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Full Length Research Paper

An application of different biotic and diversity indices for assessing water quality: A case study in the Rivers Çukurca and Isparta (Turkey)

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A number of biotic indices (Biological Monitoring Working Party-BMWP, Average Score Per Taxa-ASPT, Belgian Biotic Index-BBI, Family Biotic Index-FBI, Saproby Index-SI, Extended Biotic Index-EBI, Biotic Index for Pampean Rivers and Streams-IBPAMP), diversity indices (Margalef-MDI, Simpson-SDI and Shannon and Weaver-SWDI Diversity indices) and EPT% (Ephemeroptera, Plecoptera, Trichoptera), EPT/Chironomus%, based on benthic macroinvertebrates in relation to physicochemical parameters, have been applied in assessing the water quality of the Rivers Cukurca and Isparta (Mediterranean Region, Turkey). According to the results, the water quality in both rivers varied from weak to excellent. From the indices, SWDI index of the diversity indices and BBI index of the biotic indices seem to be the most reliable. All indices, except EBI were found applicable for Mediterranean Region in Turkey. More researches must be carried out, to get exact decisions about the applicability of EBI in Turkey's rivers.

Key words: Biotic index, diversity index, macro-zoobenthos, water quality, Turkey.

INTRODUCTION

Ecological statuses of the streams were determined by using various groups of organisms. Most of the European researchers use non-systematic units such as fish, macrophytes, phytoplankton and diatoms for regular observations (De Pauw et al., 1992). The most frequently used community to determine the water quality in the streams is the macroinvertebrates. Many studies on these groups are available (Rosenberg and Resh, 1993; Ghetti and Ravera, 1994; Metcalfe-Smith, 1994; Knoben et al., 1995; Ghetti, 1997; De Pauw and Heylen, 2001; Scuri et al., 2006). Macroinvertebrates are the heterogenic collection of various evolutionary taxa, thus being able to answer the specific changes in the chemical water quality (De Pauw and Hawkes, 1993). Despite chemical samples taken at one time, the species of macroinvertebrates are always used to observe the water flowing over them through their life time. The present systems to determine water quality were applied in various streams by many researchers. Based on these studies, some researchers modified the systems developed for feasibility to their own countries, and they added endemic taxa belonging to their countries to the indices.

However, they are known to be particular to specific geographic regions and none of them is appropriate for evaluating water pollution in other parts of the world with repeatable accuracy. For example, Biotic Index for Pampean rivers and streams-IBPAMP (Capitulo et al., 2001) in Argentina does not seem to be useful in European waters. Others, such as the Saproby indices (DIN38 410-2, 1990) produce the reliable results in Germany, while the Biological Monitoring Working Party-BMWP (Armitage et al., 1983) and Average Score Per Taxon-ASPT (Armitage et al., 1983) do so in England, and the Belgian Biotic Index-BBI (De Pauw and Hawkes, 1993) seem to give the most reliable results in Belgium. Beside biotic indices, diversity indices are also used to determine water quality, and their compatibility with the biotic indices is a subject studied intensively as well. Diversity indices also reflect pollution changes in the streams. Together, usage of biotic and diversity indices can be more suitable to determine the ecological

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structure of the stream, as well as water quality changes. There are a number of studies in which these indices are applied for the streams and the results are discussed (Metcalfe-Smith, 1994; Knoben et al., 1995; Ghetti, 1997; De Pauw and Heylen, 2001; Scuri et al., 2006).

Europe has a hundred years of experience in using biological assemblages to assess the ecological status of streams and rivers. Likely, different assessment methods (single metrics, multimetric systems or predictive models) will continue to be used for a number of European stream types. Furthermore, water managers and fresh water biologists in different member states may have different perceptions of the reference situation and of what a 'slight' or 'moderate' deviation from the reference situation is. This demands for an 'inter-calibration' of the different assessment methods to ensure comparability of the resulting ecological quality classes (Sandin and Hering, 2004). This exercise must have been carried out in 2005 when Ecological Quality Ratios (EQR) at high-good and good-moderate quality class boundaries inter-calibrated for the assessment systems used in the individual European countries (Furse et al., 2006). However, the use of organisms for assessment of water quality started in the 1990's in Turkey and special biological monitoring index has not been developed for Turkey yet. Some researchers used a number of biotic indices (e.g. BMWP, ASPT, FBI and SI) for assessment of water quality of rivers (Kazanci et al., 1992; Girgin et al., 1997; Kazanci and Girgin, 2001; Kazancı and Girgin, 2001; Barlas et al., 2002; Girgin et al., 2003; Duran et al., 2003; Dügel and Kazanci, 2004; Duran, 2006; Kazanci et al., 2008; Kalyoncu et al., 2009b). Of the water quality assessment indices based on macrozoobenthic organisms, Belgian Biotic İndex (BBI), Average Score per Taxon (ASPT), Biological Monitoring Working Party (BMWP), Saproby İndex (SI) and Modified Hilsonhof Biotic İndex (MHBI), Family Biotic Index were used. However, the number of studies related with the use of the diversity and biotic indices together are very few in Turkey (Kalyoncu et al., 2008a,b). The aim of this study is to see the results of the use of the biotic and diversity indices in Turkey –in the streams of Dariören and Isparta– and determine water quality changes.

MATERIALS AND METHODS

Sampling sites

Çukurca Stream springs from a rocky area above the Çukurköy Village on the southern slopes of Mount Davraz (Station I). There is a trout farm on the stream after this station and the stream joins to Isparta Stream on Dereboğazı Mevkii after the 4th station and named as Isparta Stream after joining. The 2nd station is 2 km far from the 1st station and the 3rd station is 6 km far from the 2nd station. The 4th station is nearly 7 km far from the 3rd station. Çukurca Stream joins to Isparta Stream after the 4th station. Wastes from leather industry and sewage treatment systems converged to Isparta stream. The 5th station is on the Isparta Stream. The 5th station was chosen from the upper part of the mixture of urban waste water. It is nearly 2 km far from the 4th station. The 6th station, 6 km far from the 5th station, is on the upper part of the bridge on Isparta- Antalya road (Figure 1).

Methods

Macroinvertebrate communities along the stream were sampled monthly from July 2006 to June 2007 at each of the six stations, using Surber net samplers (475 μm mesh, area of base 0.09 m^2) (Surber, 1970) and a bottom kick net (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 with the presence of large stones, 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 the sediment using sieves (250 μm). All the animals collected were immediately fixed in formaldehyde (4%) in the field and then transferred to 70% ethyl alcohol. The macroinvertebrates were sorted, identified to the lowest possible taxon (species, genus or families) and counted under a stereomicroscope.

At the same time of sampling macro-invertebrates, water samples were taken seasonally and analyzed for the following parameters: NH_4-N mgL^{-1}, NO_2^-N mgL^{-1}, NO_3^-N mgL^{-1}, PO_4-P mgL^{-1}, biological oxygen demand (BOD5 mgL^{-1}), chemical oxygen demand (COD mgL^{-1}) and chloride (Cl^- mgL^{-1}). All analyses were done in accordance to national standards. Water temperature (C0), pH, dissolved oxygen (DO mgL^{-1}) and electrical conductivity (EC μScm^{-1}) were measured in the field by portable equipments. Water quality assessment by physico-chemical parameters was done according to Klee (1990).

Benthic macro-invertebrate indices

This study is restricted to indices focused on the determination of water quality. The following nine indices were tested: Average Score Per Taxon (ASPT) (Armitage et al., 1983), the Saproby Index according to (SI) (DIN38 410-2, 1990), Belgian Biotic Index (BBI) (De Pauw and Vanhooren, 1983), Extended Biotic Index (EBI) (Ghetti, 1997), Biological Monitoring Working Party (BMWP) (Armitage et al., 1983), Biotic Index for Pampean rivers and streams (IBPAMP) (Capitulo et al., 2001), Family Biotic Index (Hilsenhoff, 1988), number of Ephemeroptera, Plecoptera and Trichoptera (EPT%) taxa, number of EPT/Chironomus (EPT/Chr%). And three diversity indices, obtained by using the formula of Margalef Diversity Indices (MDI), Simpson Diversity Indices (SDI) and of Shannon and Weaver Diversity Indices (SWDI) as detailed in Ludwig and Reynolds (1988) were evaluated. Correlation analysis was based on Pearson's and multiple regression analysis from SPSS version 11.5.

RESULTS

Not being contaminated, water quality values at the stations of 1, 2, 3 and 4 have been affected by the geological structure. The lowest average of water temperature was determined as 9, 03 C0 at the 1st station. At the sampling points of 5 and 6, water quality has been affected by the waste water coming from Isparta. The BOD5, PO_4-P, NH_4-N, NO_3^-N, Cl^- and conductivity showed high values especially at sampling points of 5 and 6 (Table 1). pH values of sampling points

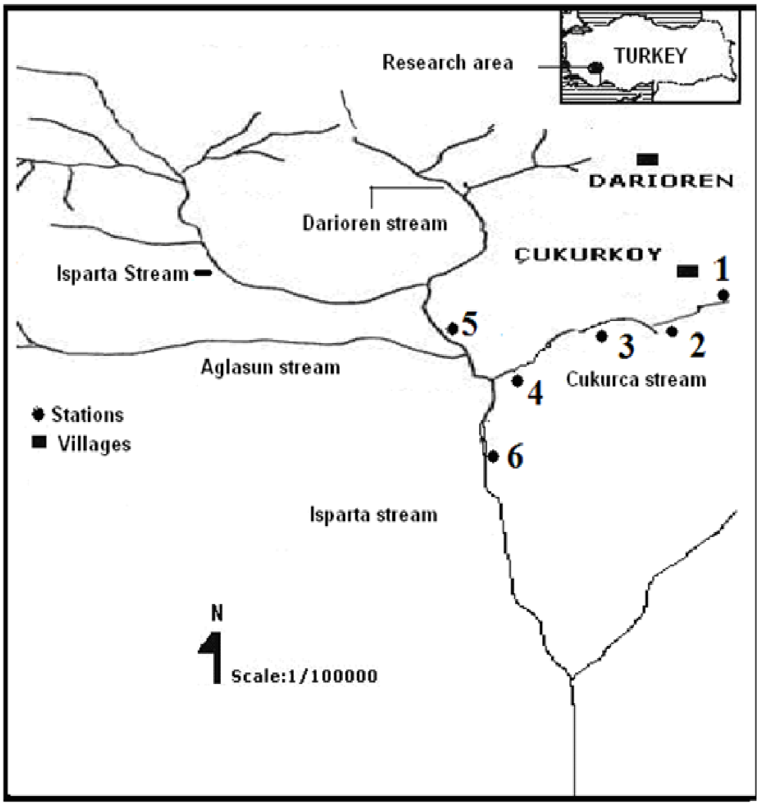

Figure 1. The study area and stations.

Table 1. Physico-chemical analyses for stations in 2006 to 2007.

Stations		1	2	3	4	5	6
	Mean	9.03	9.5	11.86	17.3	22.9	24.06
Temperature C0	Max.	10.3	11.3	14	20.3	27.4	29.1
	Min.	6.6	6.7	9	12	14	15
	Mean	7.77	7.76	8.06	8.54	8.7	8.26
pH	Max.	7.86	7.87	8.11	8.68	8.92	8.56
	Min.	7.68	7.7	7.96	8.49	8.52	8.07
	Mean	9.96	9.92	8.3	7.9	8.66	7.2
DO mgL^{-1}	Max.	10.2	10	9.1	8.5	10	8.3
	Min.	9.6	9.8	7.7	7.4	7	6.4
	Mean	231	262.2	266	309	978.25	753
EC µScm^{-1}	Max.	233	330	268	315	1113	890
	Min.	229	234	263	304	752	630
	Mean	2.5	8.12	2.5	3.1	109.2	69.5
Cl$^-$ mgL^{-1}	Max.	2.5	25	2.5	3.1	135	101
	Min.	2.5	2.5	2.5	3.1	63	47
	Mean	2.75	2.9	2.6	1.55	3.83	2.83
NO_3^-N mgL^{-1}	Max.	3.8	4	3.2	1.9	3.9	3.2
	Min.	1.4	1.6	2	1.2	3.8	2.5

Table 1. Contd.

NH_4-N mgL^{-1}	Mean	0.05	0.05	0.05	0.05	9.95	1.36
	Max.	0.05	0.05	0.05	0.05	18.1	2.15
	Min.	0.05	0.05	0.05	0.05	2.61	0.84
NO_2^-N mgL^{-1}	Mean	0.02	0.02	0.02	0.02	1.48	1.05
	Max.	0.02	0.02	0.02	0.02	1.7	1.1
	Min.	0.02	0.02	0.02	0.02	1.2	1
PO_4-P mg L^{-1}	Mean	0.08	0.092	0.23	0.1	3.57	1.2
	Max.	0.14	0.14	0.3	0.17	4.42	1.43
	Min.	0.06	0.07	0.12	0.07	1.9	1.01
BOD5 mgL^{-1}	Mean	3.67	3.27	4.47	3.9	12	7.87
	Max.	8.5	6.5	8.9	8.5	16.9	9.5
	Min.	1.1	1.2	1.2	0.8	7.8	4.5
COD mgL^{-1}	Mean	12	12	11	13	49.25	37
	Max.	14	13	11	14	58	45
	Min.	10	10	11	12	37	27

Table 2. Water quality classes according to physicochemical parameters (Klee, 1990).

	1st station	**2nd station**	**3rd station**	**4th station**	**5th station**	**6th station**
Klee (1990)	I-II oligosabrob/ betamesosaprob	I-II oligosabrob/ betamesosaprob	II Betamesasabrob	II Betamesasabrob	IV polysabrob	IV polysabrob

varied between 7.68 (sampling point 1) to 8.92 (sampling point 5). Dissolved oxygen decreased on sampling points of 5 and 6 (Table 1). Water quality classes according to physicochemical parameters are shown on Table 2.

Biological results

In this study, 18 583 individuals were collected in total. Of the sampling points, the 1st station was the one where the most individuals were collected, and the 5th station was the one where the fewest individuals were collected. The individuals collected from the sampling points belong to Turbellaria, Gastropoda, Oligochaeta, Hirudinea, Crustacea and Insecta. Identified 71 taxa are as follows: 1 of Turbellaria (genus level), 4 of Gastropoda (species level), 1 of Oligochaeta (species level), 2 of Hirudinea (species level), 3 of Crustacea (2 genus and 1 species level) and 60 of Insecta (20 genus and 40 species). Changes in physicochemical structure also affected the diversity of species at stations. The great majority of the existing taxa at 1st, 2nd, 3rd and 4th stations, have not been observed at 5th and 6th stations. This situation is clearly seen in Table 3.

DISCUSSION AND CONCLUSION

As a result of the water quality assessment using biotic indices, according to all indices, the 5th and 6th stations were determined as the excessive polluted-part of the stream, fitting in exactly with the water quality classification done according to the physico-chemical parameters. The 5th station was more polluted than the 6th station according to BBI. Diversity indices values of these stations are lower than the others. While the lowest diversity value by MDI was at the 5th station, the other diversity index values were the same at these stations. The lowest EPT% rates, too, were determined at the 5th station. The rates of EPT/Chr% were the lower in these stations. However, biotic indices differed at the stations 1, 2, 3 and 4.

The related stations were determined as the quality class IV according to BMWP, whereas FBI determined the 1st and 4th stations as the quality class III and the 2nd and 3rd stations as the quality class IV. These results were different from the water quality assessment by Klee (1990). In the assessment done according to Klee (1990), the 1st and 2nd stations were of the water quality class I-II (Oligosaprob/betamesosaprob) and the 3rd and 4th stations were of the water quality class II

Table3. The distribution of the macrozoobenthic fauna at the stations in Çukurca Stream and Isparta Stream.

Order	Taxa	1. sta.	2.sta.	3.sta.	4.sta	5.sta.	6.sta.
Tricladida	*Dugesia* sp.			+			
Arhynchobdellida	*Erpobdella octoculata* (Linnaeus, 1758)		+	+	+		
Rhynchobdellida	*Helobdella stagnalis* (Linnaeus 1758)						+
Amphipoda	*Gammarus* sp.	+	+	+	+		
Isopoda	*Asellus aquaticus* (Linnaeus, 1758)			+	+		
Decapoda	*Potamon* sp.				+		
Ephemeroptera	*Baetis* sp.	+					
	B. fuscatus (Linnaeus, 1761)			+	+		
	B. pavidus (Grandi, 1949)	+		+	+		
	B. rhodani (Pictet, 1843)	+	+	+	+		
	B. vernus (Curtis, 1834)					+	
	B. lutheri (Müller-Liebenau, 1967)	+		+			
	Ephemerella ignita (Poda 1761)	+			+		
	Ephemera vulgata (Linnaeus, 1758)				+		
	Epeorus alpicola (Eaton, 1871)	+	+	+	+		
	Leptophlebia marginata (Linnaeus, 1767)				+		
	Rhithrogena semicolorata (Curtis, 1834)	+	+	+	+		
Plecoptera	*Leuctra moselyi* (Morton, 1929)		+		+		
	L. hippopus (Kempny, 1899)	+			+		
	Protonemura montana (Kimmins, 1941)	+	+	+	+		
	P. praecox (Morton, 1894)	+	+		+		
	P. meyeri (Pictet, 1841)	+	+				
	Perla bipunctata (Pictet, 1833)				+		
	Dinocras cephalotes (Curtis, 1827)				+		
Odonata	*Onychogomphus forcipatus* (Linnaeus, 1758)				+		
	Aeshna sp	+	+	+	+		
	Epallage sp				+		
	E. fatime (Charpentier, 1840)				+		
Trichoptera	*Agapetus* sp.	-	+	+			
	A. fuscipes (Curtis, 1834)	+					
	Hydropsyche sp.	-	+	+	+		
	H. pelludicula (Curtis, 1834)	+			+		
	H. fulvipes(Curtis, 1834)	+	+	+	+		+
	H. instabilis (Curtis, 1834)	+					
	H. angustupennis (Curtis, 1834)				+		
	Rhyacophila sp.			+			
	R. septentrionis McLachlan, 1865	+		+	+		
	R.dorsalis (Curtis, 1834)	+		+			
	R. munda (McLachlan, 1862)			+			
	Lepidostoma sp.			+			
	Glossosoma sp.		+	+			+
	G. conformis (Neboiss, 1963)	+					
Coleoptera	*Agabus* sp.		+				
	Elmis aenea (Müller 1806)	+					
	E. maugetii (Latreille, 1798)	+					
	Esolus angustatus (Müller, 1821)				+		

Table3. Contd.

	Elodes marginata (Fabricius, 1798)				+		
	Hydrobius fuscipes (Linnaeus, 1758)						+
Oligochaeta	*Tubifex* sp.					+	+
	Wiedemannia sp.		+		+	+	
	W. fallaciosa (Loew, 1873)		+	+	+		
	Tabanus sp.					+	+
	Tipula lateralis (Meigen, 1804)			+	+		
	Ulomyia sp.						+
	U. fuliginosa (Meigen, 1818)			+	+		
	Berdeniella unispinosa (Tonnoir, 1919)		+				
Diptera	*Oxycera pardalina* (Meigen, 1822)	+	+				
	Simulium sp.	+	+	+	+	+	+
	Limnophora sp.				+		
	Antocha sp.	+			+		
	Chrysopilus erythrophthalmus (Loew, 1840)				+		
	Pedicia sp	+	+	+	+		
	Chironomus sp.	+	+	+	+	+	+
	Thaumalea sp.	+					
	Liponeura sp.	+					
	Chaoborus sp.			+			+
Pulmonata	*Physella acuta* (Draparnaud, 1805)						+
	Physa sp.						+
Basommatophora	*Ancylus fluviatilis* (Müller, 1774)	+	+	+	+		
Allogastropoda	*Valvata* sp.				+		

(betamesosaprob). SI and BBI seem to be the nearest to this assessment.

According to these two indices, the 1st station was not polluted and the stations 2, 3 and 4 were averagely polluted. These two indices are followed by IBPAMP and ASPT. According to IBPAMP and ASPT, the stations 1, 3 and 4 were of the water quality class II, whereas the station 2 was of the quality class III. The station 2 was found as average polluted according to EBI and the stations 1, 3 and 4 as unpolluted. Kalyoncu et al. (2009a), used 6 indices to determine water quality (MHBI, BMWP, SI, EBI, BSI and IBPAMP) in the Aksu river; and the biggest deviation was observed with BSI. By the time, the pollution was observed to have increased in Isparta stream.

According to the diversity indices, the highest diversity value was determined by SWDI and MDI at the 2nd and 4th stations, which are followed by the 3rd and 1st stations. The diversity values are the same at the stations 1, 2, 3 and 4 according to SDI. Gray and Fisher (1981) reported that, the species composition of aquatic organisms belonging to Insecta was negatively influenced on the lower basins of the stream where the water flow was high. Sager (1986), Scrimgeour and Winterborne (1989) and Cobbe et al. (1992) reached similar results as well. Habit et al. (1998) pinpointed –on the River Itata– the lowest invertebrate diversity on the sampling point of a muddy floor. The 5th and 6th stations assessed in this study have a similar benthic structure and shows parallelism with the results of Habit et al. (1998) obtained on the River Itata. However, a muddy structure formed by pollution is concerned at these stations. EPT% values were determined the highest at the 4th station, which is followed by the 1st, 2nd and 3rd stations, respectively. EPT/Chr% values were the highest at the 1st station, followed by the stations 4, 2 and 3. Although the change of the EPT/Chr% values was -on the sampling points-concordant with the change of the water quality, no significant relations were determined in terms of correlation values. EPT members are sensitive to pollution, and their number and species diversity decrease as the pollution Increases. *Chironomus* sp.

Table 4. Correlation matrix between biotic indices and diversity indices (* = p< 0.05; ** = p < 0.01; N = 72).

	EPT%	EPT/Chr%	SWDI	SDI	MDI	BMWP	ASPT	BBI	FBI	SI	EBI	IBPAMP
EPT%	1											
EPT/Chr%	0.433(**)	1										
SWDI	0.650(**)	0.098	1									
SDI	0.631(**)	0.059	0.862(**)	1								
MDI	0.709(**)	0.211	0.780(**)	0.687(**)	1							
BMWP	0.809(**)	0.307(*)	0.714(**)	0.657(**)	0.905(**)	1						
ASPT	0.769(**)	0.178	0.600(**)	0.643(**)	0.692(**)	0.849(**)	1					
BBI	0.779(**)	0.366(**)	0.621(**)	0.660(**)	0.621(**)	0.772(**)	0.821(**)	1				
FBI	-0.625(**)	-0.293(*)	-0.443(**)	-0.349(**)	-0.481(**)	-0.590(**)	-0.541(**)	-0.615(**)	1			
SI	-0.704(**)	-0.399(**)	-0.527(**)	-0.534(**)	-0.500(**)	-0.632(**)	-0.691(**)	-0.806(**)	0.628(**)	1		
EBI	0.733(**)	0.491(**)	0.533(**)	0.520(**)	0.550(**)	0.715(**)	0.743(**)	0.856(**)	-0.598(**)	-0.730(**)	1	
IBPAMP	0.666(**)	0.266	0.448(**)	0.485(**)	0.540(**)	0.680(**)	0.657(**)	0.633(**)	-0.263	-0.520(**)	0.609(**)	1

shows a reverse increase compared with the EPT orders (Plafkin et al., 1989). Because, EPT taxa are sensitive to pollution, their number and species diversity decrease as the pollution increases. *Chironomus* sp. percentage of domination shows a reverse increase compared with EPT (Plafkin et al., 1989). The results of the study, too, show parallelism with this information. EPT domination is rather low at the stations 5 and 6 exposed to intensive pollution. EPT domination was determined as 0.59% at the 5th station and 2.78% at the 6th station. The changes of EPT% are parallel to the changes of water quality.

%EPT values are in a correlation of p<0.01 level with EPT/*Chironomus* sp., diversity indices and biotic indices. Diversity indices is in significant correlation of p<0.01 with the all indices. EPT/*Chironomus* sp. is not in significant correlation with diversity indices, ASPT and IBPAMP, but is in correlation of p<0.05 level with FBI, BMWP and p<0.01 level with the other indices. Significant correlation exists between biotic indices in general (Table 4). According to Washington (1984), diversity measures are a useful method for describing community structure but not the pollution level of water bodies. The same author maintains that biotic indices must be limited to environments polluted by easily degradable organic matter (sewage) and not by other types of pollutants. Benthic macro-invertebrate species are differentially sensitive to many biotic and abiotic factors in their environment. Consequently, macro-invertebrate community structure has commonly been used as an indicator of the condition of an aquatic system (Armitage et al., 1983; Friberg et al., 2006; Ortiz and Puig, 2007). Hawkes (1978) reports that diversity indices are good for indicating physical and toxic pollution which stress most species in a community without encouraging replacement species. He warns that high diversity does indicate good quality water but low diversity may not necessarily indicate low quality. According to our results, low diversity expresses low quality and high diversity expresses good quality. The biotic index and score systems are better for assessing organic pollution and eutrafication but poor for assessing toxic and physical pollution.

Therefore, to obtain a fair overall assessment of the quality of a river, both methods are essential and need to be combined with alternative methods of evaluating biota response (Hewitt, 1991). There is a very rich literature on biotic and diversity indices, but relatively few comparisons of these methods have been made (Myslinski and Ginsburg, 1977; Murphy, 1978; Washington, 1984; Cao et al., 1996). In this study, biotic indices and diversity indices are in concordance between one another, giving more information about the ecological structure of the stream. The use of only a single indicator system is unsatisfactory for explaining the ecological status and biological potential of a particular river part (Slepukhina, 1984; Blandin, 1986). As a result of the multivaryete regression analysis done, the indices of the highest deviation are EPT/Chr% and IBPAMP (Table 4).

According to Triest et al. (2001), BBI, SI (from Sladecek) and macro-fit indices well correlated in the case of more extreme situation of pollution or when toxicity of e.g. ammonia or non-adaptation to higher chloride levels becomes more important. The diversity indices used in this study reflect the quality change of the stream quite well, and this change is clearly made known by EPT%, too. Although biotic indices give similar results in the excessive-polluted parts of the stream, the results are different in the unpolluted parts. When assessed by the water quality, BMWP and FBI shows deviation compared with the other indices. In the correlation assessment carried out, EBI shows deviation compared with the other indices as well.

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