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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Diversity of benthic macroinvertebrates and water quality of Karasu Stream (Black Sea)

Karasu Deresi'nin (Karadeniz) bentik makroomurgasız çeşitliliği ve su kalitesi

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Abstract: The study was conducted in Karasu Stream (Sinop Province, Black Sea Region of Turkey). The purpose of this study is, to determine the benthic macroinvertebrate composition of the stream, together with some of its environmental characteristics (water temperature, pH and dissolved oxygen) to evaluate the trophic level of the stream. Samplings of benthic macroinvertebrates and environmental variables were performed monthly at ten stations between February 2013 and January 2014. As a result, 18260 specimens were investigated and 175 taxa were determined. Chironomidae and Oligochaeta were the higher groups in terms of species richness with 48 and 38 taxa, respectively. The BMWP and ASPT indices indicate that all the stations belong to "slightly polluted (Class II)" or "unpolluted (Class I)" water quality levels.

Keywords: Stream, water quality, benthos, macroinvertebrate, Turkey

Öz: Çalışma; Karasu Çayı'nda (Türkiye'nin Karadeniz Bölgesi, Sinop İli) yürütülmüştür. Bu çalışmanın amacı, akarsuyun bentik makroomurgasız tür kompozisyonunu belirlemek, bazı çevresel özellikleri (su sıcaklığı, pH ve çözünmüş oksijen) ile birlikte akarsuyun trofik seviyesini değerlendirmektir. Makrobentik omurgasızların ve çevresel değişkenlerin örneklemesi, Şubat 2013 - Ocak 2014 tarihleri arasında 10 istasyonda aylık olarak gerçekleştirilmiştir. Sonuç olarak, 18260 örnek incelenmiş ve 175 takson belirlenmiştir. Tür zenginliği açısından Chironomidae ve Oligochaeta sırasıyla 48 ve 38 takson ile en yüksek gruplardır. BMWP ve ASPT endeksleri, tüm istasyonların "hafif kirli (Sınıf II)" veya "kirlenmemiş (Sınıf I)" su kalitesi seviyelerine ait olduğunu göstermektedir.

Anahtar kelimeler: Akarsu, su kalitesi, bentos, makroomurgasız, Türkiye

INTRODUCTION

The physico-chemical parameters can reflect temporary water quality levels of the region and cannot give reliable data about the amount of pollution in streams or rivers. Which can be helpful but insufficient when considering a long-term water quality assessment (Demir, 2005) but organisms such as macroinvertebrates, fish, etc. can be more adapted to a specific environment. Benthic macroinvertebrates constitute a major component of the aquatic biota in freshwater environments. Most of them have constricted ecological demands and are very beneficial as bioindicators in determining the characteristics of aquatic environments (Benetti and Garrido, 2010). They are the group of organisms most frequently used in biomonitoring studies of running waters because their responses to all kind of pollution have been extensively proven (Thorne and Williams, 1997).

Various studies have been conducted on the assessment of benthic macroinvertebrates in Sinop province (Akbulut,1996; Bat *et al*. 2000; Akbulut, 2001; Akbulut *et al.* 2001;2002; Ertorun and Tanatmış, 2004; Öktener, 2004; Tanatmış, 2004; Şendoğan, 2006; Tanatmış and Ertorun, 2008; Yardım *et al*. 2008; Aydemir-Çil, 2014; Yardım *et al*. 2017). There is no study carried out on the diversity of benthic macroinvertebrate of the Karasu Stream.

The objective of this study is to determine both the benthic macro-invertebrate composition of the stream and some environmental parameters (water temperature, pH, and dissolved oxygen) and to assess the ecological quality of the stream

MATERIALS AND METHODS

Karasu Stream, which has approximately 80 km in length, originates from Boyabat district, passes along Erfelek town in Sinop province, and flows into the Black Sea (Figure1). The stream and Erfelek Dam supply the drinking water of the surrounding settlements.

Environmental variables and benthic materials were sampled at 10 sites between February 2013 and January 2014 in monthly intervals (Figure 1, Table 1). In total, seven sites were located on the mainstream (two of them – upstream the dam) and three sites were on tributaries. Karasu River flows into the Black Sea through an estuarine system, thus the sites A1 and A2 are under the influence of water from the sea in spring and winter due to waves and currents. The A3 and A6 sites are located on Karasu Creek, while the A4, A5 and A7 sites were selected from the tributaries of the stream. A9 and A10 were selected before the Erfelek Dam. The substrate types, vegetation, and geographic data of the sites are given in Table 1.

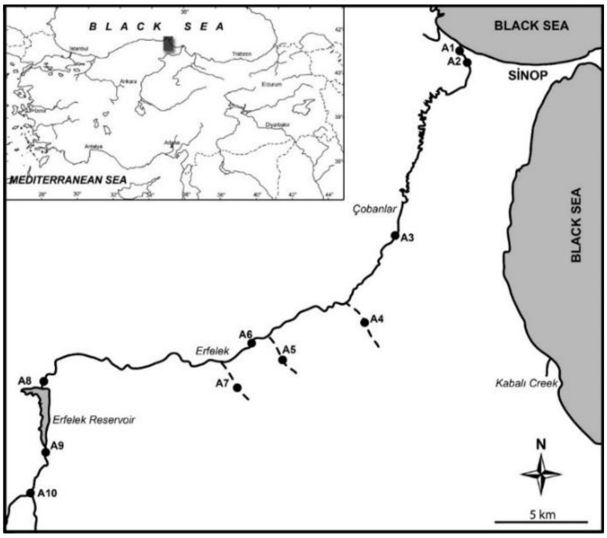


Figure 1. The geographical location of the study area (Karasu Stream) and the sampling sites.

The environmental variables were measured using Hanna 9829 HI model multiparameter device. Samples were collected by the Kick-sampling method (Letovsky *et al.* 2012) from a 1 m^2 area with a 5-minute collection standard (kick-net mesh size 180 µm).

Table 1. Geographical and ecological data about the sampling sites

Station	Latitude	Longitude	Substrate Type	Depth(m)	Riparian Vegetations
A1	42°01'56"N	35°03'33"E	sand and mud	0-4 m	grassland and reedbed
A2	42°01'52"N	35°03'34"E	sand and mud	0-4 m	grassland and reedbed
A3	41°55'05"N	35°06'14"E	stone and mud	0-1 m	grassland and moss
A4	41°54'16"N	34°59'49"E	mud	0-0.5 m	grassland
A5	41°53'32"N	34°56'04"E	mud	0-0.5 m	grassland
A6	41°52'46"N	34°51'23"E	stone and mud	0-0.5 m	grassland and *Chara* sp.
A7	41°52'59"N	34°47'45"E	rocks and mud	0-1 m	grassland and green algae
A8	41°50'53"N	34°46'31"E	calcareous rocks	0-0.5 m	-
A9	41°50'26"N	34°46'47"E	mud	0-0.5 m	grassland and *Astiboles* sp.
A10	41°49'24"N	34°46'17"E	rocks and mud	0-1 m	grassland and moss

The samples were transferred into 500-1000 ml plastic jars and fixed in 4% formalin solution in the field. Then, in the laboratory, the collected materials were washed under tap water to remove formaldehyde and filtered through 0.5- and 1-mm sieves to sort the macroinvertebrates based on size. The, organisms were transferred into small jars with 75% ethanol solution.

Fauna Europaea (2021) database was used for the current names of the taxa. All the macroinvertebrate samples were identified to the genera-species level whenever possible.

The Index of Diversity (H') (Shannon and Weaver, 1949), Pielou's Evennes Index (J') (Pielou, 1975), Similarity Index (Brayand Curtis, 1957), frequency (Soyer, 1970), and dominance values (Bellan-Santini, 1969) of the determined taxa were calculated and used to describe the characteristics of the sites and Karasu Stream. For assessing the water quality of the studied locations, Biological Monitoring Working Party (BMWP) scores (Paisley *et al.* 2013) and Average Score Per Taxon (ASPT) (Armitage *et al.* 1983) were calculated. These scores were obtained from ASTERICS 3.3.1 (AQEM/STAR Ecological River Classification System; AQEM Consortium 2002) software.

The similarity of the studied localities followed by cluster analysis (UPGMA, Unweighted Pair Group Average) was calculated starting from the quantitative data of the macroinvertebrate taxa; the Multivariate Statistical Package (MVSP) program version 3.1 (Kovach, 1998) was used to perform the cluster analysis.

The results of the physico-chemical measurements and biological analysis were evaluated according to the National Surface Water Quality Regulations of Republic of Turkey Ministry of Agriculture and Forestry (Anonymous, 2016) to classify the water quality levels of the sites.

RESULTS

Environmental variables

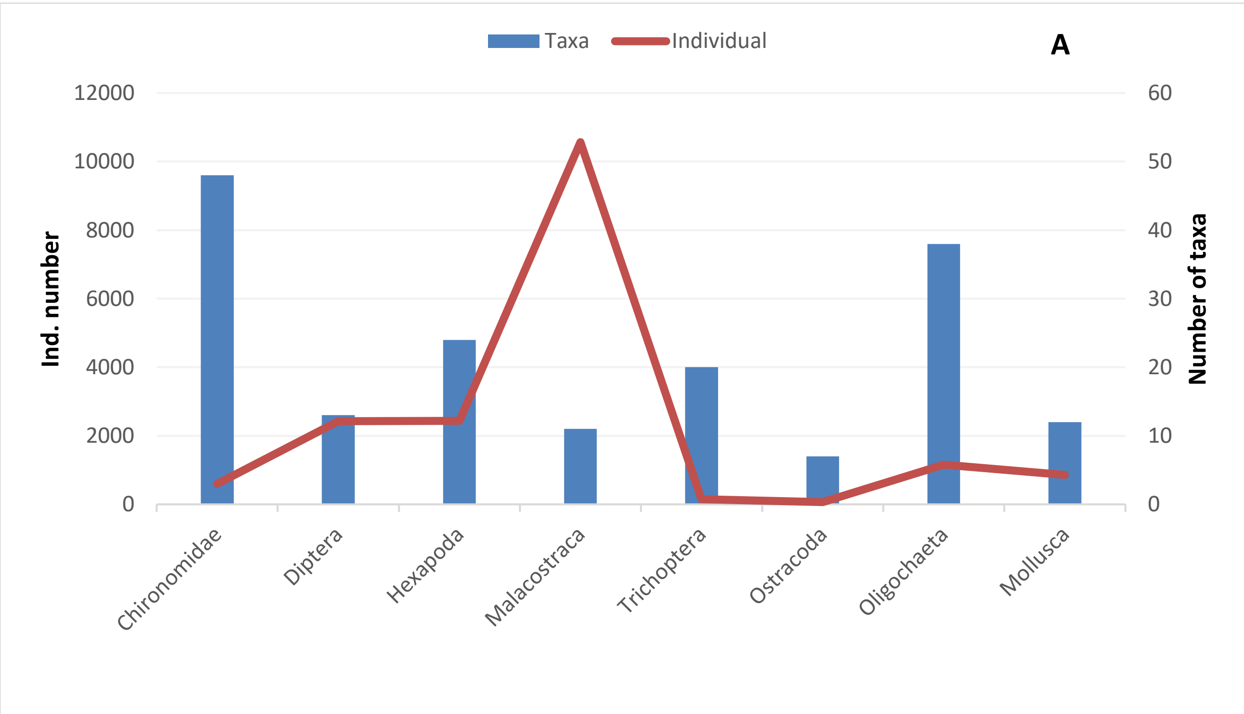
During the study, the lowest water temperature (4.06 °C, in February) was observed at the A5 station while the highest (27.6 °C, in August) was measured at A1 and A2 sites. The dissolved oxygen value (DO) was the highest at the A1 station (17.7 mg/l, in April) and the lowest at the A4 station (1.07 mg/l, in July). Similarly, the highest pH value was observed at the A2 station (11.62) in January and the lowest at the A10 station (6.18) in May. The general pattern of the pH values suggests that Karasu Stream has a slightly alkaline character (Table 2).

Table 2. Maximum and minimum values of the measured environmental variables (T: water temperature, DO: dissolved oxygen)

Months	T (°C)	pH	DO (mg/l)
February	4.06 - 6.73	8.09 - 8.48	5.7 - 8.3
March	4.08 - 8.03	8.27 - 10.44	9.18 - 11.32
April	6.66 - 10.9	7.48 - 8.39	10.7 - 11.7
May	8.34 - 14.7	6.18 - 8.57	8.09 - 11.1
June	7.81 - 14.8	8.3 - 9.17	4.8 - 8.76
July	7.5 - 17.2	7.92 - 8.41	1.07 - 8.5
August	12.7 - 27.6	7.79 - 8.85	1.24 - 5.47
September	12.7 - 24.6	7.64 - 8.27	3.7 - 9.7
October	13.6 - 27.5	8.18 - 9.04	1.9 - 10.4
November	11.2 - 16	7.55 - 8.55	5.5 - 10.3
December	9.42 - 14.93	7.75 - 8.46	10.1 - 11.8
January	7.83 - 8.53	7.19 - 11.98	5.3 - 8.4

Benthic macroinvertebrates

In total 18,260 individuals belonging to 175 taxa were determined. Almost all of them (170 taxa) except for that of Ephemeroptera (5 taxa were reported by Ertorun and Tanatmış, 2004) are new records for the Karasu Stream. The benthic macroinvertebrates diversity of the stream consisted of Mollusca (12 taxa, 860 ind.), Oligochaeta (38 taxa, 1157 ind.), Malacostraca (11 taxa, 10568 ind.), Ostracoda (7 taxa, 65 ind.), Hexapoda (26 taxa, 2437 ind.), Trichoptera (20 taxa, 151 ind), Chironomidae (48 taxa, 595 ind.) and other Dipterans (13 taxa, 2427 ind.) (Figure 2). The family of Chironomidae has the highest number of taxa among the groups. The list of the identified taxa and their occurrence, dominancy and frequency values per station are given in Table 3.



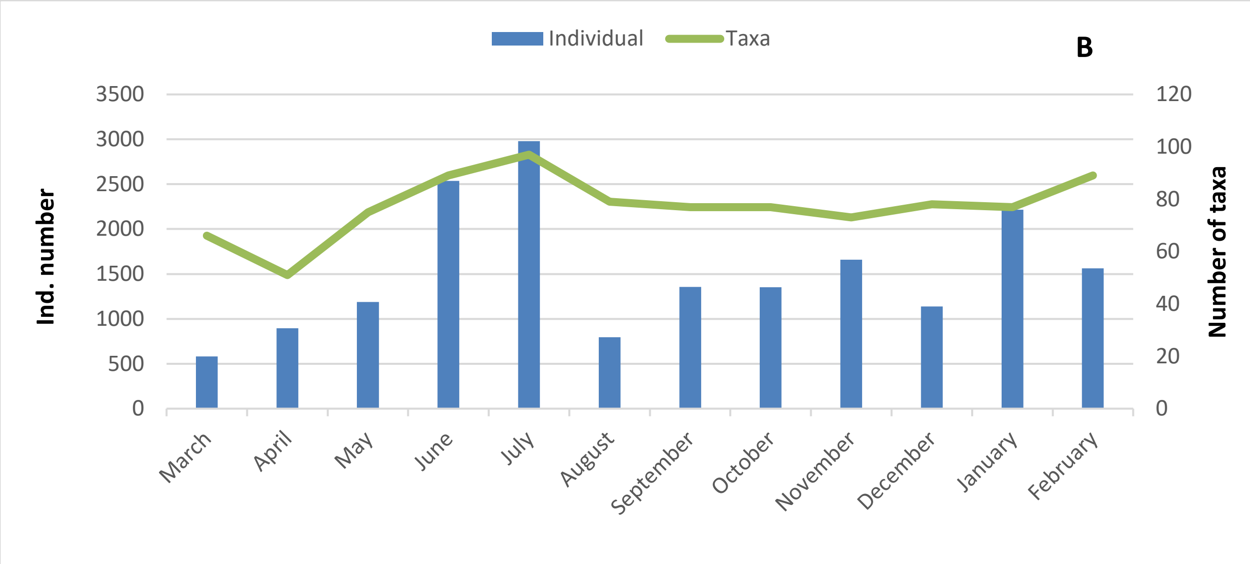


Figure 2. The number of individuals and taxa of the identified systematic groups for the whole study (A), and in time scale (B).

Table 3. List of the identified taxa and their annual abundance (ind/m²), dominance (%D), and frequency (%F) values at the sites (Ent.: Entomobryomorpha; Dec.: Decapoda).

Phylum	Classis	Ordo	Family	Taxa	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	% D	%F
Annelida	Clitellata	Tubificida	Naididae	*Dero digitata* (Müller, 1774)	0	4	0	0	0	0	0	0	0	0	0.02	10
				Nais barbata Müller, 1774	0	2	0	0	0	1	0	0	0	0	0.02	20
				N. bretscheri Michaelsen, 1899	0	1	0	0	0	0	0	0	23	3	0.15	30
				N. christinae Kasprzak, 1973	0	0	0	0	0	2	0	0	0	0	0.01	10
				N. communis Piguet, 1906	1	0	0	0	0	0	0	48	0	0	0.27	20
				N. elinguis Müller, 1774	3	2	0	0	1	9	0	16	0	0	0.17	50
				N. pardalis Piguet, 1906	0	1	0	0	0	0	0	0	0	0	0.01	10
				N. stolci Hrabě, 1981	0	0	7	0	0	0	0	0	0	7	0.08	20
				Ophidonais serpentina (Müller, 1774)	0	0	5	166	0	1	0	0	0	0	0.94	30
			Pristinidae	*Pristina menoni* (Aiyer, 1930)	0	1	0	0	3	1	0	0	3	0	0.04	40
				P.sima (Marcus, 1944)	0	2	0	0	0	0	0	1	0	2	0.03	30
			Tubificidae	*Aulodrilus limnobius* Bretscher, 1899	0	0	0	1	0	0	0	0	0	0	0.01	10
				A. pigueti Kowalewski, 1914	0	1	1	1	0	0	0	0	0	0	0.02	30
				pluriseta (Piguet, 1906)	0	1	1	2	1	1	0	0	3	0	0.05	60
				Limnodrilus claparedeanus Ratzel, 1868	0	0	18	2	0	0	0	0	0	0	0.11	20
				L.hoffmesteri Claparede, 1862	21	76	48	34	1	27	0	2	0	0	1.14	70
				L.hoffmeisteri f. parvus Southern, 1909	14	8	14	1	2	29	1	4	3	0	0.42	90
				L.udekemianus Claparede, 1862	10	3	2	3	1	4	0	0	1	0	0.13	70
				Potamothrix hammoniensis (Michaelsen, 1901)	0	0	0	0	0	0	0	0	1	0	0.01	10
				Psammoryctides albicola (Michaelsen, 1901)	0	1	0	0	1	0	0	0	0	0	0.01	20
				P.deserticola (Grimm, 1876)	14	27	0	0	2	0	0	0	10	0	0.29	40

Phylum	Classis	Ordo	Family	Taxa	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	% D	%F
				Tubifex blanchardi Vejdovsky, 1891	9	15	13	56	1	6	0	0	0	0	0.55	60
				T. newaensis (Michaelsen, 1903)	0	0	2	0	0	0	0	0	26	5	0.18	30
				T. tubifex (Müller, 1774)	2	3	6	4	3	0	3	0	0	0	0.12	50
				Tubificoides sp.	1	0	0	1	0	0	0	0	0	0	0.01	20
				Haber speciosus (Hrabě, 1931)	0	2	0	0	0	0	0	0	0	0	0.01	10
				Spirosperma ferox Eisen, 1879	0	0	0	0	0	0	0	0	2	0	0.01	10
				S.nikolskyi (Lastockin & Sokolskaya, 1935)	0	0	0	0	0	0	0	0	3	0	0.02	10
				Spirosperma sp.	0	0	0	0	0	0	0	0	3	0	0.02	10
			Enchytraeidae	*Cognettia glandulosa* (Michaelsen, 1889)	36	12	1	4	0	4	19	0	4	0	0.44	70
				Henlea ventriculosa (Udekem, 1854)	4	7	0	2	3	5	14	3	40	1	0.43	80
				Henlea sp.	1	0	0	2	0	0	0	0	0	0	0.02	20
				Marionina riparia Bretscher, 1899	0	0	0	0	0	0	6	0	1	0	0.04	20
				Fridericia spp.	0	1	0	0	0	0	2	1	0	0	0.02	30
				Mesenchytraeus sp.	0	3	0	0	14	12	2	1	1	1	0.19	70
			Haplotaxidae	*Haplotaxis gordioides* (Hartmann, 1821)	0	2	0	0	0	8	1	0	1	0	0.07	40
			Lumbriculidae	*Lumbriculus variegatus* (Müller, 1774)	1	10	3	0	0	18	3	3	14	2	0.30	80
			Lumbricidae	*Eiseniella tetraedra* (Savigny, 1826)	0	0	0	0	0	4	0	0	0	0	0.02	10
Mollusca	**Gastropoda**		**Zonitidae**	*Zonites algirus* (Linnaeus, 1758)	0	0	0	0	0	0	0	0	1	0	0.01	10
			Planorbidae	*Gyraulus albus* (O. F. Müller, 1774)	25	78	2	4	1	0	0	0	0	0	0.60	50
			Bithyniidae	*Bithynia tentaculata* (Linnaeus, 1758)	13	3	0	6	1	14	0	2	1	10	0.27	80
			Lymnaeidae	*Potamopyrgus jenkinsi* Smith, 1889	2	2	0	2	0	11	0	1	0	0	0.10	50
				*Radix peregra*Müller, 1774	2	13	0	0	0	0	0	0	0	0	0.08	20
			Succineidae	*Succinea putris* (Linnaeus, 1758)	38	38	1	1	2	9	0	0	0	1	0.49	70
	Bivalvia		**Unionoida**	*Anodonta cygnea* (Linnaeus, 1758)	2	0	0	0	0	0	0	0	0	0	0.01	10
				Unio pictorum (Linnaeus, 1758)	0	8	120	1	0	0	0	0	0	0	0.71	30
			Mytilidae	*Mytilus galloprovincialis* Lamarck, 1819	5	0	0	0	0	0	0	0	0	0	0.03	10
			Mesodesmatidae	*Donacilla cornea* (Poli, 1791)	15	2	0	0	0	0	0	0	0	0	0.09	20
			Veneridae	*Chamelea gallina* (Linnaeus, 1758)	1	0	0	0	0	0	0	0	0	0	0.01	10
			Sphaeriidae	*Pisidium casertanum* (Poli, 1791)	5	10	17	279	25	54	2	3	27	0	2.31	90
Arthropoda	**Ostracoda**	**Podocopida**	**Candonidae**	*Candona candida* (O. F. Müller, 1776)	0	0	0	1	0	3	0	0	1	0	0.03	30
				C. neglecta G.O. Sars, 1887	0	1	2	14	6	8	2	1	3	0	0.20	80
			Cyprididae	*Heterocypris* sp.	0	0	0	0	0	1	0	0	0	0	0.01	10
			Ilyocyprididae	*Ilyocypris* sp.	0	0	0	1	0	0	0	0	0	0	0.01	10
				Prionocypris zenkeri (Chyzer and Toth, 1858)	1	1	0	0	0	0	0	0	0	0	0.01	20
				Psychrodromus olivaceus (Brady and Norman, 1889)	0	0	3	4	3	2	2	0	4	0	0.10	40
				Tonnacypris lutaria (Koch, 1838)	0	0	0	0	0	1	0	0	0	0	0.01	10
	Malacostraca	**Isopoda**	**Detonidae**	*Armadilloniscus littoralis* Budde-Lund, 1885	4	4	1	7	0	1	0	2	1	0	0.11	70
			Asellidae	*Asellus aquaticus* Odenwall, 1927	35	93	5	6	0	3	0	0	2	0	0.79	60
			Trichoniscoidea	*Haplophthalmus* sp.	2	0	0	0	0	0	0	0	0	0	0.01	10
				Trichoniscus sp.	5	0	3	2	0	1	0	1	0	0	0.07	50
			Ligiidae	*Ligia italica*	0	0	3	1	0	0	0	1	0	0	0.03	30
		Amphipoda	**Gammaridae**	*Gammarus balcanicus* Schäferna, 1922	1	0	1	49	3	13	15	16	69	0	0.91	80
				G.komareki Schäferna, 1922	3	0	34	31	62	77	1431	3170	944	25	31.64	90
				G.pulex pulex (Linnaeus, 1758)	0	1	0	45	13	6	29	12	64	2	0.94	80
				G.uludagi Karaman, 1975	0	0	22	287	265	77	2456	455	542	1	22.48	80
			Niphargidae	*Niphargus sp.*	13	8	7	0	0	0	0	0	0	1	0.16	40
		Dec	**Potamidae**	*Potamon* sp.	2	4	32	0	30	21	0	9	5	32	0.74	80
	Entognatha	**Ent.**	**Isotomidae**	*Isotoma* sp.	0	0	1	0	0	2	3	0	0	0	0.03	30
		Ephemeroptera	**Beatidae**	*Baetis* sp.	10	3	56	59	131	185	180	49	38	82	4.34	100
			Caenidae	*Caenis* sp.	0	0	0	0	0	0	1	0	0	0	0.01	10
			Ephemeridae	*Ephemera* sp.	1	5	23	0	2	15	0	0	8	36	0.49	70
			Heptageniidae	*Heptagenia* sp.	0	6	16	334	14	55	8	3	3	43	2.64	90
			Leptophlebiidae	*Leptophlebia* sp.	0	0	0	163	68	9	0	0	4	42	1.54	50
		Odonata	**Calopterygidae**	*Calopteryx* sp.	10	14	36	6	2	0	1	0	0	10	0.43	70
			Euphaeidae	*Euphaea* sp.	0	0	0	0	0	0	0	0	0	1	0.01	10
			Coenagrionidae	*Coenagrion* sp.	9	18	5	5	0	0	0	0	0	0	0.20	30
			Cordulegastridae	*Cordulegaster* sp.	0	0	6	3	3	0	6	1	4	1	0.13	70
			Gomphidae	*Gomphus* sp.	0	0	16	2	3	5	5	0	2	0	0.18	60

Phylum	Classis	Ordo	Family	Taxa	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	% D	%F
			Lestidae	*Lestes* sp.	18	12	9	11	2	0	1	0	1	5	0.32	80
			Libellulidae	*Libellula* sp.	2	2	2	41	4	0	0	0	0	0	0.28	50
		Plecoptera	Capniidae	*Capnia* sp.	0	4	0	0	21	36	3	15	2	21	0.56	70
			Perlodidae	*Perlodes* sp.	0	0	0	0	0	0	3	1	0	0	0.02	20
			Perlidae	*Agnetina* sp.	0	0	0	0	2	0	1	0	0	15	0.10	30
			Leuctridae	*Leuctra* sp.	0	0	0	0	0	19	5	6	3	24	0.31	50
			Nemourida	*Nemoura* sp.	0	0	0	20	49	35	4	17	6	34	0.90	70
			Taeniopterygidae	*Taeniopteryx* sp.	0	0	1	0	0	0	1	0	0	0	0.01	20
		Coleoptera	Carabidae	*Carabus* sp.	0	0	0	0	0	0	3	0	0	1	0.02	20
			Dytiscidae	*Dytiscus* sp.	0	1	0	11	25	7	2	16	3	2	0.37	80
			Hydrophilidae	*Hydrophilini* sp.	0	0	0	0	1	0	2	13	1	0	0.09	40
			Tenebrionidae	*Tenebrio* sp.	0	0	0	0	0	0	18	0	0	0	0.10	10
		Hemiptera	Notonectidae	*Notonecta* sp.	0	1	0	5	22	9	0	0	0	0	0.20	40
			Pleidae	*Plea* sp.	0	0	0	0	0	0	0	3	0	0	0.02	10
			Pentatomidae	*Pentatoma* sp.	0	0	0	0	0	0	0	0	0	1	0.01	10
		Trichoptera	Phryganeidae	*Agrypnia obsoleta* Martynov, 1928	0	0	0	1	0	0	0	0	0	0	0.01	10
			Hydropsychidae	*Diplectrona felix* McLachlan, 1878	0	0	0	0	0	0	0	2	1	1	0.02	30
			Ecnomidae	*Ecnomus tenellus* (Rambur, 1842)	0	0	0	0	0	0	0	0	3	1	0.02	20
			Limnephilidae	*Glyphotaelius pellucidus* (Retzius, 1783)	0	0	0	0	1	0	0	0	0	0	0.01	10
			Hydropsychoidae	*Hydropsyche angustipennis* (Curtis, 1834)	0	0	4	0	0	15	2	3	0	21	0.25	50
				H.instabilis (Curtis, 1834)	0	0	0	0	0	0	3	0	0	6	0.05	20
				H.pellucida (Curtis 1834)	0	0	0	0	0	1	0	0	0	0	0.01	10
				Hydropsyche sp.	0	0	0	0	0	0	0	0	0	3	0.02	10
			Psychomyiidae	*Lype reducta* (Hagen, 1868)	0	0	0	0	0	9	0	0	0	0	0.05	10
			Limnephilidae	*Micropterna lateralis* Stephens 1837	0	0	0	0	0	5	0	0	0	0	0.03	10
			Molannidae	*Molanna angustata* Kolenati, 1858	0	0	0	9	0	4	0	1	3	0	0.09	40
			Sericostomatidae	*Notidobia ciliaris* (Linnaeus, 1761)	0	0	0	0	0	0	0	0	8	0	0.04	10
			Polycentropodidae	*Polycentropus flavomaculatus* (Pictet, 1834)	0	0	0	0	0	1	0	0	0	0	0.01	10
				P.irroratus (Curtis, 1835)	0	0	0	0	10	1	0	0	0	1	0.07	30
				P.kingi McLachlan, 1881	0	0	0	0	0	0	0	0	2	0	0.01	10
			Rhyacophilidae	*Rhyacophila dorsalis persimilis* McL	0	0	0	0	0	0	4	3	0	0	0.04	20
				R. munda Navas, 1936	0	0	0	0	0	0	1	0	0	0	0.01	10
				R.septentrionis McLachlan, 1865	1	0	0	1	0	1	3	1	0	0	0.04	40
				Rhyacaphila sp.	0	0	0	0	0	0	0	6	4	0	0.05	20
			Sericostomatidae	*Sericostoma* sp.	0	0	0	0	0	4	0	0	0	0	0.02	10
		Diptera	Athericidae	*Atherix* sp.	1	5	25	0	7	9	0	0	1	37	0.47	80
			Tabanidae	*Tabanus* sp.	7	5	19	37	28	26	15	20	9	17	1.00	100
			Dolichopodidae	*Dolichopus* sp.	0	0	0	0	0	1	1	6	1	1	0.05	50
			Ephydridae	*Ephydra* sp.	2	0	1	0	0	5	34	5	8	0	0.30	60
			Syrphidae	*Syrphus* sp.	0	0	0	0	0	0	2	0	1	0	0.02	20
			Stratiomyidae	*Stratiomys* sp.	0	0	5	1	4	10	0	12	2	1	0.19	70
			Fannidae	*Fannia* sp.	0	0	0	0	0	1	0	0	0	0	0.01	10
			Tipulidae	*Tipula* sp.	24	4	88	38	18	28	42	18	27	23	1.70	100
			Limoniidae	*Limonia* sp.	0	3	0	1	1	5	7	2	8	12	0.21	80
			Ceratopogoninae	*Bezzia* sp.	19	40	83	104	6	202	19	26	50	32	3.18	100
			Simuliidae	*Simulium* sp.	3	1	180	48	131	252	374	21	50	32	5.98	100
			Culicidae	*Aedes* sp.	0	1	0	6	16	0	0	0	0	0	0.13	30
			Psychodidae	*Psychoda* sp.	0	0	0	0	0	1	0	8	1	0	0.05	20
			Chironomidae	*Ablabesmyialongistyla* Fittkau, 1962	5	11	14	11	20	4	0	1	0	4	0.38	80
				Apsectrotanypus sp.	0	0	0	2	0	0	0	0	0	0	0.01	10
				Conchapelopia sp.	0	0	6	8	10	14	1	1	3	2	0.25	80
				Procladius (*Holotanypus*) sp.	3	2	3	18	3	0	0	0	0	1	0.16	60
				Telopelopia sp.	1	0	0	6	2	0	1	0	12	4	0.14	60
				Potthastia gaedii (Meigen, 1838)	0	0	4	0	0	5	1	0	0	0	0.05	30
				Prodiamesa olivacea (Meigen, 1818)	0	0	2	4	1	0	0	0	0	0	0.04	30

Phylum	Classis	Ordo	Family	Taxa	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	% D	%F
				Brillia flavifrons (Johannsen, 1905)	1	0	6	0	0	0	0	0	2	3	0.07	40
				B.modesta (Meigen, 1830)	0	0	0	3	7	5	10	6	10	2	0.24	70
				Cardiocladius fuscus Kieffer, 1924	0	0	0	0	0	0	0	1	0	0	0.01	10
				Cricotopus sp.	4	4	5	5	0	4	2	1	5	3	0.18	90
				Cricotopus sylvestris (Fabricius, 1794)	2	1	0	0	0	0	0	0	0	0	0.02	20
				C.triannulatus Macquart, 1826	0	0	0	0	0	2	0	0	0	0	0.01	10
				Eukiefferiella sp.	1	0	2	0	1	1	0	0	3	3	0.06	40
				Eukiefferiella claripennis (Lunnbeck, 1898)	1	1	1	0	0	0	0	0	0	0	0.02	30
				E.gracei (Edwards, 1929)	0	0	0	0	0	1	0	0	1	0	0.01	20
				Orthocladius sp.	2	0	1	0	1	1	0	0	0	2	0.04	40
				Parametriocnemus sp.	1	0	1	0	1	1	0	1	1	0	0.03	60
				Paratrissocladius sp.	0	0	1	0	0	0	0	0	0	0	0.01	10
				Psectrocladius sp.	0	0	0	0	0	0	0	0	1	0	0.01	10
				Rheocricotopus fuscipes Kieffer, 1909	0	0	1	0	0	0	0	1	0	0	0.01	20
				Rheocricotopus sp.	0	0	4	1	6	1	9	1	4	0	0.14	70
				Smittia sp.	1	1	2	0	0	0	1	0	0	0	0.03	40
				Thienemannimyia sp.	0	0	4	2	3	7	1	2	7	2	0.15	80
				Tvetenia sp.	0	0	0	0	1	0	1	0	0	0	0.01	20
				Chironomus sp.	8	8	6	8	10	3	0	0	4	2	0.27	80
				Cryptochironomus denticulatus (Goetghebuer, 1921)	0	0	1	0	0	0	0	0	0	0	0.01	10
				Dicrotendipes lobiger (Kieffer, 1921)	0	1	0	5	3	0	0	0	0	0	0.05	30
				D.nervosus (Stæger, 1839)	2	1	0	5	0	0	0	1	0	0	0.05	40
				D.notatus (Meigen, 1818)	1	1	0	0	1	0	0	0	0	0	0.02	30
				Endochironomus dispar (Meigen, 1830)	4	5	0	5	2	0	2	0	1	0	0.10	60
				E.lepidus (Meigen, 1830)	1	0	0	2	2	0	0	0	0	0	0.03	30
				Endochironomus sp.	2	1	0	1	0	0	0	0	1	0	0.03	40
				Kiefferulus sp.	4	7	0	12	3	0	0	0	0	0	0.14	40
				Microtendipes pedullus (De Geer, 1776)	0	0	1	1	1	0	0	2	1	0	0.03	50
				Phaenopsectra sp.	1	1	0	1	2	0	0	0	0	0	0.03	40
				Polypedilum laetum (Meigen, 1818)	0	2	2	0	1	0	0	0	1	2	0.04	50
				P.albicorne (Meigen, 1838)	0	0	0	0	0	1	0	2	0	0	0.02	20
				P.convictum (Walker, 1856)	0	0	0	0	0	0	1	1	0	1	0.02	30
				P.nubeculosum Meigen, 1804	2	2	0	0	0	0	0	0	0	0	0.02	20
				P.pedestre (Meigen, 1830)	0	1	2	0	1	1	0	0	1	0	0.03	50
				P.scalaenum (Schrank, 1803)	0	0	1	0	0	0	0	0	0	0	0.01	10
				P.tritum (Walker, 1856)	1	1	0	0	0	0	0	0	0	0	0.01	20
				P.uncinatum (Goetghebuer, 1921)	1	1	0	0	0	0	0	0	0	1	0.02	30
				Polypedilum sp.	6	10	1	0	1	0	0	0	1	5	0.13	60
				Micropsectra sp.	0	0	0	0	1	2	1	0	3	1	0.04	50
				Paratanytarsus sp.	0	2	1	0	2	0	0	0	0	1	0.03	40
				Tanytarsus sp.	0	2	2	4	1	0	1	2	0	0	0.07	60

According to Soyer's frequency index, 175 taxa were observed continuously all year long (Table 3). The highest number of taxa was determined in July (98 taxa), June (90 taxa), and February (89 taxa), while the least in April (52 taxa). The highest number of individuals was sampled in July (2986 ind./m²) and June (2539 ind./m²), while the lowest in March (589 ind./m²) (Figure 2).

A1 and A2 sites were located near the mouth of the stream, thus the sampled benthic organisms consist of mainly salinity-tolerant taxa such as *N. pardalis*, *P. jenkinsi*, *D. cornea*, *M. galloprovincialis*, *C. gallina*, *T. blanchardi*, and *T. tubifex*. Similarly, A3, A4, A5, and A6 sites were in the middle part of the stream where pure freshwater forms were observed (such as *G. albus*, *L. hoffmeisteri*, *H. ventriculosa*, *S. putris*, *G. uludagi*, and *G. pulex pulex*). A7, A8, A9, and A10 sites were in the upper part of the stream and are the cleanest ones because of the lack of pollutants around them. *G. balcanicus* and *G. uludagi* were the two typical taxa at these sites.

G. komareki has the highest dominance among the determined species with 31.64% and was followed by *G. uludagi* with 22.48%. Individuals belonging to the orders of Hemiptera and Trichoptera with dominance of 0.01%, also make up the least common groups.

The dominant taxon of A1 and A2 was *A. aquaticus*. All the dominant taxa observed at these sites are tolerant to organic pollution. The bottom of the A3 station consists of stone, gravel, and sand and the flow rate of water varies significantly throughout the year. The dominant taxa at the station were *Simulium* sp. and *U. pictorum*. A4 and A5 are creeks that join the Karasu Stream, and they have a rich riparian zone. The villages near the creeks were the main pollutants because of discharging wastes. The dominant taxa of these sites were *G. uludagi* and *P. casertanum*. The latter is cosmopolitan and euryoecious, which is mostly found in oligo- or beta-mesosaprobic freshwater environment (Subba Rao, 1989). Karasu River at site A6 passes through a sparse forest with a low flow rate, it has shallow with a stony-gravelly bottom and a dense *Chara* sp. population. *Simulium* sp., *Bezzia* sp., *G. komareki*, and *G. uludagi* were the dominant taxa at the station. A7 has 1–1.5 m depth, a rocky and stony bottom with rich terrestrial and aquatic plants. *G. uludagi* and *G. komareki* were the dominant taxa at the station. A8 was a small, clean waterfall outflowing to a reservoir near Erfelek town. The bottom of the station has rocks, stones, and pebbles. *G. komareki*, *G. uludagi*, and *Baetis* sp. were the dominant taxa at the station. A9 has a sandy bottom and is located near the Tatlıca Waterfall. The dominant taxa of the station were *G. komareki, G. uludagi, Bezzia* sp., and *Simulium* sp. A10, which has a rocky and stony bottom, is located above the Tatlıca Waterfall. The dominant taxa of these sites were *G. komareki and G. uludagi*.

Biological indices

According to BMWP scores, the water quality of the sites A4, A5, A6, A9, and A10 was of the first class. Only around the sites of A1, A2, and A3, settlements and agricultural activities occur; the other localities are not under the pressure of such negative effects. Results of BMWP analysis showed that A1, A2, A3, A7, and A8 sites were classified in slightly polluted (Class II) groups. Similarly, ASPT analysis indicated that A1, A2, A6, and A8 were in the third class while the remaining ones in the second class (Table 4).

Table 4. The BMWP and ASPT scores and diversity indices of the sites (S: Total number of taxa, N: Total number of individuals, D: Margalef Species Richness, J': Pielou's Evenness Index, H': Shannon-Weiner Diversity Index, 1-λ': Simpson Index of Diversity)

	BMWP			**ASPT**			**Diversity Indices**					
	Score value	**Quality class**		**Score value**	**Quality class**		**S**	**N**	**D**	**J'**	**H'**	**1-λ'**
A1	111	II.	Good	4.6	III.	Poor	68	453	10.96	**0.85**	**3.59**	**0.96**
A2	144	II.	Good	4.6	III.	Poor	77	642	**11.76**	0.77	3.36	0.94
A3	144	II.	Good	5.1	II.	Fair	72	1024	10.24	0.75	3.21	0.93
A4	159	I.	Excellent	5.1	II.	Fair	74	2030	9.59	0.69	2.96	0.91
A5	170	I.	Excellent	5.3	II.	Fair	74	1102	10.42	0.69	2.98	0.90
A6	180	I.	Excellent	4.8	III.	Poor	80	1445	10.86	0.73	3.19	0.92
A7	143	II.	Good	5.1	II.	Fair	60	4774	**6.96**	0.35	1.45	0.64
A8	141	II.	Good	4.7	III.	Poor	60	4033	7.11	**0.25**	**1.01**	**0.37**
A9	189	I.	Excellent	5.2	II.	Fair	78	2119	10.05	0.48	2.10	0.73
A10	175	I.	Excellent	5.5	II.	Fair	60	638	9.14	0.81	3.31	0.95

Both Shannon-Weiner and Simpson indices resulted in high scores. Station A1 has the highest diversity value (H'=3.59), while station A8 has the lowest (H'=1.01). Nearly all the sites have high values in terms of richness but A2 has the highest taxa while A7 has the lowest. Similarly, the evenness index suggested that A2 has the highest score (J'=0.85) while station A8 has the lowest (J'=0.25) (Table 4).

The UPGMA analysis grouped the sites with a similarity of more than 50% according to the occurred taxa. In general, all the localities have high level of similarities (more than 50%) to each other. A10 (with a stony and gravel bottom) was out grouped from the others. A7 and A8, which have a rocky bottom, were grouped; both were separated from all the other sites except A10 and constitute another group. Within this group, A1 and A2 constituted a separate group with almost 70

% similarity. Both sites are in the Abramis zone (lower part of the stream) and have a slightly brackish character. The other group was constituted by the remaining sites, which are purely freshwater. A3 with a stony and muddy bottom was separated within this group. Although the bottom structure of the other sites A4, A5, A6, and A9 were different, all have a muddy bottom and similarities in terms of faunal components; they form another cluster (Figure 3).

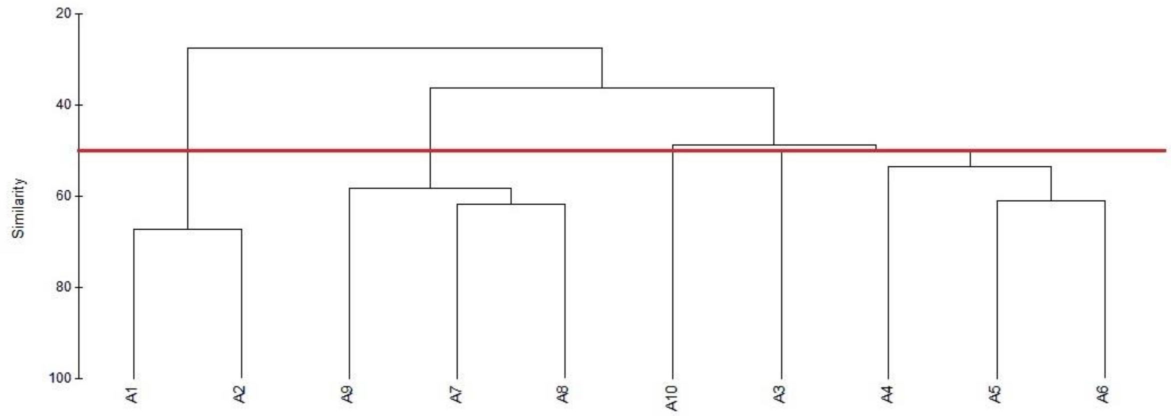


Figure 3. The UPGMA dendrogram showing the similarity of the sites

DISCUSSION

Long-term changes in water quality can be estimated more accurately if biological indicators are used as they are adapted to specific environmental conditions for a long time. For this reason, if any changes occur in running waters, they can be detected using the compositions and structures of aquatic organisms (Zamora-Muñoz and Alba-Tercedor, 1996).

In general, diverse and productive fish and macroinvertebrate communities prefer slightly alkaline aquatic environments, where pH values were between 6.5 and 8.5 (NAS, 1972). High pH and low oxygen concentrations have a lethal effect on living organisms (Tanyolaç, 2004). By having slight alkaline character, Karasu Stream offers a comfortable settlement for various benthic macroinvertebrate species.

Water temperature and dissolved oxygen values were the determinant factors in species richness at the sites. Pollution-sensitive taxa or clean water indicator species were observed frequently at the A4, A5, A6, A9, and A10 sites, where diversity values were high andwater quality levels were in first class.

Climate and regions are the main predictors for the temperature periodicity patterns (Ward, 1985) and seasonality may become weak or harsh according to locations of the stream (e.g. Hopkins, 1971). The water temperature of the sites varies between 4.06-27.6°C throughout the year and is within the seasonal norms.

Macroinvertebrates inhabit different parts of a waterbody. They can live in the sediment or water's surface, water itself, etc. Environmental conditions such as submerged rocks, leaf litter, or water velocity can be determinant which macroinvertebrates can live (Tanyolaç, 2004).

The BMWP and ASPT scores are frequently used to determine the stream quality. Biological indices are usually specific for certain types of pollution since they are based on the presence or absence of indicators organisms, which are unlikely to be equally sensitive to all types of pollution. They are considered the sensitivities of macroinvertebrates to pollution and the BMWP scores give the how much clean or polluted the sites (Chapman, 1996). In the present study, the BMWP scores, suggested that all of the localities have high (more than 100) scores and it means all of them are in good (even excellent) conditions. On the other hand, the results of ASPT indicated that A1, A2 and A8sites were in poor conditions while the other ones in fair conditions.

The content of the species is expected to have high similarities at successive sampling sites, such as A1-A2 and A7-A8 or A5-A6. Because habitat transitions are close to one another, species compositions may be similar (Figure 3). Although A3 and A10 stations are far from each other in terms of location, they have high similarity to each other. Having similar environmental characteristics such as water depth, bottom structure, presence of riparian vegetation can be main reason for the high similarity.

The species compositions expected to have high similarities at successive sampling sites, such as A1-A2 and A7-A8 or A5-A6. Because habitat transitions are close to one another, species compositions may be similar (Figure 3). Although A3 and A10 stations are far from each other in terms of location, they have high similarity to each other. Having similar environmental characteristics such as water depth, bottom structure, presence of riparian vegetation can be main reason for the high similarity. In addition, both sites have natural environmental conditions, isolated from roads and settlements.

A6 has the highest species richness (82 taxa). Rich riparian zone, diverse bottom structure (stone, gravel, sand, and mud), and relatively low water flow rates can be the main reasons for the higher macroinvertebrate diversity at the station. Reversely, A7 (with 62 taxa) has the lowest species richness where weak aquatic vegetation, rocky bottom, and rapid water flow occur. The main restrictive factor for species diversity at the station can be the high velocity of water flow. The members of the genus *Gammarus* constituted the dominant group at the station.

CONCLUSIONS

Karasu Stream is a suitable habitat for benthic macroinvertebrates in terms of its location, bottom structure, water quality, and other ecological characteristics. The biological monitoring studies should be carried out for the sustainable use of the Karasu Stream. In this way, biodiversity and water quality will remain at the desired level and its unique habitats can be protected from the destructive effects of human pressure and pollution.

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