Aquatic Oligochaetes Biodiversity in Turkey: Example of Lake Sapanca with Application of the Biotic Indices

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Abstract**—** Turkey is the only country covered almost entirely by three of the world's 34 biodiversity hotspots: the Caucasus, Irano-Anatolian, and Mediterranean. Due to the remarkable variation in its geographic features Turkey is home to 305 Key Biodiversity Areas. Although, Lake Sapanca is one of the most important lakes in Turkey in terms of Important Bird Area (IBA) it has no Ramsar designation as yet.

Oligochaeta sensu stricto, namely clitellates ocur in marine, estuarine, freshwater and terrestrial environs. Despite the ecological importance, freshwater oligochaeta fauna of Turkey still remain under-or even unexplored. Up to now, the aquatic fauna of oligochaetes has not been intensively studied, and only 107 species (5 of them endemic) have been reported from different parts of Turkey. And, given that about 43% of freshwater oligochaete species occurring in Turkey are naidids, about 37% are tubificin.

This study reports the first assessment of water quality of Lake Sapanca by using benthic macroinvertebrates, physicochemical variables and some metrics (Biological Monitoring Working Party Score (BMWP), Average Score per Taxon (ASPT), Simpson Diversity Index, Shannon-Wiener Diversity Index, Margelef Index and Evennes which are required to implement by European Union Water.

To identify the zoobenthic fauna and water quality of Lake Sapanca, samples were collected seasonally from 9 stations between June 2011 and December 2013. As a result of the study, nineteen takson and 20 oligochaeta species were determined. The water quality of Lake Sapanca was found to be polluted not only biotic indices but also physicochemical parameters. In addition, when we compare the previous study in the same lake we can conclude that Oligochaeta fauna composition and dominancy in the lake changed along ten years.

Keywords**—**ASPT, BMWP, Lake Sapanca, macroinvertebrates.

I. Introduction

Determination of the benthic community composition is a key component for aquatic systems. Oligochaeta, a subclass of the Clitellata, are broadly distributed worldwide and frequently are the most abundant in many freshwater ecosystems and they are widely used for monitoring river and lake pollution. Despite, studies about freshwater oligochaeta have increased in recent years such as, [1], [2], [3], [4], [5], [6] regarding our knowledge of the freshwater oligochaeta fauna of Turkey, large areas still remain under-or even unexplored. Up to now, only 107 species (5 of them endemic) have been reported from different parts of Turkey. And, given that about 43% of freshwater oligochaete species occurring in Turkey are naidines, about 37% are tubificin.

Turkey has 135 delineated ‘‘wetlands of international significance covering 2.2 million ha [7]. Although, Lake Sapanca is one of the most Important Bird Area (IBA) in Turkey, it has no Ramsar designation as yet [8].

Many biotic indices have been established based on macroinvertebrates, because they occupy a central role in the aquatic ecosystem by participating in the decomposition of organic matter and by constituting the major food source for other aquatic invertebrates, fishes, and some birds [9]. The BMWP index was used in several studies to examine the water quality of streams in Turkey [10]-[14]. In addition, instead of direct usage, the BMWP index was adapted for the first time in Turkey for the Yeşilırmak River (Y-BMWP) [12].

The aim of this study is to evaluate the diversity and distribution of fauna of Oligochaeta and to contribute to the Oligochaeta fauna both Lake Sapanca and Turkey.

II. Material and Methods

Study Area

Lake Sapanca is one of the biggest lakes in the province of Adapazari, which is located on the northwest of Turkey (Figure 1). Its surface area is 46.8 km^2 with a maximum depth of 55 m. It is 30 m above sea level, with 13 rivers flowing into the lake and it has one outflowing river. The lake has been used as a source of drinking and process water to the district of Adapazari and as a recreational area.

Sampling

Samples were taken from Lake Sapanca by Ekman grab and hand dredge between June 2011-December 2013 (Figure 1). Samples of zoobenthos were collected with an Ekman grab sampler (225 cm^2), two hauls per station. The samples were washed in the field on a series of sieves with decreasing mesh sizes and preserved in plastic bottles with 70% or 96% ethanol. In the laboratory, benthic samples were examined under a stereo binocular microscope and sorted into family or clasis level (only Oligochaeta samples were identified to species level). Sorting of animals proceeded in the laboratory, specimens of Oligochaeta were studied as temporary whole mounts in glycerin or polyvinyl lactophenol. For taxonomical identification of specimens, publications of [15]-[18] were used. In addition, some physicochemical variables of deep water (pH, temperature, dissolved oxygen, Coductivity) were determined in situ using Multi-Parameter Measurement Device (HQ40d Portable Multiparameter Meter, Hach, US) during the field studies. Other variables (NO_3–N, NH_4-N and biological oxygen demand (BOD)) were measured in the laboratory by following the standard methods [19].

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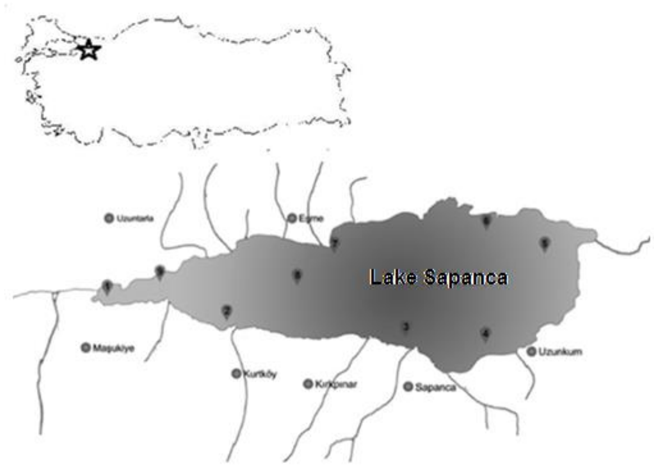

Fig. 1: Geographical situation of the study area and locations of sampling stations.

Data analyses

In each sampling site revised Biological Monitoring Working Party [20], Average Score Per Taxon (ASPT) [21], Shannon, Simpson diversity and Margelef indices were used to determine water quality based on macroinvertebrates.

III. Results and Discussion

Physicochemical parameters

The minimum, maximum, and average values of measured physical and chemical variables and water quality classes of the stations during the study period are represented in Table I.
Lake Sapanca has Class II-III water quality [22] according to the physicochemical parameters of collecting sites (Table I). As can see Table I, dissolved oxygen values ranged from 5,1 to 12,92 mg/L in sites (these values actually not low) but nutrient concentrations, especially amonium nitrogen values ranged between 0,1 and 4,92 mg/l in sites. This value is high, therefore lake’s water quality classified as III (Table I). Reference [23] reported that loading, discharge and accumulation amounts of nitrogen and phosphorus causing eutrophication in the lake, and it had passed to the mesotrophic from oligotrophic state. Our findings showed consistency with these results.

Biological results

In this study, 32 taxa (20 of them belonging to oligochaeta species) comprising 15,121 individuals were collected in total. The zoobenthos samples from Lake Sapanca contained the following invertebrate groups: Gastropoda (Neritidae, Viviparidae, Melanopsidae, Bithyniade, Lymnaeidae, Physidae, Planorbidae, Valvatidae, Lithoglyphidae), Bivalvia, Nematoda, Oligochaeta, Copepoda, Gammaridae, Chironomidae and, in few numbers, Hirudinae, Odonata, Ceratapogonidae, Simuliidae, Ephemeroptera (Baetidae) and Gammaridae.

Table I: Physicochemical Parameters And Average Water Quality Classes (*Republic Of Turkey Ministry Of Forestry And Water Affairs, 2015) For Stations In Lake Sapanca. AWQ: Average Water Quality Class, Romen Number Indicated Water Quality Class.

	Sampling Stations									Water Quality Class*				AWQ
	Min-max and (Average)													
	1	2	3	4	5	6	7	8	9	I	II	III	IV	III
General Parameters														
Temp. °C	5,3-27,2 (14,75)	4,7-28,7 (14,62)	5,5-30,1 (15)	5,4-26,6 (14,4)	6,6-30,3 (15,76)	5,3-27,0 (14,83)	5,5-25,8 (16,85)	3,3-25,5 (13,7)	3,3-24,8 (13,96)	≤25	≤25	≤30	>30	I
pH	7,9-8,4 (8,24)	7,9-8,5 (8,34)	7,5-8,6 (8,32)	7,6-8,5 (8,1)	7,6-8,4 (8,15)	7,7-8,5 (8,2)	0-8,52 (6,03)	0,08-8,5 (6,1)	7,7-8,4 (8,2)	6,5-8,5	6,5-8,5	6,0-9,0	<6,0 > 9,0	I
Oxygenation Parameters														
DO mg/L	7,02-12,2 (9,83) I	7,3-12,5 (10,03) I	6,7-12,3 (9,85) I	7,2-12,3 (10,03) I	6,3-11,8 (9,60) I	6,6-12,3 (9,87) I	5,1-12,5 (8,16) I	6,9-12,9 (10,07) I	7,3-12,9 (10,12) I	>8	6-8	3-6	<3	I
BOD mg/L	0-4,6 (2)I	0-2,5 (1,5)I	1-3,2 (2,1)I	0-4,8 (2,5)I	0-7,3 (2,1)I	0-3 (1,5) I	0-4 (1,7) I	1-3 (1,5) I	1-12,3 (4,25) II	4	8	20	> 20	II
Nutrient Parameters														
NO_3^--N mg/L	0,11-0,94 (0,46) I	0,09-0,46 (0,20) I	0,05-0,22 (0,13) I	0,04-0,11 (0,09) I	0,06-0,88 (0,29) I	0,07-0,10 (0,09) I	0-0,11 (0,07) I	0,05-0,24 (0,12) I	0,04-0,10 (0,07) I	< 5	5-10	10-20	> 20	I
NH_4^+-N mg/L	0,11-4,92 (1,54) III	0,11-0,92 (0,59) II	0,14-0,85 (0,53)II	0,14-0,74 (0,47) II	0,13-0,96 (0,54) II	0,15-0,62 (0,42) II	0-0,51 (0,29) II	0,14-2,35 (1,14) III	0,15-0,92 (0,46) II	< 0,2	0,2-1	1-2	> 2	III
AWQ	III	II	II	II	II	II	II	III	II					

Total abundance and species diversity were calculated (Table II) but apparently low.The greatest part of the material was represented by oligochaetes (about 39,24%) and Gastropoda (22,72%). Apart from these dominant groups, Bivalvia comprised 10,68 %, Chironomidae 8,86%, all others together about 14,02% (Table II). The most individuals were collected at station 5 (1092 ind) while the fewest individuals were collected at station 8 (271 ind). *Potamothrix hammoniensis* (28,7%) and *L. hoffmeisteri* (5,97%) were found to have the highest abundance in Oligochaeta. *Psammorichtydes albicola* and *P. barbatus* have also high abundance (1,67% and 1,38% respectively). The number of taxa belonging to invertebrates was the highest at the 1th station while it was the lowest at the 2nd station (Table III).

The 2nd station sandy-stone substrate and lacks vegetation. Therefore low diversity may be explained with these reasons**.**
It is known that some tubificin species, especially *Limnodrilus* and *Tubifex* spp., can tolerate bad conditions and they have clearly adapted to a wide range of environmental conditions [15] which is also supported by our results. Genus *Potamothrix* is widely distributed throughout the world [24] and other genera, *Psammoryctides*, are distributed in Holarctic [25]. In addition these species considered as a biological indicator of organic pollution and eutrophication and they inhabit together in the same habitats in muddy substrates and their abundance can reach immense sizes in aquatic systems with high trophy levels [15], [26].

Dominant and the most abundant species, *Potamothrix hammoniensis* known as freshwater euryhaline form and this species reported in several studies from eutrophic lowland lakes in Europe.

TABLE II: DISTRIBUTIONS AND DOMINANCE (%) OF MACROINVERTEBRATES AT THE STATIONS.

	Sampling Stations								
Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Gastropoda									
Neritiade	-	-	-	-	3,3	3,51	0,58	-	-
Viviparidae	0,36	-	-	-	0,09	-	0,19	-	0,29
Melanopsidae	0,24	0,33	-	0,21	2,38	3,14	2,14	-	-
Bithynidae	1,82	-	-	-	2,66	2,31	0,19	-	-
Lymnaeidae	2,78	-	1,1	-	0,46	1,02	-	-	0,29
Physidae	4,48	-	2,2	-	0,37	2,95	1,17	-	0,29
Planorbiade	2,66	-	1,1	-	3,57	2,4	2,14	-	0,88
Valvatidae	11,14	1,66	-	0,21	64,19	55,22	11,07	0,37	3,22
Hydrobiidae	0,12	-	-	-	2,47	-	0,97	-	0,29
Bivalvia	4,72	-	2,42	-	12,73	14,22	14,95	-	47,08
Nematoda	-	15,23	-	1,68	-	-	-	5,17	-
Oligochaeta									
Aulodrillus pluriseta	-	-	-	-	-	-	-	-	0,29
Dero digitata	-	-	-	-	-	-	0,19	-	-
Ophidonais serpentina	-	-	-	-	-	-	0,39	-	-
Nais elinguis	0,85	-	-	-	-	-	-	-	-
Nais communis	0,61	-	-	-	-	-	-	-	-
Limnodrilus cervix	-	0,33	-	-	-	-	-	-	-
Limnodrilus claperadeanus	0,97	0,66	0,22	-	0,09	-	0,19	0,37	-
Limnodrilus hoffmeisteri	13,2	18,54	3,52	0,42	0,37	0,92	7,18	4,06	5,56
Limnodrilus udekemianus	0,12	-	-	-	-	0,37	0,19	-	-
Potamothrix hammoniensis	16,34	49,34	53,74	34,11	4,49	3,51	45,24	37,27	14,04
Potamothrix heuscheri	-	-	-	0,21	-	-	-	-	-
Psammoryctides albicola	0,36	0,33	1,1	0,21	-	1,29	1,17	1,48	9,06
Psammoryctides barbatus	0,36	1,99	0,66	2,74	-	0,28	2,14	0,74	3,51
Psammoryctides deserticola	0,24	-	-	-	-	-	-	-	0,29
Psammoryctides moravicus	0,12	0,99	0,66	0,84	-	0,18	0,58	2,21	-
Tubifex tubifex	-	-	0,44	0,21	-	-	-	-	-
Enchytraeidae spp.	-	-	-	-	-	0,18	-	-	-
Trichodrillus sp.	0,36	-	-	-	-	-	-	-	-
Rhynchelmes sp.	-	-	-	-	-	0,09	-	-	0,29
Quistradrilus multisetosus	-	-	-	0,21	-	-	-	-	0
Hirudinae	-	-	-	-	0,09	-	-	-	1,75
Copepoda	5,45	-	-	-	-	-	-	45,76	0
Gammaridae	1,21	-	-	0,21	-	-	-	-	0,58
Cyclopidae	-	-	26,87	58,74	-	0,09	-	-	-
Ephemeroptera									
Baetidae	-	-	0,66	-	-	0,18	-	0,74	-
Chironomidae	30,51	10,6	5,07	-	2,75	8,13	9,32	1,11	12,28
Ceratapogonidae	0,97	-	0,22	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	0,74	-

Several studies data show that in the Pliocene, macroinvertebrates fauna were widely distributed in different geographic parts of the Palearctic, via the basins of the Rivers Danube and Volga, the Black Sea region, and Western Siberia. During the Pleistocene, most representatives of the genus expired or were forced out by glaciers to downstream parts of rivers belonging to basins of the Black Sea and Azov Sea. It is known that in Europe, the Caspian and Ponto-Azovian fauna have spread in different ways to Turkey (via Aral basin, Euphrates river, European river systems and the Adriatic Sea [27]. In addition, Southern corridor, one of the most important principal invasion corridors exist in Europe, links the Black Sea basin with the North Sea basin via the Danube Main Rhine waterway, including the Main–Danube Canal and the length of the corridor from the Black Sea (Sulina Arm) up to the North Sea is about 3500 km [28]. The modern pattern of *Potamothrix hammoniensis* distribution in Europe and Turkey implies that the Southern corridor could have been the main routs of its migration. From the information provided, we can conclude that the Danubian and some lakes fauna of Turkey (at least in Marmara and Aegean region) associated. Reference [5] indicated that Danube River Delta's lakes Oligochaeta communities comprise between 7.9% and 36.2% of the total biomass of benthic fauna and among them *P. hammoniensis* was the more efficient under hypertrophic conditions. Present study results show that Oligochaeta fauna of Lake Sapanca similar to of Danube River Delta's lakes.

Previous study in the same Lake [5], 13 species were found, of which 11 tubificin and 2 naidid species.They were reported that the most abundant species were *Tubifex tubifex* (707 ind.m^{-2},) and *Psammoryctides barbatus* (243 ind.m^{-2}). It was shown in the previous study that Oligochaeta were also dominant groups but it was seen that the dominancy and composition changed along ten years.

TABLE III: VALUES OF INDICES OF THE SITES AT LAKE SAPANCA (ROMEN NUMBER INDICATED WATER QUALITY CLASS).

	Sampling sites								
Indices	1	2	3	4	5	6	7	8	9
Taxa number	24	11	15	13	15	19	19	12	17
BMWP score	27 (IV)	6 (V)	16 (IV)	1 (V)	21 (IV)	25 (IV)	18 (IV)	12 (IV)	18 (IV)
ASPT	3,38 (IV)	2 (IV)	2,6 (IV)	1 (IV)	3 (IV)	3,1 (IV)	3 (IV)	3 (IV)	3 (IV)
Shannon Index	2,231	1,467	1,429	1,001	1,378	1,664	1,834	1,355	1,756
Simpson Index	0,8409	0,687	0,634	0,538	0,565	0,663	0,745	0,646	0,73
Evenness	0,3877	0,394	0,278	0,209	0,265	0,278	0,33	0,323	0,341
Margalef	3,424	1,751	2,288	1,947	2,001	2,576	2,883	1,964	2,742

The values of Simpson Diversity Index, Shannon-Wiener Diversity Index and Margalef Diversity Index varied between, 0,53 and 0,84; 1 and 2,23; 1,34 and 3,42 respectively (Table III). The lowest values were recorded at Site 4, the highest values at Site 1 in all three diversity indices. Low diversity of benthic macroinvertebrate community can emphasizes the environmental degradation. The diversity indices values decreases with negative environmental changing. According to the Reference [29] the level of diversity of invertebrate is important to define ecological status of aquatic ecosystems.

In the present study, the observed high abundance of pollution-tolerant oligochaets (*Potamothrix* spp, *Limnodrilus* spp. and *Psammoryctides* spp.-see Table II) indicated poor water quality of the lake (characterized by low dissolved oxygen and high nutrient concentrations). Although, dissolved oxygen levels of the lake not low but high value of some Ammonium ions might be limiting for many species, these conditions favoured *Potamothrix, Limnodrilus,* some Gastropods and Chironomids [30]-[31] (Kelly-Quinn, 2003; Naguma et al, 2004).

IV. CONCLUSION

Oligochaeta spp. ocur in marine, estuarine, freshwater and terrestrial environs. Around the world about 1.700 valid species of aquatic oligochaetes are known to date; of these, about 1.100 are freshwater. Despite the ecological importance, freshwater oligochaeta fauna of Turkey still remain under-or even unexplored. Up to now, the aquatic fauna of oligochaetes has not been intensively studied, and only 107 species, of which five of them were described as new species [32-34] have been reported from different parts of Turkey. And, given that about 43% of freshwater oligochaete species occurring in Turkey are naidids, about 37% are tubificin. Because of the limited information, it is impossible to speculate about extensive zoogeographical aspects. The collected data show that Oligochaeta fauna of Turkey is composed of cosmopolitan or widely distributed species, while Haplotaxidae, Lumbriculidae and Criodrilidae have small numbers of species. According to literature data, the most recorded genera are *Pristina*, *Nais* and *Dero* accompanied by *Potamothrix*, *Psammoryctides*, *Tubifex* and *Limnodrilus*. Timm [35] divided the Holoarctic region into six subregions, on the basis of the distribution of oligochaetes, the Euro-Siberian, West Balkan, Ponto-Caspien (brackish water), East Siberian, Pacific and Atlantic ones. As we indicated in result and discussion section, according to modern pattern of the most recorded genera distribution of oligochaetes in Europe and Turkey implies that the Danubian and some lakes-rivers fauna of Turkey (at least in Marmara and Aegean region) associated.

As we emphasized before Lake Sapanca is one of the most important lakes in Turkey in terms of Important Bird Area (IBA) but it has no Ramsar designation as yet. In addition loading, discharge and accumulation amounts of nitrogen and phosphorus causing eutrophication in the lake, and it had passed to the mesotrophic from oligotrophic state [23]. Our findings showed consistency with these results. Consequently, our findings for both physicochemical parameters and zoobenthic organisms indicate that the water quality of this lake is polluted.

In addition, biotic and diversity index results can emphasizes the environmental degradation. In the study which was performed by [5] in the same Lake, 13 species were found of which six of them were also found in the present study, seven of them were not found; in addition in the present study fourteen taxa determined new for lake Oligochaeta fauna. When we compare two studies results we can conclude that fauna dominancy and composition of Oligochaeta in the lake changed along ten years.

Only measuring some physicochemical parameters of water, we cant assess general health of aquatic systems, freshwaters organisms should be considered to be informed about general health of freshwater life. For this, biotic indices should be used for water quality and health of surface water studies. Aim of EU Water Framework Directive (Council of European Communities 2000) is to achieve ecological quality of all waters (inland surface waters, transitional (=estuarine) waters, coastal waters and groundwater). In Turkey, several biotic index studies were done and stil in progress. There is still a need for further intensive study and testing of the effectiveness of the BMWP and ASPT indices. These indices may require adaptation for Turkey based on its geomorphological and environmental features.

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