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The aquatic oligochaetes (Annelida: Clitellata) of eight lakes in the Aşağı Fırat River Basin (Lower Euphrates, Turkey)

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Abstract: The Aşağı Fırat River is located in the south-eastern Anatolia, Turkey. The water quality of the Aşağı Fırat River basin has been degrading for some time, primarily as the result of pollutants associated with the discharges from numerous domestic and agricultural point sources. Aquatic macroinvertebrate samples were collected from eight lakes conducted by using both hand-nets and an Ekman-Birge grab sampler during the summer and autumn of 2014, focusing on the species composition and distribution of aquatic oligochaetes in eight lakes of the Aşağı Fırat River basin, and their relationships with physico-chemical parameters measured in those lakes using Principal Component Analysis. Results of analyses of all identified benthic macroinvertebrates clearly indicate the percent dominance of oligochaetes in benthic samples in the eight dam lakes that were sampled: Hacıhıdır lake (62.9%); Atatürk lake (49.6%); Üçöz lake (28.9%); Dumluca lake (22.01%); Seve lake (13.9%); Çat lake (8.5%); Karakaya lake (7.8%) and Birecik lake (5%). During this study, 1044 oligochaete specimens representing 10 species of two subfamilies within the family Naididae were identified. The most abundant taxa were *Limnodrilus hoffmeisteri* (48.94%), *Potamothrix hammoniensis* (19.3%), *Tubifex tubifex* (13.1%), *Nais simplex* (5.2%) and *Nais communis* (4.1%).

Key words: Oligochaeta; Aşağı Fırat River basin; Turkey; lake; reservoir

Introduction

Turkey has about 120 natural lakes, including small lakes in the mountains and 555 large dam reservoirs (General Directorate of State Hydraulic Works 2015). The number of reservoirs has been steadily increasing in Turkey, as it has elsewhere in the World. The Aşağı Fırat River is located in the south-eastern Anatolia region in Turkey (Fig. 1). The Fırat has the most efficient and highest water potential river of Turkey. Originating in eastern Turkey, the Fırat flows through Syria and Iraq to join the Tigris in the Shatt al-Arab, which empties into the Persian Gulf. The Aşağı Fırat River basin is under the threat of pollution, primarily originating from several domestic and agricultural point sources (untreated and inadequately processed discharges from wastewater treatment facilities). All lakes investigated during this research project have been used for irrigation and drinking water, and water discharged from two of these lakes – Atatürk and Karakaya – generate hydroelectric power.

Benthic macroinvertebrates are integral to many key processes within lake ecosystems, e.g., food chain dynamics, productivity, nutrient cycling and decomposition (Reice & Wohlenberg 1993). Hence, any environmental changes in lakes, for example in nutrient concentrations, would be reflected by changes in the structure of the benthic macroinvertebrate community (Carvalho et al. 2002). Oligochaetes that are associated with the substrates of lakes, reservoirs, and other aquatic habitats are broadly distributed worldwide and frequently are the most abundant group in many freshwater ecosystems. Certain species show ecological adaptations in ecosystems at different trophic levels, and are known to respond to extreme environmental situations related to high temperature, hydrogen ion concentration (as pH), organic matter content in the sediment, and low dissolved oxygen in the water-sediment interface (Armitage et al. 1995).

The objective of this study was to investigate the species composition and distribution of aquatic oligochaetes, and their relationship with physico-chemical parameters in eight dam lakes of the Aşağı Fırat River basin.

Material and methods

Aquatic oligochaetes were sorted from benthic macroinvertebate samples collected in eight lakes in the Aşağı Fırat River basin during the in summer (18–25 July) and autumn (4–11 November) of 2014. Two types of sampling de-

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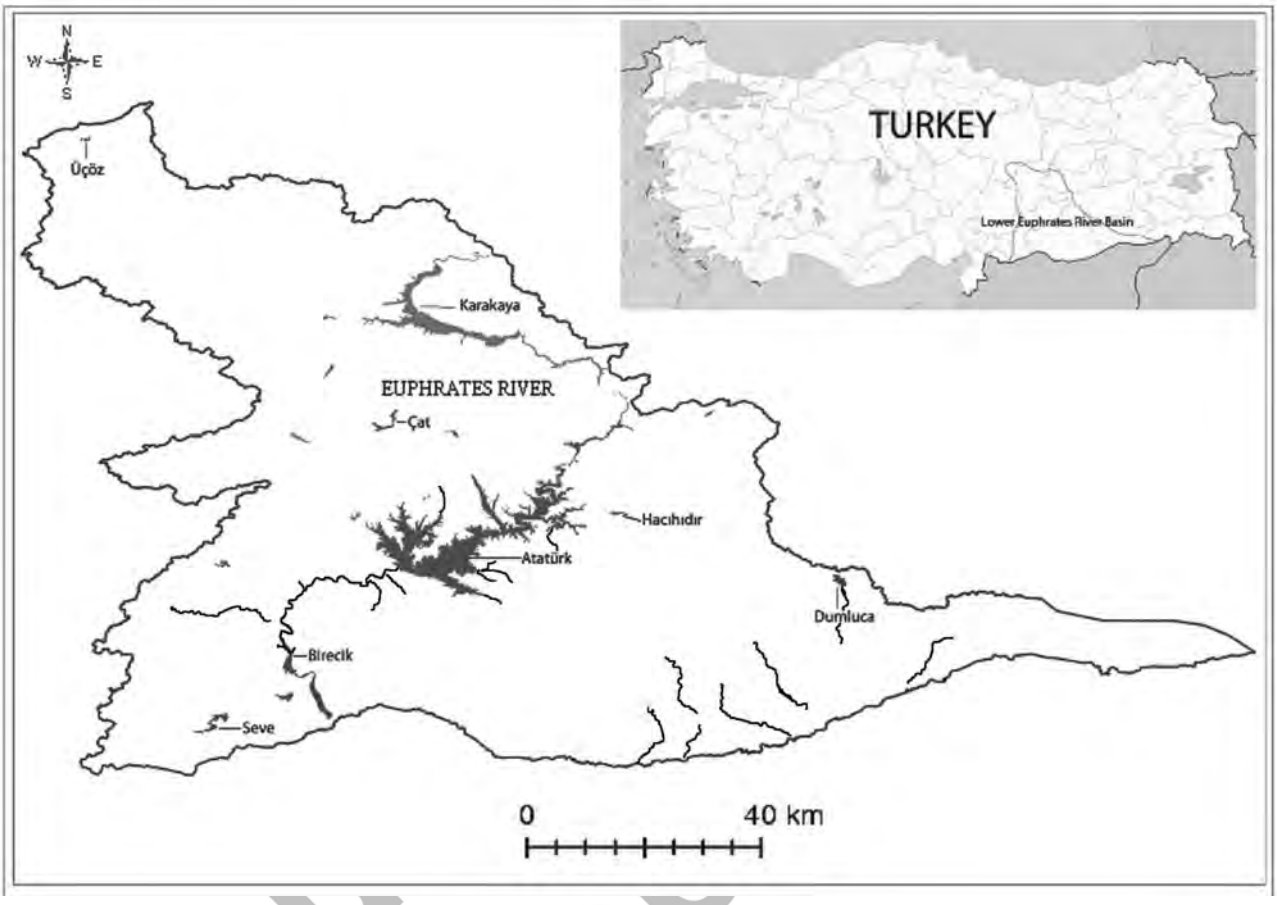

Fig. 1. Location of the Aşağı Fırat River basin and the lakes under study.

vices were used to collect aquatic oligochaetes: hand net in shallow regions where the substrate was mostly clay and macrophytes, and Ekman-Birge grab sampler for deeper areas. Oligochaetes and other aquatic macroinvertebrates were separated from substrate materials in samples using a 500 μm sieve, and thin long-nose tweezers; specimens were then fixed in 4% formalin. The samples brought to the laboratory were divided into groups and then preserved in 70% ethyl alcohol solution (Welch 1948). Samples were sorted, identified and enumerated in the laboratory using dissecting microscope. With the exception of immature and damaged/incomplete specimens, all oligochaetes sorted from benthic samples were identified to the lowest possible taxonomic level, usually to genus or species. Oligochaete specimens were identified using the keys presented in the following publications: Brinkhurst (1971a, b), Brinkhurst & Jamieson (1971), Kathman & Brinkhurst (1998), Timm (1999) and Pinder (2010). Classification and nomenclature follow that presented in the above references, and also in Erséus et al. (2008) and Reynolds & Wetzel (2015).

During the sampling period, surface temperature, hydrogen ion concentration (as pH), dissolved oxygen (DO), were measured in situ using a Hach-Lange HQ40d portable multi-parameters field water quality meter and biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia (NH_4-N), nitrite (NO_2-N), nitrate (NO_3-N) and total phosphorus (Total-P) were measured in the laboratory according to standard methods (APHA 1999).

Multivariate analysis was performed with CANOCO 5. Relationships between species and environmental parameters were determined using Principal Component Analysis (PCA). Principle Component Analysis (PCA), (as provided in CANOCO; ter Braak & Smilauer 2012) was carried out as a linear method to establish associations between oligochaetes and environment variables.

Results and discussion

During the present investigation, a total of 1,044 individuals of oligochaetes were counted in the summer and autumn season. Ten species of aquatic oligochaetes were identified from samples collected from eight dam lakes located in the Aşağı Fırat River basin (Tables 1, 2). The most abundant taxa (in decreasing order) were *Limnodrilus hoffmeisteri* (48.9%), *Potamothrix hammoniensis* (19.3%), *Tubifex tubifex* (13.1%), *Nais simplex* (5.2%), *Potamothrix bavaricus* (5%), *Nais communis* (4.1%), *Dero digitata* (2%), *Psammoryctides albicola* (1%), *Stylaria lacustris* (0.2%) and *Dero obtusa* (0.1%). With the exception of *P. albicola* (with known distributions so far restricted to Europe and western Asia), all species are considered to be widespread throughout the Holarctic region and several are considered cosmopolitan (see Brinkhurst 1971a, b).

With the exception of Birecik Dam, the oligochaete fauna of all lakes surveyed during this study was dominated by *L. hoffmeisteri*, considered to be the most ubiquitous of all freshwater oligochaetes. The greatest number of oligochaetes (652 individuals) was observed

Table 1. Oligochaete taxa identified from the dam lakes located in the Aşağı Fırat River basin, Turkey.

Species/Dam lake	Karakaya	Seve	Hacıhıdır	Atatürk	Dumluca	Birecik	Üçöz	Çat
Psammoryctides albicola (Michaelsen, 1901)	x		x		x			x
Tubifex tubifex (Müller, 1774)	x		x	x		x	x	x
Limnodrilus hoffmeisteri Claparède, 1862	x	x	x	x	x		x	x
Potamothrix hammoniensis (Michaelsen, 1901)	x						x	
Potamothrix bavaricus (Oschmann, 1913)	x							
Tubificinae (unident.)							x	
Nais communis Piguet, 1906	x	x	x		x			x
Nais simplex Piguet, 1906					x			
Dero digitata (Müller, 1774)		x	x	x	x			x
Dero obtusa Udekem, 1855								x
Stylaria lacustris (L., 1767)					x			
Lumbricidae (unident.)					x	x		

Table 2. Number of individuals of Oligochaeta collected in the lakes under study during two seasons in 2014.

Species	Summer	Autumn
Psammoryctides albicola	7	3
Tubifex tubifex	69	68
Limnodrilus hoffmesiteri	144	367
Potamothrix hammoniensis	2	200
Potamothrix bavaricus	2	50
Tubificinae (unident.)	7	–
Nais communis	2	41
Nais simplex	–	55
Dero digitata	4	17
Dero obtusa	1	–
Stylaria lacustris	–	2
Lumbricidae (unident.)	3	0

in samples collected from Hacıhıdır dam lake, and the lowest number (3 individuals) was observed in samples collected from Birecik dam lake.

Oligochaete numbers were different in two seasons – high in autumn but low in summer. *Nais simplex* and *S. lacustris* were not present in samples collected in summer months, and *D. obtusa* was not present in samples collected in autumn months (Table 2).

The oligochaete fauna of the lakes was dominated by *L. hoffmeisteri* (Table 2), both in summer and autumn. *Limnodrilus hoffmeisteri* is considered as a biological indicator of organic pollution and eutrophication (Brinkhurst 1969) and has been called a saprophilous species (Milbrink 1980).

Potamothrix hammoniensis is the other dominant species and a freshwater euryhaline organism (Grigelis 1980). It has a wide distribution pattern and can be found in brackish waters occasionally. This species is probably the most common tubificine taxon collected from eutrophic lowland lakes in Europe. On the other hand, it has an intermediate position between and sensitive species (Milbrink 1980).

The Naidinae were represented by five species identified during this study – *Nais simplex, N. communis, Dero obtusa, D. digitata* and *Stylaria lacustris.* Most naidine; species are also cosmopolitan, occurring throughout the world (Wetzel et al. 2000) and they have clearly adapted to a wide range of environmental conditions (Brinkhurst & Jamieson 1971).

Stylaria lacustris and *N. simplex* were only present in samples collected from Lake Dumluca. *Stylaria lacustris* is found in less polluted environments considered as clean. Lake Dumluca is an impoundment used primarily for irrigation of agricultural lands. The highest dissolved oxygen value recorded from lakes in this study, 9.8 mg L^{-1}, was measured in Lake Dumluca.

Values resulting from measurement of physicochemical parameters in the eight lakes are presented in Table 3. It is important in water management to monitor the concentrations of the various natural and anthropogenic constituents in water, especially reservoirs that are used as domestic water supplies. In the most commonly observed form of pollution – organic biodegradable wastes – the physicochemical assessment of the water quality is usually based on five parameters: BOD, ammonia, nitrate, phosphates and DO (Kökmen 2007).

In Turkey, surface water quality is classified according to: a) physical and inorganic-chemical parameters, b) organic parameters and c) inorganic parameters, d) bacteriological parameters. In addition, each group contains four water quality classes – class I: high quality waters; class II: slightly contaminated waters; class III: contaminated waters; and class IV: severely polluted waters (SKKY 2008). According to the Turkish Water Pollution Control Regulations, the values recorded for temperature, DO, and NO_3-N were considered to be normal levels for the all lakes studied (Table 3). Other parameters measured included BOD concentrations in Dumluca, Birecik and Üçöz dam lake all considered to be third class quality; the COD concentrations of these lakes are considered to be second and third class quality. The Total-P concentrations of all lakes corresponded to the place them in the third and fourth class quality level, and the NO_2 concentrations of all lakes place them in the second and fourth class quality level.

Principal Component Analysis (PCA) has been widely used in the evaluation of spatial and temporal variations in water quality and benthic characteristics of aquatic ecosystems (Ingole et al. 2010; Wang et al. 2011; Satheeshkumar et al. 2012). Temperature, salinity, DO, sulphide, sediment composition and organic matter content all proved to be important descriptive parameters in terms of the abundance and distribution

Table 3. Physico-chemical parameters recorded in the lakes studied (averages for two seasons).

Dam lake	pH	Temperature (°C)	DO (mg L^{-1})	BOD (mg L^{-1})	COD (mg L^{-1})	Ammonia (mg L^{-1})	NO_2 (mg L^{-1})	NO_3 (mg L^{-1})	Total-P (mg L^{-1})
Karakaya	8.7 III	22.6	8.8	7.2	24.1	0.18	0.007 IV	0.1	0.380 III
Seve	8.8 III	20.5	8.9	4.5	18.9	0.15	0.100 IV	1.1	0.195 III
Hacıhıdır	8.8 III	23.8	6.7	9.4	40.4	0.60	0.400 IV	2.8	3.950 IV
Atatürk	8.9 III	24.0	9.1	7.7	32.3 II	0.09	0.010 II	0.2	0.370 III
Dumluca	9.2 IV	23.4	9.8	14.9 III	69.0 III	0.70 II	0.200 IV	1.3	0.720 IV
Birecik	8.6 III	22.4	8.3	11.2 III	48.5 II	0.20	0.010 II	0.4	3.745 IV
Üçöz	8.6 III	17.3	8.1	15.7 III	50.5 III	0.10	0.004 II	0.4	0.955 IV
Çat	8.6 III	20.9	7.5	7.7	34.3 II	0.30 II	0.010 II	0.3	0.745 IV
	Water quality criteria after Turkish Guidelines								
Class I	6.5–8.5	25.0	8.0	4.0	25.0	0.20	0.002	5.0	0.02
Class II	6.5–8.5	25.0	6.0	8.0	50.0	1.00	0.010	10.0	0.16
Class III	6.0–9.0	30.0	3.0	20.0	70.0	2.00	0.050	20.0	0.65
Class IV	6.0–9.0>	>30.0	<3.0	>20.0	>70.0	>2.00	>0.050	>20.0	>0.65

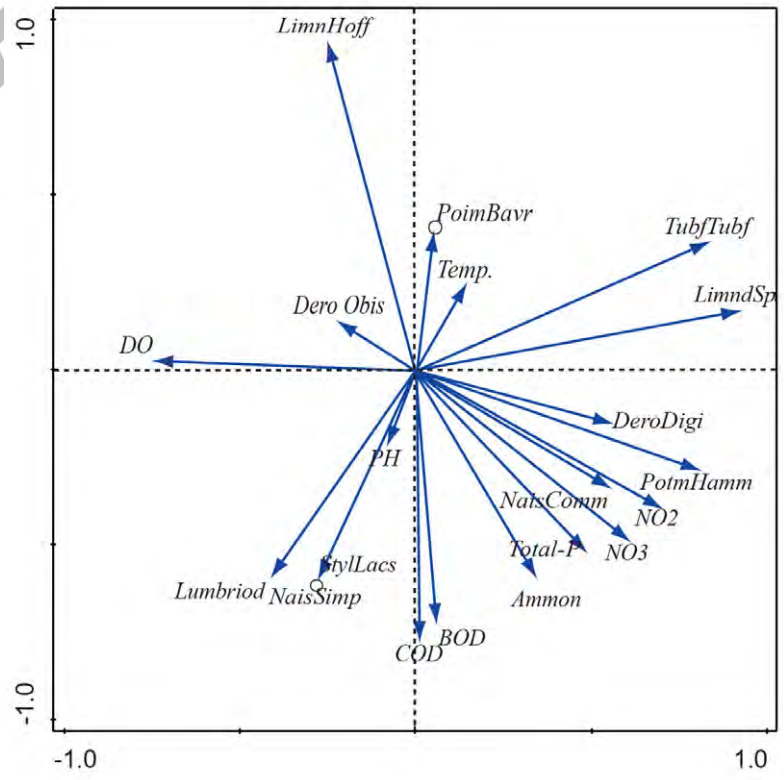

Fig. 2. Species-environment diagram from Principal Component Analysis. Species abbreviations: LimHoff: *Limnodrilus hoffmeisteri*; PoimBavr: *Potamothrix bavaricus*; PotmHamm: *Potamothrix hammoniensis*; NaisSimp: *Nais simplex*; DeroDigi: *Dero digitata*; NaisComm: *Nais communis*; TubfTubf: *Tubifex tubifex*; StylLacs: *Stylaria lacustris*; DeroObis: *Dero obtusa*; LimndSp: *Limnodrilus* sp.; Lumriod: Lumbricidae

of benthic fauna. Relationships between species and environmental parameters were determined using Principal Component Analysis (PCA). PCA considered some environmental variables (temperature, pH, DO, BOD, COD, total phosphorus, nitrite (NO_2-N), nitrate (NO_3-N), ammonia and oligochaete species which showed a common distribution Fig. 2.

Temperature was a positive factor affecting the presence and density of *P. bavaricus* and *T. tubifex*, while *D. obtusa* and *L. hoffmeisteri* were positively related to dissolved oxygen. Three other species – *D. digitata*, *P. hammoniensis* and *N. communis* – were positively associated with nitrite (NO_2-N), nitrate (NO_3-N), total phosphorus, ammonia and BOD. *Nais simplex* and *S. lacustris* were positively associated with pH.

Tubifex tubifex, *L. hoffmeisteri* and *P. hammoniensis* are often associated with each other; these three species are commonly the dominant oligochaetes, even the dominant or exclusive benthic macroinvertebrates (Brinkhurst 1996) in lakes. *Limnodrilus hoffmeisteri* (present in 7 lakes) and *T. tubifex* (present in 6 lakes) were the most frequently observed species.

In conclusion, of the 12 oligochaete taxa collected during this study, 10 were identified to the species level and two were identified to the family and subfamily level. The family Naididae was the most diverse group, with 10 species and one undetermined taxon: the subfamily Naidinae was represented by five species, the subfamily Tubificinae was represented by five species and one other taxon. The family Lumbricidae was represented by a single taxon. Among the lakes surveyed during this study, species-poor Lake Birecik differs from the other species-rich lakes.

In this study, the dominant oligochaetes were *T. tubifex*, *L. hoffmeisteri* and *P. hammoniensis*. These tubificine genera (*Tubifex*, *Potamothrix* and *Limnodrilus*) are considered as cosmopolitan 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 trophic levels. The results demonstrated that they can be impacted by different sources of pollution. In fact, this area is under the threat of pollution (domestic and agricultural pollution).

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