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The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Küçük Menderes River (Turkey)

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Abstract: This study was carried out in the Küçük Menderes River basin in order to determine the water quality and investigate the environmental quality and the applicability of both the Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT). Monitoring took place in May, July and September 2014 at 10 stations (7 rivers and 3 lakes) according to the method of Intercalibration Common Metrics. Some metrics (BMWP, ASPT, Family Biotic Index, Simpson Diversity Index, Shannon-Wiener Diversity Index, Margalef Diversity Index, dominance, frequency and existence of sensitive species) were calculated. In total, 69 taxa comprising 5,814 individuals were detected. The taxa having the highest frequency rate were *Limnodrilus hoffmeisteri* (70%), *Chironomus (Camptochironomus) tentans* (70%), *Psammoryctides albicola* (60%), *Physella acuta* (60%), *Nais elinguis* (60%) and *Stylaria lacustris* (50%), which are alpha mesosaprobic and polysaprobic species, respectively. The presence and high dominance and frequency rate of these species have indicated basin pollution. Positive indicator species for water quality are *Gomphus schneideri*, *Trithemis annulata*, *Lindenia tetraphylla*, *Orthetrum cancellatum*, *Hydropsyche angustipennis*, *Cricotopus (Cricotopus) fuscus* and *Cricotopus (Cricotopus) annulator*, while negative indicator species are *Culex pipiens*, *Chironomus (Camptoch.) tentans*, *Chironomus thummi*, *Stylaria lacustris* and *Eristalis tenax*. Habitat quality of the Küçük Menderes River basin was not high (it was found to be heavily polluted/polluted/slightly polluted according to the physicochemical data, BMWP and ASPT) due to physical habitat degradation, urban waste waters, touristic, seasonal dwelling and agricultural activities.

Key words: Küçük Menderes River; benthic macroinvertebrates; biodiversity indices; BMWP; ASPT

Introduction

Benthic macroinvertebrates are important indicators of river health and some species have bioindicative potential, thus their absence or presence can give information about pollution status. Bio-indices have been recognized as suitable criteria for understanding the quality of aquatic environment. They are numerical expressions that combine quantitative values of species diversity with qualitative information on the ecological sensitivity of each taxon (Czerniawska-Kusza 2005). Many biotic indices have been established based on macroinvertebrates (Callisto et al. 2001). Unification of stream classification and the use of a common biotic index are impossible due to the different geographic distribution of macroinvertebrate species and biotypological differences among streams (Korycińska & 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 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 higher than 100 are associated with clean streams, while the scores of heavily polluted streams are lower 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).

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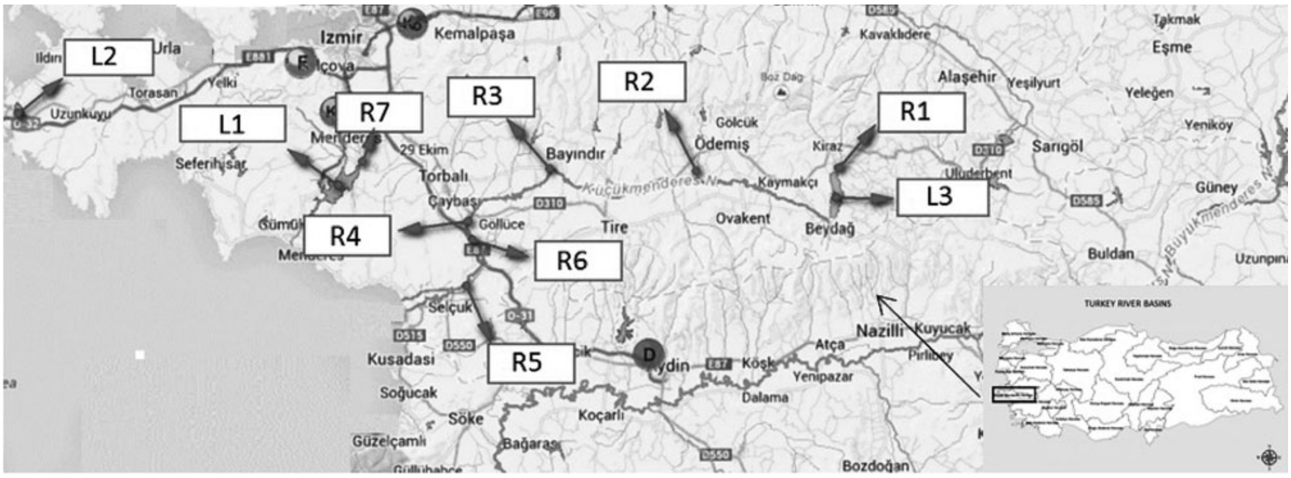

Fig. 1. Geographical distribution and coordinates of sampling sites: R1 (28°13′10.55″ E, 38°9′55.27″ N); R2 (28°0′48.49″ E, 38°9′56.71″ N); R3 (27°40′56.53″ E, 38°9′11.05″ N); R4 (27°24′52.89″ E, 38°4′23.92″ N); R5 (27°22′44.02″ E, 37°58′41.05″ N); R6 (27°23′45.49″ E, 38°5′46.76″ N); R7 (27°9′59.25″ E, 38°11′47.24″ N); L1 (27°2′58.32″ E, 38°5′26.38″ N); L2 (26°24′28.46″ E, 38°17′3.24″ N); L3 (28°13′11.18″ E, 38°6′32.42″ N) (L refers to dam lakes and R refers to river sampling stations).

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 in the EU, running-water health should be assessed by the usage of macroinvertebrates in terms of the introduction of the WFD (Directive 2000/60/ CE 2000) (Kazancı et al. 2010).

Relationship between macroinvertebrate community structure and environmental variables has been used as subject of numerous studies in Turkey (Dugel & Kazancı 2004; Duran 2006; Duran & Suiçmez 2007; Çamur Elipek et al. 2010; Zeybek et al. 2014). 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). Up to now, some researchers have studied the Küçük Menderes River macroinvertebrates (Özbek & Ustaoğlu 2001; Aygen & Balık 2002; Balık et al. 2006; Yıldız et al. 2010).

The Küçük Menderes River basin was chosen for this study due to very high human impact and there has been no enough research on the basin during the last five years. The purposes of this study are: 1) to evaluate macroinvertebrate communities along the Küçük Menderes River basin in Turkey, 2) to determine the biological water quality of the basin by using various metrics (benthic macroinvertabrates based biotic indices and biodiversity indices).

Material and methods

Study area

The Küçük Menderes River rises from the Karakoyun high plateau of the Bozdağ Mountains in the Aegean region, it is approximately 107 km long, has a drainage area of 3,617 km^2 and flows from east to west into the Aegean Sea, just south of Izmir, in western Turkey. The important towns located in the basin are: Bayındır, Beydağ, Kiraz, Ödemiş, Selçuk, Tire, Torbalı, together with 260 villages (Fig. 1). The average total annual precipitation in the basin is about 570 mm/yr., and the mean annual temperature is 16.7 °C. Precipitation occurs mainly in winter while during the summer irrigation period there is very little rain. The river flows through many residential, industrial and agricultural areas, so it collects domestic sewage and chemical wastes which inevitably impact water quality.

Sampling procedures and environmental variables

Ten sampling sites in the Küçük Menderes River basin (7 rivers and 3 dam lakes) were studied in 2014 (May, July and September). Benthic macroinvertebrates were collected from different habitat types in the river by a bottom kick net with 500 μm mesh size. In addition, in dam lakes Oligochaeta samples were collected with an Ekman grab sampler, one haul per station at depths of 5.1–25.3 m (Table 2). All collected samples were immediately fixed in 4% formaldehyde in the field and then transferred to 70% ethyl alcohol. Temperature, dissolved oxygen, and pH of sampling sites were measured *in situ*. Water samples were also taken from the sites to analyze total phosphorus, total nitrogen, nitrite nitrogen, nitrate nitrogen. Also, depth, structure of substratum and riparian vegetation were recorded. In the laboratory, collected macroinvertebrates were sorted and counted by using a stereomicroscope and then identified to the possible lowest taxon (species, genus or family).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, total phosphorus and total nitrogen) were measured in the laboratory following the standard methods (APHA 1998). All water samples were analyzed by Segal Environmental Measurement and Analysis Laboratory.

Data analyses

Macroinvertebrate data were analyzed using ASTERICS 3.1 (AQEM/STAR Ecological River Classification System; AQEM Consortium 2002) software. BMWP (Revised Biological Monitoring Working Party [(rev.BWMP), Paisley et al. 2013), ASPT (Average Score Per Taxon [(ASPT), Armitage et al. 1983), and diversity indices (Shannon-Wiener, Margalef and Simpson diversity indices) were used to determine water quality. The BMWP system considers the sensitivity of invertebrates to pollution; families are assigned

Table 1. Physicochemical variables and average water quality classes for stations in Küçük Menderes Basin.

	Station									
	R1	R2	R3	R4	R5	R6	R7	L1	L2	L3
	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average	Min–Max Average
Temp. (℃)	19.2–19.4 19.2 (I)	19.4–19.6 19.4 (I)	18.7–30.5 23.87 (I)	18.6–24.0 24.33 (I)	18.4–29.8 24.13 (I)	19.1–30.1 24.6 (I)	19.0–27.1 23.2 (I)	18.3–27.5 22.9 (I)	20.6–28.0 23.9 (I)	19.5–28.7 23.6 (I)
pH	7.50–9.80 7.59 (I)	8.40–8.40 8.40 (I)	7.44–7.70 7.57 (I)	7.18–7.42 7.31 (I)	7.27–7.75 7.52 (I)	7.28–7.76 7.60 (I)	8.12–8.27 8.20 (I)	8.16–8.41 8.30 (I)	8.21–8.42 8.30 (I)	7.32–8.47 7.80 (I)
DO (mg L^{-1})	7.22–7.80 7.34 (I)	8.02–8.06 8.04 (I)	0.92–1.20 1.07 (IV)	1.01–1.26 1.12 (IV)	0.95–1.20 1.09 (IV)	0.84–2.91 1.80 (IV)	7.16–11.2 8.80 (I)	7.70–8.07 7.90 (II)	7.80–8.61 8.30 (I)	6.70–8.15 7.38 (II)
Total nitrogen (mg L^{-1})	5.52–6.10 5.56	6.65–6.84 6.70	29.3–42.9 36.73	71.3–82.00 76.20	11.30–14.60 12.90	16.00–42.30 28.70	3.60–24.32 12.37	0.56–1.23 0.86	0.65–1.43 1.02	0.63–0.92 0.73
NO_2-N (mg L^{-1})	0.088–0.095 0.091 (IV)	0.081–0.090 0.085 (IV)	<0.002–0.300 0.11 (IV)	0.017–0.032 0.020 (III)	0.006–0.008 0.007 (II)	<0.002–0.012 0.022 (II)	0.0024–0.0061 0.0029 (II)	0.010–0.013 0.010 (II)	<0.002–0.018 0.0073 (II)	0.006–0.024 0.0073 ((II)
NO_3-N (mg L^{-1})	1.03–1.50 1.24 (I)	1.27–1.86 1.48 (I)	0.23–0.28 0.26 (IV)	0.286–0.650 0.43 (I)	<0.10–1.20 0.49 (I)	<0.10–0.38 0.26 (I)	0.52–24.30 8.90 (II)	0.139–0.440 0.200 (I)	<0.10–0.30 0.30 (I)	<0.100–0.396 0.230 (I)
P (mg L^{-1})	3.27–3.45 3.36 (IV)	0.17–0.21 0.19 (II)	1.32–4.80 3.44 (IV)	1.48–19.20 12.06 (IV)	1.305–1.500 1.405 (IV)	1.32–5.50 2.76 (IV)	<0.010–0.035 0.031 (II)	0.017–0.062 0.040 (III)	0.070–0.089 0.070 (IV)	0.034–0.056 0.044 (III)
Depth (m)	0.25	0.2	1.0	0.6	0.9	0.5	0.5	25.3	5.1	21
Average water quality class*	IV	IV	IV	IV	IV	IV	II	III	IV	III

Abbreviations: DO – dissolved oxygen, Temp – temperature. * Numbers given in parentheses indicate classes of water quality according to Surface Water Quality Management Regulation (2012) (Class I: High quality water; Class II: Slightly polluted water; Class III: Polluted water; Class IV: Heavily polluted water).

Table 2. Distributions dominance (D%) and frequency (F%) of invertebrates at the stations.

Taxa	F%	Station (D%)										D% (Average)
		R1	R2	R3	R4	R5	R6	R7	L1	L2	L3	
Gastropoda												
Planorbidae												
Gyraulus piscinarum (Bourguignat, 1852)	20.0	1.3	–	–	–	–	9.2	–	–	–	–	1.05
Planorbis intermixtus Mousson, 1874	20.0	–	3.7	–	–	–	–	2.1	–	–	–	0.58
Physidae												
Physella acuta (Draparnaud, 1805)	60.0	1.9	6.0	–	2.6	–	2.8	23.9	3.7	–	–	4.08
Melanopsidae												
Melanopsis buccinoida (Olivier, 1801)	20.0	4.5	–	–	–	–	–	4.3	–	–	–	0.88
Lymnaeidae												
Radix labiata (Rossmassler, 1835)	10.0	–	–	–	–	–	–	5.3	–	–	–	0.53
Naididae												
Nais elinguis Muller, 1774	60.0	6.4	4.2	–	–	4.7	–	–	6.1	3.0	5.3	2.97
Stylaria lacustris (L., 1767)	50.0	–	20.8	–	–	8.3	–	–	7.4	17.8	7.0	6.13
Nais barbata Muller, 1774	10.0	–	–	–	–	–	–	–	–	–	1.7	0.17
Nais pardalis Piguet, 1906	20.0	1.3	–	–	–	–	–	–	–	–	4.9	0.63
Tubificidae												
Psammoryctides albicola (Michaelsen, 1901)	60.0	3.7	–	–	–	4.3	12.8	–	5.5	8.6	9.3	4.43
Limnodrilus hoffmeisteri Claparede, 1862	70.0	2.4	11.6	–	38.9	19.1	23.9	–	14.7	–	13.3	12.38
Limnodrilus udekemianus Claparede, 1862	20.0	–	8.8	–	10.0	–	–	–	–	–	–	1.88
Potamothrix hammoniensis (Michaelsen, 1901)	50.0	–	2.8		4.1	5.0	9.2	0.8	–	–	–	2.18
Potamothrix heuscheri (Bretscher, 1900)	10.0	–	–	–	–	–	–	–	3.1	–	–	0.31
Limnodrilus claparedeanus Ratzel, 1868	10.0				14.8							1.48
Gammaridae												
Gammarus aequicauda (Martynov, 1931)	20.0	–	–	–	–	–	—	0.4	9.8	–	–	1.03
Decapoda												
Potamonidae												
Potamon sp.	10.0	–	–	–	–	–	–	0.1	–	–	–	0.01
Heteroptera												
Corixidae												
Sigara lateralis (Leach, 1817)	10.0	6.4	–	–	–	–	–	–	–	–	–	0.64
Sigara scripta (Rambur, 1840)	30.0	–	1.9	–	–	6.5	–	–	–	15.2	–	2.35
Micronecta p. poweri (Douglas et Scott, 1869)	30.0	–	–	–	–	1.8	–	–	3.1	24.1	–	2.90
Gerridae												
Gerris thoracicus Schummel, 1832	30.0	3.5	–	–	–	–	–	0.2	11.0	–	–	1.47
Aquarius paludum (F., 1794)	10.0	–	–	–	–	–	–	–	1.8	–	–	0.18
Nepidae												
Nepa cinerea L., 1758	20.0	–	–	–	–	0.7	–	0.3	–	–	–	0.10
Hydrometridae												
Hydrometra stagnorum (L., 1758)	10.0	–	–	–	–	–	–	0.6	–	–	–	0.06
Notonectidae												
Anisops sardeus Herrich-Schaeffer, 1849	10.0	–	–	–	–	–	–	–	–	0.7	–	0.07
Coleoptera												
Helophoridae												
Helophorus b. brevipalpis Bedel, 1881	20.0	–	–	–	–	1.8	–	1.2	–	–	–	0.30
Dytiscidae												
Ilybius chalconatus (Panzer, 1797)	10.0	–	–	–	–	–	–	0.2	–	–	–	0.02
Laccophilus hyalinus (De Geer, 1774)	10.0	–	–	–	–	–	–	1.5	–	–	–	0.15
Haliplidae												
Peltodytes caesus (Duftschmid, 1805)	10.0	–	–	–	–	–	–	0.2	–	–	–	0.02
Hygrobidae												
Hygrobia hermanni (F., 1775)	10.0	–	–	–	–	–	–	–	–	0.7	–	0.07
Odonata												
Libellulidae												
Orthetrum brunneum (Fonscolombe, 1837)	10.0	–	–	–	–	1.4	–	–	–	–	–	0.14
Orthetrum cancellatum (L., 1758)	10.0	–	–	–	–	–	–	–	–	0.7	–	0.7
Trithemis annulata (Palisot de Beauvois, 1807)	10.0	–	–	–	–	–	–	–	1.2	–	–	0.12
Platycnemididae												
Platycnemis pennipes (Pallas, 1771)	30.0	1.1	–	–	–	–	–	2.5	1.2	–	–	0.48
Gomphidae												
Gomphus schneideri Selys, 1850	10.0	–	–	–	–	–	–	2.3	–	–	–	0.23
Lindenia tetraphylla (Vander Linden, 1825)	10.0	–	–	–	–	–	–	–	1.2	–	–	0.12
Coenagrionidae												
Ischnura elegans (Vander Linden, 1820)	10.0	–	–	–	–	–	–	0.5	–	–	–	0.05

Table 2. (continued)

Taxa	F%	Station (D%)										D% (Average)
		R1	R2	R3	R4	R5	R6	R7	L1	L2	L3	
Diptera												
Chironomidae												
Tanypus vilipennis (Kieffer, 1918)	10.0	3.7	–	–	–	–	–	–	–	–	–	0.37
Procladius (Holotanypus) sp.	20.0	5.3	–	–	–	–	–	1.4	–	–	–	0.67
Arctopelopia barbitarsis (Zetterstedt, 1850)	10.0	–	–	–	–	–	–	0.3	–	–	–	0.03
Natarsia punctata (F., 1805)	10.0	–	–	–	–	–	–	0.3	–	–	–	0.03
Paracladius conversus (Walker, 1856)	10.0	–	–	–	–	–	–	1.7	–	–	–	0.17
Rheocricotopus fuscipes (Kieffer, 1909)	10.0	–	–	–	–	–	–	2.3	–	–	–	0.23
Tanypus punctipennis Meigen, 1818	30.0	–	–	–	–	4.3	–	0.9	–	8.3	–	1.34
Paratendipes albimanus (Meigen, 1818)	10.0	–	–	–	–	–	–	0.7	–	–	–	0.07
Cricotopus (C.) tremulus (L., 1756)	10.0	–	–	–	–	–	–	0.5	–	–	–	0.05
Cricotopus (C.) fuscus (Kieffer, 1909)	30.0	3.2	–	–	–	–	–	–	–	6.3	12.5	2.20
Cricotopus (C.) annulator Goetghebuer, 1927	10.0		–	–	–	–	–	–	–	–	1.5	0.15
Orthocladius (O.) thinemanni Kieffer & Thienemann, 1906	10.0	2.1	–	–	–	–	–	3.3	–	–	–	0.54
Einfeldia pagana (Meigen, 1838)	20.0	2.7	17.1	–	–	–	–	–	–	–	–	1.98
Einfeldia carbonaria (Meigen, 1804)	10.0	–	–	–	–	–	–	–	–	–	0.6	0.06
Cryptotendipes holsatus Lenz, 1959	10.0	–	–	–	–	–	–	–	–	3.6	–	0.36
Chironomus thummi Kieffer, 1911	40.0	9.1	9.7	–	7.4	–	–	–	3.1	–	–	2.93
Chironomus (Camptoch.) tentans F., 1805	70.0	12.8	13.4		20.4	11.2	21.1		27.0	–	38.1	14.40
Stictochironomus yalvacii Şahin, 1971	10.0	1.9	–	–	–	–	–	–	–	–		0.19
Dicrotendipes tritomus (Kieffer, 1916)	30.0	–	–	–	–	10.1	–	1.4	–	–	1.5	1.30
Endochironomus tentans (F., 1775)	30.0	–	–	–	–	5.4	18.3	7.0	–	–	–	3.07
Polypedilum scalaenum (Schrank, 1803)	10.0	–	–	–	–	–	–	–	–	–	1.1	0.11
Polypedilum aberrans Chernovskii, 1949	10.0	–	–	–	–	–					0.4	0.04
Rheotanytarsus exiguus (Johannsen, 1905)	20.0	–	–	–	–	–		0.7			0.4	0.11
Cladotanytarsus mancus (Walker, 1856)	20.0	–	–	–	–	–	–	–	–	11.2	0.9	1.22
Simuliidae												
Simulium (Wilhelmia) lineatum (Meigen, 1804)	20.0	6.4	–	–	–	–	–	0.1	–	–	–	0.65
Culicidae												
Culex pipiens L., 1758	20.0	14.7	–	–	–	15.5	–	–	–	–	–	3.01
Syrphidae												
Eristalis tenax (L., 1758)	20.0	–	–	100	1.5	–	–	–	–	–	–	10.15
Stratiomyidae												
Stratiomys longicornis (Scopoli, 1763)	10.0	–	–	–	0.4	–	–	–	–	–	–	0.04
Ephemeroptera												
Baetidae												
Baetis rhodani (Pictet, 1843)	30.0	3.5	–	–	–	–	2.8	31.2	–	–	–	3.74
Serretella ignita (Poda, 1761)	10.0	–	–	–	–	–	–	0.5	–	–	–	0.05
Tipulidae												
Tipula sp.	10.0	–	–	–	–	–	–	0.1	–	–	–	0.01
Trichoptera												
Hydropsyche angustipennis (Curtis, 1834)	30.0	2.1	–	–	–	–	–	1.4	–	–	1.3	0.49

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).

Bellan-Santini's (1969) quantitative dominance index of a certain species was estimated by $Di = Ni/Nt \times 100$, where Ni = number of individuals of species i; and Nt = total number of macrobenthic specimens. Soyer's (1970) frequency index of a particular species was estimated by $f = m/M \times 100$, where m = number of stations where the species was found and M = total number of stations × total number of seasons. Bray Curtis similarity index based on UPGMA (Unweighted Pair Group Average) algorithm as well as Bray-Curtis analyses were calculated using PAST 1.75b (Hammer et al. 2001). Results of the physicochemical analysis were also classified according to Surface Water Quality Management Regulation (Republic of Turkey Ministry of Environment and Forest 2012) to demonstrate water quality.

Results

Physicochemical variables

The minimum, maximum, and average variables and water quality classes of the Küçük Menderes River basin in May, July and September 2014 are indicated in Table 1. The results of physicochemical analyses of water samples have been classified in Surface Water Quality Management Regulation (2012). Water quality was determined as between fairly clean (Class II) and polluted (Class IV) as a result of these standards. Accord-

Table 3. Score and values of indices of the sampling sites at Küçük Menderes.

Biotic indices	Station									
	R1	R2	R3	R4	R5	R6	R7	L1	L2	L3
Taxon number	22	11	1	9	15	8	34	15	12	16
Individual number	375	216	4	270	278	109	1149	163	303	527
Diversity (Shannon Index H′)	2.838	2.186	0	1.706	2.428	1.881	3.391	2.308	2.096	2.029
Diversity (Simpson Index 1-D)	0.82	0.87	0	0.76	0.89	0.83	0.83	0.86	0.85	0.80
Diversity (Margalef Index)	1.86	0.74	0	0.71	1.07	0.85	2.41	1.57	0.87	0.72
FBI	6.40	7.30	0	8.12	7.20	7.40	5.90	6.70	6.20	7.04
BMWP score	38	13	0	5	20	12	75	43	25	7
ASPT score	4.22	3.25	0	2.50	5	3	5	5.30	5	3.50
Water quality class	4	4	4	4	4	4	2	2	4	5

ing to these results, the water quality level was determined as fairly clean (Class II; R7), polluted (Class III; L1 and L3), while the poor water quality level was determined as heavily polluted (Class IV; R1, R2, R3, R4, R5, R6 and L2).

Biological results

In this study, 5,814 benthic macroinvertebrate individuals belonging to 69 taxa were identified in 10 sites. The highest number of individuals were collected at station R7 (1149 ind.), while the fewest individuals were collected at station R3 (4 ind.).

The species collected from the stations, their distribution, frequency and dominance (%), along with a list of the recorded taxa, are given in Table 2. Insecta was the most abundant group with a total of 52 taxa recorded including Heteroptera (8 taxa), Coleoptera (5), Odonata (7), Diptera (29), Ephemeroptera (2) and Trichoptera (1).

Amphibiotic insects of different groups dominated in the lake and river sites, with the exception of R2, R4, R5 and R6, where the oligochaete worms *Stylaria lacustris* (20.83% at R2) and *Limnodrilus hoffmeisteri* were the predominant species (38.89%, 19.06% and 23.85% at R4, R5 and R6, respectively). *Chironomus* (*Camptoch.*) *tentans* was the dominant species at the sites L1 and L3 with 26.99% and 38.14%, respectively. At site R1, larvae of *Chironomus* (*Camptoch.*) *tentans* co-dominated with larvae of *Culex pipiens* (12.80% and 14.67%, respectively). The snail *Physella acuta* and the mayfly *Baetis rhodani* were the dominant species at site R7 with 23.93% and 31.96%, respectively. The boat-fly *Micronecta poweri poweri* was the dominant species with 24.09% at site L2. In addition, the indicator species for polysaprobic environments, *Eristalis tenax,* was recorded as a single taxon at site R3.

The values of Diversity Indices (Shannon-Wiener, Simpson and Margalef) varied between 1.716 and 3.391; 0.76 and 0.89; 0.71 and 2.41, respectively (Table 3). ASPT score values were between 0 and 5.3 in all stations (Table 3). The highest BMWP score value (75) belonged to R7, the lowest BMWP score value (0 and 5) belonged to sites R3 and R4 (in sampling site R3, only one taxon, *E. tenax,* recorded). When the indices were examined in terms of water quality classes, the R7 and L1 stations were determined as clean but slightly impacted (Class II), L3 station was determined as heavily polluted (Class V) and while the other stations were determined as polluted or impacted (Class IV) based on all versions of the biotic index. Shannon-Wiener, Simpson and Margalef diversity indices were calculated for each station. Three indices showed that the lowest diversity was seen at R3 and R4 and the highest diversity was found at R7 (Table 3).

Classification of the stations by representation of invertebrates was defined in terms of UPGMA analysis. According to the results of the analysis, stations R1 and R2 stations were most similar to each other and stations R3 and R7 were found to have the lowest similarity in dynamics (distribution both in terms of species and the number of individuals) of invertebrates in the study area (Fig. 2). The hydromorphological structures, habitat and physicochemical variables were similar at stations R1 and R2 while these features were different at stations R3 and R7. In addition, seasonal variations may affect the features of the water and the dynamics of benthic macroinvertebrates.

Discussion

Biotic indices for biomonitoring in streams were first developed in Europe and subsequently in the United States (Richardson 1928; Woodiwiss 1964). Recent years have shown renewed efforts to develop more effective use of macroinvertebrates as monitoring and assessment tools for management of rivers in Turkey. Considering the requirements of the EU WFD, the composition and abundance of the macroinvertebrate fauna, apart from aquatic flora or fish fauna, constitutes one of the quality elements for classification of the ecological status of streams (WFD 2000). In this study, a total of 69 taxa were identified in the Küçük Menderes River basin. Insecta was determined to be the most dominant group among benthic macroinvertebrates that confirms the results of previous studies in which Insecta was found to be the most dominant group in some streams (Duran 2006; Kalyoncu & Gulboy 2009; Türkmen & Kazancı 2010).

In the current study, water quality of each station was examined in light of physicochemical variables (Surface Water Quality Management Regulation) and biotic indices by comparison with each other. Both re-

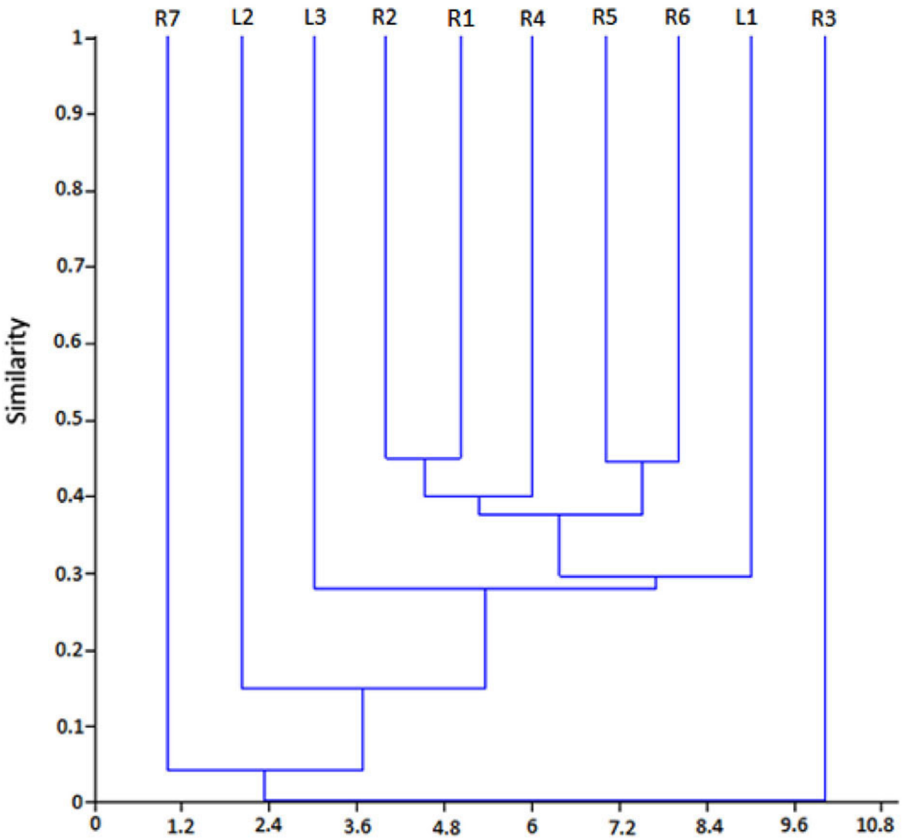

Fig. 2. Classification of stations based on similarities of invertebrate communities.

sults applied in the study indicated that the sampling station R7 was clean but slightly impacted while the others were polluted (Table 3). 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, BMWP's 5-level quality classes have been applied in this research, while the ASPT has 4-level quality classes.

The results of the current study show the important role of physicochemical variables of water for the community composition of macroinvertebrates. Especially, poly- and mesosaprobic oligochaete worm species (*Limnodrilus hoffmeisteri, Potamothrix hammoniensis, Psammoryctides albicola* and *Stylaria lacustris*) and polysaprobic chironomid larvae (*Chironomus* (*Camptoch.*) *tentans*) which are tolerant to organic pollution (Hellawell 1986) showed the highest dominance and frequency in the basin. The results of the current study show parallels with the results of previous studies on Küçük Menderes fauna and pollution (Balık et al. 2006; Yıldız et al. 2010). Although Balık et al. (2006) have determined 44 taxa belonging to Mollusca, Arthropoda and Annelida, the taxonomical range of macroinvertebrates was enlarged and 69 taxa were identified from the the Küçük Menderes River basin in the present study.

In this study, it was shown that invertebrate fauna of the Küçük Menderes River basin was dominated by three groups, Oligochaeta (*L. hoffmeisteri* 70%, *P. albicola* 60%, *P. hammoniensis* 50% frequency), Chironomidae (*Chironomus* (*Camptoch.*) *tentans* 70% frequency) and Gastropoda (*Physella acuta* 60%) (Table 2), known as pollution tolerant organisms, which are typical of many freshwater habitats (Armitage et al. 1995; Svensson 1999). According to BMWP results these species are negative indicators for water quality while *Gomphus schneideri, Trithemis annulata, Lindenia tetraphylla, Orthetrum cancellatum, Hydropsyche angustipennis, Cricotopus (C.) fuscus* and *Cricotopus (C.) annulator* were positive indicator species. In addition, only one benthic inhabitant *Eristalis tenax* was recorded in site R3. This species is an indicator for polysaprobic (heavy polluted) environments (Šporka 2003; Robinson 2005).

When the Küçük Menderes River basin was evaluated according to the distribution of bottom macroinvertebrates, Oligochaeta and Chironomidae were determined as highly dominant at all stations, while Syrphidae, Odonata, Ephemeroptera and Trichoptera species had the lowest dominance. Diptera taxa were determined at all stations. On one hand, Ephemeroptera and Trichoptera species are sensitive to pollution; their number and species diversity decrease when 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 to polluted ones (Stribling et al. 1998). Moreover, some research claims that Oligochaeta numbers increase in terms of pollution effects (Plafkin et al. 1989). By comparison with the chemical water quality grading, taxa-specific indicators for various water pollution levels have been found. *Gomphus schneideri*, *Trithemis annulata*, *Lindenia tetraphylla*, *Orthetrum cancellatum*, *Hydropsyche angustipennis*, *Cricotopus* (*Cricotopus*) *fuscus* and *Cricotopus* (*Cricotopus*) *annulator* indicate slightly polluted or moderate water quality while *Culex pipiens*, *Chironomus* (*Camptoch.*) *tentans*, *Ch. thummi*, *S. lacustris* and *E. tenax* indicate poor or very poor water quality.

Our findings on both physicochemical variables and macrozoobenthic organisms indicate that the water quality in the Küçük Menderes River is polluted. Consequently, irrigation, sewage system, variable flow rate, temperature, etc. affect the quality of water in the river. Organic pollutants affect macroinvertebrate taxa richness and composition. Taxa richness decreases dramatically with increasing pollution. The structure of benthic macrofauna in the river changes with effects of environmental variables. Therefore, policy implications on conservation efforts of water quality should be enhanced.

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