Acta Aquatica Turcica

E-ISSN: 2651-5474 17(3), 334-349 (2021) DOI: https://doi.org/10.22392/actaquatr.819579

Evaluation of the Water Quality of Karabal Stream (Gediz River, Turkey) and Comparative Performance of the Used Indices

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Research Article

Received 02 November 2020; Accepted 21 January 2021; Release date 01 September 2021.

How to Cite: Ertaş, A., Yaşartürk, M., Boz, T., & Tüney Kızılkaya, İ. (2021). Evaluation of the water quality of Karabal Stream (Gediz River, Turkey) and comparative performance of the used indices. *Acta Aquatica Turcica, 17*(3), 334-349. https://doi.org/10.22392/actaquatr.819579

Abstract

We used seven biotic indices to determine the water quality of Karabal Stream (Gediz River) in West Anatolia, Turkey. The indices were based on benthic macroinvertebrate and physicochemical parameters: Saprobi Index (SI), Biological Monitoring Working Party (BMWP), Average Score per Taxon (ASPT), Family Biotic Index (FBI), Belgian Biotic Index (BBI), EPT-Taxa [%] were used as biotic indices and Shannon-Weaver index (SWDI), Simpsons index (SDI) and Margalef index (MDI) for diversity. Ten taxonomic groups were found in Karabal Stream consisting of Crustacea, Oligochaeta, Gastrapoda, Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Diptera, and Hemiptera. The water quality along the stream varied from good class in the upstream stations, to moderate in downstream stations according to the most suitable indices. According to canonic correspondence analysis (CCA), the distributions of Diptera, Oligochaeta, and Hemiptera species are positively correlated to EC, Cl, Turbidity, Temperature, NH_4-N, NO_2-N, and NO_3-N while they are negatively correlated to DO, DOS and pH. The distributions of EPT species are positively correlated to DO, DOS and pH. According to Pearson's correlation, the BBI, BMWP (Original), BMWP (Spanish), and EPT-Taxa [%] metrics were sufficient in the estimation of water quality in the examined watercourse. Considering studies in surface waters of Turkey, the BMWP and EPT-Taxa [%] indices reflect the water quality as correctly in all studies we examined, however, BBI did not always show reliable results. Therefore there is a need for the establishment of a Turkish Biotic Index which takes into account country-specific macroinvertebrates, their abundance, biology, and ecology.

Keywords: Karabal Stream, Water Quality, Benthic Macroinvertebrates, Physicochemical Parameters, Biotic and Diversity Indices.

Karabal Çayı'nın (Gediz Nehri, Türkiye) Su Kalitesinin Değerlendirilmesi ve Kullanılan Endeks Performanslarının Karşılaştırılması

Özet

Türkiye'nin Batı Anadolu Bölgesi'ndeki Karabal Çayı'nın (Gediz nehri kolu) su kalitesini belirlemek için yedi biyotik indeks kullanılmıştır. Kullanılan indeksler bentik makroomurgasızlar ve fizikokimyasal parametreler temellidir. Biyotik indeks olarak; Saprobi İndeks (SI), Biyolojik Çalışma Grubu İndeksi (BMWP), Takson Başına Ortalama Puan (ASPT), Familya Biyotik İndeksi (FBI) ve Belçika Biyotik İndeksi (BBI), çeşitlilik indeksi olarak; Shannon-Weaver indeksi (SWDI), Simpsons indeksi (SDI) ve Margalef indeksi (MDI) kullanılmıştır. Karabal Çayı'nda Crustacea, Oligochaeta, Gastrapoda, Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Diptera ve Hemiptera'dan oluşan 10 taksonomik grup saptanmıştır. Akarsu boyunca su kalitesi, indekslere göre akarsuyun memba kesimlerinde iyi sınıftan akarsuyun aşağı mansap kesimlerinde orta seviyeye kadar değişmektedir. Kanonik korelasyon analizi (CCA)'ne göre, Diptera, Oligochaeta ve Hemiptera türlerinin dağılımları, ÇO, ÇOS ve pH ile negatif korelasyon gösterirken EC, Cl, Turbidite, Sıcalık, NH_4-N, NO_2-N ve NO_3-N ile pozitif korelasyon göstermektedir. EPT türlerinin dağılımları ÇO, ÇOS ve pH ile pozitif korelasyon göstermiştir. Pearson korelasyon analizine göre BBI, BMWP (Orijinal), BMWP (İspanyol) ve EPT-Taksa [%] indeksleri incelenen akarsu üzerindeki su kalitesi tahmini için yeterli bulunmuştur. Türkiye yüzey sularında yapılan diğer çalışmalar da dikkate alındığında BMWP ve EPT-Taxa [%] indeksleri su kalitesi belirlemeye yönelik yapılan tüm çalışmalarda olduğu gibi bu çalışmada da su kalitesi açısından yeterli doğruluk yansıtmaktadır, ancak BBI her zaman güvenilir sonuçlar vermemiştir. Bu nedenle, ülkeye özgü makroomurgasız gruplarının bolluklarını, biyolojilerini ve ekolojilerini dikkate alan bir Türkiye Biyotik İndeksi'nin oluşturulmasına ihtiyaç vardır.

Anahtar Kelimeler: Karabal Çayı, Su Kalitesi, Bentik Makroomurgasızlar, Fizikokimyasal Parametreler, Biyotik ve Çeşitlilik İndeksleri.

INTRODUCTION

The existence of a sufficient amount of good quality water is an essential need for the future of humanity and sustainable development. Monitoring studies on freshwater resources is the first step in conservation policies. In the late 20th century, the scarcity of freshwater resources reached the point that would threaten food safety, livelihood, and health of people (Falkenmark, 1989; Kundzewicz, 1997; Vorosmarty et al., 2000). The freshwater ecosystems supply 40% of all food and agricultural crops production by irrigation, 12% of fish consumed by humans, and produces 20% of electrical energy in the World (Johnson et al., 2001). In addition to the direct effects of water scarcity, the degradation of water quality reduces its usability.

More than 3 billion people in the world can not access clean water, and this problem is of particular importance in developing countries where 90% of untreated wastewater is discharged into streams (Johnson et al., 2001). So to maintain the water quality of the existing freshwater ecosystems very important. Biological water quality monitoring in all surface water systems was obligated by the EU Water Framework Directive (WFD). According to the WFD, the bio-indicators such as benthic macroinvertebrates, phytoplankton, phytobentose (diatom), fish, aquatic macrophyte, macroalgae, and angiosperm are biological quality components in water quality monitoring. Among all these groups, benthic invertebrates are the most advantageous. Benthic macroinvertebrates live above or inside the bottom substrates of freshwater and marine ecosystems. They have limited mobility and have an important place in the food chain of freshwater ecosystems. The responses of the macroinvertebrate community to environmental changes are particularly useful in assessing the impact of every kind of pollutants in surface waters.

Many biotic indices were created according to specific geographic and climatic regions. European countries have created various indices with variable diagnosis and counting of different organisms (Korycińska and Królak, 2006; Yorulmaz et al., 2015). The Saprobi Index (SI) (Kolkwitz and Marsson, 1902) in Germany, the BMWP and ASPT (De Pauw and Hawkes, 1993) in England, the BBI (De Pauw and Heylen, 2001) in Belgium, the FBI (Hilsenhoff, 1988) in the USA, Danish Stream Fauna Index (DSFI) (Skriver et al., 2001) in Denmark, give the most reliable results specific to geographical regions. A lot of biotic indices have been used to determine water quality in Turkey (Kazancı and Dügel, 2000; Kalyoncu and Zeybek, 2009; Kazancı et al., 2010; Zeybek et al., 2014; Yorulmaz et al., 2015; Zeybek, 2017). Since the studies are conducted for 25 years, a biological water quality index specific to Turkey has not been developed.

Gediz River watercourse have been polluted due to increasing industrialization and population growth. It's aimed to investigate the level of pollution and its effect on the macroinvertebrates in the Karabal Stream. With this study, to compare the performances of biotic and diversity indices.

MATERIALS and METHODS

Study Area

This study was carried out on Karabal Stream (Gediz River, Turkey) (Figure 1). The length of the stream is 58 km. Karabal Stream is 20 km away from Uşak ctiy center. Uşak Industrial Zone was established 6 km east of the stream. Güre Plain is located at the junction of Karabal Stream and Gediz River. The Mediterranean climate prevails in the region.

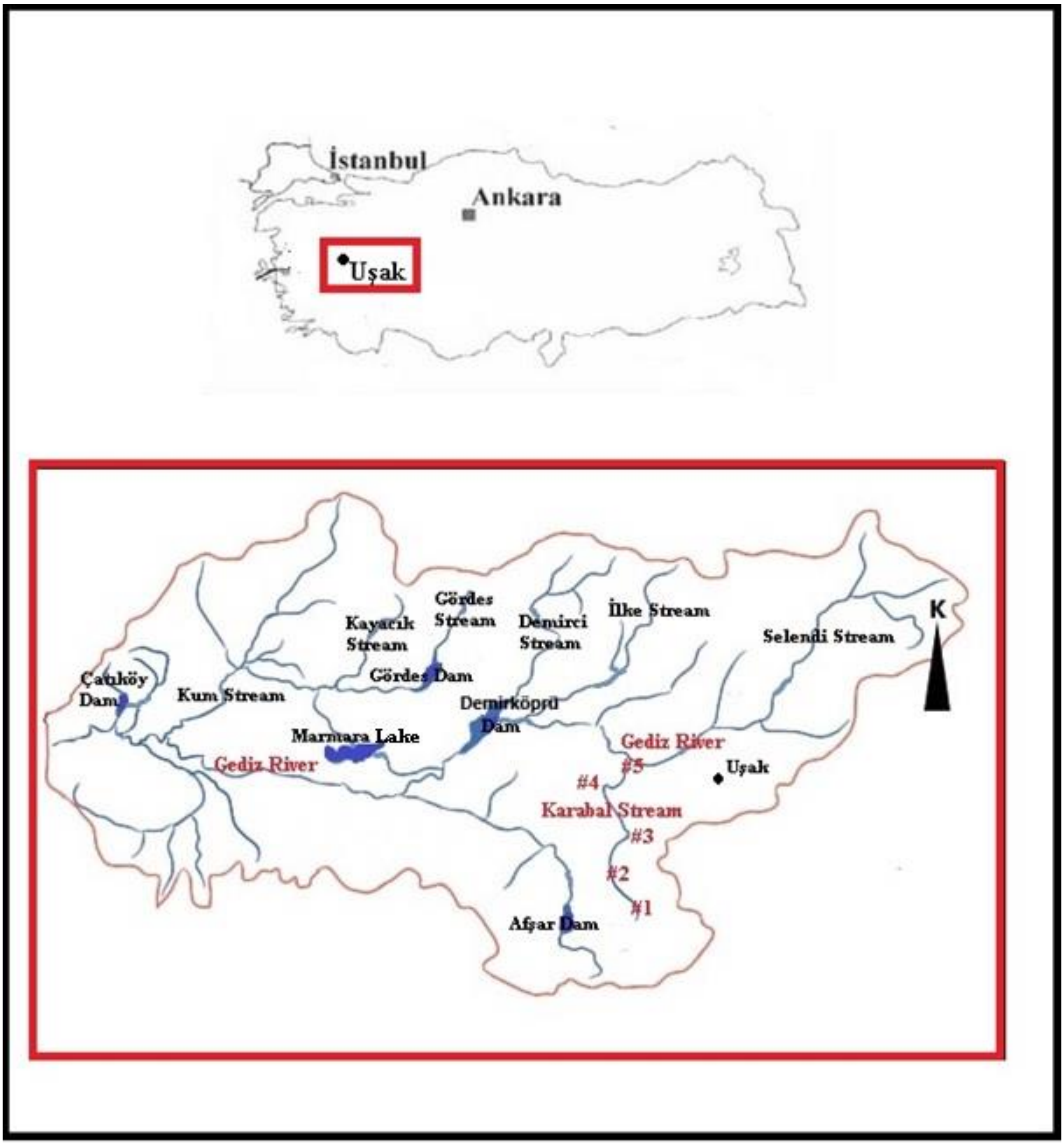

Figure 1. Map of the sampling stations in Karabal Stream.

Karabal Stream is used as an irrigation water source for the surrounding agricultural fields. The sampling stations were chosen based on stream source and domestic areas. The research was conducted between April 2019 and March 2020 at five monitoring stations that included the upstream (#1, #2, #3), and downstream (#4 and #5) sections. The sampling was carried out seasonally (April, August, November, February) over a year in the stream. Some key characteristics of sampling stations are presented in Table 1.

Table 1. Some key characteristics of sampling stations in Karabal Stream.

	Sampling Station	Coordinates (N-E)	Habitat	Stream morphology	Riparian vegetation
#1	The source point of the stream	38° 64' N 29° 34' E	Large rocks (> 80 cm) mixed with gravel and wood debris	No Macrophyte was present	It's not well developed.
#2	Karabal Stream in village Kayağıl. Agricultural areas and thermal pools are intense around the stream.	38° 63' N 29° 29' E	Large rocks, gravel, and wood debris.	Macrophyte was present	Well developed on both sides.
#3	Karabal Stream in village Eskisarat. Agricultural areas and domestic settlements are intense around the stream.	38° 64' N 29° 24' E	Sand, gravel, silt, and cobbles	Domestic wastes inflow. No Macrophyte was present	It's not well developed.
#4	Karabal Stream in village Güre. Agricultural areas and domestic settlements are intense around the stream.	38° 64' N 29° 16' E	Sand, gravel, silt, and cobbles	Domestic wastes inflow. No Macrophyte was present	It's not well developed.
#5	The point where the Karabal Stream drains into the Gediz River.	38° 67' N 29° 13' E	Cobbles, pebbles, sand, and muddy	Macrophyte present.	Well developed on both sides.

Benthic macroinvertebrates were collected from each station by using a classic 50x30 cm size with a 250 µm mesh hand net. Macroinvertebrate sampling was done from downstream towards upstream. Macroinvertebrates were obtained from the different substrate types such as rock, sand, and gravel present at the stations. Some sessile organisms adhering to the large stone, rock, or any other substrate, were collected by using forceps (AQEM Consortium, 2002). The taken organisms were stored in 70% alcohol and 4% formaldehyde and then brought to the Ege University Hydrobiology Research Laboratory. Brought samples from the stream were categorized and diagnosed to the lowest possible taxonomic level such as genus or species, under a stereomicroscope.

Physicochemical Parameters

To determine the water quality classes, 16 physicochemical parameters were monitored seasonally. Water temperature (°C), pH, electrical conductivity (EC), turbidity, oxygen saturation (DOS), and dissolved oxygen (DO) of each water sample were measured at the sampling points by oxygen meter and multiparameter. The biochemical oxygen demand (BOI_5) was assessed by using a spectrophotometer on the base of the Winkler azide method with Merck BOD Cell Test Kits. The orthophosphate (PO_4-P), ammoniacal nitrogen (NH_4-N), nitrate (NO_2-N), nitrite (NO_3-N), and chloride (Cl^-) were by using appropriate Merck kits according to manufacturer's instructions (Merck Phosphate, Ammonium, Nitrite, Nitrate, and Chloride Test Kits). Major cations such as K, Ca and Na were evaluated by flame photometry after the acid-treated on water samples, while Mg was evaluated by using the Flame Atomic Absorption Spectrometer (FAAS). All water samples were stored in an insulated cooler containing ice and taken on the same day to the laboratory and stored at 4°C until processing and analysis (APHA, 2005).

Biotic Indices

The benthic macroinvertebrates were analyzed to determine the biological quality score by using ASTERICS 4.04 software program (AQEM Consortium, 2002). With this purpose, the BBI, FBI, SI, ASPT, BMWP (Original), BMWP (Spanish) biotic indices, and SWDI, SDI, MDI diversity indices were used to determine the water quality of Karabal Stream.

Data Analysis

All statistical analyses between the physicochemical data sets, Pearson correlation analysis and biotic parameters were made using Excel 2019 (Microsoft Office^R) and SPSS version 20.0. In this study, the relationship between physicochemical parameters and macroinvertebrates were determined by using CCA based on multivariate statistical analysis (Ter Braak, 1995). Pearson correlation analysis is used to express the relationships between indices and physicochemical parameters. The faunal similarities based on benthic macroinvertebrates between the sampling stations were assessed by using the Bray-Curtis similarity index (Sommerfield, 2008; Yoshioka, 2008).

RESULTS and DISCUSSION

Physical and Chemical Parameters

The results of physicochemical variables were presented in Table 2.

Table 2. The mean and standard deviation values of physicochemical parameters in sampling stations.

Parameters		Station 1	Station 2	Station 3	Station 4	Station 5
T	M±SD	11.4±0.21	11.8±0.28	13.0±0.67	13.9±0.85	14.4±0.62
(°C)	SE	0.062	0.081	0.185	0.228	0.163
pH	M±SD	7.13±0.04	7.03±0.04	6.70±0.08	6.60±0.08	6.95±0.05
	SE	0.014	0.015	0.030	0.031	0.018
EC	M±SD	149.2±10.6	159.7±10.7	393.2±25.8	405.0±24.5	210.2±8.22
(mS/m)	SE	0.867	0.846	1.301	1.217	0.566
Turbidity	M±SD	1.64±0.22	1.90±0.18	60.8±11.2	64.2±11.8	8.77±1.11
(NTU)	SE	0.171	0.130	1.436	1.472	0.374
DO	M±SD	11.9±0.25	11.4±0.31	10.8±0.29	10.4±0.29	10.1±0.18
(mg/l)	SE	0.072	0.091	0.088	0.089	0.056
DOS	M±SD	126.2±9.74	113.2±4.99	95.7±3.59	92.5±3.69	101.0±5.09
(%)	SE	0.867	0.469	0.367	0.383	0.506
BOI_5	M±SD	1.11±0.05	1.24±0.11	6.26±0.86	6.76±1.10	2.00± 0.11
(mg/l)	SE	0.047	0.098	0.343	0.423	0.077
NH_4-N	M±SD	0.035±0.012	0.24±0.06	7.67±2.25	7.90±2.26	1.21±0.10
(mg/L)	SE	0.064	0.122	0.812	0.804	0.090
NO_2-N	M±SD	0.06±0,01	0.13±0.035	4.94±0.68	5.10±0.36	1.95±0.17
(mg/L)	SE	0.040	0.097	0.306	0.159	0,121
NO_3-N	M±SD	1.06±0.04	1.09±0.03	5.92±0.82	6.00±0.66	1.85±0.12
(mg/L)	SE	0.038	0.028	0.337	0.269	0.088
Cl^-	M±SD	2.01±0.13	2.50±0.48	23.2±4.38	22.9±3.67	3.80±0.41
(mg/L)	SE	0.091	0.303	0.909	0.766	0.210
Ca	M±SD	21.1±2.12	24.6±5.16	56.0±8.28	54.1±8.30	30.7±4.11
(mg/L)	SE	0.461	1.040	1.106	1.128	1.347
Mg	M±SD	10.7±1.26	11.5±1.49	27.7±5.78	29.8±7.54	17.3±2.15
(mg/L)	SE	0.385	0.439	1.098	1.381	0.516
K	M±SD	12.1±0.80	12.9±1.00	27.9±3.25	29.2±3.94	15.1±0.98
(mg/L)	SE	0.230	0.278	0.425	0.729	0.252
Na	M±SD	15.9±0.40	16.4±0.49	30.9±7.56	31.9±7.04	17.5±0.86
(mg/L)	SE	0.100	0.121	1.360	1.246	0.205
PO_4	M±SD	0.025±0.019	0.032±0.017	5.43±1.10	5.34±0.86	0.77±0.17
(mg N/L)	SE	0.120	0.095	0.472	0.372	0.193

M: Mean; SD: Standard deviation; SE: Standard error

It is known that the metabolism of organisms varies with temperature. DO and DOS which is vital for aquatic organisms varies depending on the temperature (Wetzel, 2001; Tanyolaç, 2004). Benthic macroinvertebrates are sensitive to changing temperature and oxygen in the water and as temperature increases and oxygen decreases, sensitive organisms are being replaced by tolerant organisms (Wetzel, 2001; Tanyolaç, 2004; Walczyńska and Sobczyk, 2017). The Karabal Stream is suitable for organisms in terms of temperature, DO and DOS. Uyanık et al., (2005) reported the lowest DO value at the sampling point (8.3 mg/L) after the mixture of industrial and domestic wastewater in their study on Eğri Stream. Kara and Çömlekçioğlu (2004) examined the pollution of Karaçay Stream with biological and physicochemical parameters and stated that the amount of DO was low at the sampling point after the domestic wastes mixed. Dügel (1995) and Barlas et al., (2000) reached similar results in their studies on Yuvarlakçay Stream. Kalyoncu et al., (2008) reached similar results in their studies on Aksu Stream BOI_5 is of great importance as it is a measure of organic pollution in aquatic ecosystems (WHO, 2011). In Karabal Stream, the highest BOI_5 values were measured at the sampling points (#3 and #4) affected by domestic wastes. pH, which is an indicator of the acidity of water, is one of the important factors affecting life (Wetzel, 2001; Tanyolaç, 2004). According to the pH data determined in Karabal Stream, there is no risk for organisms. The turbidity of the downstream stations of the Karabal Stream was found to be high. EC values are quite high at stations #3 and #4. At these sampling points, the accumulation of suspended solids due to the low slope and pollution pressure. This increased both density and EC values. Kalyoncu et al., (2005) and Kalyoncu and Zeybek (2009) obtained similar results in Aksu Stream and Isparta Stream, respectively. The high Cl^- values indicate that the electrical conductivity is also high. The amount of chloride in many drinking waters does not exceed 30 mg/L (Egemen and Sunlu, 1996). Cl^- values are quite high at stations #3 and #4 parallel with the turbidity and EC values. The increasing major cations such as K, Ca, Na and Mg amounts in water are due to household detergents (Tanyolaç, 2004). These major cations were found to be quite high at stations #3 and #4 due to dense domestic settlements. Elements that limit efficiency in aquatic environments are mostly PO_4, NH_4-N, NO_2-N, NO_3-N (Moss, 1987). The NO_3-N in groundwater and surface waters results from the oxidation of ammonia, which occurs as a result of the decomposition of proteins contained in vegetable and animal wastes, and nitrate fertilizers used in agricultural areas. NO_3-N is the most common form of nitrogen in freshwaters, and it is very rare in uncontaminated waters (Wetzel, 2001). It is also below the limit value reported as 50 mg/L in WHO, where the NO_3-N values determined at all stations examined in the stream are below the recommended 10 mg/L limit value in healthy waters reported by EPA. (WHO, 2011). The increase of PO_4, NH_4-N, NO_2-N, NO_3-N in stations #3 and #4 showed the richness of these two stations with nutrients caused by discharges of domestic wastes in the vicinity of Karabal Stream.

Benthic Macroinvertebrate Data

In this study, a total of 3.748 benthic macroinvertebrate samples were collected; all the specimens collected belong to nine groups: Crustacea, Oligochaeta, Gastropoda, Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Diptera and Hemiptera. The maximum numbers of individuals were collected at station #1 (1.013 individuals), while the minimum numbers of individuals were collected at station #4 (572 individuals). The lowest number of individuals was determined in autumn while the highest number of individuals was determined in spring with the collection of all benthic invertebrate samples (Figure 2).

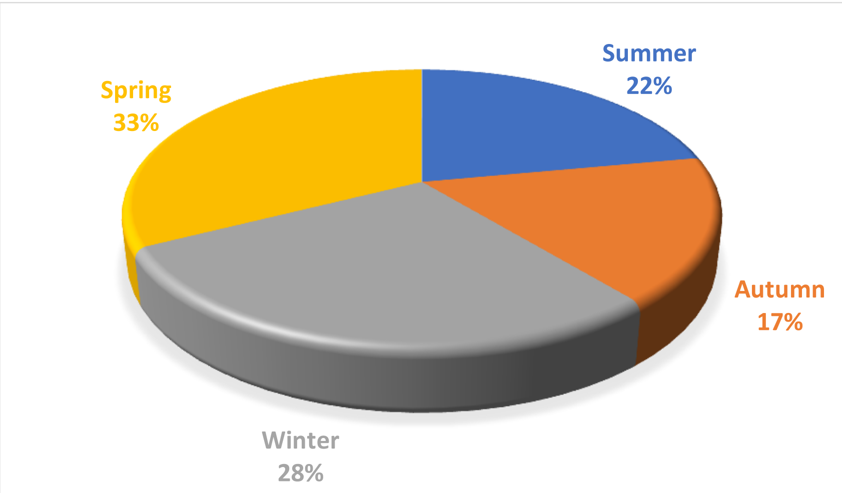

Figure 2. The total percent of benthic macroinvertebrates according to season.

As a result of this count, the most dominant group in all benthic macroinvertebrate groups was Insecta in the stream (Figure 3).

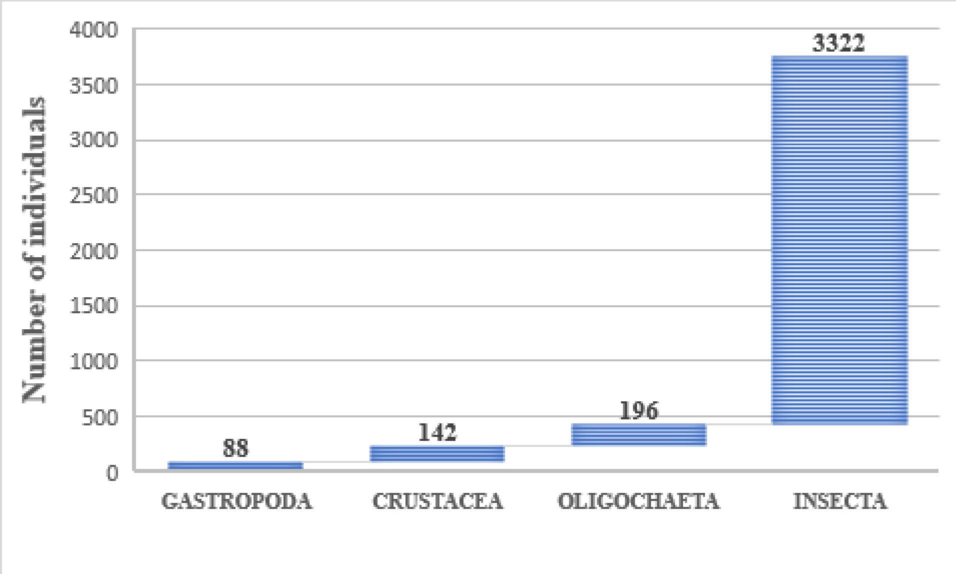

Figure 3. Benthic invertebrate groups in Karabal Stream.

Considering all taxonomic groups in Karabal Stream, Ephemeroptera was the most dominant group in station #1 (40.8%), station #2 (41%) and station #5 (31.2%); Diptera was the most dominant group in station #3 (28.6%), and station #4 (28.3%); Pleoptera was the second dominant group in station #1 (26.8%) and #2 (22.7%); Trichoptera was the second dominant group in station #3 (18.9%) and #5 (23.3%) (Figure 4).

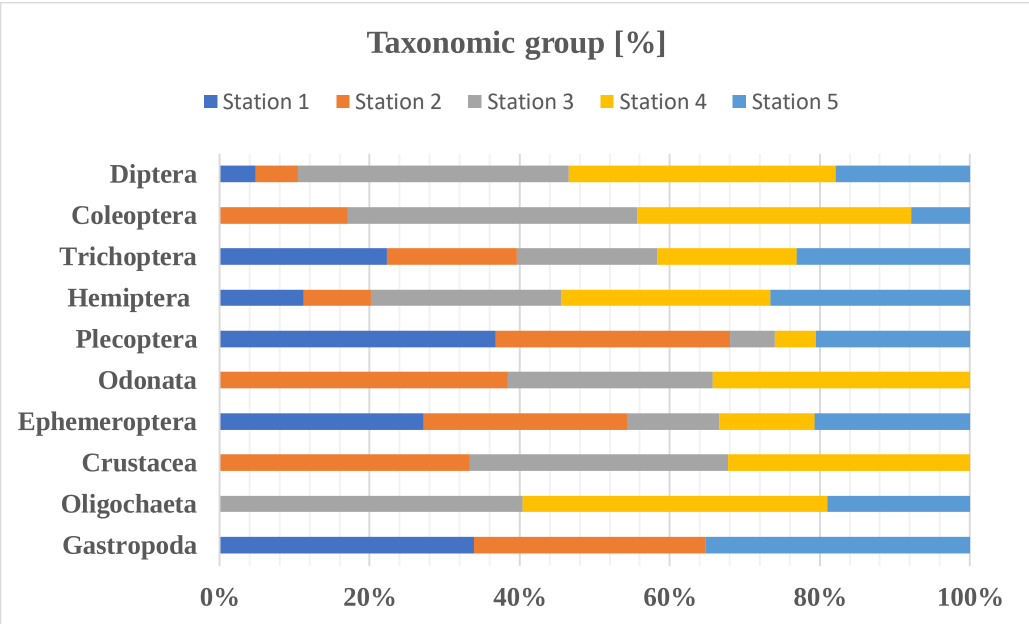

Figure 4. Distribution of taxonomic groups in Karabal Stream.

Out of 25 families identified, Insects are the richest group represented with 21 families: Ephemeroptera (6), Plecoptera (4), Trichoptera (4), Odonata (1), Coleoptera (1), Diptera (3), and Hemiptera (2) that make up 89.15% of the macroinvertebrates of the Karabal Stream Crustacea were represented with 1 family: Gammaridae, which consists 3.79% of macroinvertebrates; Oligochaeta were represented with 1 family: Tubificidae, which consists 5.23% of macroinvertebrates; Gastropoda were represented with 2 families: Bithyniidae and Lymnaeidae, which consists 2.35% of macroinvertebrates.

The dominance of benthic macroinvertebrate species according to the stations is shown in the Figure 5. As a result of the observations, *Gammarus* sp. was dominant at the station #2, #3 and #4.

Gammarus sp., which belongs to the group of Amphipoda is found in low polluted river sections (Meyer, 1987). *Chironomus* sp. and *Chironomus plumosus* were dominant species at the station #3 and #4. These species are an indicator for polysaprobic (heavily polluted) aquatic systems (Kalyoncu and Zeybek 2010; Arslan et al., 2016; Zeybek, 2017). According to Moisan and Pelletier (2008), the tolerance range of these organisms are high They can inhabit an environment with low or high DO (mg/l), DOS (%) and T (°C). The abundance of organic matter is favorable for benthic macroinvertebrates such as Diptera and Oligochaeta (Rashid and Pandit, 2014). Kalyoncu and Zeybek (2009) determined that the 6th station, which is the downstream point of the stream, has low organism diversity. On the other hand, the most dominant group was Diptera followed by Oligochaeta (*Tubifex tubifex*). *Chironomus thummi* from Diptera, and *Simulium* sp. were the most dominant taxa in Isparta Stream.

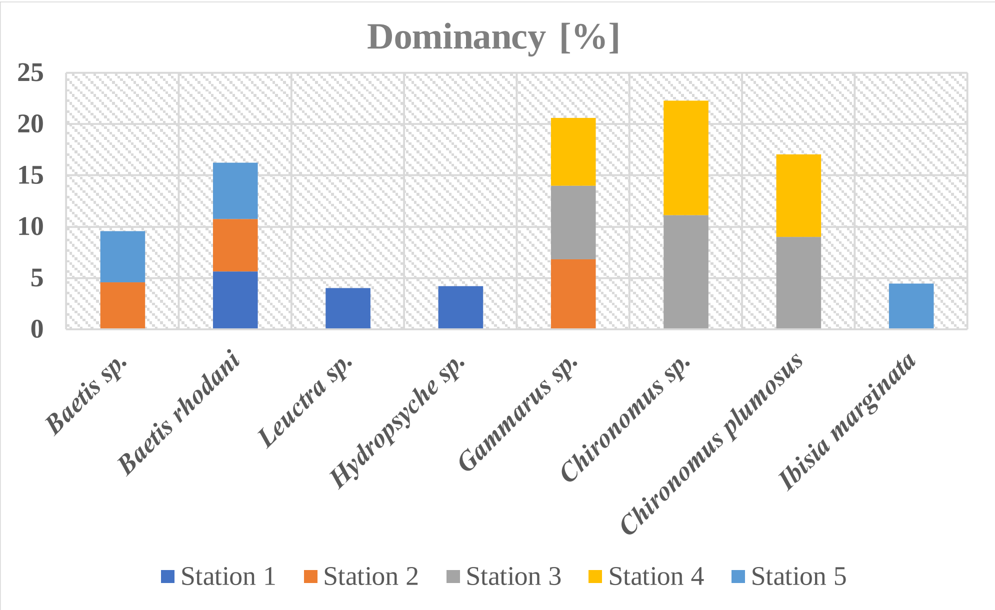

Figure 5. Dominancy (%) of taxon of benthic macroinvertebrates at the stations.

In terms of diversity, the richest were sampling station #1 and station #2 with 20 families each, 14 of them belonging to Ephemeroptera- Plecoptera- Trichoptera (EPT) group that are classified as sensitive organisms to the oxygen concentration in the water. The high percentage of EPT taxa indicates high water quality (Lenat, 1993). In stations #1 and #2, the most dominant within EPT were Ephemeroptera, with 6 families. The dominance of the orders Ephemeroptera, Plecoptera, and Trichoptera which are considered to be sensitive to environmental stress signifies relatively clean conditions (Merritt, 1978). Two Diptera, Gastropoda, and Hemiptera families composed the rest of the macroinvertebrates in these two stations. Both these stations are upstream of the Karabal Stream. According to Meyer (1987), *Baetis* sp. located in the organically less polluted stream section and included in water quality class I-II. Zeybek et al., (2014) determined most dominant taxon was Ephemeroptera (a pollution-sensitive species) in upstream sampling stations in Değirmendere Stream. Macroinvertebrate fauna consists of 19 families in stations #3 and #4. However, the number of EPT families decreased in these station.

In sampling stations #3 and #4 due to heavy pollution with domestic wastewaters, diversity of macroinvertebrates decreased and was dominated by semi tolerant and tolerant families to pollution, such as Baetidae, Chironomidae, Tubificidae, Athericidae, Dixidae, Corixidae, and Gerridae. According to Hynes (1994), the presence of highly tolerant groups of organisms in freshwater ecosystems is generally an indicator of poor water quality. In freshwater ecosystems, the number of sensitive species declines over time due to water pollution, while environmental conditions gradually change in favor of semi-tolerant and tolerant species. (Zimmerman, 1993). Going downstream, sampling stations #3, #4 and # macroinvertebrate samples consisted of Oligochaeta worms and Diptera which were present in high abundance. Oligochaeta is one of the indicator groups of poor water quality in streams and rivers, and they can tolerate heavy to extreme pollution. Many species of

Oligochaeta are tolerant of low oxygen concentration and can live in anoxic conditions (Brinkhurst and Kennedy, 1965). Oligochaeta species are also a group of organisms with high tolerance to organic pollution. (Barbour, 1996).

The increased number of species in station #5 occurred as the result of increased water level and flow velocity in this station. Due to this improvement in environmental conditions, in station #5, the number of taxa further increased. In total 22 families were present, 13 belonging to the sensitive and semi-sensitive EPT group, and the rest consisted of semi tolerant-tolerant organisms (Dytiscidae, Oligochaeta, Bithyniidae, Lymnaeidae).

The classification of the stations based on benthic macroinvertebrates composition was illustrated by using Bray-Curtis UPGMA analysis (Figure 6). As a result of the UPGMA analysis, the station #3 and #4 (96%) were the most similar to each other. The second most similar stations to each other were determined as the station #1 and #2 (86%).

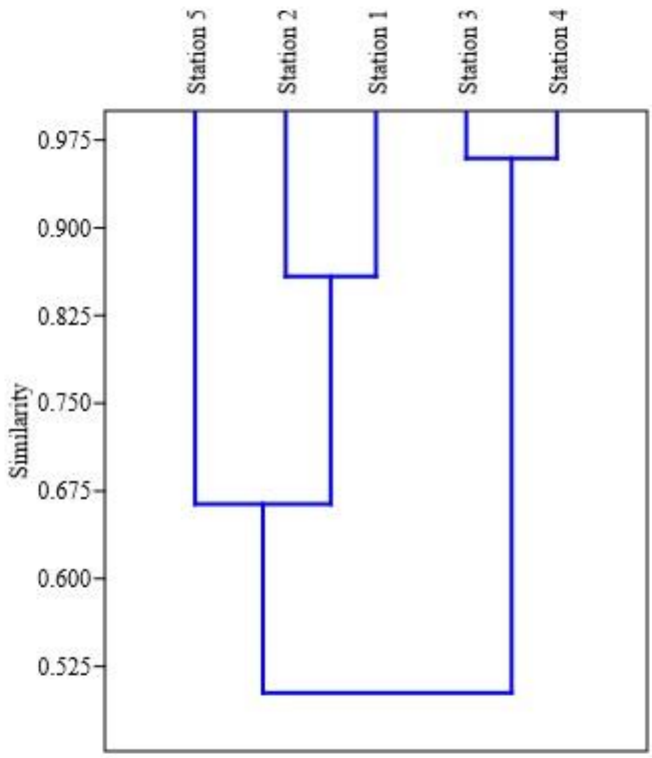

Figure 6. Classification of stations based on similarities in Karabal Stream.

The ecological conditions of Karabal Stream indicate that the stream is disturbed by anthropogenic activities. The water classification with biotic and diversity indices is shown in Table 3.

All diversity indices have shown the highest values in station #5, whereas the lowest values are registered in station #3. High species diversity at the upstream stations indicates unpolluted conditions whereas low species diversity in stations #3 and #4 indicates environmental stress. The sampling station #3 and #4 are heavily disturbed due to many domestic wastes discharged in this part of the stream. The highest BOI_5 value in these two stations indicates the presence of organic pollution in the water and the oxygen consumption for the separation of organic matter. Oxygen depletion at these stations is characterized by low species diversity. Diversity indices have proven to be useful tools for defining the structure of communities, but they do not indicate the level of pollution of water bodies. In this context, diversity indices are good for assessing organic pollution and eutrophication but are insufficient for assessing toxicity and physical changes.

The both BMWP (Original) and BMWP (Spanish) values were highest in stations #1, #2 and #5. The water is classified in Class II in these stations. The stream water quality decreased drastically and became of moderate quality at stations #3 and #4. ASPT and BBI index qualifies the water quality at all stations in Class I-High. According to SI, all stations are *Betamesosaprob*- Class II. According to FBI, the water quality is Class I in stations #1, #2, and #5 while the water quality is Class II in stations

#3 and #4 in the stream. These index scores indicate that upstream of the water body, due to the distance with inhabited areas and lack of waste discharge, the water has a minimum human impact and is of high quality. Going downstream, in urban and rural areas, human activities become more intensive and impact physical and chemical parameters of the water that is manifested with moderate water quality.

EPT-Taxa [%] was one of the metrics which gave the best response to the physicochemical variables of water. These metrics are indicated that Ephemeroptera, Plecoptera, and Trichoptera taxa are sensitive to anthropogenic effects while Oligochaeta taxa are tolerant to anthropogenic effects in aquatic ecosystems (Ode et al. 2005). In this study, the highest EPT-Taxa [%] values are obtained at the station #1 and #2. These stations are the upstream part of the water body and they are less affected by domestic wastes. On the contrary, the station #3 and #4 are downstream part of the water body. These stations are mostly affected by domestic wastes. The cause of low EPT-Taxa [%] values at the downstream stations in the stream is the pollution that accumulates in the stream as a result of the anthropogenic activities. Other factors depend on the physical properties of the stream such as high temperature, low stream slope, and reduction of streamflow.

Table 3. Average score values and water quality classes of all indices in the stream.

Metric	Station 1	Station 2	Station 3	Station 4	Station 5
SI	2.006	2.024	2.140	2.140	2,200
Water quality class	II	II	II	II	II
BMWP (Original)	133	132	98	98	131
Water quality class	II	II	III	III	II
BMWP (Spanish)	137	134	99	99	133
Water quality class	II	II	III	III	II
ASPT	7.389	7.238	6.588	6.588	6.550
Water quality class	I	I	I	I	I
BBI	10	10	9,5	9,5	10
Water quality class	I	I	I	I	I
FBI	3.270	3.340	4.270	4.270	3.730
Water quality class	I	I	II	II	I
EPT-Taxa [%]	90.227	81.264	28.667	29.783	69.507
SDI	0.971	0.971	0.954	0.955	0.973
SWDI	3,600	3.645	3.292	3.308	3.660
MDI	6.069	6.743	5.664	5.670	6.763

Our results show that there are differences between indices in water quality classification as a result of applied different indices. When similar studies using biotic and diversity indices in other countries are examined, we can see that some macro invertebrate-based indices are more sensitive, while others are less sensitive. For this reason, it is difficult to choose which index is more reliable to apply in river quality assessment in a country. (Kalyoncu and Zeybek, 2010). In our research EPT-Taxa [%], BMWP (Original), and BMWP (Spanish) seem to be more reliable and reflect the environmental situation better since they both are based on the presence of sensitive species to environmental variables. The reason why EPT-Taxa [%] shows high water quality is that Ephemeroptera, Plecoptera, and Trichoptera are considered very sensitive to pollution (Lenat, 1993). Our results show that a high number of EPT-Taxa [%] were registered upstream, in stations #1 and #2 whereas, with the increased level of pollution in station #3 and #4, the number of EPT families is reduced and was represented by semi-tolerant family Baetidae and Hydropsychidae.

In this study, the random sample cases (*10% select case*) were made on the biotic indices and physicochemical parameters to verify data sets and to determine that the data was transferred without errors in the SPSS version 20.0. Table 4 indicates the correlations of biotic and diversity indices.

As a result of the correlation analysis, the highest positive significant correlation was found between the BMWP (Original) and BMWP (Spanish) *(r-value 0.999, $p<0.01$)*. There was a positive significant correlation between the BMWP (Original) and BBI *(r-value 0.999, $p<0.01$)*. There was a positive significant correlation between the BMWP (Spanish) and BBI *(r-value 0.997, $p<0.01$)*. There was a positive significant correlation between the BMWP (Spanish) and EPT-Taxa [%] *(r-value 0.965, $p<0.01$)*. There was a positive significant correlation between the FBI and EPT-Taxa [%] *(r-value -0.987, $p<0.01$)*. BBI, BMWP (Original), BMWP (Spanish) and EPT-Taxa [%] are positively significant correlated with SDI and SWDI diversity indices. However, the increase in index values of BBI, BMWP (Original), BMWP (Spanish), and EPT-Taxa [%] shows good ecological quality.

Table 4. Pearson's based correlation assesment between biotic and diversity indices in the stream

	SI	**BMWP (Original)**	**BMWP (Spanish)**	**ASPT**	**BBI**	**FBI**	**EPT-Taxa [%]**	**SDI**	**SWDI**	**MDI**
SI	1	-0,447	-0,466	-,965**	-0,416	0,769	-0,672	-0,336	-0,331	-0,083
BMWP (Original)		1	,999**	0,659	,999**	-,915*	,956*	,992**	,987**	0,842
BMWP (Spanish)			1	0,677	,997**	-,924*	,965**	,988**	,981**	0,82
ASPT				1	0,632	-,906*	0,842	0,563	0,553	0,283
BBI					1	-,901*	,945*	,996**	,992**	0,86
FBI						1	-,987**	-0,859	-0,853	-0,633
EPT-Taxa [%]							1	,915*	,901*	0,671
SDI								1	,996**	,879*
SWDI									1	,913*
MDI										1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

CCA analysis showed 84.64% total variance between the benthic macroinvertebrate species and physicochemical parameters (Figure 7). The distributions of *Simulium* sp., *Chironomus* sp., *Chironomus plumosus*, *Tubifex tubifex*, and *Limnodrilus hoffmeisteri* are positively correlated with EC, Cl, Turbidity, T^{o}C, NH_4-N, NO_2-N and NO_3-N while they are negatively correlated with DO, DOS, and pH. The distributions of EPT species are positively correlated with DO, DOS, and pH.

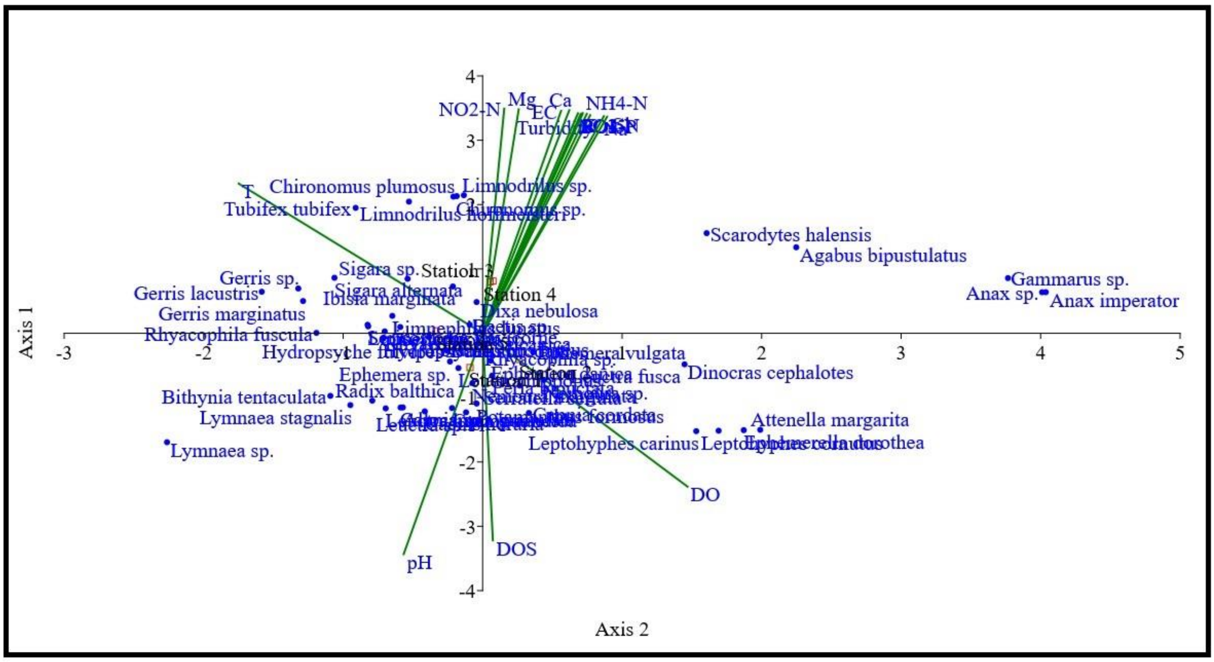

Figure 7. CCA plot of reference-, test-, and the most disturbing stations distributions with environmental variables.

Pearson correlation analyses between Biotic and diversity indices with physicochemical parameters show that all physicochemical parameters have a significant correlation with at least one biotic and diversity indices (Table 5). There is a strong positive correlation *($p<0.01$)* of temperature, DO, with SI and ASPT ($p<0.05$), which means if temperature increases, these parameters will increase too. These results indicate that the macroinvertebrate species are sensitive to increased temperature in water and as DO decreases, sensitive taxa are being replaced by highly tolerant taxa (Horrigan et al. 2005). The turbidity, EC, BOI_5, NH_4-N, NO_2-N, NO_3-N, PO_4-P, Ca, Mg, K, Na, and Cl^- concentration in the water is in negative correlation with BMWP (Original), BMWP (Spanish), BBI, FBI, EPT-Taxa [%], SDI and SWDI *(significance $p<0.01$ and $p<0.05$)* whereas pH has positive correlations *(significance $p<0.01$ and $p<0.05$)* with BMWP (Original), BMWP (Spanish), BBI, FBI, EPT-Taxa [%], SDI and SWDI. We can conclude that temperature, DO and pH have influenced the macroinvertebrate richness and abundance in Karabal Steam.

Table 5. Pearson's based correlation assessment between biotic indices and species diersity indices with physicochemical parameters of the stream.

	SI	BMWP (Original)	BMWP (Spanish)	ASPT	BBI	FBI	EPT-Taxa [%]	SDI	SWDI	MDI
T	,967**	-0,43	-0,45	-,935*	-0,399	0,743	-0,652	-0,312	-0,306	-0,056
DO	-,966**	0,446	0,47	,946*	0,414	-0,755	0,677	0,33	0,314	0,027
DOS	-0,841	0,786	0,807	,945*	0,763	-,944*	,930*	0,709	0,68	0,365
Turbidity	0,495	-,998**	-,997**	-0,697	-,995**	,935*	-,967**	-,982**	-,979**	-0,831
pH	-0,631	,954*	,962**	0,808	,943*	-,967**	,987**	,912*	,897*	0,676
EC	0,575	-,988**	-,991**	-0,763	-,983**	,964**	-,986**	-,961**	-,957*	-0,783
BOI_5	0,523	-,994**	-,995**	-0,72	-,990**	,945*	-,973**	-,973**	-,970**	-0,812
NH_4-N	0,513	-,997**	-,998**	-0,713	-,994**	,943*	-,973**	-,979**	-,975**	-0,818
NO_2-N	0,674	-,961**	-,965**	-0,837	-,952*	,989**	-,991**	-,920*	-,918*	-0,732
NO_3-N	0,525	-,996**	-,996**	-0,722	-,992**	,947*	-,975**	-,977**	-,974**	-0,818
PO_4-P	0,512	-,997**	-,997**	-0,711	-,994**	,942*	-,971**	-,981**	-,978**	-0,825
Ca	0,587	-,985**	-,989**	-0,775	-,978**	,968**	-,991**	-,958*	-,949*	-0,757
Mg	0,655	-,965**	-,969**	-0,823	-,956*	,984**	-,990**	-,924*	-,920*	-0,733
K	0,532	-,994**	-,995**	-0,729	-,989**	,949*	-,978**	-,972**	-,967**	-0,8
Na	0,477	-,999**	-,998**	-0,684	-,997**	,928*	-,964**	-,985**	-,980**	-0,829
Cl^-	0,468	-1,000**	-,999**	-0,676	-,998**	,924*	-,962**	-,989**	-,985**	-0,836

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

Kazancı and Dügel (2000) have applied BBI in their study in Turkey and they stated that BBI complied with the physicochemical parameters. Kantzaris et al., (2002) used biotic indices at two streams in Greece. The BMWP, ASPT, and Land Quality Indicators (LQI) were indicated insufficient in evaluating water quality while BBI and IBE were proper according to Kantzaris et al., (2002). Öz and Şengörür (2004) used the BBI index in their study on Melen Stream. They tried to reveal the water quality in Melen Stream. They stated that BBI was in harmony with the other indices they use. Balık et al., (2006) used the BBI in their study on the Menderes River and they stated that the water quality values of the stations determined were extremely dirty. Kalyoncu et al., (2008) stated that the BBI and physicochemical data reflect the water quality level in Aksu Stream. However, they stated that the quality values obtained from physicochemical data showed better water quality. Kazancı et al., (2010) utilized BMWP and ASPT indices in Aksu Stream. They stated that the BMWP and ASPT were adequate in assessing water quality. Ogleni and Topal (2011) applied four biotic indices in the Mudurnu River. They determined that the BMWP and ASPT were sufficient in evaluate surface water quality. Yorulmaz et al. (2015) applied five biotic indices in the Esen River. They stated that the FBI was insufficient in evaluating water quality while ASPT, BMWP, SI, and BBI were appropriate in Esen River. Zeybek et al., (2014) utilized a diverse type of BMWP and ASPT indices in Değirmendere Stream. Zeybek (2017) applied the BBI, all types of BMWP, and ASPT indices in Kargı Stream. She obtained inconsistent score values and indicated that used biotic indices don't reflect Turkish freshwater fauna and topographic characteristics as a result of her study. The results obtained according to the BBI and BMWP which are applied to the various regions in Turkey is that they reflect as well the stream quality. The fact that very few of these studies makes it difficult to determine the availability in Turkey. More studies are needed on this subject and it should be applied in streams in different regions.

DISCUSSION

The results obtained in this study show that Karabal Stream was affected by many anthropogenic activities. The main factors are industrial discharges, agricultural runoff, and land use, as well as the direct discharge of untreated wastewater into the stream. While upstream stations are less polluted as they are distant from agricultural activities, in urban areas, the stream is moderately polluted and this is reflected in the benthic macroinvertebrate community and distribution. Increased pollution at stations #3 and #4 resulted in the disappearance of sensitive species from this part of the stream, and the emergence of more pollution-tolerant species adapted to specific habitats. Our results have shown that the ecological status of the Karabal Stream is of moderate quality and urgent measures for the protection of the Gediz River Basin and other water resources in Turkey must be implemented through professional management plans for river basins.

ACKNOWLEDGEMENT

The authors are thankful for the support and experience of Prof Dr. Hasan KALYONCU.

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