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Zooplankton Fauna of Demrek Dam Lake (Kırıkhan, Hatay)

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ABSTRACT

The annual average of Secchi disk depth (100.42 ±38. 99 cm), water temperature (21.06±5.96 ºC), dissolved oxygen (8.33±0.99 mg/l), nitrate (0.43±0.19 mg/l), nitrite (0.02±0.01), hardness (172±17.27 mg/l), silica (1.17±0.28 mg/l), phosphate (0.14±0.03 mg/l), organic phosphate (1.09 ±0.56 mg/l) and chlorophyll-*a* (0.05±0.03 mg /l) were detected and according to these values, it was determined that the reservoir water has eutrophic and hyperneurophic character. Rotifera had the highest proportion with 45 taxa, followed by Cladocera with 11 species and Copepoda with 7 species. *Asplanchna priodonta*, *Keratella cochlearis*, *Polyarthra dolichoptera*, *Sychaeta stylata Bosmina longirostris*, *Diaphanosoma birgei*, and *Disparalona rostrata* were present throughout the whole study period. The most abundant species from Rotifera was *Sychaeta stylata* (26034±56482.24 ind./m^3) followed by *Polyarthra dolichoptera* (15356±9593.48 ind./m^3) and *Keratella cochlearis* (11850±15441.51 ind./m^3). In the study, the most common species belonging to Cladocera was *Ceriodaphnia pulchella* (7042±6759.93 ind./m^3) and the most abundant copepod species was *Cyclops vicinus* (2553±1596.48 ind./m^3).

Keywords: Demrek Dam Lake, water quality, zooplankton

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Demrek Baraj Gölü (Kırıkhan, Hatay) Zooplankton Faunası

Öz: Yıllık ortalama secchi disk derinliği (100,42 ± 38,99 cm), su sıcaklığı (21,06 ± 5,96 ºC), çözünmüş oksijen (8,33 ± 0,99 mg / l), nitrat (0,43 ± 0,19 mg / l), nitrit (0,02 ± 0,01), sertlik (172 ± 17,27 mg / l), silikat (1,17 ± 0,28 mg / l), fosfat (0,14 ± 0,03 mg / l), organik fosfat (1,09 ± 0,56 mg / l) ve klorofil-a (0,05 ± 0,03 mg / l) tespit edildi ve bu değerlere göre rezervuar suyunun ötrofik ve hiperneurofik karaktere sahip olduğu belirlendi. Rotifera 45 taksonla en yüksek orana sahipken, onu 11 tür ile Cladocera ve 7 tür ile Copepoda izledi. Bütün çalışma süresince *Asplanchna priodonta*, *Keratella cochlearis*, *Polyarthra dolichoptera*, *Sychaeta stylata*, *Bosmina longirostris*, *Diaphanosoma birgei* ve *Disparalona rostrata* mevcuttu. Rotifera'dan en bol bulunan tür *Sychaeta stylata* (26034 ± 56482,24 birey /m^3) iken, bunu *Polyarthra dolichoptera* (15356 ± 9593,48 birey /m^3) ve *Keratella cochlearis* (11850 ± 15441,51 birey/m^3) takip etmiştir. Çalışmada Kladosera'ya ait en yaygın türün *Ceriodaphnia pulchella* (7042 ± 6759,93 birey /m^3) ve Kopepoda'ya ait en bol türün ise *Cyclops vicinus* (2553 ± 1596,48 birey /m^3) olduğu belirlenmiştir.

Anahtar kelimeler: Demrek Baraj Gölü, su kalitesi, zooplankton

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Introduction

The zooplanktonic organisms living in the lake ecosystem not only form the nutrients of planktivorous fish but also become a source of food for all insects, fish larvae, invertebrates, and other aquatic animals in the ecosystem. Besides, zooplankton are potential indicators for the water properties, pollution, and eutrophication status of the waters in which they are found (Hecky and Kilham 1973; Bērzinš and Pejler 1987; Mikschi 1989).

Various studies have reported that there is a close relationship between the efficiency of the aquatic environment and zooplanktonic organisms; since pollution has negative effects on zooplankton. In lake ecosystems, there is a balance between the living and inanimate factors of the lake.

Since the damages caused by people to nature disrupt the balance of the ecosystem, a considerable part of the living organisms in the lakes are destroyed due to pollution. The most important factor that disrupts the balance in the ecosystem is the unconscious exploitation of the environment to meet the luxurious living needs of the growing population. Studies on zooplanktonic organisms, which constitute the nutrients of many fish species in their younger periods and that transform the plant foods into animal proteins in the aquatic environment, have also been accelerated (Güher 1999).

As a result of the increase in industrial, domestic, and agricultural waste disposal into water systems, there is an accumulation of highly nutritious elements leading to eutrophication.

Since excessive phytoplankton growth and biological pollution are involved in eutrophication, plankton studies are important to provide information about ecosystems on topics such as the biodiversity of the lakes, pollution, and trophic levels. Turkey is considered as rich in terms of inland water resources. It is necessary to know the inland waters, aquatic organisms, and their distribution in our country for using these inland water resources efficiently.

No previous studies have been conducted in Demrek Dam Lake, where zooplankton species diversity and some water quality characteristics were investigated. On the other hand, this study, which is carried out in the dam lake, is important in terms of being an example for the next studies.

Materials and Methods

The study was carried out between April 2013 and March 2014 in Demrek Dam Lake, which has 48 ha lake area, in Hatay province Hassa district (Figure 1). Demrek Dam Lake has 1995 hm^3 water storage volume, 276 ha irrigation capacity, its construction started in 1997, its construction was completed in 2006 and it was put into operation in 2006 (Anonymous 2006).

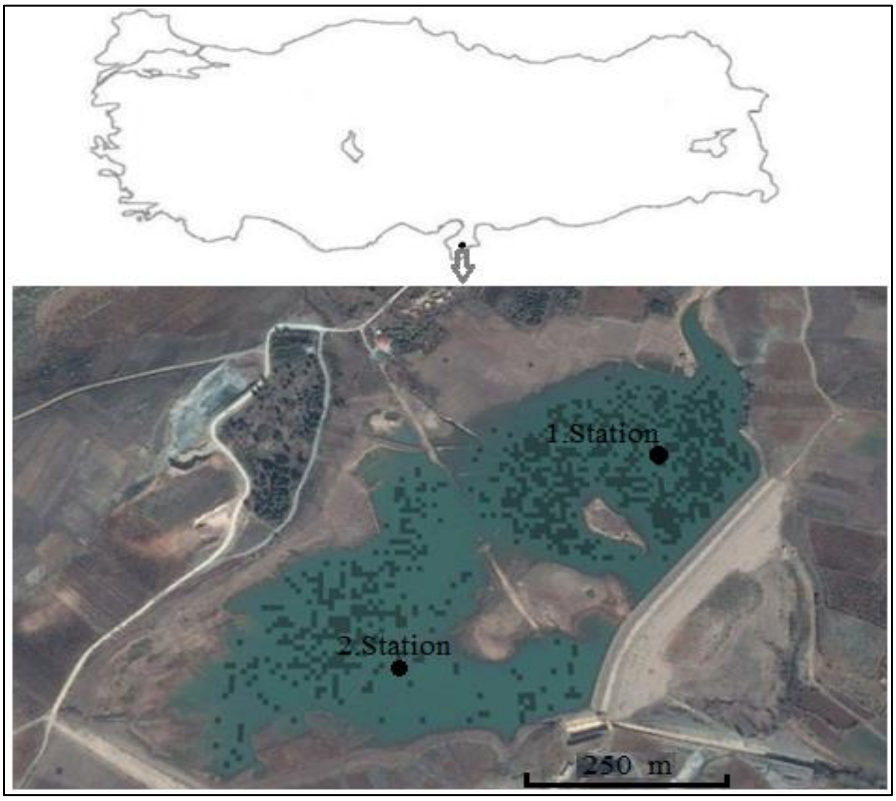

Figure 1. Demrek Dam Lake and sampling stations.

Zooplankton samples were taken from 2 stations with horizontal and vertical hauls by using 60 µm mesh size plankton nets monthly for systematic analyses. Using the Nansen bottle, two liters of water samples were collected from each depth of the different water layers (surface, medium and deep) of both stations. Water quality parameters and chlorophyll-*a* were analyzed from water samples. For the chlorophyll-*a* analysis and chemical analyzes, one lt and 100 ml of the total water samples were used, respectively. The remaining part (4.9 lt) was filtered from a collector having a mesh size of 60 µm for zooplankton analyses. All zooplankton samples were fixed in 4% formaldehyde. Dissolved oxygen, water temperature, and conductivity were measured directly in the field using digital instruments (oxygen and temperature: YSI model 52 oxygen meter; conductivity: YSI model 30 salinometer). YSI 950 photometer and its procedure were used to determine nitrite nitrogen, nitrate nitrogen, phosphate phosphorus, Organic phosphate; the method in APHA 1995 was used to determine chlorophyll-*a* spectrophotometrically. Secchi depth was measured using a Secchi disk with a diameter of 20 cm.

The lowest depth at the stations was 4 m (station 1) and 7 m (station 2) in October, and the highest depth was 9 m and 12 m in May, respectively. Species identifications were made using a binocular microscope according to the works of Edmondson (1959), Scourfield and Harding (1966), Dussart (1967), Kiefer and Fryer (1978), Koste (1978), Negrea (1983), Segers (1995), De Smet (1996, 1997), Nogrady and Segers (2002), Hołyńska et al. (2003) and Benzie (2005). Zooplankton count was performed using an inverted microscope in a petri dish with 2 mm lines at the bottom. The sample cup was made homogenized by shaking and 2 cc sub-sample was taken from the cup and it was placed in a petri dish and the individuals of each species were separately counted. This process has been repeated 4-5 times.

CTM tolerance of the species (SPSS 20.1). Duncan's multiple range test (DMRT) was carried out for post hoc mean comparisons. Regression analysis was also carried out to evaluate the relationship between acclimation temperature and CTMin and CTMax ($p \leq 0.05$).

Results

Secchi disk depth reached the maximum depth of 160 cm in May and the minimum depth of 55 cm in September, with a mean value of 100.42 ±38. 99 cm (Table 1, Figure 2). The water temperature was close to regional seasonal norms, increased from spring to summer, and decreased from autumn to winter. Thus, it was ranged from 13.58 ºC in December to 31.42 ºC in August (annual average 21.06±5.96 ºC)

The highest and the lowest dissolved oxygen values were recorded in February and July as 9.70 and 6.83 mg/l, respectively (average 8.33±0.99 mg/l, over the study period; Table 1, Figure 2).

Nitrate and nitrite levels showed similar patterns during the study period and maximum levels were recorded in December and January (0.595 mg/l and 0.056 mg/l), respectively. The minimum nitrate level was 0.035 mg/l in November, but the minimum nitrite level was 0.009 mg/l in November and March (Figure 2). The mean nitrate and nitrite concentrations were 0.43±0.19 mg/l and 0.02±0.01 mg/l at the end of the study (Table 1).

Hardness showed irregular ups and downs in the summer, increasing properly from September to February, but remained almost stable in spring. The average, maximum, and minimum total hardness values were 172±17.27 mg/l, 205 mg/l, and 133.33 mg/l respectively.

The average silica level was 1.17±0.28 mg/l. Silica concentrations were observed as 0.635 mg/l in May, gradually increased to 1.588 mg/l in August, decreased to 0.932 mg/l until December, and reincreased to 1.422 mg/l in May.

Phosphate, the most vital nutrient affecting the productivity of natural water resources, was 0.14±0.03 mg/l, on average. The highest and the lowest phosphate values recorded in February and June were 0.192 mg/l and 0.104 mg/l, respectively (Table 1, Figure 2). Phosphate levels increased during the summer until August following a gradual decrease this month. It increased from October to February and decreased from here until June. The maximum, minimum, and mean organic phosphate values were 1.83 mg/l (November at the first station), 0.38 mg/l (January at the second station), and 1.09 ±0.56 mg/l, respectively (Table 1, Figure 2).

Chlorophyll-*a* ranging from 0.013 mg/l in March to 0.086 mg/l in June and September was averaged to be 0.05±0.03 mg/l (Table 1, Fig. 2). Chlorophyll a fluctuated irregularly from April to September, and it decreased from here to March.

Table 1. Maximum, minimum, and average values of water quality parameters.

	Secchi-disk(cm)	Temp (°C)	DO (mg/l)	Chl-a (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	SiO-Si (mg/l)	PO_4-P (mg/l)	Hard-ness	Org. PO_4 (mg/l)
Max	160.00	31.42	9.70	0.086	0.056	0.595	1.588	0.192	205.00	1.83
Min	55.00	13.58	6.83	0.013	0.009	0.035	0.635	0.104	133.33	0.38
Average	100.42 ±38.99	21.06 ±5.96	8.33 ±0.99	0.05 ±0.03	0.02 ±0.01	0.43 ±0.19	1.17 ±0.28	0.14 ±0.03	172.36 ±17.27	1.09 ±0.56

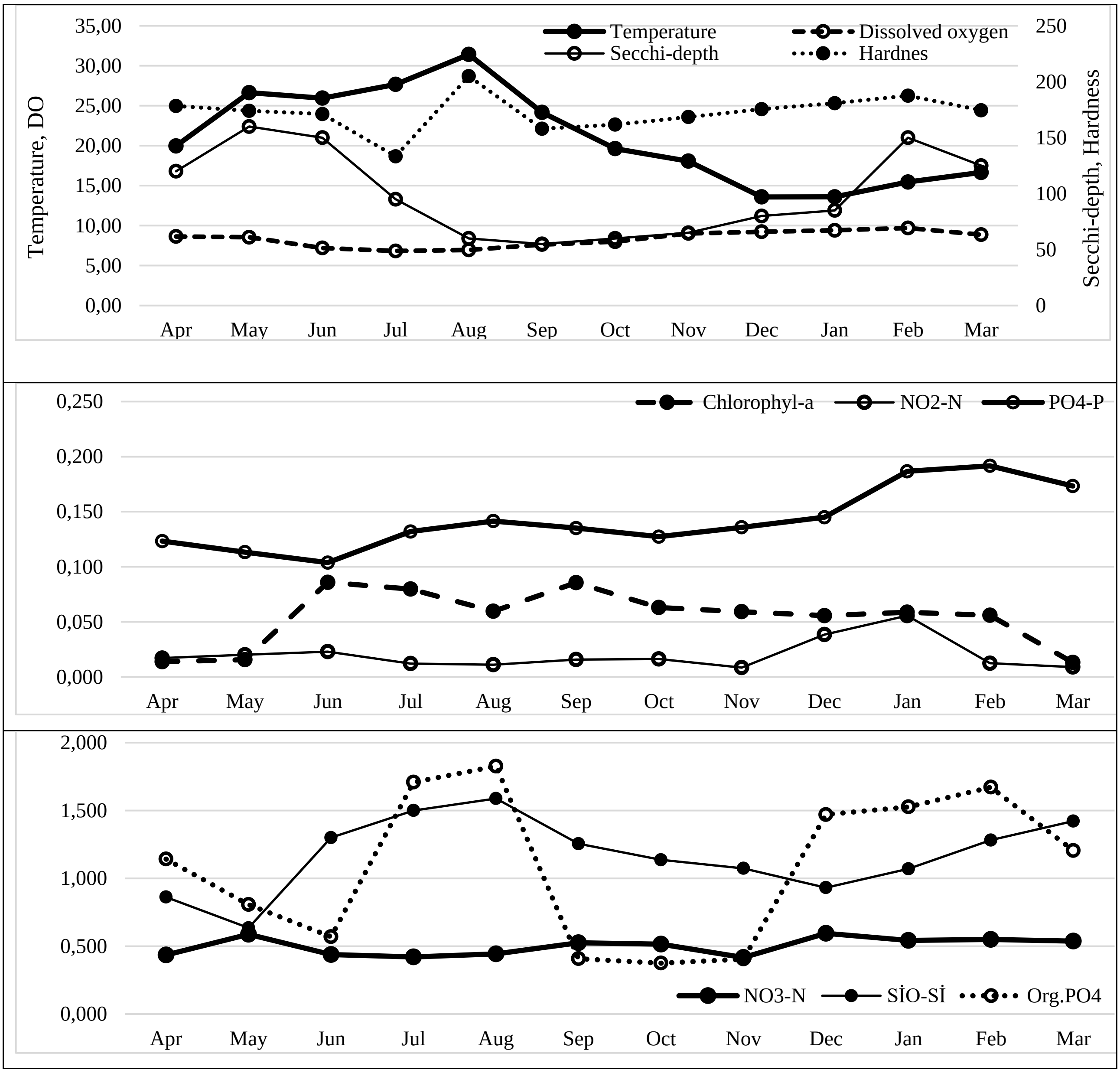

Figure 2. Monthly change of water quality parameters.

The zooplankton taxa identified in Demrek Dam Lake are shown in Table 2. The zooplankton assemblage included 63 species. Rotifera had the highest proportion with 45 taxa, followed by Cladocera with 11 species and Copepoda with 7 species.

A. priodonta, *K. cochlearis*, *P. dolichoptera*, *S. stylata B. longirostris*, *D. birgei* and *D. rostrata* were present throughout the whole study period. It was determined that these species were followed by *A. ovalis*, *F. longiseta*, *K. valga*, which were found for 11 months, and *T. similis*, which were found for 10 months.

Copepoda were found for 8 months. The least recorded species were as follows: *A. fissa*, *B. budapestinensis*, *B. urceolaris*, *B. quadridentatus*, *B. nilsoni*, *C. adriatica*, *C. colurus*, *Conochiloides* sp., *D. epicharis*, *E. dilatata*, *H. oxyuris*, *K. tecta*, *L. closterocerca*, *L. luna*, *L. hastata*, *L. hamata*, *L. stenroosi*, *L. tenuiseta*, *L. patella*, *L. rhomboides*, *L. ovalis*, *L. salpina*, *P. quadricornis*, *S. longicaudum*, *T. patina*, *T. porcellus*, *T. tigris*, *A. guttata*, *C. sphaericus*, *I. sordidus*, *P. laevis*, *C. vicinus*, *D. bicuspidatus*, *M. albidus*, *M. leuckarti*, *P. chiltoni*, *B. minutus*, *N. hibernica*

In terms of numbers, according to the monthly distribution of the groups, the highest numbers of Rotifera were found with 22 taxa in July, followed by 21 taxa recorded in November, 20 taxa in October, but only 10 taxa were determined in April. Cladocera showed the highest number of taxa in May with 9 taxa, followed by April, June, July, October, and March with 7 taxa and November with 6 taxa. Only 3 species of Cladocera was found in January. Copepoda showed the maximum diversity with 3 taxa in July and

October, followed by June and November with 2 taxa and April, September, January, March with 1 taxa. Copepoda species did not appear in May, August, December, and February. Total zooplankton was the highest with 32 species in July, followed by October with 30 species. It was determined to be the least with 18 species in April and August (Table 2).

Table 2. Zooplankton species list and monthly availability.

	Apr 2013	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2014	Feb	Mar
Rotifera												
Anuraeopsis fissa Gosse, 1851			+	+		+						
Ascomorpha ovalis (Bergendahl, 1892)		+	+	+	+	+	+	+	+	+	+	+
Asplanchna priodonta Gosse, 1850	+	+	+	+	+	+	+	+	+	+	+	+
Brachionus angularis Gosse, 1851	+	+	+	+	+	+		+	+			
Brachionus budapestinensis Daday, 1885				+			+	+				
Brachionus urceolaris Müller, 1773	+											
Brachionus quadridentatus Hermann, 1783				+			+	+				
Brachionus nilsoni Ahlstrom, 1940		+										
Cephalodella gibba (Ehrenberg, 1830)		+	+	+			+	+	+	+	+	+
Collotheca pelagica (Rousselet, 1893)			+	+				+	+			
Colurella adriatica Ehrenberg, 1831										+	+	
Colurella colurus (Ehrenberg, 1830)	+											
Conochiloides sp.						+	+	+			+	
Dicranophorus epicharis Harring & Myers, 1928	+											
Euchlanis dilatata Ehrenberg, 1832									+	+	+	
Filinia longiseta (Ehrenberg, 1834)		+	+	+	+	+	+	+	+	+	+	+
Filinia opoliensis (Zacharias, 1898)			+	+		+	+	+		+		
Hexarthra oxyuris (Sernov, 1903)									+			
Itura aurita (Ehrenberg, 1830)				+	+	+	+	+		+	+	
Keratella tecta (Gosse, 1851)			+	+		+						
Keratella cochlearis (Gosse, 1851)	+	+	+	+	+	+	+	+	+	+	+	+
Keratella valga (Ehrenberg, 1834)		+	+	+	+	+	+	+	+	+	+	+
Lecane closterocerca (Schmarda, 1859)										+		+
Lecane luna (Müller, 1776)												+
Lecane lunaris (Ehrenberg, 1832)							+		+	+		+
Lecane hastata (Murray, 1913)								+				
Lecane hamata (Stokes, 1896)											+	
Lecane stenroosi (Meissner, 1908)			+									
Lecane tenuiseta Harring, 1914								+				
Lepadella patella (Müller, 1773)		+				+					+	
Lepadella rhomboides (Gosse, 1886)							+					
Lepadella ovalis (Bergendahl, 1892)	+											
Lophocharis salpina (Ehrenberg, 1834)									+			
Notholca squamula (Müller, 1786)			+	+				+	+	+	+	+
Platyias quadricornis (Ehrenberg, 1832)							+					
Polyarthra dolichoptera Idelson, 1925	+	+	+	+	+	+	+	+	+	+	+	+
Rotaria neptunia (Ehrenberg, 1830)	+		+	+			+					+
Scaridium longicaudum (Müller, 1786)					+							
Sychaeta stylata Wierzejski, 1893	+	+	+	+	+	+	+	+	+	+	+	+
Testudinella patina (Hermann, 1783)				+	+							
Trichocerca similis (Wierzeski, 1893)		+	+	+	+	+	+	+	+		+	+
Trichocerca pusilla (Jennings, 1903)		+	+	+	+	+				+		
Trichocerca porcellus (Gosse, 1851)							+					
Trichocerca tigris (Müller, 1786)			+					+				
Trichotria tetractis (Ehrenberg, 1830)				+			+	+			+	
Total rotifer	**10**	**13**	**19**	**22**	**13**	**16**	**20**	**21**	**16**	**16**	**17**	**14**
Cladocera												
*Bosmina longirostris (Müller, 178*5)	+	+	+	+	+	+	+	+	+	+	+	+
Ceriodaphnia pulchella Sars, 1862	+	+		+			+				+	+
Diaphanosoma birgei Korinek,1981	+	+	+	+	+	+	+	+	+	+	+	+
Macrothrix laticornis (Jurine, 1820)	+	+	+	+	+		+	+				
Moina micrura Kurz, 1875		+	+	+	+	+	+	+				
Alona guttata Sars, 1862	+	+	+	+			+	+	+			+
Coronatella rectangula (Sars, 1862)											+	
Chydorus sphaericus (Müller, 1776)		+										+

Table 2. Continued.

	Apr 2013	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2014	Feb	Mar
Cladocera												
Disparalona rostrata (Koch, 1841)	+	+	+	+	+	+	+	+	+	+	+	+
Ilyocryptus sordidus (Lievin, 1848)	+											+
Pleuroxus laevis Sars, 1862		+	+									
Total cladocer	**7**	**9**	**7**	**7**	**5**	**4**	**7**	**6**	**4**	**3**	**5**	**7**
Copepoda												
Cyclops vicinus Ulyanin, 1875	+						+					+
Diacyclops bicuspidatus (Claus, 1857)										+		
Macrocyclops albidus (Jurine, 1820)							+					
Mesocyclops leuckarti (Claus, 1857)			+	+			+					
Paracyclops chiltoni (Thomson, 1882)			+					+				
Bryocamptus minutus (Claus, 1863)				+		+						
Nitokra hibernica (Brady, 1880)				+				+				
Total copepod	**1**	**0**	**2**	**3**	**0**	**1**	**3**	**2**	**0**	**1**	**0**	**1**
Total zooplankton	**18**	**22**	**28**	**32**	**18**	**21**	**30**	**29**	**20**	**20**	**22**	**22**

Table 3. Monthly abundance of zooplankton

Species Months	**April 2013**	**May**	**June**	**July**	**Aug**	**Sept**
Rotifera						
A. fissa			6702	1126		355
A. ovalis		1858	4204	74275	1879	15074
A. priodonta	728	9299	13241	9081	4442	4402
B. angularis	666	1423	909	15268	728	1634
B. budapestinensis				293		
B. quadridentatus				327		
C. gibba		306	303	502		
C. pelagica			758	248		
C. colurus	259					
Conochiloides sp						1862
D. epicharis	476					
E. dilatata						
F. longiseta		1000	1352	2519	571	939
F. opoliensis			294	250		692
H. oxyuris						
I. aurita				2055	284	370
K. tecta			1251	327		357
K. cochlearis	3686	13508	5849	9333	1270	852
K. valga		4686	2552	10566	2277	2491
L. closterocerca						
L. luna						
L. lunaris						
L. hamata						
L. stenroosi			256			
L. patella		1143				365
L. salpina						
N. squamula			769	333		
P. quadricornis						
P. dolichoptera	18620	4530	4440	19608	4719	23590
R. neptunia	667		825	770		
S. stylata	11007	6251	9802	21244	712	14023
T. patina				250	313	
T. similis		625	13036	6355	822	1987
T. pusilla		625	10852	2766	15397	706
T. tigris			513			
T. tetractis				251		
Average rotifer	**4514± 6763.08**	**3771± 4139.50**	**4100± 4529.23**	**8079± 16171.94**	**2785± 4248.77**	**4356±6906.58**

Table 3. Continued.

Species Months	**April 2013**	**May**	**June**	**July**	**Aug**	**Sept**
Cladocera						
B. longirostris	1567	5983	11564	4372	33154	2271
C. pulchella	15423	13799		1154		
D. birgei	1095	1508	640	3787	28102	10512
M. laticornis	1664	283	431	438	455	
M. micrura		287	280	1928	851	713
C. rectangula	1997	6990	464	894		
A. guttata						
D. rostrata	913	2087	1080	1269	690	763
Average cladocer	**3777± 5719.13**	**4420± 4918.21**	**2410± 4493.06**	**1977± 1512.97**	**12650± 16508.74**	**3565±4687.58**
Copepoda						
C. vicinus	3788					
D. bicuspidatus						
M. albidus						
M. leuckarti			303	580		
P. chiltoni			303			
N. hibernica				763		
Average copepod	**3788±0**	**0±0**	**303±0**	**672±129,40**	**0±0**	**0±0**
Average zooplankton	**4026± 422.30**	**4095± 2386.59**	**2271± 1902.51**	**3576± 3954.25**	**7717± 6647.33**	**3960± 2320.57**

Species Months	**Oct**	**Nov**	**Dec**	**Jan 2014**	**Febr**	**Marc**	**Average**
Rotifera							
A. fissa							**2728±3463.39**
A. ovalis	2616	889	290	784	4371		**10624±22772.80**
A. priodonta	27286	1080	20476	1612	1201	891	**7812±8641.56**
B. angularis		521	276				**2678±5107.07**
B. budapestinensis	2483	3141					**1972±1491.09**
B. quadridentatus							**327±0**
C. gibba	451	520	295	1863	692		**617±521.99**
C. pelagica		272	279				**389±246.19**
C. colurus							**259±0**
Conochiloides sp	1403	3867			939		**2018±1289.13**
D. epicharis							**476±0**
E. dilatata			267	882	293		**481±347.81**
F. longiseta	14606	2194	537	907	999	253	**2352±4121.02**
F. opoliensis	1462	771		293			**627±466.21**
H. oxyuris			273				**273±0**
İ. aurita	12132	257		295	2056		**2493±4330.34**
K. tecta							**645±525.03**
K. cochlearis	48237	6669	2949	38695	10508	640	**11850±15441.51**
K. valga	76334	13275	2008	1858	1567		**11761±23048.84**
L. closterocerca				291		2562	**1427±1605.84**
L. luna						258	**258±0**
L. lunaris	998		276	577		945	**699±338.49**
L. hamata					287		**287±0**
L. stenroosi							**256±0**
L. patella					295		**601±470.69**
L. salpina			280				**280±0**
N. squamula		274	4845	2944	557	262	**1426±1782.20**
P. quadricornis	325						**325±0**
P. dolichoptera	27206	25262	1566	26716	12435	15574	**15356±9593.48**
R. neptunia	332					927	**704±228.30**
S. stylata	204367	4407	16644	13529	8485	1936	**26034±56482.24**
T. patina							**282±44.55**
T. similis	2714	8982	172		1079	989	**3676±4351.43**

Table 3. Continued.

Species Months	Oct	Nov	Dec	Jan 2014	Febr	Marc	Average
T. pusilla				285			**389±6435.50**
T. tigris		265					**389±175.36**
T. tetractis	318	276			317		**291±32.81**
Average rotifer	**24898± 50776.53**	**4051± 6401.44**	**3215± 6167.40**	**6102± 11515.92**	**2880± 3964.39**	**2294± 4462.00**	**5920±6180,93**
Cladocera							
B. longirostris	14780	1653	2235	3583	803	2188	**7013±9291.93**
C. pulchella	1988				276	9610	**7042±6759.93**
D. birgei	2719	3755	3210	2209	2125	1210	**5073±947.53**
M. laticornis	2856	772					**986±947.53**
M. micrura	2844	255					**1023±995.35**
C. rectangula	935	268	315			375	**1530±2278.08**
A. guttata					262		**262±0**
D. rostrata	4726	1291	1054	946	577	386	**1315±1158.28**
Average cladocer	**4407± 4713.55**	**1332± 1310.06**	**1704± 1278.26**	**2246± 1318.89**	**809± 769.58**	**2754± 3904.36**	**3504±3108.37**
Copepoda							
C. vicinus	750					3120	**2553±1596.48**
D. bicuspidatus				288			**288±0**
M. albidus	993						**993±0**
M. leuckarti	987						**623±344.053**
P. chiltoni		266					**285±26.16**
N. hibernica		780					**772±12.02**
Average copepod	**523± 138,60**	**523± 363,45**	**0±0**	**288±0**	**0±0**	**3120±0**	**768±1285.49**
Average zooplankton	**9943± 13096.48**	**1969± 1848.16**	**2459± 1608.47**	**2879± 2958.18**	**1844± 1485.37**	**2723± 413.89**	**3398±2319.00**

The most abundant species from Rotifera was *S. stylata* (annual average 26034±56482.24 ind./m^3). *P. dolichoptera* (15356±9593.48 ind./m^3) and *K. cochlearis* (11850±15441.51 ind./m^3) were found the second and third abundant species, respectively. The least abundant species was *L. stenroosi* (256±0 ind./m^3).

In this study, the most common species belonging to Cladocera was *C. pulchella* (7042±6759.93 ind./m^3) according to their annual averages. The second abundant species was *B. longirostris* (7013±9291.93 ind./m^3) and followed by *D. birgei* (5073±7700.78 ind./m^3). The most abundant copepod species was *C. vicinus* (2553±1596.48 ind./m^3) followed by *M. albidus* (993±0 ind./m^3) and *N. hibernica* (772±12.02 ind./m^3). The least abundant cladoceran species were *A. guttata* (262±0 ind./m^3) and copepod *P. chiltoni* (285±26.16 ind./m^3).

Considering their monthly abundance, the most abundant species was rotifer *S. stylata* (October 2013, 204367 ind./ m^3) and followed by *K. valga* (October 2013, 76334 ind./ m^3), and *A. ovalis* (July 2013, 74275 ind./m^3). The least abundant species was *T. similis* obtained in December 2013 (172 ind./m^3) (Table 3).

The most abundant species were copepod *C. vicinus* (April 2013, 3788 ind./m^3) and cladoceran *B. longirostris* (August 2013, 33154 ind./m^3). Other abundant species were cladoceran *D. birgei* (August 2013, 28102 ind./m^3), *C. pulchella* (April 2013, 15423 ind./m^3), copepod *M. albidus* (October 2013, 993 ind./m^3), *M. leuckarti* (October 2013, 987 ind./m^3) and *N. hibernica* (780 ind./m^3). The least abundant species from Cladocera were *A. guttata* (February 2014, 262 ind./m^3) and copepod *P. chiltoni* (November 2013, 266 ind./m^3) (Table 3).

The most dominant rotifer (24898±50776.53 ind./m^3), and total zooplankton (9943±12231.09 ind./m^3) were obtained in October 2013, cladocer in August 2013 (12656±16508,74 ind./m^3) and copepod in April 2013 (3788±0 ind./m^3). The mean rotifer, cladocer and copepod abundance were 5920±6180.91 ind./m^3, 3504±3108.29 ind./m^3 and 768±1285.49 ind./m^3 in the dam lake respectively. The mean zooplankton was the most abundant in October (9943 ± 41292.83), followed by August (7717 ± 10100.33) and May (4095 ± 4317.16), but the least abundant zooplankton was in February (1844 ± 3566.94) (Table 3).

It has been determined that Rotifera, Cladocera, Copepoda and average zooplankton showed monthly irregular and unstable fluctuations, and peaked in the middle of summer and autumn. Copepod was not found in quantitative samples in May, August, September, December, and February (Figure 3, Table 3).

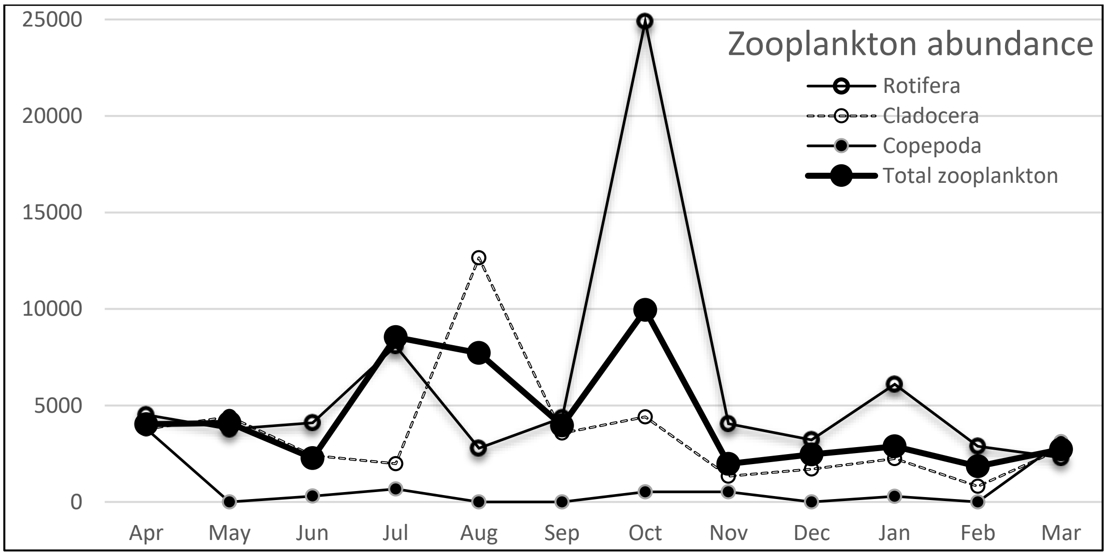

Figure 3. Monthly abundances of zooplankton.

Table 4. Relationship levels between water quality parameters and zooplankton abundance.

	Rotifera	**Cladocera**	**Zooplankton**
Temp (°C)	$R^2 = 0.09$	$R^2 = 0.61$	$R^2 = 0.34$
DO (mg/l)	$R^2 = 0.17$	$R^2 = 0.34$	$R^2 = 0.45$
Chl-a (mg/l)	$R^2 = 0.14$	$R^2 = 0.04$	$R^2 = 0.04$
NO_2-N (mg/l)	$R^2 = 0.01$	$R^2 = 0.05$	$R^2 = 0.08$
NO_3-N (mg/l)	$R^2 = 0.07$	$R^2 = 0.07$	$R^2 = 0.12$
SiO-Si (mg/l)	$R^2 = 0.04$	$R^2 = 0.46$	$R^2 = 0.21$
PO_4-P (mg/l)	$R^2 = 0.08$	$R^2 = 0.17$	$R^2 = 0.24$
Hardnes	$R^2 = 0.54$	$R^2 = 0.57$	$R^2 = 0.43$
Org. PO_4 (mg/l)	$R^2 = 0.15$	$R^2 = 0.18$	$R^2 = 0.26$

A significant functional relationship was found between zooplankton and water quality parameters (hardness-rotifer, $R^2 = 0.54$; temperature-cladocer, $R^2 = 0.61$; hardness-cladocer, $R^2 = 0.57$). A weak correlation was found between zooplankton and other water quality parameters (Table 4).

Discussion

Water quality parameters and zooplankton communities together form a comprehensive ecosystem having interaction between both zooplankton and phytoplankton and the water quality parameters. These interactions are directly or indirectly subjected to the complex influences, some of which results in quantitative changes (Welch 1952). Water quality parameters in the study were observed to be within the normal values for animals in the water. According to this, water temperature values (13.58-31.42 ºC) in the study generally reflect the climatic conditions of the region and they are ideal for zooplankton and their development. Mean dissolved oxygen concentrations were above 5 mg/l (6.83-9.70 mg/L) which was enough to support aquatic life, especially the zooplankton community (Karpowicz and Ejsmont-Karabin 2017).

The mean value of chlorophyll-*a* was relatively high (0.013-0.086 mg /L) and indicated that the lake has a eutrophic character, according to Wetzel (1975).

Inorganic forms of nitrogen (NO_3^- and NO_2^-) can be used by aquatic plants and algae (Tepe and Boyd 2002). If these inorganic forms of nitrogen exceed 0.3 mg/l (as N) in spring, it means there is enough nitrogen to support summer algal blooms. The concentrations of nitrogen forms in Demrek Dam

Lake were enough to support algae blooms and indirectly zooplankton biomass. The quality of reservoir waters generally varied between clean water and much-polluted water throughout the year in terms of nitrite values (YSKY 2012). As the nitrate-nitrogen values determined in the study were below 10 mg/l, thus the reservoir waters were in the category of clean and less polluted water.

Orthophosphate values changed between 0.104 mg/l and 0.192 mg/l and the reservoir waters generally have the second-class polluted water and the third-class polluted water in terms of phosphate according to the YSKY (2012). As a result, according to the Regulation on Surface Water Quality, reservoir water was first-class water in point of NO_3-N, partly also dissolved oxygen, and third class water in point of NO_2-N (YSKY 2012).

The annual mean values of total phosphorus and chlorophyll-a with 0.14 mg/L and 0.05 mg/L respectively also make the lake in hyper-eutrophic class according to YSKY (2012). The Dam Lake was determined to be eutrophic in terms of average Secchi disc depth and mesotrophic in terms of nitrogen (YSKY 2012).

Since there is a close relation between phytoplankton and zooplankton because of the food chain, increases were observed in zooplankton biomass following the phytoplankton bloom. The highest amount of Rotifera was reported in the area where phytoplankton bloom occurred, as they consequently found abundant food sources (Ruttner-Kolisko 1974; Horn and Goldman 1994; Noges 1997). Similar results were found in the present study. In May, chlorophyll increased due to decreased zooplankton. In the following months, the amount of zooplankton was decreased with a decrease in chlorophyll-*a* but increased with an increase in chlorophyll-*a*.

Zooplankton species diversity and abundance of Demrek Dam Lake seem to be considerably rich compared with other studies carried out in different Turkish lakes [17 Rotifera species in Yamansaz Lake (Yalım 2006); 16 Rotifera species in Hazar Lake (Tellioğlu and Şen 2002); a total of 17 species, 10 belong to Rotifera, 5 to Cladocera and 2 to Copepoda, in Lake Burdur (Altındağ and Yiğit 2002). Yıldız et al. (2007) declared that 41 species were found in Lake Marmara, including 29 Rotifera, 8 Cladocera, and 4 Copepoda. Bekleyen and Taş (2008) had found 10 species from Cladocera, 3 from Copepoda, and 18 from Rotifera (a total 31 species) in Çernek Lake. The same situation was observed in dam lakes. Results of some studies were as follow: 54 species were declared in Aslantaş Dam Lake, including 35 Rotifera, 14 Cladocera, and 5 Copepoda (Bozkurt et al. 2009; Bozkurt and Göksu 2010); totally 39 taxa declared, containing 21 rotifer, 11 cladocer and 7 copepod in Birecik Dam Lake (Bozkurt and Sağat 2008). Some others; 11 rotifer, 7 cladocer and 1 copepod, 19 species in total in Çamlıgöze Dam Lake (Dirican and Musul 2008); 12 cladocer, 5 copepod, 17 species in total in Devegeçidi Dam Lake (Bekleyen 2006); 8 cladocer, 2 copepod, 10 species in total in Çatalan Dam Lake (Aladağ et al. 2006); 18 rotifer, 9 cladocer and 4 copepod, 31 species in total in Hirfanlı Dam Lake (Yiğit and Altındağ 2005); 11 rotifer in Kesikköprü Dam Lake (Yiğit 2002); 21 rotifer, 7 cladocer and 4 copepod, 32 species in total in Kurtboğazı and Çamlıdere Dam Lakes (Demir 2005); 8 cladocer and 4 copepod, 12 species in total in İkizcetepeler Dam Lake (Alper et al. 2007); 34 rotifer at Devegeçidi Dam Lake (Bekleyen 2001) and 28 rotifer, 16 cladocer and 3 copepod, 47 species in total were declared (Bekleyen 2003).

The simultaneous presence of several species of the genus *Brachionus* is a good indication for the eutrophic nature of an aquatic ecosystem (Angeli 1976; Mageed 2008; Uzma 2009). Patalas (1972) noticed that in the lakes of EUA the cyclopoid copepods were more abundant in eutrophic waters than calanoid copepods.

The results of the study are in accordance with the above information and a large number of species reported by various researchers as eutrification indicators have also been identified in the study. These species are *A. fissa*, *N. squamula*, *P. quadricornis*, *A. priodonta*, *K. cochlearis*, *P. dolichoptera*, *B. angularis*, *R. neptunia*, *B. urceolaris*, *B. quadridentatus*, *L. luna*, *L. lunaris*, *L. patella*, *T. patina*, *B. nilsoni*, *T. pusilla*, *T. tetractis*, *E. dilatata*, *F. longiseta*, *F. opoliensis*, *I. aurita*, *B. longirostris*, *M. micrura*, *K. tecta*, *D. birgei*, *C. rectangula*, *C. sphaericus*, *C. vicinus*, *M. leuckarti* (Pourriot 1964; Hutchinson 1967; Flössner 1972; Ruttner-Kolisko 1974; Koste 1978; Braioni and Gemlini 1983; Gulati 1983; Margaritora 1985; Koste and Shiel 1986; Saksena 1987; Pejler and Bērziņš 1994; Smith 2001; Lucinda et al. 2004; Baião and Boavida 2005). Considering the water quality parameters and the determined species, it can be said that the Demrek Dam Lake is eutrophic. The remaining species in the study are widely distributed in the inland water of Turkey and have been identified in many studies (Ustaoğlu et al. 2012; Ustaoğlu 2015).

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