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Analysis of Benthic Macroinvertebrates in Relation to Environmental Variables of Lake Gala, a National Park of Turkey

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Abstract

In order to determine the relationships between the dynamics of benthic macroinvertebrates (both species number and individual number) and environmental variables, sampling was made at four different stations at monthly intervals during a year between March 2004 and January 2005 of Lake Gala which is a part of an important wetland and a national park in European part of Turkey (Enez/Edirne). Altogether, a total of 49 zoobenthic taxa which were grouped as "Oligochaeta", "Chironomidae", and "Varia", comprised of 1,628 individuals in per m^2 at average were recognised in the sampling stations of the Lake. The present study showed that larval chironomids comprising 57% abundance of the total specimens are the biggest part of benthic macroinvertebrates. It is followed by oligochaetes and the group varia comprising 34% and 9% abundance, respectively. Also, it was seen changing that the composition of zoobenthic group dominancy in the Lake as time passes.

Furthermore, according to Shannon-Weaner index, species diversity for zoobenthic macroinvertebrate fauna of the lake was found as H'=1.21 at average. Also, similarities of the sampling stations and months, both the dynamics of benthic macroinvertebrates and physicochemical features were evaluated by using Bray-Curtis similarity index.

According to Spearman correlation index, relationship between the number of individuals and some physicochemical variables such as temperature, turbidity (light permeability), and depth of the lake was determined statistically significant.

Keywords: Meriç Delta, wetland, zoobenthos, biodiversity, Turkish Thrace.

Gala Gölü (Türkiye'nin bir Milli Parkı) Bentik Makroomurgasızlarının Çevresel Değişkenlerle İlişkisinin Analizi

Özet

Çevresel değişkenlerle bentik makroomurgasız dinamiği (hem tür sayısı hem de türlerin içerdiği birey sayısı) arasındaki ilişkiyi belirlemek amacıyla, Türkiye'nin Avrupa parçasında yer alan, önemli bir sulak alan ve bir milli parkın parçasını oluşturan Gala Gölü'nde (Enez/Edirne), Mart 2004 ve Ocak 2005 tarihleri arasında bir yıl boyunca aylık periyotlarla 4 farklı istasyondan örneklemeler yapıldı. Örnekleme istasyonlarında, m^2'de ortalama 1.628 bireyden oluşan; "Oligochaeta", "Chironomidae" ve "Diğerleri" olarak gruplanan, toplamda 49 zoobentik taxaya ait örnek saptandı. Çalışma, bentik makroomurgasızların büyük bir kısmını, %57 bollukla temsil edilen chironomid larvalarının oluşturduğunu gösterdi. Bunu, %34 bollukla oligoketler ve %9 bollukla "diğerleri" grubunun izlediği belirlendi. Ayrıca, geçen zaman içerisinde, gölün zoobentik gruplarının bolluk pozisyonunun değiştiği de gözlemlendi.

Shannon-Weaner indeksine göre, gölün zoobentik makroomurgasız faunası tür çeşitliliği ortalaması H'=1,21 olarak tespit edildi. Ayrıca, hem bentik makroomurgasız dinamiği hem de fizikokimyasal özellikler açısından örnekleme istasyonlarının ve ayların birbirleriyle olan benzerlikleri, Bray-Curtis benzerlik indeksinden yararlanılarak belirlendi.

Ayrıca, Spearman korelasyon indeksine göre, birey sayıları ile gölün sıcaklık, bulanıklık (ışık geçirgenliği), ve derinlik gibi bazı fizikokimyasal değişkenleri arasında istatistiksel açıdan anlamlı ilişkiler olduğu da saptandı.

Anahtar Kelimeler: Sulak alan, Meriç Deltası, zoobentoz, biyoçeşitlilik, Trakya

Introduction

Wetlands have many of the functions: such as to prevent flooding by holding water much like a sponge, to provide the area for migration or reproduction of many animals that live in other habitats, to control erosion by wetland plants, to clean the water by filtering out sedimentation, decomposing vegetative matter and converting chemical into usable form.

A wetland consists of a lot of physical, chemical, and biological materials such as soil, water, nutrients, foods, and living things. There are three fundamental living groups in a wetland to determine its efficiency. The group of zoobenthos is one of them and it has a very important role in benthic biomass (Svensson *et al.*, 1999; Kundak-Ertosun, 2007). Although the studies on the relationships between benthic macrofauna and environmental variables of inland water resources in Turkey have increased in last decades, a few of them have been performed in lakes (Sözen and Yiğit, 1999; Akbulut *et al*., 2002; Çamur-Elipek, 2003).

The Meriç Delta which is formed on 45000 ha area at the mouth of Meriç River (Maritza, Evros) is listed in Class A of International Wetlands. About 10000 ha. part of the delta lies in Greece lands and remaining area lies in Turkey (Kantarcı, 1989; Yarar and Magnin, 1997). Lake Gala, which is declared to be National Park in 2005, is an important part of the Meriç Delta with its 750 ha area. Because mankind activities are greatly made in the surround of the lake, it is under two important fundamental dangers: pollution, and draught.

In order to prevent the destruction of wetlands, we have to learn to balance today's needs with future environmental needs. Therefore, the present study was conducted to determine benthic macroinvertebrates, which are the most important group of the water resources. Up to now, although there are two studies which were performed by Kırgız (1988 and 1989), there has been no detailed study on benthic macroinvertebrates and their relationships with the physicochemical variables of Lake Gala.

Materials and Methods

Study Area: A total area of Lake Gala is 5.6 km^2, depth changes between 0.4-2.2 meters and sea level is 2 meters. During summer, the lake is separeted into two sections because of drying, Big and Small Gala Lakes (DSİ, 1986). The bank of the Lake is accompained by macrovegetation consisting of *Phragmites australis* and *Typha* sp. There are a lot of agricultural areas (essential rice plant) around the lake (DSİ, 1986).

Sampling: Four stations which characterised the Lake were selected for sampling (Figure 1): Station 1 is the location that the overloaded Lake water is discharged into the sea; Station 2 is the center of Big Gala; Station 3 is the location where intensive macro vegetation is the most; and Station 4 is the section of Small Gala.

The sampling stations were sampled monthly during a year between March 2004 and January 2005 for benthic fauna and physicochemical surveys. Sampling was not done at February 2005 because of unsuitable climatic conditions. Sediment samples were taken twice from each station using an Ekman-Birge grab (15×15 cm^2) and washed through on sieve series (1.5 mm, 0.7 mm, and 0.3 mm mesh net sieves, respectively). The remaining materials were preserved in plastic bottles containing 70% ethanol. In the laboratory, benthic samples were examined under a stereo binocular microscope and sorted into three groups, Oligochaeta, Chironomidae, and Varia. Samples were examined and sorted into the lowest possible taxonomic level to analyze the numerical data. Also, empty shells belonging to some benthic macroinvertebrates like Gastropoda, Bivalvia, and Ostracoda were not added to data because the empty shells do not play a role in benthic biomass.

Furthermore, at each station, water temperature (as ºC using an ordinary thermometer), light permeability (turbidity) (as cm using a Secchi disk), pH (using a Lovibond mark CG 837 type pHmeter), conductivity (as $\mu mho.cm^{-1}$ using a Lovibond CM 35 mark conductivitymeter), dissolved oxygen (as $mg.L^{-1}$ using a Lovibond mark 3040 model oxygenmeter), and depth (as meter using an ordinary tape-measure)

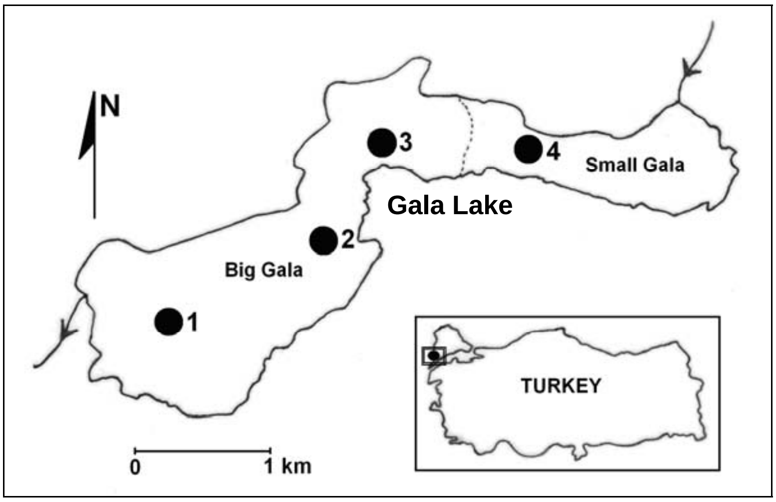

Figure 1. Location of Lake Gala and sampling stations (1: 1st station; 2: 2nd station; 3: 3rd station; 4: 4th station).

were measured at the time when benthic sample was taken monthly. Also, water samples taken by Ruttner water sampler were carried to the laboratory in black glass bottles at 5 ºC. Within one day after sampling, the other parameters included Total Hardness as FSº, Salinity as ‰, and Calcium, Magnesium NO_3-N, NO_2-N, PO_4^{-3}, Sulphate, Chlorophyl-*a* of the lake water were measured as mg.L^{-1} using classical titrimetric and spectrophotometric methods (Egemen and Sunlu, 1999). The quality level of the water was determined according to Turkish Water Pollution Control Regulation (SKKY, 2004).

Statistical Analysis: Shannon-Weaner index was performed in order to evaluate the species diversity of the Lake. Before using the Bray-Curtis index, the numerical data were transformed to new data by using Log 10 (N+1), and then the index was performed both in order to determine the similarities of the sampling stations and months for the dynamics (distribution both in terms of species and number of individuals) of benthic macroinvertebrates and in order to determine the similarities of the sampling stations and months for the physicochemical variables (Krebs, 1999). Also, relationships between the distribution of the zoobenthos and environmental variables were determined using Spearman correlation in SPSS 9.0 for windows.

Results and Discussion

Altogether, 49 zoobenthic taxa comprised of 1628 individuals per m^2 at average were collected at the sampling stations of Lake Gala during the studying period. Samples were grouped as "Oligochaeta" included members belonging to the families Enchytraeidae and Lumbricidae with the exception of immature or damaged individuals; "Chironomidae" included larvae belonging to the subfamilies Tanypodinae, Chironomini, Orthocladini and Tanytarsini; and "Varia" included a few number of members belonging to the order Diptera (except Chironomidae), Hemiptera, Ephemeroptera, Odonata, Mysidacea, Trichoptera, Coleoptera, and Gastropoda. It was found that a total of 11 taxa belonging to Oligochaeta group comprised of 558 individuals/m^2, a total of 30 taxa belonging to Chironomidae group comprised of 920 individuals/m^2, and a total of 8 taxa belonging to varia group comprised of 150 individuals/m^2 (Table 1 and Table 2). The present study showed that the biggest part of benthic macroinvertebrates consists of larval chironomids comprising 57% abundance of the total specimens. It is followed by oligochaetes and the group varia comprising 34% and 9% abundance, respectively (Table 1 and Table 2).

Large numbers of pollution-tolerant oligochaets and chironomids are often indicative of poor water quality (characterized by low dissolved oxygen and high nutrient concentrations). Chironomid species diversity and their sensitivity to eutrophic conditions have been used to create trophic status classifications of lakes (Langdon *et al.* 2006).

In the study which was performed by Kırgız (1989) in the Lake, 4988 individuals/m^2 belonging to benthic macroinvertebrates were found in Lake Gala (Oligochaeta was found to have 44.9% abundance while larval Chironomidae was found to have 37.8% abundance and the other macroinvertebrates were found to have 17.3% abundance). It was shown in the previous study that Chironomidae and Oligochaeta were also dominant groups but it was seen that the dominancy composition changed along ten years.

In the recent studies which were performed in different inland water resources in Turkey, similar findings are also seen. While Chironomidae larvae was found as dominant group in Lake Akşehir (Konya) (51.55% Chironomidae larvae, 45.97% Oligochaeta, and 2.48% other benthic macroinvertebrates) by Sözen and Yiğit (1999), Oligochaeta was found as dominant group (82% Oligochaeta, 10% Chironomidae larvae, and 8% other animals) in Terkos lake by Çamur-Elipek (2003). The insecta was found as the dominant group in the study by Akbulut *et al.* (2002).

Of the total number of chironomids, 15 taxa commonly occurred in all sampling stations (Table 1). While *Chironomus plumosus* was found to have the highest abundance (25%) in this group, *Psectrocladius limbatellus, P. sordidellus, Glyptotendipes signatus, Cryptochironomus* sp., and *Cladotanytarsus mancus* were found to have the lowest abundance (0.1%). Chironomids were found to have the highest number at the 2nd station, which may result from the number of *C. plumosus* (Table 1). However, *Psectrocladius sordidellus* and *Cryptochironomus* sp. were present at the 1st station, *Psectrocladius limbatellus, Cryptotendipes holsatus, Glyptotendipes sygnatus, Tanytarsus gregarius*, and *Cladotanytarsus mancus* were present at the 2nd station, *Chironomus anthracinus* and *Chironomus* sp. were present at the 3rd station, only. Our result indicated that Chironomidae fauna of Lake Gala consists mainly of taxa with wide ecological tolerances and extensive geographical ranges. Winberg (1978) proposed a pollution index, which assumes that unpolluted waters are dominated by larvae of the subfamily Orthocladiinae and polluted water by larvae of the subfamily Tanypodinae. Winner *et al.* (1980) did not validate this index in relation to heavy metal pollution. They found no dominance of Tanypodinae but that of Orthocladiinae in streams polluted with heavy metals. In addition, similar results were also reported by Mousavi *et al.* (2003). Existence of Orthocladiinae larvae (especially *Cricotopus flavocinctus* with 5.4% abundance) in Lake Gala may indicate pollution (Winner *et al.* 1980). In the study which was performed in the Lake by Kırgız (1988), it was reported that *Polypedilum nubifer, Chironomus plumosus,* and *Camptochironomus tentans* were found to have the

Table 1. List and individual numbers of benthic macroinvertebrates which are determined from sampling stations of Lake Gala (AIG: Abundance in group; AIT: Abundance in total as %)

Macroinvertebrates	Stations				AIG	AIT
	1st	2nd	3rd	4th		
CHIRONOMIDAE	732	1428	450	1048	100	57
Tanypus punctipennis Meigen, 1818	15	47	7	1	1.9	1.1
Procladius(Holotanypus) sp.	13	62	28	43	4.0	2.3
Cricotopus bicinctus (Meigen, 1818)	-	2	11	2	0.4	0.3
Cricotopus sylvestris (Fabricius, 1794)	15	30	4	2	1.4	0.8
Cricotopus flavocinctus (Kieffer, 1924)	11	59	4	279	9.6	5.4
Psectrocladius limbatellus (Holmgren, 1869)	-	3	-	-	0.1	0.1
Psectrocladius sordidellus (Zetterstedt, 1838)	2	-	-	-	0.1	0.1
Chironomus anthracinus Zetterstedt, 1860	-	-	8	-	0.2	0.1
Chironomus aprilinus Meigen, 1818	2	6	2	-	0.3	0.2
Chironomus plumosus (Linnaeus, 1758)	192	333	243	165	25.6	14.4
Chironomus sp.	-	-	10	-	0.3	0.2
Camptochironomus tentans Fabricius, 1805	32	162	36	91	8.7	4.9
Cryptotendipes holsatus Lenz, 1959	-	8	-	-	0.2	0.1
Polypedilum sordens (van der Wulp, 1874)	10	8	4	6	0.7	0.4
Dicrotendipes tritomus (Kieffer, 1916)	2	8	4	8	0.6	0.3
Einfeldia sp.	2	8	4	-	0.4	0.3
Endochironomus tendens (Fabricius, 1775)	11	-	2	-	0.3	0.2
Glyptotendipes signatus (Kieffer, 1909)	-	4	-	-	0.1	0.1
Parachironomus arcuatus (Goetghebuer, 1919)	4	25	4	2	0.9	0.6
Cryptochironomus defectus (Kieffer, 1913)	29	31	10	37	3.0	1.7
Cryptochironomus sp.	2	-	-	-	0.1	0.1
Polypedilum pedestre (Meigen, 1830)	5	16	2	5	0.7	0.4
Polypedilum convictum (Walker, 1856)	12	22	6	-	1.0	0.6
Endochironomus albipennis (Meigen, 1830)	82	94	13	43	6.3	3.6
Rheotanytarsus sp.-1	11	-	4	6	0.6	0.3
Rheotanytarsus sp.-2	15	45	7	1	1.9	1.1
Virgatanytarsus arduennensis (Goetg.,1922)	15	296	17	274	16.6	9.3
Paratanytarsus lauterborni (Kieffer, 1909)	250	136	20	83	13.3	7.5
Tanytarsus gregarius Kieffer, 1909	-	20	-	-	0.6	0.3
Cladonytarsus mancus (Walker, 1856)	-	3	-	-	0.1	0.1
Number of chironomid taxa at the stations	22	24	23	17		
OLIGOCHAETA	800	458	507	455	100	34
Limnodrilus claparedianus Ratzel, 1869	53	32	74	2	7.2	2.4
Limnodrilus hoffmeisteri Claparéde, 1862	298	144	171	34	29.1	10.0
Limnodrilus profundicola (Verrill, 1871)	39	16	9	-	2.8	0.9
Limnodrilus sp.	138	95	44	18	13.3	4.5
Tubifex tubifex (Müller, 1774)	72	57	92	51	12.2	4.2
Potamothrix hammoniensis (Michaelsen, 1901)	200	90	68	190	24.8	8.5
Potamothrix sp.	-	10	7	65	3.7	1.2
Psammoryctides albicola (Michaelsen,1901)	-	-	-	59	2.7	0.9
Psammoryctides sp.	-	-	-	18	0.8	0.3
Nais communis Piguet, 1906	-	10	20	4	1.6	0.5
Nais variabilis Piguet, 1906	-	4	22	14	1.8	0.6
Number of oligochaet taxa at the stations	6	9	9	10		
VARIA	64	190	49	302		9.0
Diptera (Ceratopogonidae)	2	6	-	21	4.8	0.4
Gastropoda	2	4	2	6	2.8	0.2
Mysidacea	10	18	2	12	7.4	0.6
Coleoptera (larvae)	22	20	4	8	9.4	0.8
Hemiptera (nymph)	2	10	17	12	6.7	0.6
Odonata	2	12	4	110	21.2	2.0
Trichoptera	20	63	14	-	15.9	1.4
Ephemeroptera	4	47	6	133	31.7	3.0
Number of varia taxa at the stations	8	8	7	7		
Shannon H' Log Base 10	1.14	1.30	1.18	1.20		1.21
Number of Total Taxon	36	41	39	34		

Table 2. The individual numbers in m^2 of benthic macroinvertebrates which are determined from sampling stations of Lake Gala at monthly intervals

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
CHIRONOMIDAE	124	785	1523	831	1386	2318	912	695	647	707	169
Tanypus punctipennis	0	6	36	0	0	0	150	0	0	0	0
Procladius sp.	28	89	47	50	38	7	0	0	75	13	56
Cricotopus bicinctus	0	11	0	0	0	0	0	26	6	0	0
Cricotopus sylvestris	0	0	53	45	43	0	0	0	0	0	0
Cricotopus flavicinctus	0	0	165	0	99	707	0	0	0	0	0
Psectrocladius limbatellus	0	0	0	0	0	7	0	0	0	0	0
Psectrocladius sordidellis	0	0	0	0	0	6	0	0	0	0	0
Chironomus anthracinus	0	22	0	0	0	0	0	0	0	0	0
Chironomus aprilinus	17	0	0	0	0	0	0	0	0	11	0
Chironomus plumosus	0	395	421	389	153	109	139	267	304	280	111
Chironomus sp.	0	22	0	0	0	0	0	0	0	0	0
Camptochironomus tentans	17	228	58	56	82	0	303	0	0	139	0
Cryptotendipes holsatus	0	0	0	0	0	23	0	0	0	0	0
Polypedilum sordens	0	0	0	0	43	17	0	0	0	16	0
Dicrotendipes tritomus	0	0	0	0	43	17	0	0	0	0	0
Einfeldia sp.	0	0	0	0	38	0	0	0	0	0	0
Endochironomus tendens	0	0	36	0	0	0	0	0	0	0	0
Glyptotendinpes signatus	0	0	0	0	0	0	0	6	0	6	0
Parachironomus arcuatus	0	0	0	45	38	7	0	0	6	0	0
Cryptochironomus defectus	17	0	121	50	49	18	0	0	6	33	0
Cryptochironomus sp.	0	0	0	0	0	0	6	0	0	0	0
Polypedilum pedestre	17	0	0	45	0	6	12	0	0	0	0
Polypedilum convictum	0	0	0	45	43	0	0	0	0	21	0
Endochironomus albipennis	0	6	154	61	77	28	0	140	97	76	0
Rheotanytarsus sp.-1	0	0	36	0	0	0	0	0	16	6	0
Rheotanytarsus sp.-2	0	0	36	0	0	0	151	0	0	0	0
Virgatanytarsus arduennensis	28	6	360	0	110	834	151	0	131	33	0
Paratanytarsus lauterborni	0	0	0	45	500	525	0	256	6	17	0
Tanytarsus gregarius	0	0	0	0	0	0	0	0	0	56	0
Cladonytarsus mancus	0	0	0	0	0	7	0	0	0	0	0
Chiro. taxa at months	6	9	12	10	14	15	7	5	9	13	2
OLIGOCHAETA	593	889	991	563	785	234	151	595	426	728	151
Limnodrilus claparedeanus	59	50	100	39	89	11	0	0	29	33	33
Limnodrilus hoffmeisteri	115	244	273	108	273	39	28	297	134	229	39
Limnodrilus profundicola	24	11	78	23	34	0	0	0	0	0	6
Limnodrilus sp.	46	117	167	72	215	0	17	0	67	111	0
Tubifex tubifex	125	78	211	80	22	28	53	0	33	72	45
Potamothrix hammoniensis	192	267	78	85	98	122	53	236	124	250	0
Potamothrix sp.	19	22	28	22	37	11	0	37	22	0	28
Psammoryctides albicola	13	33	17	39	0	18	0	25	17	0	0
Psammoryctides sp.	0	0	0	45	0	5	0	0	0	0	0
Nais communis	0	29	17	11	17	0	0	0	0	11	0
Nais variabilis	0	28	22	39	0	0	0	0	0	22	0
Oligo. taxa at months	8	10	10	11	8	7	4	4	7	7	5
VARIA	6	156	124	68	87	557	86	189	259	112	6
Diptera (Ceratopogonidae)	6	17	0	0	0	0	6	11	25	17	0
Gastropoda	0	0	6	0	6	22	6	0	0	0	0
Mysidacea	0	11	6	39	11	17	0	11	11	6	6
Coleoptera (larvae)	0	0	0	0	44	34	0	67	6	0	0
Ephemeroptera	0	28	72	6	11	222	11	11	156	6	0
Hemiptera (nymph)	0	89	17	0	3	0	6	0	0	0	0
Odonata	0	11	17	6	6	239	34	17	28	0	0
Trichoptera (nymph)	0	0	6	17	6	23	23	72	33	83	0
Varia taxa at months	1	5	6	4	7	6	6	6	6	4	1
Shannon H'	0.98	1.09	1.23	1.22	1.22	0.96	0.97	0.94	1.11	1.12	0.78
Number of Total Taxon	15	24	28	25	29	28	17	15	22	24	8

highest abundance, respectively. In the present study, no samples belonging to *P. nubifer* were found.

Of the total number of oligochaets, 5 taxa commonly occurred in all sampling stations (Table 1). However, *Psammoryctides albicola* and *Psammoryctides* sp. were only present at the 4th station, whereas *Limnodrilus profundicola* was never found at this location. While *Limnodrilus hoffmeisteri* was found to have the highest abundance in Oligochaeta group (29%), *Psammorichtydes* sp. was found to have the lowest abundance in this group (0.9%). Oligochaeta had the highest number at the 1st station and in May because of the presence of *L. hoffmeisteri*. Most naidid species occurring throughout the world are also cosmopolitan, (Wetzel *et al.*, 2000) and they have clearly adapted to a wide range of environmental conditions (Brinkhurst and Jamieson, 1971). Only two naidid species were found in the study area (Table 1). Their abundance was not high but *N. variabilis'* abundance was higher than that of *N. communis.* It is known that most naidid species are intolerant of saline conditions; however, Learner and Edwards (1963) found that *N. variabilis* and *N. communis* were unlikely to tolerate a salt concentration much greater than about 0.5% (3000 mg Cl^{-1}). In addition, Davis (1982) reported *N. variabilis* in brackish water, which is supported by our findings. Low abundance of the naidid sample may be explained in the way that marine water enters to the lake. The number of taxa belonging to Oligochaeta group was the highest at the 4th station and in May while it was the lowest at the 1st station and in months September and October. The 1st station was located in the part of the Lake where the overloaded water is discharged into to the sea and it has sandy-stone substrate and lacks vegetation. Therefore low abundance of the Oligochaeta sample may be explained with these reasons**.** It is known that some species of Oligochaeta (especially *Tubifex tubifex, Limnodrilus hoffmeisteri* and *L. udekemianus*) and larval Chironomidae (e.g. *C. plumosus*) can tolerate bad conditions and they have clearly adapted to a wide range of environmental conditions (Brinkhurst and Jamieson, 1971), which is also supported by our results. These euryoic species especially inhabit shallow and muddy substrates. According to their ecological valence they are considered to be cosmopolitan species occurring throughout the world and they have clearly adapted to a wide range of environmental conditions and their abundance can reach immense sizes in aquatic systems with high trophy levels (Brinkhurst and Jamieson, 1971).

Of the total number of group varia, 6 taxa commonly occurred in all sampling stations (Table 1). However, Trichoptera was never found at the 4th station while Ceratopogonidae was never found at the 3rd station. In the group varia, Ephemeroptera was found to have the highest abundance (31%) with two species (*Caenis horaria* and *Cloeon dipterum*), it was followed by Odonata (21%) with three species (*Ischnura* sp., *Platycnemis* sp. and *Anax* sp.). Gastropoda which was found as *Unio* sp., *Viviparus* sp., and Planorbiidae only was found to have the lowest abundance in this group (2.8%). The number of taxa belonging to varia group was the highest at the 1st and 2nd station and in July while it was the lowest at the 3rd and 4th station and in months March and January. The group Varia had the highest numbers at the 4th station and in August because of Odonata and Ephemeroptera. Members of the order Trichoptera are considered to be sensitive to environmental stress and their presence signified relatively unpolluted conditions (Merritt and Cummins, 1978). The numbers of Trichoptera were not the highest at the Lake Gala; they were also absent at the 4th station.

In this study, it was shown that benthic fauna of Lake Gala was dominated by two groups, Chironomidae and Oligochaeta known as pollution-tolerant organisms, which is typical of many freshwater habitats (Armitage *et al.*, 1995, Svensson *et al.*, 1999). The proportion of larval chironomids was relatively lower at the 1st and 3rd stations where the abundance of Oligochaeta was significantly higher than it. The consistent presence of the resistant *Limnodrilus* spp. and *Chironomus* spp. at the sampling stations indicated regular point sources of pollution discharge due to human activities and this caused the water quality deterioration.

According to Shannon-Weaner diversity index, species diversity for benthos of the lake was found as 1.21 at average. While the 2nd station and month May were determined to have the widest diversity (H'=1.30 and H'=1.23, respectively), the 1st station and month January were determined to have the poorest (H'=1.14 and H'=0.78, respectively) (Table 1 and 2). The 2nd station is the center of Big Gala and it has also the highest number of taxa. It can be thought that the lake has gained its character in this location. In the results, both the total number of taxa and Shannon results is very close at the months May, June, and July. In the month August, although the number of taxa was found very high, the Shannon result was found very low. This situation may be explained by environmental factors (especially high light permeability) seen in month August.

According to Bray-Curtis similarity index, stations 1 and 3 and, months April and December are similar to each other the most (60% and 71% similarities, respectively) while the 3rd and 4th station and month August and January are the most different (38% and 12% similarities, respectively) for the dynamics (distribution both in terms of species and the number of individuals) of macrobenthos in Lake Gala (Figure 2). Bray-Curtis similarity index compares the stations or months according to both species findings and frequency of the specimens. The proportions of chironomids and oligochaetes may be considered to have a very important role on these similarities.

According to SSKY (2004), the values of pH, conductivity, temperature, and turbidity were found at normal levels in the course of the present study (Table 3). The lake water was generally found as supersaturated for dissolved oxygen. These supersaturated findings were also reported by Kırgız (1989). The total hardness of the water was found at very hard water quality level. When the water quality was evaluated for nutrients, the values of NO_3N and NO_2N were found at second quality level while the values of SO_4 and PO_4 were found at first quality level, generally.

The results of Bray-Curtis index indicated that July and August, November and December; April and May are similar to each other the most (95%, 94%, and 93% similarities, respectively) while March, June and August are the most different months from month December (76% similarity) in terms of the physicochemical variables in Lake Gala (Figure 3). It is very usual that the month July and August, November and December, April and May have similar physicochemical features because each month follows the other. Looking at the proportions of the similarities, differences among the months according to the physicochemical features, are very low (24% differences). For this reason, the physicochemical features of the lake may be generalized on average.

With regard to the Spearman correlation index between the average number of macrobenthos and the physicochemical variables, the relation between the number of total individuals of benthic macroinvertebrates and light permeability (turbidity) ($r=+0.658$, $P<0.05$) was directly proportional. Also, the relation between the total number of Chironomidae larvae and temperature ($r=+0.791$, $P<0.01$) was directly proportional while the relation between the number of Varia individuals and depth ($r= -0.674$, $P<0.05$) were inversely proportional.

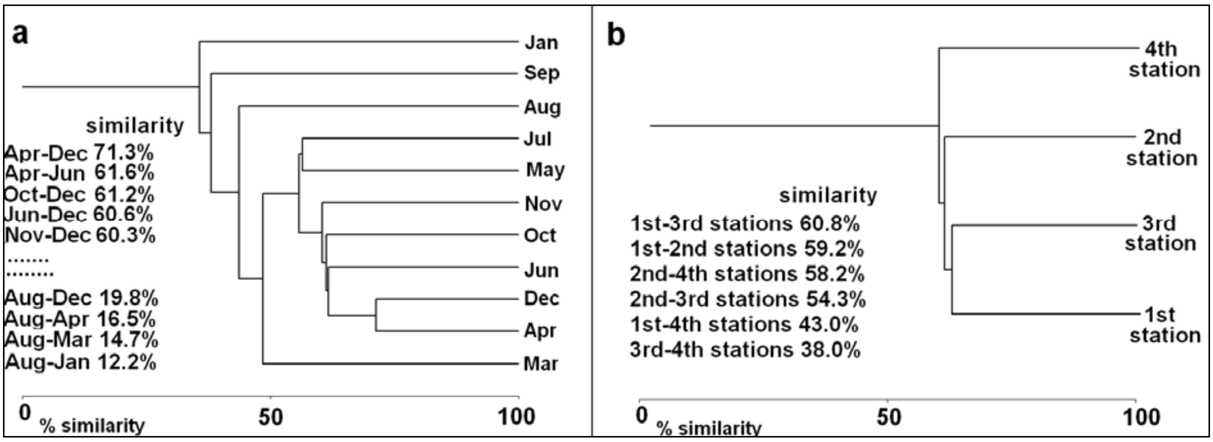

Figure 2. a-The dendrogram of similarity of months in Lake Gala Gala in respect of benthic macroinvertebrates;
b- the dendrogram of similarity of stations in Lake Gala in respect of benthic macroinvertebrates (single-linkage, Bray-Curtis, Log base 10).

Table 3. Physicochemical variables in Lake Gala during the study period

	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Average	Standart Deviation
pH	8.2	8.4	8.7	8.2	8.3	8.2	8.3	8.4	8.6	8.5	8.4	8.41	± 0.14
Cond.	145	143	187	163	270	250	310	320	209	250	150	219	± 2.63
Temp	14.8	17.8	19.3	26.7	27.6	25.6	23.6	19	8.3	9.1	6.2	18	± 0.1
Ch-*a*	21.9	15.8	20.0	17.8	16.2	4.8	26.5	20.2	58.3	65.5	18.9	24.2	± 2.19
DO	16.3	14.4	17.8	12.8	12.9	11.4	14.9	16.3	12.8	8.6	12.3	13.45	± 0.65
Dep.	199	111	126	164	128	131	145	109	121	106	156	139	± 14.9
Turb.	48	48	56	47	76	91	28	51	29	24	38	48.7	± 5.73
Mg	67.8	41.4	52.7	69.9	78.8	78.0	98.6	88.4	85.7	87.8	80.5	79.5	± 5.06
Ca	96.1	86.0	81.6	52.9	57.7	54.3	52.1	105.8	78.1	69.7	67.5	72.25	± 5.25
TH	52	40	42	42	47	46	54	63	55	49	50	45.5	± 1.89
NO_3N	7.20	4.04	1.80	4.40	1.19	1.88	3.32	0.00	0.01	0.00	0.00	2.04	± 0.71
NO_2N	0.001	0.00	0.00	0.00	0.00	0.00	0.24	0.02	0.01	0.00	0.00	0.02	± 0.04
SO_3	3.80	3.00	2.80	3.20	3.60	2.50	3.73	4.43	2.53	0.06	2.58	2.96	± 0.01
PO_4	0.01	0.01	0.01	0.06	0.03	0.03	0.03	0.06	0.00	0.01	0.02	0.02	± 0.1

values of minimum and maximum were indicated bold character; Cond: Conductivity (µmho cm^{-1}); Temp: Temperature (ºC); Ch-a: Chlorophyll-a (µgr L^{-1}), DO: Dissolved Oxygen (mg L^{-1}), Dep.: Depth (cm), Turb.: Turbidity (cm), TH: Total Hardness (Frº)

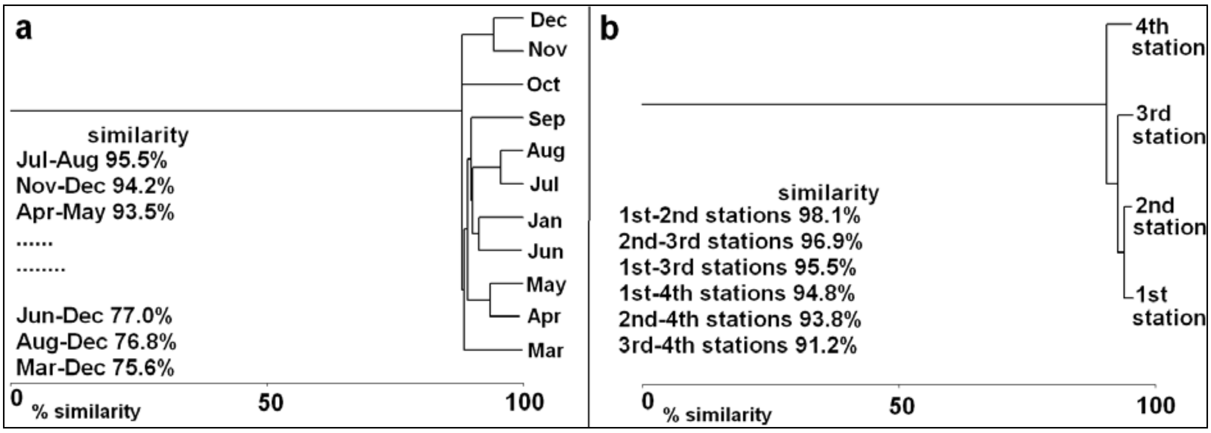

Figure 3. a-The dendrogram of similarity of months in Lake Gala in respect of physicochemical variables.
b- the dendrogram of similarity of stations in Lake Gala in respect of physicochemical variables
(single-linkage, Bray-Curtis, Log base 10).

Although a wetland often hosts considerable biodiversity and endemism, the results of the present study indicated that benthic invertebrates richness and diversity of Lake Gala were low but the number of individual was high. Furthermore, euryoic species distributed in the lake, such as *Chironomus plumosus* and *Limnodrilus hoffmeisteri*, are generally widespread, which is also statistically supported by Shannon index . Some certain taxa relate taxa to general nutrient state, denoted by the terms oligotrophic, mesotrophic and eutrophic. Lang (1985) proposed a list of oligochaeta species identified as indicator species, also Sæther (1979) developed a lake trophic classification identifying 15 lake types using profundal chironomid assemblages from Nearctic and Palaearctic lakes. Community structure was examined in terms of the ratio between phosphorus concentration and depth. However, Solimini *et al.* (2006) indicated that 15 chironomid assemblages proposed by Sæther (1979) also include many species never recorded in Southern Europe. It is known that some littoral invertebrates such as some Chironomidae species (e.g., *Chironomus* sp., *Chironomus plumosus, Cricotopus* sp.) (Kansanen *et al.*, 1984; Petridis, 1993; Brodersen *et al.*, 1998) and some Oligochaeta species (e.g., *Limnodrilus* sp., *Limnodrilus hoffmeisteri*, *Potamothrix hammoniensis*) (Kuklińska, 1989; Pinel-Alloul, 1996; Kangur *et al.*, 1998) are associated with eutrophic state.

Irrigation, pesticides, uncontrollable anthropogenic deposits, etc. affect the quality of water in Lake Gala negatively. The structure of invertebrate fauna in the Lake may change due to the effects of environmental variables. This situation may affect the food chain. Aquatic organisms rely upon the great diversity of aquatic habitats and resources for food, materials and breeding grounds. Factors such as overexploration of species, pollution from agricultural areas, increased sediments, destruction of the aquatic plants around the lake, as well as habitat loss and alteration through damming and water diversion contribute to the declining levels of aquatic biodiversity in the wetland. As a result, valuable aquatic resources are becoming increasingly susceptible to both natural and environmental changes. Thus, conservation strategies to protect and conserve the aquatic life in the lake are necessary to maintain the balance of nature and support the availability of resources for future generations. Consequently, it is recommended to perform similar studies in the aquatic areas periodically to determine the future of the water resource.

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