinick Diversity Index, and Evenness E1 indices were applied by using PAST3 software program. Pielou J diversity index and TSI_{NRot} were applied by using Excel 2019 (Microsoft Office^R).

SWDI is one of the most commonly used method to determine diversity. This index reflects the mathematical measure of species diversity in a community. In this index,''H''' is the value of the index. ''n'', the total number of taxa in the community. ''Pi'', the proportion of individuals in the i^{th} taxa in the community.

$$\boldsymbol{H' = \sum_{n=1}^{n} (pi)(lnpi)}$$

SDI is a system created by giving high values to taxa, which are predominantly found in freshwater

systems other than rare taxa. The most commonly found taxa have a high value. ''*ni*'' is the dominance of i^{th} taxon. ''*N*'' is the dominance value of all taxon (Ghosh and Biswas 2005).

$$D = \sum (pi)^2 = \sum \frac{ni}{N}$$

In MDI, the data consist of two matrices that specify absolute numbers (Gamito, 2010). In this index, "*S*" is the number of species while''*n*'' is the total number of individuals observed in the community (Margalef 1958).

$$d = \frac{S-1}{\ln N}$$

In Pielou J index,"*H*" value is the SWDI index value while "*Hmax*" stands for log_2^S."*S*" value is the total number of species.

$$J = H/\log(S)$$

TSI_{NRot} biotic index was created by the modified Trophic State Index (*TSI*). TSI_{SD}, TSI_{TP} and Carlson's *TSI* except for TSI_{NRot} (Ejsmont-Karabin 2012).

$$TSI\ rot = 5{,}38.\ln(Nrot) + 19{,}28$$

In this research, the faunal similarity between the sites was assessed by using the Sorensen similarity index (Krebs 1989) while correlation analysis between the diversity indices and TSI_{NRot} index was applied by using the SPSS version 11.5.

Results

In this investigation, as a result of diagnosed organisms from the eight stations, a total of 73 taxa were determined in Bafa Lake. In this research, 49 taxa belong to Rotifera, 7 taxa which belong to Cladocera, 12 taxa which belong to Copepoda, and finally 5 taxa which belong to Meroplankton were determined in Bafa Lake.

Rotifera was the most dominant group between the other zooplanktonic groups. As a result of the determination of zooplanktonic groups, the maximum numbers of individuals were collected at 6th station while the minimum numbers of individuals were collected at 8th station. As a result of the morphologic diagnosis, *Hexarthra oxyura*, Copepodit and Nauplius larvae were dominant on station #1, #2, #3, #4 and #8. *Lecane clostrocerca*, *Synchaeta balticaa*, and Nauplius larvae were dominant on station #5. *Brachionus angularis*, *Polyarthra vulgaris*, and Nauplius larvae were dominant on station #6. *Brachionus plicatilis*, *Brachionus quadridentatus* and Nauplius larvae were dominant on station #7. As a result of the analysis, it was determined that Nauplius larvae was at least one of the dominant taxon at all stations (Figure 2).

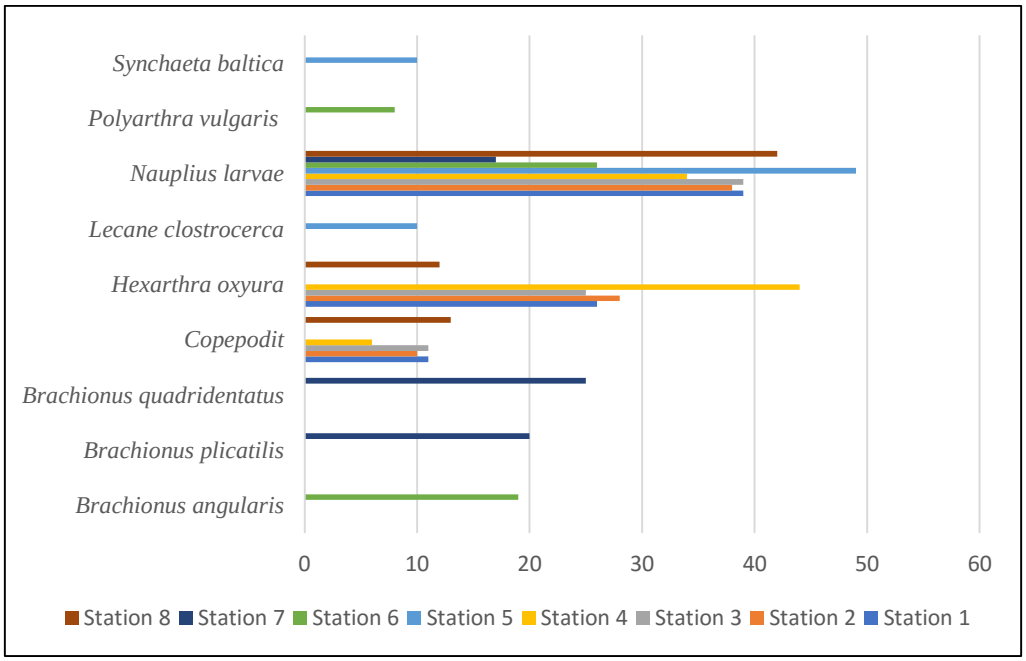

Figure 2. Zooplankton dominancy (%) in all stations of Bafa Lake

Relative occurrence (%) and distributions of the assessed zooplanktons in Bafa Lake are given in Table 1. On the other hand, the percentage of diverse zooplankton groups are illustrated in Figure 3. According to Figure 3, the percentage of Rotifera is 58%, Copepoda is 36%, Meroplankton is 5% and Cladocera is 1%, respectively.

Table 1. The occurrence of the different group of zooplankton in Bafa Lake.

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8
ROTIFERA								
Anuraeopsis fissa Gosse, 1851						+		
Asplanchna priodonta Gosse, 1851						+		
Asplanchna sp.						+		
Brachionus angularis Gosse, 1851						+	+	
B. calyciflorus Pallas, 1766				+	+	+	+	+
B. budapestinensis Daday, 1885						+		
B. plicatilis Mller, 1786	+	+		+	+	+	+	+
B. quadridentatus Hermann, 1783				+	+	+	+	
B. rubens Ehrenberg, 1838						+		
B. urceolaris O. F. Muller, 1773	+	+	+	+	+	+	+	+
Cephalodella gibba (Ehrenberg, 1830)						+		
C. forficula (Ehrenberg, 1832)							+	
Cephalodella sp.					+	+		
Colurella adriatica Ehrenberg, 1831	+				+	+	+	+
C. unicinata (Müller, 1773)						+	+	
C. colurus (Ehrenberg, 1830)				+	+			
Colurella sp.					+			
Eucentrum sp.				+	+		+	
Euchlanis dilatata Ehrenberg, 1832							+	
Filina longiseta Ehrenberg, 1832						+	+	
F. terminalis (Plate, 1886)						+	+	
Hexarthra oxyura	+	+	+	+	+	+	+	+
H. fennica Levander, 1892	+	+	+	+	+	+	+	+
H. mira (Hudson, 1871)						+	+	
Keratella cochlearis Gosse, 1851						+	+	
K. quadrata (Müller, 1786)						+	+	
K. tropica (Apstein, 1907)						+	+	
K. valga (Apstein, 1907)							+	
Lecane bulla Gosse, 1851						+	+	
L. clostrocerca (Schmarda, 1859)					+	+	+	
L. luna (Müller, 1776)						+	+	
L. lunaris (Ehrenberg, 1832)					+	+	+	
Lecane sp.					+	+	+	
Lepadella ovalis (O.F. Müller, 1786)					+	+	+	
Mytilina ventralis (Ehrenberg 1830)						+		
Notholca acuminata (Ehrenberg, 1832)						+	+	
N. squamula (Müller, 1786)						+	+	
Platyias quadricornis (Ehrenberg, 1832)						+	+	
Polyarthra remata Skorikov, 1896						+	+	

Table 1. Continued.

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8
ROTIFERA								
P. vulgaris Carlin, 1943						+	+	
Pompholyx sp.							+	
Scaridium longicaudum (Müller, 1786)						+		
Synchaeta baltica Ehrenberg, 1834	+	+	+	+	+	+	+	+
S. oblonga Ehrenberg, 1832	+	+	+	+	+	+	+	+
S. pectinata Ehrenberg, 1832						+	+	
Testudinella pseudoelliptica Bartoš, 1951	+					+	+	
Trichocerca pusilla (Jennings 1903)						+	+	
Trichocerca sp.						+		
Trichotria tetractis (Ehrenberg, 1830)						+		
CLADOCERA								
Coronatella rectangula (Sars, 1861)						+	+	
Bosmina longirostris (O.F. Müller, 1785)							+	
Daphnia longispina (O.F. Müller, 1776)						+		
Diaphanosoma birgei Korinek, 1981						+	+	
Moina micrura Kurz, 1875						+	+	
Podon sp.	+	+	+	+	+	+	+	+
Pleopsis polyphemoides (Leuckart, 1859)		+	+	+	+		+	
COPEPODA								
Calanipeda aquaedulcis Krichagin, 1873	+	+	+	+	+	+	+	+
Coryoceus sp.				+				
Oithonina nana (Giesbrecht, 1892)	+	+	+	+	+	+	+	+
Cyclopoida (undifined)		+			+	+	+	+
Mesocyclops leuckarti (Claus, 1857)								+
Mesocyclops sp.				+		+	+	
Sapphirina sp.	+							
Euterpina acutifrons (Dana, 1847)			+					
Microsetella norvegica (Boeck, 1865)	+	+		+			+	+
Harpacticoid (undifined)	+	+	+	+	+	+	+	+
Copepodit	+	+	+	+	+	+	+	+
Nauplius larvae	+	+	+	+	+	+	+	+
MEROPLANKTON								
Cirripedia larvae				+				
Euphasidae larvae	+	+						
Polychaete larvae	+	+	+	+	+	+	+	+
Tunicata larvae					+			
Veliger larvae	+	+	+	+	+	+	+	+

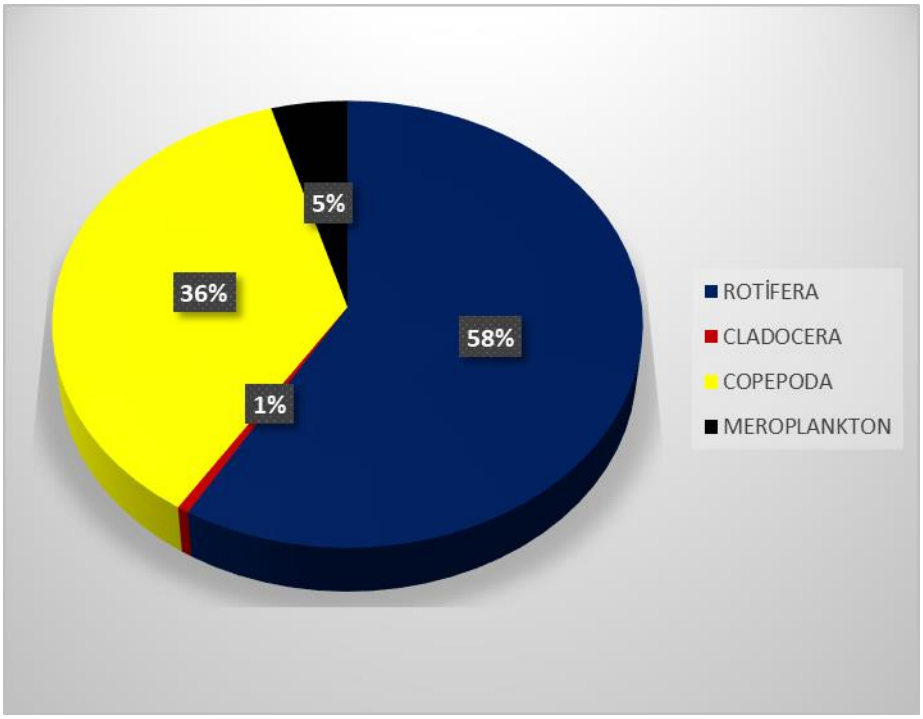

Figure 3. Proportional (%) distributions of zooplankton groups according to lake average density values.

In this study, the Rotifera group was found the most dominant zooplankton group in summer in Bafa Lake (Figure 4). The second most dominant group was Copepeoda in summer. Meroplankton was the most dominant group in autumn, winter, and spring seasons in Bafa Lake. The second most dominant group was Copepoda on autumn, winter, and spring seasons. In general, Rotifera is dominant in term of species and individual numbers. Sharmila-Sree and Shameem (2017) have reached the same results in their study on the Meghadrigedda reservoir, Visakhapatnam, Andhra Pradesh, India.

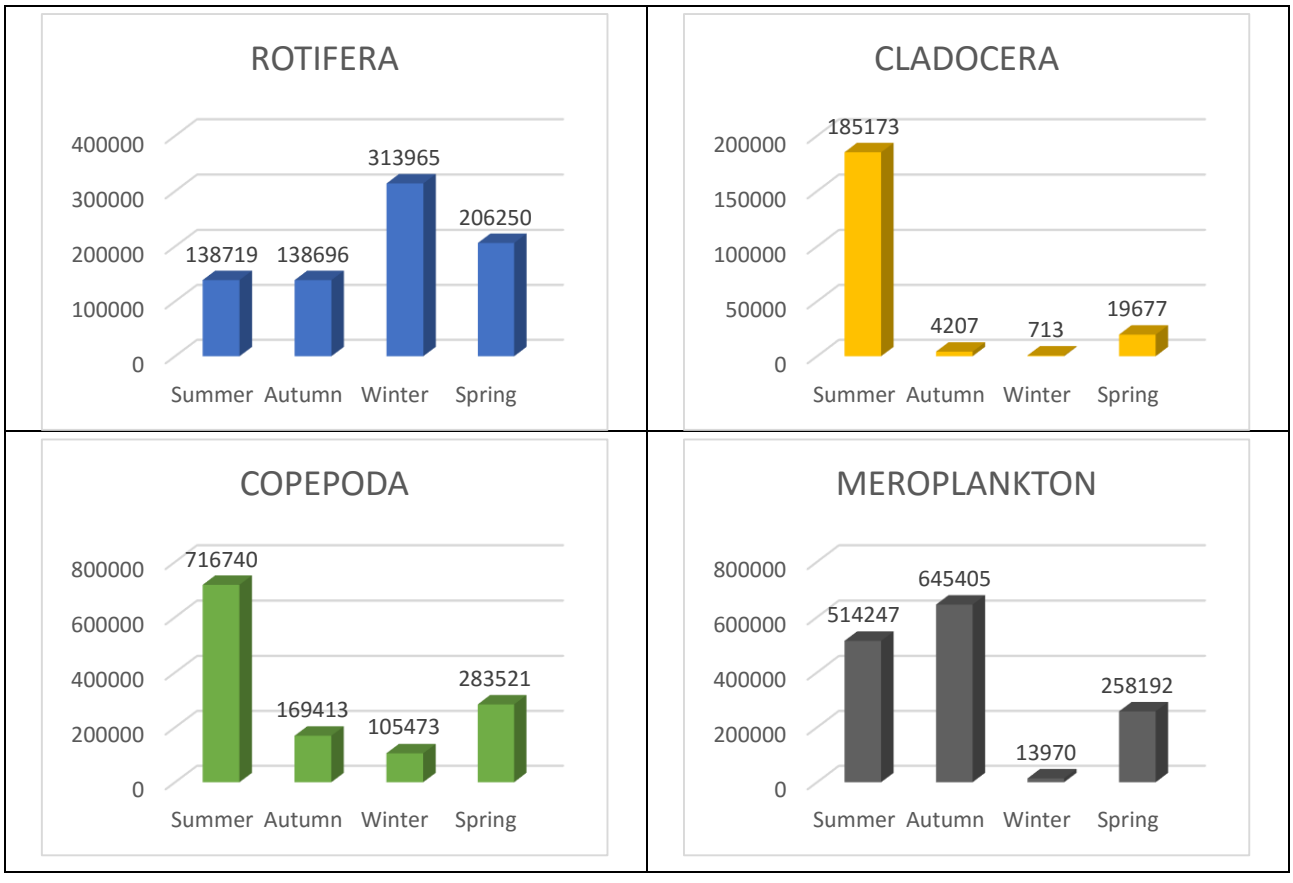

Figure 4. Seasonally average density values (individual/m^3) of zooplankton groups.

Based on UPGMA analysis, classification, and similarities of the sampling stations based on zooplankton communities were demonstrated and defined in Table 2 and Figure 5. In this analysis, station #1, #2, and #8 have closer similarity value with each other. Higher similarities was determined between station #1 and station #2 (86%), station #2 and station #8 (86%) while lowest similarities was determined between the station #3 and station #6 (37%).

Table 2. Cluster analysis dendrogram (UPGMA method) based on the Sørensen index.

	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**	**Station 7**	**Station 8**
Station 1	1	0.86	0.76	0.70	0.64	0.43	0.48	0.84
Station 2		1	0.85	0.76	0.69	0.40	0.49	0.86
Station 3			1	0.72	0.65	0.37	0.42	0.76
Station 4				1	0.73	0.45	0.55	0.74
Station 5					1	0.55	0.60	0.72
Station 6						1	0.81	0.45
Station 7							1	0.51
Station 8								1

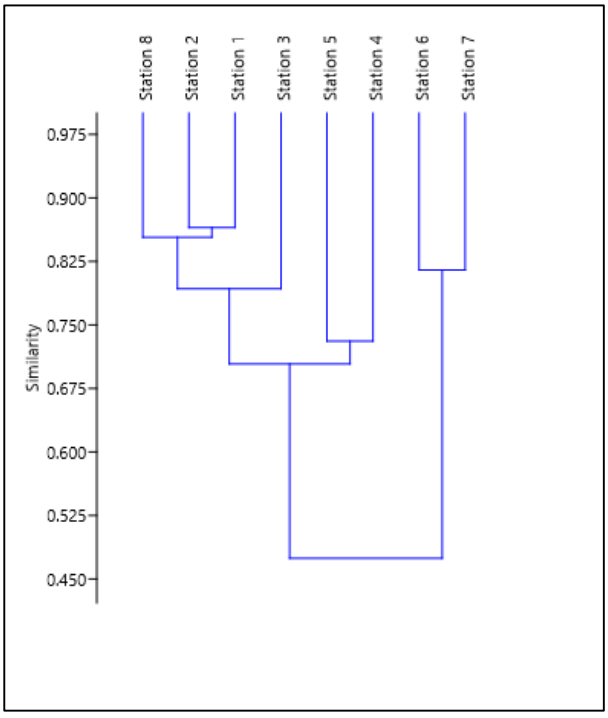

Figure 5. Classification of stations based on similarities of zooplankton communities.

Since there is a strong relationship between the ecosystem efficiency and species diversity in a community, diversity indices are used to determine species richness and species evenness, effectively. SWDI, SDI, MDI, Pielou J, Menhinick, and Evenness E1 diversity indices were calculated for each station to determine species diversity ratio. According to SWDI, the highest diversity value was seen at site #8 (1.92), while the lowest value was seen at site #7 (1.24). According to SDI, the highest diversity value was seen at site #6 (0.87), while the lowest value was seen at site #4 (0.69). According to MDI, the highest diversity value was seen at site #5 (2.89), while the lowest value was seen at site #7 (1.01). According to the Pielou J index, the highest diversity value was seen at site #5 (0.46), while the lowest value was seen at site #7 (0.32). According to the Menhinick index, the highest diversity value was seen at site #7 (0.32), while the lowest value was seen at site #3 (0.16). On the other hand, according to the Evenness E1 index, the highest diversity value was seen at site #3 (0.39), while the lowest value was seen at site #7 (0.18) (Table 3).

Table 3. Score values of biotic and diversity indices and water quality classes.

İndices		**Sta. 1**	**Sta. 2**	**Sta. 3**	**Sta. 4**	**Sta. 5**	**Sta. 6**	**Sta. 7**	**Sta. 8**
Biotic indices									
TSI_{NRot}	Score	61	62	62	68	63	73	72	57
	Class	eutrophic	eutrophic	eutrophic	hypertrophic	eutrophic	hypertrophic	hypertrophic	eutrophic
Species Diversity Indices									
SDI		0,76	0,76	0,76	0,69	0,73	0,87	0,85	0,77
SWDI		1,75	1,74	1,78	1,55	1,88	1,59	1,24	1,92
MDI		1,99	1,88	1,55	2,33	2,89	1,20	1,01	2,12
Evenness E1		0,30	0,32	0,39	0,20	0,23	0,24	0,18	0,36
Menhinick		0,21	0,20	0,16	0,17	0,26	0,28	0,32	0,27
Pielou J		0,45	0,44	0,45	0,36	0,46	0,36	0,31	0,32
		β-mesosaprob	β-mesosaprob	β-mesosaprob	α-mesosaprob	β-mesosaprob	α-mesosaprob	α-mesosaprob	α-mesosaprob

One of the most commonly used biotic index, TSI_{NRot}, was used for assessing the ecological quality of Bafa Lake is shown in Table 3. According to the TSI_{NRot} index, the highest ratio belongs to site #8 (57). The sampling site #8 is determined as a eutrophic ecological state just like other station but it has the lowest ratio than others. On the other hand, other stations were also determined as eutrophic with a high ratio.

Table 4, summarizes the correlations of TSI_{NRot} and species diversity indices. In this study, the random sample cases (10% select case) was made on the biotic and diversity indices to verify datasets and to determine that the data was entered without errors in the SPSS version 20.0. The significant correlation between TSI_{NRot} and *SWDI* ($r = 0.912$; $p<0.01$) was strong. The second strong significant correlation was between TSI_{NRot} and *MDI* ($r = 0.843$; $p<0.01$). Among species, diversity indices highest significant correlation was found between *SWDI* and *MDI* (*r value 890, p<0.01)*. The second strong significant correlation between the diversity indices was *SWDI* and *Pielou J (r value 889, p<0.01)*. *SWDI* and *MDI* indices are coherent with TSI_{NRot}, because of the increase or decrease of TSI_{NRot} value can relate with *SWDI* and *MDI* indices value. All species diversity indices were in accordance with each other except Menhinick Diversity Index.

Table 4. Correlation assesment between biotic and diversity indices used in Bafa Lake.

	SDI	SWDI	MDI	Evenness E1	Menhinick	Pielou J	TSI_{NRot}
SDI	1	.933**	.805*	-.165	.713*	.874**	.542
SWDI		1	.890**	-.298	.767*	.889**	.912**
MDI			1	-.668	.790*	.638	.843**
Evenness E1				1	-.449	.057	-.776*
Menhinick					1	.795*	.359
Pielou J						1	.193
TSI_{NRot}							1

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Discussion

Many aquatic organisms feed on zooplanktonic organisms, at least for a certain period of their lives. Therefore, there is a close relationship between the efficiency of the aquatic environment and zooplanktonic organisms. Rotifera, Cladocera and Copepoda groups make up the bulk of the zooplankton fauna in freshwater ecosystems.

Zooplankton fauna of Bafa Lake was determined in this research. With this study, the TSI_{NRot} index and various versions of diversity indices were used on identified zooplankton organisms to determine the ecological status of Bafa Lake. In this study, a total of 73 taxa were determined during the two years of study in Bafa Lake. According to Altındağ and Yiğit (2004), When the zooplankton fauna of Beyşehir Lake was examined, a total of 43 species were identified, 32 from Rotifera, 9 from Cladocera and 2 from Copepoda. After the identification of zooplankton samples, Rotifera, Cladocera, Meroplankton, and Copepoda groups were revealed. In some similar studies conducted in other trophic lakes, Altındağ and Yiğit (2004); Türkmen et al. (2006); Dirican and Musul (2008); Offem et al. (2011); Ren et al. (2011); Apaydın Yağcı and Ustaoğlu (2012); Haberman and Haldna (2014); İpek Alış and Saler (2016); Ochocka and Pasztaleniec (2016); Tuna and Ustaoğlu (2016); Sharmila-Sree and Shameem (2017); De-Carli et al. (2019) and Sgarzi et al. (2019) reached approximately similar results in their researches.

As a result of the determination of zooplankton groups, the most dominant zooplankton group was found as Rotifera in Bafa Lake. According to Türkmen et al. (2006), the Rotifera species composition detected in Gölbaşı Lake is quite wide compared to Cladocera and Copepoda species compositions. Although the Keratella species, which is used as the eutrophication indicator, is 39.8% among the species forming the Rotifera population, the Brachionus and Filinia species used as the eutrophication indicator were found at a low rate of 1.52% and 0.23% in Gölbaşı Lake, respectively. The Keratella, Brachionus, and Filinia species are also found in Bafa Lake. According to Dirican and Musul (2008), *Filinia* sp., *Keratella* sp., *Polyarthra* sp., *Trichocerca* sp., *Bosmina* sp. sp, *Daphnia* sp. and *Cyclops* sp. have been reported in the Kelkit Stream, which is one of the branches of Yeşilırmak and a little behind the Çamlıgöze Dam Lake, on the Kılıçkaya Dam Lake. In a study conducted in Çamlıgöze Dam Lake, individuals belonging to *Filinia* sp., *Keratella* sp., *Trichocerca* sp. and *Cyclops* sp. reported in Kılıçkaya Dam Lake were not encountered (Dirican and Musul, 2008). According to İpek Alış and Saler (2016), Rotifera was represented in higher number of species compared with Cladocera and Copepoda in Cip,

Göksu, Keban, Kesikköprü and Asartepe dam lakes.

The similar results were obtained by Negreiros et al. (2010) in Sapucai River; Saygı et al. (2011) in Liman Lake; İsmail and Adnan (2016) in Harapan and Aman Lakes; and lastly Dorak et al. (2019) in several reservoirs in Turkey.

According to Ejsmont-Karabin (2012), based on the biotic index, the TSI_{NRot} is created as the main mean of specific zooplankton indices. For this reason, TSI_{NRot} under 45 means, the lake's ecological state is mesotrophic. If TSI_{NRot} value is between 45-55 means, the lake's ecological state is meso-eutrophic. While TSI_{NRot} value is between 55-65, the lake is eutrophic, and if TSI_{NRot} value above 65, the lake is hypertrophic.

In this study, species diversity values ranged from 0,16 to 2,89 in Bafa Lake. Mason (2002) reported that *SWDI* values range from >3 it indicates clean water, 1-3 indicates moderate pollution, and 1< indicates heavy pollution. According to Ghosh and Biswas (2005), the diversity value ranges from 0 (low density) to 1 at *SDI*. According to Gamito (2010), the datasets consist of two matrices that specify absolute numbers at *MDI*. In this study carried out in Bafa Lake, we used the *SWDI*, *MDI*, *SDI*, Evenness E1, Pielou J, and Menhinick Diversity Indices.

Ejsmont-Karabin (2012) reported that differences in the taxonomic structure of Rotifera communities in Suwalki Lake Districts and other lakes can source from climatic and seasonal variations. In this research, Rotifera group was dominant in the summer season and the population density of Rotifera group started to decrease since the autumn season.

Brachionus and Filinia species used as eutrophication indicators were found in this study carried out in Lake Bafa. The high rate of these species strengthens the view that the lake may be in the mesotrophic-eutrophic transition phase. According to Haberman (1998), in addition to Keratella species, Brachionus and Filinia species have been accepted by various researchers as eutrophication indicators. While Rotifera species are generally found more frequently in eutrophic lakes, Copepoda species are mostly found in oligotrophic lakes (Herzig 1987). This situation is seen when the seasonal distribution of the groups forming the zooplankton population in Lake Bafa is examined. In the months when Cladocera and Copepoda species are intense, there is a decrease in Rotifera populations. Many studies of Williamson and Buttler (1986) have made it clear that the majority of Cladocera and Copepoda species feed on Rotifera species. The reason for the increase in the Rotifera populations observed in months when these species are dense is especially in these periods which can be attributed to phytoplankton increases.

According to UPGMA, the highest similarities are found between station #1 and #2, station #2, and #8 while the lowest similarities were determined between station #3 and #6. UPGMA is a sequential clustering method and it is the simplest method for determining the distance by constructing trees. This method which developed by Sokal and Michener (1958), starts with a matrix of pairwise distances, and each sample is indicated as "cluster".

Bafa Lake zooplankton composition is very similar to other lakes in our country. According to the biological data obtained in our study, it was determined that the lake consists of taxa belonging to the Rotifera, Cladocera and Copepoda groups, its depth is quite variable and it is passing from oligotrophic to eutrophic. Fisheries, industrial and domestic factors in the lake are also thought to have an important share in this transformation.

The present research reveals seasonal variations and distributions of zooplankton fauna in Bafa Lake. Furthermore, this investigation reveals the ecological status and trophic state of Bafa Lake by using TSI_{NRot} and various versions of species diversity indices. During the two years of the study period, all four groups of zooplankton were recorded. This study revealed the Bafa Lake zooplankton biodiversity is facing to extinct just like the other surface water sources (lakes, rivers, and streams) in Europe. Water source's ecological quality is primarily subject to *WFD*. With this respect, intermittent biomonitoring studies, bioconservation studies, and bio-modeling studies must conduct o the Bafa Lake basin and other polluted water sources in Turkey.

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