Relationships between the physicochemical parameters and zooplankton in Eğirdir Lake (Turkey)

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Abstract

The zooplankton community structure in Eğirdir Lake (Isparta-Turkey) was studied monthly throughout an annual cycle (January 2010-December 2010). The zooplankton community was represented by three main groups: Rotifera, Cladocera and Copepoda, respectively comprised 89.62%, 7.78% and 2.60% of the total zooplankton abundance. Eğirdir Lake was dominated by the rotifera *Polyarthra dolichoptera* in September and October, that succeeded by cladocera *Bosmina longirostris* species during December. Canonical correspondance analysis (CCA) was used to relate species distribution to environmental factors. The variation in the species data was significantly ($p< 0.05$) related to a set of environmental variables (conductivity, carbonate, pH, ammonium, organic substances, dissolved oxygen, saturation of dissolved oxygen, chloride and temperature). According to the CCA result, variables were able to explain 81.9% of the total variation suggesting a significant result. The rotifer, *Asplanchna priodonta*, and the crustaceans, *B. longirostris* and *Nauplius larvae* seemed to be affected by environmental gradients.

Keywords: Physicochemical parameters, Zooplankton, Eğirdir Lake, Isparta, Turkey

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Introduction

Zooplankton is a considerable nutrition resource for waterfowl and fish (Altındağ *et al.,* 2009). The species distribution and abundance of zooplankton in any water body depend upon the physicochemical parameters of water (Patra *et al.,* 2011). Zooplanktons occupy an intermediate position in the food web. Also, they play an important role as indicators of trophic condition in both cold temperate and trophical waters (Ahmad *et al.,* 2011). Eğirdir Lake is important for different sectors such as, irrigation, tourism and drinking water.

There are some researches which show relations between zooplankton and environmental parameters in various water systems (Makarewicz *et al.,* 1998; Tackx *et al.,* 2004; El-Bassat and Taylor, 2007; Arimoro and Oganah, 2010; Ahmad *et al.,* 2011; Sharma, 2011) but in Turkey inland water systems (Altındağ *et al.,* 2009; Deveci *et al.,* 2011) have rarely been studied in this respect. In addition, some researches in Eğirdir Lake as the second drinking and freshwater source are available on taxonomy of zooplankton (Mann, 1940; Kiefer, 1952, 1955; Numann, 1958; Fiers, 1978; Gündüz, 1984; Dumont and De Ridder, 1987; Gündüz, 1987; Rahe and Pelister, 1987; Demirhindi, 1991; Emir, 1991; Gündüz, 1997; Kazancı *et al.,* 1999; Kaya and Altındağ, 2007a,b; Aksoylar and Ertan, 2002; Didinen and Boyacı, 2007; Apaydın Yağcı *et al.,* 2014). However, relations between zooplankton species and physicochemical parameters have not been studied so far in this lake. Therefore, a detailed study on the monthly distributions of zooplankton species and their relations with physio-chemical parameters of Eğirdir Lake was carried out during the study period. The objectives of this study were i) to study the monthly distributions of zooplankton abundance of Eğirdir Lake, and ii) to find out the relationship between physicochemical parameters and zooplankton abundance in Eğirdir Lake.

Materials and methods

Study site

Eğirdir Lake, which is a tectonic lake, is located at about 918 m from sea level with a total surface area of 47.250 ha (Yarar and Magnin, 1997). The maximum depth of the lake is 13 m with approximately 48 km maximum length and 16 km maximum width (Kosswig and Geldiay, 1952; Numann, 1958; Çubuk *et al.,* 2006).

Sampling and sample processing

Sampling was carried out monthly from January to December 2010 at 4 stations (Fig. 1). Vertical water samples were collected monthly from four sites. Station 1 is in the northern area which is called Hoyran. Station 2 is in the southwest of the lake, near Barla Town. Station 3 is in the southeast of the lake, near Gelendost. Station 4 is in the southern most area of the lake, near the Köprü site. At each station the following environmental variables were measured: pH and temperature using a YSI 63; dissolved oxygen concentration, saturation of dissolved oxygen and conductivity using a YSI 55. Water samples were taken for determination of transparency (Secchi disk), chlorophyll-a (chl-a), turbidity, chloride, organic substances, bicarbonate, carbonate, total hardness, calcium, magnesium, nitrate, nitrite, ammonium, sulphate, silica, phosphate and acid power (SBV) (Egemen and Sunlu, 1996; Wetzel and Likens, 2000). At each station, zooplankton samples were collected with a Hydro-Bios plankton net vertically within the water column filtered through a 55 µm net and fixed in a 4 % formaldehyde solution. Samples were analyzed by binocular for zooplankton species composition and abundance.

Community analysis

The relationship between species distribution and environmental factors was investigated by means of the Canonical Correspondence Analysis (CCA) (Özkan, 2009). A Monte Carlo test for the significance of the correlations between the environmental factors and the species distribution was applied. Zooplankton species were identified following the work of Dussart (1967, 1969); Koste (1978); Negrea (1983); Korovchinsky (1992); Nogrady and Segers (2002). A zooplankton species checklist was formed according to Ustaoğlu (2004) and Ustaoğlu *et al.* (2012). Ouantitative enumeriation (Ind.L^{-1}) of zooplankton and their constituent groups was implemented with a Sedgewick Rafter counting cell (Edmondson, 1959).

Results

Ecological conditions

Eğirdir Lake is moderately alkaline, with pH ranging between 8.63±0.53 and 8.98±0.30. Secchi disk readings varied from a minimum of 0.93±0.53 at site III to a maximum of 1.95±0.95 at site I, while the mean Secchi depth at all sites and months was 1.54±0.53 m (Table 1). Rotifers, Cladocers and Copepods exhibited monthly dynamics (Table 2) as illustrated in Fig. 2. Total mean zooplankton abundance averaged over all stations varied from 42 Ind.L^{-1} in March, to 3092 Ind.L^{-1} in October (Fig. 2).

Zooplankton was most abundant at site IV, with a maximum population density of 1.889 Ind.L^{-1} recorded in October. The lowest zooplankton abundance of 2 Ind.L^{-1} was recorded at site I in March (Fig. 3).

Rotifers of Eğirdir Lake were represented by 21 species (Table 2), with *P. dolichoptera* (2332 Ind.L^{-1}-October), *K. cochlearis* (199 Ind.L^{-1}-November), *B. angularis* (344 Ind.L^{-1}-October) being dominant. Similarly, *P. dolichoptera* dominated the rotifer population at all sites during October (Fig. 4).

The highest population density of *B. longirostris* was 245 Ind.L^{-1} during December. *D. cucullata* (maximum of 28 Ind.L^{-1} during August) was the second one and the most abundant, comprising 0.49 % of the total zooplankton (Fig. 5).

Table 1: The mean change in physicochemical condition of Eğirdir Lake by stations (January-December 2010).

Physicochemical parameters	Station 1	Station 2	Station 3	Station 4
Depth (m)	5.13±0.90	5.67±1.15	4.02±1.09	6.01±0.46
Transparency (Secchi disk) (m)	1.95±0.95	1.56±0.77	0.93±0.53	1.72±0.70
Chlorophyll-a (mg m^{-3})	3.27±2.29	2.89±1.13	3.03±179	2.91±1.31
Turbidity (NTU)	3.65±4.94	5.75±4.96	8.06±4.58	4.73±3.56
Temperature (° C)	16.86±7.13	16.51±7.32	16.08±7.14	16.00±7.18
pH	8.63±0.53	8.97±0.29	8.96±0.29	8.98±0.30
Conductivity (µS,20 ºC)	346±45.7	343±59.4	344±69.5	342±53.8
Dissolved oxygen (mg L^{-1})	9.46±1.99	9.43±2.70	9.42±2.55	9.45±2.77
Saturation of dissolved oxygen (%)	93.72±14.90	93.52±16.27	90.37±14.55	91.86±16.32
Chloride (mg L^{-1})	8.29±3.70	8.77±3.82	9.14±4.64	9.05±4.79
Organic substance (mg L^{-1})	16.40±3.86	17.19±4.31	18.27±3.66	17.43±3.16
Bicarbonate (mg L^{-1})	259.35±24.75	252.74±21.14	245.83±22.35	249.78±24.27
Carbonate (mg L^{-1})	13.90±2.78	18±4.66	18.35±5.00	17.40±4.48
Total Hardness (º F)	27.67±3.75	25.50±2.88	26.75±2.73	27.08±2.19
Calcium (mg L^{-1})	46.42±13.39	40.17±11.14	36.84±3.47	38.51±6.76
Magnesium (mg L^{-1})	39.07±11.60	38.41±10.33	45.57±7.25	41.96±6.76
Nitrate (mg L^{-1})	1.56±0.92	1.72±1.05	1.67±0.99	1.89±1.32
Nitrite (mg L^{-1})	0.03±0.01	0.03±0.01	0.04±0.02	0.03±0.02
Ammonium (mg L^{-1})	0.10±0.06	0.12±0.13	0.09±0.03	0.20±0.26
Sulphate (mg L^{-1})	23.51±8.24	44.50±15.28	46.59±15.88	43.34±11.42
Silica (mg L^{-1})	4.44±1.82	4.77±1.51	4.12±1.56	4.19±1.67
Phosphate (mg L^{-1})	0.14±0.13	0.14±0.16	0.19±0.22	0.26±0.27
Acid power SBV (mL acid)	5.27±0.33	5.17±0.19	5.08±0.28	5.17±0.21

Table 2: Codes of monthly distribution of vertical zooplankton and species which are related with correspondance analysis.

Species	Codes (CCA)	J	F	M	A	M	J	J	A	S	O	N	D
Rotifera													
Keratella cochlearis (Gosse 1851)	Kelcoc	*	*	*	*	*	*	*	*	*	*	*	*
Keratella quadrata (Müller 1786)	Kelqua	*	*								*		
Asplanchna priodonta Gosse 1850	Asppir	*	*	*	*	*	*	*	*	*	*	*	*
Synchaeta pectinata Ehrenberg 1832	Synpec	*		*	*	*	*	*		*	*	*	*
Polyarthra dolichoptera Idelson 1925	Poldol	*	*	*	*	*	*	*	*	*	*	*	*
Filinia longiseta (Ehrenberg 1834)	Fillon						*	*	*	*	*		*
Brachionus angularis Gosse 1851	Braang						*	*	*	*	*		
Brachionus calyciflorus (Pallas 1766)	Bracal	*		*		*							
Brachionus patulus (Müller 1786)	Brapat						*						
Hexarthra mira (Hudson 1871)	Hexmir						*		*	*	*		
Ascomorpha sp.	Ascomo		*					*	*				*

Table 2 continued:

Conochilus dossuarius (Hudson 1885)	Condos									*	*	*	*	*			
Trichocerca similis (Wierzejski 1893)	Trisim									*	*	*	*	*	*		
Trichocerca cylindrica (Imhof 1891)	Tricylin										*	*	*	*	*		
Trichocerca bicristata (Gosse 1887)	Tribic													*			
Trichocerca capucina Wierzejski & Zacharias 1893	Tricap											*	*	*			
Testudinella patina (Hermann 1783)	Tespat															*	
Notholca squamula (Müller 1786)	Notsqu					*											
Lecane flexilis (Gosse 1886)	Lecflexi													*			
Platyias quadricornis (Ehrenberg 1832)	Platquad									*							
Cephalodella gibba (Ehrenberg 1830)	Cepgib										*						
Cladocera																	
Bosmina longirostris (Müller 1785)	Boslong	*	*				*		*	*	*	*	*	*	*	*	*
Alona quadrangularis (Müller 1785)	Aloquad		*								*						
Coronatella rectangula (Sars 1861)	Alorec											*	*			*	
Chydorus sphaericus (Müller 1776)	Chyspha		*						*		*	*		*		*	
Ceriodaphnia quadrangula (Müller 1785)	Ceriquad											*	*	*			
Daphnia cucullata Sars 1862	Dapcuc											*	*		*		
Acroperus harpae (Baird 1835)	Acrohar												*			*	
Diaphanosoma lacutris Korinek 1981	Dialac												*	*	*		
Graptoleberis testudinaria (Fischer 1848)	Graptes										*						
Copepoda																	
Nitocra hibernica (Brady 1880)	Nithib	*								*	*	*		*	*		
Eucyclops speratus (Lilljeborg 1901)	Eusphae		*														*
Mesocyclops leuckarti bodanicola (Kiefer 1928)	Mesoleuc	*							*	*	*	*	*	*	*	*	*
Nauplius larvae	Naupli	*	*				*		*	*	*	*	*	*	*	*	*

Table 3: Results of Monte Carlo test.

Axis	Variance	Mean	Minimum	Maximum	*p*
1	0.492	0.387	0.265	0.485	0.0010
2	0.327	0.270	0.159	0.347	0.0230
3	0.254	0.192	0.118	0.304	0.0480

Table 4: Test results of monte Carlo's correlation of species and physicochemical variables.

Axis	Variance	Mean	Minimum	Maximum	*p*
1	0.971	0.884	0.750	0.966	0.0010
2	0.926	0.854	0.706	0.983	0.0460
3	0.902	0.830	0.626	0.971	0.1331

Table 5: Correlations between variables.

Parameters	Cod	Axis I	Axis II	Axis III
Depth	Depth	0.167	0.051	-0.025
Light permeability	Secchi	-0.044	0.256	-0.007
Turbidity	Turbid	0.095	-0.193	-0.087
Temperature	Temper	-0.492	0.214	0.363
Conductivity	Konduct	-0.750	-0.023	-0.141
pH	pH	0.556	-0.253	0.284

Table 5 continued:

Dissolved oxygen	Oxygen	0.251	-0.410	-0.473
Saturation of dissolved oxygen	Satuoxyg	0.095	-0.475	-0.583
Silica	Silica	-0.313	-0.164	-0.032
Nitrate	Nitrate	0.381	0.138	0.305
Nitrite	Nitrite	0.067	-0.185	-0.143
Ammonium	Ammonium	0.571	-0.153	-0.056
Phosphate	Phospha	-0.039	0.127	0.245
Organic substance	Orgasubs	0.513	-0.372	-0.118
Chloride	Chloride	-0.498	-0.265	0.466
Bicarbonate	Bicarbon	-0.194	0.189	0.037
Carbonate	Carbon	-0.528	-0.240	-0.322
Total Hardness	Hardness	0.394	-0.184	-0.158
Calcium	Calci	0.454	0.306	-0.144
Magnesium	Magne	-0.059	-0.359	-0.007
Acid Power	SBV	-0.022	0.166	-0.263
Sulphate	Sulfate	-0.443	-0.362	0.192
Chlorophyll-a	Chlorop-a	-0.229	-0.031	-0.281

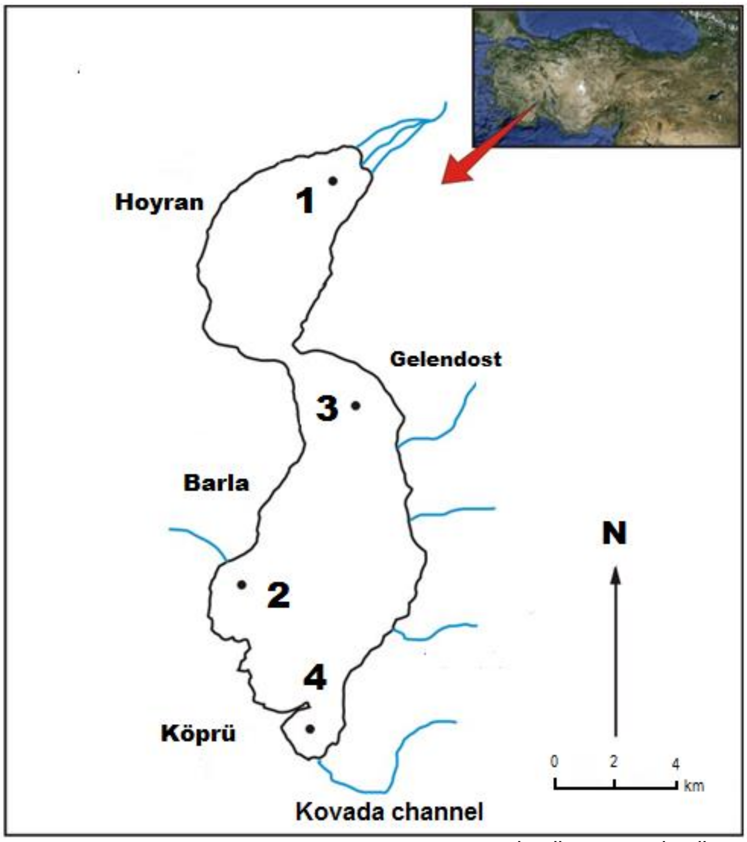

Figure 1: Map of Eğirdir Lake and stations (Station 1: 38° 15′ 48″ N, 30° 49′ 17″ E; Station 2: 37° 58′ 50″ N, 30° 47′ 32″ E; Station 3: 38° 05′ 14″ N, 30° 55′ 45″ E; Station 4: 37° 50′ 52″ N, 30° 51′ 29″ E.

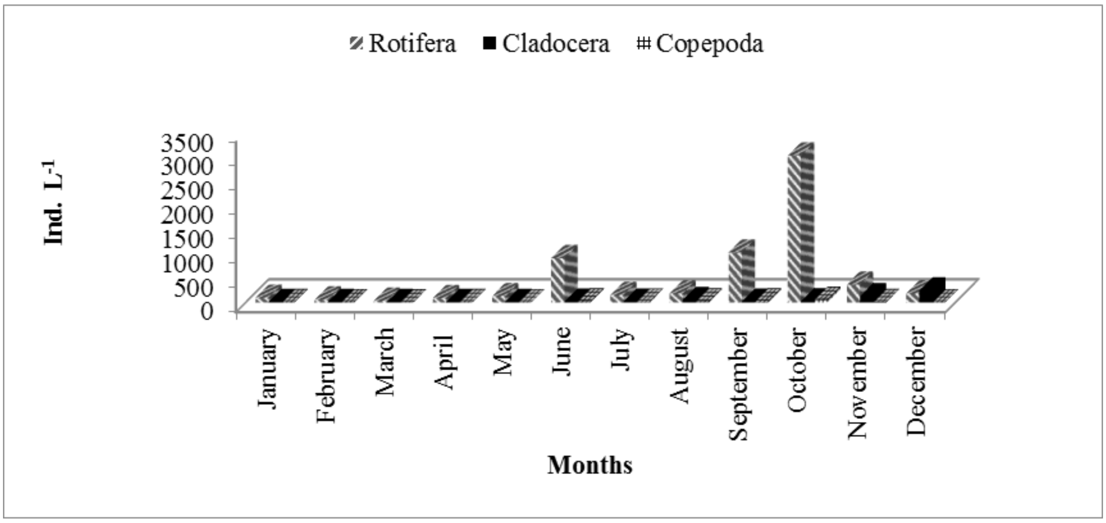

Figure 2: Density variations of zooplanktonic groups during the study period.

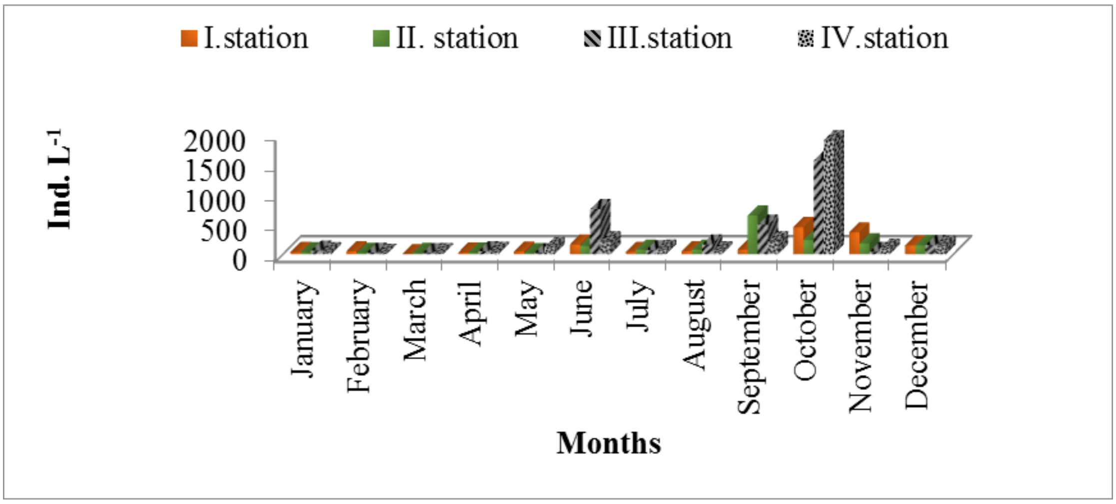

Figure 3: Density variations of zooplankton in four sampling stations during the study period.

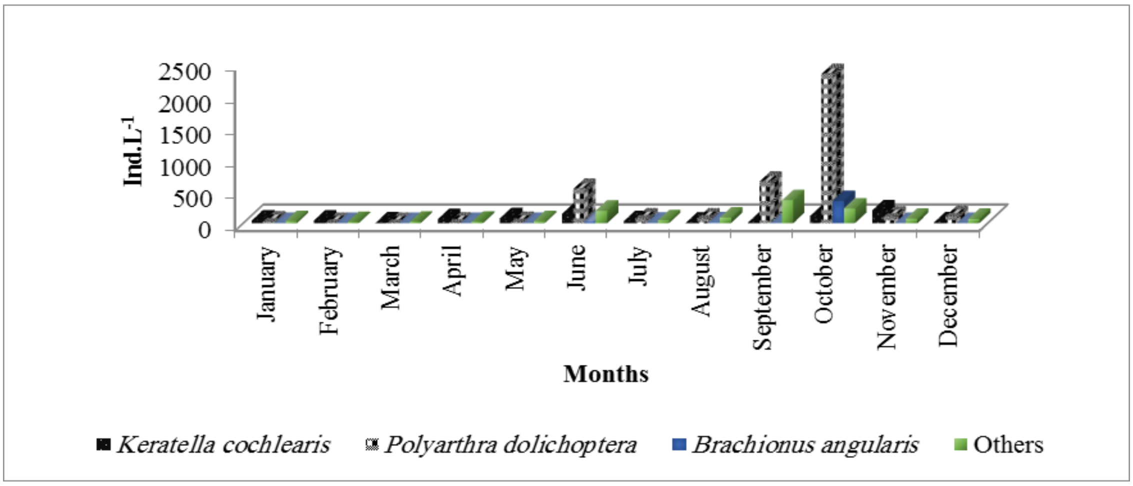

Figure 4: Average abundances of dominant rotifer taxa at all sampling sites in Eğirdir Lake.

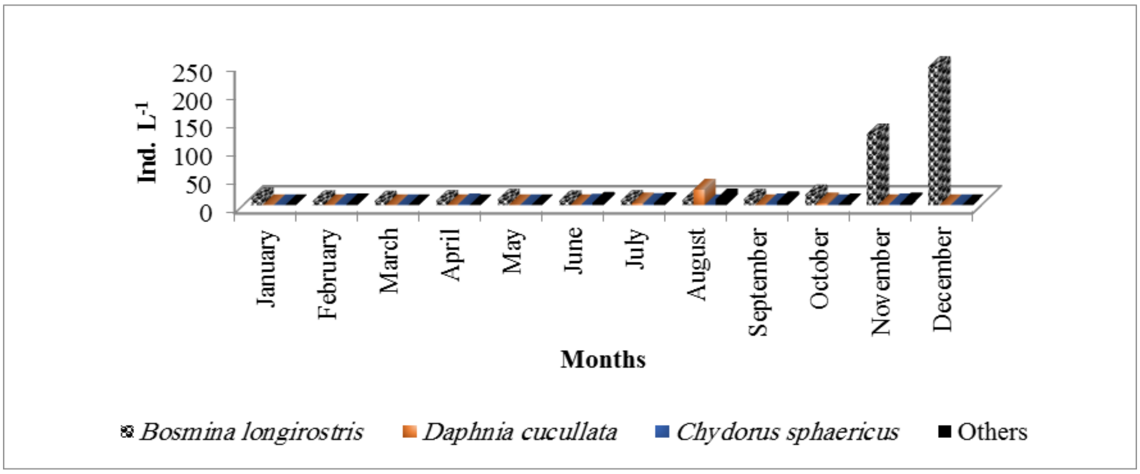

Figure 5: Average abundances of dominant cladocera taxa at all sampling sites in Eğirdir Lake.

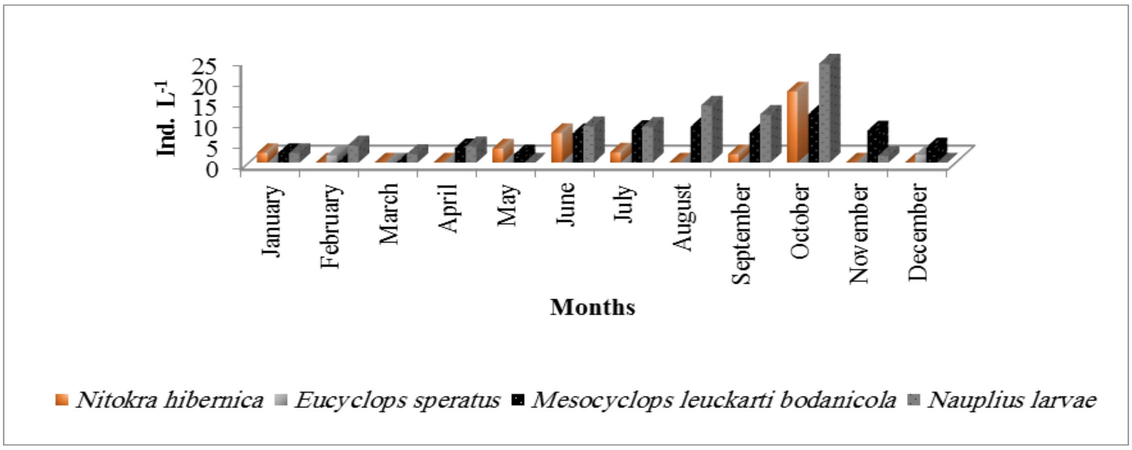

Figure 6: Average abundances of dominant copepod taxa at all sampling sites in Eğirdir Lake.

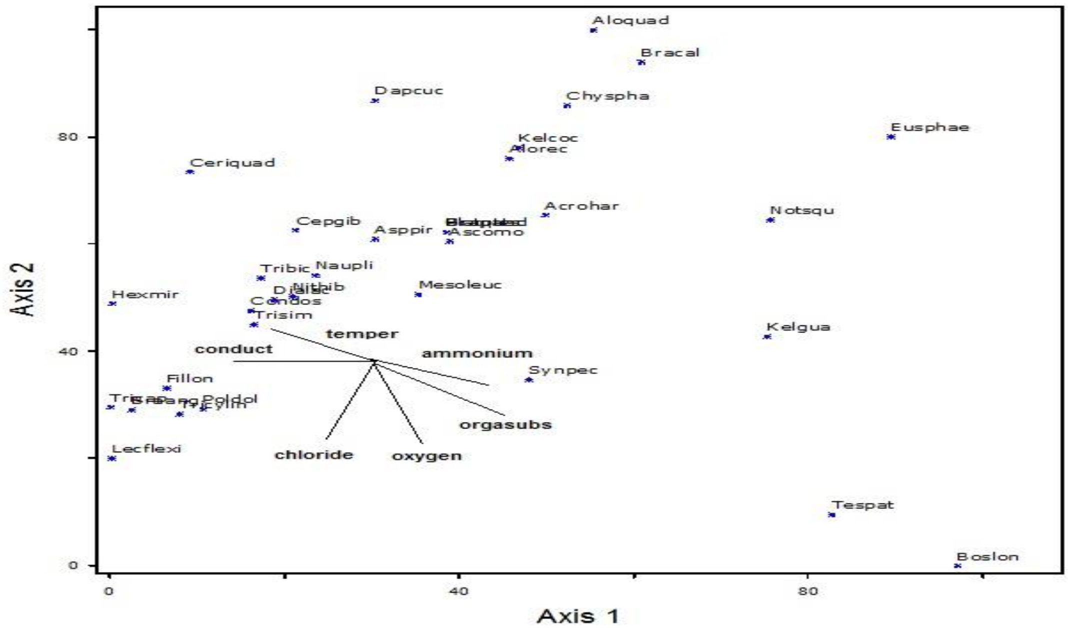

Figure 7: Canonical correspondance analysis of the zooplankton species and selected physical and chemical parameters at four sampling sites in Eğirdir Lake.

Copepoda was the third and the most abundant zooplankton group. *N.hibernica, E. speratus, M. leuckarti bodanicola* and *Nauplius larvae* comprised about 2.60 % of the total zooplankton present during the period of study. The population density of Copepoda reached a maximum of 53 Ind.L^{-1} during September (Fig. 2). The lowest copepoda density was encountered during March, with a value of about 2 Ind.L^{-1}. *E. speratus* was only recorded during February and December (Fig. 6).

Statistical analysis

Canonical correspondance analysis of zooplankton against water quality parameters (Fig. 7) summarized the major trends in the distribution of the zooplankton groups during the study period. According to the CCA; variance of the 1st axis was 0.492, variance of the 2nd axis was 0.327, and variance of the 3rd axis was 0.254. Here, share of the 1st and the 2nd axes are relatively high (81.9%) in the total varience (Table 3). The 1st and 2nd axes were found significant according to results of Monte Carlo Test (p<0.05) (Tables 3, 4).

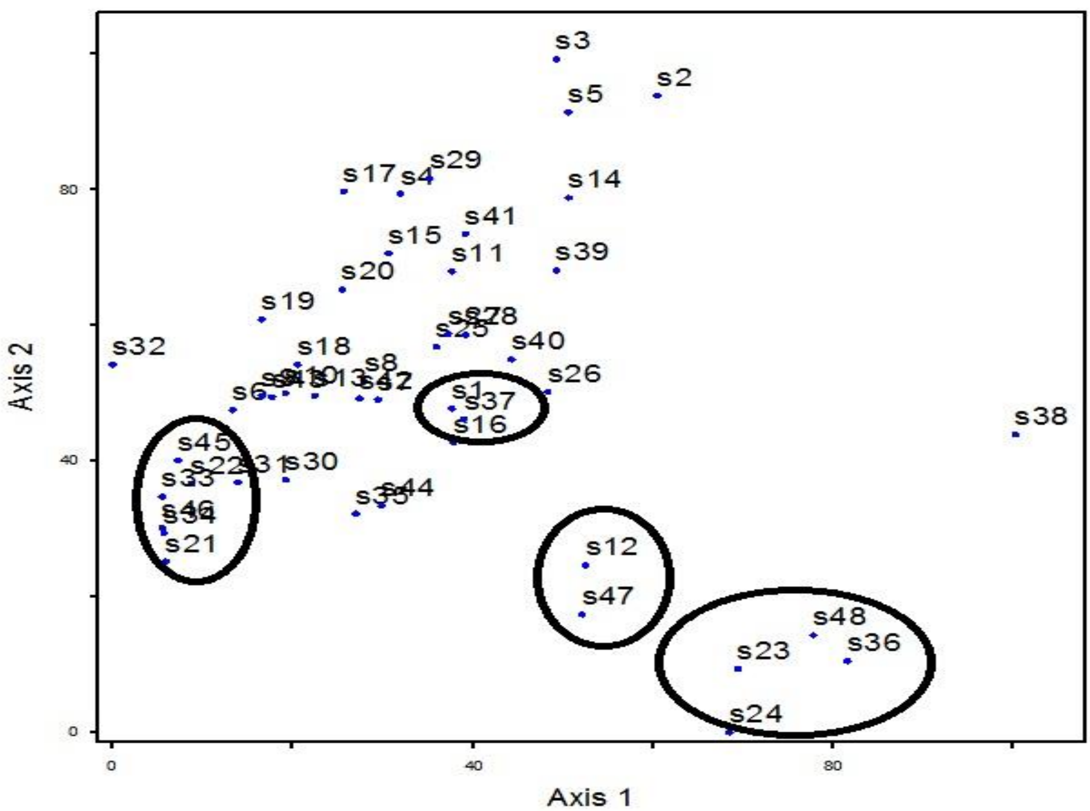

Figure 8: Canonical correspondance analysis (CCA) ordination plots for stations, months and environmental variables (Monthly and stations codes are s1: January-1st station; s12: December-1st station; s16: April-2nd station; s21: March-2nd station; s22: October-2nd station; s23: November-2nd station; s24: December-2nd station; s33: September-3rd station; s34: April-3rd station; s36: December-3rd station; s43: January-4th station; s45: September-4th station; s46: October-4th station; s47: November-4th station; s48: December-4th station).

In terms of the correlation of physicochemical variables, in the 1st axis conductivity and carbonate showed negative correlation, and pH, ammonium and organic substance showed positive correlation. Beside this, in the 2 nd axis, dissolved oxygen and saturation of dissolved oxygen showed negative correlation (Table 5). Distribution similarity of zooplankton species between stations is shown in Fig. 8.

Discussion

Rotifera were strongly dominant throughout the year and were the main contributors to the above mentioned abundance peaks. Dominant species were *P. dolichoptera*, *K. cochlearis* and *B. angularis*. Dominant cladocera species was *B. longirostris*. The annual mean zooplankton recorded during the present study of 581 Ind.L^{-1}, were recorded for Rotifera 89.62%, Cladocera 7.78 % and Copepoda 2.60%.

In this research, when the zooplanktonic organisms are evaluated according to CCA, with the 1st axis *A. priodonta*, *B. longirostris*, *M. leuckarti bodanicola*, *H. mira*, *P. dolichoptera*, *C. dossuarius*, *T. similis*, *T. cylindrica*, *F. longiseta and B. angularis* are highly related species. *B. longirostris* which are of these species shows positive correlation in the 1st axis, but the others show negative correlation. In the 2nd axis, only *S. pectinata*, *B. longirostris* and *M. leuckarti bodanicola* species are related negatively (Fig. 7). According to CCA, *B. longirostris* was found in some areas where pH, ammonium, organic substance and dissolved oxygen are high, temperature and conductivity are low. Besides; another research in Niger Delta by Arimora and Oganah (2010) shows that *B. longirostris* is seen in areas where conductivity level is high. This species was recorded in Lake Sünnet where level of conductivity and pH is high (Deveci *et al.*, 2011).

El-Bassat and Taylor (2007) reported that in Lake Abu Zaabal in Egypt, *B. longirostris* was found in areas where the temperature is low. On the contrary to our research, a research was done by Lougheed and Chow-Fraser (2002) that shows that *B. longirostris* is found in areas where dissolved oxygen and temperature are high. In this research, while *T. patina* was found in areas where the proportion of dissolved oxygen, ammonium and organic substance is high, in Niger Delta, it was recorded in areas where the conductivity level is high (Arimora and Oganah, 2010). During our research the species *A. priodonta*, *H. mira*, *C. dossuarius* and *T. similis* were found in places where the temperature level is high. In the spring of River Tejo in Portugal, *A. priodonta* and *T. similis* were found where the temperature level is high (Baião and Boavida, 2005), in Lake Abu Zaabal, Egypt; (El-Bassat and Taylor, 2007), *A. priodonta* was found in places where the temperature level is high. A research by Deveci *et al*. (2011) in Lake Sünnet, found *T. similis* in areas where pH and conductivity level were low. Our research shows that *S. pectinata* and *K. quadrata* are found in places where dissolved oxygen, organic substance and ammonium level are high in Eğirdir Lake. In the Lake Sünnet, with cold water (Deveci *et al*., 2011) *K. quadrata* was recorded in areas where the dissolved oxygen level is high. In Lake Abu Zaabal, Egypt; *K. quadrata* was found in places where the temperature level is high (El-Bassat and Taylor, 2007). In addition to our research, *T. capucina*, *B. angularis*, *T. cylindrica*, *P. dolichoptera*, *L. flexilis* and *F. longiseta* were found in areas where temperature, conductivity and chloride level are high. In Lake Sünnet *B. angularis* was seen in places where pH and conductivity level are high, *P.dolichoptera* was found in places where the temperature level is high that is similar with our results. Also, *F. longiseta* cold water species was recorded in Lake Sünnet. According to our CCA; *B. calyciflorus, K. cochlearis, C. rectangula* and *A. quadrangularis* were found in areas where dissolved oxygen, ammonium, organic substance, conductivity and temperature levels are low. In contrast to that; in River Tejo, Portugal, *B. calyciflorus* and *K. cochlearis* were found in places where temperature level is high. According to the results of our research; *N. hibernica* was found in areas where conductivity and temperature level are high, *D. lacustris* was found in areas where dissolved oxygen level is low. At the same time, *C. sphaericus* was found in places where the conductivity level is low, *M. leuckarti bodanicola* was in places where the chloride level is low. In Niger Delta, *Chydorus reticulatus* and *Cyhdorus ventricosus* were found in areas where the conductivity level is high, *Alona* sp., was found in where the dissolved oxygen level is high. Tackx *et al*. (2004) work in an estuary showed that, *M. leuckarti bodanicola* was found in places where pH and chloride levels are high. According to CCA in Lake Sünnet while *Daphnia longispina* has positive relation with pH and conductivity, *C. sphaericus, N. acuminata*, *L. luna* and *L. lunaris* have negative relations with dissolved oxygen. In River Tejo, Portugal, CCA on Rotifers *K. quadrata* and *K. cochlearis* showed their presence in areas where chlorophyll-a level is high while *H. mira*, also a Rotifer was found in areas where chlorophyll-a level is low. In Lake Abu Zaabal of Egypt, according to CCA; *B. quadridentatus* of the Rotifers has high relation with temperature. According to CCA; *C. sphaericus* was in areas where dissolved oxygen and temperature level are low (Lougheed and Chow-Fraser, 2002). Lougheed and Chow-Fraser (2002) reported that *C. quadrangula* was found in places where chlorophyll-a, conductivity and pH levels are low.

Similarities between stations with our CCA in the evaluation species distribution are similiar in December in the 3rd and the 4th stations, but the 2nd station has similarities in November and December. In addition, the 2nd

station has similarities in March and October, the 3rd station has similarities in September and April (Fig. 8).

The result of this study suggests that the rotifers, *S.pectinata, P. dolichoptera, F. longiseta, B. angularis, H. mira, C. dossuarius, T. similis, T. cylindrica* and *T. capucina* and the crustaceans; *M. leuckarti bodanicola* were less sensitive to environmental variables.

Pearson and Kendall's correlation coefficient indicated that several environmental variables including temperature, conductivity, dissolved oxygen, ammonium, pH, organic substance and chloride a considerable influence on the zooplankton abundance.

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