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Research Article

Determination of diversity and species composition of the benthic macroinvertebrates in Sangı stream (Izmir, Turkey)

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Abstract
Though benthic invertebrates are an important indicator for determining biological quality in freshwater ecosystems, there are still significant deficiencies in their faunistic composition. This study aimed to determine the diversity and species composition of benthic macroinvertebrates in Sangı Stream, Izmir (Turkey). Benthic macroinvertebrates were collected monthly from February 2018 to March 2019 in predefined six sampling stations. As a result of the analysis, four benthic macroinvertebrate groups, including Crustacea, Oligochaeta, Gastropoda, and Insecta, were identified in the Sangı stream. The most dominant taxa were Insecta among all benthic macroinvertebrates. Using species-based biodiversity indices and analyses spatial similarities and differences were also determined. This study is the first study for determining Sangı Stream benthic fauna; that's why all taxa diagnosed in the stream has been recorded for the first time.

Keywords: Stream, Benthic macroinvertebrate**,** Species diversity, Turkey

Introduction
The rapid growth of the population increases the need for water, besides climate change causes a decrease in clean water resources. To ensure the sustainability of clean water resources, the investigation of biological variables in water pollution determination has started to become an important issue today to monitor the sources' pollution levels. Biological monitoring studies have begun to be used more widely than chemical methods because they are more reliable in examining long-term effects and are less costly (Kalyoncu and Gülboy, 2009).
In biological monitoring studies, fishes, macrophytes, phytoplankton, diatoms, or benthic invertebrates are used to determine the streams' ecological status and ecological quality. The vast majority of organisms used as bioindicators are benthic organisms that live to the bottom or move very slowly. Benthic macroinvertebrates are preferred as an indicator in water quality studies, as they are visible in size, they can be sampled without the need for complex instruments, their habitats are limited, they react to changes in water quality and can be found throughout the year (Bayrak Arslan 2015).
There are some studies in Turkey for

determining benthic fauna in streams with a sampling strategy in discrete periods (Kazancı and Dügel 2000, Duran 2006, Duran and Suicmez 2007, Kalyoncu *et al*. 2009, Kalyoncu and Gülboy 2009, Kalyoncu and Zeybek 2009, Girgin 2010, Zeybek *et al*. 2012, Serdar and Verep 2018, Topkara *et al*. 2018, Koşalşahin and Zeybek 2019), however, monitoring studies are ongoing studies and should be conducted in certain periods.

İzmir is located on the west coast of Turkey, the third-largest city with a population above four million (2019). Sangı Stream is vital by providing a drinking water source for İzmir (Barış 2008). Besides the importance of water quality for community health, there is no single study for determining or monitoring benthic macroinvertebrate fauna. This study aims to provide baseline information on the composition of macroinvertebrate diversity of the stream. Additionally, the determination of the benthic macroinvertebrate fauna of the Sangı Stream as a new locality is significant in terms of contribution to the biological diversity of the freshwater ecosystem in Turkey.

Material and methods

Sampling Strategy

The study was carried out on Sangı Stream in the Tahtali Dam Lake Basin. The length of the Sangı Stream is 25 km. The stream originates from the Sandı Mountain (700 m) located on the west of Tahtalı Dam Lake. The six sampling stations were determined throughout the stream, and sampling was carried out monthly from February 2018 to March 2019 (Fig. 1). However, the sampling was carried out only in June for the summer season because of the stream's droughtiness. The sampling stations were chosen based on stream source, domestic and agricultural areas. In this study, station #1 was selected in the stream's headwaters, while site #6 was located in the part of stream drain into the Tahtalı Dam Lake. The bottom structure of site #1, #2 and #3 consist of large rocks, gravel, and stones. The flow rate was high at site #1, #2, and #3. The bottom structure of station #4 and #5 consists of gravel and mostly sandy sediments. Site #6 is at the widest part of the streambed. The bottom structure of this station also consists of small stones and generally sandy areas. The flow rate was slow at station #5 and #6 (3 m/sec.).

Sampling Procedure

In Sangı Stream, the benthic organisms were collected from each station by using a classic 50x30 size with 250 µm mesh hand net, and this sampling was done by moving downstream of the steam towards the upstream. Sampling, categorization, storage, and preservation of benthic macroinvertebrates were performed according to AQEM Consortium (2002). The taken macroinvertebrates from the Sangı Stream were kept in 70% alcohol and 4% formaldehyde throughout the field study and then brought to the Ege University Hydrobiology Research Laboratory. Benthic macroinvertebrates were categorized and diagnosed to the level of genus or species using a stereomicroscope.

In the diagnosis of the Ephemeroptera samples Schumacker (1970), Kimmins (1972), Roldon (1980), Berner and Pescador (1987), Eliot *et al*. (1988), Hubbard (1990), Tercedor (1990), Haybach and Thomas (2000), Belfiore *et al*. (2000) was used. Illies (1955), Hynes (1977) were used to diagnose the Plecoptera samples. Brauer (1909), Almeida, and Mise (2009) were used to diagnose the Coleoptera samples. Edington and Hildrew (1981), Morse (1983), Wallace *et al*. (1887) were used to diagnose the Trichoptera samples. Only Gledhill *et al.* (1993) were used in the diagnosis of the Crustacea sub-class. Korneyev and Evstigneev (2013) were used to diagnose Diptera samples. Brinkhurst and Jamieson (1971), Norman (1998), and Siddiqui *et al*. (2007) were used to diagnose the Gastropoda samples based on morphological characteristics of the Shell. Brinkhurst and Wetzel (1984) and Timm (1999) was used to diagnose the Oligochaeta samples. Additionally, Oligochaeta species were identified after making temporary preparations of samples (glycerin/water 1/5 v/v).

Figure 1. Map of the sampling stations in Sangı Stream

Data Analysis

We analyzed benthic and macroinvertebrates diversity indices using the Shannon-Wiener Diversity Index (SWDI), Simpson's Diversity Index (SDI), and Margalef Diversity Index (MDI).

SWDI, which was developed by Claude E. Shannon in 1949, reflects the mathematical measure of species diversity in a community.

$$\boldsymbol{H' = \sum_{n=1}^{n} (pi)(lnpi)}$$

Where "H' "is index value, "n" is the total number of taxa in the community; "Pi" is the proportion of individuals in the " i " taxon in the community.

SDI is a measure of dominance and weighs towards the abundance of the most common taxa. As a measure of diversity, it is expressed as the reciprocal (1-D).

$$\mathbf{D} = \sum (\boldsymbol{pi})^{\mathbf{2}} = \sum \left[\frac{\boldsymbol{ni(ni-1)}}{\boldsymbol{N(N-1)}}\right]$$

Where "ni" is the number of individuals of i^{th} taxon; "N" is the total number of individuals of all taxa.

MDI, presented by Margalef (1958), is calculated as the species number (S) minus 1 divided by the logarithm of the total number of individuals (N) (Gamito 2010).

$$\boldsymbol{d = \frac{S-1}{\ln N}}$$

The faunal similarity in the section of the stream based on benthic macroinvertebrates was assessed by using the Bray-Curtis similarity index.

$$\mathbf{BCy = 1 - \frac{2Cij}{S1 + S2}}$$

Where *i* and *j* are the two sites, *Si* is the total number of specimens counted on site i, *Sj* is the total number of specimens counted on-site j, *Cij* is the sum of only the lesser counts for each species found in both sites.

Besides, the unweighted pair group method with arithmetic mean (UPGMA) was used to illustrate existing clustering relationships based on the Bray-Curtis similarity index. The UPGMA analysis was made by using the PAST3 software program. All the biological data sets were made by using Excel 2019 (Microsoft Office^{R}).

Results

A total of 68 samplings were conducted during the period of study. Sampling was not able to perform in station #2 and #3 between June and August (2018) since the droughtiness of the stream. A total of 5.363 individuals belonging 38 taxa were found in Sangı Stream. As a result of identification, the four benthic macroinvertebrate groups such as Crustacea, Oligochaeta, Gastropoda, and Insecta were determined. The maximum numbers of individuals were collected at station #1 (996 individuals), while the minimum numbers of individuals were collected at station #5 (770 individuals) (Fig. 2). The most dominant group in all benthic macroinvertebrate groups was Insecta in Sangı Stream (Fig. 3).

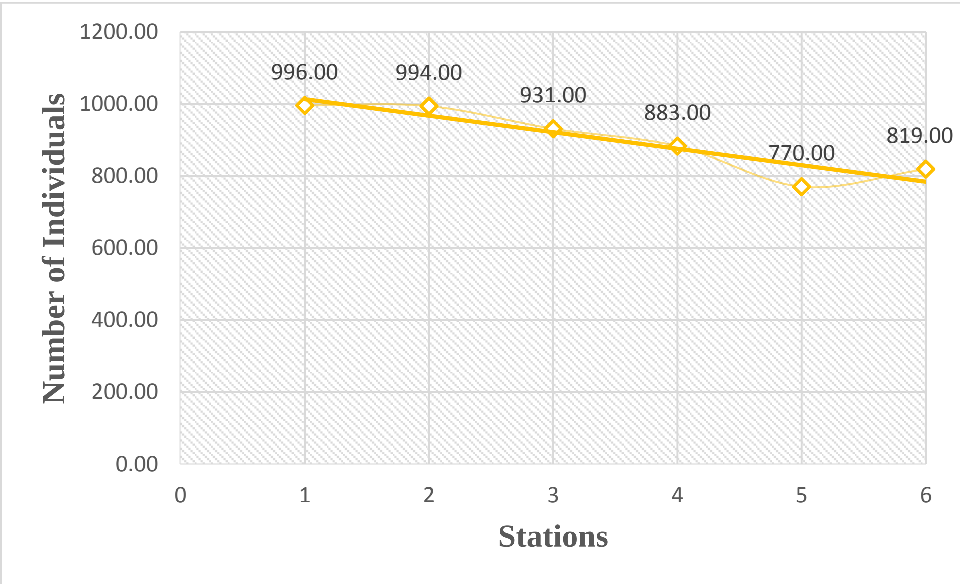

Figure 2. Distribution of individuals by stations in Sangı stream

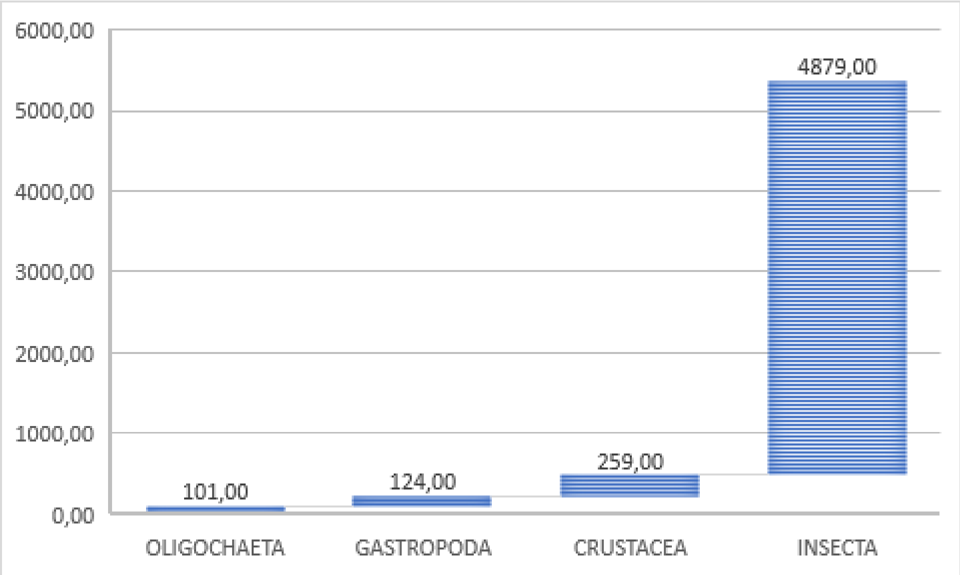

Figure 3. Benthic invertebrate groups in Sangı stream

This study was carried out in 12 months between February 2018 and March 2019 to determine Sangı Stream benthic invertebrate fauna. The most dominant group in all benthic macroinvertebrate groups was Insecta (32 taxa) in Sangı Stream (Fig. 3). Ephemeroptera (13 taxa) was the most dominant order in the Insecta class. The Plecoptera order with five taxa followed this.

Regarding temporal evaluation, the lowest percentage and numbers of individuals were determined in the summer season. On the other hand, the highest percent and numbers of individuals were selected in the spring season (Fig. 4). The distribution of benthic macroinvertebrate taxa according to the season, was shown in Fig. 5. As a result of the observations, Ephemeroptera was the most dominant taxa during a year. The second most dominant taxa were Diptera and were abundant in the summer, while Trichoptera as the third most dominant taxa was abundant in the autumn and winter. Plecoptera was the second most dominant group in spring. One species belong to Odonata in the autumn. At least one of the individuals belonging to Ephemeroptera, Plecoptera, Trichoptera, and Diptera was found at all stations in all seasons.

A total of 34 taxa were detected in the 3rd and 4th stations. The dominant class was Insecta; the dominant group was Amphipoda, followed by Diptera and Trichoptera. A total of 38 taxa were detected in the 5th and 6th stations. The dominant class was Insecta; the dominant group was Ephemeroptera, followed by Diptera and Trichoptera.

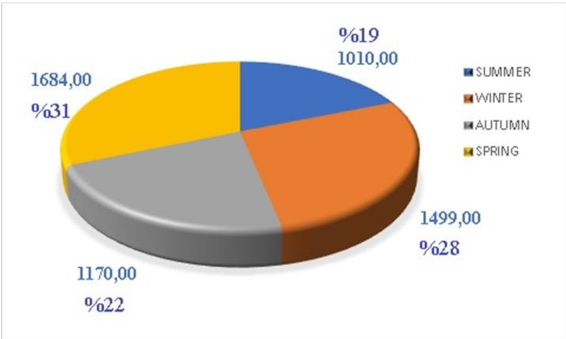

Figure 4. The total number and percent of benthic macroinvertebrates which collected seasonally in Sangı Stream

Regarding spatial distribution, the dominancy of benthic macroinvertebrate species is shown in Fig. 6. As a result of the observations, *Simulium* sp., *Baetis* sp., and *Baetis rhodani* were dominant at station #1 and #2. *Gammarus* sp., *Simulium* sp., and *Hydropsyche* sp. were dominant at station #3 and #4. *Caenis* sp., *Hydropsyche* sp., and *Simulium* sp. were dominant at station #5 while *Baetis* sp., *Simulium* sp., and *Hydropsyche* sp. were dominant at station #6. On the other hand, *Simulium* sp., *Blepharicera* sp., *Chironomus* sp, and all Trichoptera species were found in all stations.

Figure 5. Benthic macroinvertebrate compositions according to the season in Sangı Stream

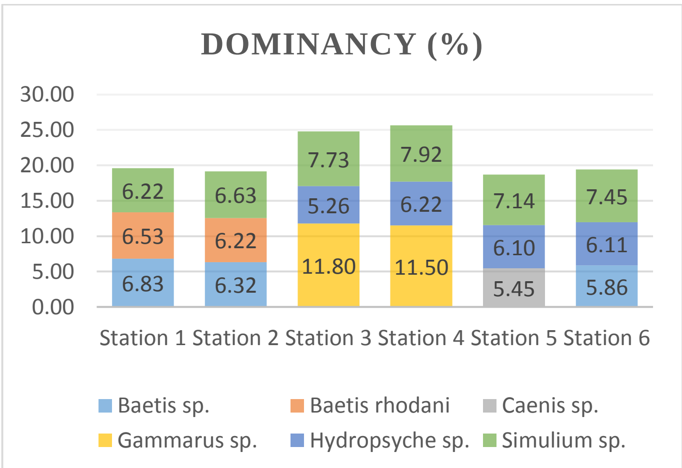

Figure 6. Dominance (%) of the taxon of benthic macroinvertebrates at the stations

SWDI, SDI and MDI values were given in Fig. 7. According to SWDI, the highest species diversity value was found at station #2 while the lowest value at #4. According to SDI, the highest species diversity value was found at stations #1, #2, #3, #5, and #6 while the lowest value at #4. According to MDI, the highest species diversity value was found at station #3 while the lowest value at #4.

The classification of the stations based on benthic macroinvertebrates composition was illustrated by using Bray-Curtis UPGMA analysis (Fig. 8 and Table 1). As a result of the UPGMA analysis, the station (#1- #2) and (#3-#4) were the most similar to each other (94% and 93%) according to benthic macroinvertebrates composition. The second most similar stations to each other were determined at station #5 and #6 (77%), according to benthic macroinvertebrates composition. The lowest similarity was determined between station #1 and #5 (60%).

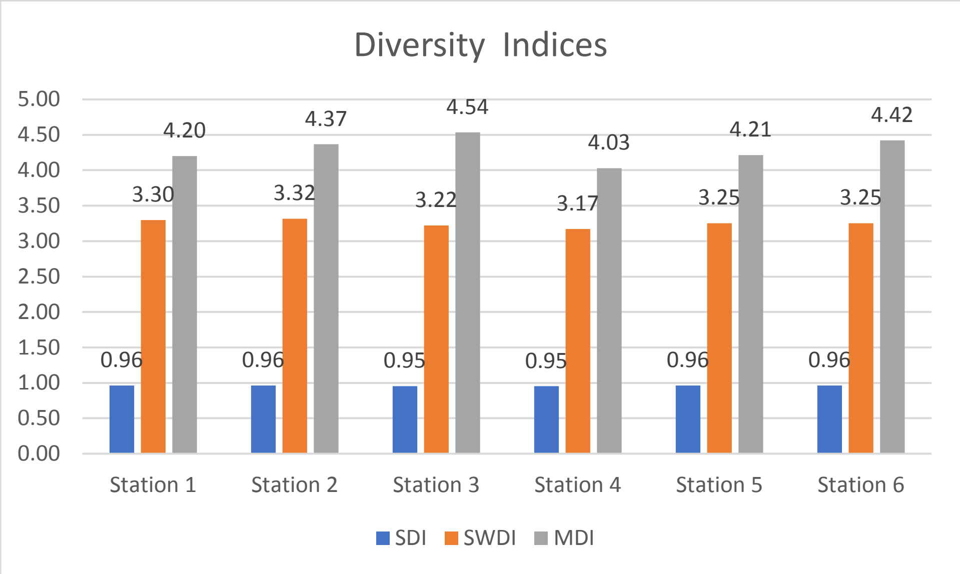

Figure 7. The values of SWDI, SDI, and MDI indices.

Table 1. The similarity matrix is based on the Bray-Curtis index.

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Station 1	1	0,93	0,79	0,75	0,60	0,71
Station 2		1	0,84	0,80	0,63	0,76
Station 3			1	0,93	0,66	0,78
Station 4				1	0,68	0,79
Station 5					1	0,76
Station 6						1

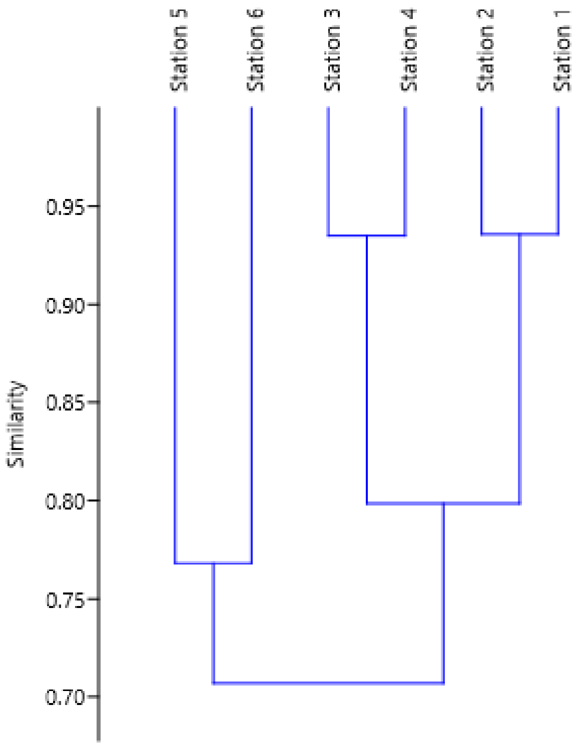

Figure 8. Dendrogram of stations based on the similarity matrix

Discussion

There are a few studies were conducted in the freshwater systems in the Mediterranean region of Turkey. Previous studies determined the most dominant group was Insecta in Yuvarlak Stream (Dügel 1995), in Ağlasun Stream (Kalyoncu and Zeybek 2009); in Çukurca and Isparta Streams (Kalyoncu and Zeybek 2011), in Degirmendere Stream (Zeybek *et al*. 2014); in Kargı Stream (Zeybek 2016), in İyidere and Ciftekavak Streams (Serdar and Verep 2018) and in Sürgü Stream (Kosalsahin and Zeybek 2019).

Results highlighted that station #5 and #6 have indicated that the slightly affected sampling stations from domestic and agricultural pollution because of the existence of species adapting to pollution by regulating life cycles. Oligochaeta species such as *Limnodrilus* sp., and *Limnodrilus hoffmeisteri* are found in these stations. These species appear in the area where the stream flows into the lake. In these areas, the bottom structure was muddy, and the amount of organic detritus was high. However, it was determined that the species number of the Ephemeroptera, Plecoptera, and Trichoptera were low in these sampling stations where the river drained to the dam. Kalyoncu and Zeybek (2009) determined that the 6th station, which was the downstream point of the stream, had low organism diversity. On the other hand, the most dominant group was Diptera, followed by Oligochaeta (*Tubifex tubifex*). *Chironomus thummi* (Diptera) and *Simulium* sp. were the most dominant taxa in Isparta Stream.

Amphipoda groups are frequently preferred river mouth where the water flow rate is low, and macrophytes are dense (Tanyolaç, 2004). They can be found in environments with a high degree of organic pollution at the same time. Gammarus species has a widespread area in freshwater ecosystems. In this study, *Gammarus* sp. was found at the site #2, #3, #4, #5 and #6. The reason for Gammarus species to be found in the second and third stations is since there is a lot of organic drift and wood debris.

Ephemeroptera, Plecoptera, and Trichoptera species are frequently distributed in the headwater region of the aquatic ecosystems. They distribute in cold and clean areas with oxygen-rich and fast water flow. In this study, these groups were mostly distributed at station #1, #2, #3, and #4 in Sangı Stream. Zeybek *et al*. (2014) determined most dominant taxon was Ephemeroptera (a pollution-sensitive species) in upstream sampling stations in Değirmendere Stream.

According to Meyer (1987), *Baetis* sp. organically located in the less polluted streams section and included in water quality class I-II. Many Diptera taxa, especially Chironomidae taxa, have a cosmopolitan distribution and can be found in all kinds of environments, from clean water to filthy water (Stribling *et al*. 2003, Kalyoncu *et al*. 2009). In this study, *Chironomus* sp. found at all stations. It has been a taxon that is continuously present at all stations. In addition, it was found that there were taxa belonging to the Diptera at all stations. Zeybek *et al*. (2012) found *Baetis* sp. less polluted sampling point in Köprüçay River. In this study, the species belong to Trichoptera, Ephemeroptera, and Gammarus species were detected in the same sampling points. *Gammarus* species are found intensively in slightly polluted areas of the freshwater ecosystems (Meyer 1987, Kalyoncu and Zeybek 2009). Members of Ephemeroptera-Plecoptera-Trichoptera (EPT) are considered sensitive to environmental stress and their presence in high abundance at the spring of the stream, where the quality of the water is high (Armitage *et al*. 1983). Therefore, the presence of EPT was assigned as a bioindicator for a pristine freshwater ecosystem. According to Lenat (1988), EPT taxa are mostly found in clean waters, and they give us information about the pollution status of the freshwaters. The EPT members include intolerant organisms and found in areas protecting its species diversity (Armitage *et al*. 1983, Wahizatul *et al*. 2011).

In this study, the lowest species diversity value was found at the 4th station. Habit *et al*. (1998) found the lowest benthic macroinvertebrate diversity at the sampling point with mud-like sediment in the Itata River. Zeybek *et al*. (2012) determined the lowest benthic macroinvertebrate diversity at the same sediment type in Köprüçay Stream. The 4th station evaluated in this study has a similar benthic structure with Itata and Köprüçay River.

Conclusion

Agricultural activities in the region impoverish the soil in terms of many minerals. In this regard, inorganic and phosphate fertilizers are used extensively almost throughout the basin. According to the biological data obtained as a result of our study; It was determined that many agricultural areas located around the basin and which are of great importance for our country have not yet created any significant pressure on the ecosystem. Intermittent monitoring research should be carried out on both Sangı Stream and all other surface water resources in the Tahtalı Dam Lake basin to prevent agricultural activities' adverse effects. With this aim, all stream sources' ecological quality in the Tahtalı Dam Basin should be determined based on benthic macroinvertebrates. By considering the data to be obtained, the cumulative effect of the basin's pollutant factors should be determined through a large-scale biological monitoring study in Tahtalı Dam Lake. To make a more accurate assessment in terms of water quality, biological data obtained from freshwater ecosystems should be evaluated with biotic indices. However, physicochemical measurements should be made in freshwaters, and biotic index results should be supported. A biological index that will cover the Mediterranean region must be created in order to evaluate water quality more accurately.

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