WATER QUALITY DETERMINATION of THE LAKES MOGAN and CERNEK (TURKEY) BY USING MACROINVERTEBRATES ACCORDANCE WITH WATER FRAMEWORK DIRECTIVE

Naime ARSLAN[1*], Deniz MERCAN[1]
[1] Department of Biology, Faculty of Arts and Sciences, Eskişehir Osmangazi University, Eskisehir, Turkey
**e-mail: oligo2009@gmail.com*

Abstract
Turkey is one of the most important zoogeographical regions in Palearctic with having inland water sources and paleogeographic and hydrogeographic structure of these sources. Lakes Mogan and Cernek are also important aquatic habitats located in different geographic regions of Turkey. Studies about invertebrates' fauna in both of lakes are very few. This study was carried out between May and August on 2013 in Lakes Mogan and Cernek to determine; diversity of invertebrate fauna, ecological status of the lakes by using macroinvertebrates accordance with WFD. For this purpose, benthic invertebrate samples were collected at totally 8 stations, at the same time, some environmental parameters also were measured in situ. Only Clitellata samples were identified to species level (because, among the benthic invertebrates community, Clitellata species' existence and distribution have the most important signs not only faunistic data but also water quality situation for inland freshwater ecosystems). In addition, some metrics were calculated, Shannon Index values of lakes were between 1.031-1.722 and 1.49-2.104, respectively Lakes Mogan and Cernek. Totaly 11 Clitellata species were determined in Lakes of Mogan and Cernek. Nais communis and Potamothrix hammoniensis were common in these lakes. Water quality class of Mogan and Cernek Lakes is III according to results of environmental parameters.

Keywords: Freshwater Oligochaeta, water quality.

INTRODUCTION

Turkey is one of the most important zoogeographical regions in Palearctic with having inland water sources and paleogeographic and hydrogeographic structure of these sources [1]. As well, it has high potential in respect to fresh water sources. Benthic organisms take an important place in inland water fauna. Within benthic organisms, Clitellata species which can found almost every aquatic system are one of the most important factors using in biological examination of surface waters [2]. Oligochaeta sensu stricto, namely clitellates, occur in marine, estuarine, freshwater and terrestrial environments. About 1.700 valid species of aquatic oligochaetes are known to date; of these, about 1.100 are freshwater [3]. The Palaearctic region, which also covers our country, supports the most abundant and diverse freshwater Oligochaeta fauna, with more than 600 valid species described to date; 80% of these are considered endemic.

Lakes Mogan and Cernek are also important aquatic habitats located in different geographic regions of Turkey. Although Lake Mogan is declared as B class wetland [4], presence of small scale industries in Lake Basin, untreated sewage effluent of Gölbaşı Municipality and TEAŞ, uncontrolled fishing technics and used as picnic area and recreational activities by people of lake basin are the main threats on lake. In addition to this, though Lake Cernek has many protection status (Ramsar Sites, Natural Protected Area, Wildlife Improvement Area), lake is deteriorated rapidly with pressure of hunting, pollution and agricultural activity.

Wetlands like Lakes Mogan and Cernek are aquatic ecosystems which are needed both provided their ecological balances and protected their biological diversity, having regard to also economical values, beside their important ecological functions. However, detailed studies about invertebrate fauna (especially Clitellata) in both of lakes are very few. Previous study which was the only research related to the clitellat fauna of Cernek Lake, 4 tubificin (*Tubifex tubifex*, *Potamothrix hammoniensis*, *Potamothrix bavaricus* and *Potamothrix bedoti*) were identified and discussed ecology of species [5]. Despite the identification at species level of Clitellata that can be found in almost any aquatic systems and exact species used as pollution indicator, is extremely difficult, but studies about Clitellata fauna in Turkey have accelerated in recent years [6, 7, 8, 9, 10, 11]. In addition, according to the Water Framework Directive, the use of Clitellata in biological monitoring studies has also increased [12, 13, 14].

As mentioned above, negative environment conditions in both of the lakes are gradually increased and their water quality, natural benthic and littoral vegetation structure have been changing. It is a known fact that these negative changing are limited to habitat of aquatic organisms or caused extinct of aquatic organisms. These reasons by taking into consideration this study is aimed to determine the diversity of Clitellat fauna and ecological status of the lakes based on some metrics of Water Framework Directive (such as BMWP). In addition, by comparing the clitellata fauna of both lakes, the morphological differences among the populations of the same species were also revealed.

MATERIALS AND METHODS

Study Area

Lake Mogan is a shallow one (area 6.35 km^2), located 20 km south of Ankara (39º47′ N; 32º47′ E) within Gölbaşı (Figure 1). Its altitude is 972 m and its depth, on average, 2-2.5 m throughout length, reaching 3-4 m at its deepest point. The length and width of Mogan Lake is 6 km and 900 m, respectively. The average depth is 3.5-4 m. The lake outlet empties directly into Lake Eymir through an alluvial channel. More than 80% of the surface area of the lake is covered by submersed macrophytes [15].

Cernek Lake is located in the Kızılırmak Delta ($41^0$40' N and $35^0$46' E) which is one of the most valuable wetland systems in the Northern Turkey (Figure 1). The surface area of the lake is 370 hectare and shallow, 1-3 m depth. Cernek Lake, located at the sea level, is a typical lagoon lake which is separated from Black Sea by narrow dune barrier. The lake water is slightly saline (average 0.75-1.28 ppt) and the lake is also non-stratified as a result of continuous mixtures. Despite its small size, Cernek Lake is one of the most valuable wetlands in Turkey, because the lake and surrounding wetlands are characterized by a high degree of biodiversity with reference to the species and natural habitats, so it has been recognized as a "Ramsar Site" [4, 16].

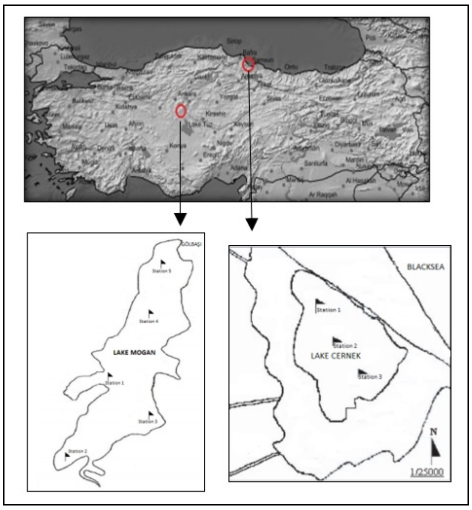

Figure 1. *Location of Lakes Cernek and Mogan in Turkey and samplig sites in lakes*

Sampling

Clitellata samples were collected at totally 8 stations (5 stations in Lake Mogan, 3 stations in Lake Cernek) (Figure 1) between May and August on 2013. Clitellata samples were collected from different habitat types in the lakes by a bottom kick net with 500 µm mesh size and then sieving. All collected sieving samples were immediately fixed in 80% ethyl alcohol. In the laboratory, collected samples were sorted and counted by using a stereomicroscope and then Clitellata samples identified to species level by using different identification keys [17, 18, 19, 20, 21, 22, 23, 24]. Three environmental parameters of bottom water were measured all the sampling stations in each lake. Water temperature, pH and dissolved oxygen (DO) were measured during sampling in situ by Hach Lange HQ40D.

In each certain stations, Bellan-Santini's (1969) quantitative dominance index [25], Shannon index, Margalef's richness index, Pielou (Evenness) index and Bray Curtis similarity index according to UPGMA (Unweighted Pair Group Average) algorithm as well as Bray-Curtis measurements were calculated using PAST 1.75b [26].

RESULTS and DISCUSSION

Water Quality

The measured environmental variables of the stations during the study period, the average values of the parameters and water quality classes (WQC) are shown in Table 1. According to our results (Table 1), Lake Mogan has Class III, Lake Cernek has Class II water quality. It is seen that especially value of dissolved oxygen in Lake Mogan was low. It is indicated that nutrition and other pollutants input to Lake Mogan that is important recreational area for Ankara with carried materials from streambed and agricultural area, in addition to domestic and industrial wastewater discharge [28, 29]. In addition, the latest study by Manav and Yerli (2008) indicated the Lake Mogan was meso- to eutrophic, according to water quality criteria [30]. In this study, only four environmental parameters were measured and reported that especially dissolved oxygen level of Lake Mogan was low. Also Lake Cernek has similar situation. It is indicated that eutrophic Lake Cernek has muddy and clay bottoms, macrophyte vegetation of lake is abound in littoral and lake is exposed to pollutant. Also, it is stated that the main reason of pollution in lake is nitrogen and phosphorus compound that input to lake from chemical fertilizer [31]. In many water quality studies, it is implied that the lake has high eutrophication potential and nutrition level of lake progress to hypertrophic [31, 32].

Table 1. *Some environmental parameters of Lakes Mogan and Cernek (*CWQ: Classes of water quality according to Surface Water Quality Management Regulation in Turkey).*

	Lake Mogan		Lake Cernek	
Paramaters	**Mean value**	**CWQ***	**Mean value**	**CWQ***
Temperature (^oC)	12.34	II	15.46	II
pH	8.59	III	8.27	II
Dissolved oxygen (mg O_2/L)	6.58	II	8.4	I

The zoobenthos samples from Lake Mogan consisted of six invertebrate groups: Clitellata (39.49%), Chironomidae (41.75%), Gastropoda (13.46%), Bivalvia (4.24%) and, in few numbers Hirudidae and Odonata. According to the number of individuals, Clitellata is the dominant taxon in the Lake Mogan. However, dominant taxon is Gastropoda with the mean dominancy 50.14% in Lake Cernek. The second dominant taxa Bivalvia (27.01%) and third one is Clitellata (20.78%) and in very few numbers Chironomidae, Ostracoda, Trichoptera, Ephemeroptera, Plecoptera and Odonata.

Although the zoobenthos of Lake Cernek seems to have higher taxon diversity, the number of individuals is few, except Gastropoda, Bivalvia and Clitellata. During this study, only Clitellata samples were identified to species level. A total of 11 clitellat species representing 6 genera were identified. The dominancy and distribution of clitellat species by stations in Lakes Mogan and Cernek are shown in Table 2.

Our results indicated that species richness and diversity of Clitellat fauna of the lakes were not high. Seven Clitellata species (*Nais communis*, *Nais elinguis*, *Tubifex tubifex*, *Psammoryctides albicola*, *Limnodrilus hoffmeisteri*, *Limnodrilus udekemianus* and *Potamothrix hammoniensis*) were identified in Lake Mogan, whereas nine species (*Nais communis*, *Nais elinguis*, *Nais pardalis*, *Nais barbata*, *Stylaria lacustris*, *Tubifex tubifex*, *Psammoryctides albicola*, *Potamothrix hammoniensis* and *Limnodrilus hoffmeisteri*) were identified in Lake Cernek (Table 2). It looks like that species diversity in Lake Cernek was higher and *Nais* species were consisted of 34.05% of Cilitellata fauna in the Lake. It is indicated that most naidid species occurring throughout the world are also cosmopolitan [33] and they have clearly adapted to a wide range of environmental conditions [18]. It is reported that the salinity of the lake homogenous throughout the year, ranged from 0.75 to 1.28 ppt and Lake Cernek can be characterized as a mixooligohaline brackish water [32]. Some Clitellates, especially pollution-tolerant naidids can withstand exposure to high salinity. Rodriguez

Table 2. *Dominancy and distribution of benthic invertebrates species and values of some indices in the stations in Lakes Mogan and Cernek (Numbers given in parentheses indicate classes of water quality according to Surface Water Quality Management Regulation in Turkey).*

	Lake Cernek			**Lake Mogan**					**Mean D%**	
Taxa / Stations	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**Cernek**	**Mogan**
Gastropoda	62,41	49,50	11,90	23,75	2,50	0,00	18,85	0,00	50,14	13,46
Bivalvia	19,76	28,85	47,14	15,00	5,00	0,00	0,00	0,00	27,01	4,24
Oligochaeta									20,78	13,46
Nais communis Piguet, 1906	12.50	13.79	17.07	17.65	7.35	12.70	0.00	9.68	14.08	8.05
Nais elinguis Müller, 1974	6.94	0.00	7.32	35.29	0.00	7.94	0.00	0.00	5.63	4.66
Nais pardalis Piguet, 1906	4.17	0.00	17.07	0.00	0.00	0.00	0.00	0.00	7.04	0.00
Nais barbata Müller, 1774	9.72	13.79	0.00	0.00	0.00	0.00	0.00	0.00	7.75	0.00
Stylaria lacustris (Linnaeus, 1767)	8.33	13.79	21.95	0.00	0.00	0.00	0.00	0.00	13.38	0.00
Tubifex tubifex (Müller, 1774)	9.72	0.00	0.00	0.00	0.00	9.52	8.77	22.58	4.93	7.63
Psammoryctides albicola (Michaelsen, 1901)	19.44	10.34	0.00	0.00	13.24	0.00	5.26	12.90	11.97	6.78
Limnodrilus hoffmeisteri Claparède, 1862	9.72	13.79	0.00	0.00	23.53	33.33	29.82	19.35	7.75	25.42
Limnodrilus udekemianus Claparède, 1862	0.00	0.00	0.00	0.00	35.29	25.40	36.84	25.81	0.00	29.24
Potamothrix hammoniensis (Michaelsen, 1901)	19.44	34.48	36.59	47.06	20.59	11.11	19.30	9.68	27.46	18.22
Hirudidae	0,00	0,00	0,00	0,00	0,00	1,35	0,00	4,60	0,00	0,76
Chironomidae	0,15	0,57	0,24	28,75	15,00	24,32	60,77	48,28	0,28	41,75
Trichoptera	0,00	0,00	0,48	0,00	0,00	0,00	0,38	0,00	0,08	0,15
Ephemeroptera	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00
Plecoptera	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00
Odonata	0,22	0,00	0,00	0,00	0,00	0,00	0,38	0,00	0,12	0,15
Ostracoda	2,75	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,50	0,00

Values of some indices in the stations of Lakes Mogan and Cernek

	Lake Cernek			**Lake Mogan**					**Mean**	
Paramaters / **Stations**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	Cernek	Mogan
Temperature (^oC)	15.6	16.3	15.9	14.3	11.2	13.1	12.1	11.5	15,93 (II)	12,44 (II)
pH	8.01	7.89	8.24	8.0	8.6	8.3	8.7	8.2	8,04 (II)	8,36 (III)
Dissolved oxygen (mg O_2/L)	8.24	8.64	8.12	4.42	7.14	5.23	6.44	6.82	8,33 (I)	6,01 (II)
Shannon	2.10	1.69	1.49	1.03	1.48	1.65	1.41	1.72	1,76	1,45
Simpson	0.86	0.79	0.752	0.62	0.75	0.78	0.72	0.81	0,80	0,73
Evenness	0.91	0.910	0.88	0.93	0.88	0.87	0.82	0.93	0,86	0,88
Margalef	1.73	1.08	0.86	0.43	0.86	1.08	0.86	1.08	1,22	0,86
BMWP	III	II	II	III	IV	III	III	IV	II	III

and Reynoldson indicated that *Nais communis* can survive up to 6‰ salinity and between 3.9-9.9 pH [34]. In addition, *Stylaria lacustris* was found in in brackish water with salinity less than 7%, also in open water and even in the profundal by Timm [35].

Nais elinguis's echophysiology study has shown that the nutritional ratio remains unchanged from fresh water to 20‰ salinity, and it was shown to be a good osmoregulator, remaining hyperosmotic below 7‰ S, and hypo-osmotic above this [36].

As seen in Table 2, in Cernek Lake four *Nais* species have been identified. Salinity variation is limiting factor for diversity and distribution for several benthic invertebrates. But, it is clear that five naidid and other tubificin species (Table 2) identified in the Cernek Lake can tolerate this salinity value.

For the Lake Mogan, values of Shannon, Simpson and Margalef Diversity Index, varied between 1.031 and 1.722; 0.8103 and 0.624; 0.4343 and1.086; for Lake Cernek varied between 1.49 and 2.104; 0.752 and 0.868; 0.868 and 1.737, respectively (Table 3). The highest taxa number was identified in Lake Cernek station 1 and 2 and values of Shannon diversity index were 2.104 and 1.698, respectively. The lowest value of Shannon diversity index was identified in Lake Mogan station 1 (as 1.031). The values of BMWP varied between III-III in Lake Cernek and III-IV in Lake Mogan. When the BMWP indices were examined in terms of water quality classes, Lake Cernek was determined as clean but slightly impacted (Class II), but Lake Mogan was determined as impacted (slightly polluted Class III).

In Lake Mogan, *Limnodrilus udekemianus* and *Limnodrilus hoffmeisteri* have the highest abundance (29.24% and 25.42%, respectively). However *Nais elinguis* has lowest dominancy (Table 2). Although population density was not high *Potamothrix hammoniensis* occurred in all sampling stations in the lake (Table 2) among the identified Clitellata species. In general, three species *Limnodrilus hoffmeisteri, Limnodrilus udekemianus* and *Tubifex tubifex* were found together.

It is known that existence and abundance of clitellat species in aquatic systems based on diverse environmental parameters such as substrate structure, water temperature, flow rate, oxygen concentration and availability of nutrients [37]. Although the subfamily Tubificinae originated in the Northern Hemisphere it is distributed everywhere in the world [18]. Members of this subfamily are adapted for entrenchment in a soft substrate. They live in muddy substrates, tolerate organic pollution, and are indicators of an alpha-mesosaprobic or polysaprobic zone [38]. In addition, freshwater euryhaline form *Potamothrix hammoniensis* was dominant and the most abundant species, and has been reported in many surveys from eutrophic lowland lakes in Europe. Timm was detected that *Potamothrix hammoniensis* is the climax species in eutrophic lakes [39]. It is found in this study that *P. hammoniensis* is dominant species in Lake Cernek and often accompanied by *L. hoffmeisteri* and some others tubificids. Tubificin members were dominant in Lake Mogan that is going to be eutrophic according to results of previous studies [30, 31, 32] and our results are supported the other previous studies.

Prior to the present study which was performed by Yıldız et al. in the Lake Cernek, four Tubificin (*Tubifex tubifex, Potamothrix hammoniensis, Potamothrix bavaricus* and *Potamothrix bedoti*) had been recorded [5]. The last two species which were not found in the present study, brackish-water species tolerating also slightly mineralized fresh water [40]. In addition, there is no record of five naidids (*Nais communis, Nais elinguis, Nais pardalis, Nais barbata* and *Stylaria lacustris*) in Lake Cernek. It was shown in the previous study that Tubificin species were also dominant groups but it was seen that the dominancy composition changed along ten years. With these two results, we can conclude that if environmental factors change, ecosystem structure often is influenced and alterations occur. These alterations take place in species composition, distribution and (or) biodiversity as well as ecosystem function. In the previous study tubificin species were also shown to be dominant group, but dominancy and composition changed over a decade.

One of the most important results in this study is morphological differentiation between population of *Nais communis* and *Potamothrix* *hammoniensis* which are distributed in both of lakes. *P. hammoniensis* which is originated Ponto-Caspian was commonly identified in both of lakes. Prostomium of *P. hammoniensis* samples in Lake Mogan was conical and sharp, dorsal bundles were rigid and pectinate chaeta was thicker. Widening rate in distal of spermathecal chaetae in these samples was higher and more bent. Prostomium of samples in Lake Cernek is less conical and there is no differentiation between hair and pectinate chaetae in anterior and posterior dorsal bundles. *P. hammoniensis* population in both of lakes were showed some taxonomical differentiations. The same situation was present in *N. communis* samples. Samples of this species collected in Lake Cernek and Mogan were identified as *N. communis* based on valid identification keys (such as [20, 23, 24]) because of not yet revising identification keys. The largest difference between the two species can be observed when the worms are alive, because *N. variabilis* swims with spiral movements with the oesophagus abruptly dilating to the midgut while *N. communis* is not able to swim and the oesophagus gradually dilates to the midgut. According to these morphological identification keys, the only taxonomical character in fixed samples for *Nais communis/variabilis* complex is that differentiation between anterior and posterior ventral chaetae is much distinct in *N. variabilis* than *N. communis*. Envall, Gustavsson and Erséus were conducted a study with eighty-one Nais individuals and identified that five or probably more morphotypes were comprised morphologically differentiation variations of *Nais communis/variabilis* complex and indicated that there is some relationship between genetical differentiation and chaetal morphology in this genus [41]. These differentiations can be related to geographical isolation. It is obvious that this is a morphological differentiation between populations having same species in these two lakes which are located in different parts of Turkey and seperated with natural barriers. However, differentiation for both *P. hammoniensis* and *Nais communis/variabilis* complex must be searched genetically with molecular analyses. Because, one species has two reasons for live in its habitat; one is ecological reasons and second is its evolutionary history [42]. When considered in this respect, probability of observation is considerably higher both old fauna inhabitant and effects of geographical isolation in our aquatic ecosystems which are old concerning their histories and connections. For this reason, both of populations showing differentiations (*N.communis* and *P. hammoniensis*) in Lakes Mogan and Cernek must be examined with molecular analysis.

CONCLUSION

Our results indicate that species richness and diversity of Clitellat fauna of lakes Mogan and Cernek are not high. In the present study, it was shown that clitellat fauna of Lake Mogan was dominated by tubificin species (*Limnodrilus hoffmeisteri, Limnodrilus udekemianus* and *Potamothrix hammoniensis*) known as pollution tolerant organisms, which is typical of many freshwater habitats. While, Lake Cernek Clitellat fauna more diverse than Mogan and was dominated by Naidid species (more than 30% in total clitellat fauna). But, common characteristic of both lakes has pollutant tolerant species. Large numbers of pollution-tolerant clitellats are often indicative of poor water quality and prior water quality studies conducted at both lakes also support these taxonomical results. Because benthic macroinvertebrates are the most useful biological indicators for surface water quality and they have often been used to evaluate the degree of anthropogenic impacts to aquatic ecosystems [43, 44]. Among them Clitellata are tolerant to high levels of organic pollution, and have been observed to replace other benthic macroinvertebrates that cannot tolerate high concentrations of nutrients [45, 46]. According to previous studies about water quality of Lake Mogan, it appear to be in an euthrophic status (such as [30, 31, 32, 47]). Although, Lake Cernek is one of the most valuable wetlands in Kızılırmak Delta, several studies indicated that the lake has a strong eutrophication potential owing to hypertrophic capacity [48, 49, 50]. The results of the studies on water quality overlap with the clitellat fauna structure in both lakes. In lake ecosystems, the composition and distribution of zoobenthos is known to be highly influenced by short and long term environmental changes. Comparing the results of recent studies with results obtained ten years ago may have important consequences for lake Clitellat fauna changes over time [5].

One of the most important results in this study was morphological differentiation between population of *Nais communis* and *Potamothrix hammoniensis* which were distributed in both of lakes. These differentiations can be ecophenotypically variations as a result of adaptation or subspeciation and (or) speciation. Taxonomical part of these differentiations can be determined with molecular analysis (DNA taxonomy and associated molecular markers could be the only way to reveal the true level of differences on taxonomical character for these two species). Because, several molecular studies have revealed the existence of cryptic species within aquatic oligochaetes. It is obvious that populations of *P. hammoniensis* and *N. communis* in both of lakes are required to examined in molecular level.

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