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The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Değirmendere Stream (Isparta, Turkey)

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Abstract: This study was carried out between March 2011 and February 2012 on Değirmendere Stream in order to determine the water quality of the stream, and to investigate the environmental quality and the applicability of both the Biological Monitoring Working Party (BMWP; Original, Spanish, Hungarian, Czech, and Polish versions) and Average Score Per Taxon (ASPT; Original, Hungarian, and Czech versions) indices. The biotic and diversity indices were applied using the ASTERICS software program. As a result, a total of 59 taxa were detected: 4 taxa from Gastropoda, 1 taxon from Bivalvia, 1 taxon from Oligochaeta, 1 taxon from Hirudinea, 2 taxa from Crustacea, and 50 taxa from Insecta. The water quality of Değirmendere Stream was found to be unpolluted/slightly polluted according to the physicochemical data and the different versions of the BMWP and ASPT. However, the score values of the different versions of the BMWP were different from each other because the versions of the BMWP were adapted based on the geological and ecological features of their source countries. The results of this study suggest that there is still a need for much intensive investigation and further testing of the effectiveness of the BMWP and ASPT indices for use in the streams of Turkey. The findings also strongly indicate that these indices should be adapted based on the geomorphological and environmental features of Turkey.

Key words: Değirmendere Stream, water quality, BMWP, ASPT, biomonitoring

1. Introduction

Biotic indices are numeric expressions that classify water quality based on the ecological sensitivity of the taxa present and the richness of the taxa. 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 (Callisto et al., 2001).

Unification of stream classification and the use of a common biotic index are impossible due to the differing geographic distributions of macroinvertebrate species and biotypological differences among streams (Korycińska and Królak, 2006). Therefore, researchers have used a variety of indices that have been mainly based on the Biological Monitoring Working Party (BMWP) index, established in the UK (Armitage et al., 1983). The BMWP index may require adaptation for application to other regions, not only because some macroinvertebrate families may be absent from the respective area and replaced by different taxa, but also because families may exhibit different pollution tolerances from region to region (Buss and Salles, 2006). This index has been successfully applied in other countries, e.g., Canada (Barton and Metcalfe-Smith, 1992), Spain (Zamora-Munoz and Alba-Tercedor, 1996), Argentina (Capitulo et al., 2001), Thailand (Mustow, 2002), and Poland (Czerniawska-Kusza, 2005).

The BMWP system considers the sensitivity of invertebrates to pollution; families are assigned a score between 1 and 10 accordingly. The BMWP score is the sum of the values for all families present in the sample. Values greater than 100 are associated with clean streams, while the scores of heavily polluted streams are less than 10 (Mason, 2002).

The average sensitivity of the families of the organisms present is known as the Average Score Per Taxon (ASPT) and can be determined by dividing the BMWP score by the number of taxa present. A high ASPT score is considered indicative of a clean site containing large numbers of high-scoring taxa (Armitage et al., 1983).

According to the Water Framework Directive (WFD), which is obligatory for examining water quality in EU countries, macroinvertebrates are a group commonly used for assessing water quality. Therefore, considering the participation of Turkey with the EU, running-water health should be assessed by the usage of macroinvertebrates in

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terms of the introduction of the WFD (Directive 2000/60/CE 2000) (Kazancı et al., 2010b). In streams, benthic macroinvertebrates reflect such factors as anthropogenic disturbance, organic pollution, acidification, or other types of stream degradation (Tripole et al., 2008; Mykrä et al., 2012).

The BMWP index was used for the first time in Turkey by the General Directorate for State Hydraulic Works (DSİ) in order to assess the water quality of the Sakarya River (DSİ, 1992). It was then applied in several studies to examine the water quality of streams in Turkey (e.g., Kazancı, 1993; Kazancı et al., 1997, 2008, 2010a, 2010b, 2011, 2013; Duran et al., 2003; Duran, 2006; Duran and Suicmez, 2007; Kucuk and Alpbaz, 2008; Kalyoncu and Zeybek, 2011; Ekingen and Kazancı, 2012). In addition, instead of direct usage, the BMWP index was adapted for the first time in Turkey for the Yeşilırmak River; the adaptation was called the Yeşilırmak BMWP (Y-BMWP) (Kazancı et al., 2013).

The purposes of this study are 1) to present an overall picture of the macroinvertebrate communities along the Değirmendere Stream in Turkey, 2) to determine the biological water quality of the stream based on benthic communities, and 3) to examine the applicability of different versions of both the BMWP index (Original, Spanish, Hungarian, Czech, and Polish) and the ASPT index (Original, Hungarian, and Czech) for Değirmendere Stream in Turkey.

2. Materials and methods

2.1. Study area

Değirmendere Stream flows through Yazılı Canyon National Park. This park consists of a 600-ha area that was registered as a nature park in 1989. The source of Değirmendere Stream is located approximately 5 km upstream of Yazılı Canyon Valley (Sütçüler, Isparta/Turkey) and pours into Karacaören I Dam Lake. The length of the study area is approximately 10 km. There are trout farms and recreation areas along this stream. In this study, 6 stations were chosen on the stream. The first station is about 350 m away from the source of Değirmendere Stream and is located in Sütçüler District (Isparta, Turkey). The bottom structure of this station consists of large rocks, with very little sand and gravel. The second station is a second source of this stream and connects with the stream 10 m from the spring point. The flow rate is high at the second station. The third station is at the widest part of the streambed. It is located in the upper part of the recreation areas. The bottom structure of this station also consists of large stones. It is important to point out that there is human impact on the research field, particularly after the third station, although it is a Natural Protected Area. For instance, there is a medium-scale fish production facility (trout farm) between the third and fourth stations. The streambed of the fourth station is composed of large stones, but there are also some areas with sand and gravel. Flow rate is increased, and the water is clear. Next to the fourth station, there is a bigger fish production facility; the wastewater of the facility pours into the stream.

The fifth station is close to the village of Çandır, nearly 2 km away from the fourth station. Finally, the sixth station is located 300 m above the region where the stream is connected to Karacaören I Dam Lake. All stations are shown in Figure 1, and the altitude, latitude, and longitude of the stations are presented in Table 1.

2.2. Sampling procedures and environmental variables

All water samples were analyzed within 24 h after sampling. Water temperature, pH, dissolved oxygen (DO), and conductivity were measured during sampling in situ. Other variables [Cl^-, NH_4^+–N, NO_2^-–N, NO_3^-–N, PO_4^-–P, biological oxygen demand (BOD)] were measured in the laboratory by following the standard methods (APHA, 1998). Water quality assessment by physicochemical variables was done according to Klee's (1990) method.

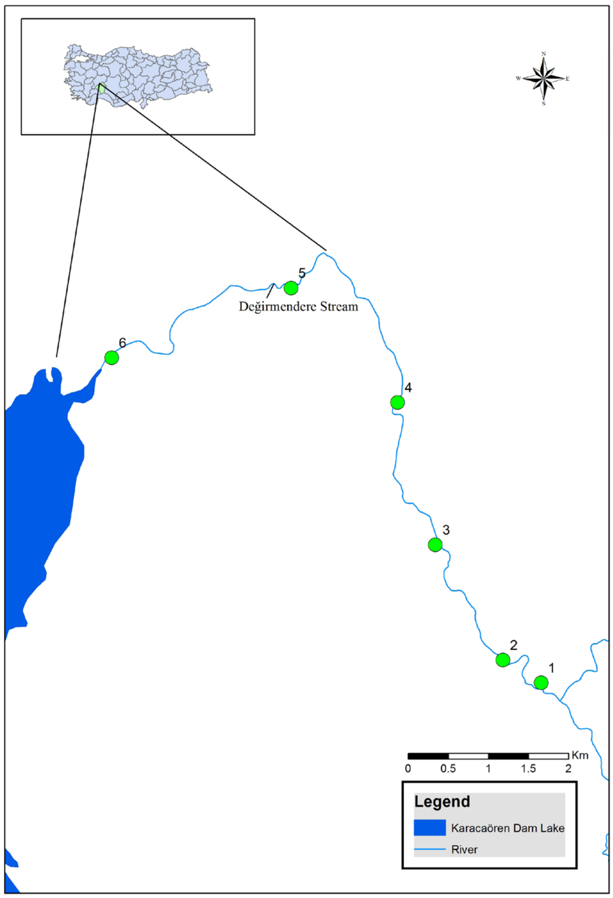

Figure 1. Study area and stations.

Table 1. Altitude, latitude, and longitude of the stations.

Stations	Altitude (m)	Latitude	Longitude
Station 1	353	37°28.091′N	30°55.276′E
Station 2	350	37°28.084′N	30°55.241′E
Station 3	329	37°27.750′N	30°54.646′E
Station 4	288	37°26.949′N	30°54.071′E
Station 5	265	37°26.734′N	30°53.882′E
Station 6	259	37°26.637′N	30°53.803′E

Macroinvertebrate communities along the stream were sampled monthly from March 2011 to February 2012 at each of the 6 stations using a standard hand net (50 × 30 size with 500-µm mesh). The samples were taken from an area of nearly 100 m^2 in order to include all possible microhabitats at each station. In some areas where large stones were present, these were first picked out and washed into the kick net to remove pupae and other attached macroinvertebrates. In addition, macroinvertebrate samples were separated from the macrophytes and sediment using sieves (250 µm). All of the animals collected were immediately fixed in formaldehyde (4%) in the field and then transferred to 70% ethyl alcohol back in the laboratory. The macroinvertebrates were sorted and identified to the lowest possible taxonomic level and were counted under a stereomicroscope.

2.3. Data analyses

In order to determine water quality, macroinvertebrate data were analyzed using ASTERICS 3.1 (AQEM/STAR Ecological River Classification System; AQEM Consortium, 2002) software. Five BMWP versions (BMWP Original, Spanish, Hungarian, Czech, and Polish), 3 ASPT versions (ASPT Original, Hungarian, and Czech), and 2 diversity indices (Shannon–Wiener and Simpson diversity indices) were used to determine water quality. The unweighted pair group method with arithmetic mean (UPGMA), applied by using MVSP version 3.1 (Kovach, 1998), was used to show possible clustering relationships among the 6 sampling sites based on macroinvertebrates.

3. Results

3.1. Physicochemical variables

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 2.

3.2. Biological results

In this study, 59 taxa comprising 15,134 individuals were collected in total. The most individuals were

Table 2. Physicochemical variables and average water quality classes (Klee, 1990) for stations in Değirmendere Stream.

		°C	DO (mg/L)	pH	EC (µS/cm)	Cl^- (mg/L)	NH_4^+–N (mg/L)	NO_2^-–N (mg/L)	NO_3–N (mg/L)	PO_4–P (mg/L)	BOD (mg/L)	Average water quality class
	Min.	11.00	5.89	7.99	263.00	2.60	0.03	0.001	0.80	0.02	1.00	
Sta. 1	Avg.	15.86	7.94	8.59	319.63	4.34	0.11	0.001	1.11	0.02	2.86	I
	Max.	25.40	10.26	10.83	385.00	6.70	0.21	0.001	1.80	0.02	5.48	
	Min.	12.70	5.92	7.54	211.60	1.90	0.03	0.001	0.80	0.02	0.20	
Sta. 2	Avg.	14.55	8.21	8.51	328.69	3.76	0.07	0.001	1.31	0.15	2.62	I
	Max.	16.80	10.60	10.93	370.00	5.20	0.10	0.001	3.90	0.75	5.20	
	Min.	12.00	5.82	7.87	313.00	2.50	0.03	0.001	0.80	0.02	0.60	
Sta. 3	Avg.	15.50	8.15	8.66	335.73	3.80	0.10	0.001	1.46	0.02	2.81	I
	Max.	23.40	9.80	10.68	373.00	6.10	0.22	0.001	5.50	0.02	6.59	
	Min.	12.40	6.00	8.13	249.70	2.90	0.03	0.001	0.80	0.02	0.20	
Sta. 4	Avg.	16.55	7.65	8.62	323.97	4.73	0.12	0.001	1.14	0.02	2.69	I
	Max.	24.00	9.97	10.69	347.00	8.90	0.28	0.001	2.30	0.02	6.30	
	Min.	12.40	6.40	8.08	324.00	2.70	0.03	0.001	0.80	0.02	0.60	
Sta. 5	Avg.	16.47	7.70	8.60	331.82	3.76	0.19	0.002	1.57	0.09	2.71	I–II
	Max.	24.00	10.63	10.82	344.00	6.10	0.48	0.007	5.30	0.38	5.73	
	Min.	13.40	6.20	8.09	16.50	2.50	0.03	0.001	0.80	0.02	0.30	
Sta. 6	Avg.	18.23	7.73	9.13	295.32	3.74	0.22	0.002	1.21	0.02	2.38	I
	Max.	33.90	10.00	13.80	362.00	5.80	0.76	0.007	2.50	0.02	5.20	

collected at station 5, while the fewest individuals were collected at station 6. The individuals collected from the stations belonged to Gastropoda (4 taxa), Bivalvia (1 taxon), Oligochaeta (1 taxon), Hirudinea (1 taxon), Malacostraca (2 taxa), and Insecta (50 taxa). Distributions and dominancy (%), along with a list of the recorded macroinvertebrate taxa, are given in Table 3. Table 4 shows the dominancy (%) of the identified classes and orders at the stations.

Classification of the stations by macroinvertebrate composition was defined in terms of UPGMA analysis. According to the results of the analysis, the first and third stations were the most similar to each other (76%) and the fifth and sixth stations were found to have the lowest similarity (59%) in dynamics (distribution both in terms of species and the number of individuals) of macroinvertebrates in the study area (Figure 2).

The various versions of the BMWP and ASPT indices were applied for determining biological water quality. Score values of biotic indices and water quality classes are shown in Table 5.

Results from each of the 5 versions of the BMWP (Original, Spanish, Hungarian, Czech, and Polish) showed that the highest score values belonged to the fourth station, while the lowest scores belonged to the second station. Moreover, each of the 3 different versions of the ASPT indicated that the highest score values were found at the third station; however, the original and Hungarian versions of the ASPT indicated that the lowest values were at the sixth station, but the Czech version indicated that the fourth station had the lowest score. When the biotic indices were examined in terms of water quality classes, the second station was determined as slightly polluted (Class II), while the other stations were determined as unpolluted (Class I) based on all versions of the BMWP index. The quality classes of the stations differed from each other according to the 3 versions of the ASPT. However, all of the stations were determined as unpolluted (Class I) or slightly polluted (Class II) (Table 5).

Shannon–Wiener and Simpson diversity indices were calculated for each station to examine whether there was diversity of the macroinvertebrate species. Both indices showed that the lowest diversity was seen at the second station and the highest diversity was found at the fourth and fifth stations (Table 5).

4. Discussion

The use of biotic indices for biomonitoring in streams was first developed in Europe and subsequently in the United States (Richardson, 1928; Woodiwiss, 1964). Indices have been developed for a number of different target groups, including higher plants, algae, protozoa, fish, and macroinvertebrates (Pont et al., 2009; Waite et al., 2010). Macroinvertebrates are among the most popular indicators used in biotic indices and other biological methods due mainly to their relative large size, low cost and ease of sampling, relatively easy identification, and relatively long life cycles (Hellawell, 1986; Metcalfe, 1989; Rosenberg and Resh, 1993; Metcalfe-Smith, 1996; Kazancı et al., 1997, Reece and Richardson, 2000). Recent years have seen renewed efforts to develop more effective use of macroinvertebrates as monitoring and assessment tools for management of rivers in Turkey (e.g., Kazancı, 1993; Kazancı et al., 1997, 2008, 2009, 2013; Girgin, 1997; Kazancı and Dügel, 2000; Kazancı and Girgin, 2001; Duran et al., 2003; Çabuk et al., 2004; Dügel and Kazancı, 2004; Uyanık et al., 2005; Balık et al., 2006; Camur-Elipek et al., 2006; Duran, 2006; Duran and Suicmez, 2007; Kucuk and Alpbaz, 2008; Akbulut et al., 2009; Kalyoncu and Gülboy, 2009; Kalyoncu and Yıldırım, 2009; Tellioğlu and Kara, 2009; Girgin, 2010; Girgin and Kazancı, 2010; Kazancı and Dügel, 2010; Yıldız et al., 2010; Kalyoncu and Zeybek, 2011; Ogleni and Topal, 2011; Topkara et al., 2011; Ekingen and Kazancı, 2012; Zeybek et al., 2012).

Considering the requirements of the EU WFD, the composition and abundance of macroinvertebrate fauna, apart from aquatic flora or fish fauna, constitutes one of the quality elements for the classification of the ecological status of streams (WFD, 2000). In this study, a total of 59 taxa were identified in Değirmendere Stream, and Insecta was determined to be the most dominant group among benthic macroinvertebrates. This finding confirms previous studies in which Insecta was found to be the most dominant group in some streams (e.g., Zamora-Munoz and Tercedor, 1996; Duran, 2006; Kalyoncu and Zeybek, 2009, 2011; Türkmen and Kazancı, 2010).

In the current study, water quality of each station was examined in light of physicochemical variables (Klee, 1990) and biotic indices by comparison with each other. Klee's method (1990) as applied in the study indicated that the fifth station was slightly polluted while the others were unpolluted.

It is seen in the relevant literature that the various versions of the BMWP and ASPT indices have been used to determine water quality in streams, and the results have been compared by researchers (Ferreira et al., 2004; Czerniawska-Kusza, 2005; Roche et al., 2010; Ogleni and Topal, 2011; Kazancı et al., 2013; Lewin et al., 2013). Therefore, in the present study, following the applications in the literature, examining all versions of the BMWP suggested that the second station was slightly polluted; the other stations seemed to have good water quality, or were at least unpolluted. However, physicochemical variables were also examined in the current study and the results showed that the fifth station was slightly polluted, which was not the case for the other stations, which were

Table 3. Distributions and dominance (%) of macroinvertebrates at the stations.

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6
Ancylus fluviatilis O. F. Müller, 1774	0.44	-	0.48	0.23	0.47	2.04
Radix labiata (O. F. Müller, 1774)	0.05	-	-	-	-	-
Physa acuta (Draparnaud, 1805)	-	-	-	1.58	1.81	1.84
Gyraulus albus (O. F. Müller, 1774)	-	-	-	0.24	-	-
Pisidium sp.	-	-	-	0.2	-	0.15
Oligochaeta	0.74	0.75	-	0.04	0.18	0.05
Erpobdella octoculata (Linnaeus, 1758)	-	-	-	0.04	-	0.05
Gammarus sp.	1.63	35.98	30.22	15.97	8.8	14.1
Asellus aquaticus (Linnaeus, 1758)	-	-	-	-	0.06	-
Baetis sp.	6.76	6.17	4.99	9.51	33.67	1.94
Baetis rhodani (Pictet, 1845)	54.98	45.81	37.91	34.19	19.18	51.02
Baetis lutheri Liebenau, 1967	-	-	-	0.2	0.12	-
Baetis muticus (Linnaeus, 1758)	-	0.2	-	-	-	-
Serratella ignita (Poda, 1761)	0.05	0.14	0.96	1.03	1.33	4.49
Caenis luctuosa (Burmeister, 1839)	0.89	0.03	2.34	0.2	0.21	0.05
Ephemera vulgata Linnaeus, 1758	-	-	-	-	-	0.05
Ephemera danica Müller, 1764	0.05	-	0.04	0.44	-	0.05
Rhithrogena semicolorata (Curtis, 1834)	-	0.03	-	0.04	-	0.2
Ecdyonurus dispar (Curtis, 1834)	0.09	0.08	0.17	0.28	0.21	0.05
Electrogena lateralis (Curtis, 1834)	-	-	0.04	0.08	-	-
Ecdyonurus venosus (Fabricius, 1775)	-	-	0.17	0.79	0.06	-
Ecdyonurus insignis (Eaton, 1870)	0.05	-	-	-	0.15	-
Epeorus sp.	-	-	-	1.15	0.06	-
Epeorus alpicola (Eaton, 1871)	0.54	-	-	0.83	0.92	-
Rhyacophila sp.	0.2	0.03	0.48	0.4	0.71	0.26
Rhyacophila torrentium Pictet, 1834	0.09	0.1	0.04	0.52	-	0.15
Rhyacophila obliterata McLachlan, 1863	-	-	-	-	0.03	-
Rhyacophila dorsalis (Curtis, 1834)	-	-	-	-	0.06	-
Rhyacophila fasciata Hagen, 1859	0.2	0.08	0.17	0.83	1.24	0.56
Polycentropus flavomaculatus (Pictet, 1834)	-	-	-	-	0.09	-
Hydropsyche sp.	-	-	-	0.12	0.77	0.56
Hydropsyche fulvipes Curtis, 1834	5.72	0.58	3.47	1.78	4.71	2.04
Hydropsyche angustipennis (Curtis, 1834)	-	-	-	0.08	-	-
Hydropsyche dinarica Marinkovic-Gospodnetic, 1979	0.05	-	-	-	-	-
Hydropsyche instabilis (Curtis, 1834)	0.35	0.03	0.3	0.08	0.5	0.41
Hydropsyche tenuis Navas, 1932	0.09	-	-	-	-	-
Cheumatopsyche lepida (Pictet, 1834)	-	-	-	-	0.03	-
Philopotamus montanus (Donovan, 1813)	-	-	-	0.04	0.03	-
Sericostoma personatum (Kirby & Spence, 1826)	-	-	0.04	-	-	0.05
Glossosoma sp.	0.25	0.03	-	-	-	-
Agapetus sp.	0.94	1.4	-	-	0.71	0.1
Leuctra sp.	-	-	0.04	0.04	-	-

Table 3. (continued).

Leuctra hippopus Kempny, 1899	0.09	-	1.91	-	0.5	-
Protonemura meyeri (Pictet, 1841)	1.48	3.26	-	0.87	0.27	-
Elmis aenea (Müller, 1806)	0.39	1.4	0.43	0.04	-	-
Elmis maugetii Latreille, 1798	9.92	1.15	3.73	1.03	4.89	1.07
Anax sp.	0.84	0.03	0.83	0.4	0.39	-
Epallage fatime (Charpentier, 1840)	-	0.03	-	-	-	-
Ibisia marginata (Fabricius, 1781)	0.49	-	0.83	0.63	0.71	0.1
Odontomyia sp.	-	-	-	-	-	0.05
Pedicia sp.	0.09	0.03	0.04	0.08	0.24	-
Tipula sp.	0.05	-	0.04	0.08	-	-
Hexatoma sp.	0.05	-	0.04	0.08	-	-
Simulium sp.	8.64	0.85	3.91	9.51	6.08	2.09
Antocha sp.	-	-	-	-	-	0.26
Chironomus sp.	3.65	1.83	6.34	16.32	10.79	16.19
Dixa sp.	-	-	-	0.04	0.03	-
Tabanus sp.	-	-	-	-	0.12	-
Ceratopogonidae	0.09	-	-	-	-	-

unpolluted. However, the ASPT's Czech version suggested that all stations were unpolluted, while the Hungarian version of the index showed that all stations seemed to be polluted except for the third station. The deviations between indices may occur, as indicated in previous reports, due to deviation between physicochemical and biological water quality classes (Gómez and Licursi, 2001; Duran and Akyildiz, 2011; Kalyoncu and Zeybek, 2011).

Although the biotic indices and physicochemical variables generally support each other, the deviation between indices might be explained in light of the quality classes, since the quality class levels and the systems of categorization have been limited by different values. For example, Klee's (1990) 7-level quality classes have been applied in this research, while the ASPT's 4-level quality classes and the BMWP's 5-level quality classes have also been applied to the data.

The results of the current study show parallels with previous results in the literature (Roche et al., 2010; Kazancı et al., 2013). Each country modifies and uses the BMWP index based on its environmental features (Alba-Tercedor and Sánchez-Ortega, 1988; Zamora-Munoz and Alba-Tercedor, 1996; Junqueira and Campos, 1998; Junqueira et al., 2000; Capitulo et al., 2001; Mustow, 2002;

Table 4. Dominancy (%) of orders and classes of macroinvertebrates at the stations.

Taxa	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6
Gastropoda	0.49		0.48	2.05	2.28	3.88
Bivalvia	-	-	-	0.20	-	0.15
Oligochaeta	0.74	0.75	-	0.04	0.18	0.05
Hirudinea	-	-	-	0.04	-	0.05
Malacostraca	1.63	35.98	30.22	15.97	8.86	14.10
Ephemeroptera	63.41	52.46	46.62	48.74	55.91	57.85
Trichoptera	7.89	2.25	4.50	3.85	8.88	4.13
Plecoptera	1.57	3.26	1.95	0.91	0.77	-
Coleoptera	10.31	2.55	4.16	1.07	4.89	1.07
Odonata	0.84	0.06	0.83	0.40	0.39	-
Diptera	13.06	2.71	11.20	26.74	17.97	18.69

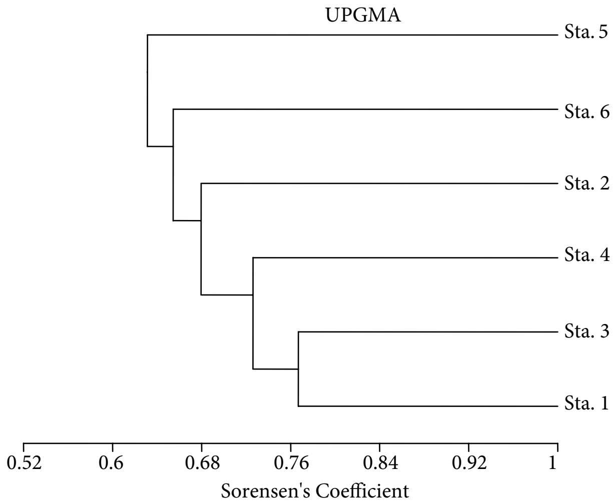

Figure 2. Classification of stations based on similarities of macroinvertebrate communities.

Monteiro et al., 2008). Therefore, in the current study, the scores differed from each other because the versions of the BMWP had been adapted in terms of the geological and ecological differences of the originating countries; it is possible that the deviations of the indices were due to the unique environmental composition of Turkey. These differences in the score values for the versions of the BMWP, found at all stations, might be principally explained by evaluating the number of indicator taxa.

Classification of the stations based on macroinvertebrates was conducted by UPGMA analysis using Sørensen's similarity coefficient. However, stations were clustered in a single group of the UPGMA dendrogram. This is probably related to similarities in distribution both in terms of species and the number of individuals of macroinvertebrates in the field. The clustering method using UPGMA has been applied in streams by many researchers (Akbulut et al., 2009; Kazancı et al, 2010b; Türkmen and Kazancı, 2011; Ertunç Başören and Kazancı, 2012; Başak et al., 2014).

Table 5. Score values of biotic-diversity indices and water quality classes.

Biotic indices		Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6
	Score	111	82	110	128	119	102
BMWP (Original)	Class	I	II	I	I	I	I
	N. taxa	18	14	16	22	20	18
	Score	131	84	118	140	139	117
BMWP (Spanish ver.)	Class	I	II	I	I	I	I
	N. taxa	22	15	18	25	24	21
	Score	115	82	105	125	116	106
BMWP (Hungarian ver.)	Class	I	II	I	I	I	I
	N. taxa	21	14	17	23	20	20
	Score	139	93	124	145	139	123
BMWP (Czech ver.)	Class	I	II	I	I	I	I
	N. taxa	21	13	18	23	21	19
	Score	116	72	106	121	111	108
BMWP (Polish ver.)	Class	I	II	I	I	I	I
	N. taxa	20	12	16	22	19	19
ASPT (Original)	Score	6.17	5.86	6.88	5.82	5.95	5.67
	Class	I	II	I	II	II	II
ASPT (Hungarian ver.)	Score	5.48	5.86	6.18	5.44	5.80	5.30
	Class	II	II	I	II	II	II
ASPT (Czech ver.)	Score	6.62	7.15	6.89	6.30	6.62	6.47
	Class	I	I	I	I	I	I
Diversity indices							
Shannon–Wiener		1.76	1.42	1.86	2.12	2.19	1.68
Simpson		0.67	0.66	0.75	0.81	0.82	0.69

The maintenance of good water quality, both sanitary and environmental, is essential, since it depends largely on the conservation of biodiversity (Fernández-Díaz, 2003). According to the Shannon–Wiener diversity index, the index value is between 1 and 3 in moderately polluted streams (Mason, 2002). Diversity measures are a useful method for describing community structure but not for determining the pollution level of water bodies. However, biotic indices readily give us knowledge on environments polluted by degradable organic matter (sewage), but not other types of pollutants (Washington, 1984). The diversity values of the current study showed that there was a varied range of diversity in the field, from 1.42 at the second station to 2.19 at the fifth station. Similar results to those of biotic indices were expected for biodiversity values. Therefore, as seen in biotic indices, the results of biodiversity values indicated that the highest diversity of species was observed at station 4, while indigenous fauna of the source area might be responsible for the lowest biodiversity, which was observed at the second station.

When the stream was evaluated according to distribution of organisms, Ephemeroptera was determined as the most dominant at all stations, while Oligochaeta and Hirudinea had the lowest dominancy. Diptera taxa were determined at all stations. On one hand, Ephemeroptera species are sensitive to pollution; their number and diversity in species decrease if pollution increases (Plafkin et al., 1989). They usually live in unpolluted habitats. On the other hand, Diptera species generally have a cosmopolitan distribution. For instance, they can be found in all stream types, ranging from clean streams to polluted streams (Stribling et al., 1998). Moreover, some research claims that Oligochaeta shows an increase in terms of pollution effects (Plafkin et al., 1989). Our results confirm these previous suggestions from the literature.

Consequently, our findings for both physicochemical variables and macrozoobenthic organisms indicate that the water quality of this stream is slightly polluted. This stream starts in a nature conservation area and flows through Çandır, then pours into Karacaören I Dam Lake. Therefore, it is recommended that pollutants should be completely isolated from the stream and increases in pollution over time should be prevented. In addition, policy implications on conservation efforts of water quality should be enhanced.

The findings of the current study also suggest that biotic indices developed for a particular geographical region introduce deviations between indices into a researcher's evaluation. Thus, the findings strongly indicate that 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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References

Akbulut M, Odabasi DA, Kaya H, Celik ES, Yildirim MZ, Odabasi S, Selvi K (2009). Changing of Mollusca fauna in comparison with water quality: Saricay Creek and Atikhisar Reservoir models (Canakkale-Turkey). J Anim Vet Adv 8: 2699–2707.

Alba-Tercedor J, Sánchez-Ortega A (1988). A quick and simple method to evaluate biological quality of running fresh water based on Hellawell (1978). Limnetica 4: 51–56 (article in Spanish with an abstract in English).

APHA (1998). Standard Methods for the Examination of Water and Wastewater. 20th ed. Washington, DC, USA: American Public Health Association.

AQEM Consortium (2002). Manual for the Application of the AQEM System. A Comprehensive Method to Assess European Streams Using Benthic Macroinvertebrates, Developed for the Purpose of the Water Framework Directive. Duisburg, Germany: AQEM Consortium.

Armitage PD, Moss D, Wright JF, Furse MT (1983). The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res 17: 333–347.

Balık S, Ustaoğlu MR, Özbek M, Yıldız S, Taşdemir A, İlhan A (2006). Determination of pollution at lower basin of Küçük Menderes River (Selçuk, İzmir) by using macro benthic invertebrates. Ege JFAS 23: 61–65.

Barton DR, Metcalfe-Smith JL (1992). A comparison of sampling techniques and summary indices for assessment of water quality in the Yamaska River, Québec, based on benthic macroinvertebrates. Environ Monit Assess 21: 225–244.

Başak E, Aygen C, Külköylüoğlu O (2014). Taxonomy, distribution, and ecology of crustacean zooplankton in trough waters of Ankara (Turkey). Turk J Zool 38: 1–10.

Buss DF, Salles FF (2006). Using Baetidae species as biological indicators of environmental degradation in a Brazilian river basin. Environ Monit Assess 130: 365–372.

Çabuk Y, Arslan N, Yılmaz V (2004). Species composition and seasonal variations of the Gastropoda in Upper Sakarya River System (Turkey) in relation to water quality. Acta Hydroch Hydrob 32: 393–400.

Callisto M, Moreno P, Barbosa FAR (2001). Habitat diversity and benthic functional trophic groups at Serra do Cipó, southeast Brazil. Rev Bras Biol 61: 259–266.

Camur-Elipek B, Arslan N, Kirgiz T, Oterler B (2006). Benthic macrofauna in Tunca River (Turkey) and their relationships with environmental variables. Acta Hydroch Hydrob 34: 360–366.

Capitulo AR, Tangorra M, Ocon C (2001). Use of benthic macroinvertebrates to assess the biological status of Pampean streams in Argentina. Aquat Ecol 35: 109–119.

Czerniawska-Kusza I (2005). Comparing modified biological monitoring working party score system and several biological indices based on macroinvertebrates for waterquality assessment. Limnologica 35: 169–176.

DSİ (1992). Sakarya ve Seyhan Havzalarinda kirlenme durumlarının incelenmesi ve bu havzalarda kalite sınırlarının tespiti projesi. Ankara, Turkey: DSİ Genel Müdürlügü Yayınları.

Dügel M, Kazancı N (2004). Assessment of the water quality of the Büyük Menderes River by using ordination and classification of macroinvertebrates and environmental variables. J Freshwater Ecol 19: 605–611.

Duran M (2006). Monitoring water quality using benthic macroinvertebrates and physicochemical parameters of the Behzat Stream (Tokat, TURKEY). Pol J Environ Stud 15: 709–717.

Duran M, Akyildiz GK (2011). Evaluating benthic macroinvertebrate fauna and water quality of Suleymanli Lake (Buldan-Denizli) in Turkey. Acta Zool Bulgar 63: 169–178.

Duran M, Suicmez M (2007). Utilization of both benthic macroinvertebrates and physicochemical parameters for evaluating water quality of the Stream Çekerek (Tokat, Turkey). J Environ Biol 28: 231–236.

Duran M, Tüzen M, Kayım M (2003). Exploration of biological richness and water quality of stream Kelkit, Tokat-Turkey. Fresen Environ Bull 12: 368–375.

Ekingen P, Kazancı N (2012). Benthic macroinvertebrate fauna of the Aksu Stream (Giresun, Turkey) and habitat quality assessment based on European Union Water Framework Directive criteria. Review of Hydrobiology 5: 35–55.

Ertunç Başören Ö, Kazancı N (2012). Clustering of Simuliidae (Insecta, Diptera) species and sampling sites according to their similarities by using UPGMA method. Review of Hydrobiology 5: 19–33.

Fernández-Díaz M (2003). Estudio faunístico y ecológico de los coleópteros acuáticos (Adephaga y Polyphaga) en la cuenca del río Ávia (Ourense, NO España): Distribución espacial y temporal. MSc, Universidad de Vigo, Vigo, Spain (in Spanish with an abstract in English).

Ferreira V, Graça MAS, Feio MJ, Mieiro C (2004). Water quality in the Mondego river basin: pollution and habitat heterogeneity. Limnetica 23: 295–306.

Girgin S (1997). A comparision of diversity of benthic macroinvertebrates using different indices in Ankara Stream. Turk J Zool 21: 269–274.

Girgin S (2010). Evaluation of the benthic macroinvertebrate distribution in a stream environment during summer using biotic index. IJEST 7: 11–16.

Girgin S, Kazancı N (2010). Biomonitoring of an urban stream (Ova Stream, Ankara, Turkey) using the Belgian Biotic Index. Review of Hydrobiology 3: 73–87.

Gómez N, Licursi M (2001). The Pampean Diatome Index (PDI) for assessment of rivers and streams in Argentina. Aquat Ecol 35: 173–181.

Hellawell JM (1986). Biological Indicators of Freshwater Pollution and Environmental Management. London, UK: Elsevier Applied Science.

Junqueira MV, Amarante MC, Dias CFS, França ES (2000). Biomonitoramento da qualidade das águas da Bacia do Alto Rio das Velhas (MG/Brazil) através de macroinvertebrados. Acta Limnol Bras 12: 73–87.

Junqueira MV, Campos SCM (1998). Adaptation of the "BMWP" method for water quality evaluation to Rio das Velhas watershed (Minas Gerais, Brazil). Acta Limnol Bras 10: 125–135.

Kalyoncu H, Gülboy H (2009). Benthic macroinvertebrates from Darıören and Isparta streams (Isparta/Turkey) - biotic indices and multivariate analysis. JABS 3: 100–107.

Kalyoncu H, Yıldırım MZ (2009). Species composition of the Mollusca in Aksu River system (Turkey) and its relation to water quality. Fresen Environ Bull 18: 1446–1451.

Kalyoncu H, Zeybek M (2009). Benthic fauna of Ağlasun and Isparta streams and determination of water quality according to physicochemical parameters and Belgium biotic index. BİBAD 1: 41–48 (article in Turkish with an abstract in English).

Kalyoncu H, Zeybek M (2011). An application of different biotic and diversity indices for assessing water quality: a case study in the rivers Çukurca and Isparta (Turkey). Afr J Agric Res 6: 19–27.

Kazancı N (1993). Protection of Environment and Nature in Köyceğiz-Dalyan, Final Report of Hydrobiological Subproject (GTZ). Darmstadt, Germany: Hydrobiological Subproject (GTZ) GmbH.

Kazancı N, Dügel M (2000). An evaluation of the water quality of Yuvarlakçay Stream, in the Köyceğiz-Dalyan Protected Area, SW Turkey. Turk J Zool 24: 69–80.

Kazancı N, Dügel M (2010). Determination of influence of heavy metals on structure of benthic macroinvertebrate assemblages in low order Mediterranean streams by using canonical correspondence analysis. Review of Hydrobiology 3: 13–26.

Kazancı N, Dügel M, Girgin S (2008). Determination of indicator genera of benthic macroinvertebrate communities in running waters in western Turkey. Review of Hydrobiology 1: 1–16.

Kazancı N, Ekingen P, Türkmen G (2009). A study on Hirudinea fauna of Turkey and habitat quality of the species. Review of Hydrobiology 2: 81–95.

Kazancı N, Ekingen P, Türkmen G, Ertunç Ö, Dügel M, Gültutan Y (2010a). Assessment of ecological quality of Aksu Stream (Giresun, Turkey) in Eastern Black Sea Region by using Water Framework Directive (WFD) methods based on benthic macroinvertebrates. Review of Hydrobiology 3: 165–18

Kazancı N, Girgin S (2001). Physico-chemical characteristics of thermal springs in Köyceğiz Dalaman basins in south-western Turkey and recommendations for their protection. Water Sci Technol 45: 211–221.

Kazancı N, Girgin S, Dügel M, Oğuzkurt D (1997). Inland Waters of Turkey Series II: Biotic Index Methods for Evaluating Environmental Quality of Running Waters. Ankara, Turkey: Imaj Press.

Kazancı N, Türkmen G, Bolat HA (2011). Habitat characteristics of endangered species *Marthamea vitripennis* (Burmeister 1839) (Insecta, Plecoptera). Review of Hydrobiology 5: 1–18.

Kazancı N, Türkmen G, Ekingen P, Başören Ö (2013). Preparation of a biotic index (Yeşilırmak-BMWP) for water quality monitoring of Yeşilırmak River (Turkey) by using benthic macroinvertebrates. Review of Hydrobiology 6: 1–29.

Kazancı N, Türkmen G, Ertunç Ö, Ekingen P, Öz B, Gültutan Y (2010b). Assessment of ecological quality of Yeşilırmak River (Turkey) by using macroinvertebrate-based methods in the content of Water Framework Directive. Review of Hydrobiology 3: 89–110 (article in Turkish with an abstract in English).

Klee O (1990). Wasser untersuchen. Biologische Arbeitsbücher 42. Heidelberg/Wiesbaden, Germany: Verlag Quelle & Meyer (book in German).

Korycińska M, Królak E (2006). The use of various biotic indices for evaluation of water quality in the lowland rivers of Poland (exemplified by the Liwiec River) Pol J Environ Stud 15: 419–428.

Kovach WL (1998). MVSP, A Multivariate Statistical Package for Windows, ver. 3.1. Pentraeth, UK: Kovach Computing Services.

Kucuk S, Alpbaz A (2008). The impact of organic pollution on the Kirmir Creek and Sakarya River in Turkey. Water Res 35: 591–597.

Lewin I, Czerniawska-Kusza I, Szoszkiewicz K, Ławniczak AE, Jusik S (2013). Biological indices applied to benthic macroinvertebrates at reference conditions of mountain streams in two ecoregions (Poland, the Slovak Republic). Hydrobiologia 709: 183–200.

Mason CF (2002). Biology of Freshwater Pollution. 4th ed. New York, NY, USA: Prentice Hall.

Metcalfe JL (1989). Biological water quality assessment of running waters based on macroinvertebrate communities: history and present status in Europe. Environ Pollut 60: 101–139.

Metcalfe Smith JL (1996). Biological water-quality assessment of rivers: use of macroinvertebrate communities. In: Petts G, Calow P, editors. River Restoration. Oxford, UK: Blackwell Science, pp. 17–43.

Monteiro TR, Oliveira LG, Spacek Godoy BS (2008). Biomonitoramento da qualidade de água utilizando macroinvertebrados bentônicos: adaptação do índice biótico BMWP à bacia do rio Meia Ponte-GO. Oecol Bras 12: 553–563 (article in Portuguese).

Mustow SE (2002). Biological monitoring of rivers in Thailand: use and adaptation of the BMWP score. Hydrobiologia 479: 191–229.

Mykrä H, Saarinen T, Tolkkinen M, McFarland B, Hämäläinen H, Martinmäki K, Kløve B (2012). Spatial and temporal variability of diatom and macroinvertebrate communities: how representative are ecological classifications within a river system? Ecol Indic 18: 208–217.

Ogleni N, Topal B (2011). Water quality assessment of the Mudurnu River, Turkey, using biotic indices. Water Resour Manag 25: 2487–2508

Plafkin JL, Barbour MT, Porter KD, Gross SK, Hughes RM (1989). Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. Washington, DC, USA: United States Environmental Protection Agency, Office of Water Regulations and Standards.

Pont D, Hughes RM, Whittier TR, Schmutz S (2009). A predictive index of biotic integrity model for aquatic vertebrate assemblages of Western U.S. streams. Trans Am Fish Soc 138: 292–305.

Reece PF, Richardson JS (2000). Benthic macroinvertebrate assemblages of coastal and continental streams and large rivers of southwestern British Columbia, Canada. Hydrobiologia 439: 77–89.

Richardson RE (1928). The bottom fauna of the Middle Illinois River 1913-1925; its distribution, abundance, variation and index value in the study of stream pollution. Illinois Nat Hist Surv Bull 17: 387–475.

Roche KF, Queiroz EP, Righi KO, de Souza GM (2010). Use of the BMWP and ASPT indexes for monitoring environmental quality in a neotropical stream. Acta Limnol Bras 22: 105–108.

Rosenberg DM, Resh VH (1993). Freshwater Biomonitoring and Benthic Macroinvertebrates. New York, NY, USA: Chapman and Hall.

Stribling JB, Jessup KB, White JS (1998). Development of a Benthic Index of Biotic Integrity for Maryland Streams. Annapolis, MD, USA: Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division.

Tellioğlu A, Kara T (2009). Seasonal abundance of Chironomidae larvae (Diptera) in Büyük Stream, Elazığ, Turkey. J Freshwater Ecol 24: 169–171.

Topkara E, Özbek M, Taşdemir A, Yıldız S, Balık S, Ustaoğlu MR (2011). Determination of pollution level of Yuvarlak Stream (Köyceğiz-Muğla) by using benthic macroinvertebrates. J Anim Vet Adv 10: 1194–1201.

Tripole S, Vallania EA, Corigliano MC (2008). Benthic macroinvertebrate tolerance to water acidity in the Grande river sub-basin (San Luis, Argentina). Limnetica 27: 29–38.

Türkmen G, Kazancı N (2010). Applications of various biodiversity indices to benthic macroinvertebrate assemblages in streams of a national park in Turkey. Review of Hydrobiology 3: 111–125.

Türkmen G, Kazancı N (2011). Assessment of benthic macroinvertebrate communities of some sites at Kelkit Stream and its tributaries (Yeşilırmak River Basin) with the application of cluster analysis. Review of Hydrobiology 4: 29–45.

Uyanık S, Yılmaz G, Yeşilnacar MI, Aslan M, Demir Ö (2005). Rapid assessment of river water quality in Turkey using benthic macroinvertebrates. Fresen Environ Bull 14: 268–272.

Waite IR, Brown LR, Kennen JG, May JT, Cuffney JLO, Jones KA (2010). Comparison of watershed disturbance predictive models for stream benthic macroinvertebrates for three distinct ecoregions in western US. Ecol Indic 10: 1125–1136.

Washington HG (1984). Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. Water Res 18: 653–694.

WFD (2000). The EU Water Framework Directive - 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities: L 327, 22.12.2000.

Woodiwiss FS (1964). The biological system of stream classification used by the Trent River Board. Chemy Indust 11: 443–447.

Yıldız S, Özbek M, Taşdemir A, Balık S (2010). Identification of predominant environmental factors structuring benthic macroinvertebrate communities: a case study in the Küçük Menderes coastal wetland (Turkey). Fresen Environ Bull 19: 30–36.

Zamora-Munoz C, Alba-Tercedor J (1996). Bioassessment of organically polluted Spanish rivers, using a biotic index and multivariate methods. J N Am Benthol Soc 15: 332–352.

Zeybek M, Kalyoncu H, Ertan ÖO (2012). Species composition and distribution of Mollusca in relation to water quality. Turk J Fish Aquat Sc 12: 721–729.