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Research article/Araştırma makalesi

Assessment of water quality in three sub-basins of Susurluk River (Northwest Anatolia) according to invertebrates and biotic indices

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Abstract

Turkey has 25 main drainage river basins by the hydrological features. One of the 25 main drainages is the Susurluk basin which is located in the Northwest of the Anatolia. The Orhaneli, Emet and Mustafakemalpaşa rivers are the three sub-basins of the Susurluk river system. The Mustafakemalpaşa River, which is formed by the joining of Emet and Orhaneli rivers, is one of the most important water resources feeding the Lake Uluabat. During the study period (November 2004, July 2005, May 2006 and June 2007) zoobenthic samples were collected in three sub-basins of Susurluk. Also some environmental variables (water temperature, pH, dissolved oxygen, biological oxygen demand, nitrate nitrogen, nitrite nitrogen and ammonium nitrogen) were analyzed. In addition some biological metrics (Shannon-Wiener diversity indices, Biological Monitoring Working Party (BMWP) score and Average Score Per Taxon (ASPT), dominance) were also calculated.

In Orhaneli, Emet and Mustafakemalpaşa Rivers, 35 taxonomic groups were identified on class, order and family level along with 36 Oligochaeta species. In the present study zoobenthic communities of these three rivers were dominated mainly by four taxa; Oligochaeta (41.3%), Chironomidae (18.2%), Gammaridae (10.7%) and Ephemeroptera (6%). The oligochaete fauna of the three sub-basins was dominated by widely distributed tubificid *Potamothrix hammoniensis* and naidid *Nais communis*. Shannon-Wiener diversity indices, BMWP score and ASPT values varied between 0.2-2.7; 9-95 and 2.3-5.9 respectively. Our results indicated that upper Orhaneli and Emet River rhitral zone (stations 10 and 19) was nonimpacted and their fauna diverse while the potamal zone (stations 1, 11, 16 and 17) was polluted. Our both biological and water quality parameters showed that ten out of the nineteen stations were determined as water quality classes I and II (nonimpacted and slighltly impacted) in the study area.

Key words: Water quality, Orhaneli, Emet and Mustafakemalpaşa Rivers, Oligochaeta

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Orhaneli, Emet ve Mustafakemalpaşa Çaylarının Oligochaeta faunası ve su kalitesi

Özet

Türkiye 25 akarsu havzasına sahiptir ve bu havzalardan bir tanesi de kuzeybatı Anadolu bölgesinde yer alan Susurluk Nehir Havzası'dır. Orhaneli, Emet and Mustafakemalpaşa nehirleri, Susurluk havzası içinde yer alan üç alt havzadır. Emet ve Orhaneli çaylarının birleşmesiyle oluşan Mustafakemalpaşa Çayı, Uluabat Gölü'nü besleyen en önemli su kaynaklarından biridir. Bu üç akarsu Karacabey yakınında birleşerek Kocasu Nehri'ni oluşturur ve denize dökülür. Çalışma süresince (Kasım 2004, Temmuz 2005, Mayıs 2006 ve Haziran 2007) zoobentik örnekler Susurluk'un üç alt havzasından toplanılmıştır. Ayrıca, bazı çevresel parametreler de (su sıcaklığı, pH, çözünmüş oksijen, biyolojik oksijen ihtiyacı, amonyum azotu, nitrat azotu ve amonyum azotu) analiz edilmiştir. İlaveten, bazı biyolojik metrikler de (Shannon-Wiener Çeşitlilik İndeksi, Biyolojik İzleme Çalışma Grubu (BMWP) ve her taksonun ortalama değeri (ASPT), baskınlık) hesaplanılmıştır.

Orhaneli, Emet ve Mustafakemalpaşa Çayları'nda 36 Oligochaeta türü ile birlikte sınıf, takım ve familya düzeyinde 35 taksonomik grup teşhis edilmiştir. Bu çalışmada; Mustafakemalpaşa, Orhaneli ve Emet çaylarının zoobentik komünitesi başlıca Oligochaeta (%41,3), Chironomidae (%18,2), Gammaridae (%10,7) ve Ephemeroptera (%6) olmak üzere dört gruptan oluşmaktadır. 3 alt havzanın Oligochaeta faunasında, geniş yayılış gösteren tubificid *Potamothrix*

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hammoniensis ve naidid *Nais communis* türleri baskındı. Shannon-Wiener Çeşitlilik İndeks, BMWP skor ve ASPT değerleri sırasıyla 0,2-2,7; 9-95 ve 2,3-5,9 arasında değişmektedir. Araştırma sonucunda Orhaneli e Emet Çay'ları üst kesimlerinin (rhitral bölge, 10 ve 19. istasyonlar) temiz ve faunasının yüksek çeşitlilik gödterdiği, buna karşılık potamal bölgelerin (1, 11, 16 ve 17.istasyonlar) kirlenmiş su sınıfında olup faunalarının fakir olduğu tespit edilmiştir. Hem biyolojik hem de su kalite parameter sonuçları ondokuz örneklem noktasından on tanesinin I. ve II. kalite su sınıfında olduğunu ortaya koymuştur.

Anahtar kelimeler: Orhaneli, Emet ve Mustafakemalpaşa Çayları, Oligochaeta

1. Introduction

Oligochaeta, or non-hirudinean Clitellata are common and widely distributed organisms, they inhabit estuarine, brackishwater, freshwater and terrestrial environments. To date, about 5,000 valid species have been known and about one third of them have been identified from aquatic environments (Martin et al., 2008). Lumbricidae and Enchytraeidae are mainly terrestrial but also include some species that live in fresh water as semiaquatic. The other families of Oligochaeta are predominantly freshwater. According to literature data, to date 1700 valid aquatic oligochaete species were reported around the world and approximately 1100 of them have been reported from freshwater systems.

Oligochaetes constitute almost half of the total benthic invertebrate community in several aquatic ecosystems. They can survive in very different environments, from small ponds, puddles to sewage. Some species of Oligochaeta (especially of the Tubificidae members) species have wide ecological tolerance to low concentration of dissolved oxygen, high or low pH, high temperature etc. Because of this they are widely used for monitoring river and lake pollution as biondicator organisms. A recent study indicated that 94 Oligochaeta species are recorded in fresh waters of Turkey (Arslan 2006). Later on, several studies were published on the freshwater Oligochaeta in Turkey and several additional species were identified (Arslan et al. 2006; Matamoros et al. 2007; Timm et al. 2013; Arslan et al. 2018). According to published data, the Turkish freshwater Oligochaeta fauna now consists of 149 described species Although studies on Turkey's aquatic Oligochaeta fauna have increased in the last 15-20 years, Oligochaeta species diversity is still maybe not fully known.

Turkey has 107 major rivers belonging to 25 main drainage basins by the hydrological features. One of the 25 main drainages is the Susurluk basin. The objective of this study were; i- to examine zoobenthic community structure in three sub-basin of the Susurluk River, ii- to determine the fauna and distribution of Oligochaeta in the Orhaneli, Emet and Mustafakemalpaşa Rivers, not investigated in detail before, iii- to determine the biological water quality of the sub-basins by using several metrics (diversity and biotic indices).

2. Materials and methods

2.1.Study Area

One of the 25 main drainages in Turkey is the Susurluk basin which is located in the Northwest of the Anatolia. Covering about 3.1% of Turkey's land, the total area of the river basin district is 26,790 km^2. The Orhaneli, Emet and Mustafakemalpaşa Rivers form the 3 different sub-basins (Figure 1),covering about 10,647 km^2 area of Susurluk (4,745 km^2, 4,921 km^2 and 981 km^2, respectively). The Mustafakemalpaşa River, which is formed by the joining of Emet (former name Aliova Creek) and Orhaneli rivers (former name Kocasu), is one of the most important water resources feeding the Lake Uluabat (in this study except station 1).

2.2.Sampling and Data Analysis

During the study period (November 2004, July 2005, May 2006 and June 2007) zoobenthic samples were collected in three sub-basins of Susurluk (seven stations from Orhaneli; nine stations from Emet River and three stations from Mustafakemalpaşa River). All zoobenthic samples were collected with hand net or grab sampler. All obtained materials were preserved in 70% ethyl alcohol in situ. Zoobenthic samples were examined under stereomicroscope in the laboratory and firstly they were identified at order-family level and only Oligochaeta specimens were identified at species level (Sperber 1948, 1950; Brinkhurst and Jamieson 1971; Timm 1999).

During each sampling period, the water temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), nitrate nitrogen, nitrite nitrogen and ammonium nitrogen were measured. All water samples were analyzed within 24 h after sampling. Water temperature, pH, dissolved oxygen (DO) and depth were measured during sampling in situ. Other variables [NO_2-N, NO_3-N, and NH_4-N) were measured in the laboratory following the standard methods (APHA, 1998). All parameters results measured in the study were compared with limit of Inland Water Quality Management in Turkey (Turkish Surface Water Quality Management Regulation, 2015).

Macroinvertebrate data were analyzed using ASTERICS 3.1 (AQEM/STAR Ecological River Classification System; AQEM Consortium, 2002) software. BMWP (Biological Monitoring Working Party (Spanish version), ASPT

(Average Score Per Taxon (Armitage et al., 1983), and diversity indices (Shannon-Wiener and Margalef diversity indices) were used to determine water quality. In addition, dominancy and frequency indices were also used (Bellan-Santini, 1969; Soyer, 1970).

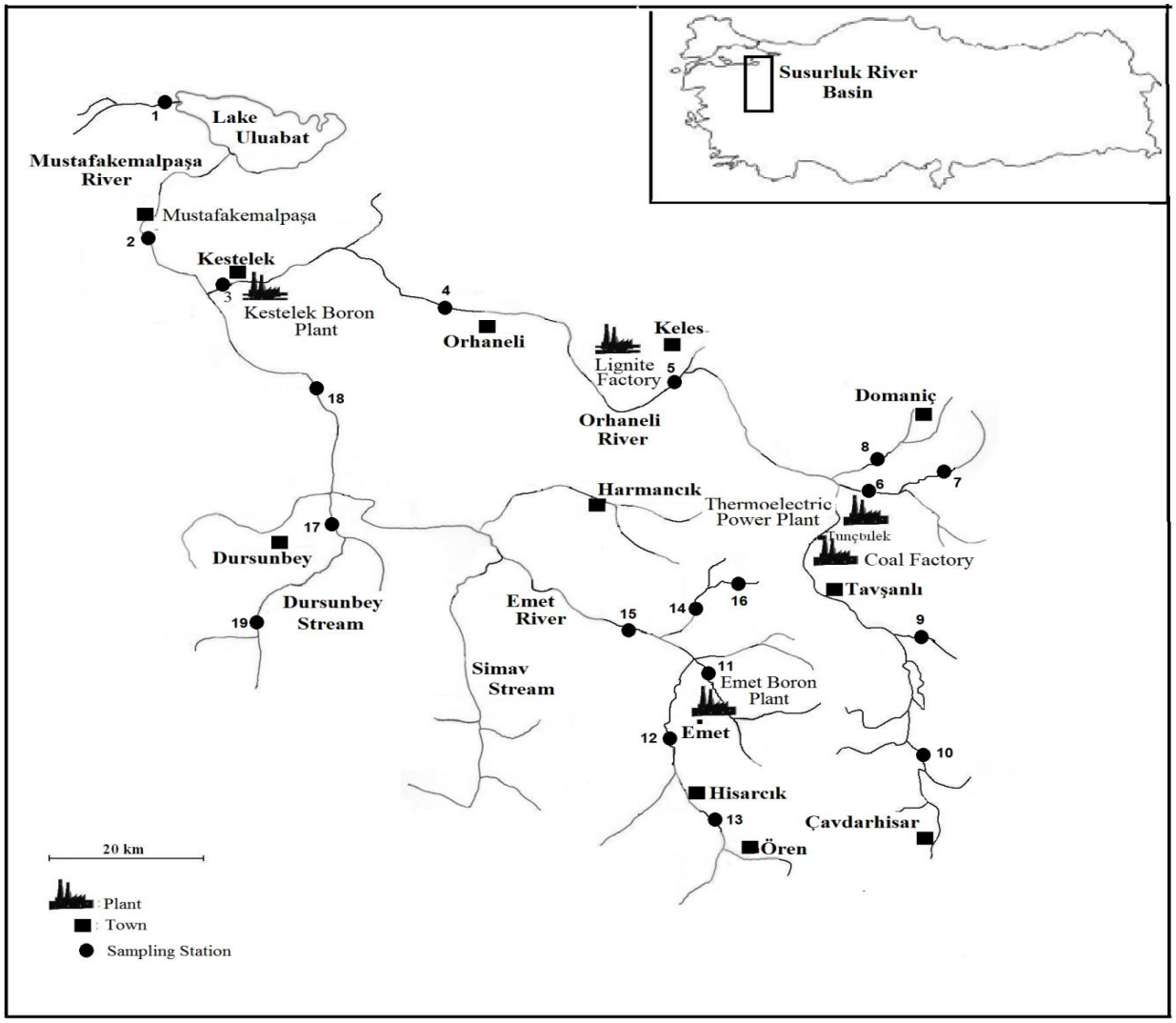

Figure 1. Geographical position of Susurluk River basin and sampling stations of three sub-basin (Orhaneli, Emet and Mustafakemalpaşa River Systems)

3. Results

3.1.Biological results

In Orhaneli, Emet and Mustafakemalpaşa Rivers, 35 taxonomic groups were identified on class, order and family level along with 36 Oligochaeta species (Tables 1 and 2). According to average dominancy value in the basin, the Class Oligochaeta was the most dominant taxon for over 41.3% of total abundance followed by families Chironomidae and Gammaridae with dominancy of 18.2% and 10.7% respectively. All the remaining taxa had relative abundance less than 10% (Table 1). Although the Ephemeroptera mean dominacy value is below 10%, it has a high population ratio at some stations in the basin. Especially at some stations (9, 10 and 18) their relative abundance was 14.2, 16.6 and 14.1 respectively. Similarly, mean dominancy value of Trichoptera which has also pollution sensitive species, was also high at the stations 2, 3, 9,10 and 18. The highest EPT (Ephemeroptera, Plecoptera, Trichoptera) values were recorded from the stations 18 and 19 on the sampling dates between 2004 and 2007 while Plecoptera had the lowest values in this group (Tables 1 and 2).

Thirty six Oligochaeta species were detected in the study area. During the whole study period, *Potamothrix hammoniensis* which was detected at 18 stations and *Nais communis* at 15 stations, were the most widespread species (Table 2). The highest taxonomic diversity of Oligochaeta fauna with 13 species was found at the station 17, followed by at the stations 14 and 19 with 12 species. On the other side, the station 13 had the lowest species diversity with 5 species.

Table 1. Average dominance values (as %) of taxa identified at the sampling stations during the research period in three sub-basin of Susurluk River (Orhaneli, Emet and Mustafakemalpaşa Rivers (MKP: Mustafakemalpaşa, RS: River system))

		MKP RS			Orhaneli RS							Emet RS									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**MD**
1	**Nematoda**	3,1	15,2	2,9	26,2	0,3	9,0	-	-	-	0,4	-	-	1,5	0,7	-	-	3,4	2,3	-	3,4
	Gastropoda (as total)	24,8	4,0	-	-	0,9	-	-	-	5,1	0,2	-	-	-	-	-	-	0,8	-	-	1,9
2	Valvatidae	7,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,4
3	Lymnaeidae	1,2	-	-	-	-	-	-	-	1,6	-	-	-	-	-	-	-	-	-	-	0,1
4	Physidae	9,9	4,0	-	-	-	-	-	-	2,4	0,2	-	-	-	-	-	-	0,8	-	-	0,9
5	Planorbidae	6,2	-	-	-	0,9	-	-	-	1,2	-	-	-	-	-	-	-	-	-	-	0,4
6	**Bivalvia**	2,5	-	-	-	-	-	-	-	-	-	17,9	-	-	-	-	1,5	2,1	-	-	1,3
7	**Oligochaeta**	37,9	48,5	38,6	38,1	78,7	81,1	4	27,9	40,8	20,9	25,4	18,9	63,6	53,7	36,3	8,4	47,3	43,8	70,7	41,3
8	**Hirudinea**	1,9	-	-	-	-	0,8	-	-	-	-	3,7	-	3,0	-	-	1,3	2,1	-	-	0,7
9	**Asellidae**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,1	0,1
10	**Gammaridae**	2,5	-	3,6	3,6	5,9	-	1,3	54,1	25,5	17,3	-	78,6	-	-	9,8	0,4	0,4	-	-	10,7
11	**Hydracarina**	2,5	1,0	0,7	-	-	-	-	-	-	0,2	-	-	-	9,6	-	-	0,4	-	-	0,8
	Ephemeroptera (as total)	2,5	6,1	5,7	6,0	2,2	-	7,5	6,6	14,2	16,6	1,5	0,2	4,5	7,4	1,4	-	8,9	14,1	8,0	6
12	Potamanthidae	-	1,0	1,4	-	-	-	-	1,6	1,2	4,9	-	-	-	-	0,5	-	-	1,6	1,1	0,7
13	Baetidae	2,5	5,1	4,3	2,4	0,6	-	7,5	3,3	5,9	3,8	1,5	0,1	4,5	4,4	0,9	-	8,9	5,5	2,3	3,3
14	Caenidae	-	-	-	3,6	0,9	-	-	1,6	2,0	2,3	-	-	-	1,5	-	-	-	4,7	2,9	1,0
15	Oligoneuriidae	-	-	-	-	-	-	-	-	-	0,9	-	-	-	-	-	-	-	-	0,6	0,1
16	Heptageniidae	-	-	-	-	0,6	-	-	-	2,4	-	-	0,1	-	-	-	-	-	2,3	1,1	0,3
17	Ephemerellidae	-	-	-	-	-	-	-	-	2,7	4,7	-	-	-	1,5	-	-	-	-	-	0,5
	Odonata (as total)	2,5	-	2,9	-	0,9	-	-	-	2,4	12,4	-	0,7	-	-	3,7	-	-	8,6	1,7	1,9
18	Coenagrionidae	1,9	-	-	-	-	-	-	-	-	2,6	-	-	-	-	-	-	-	3,1	1,7	0,5
19	Calopterygidae	0,6	-	2,9	-	0,9	-	-	-	2,4	9,8	-	0,4	-	-	3,7	-	-	5,5	-	1,4
20	Gomphidae	-	-	-	-	-	-	-	-	-	-	-	0,3	-	-	-	-	-	-	-	-
	Hemiptera (as total)	5,6	3,0	24,3	-	-	-	26,3	-	-	-	-	-	-	5,1	-	-	3,0	-	-	3,5
21	Corixidae	1,9	-	18,6	-	-	-	15,0	-	-	-	-	-	-	-	-	-	3,0	-	-	2,0
22	Pleidae	1,2	-	-	-	-	-	-	-	-	-	-	-	-	3,7	-	-	-	-	-	0,3
23	Gerridae	2,5	3,0	5,7	-	-	-	11,3	-	-	-	-	-	-	1,5	-	-	-	-	-	1,3
24	**Chironomidae**	6,8	15,2	12,1	4,8	5,6	9,0	23,8	11,5	3,1	18,1	39,6	1,0	21,2	0,7	43,3	87,9	25,3	13,3	3,4	18,2
25	**Tipulidae**	-	-	-	-	-	-	-	-	1,6	-	-	-	6,1	-	-	-	-	-	-	0,4
26	**Simuliidae**	-	-	-	6,0	3,7	-	-	-	3,5	-	-	0,2	-	4,4	-	-	-	7,0	8,0	1,7
27	**Tabanidae**	-	-	-	-	-	-	-	-	-	-	3,7	-	-	-	-	0,4	1,3	-	-	0,4
28	**Ceratopogonidae**	6,2	-	-	15,5	-	-	-	-	0,4	6,6	8,2	0,1	-	11,0	-	-	3,0	-	-	2,7
28	**Psychodidae**	1,2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,7	-	-	0,2
30	**Neuroptera**	-	-	-	-	-	-	-	-	-	0,4	-	-	-	-	-	-	-	-	-	-
	Trichoptera (as total)	-	5,1	8,6	-	1,9	-	-	-	3,5	5,3	-	0,3	-	4,4	4,7	-	-	7,0	3,4	2,3
31	Hydropsychidae	-	5,1	8,6	-	1,2	-	-	-	1,6	3,2	-	0,3	-	2,9	3,3	-	-	4,7	2,3	1,7
32	Rhyacophilidae	-	-	-	-	-	-	-	-	0,8	1,3	-	-	-	-	-	-	-	-	-	0,1
33	Hydroptilidae	-	-	-	-	0,6	-	-	-	-	-	-	-	-	1,5	-	-	-	2,3	1,1	0,3
34	Psychomyiidae	-	-	-	-	-	-	-	-	1,2	0,9	-	-	-	-	1,4	-	-	-	-	0,2
	Plecoptera																				0,8
35	Perlidae	-	2,0	-	-	-	-	1,3	-	-	1,5	-	-	-	2,9	-	-	-	3,9	3,4	0,8

Shannon-Wiener diversity index values varied between 0.2-2.7; the highest and lowest values were reported in the same basin (Orhaneli River, stations 9 and 6 respectively). The highest taxonomic diversity are reported with 29 taxa at the station 9 and 27 taxa at the stations 1and 10. On the other side, stations 3, 7 and 13 are the ones having the lowest taxa diversity with 10, 9 and10 species respectively. During the whole study period the highest Biological Monitoring Working Party (BMWP) score value was detected in station 9 (average score 95) and it is followed by stations 19, 10 and 18 (as average score 85, 80 and 72 respectively). Average Score Per Taxon (ASPT) score values varied between 2.3-5.8 in all sampling stations (Table 3). All zoobenthic community members are categorized according to the feeding types as given in Table 3.

3.2.Environmental Parameters

The minimum, maximum and average values and standard deviation of the environmental variables and water quality classes of the three sub-basins of Susurluk River (Mustafakemalpaşa, Emet and Orhaneli River system) during the study period are given in Table 4. All environmental variables results have been classified in Surface Water Quality Management Regulation of Turkey (Turkish Surface Water Quality Management Regulation, 2015). When the indices were examined in terms of environmental parameters (as water quality classes), the stations 10 (Orhaneli River) , 18 and 19 (Emet River) were determined as clean (class I); the stations 4, 5, 8, 9 (Orhaneli River), 12 and 15 (Emet River) were determined as clean but slightly impacted (Class II), 2, 3 (Mustafakemelpaşa River), 6, 7 (Orhaneli River) and 13 (Emet River) were determined as polluted (Class III) and while the other stations (1, 11, 16 and 17) were determined as polluted or impacted (Class IV). Only water temperature and pH did not present significant differences between the sampling sites.

Table 2. Average dominance values of Oligochaeta species at the 19 stations during the research (as %), (Ns: Number of stations where the species was detected; F: frequency in %, MD: Mean dominancy)

	Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**Ns**	**F**	**MD**
1	*Haplotaxis gordioides*	-	-	-	-	-	-	-	-	-	7,1	-	-	-	-	-	-	-	8,9	4,9	3	15,8	1,1
2	*Lumbriculus variegatus*	-	-	-	-	-	-	-	-	-	-	-	3,5	-	11,0	-	-	-	-	3,3	3	15,8	0,9
3	*Chaetogaster diastrophus*	-	-	-	-	0,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5,3	-
4	*Chaetogaster diaphanus*	-	4,2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,5	0,8	2	5,3	0,2
5	*Chaetogaster langi*	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	1	5,3	0,1
6	*Paranais frici*	-	4,2	3,7	-	1,6	-	-	-	3,8	6,1	8,8	-	-	2,7	2,6	-	0,9	76,8	-	10	52,6	5,9
7	*Paranais simplex*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5,3	0,6
8	*Dero dorsalis*	-	-	-	-	-	-	-	-	-	-	11,2	-	-	-	-	-	1,8	-	-	1	5,3	0,1
9	*Dero furcata*	8,2	-	-	-	-	-	-	-	-	-	23,5	-	-	-	-	20,5	3,6	-	-	4	21,1	2,9
10	*Pristina longiseta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,8	-	-	1	5,3	0,1
11	*Pristinella jenkinae*	-	10,4	-	-	-	-	3,1	-	-	-	2,9	-	4,8	4,1	-	-	4,5	-	-	6	31,6	1,6
12	*Pristina aequiseta*	-	-	-	-	-	-	-	-	-	-	-	-	-	1,4	-	-	-	-	-	1	5,3	0,1
13	*Pristina proboscidea*	-	-	-	15,6	-	-	-	-	-	-	-	-	-	-	-	-	-	7,1	2,4	3	15,8	1,3
14	*Stylaria lacustris*	-	10,4	-	3,1	0,8	-	-	-	1,9	20,4	-	-	-	1,4	-	11,4	-	-	1,6	8	42,1	2,7
15	*Nais pardalis*	-	-	-	21,9	2,4	-	-	-	-	-	-	-	-	12,3	7,7	6,8	-	-	-	5	26,3	2,7
16	*Nais bretscheri*	-	-	-	-	-	-	-	-	-	-	-	-	-	1,4	-	-	-	-	2,4	1	5,3	0,2
17	*Nais communis*	3,3	14,6	1,9	6,3	83,9	-	-	5,9	26,0	6,1	-	3,9	26,2	46,6	-	9,1	66,1	3,6	0,8	15	78,9	16,0
18	*Nais variabilis*	-	4,2	-	-	-	-	-	-	4,8	-	-	-	-	1,4	-	-	-	-	-	3	15,8	0,5
19	*Nais elinguis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,8	-	-	1	5,3	0,1
20	*Nais simplex*	-	4,2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5,3	0,2
21	*Nais pseudobtusa*	-	4,2	-	-	-	-	-	-	-	3,1	-	-	-	-	-	-	-	-	-	2	10,5	0,4
22	*Nais barbata*	-	18,8	-	-	-	-	-	-	-	9,2	-	-	16,7	-	-	-	-	-	-	3	15,8	2,3
23	*Ophidonais serpentina*	9,8	-	-	-	-	1,2	43,8	-	-	-	14,7	-	-	-	-	15,9	3,6	-	-	6	31,6	4,7
24	*Uncinais uncinata*	-	-	-	-	-	0,7	9,4	29,4	3,8	-	-	-	-	-	-	-	-	-	-	4	21,1	2,3
25	*Slavina appendiculata*	-	-	-	-	-	1,2	-	-	-	11,8		2,5	-	-	-	-	-	-	-	3	15,8	0,8
26	*Aulodrilus pluriseta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,1	1	5,3	0,2
27	*Tubifex tubifex*	13,1	4,2	9,3	-	5,5	35,4	21,9	5,9	5,8	3,1	5,9	-	-	2,7	2,6	-	0,9	-	0,8	14	73,7	6,2
28	*Psammoryctides albicola*	1,6	-	-	6,3	-	-	-	5,9	28,8	-	2,9	-	-	-	1,3	6,8	0,9	-	-	8	42,1	2,9
29	*Psammoryctides barbatus*	3,3	-	-	3,1	0,8	-	3,1	-	7,7	-	5,9	12,7	-	-	5,1	-	-	-	0,8	9	47,4	2,2
30	*Psammoryctides moravicus*	6,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5,3	0,3
31	*Potamothrix hammoniensis*	4,9	-	35,2	31,3	2,7	37,3	18,8	23,5	16,3	29,6	20,6	76,1	31,0	2,7	78,2	13,6	4,5	1,8	77,2	18	94,7	26,6
32	*Potamothrix heuscheri*	21,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5,3	1,1
33	*Potamothrix bedoti*	-	12,5	14,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	10,5	1,4
34	*Limnodrilus hoffmeisteri*	3,3	2,1	1,9	-	-	9,4	-	-	-	-	-	-	-	-	1,3	15,9	2,7	-	0,8	8	42,1	2,0
35	*Limnodrilus claparedianus*	24,6	6,3	20,4	12,5	0,4	13,8	-	29,4	-	-	2,9	1,4	21,4	12,3	1,3	-	7,1	-	-	13	84,2	8,4
36	*Spirosperma ferox*	-	-	13,0	-	1,2	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	3	15,8	0,8
	Number of species at station	11	11	8	8	10	8	6	6	10	9	10	6	5	12	8	8	13	6	12			

Table 3. Index values calculated for 19 stations in the study area (EPT: Ephemeroptera-Plecoptera-Trichoptera; Olig: Oligochaeta; BMWP Score (Spanish version); Gat./Coll.: Gatherers/Collectors; Gra./Scr.: Grazers and scrapers; Oth.Fee.Typ.: Other Feeding types; Tax. Grp.: Taxonomic group)

	MKP RS			**Orhaneli RS**							**Emet RS**								
Indices\Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
ASPT	4,1	4,3	5,1	4,2	5,2	2,3	3,8	5,0	5,7	5,9	2,5	5,4	3,0	5,0	5,5	3,0	3,4	5,8	5,4
BMWP	59	28	46	26	54	9	19	27	95	80	18	53	15	44	48	16	34	72	85
Shannon-Wiener	2,3	1,8	2,0	1,7	1,0	0,2	1,7	1,2	2,7	2,4	1,5	0,6	1,1	1,7	1,4	0,4	1,6	2,1	2,3
Margalef Index	3,4	1,8	2,1	1,6	1,9	0,5	1,4	1,2	3,1	2,6	1,3	1,2	1,2	2,6	1,5	0,8	2,0	2,5	2,4
Feeding types																			
- [%]Gra./Scr.	6,1	8,3	11,2	2,5	2,3	0,4	14,6	4,3	6,4	8,9	9,9	0,3	7,0	5,5	10,1	18,2	11,2	7,8	3,1
- [%] Miners	1,3	1,9	7,6	0,6	0,8	0,2	8,7	1,3	0,3	1,9	4,5	0,1	2,3	0,9	4,5	9,1	3,6	2,4	0,9
- [%] Shredders	3,0	3,8	0,6	6,2	0,4	0,4	-	-	3,0	1,0	-	-	4,9	0,2	1,4	-	0,9	0,5	-
- [%]Gat./Coll.	45,3	51,8	51,3	43,4	81,5	97,3	47,1	30,4	49,0	35,2	29,0	18,4	72,5	58,9	48,5	32,4	61,1	54,3	73,9
- [%] Filter feeders	4,1	7,2	7,7	8,1	5,6	0,4	6,0	2,7	5,2	6,9	29,6	0,6	4,6	7,8	10,7	19,8	7,6	13,1	11,9
- [%] Predators	15,0	13,5	15,6	28,2	2,1	0,7	17,3	1,3	4,4	24,2	18,2	1,0	2,8	22,7	10,3	9,5	8,8	13,2	3,2
- [%] Parasites	3,4	5,8	2,0	6,8	0,6	0,7	3,0	1,3	0,3	2,0	8,8	0,1	5,9	0,3	4,5	10,5	5,6	1,9	0,4
- [%]Oth.Fee.Typ.	0,8	-	-	-	0,1	-	-	-	0,3	-	-	-	-	-	-	-	-	-	-
Tax. Grp [%]																			
- Oligochaeta [%]	37,9	48,5	38,6	38,1	78,7	81,1	4	27,9	40,8	20,9	25,4	18,9	63,6	53,7	36,3	8,4	47,3	43,8	70,7
- Ephemeroptera [%]	2,5	6,1	5,7	6,0	2,2	-	7,5	6,6	14,1	16,6	1,5	0,2	4,5	7,4	1,4	-	8,9	14,1	8,0
- EPT/Olig [%]	0,1	0,3	0,4	0,2	0,1	-	0,2	0,2	0,4	1,1	0,1	-	0,1	0,3	0,2	-	0,2	0,6	0,2
- EPT [%]	2,5	13,1	14,3	6,0	4,0	-	8,8	6,6	17,6	23,5	1,5	0,5	4,5	14,7	6,0	-	8,9	25,0	14,9

Table 4. Minimum, maximum, average and standard deviation of some environmental variables for 19 stations during the research period in the study area (Min-Max (Average) ±SD, WQC: Water Quality Class; ADL: Above detection limit). Numbers in parentheses indicate water quality classes

	Temperature °C	pH	D.O mg/l	BOD mg/l	NO_3^-N/L mg/l	NO_2^--N/L mg/l	NH_4^+N/L mg/l	WQC
1	16,6-25,2 (19,8)±4,6	7,9-8,9 (8,37) ±35,18	3-16 (8,20) ±6,88	1-22 (11,5) ±14,85	0,10-0,80 (0,40) ±0,36	0,02-0,04 (0,03) ±0,01	0,07-0,10 (0,09) ±0,02	IV
2	15,9-24,5 (18,9) ±4,85	8,20-8,50 (8,33) ±0,15	8,80-11,3 (10,07) ±1,25	0,00-16 (8,33) ±8,02	0,365-1,40 (0,76) ±0,56	0,014-0,06 (0,03) ±0,02	0,074-0,19 (0,09) ±0,09	III
3	14,4-23 (17,63) ±4,68	8,20-8,70 (8,37) ±0,29	10,10-11,20 (10,6) ±0,56	0,00-13 (7) ±6,56	0,70-1395 (466,17) ±804,39	0,011-0,10 (0,07) ±0,05	0,00-0,06 (0,06) ±0,00	III
4	13,7-21,5 (16,9) ±4,08	8-8,2 (8,07) ±0,11	8,9-11,7 (10,1) ±1,44	0,00-6 (2,33) ±3,21	0,30-1,815 (1,14) ±0,77	0,01-0,209 (0,09) ±0,11	0,00-0,09 (0,02) ±0,03	II
5	12,1-20,5 (15,13) ±4,66	7,9-8,28 (8,06) ±0,2	8,6-9,9 (9,4) ±0,7	1-8 (4,5) ±4,95	1,7-4,43 (2,84) ±1,42	0,021-0,10 (0,06) ±0,04	0,00-0,17 (0,06) ±0,09	II
6	11,8-21,7 (15,33) ±5,52	7,6-7,8 (7,73) ±0,12	2-5 (3,67) ±1,53	0,00-13 (6,67) ±6,51	0,595-2,2 (1,43) ±0,80	0,028-0,06 (0,04) ±0,02	0,61-1,846 (1,25) ±0,62	III
7	12,1-26,6 (17) ±8,31	8,4-8,75 (8,55) ±0,18	9,3-10,3 (9,9) ±0,53	0,00-5 (2,67) ±2,52	0,00-1,4 (0,06) ±0,72	0,01-0,19 (0,07) ±0,10	0,02-0,76 (0,27) ±0,42	III
8	10,4-19 (14,53) ±4,31	8,1-8,62 (8,37) ±0,26	8,5-11,6 (10,33) ±1,63	0,00-9 (3) ±5,20	0,10-1,905 (0,97) ±0,90	0,00-0,03 (0,02) ±0,02	0,00-0,08 (0,03) ±0,04	II
9	8,1-20,07 (14,23) ±6,31	7,4-8,2 (7,87) ±0,42	9,4-12,1 (10,67) ±1,36	0,00-8 (3,67) ±4,04	0,5-1,9 (1,2) ±0,99	0,009-0,02 (0,02) ±0,00	0,023-0,06 (0,05) ±0,01	II
10	8,6-21,2 (14,1) ±6,45	7,8-8,1 (7,9) ±0,17	8,5-12,4 (10,03) ±2,08	1-7 (3,33) ±3,21	0,535-1,9 (1,25) ±0,92	0,008-0,01 (0,01) ±0,00	0,00-0,11 (0,07) ±0,06	I
11	14-22,6 (17,67) ±3,21	7,9-8,5 (8,13) ±0,32	2,5-6,3 (4,17) ±1,19	2,6-17,8 (12,33) ±2,31	ADL(IV)	0,03-0,084 (0,04) ±0,01	ADL(IV)	IV
12	9-16,4 (12,1) ±3,84	7,5-8 (7,8) ±0,26	6,3-10,8 (8,63) ±2,25	0,00-3 (2) ±1,73	0,08-2,1 (1,7) ±0,57	0,017-0,04 (0,04) ±0,01	0,022-0,04 (0,04) ±0,01	II
13	14,9-19,7 (16,57) ±2,72	7,5-8,1 (7,8) ±0,30	7,2-9,6 (8,7) ±1,31	0,00-5 (2,33) ±2,52	0,08-2,2 (1,35) ±1,20	0,017-0,12 (0,09) ±0,05	0,022-0,11 (0,1) ±0,02	III
14	14,3-20,8 (16,7) ±3,57	7,8-8,6 (8,13) ±0,42	7,8-9,6 (8,9) ±0,96	0,00-10 (4) ±5,29	0,00-5,3 (2,85) ±3,46	0,02-0,028 (0,02) ±0,00	0,03-0,078 (0,04) ±0,01	II
15	15,7-23,2 (18,33) ±4,22	8-8,3 (8,1) ±0,17	8,4-16,4 (11,67) ±4,20	0,00-3 (1,67) ±1,53	0,00-2,1 (1,8) ±0,42	0,01-0,02 (0,02) ±0,01	0,028-0,16 (0,1) ±0,09	II
16	13,4-18,2 (15,53) ±2,44	7,6-8,5 (7,9) ±0,52	2,7-8,5 (5,5) ±2,91	10-15 (12,5) ±3,54	ADL(IV)	0,018-0,27 (0,19) ±0,12	0,006-1,98 (1,04) ±1,33	IV
17	14,3-23,9 (17,77) ±5,33	8,6-8,8 (8,67) ±0,12	5,8-10,9 (8,63) ±2,60	0,00-4 (1,67) ±2,08	0,00-1,3 (0,7) ±0,85	0,01-0,0075 (0,03) ±0,02	ADL(IV)	IV
18	16,8-23,9 (19,2)±4,1	7,3-7,6 (7,5) ±0,12	8,9-11,7 (10,2) ±1,1	1-3 (1,24) ±0,9	0,0-0,9 (0,6) ±0,75	0,006-0,01 (0,01) ±0,0	0,0-0,13 (0,08) ±0,07	I
19	12,4-19,2 (15,6))±3,1	7,8-8,6 (8,67) ±0,42	7,6-12,4 (9,03) ±1,6	1-3 (1,4) ±0,04	0,682-1,7 (1,5) ±0,84	0,008-0,01 (0,01) ±0,00	0,00-0,11 (0,07) ±0,06	I

4. Conclusions and discussion

According to the present study zoobenthic communities of Mustafakemalpaşa, Orhaneli and Emet Rivers were dominated mainly by four animal groups; Oligochaeta (41.3%), Chironomidae (18.2%), Gammaridae (10.7%) and Ephemeroptera (6%). Although the first three taxa contain tolerant species, Ephemeroptera includes pollution-sensitive species as well as semi-tolerant (such as family Baetidae) species. In addition, Plecoptera and Trichoptera which contain pollution-sensitive species were inabundant in all three sub-basins of Susurluk. The highest EPT values in the three sub-basins were identified in four stations; two out of four stations (9 and 10) and EPT ratio (17.6% and 23.5%, respectively) located on upper Orhaneli River (rhitral region, Figure 1), and remaining two stations (18 and 19 with EPT ratio 25% and 14.9%, respectively) located on Emet river. As seen in Table 4, three of the four stations (10, 18 and 19) demonstrated the first class water quality while station 9 had second water quality class.

The biological state in any freshwater system is the combination of the habitat and water quality. Biological situation is demonstrated by biological metrics (such as BMWP, ASPT, Shannon-Wiener, Margalef indices, EPT%, Oligochaeta% and EPT/Oligochaeta% ratio) depending on the zoobenthic community; water quality represents environmental variables (such as pH, dissolved oxygen, temperature etc.) and habitat quality represents geomorphological and some bioecological conditions (zonation) at the region (Hauer and Lamberti 2007). In nonimpacted freshwater systems (first class water quality, or the oligosaprobic region) zoobenthic community is diverse, and community is dominated by pollution-sensitive taxa including EPT as the stations 10 (Orhaneli River), 18 and 19 (Emet River) in the present study. The station 9 may categorized as slightly impacted (water quality class II). At all these four stations, not only is the EPT value but also the other biological metrics such as BMWP, ASPT, Shannon-Wiener and Margalef indices, are high (Table 3). According to the Turkish Surface Water Quality Management Regulation (2015) two stations of the Mustafakemalpaşa River (2 and 3) and two stations of Orhaneli River (6 and 7) are categorized as moderately impacted water quality class (III). The common characteristic of these four sampling points is that some factories (Boron, Lignite, Thermoelectric Power Plants and Coal Factory) are located upstream of these stations (Figure 1). At these stations, while the relative abundance of Oligochaeta increased, the decrease in EPT is not surprising due to poor habitat and water quality (Table 3 and 4).

The lowest EPT % were identified on the stations 11 and 16 (1.5% and 0 respectively) on Orhaneli River during the whole research period. These two stations were determined as belonging to quality class IV (severely impacted) and dominated by tolerant Oligochaeta (25.4%) and Chironomidae (39.6%) members, what constituted more than half of the zoobenthic community. It is known that in severely impacted region zoobenthic community has poor diversty and the community consist of low numbers of individuals or high numbers of a few taxa (Hauer and Lamberti 2007). Not only biological metrics (BMWP, ASPT, Shannon-Wiener, EPT%, Oligochaeta%) but also water quality parameters and habitat quality of these two stations support this information. In addition, severely impacted sites generally are receiving heavy wastewater inputs and agricultural or urban runoff. Station 11 is downstream of the Emet Boron Plant.

In a freshwater system, zoobenthic community structure diversity and distribution of taxa are controlled, besides the habitat and water quality, also by food and predators. Feeding types of the taxa and their percentages in habitat also provide information about the environment in which samples are collected. In running water system basic feeding groups are categorizes as scrapers (grazers) which consume algae and organic matter (some Gastropoda and Ephemeroptera); shredders which consume coarse particulate organic material including wood (Amphipoda, Isopoda and Trichoptera); collectors (gatherers) which consume fine organic matter from stream substrate (some Ephemeroptera, insect larvae and Oligochaeta); filterers which collect fine organic matter from the water column and predators which feed on other orgamisms, some Odonata, Coleoptera, Chironomidae and Plecoptera (Hauer and Lamberti 2007).

All zoobenthic community members are categorized according to the feeding types in Table 3. The zoobenthic community structure of all three sub-basins proved to be formed mainly by collectors (gatherers).The presence or absence of certain pollution-sensitive taxa (EPT) in the study area may of course be explained by the availability of nutrients in the habitat. The quality and amount of nutrients of the freshwater sites, which are receiving heavy wastewater inputs and agricultural or urban runoff, may change at short notice. In such a case, sensitive zoobenthic taxa either disappear or migrate to a different suitable habitat. If the biological and chemical quality of the habitat is changed, the zoobenthic community structure also changes.

In the present study a total of 35 higher taxonomic groups and 36 Oligochaeta species were identified. Oligochaeta proved to be most dominant higher taxon in the zoobenthos. Among them, *Potamothrix hammoniensis* and *Nais communis* were the most widespread species (Table 2). These two species are known as alfa-mesosaprobic (Brinkhurst and Jamieson 1971). Like *Potamothrix hammoniensis,* several other oligochaete species have been used as water quality indicators for freshwater systems. (Särkkä, 1994; Çamur-Elipek et al., 2006, Arslan et al. 2016).

P. hammoniensis is common at the bottom of lake and running water systems and can even survive in the high eutrophication and in brackish waters of low salinity (Timm, 2013; Erséus et al. 1999). The highest relative abundance value of the *P. hammoniensis,* which was found in eighteen out of nineteen stations, was detected at the station 15. This station is located on the Emet River and the water quality class was II. At the other stations where the species was detected, its dominancy values were also high, but the interesting thing is that although these stations had the third and fourth quality water class (especially stations 1, 11, 16 and 17), the dominancy value of *P. hammoniensis* was not as high as at the station 15. The station 1 is on the discharge of the Lake Uluabat and the temperature and BOD values were high (Table 4). Erséus et al. (1999) reported that *P. hammoniensis* can be replaced by *P. heuscheri* during a long time of oxygen deficiency combined with elevated temperature. Station 1 is the only station where *Potamothrix heuscheri* is detected on the study area as seen in Table 2. *P. heuscheri* was the second species (after the *Limnodrilus claparedianus*) which had its highest dominacy value (21.3%) at this station. Although there is no definite inference, *P. hammoniensis* was replaced by *P. heuscheri* because of changing environmental conditions at this station. The population density of both species should be monitored in order to be able to say this inference exactly. In addition, the polysaprobic *Limnodrilus claparedianus* was the dominant species at the same station. The station 11, another sampling point with the water quality class IV, is very close to the Emet Boron Plant.

Apart from *P. hammoniensis* (20.6%), the oligochaete fauna of the sampling point 11 also included several other tolerant species such as *Dero furcata* (23.5%), *Dero dorsalis* (11.2%), *Ophidonais serpentina* (14.7%) and *Paranais frici* (8.8%). *Dero* spp. tend to occur in various environments from swampy areas in ponds and rivers to slow moving marshy rivers (Hedge and Sreepadak, 2015). Thanks to their gills, they can tolerate very low levels of dissolved oxygen concentrations (Brinkhurst and Jamieson 1971). It is recognized that DO levels of this station dropped to 2.5 mg/L and BOD values raised to 17.8 mg/L (Table 4). The evident increase in the dominance values of the polysaprobic *Dero* spp. and other mesosaprobic species can be regarded as a biological response to the negative change in the environmental conditions.

Other widespread oligochaete species in the study area were *Tubifex tubifex, Psammoryctides barbatus, Psammoryctides albicola, Paranais frici* and *Stylaria lacustris,* which are tolerant to organic pollution and known as poly- and mesosaprobic species (Hellawell 1986). Several naidine species are cosmopolitan and occur across the world. They inhabit submerged vegetation and sediment (Wetzel et al. 2000). It is known that relative abundances of *Stylaria lacustris* and *Paranais frici* have increased especially in moderately dense macrophytes. Although some authors reported these species in relatively clean waters (Dumnicka 1978; Davis 1982).

Our results indicated that upper Orhaneli and Emet Rivers stations (10 and 19) were nonimpacted and their fauna was diverse while the stations 1, 11, 16 and 17 were polluted. Our both biological and water quality parameters showed that ten out of nineteen stations were determined as water quality classes I and II (nonimpacted and slighltly impacted) in

the study area (Tables 3 and 4). In freshwater systems, biological metrics of nonimpacted regions indicate good stream quality, and its benthic community is dominated by pollution sensitive taxa while slightly impacted regions' community is less diverse and dominated by few taxa including Epmeroptera, some Trichoptera, Oligochaeta and Chironomidae. Remaining nine stations are categorized as water quality classes III and IV (moderately and severely impacted). At these stations biological metrics indicate zoobenthic community dominated by tolerant higher taxa such as Oligochaeta and Chironomidae.

When all three sub-basins together were examined in terms of diversity and distribution of benthic invertebrates, Oligochaeta, Chironomidae and Gammaridae were highly dominant at all stations while Trichoptera and Plecoptera species had the lowest abundancy. The biological state in any freshwater system is the combination of the habitat and water quality (Hauer and Lamberti 2007). From water quality the most important parameters are dissolved oxygen, temperature and pH because of they directly affect aquatic life. Results of the present study on both water quality and biotic indices indicated that all stations of the Mustafakemalpaşa River and some stations of Emet and Orhaneli rivers' are polluted, and this pollution affects the zoobenthic community structure and diversity.

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