

The effects of physicochemical parameters on fish distribution in Eğirdir Lake, Turkey

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Abstract

The present study was conducted based on the fish species and physicochemical parameters of Eğirdir Lake. Sampling was carried out monthly from January through December 2010 between 9 am and 11 am. The parameters measured were water temperature, depth, secchi disk depth, turbidity, dissolved oxygen, saturation of dissolved oxygen, pH, conductivity, chloride, hardness, calcium, magnesium, bicarbonate, carbonate, nitrate, nitrite, ammonium, sulphate, phosphate, silica, organic substance, acid power (SBV) and chlorophyll-a. Monthly sampling was performed at four stations at different depths. Water temperature ranged from 6.9 ± 0.5 °C in February to 26.8 ± 0.4 °C in August. Minimum secchi disk depth recorded was 0.5 m while the maximum was 2.4 m. Dissolved oxygen ranged from 4.2 ± 0.2 to 12.6 ± 0.6 mgL⁻¹. The pH values ranged from 8.4 to 9.6. In this study, 15 fish species, belonging to eight families were identified. Among the 15 fish species recorded, Cyprinidae was the dominant family followed by Percidae (3 %). According to detrended correspondence analysis (DCA), variables were able to explain 90 % of total variation suggesting a significant result. The results showed that water temperature, dissolved oxygen and saturation of dissolved oxygen were the most important physicochemical parameters affecting fish distribution. Other physicochemical parameters of this lake did not show any significant statistical differences in determining fish distribution.

Keywords: Eğirdir Lake, Fish distribution, Physicochemical parameters, Turkey

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Introduction

The distribution of fish species was effected by both biotic and abiotic factors (Kadye *et al.*, 2008). Predation factor was the main factor affecting fish populations with direct and indirect movements. Besides, the literature associated with resource fractionalisation among fishes suggest that competition plays an important role in the local organization of communities. On the other hand, abiotic components of both systems can be divided into chemical and physical factors (Ross, 1986; Jackson *et al.*, 2001).

Some physicochemical parameters such as temperature of water and oxygen are significant parameters that restrict survival, growth and distribution of fish (Akbulut, 2009). High temperatures may generate high physiological demands apart from reducing the dissolved oxygen levels in a water body. This phenomenon indicates the importance of oxygen and its relationship with water temperature (Jackson *et al.*, 2001). In Turkey, the study of physicochemical parameters with relation to fish were conducted at Köyceğiz Lagoon (Akin *et al.*, 2005) and Köprüçay River Estuary (Innal, 2012).

Historically, the first scientific research in Eğirdir Lake on fish community was done by Devedjian (1926). Several fish species such as Pike-perch (*Sander lucioperca*) (Akşiray, 1961), Prussian Carp (*Carassius gibelio*), Tench (*Tinca tinca*)

(Balık and Çubuk, 1999), Danube bleak (*Chalcarburnus chalcoides*) (Balık *et al.*, 2002) and Sand smelt (*Atherina boyeri*) (Yeğen *et al.*, 2006; Yerli *et al.*, 2013) were introduced into Eğirdir Lake. It was reported that, among the endemic species of Eğirdir Lake, Eğirdir minnow (*Pseudophoxinus egridiri* Karaman, 1972) is critically endangered (CR) (Küçük *et al.*, 2009). Several studies regarding the fish fauna in Eğirdir Lake which is the second largest freshwater source have been conducted (Kosswig and Geldiay, 1952; Ekmekçi and Erk'akan, 1997). However, the research about relationship between fish and physicochemical parameters have not been encountered. Hence, this study was conducted with the aim: - to describe the present fish fauna – and to determine the relationship between the fish distributions and physicochemical parameters.

Materials and methods

Study area

Eğirdir Lake is located at about 918 m above sea level with a maximum deepest of 13 m. With a total surface area of 47.250 ha. Eğirdir Lake is tectonic and oligotrophic. This lake is divided into two parts; the smaller part in the North is called Hoyran while the other part is called Eğirdir Lake. This lake generally has an inflow from three streams which are dried up and some springs in summers and it flows into Kovada Lake through a channel (Yarar and Magnin, 1997).

Sampling procedure

The fish specimens were collected monthly from January through December 2010 from four stations of Eğirdir Lake (Table 1, Fig. 1). Fishing was carried out with gillnets and trammel nets of different mesh sizes (10, 16, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 80, 100 mm) and seine-net (mesh size 0.9 mm). Water quality parameters were measured at each site. Physicochemical parameters such as dissolved oxygen and saturation dissolved oxygen were measured with a multiprobe YSI model 55 while conductivity, water temperature and pH were measured with a multiprobe YSI model 63. The other parameters such as chloride (Cl^-), bicarbonate (HCO_3^-),

carbonate (CO_3^{2-}), calcium (Ca^{2+}), magnesium (Mg^{++}), nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), silica (SiO_2), organic substance, acid power, hardness ($^\circ\text{F}$) and chlorophyll-a were measured using classical titrimetric and spectrophotometric methods (Egemen and Sunlu, 1996; Wetzel and Likens, 2000). Fish specimens were identified to species level according to Geldiay and Balık (2002) and Balık and Ustaoglu (2004). Secchi disk measurements were determined using a Secchi disk. Turbidity was measured with a Hatch Radio Turbidimeter.

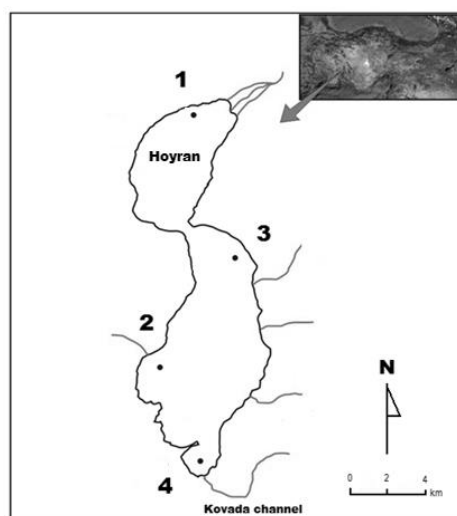


Figure 1: Location of sampling stations in Eğırdir Lake, Turkey.

Table 1: The coordinates of the study area

Stations	Coordinates
1 st station	38° 15' 48" N, 30° 49' 17" E
2 nd station	37° 58' 50" N, 30° 47' 32" E
3 rd station	38° 05' 14" N, 30° 55' 45" E
4 th station	37° 50' 52" N, 30° 51' 29" E

Statistical analyses

The PC-ORD version 4.14 for windows was used for the statistical analysis. Statistically, the relationship between fish and physicochemical parameters was analyzed with Detrended Correspondance Analysis (DCA) (Hill and Gauch 1980; Özkan *et al.*, 2010).

Results

A total of 15 taxa represented by eight families were identified. The fishes recorded during the study comprised Cyprinidae, Cobitidae, Cyprinodontidae, Poeciliidae, Atherinidae, Percidae and Gobiidae besides Balitoridae (Table 2) (Fig. 2). Furthermore, fish from seine-net, *Knipowitschia caucasica* formed (3 %) followed by *Gambusia affinis* (0.0048 %). The mean values of physicochemical parameters of water recorded according to months are given in Table 3a-c. The mean values of water temperature in Eğirdir Lake varied from 6.9 ± 0.5 to $26.8 \pm 0.4^\circ\text{C}$. Mean monthly temperature was 16.4 ± 0.4 . Values of pH ranging from 8.6 ± 0.8 to 9.6 ± 0.1 were measured and mean pH was 8.9 ± 0.2 . Conductivity recorded was between 261.8 ± 11.3 and 417.5 ± 39.7 μmhoscm^{-1} and mean conductivity was measured as 342 ± 5.03 μmhoscm^{-1} . Dissolved oxygen was between 4.2 ± 0.2 and 12.6 ± 0.6 mgL^{-1} and monthly average was recorded as 9.4 ± 0.02 mgL^{-1} . Chlorophyll-a concentration varied ranging from 1.3 ± 0.5 to 6.1 ± 2.7 mgm^{-3} . The highest chlorophyll-a concentration recorded at site 1 was in May. Mean chlorophyll-a

concentrations of all months was 3.0 ± 0.2 mg m^{-3} (Table 3a-c). According to statistical results of DCA; variances of axis constructed from the 1st axis to 3rd axis were 0.65, 0.24 and 0.09, respectively. As shown in Table 4, the relation between the 1st axis and temperature was positive while the, relation between dissolved oxygen and saturation of dissolved oxygen was negative. In addition, the relation between the 2nd axis and calcium was positive.

In this research, when the fish fauna are evaluated according to DCA, in the first axis, fish species such as *A.anatoliae*, *C.pestai* and *A.boyeri* were strongly correlated species. Based on this result, *A. anatoliae* ($r=0.778$) and *C.pestai* ($r=0.356$) showed positive correlation in the first axis, whereas *A.boyeri* ($r=-0.399$) showed negative correlation (Table 5). Meanwhile, in the second axis, fish species such as, *S.luciperca* ($r=0.855$) and *K.caucasica* ($r=-0.430$) were strongly correlated species. Based on these results, *S. luciperca* showed positive correlation, whereas *K.caucasica* showed negative correlation (Fig. 3).

Similarities between stations with DCA in the evaluation of species distribution are similar in May, June, August and October in all stations. In addition, the 3rd station has similarities in September and October (Fig. 4).

Table 2: Fish fauna of Eğirdir Lake, Turkey.

Family	Species
Cyprinidae	<i>Cyprinus carpio</i> L., 1758 (common carp)
	<i>Cyprinus carpio</i> L., 1758 (mirror carp)
	<i>Carassius gibelio</i> (Bloch, 1782)
	<i>Capoeta pestai</i> (Pietschmann, 1933)
	<i>Pseudophoxinus egridiri</i> (Karaman, 1972)
	<i>Pseudorasbora parva</i> (Temminck & Schlegel, 1846)
	<i>Vimba vimba</i> (Nordmann, 1840)
Cobitidae	<i>Cobitis turcica</i> Hankó, 1925
Cyprinodontidae	<i>Aphanius anatoliae</i> (Leidenfrost, 1912)
Poeciliidae	<i>Gambusia affinis</i> Baird and Girard, 1853
Atherinidae	<i>Atherina boyeri</i> Risso, 1810
Percidae	<i>Sander lucioperca</i> L., 1758
Gobiidae	<i>Knipowitschia caucasica</i> (Kawrajsky, 1899)
Balitoridae	<i>Seminemacheilus ispartensis</i> Erk' Akan, Nalbant & Özeren, 2007
	<i>Oxynoemacheilus mediterraneus</i> Erk' Akan, Nalbant & Özeren, 2007

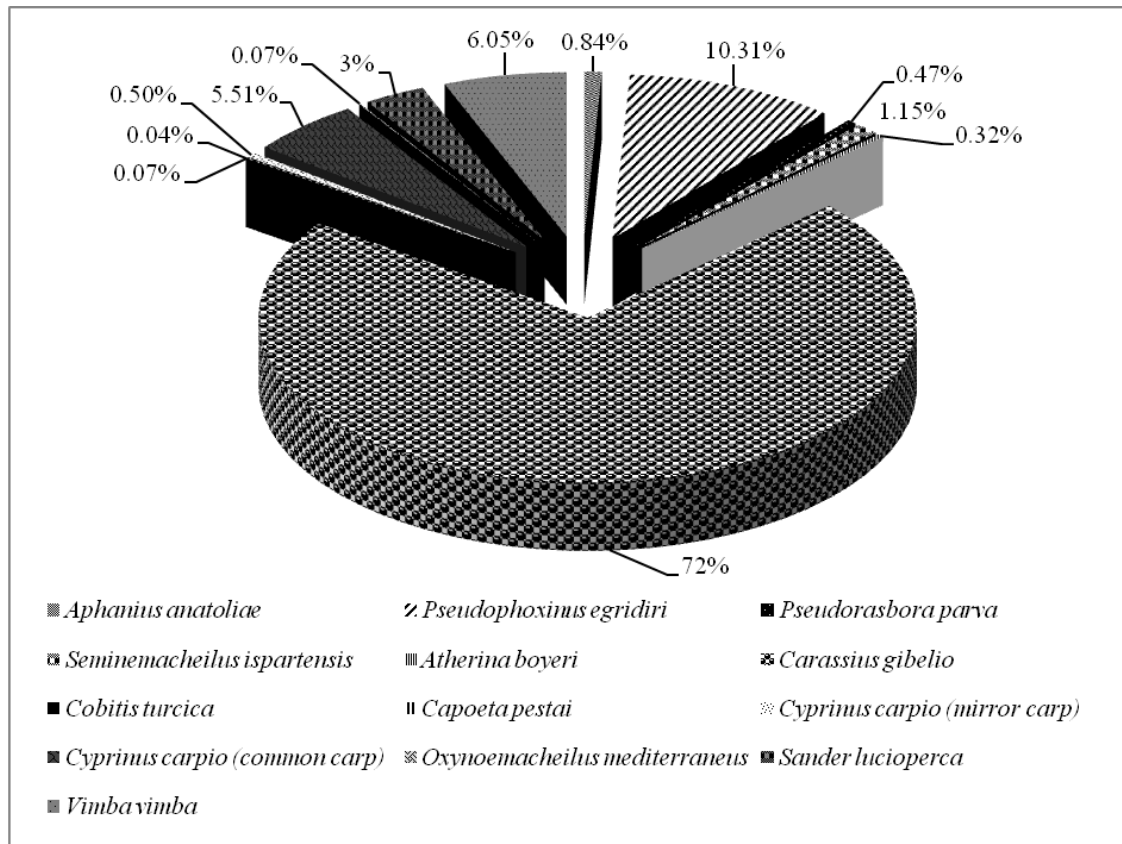


Figure 2: Distribution of the fish families in 2010.

Table 3a: The monthly mean values of some physicochemical parameters in Eğirdir Lake during the study in 2010.

Parameters Months	Water temperature (° C)	Secchi depth (m)	DO (mgL ⁻¹)	Saturation of DO (%)	pH	Conductivity (µmhoscm ⁻¹)	Depth (m)
January	7.2±0.2	1.7±1.0	11.3±0.7	93.3±5.1	8.7±0.2	271.4±5.4	4.7±2.0
February	6.9±0.5	0.5±0.3	11.9±0.3	95.5±6.6	8.7±0.2	261.8±11.3	5.4±1.0
March	12.5±1.9	1.3±0.4	10.6±0.4	98.7±2.6	8.7±0.1	310.5±20.8	5.9±1.0
April	15.0±1.9	1.2±0.2	10.0±0.4	98.2±5.0	8.8±0.1	336.1±25.9	5.1±0.7
May	18.8±0.5	1.6±0.2	8.0±0.5	87.3±6.3	8.8±0.2	365.3±11.3	5.1±1.5
June	22.8±0.7	1.8±0.8	7.6±0.2	91.5±2.7	8.6±0.8	390.5±10.2	5.8±1.2
July	26.2±1.0	2.0±0.8	7.6±1.4	94.0±18.1	8.9±0.1	417.5±39.7	5.1±0.9
August	26.8±0.4	2.4±1.1	4.2±0.2	52.3±2.8	9.0±0.2	379.1±50.6	4.9±1.3
September	22.8±0.4	1.5±0.4	7.8±1.2	87.7±8.2	9.1±0.2	372.8±49.2	5.6±1.1
October	16.3±0.4	1.7±0.8	10.8±0.7	102.1±7.9	8.4±0.1	400.5±15.3	4.1±1.9
November	13.0±0.6	2.0±1.2	10.9±1.1	101.6±10.1	9.1±0.3	323.6±9.7	5.1±0.6
December	8.2±0.1	0.8±0.4	12.6±0.6	106.5±4.8	9.6±0.1	273.8±19.9	5.7±0.4

Table 3b: The monthly mean values of some physicochemical parameters in Eğirdir Lake during the study in 2010.

Parameters Months	Turbidity (NTU)	Chloride (mgL ⁻¹)	Organic substance (mgL ⁻¹)	Bicarbonate (mgL ⁻¹)	Carbonate (mgL ⁻¹)	Hardness (° F)	Acid power SBV (mL acid)	Phosphate (mgL ⁻¹)
January	4.6±2.9	6.5±5.4	20.2±1.3	207.4±26.5	18.0±6.0	26.3±1.0	5.2±0.1	0.3±0.2
February	14.2±6.9	4.6±0.8	16.9±1.6	272.1±5.1	14.1±3.8	24.5±2.6	5.3±0.1	0.3±0.1
March	5.2±2.0	4.9±0.3	13.7±0.9	261.1±16.5	16.3±1.1	27.3±2.8	5.1±0.1	0.1±0.0
April	7.7±6.0	4.3±0.6	16.6±1.9	247.7±8.7	14.1±1.1	30.3±1.9	5.3±0.1	0.1±0.0
May	7.3±1.4	4.7±0.4	15.1±1.4	267.2±23.8	14.1±3.2	26.5±2.1	5.2±0.2	0.1±0.0
June	2.3±1.8	9.1±0.9	20.6±0.5	251.6±17.5	21.3±4.1	24.5±0.6	5.5±0.2	0.1±0.0
July	3.9±1.6	13.8±3.5	12.2±0.8	242.5±18.1	18.0±2.2	24.3±2.5	4.9±0.1	0.2±0.1
August	1.8±0.2	14.9±2.1	13.4±0.7	258.0±11.8	15.0±3.7	24.3±1.7	5.2±0.1	0.4±0.4
September	3.9±2.6	12.8±0.8	18.9±1.4	257.7±7.4	16.2±1.5	25.3±2.5	5.0±0.2	0.1±0.1
October	4.2±5.7	11.0±1.0	15.4±1.5	255.0±7.8	24.9±6.9	27.3±1.7	5.1±0.1	0.1±0.1
November	2.4±1.1	11.1±0.3	20.6±2.3	276.3±14.3	18.6±1.5	30.0±0.8	5.4±0.0	0.4±0.4
December	9.1±4.3	8.2±0.7	24.3±0.6	226.6±5.3	13.5±2.7	30.8±2.9	5.0±0.1	0.1±0.0

Table 3c: The monthly mean values of some physicochemical parameters in Eğirdir Lake during the study in 2010.

Parameters Months	Calcium (mgL ⁻¹)	Magnesium (mgL ⁻¹)	Nitrate (mgL ⁻¹)	Chlorophyll-a (mg/m ³)	Ammonium (mgL ⁻¹)	Sulphate (mgL ⁻¹)	Silica (mgL ⁻¹)	Nitrite (mgL ⁻¹)
January	54.0±15.3	31.6±8.2	1.2±0.3	4.3±1.6	0.1±0.0	19.7±10.5	4.4±1.7	0.04±0.02
February	49.1±14.0	29.8±11.1	1.0±0.7	1.3±0.5	0.3±0.4	47.1±21.8	4.8±1.9	0.03±0.01
March	38.1±4.0	42.9±5.8	1.0±0.4	2.4±0.6	0.1±0.0	50.9±17.3	2.4±0.9	0.04±0.02
April	43.1±10.0	47.6±1.6	1.1±0.1	3.2±0.3	0.1±0.0	43.6±12.3	2.4±0.4	0.03±0.01
May	39.1±2.0	40.7±5.0	1.3±0.3	6.1±2.7	0.1±0.1	39.4±14.6	3.2±0.9	0.03±0.00
June	52.1±3.3	28.0±1.4	2.6±0.2	2.4±0.8	0.1±0.0	35.3±3.1	3.3±0.8	0.01±0.00
July	33.1±6.8	38.9±4.4	2.6±1.2	1.7±0.7	0.1±0.0	25.7±6.5	4.7±1.7	0.02±0.00
August	33.1±3.8	38.9±2.0	3.8±0.7	2.8±0.6	0.1±0.0	53.3±19.4	4.6±0.7	0.03±0.01
September	36.1±7.3	39.5±8.7	0.9±0.2	2.0±0.3	0.1±0.0	42.9±14.5	5.3±0.4	0.03±0.00
October	27.1±3.8	49.8±3.1	1.1±0.2	4.4±1.4	0.1±0.0	48.3±16.3	6.7±0.5	0.04±0.00
November	39.1±3.8	49.1±3.8	1.4±0.5	2.8±1.3	0.4±0.3	27.3±7.8	6.3±0.7	0.06±0.01
December	42.1±5.2	49.2±7.0	2.6±1.1	2.9±0.4	0.2±0.0	40.4±5.2	4.6±0.5	0.04±0.01

Table 4: Pearson and Kendall correlations with ordination axes of physicochemical parameters.

	Axis I (r)	Axis II (r)	Axis III (r)
Depth	0.052	0.234	0.005
Secchi disk depth	0.323	-0.095	0.053
Turbidity	-0.134	0.331	-0.228
Temperature	0.526	-0.120	0.482
Conductivity	0.435	-0.160	0.291
pH	-0.062	-0.174	-0.029
DO	-0.556	0.038	-0.547
Saturation of DO	-0.460	-0.012	-0.457
Silica	-0.052	-0.123	-0.065
Nitrate	0.304	0.007	0.334
Nitrite	-0.224	-0.216	-0.264
Ammonium	-0.091	-0.067	-0.187
Phosphate	0.012	-0.070	0.147
Organic substance	-0.349	-0.011	-0.046
Chloride	0.228	-0.267	0.363
Bicarbonate	0.151	0.081	0.040
Carbonate	0.175	-0.374	-0.147
Hardness	-0.326	-0.113	-0.291
Calcium	-0.183	0.450	-0.120
Magnesium	-0.131	-0.397	-0.148
Acid power (SBV)	-0.028	0.145	-0.014
Sulphate	0.263	-0.350	-0.057
Chlorophyll-a	-0.056	-0.191	-0.044

Table 5: Pearson and Kendall correlations with ordination axes of fish species.

	Axis I (r)	Axis II (r)	Axis III (r)
<i>Atherina boyeri</i>	-0.399	-0.062	-0.146
<i>Carassius gibelio</i>	0.137	0.038	0.539
<i>Knipowitschia caucasica</i>	0.216	-0.430	-0.428
<i>Aphanius anatoliae</i>	0.778	0.013	-0.104
<i>Seminemacheilus ispartensis</i>	-0.048	-0.002	0.249
<i>Pseudorasbora parva</i>	0.003	-0.046	0.179
<i>Cyprinus carpio</i> (Common carp)	0.232	0.029	-0.006
<i>Oxynoemacheilus mediterraneus</i>	-0.137	0.012	-0.039
<i>Sander lucioperca</i>	0.051	0.855	-0.097
<i>Vimba vimba</i>	0.195	-0.086	-0.063
<i>Cyprinus carpio</i> (Mirror carp)	0.102	0.050	0.004
<i>Capoeta pestai</i>	0.356	-0.006	-0.057
<i>Pseudophoxinus egridiri</i>	-0.024	-0.182	0.563
<i>Cobitis turcica</i>	0.264	-0.127	0.519
<i>Gambusia affinis</i>	0.010	-0.133	0.332

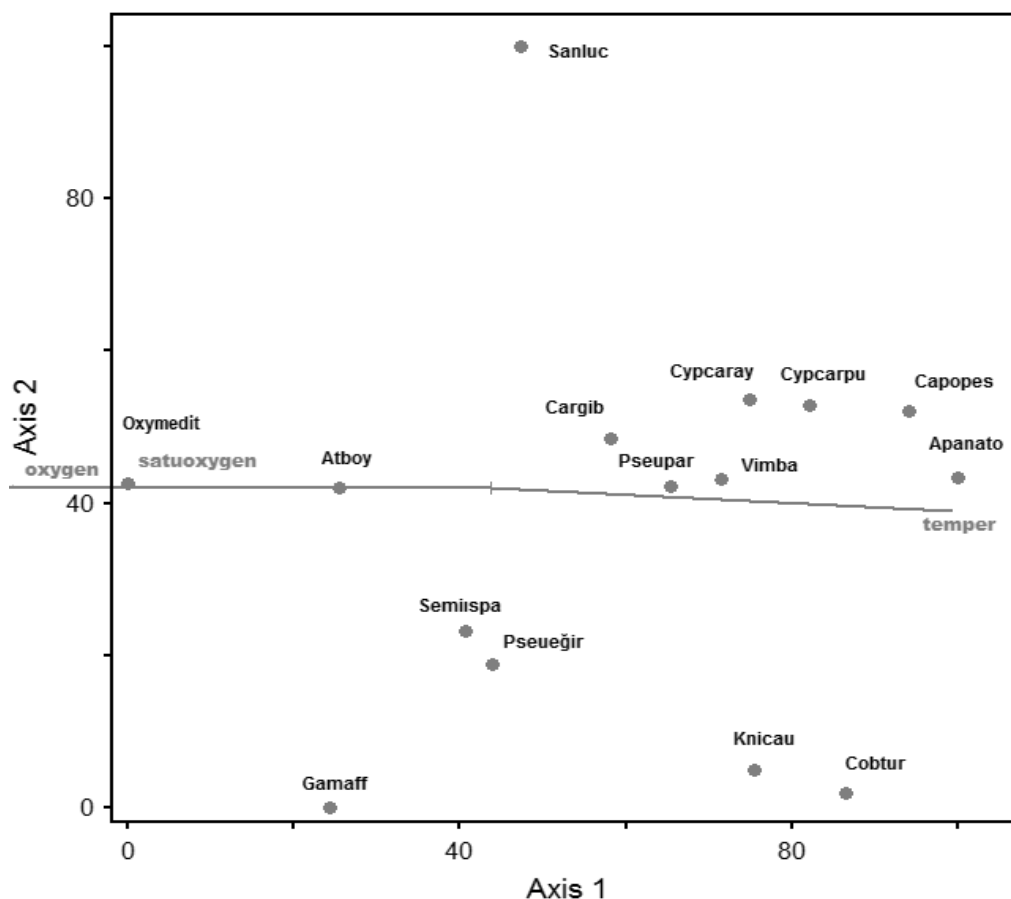


Figure 3: Detrended correspondance analysis of the fish species and physicochemical parameters in Lake Eğirdir (Sanluc: *Sander lucioperca*; Oxymedit: *Oxynoemacheilus mediterraneus*; Atboy: *Atherina boyeri*; Cargib: *Carassius gibelio*; Pseupar: *Pseudorasbora parva*; Vimba: *Vimba vimba*; Cypcaray: *Cyprinus carpio* (mirror carp); Apanato: *Aphanius anatoliae*; Capopes: *Capoeta pestai*; Cypcarpu: *Cyprinus carpio* (common carp); Semispa: *Seminemacheilus ispartensis*; Pseueğir: *Pseudophoxinus egridiri*; Knicau: *Knipowitschia caucasica*; Cobtur: *Cobitis turcica*; Gamaff: *Gambusia affinis*; oxygen: dissolved oxygen; satuxygen: saturation of dissolved oxygen; temper: temperature).

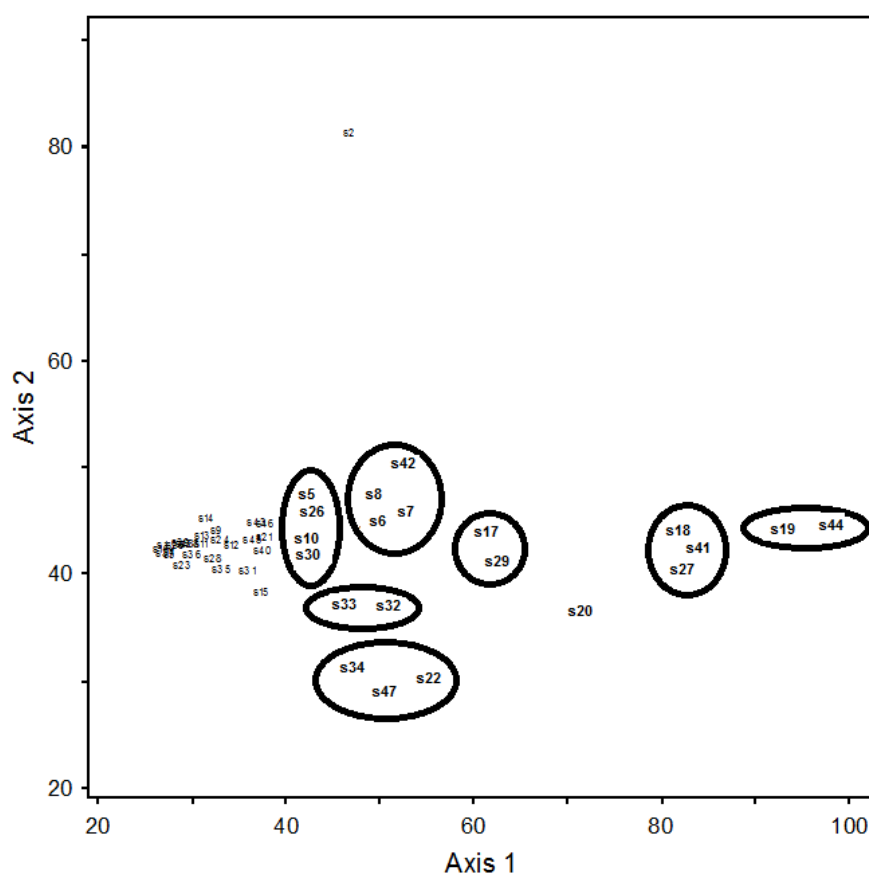


Figure 4: Detrended correspondence analysis (DCA) ordination plots for stations, months and physicochemical parameters (Monthly and stations codes are s5: May-1st station, s6: June-1st station, s7: July-1st station, s8: August-1st station, s10: September-1st station, s17: May-2nd station, s18: June-2nd station, s19: July-2nd station, s20: August-2nd station, s22: September-2nd station, s26: February-3rd station, s27: March-3rd station, s29: May-3rd station, s30: June-3rd station, s32: August-3rd station, s33: September-3rd station, s34: October-3rd station, s41: May-4th station, s42: June-4th station, s44: August-4th station, s47: November-4th station.

Discussion

Data showed that fish belonging to the family Cyprinidae were the most abundant (94.58% of total fish from gillnets and trammel nets), despite being restricted to colder months. Eğirdir Lake showed almost neutral and alkaline characteristics. The highest pH values (9.6) was recorded in December while the lowest value (8.6) was determined in June in Eğirdir Lake. Beyhan and Koç (2014) reported that the pH values from 7.34 to 9.32

represented low values in January. At a different time, the present pH results, being in agreement with Beyhan and Koç (2014), showed a significant increase after March. High pH values show the presence of calcium and magnesium carbonates (Begum *et al.*, 2009). According to results, in the second axis, *S. lucioperca* was found in areas where calcium level was high, while *K. caucasica* was found in areas where calcium level was low. According to canonical correspondence

analysis (CCA), in Köyceğiz Lagoon-Estuary of Turkey, *Cyprinus carpio* (common carp) has low correlation with dissolved oxygen and water temperature (Akin *et al.*, 2005). Moreover, it is reported that *C. carpio* (common carp) was found in the lake where the dissolved oxygen level is low (Innal, 2012). In the two estuarine systems of Strymonikos Gulf, *K. caucasica* species is found in the area where the temperature level is high (Koutrakis *et al.*, 2000). Meanwhile, *C. gibelio* was found in areas where the dissolved oxygen level is low in the Mures River (Grama and Bud, 2009). These results concur with our findings in this study.

Based on DCA, *A. anatoliae* and *C. pestai* were found in some areas where water temperature was considered high, and dissolved oxygen and saturation of dissolved oxygen were regarded as low. During our research, *Oxynoemacheilus mediterraneus* was found in places where the dissolved oxygen and saturation of dissolved oxygen levels were high. Besides, *A. boyeri* was found in some areas where dissolved oxygen was regarded as being high, and water temperature was considered low. Moreover, in the first axis, *Pseudophoxinus egridiri*, *Pseudorasbora parva*, *Seminemacheilus ispartensis*, *G. affinis* and *S. lucioperca* did not correlate with water temperature and oxygen and saturation of dissolved oxygen. In this research, *C. gibelio*, *Vimba vimba*, *C. carpio* (common carp), *C. carpio* (mirror carp), *K. caucasica* and *Cobitis turcica* were

found in some areas which were included in high level water temperature, and dissolved oxygen and saturation of dissolved oxygen were included in the low level. Consequently, these results show that water temperature is one of the most important variables for fish distribution. Fish specimens; *P. parva*, *V. vimba* and *O. mediterraneus* seemed to get affected by physicochemical parameter gradients. Of the species determined in previous studies, *P. parva* was reported by Yağcı *et al.*, (2014) in this lake. The phenomenon cited from other studies, stated that this species is really aggressive or could threaten other native fish species (important predator on invertebrates and in the aquatic environment). Therefore, this species is considered to be hazardous for the lake in the future.

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