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Research Article **Araştırma Makalesi**

Macrozoobenthic Fauna of Demre Stream (Antalya, Türkiye)

Demre Çayı (Antalya) Makrozoobentik Faunası

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Abstract: In this study, it was aimed to determine the benthic macroinvertebrate fauna of Demre Stream in Antalya. Benthic macroinvertebrate samples were taken seasonally from 12 stations determined on Demre Stream between April 2015 and December 2015 and the obtained individuals belonging to Clitellata, Rhabditophora, Gastropoda, Insecta, and Arachnida groups Macroinvertebrate based clustering of stations was calculated by using UPGMA analysis. The lowest similarity was determined between the 3rd and 10th stations, and the highest similarity was between the 8th and 11th stations. Simpson and Shannon-Wiener diversity indices were applied to determine the diversity values of the stations. According to both diversity indices, the highest diversity value was reached at the 5th station, while the lowest diversity value was reached at the 3rd station. This study is the first study to determine the benthic fauna of the Demre Stream and therefore all the groups identified are the first records for the Demre Stream.

Keywords
- Benthic invertebrate
- Biodiversity
- Species distribution
- Dominance

Özet: Nisan 2015 ile Aralık 2015 tarihleri arasında Demre Çayı üzerinde belirlenen 12 istasyondan bentik makroomurgasız örnekleri mevsimsel olarak alınmış ve Clitellata, Rhabditophora, Gastropoda, Insecta and Arachnida gruplarına ait bireyler elde edilmiştir. UPGMA analizi kullanılarak, istasyonların makroomurgasız temelli gruplandırılmaları yapılmıştır. En düşük benzerlik 3. ve 10. istasyonlar arasında, en yüksek benzerlik ise 8. ve 11. istasyonlar arasında belirlenmiştir. Yine istasyonlara ait çeşitlilik değerlerinin belirlenmesi amacıyla Simpson ve Shannon-Wiener çeşitlilik indeksleri uygulanmıştır. Her iki çeşitlilik indeksine göre de en yüksek çeşitlilik değerine 5. istasyonda ulaşılırken, en düşük çeşitlilik değerine 3. istasyonda ulaşılmıştır. Bu çalışma, Demre Çayı'nın bentik faunasının belirlenmesi amacıyla yapılan ilk çalışmadır ve bu sebeple belirlenen tüm gruplar Demre Çayı için ilk kayıttır.

Anahtar kelimeler
- Bentik omurgasız
- Biyolojik çeşitlilik
- Tür dağılımı
- Baskınlık

1. INTRODUCTION

Water is an indispensable source of life for all organisms, and they use water for nutrition, shelter, and the balanced functioning of their bodies. In addition to being one of the essential elements in the formation of aquatic habitats, water is a living environment for aquatic ecosystems (Shannon et al., 2008). Wastes from residential areas and mining, industrial and agricultural activities around rivers and lakes are important factors in the pollution of inland waters. Streams are considered the most threatened ecosystems in the world (Cairns & Prall, 1993; Malmqvist & Rundle, 2002; Gatti, 2016) as local and global changes have significantly and irreversibly affected the river ecosystem structure through human encroachment, pollution, and hydrological constraints such as channelization, dams and dykes (Dynesius & Nilsson, 1994; Nilsson & Berggren, 2000; Abell, 2002).

The biological approach for water quality determination has been developed as a complementary method to chemical water analysis. Many organisms are extremely sensitive to changes in their environment and respond to these changes in different ways. When the responses of aquatic organisms to changes are determined, the quality of the existing aquatic environment is also determined (Hynes, 1960; Rosenberg & Resh, 1993; Ghetti & Ravera, 1994; Metcalfe-Smith, 1994; Knoben et al., 1995; Dolédec & Statzner 2010; Lunde & Resh, 2012).

Macroinvertebrates are used as indicators of water quality as they are resident long-lived species and have strong responses to the effects of humans on aquatic environments (Cairns & Prall, 1993). Since macroinvertebrates can reflect the ecological conditions of the aquatic ecosystems in which they live, understanding their habitat preferences allows for the protection and biological monitoring of aquatic habitats. (Callisto et al., 2005; Behrend et al., 2012, Demars et al., 2012). Furthermore, identifying the spatial distribution of benthic macroinvertebrate enable the determination of their responses to environmental gradients (Wills et al., 2006; Angradi et al., 2009; Pelletier et al., 2010). The main purpose of this study is to reveal the macroinvertebrate composition and diversity of Demre Stream. In addition, this research provides important data about the existing macroinvertebrate community structure and ecological status assessment of the Demre Stream and aquatic biodiversity list of Turkey.

2. MATERIAL and METHODS

2.1. Study Area

Demre Stream is located within the borders of Antalya province, starting at the Sıdrek Mountain, which is across the Boğazcık Island, and disemboguing at the east of Kumburnu; Demre Stream is named Felendere-Myros in Antiquity where it starts. Its length is 45 kilometers. It can hold approximately 1000 square kilometers of water (Keser, 2012).

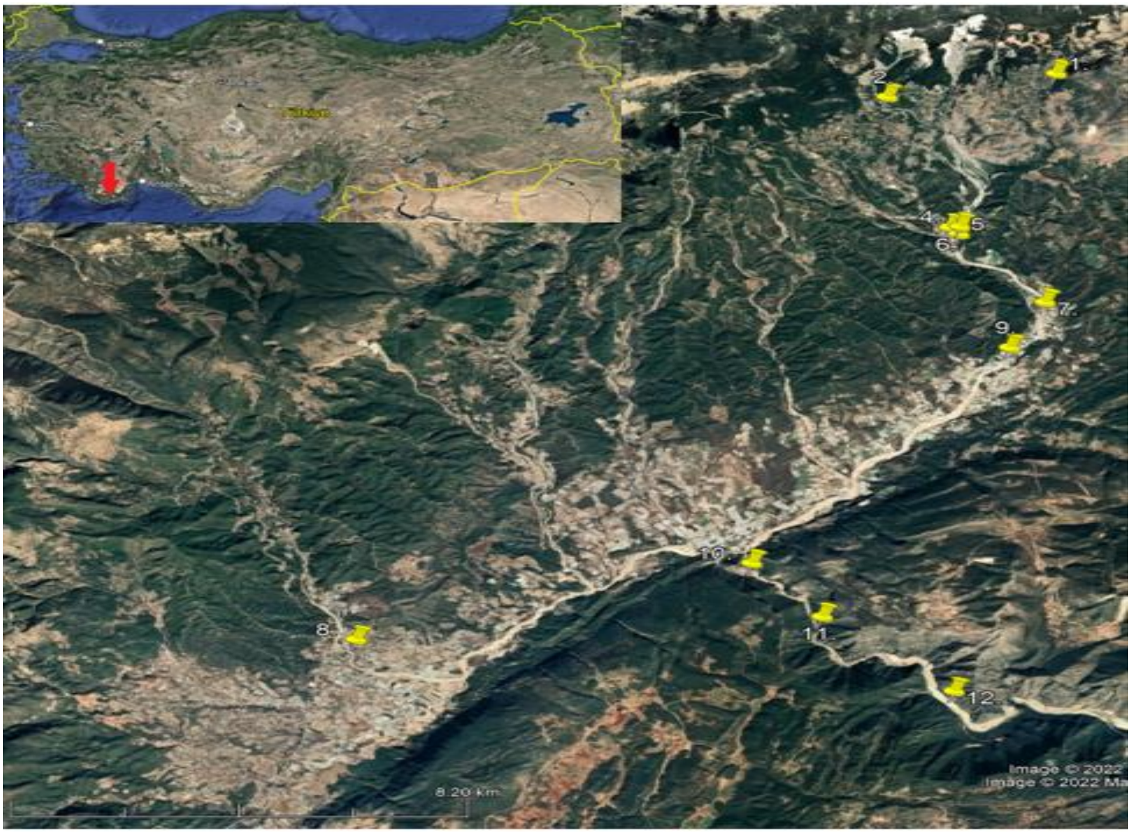

Figure 1. The study area and stations (taken from google earth)

2.2. Sampling Area

This study was conducted in April-2015, July-2015, October-2015, and Decemeber-2015 at 12 sampling stations from Demre Stream (Figure 1). The stations were chosen by considering the presence of settlements and agricultural areas, tributaries, and stream source features. Stations 3, 4, 5, 7, 8, 9, and 10 pass through agricultural areas and settlements. In the 3rd station, there was flow only in spring, and the 1st, 4th, 5th, and 6th stations were dry in the autumn and winter. Stream water was drawn for agricultural irrigation from the 10th station. Since there were marble quarries in the riverside region before the 11th station, a lot of marble dust was found on the floor and formed a hard floor. This situation created an unfavorable environment for macrozoobenthic organisms. Macroinvertebrate samples were taken by using a standard hand net (30x50 size with 500µ mesh) and taken from an area of 100 m to include all possible microhabitats at each station. In addition, the bottoms of the large stones were removed and the samples in those regions were taken with the help of forceps. Collected organisms were fixed into %70 ethyl alcohol (Plafkin et al., 1989).

The samples were identified according to Hynes (1977), Wallace et al., (1990), Elliott et al., (1988), Nilsson (1996), Nilsson (1997), Waringer & Graf (2011), Glöer (2002), Crosskey (2002), Crosskey & Crosskey (2000), Crosskey and Zwick (2007), Jedlicka et al., (2004), Lechthaler & Car (2005), Rubtsov (1990), Lechthaler & Stockinger (2005), Gerecke et al., (2016) and Gerecke (2003).

2.3. Data Analysis

Dominance analysis (Kocataş, 1997), Sorensen similarity index method (UPGMA) (Kocataş 1997), Shannon-Weiner (H') (Shannon, 1948), and Simpson's (D) diversity indices (Krebs, 1989) were used for data analysis.

3. RESULTS and DISCUSSION

In this study, which was carried out seasonally in Demre Stream between Spring 2015 and Winter 2015, a total of 36973 individuals were examined. Among the selected 12 stations, the highest number of individuals was reached at station 4 (8366), and the lowest number of individuals was reached at station 3 (88). The numerical distribution of the individuals from the Demre Stream based on the stations were given in Figure 2.

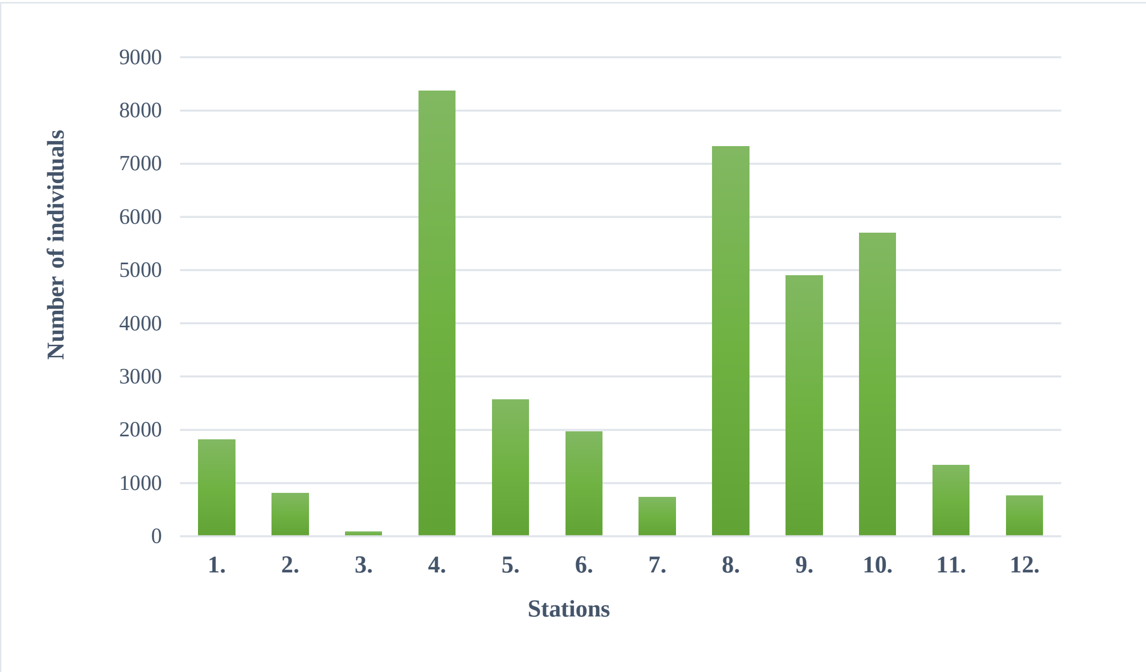

Figure 2. Distribution of the number of individuals in stations.

As a result of the identifications, taxa belonging to the classes Clitellata, Rhabditophora, Gastropoda, Insecta, and Arachnida were found in the study area. Oligochaeta and Chironomidae taxa were taken as groups and no systematic classification was made. The highest number of individuals was determined at station 4, while the lowest number of individuals was determined at station 3. It was thought that the fact that the 3rd station has only one single-season flow. Except for the spring season, the 3rd station was dry. The distribution, dominance and mean dominance of the species detected in Demre Stream according to the stations are given in Table 2.

Table 2. Species distribution, dominance, and mean dominance of Demre Stream.

Identified Taxa	**Stations**												**Mean**
	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**	
Class: CLITELLATA													
Subclass: HIRUDINEA													
Order: ARHYNCHOBDELLIDA													
Family: Erpobdellidae													
Erpobdella octoculata Linnaeus, 1758		0.123						0.013					0.011
Subclass: Oligochaeta	0.055	0.247		0.119					0.017	0.07	0.074	0.138	0.060
Class: Turbelleria													
Order: TRICLADIDA													
Family: Planariidae													
Dugesia sp.										0.017			0.001
Class: GASTROPODA													
Family: Planorbidae													
Gyraulus albus O. F. Müller, 1774	0.055									0.017			0.005
Gyraulus spp.		2.595		0.023		0.05	0.401		0.143			4.016	0,602
Planorbis planorbis Linnaeus, 1758										0.211			0.017
Class: INSECTA													
Order: EPHEMEROPTERA													
Family: Heptageniidae													
Rhitrogena semicolorata Curtis, 1834								0.068			0.074		0,011
Rhitrogena spp.								0.109		0.017	0.598	0.138	0.072
Heptagenia sulphurea Müller, 1776								0.068		0.105		0.969	0.095
Heptagenia spp.								0.737		0.228	0.598		0.130
Ecdyonurus venosus Fabricius, 1775								0.355					0.029
Family: Ephemerellidae													
Seratella ignita Poda, 1761								0.778		0.351	2.17	0.415	0.309
Family: Caenidae													
Caenis rivulorum Eaton, 1884										0.017			0.001
Caenis macrura Stephens, 1835												0.27	0.023
Caenis luctuosa Stephens, 1835								6.544	0.071	1.142	1.871	1.138	0.814
Caenis spp.								5.383	0.017	0.351	1.497	0.138	0.615
Family: Baetidae													
Baetis rhodani Pictet, 1843	14.64	3.708	23.863	20.494	15.421	4.735	17.402	9.318	8,991	28.749	26.422	18.698	15.26

Baetis pavidus Grandi, 1949					23.724		0.937		3.646			2.77	2.589
Baetis alpinus Pictet, 1843									1.43				0.119
Baetis fuscatus Linnaeus, 1761									1.893				0.074
Baetis digitatus Bengtsson, 1912					4.744								0.395
Baetis spp.	17.403	3.213	59.09	3.477	11.071	17.158	5.22	44.022	7.275	16.775	43.637	43.628	22.664
Order: PLECOPTERA													
Family: Taeniopterygidae													
Brachyptera spp.										0.052		0.138	0.015
Family: Perlodidae													
Isoperla grammatica Poda, 1761				0.023									0.001
Family: Leuctridae													
Leuctra hippopus Kempny,1899		0.123						0.792		0.105	5.389	1.385	0.649
Leuctra inermis Kempny, 1899											0.898		0.074
Leuctra spp.									0.053				0.004
Family: Nemouridae													
Protonemura meyeri Pictet, 1841	0.055												0.004
Nemoura sp.	0.055												0.004
Order: ODONATA													
Family: Euphaeidae													
Epallage fatima (Charpentier, 1840)										0.052	0.074		0.01
Family: Gomphidae													
O. forcipatus albotibialis Schmidt, 1964								0.109		0.052			0.013
Family: Libellulidae													
Sympetrum sp.								0.013					0.001
Order: COLEOPTERA													
Family: Elmidae													
Elmis maugetii Latreille, 1798	0.441			1.23	1.423	0.356	1.204	0.081	0.321		0.598	0.138	0.483
Elmis spp.	0.110												0.009
Family: Haliplidae													
Haliplus spp.	0.055							0.122			0.074		0.021
Family: Dytiscidae													
Agabus bipustulatus Linnaeus, 1767				0.011									0.001
Agabus spp.	0.441	0.37	1.136	0.191	0.039								0.181
Laccophilus spp.	0.22												0.018
Ilybius spp.			1.136		0.039	0.05							0.102
Stictotarsus sp.				0.011									0.001

Nebrioporus sp.												0.138	0.011
Deronectes spp.				0.059									0.004
Hydroporinae sp.									0.017				0.001
Order: TRICHOPTERA													
Family: Hydropsychidae													
Hydropsyche dinarica Marinkovic-Gospodnetic, 1979					0.158			0.136	0.053	0.386	2.095	0.138	0.247
Hydropsyche bulbifera McLachlan, 1878										0.07			0.005
Hydropsyche saxonica McLachlan, 1884				0.035				0.081		0.052	0.673		0.07
Hydropsyche instabilis Curtis, 1834				0.011	0.039					0.017	0.149		0.018
Hydropsyche guttata Pictet 1834								0.013		0.07	0.074		0.013
Hydropsyche tenuis Navás, 1932										0.035			0.002
Hydropsyche fulvipes Curtis, 1834										0.017	0.074		0.007
Hydropsyche pellucidula Curtis, 1834								0.081	0.035	0.386			0.042
Hydropsyche angustipennis Curtis, 1834								0.013	0.017		0.074		0.008
Cheumatopsyche lepida Pictet, 1834										0.14		0.554	0.057
Hydropsyche spp.				0.095	0.434	0.05		1.379	0.536	2.268	4.266	2.77	0.983
Family: Hyroptilidae													
Hydroptila spp.								1.239	0.035				0.105
Order: DIPTERA													
Family: Simuliidae													
Simulium auricoma Meigen, 1818	0.055			0.011									0.005
Simulium bezzi Corti, 1914	0.05												0.004
Simulium (Simulium) posticatum Meigen, 1838		0.618			3.163								0.315
Simulium (Simulium) ornatum Meigen, 1818	1.657			8.986	2.767								1.117
Simulium (Eusimulium) angustipes Edwards, 1915				18.283	9.727	30.549	0.803	0.587	0.107	6.699		0.831	5.632
Simulium maculatum Meigen, 1804					1.977								0.164
Simulium (Wilhelmia) pseudequnium Seguy 1921								0.081		0.105			0.015
Simulium (Wilhelmia) balcanicum Enderlein 1924				0.298						0.011			0.025
Simulium (Nevermannia) angustitarse				0.191									0.015

Lundstrom, 1911													
Simulium (Simulium) trifasciatum Curtis, 1839				0.286	0.197					0.017			0.041
Simulium (Wilhelmia) equnium Linnaeus, 1758				0.011									0.001
Simulium (Obuchovia) sp.				0.011									0.001
Simulium spp.	0.55	33.86		37.96	3.12	20.41	38.95	16.61	58.00	35.25		11.63	25.63
Family: Tipulidae													
Dicronata spp.				0.011				0.04					0.004
Tipula spp.	0.055	0.123			0.079		0.401	0.068			0.074		0,066
Family: Chironomidae													
Chironomus spp.	59.11	53.52	13.63	7.76	20.79	26.42	33.60	10.32	17.78	5.57	7.63	9.83	22.16
Family: Dixidae													
Dixa nebulosa Meigen, 1830	1.823	0.494			0.079	0.101		0.016				0.138	0.22
Family: Empididae													
Wiedemannia spp.	1.767		1.136	0.083	0.039			0.177					0.267
Hemerodromia spp.	0.055	0.247		0.095	0.118	0.05		0.136	0.143	0.052			0.075
Family: Ephydridae													
Scatella spp.		0.37		0.023			0.267						0.055
Family: Muscidae													
Limnophora riparia Fallen, 1824	0.055			0.023	0.316								0.032
Family: Psychodidae													
Pericoma spp.	0.994	0.123											0.093
Ulomyia sp.		0.123											0.01
Family: Tabanidae													
Hybomitra spp.	0.055							0.068			0.299		0.035
Tabanus spp.								0.081		0.035			0.035
Hexatoma sp.					0.039								0.003
Family: Syrphidae													
Sericomyia sp.							0.133						0.011
Class: Arachnida													
Order: Trombidiformes													
Family: Hygrobatidae													
Atractıdes polyporus (K. Viets, 1922)	0.11												0.009
Atractides nodipalpis (Thor, 1899)		0.123		0.418	0.474	0.05	0.535	0.191	0.393		0.598	0.969	0.312
Hygrobates longipalpis (Hermann, 1804)				0.023						0.175			0.016

Family: Lebertiidae				
Lebertia sp.	0.11			0.009
Family: Torrenticolidae				
Torrenticola sp.		0.013		0.001
Family: Sperchontidae				
Sperchon sp.		0.06	0.017	0.007

Among the determined taxa, Insecta was the most dominant group. This class has been obtained as the dominant group many times in different studies in Turkey (Sukatar et al., 2006; Türkmen & Kazancı, 2018; Baytaşoğlu & Gözler, 2021; Ertaş & Yorulmaz, 2021, Ertaş et al., 2022). In this study, the Diptera was the most dominant order, and the families Simuliidae and Chironomidae are included in the order Diptera, which was very effective in the emergence of this situation. There are similar studies in which these groups are dominant (Raczyńska & Chojnacki 2009; Akbaba & Boyacı, 2016; Albayrak & Özuluğ 2016; Gültekin et al., 2017; Topkara et al., 2018; Khamenkova et al., 2017; Özbek et al., 2019). Ephemeroptera was the second most dominant order. Although members of the order Acari and Coleoptera were found in almost all stations, they didn't have a significant dominance in the study area. Members of the other groups determined in Demre Stream also didn't have a significant dominance. The dominance values of the other orders determined were quite low and varied between 0.0014 and 1.563.

Members of the genus Simulium were an important component of macroinvertebrate communities and are used as bioindicators of aquatic habitats due to their high susceptibility to environmental degradation (Hyder 1998; Docile et al., 2015). They were found in fast-flowing and well-oxygenated parts of streams (Vijayan and Anbalagan, 2018). Simulium genus members were determined at all stations except the 3rd and 11th stations and emerged as the most dominant taxon of the 4th, 6th, 7th, and 9th stations. The absence of individuals belonging to the genus Simulium at station 3, may be due to the fact that this station was dry during the three periods during which the study was conducted and showed relatively slow flow. It is thought that the bottom structure of the 11th station is quite hard due to the high amount of marble dust, the marble dust fills the surface parts of the stones, which are the habitat of Simuliums, and sticks like cement, the reason for the absence of individuals belonging to this taxon at this station. In this study, Simulium taxon was determined as the most dominant group and in Turkey, there are various studies on Simulium group distribution (Bolat et al., 2016; Özel et al., 2019; Başören & Kazancı, 2022).

Members of the Chironomus group were constantly present at all stations and were the most dominant group of the 1st and 2nd stations. Chironomidae taxa have a very cosmopolitan distribution and are found in all stream types and substrate surfaces. They can be found in almost any environment, from clean water to very polluted water (Nilsson, 1997; Stribling et al., 1998). They can reveal the water quality, pollution level, and eutrophication status of the aquatic environment (Kırgız, 1988; Yalçın, 1991). Studies have been carried out on the Chironomidae taxon in our country, and our study is compatible with these studies (Taşdemir et al., 2010; Aydın, 2014; Albayrak and Özuluğ, 2016; Ertaş et al., 2021).

Genus Baetis was determined at all stations, with the most dominant taxon at stations 3rd, 5th, 8th, 10 th, 11th, and 12th. Individuals of this genus are used as indicator group for determining water quality and prefer oligosaprob and betamezosaprobe regions as habitat (DIN38410, 2004). In our study, individuals belonging to this taxon were determined in oligosaprob and betamezosaprobe water quality and *Baetis rhodani* was consistently found at all stations. Similarly, there are some studies indicating that individuals belonging to the Baetis taxon are widely found in oligosaprob and betamezosaprobe regions of the study areas (Uzun, 2018; Bakioğlu, 2019; Varadinova et al., 2022).

In this study, Oligochaeta taxon members were found at stations 1st, 2nd, 4th, 9th, 10th, 11th, and 12th. Oligochateta group members are used as indicator organisms to determine pollution levels or environmental changes in aquatic ecosystems, as they have a high species diversity and wide ecological range (Lafont, 1984; Milbrink, 1994; Sarkka, 1994; Finogenova, 1996). In some biotic index applications, the presence or absence of these group members in the environment is effective in determining the water quality, while in some index applications, the numerical values and the number of individuals are effective and have a negative effect on the water quality. That is why they are of great importance. There are various studies in which the Oligochaeta group is commonly determined (Arslan & Şahin, 2004; Arslan et al., 2007; Yıldız et al., 2012; Odabaşı et al., 2018., Fındık et al., 2019, Arslan & Mercan, 2020; Odabaşı, 2021). In our study, the members of this group show a widespread and are in parallel with other studies.

Trichoptera members were absent at the first 3 stations and were represented by only one individual at the 6th station. It is thought that the fact that the stations, where team members are not present are, dry in autumn and winter and that the microhabitat structure is not suitable for the group members to live in are effective in the emergence of this situation. Trichoptera were represented with more individuals at the 8th and later stations and showed higher diversity value. Some species of the Hydropsyche genus are common in streams as they are resistant to slight to moderate pollution (Hynes, 1960; Karakaş, 2018). Individuals of the Hydropsyche genus were identified at stations 4 th, 5 th, 6th, 8 th, 9 th, 10 th, 11 th, and 12 th. Members of this taxon live in oligosaprob and alpha-mesosaprobe regions and do not show distribution in other regions (DIN38410, 2004).

Elmis maugetii was determined at all stations in the study area, except for stations 2nd and 3 nd. Individuals of this species were only found in spring at station 6, only in summer at stations 10 and 11, and in both spring and summer at other stations. No individuals belonging to this taxon were found in other seasons. According to DIN38410 (2004), individuals belonging to this species are used as indicators in determining the water quality and prefer oligosaprob and betamezosaprobe regions as habitats. In this study, it was determined that the stations with *Elmis maugetii* species had oligosaprobic and alpha-mesosaprobic properties.

In this study, Simpson and Shannon-Wiener diversity indices were applied to each station to determine species diversity. In the Shannon-Wiener (H') species diversity index, the proportional contribution shares among the species are taken into account as well as the number of species. In cases where species are rich and there is an equal distribution between species in terms of quantity, the indices value is high (Odum and Barrett, 2008; Jorgensen et al., 2005). The limits of this index vary between 0-5 values, and as the obtained value approaches 5, the diversity of species increases (Kocataş, 2014). The Simpson (D) diversity index gives the probability that two randomly selected species are different from all samples. The value obtained varies between 0 and 1, as the value approaches 1, the diversity of species increases (Krebs, 1989). According to both diversity indices, the highest diversity value was reached at the 5th station. It is thought that the 5th station's creation of a suitable microhabitat especially for the members of the Diptera order is effective in the emergence of this situation. The lowest diversity value was determined at the 3rd station, and it is thought that only single-season flow, the widening of the creek bed, the low amount of water, and the fact that it passed through agricultural lands and settlements were effective in the emergence of this situation. There are many studies in which Shannon-Wiener (H') and Simpson (D) diversity indices are applied (Arslan et al., 2016; Spyra et al., 2017; Nurhafizah & Ahmad, 2018; Özbek et al., 2019; Ertaş et al., 2022). The average diversity values of the stations are given in Table 3.

Table 3. The average diversity values of stations

Diversity Indices	Stations											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Simpson's (D)	0.597	0.590	**0.575**	0.765	**0.829**	0.764	0.701	0.750	0.667	0.757	0.728	0.707
Shannon-Weiner (H')	1.320	1.169	**1.077**	1.703	**2.706**	1.532	1.409	1.847	1.470	1.728	1.767	1.664

In this study, the similarity values between the stations were calculated using the Sorensen similarity index. The highest similarity value between stations was determined between the 8th and 11th stations (0.66), and the lowest similarity value was determined between the 3rd and 10th stations (0.143). In addition, high similarity was found between stations 6 and 7 (0.64), between stations 9 and 12 (0.62), and between stations 5 and 6 (0.61). It is thought that the fact that there is flow in both stations in every season, the amount of water they carry, and the similarity of the river bottom structures are effective in the formation of this situation. Similarity values between stations are given in Figure 3.

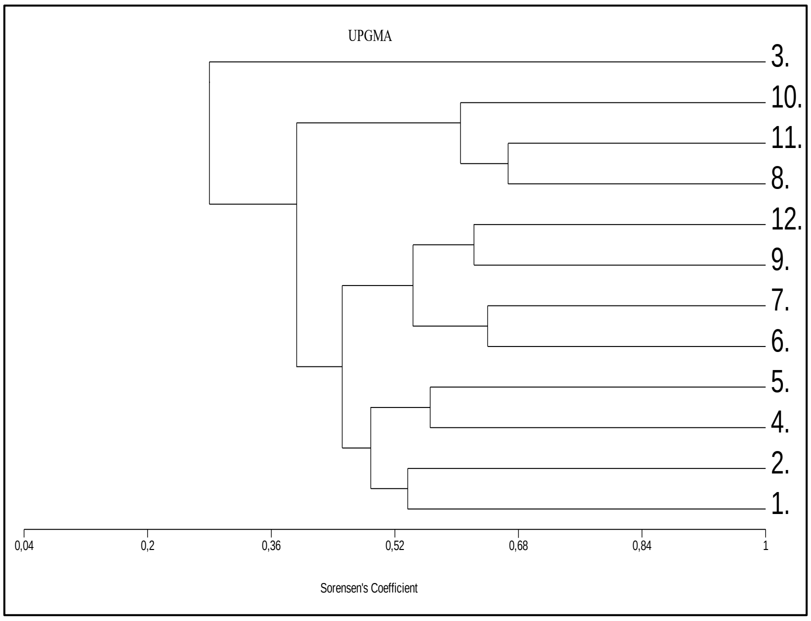

Figure 3. Similarity values between stations

With this study on the Demre Stream, the macroinvertebrate fauna of the region, the distribution of the obtained groups according to the stations, and the similarity and diversity values of the stations were revealed. In this respect, it is the first study in this field. All given groups are the first to register for Demre Stream.

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CONFLICT of INTEREST

The authors declare that there are no financial interests or personal relationships that could affect this work.

AUTHOR CONTRIBUTIONS

Planning the study: F.K., S.T.Ö., Field study: F.K., Laboratory study: F.K., Evaluation of results: F.K., S.T.Ö., Article writing: F.K., S.T.Ö. Both authors approved the final draft.

ETHICAL STATEMENT

There are no ethical issues regarding the publication of this article.

DATA AVAILABILITY STATEMENT

Data used in this study are available from the corresponding author upon reasonable request.

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