AQUATIC RESEARCH

AQUATIC RESEARCH
E-ISSN 2618-6365

Aquatic Research 7(1), 39-50 (2024) • https://doi.org/10.3153/AR24005 Research Article

Investigation of seasonal changes in Annelida fauna and some physicochemical parameters of Riva stream (Istanbul)

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Cite this article as:
Dökümcü, N. Koşal Şahin, S., Taş Divrik, M., Odabaşı, S. (2024). Investigate seasonal changes in Annelida fauna and some physicochemical parameters of Riva stream (Istanbul). *Aquatic Research*, 7(1), 39-50. https://doi.org/10.3153/AR24004

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Submitted: 07.11.2023
Revision requested: 24.11.2023
Last revision received: 28.11.2023
Accepted: 29.11.2023
Published online: 03.01.2024

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ABSTRACT

Annelids were collected seasonally at Riva Stream from March 2018 to January 2019. In this study, 1241 individuals (28 taxa; 4 families) of Annelida were identified. Various physicochemical parameter values [depth, width, flow rate, water temperature, dissolved oxygen, pH, electrical conductivity, salinity, TP, o-PO_4, NH_4-N, NO_2-N, NO_3-N, TSS] were measured seasonally. The results of the analyses were evaluated according to TSWQR (2021). NPI water index values of the stations were also calculated in the study. Accordingly, it was found that the water quality of Riva and Değirmendere was more polluted than other stations. Bray Curtis similarity analysis was also evaluated regarding physicochemical parameters and taxa. Stations 2 and 3 were the most similar in terms of physicochemical parameters. In terms of taxa, stations 3 and 4 were found to be the most similar stations. According to CCA analysis, *U. uncinata* and *L. hoffmeisteri* appeared closely related to salinity, while *E. tetraedra, H. naidina, H. stagnalis, P. deserticola* and *Nais* sp. were shown closely related to width.

Keywords: Oligochaeta, Annelida, NPI, Bray-Curtis, Aquatic ecology, Freshwater

Introduction

A stream is a continuous body of surface water flowing within the bed and banks of a channel. Depending on its location or certain characteristics, various local or regional names may refer to a stream. Long, large streams are usually called rivers, while smaller, less voluminous, intermittent streams are known as brooks or creeks (Langbein & Iseri, 1995).

Benthic macroinvertebrates are widespread all over the world. They can be found in large rivers, small creeks, ponds, wetlands, and lakes and live on all bottom types, such as sand or rocks. Most benthic macroinvertebrates are present throughout the year; however, they are most easily found in summer. Many species burrow deep in the sediment during the colder months or remain inactive on rock surfaces (IIHR, 2023).

Benthic macroinvertebrates in the river ecosystem are distributed along the river under varying physical and chemical conditions. At the same time, since these organisms are the organisms that are most affected by environmental changes in the river and best reflect the structure of the ecosystem in which they are located, they are the most widely used in biomonitoring studies (Bo et al., 2017; Akay et al., 2018). They are large enough to be seen with the naked eye and are abundant in freshwater. They can be easily collected using a sieve with a pore diameter of 500 μm and examined in the field with a magnifying glass (Fındık, 2013).

The phylum Annelida is divided into three orders: Polychaeta (marine), Oligochaeta (terrestrial and freshwater) and Hirudinea (terrestrial, marine and freshwater leeches) (Wetzel et al., 2009).

The aquatic oligochaetes are the most important macroinvertebrates, adapted to every type of water, such as saltwater, brackish water, and freshwater, including small streams, large rivers, marshes, ponds, lakes, springs, and groundwater. They are found in algae, aquatic vegetation, floating rotting material, and bottom mud (Wetzel et al., 2000). They are an important food source for some invertebrates and fishes. They can be of importance in water management because of their potentially high densities (Brinkhurst & Jamieson, 1971), their wide distribution, and their indicator value (Milbrink, 1973; Chapman et al., 1982; Särkkä, 1994). Leeches live in various extreme environments, including extreme temperatures, humidity, salinity, pressure, pollution, and light (Phillips et al., 2020). Members of the aquatic Hirudinea are tolerant of pollution or habitat disturbance (Demirsoy, 2005).

Riva Stream is a freshwater basin with a length of 70 km located on the Anatolian side of Istanbul. It connects to Ömerli Dam Lake, which provides 43% (approximately 395 million m^3 per year) of the drinking water requirement of Istanbul (Anonymous, 2014).

This study aimed to determine the Annelida fauna of Riva Stream and investigate the seasonal changes of some physicochemical parameters. The study is important as the first record of this group in the region.

Materials and Methods

The Study Area

The Riva Basin has a catchment area of approximately 859 km² (Selçuk & Ongan, 1991; Tarkan, 2007). The stream starts from the village of Tepecik in Gebze and flows into the Black Sea from the town of Riva in Beykoz. Its length between Ömerli Dam Lake and the Black Sea is 32.2 km, and its average slope is 0.06 percent. The area is between 41º14'-41º02' north latitude and 29º08'-29º22' east longitude (Pamukçu, 2011).

Riva Stream, also known as "Çayağzı Stream", lies within the provincial borders of Istanbul and Kocaeli. There are 15 villages in total in Beykoz, Sancaktepe, Çekmeköy and Şile districts of Istanbul and 6 villages in Gebze district of Kocaeli (Akkaya, 2003). The stream passes through the villages of Koçullu, Ömerli, Sırapınar, Hüseyinli, Bozhane, Öğümce, Göllü and Paşamandıra and reaches Çayağzı. The section of the stream after the Ömerli Dam, which meets 48% of Istanbul's drinking water demand, is 75-80% covered with northern forests. The rest of the catchment area consists of agricultural areas and pastures. The people in this part of the basin make a living from agriculture, forestry, animal husbandry and tourism and work as labourers in facilities. Recreation areas, restaurants, and picnic areas are active along the Riva Stream.

A map of the study area and sampling stations is given in Figure 1.

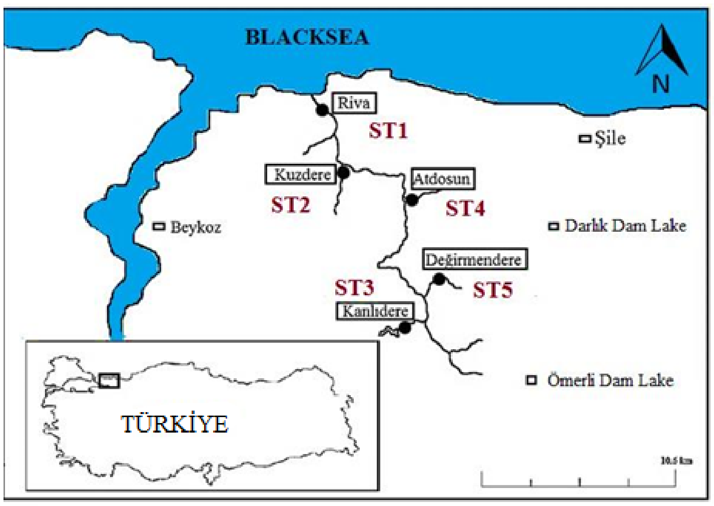
ST1. Riva: It is one of the closest points of the Riva Stream to the Black Sea and is located on the main branch of the stream. Heading towards the station's north, one reaches the centre of Riva, the settlement area within the village and the recreational boats. It is quite wide and deep, but the flow velocity is low. Large stones are at the bottom, and the sediment is covered with slime.

ST2. Kuzdere: The bottom is covered with large pebbles. Water quality and flow rate vary according to the season. Access to the sampling point is difficult due to private properties and weeds.

ST3. Kanlıdere: It is located on the road connecting the old settlement of Reşadiye and Cumhuriyet villages. Except for the spring season, it is a shallow line. The water is clear although the bottom is covered with large and small pebbles.

ST4. Atdosun: It is located in Göllü Village. In 2015, it was covered in the national press, and it was observed that there was a line connecting to the tributary where sudden fish deaths occurred. It is narrow and shallow. The bottom is covered with large and small pebbles. In summer, reaching the stream is difficult due to weeds and thorny plants.

Figure 1. The study area and sampling stations



Sampling stations and their coordinates are presented in Table 1.

Table 1. The sampling stations' coordinates.

No	Station	Coordinates
ST1	Riva	N41°12'45.88" E29°13'31.22"
ST2	Kuzdere	N41°10'57.64" E29°13'59.15"
ST3	Kanlıdere	N41°07'08.30" E29°16'09.80"
ST4	Atdosun	N41°10'25.00" E29°16'17.60"
ST5	Değirmendere	N41°07'58.30" E29°16'55.50"

ST5. Değirmendere: The side road opposite the gas station on the right to Ishaklı Village. There are few settlements around it. It is a very deep station. The bottom is covered with loam. *Lemna* sp. covered the water surface in summer.

Sampling

Samples were collected seasonally from the stations from March 2018 to January 2019. A 0.5 mm mesh D-frame hand net was used to collect the samples. Annelid samples were preserved in 70% ethyl alcohol. Annelida samples brought to the laboratory were separated from the sediment, placed in tubes containing 70% alcohol and labelled. After permanent preparation using CMCP-10 (polyvinyl lactophenol), annelids were described by Brinkhurst & Jamieson (1971), Brinkhurst (1975, 1986), Kathman & Brinkhurst (1998), Timm (2009), Wetzel et al. (2000). Since some individuals are deformed or young, they are given as subfamilies. Dominance values were calculated according to Bellan-Santini (1969).

Depth (as cm), width (as cm), flow rate (as m/s), water temperature (as °C), dissolved oxygen (as mg/L), pH, conductivity (as µS/cm), and salinity (as ppm) values were measured by using multiparameter in situ. NO_3-N (as mg/L), NO_2-N (as µg/L), o-PO_4 (as µg/L), TP (as µg/L), and TSS (as g/L) values analysed according to APHA, AWWA, and WPCF (1989). NH_4-N (mg/L) values were measured using the SM 4500 NH_3 B, F methodology.

Water Quality Indice (NPI)

The nutrient Pollution Index (NPI) is a widely used tool in assessing nutrient pollution in surface water resources based on NO_3 and PO_4 concentrations (Isiuku & Enyoh, 2020; Larrea-Murrell et al., 2022). The nutrient pollution index calculation formula is given below.

$$NPI = \frac{C_N}{MAC_N} + \frac{C_P}{MAC_P}$$

C_N: The levels of NO_3-N in water sample (mg/L)

C_P: The levels of PO_4-P in water sample (mg/L)

MAC_N: The maximum limit of NO_3-N (mg/L)

MAC_P: The maximum limit of PO_4-P (mg/L)

MAC_N and MAC_P they are taken from (TSWQR, 2016).

Statistical Analysis

All results obtained were transformed using statistical techniques with LogBase10 in Microsoft Office Excel 2003 and SPSS 9.0 for Windows programs (Krebs, 1999). The similarity of the selected sampling stations in terms of physicochemical parameters and species was compared using Bray-Curtis Cluster Analysis in the BioDi-versity Pro 2.0 programme (McAleece et al., 1997). Canonical Correspondence Analysis was applied to understand the relationship between some physicochemical and biological data (Hammer et al., 2001).

Results and Discussion

In this study, 1241 individuals total (in m^2) belonging to 28 taxa and 4 families of Annelida that 2 taxa belonging to the Lumbricidae family; Lumbricidae, *Eiseniella tetraedra* Savigny, 1826; 1 taxon were identified belonging to Glossiphoniidae family; *Helobdella stagnalis* (Linnaeus, 1758); 3 taxa belonging to the Enchytraeidae family; *Henlea ventriculosa* d'Udekem, 1854; *Henlea perpusilla* Friend, 1911; *Enchytraeus buchholzi* Vejdovský, 1879; 21 taxa belonging to the Naididae family; *Aulodrilus limnobius* Bretscher, 1899; *Homochaeta naidina* Bretscher, 1896; *Limnodrilus claparedeanus* Ratzel, 1868; *Limnodrilus profundicola* Verril, 1871; *Limnodrilus hoffmeisteri* Claparède, 1862; *Limnodrilus udekemianus* Claparède, 1862; *Limnodrilus* sp.; Naidinae; Nais sp.; *Ophidonais serpentina* Müller, 1773; *Pristina* sp.; *Psammoryctides albicola* (Michaelsen, 1901); *Psammoryctides deserticola* (Grimm, 1877); *Potamothrix hammoniensis* (Michaelsen, 1901); *Psammoryctides* sp.; *Rhyacodrilus coccineus* (Vejdovsky, 1875); *Stylaria lacustris* Linnaeus, 1767; *Tubifex tubifex* (Müller, 1774); Tubificinae; *Uncinais uncinata* (Ørsted, 1842); *Vejdovskyella intermedia* Bretscher, 1896 and a subclass, Hirudinea, were identified. The identified taxons are new records for the region.

With 595 individuals (47.95%), the ST5 had the highest number of individuals in all stations. It was followed by ST3 and ST4 with 286 individuals (23.05%) and 226 individuals (18.21%), while ST1 had 85 individuals (6.85%) and ST2 had 49 individuals (3.95%) in total.

According to family dominance (%) in all stations, Naididae was determined to be 91.46%. 21 of 28 taxa belonging to the naidids. The other families were also determined as Lumbricidae 5.40%, Hirudinea 1.53%, Enchytraeidae 1.21%, and Glossiphoniidae 0.40% (Figure 2).

Considering the dominance (%) of seasons according to individual numbers, the winter season had the highest percentage of Annelid at 44.32%. The Autumn season was determined as 31.02%, the summer season was determined as 14.10%, and the spring season was determined as 10.56% (Figure 3).

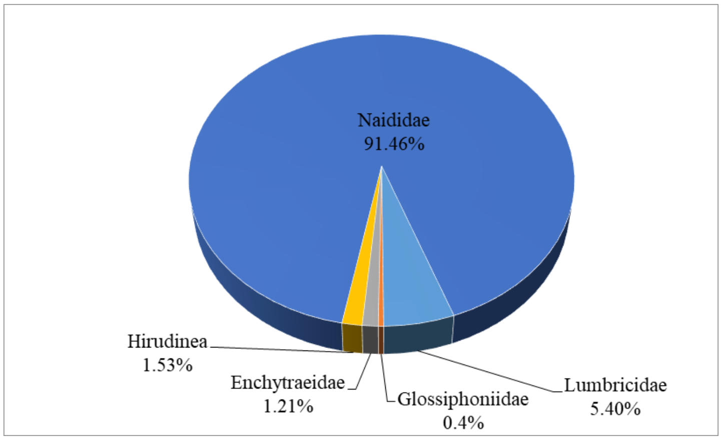


Figure 2. The dominance ratio (%) of Annelid families.

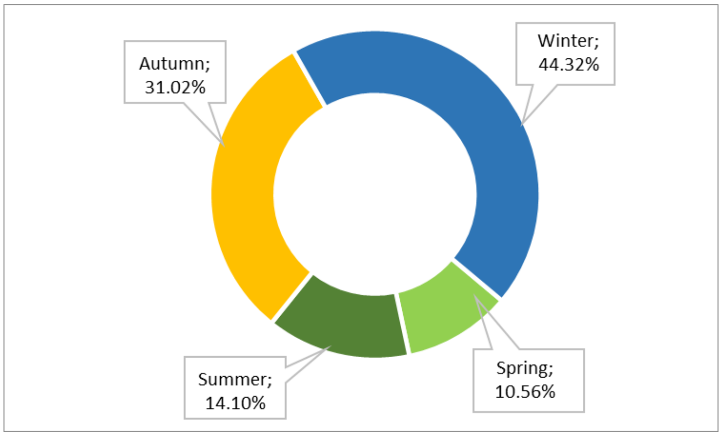


Figure 3. The distribution and dominancy rate (%) of taxa in terms of the seasons.

Most Naidid species are cosmopolitan and adapt to different conditions (Brinkhurst & Jamieson, 1971; Wetzel et al., 2000). The most dominant species was *Tubifex tubifex* (293 individuals (23.61%). The Tubificinae subfamily followed up the taxon with 245 individuals (19.74%). Individuals belonging to this subfamily are deformed or juveniles and are therefore given as a subfamily. Therefore, it represents a large group. *L. hoffmeisteri* (77 individuals and 6.20%) was also determined as one of the most dominant species in this study. Together with *T. tubifex* and Tubificane, they were both the most dominant and widely distributed in all stations, despite the difference between the measured physicochemical parameter values. Both *T. tubifex* and *L. hoffmeisteri* are found in organically rich surface water habitats (Brinkhurst & Jamieson, 1971; Brinkhurst, 1975; Wetzel et al., 2000; Hare & Shooner, 1995) *L. hoffmeisteri,* a highly pollution-tolerant species, is one of the most widely distributed freshwater Oligochaeta worldwide (Arslan & İlhan, 2010).

In order, *P. albicola* (228 individuals, 18.38%) and *O. serpentina* (83 individuals, 6.69%) were determined as the other dominant species. At the same station, *L. udekemianus* was found with 36 individuals, and it is a highly cosmopolitan species that can be distributed even in very different environments (Timm, 1970).

According to Timm (1980), although *A. limnobius, E. tetraedra, L. claparedeanus, Pristina* sp., *R. coccineus*, Lumbricidae, Naidinae, *Nais* sp., *Limnodrilus* sp. are widely distributed and cosmopolitans; except for Lumbricidae, they were found in one or two different stations in this study. Lumbricidae was determined in all stations except the second station.

19 individuals (1.53%) from the Hirudinea subclasses have been examined. While this taxon was found in winter at station 5, it was found in the summer and autumn seasons at station 3. The leeches get oxygen through their skin, and they have a tolerance for pollution or habitat disturbance (Demirsoy, 2005).

The determined species were generally found in previous studies (Arslan, 2006; Demiroğlu & Mısıroğlu, 2010; Koşal Şahin & Yıldız, 2011; Odabaşı et al., 2018; Özbek et al., 2018). *E. tetraedra, E. buchholzi, H. perpusilla, L. hoffmeisteri, L. udekemianus,* Naidinae, *Nais* sp., *O. serpentina P. albicola P. deserticola, S. lacustris, T. tubifex*, Tubificinae species were also reported from Thrace Region (Taş et al., 2012; Aydın & Çamur Elipek, 2019*). H. ventriculosa; H. perpusilla*; *Nais* sp.; *Pristina* sp. and *S. lacustris* were found as single individuals in all stations (0.08%). Total numbers and dominance ratios (%) of taxa in terms of stations are shown in Table 2.

Table 2. According to the stations, the individual number of taxa and the dominance (%).

Familia	Taxon	ST1	ST2	ST3	ST4	ST5	T	%D
Lumbricidae	Lumbricidae	1	-	18	22	23	64	5.16
	Eiseniella tetraedra Savigny, 1826	-	2	1	-	-	3	0.24
Glossiphoniidae	*Helobdella stagnalis* (Linnaeus, 1758)	-	5	-	-	-	5	0.40
Enchytraeidae	*Henlea ventriculosa* d'Udekem, 1854	-	1	-	-	-	1	0.08
	Henlea perpusilla Friend, 1911	-	-	1	-	-	1	0.08
	Enchytraeus buchholzi Vejdovský, 1879	-	-	3	-	10	13	1.05
Hirudinea	Hirudinea	-	-	11	-	8	19	1.53
Naididae	*Aulodrilus limnobius* Bretscher, 1899	-	-	6	-	-	6	0.48
	Homochaeta naidina Bretscher, 1896	-	-	-	7	-	7	0.56
	Limnodrilus claparedeanus Ratzel, 1868	-	-	-	10	-	10	0.81
	Limnodrilus profundicola Verril, 1871	-	-	-	-	10	10	0.81
	Limnodrilus hoffmeisteri Claparède, 1862	21	1	23	30	2	77	6.20
	Limnodrilus udekemianus Claparède, 1862	-	3	3	11	19	36	2.90
	Limnodrilus sp.	2	-	-	-	24	26	2.10
	Naidinae	-	-	-	7	-	7	0.56
	Nais sp.	1	-	-	-	-	1	0.08
	Ophidonais serpentina Müller, 1773	-	2	-	1	80	83	6.69
	Pristina sp.	-	1	-	-	-	1	0.08
	Psammoryctides albicola (Michaelsen, 1901)	7	5	28	-	188	228	18.38
	Psammoryctides deserticola (Grimm, 1877)	1	14	-	-	9	24	1.93
	Potamothrix hammoniensis (Michaelsen, 1901)	10	-	49	-	2	61	4.92
	Psammoryctides sp.	5	1	-	-	2	8	0.64
	Rhyacodrilus coccineus (Vejdovsky, 1875)	-	2	-	-	-	2	0.16
	*Stylaria lacustris*Linnaeus, 1767	-	-	-	1	-	1	0.08
	Tubifex tubifex (Müller, 1774)	15	3	73	46	156	293	23.61
	Tubificinae	18	6	68	91	62	245	19.75
	Uncinais uncinata (Ørsted, 1842)	-	3	2	-	-	5	0.40
	Vejdovskyella intermedia Bretscher, 1896)	4	-	-	-	-	4	0.32
	Total	85	49	286	226	595	1241	
	Dominance%	6.85	3.95	23.05	18.21	47.95		

With 595 individuals (47.95%), the ST5 had the highest number of individuals in all stations. It was followed by ST3 and ST4 with 286 individuals (23.05%) and 226 individuals (18.21%), while ST1 had 85 individuals (6.85%) and ST2 had 49 individuals (3.95%) in total (Table 2).

Depth values were ranged 19.75-46.5 cm; width values were ranged 174-6749 cm; flow rate values were ranged 0-0.85m/s; water temperature values were ranged 12.58-14.88°C; dissolved oxygen values were ranged 5.815-9.46 mg/L; pH values were ranged 7.73-8.08; conductivity values were ranged 130-1900 µS/cm; salinity values were ranged 0.045-1.31; TP values were ranged 86.93- 366.71 µg/L; o-PO4 values were ranged 22.66-186.47 µg/L; NH_4-N values were ranged <0.5- 4.99 mg/L; NO_2-N values were ranged 12.46-83.28 µg/L, NO_3-N values were ranged 0.24-0.54 mg/L and TSS values were ranged 0.17-2.08 g/L measured. The average of physicochemical parameter values is shown in Table 3.

When the physicochemical data were analysed seasonally, dissolved oxygen values were found to be of class III water quality at station 1 and class I at the other stations. Electrical conductivity values were of class III water quality at the first and 5th stations, class II water quality at the 2nd and class I at the other stations. Total phosphate was found to be class III at stations 1 and 5, class II at stations 2, 3 and 4, o-PO_4 was class III at stations 1, class I at stations 2 and 4, and class II at stations 3 and 5. NH_4-N was found to be class III water quality at the first station and class II at the other stations (TSWQR, 2021).

Table 3. Seasonal and average values of sampling stations

	RİVA							
	Unit	**Spring**	**Summer**	**Autumn**	**Winter**	**Average**	**TSWQR, 2021**	**Quality Parameters**
Depth	cm	36	34	371.4	24	32.75		
Width	cm	6916	6578	6646	6676	6749		
FR	m/s	0	0	0	0	0		
Temp.	°C	11.5	24.5	18.1	5,4	14.88		
DO	mg/L	4.82	3.46	3.47	11,5	5.81	<6	III
pH	-	8.67	7.7	7.14	7,91	7.86		
EC	µS/cm	2440	1120	3070	970	1900	>1000	III
Salinity	ppm	1.25	2.4	1.4	0.2	1.31		
TP	µg/L	265.74	569.39	476.28	155.43	366.71	>0,2	III
o-PO_4	µg/L	43.47	332.82	293.67	75.92	186.47	>0,16	III
NH_4-N	mg/L	3.12	6.55	9.45	0.83	4.99	>1	III
NO_2-N	µg/L	77.08	104.37	108.23	43.43	83.28		
NO_3-N	mg/L	0.46	0.22	0.33	0.73	0.44		
TSS	g/L	2.5	3.1	1.93	0.79	2.08		
	KUZDERE							
	Unit	**Spring**	**Summer**	**Autumn**	**Winter**	**Average**	**TSWQR, 2021**	**Quality Parameters**
Depth	cm	17	19	18	25	19.75		
Width	cm	370	280	193	370	303.25		
FR	m/s	1.2	0.2	0.2	0.6	0.55		
Temp.	°C	10.5	21.5	17.7	5.8	13.88		
DO	mg/L	9.7	5.82	4.7	13.76	8.50	>8	I
pH	-	8.82	7.69	7.07	8.04	7.91		
EC	µS/cm	410	600	440	320	422.5	1000	II
Salinity	ppm	0.34	0	0	0	0.09		
TP	µg/L	218.06	66.59	79.89	85.13	112.42	0,2	II
o-PO_4	µg/L	20.38	15.22	28.23	26.79	22.66	<0,05	I
NH_4-N	mg/L	0.59	<0.5	<0.5	<0.5	<0.5-0.59	1	II
NO_2-N	µg/L	18.12	42.36	55	8.37	30.96		
NO_3-N	mg/l	0.6	0.27	0.39	0.41	0.42		
TSS	g/l	0.4	0.4	0.28	0.16	0.31		

	Unit	Spring	Summer	Autumn	Winter	Average	TSWOR, 2021	Quality Parameters
KANLIDERE								
Depth	cm	24	17	20	47	27		
Width	cm	297	267	220	490	318.5		
FR	m/s	2.3	0.2	0.2	0.7	0.85		
Temp.	°C	11.5	16.6	15.7	6.5	12.58		
DO	mg/L	10.08	6.78	6.8	12.39	9.01	>8	I
pH	-	8.88	6.32	7.16	9.63	8.00		
EC	µS/cm	310	40	20	150	130	<400	I
Salinity	ppm	0.17	0	0	0	0.04		
TP	µg/L	50.46	46.95	186.1	64,19	86.93	0,2	II
$o\text{-}PO_4$	µg/L	12.79	8.54	83.12	37,05	35.38	<0,05	I
$NH_4\text{-}N$	mg/L	<0.5	0.59	0.82	<0,5	<0.5-<0.7	<0,05	II
$NO_2\text{-}N$	µg/L	5.47	5.59	27.46	11,3	12.46		
$NO_3\text{-}N$	mg/L	0.41	0.18	0.16	0,31	0.27		
TSS	g/L	0.1	0.1	0.45	0.01	0.17		
ATDOSUN								
	Unit	**Spring**	**Summer**	**Autumn**	**Winter**	**Average**	**TSWQR, 2021**	**Quality Parameters**
Depth	cm	15	12	18	52	24.25		
Width	cm	163	177	132	224	174		
FR	m/s	0.4	0.15	0.2	0.2	0.24		
Temp.	°C	11	21.6	15.9	4.4	13.23		
DO	mg/L	10.34	8.83	6.02	12.65	9.46	>8	I
pH	-	8.59	7.57	7.2	8.96	8.08		
EC	µS/cm	580	10	40	250	220	<400	I
Salinity	ppm	0.16	1.2	0	0	0.34		
TP	µg/L	234.19	135.31	85.88	82.89	134.57	0,2	II
$o\text{-}PO_4$	µg/L	55.01	35.72	49.64	55.76	49.03	>0,2	I
$NH_4\text{-}N$	mg/L	0.63	0.63	<0.5	<0.5	<0.5-0.63	<0,05	II
$NO_2\text{-}N$	µg/L	9.81	12,32	35.02	13.03	17.55		
$NO_3\text{-}N$	mg/l	0.31	0,15	0.16	0.34	0.24		
TSS	g/l	0.1	0,3	0.29	0.05	0.19		
DEĞİRMENDERE								
	Unit	**Spring**	**Summer**	**Autumn**	**Winter**	**Average**	**TSWQR, 2021**	**Quality Parameters**
Depth	cm	84	23	32	47	46.50		
Width	cm	484	350	370	592	449		
FR	m/s	0.2	0	0	0.12	0.08		
Temp.	°C	12	24.9	16,2	5.4	14.63		
DO	mg/L	7.58	5.52	6.76	12.57	8.11	>8	I
pH	-	7.92	7.51	7.4	8.1	7.73		
EC	µS/cm	550	390	1100	480	630	1000	II
Salinity	ppm	0.27	0.4	0.3	0	0.24		
TP	µg/L	114.27	558.87	429.16	186.84	322.29	>0,2	III
$o\text{-}PO_4$	µg/L	66.1	163.92	292.95	172.92	173.97	0,16	II
$NH_4\text{-}N$	mg/L	0.71	6.47	4.56	<0.5	3.91	1	II
$NO_2\text{-}N$	µg/L	28.3	53.86	203.89	15.94	75.50		
$NO_3\text{-}N$	mg/l	0.7	0.12	0.93	0.4	0.54		
TSS	g/l	0.3	0.8	0.7	0.26	0.52		

When the NPI values of the stations are analysed in terms of seasons

Spring season; ST3<ST2<ST4<ST1<ST5

Summer season; ST3<ST2<ST4<ST5<ST1

Autumn season; ST2<ST4<ST3<ST1<ST5

Winter season; ST2<ST3<ST4<ST1<ST5.

NPI values were found as no pollution at station 3 in the spring season and moderate pollution at other stations. In the summer season, stations 2, 3, and 4 were no pollution, while stations 1 and 5 were considerably polluted. In autumn, station 2 was not polluted while stations 3 and 4 were moderately polluted. In this season, stations 1 and 5 were considerably polluted. In the winter season, stations 1, 2, 3, and 4 were found to be moderately polluted. In the same season, station 5 was found to be considerably polluted. According to the NPI index, Riva and Değirmendere were more polluted than other streams (Table 4).

Table 4. NPI Indices of the stations in terms of seasons

	ST1	ST2	ST3	ST4	ST5
Spring	1.478	1.285	0.804	1.456	2.232
Summer	6.924	0.598	0.425	0.753	3.377
Autumn	6.286	0.975	1.836	1.036	7.170
Winter	2.477	1.004	1.057	1.501	3.990

When the stream waters are evaluated regarding physicochemical parameters, the 2nd and 3rd stations are the most similar (76.37%). The 4th station joins this similarity. ST1 and ST3 were the least similar stations (12.75%) (Figure 4a).

When the similarity of the taxa detected in the sampling stations in terms of stations was analysed, it was seen that the 3rd and 4th stations were the most similar stations with a rate of 61.71%. The 5th station participates in this similarity. ST2 and ST5 were the least similar stations (9.31%) (Figure 4b).

The CCA triplot shows that lines represent environmental variables and dots represent taxa (Figure 5).

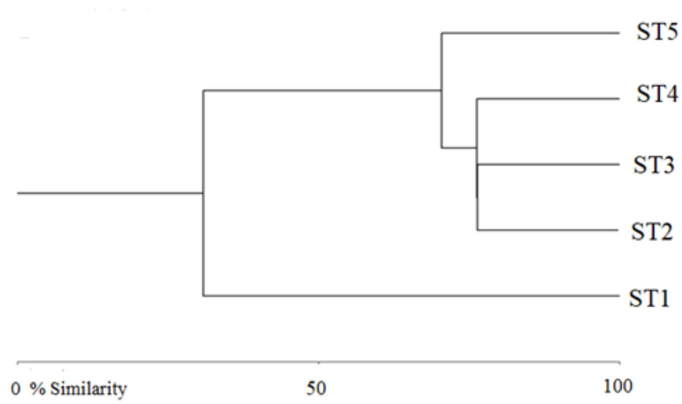


Figure 4a. The similarity of the stations in terms of physicochemical parameters

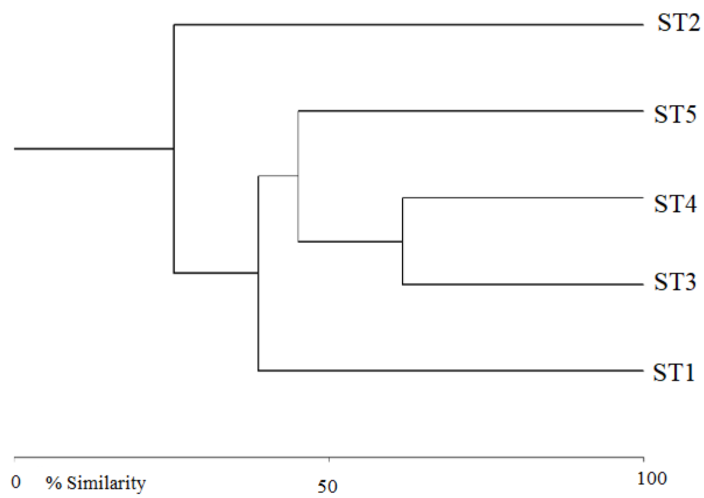


Figure 4b. Similarity of the stations in terms of taxons

Two axes, 43.44% (first Axis) and 24.29% (second Axis), explain a total of 67.73%. The CCA triplot shows that the species distributed parallel to the second axis, and width, salinity and TSS values were closest to the second axis. Considering the triplot, TSS was found to be the key parameter for the distribution of taxa. *U. uncinata* and *L. hoffmeisteri* appeared closely related to salinity, while *E. tetraedra, H. naidina, H. stagnalis, P. deserticola* and *Nais* sp. were shown closely related to width (Figure 5). *L.udekemianus* was not found in the main tributary, which is quite different from the other stations regarding physical and chemical properties. The CCA triplot given in Figure 5 shows that the distribution of this species and the salinity value were positioned oppositely. Both measurements and statistical analysis show that salinity should be important in the distribution of this species.

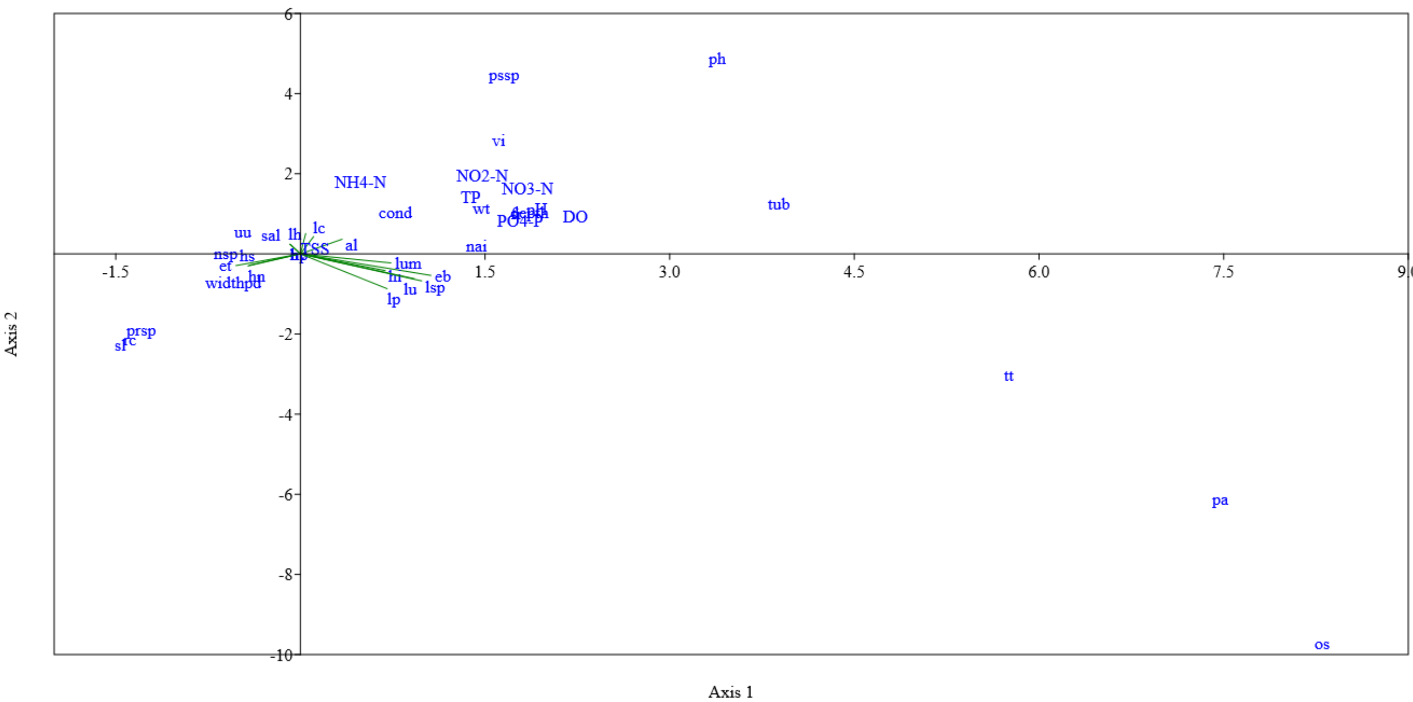


Figure 5. CCA triplot [*Abbrv.: Lum:* Lumbricidae*; et: E. tetraedra; hs: H. stagnalis; hv: H. ventriculosa; hp: H. perpusilla; eb: E. buchholzi; hi:* Hirudinea*; al: A. limnobius; hn: H. naidina; lc: L. claparedeanus; lp: L. profundicola; lh: L. hoffmeisteri; lu: L. udekemianus; lsp: Limnodrilus* sp.*; nai:* Naidinae*; nsp: Nais* sp.*; os: O. serpentina; prsp: Pristina* sp.*; pa: P. albicola; pd: P. deserticola; ph: P. hammoniensis; pssp: Psammoryctides* sp.*; rc: R. coccineus; sl: S. lacustris; tt: T. tubifex; tub:* Tubificinae*; uu: U. uncinata; Vi: V. intermedia;* wt: water temperature, sal: salinity, TSS: suspended solid, cond: conductivity, fr: flow rate]

Our study can be compared with previous studies conducted in the Riva stream. Karadeniz (2007) reported that the pH of the stream varied between 6.7-8.54. Uzun (2012) reported that the pH varied between 7.08 and 7.68. Compared to our study, it can be said that the water of the Riva stream is slightly more basic. Karadeniz (2007) reported that the temperature of the stream was between 4-26.7°C; Uzun (2012) reported that it was between 8.51-26.26°C. It is seen that there is not much change between the temperature values, and the values are close to each other in these three studies. When compared with our study, it was reported that the water of the Riva stream was slightly more basic and dissolved oxygen values varied between 0.6-7.8 mg/L by Karadeniz (2007) and between 2.16-5.77 mg/L by Uzun (2012). In our study, dissolved oxygen values were higher than in other studies. Electrical conductivity values were reported to vary between 292-1725 µS/cm by Karadeniz (2007) and 537-2164 µS/cm by Uzun (2012). Our study shows that electrical conductivity values are quite high in Riva and Değirmendere (Table 3).

Conductivity, which is a measure of the electrical capacity of water, expresses the change in the concentration of dissolved solids in water (Kara & Çömlekçioğlu, 2004). Both the rock structure in the riverbed and pollution can affect the electrical conductivity of water (Barlas, 1988).

As the temperature increases, the concentration of dissolved ions increases due to evaporation and electrical conductivity increases (Durhasan, 2006). Karadeniz (2007) reported that PO_4-P values vary between 1.06-3.54 mg/L. In our study, it is seen that o-PO_4 values are quite high (Table 3).

When the study found similar results compared with previous studies, Odabaşı et al. (2018) investigated the aquatic oligochaeta fauna of the Biga Peninsula rivers and their seasonal changes. They reported that 33 taxa belonged to oligochaeta. They found that the pH and NO_3-N values of the streams were in the 1st class quality, and the EC, DO, and BOD values were between the 1st and 2nd class water quality. Albayrak et al.

(2023) determined 9 taxa from oligochaeta in their study in Göksu stream. They reported that the DO values of the stream are between the 1st and 2nd class, EC values are in the 2nd class, TP values in the 3rd class, o-PO_4 values in the 1st class, and NH_4-N values in the 2nd class.

As a result, high electrical conductivity and o-PO_4 values can be attributed to increased pollution load in the streams. In this study, while the first records were given for Kuzdere, Kanlıdere, Atdosun and Değirmendere, time-dependent changes were presented for Riva.

Conclusion

In terms of water quality, Kuzdere, Kanlıdere, and Atdosun can be considered as potable water. However, water use from these areas is not recommended until monitoring continues and good-quality water is identified.

Riva and Değirmendere were found to be heavily polluted both physically and chemically. Both physicochemical parameters and the NPI index supported this. For these stations, where only tolerant species can shelter, pollution sources should be identified, and these sources should be cut. As one of these stations is a main tributary and is close to the sea, protecting the entire settlement pattern around the Riva Stream and all biological elements, including marine life is of utmost priority. It is recommended that the investigations continue along the stream following the main tributary and that the pollution status be determined in other tributaries.

Compliance with Ethical Standards

Conflict of interest: The authors declare no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: Ethics committee approval is not required for this study.

Data availability: Data will be made available on request.

Funding disclosure: No funding provided.

Acknowledgements: We thank Istanbul University Institute of Graduate Studies in Sciences and Istanbul University Faculty of Aquatic Sciences Inland Water Laboratory for their valuable contributions.

Disclosure: This study is based on a part of the Ph.D. dissertation.

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