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ORIGINAL ARTICLE

Distribution of macroinvertebrates in Ceyhan River Basin (Turkey) and determination of environmental quality by Multimetric Index

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Abstract
In the present study, the distribution of macroinvertebrates among 44 sites in the Ceyhan River Basin and the determination of the ecological status of these sites using the macroinvertebrate multimetric index were investigated. Samples were taken between April 2021 and August 2022, covering the spring, summer, and autumn seasons. A total of 14,839 individuals belonging to 166 taxa were collected. According to the Shannon Diversity Index values, the highest and lowest values were calculated at site 27 (2.45) and 22 (0.22) in spring, site 39 (2.24) and 8 (0.1) in summer, and site 17 (2.28) and 8 (0.17) in autumn, respectively. The highest Shannon all-sample index value was found in the spring season (3.00). Analysis of similarity results (ANOSIM) showed that there were low but significant differences between the spring–summer ($p = 0.001$; $R = 0.236$) and spring–autumn ($p = 0.001$; $R = 0.232$) seasons in terms of species compositions. The first two axes of the canonical correspondence analysis elucidated 51.4% of the relationships between species and environmental variables, along with the significant effects of altitude, temperature, and pH on the distribution of macroinvertebrates. The ecological quality ratios of the sites were calculated with the Ceyhan Basin Multimetric Index (MMI-C). The ecological status of sites was evaluated over three seasons and divided into the following categories: 19 good, 16 moderate, 3 poor, and 4 bad. The results suggest that sites in residential areas have mostly bad ecological conditions, whereas the ecological status of sites situated farther away from residential areas, at high-altitude sites, tends to improve.

Keywords Ceyhan Basin · MMI-C · Ecological quality assessment · Macroinvertebrates · Multimetric index

Introduction

Aquatic macroinvertebrates are one of the most important bioindicators of environmental river quality (Metcalfe 1989). Over time, the use of macroinvertebrates as bioindicators has become widely adopted across Europe due to their ease of collection, identification, and well-known indicator properties (Kolkwitz and Marsson 1909; Hellawell 1986; Rosenberg and Resh 1993). Initially, macroinvertebrate indices based on saprobic systems and indicator traits were used in biological assessment studies. Subsequently, multimetric indices using more than one metric were developed in the United States (Wilhm and Dorris 1968; Barbour et al. 1996, 1999) and in the European Union AQEM project (Hering et al. 2004). The utilization of multimetric indices took a different format with the adoption of "Water Framework Directive" (WFD) (Council of European Communities 2000/60/EC) in 2000. A typological framework was also defined for assessing the ecological quality of water bodies in the future. The scope of WFD was to use the type-specific multimetric index method, which has also been recommended for biological assessment. With this perspective, AQEM and STAR projects have been developed and implemented biological assessment methods in Europe (Furse et al. 2006, AQEM 2002). In this study, the previously developed Ceyhan Basin Multimetric Index (MMI-C) was carried out within the scope of this objective of the WFD.

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In developing countries like Turkey, rivers are under intense domestic and industrial pollution pressure. Biological methods play an important role in the integrated management of water resources and have several advantages over physicochemical methods (Rosenberg and Resh 1993). Biological monitoring provides valuable information allowing estimates of deleterious influences on lotic habitats, at low cost and with minimal technical requirements. The use of macroinvertebrates in biological assessment studies of lotic systems, in combination with mathematical indices began at the end of the twentieth century in Turkey (Kazancı et al. 1997; Kazancı and Dügel 2000). Gradually, the number of studies started to increase using different biotic indices (Dügel and Kazancı 2004; Duran 2006; Kazancı et al. 2010, 2013; Kalyoncu and Zeybek 2011; Zeybek et al. 2014; Yorulmaz et al. 2015; Arslan et al. 2016; Zeybek 2017).

The method of developing multimetric indices for rivers was demonstrated by European studies (e.g., Hering et al. 2006) and in the United States of America (e.g., Hughes et al. 2009). In these countries, stream types were delineated and mapped with clear boundaries (Omernik 1995) (Verdonschot and Nijboer 2004). As a result of the utilization of stream types in the multimetric index development process, type-specific indices have been developed and used. Studies including the multimetric index concept have been initiated within the framework of harmonization laws between Turkey and the European Union (Dügel 2016). In these studies, country-specific typologies were determined (Digitizing Project 2022) but could not be used in the development of multimetric indices. The developed and used multimetric indices were mostly basin-specific indices or a single index covering all of Turkey instead of type-specific multimetric indices (Dügel 2016; Akay and Dalkıran 2020; Odabaşı et al. 2022; Koyuncuoğlu et al. 2023; Öztürk et al. 2023).

River basins provide an optimal setting for researching the assessment and monitoring of streams, as well as evaluating the environmental implications of both biotic and abiotic factors (Dawei and Jingsheng 2001). Water management issues, at the scale of whole river basins, have been of significant public concern in Turkey. Therefore, integrated basin management studies in Turkey have gained momentum since 2009. After that, conducted and continued river basin-related studies followed the rules of the WFD within the scope of the harmonization laws between the European Union and Turkey. In this study, we expect that evaluations performed with biological data in the Ceyhan River basin will contribute to holistic basin management. Additionally, the present study will provide data for multimetric index development studies and contribute to a robust biological assessment system for Turkey in the future. The multimetric index values of the sampling sites were calculated on a seasonal basis using four selected metrics in a previous study (Dügel 2016). The objectives of the current study were: (1) to make ecological evaluations of the streams in the Ceyhan River basin; (2) to increase multimetric index applications in Turkey with new data; (3) to provide data for type-specific multimetric index development studies; and (4) to contribute to the knowledge of macroinvertebrate fauna of the Ceyhan River Basin and Turkey.

Material and Methods

Study area

The sampling sites belong to the Ceyhan River Basin (Table 1, Fig. 1). The Ceyhan River, formerly the Pyramos, is one of the largest rivers in Anatolia. It is located between 36°55' and 38°72' north latitudes and 35°45' and 37°81' east longitudes in the Eastern Mediterranean Region of Turkey (Fig. 1). The basin covers 2.73% of Turkey's surface area, and the river flows through a mountainous catchment area in the eastern Taurides, characterized by Palaeozoic, Mesozoic, and tertiary karstic carbonate bedrock. The Ceyhan River has a tributary length of 510 km. It originates in the mountains around the Elbistan Plain (Kahramanmaraş) and joins large tributaries such as the Aksu and Göksun streams. The river flows in a southwestern direction, passing through the Çukurova floodplain and delta, before entering the Mediterranean Sea at the Bay of Iskenderun (CHKYP 2019; Akbulut et al. 2022).

Sampling

Before macroinvertebrate sampling, the coordinates of each site were noted using a global positioning system (GPS), and details of the sampling sites are provided in Table 1. A YSI Professional Plus multi-probe was used to measure dissolved oxygen concentration (DO, mg L^{-1}), water temperature (Tw, °C), electrical conductivity (EC, µS cm^{-1}), pH, salinity (ppt), total dissolved solids (TDS, mg L^{-1}) and oxidation and reduction potential (ORP, mV). For chemical analyses and estimation of biological oxygen demand (BOD_5, mg L^{-1}), 500 mL water samples were collected from each site in polyethylene bottles and preserved in a container maintained at a temperature of + 4 °C during the field survey.

Macroinvertebrate sampling was carried out using the multihabitat sampling method with a hand-net featuring a 500 µm mesh size (STAR 2003). Each site was sampled three times: in April (for the spring) and October (for the

Table 1 Codes and geographical information of sampling sites in the present study

Code	Name	Latitude	Longitude	Altitude (m a.s.l.)
S1	Gökpınar	37.36239	37.03063	531
S2	Aksu1	37.53999	37.34684	746
S3	Aksu2	37.77544	37.38601	1139
S4	Erkenez	37.59322	37.18652	919
S5	Ceyhan1	37.51545	36.92692	477
S6	Ceyhan2	37.61983	36.79717	445
S7	Nergele	37.98722	37.10826	1163
S8	Gözpınar	37.81868	36.96558	610
S9	Söğütlü1	38.25441	37.53351	1350
S10	Söğütlü 2	38.22486	37.23786	1123
S11	Ceyhan3	38.19979	37.08428	1114
S12	Söğütlü3	38.14764	37.00002	1116
S13	Kömürsuyu1	38.23841	36.58579	1570
S14	Kömürsuyu2	38.11093	36.54157	1428
S15	Göksun1	38.10745	36.44751	1430
S16	Güredin1	37.91594	36.61908	1022
S17	Güredin2	37.91292	36.60929	1018
S18	Zeytin	37.78034	36.77827	652
S19	Tekir	37.76837	36.69721	655
S20	Kayaözü	37.75815	36.63021	733
S21	Köprüağzı1	37.63968	36.58646	500
S22	Karsulu	37.64484	36.39985	505
S23	Köprüağzı2	37.59671	36.44672	944
S24	Köprüağzı3	37.73142	36.48229	1256
S25	Fırnız	37.83092	36.51509	1245
S26	Köprüağzı4	37.81494	36.42205	1306
S27	Köprüağzı5	37.77111	36.36455	1380
S28	Geben	37.75105	36.34813	1280
S29	Keşiş	37.60416	36.25824	743
S30	Sumbas	37.45519	36.04103	97
S31	Savrun	37.39124	36.0831	85
S32	Çatak	37.29504	36.50844	477
S33	Karlıca	37.2543	36.53388	1169
S34	Akçasu1	37.12891	36.2932	99
S35	Akçasu2	37.13415	36.22772	67
S36	Karaçay1	37.04428	36.29851	288
S37	Karasu1	37.06545	36.07368	38
S38	Cingöz	37.03049	35.75386	19
S39	Ceyhan4	37.12891	36.2932	22
S40	Akçasu	37.13415	36.22772	67
S41	Karaçay2	37.04428	36.29851	288
S42	Karasu2	37.06545	36.07368	38
S43	Cingöz	37.03049	35.75386	29
S44	Ceyhan5	37.12891	36.29320	22

autumn) of 2021 and August 2022 (for the summer). Collected specimens were placed on a large tray, and sensitive specimens were manually collected and stored in 50 ml falcon tubes containing ethanol (70°). The remaining substrate was placed in 500 ml plastic containers and fixed with 95° ethanol for transportation to Limnology laboratory, Bolu Abant İzzet Baysal University.

Laboratory analyses

Sulfate (SO_4^{2-}, mg L^{-1}), total nitrogen (TN, mg L^{-1}), total phosphorus (TP, μg L^{-1}), nitrate (NO_3^-, mg L^{-1}), nitrite (NO_2^-, mg L^{-1}), fluorine (F, mg L^{-1}) and chloride (Cl^-, mg L^{-1}), ammonium (NH_4^+, mg L^{-1}), iron (Fe, mg L^{-1}), calcium (Ca^{2+}, mg L^{-1}), magnesium (Mg^{2+}, mg L^{-1}), potassium (K^+, mg L^{-1}) and sodium (Na^+, mg L^{-1}) and total organic carbon (TOC, mg L^{-1}) of water samples were measured using the Hach LT 200 Thermoreactor, Hach Cuvette tests and Hach Lange DR 5000 spectrophotometer. For BOD_5 (mg L^{-1}), water samples in 420 mL opaque dark bottles were incubated at 20 °C for 5 days, and then BOD_5 values were recorded using a Hach BOD Trak 2 device (Hach 2015). The standard procedure provided in APHA (2012) was used to record the total hardness (mmol $CaCO_3$ L^{-1}) values of each water sample.

Samples were gently rinsed to separate macroinvertebrate specimens from sediments, both with the naked eye and under a stereo microscope (Olympus ACH 1X) when necessary. Specimens were sorted into groups (e.g., Ephemeroptera, Odonata, Gastropoda), and each group was then placed into 50 ml falcon tubes and fixed with 70° ethanol. Some specimens were dissected in glycerol solution to prepare permanent slides for identification. Macroinvertebrate specimens were identified using both stereo (Olympus ACH 1X) and light (Olympus BX-51) microscopes to the lowest possible systematic category, following suitable taxonomic keys (Hliley 1976; Franke 1979; Carchini 1983; Brinkhurst and Wetzel 1984; Vepsäläinen and Krajewski 1986; Zimmermann 1987; Sivec et al. 1988; Nilsson 1989; Müller 1990; Savage 1990; Zwick 1991, 2004; Schmedtje and Kohmann 1992; Bauernfeind 1994; Engblom 1996; Jansson 1996; Solem and Gullefors 1996; Norling and Sahlén 1997; Jensen 1997; Butler 1998; Bauernfeind and Humpesch 2001; Eggers and Martens 2001; Malicky 2004; Neu and Tobias 2004; Eiseler 2005, 2015; Vallenduuk and Moller Pillot 2007; Moller Pillot 2009, 2013; Tachet et al. 2010; Waringer and Graf 2011; Bauernfeind and Soldan 2012; Andersen et al. 2013; Cranston and Epler 2013; Dobson 2013; Van Haaren and Soors 2013). Specimens were stored in the Limnology Laboratory of Bolu Abant İzzet Baysal University, Turkey, and are available upon request.

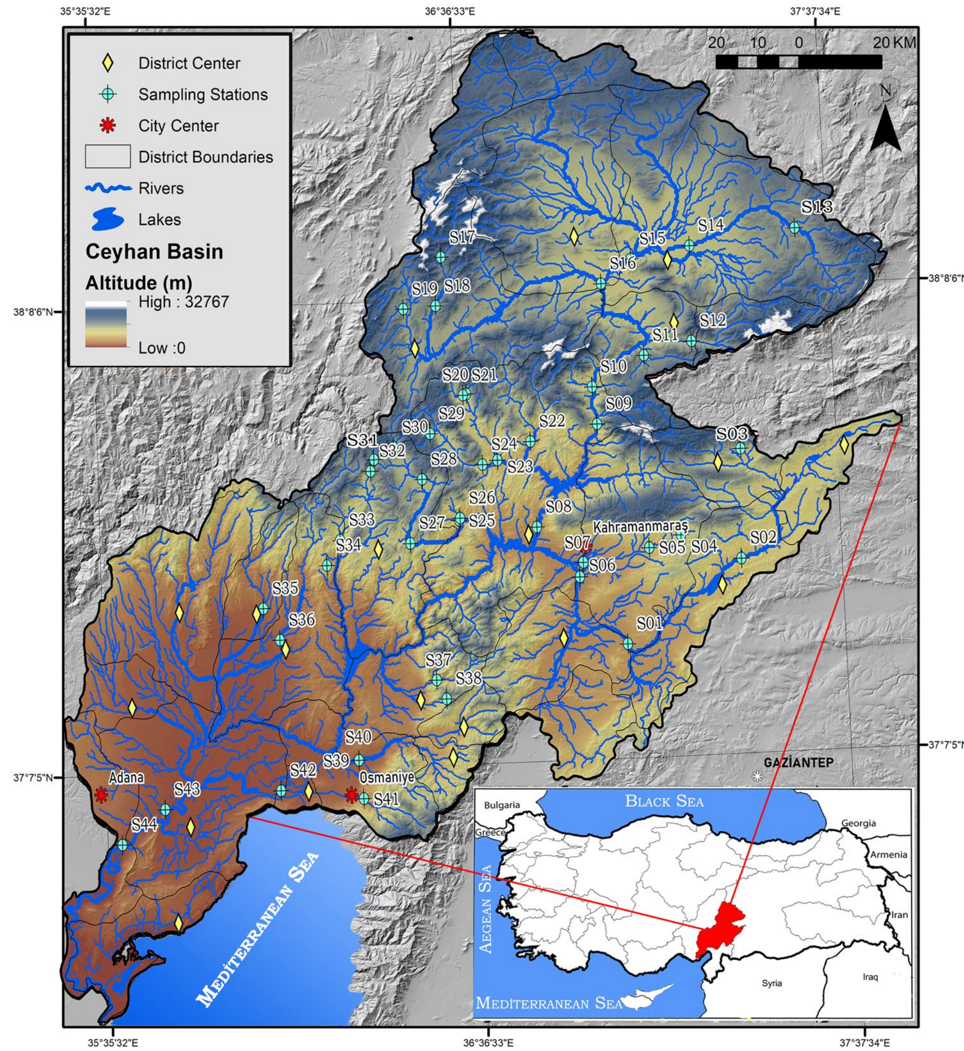

Fig. 1 Location of sampled sites in the Ceyhan River Basin. Full names and codes of sites are available in Table 1

Statistical analyses

The species diversity of each site during different seasons (spring, summer, and autumn) was estimated by calculating Shannon–Wiener diversity (H) (Shannon and Weaver 1949) and Shannon Evenness (E) density indices with the aid of the Species Diversity and Richness Package (SDR) (Seaby and Henderson 2006). Analysis of Similarity (ANOSIM) and Similarity Percentages (SIMPER) analyses (Clarke 1993) were applied using the Community Analysis Package (CAP 4.0) (Henderson and Seaby 2007) to understand the level of possible differences between the seasonal occurrence of species and to evaluate the taxa that contribute to these differences, respectively. Dissociation between seasons was visualized by non-metric multidimensional scaling (NMDS) analysis (CAP 4.0). The relationships between environmental variables and macroinvertebrate species that occurred two or more times were explored by Canonical Correspondence Analysis (CCA) using CANOCO 4.5, and statistical significance between axes of ordination was tested with the Monte Carlo Permutation test (999) (ter Braak 1988).

The water quality of the sites was evaluated by a multimetric biotic index based on macroinvertebrate metrics (Multimetric Index-Ceyhan, MMI-C). To determine the ecological water quality, seasonal ecological quality ratios were calculated over the abundance values of the determined macroinvertebrate groups. Four metrics were used; i) Biological Monitoring Working Party Score System-Spanish version (BMWP-Sp, sensitivity/tolerance metric), ii) Shannon Wiener Diversity index (richness/diversity metric), iii) [%] epirhithral (functional metric) and iv) EPT (Ephemeroptera, Plecoptera and Trichoptera) Taxa (%, composition/abundance metric). To calculate the multimetric index, the 75th percentile of the metric values obtained was used for standardization processes, then the final index values of the sites were determined. Class boundaries between ecological quality ratios were used

Table 2 Number of taxa and individuals of macroinvertebrate groups encountered in the Ceyhan River Basin streams in three seasons

Macroinvertebrate group	Number of taxa	Abundance
Chironomidae	29	595
Ephemeroptera	24	6362
Diptera (except Chironomidae and Simuliidae)	19	100
Trichoptera	17	540
Coleoptera	12	82
Odonata	11	144
Simuliidae	13	1352
Gastropoda	9	982
Plecoptera	8	343
Heteroptera	6	95
Bivalvia	4	19
Oligochaeta	4	106
Amphipoda	3	3956
Hirudinea	3	45
Arachnida	1	18
Decapoda	1	90
Isopoda	1	2
Turbellaria	1	8
TOTAL	166	14839

for the MMI-C index (Dügel 2016). All community metrics were calculated using the ASTERICS 4.0.4 software (AQEM/STAR Ecological River Classification System) (AQEM 2002).

Results and discussion

A total of 166 taxa and 14,839 macroinvertebrate individuals were collected from the 44 sampling sites across the three seasons. Among the reported 18 groups, the highest number of taxa was observed in the Chironomidae and Ephemeroptera. The highest number of individuals was found among amphipods, while the lowest count was recorded for isopods (Table 2). The distribution of macroinvertebrate taxa among the sampled sites is presented in Table 3.

Analysis of macroinvertebrate communities by ANOSIM shows significant differences between species compositions in spring–autumn and spring–summer pairwise comparisons ($R = 0.17$, $p < 0.05$). The ordination chart shows the sampling sites in the spring period are positioned differently from the other sampling sites. (Fig. 2).

Results of the SIMPER analysis to assess the degree of dissimilarity within groups (seasonal sampling sites) are shown in Table 4. According to the SIMPER results, within-group similarity rates for each of the spring, summer, and autumn seasons showed approximately 15% similarity. Spring sampling sites differed significantly from autumn sampling sites (ANOSIM: $R = 0.23$, $p < 0.05$, average dissimilarity of 88.61%), with *Baetis rhodani* as the major contributor (20.42%) to those differences. Similarly, spring sampling sites differed significantly from summer sampling sites (ANOSIM: $R = 0.24$, $p < 0.05$, average dissimilarity of 88.21%), with *B. rhodani* as the major contributor (22.42%) to those differences. Although the dissimilarity between autumn and summer was not statistically significant, two species, *B. rhodani* (19.47%) and *G. balcanicus* (21.10%), contributed the most to the 84.60% dissimilarity between both seasons. The contribution of species other than *B. rhodani* and *G. balcanicus* to the discrepancies between seasons was less than 6% (Table 4).

Baetis rhodani and *Gammarus balcanicus* are taxa that characterize the autumn and summer seasons, but *G. balcanicus* was completely absent from spring sampling sites. This indicates that this species colonizes in early summer and is not abundant in the cold spring.

A study on gammarids shows that their density increased in early summer (Pöckl et al. 2002). In another study in Yeşilırmak (Turkey) shows that gammarids are more common after the spring months (Duran 2007). *Baetis rhodani*, one of the common Ephemeroptera, was the species with the highest contribution percentages in spring (79.81%) to these within-group similarities, while its lowest contribution was observed in autumn with a rate of 46.96% (Table 4). The life cycle of *B. rhodani* changes between different environments (Bauernfeind and Humpesch 2001). In some studies conducted in karst areas, this species had a polyvoltine life cycle (Buffagni et al. 2003, Erba et al. 2003), although some researchers stated that this species has a univoltine life cycle (Bottová and Derka 2013). These results shows that *B. rhodani* has a flexible life cycle. Moreover, since this species has a wide ecological tolerance, it can survive in unpolluted and moderate organically polluted waters (Hellawell 1986).

Taxa are ranked according to their average contribution to similarity/dissimilarity values within (top of the table) or between (down of the table). Average abundances, ratio (similarity or dissimilarity) and percentage of cumulative similarity are also included. Only the three taxa that contributed the most to the distribution are shown.

In spring, the highest Shannon diversities (H) were calculated at sites 27 (2.46) and 17 (2.13), while the lowest were at sites 21 (0.23) and 33 (0.42). A similar situation was observed for sites 27, 17, 21 and 33 for evenness (E). In the summer season, the sites 39 (2.24) and 31 (2.20) had the highest diversities (H') while the lowest diversity values were found at sites 8 (0.10) and 16 (0.15), and evenness values showed similar patterns for these sites (Table 5).

Table 3 Names and codes of macroinvertebrate taxa collected in the sampling sites in different seasons

Group	Taxon	Code	Site
Amphipoda	*Gammarus balcanicus* Schäferna, 1923	Gam bal	S01c, S03b, S03c, S08b, S08c, S09b, S09c, S11b, S11c, S12b, S12c, S15c, S16b, S16c, S17b, S17c, S18b, S18c, S19b, S19c, S20b, S20c, S21b, S21c, S23c, S24b, S24c, S25c, S27b, S27c, S29c, S30b, S30c, S31b, S31c, S33b, S33c, S40c, S44c
	Gammarus roeselii Gervais, 1835	Gams roe	S01b
	Gammarus sp.	Gam sp	S01b, S04b
Arachnida	Hydrachnidia Gen. sp.	Hyd gsp	S03b, S04b, S13b, S21b, S22b, S37b, S39b, S40b, S41b
Bivalvia	*Anodonta cygnea* (Linnaeus, 1758)	Ano cyg	S36b
	Bivalvia Gen. sp.	Biv gsp	S35a
	Pisidium casertanum (Poli, 1791)	Pis cas	S04c, S14c, S15a, S15c, S16a, S27a
	Sphaerium corneum (Linnaeus, 1758)	Sph cor	S42a, S42c
Chironomidae	*Ablabesmyia monilis* (Linnaeus, 1758)	Abl mon	S22b, S37b, S40b, S42b
	Brillia bifida (Kieffer, 1909)	Bri bif	S09b, S38b
	Chironomini Gen. sp.	Chi gsp	S16c, S20c, S37a, S37c
	Chironomus (Chironomus) riparius Meigen, 1804	Chi rip	S15a
	Conchapelopia sp.	Con sp	S28a, S39a, S39b, S39c, s43a
	Cricotopus (*Cricotopus*) *bicinctus* (Meigen, 1818)	Cri bic	S33b, S33c, S38c, S39b, S39c, S40c, S41b, S41c, S42a, S42c
	Cricotopus (*Cricotopus*) *tremulus (*Linnaeus, 1758)	Cri tre	S14c, S35a
	Cricotopus (*Cricotopus*) *trifascia* Edwards, 1929	Cri tri	S35a, S35b
	Cricotopus (*Isocladius*) *reversus* Hirvenoja, 1973	Cri rev	S23a, S27a, S27b
	Cricotopus (*Isocladius*) sp.	Cri sp	S42c, S43a
	Cricotopus (*Isocladius*) *tricinctus* (Meigen, 1818)	Cri tric	S15a, S15c
	Diamesa sp.	Dia sp	S02b, S02c, S04b, S04c, S10a, S12a, S12b, S12c, S13b, S14b, S20b, S21a, S21b, S21c, S23a, S24b, S27a, S27b, S29a, S32a
	Eukiefferiella brevicalcar (Kieffer, 1911)	Euk bre	S13a, S27a, S32a, S33c, S36b, S36c, S37a, S37b, S37c
	Limnophyes transcaucasicus Tschernovskij, 1949	Lim tra	S34a
	Micropsectra sp.	Mic sp	S17b
	Orthocladiinae Gen. sp.	Ort gsp	S04a, S04b, S04c, S13a, S13b, S17c, S25c, S28a, S29a, S30b, S30c, S34a
	Orthocladius (*Euorthocladius*) *thienemanni* Kieffer, 1906	Ort thi	S15a, S15c, S27a, S27c
	Paramerina cingulata (Walker, 1856)	Par cin	S43c, S44a
	Polypedilum convictum Walker, 1856	Pol con	S41c, S43c, S44a
	Polypedilum pedestre (Meigen, 1830)	Pol ped	S31b, S31c, S36b, S36c, S37a, S37c, S39a, S39c
	Polypedilum sp.	Pol sp	S43c, S44a
	Procladius (*Holotanypus*) sp.	Proh sp	S35a, S35c
	Procladius sp.	Pro sp	S13b, S24b, S28b, S40b
	Psammoryctides albicola (Michaelsen, 1901)	Psa alb	S19c, S20a
	Rheocricotopus effusus (Walker, 1856)	Rhe eff	S27a, S27c, S34a, S39a, S42a, S42b
	Tanypodinae Gen. sp.	Tan gp	S18b
	Tanytarsus gregarius Kieffer, 1909	Tan gre	S34a, S43a, S43c
	Tanytarsus sp.	Tan sp	S34a
	Tvetenia discoloripes (Goetghebuer & Thienemann, 1936)	Tve dis	S02c, S03a, S03c, S04c, S08c, S11c, S12a, S12b, S12c, S13a, S14a, S14c, S17c, S20c, S24a, S24c, S25c, S26a, S27a, S34a
Coleoptera	*Agabus* sp.	Aga sp	S05a, S26a
	Aulonogyrus concinnus (Klug, 1834)	Aul con	S15a, S18c, S33c

Table 3 (continued)

Group	Taxon	Code	Site
	Elmis sp.	Elm sp	S03a, S03b, S17b, S18b, S18c, S19a, S19c, S24c, S27b, S37a
	Gyrinus sp.	Gyr sp	S11b, S13b
	Haliplus sp.	Hal sp	S14c
	Hydrobius sp.	Hyd sp	S13b
	Hydrophilidae Gen. sp.	Hyd gsp	S04b
	Hygrotus sp.	Hyg sp	S38b
	Laccophilus sp.	Lac sp	S12a, S13b, S30c
	Limnius sp.	Lim sp	S02c, S13c, S25c, S33c, S35c, S37c
	Oulimnius sp.	Oul sp	S36b, S37b, S37c
	Platambus sp.	Pla sp	S11c, S14b
Decapoda	*Atyaephyra orientalis* Bouvier, 1913	Aty ori	S01a, S01b, S01c, S44c
Diptera	*Antocha* sp.	Ant sp	S13b, S23a, S33b, S37b
	Atrichopogon sp.	Atr sp	S04b
	Bezzia sp.	Bez sp	S11b, S39b, S41b
	Blepharicera fasciata (Westwood, 1842)	Ble fas	S10a, S17a, S24a, S29a, S30a, S37a, S38a
	Ceratopogonidae Gen. sp.	Cer gsp	S04a
	Chelifera sp.	Che sp	S24b, S31b
	Chrysops sp.	Chr sp	S37b
	Clinocera sp.	Cli sp	S26a
	Culex sp.	Cul sp	S14b
	Dicranota sp.	Dic sp	S04c, S11b, S12c, S23a, S24b, S24c, S30a, S30b, S37a
	Dixa sp.	Dix sp	S13c, S18c
	Hexatoma sp.	Hex sp	S17b, S17c, S18a, S18b, S18c, S31a, S31b, S31c
	Ibisia marginata (Fabricius, 1781)	Ibi mar	S13c, S18b, S32a, S34a, S37a
	Limnophora sp.	Limn sp	S12b, S12c, S27b, S31c, S39b
	Odontomyia sp.	Odo sp	S13a
	Pedicia sp.	Ped sp	S02a
	Psychoda sp.	Psy sp	S17b
	Tabanus sp.	Tab sp	S25c, S35c, S39b
	Tipula sp.	Tip sp	S03b, S10a, S17a, S33b, S35c
Ephemeroptera	*Baetis melanonyx* (Pictet, 1843)	Bae mel	S24a, S24b, S24c, S25a, S29a, S30a, S30b, S30c
	Baetis pavidus Grandi, 1951	Bae pav	S02a, S02b, S02c, S09a, S09c
	Baetis rhodani (Pictet, 1843)	Bae rho	S03a, S03b, S03c, S04a, S04b, S04c, S05a, S09a, S09b, S09c, S10a, S11b, S11c, S12a, S12b, S12c, S13a, S13b, S13c, S14a, S14b, S14c, S15a, S15c, S16a, S16b, S16c, S17a, S17b, S17c, S18a, S18b, S18c, S19a, S19b, S19c, S20a, S20b, S20c, S21a, S21b, S21c, S22a, S22b, S22c, S23a, S25a, S25c, S26a, S27a, S27b, S27c, S28a, S28b, S29a, S29b, S29c, S31a, S31b, S31c, S32a, S33a, S33b, S33c, S34a, S35b, S35c, S36b, S36c, S37a, S37b, S37c, S38a, S38b, S38c, S39a, S39b, S39c, S40b, S40c, S41a, S41b, S41c, S42a, S42b, S42c, S43a, S43c, S44a
	Baetis sp.	Bae sp	S35a, S36a
	Caenis luctuosa (Burmeister, 1839)	Cae luc	S11c, S14b, S14c, S36b, S36c

Table 3 (continued)

Group	Taxon	Code	Site
	Caenis macrura Stephens, 1835	Cae mac	S02b, S02c, S04b, S04c, S13b, S22b, S25c, S27b, S27c, S28a, S28b, S29c, S33b, S33c, S35a, S35b, S35c, S39b, S39c, S40b, S40c, S41b, S41c, S42a, S42b, S42c, S43a
	Choroterpes picteti (Eaton, 1871)	Cho pic	S02c
	Ecdyonurus picteti Meyer-Dur, 1864	Ecd pic	S37b
	Ecdyonurus submontanus Landa, 1969	Ecd sub	S17a, S17c, S18c, S19a, S19b, S19c, S21a, S21b, S24b, S27a, S27b, S31c, S33a, S33b, S33c, S41a
	Ecdyonurus torrentis Kimmins, 1942	Ecd tor	S37a
	Electrogena affinis (Eaton, 1883)	Ele aff	S02a, S02b, S02c, S13b, S18a, S21c, S22b, S23a, S25c, S27b, S29b, S33b, S33c, S38a, S38b, S38c
	Electrogena lateralis (Curtis, 1834)	Elec lat	S32a, S34a, S36b, S41a
	Epeorus assimilis Eaton, 1885	Epe ass	S13a, S17a, S17b, S17c, S18a, S18b, S19a, S19c, S21a, S21c, S24a, S24b, S24c, S27a, S27b, S30b, S31a, S31b, S33b, S37a
	Epeorus caucasicus (Tshernova, 1938)	Epe cau	S03a, S03b, S03c, S12a, S12c, S17a, S17b, S17c, S18a, S19a, S19b, S24a, S28a, S29a, S31a, S31b, S31c, S38a
	Epeorus znojkoi (Tshernova, 1938)	Epe zno	S30a, S30b
	Ephemera danica Müller, 1764	Eph dan	S18b
	Ephemera vulgata Linnaeus, 1758	Eph vul	S10a, S11b, S17a, S17c, S33b, S33c, S35a, S35b, S38a
	Ephemerella ignita (Poda, 1761)	Eph ign	S17b, S18b, S19a, S19b, S21c, S27a, S28a, S29b, S30b, S31b, S33b
	Ephemerella notata Eaton, 1887	Eph not	S13a, S14a
	Oligoneuriella rhenana (Imhoff, 1852)	Oli rhe	S02b, S36b
	Paraleptophlebia werneri Ulmer, 1920	Par wer	S29a, S38a
	Potamanthus luteus (Linnaeus, 1767)	Pot lut	S02a, S02c
	Rhithrogena picteti Sowa, 1971	Rhi pic	S02a, S02c, S04a, S04b, S09b, S09c, S11c, S13a, S17a, S17b, S17c, S18a, S18c, S27a, S29a, S33a, S37a, S41a
	Rhithrogena semicolorata (Curtis, 1834)	Rhi sem	S19a, S28a, S30a, S30c, S31a, S31b, S31c, S38a
Gastropoda	*Acroloxus lacustris* (Linnaeus, 1758)	Acr lac	S21c
	Bithynia tentaculata (Linnaeus, 1758)	Bit ten	S02c, S03b, S03c, S12c, S15a, S16a, S16b, S16c, S20c, S29c, S31c, S35b, S39b
	Gyraulus piscinarum (Bourguignat, 1852)	Gyr pis	S13a, S13b, S13c, S15c, S27a, S27b, S27c, S29c, S31b, S35b, S39c
	Melanopsis buccinoidea (Olivier, 1801)	Mel buc	S01a, S02c, S35a, S35b, S35c, S36a, S36b, S37a, S39a, S39b, S39c, S42a, S42b, S44a
	Melanopsis costata (Olivier, 1804)	Mel cos	S01b, S36c, S40b, S42b, S42c, S43c, S44c
	Physella acuta (Draparnaud, 1805)	Phys acu	S08c, S13a, S13b, S14b, S14c, S15a, S15c, S16b, S28a, S39b, S39c, S40b, S40c, S43c
	Radix labiata (Rossmässler, 1835)	Radlab	S15a, S35b, S37b, S39b, S40b
	Theodoxus fluviatilis (Linnaeus, 1758)	The flu	S01a, S01b, S01c, S39b, S42c, S44a, S44c
	Valvata piscinalis (O.F.Müller, 1774)	Val pis	S08c, S15a, S15c, S27b, S28a, S35a
Heteroptera	*Aquarius najas* (De Geer, 1773)	Aqu naj	S11b, S13b, S38b
	Aquarius ventralis (Fieber, 1860)	Aqu ven	S11c, S13c, S25a, S38a, S38c
	Hydrometra stagnorum (Linnaeus, 1758)	Hyd sta	S27b

Table 3 (continued)

Group	Taxon	Code	Site
	Micronecta minutissima (Linnaeus, 1758)	Mic min	S39b, S40b
	Notonecta maculata Fabricius, 1794	Not mac	S38b
	Notonecta obliqua Thunberg, 1787	Not obli	S38b
Hirudinea	*Erpobdella octoculata* (Linnaeus, 1758)	Erp oct	S03a, S03b, S04c, S12a, S12b, S12c, S15c, S18a, S19a, S19b, S19c, S20a, S21a, S21c, S27a, S27c, S29a, S30a
	Glossiphonia complanata (Linnaeus, 1758)	Glo com	S42b
	Helobdella stagnalis (Linnaeus, 1758)	Hel sta	S03b
Isopoda	*Asellus aquaticus* (Linnaeus, 1758)	Ase aqu	S39b, S42b
Odonata	*Aeshna affinis* Vander Linden, 1820	Aes aff	S04a, S04b, S04c, S10a, S11b, S18a, S24c, S27a, S27c, S29a, S30a, S30c, S31a, S32a, S33a, S33c, S38c
	Calopteryx splendens (Harris, 1782)	Cal spl	S13b
	Calopteryx virgo (Linnaeus, 1758)	Cal vir	S02c, S34a, S35a, S38b
	Coenagrion pulchellum (Vander Linden, 1825)	Coe pul	S35c, S43c, S44c
	Cordulegaster bidentata (Selys, 1843)	Cor bid	S44c
	Crocothemis erythraea (Brullé, 1832)	Cro ery	S15c
	Epallage fatime (Charpentier, 1840)	Epa fat	S11b, S22c, S25c, S33b, S33c, S37b, S37c, S38a, S41a
	Ischnura elegans (Vander Linden, 1820)	Isc ele	S40b
	Onychogomphus forcipatus (Linnaeus, 1758)	Ony for	S05a, S13b, S22a, S35a, S36a, S40b
	Orthetrum cancellatum (Linnaeus, 1758)	Ort can	S14a, S14b, S40b
	Platycnemis pennipes (Pallas, 1771)	Pla pen	S01a, S13b, S13c, S35a, S35b, S43a, S43c
Oligochaeta	*Eiseniella tetraedra* (Savigny, 1826)	Eis tet	S02b, S08c, S10a, S13a, S14a, S17c, S18a, S18b, S20a, S21a, S23a, S24a, S27a, S27b, S27c, S28a, S35b, S36a, S37a, S37b, S38b, S40b
	Oligochaeta Gen. sp.	Oli gsp	S03b, S08b, S08c, S13a, S16b, S18b, S21b, S24b, S33c, S35c, S39b, S40b, S42b
	Tubifex blanchardi Vejdovsky 1891	Tub bla	S12c, S15a, S15c
	Tubificidae Gen. sp.	Tub gsp	S15a
Plecoptera	*Brachyptera risi* (Morton, 1896)	Bra ris	S32a
	Isoperla grammatica (Poda, 1761)	Iso gra	S17a, S18a, S19a, S19b, S19c, S24a, S31a, S31b, S31c, S32a, S38a
	Leuctra hippopus Kempny, 1899	Leu hip	S04b, S04c, S11c, S13b, S13c, S14c, S24c, S29b, S29c, S31b, S32a, S33b, S33c, S37b, S37c, S38b, S38c
	Nemoura cambrica Stephens, 1836	Nem cam	S10a
	Nemoura erratica Claassen, 1936	Nem err	S34a
	Nemoura taurica Zhiltzova, 1967	Nemtau	S25a, S30a, S31a
	Perla marginata (Panzer, 1799)	Per mar	S17a, S17b, S17c, S18c, S19a, S19b, S19c, S38a
	Protonemura bithynica Aubert, 1964	Pro bit	S12c, S17c, S18a, S18c, S19c, S31b, S31c, S38a
Simuliidae	*Prosimulium rufipes* (Meigen, 1830)	Pro ruf	S29a
	Prosimulium sp.	Pros sp	S10a, S12c, S29a, S32a
	Prosimulium tomosvaryi (Enderlein, 1921)	Pro tom	S08a, S12a, S14a, S14c, S29a, S29c, S38a
	Metacnephia lyra (Lundstroem, 1911)	Met lyr	S29a, S29c
	Metacnephia subalpina (Rubtsov, 1956)	Met sub	S10a, S29a, S29c
	Simulium (*Eusimulium*) *angustipes* Edwards, 1915	Sime ang	S23a, S26a, S28a, S32a, S36c, S37a, S39a
	Simulium (*Nevermannia*) *angustitarse* (Lundström, 1911)	Simn ang	S02b, S11b, S13a, S13c, S18b, S19b, S22b, S26a, S27a, S27c, S28a, S28b, S32a, S41b
	Simulium (*Nevermannia*) *cryophilum* (Rubtsov, 1959)	Sim cry	S11c, S18b, S18c, S21a, S21b, S21c, S23a, S24a, S24b, S24c, S25a, S25c, S27b, S28a, S33a, S33c, S38a, S38c
	Simulium (*Simulium*) *argyreatum* (Meigen, 1838)	Sim arg	S26a
	Simulium (*Simulium*) *ornatum* Meigen, 1818	Sim orn	S26a

Table 3 (continued)

Group	Taxon	Code	Site
	Simulium (*Simulium*) *trifasciatum* Curtis, 1839	Sim tri	S33a
	Simulium (*Simulium*) *variegatum* Meigen, 1818	Sim var	S10a, S17b, S17c, S20c
	Simulium sp.	Sim sp	S03a, S04b, S05a, S09a, S09b, S09c, S10a, S14a, S17c, S18a, S18c, S19c, S22a, S24a, S25a, S25c, S26a, S27a, S27c, S28a, S29a, S30a, S30b, S31a, S31b, S31c, S32a, S34a, S35a, S35b, S35c, S36c, S37a, S37c, S38a, S39a, S40c, S41c, S42a
Trichoptera	*Cheumatopsyche lepida* (Pictet, 1834)	Che lep	S10a, S22a, S23a, S25a, S37a, S41a
	Drusus sp.	Dru sp	S16b
	Glossosoma conformis Neboiss, 1963	Glo con	S21b
	Glossosoma sp.	Glo sp	S12c, S20c, S25a
	Hydropsyche botosaneanui Marinkovic, 1966	Hyd bot	S35a, S41a, S41c
	Hydropsyche instabilis (Curtis, 1834)	Hyd ins	S02b, S02c, S03b, S03c, S04b, S04c, S09b, S09c, S10a, S11b, S11c, S13b, S13c, S14b, S14c, S15c, S17a, S17b, S17c, S18b, S18c, S19b, S21c, S22b, S22c, S23c, S24b, S24c, S25c, S27b, S27c, S29c, S30b, S30c, S31b, S31c, S33a, S33b, S33c, S36b, S36c, S37b, S37c, S38b, S39b, S39c, S40b, S41b, S42c
	Hydropsyche sp.	Hydr sp	S02c, S32a
	Hydroptila sp.	Hydrop sp	S36b, S40b, S41b
	Limnephilidae Gen. sp.	Lim gsp	S18b, S30b
	Micropterna lateralis (Stephens, 1837)	Mic lat	S17a
	Philopotamus montanus (Donovan, 1813)	Phil mon	S27a
	Plectrocnemia sp.	Ple sp	S17a, S17c
	Rhyacophila dorsalis (Curtis, 1834)	Rhy dor	S09a, S09b, S09c, S11b, S14c, S17a, S17b, S17c, S18c, S19b, S19c, S21b, S21c, S24b, S24c, S30c, S31b, S31c, S37a, S37c
	Sericostoma personatum (Kirby & Spence, 1826)	Ser per	S03c, S15c, S17a, S17b, S21c, S30b, S30c, S38b
	Sericostoma sp.	Ser sp	S19b
	Stenophylax permistus McLachlan, 1895	Ste per	S03b, S17b, S18b, S31b
	Wormaldia subnigra McLachlan, 1865	Wor sub	S26a, S32a, S34a
Turbellaria	*Dugesia* sp.	Dug sp	S09b, S21b, S30a, S39b, S41c

a - spring (April 2021), b - autumn (October 2021) and c - summer (August 2022)

In autumn, a slightly higher diversity (H') value than in summer, but lower than in spring. This indicates the elimination of some species from the systems due to both the drying up of the waters and changing water parameters due to increasing air temperatures. The highest diversities (H') in autumn were calculated at sites 17 (2.28) and 13 (2.11). While the most homogenous distributions in autumn were observed at sites 17 (E = 0.50) and 13 (E = 0.46), non-homogenous distributions were observed at sites 8 (0.04) and 16 (0.11) (Table 5).

The difference in diversity among sites with the same taxon numbers depends on the different distribution patterns of individuals of the taxa. Although the same number of taxa were found (S = 16) in four sites (17, 18, 27, and 40) during the summer period, the species diversity started to decrease when the number of individuals increased. The "evenness" (E) values of the same sites decreased as the number of individuals increased. "Evenness" describes the variability in species abundances (Magurran 2004). A community in which all species have approximately equal numbers of individuals (or similar biomasses) would be rated as extremely even. Conversely, a large disparity in the relative abundances of species would result in the descriptor "uneven" (Magurran 2004). Although the lowest number of taxa were found in autumn, the high (E) value indicates a more homogeneous distribution of the

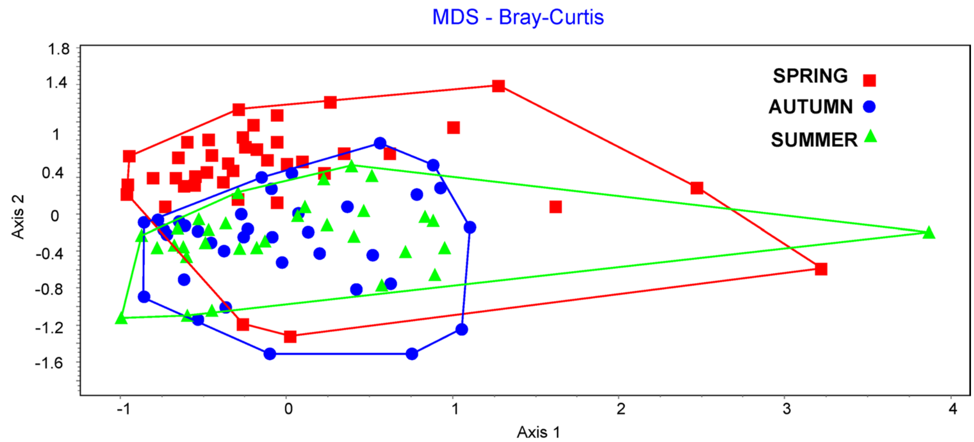

Fig. 2 Graphic representation of ANOSIM results using Non-metric Multidimensional Scaling of the similarity (Bray–Curtis) for the macroinvertebrate composition among the spring, summer, and autumn seasons

species compared to summer. The Shannon diversity index calculates diversity values independently from the number of individuals, while the evenness index gives important results by testing whether the species are homogeneously distributed. As expected, the representation of species in a population with a relatively equal number of individuals is an indicator of ecosystem health. Considering taxon richness, it is seen that the most taxa were found in spring (114), and the fewest were found in autumn (93). However, when the diversity index values calculated according to

Table 4 SIMPER and ANOSIM results for macroinvertebrate community composition between autumn (A), spring (Sp) and summer (Su) sampling sites

	SIMPER (between groups)					ANOSIM	
Autumn & Spring	Av. Abund	Av. Abund	Av. Diss./%	Contrib./%	Cum./%	*R*	*p*
(Av. Diss.: 88.61%)	(A)	(Sp)	(A & Sp)				
Baetis rhodani	28.61	31.10	18.09	20.42	20.42	0.23	**0.001**
Gammarus balcanicus	43.28	0.00	13.04	14.71	35.13		
Caenis macrura	3.53	1.58	3.16	3.57	38.70		
Autumn & Summer	Av. Abund	Av. Abund	Av. Diss./%	Contrib./%	Cum./%	*R*	*p*
(Av. Diss.: 84.61%)	(A)	(Su)	(A & Su)				
Gammarus balcanicus	43.28	74.09	17.85	21.10	21.10	0.02	0.16
Baetis rhodani	28.61	51.41	16.47	19.47	40.57		
Caenis macrura	3.53	10.28	5.33	6.30	46.86		
Spring & Summer	Av. Abund	Av. Abund	Av. Diss./%	Contrib./%	Cum./%	*R*	*p*
(Av. Diss.: 88.21%)	(Sp)	(Su)	(Sp & Su)				
Baetis rhodani	31.10	51.41	19.78	22.42	22.42	0.24	**0.001**
Gammarus balcanicus	0.00	74.09	12.13	13.76	36.18		
Caenis macrura	1.58	10.28	5.68	6.44	42.62		
	SIMPER (within groups)						
Autumn (Av. Sim: 15,06%)	Av. Abund	Av. Sim./%	Contrib./%	Cum./%			
Baetis rhodani	28.61	7.08	46.96	46.96			
Gammarus balcanicus	43.28	3.99	26.49	73.45			
Hydropsyche instabilis	3.69	1.44	9.54	82.99			
Spring (Av. Sim: 15.63%)							
Baetis rhodani	31.10	12.48	79.81	79.81			
Simulium sp.	4.98	1.03	6.61	86.41			
Melanopsis buccinoidea	2.83	0.26	1.69	88.10			
Summer (Av. Sim: 15.17%)							
Baetis rhodani	51.41	8.01	52.81	52.81			
Gammarus balcanicus	74.09	2.52	16.64	69.46			
Hydropsyche instabilis	5.63	1.78	11.76	81.22			

Table 5 The number of individuals (N), taxa (S) and Shannon–Wiener diversity (H') and Evenness (E) values for macroinvertebrates collected in 44 sites according to season

Site	Seasons											
	Spring				Summer				Autumn			
	N	S	H'	E	N	S	H'	E	N	S	H'	E
S01	77	4	0.93	0.20	51	5	1.24	0.27	55	3	0.93	0.21
S02	15	5	1.36	0.29	147	8	1.52	0.33	97	13	1.93	0.43
S03	148	6	0.71	0.15	231	12	1.68	0.36	139	7	1.20	0.26
S04	23	5	1.15	0.24	135	13	1.43	0.31	46	10	2.06	0.46
S05	14	4	0.90	0.19	*	*	*	*	*	*	*	*
S08	2	1	0.00	0.00	46	2	0.10	0.02	313	7	0.18	0.04
S09	38	5	1.04	0.22	294	8	1.12	0.24	145	7	1.36	0.30
S10	129	14	1.85	0.39	*	*	*	*	*	*	*	*
S11	*	*	*	*	177	12	1.53	0.33	152	10	1.42	0.31
S12	168	7	0.52	0.11	284	6	0.85	0.18	193	12	1.37	0.30
S13	101	13	1.54	0.32	135	19	2.12	0.46	28	10	2.11	0.46
S14	20	7	1.73	0.37	70	8	1.06	0.23	55	10	1.47	0.33
S15	157	12	1.11	0.23	*	*	*	*	99	13	1.85	0.41
S16	62	3	0.65	0.14	1538	6	0.15	0.03	561	5	0.48	0.11
S17	93	15	2.13	0.45	381	16	1.35	0.29	171	18	2.28	0.50
S18	55	12	1.66	0.35	297	16	1.77	0.38	233	14	1.74	0.38
S19	102	11	1.84	0.39	369	12	1.01	0.22	240	12	1.24	0.27
S20	10	3	0.85	0.18	80	3	0.56	0.12	190	7	1.15	0.25
S21	208	7	0.23	0.05	554	10	0.99	0.21	177	12	1.76	0.39
S22	41	4	0.64	0.13	44	7	1.70	0.36	19	3	0.63	0.14
S23	30	10	1.77	0.37	*	*	*	*	5	2	0.67	0.15
S24	206	9	1.28	0.27	342	12	1.21	0.26	155	11	1.30	0.29
S25	16	8	1.84	0.39	*	*	*	*	67	13	2.06	0.45
S26	36	10	1.90	0.40	*	*	*	*	*	*	*	*
S27	88	20	2.46	0.52	143	16	2.06	0.44	163	12	1.70	0.37
S28	76	13	1.86	0.39	71	4	0.93	0.20	*	*	*	*
S29	261	16	2.10	0.44	12	4	1.08	0.23	153	10	1.07	0.24
S30	116	10	1.48	0.31	337	11	1.70	0.37	104	9	1.65	0.36
S31	53	9	1.30	0.27	115	17	2.20	0.47	265	14	1.58	0.35
S32	93	15	2.10	0.44	*	*	*	*	*	*	*	*
S33	87	7	0.42	0.09	118	14	2.04	0.44	135	11	1.92	0.42
S34	78	13	1.72	0.36	*	*	*	*	*	*	*	*
S35	76	14	1.65	0.35	107	11	1.46	0.31	52	10	1.90	0.42
S36	55	4	1.33	0.28	60	11	2.00	0.43	70	7	1.43	0.32
S37	44	16	1.82	0.38	52	13	1.99	0.43	104	12	1.91	0.42
S38	134	17	2.08	0.44	66	12	1.94	0.42	72	7	1.60	0.35
S39	176	7	0.65	0.14	70	18	2.24	0.48	69	9	1.45	0.32
S40	*	*	*	*	206	16	1.53	0.33	143	6	1.15	0.25
S41	73	7	1.16	0.24	100	8	1.25	0.27	45	7	1.25	0.27
S42	33	7	1.67	0.35	53	8	1.43	0.31	122	8	1.69	0.37
S43	80	9	1.13	0.24	*	*	*	*	96	9	1.65	0.36
S44	66	3	0.96	0.20	*	*	*	*	81	6	1.13	0.25
All samples	3340	114	3.01	0.63	6685	105	2.45	0.53	4814	93	2.78	0.61

* represents no specimens or dried site bed

all sites were examined, the highest value was observed in spring (3.01), and the lowest one in summer (2.45) (Table 5).

Considering the three-season sampling sites, in two sites in spring, ten sites in summer and six sites in autumn no macroinvertebrate specimens were found, which could be related to drought. Similar findings also show that diversity values in summer were lower than in the other seasons. When examining the total number of individuals, the highest number (6685) was found in summer and the lowest one (3340) was found in spring. During summer, the ratio of the number of individuals of gammarids to other taxa was 35%. Similarly, the ratio in autumn was 32%.

The total number of individuals in spring was lower than in the other periods as gammarids were not present in the spring sampling period.

The ecological quality ratio (EQR) of the sites was calculated using the Ceyhan Basin Multimetric Index (MMI-C) (Table 6). The highest ecological quality ratios were found at sites 17 (1.00) and 19 (0.99) in spring when the lowest EQR values were calculated for sites 1 (0.19) and 44 (0.26). In summer, the highest EQR ratios were calculated for sites 17 (0.93) and 30 (0.93), while the smallest values were calculated for sites 8 (0.04) and 16 (0.12) sites. Sites 17 (1.00) and 30 (0.98) had the highest EQS values in autumn, sites 8 (0.11) and 16 (0.19) displayed the lowest values. Considering the average of the three-period EQR values, the highest values were calculated

Table 6 MMI-C (Ceyhan Basin Multimetric index) – EQR (Ecological Quality Ratio) and ES (Ecological Status) values of sampling sites in the present study. EQR values are between 1 and 0

Site	Spring		Summer		Autumn		Final	Final
	MMI-C EQR	ES	MMI-C EQR	ES	MMI-C EQR	MMI-C ES	EQR	ES
S01	0.19	Bad	0.22	Bad	0.19	Bad	0.20	Bad
S02	0.78	Good	0.80	Good	0.90	Good	0.82	Good
S03	0.74	Moderate	0.83	Good	0.73	Moderate	0.76	Good
S04	0.72	Moderate	0.91	Good	0.94	Good	0.85	Good
S05	0.56	Moderate		*		*	0.56	Moderate
S08	0.27	Bad	0.04	Bad	0.11	Bad	0.14	Bad
S09	0.66	Moderate	0.59	Moderate	0.75	Good	0.67	Moderate
S10	0.85	Good		*		*	0.85	Good
S11	*	*	0.89	Good	0.82	Good	0.85	Good
S12	0.67	Moderate	0.43	Bad	0.87	Good	0.66	Moderate
S13	0.76	Good	0.64	Moderate	0.84	Good	0.75	Good
S14	0.65	Moderate	0.59	Moderate	0.73	Moderate	0.66	Moderate
S15	0.64	Moderate		*	0.55	Moderate	0.60	Moderate
S16	0.26	Bad	0.12	Bad	0.19	Bad	0.19	Bad
S17	1.00	High	0.93	Good	1.00	High	0.98	Good
S18	0.97	Good	0.90	Good	0.95	Good	0.94	Good
S19	0.99	High	0.56	Moderate	0.64	Moderate	0.73	Moderate
S20	0.52	Poor	0.22	Bad	0.63	Moderate	0.45	Poor
S21	0.61	Moderate	0.79	Good	0.86	Good	0.75	Good
S22	0.61	Moderate	0.79	Good	0.63	Moderate	0.68	Moderate
S23	0.68	Moderate		*	0.62	Moderate	0.65	Moderate
S24	0.88	Good	0.76	Good	0.93	Good	0.86	Good
S25	0.68	Moderate		*	0.85	Good	0.76	Good
S26	0.61	Moderate		*		*	0.61	Moderate
S27	0.87	Good	0.87	Good	0.68	Moderate	0.80	Good
S28	0.63	Moderate	0.59	Moderate		*	0.61	Moderate
S29	0.78	Good	0.76	Good	0.43	Bad	0.65	Moderate
S30	0.80	Good	0.93	Good	0.98	High	0.90	Good
S31	0.91	Good	0.91	Good	0.94	Good	0.92	Good
S32	0.89	Good		*		*	0.89	Good
S33	0.68	Moderate	0.89	Good	0.91	Good	0.83	Good
S34	0.73	Moderate		*		*	0.73	Moderate
S35	0.51	Poor	0.71	Moderate	0.63	Moderate	0.62	Moderate
S36	0.38	Bad	0.71	Moderate	0.41	Bad	0.50	Poor
S37	0.85	Good	0.92	Good	0.91	Good	0.89	Good
S38	0.93	Good	0.79	Good	0.82	Good	0.85	Good
S39	0.54	Poor	0.58	Moderate	0.55	Moderate	0.56	Moderate
S40			0.78	Good	0.41	Bad	0.59	Moderate
S41	0.75	Moderate	0.79	Good	0.73	Moderate	0.76	Good
S42	0.47	Poor	0.45	Poor	0.70	Moderate	0.54	Moderate
S43	0.58	Moderate		*	0.43	Bad	0.51	Poor
S44	0.26	Bad		*	0.28	Bad	0.27	Bad

Index values	Ecological Quality Status
0.98 and above	High
0.75-0.97	Good
0.54-0.74	Moderate
0.46-0.53	Poor
0.45 and below	Bad

Class boundaries are shown at the bottom of the table. * Indicates the sites that totally dried up

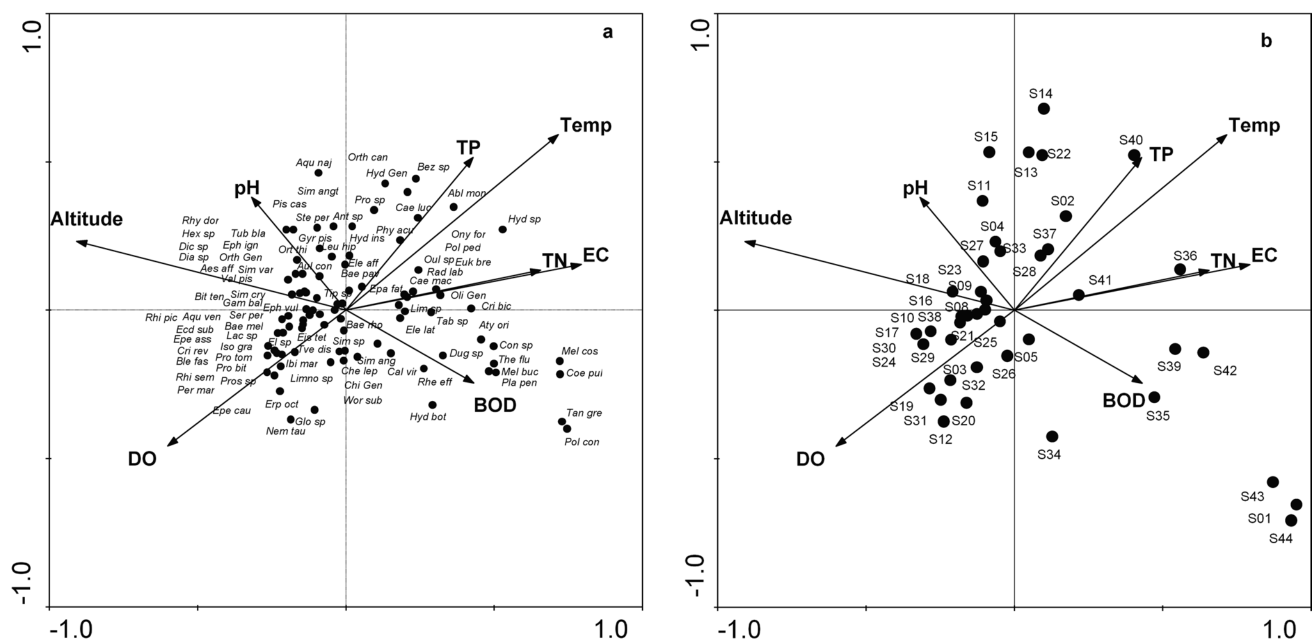

Fig. 3 Canonical Correspondence Analysis diagrams for species (**a**) and for sampling sites (**b**) showing relationships between macroinvertebrates, sites, and physicochemical variables. For species codes see Table 3. ●: Species; TN: total nitrogen; TP: total phosphorus EC: electrical conductivity; DO: dissolved oxygen; Temp: water temperature. BOD: biological oxygen demand

for sites 17 (0.98) and 18 (0.94) and the lowest values for sites 8 (0.14 and 16 (0.19). As a result, site 17 had the best ecological status and site 8 the worst ecological status (Table 6).

While the number of sites with “good” and “high” ecological status (ES) values was 14 in spring, 18 sites were classified as "good" in summer. There were two sites with “high” and 14 sites with “good” ES in autumn. In total, there were 19 “good”, 16 “moderate”, 3 “poor” and 4 “bad” sites. Thus, it seems that a significant part of the sampled sites were far from achieving good ecological status. The altitude (a.s.l) of almost all sites with “good” ecological quality status is approximately over 1000 m, indicating that the sites located at high-altitude areas in the Ceyhan Basin are in better condition. Similarly, sites with "poor" or "moderate" ecological status appear to be located downstream of rivers and in urbanized areas (Tables 1 and 6). Ceyhan Multimetric Index was used for the first time in this study and provided important data for subsequent studies. Therefore, these results were not compared with previous findings.

According to the results of Canonical Correspondence Analysis (CCA), the eigenvalues of the first two axes were as follows: 0.45 and 0.20, respectively. The first two axes of CCA elucidated a moderately low relationship (51.4%) between species distribution and environmental variables. In the CANOCO 4.5 program, the importance of the variables was calculated according to the best variance explanation percentages by using the forward selection method (Leps and Smilauer 2003). The three most important variables were altitude, temperature and pH. With the "collinearity test" application in the ECOM program, the variables that were correlated with each other were eliminated, and distribution analysis was performed using eight variables suitable for these characteristics. According to the CCA diagram, dissolved oxygen is positioned separately from the other variables on the opposite side of temperature. This also indicates the negative relationships between dissolved oxygen and temperature (Fig. 3a). *Coenagrion pulchellum* (Odonata), *Tanytarsus gergarius* (Chironomidae), and *Polypedilum convictum* (Chironomidae) showed close associations with BOD, which is inversely correlated with altitude. It is known that these species can live in low-oxygen environments (Hynes 1970; Hellawell 1986). The species *Epeorus caucasicus* (Ephemeroptera), *Prosimulium tomosvaryi* (Simuliidae), *Blepharicera fasciata* (Diptera), and *Rhithrogena semicolorata* (Ephemeroptera) were located in the same direction as dissolved oxygen but in the opposite direction of temperature and other nutrient salts (total nitrogen and total phosphorus). These results support the indicator properties of these species in well-oxygenated, clean waters (Hynes 1970) (Fig. 3a).

The CCA diagram shows that sites with low ecological quality ratios (e.g., S01, S44, S43, S35, S39) are directly related to BOD values. Similarly, sites with high ecological quality ratios (e.g., S17, S18, S31, S30) appear to be directly related to their dissolved oxygen values (Fig. 3b). It is known that sensitive macroinvertebrates disappear at low dissolved oxygen values. In this case, indicator taxa for good ecological status disappeared, and EQR values decreased (Hellawell 1986).

Conclusion

Results from this study carried out in the Ceyhan River Basin reveal that sites with bad ecological status are located near cities. As the altitude increases, the number of sites in good status starts to increase. Altitude is a variable that affects the distribution of species in this area. Generally, MMI-C values were high in areas with high diversity (H') values. The biotic and abiotic data obtained in this study will provide essential information for type-specific multimetric index development studies inside and outside of Turkey. Additionally, the macroinvertebrate fauna of a basin was postulated for the first time in Turkey. It is necessary to carry out studies in developing countries such as Turkey to detect aquatic macroinvertebrates throughout the country and reveal the bioindicator characteristics of these organisms for use in ecological assessment studies. With such studies, it will be possible to conduct ecological assessment studies much faster, more effectively, and at a lower cost than by using abiotic data. Therefore, the number of studies similar to the current study should be increased in the future.

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Declarations

Conflict of interest The authors declare that they have no conflicts of interest disclosed in this work.

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