A RESEARCH ON SOME PHYSICOCHEMICAL PARAMETERS AND AQUATIC COLEPTERA DIVERSITY IN ACI, SÜLEYMANLI, KARA AND SAKLI LAKES (DENIZLI, TURKEY)

Hakan Özdamar* and Suat Kıyak*

* Gazi University, Science Faculty, Department of Biology, Ankara, TURKEY. E-mail: hakanozdamar@gazi.edu.tr

[**Özdamar, H. & Kıyak, S.** 2017. A research on some physicochemical parameters and aquatic Coleptera diversity in Acı, Süleymanlı, Kara and Saklı Lakes (Denizli, Turkey). Munis Entomology & Zoology, 12 (2): 630-643]

ABSTRACT: This study was conducted to determine the physicochemical parameters (pH, temperature, electrical conductivity, salinity and dissolved oxygen) of water quality at Acı Lake, Süleymanlı Lake, Kara Lake and Saklı Lake in Denizli province. Additionally we determined the effects of these parameters on aquatic Coleoptera diversity by taking water and insect samples were collected every month from these lakes between May 2009 - September 2009 and April 2010 - September 2010. As a result of the study 49 aquatic Coleoptera species were identified in these lakes. It has been determined that lakes have I-II water quality according to their average values (pH, temperature, dissolved oxygen) according to WPCR. This study also showed the monthly fluctuations and the differences in the mean values in the physicochemical parameters are considered to be effective in the distributions of aquatic Coleoptera.

KEY WORDS: Aquatic Coleoptera, physicochemical parameters, water quality, Denizli province, diversity.

Water quality affects the composition, fertility and abundance of the species and physiological status of aquatic species. As the lakes are constantly showing the receiving environment feature, they are affected at first degree from environmental pollution. This pollution does not only negatively affect the living organisms, this negative effect reaches to the human body through the food chain (Yılmaz, 2004). Macrobenthic invertebrates are useful biological indicators that allow a more accurate understanding of the changing water conditions, both chemically and microbiologically (George et al., 2009). Aquatic insects are very good indicators of water quality because they have various environmental disturbance tolerance levels. Some of them are very vulnerable and susceptible to pollution, others can live and multiply in distressing and extreme polluted waters. Among benthic macroinvertebrate animals, aquatic insects are one of the most common groups of organisms used to evaluate the health status of aquatic ecosystems. It shows the degree of pollution in which some special water insects are found or not, but it can be determined by physicochemical methods (Prommi & Payakka, 2015). pH, temperature, electrical conductivity, dissolved oxygen and inorganic compounds are characteristic properties of water quality (OMM, 2012). Aquatic insect variety can be affected by various environmental factors such as pH and electrical conductivity (Bloechl et al., 2010).

This work aims to determine the some physicochemical parameters (pH, temperature, dissolved oxygen, electrical conductivity and salinity) Acı Lake, Süleymanlı Lake, Kara Lake and Saklı Lake in Denizli province and their effects to aquatic Coleoptera fauna.

MATERIALS AND METHODS

1. Procedure and Physicochemical Analyses

This work aims to determine the some physicochemical parameters of Acı Lake, Süleymanlı Lake, Kara Lake and Saklı Lake in Denizli province and their effects to aquatic Coleoptera fauna. In the present study, we determined the effects of some physicochemical parameters on aquatic Coleoptera diversity by taking water and insect samples were collected every month from these lakes between May 2009 - September 2009 and April 2010 - September 2010. Water samples of lakes were taken in pots with 120 ml. At the same time samples were measured with the Hagh Lange HQ40d multiparameter device. Then, pH, temperature, electrical conductivity, salinity and dissolved oxygen values were obtained from the lakes were recorded together and transferred to the pc. Insect samples were catched by diggers and fishnets from the lakes, and placed in glass bottles containing 70% ethyl alcohol then determined in the laboratory and formed to museum material.

2. Research Area

Acı Lake is the biggest lake of Denizli is a tectonic formation which is part of Denizli borders. The surface area is 41,34 km^2. It is located between Denizli Çardak and Afyon-Dazkırı districts. The lake is fed by the waters descending from the Söğüt Mountains. This lake is also called Acıtuz Lake has an altitude of 836 meters (Anonymous, 2012).

Süleymanlı Lake has an area of 0,5 km^2 and an altitude of 1150 meters also called Buldan Yayla Lake. It is about 8 km west of the Buldan district.

Kara Lake is located in Bozkurt District, Çambaşı quarter, with an area of 0.2 km^2 and a height of 1250 meters from the sea. A crater is fed by rivers. The lake is located in pine forest and lake water is freshwater (Anonymous, 2015).

Saklı Lake is located in the Honaz district and a height of 965 meters from the sea. This lake does not exceed 300 meters in diameter. It is nourished from its source, not from the lake, small stream and streams. There is a floating island of 180-200 m^2 consisting of reeds in the lake. The island is changing occasionally due to the effect of the wind (Bulut & Kantürk, 2010).

3. Statistics

Statistical significance was performed by ANOVA using SPSS 16.0. Means for physicochemical parameters were separated using by Fisher's least significant difference (LSD) at $p<0.05$ level. Relationships between parameters and distribution were analyzed by correlation and regression tests. Cluster analyses were performed by Biodiversity Pro ver. 2 programme.

RESULTS

1. Physicochemical Results

pH, temperature, electrical conductivity salinity and dissolved oxygen values of the physicochemical water quality parameters obtained from Acı Lake, Süleymanlı Lake, Kara Lake and Saklı Lake are given in the table below (Table 1).

In figs. 2-6, various physicochemical parameters of the surveyed Acı Lake, Süleymanlı Lake, Kara Lake and Saklı Lake are shown in terms of months during the research period. Projections and interpretations related to these pictures are discussed in the results section.

2. Biological Results

In the present study, total of 49 aquatic beetle species have been identified and listed on the table below (Table 2). There were 23 species in Acı Lake, 20 species in Süleymanlı Lake, 17 species in Kara Lake and 14 species of aquatic Coleoptera in Saklı Lake.

DISCUSSION

1. Physicochemical Results

As a result of this 11-month study, when the physicochemical parameter values of these lakes were statistically examined ($p<0.05$); the highest mean of pH value was determined in the Süleymanlı Lake (8.04), the highest mean of temperature value (24.7 °C), electrical conductivity value (1813 μs/cm), salinity value (1.03 ‰) and dissolved oxygen value (8.2 mg/l) was determined in Acı Lake (Table 1). It is thought that the snow water which is added to the Acı Lake in the Afyon part, especially after the winter months, is effective on the highest dissolved oxygen level.

High pH and low oxygen have lethal effect on organisms (Tanyolaç, 2006). pH and electrical conductivity are the most important factors affecting the distribution of the Dytiscidae family (Eyre et al., 1986). Each organism has tolerate a certain pH range. There is a negative relationship between pH and oxygen value (Ünlü & Uslu, 1999). This relationship was not fully visible in our studied lakes ($p>0.05$). During the study, the lowest pH value was measured as 6.64 in Acı Lake in June 2009 and the highest pH value was measured as 8.39 in Süleymanlı Lake in July 2010 at (Fig. 2).

Dissolved oxygen which is inversely correlated to temperature, decreases with increasing temperature, increases with decreasing temperature (Sarıhan, 1985). In this case, the dissolved oxygen values are expected to be high in the winter months. This situation was clearly seen in Acı Lake ($r=-0.660$) and Süleymanlı Lake ($r=-0.613$), but this relationship was not seen in Kara Lake and Saklı Lake. It is thought that the lakes are higher mountainous lakes and that they are isolated from seasonal and other factors. The lowest temperature value was measured in April 2010 at 14.7 °C in Süleymanlı Lake and the highest temperature value was measured at Acı Lake in September 2009 at 30.3 °C (Fig. 3).

Electrical conductivity is an environmental factor affecting aquatic insects (Eyre et al., 1986). Salinity increases in the summer, when evaporation is very common (Tepe, 2009). While the relationship between temperature and salinity was found to be strong in Kara Lake ($r=0.860$) and Saklı Lake ($r=0.902$), this situation was not seen in Süleymanlı Lake and Acı Lake. Electrical conductivity increases in parallel with salinity and temperature increase (Barlas et al., 1995). The relationship between electrical conductivity and salinity was found to be strong in Acı Lake ($r = 0.730$), Saklı Lake ($r=0.848$), Süleymanlı Lake ($r=0.899$) and Kara Lake ($r=0.783$).

According to the US Salinity Laboratories System, waters are separated into four groups according to their electrical conductivity. These are 0-250 μS / cm (low saline), 250-750 μS / cm (medium saline), 750-2250 μS / cm (high saline) and more than 2250 μS / cm (very high saline) (Tanyol and Uslu, 2013). When the average electrical conductivity values are taken into account, it is seen that Lakes in our study seem to be included in the high salt water class. The lowest electrical conductivity value was measured as 645 μS / cm in Süleymanlı Lake in April 2010 and the highest electrical conductivity value was measured as 2753 μS

/ cm in Acı Lake in September 2010 (Fig. 4). Accordingly, it can be said that aquatic beetles preferred high saline water in terms of electrical conductivity.

Salinity affects directly on osmoregulation of the living organisms the or indirectly the amount of dissolved gas, density and viscosity (Tanyolaç, 2006). In order to comment on salinity values and the relationship with other parameters, it is considered that other anions, cations and compounds dissolved in water should be examined and evaluated in detail. In our study, the lowest salinity value was measured as 0.3 ‰ in Süleymanlı Lake in April 2010 and the highest salinity value was measured as 1.34 ‰ in Acı Lake in July 2010 (Fig. 5).

Oxygen is directly influence on the distribution, behavior and association of specimens with other organisms (Tanyolaç, 2006). The ability of aquatic beetles to absorb and store oxygen from the water surface under water reduces their direct dissolved oxygen dependence. Furthermore, it should not be overlooked that the dissolved oxygen in the water can be displaced due to active swimming properties. Studies conducted during larval stages, where the samples are more stable, would better demonstrate their dissolved oxygen response. The lowest dissolved oxygen value was measured in Kara Lake as 3.67 mg/l in June 2009 and the highest dissolved oxygen value was measured in Acı Lake as 11.6 mg/l in May 2009.

The classes of inland water resources according the Ministry of Environment (2004); pH value of water between 6.5-8.5 named as I and II. Class, between 6-9 named as III. Class and above to 9, named as IV. Class. From our results, we found that according to mean pH values, our lakes have Class I. and II. water quality (Table 1). However, the average pH values found in both lakes were found to be in line with the freshwater pH values reported by the EPA (EPA, 2002).

According to the classes of inland water resources given by the Ministry of Environment (2004); when temperature value of lake is 25 °C, named as I and II. Class, 30 °C, named as III. Class, above 30 °C, named as IV. Class water quality. When the measured values are taken into consideration, the average temperature values of the lakes of our study, lakes have I and II. Class water quality (Table 1).

According to the classes of inland water resources given by the Ministry of Environment (2004); dissolved oxygen values of less than 8 mg/l for the clean water class, 6 mg/l for the less polluted water class, 3 mg/l for the polluted water class and 3 mg/l for the very polluted water class. When the measured values are taken into consideration, the average temperature values of the lakes of our study, lakes have I and II. Class water quality (Table 1).

2. Biological Results

As a result of this work, 49 aquatic beetle species belong to 7 families including Gyrinidae, Haliplidae, Noteridae, Dytiscidae, Helophoridae, Hydrochidae and Hydrophilidae were identified. The most abundant species were Hydrophilidae (Table 2).

The Margaleff index which expresses richness of species by evaluating different samples living in different habitats is a measure of the number of species found for the number of individuals obtained (Margalef, 1958). According to the Margaleff diversity index the highest diversity in terms of the number of months during our research was identified in the Süleymanlı Lake in April 2010. The lowest diversity value was found in Saklı Lake in August 2009. The diversity values by sampling points are given in Table 3 on a monthly basis.

As a result of the dominance analysis (Kocataş, 2006) on the samples collected in the lakes during the study, *Noterus clavicornis* was the most dominant species.

The Bray-Curtis Cluster similarity index is used to examine the degree of similarity between different communities (Bayram and Aslan, 2015). According to the similarity index, Acı Lake and Saklı Lake were identified as 38% and Acı Lake and Süleymanlı Lake were identified as 37% of the most similar aquatic beetle fauna (Fig. 7).

The suitable pH value of aquatic beetle is between 6.5-8.5 (Kara and Çömlekçioğlu, 2004), In our study lakes have these pH values. There was no significant correlation between pH values and diversity of species in these lakes ($p>0.05$). The highest diversity value was seen in April 2010 when pH was 8.2 in Süleymanlı Lake (Fig. 2).

As the average temperature values detected in the study lakes become lower than the upper temperature values in the clean water criteria, diversity value has increased (WPCR, 2004, Fig. 9). There was a strong negative correlation between temperature values and diversity of species in Acı Lake ($r=-0.717$), Süleymanlı Lake ($r=-0,943$) and Kara Lake ($r=-0.744$). In Saklı Lake this relationship was not fully seen ($p> 0.05$). This is thought to be caused by the spring water that is continuously added to the bottom part of the lake. This has shown us that high temperatures are not suitable for aquatic beetles and their diversity decreases as the upper boundary approaches. The highest diversity value was seen at 14.7 °C in the Süleymanlı Lake in April 2010 (Fig. 3).

It is known that electrical conductivity increases in parallel with salinity and temperature increase (Barlas et al., 1995). The electrical conductivity values of our study lakes paralleled with the salinity values. Negative strong correlation was found between the electrical conductivity values and diversity of species in Acı Lake ($r=-0,726$), Süleymanlı Lake ($r=-0,892$) and Kara Lake ($r=-0,755$). In Saklı Lake, this relationship was not fully seen ($p> 0.05$). This is thought to be caused by the spring water that is continuously added to the bottom part of the lake. The highest diversity value was seen in April 2010 at 648 µS / cm on the Süleymanlı Lake (Fig. 4). This has shown us that aquatic beetles can also exhibit high variability in their lower electrical conductivity values.

Salinity directly affects on osmoregulation of the living organisms the or indirectly the amount of dissolved gas, density and viscosity (Tanyolaç, 2006). There was a strong correlation between salinity values and diversity of species with negative strength in Süleymanlı Lake ($r=-0.902$) and Kara Lake ($r=-0.638$). This relationship was not observed in Acı Lake and Saklı Lake ($p>0.05$). Aquatic Coleoptera species showed salinity adaptation due to intense salty structure and did not react to changes in salinity. In Saklı Lake this relationship was not fully seen ($p>0.05$). This is thought to be caused by the spring water that is continuously added to the bottom part of the lake. The highest diversity was observed in April 2010 at the rate of 0.3 ‰ in the Süleymanlı Lake (Fig. 5). Aquatic beetles have been shown to prefer lower salinity values, which are affected by high salinity.

When we examine the dissolved oxygen values in the lakes of our study, only Süleymanlı Lake has positive relationship between the amount of dissolved oxygen and the diversity of species ($r=0.641$). In other lakes, this relationship was not fully observed ($p>0.05$). In general, when viewing the studied lakes, aquatic beetles were also found to vary at low-dissolved oxygen values (WPCR, 2004, Fig. 12). It is believed that the ability of aquatic beetles to store air in the water and use it in water is effective in this case, and this property is thought to make them independent of dissolved oxygen values directly. The highest diversity was seen in April 2010 when the Süleymanlı Lake was 8.55 mg/l dissolved oxygen (Fig. 6).

Considering the temperature, pH and dissolved oxygen parameters used in the classification of in-continental water resources, all studied lakes classified as I. and II. Class water quality (Table 1). Additionally, aquatic Coleoptera has the largest species and Süleymanlı Lake has the most diversity value. When the lakes in the studied area were examined, it was observed that diversity values were higher in April, May and June. The lowest diversity values were seen in August and September (Table 3).

It has been considered that the increasing values of pH, temperature, salinity and conductivity were negatively affect the diversity since June. Many aquatic Coleoptera need aquatic plants for spawning and hiding (Bloechl et al., 2010). In August and September, due to increased evaporation resulted warming, the lake is drawn in leads to the drying of the coastal plants and the habitat is removed. It is known that many aquatic beetles are active flyer and migrate to other habitats due to negative changes in the environment (İncekara, 2009). These lakes are used as a recreation area and preferred as handline fishing in summer, areas are also used by the villagers and exposes pollutants the coastal areas. These activities resulted in destroying habitat of the aquatic Coleoptera species and caused to migrating other habitats.

Yılmaz & Aslan (2017) indicated that Helophorus group was the largest group in terms of abundance in the study on Hydrophilidae and Helophoridae. In the present study, Helophorus is the second most populous group of genus.

In a study conducted in Northern Germany, two species belonging to the genus *Noterus* and *Helophorus* were detected with the highest abundance (Bloechl et al., 2010). From our results we found that, the most abundant species of studied area are *Noterus clavicornis* and *Helophorus syriacus* and the most dominant species of studied area is *Noterus clavicornis*. Although the genus, species and zoogeography are different from our study, this result shows that Noterus genus is more tolerant to physicochemical parameter changes of water.

This study will contribute more detailed basal grand invertebrata and water quality studies in the future.

ACKNOWLEDGEMENTS

The study was supported by Department of Scientific Research Project Management of Gazi University with the Project number 05/2009-14.

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Table 1. Water quality according to the average of physicochemical parameters is classified according to WPCR (Water Pollution Control Regulation), 2004. I: High quality water, II: Lightly polluted water.

Parameter	Lakes/ Mean Value				WPCR Class
	Acı Lake	Süleymanlı Lake	Kara Lake	Saklı Lake	
pH	7,78	8,04	7,65	7,8	I. and II
Temperature (ºC)	24,77	19,14	22,5	22,7	I. and II
Electrical conductivity (µs/cm)	1813	1138	1283	1096	-
Salinity (‰)	1,03	0,51	0,62	0,48	-
Dissolved oxygen (mg/l)	8,2	6,7	5,8	6,06	I. and II

Table 2. Aquatic Coleoptera species and their distribution.

Family	**Species**	**Acı Lake**	**Süleymanlı Lake**	**Kara Lake**	**Saklı Lake**
Gyrinidae	*Gyrinus caspius*	*			
	Gyrinus distinctus	*			
Haliplidae	*Haliplus mucronatus*	*			
Noteridae	*Noterus clavicornis*	*	*	*	*
Dytiscidae	*Agabus bipustulatus*			*	
	Agabus conspersus			*	*
	Agabus nebulosus				*
	Colymbetes fuscus			*	
	Graphoderus cinereus		*		
	Hydaticus transversalis laevisculptus	*			
	Bidessus nasutus	*			
	Hydroglyphus geminus	*		*	*
	Graptodytes sedilloti phrygius			*	
	Hydroporus angustatus			*	
	Hydroporus planus			*	
	Hydrovatus cuspidatus	*			*
	Hygrotus lernaeus				*
	Hygrotus saginatus			*	

	Hygrotus inaequalis		*	*	
	Laccophilus minutus	*	*		
	Laccophilus poecilus	*	*		*
Helophoridae	*Helophorus nubilus*			*	
	Helophorus micans	*	*		
	Helophorus syriacus	*	*	*	*
	Helophorus brevipalpis		*		*
	Helophorus daedalus			*	
	Helophorus longitarsis		*		
	Helophorus obscurus		*	*	
Hydrochidae	*Hydrochus flavipennis*		*		
Hydrophilidae	*Anacaena limbata*	*			
	Anacaena lutescens	*	*		
	Berosus affinis	*			
	Berosus signaticollis		*		
	Berosus frontifoveatus		*		
	Chasmogenus livornicus				*
	Cymbiodyta marginella	*	*		
	Enochrus melanocephalus	*			
	Enochrus bicolor	*			*
	Enochrus fuscipennis	*		*	
	Enochrus testaceus	*	*		
	Enochrus coarctatus			*	
	Enochrus nigritus		*		
	Helochares lividus		*		
	Hydrobius fuscipes		*		
	Limnoxenus niger	*		*	*
	Hydrochara flavipes	*			
	Laccobius syriacus	*			
	Laccobius gracilis				*
	Coelostoma orbiculare		*		*

Table 3. Monthly diversity values of sampling points according to Margaleff Diversity Index.

		LAKES			
	MONTHS	**Acı Lake**	**Süleymanlı Lake**	**Kara Lake**	**Saklı Lake**
2009	May	1.74	1.44	1.53	1.64
	June	1.14	1.24	1.25	1.51
	July	1.76	1.16	0.76	1.08
	August	0.96	0.86	0.83	0.4
	September	0.72	0.91	0.45	0.48
2010	April	1.87	2.02	1	0.91
	May	1.69	1.79	1.67	1.24
	June	1.44	1.27	1.08	1.2
	July	1.20	1.36	1.08	0.51
	August	0.51	0.63	0.65	0.8
	September	0.55	0.96	0.91	0.62

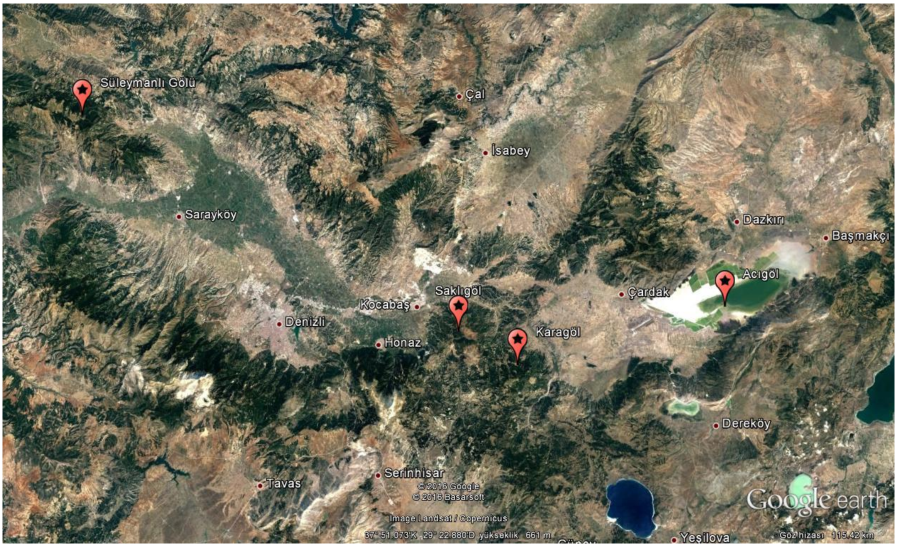

Figure 1. Lakes in the research area.

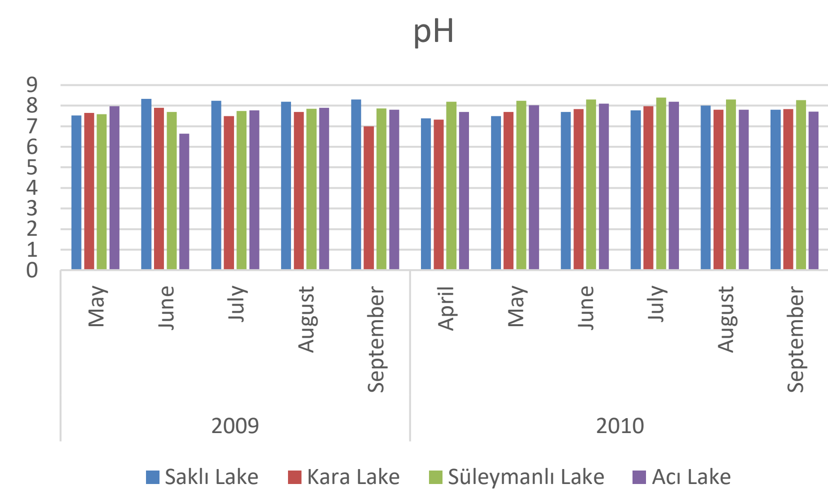

Figure 2. Monthly alterations of pH values.

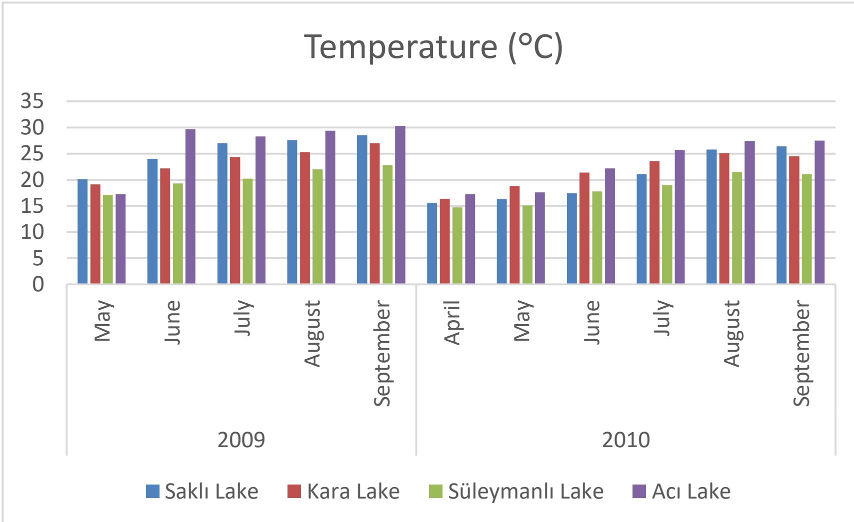

Figure 3. Monthly alterations of temperature values.

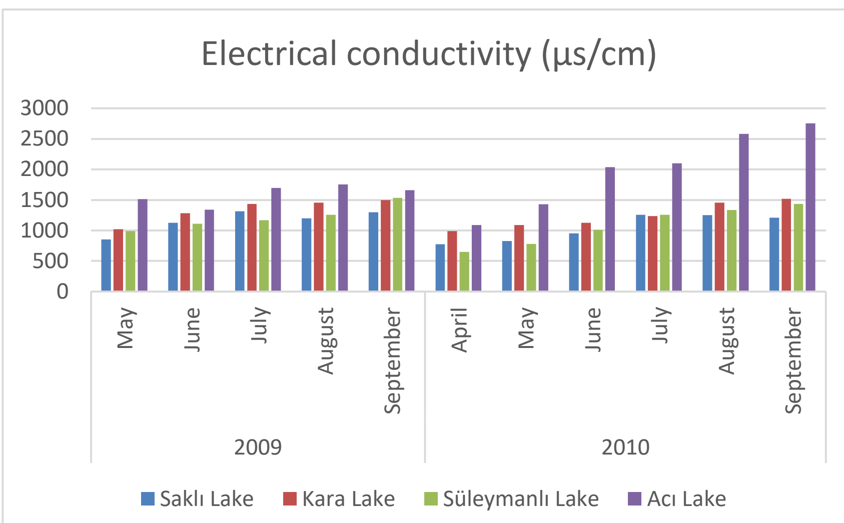

Figure 4. Monthly alterations of electrical conductivity values.

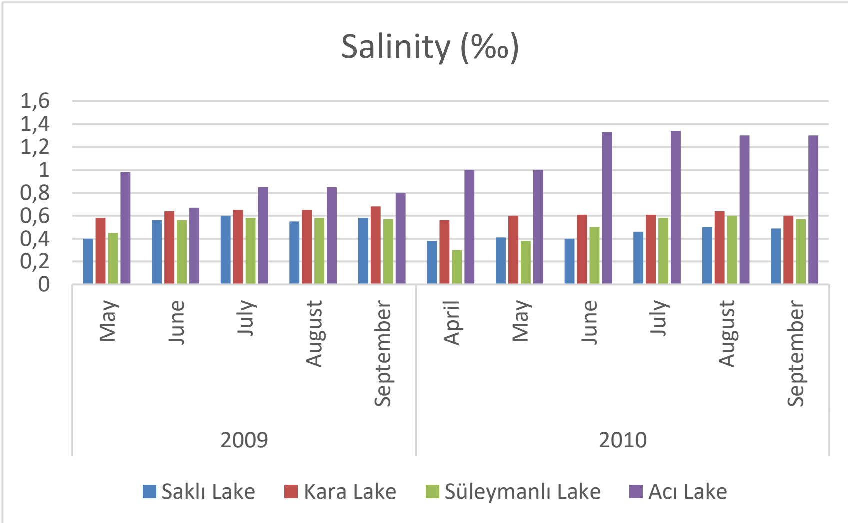

Figure 5. Monthly alterations of salinity values.

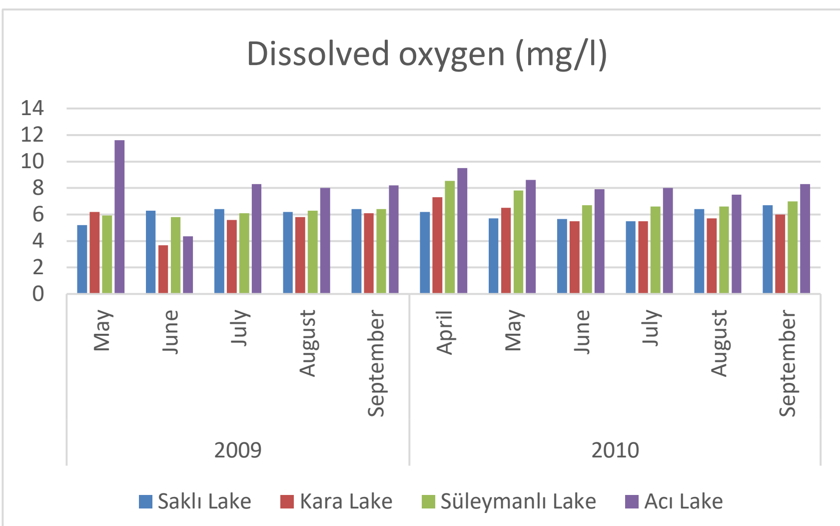

Figure 6. Monthly alterations of dissolved oxygen values.

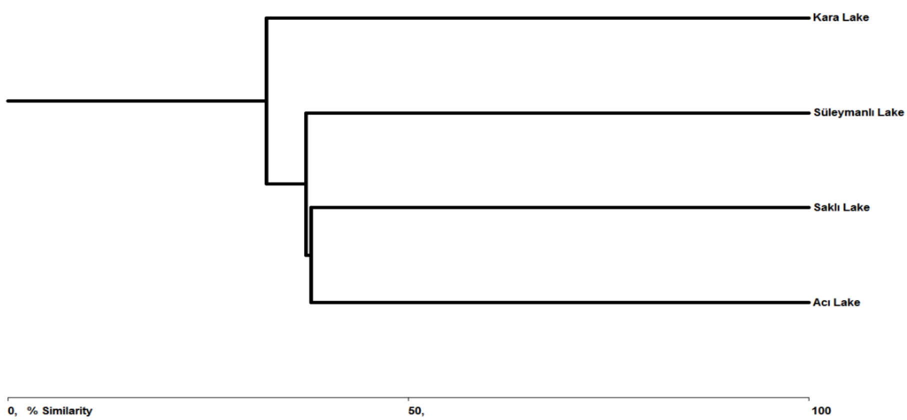

Figure 7. Similarity relationship between lakes according to cluster index.

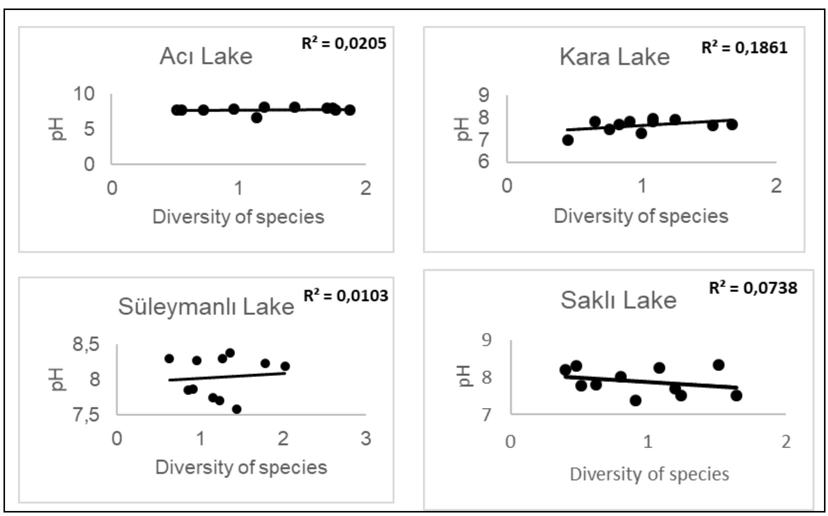

Figure 8. The relationship between aquatic Coleoptera diversity and pH in studied lakes.

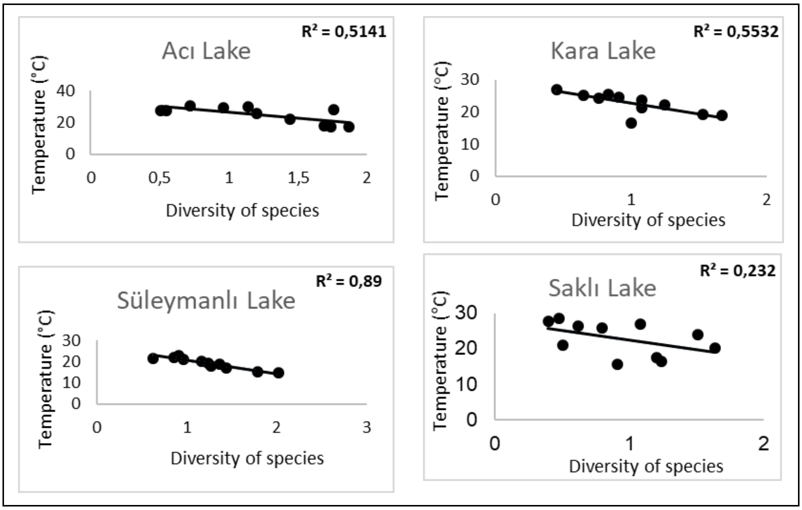

Figure 9. The relationship between aquatic Coleoptera diversity and temperature in studied lakes.

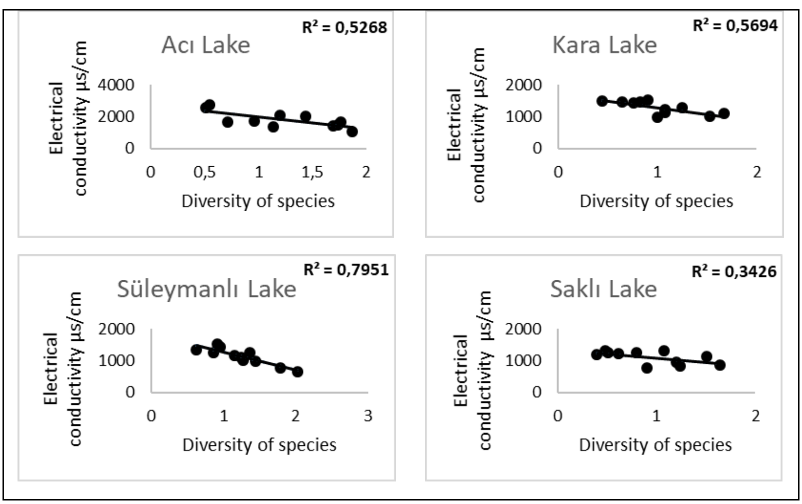

Figure 10. The relationship between aquatic Coleoptera diversity and electrical conducivity in studied lakes.

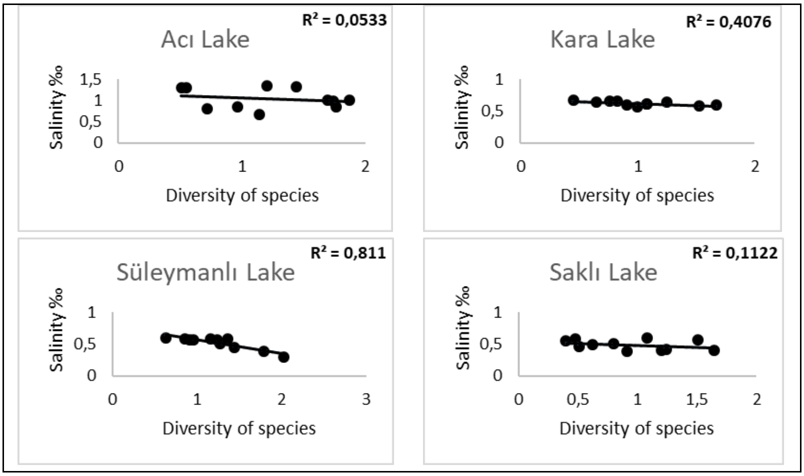

Figure 11. The relationship between aquatic Coleoptera diversity and salinity in studied lakes.

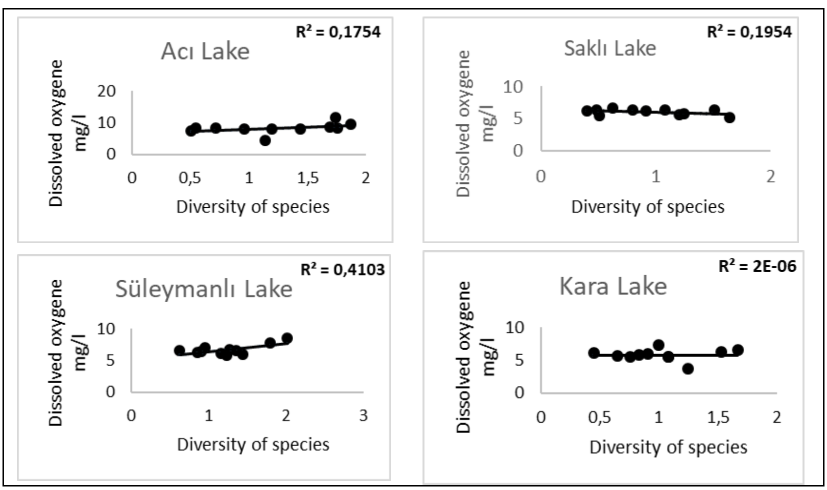

Fig. 12. The relationship between aquatic Coleoptera diversity and dissolved oxygen in studied Lakes.