

Evaluation of the Water Quality of the Ilke Stream According to Biotic Indices Based on Benthic Macroinvertebrates (West Anatolia, Turkey)

Alperen Ertaş^{a,*} (ORCID: 0000-0001-8510-6100), Merve Yaşartürk^a (ORCID: 0000-0002-9786-4512),
Bulent Yorulmaz^b (ORCID: 0000-0003-1654-8874), and Ferah Sayim^a (ORCID: 0000-0002-1496-8878)

^a Ege University, Faculty of Science, Department of Biology, Bornova, İzmir, 35100 Turkey

^b Muğla Sıtkı Koçman University, Faculty of Science, Department of Biology, Kötekli, Muğla, Turkey

*e-mail: alperenertas@hotmail.com

Received March 3, 2022; revised April 4, 2022; accepted April 7, 2022

Abstract—Benthic macroinvertebrates can provide an integrated picture of environmental changes. Health of freshwaters can be assessed based on measured changes in the ecological structure of benthic macroinvertebrates. During the study period, 33 taxa were determined in Ilke Stream. As a result of principle component analysis (PCA), mainly nine components ($T^{\circ}\text{C}$, EC, TDS, BOD_5 , $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, $\text{PO}_4\text{-P}$ and Cl^-) account for 92% of the total variance among the water quality parameters. As a result of the UPGMA analysis, the highest similarity value was observed between the 1th and 2nd sampling points. SI, BMWP, ASPT and BBI indices were more proper than FBI index to determine the water quality of Ilke Stream. The results indicate that these indices should be adapted based on the ecological, geomorphological and environmental features of the regions.

Keywords: Biotic Indices, Biomonitoring, Bioassessment, Benthic Macroinvertebrates, Water Quality

DOI: 10.1134/S199542552205002X

INTRODUCTION

Surface freshwater resources are increasingly being subjected to pollution and a wide range of pollutants such as nutrients, biocides, pathogenic microorganisms, industrial and household chemicals, metals and pharmaceutical products can be found fresh waters (Bedoya et al., 2009; Ertaş et al., 2020; Qadri and Faiq, 2020; Sukatar et al., 2020). A comprehensive range of legislation has been established in Europe for conservation of freshwaters. Water Framework Directive (WFD), which represents the single most important piece of EU legislation relating to the quality of fresh and coastal waters, aims to attain good ecological status (WFD, 2000).

The water quality of lotic ecosystems should be assessed by the use of physical, chemical and biological parameters (Atique et al., 2019). The use of traditional methods in running waters, by evaluating the physical and chemical parameters, reflect instantaneous situation and insufficient because the obtained data provides information restricted to the sampling time (Keck et al., 2017). So, biomonitoring techniques using bioindicators were developed. The use of benthic macroinvertebrates in assessing the water quality of lotic ecosystems has gained much recognition among biologists and there have been many different

biotic indices for such assessments (Birk et al., 2012; Chang et al., 2014). In Turkey the assessment of water quality is based mainly on physicochemical variables. An ecosystem analysis using benthic macroinvertebrates together with physical and chemical variables has recently been conducted in Turkey (Girgin and Kazancı, 1994; Kazancı and Girgin, 2001; Kalyoncu et al., 2008; Zeybek et al., 2014; Yorulmaz et al., 2015; Duran, 2011; Zeybek, 2017; Özbek et al., 2018; Akay and Dalkıran, 2019; Ertaş et al., 2020; Yorulmaz and Ertaş, 2021; Ertaş and Yorulmaz, 2021). However, biotic indices were developed for countries or regions and their effective application to Turkish ecosystems requires significant research. Most of the biological approaches are particular to specific geographic regions. Various countries use various indices with different levels of identification of organisms, and different assumptions of final interpretation of results (Korycińska and Królak, 2006). The Saprobe indices in Germany, Biological Monitoring Working Party-BMWP and Average Score Per Taxon-ASPT in England, Belgian Biotic Index-BBI in Belgium, seem to give the most reliable results specific to geographic regions. The Turkish-BMWP biotic index (TR-BMWP), the first assessment method using benthic invertebrates, has recently been developed (Kazancı et al., 2016).

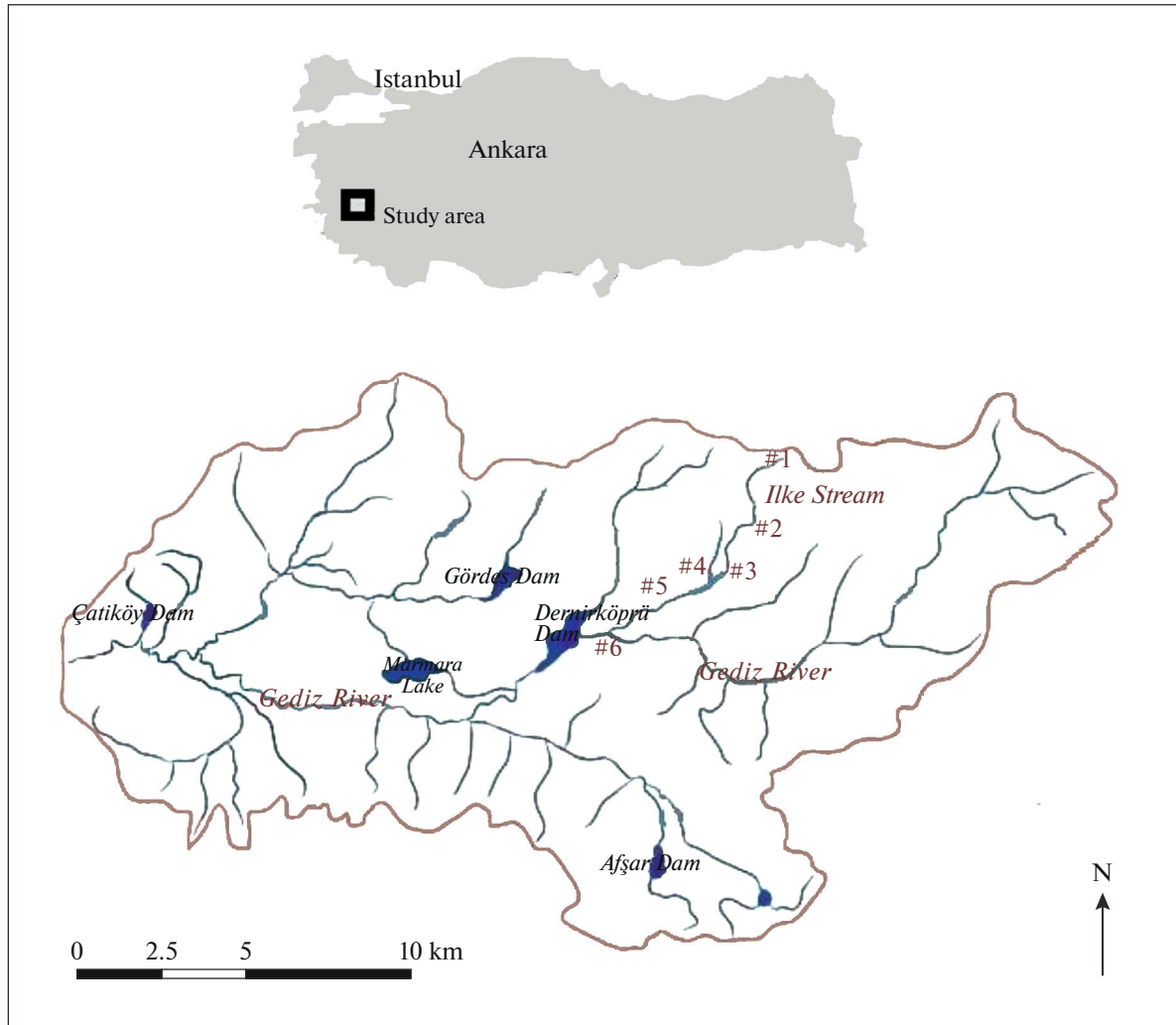


Fig. 1. Sampling area and sampling points.

Benthic macroinvertebrates response to the change of water quality and have been widely used (Hering et al., 2006; Yorulmaz et al., 2015; Gültekin et al., 2017). Biological composition of the ecosystem is an important component of determination of water quality (Graf et al., 1995; Custodio and Penaloza, 2019; Tirsch and Male, 1984; Sanders et al., 1983; Ward and Loftis, 1986).

The industrial development, intensive agricultural activities and rapidly increasing population in the Gediz River Basin cause pollution on the surface waters and deterioration of the water quality (Şenol et al., 2016). Besides, the pollution situation and the ecological fauna of the upper basin of Gediz River have not been researched yet. With this respect, it is aimed to determine the water quality of Ilke Stream, located in upper basin of Gediz River, by using benthic macroinvertebrates and physicochemical parameters. The other objective of this study is to compare the results of water quality indices and to determine the

most adequate estimate of water quality in accordance with physicochemical characteristics of the examined watercourse.

MATERIALS AND METHODS

Gediz River Basin is located between $38^{\circ}04'39''13'$ N with $26^{\circ}42'29''45'$ E. Ilke Stream is one of the most important streams of Gediz River Basin which has approximately 17500 km^2 drainage area and 1.95 billion m^3 surface water potential. Ilke Stream is fed by the Gümele and Alağaç creeks and reaches the Gediz River (Fig. 1). This study was carried out between January 2019 and February 2020. Six sampling points were chosen and samplings were carried out monthly. Sampling points were chosen according to criteria for selecting operational monitoring sites given in WFD Annex V 1.3.2. (WFD, 2000).

Benthic macroinvertebrates were sampled monthly, using a classic bottom kick net with 91×30 size and

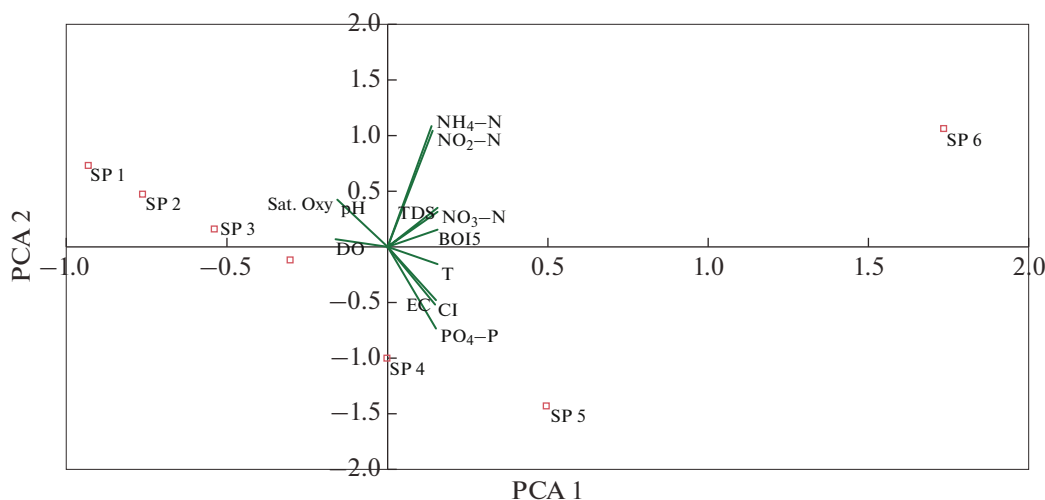


Fig. 2. Biplots for PCA analysis of physicochemical variables.

250 μm mesh according to the literature (AQEM Consortium, 2002). Collected organisms were immediately fixed in formaldehyde (4%) in the field and then transferred to 70% ethyl alcohol. The benthic macroinvertebrates were first sorted out then identified to the lowest possible taxon (species, genus or families) and counted under a stereomicroscope. Simultaneous with macroinvertebrate samplings, water samples were taken and analysed for $\text{PO}_4\text{-P}$, $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, Cl^- and BOD_5 parameters, using spectrophotometer. All analyses were done by following the standard methods (APHA, 1998). Water temperature ($^\circ\text{C}$), pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), oxygen saturation (Sat. O_2) were measured in the field by portable equipment.

Water quality assessment by physicochemical parameters was done according to Klee (1991). Saprobe Index (SI), several modifications of Biological Monitoring Working Party (BMWP), BMWP Original (BMWP-O), BMWP Spanish (BMWP-S), BMWP Hungarian (BMWP-H), BMWP Polish (BMWP-P), BMWP Czech (BMWP-C), BMWP Greek (BMWP-G) and Average Score Per Taxon (ASPT), ASPT Original (ASPT-O), ASPT Hungarian (ASPT-H), ASPT Czech (ASPT-C), Belgian Biotic Index (BBI), Family Biotic Index (FBI), Percentage of Ephemeroptera, Plecoptera, Trichoptera taxa (EPT-Taxa [%]), Ratio of EPT taxa and Oligochaete (EPT/OL [%]), Simpson's (SDI), Shannon-Wiener (SWDI) and Margalef (MDI) diversity indices were applied on benthic macroinvertebrate data set by using ASTERICS Software Programme. Similarity analyses were assessed by using Bray-Curtis similarity index (Sommerfield, 2008; Yoshioka, 2008). Pearson's based correlation analysis was undertaken by using SPSS version. Principal component analysis (PCA) was applied to determine the effectiveness of physicochemical parameters.

RESULTS

The mean, standard deviation and range values of physicochemical parameters were given in Table 1.

The results of correlation matrix of physicochemical based on PCA and the biplots, which are the graphical representation of factor loadings in different components (Component 1 and Component 2) are given in Fig. 2. The sampling points function to determine the location of the ordinations. In the current study, the eigenvalues are greater than 1 at the Component 1 and Component 2. According to PCA, 92% variance between components was determined. The PCA 1 has positive loading on temperature, $T^\circ\text{C}$, EC, TDS, BOI_5 , $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, $\text{PO}_4\text{-P}$ and Cl^- and negative loading on pH, DO and Sat. O_2 . Positive loading on $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$ have been considered to be related to organic pollution. Thus, components are representing pollution from agricultural and domestic wastewaters.

A total of 33 taxa and 4861 individuals were revealed. The maximum numbers of individuals were collected at sampling point 1, while the minimum numbers of individuals were collected at sampling point 5. Lowest numbers of individuals were collected in autumn while highest numbers of individuals were collected in spring (Fig. 3).

Ephemeroptera was dominant order at the all sampling points along in four season. Trichoptera was the second dominant order at the sampling points 1, 2, 3 and 4, respectively. Oligochaeta and Diptera are the most dominant benthic macroinvertebrate orders at the sampling point 6 (Fig. 4).

As a result of the UPGMA analysis, the sampling points 1 and 2 were the most similar to each other according to physicochemical parameters (97%) and benthic macroinvertebrates (93%). The second most similar sampling points to each other was determined

Table 1. Range, Mean and Standard deviations of physicochemical parameters

Parameters		SP 1	SP 2	SP 3	SP 4	SP 5	SP 6
$T, ^\circ\text{C}$	R	9.0–13.0	9.0–13.0	10.0–13.0	11.0–15.0	13.0–18.0	14.0–20
	M \pm SD	10.7 \pm 2.06	11.2 \pm 2.06	11.7 \pm 1.50	13.0 \pm 1.82	15.7 \pm 2.21	18.2 \pm 2.87
pH	R	6.9–7.0	6.9–7.0	6.85–6.90	6.8–6.9	6.75–6.9	6.7–6.8
	M \pm SD	6.9 \pm 0.05	6.9 \pm 0.05	6.8 \pm 0.02	6.85 \pm 0.05	6.8 \pm 0.06	6.76 \pm 0.04
EC, $\mu\text{S cm}^{-1}$	R	220–287	227–307	236–346	258–373	295–394	318–401
	M \pm SD	240 \pm 31.3	254 \pm 35.8	277 \pm 47.7	304 \pm 48.8	338 \pm 42.6	367 \pm 36.1
TDS, ppt	R	122–168	128–183	136–199	144–216	169–249	226–325
	M \pm SD	140 \pm 19.6	148 \pm 23.9	157 \pm 28.5	176 \pm 30.0	201 \pm 34.0	287 \pm 42.7
DO, mg L^{-1}	R	9.33–11.2	9.01–10.8	8.76–10.3	8.23–9.7	8.04–9.24	6.94–8.11
	M \pm SD	10.0 \pm 0.86	9.73 \pm 0.87	9.46 \pm 0.77	8.96 \pm 0.82	8.64 \pm 0.62	7.47 \pm 0.56
Sat. $\text{O}_2, \%$	R	107–134	101–131	93–126	91–115	87–99	76–88
	M \pm SD	117.7 \pm 12.1	112.7 \pm 13.5	105 \pm 15.3	99.2 \pm 10.9	92.5 \pm 5.19	82 \pm 5.88
$\text{BOD}_5, \text{mg L}^{-1}$	R	1.53–1.74	1.59–1.80	1.62–2.15	1.71–2.44	1.84–2.75	2.20–3.04
	M \pm SD	1.65 \pm 0.09	1.71 \pm 0.09	1.84 \pm 0.22	1.96 \pm 0.32	2.18 \pm 0.39	2.75 \pm 0.38
$\text{NH}_4\text{-N}, \text{mg L}^{-1}$	R	0.07–0.09	0.07–0.09	0.08–0.10	0.09–0.12	0.12–0.21	1.48–2.43
	M \pm SD	0.08 \pm 0.008	0.08 \pm 0.009	0.09 \pm 0.009	0.10 \pm 0.01	0.18 \pm 0.04	2.02 \pm 0.43
$\text{NO}_2\text{-N}, \text{mg L}^{-1}$	R	0.003–0.01	0.004–0.01	0.005–0.01	0.012–0.02	0.02–0.04	0.2–0.27
	M \pm SD	0.006 \pm 0.002	0.006 \pm 0.002	0.007 \pm 0.002	0.01 \pm 0.003	0.02 \pm 0.008	0.23 \pm 0.03
$\text{NO}_3\text{-N}, \text{mg L}^{-1}$	R	0.86–1.03	0.97–1.18	1.13–1.32	1.43–1.78	2.01–2.57	3.97–4.63
	M \pm SD	0.96 \pm 0.07	1.11 \pm 0.09	1.24 \pm 0.08	1.66 \pm 0.16	2.35 \pm 0.24	4.3 \pm 0.35
Cl, mg L^{-1}	R	1.19–1.36	1.26–1.47	1.68–1.99	1.93–2.99	2.24–3.05	2.97–3.97
	M \pm SD	1.25 \pm 0.07	1.38 \pm 0.09	1.88 \pm 0.14	2.56 \pm 0.47	2.77 \pm 0.36	3.50 \pm 0.49
$\text{PO}_4\text{-P}, \text{mg P L}^{-1}$	R	0.83–1.03	0.95–1.24	1.06–1.35	1.39–2.57	1.85–2.86	2.09–2.91
	M \pm SD	0.91 \pm 0.08	1.03 \pm 0.13	1.15 \pm 0.13	1.77 \pm 0.54	2.13 \pm 0.48	2.33 \pm 0.38

R: Range; M: Mean; SD: Standard deviation.

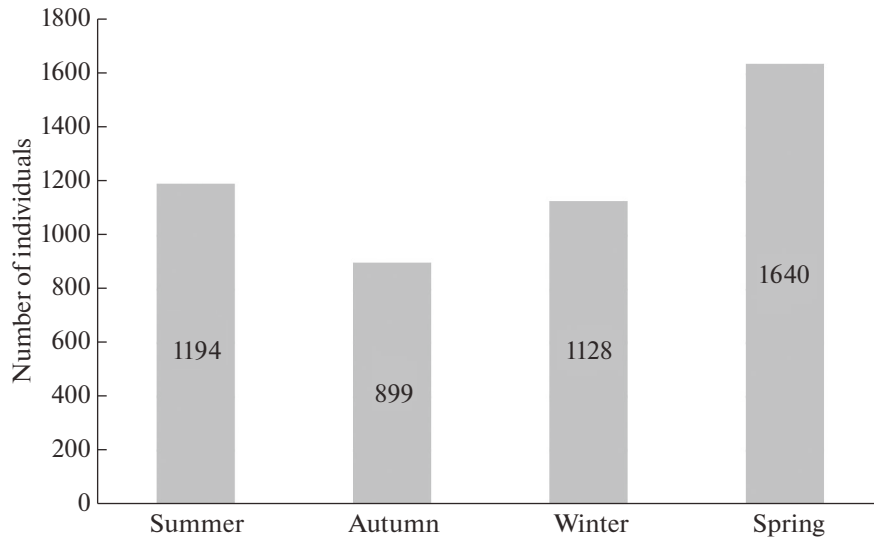


Fig. 3. The total numbers and percent of benthic macroinvertebrates.

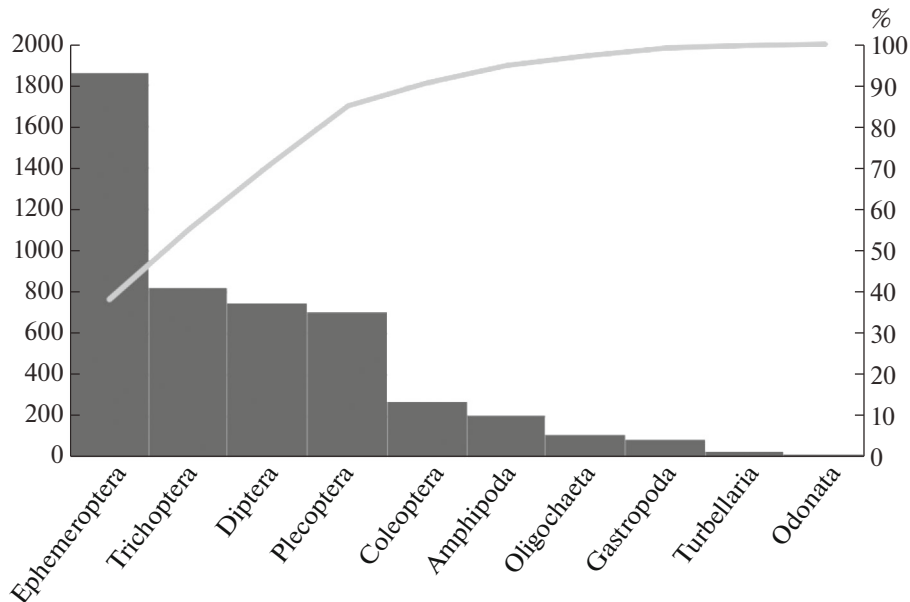


Fig. 4. Distribution of taxa on order base.

between the 2-3 (96%) and 1-3 (95%) according to physicochemical parameters (Fig. 5). Sampling points 2-3 were similar according to benthic macroinvertebrates (88%).

The average biological quality scores of biotic indices and water quality classes are shown in Table 2.

In this study, the random sample cases (10% select case) were applied on the biotic and diversity indices to verify datasets (Table 3). In this correlation analysis, the significant negative correlation was determined between SI and BMWP-C ($r = -0.925, p < 0.01$); SI and BMWP-G ($r = -0.938, p < 0.01$); SI and ASPT-O

($r = -0.979, p < 0.01$); SI and ASPT-C; SI and BBI ($r = -0.964, p < 0.01$). On the other hand, the significant positive correlation was determined between SI and FBI ($r = 0.949, p < 0.01$). Also, significant positive correlations were determined between BMWP-S and BMWP-H ($r = 0.980, p < 0.01$); BMWP-S and BMWP-C ($r = 0.937, p < 0.01$). BMWP-P showed significant positive correlation with BMWP-G ($r = 0.945, p < 0.01$) while BMWP-P showed significant negative correlation with FBI ($r = -0.918, p < 0.01$). ASPT-O showed significant positive correlation with ASPT-C ($r = 0.971, p < 0.01$) while ASPT-O showed

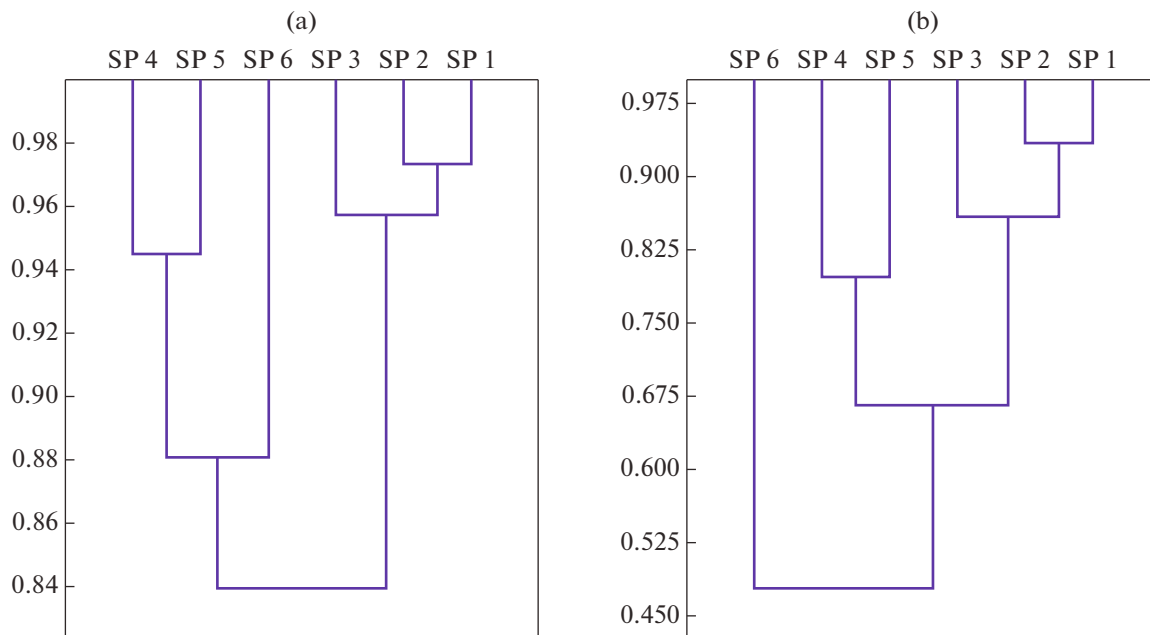


Fig. 5. The similarities of the sampling points (a) Physicochemical parameters, (b) Benthic macroinvertebrates).

significant negative correlation with FBI ($r = -0.977$, $p < 0.01$). ASPT-H showed significant positive correlation with ASPT-C ($r = 0.957$, $p < 0.01$) and BBI ($r = 0.978$, $p < 0.01$). ASPT-C showed significant positive correlation with BBI ($r = 0.985$, $p < 0.01$). SWDI showed significant positive correlation with SDI ($r = 0.985$, $p < 0.01$). According to Pearson's based correlations, The SI, BMWP, ASPT and BBI indices were the more adequate estimate of water quality in Ilke Stream.

DISCUSSION

For aquatic life in streams, dissolved oxygen concentrations are important variables that influence the composition of freshwater communities (Bremond and Vuichard, 1973; EPA, 1997; Nikolsky, 1963; Wetzel, 2001). In this study, highest DO and Sat. O_2 values were observed at the upstream stations of the Ilke Stream. The BOD_5 is of great importance as it is a measure of organic contamination in water. The BOD_5 value of a region gives the amount of organic matter in that region, in other words, the amount of organic pollutants (Kocataş, 2008; Kalyoncu and Zeybek, 2011). In this study, highest BOD_5 values were observed at the downstream stations of the Ilke Stream. Yorulmaz et al. (2015) reported that the highest BOD_5 values were measured at the sampling points effected by the discharge of trout farms in their studies. Similarly, the fifth sampling point on Ilke Stream was chosen after the discharge point of trout farms, however BOD_5 values were relatively low when compared with other studies given above. The highest Cl^- , EC

and TDS values in this study were measured in sampling point 6 in the downstream area. Elements that limit efficiency in aquatic environments are mostly PO_4-P , NH_4-N , NO_2-N , NO_3-N (Moss et al., 1987; Zeybek and Kalyoncu, 2016; Özbek et al., 2018). Ammonium content increases by deterioration of organic materials, organic fertilizer and chemical fertilization with inorganic ammonium and discharge of domestic and industrial wastewater. Nitrite, which is formed as an intermediate product as a result of oxidation of ammonium nitrogen, is either absent or as trace in unpolluted waters. Nitrate is found in very small amounts in unpolluted waters (Tanyolaç, 2004). In this study, highest PO_4-P , NH_4-N , NO_2-N , NO_3-N values were observed at the downstream stations of the Ilke Stream.

Principal component analysis (PCA) was applied to reduce the dimensionality of a data set consisting of a large number of interrelated variables (Kazi et al., 2009; Najar and Khan, 2012; Shrestha and Kazama, 2007). In the present study, the PCA analysis showed a clear spatial and temporal division, and the sampled stations subdivide into two groups. PCA separates slightly downstream from unpolluted upstream and $T^{\circ}C$, EC, TDS, BOI_5 , NH_4-N , NO_2-N , NO_3-N , PO_4-P and Cl^- accounted for 92% of total variance. The last sampling points (SP 6) were separated from others with relatively lower pH and DO levels and higher nutrient levels which could be explained by organic pollution, originating from agricultural activities, aquaculture and urban waste waters.

In several studies on different streams and rivers, parallel to our findings, Insecta was found the most

Table 2 Average score values of indices and water quality classes

Metric	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6
Klee's (1991)	I–II	I–II	I–II	II	II	II–III
SI	1.625	1.616	1.72	1.688	1.728	1.946
	I–II	I–II	I–II	I–II	I–II	II
BMWP-O	129	128	120	120	125	117
	II	II	II	II	II	II
BMWP-S	136	135	132	127	127	124
	II	II	II	II	II	II
BMWP-H	129	127	126	119	119	118
	II	II	II	II	II	II
BMWP-P	151	149	141	141	135	128
	I	II	II	II	II	II
BMWP-C	126	120	120	120	117	117
	II	II	II	II	II	II
BMWP-G	1359	1356	1300	1341	1296	1253
	I–II	I–II	I–II	I–II	II	II
ASPT-O	6.944	6.882	6.667	6.667	6.737	6.143
	I	I	I	I	I	I
ASPT-H	6.632	6.556	6.611	6.611	6.684	6.143
	I	I	I	I	I	I
ASPT-C	7.526	7.50	7.421	7.421	7.45	6.864
	I	I	I	I	I	I
BBI	10	10	10	10	10	9
	I	I	I	I	I	I–II
FBI	4.50	4.50	4.70	4.80	4.70	5.10
	II	II	II	II	II	II–III
-EPT-Taxa [%]	82.358	81.194	75.131	65.918	52.672	32.485
-EPT/OL [%]	–	–	42.118	31.188	18.40	2.594
SDI	0.954	0.953	0.956	0.95	0.927	0.924
SWDI	3.156	3.139	3.178	3.078	2.786	2.838
MDI	4.009	3.85	3.936	3.771	3.761	3.514

dominant class (Kalyoncu et al., 2008; Kalyoncu and Zeybek, 2011; Zeybek et al., 2014; Gültekin et al., 2017; Özbek et al., 2018; Koşalşahin and Zeybek, 2019). According to Moisan and Pelletier (2008), Diptera and Oligochaeta are tolerant to pollution. Existent abundant of the organic matter are favourable for benthic macroinvertebrates such as Oligochaeta's (Rashid and Pandit, 2014). *Limnodrilus* sp. and *Tubifex tubifex* were found abundant at sampling points 5 and 6. These organisms are indicators for polysaprobic (heavy polluted) aquatic systems (Kalyoncu and Zeybek, 2011; Arslan et al., 2016; Zeybek, 2017). The members of Plecoptera and Trichoptera orders are sensitive to pollution; their number and species diversity decrease when pollution increases (Plafkin et al., 1989). On the other hand, Ephemeroptera species (eg *Baetis* sp.) have a wider range of tolerances (Tanyolaç,

2004). Ephemeroptera, Plecoptera and Trichoptera are the most dominant orders in the upstream sampling points (1, 2 and 3).

[%] EPT was one of the metrics that gave the best response to the physical and chemical variables of water in biomonitoring studies. According to Ode et al. (2005), the Ephemeroptera, Plecoptera and Trichoptera orders are sensitive to anthropogenic effects in aquatic ecosystems. For this reason, [%] EPT is one of the preferred metrics for water quality research (Hering et al., 2006; Oliveira et al., 2011; Helson and Williams, 2013; Huang et al., 2015). The highest [%] EPT-Taxa scores were obtained at the sampling points 1, 2 and 3 while the lowest [%] EPT-Taxa scores were obtained at the sampling point 6. The lowest [%] EPT- OL scores are obtained at the sampling

Table 3 Pearson's correlation assessment between indices

	SI	BMWP-O	BMWP-S	BMWP-H	BMWP-P	BMWP-C	BMWP-G	ASPT-O	ASPT-H	ASPT-C	BBI	FBI	SWDI	MDI	SDI
SI	1	-0.798	-0.812*	-0.693	-0.925**	-0.645	-0.938**	-0.979**	-0.850*	-0.964**	-0.921**	0.949**	-0.679	0.437	-0.676
BMWP-O		1	0.79	0.684	0.794	0.599	0.755	0.870*	0.594	0.74	0.62	-0.905*	0.328	-0.488	0.388
BMWP-S			1	0.980**	0.937**	0.786	0.775	0.819*	0.519	0.716	0.62	-0.905*	0.795	0.015	0.798
BMWP-H				1	0.868*	0.789	0.657	0.706	0.405	0.599	0.504	-0.813*	0.808	0.183	0.784
BMWP-P					1	0.829*	0.945**	0.894*	0.627	0.815*	0.732	-0.918**	0.823*	-0.109	0.858*
BMWP-C						1	0.74	0.649	0.402	0.542	0.447	-0.655	0.729	0.187	0.718
BMWP-G							1	0.881*	0.661	0.825*	0.758	-0.849*	0.713	-0.273	0.778
ASPT-O								1	0.877*	0.971**	0.916*	-0.977**	0.581	-0.509	0.681
ASPT-H									1	0.957**	0.978**	-0.783	0.4	-0.658	0.544
ASPT-C										1	0.985**	-0.917*	0.567	-0.561	0.689
BBI											1	-0.843*	0.544	-0.575	0.676
FBI												1	-0.62	0.405	-0.694
SWDI													1	0.34	0.985**
MDI														1	0.183
SDI															1

* Correlation is significant at $p < 0.05$ (2-tailed). ** Correlation is significant at $p < 0.01$ (2-tailed).

points 5 and 6 while no score could be obtained at the sampling point 1 and 2 because of absence of Oligochaeta species. According to observations of Akay and Dalkıran (2019) on Yalakdere stream, the average [%] EPT was found over 53% at upstream sampling points while it was found less than 1% in sampling point 4 which was damaged by high way construction.

Kantzaris et al. (2002) recorded that the BMWP, ASPT and Land Quality Indicators (LQI) were insufficient in evaluating water quality while BBI and IBE were proper. Kalyoncu et al. (2008) stated that the BBI and physicochemical data were more proper to evaluate the water quality. Kazancı et al. (2010) mentioned that the BMWP and ASPT were sufficient to evaluate water quality in Aksu Stream. Ogleni and Topal (2011) mentioned that the BMWP and ASPT were sufficient to evaluate water quality. Kalyoncu and Zeybek (2011) found that SWDI and BBI seem to be the most reliable to determine the water quality. Yorulmaz et al. (2015) applied five biotic indices and noted that the FBI was insufficient in evaluating water quality while ASPT, BMWP, SI, and BBI were appropriate. Zeybek (2017) found that the most appropriate indices for the physical and chemical indices were BMWP-O and ASPT-O and ASPT-C. Yorulmaz and Ertaş (2021) found that the the BMWP Polish, BMWP Spanish, BMWP Hungarian, BMWP Greek versions and all versions of ASPT indices are more proper than FBI and BBI indices to determine the water quality of Selendi Stream. Ertaş and Yorulmaz (2021) found that the BMWP (Original), BMWP (Spanish), BMWP (Greek) and ASPT indices are suitable for assessing the water quality in Kelebek Stream. Ertaş et al. (2021) found that the ASPT, BBI, BMWP-O, BMWP-S, BMWP-G and EPT-Taxa [%] are more proper than FBI and SI indices to determine the water quality of Kozluoluk Stream. Ertaş et al. (2022) found that the BMWP-O, BMWP-S, BMWP-H, ASPT-O, ASPT-H and ASPT-C indices were more proper than SI, FBI and BBI indices to determine the water quality of Balaban Stream.

CONCLUSION

This is the first study that determines the benthic fauna of Ilke Stream, for this reason, all taxa are new records for the stream. In this study, SI, BBI, BMWP and ASPT indices were in correlation. The FBI index was not in correlation with other indices and found inappropriate to determine the water quality of Ilke Stream. Detailed studies should be carried out to determine more reliable and useful results about the water quality of streams in Turkey and a specific biotic index according to the ecological characteristics of Turkey should be developed.

FUNDING

No funding was received for conducting this study.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors have no competing interests to declare that are relevant to the content of this article.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

REFERENCES

- Akay, E. and Dalkıran, N., Assessing biological water quality of Yalakdere stream (Yalova, Turkey) with benthic macroinvertebrate-based metrics, *Biologia*, 2019, vol. 75, no. 9, pp. 1347–1363.
- American Public Health Association (APHA), Method 2130- Turbidity, standard methods for the examination of water and wastewater, in American Public Health Association, American Water Works Association, and Water Environment Federation, Washington D.C., 1998.
- AQEM Consortium, The AQEM sampling method to be applied in STAR, 2002, Chapters 7–8.
- Arslan, N., Salur, A., Kalyoncu, H., Mercan, D., Barışık, B., and Odabaşı, D.A., The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Küçük Menderes River (Turkey), *Biologia*, 2016, vol. 71, no. 1, pp. 49–57.
- Atique, U., Lim, B., Yoon, J., and Kwang-Guk, A., Biological health assessments of lotic waters by biotic integrity indices and their relations to water chemistry, *Water*, 2019, vol. 11, no. 3, art. ID 436.
- Bedoya, D., Novotny, V., and Manolagos, E.S., Instream and offstream environmental conditions and stream biotic integrity: Importance of scale and site similarities for learning and prediction, *Ecol. Modell.*, 2009, vol. 220, no. 19, pp. 2393–2406.
- Birk, S., Bonne, W., Borja, A., Brucet, S., Courrat, A., Poikane, S., Solimini, A., van de Bund, W., Zampoukas, N., and Hering, D., Three hundred ways to assess Europe's surface waters: An almost complete overview of biological methods to implement the Water Framework Directive, *Ecol. Indic.*, 2012, vol. 18, pp. 31–41.
- Bremond, R. and Vuichard, R., *Parameters de la Qualite des Eaux: Ministere de la Protection de la Nature et de l'Environnement, Documentation*, Paris, 1973.
- Chang, F.H., Lawrence, J.E., Rios-Touma, B., and Resh, V.H., Tolerance values of benthic macroinvertebrates for stream biomonitoring: assessment of assumptions underlying scoring systems worldwide, *Environ. Monit. Assess.*, 2014, vol. 186, pp. 2135–2149.
- Custodio, M. and Penalzoza, R., Influence of water quality on the variation patterns of the communities of benthic macroinvertebrates in the lakes of the central highlands of Peru, *Open J. Mar. Sci.*, 2019, vol. 9, no. 1, pp. 1–17.
- Duran, M. and Akyildiz, G.K., Evaluating benthic macroinvertebrate fauna and water quality of Suleymanli Lake (Buldan-Denizli) in Turkey, *Acta Zool. Bulg.*, 2011, vol. 63, no. 2, pp. 169–178.
- EPA, *Volunteer Stream Monitoring: A Methods Manual*, United States Environmental Protection Agency, 1997.
- Ertaş, A. and Yorulmaz, B., Assessing water quality in the Kelebek Stream branch (Gediz River Basin, West Ana-

- tolia of Turkey) using physicochemical and macroinvertebrate-based indices, *Aquat. Res.*, 2021, vol. 4, no. 3, pp. 260–278.
- Ertaş, A., Boz, T., and Tüney-Kızılkaya, İ., Comparative analysis of benthic macroinvertebrate-based biotic and diversity indices used to evaluate the water quality of Kozluoluk Stream (West Anatolia of Turkey), *Community Ecol.*, 2021, vol. 22, pp. 381–390.
- Ertaş, A., Tüney-Kızılkaya, İ., and Yorulmaz, B., Determination of diversity and species composition of the benthic macroinvertebrates in Sangı stream (Izmir, Turkey), *J. Wildl. Biodiversity*, 2020, vol. 4, pp. 19–30.
- Ertaş, A., Yorulmaz, B., and Sukatar, A., Comparative analysis of biotic indices for assessment of water quality of Balaban Stream in West Anatolia, Turkey, *Biologia*, 2022, vol. 77, pp. 721–730.
- Girgin, S., and Kazancı, N., Ankara Çayı'nda su kalitesinin fiziko – kimyasal ve biyolojik yöntemlerle belirlenmesi, in *Türkiye İç Suları Araştırmaları Dizisi*, Kazancı, I.N., Ed., Ankara: Özyurt Press, 1994.
- Graf, W., Grasser, U., and Waringer, J., Trichoptera, in *Fauna Aquatica Austriaca-A Comprehensive Species Inventory of Austrian Aquatic Organisms with Ecological Notes*, Moog, O., Ed., Wasserwirtschaftskataster Vienna: Federal Ministry for Agriculture and Forestry, 1995.
- Gültekin, Z., Aydın, R., and Winkelmann, C., Macroinvertebrate composition in the metarhithral zones of the Munzur and Pülümür rivers: a preliminary study, *Turk. J. Zool.*, 2017, vol. 41, pp. 1100–1104.
- Helson, J. and Williams, D., Development of a macroinvertebrate multimetric index for the assessment of lowland streams in the neotropics, *Ecol. Indic.*, 2013, vol. 29, pp. 167–178.
- Hering, D., Johnson, R.K., Kramm, S., Schmutz, S., Szożkiewicz, K., and Verdonshot, P.F., Assessment of European streams with diatoms, macrophytes, macroinvertebrates and fish: a comparative metric-based analysis of organism response to stress, *Freshwater Biol.*, 2006, vol. 51, no. 9, pp. 1757–1785.
- Huang, Q., Gao, J., Cai, Y., Yin, H., Gao, Y., Zhao, J., Liu, L., and Huang, J., Development and application of benthic macroinvertebrate-based multimetric indices for the assessment of streams and rivers in the evaluate ecological quality of French wadeable streams fulfilling the WFD demands: A taxonomical and trait approach, *Ecol. Indic.*, 2015, vol. 18, pp. 452–467.
- Kalyoncu, H. and Zeybek, M., An application of different biotic and diversity indices for assessing water quality: A case study in the Rivers Çukurca and Isparta (Turkey), *Afr. J. Agric. Res.*, 2011, vol. 6, no. 1, pp. 19–27.
- Kalyoncu, H., Yorulmaz, B., Barlas, M., Yıldırım, M.Z., and Zeybek, M., Water quality of Aksu stream and effect of physicochemical parameters on the macroinvertebrate diversity, *Sci. Eng. J. Firat Univ.*, 2008, vol. 20, no. 1, pp. 23–33.
- Kantzaris, V., Iliopoulou- Georgudaki, J., Katharios, P., and Kaspiris, P., A comparison of several biotic indices used for water quality assessment at the Greek Rivers, *Fresenius Environ. Bull.*, 2002, vol. 11, no. 11, pp. 1000–1007.
- Kazancı, N. and Girgin, S., Physico-chemical and biological characteristics of thermal springs in Köyceğiz and Dalaman basins in south-western Turkey and recommendations for their protection, *Water Sci. Technol.*, 2001, vol. 43, no. 5, pp. 211–221.
- Kazancı, N., Ekingen, P., Türkmen, G., Ertunç, Ö., Dügel, M., and Gültutan, Y., Assesment of ecological quality of Aksu Stream (Giresun, Turkey) in Eastern Black Sea Region by using Water Framework Directive (WFD) methods based on benthic macroinvertebrates, *Rev. Hydrobiol.*, 2010, vol. 3, no. 2, pp. 165–184.
- Kazancı, N., Türkmen, G., Basören, Ö., and Ekingen, P., TR-BMWP (Turkish-BMWP) biotic index, *Rev. Hydrobiol.*, 2016, vol. 9, no. 2, pp. 147–151.
- Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Baig, J.A., and Shah, A.Q., Assessment of water quality of polluted lake using multivariate statistical techniques: A case study, *Ecotoxicol. Environ. Saf.*, 2009, vol. 72, pp. 301–309.
- Keck, F., Vasselon, V., Tapolczai, K., Rimet, F., and Bouchez, A., Freshwater biomonitoring in the Information Age, *Front. Ecol. Environ.*, 2017, vol. 15, no. 5, pp. 266–274.
- Klee, O., *Angewandte Hydrobiologie*, Stuttgart: Theieme, 1991.
- Kocataş, A., *Ecology and Environmental Biology*, Izmir: Ege Univ. Fac. Sci., 2008.
- Korycińska, M. and Królak, E., The use of various biotic indices for evaluation of water quality in the lowland rivers of Poland (exemplified by the Liwiec River), *Pol. J. Environ. Stud.*, 2006, vol. 15, no. 3, pp. 419–428.
- Koşalşahin, S. and Zeybek, M., Diversity and species composition of the macrobenthic invertebrates in Sürgü Stream (Malatya, Turkey), *Mehmet Akif Ersoy Univ. Fen Bilim. Enst. Derg.*, 2019, vol. 10, no. 1, pp. 60–67.
- Moisan, J. and Pelletier, L., *Guide de Surveillance Biologique Basée sur les Macroinvertebrés Benthiques d'eau Douce du Québec-Cours d'eau peu Profonde à Substrat Grossier*, Direction de Suivi de l'Etat de l'Environnement, Ministère du Développement Durable de l'Environnement et des Parcs, 2008.
- Moss, D., Furse, M.T., Wright, J.F., and Armitage, P.D., The prediction of the macro-invertebrate fauna of unpolluted running-water sites in Great Britain using environmental data, *Freshwater Biol.*, 1987, vol. 17, no. 1, pp. 41–52.
- Najar, I.A., and Khan, A.B., Assessment of water quality and identification of pollution sources of three lakes in Kashmir, India, using multivariate analysis, *Environ. Earth Sci.*, 2012, vol. 66, pp. 2367–2378.
- Nikolsky, G.V., *The Ecology of Fishes*, London: Academic Press, 1963.
- Ode, P.R., Rehn, A.C., and May, J.T., A quantitative tool for assessing the integrity of southern coastal California streams, *Environ. Manage.*, 2005, vol. 35, pp. 493–504.
- Ogleni, N. and Topal, B., Water quality assessment of the Mudurnu River (Turkey) using biotic indices, *Water Resour. Manage.*, 2011, vol. 25, art. ID 2487.
- Oliveira, R.B.S., Baptista, D.F., Mugnai, R., Castro, C.M., and Hughes, R.M., Towards rapid bioassessment of wadeable streams in Brazil: Development of the Guapiaçu-Macau Multimetric Index (GMMI) based on benthic macroinvertebrates, *Ecol. Indic.*, 2011, vol. 11, pp. 1584–1593.

- Özbek, M., Taşdemir, A., Cil, E.A., Sömek, H., and Yıldız, S., Assessing the trophic level of a Mediterranean Stream (Nif Stream, İzmir) using benthic macro-invertebrates and environmental variables, *Turk. J. Fish. Aquat. Sci.*, 2018, vol. 19, no. 3, pp. 179–190.
- Plafkin, J.L., Barbour, K.D., Gross, S.K., and Hughes, R.M., *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish*, Washington: U.S. Environ. Prot. Agency, 1989.
- Qadri, R. and Faiq, M.A., Freshwater Pollution: Effects on aquatic life and human health, in *Fresh Water Pollution Dynamics and Remediation*, Qadri, H., Bhat, R., Mehmood, M., and Dar, G., Eds., Singapore: Springer-Verlag, 2020.
- Rashid, R. and Pandit, A.K., Macroinvertebrates (oligochaetes) as indicators of pollution: A review, *J. Ecol. Nat. Environ.*, 2014, vol. 6, no. 4, pp. 140–144.
- Sanders, T.G., Ward, R.C., Loftis, J.C., Steele, T.D., Adrian, D.D., and Yevjevich, V., *Design of Networks for Monitoring Water Quality*, Littleton: Water Resour. Publ., 1983.
- Şenol, M., Gül, T., Atış, E., and Salalı, H.E., The Role of agriculture to prevent the water pollution in Gediz Basin, *XII National Agricultural Economics Congress*, Isparta, 2016.
- Shrestha, S. and Kazama, F., Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan, *Environ. Model. Software*, 2007, vol. 22, no. 4, pp. 464–475.
- Somerfield, P.J., Identification of the Bray-Curtis similarity index: Comment on Yoshioka (2008), *Mar. Ecol.: Prog. Ser.*, 2008, vol. 372, pp. 303–306.
- Sukatar, A., Ertaş, A., Gülle, İ., and Tuney Kızılkaya, İ., Trophic state assessment of brackish Bafa Lake (Turkey) based on community structure of zooplankton, *J. Limnol. Freshwater Fish. Res.*, 2020, vol. 6, no. 2, pp. 88–99.
- Tanyolaç, J., *Limnology* (in Turkish), Ankara: Hatipoğlu Press, 2004.
- Tirsch, F.S. and Male, J.W., River basin water quality monitoring network design: Options for researching water quality goals, *Proc. 20th Annu. Conf. American Water Resources Associations*, Schad, T.M., Ed., AWRA, 1984, pp. 149–156.
- Ward, R.C., and Loftis, J.C., Establishing statistical design criteria for water quality monitoring systems: Review and synthesis, *Water Resour. Bull.*, 1986, vol. 22, no. 5, pp. 759–767.
- Water Framework Directive (WFD), Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for community action in the field of water policy, PE-CONS 3639/1/00 REV 1 EN, 2000.
- Wetzel, R.G., *Limnology Lake and Reservoir Ecosystems*, San Diego: Academic Press, 2001.
- Yorulmaz, B. and Ertaş, A., Water quality assessment of Selendi Stream and comparative performance of the indices based on benthic macroinvertebrates and physicochemical parameters, *Biologia*, 2021, vol. 76, pp. 2599–2607.
- Yorulmaz, B., Sukatar, A., and Barlas, M., Comparative analysis of biotic indices for evaluation of water quality of Esen river in South-West Anatolia, Turkey, *Fresenius Environ. Bull.*, 2015, vol. 24, no. 1, pp. 188–194.
- Yoshioka, P.M., Misidentification of the Bray-Curtis similarity index, *Mar. Ecol.: Prog. Ser.*, 2008, vol. 368, pp. 309–310.
- Zeybek, M., Macroinvertebrate-based biotic indices for evaluating the water quality of Kargı Stream (Antalya, Turkey), *Turk. J. Zool.*, 2017, vol. 41, no. 3, pp. 476–486.
- Zeybek, M. and Kalyoncu, H., The determination of water quality of Kargı Stream (Antalya, Turkey) in terms of physicochemical parameters, *EgeJFAS*, 2016, vol. 33, no. 3, pp. 223–231.
- Zeybek, M., Kalyoncu, H., Karakaş, B., and Özgül, S., The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Değirmendere Stream (Isparta, Turkey), *Turk. J. Zool.*, 2014, vol. 38, pp. 603–613.