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Macroinvertebrate-based biotic indices for evaluating the water quality of Kargı Stream (Antalya, Turkey)

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Abstract: The aim of this study was to determine the water quality of Kargı Stream, Antalya, Turkey, in terms of physical and chemical parameters and biotic indices. For this purpose, macrozoobenthic invertebrates and water samples were taken from each of the selected seven stations seasonally. The Belgian Biotic Index, BMWP and ASPT indices, and species diversity indices were applied for determining the water quality by using the ASTERICS software program. With the identification of the collected organisms, a total of 126 taxa including 4 taxa from Gastropoda, 5 taxa from Oligochaeta, 1 taxon from Malacostraca, 84 taxa from Insecta, and 32 taxa from Arachnida were detected. Stations were clustered by using UPGMA, based on organisms. Station 7 in the estuarine zone was the most different one for the macrozoobenthic invertebrates. The lowest species diversity values were also found at this station. The water quality of Kargı Stream was unpolluted/slightly polluted. Considering the physical and chemical parameters, biotic indices revealed changes in the pollution load of the study area with some deviations. It is thought that the reason for these deviations was not taking into account the geomorphological and ecological characteristics of Turkey in the biotic indices used in the current study.

Key words: Macrozoobenthic invertebrates, water quality, biotic indices, ASTERICS

1. Introduction

The amount of available water resources is steadily decreasing for various reasons all over the world. Due to the increasing impact of human activities on the freshwater ecosystem in recent years, the need for the assessment of the ecological quality status has become increasingly important. However, physical and chemical assessment is not enough to explain the habitat quality of streams because physical and chemical parameters give the most accurate information about the status of the stream's pollution, not long-term pollution, and they are highly variable, so they may easily obscure the exact environmental conditions (Barlas, 1995; Bedoya et al., 2009). Physical and chemical parameters have been predominantly used to assess the surface water quality, but analyzing some of these parameters is costly, i.e. it requires highly expensive laboratory equipment (USEPA, 2013). However, using biological methods is not only highly reliable; they are also a low-cost way to assess these parameters (Ellenberg et al., 1991). The usage of biological approaches together with physical and chemical evaluations provides better results for determining the ecological quality of aquatic ecosystems (USEPA, 2011).

Biomonitoring of freshwater ecosystems using macrozoobenthic invertebrates is a common practice in developed countries, but the use of biomonitoring metrics as part of regular monitoring programs in developing countries is limited (Balderas et al., 2015). However, biomonitoring by using a biotic index has been applied for nearly the last 30 years in Turkey.

Many indices have been developed based on macrozoobenthic invertebrates to evaluate the water quality of streams (Armitage et al., 1983; De Pauw and Vanhooren, 1983; Hilsenhoff, 1988; Ghetti, 1997; Capítulo et al., 2001). Macroinvertebrate-based metrics have better explained the changing of the pollution in stream integrity (Johnson et al., 2006). Macrozoobenthic invertebrates are the most commonly used group for biomonitoring of freshwater ecosystems (Bonada et al., 2006; Carter et al., 2006) because they are sensitive to multiple ecological alterations and reflect such factors as anthropogenic impacts and organic pollution (Mykrä et al., 2012; Johnson and Ringler, 2014). These organisms are described as one of the biological quality elements in the implementation of the EU Water Framework Directive (WFD). The WFD requires all member states to protect, enhance, and restore and prevent the deterioration of aquatic ecosystems. All

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water bodies needed to achieve good ecological status or potential under the related regulations by the year 2015 (WFD, 2000).

Kargı Stream, selected as a study case, is a critical water source for Alanya and it is used for agricultural irrigation. Another important aspect is that the Kargı Stream is one of the region's tourism centers. However, the pollution status and the macrozoobenthic invertebrate fauna of this stream have not been identified yet. Therefore, in this study, it was aimed to determine the macrozoobenthic invertebrate fauna and together with physical and chemical parameters through the use of these organisms to make a biological survey, to investigate the applicability of different versions of both the BMWP index and the ASPT index, and the Belgian Biotic Index (by using ASTERICS), for Kargı Stream in Turkey.

2. Materials and methods

This study was carried out on Kargı Stream, located in the Alanya district of Antalya, Turkey, between July 2014 and April 2015. The length of this stream is approximately 45 km. Seven stations were chosen on the stream and samples were taken seasonally (four seasons). Totally, 28 samples were obtained per site/single sampling from seven stations in four seasons. The first station was located in the headwaters of Kargı Stream while the last station (seventh station) was situated in the estuarine zone (Figure 1).

Macroinvertebrate communities were collected from each station by using a standard hand net (50 × 30 size with 500 µm mesh). The samples were taken from the various substrate types present (e.g., silt, gravel, sand) at these stations. In some areas with the presence of large stones, the collected macroinvertebrates were first picked out and washed into a kick net in order to remove pupae and other attached individuals. The collected samples were kept in 70% alcohol and brought to the laboratory and they were sorted and identified to the lowest possible taxonomic level (genus or species) under a stereomicroscope.

Water temperature (°C), pH, dissolved oxygen (DO), and electrical conductivity (EC) were measured in situ while benthic macroinvertebrates were being sampled by using portable YSI Multi-Plus professional equipment. Cl^-, NH_4^+-N, NO_2^--N, NO_3-N, PO_4-P, and biological oxygen demand (BOD_5) were measured in the laboratory following standard methods (APHA, 1998). The faunal similarity among stations was determined by using Sørensen's similarity index (Krebs, 1989). The unweighted pair group method with arithmetic mean (UPGMA) algorithm was used to show possible clustering relationships among the 6 sampling sites based on macroinvertebrates. The Shannon–Weaver (1963) and Simpson (1949) indices were applied to detect the species diversity of the stations. UPGMA, similarity index, and biological diversity indices were used by using MVSP version 3.1 (Kovach, 1998). Macroinvertebrate data were analyzed to determine biological water quality by using the ASTERICS 3.1 (AQEM Consortium, 2002) software program. Various versions of BMWP, ASPT, and the Belgian Biotic Index (BBI) were

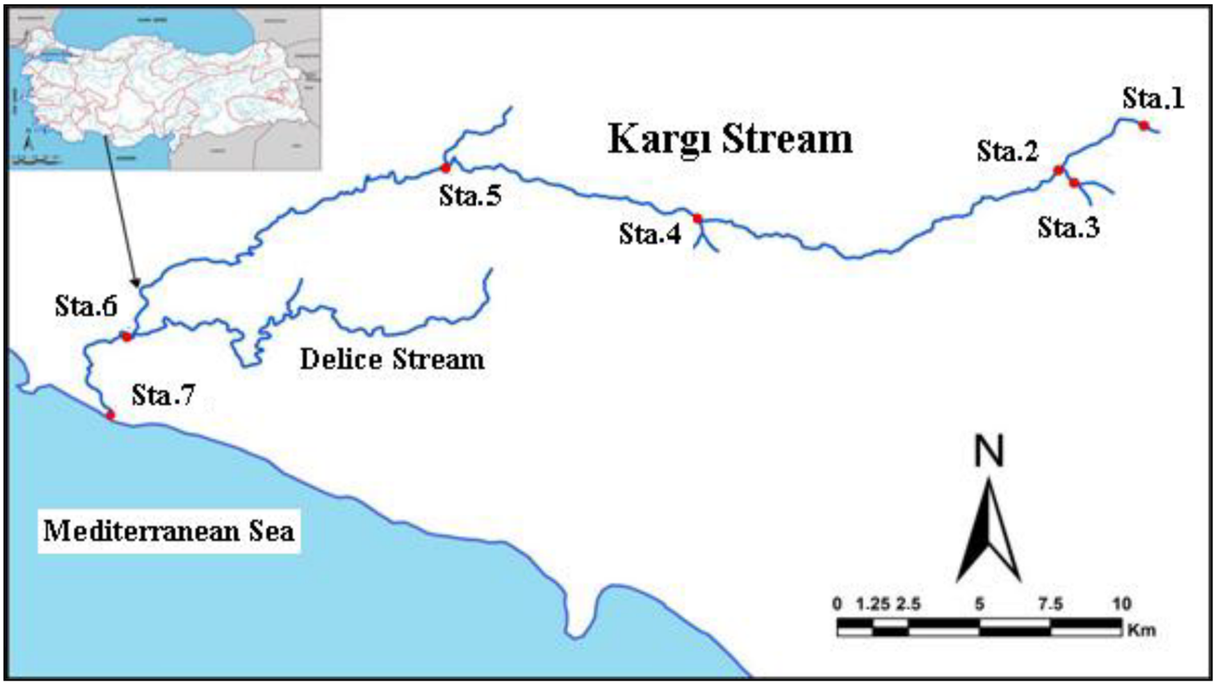

Figure 1. Study area and stations.

used to determine water quality. The relative percentage of occurrence was calculated for each species by using the simple formula Ni/Nt × 100 (Ni = individuals of species i, Nt = total number of collected species). Physical and chemical water quality classes were determined according to TWPCR (2008).

3. Results

3.1. Physical and chemical parameters

The minimum, average, and maximum values of the measured physical and chemical parameters and the average water quality classes of the stations during the study period are given in Table 1.

3.2. Biological results

As a consequence of the examination of the collected organisms from seven stations, a total of 126 taxa and 4610 individuals were detected, 4 of which belong to Gastropoda, 5 of which belong to Oligochaeta, 1 of which belongs to Malacostraca, 84 of which belong to Insecta, and 32 of which belong to Arachnida. Insecta was found to be the most dominant group among the macrozoobenthic invertebrates. The maximum and minimum numbers of individual were collected at station 2 and station 7 in the estuarine zone, respectively. Distributions and relative occurrence (%), along with a list of the recorded macrozoobenthic invertebrates, are given in Table 2. The lowest and highest numbers of individuals were determined in autumn and summer, respectively (Figure 2).

Percent similarities of each sampling station based on macrozoobenthic invertebrates were detected using UPGMA analysis. According to this analysis, similarity values were found to be close to each other in the first six stations. The highest similarity values (61%) were observed between the fourth and fifth stations and the fourth and sixth stations. In contrast, the seventh station was found to be the most different one from all the other stations for macrozoobenthic invertebrates (Figure 3).

Table 1. Minimum, average, and maximum values of physical and chemical parameters at the stations.

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7
	Aver. Min–max.	Aver. Min–max.	Aver. Min–max.	Aver. Min–max.	Aver. Min–max.	Aver. Min–max.	Aver. Min–max.
DO (mg/L)	8.95	8.99	8.41	8.37	8.46	7.83	7.19
	8.14–9.63	8.07–9.62	7.28–8.98	7.15–9.49	7.40–9.80	7.15–9.60	5.13–8.78
pH	7.87	8.15	8.13	8.12	8.22	8.07	8.26
	7.03–8.38	7.96–8.40	7.56–8.50	7.25–8.90	7.82–8.8	7.79–8.6	7.64–9.4
°C	12.58	12.95	15.25	14.63	15.20	17.95	18.78
	10.70–14.90	11.20–15.10	14.10–16.90	11.90–17.30	11.60–19.30	11.70–23.30	12.10–26.90
EC (µS/cm)	351.65	347.45	379.48	346.95	381.95	415.33	599.13
	301.20–396.70	299.50–392.90	350.30–412.00	304.40–393.40	318.80–411.50	370.30–430.70	457.20–916.00
NH_4-N (mg/L)	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*
NO_2-N (mg/L)	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*
NO_3-N (mg/L)	0.22	0.50	0.84	0.32	0.31	0.48	0.53
	0.16–0.28	0.21–1.26	0.15–1.26	0.23–0.40	0.25–0.36	0.25–0.70	0.15–1.00
PO_4-P (mg/L)	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*
Cl^- (mg/L)	3.18	4.64	6.11	4.17	4.77	6.92	56.50
	2.39–3.72	2.78–8.01	3.03–8.03	3.55–4.56	4.24–5.10	5.96–8.40	15.33–132.21
BOD_5 (mg/L)	1.50	1.00	1.75	2.00	1.25	2.00	1.25
	1.00–3.00	1.00–1.00	1.00–2.00	1.00–4.00	1.00–2.00	1.00–3.00	1.00–2.00
Average water quality classes, TWPCR (2008)	I	I	I	I	I	I	II
	Unpolluted						Slightly polluted

*BDL: Below detection limit.

Table 2. Distributions and relative occurrence (%) of macrozoobenthic invertebrates at the stations.

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7
OLIGOCHAETA							
Limnodrilus hoffmeisteri Claparede, 1862	–	0.32	0.46	0.87	1.11	0.55	0.58
L. uedekemianus Claparède, 1862	–	–	–	–	–	0.11	–
Potamothrix hammoniensis (Michaelsen, 1901)	–	0.21	–	–	0.32	0.22	0.58
Stylaria lacustris (Linnaeus, 1767)	–	–	–	–	–	0.22	–
Tubifex tubifex (O. F. Müller, 1774)	–	–	0.31	0.44	0.63	0.44	0.58
ARACHNIDA							
Atractides distans (Viets, 1914)	–	–	–	0.22	–	–	–
A. fissus (Walter, 1927)	–	–	0.46	–	–	–	–
A. fluviatilis (Szalay, 1929)	–	–	–	1.09	–	–	–
A. lunipes Lundblad, 1956	0.59	–	–	–	–	–	–
A. nodipalpis (Thor, 1899)	–	0.11	–	–	–	–	–
A. walteri (Viets, 1925)	–	–	–	0.87	–	–	–
Aturus crinitus Thor, 1902	–	0.43	–	–	–	0.44	–
Hydrodroma despiciens (O.F. Müller, 1776)	0.24	–	0.15	0.22	0.63	–	–
Hygrobates decaporus (Koenike, 1895)	–	–	–	–	–	0.66	–
H. fluviatilis (Ström, 1768)	–	0.43	0.61	0.65	1.90	0.99	–
H. longipalpis (Hermann, 1804)	–	–	–	–	–	0.22	–
Lebertia fimbriata Thor, 1899	0.59	0.85	–	–	–	–	–
L. lineata Thor, 1906	–	–	–	–	0.48	–	–
L. porosa Thor, 1900	–	0.74	–	1.53	–	1.87	–
Mideopsis orbicularis (O.F. Müller, 1776)	–	–	0.77	1.31	0.79	–	–
Monatractides aberratus (Lundblad 1941)	–	0.21	–	–	–	–	–
M. lusitanicus (Lundblad, 1941)	–	–	0.15	–	0.48	0.55	–
M. stadleri (Walter, 1924)	–	–	–	1.09	–	–	–
Protzia eximia (Protz, 1986)	–	–	0.92	–	–	–	–
P. rotundus Walter, 1918	0.12	–		–	–	–	–
Sperchon brevirostris Koenike, 1895	–	–	–	1.09	0.79	–	–
S. clupeifer Piersig, 1896	0.59	1.17	–	0.22	–	–	–
S. plumifer Thor, 1902	–	0.21	–	–	–	–	–
S. rostratus Lundblad, 1969	–	–	–	–	1.59	–	–
S. senguni Özkan, 1982	–	–	–	–	0.32	–	–
S. thori Koenike, 1900	–	–	–	0.87	–	–	–
Thyas setipes Viets, 1911	0.24	0.21	–	–	–	–	–
Torrenticola anomala (C.L. Koch, 1837)	–	–	–	–	1.11	0.33	–
T. barsica (Szalay,1933)	–	0.53	–	0.22	–	0.77	–
T. brevirostris (Halbert, 1911)	–	0.32	0.92	0.87	–	–	–
T. disabatinola Pesic 2004	–	–	–	–	–	0.22	–
T. dudichi (Szalay, 1933)	–	–	–	0.65	0.79	2.20	–
GASTROPODA							
Melanopsis sp.	–	–	–	–	–	–	0.58
M. praemorsa ferussaci (Roth, 1839)	–	–	–	–	–	8.90	11.11

Table 2. (Continued).

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7
Physella acuta (Draparnaud, 1805)	–	–	–	–	–	0.33	1.17
Theodoxus jordani Sowerby, 1844	–	–	–	–	–	–	29.24
MALACOSTRACA							
Gammarus sp.	–	–	–	0.22	–	–	–
INSECTA							
Ephemeroptera							
Baetis buceratus Eaton, 1870	6.85	4.04	–	–	0.48	–	–
B.fuscatus (Linnaeus, 1761)	6.49	1.28	3.83	1.96	2.86	3.19	–
B.lutheri Müller-Liebenau, 1967	3.66	4.57	2.45	7.19	2.70	5.71	–
B.muticus (Linnaeus, 1758)	7.32	4.89	7.04	1.31	3.02	2.42	–
B.pavidus Grandi, 1949	5.31	5.64	7.50	3.49	2.38	5.82	–
B. rhodani (Pictet, 1845)	32.59	28.19	24.20	19.17	10.48	15.05	5.26
B.scambus Eaton, 1870	1.18	0.64	1.84	1.96	0.32	–	–
B.vernus Curtis, 1834	3.19	2.23	–	0.44	0.48	0.33	–
Nigrobaetis digitatus (Bengtsson, 1912)	1.42	2.23	–	–	0.79	–	–
Caenis horaria (Linnaeus, 1758)	–	–	–	0.65	1.59	2.09	–
C. luctuosa (Burmeister, 1839)	0.24	–	–	1.31	1.90	0.22	0.58
C. macrura Stephens, 1835	0.24	–	–	0.65	0.63	0.66	–
C. pusilla Navas, 1913	–	–	–	–	0.16	–	–
C. rivulorum Eaton, 1884	–	–	–	–	0.32	–	–
Cloeon dipterum (Linnaeus, 1761)	–	1.17	–	–	0.16	–	4.09
Ecdyonurus torrentis Kimmins, 1942	–	–	–	–	0.16	–	–
E. venosus (Fabricius, 1775)	–	–	–	0.65	0.63	–	–
Epeorus alpicola (Eaton, 1871)	1.18	–	–	–	0.48	–	–
Ephemera danica Müller, 1764	–	–	–	–	0.48	–	–
E. vulgata Linnaeus, 1758	–	–	–	0.22	–	–	
Heptagenia sulphurea (Müller, 1776)	0.94	0.32	–	–	1.27	–	–
Leptophlebia marginata (Linnaeus, 1767)	–	0.85	0.46	–	–	–	–
Potamanthus luteus (Linnaeus, 1767)	–	–	0.31	–	–	0.33	–
Rhithrogena semicolorata (Curtis, 1834)	1.18	0.74	–	0.44	0.32	–	–
Serratella ignita (Poda, 1761)	–	1.60	0.46	1.31	–	0.77	–
Siphlonurus alternatus (Say, 1824)	–	0.96	–	0.22	–	–	–
Odonata							
Aeshna sp.	0.24	–	–	0.87	–	0.33	–
Anax imperator Leach, 1815	0.47	–	0.15	0.44	–	0.11	–
Calopteryx splendens (Harris, 1782)	–	0.11	0.15	–	–	0.33	2.92
Cordulegaster boltoni (Donovan, 1807)	–	–	–	0.44	–	–	–
Epallage fatime (Charpentier, 1840)	0.24	–	–	0.44	0.16	–	–
Onychogomphus forcipatus (Linnaeus, 1758)	–	–	–	–	0.16	–	–
Plecoptera							
Leuctra hippopus Kempny, 1899	1.30	0.21	0.31	0.22	0.63	–	–
L. moselyi Morton, 1929	0.47	–	–	0.22	0.16	0.11	–

Table 2. (Continued).

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7
L. inermis Kempny, 1899	0.12	–	–	–	–	–	–
Protonemura montana Kimmins, 1941	0.24	–	–	–	–	–	–
P. meyeri (Pictet, 1841)	–	–	–	0.22	–	0.33	–
Hemiptera							
Sigara sp.	–	–	–	–	6.35	0.55	3.51
Notonecta sp.	–	–	–	0.44	1.43	–	8.77
Gerris lacustris (Linnaeus, 1758)	–	–	3.37	–	–	–	–
Megaloptera							
Corydalus sp.	–	0.11	–	–	–	–	–
Trichoptera							
Agapetus fuscipes Curtis, 1834	–	0.32	0.15	0.44	0.16	–	–
Agraylea multipunctata Curtis, 1834	–	–	–	–	–	0.11	–
Cheumatopsyche lepida (Pictet, 1834)	–	–	–	1.31	1.59	–	–
Diplectrona felix McLachlan, 1878	–	–	–	–	0.48	–	–
Hydropsyche angustipennis (Curtis, 1834)	0.24	0.11	0.15	0.22	1.11	0.99	–
H. contubernalis McLachlan, 1865	–	–	0.31	–	0.48	0.33	–
H. fulvipes Curtis, 1834	0.71	1.28	0.77	2.83	3.02	2.42	–
H. incognita Pitsch, 1993	–	–	–	–	0.48	–	–
H. instabilis (Curtis, 1834)	–	0.11	–	0.22	2.86	0.88	–
H. pelludicula (Curtis, 1834)	0.24	–	–	–	–	0.33	–
H. siltalai Döhler, 1964	–	–	–	–	0.16	0.22	–
Hydroptila occulta (Eaton, 1873)	–	–	0.31	–	0.16	–	–
Limnephilus lunatus Curtis, 1834	–	–	–	0.44	–	–	–
Rhyacophila aurata Brauer, 1857	–	–	–	0.22	–	–	–
R. bonaparti Schmid, 1947	–	–	0.15	–	–	–	–
R. dorsalis (Curtis, 1834)	0.24	0.43	0.31	0.65	0.63	–	–
R. fasciata Hagen, 1859	0.47	–	0.46	0.22	0.48	0.55	–
Coleoptera							
Agabus sp.	0.24	–	–	–	–	–	–
Elmis aenea (Müller, 1806)	2.48	0.43	0.46	5.66	2.22	0.66	–
E. maugetii Latreille, 1798	3.42	1.17	2.91	11.11	3.97	–	–
Diptera							
Chironomus sp.	–	–	–	1.09	–	1.32	–
C. plumosus (Linnaeus, 1758)	–	–	–	–	–	–	1.75
Cryptochironomus defectus (Kieffer, 1913)	–	–	–	–	–	–	1.75
Tanypus sp.	0.35	–	0.46	0.65	–	0.55	–
Tanypus punctipennis Meigen, 1818	0.83	9.89	17.61	6.97	8.41	11.87	9.36
T.vilipennis (Kieffer, 1918)	3.07	10.43	3.52	1.09	13.02	17.36	17.54
Antocha sp.	0.24	0.11	–	0.65	6.51	0.11	–
Atherix sp.	–	0.11	–	–	–	–	–
Chaoborus sp.	–	1.06	0.92	1.31	–	0.77	0.58
Ceratopogon sp.	0.12	0.11	0.15	1.09	–	0.11	–

Table 2. (Continued).

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7
Chrysops sp.	–	–	0.15	–	–	–	–
Culex sp.	–	–	0.31	0.22	–	0.22	–
Dixa sp.	0.12	0.21	0.77	0.44	0.32	–	–
Dixella sp.	0.47	–	0.31	–	–	–	–
Hexatoma sp.	–	–	–	–	0.16	–	–
Ibisia marginata (Fabricius, 1781)	7.08	1.28	1.38	3.70	0.32	0.22	–
Liponeura sp.	0.12	–	–	0.44	–	–	–
Odontomyia sp.	0.12	0.21	–	–	–	–	–
Pedicia sp.	–	0.43	–	0.22	–	0.11	–
Simulium sp.	1.89	6.60	11.49	0.65	1.75	3.30	–
Tabanus sp.	–	0.11	–	1.31	0.16	0.22	–
Tipula sp.	0.12	–	0.15	–	0.16	–	–
Ulomyia fuliginosa (Meigen 1818)	0.24	0.11	–	0.22	–	–	–
TOTAL NUMBER	847	940	653	459	630	910	171

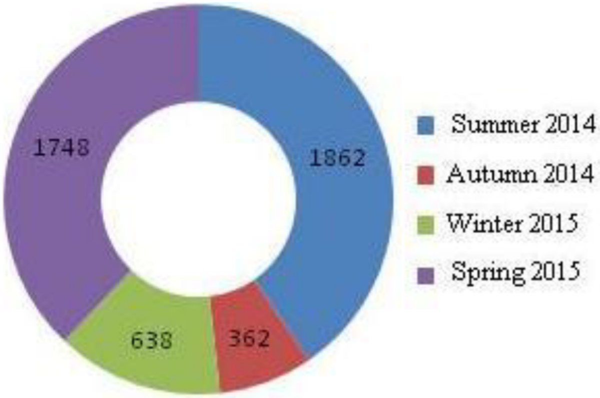

Figure 2. The number of individuals collected seasonally.

The Shannon–Weaver and Simpson diversity indices were calculated for each station to determine species diversity. Both indices showed that the lowest and highest diversity values were seen at the seventh and fifth stations, respectively (Table 3).

Various biotic indices were applied for determining biological water quality. Score values of biotic indices and water quality classes are shown in Table 3. Both versions of the BMWP index and versions of the ASPT index indicated that the highest and lowest score values belonged to the fourth and seventh stations, respectively. According to the BBI, water quality classes ranged from unpolluted (Class I) to moderately polluted (Class III) (Table 3).

4. Discussion

In this study, the macrozoobenthic invertebrate fauna of Kargı Stream was revealed and biotic indices based on these organisms were applied. A total of 126 taxa were determined during the survey, and Insecta was found to be the most dominant group among macrozoobenthic invertebrates. Similar results were found by other researchers in various streams (Duran, 2006; Kalyoncu and Zeybek, 2011; Zeybek et al., 2014; Yorulmaz et al., 2015). The lowest number of individuals was determined in autumn while the highest was in summer. It is thought that the specified small number of individuals in fall probably resulted from heavy rains during this period in

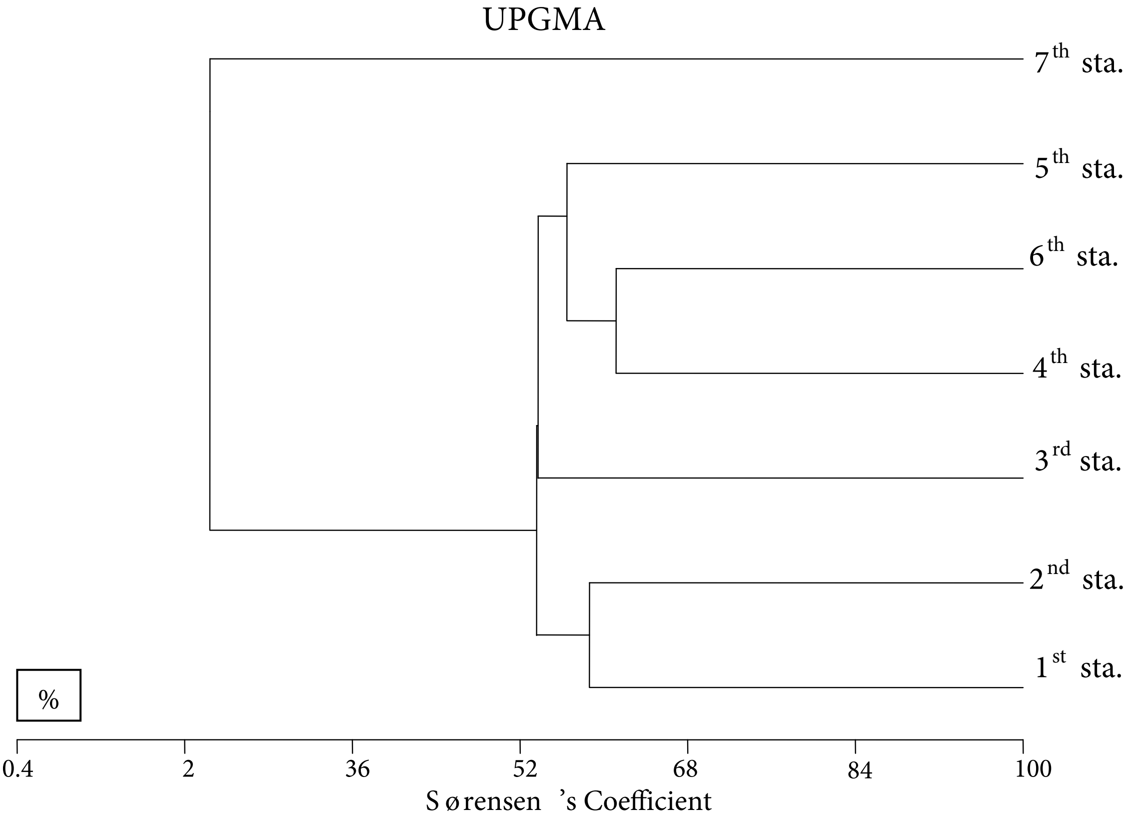

Figure 3. Cluster analysis dendrogram (UPGMA method) based on the Sørenson index.

the study area. This result showed parallelism with that found by Stamenković et al. (2010).

Species diversity values ranged from 3.21 to 4.924. The lowest species diversity value was found at the seventh station in estuarine zone. According to Wilhm and Dorris (1966) and Mason (2002), if the Shannon–Weaver index value ranges from >3 it indicates clean water, 1–3 indicates moderate pollution, and <1 indicates heavy pollution. Accordingly, the studied stream has high water quality in terms of species diversity indices. Higher values of species diversity in this stream may be ascribed to less human interference and better water quality because species diversity indices appear to be especially sensitive to habitat change (Rabeni, 2000). According to Boyle and Fraleigh (2003), regions with high species diversity are in better condition and show less degradation, while the opposite condition of low biological diversity often indicates an area with more degradation. Although some authors have doubts about species diversity index sensibility to low and intermediate levels of pollution, it is thought that species diversity values are compatible with pollution parameters in this study. The lowest species diversity values were found at the last station, which had the highest EC and NO_3-N values and the lowest DO values. Because the estuarine zone not only has high particle deposit but is also a nonshadowed region, cosmopolite species live there (such as *Limnodrilus hoffmeisteri*, *Tubifex tubifex*, and *Tanypus villipennis*) and low species diversity is seen in the area.

A similarity matrix based on Sørensen's coefficient was classified by hierarchical clustering using the UPGMA linking method. The dendrogram constructed by this method gives information about similarities in distribution both for the related species and the number of individuals of macrozoobenthic invertebrates in the study area. The seventh station was found to be the most different from the other stations in terms of organisms. The similarity values for the first six stations were found to be very close to each other. This is probably related to the ecological properties of the stations. The bottom structure and physical and chemical properties of these stations are quite similar while the last station is quite different. The last station is under the sea effect and has a sandy-muddy sediment type. If a stream has this kind of bottom structure, then there is lower diversity and more cosmopolite species than in other parts of the stream (Zeybek et al., 2012). It is expected that the closer the ecological characteristics of the stations are, the higher their similarity values are.

Table 3. Scores of biotic diversity indices and water quality classes based on macrozoobenthic invertebrates.

Indices		Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7
Biotic indices								
BMWP (original)	Score	80	92	101	132	95	108	41
	Class	III	III	II	II	III	II	IV
BMWP (Spanish ver.)	Score	135	155	148	198	142	140	34
	Class	I	I	I	I	I	I	IV
BMWP (Hungarian ver.)	Score	83	96	104	136	96	107	41
	Class	III	III	II	II	III	II	IV
BMWP (Czech ver.)	Score	115	123	134	174	131	133	44
	Class	II	II	II	I	II	II	IV
BMWP score (Polish ver.)	Score	93	98	104	143	107	109	42
	Class	II	II	I	I	I	I	III
BMWP score (Greek ver.)	Score	1234	1297	1245	1732	1133	1146	327
	Class	II	III	III	I	III	III	V
ASPT (original)	Score	6,154	6,571	6,312	6,6	5,938	6	4,556
	Class	I	I	I	I	II	I	III
ASPT (Hungarian ver.)	Score	5,188	6	5,778	6,182	5,647	5,35	4,556
	Class	II	I	II	I	II	II	III
ASPT (Czech ver.)	Score	6,389	6,474	6,7	6,692	6,55	6,045	4,889
	Class	I	I	I	I	I	I	III
BBI	Score	10	10	8	10	10	9	5
	Class	I	I	II	I	I	I	III
Species diversity indices								
Shannon–Weaver		3.935	4.042	3.821	4.817	4.924	4.275	3.21
Simpson		0.865	0.883	0.88	0.93	0.947	0.913	0.847

The water quality of each station was determined based on physical and chemical parameters (TWCPR, 2008) and various biotic indices. The evaluation based on TWCPR indicated that the first six stations were unpolluted while the seventh station was slightly polluted. Six versions of BMWP and three versions of ASPT were applied to determine the water quality of this stream. There have been many different successful adaptations of the BMWP and ASPT indices to countries other than the UK (Alba-Tercedor and Sanchez-Ortega, 1988; Jacobsen, 1998; Ferreira et al., 2004; Czerniawska-Kusza, 2005; Roche et al., 2010; Kazancı et al., 2013; Lewin et al., 2013). It was found that the most appropriate indices for the physical and chemical indices are BMWP (original version) and ASPT (original and Czech versions) among all indices used in the current study.

The BBI showed deviation at only two stations. It was compatible with the physical and chemical results at the other stations. However, the other versions of the BMWP and ASPT indices were not as responsive as expected.

The used indices represent pollution load changes in the study area but have shown some deviations in terms of the quality class to which they belong. This is expected because physical and chemical parameters provide information mainly on instantaneous pollution level. To be able to obtain more reliable knowledge, physical and chemical results should be supported by biological data for water quality assessment (Barlas, 1995).

These deviations derive from the structural differences among the indices. For instance, the situation is different from other indices while four quality grades exist in the method of TWCPR. As the biotic indices are arranged according to the determined indicator species and the ecologic and geomorphologic conditions of the countries in which they were developed, it is not expected that these indices show literal compliance with each other. As a matter of fact, the classification categories of the biotic indices and the score values determined are different from one another. For example, according to the Polish version of the BMWP index, five quality grades are used in the evaluation of water quality of streams, and while areas with a BMWP score value of over 100 are considered as high-quality water, areas with a score value of under 11 are considered as very polluted (Czerniawska-Kusza, 2005). According to the Spanish version of the BMWP index, streams are grouped into four quality grades according to their pollution levels and areas with a score value of under 36 are considered as polluted while areas with a value of over 100 are considered as unpolluted (Prat et al., 2000). Several studies have reported a deviation between biologically and physically/chemically determined water quality grades (Gómez and Licursi, 2001; Kalyoncu et al., 2009; Duran and Akyildiz, 2011; Zeybek et al., 2014). In addition, the ASPT and BMWP indices identify the taxa at the family level while the BBI identifies them at the genus and family level, but none of them use the species level (De Pauw and Vanhooren, 1983; Metcalfe, 1989). This reduces the sensitivity of the indices used.

In conclusion, Kargı Stream is not threatened by intensive pollution effects and it generally has high water quality in spite of some trout farms and settlements located in its vicinity. Water quality values were determined to be lower at the last station located in the estuarine zone than at other stations because of marine effects and recreational activities in the area.

There are no other studies based on the determination of the macrozoobenthic invertebrate fauna of Kargı Stream. Therefore, all taxa identified for the region have been recorded for the first time. On the other hand, to provide more reliable and useful results about the water quality of streams in Turkey, all indices used in the current study should be organized according to the geomorphologic and ecological characteristics of Turkey.

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