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Research Article

Aquatic Oligochaeta (Annelida: Clitellata) Assemblages in the Streams of Biga Peninsula (Marmara-Turkey) and Their Seasonal Variations

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Abstract: In the present study, aquatic Oligochaeta (Annelida: Clitellata) fauna and environmental parameters from 15 predetermined stations in Sarıçay, Karamenderes, Tuzla, and Kocabaş streams in Biga Peninsula (North-West Anatolia) were seasonally studied. Benthic samplings were collected via Hess Sampler and Ekman Birge Grab. During benthic samplings, temperature, electrical conductivity, pH, and dissolved oxygen were analysed on-site whereas chemical oxygen demand (COD), biological oxygen demand (BOD_5), and water quality parameters such as PO_4-P, and NO_3-N were analysed in laboratory. In this study, a total of 340.993 individuals of Oligochaeta belonging 33 different taxawere obtained. The family Naididae had the highest number of species (29 taxa); and followed by Enchytraeidae (2 taxa) and Lumbriculidae (2 taxa).It was demonstrated through Multidimensional Scaling (MDS) that species that are tolerant to organic pollution, including *Potamothrix hammoniensis* (Michaelsen, 1901), *Tubifex tubifex* Müller, 1774, *Limnodrilus hoffmeisteri* Claparede, 1862 are dominant in the stations located in sub tributary basins. In addition, *Bothrioneurum vejdovskyanum* Stolc, 1886, *Mesenchytraeus sanguineus* Nielsen & Christensen, 1959 and *Enchytraeus christenseni* Dozsa-Farkas, 1992, found in this study, are recorded for the first time for the aquatic Oligochaeta Fauna in Turkey.

Keywords: Oligochaeta, Biga Peninsula, Streams, Environmental Parameters, MDS.

Biga Yarımadası Akarsularının Sucul Oligochaeta (Annelida: Clitellata) Toplulukları ve Mevsimsel Değişimleri

Özet: Bu çalışmada, Biga Yarımadası akarsularından Sarıçay, Karamenderes, Tuzla ve Kocabaş'ta belirlenmiş 15 örnekleme istasyonunda, Oligochaeta (Annelida: Clitellata) faunası çevresel değişkenler ile birlikte mevsimsel olarak araştırılmıştır. Bentik örneklemeler Hess Sampler ve Ekman Birge Grab ile gerçekleştirilmiş ve örnekler kantitatif olarak değerlendirilmiştir. Bentik örneklemeler sırasında, su sıcaklığı (T), elektrik iletkenliği (EC), pH ve çözünmüş oksijen (DO) yerinde, kimyasal oksijen ihtiyacı (COD), biyolojik oksijen ihtiyacı (BOD_5), PO_4-P, NO_3-N gibi su kalitesi laboratuvarda analiz edilmiştir. Araştırma sonucunda, Naididae familyasından 29 taksa, Enchytraeidae 2 taksa ve Lumbriculidae 2 taksa olmak üzere 33 taksaya ait toplam 340993 birey tespit edilmiştir. Organik kirliliğe toleranslı *Potamothrix hammoniensis* (Michaelsen, 1901), *Tubifex tubifex*Müller, 1774, *Limnodrilus hoffmeisteri* Claparede, 1862 türlerinin alt akarsu havzalarında yer alan istasyonlarda baskın olduğu MD Sanalizi ile gösterilmiştir. Ayrıca, çalışmada tespit edilen *Bothrioneurum vejdovskyanum* Stolc, 1886, *Mesenchytraeus sanguineus* Nielsen & Christensen, 1959 ve *Enchytraeus christenseni* Dozsa-Farkas, 1992 türleri Türkiye sucul Oligochaeta Faunası için ilk kayıt niteliğindedir.

Anahtar Kelimeler: Oligochaeta, Biga Yarımadası, Akarsular, Çevresel Değişkenler, MDS.

Introduction

Aquatic Oligochaeta species constitute an important part of the benthic fauna in fresh waters and generally most of them live freely on the benthos (especially members of Naidinae subfamily) while some species actively swim and live in the vegetation (Sperber, 1950; Brinkhurst & Jamieson 1971; Meadows & Bird, 1974; Bouguenec & Giani 1989). Most of the members of aquatic Oligochaeta feed uponfine particles deposited on sand and mud and therefore, help clean the substrate.

Members of Oligochaeta are used in the assessment of water and sediment quality as they can be used as an indicator for the type and level of various pollution sources due to their tolerance to variable environmental conditions (Goodnight & Whitley, 1961; Reynoldson & Rodriguez, 1999). Also, since they constitute a major food for fishes and other invertebrates, they are important components of the food chain (Milbrink, 1983; Chapman & Brinkhurst, 1987).

In this study, seasonal distribution of Oligochaeta members were correlated with environmental variables in the sub and upper tributary basins of Sarıçay, Karamenderes, Tuzla, and Kocabaş streams in Biga Peninsula.

Materials and Methods

Study Area

The study area is located in the western part of the Marmara Region in North-West Anatolia (Fig. 1). Previous works have indicated high levels of nitrogen and phosphorus due to extensive use of agriculture fertilizers and discharges of domestic waste in Karamenderes and Sarıçay Streams as well as excessive concentrations of some heavy metals due stations were established in 4 different streams from upstream to downstream (Table 1).

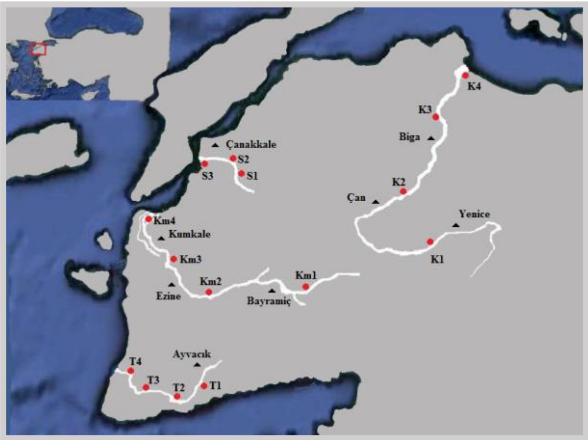

Figure 1. Sampling stations (S: Sarıçay, Km: Karamenderes, T: Tuzla, K: Kocabaş).

The idenfication of the Oligochaeta species was performed following Brinkhurst (1986), Brinkhurst & Jamieson (1971), Kathman & Brinkhurst (1998), Timm (2009), Wetzel et al., (2009).

Table 1. Sampling stations and their coordinates

	St. 1.(S1,Km1,T1,K1)	St. 2. (S2,Km2,T2,K2)	St. 3. (S3,Km3,T3,K3)	St. 4. (Km4,T4,K4)
Sarıçay	40° 12′ 557″ N 26° 51′ 852″ E	40° 12′ 556″ N 26° 51′ 848″ E	40° 14′ 326″ N 26° 40′ 454″ E	_
Karamenderes	39° 77′ 538″ N 26° 69′ 165″ E	39° 50′ 484″ N 026° 19′ 322″ E	39° 59′ 617″ N 26° 12′ 619″ E	40° 00′ 500″ N 26° 12′ 399″ E
Tuzla	39° 35′ 246″ N 26° 25′ 109″ E	39° 29′ 991″ N 26° 19′ 989″ E	39° 31′ 590″ N 26° 17′ 231″ E	39° 55′ 813″ N 26° 15′ 915″ E
Kocabaş	39° 93′ 861″ N 27° 23′ 224″ E	40°22′999″N 27°24′304″ E	40°05′670″N 27°12′708″ E	40°37′807″ N 27°31′715″ E

Sampling and Analysis

Benthic samples were taken seasonally using a Hess sampler dredge (covering a surface of 900 cm^2), and Ekman Birge Grap (15*15 cm) between Autumn 2008 and Summer 2009. Benthic samples were taken as two replicate and the sampling materials were fixed with 4% formaldehyde after sieving. While some parameters (temperature, pH, electrical conductivity, and dissolved oxygen values) were measured *in situ*, other parameters (Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), PO_4-P and NO_3-N measurements) were measured in the laboratory after transportation of samples collected in the field. Environmental variables were assigned to quality classes according to Legislation of Water Quality Control (LWQC) of Turkey (Anonymous, 2012) (Table 2). The data set subjected to multi-dimensional Scaling (MDS) analysis using SPSS 10.1.

Table 2. Legislation of Water Quality Control (LWQC) of Turkey.

	Classes of Water Quality			
WATER QUALITY PARAMETERS	I	II	III	IV
A) Physical and inorganic- Chemical parameters				
1) Temperature (ºC)	25	25	30	> 30
2) pH	6.5-8.5	6.5-8.5	6.0-9.0	6.0-9.0 except
3) Dissolved Oxygen (mg O_2/L)[a]	8	6	3	< 3
4) Oxygen saturation (%)[a]	90	70	40	< 40
5) Nitrate Nitrogen (mg NO_3^--N/L)	5	10	20	> 20
6) Total Phosphorus (mg P/L)	0.02	0.16	0.65	> 0.65
B) Organic parameters				
1) Chemical Oxygen Demand (COD) (mg/L)	25	50	70	> 70
2) Biological Oxygen Demand (BOD) (mg/L)	4	8	20	> 20

(a): Concentration or percentage of saturation

Results

In the present study, 33 taxa belonging to Oligochaeta were identified. Among these, Naididae had the highest number of species (29 taxa) followed by Enchytraeidae (2 taxa) and Lumbriculidae (2 taxa). A total of 340993 individuals belonging to3 orders, 3 families, 4 subfamilies, 18 genera and 31 species were collected.

Sarıçay

A total of 69586 individuals from 20 Oligochaeta species were collected in three stations (Table 3). Species distributions between stations and seasons also showed variability. While the highest number was observed in station 2 (S2) in the autumn (16716 individuals/m^2), 13066 individuals/m^2 and 10656 individuals/m^2 were observed in the summer and spring respectively. The lowest number of individuals was observed in station 1 in the autumn with a density of 322 individuals/m^2 and in summer with a density of 888 individuals/m^2.

While *Tubifex tubifex* (28250 individuals/m^2), *Potamothrix bavaricus* (4307 individuals/m^2, % D=6.19), *Stylaria lacustris* (2986 individuals/m^2), *Slavina appendiculata* (3752 individuals/m^2) and *Nais barbata* (2597 individuals/m^2) were the most dominant species in Sarıçay, population densities of *Nais elinguis* (11 individuals/m^2, % D=0.02), *Dero obtusa* and *Nais variabilis* (33 individuals/m^2, % D=0.05) were significantly lower (Table 3).

Table 3. The Dominancy and Frequency values of Oligochaeta Fauna in Sarıçay Stream (St:Stone, P:Plant, S:Sand, M:Mud)

SARIÇAY	AUTUMN (26.11.2008)			WINTER (18.02.2009)			SPRING (04.05.2009)			SUMMER (13.08.2009)						
Stations	1	2	3	1	2	3	1	2	3	1	2	3	TOTAL	%D	F	%F
Habitat Type	St,M	S,M,P	M	St,P	P	M	St,S	P,M	M	St,P	M,P,S	M				
Familya: Naididae																
Chaetogaster diaphanus	0	0	0	0	0	0	0	333	0	0	0	0	**333**	0.48	1	8.33
Ophidonais serpentina	0	0	0	0	0	0	0	0	0	0	1432	0	**1432**	2.06	1	8.33
Stylaria lacustris	133	555	0	122	1066	0	0	722	0	33	355	0	**2986**	4.29	7	58.33
Dero obtusa	0	11	0	0	22	0	0	0	0	0	0	0	**33**	0.05	2	16.67
Aulophorus furcatus	0	0	0	0	0	0	0	0	0	0	78	0	**78**	0.11	1	8.33
Slavina appendiculata	100	0	0	2842	0	0	810	0	0	0	0	0	**3752**	5.39	3	25.00
Nais barbata	0	966	0	0	333	0	11	1288	0	0	0	0	**2597**	3.73	4	33.33
Nais pardalis	0	0	0	0	0	0	0	78	0	0	0	0	**78**	0.11	1	8.33
Nais elinguis	0	0	0	0	0	0	0	0	0	11	0	0	**11**	0.02	1	8.33
Nais christinae	0	0	0	0	44	0	0	133	0	0	0	0	**178**	0.26	2	16.67
Nais variabilis	0	0	0	0	0	0	33	0	0	0	0	0	**33**	0.05	1	8.33
Nais communis	0	500	0	11	655	0	44	0	0	0	0	0	**1210**	1.74	4	33.33
Subfamilya: Pristininae																
Pristina aequiseta	0	133	0	0	11	0	0	0	0	0	0	0	**144**	0.21	2	16.67
Subfamilya: Tubificinae																
Juvenil Tubificinae	0	2520	4440	1809	78	2964	78	1987	1499	189	2398	0	**17960**	25.81	10	83.33
Tubifex tubifex	89	5916	2842	622	133	5028	56	4784	1277	211	6338	955	**28250**	40.60	12	100.00
Psammoryctides albicola	0	0	0	0	0	0	0	0	0	133	0	0	**133**	0.19	1	8.33
Potamothrix bavaricus	0	4040	0	0	0	0	0	266	0	0	0	0	**4307**	6.19	2	16.67
Potamothrix heuscheri	0	566	0	0	22	0	0	44	0	0	0	0	**633**	0.91	3	25.00
Potamothrix hammoniensis	0	1332	0	0	133	0	0	888	0	0	833	0	**3186**	4.58	4	33.33
Limnodrilus udekemianus	0	133	0	0	0	0	0	133	0	222	0	0	**488**	0.70	3	25.00
Limnodrilus hoffmeisteri	0	44	0	0	0	0	0	0	0	89	1632	0	**1765**	2.54	3	25.00
TOPLAM	**322**	**16717**	**7282**	**5406**	**2498**	**7992**	**1032**	**10656**	**2775**	**888**	**13065**	**955**	**69586**			
Shannon Index (H')	1.084	1.792	0.6689	1.051	1.582	0.6594	0.8364	1.686	0.6899	1.709	1.468	0				

In Sarıçay, a high level of Shannon (H') diversity index between seasons and stations of Oligochaeta fauna was found in station 2 (autumn H'=1.792) (Table 3).

The results of the multi-dimensional scaling analysis (MDS) are given in Figure 2 (Stress=0.234 and R^2=72.8%). According to MDS plot (Figure 2), it was observed that the relationship between Oligochaeta species identified in Sarıçay and environmental variables were collected in 4 different groups.

Karamenderes Stream

In Karamenderes, a total of 59097 individuals belonging 20 species and 1 genus was determined. The highest densities were observed in the stations 3 and 2 (10933 and 10179 individuals/m^2, respectively). In the autumn, in station 1 a total of 8259 individuals/m^2 were observed. The lowest densities were observed in stations 3 and 2in the summer (233 and 355 individuals/m^2, respectively). While *T. tubifex* (9524 individuals/m^2, % D=16), *Limnodrilus hoffmeisteri* (7359 individuals/m^2, % D=12.40), and *S. lacustris* (5939 individuals/m^2, % D=10.00) were dominant, *Potamothrix heuscheri* (11 individuals/m^2, % D=0.02), *Chaetogaster diaphanus* and *Bothrioneurum vejdovskyanum* (33 individuals/m^2, % D=0.06) were frequently identified although with much less densities. The F% values were identified as *T. tubifex* (100%), *L. hoffmeisteri* (87.5%), *Psammoryctides albicola* (68.75%) and *Limnodrilus udekemianus* (56.25%).

Shannon (H') diversity index between seasons and stations of Oligochaeta fauna of Karamenderes Stream in Station, 3in the autumn was H'=2.007 (Table 4). The MDS plot showed 3 different groups with respect to the relationships between Oligochaeta species and environmental variables (Fig. 3). Over % 80 of the relationships was explained by MDS analysis (Stress= 0.196 and R^2= 83.1%).

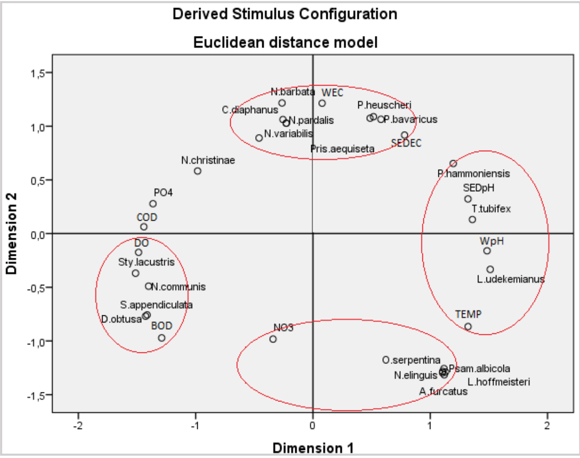

Figure 2. The relations between the physicochemical parameters and Oligochaeta species detected in Sarıçay Stream.

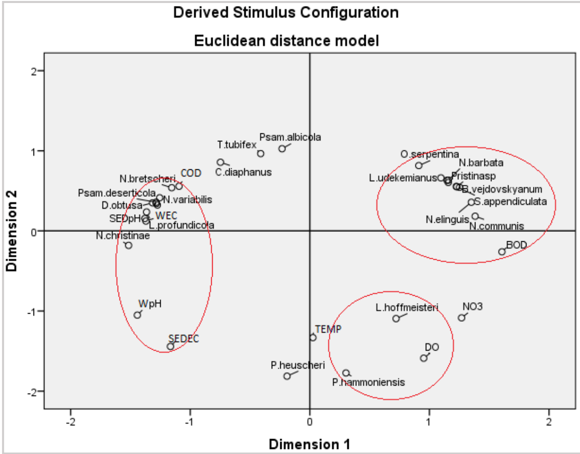

Figure 3.The relationsbetween the physicochemical variables andOligochaeta species detected in Karamenderes Stream.

Table 4. The Dominancy and Frequency values of Oligochaeta Fauna of the Karamenderes Stream (St:Stone, P:Plant, S:Sand, P+St:Plant+Stone, S+P:Sand+Plant)

KARAMENDERES	AUTUMN (26.11.2008)				WINTER (18.02.2009)				SPRING (04.05.2009)				SUMMER (13.08.2009)							
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	TOTAL	%D	F	%F
Habitat Type	S,St	P+St,S	P,S+P	S,S+P	St,S	St,K	S	S	St,S	S,St,P	S,P	S,P	S,P	S,S,t,P	P,S	P				
Familya: Naididae																				
Chaetogaster diaphanus	0	22	0	0	0	0	0	0	11	0	0	0	0	0	0	0	**33**	0.06	2	12.5
Ophidonais serpentina	0	0	844	0	0	0	0	0	200	1754	699	167	133	0	44	133	**3974**	6.69	8	50
Stylaria lacustris	0	0	422	0	0	0	0	0	11	1066	4440	0	0	0	0	0	**5939**	10.00	4	25
Dero obtusa	0	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	**56**	0.09	1	6.25
Slavina appendiculata	0	0	0	0	0	0	0	0	11	0	111	0	0	0	0	0	**122**	0.21	2	12.5
Nais barbata	0	0	278	0	0	0	0	0	22	3030	0	0	100	0	0	0	**3430**	5.78	4	25
Nais bretscheri	0	67	0	0	0	0	0	0	0	11	0	0	0	0	0	0	**78**	0.13	2	12.5
Nais christinae	0	22	100	0	0	0	0	0	0	0	0	0	0	0	78	0	**200**	0.34	3	18.75
Nais communis	0	0	22	0	0	0	0	0	0	0	344	56	0	0	0	233	**655**	1.10	4	25
Nais elinguis	0	11	44	0	**0**	0	0	33	0	0	0	1709	0	0	0	622	**2420**	4.08	5	31.25
Nais variabilis	0	56	178	0	0	0	0	0	0	11	0	0	0	0	0	0	**244**	0.41	3	18.75
Subfamilya: Pristininae																				
Pristina sp.	**0**	0	0	0	0	0	0	0	0	**0**	0	932	0	0	0	0	**932**	1.57	1	6.25
Subfamilya: Tubificinae																				
Tubifex tubifex	1365	244	1887	89	11	1132	777	122	111	999	1066	699	67	33	56	866	**9524**	16.04	16	100
Psammoryctides albicola	1088	33	433	44	155	11	122	155	0	1332	0	133	0	0	0	500	**4007**	6.75	11	68.75
Psammoryctides deserticola	0	0	11	100	0	0	0	0	0	0	0	0	0	0	0	0	**111**	0.19	2	12.5
Potamothrix heuscheri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	**11**	0.02	1	625
Potamothrix hammoniensis	0	11	0	0	0	1066	0	0	0	0	0	0	0	11	11	0	**1099**	1.85	4	25
Limnodrilus udekemianus	244	0	33	111	0	400	78	0	477	89	366	0	78	0	0	0	**1876**	3.16	9	56.25
Limnodrilus profundicola	500	0	0	0	33	67	0	0	0	0	0	0	0	0	0	0	**599**	1.01	3	18.75
Limnodrilus hoffmeisteri	999	22	722	0	322	1931	1121	89	222	500	1043	266	22	56	44	0	**7359**	12.40	14	87.5
Juvenil Tubificinae	4063	167	1254	56	167	2442	511	100	411	1376	2864	1854	289	133	111	599	**16395**	27.62	16	100
Subfamilya: Rhyacodrilinae																				
Bothrioneurum vejdovskyanum	0	0	0	0	0	0	0	0	22	11	0	0	0	0	0	0	**33**	0.06	2	12.5
TOTAL	**8258**	**655**	**6283**	**400**	**688**	**7049**	**2609**	**500**	**1476**	**10168**	**10934**	**5817**	**688**	**233**	**355**	**2953**	**59097**			
Shannon Index (H')	1.443	1.79	2.007	1.555	1.247	1.518	1.291	1.517	1.696	1.876	1.613	1.647	1.545	1.084	1.721	1.652				

Tuzla Stream

In Tuzla Stream, a total of 174592 individuals belonging 25 species and 1 genus were determined. The highest density was observed in Station 3, in the spring with 36910 individuals/m^2, and in the Station 2, with 30624 individuals/m^2. The lowest density was observed in the Station 2, in the winter with 665 individuals/m^2, and in the Station 4, with 1878 individuals/m^2 (Table 5).

In Tuzla Stream, species with the highest densities were identified as the following: *O. serpentina* 26529 individuals/m^2, (% D=15.20), *Nais christinae*20158 individuals/m^2, (% D=11.55), *N. barbata*19481 individuals/m^2, (% D=11.16), *N. variabilis*18903 individuals/m^2, (% D=10.83) and *T. tubifex* 15984 individuals/m^2, (% D=9.16). Species with the lowest densities were as follows: *P. bavaricus* and *Pristina* sp. 11 individuals/m^2, (% D=0.01), *Enchytraeus*

Table 5. The Dominancy and Frequency values of the Oligochaeta Fauna determined in the Tuzla Stream (St:Stone, P:Plant, S:Sand, St+P:Stone+Plant, S+St:Sand+Stone)

TUZLA	AUTUMN (26.11.2008)				WINTER (18.02.2009)				SPRING (04.05.2009)				SUMMER (13.08.2009)							
Stations	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	TOTAL	%D	F	%F
Habitat Type	P,S	S,P	St+P,P	St,P,S+St	S,St,P	P,S	S,St	S,St	S,P	P,St,S	St,S,P	S,St,P	P	P,St	P,St,S	St,S,P				
Family: Naididae																				
Subfamily:Naidinae																				
Ophidonais serpentina	1010	1110	8958	677	255	11	244	766	855	2475	2975	1388	666	3896	766	477	**26529**	15.20	16	100
Stylaria lacustris	3319	1765	78	244	44	0	11	56	2675	1199	1277	2708	0	0	0	67	**13442**	7.70	12	75
Dero dorsalis	0	22	0	0	0	0	0	0	0	0	0	0	0	133	0	0	**155**	0.09	2	12.5
Dero digitata	0	0	0	0	0	0	0	0	0	0	0	0	0	44	0	0	**44**	0.03	1	6.25
Dero obtusa	0	0	488	0	0	0	11	33	0	0	111	0	0	0	22	0	**666**	0.38	5	31.25
Slavina appendiculata	0	0	0	111	0	0	0	89	0	0	0	0	0	0	0	0	**200**	0.11	2	12.5
Nais barbata	433	67	1465	89	178	11	22	11	666	6738	6760	1565	0	0	22	1454	**19481**	11.16	14	87.5
Nais pardalis	0	0	0	0	0	0	0	0	133	3075	733	333	0	0	0	0	**4274**	2.45	4	25
Nais bretscheri	0	0	0	0	0	0	0	0	0	1221	333	344	0	0	0	0	**1898**	1.09	3	18.75
Nais elinguis	0	0	0	0	11	44	56	0	0	0	56	0	0	0	0	0	**167**	0.10	4	25
Nais christinae	1010	100	444	33	11	0	111	56	477	6793	5883	5073	0	0	33	133	**20158**	11.55	13	81.25
Nais variabilis	433	56	289	11	222	0	144	22	1265	7592	8092	777	0	0	0	0	**18903**	10,83	11	68.75
Nais communis	0	0	289	0	0	0	0	22	0	0	89	0	0	0	0	11	**411**	0.24	4	25
Subfamily: Pristininae																				
Pristina sp.	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11**	0.01	1	6.25
Subfamily: Tubificinae																				
Tubifex tubifex	2631	455	4895	599	111	78	377		67	533	1188	133	3319	200	866	355	**15984**	9.16	16	100
Psammoryctides albicola	133	0	2098	366	33	44	89	0	0	44	0	0	1154	0	1443	211	**5617**	3.22	10	62.5
Psammoryctides deserticola	11	56	3186	100	0	0	0	56	0	0	0	0	1221	0	3219	22	**7870**	4.51	8	50
Potamothrix bavaricus	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11**	0.01	1	6.25
Potamothrix hammoniensis	0	488	0	0	0	0	0	33	0	0	566	0	0	0	0	0	**1088**	0.62	3	18.75
Limnodrilus udekemianus	0	0	0	0	0	0	0	0	0	0	0	0	2642	0	100	0	**2742**	1.57	2	12.5
Limnodrilus profundicola	0	0	0	11								0	0	0	0	0	**56**	0.03	2	12.5
Limnodrilus hoffmeisteri	0	0	78	33	89	78	1554	167	67	0	1510	11	2531	2431	22	22	**8591**	4.92	13	81.25
Juvenil Tubificinae	2509	111	3696	755	222	266	921	300	0	921	7337	0	7393	488	655	355	**25930**	14.86	14	87.5
Subfamily: Rhyacodrilinae																				
Rhyacodrilus coccineus	0	0	0	33	0	0	0	0	0	33	0	0	0	0	0	0	**67**	0.04	2	12.5
Family: Enchytraeidae																				
Mesenchytraeus sanguineus	0	0	0	0	33	111	0	89	0	0	0	0	0	0	0	0	**233**	0.13	3	18.75
Enchytraeus christenseni	**0**	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	**22**	0.01	1	6.25
Family: Lumbriculidae																				
Lumbriculus variegatus	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	**22**	0.01	1	6.25
Stylodrilus sp.	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	**22**	0.01	1	6.25
TOTAL	**11500**	**4240**	**25963**	**3108**	**1210**	**666**	**3585**	**1876**	**6205**	**30625**	**36908**	**12332**	**18926**	**7193**	**7148**	**3108**	**174592**			
Shannon Index (H')	1.767	1.61	1.861	2.032	2.047	1.776	1.646	1.977	1.577	1.895	2.044	1.633	1.682	1.086	1.534	1.629				

christenseni, *Lumbriculus variegatus* and *Stylodrilus* sp. 22 individuals/m^2, (% D=0.01). The highest F% values identified were as follows: *T. tubifex* and *O. serpentina* (100%), *N. barbata* (87.5%), *N. christinae* (81.25%), *S. lacustris* (75%), *N. variabilis* (68.75%) and *P. albicola* (62.5%) (Table 5).

The highest Shannon (H') diversity index between seasons and stations of Oligochaeta fauna of Tuzla Stream was found in the Station 1 (winter H'=2.047) > Station 3 (spring H'=2.044) > station 4(autumn H'=2.032). The lowest Shannon (H') diversity index was found in Station 2(summer H'=1.086) < Station 3 (summer H'=1.534) < Station 1(spring H'=1.577) (Table 5).

A significant part of the relationships could be explained by MDS analysis (Stress= 0.24 and R^2= 71.12%). The relationships between Oligochaeta species and environmental variables can be evaluated in 5 different groups.

Kocabaş Stream

In Kocabaş Stream, a total of 37718 individuals belonging to 17 species were determined. Species with the highest densities were as follows: *S. lacustris* 12876 individuals/m^2, (% D=34.14), *T. tubifex* 8714 individuals/m^2, (% D=23.10) and *L. hoffmeisteri* 3297 individuals/m^2, (% D=8.74). Species with the lowest densities were as follows: *N. christinae*, *Nais pardalis* and *N. variabilis* (11 individuals/m^2, % D=0.03). The highest F% values were 93.75% for *T. tubifex*, 68.75% for *L. hoffmeisteri* and 56.25% for *L. udekemianus* (Table 6).

The highest Shannon (H') diversity index between seasons and stations of Oligochaeta fauna of Kocabaş Stream was found in Station 2 (spring H'=1.695) > Station 2 (autumn H'=1.661) > Station 3 (spring H'=1.574). The lowest Shannon (H') diversity index was identified in the Station 4 (autumn H'=0.3344) <

Station 1(autumn H'=0.465) < Station 1 (summer H'=0.634) (Table 6).

The MDS analysis explained a significant part of the relationships (Stress= 0.197 and R^2= 86%). The environmental variables and Oligochaeta species indicated 3 different groups according to their level of relevance (Fig. 5).

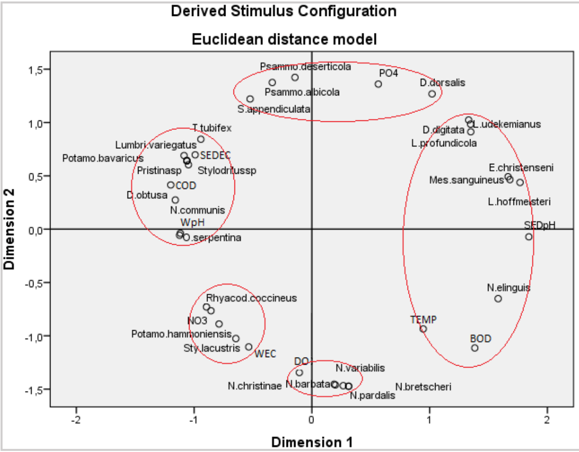

Figure 4. The relations between the physicochemical variables and Oligochaeta species detected in Tuzla Stream.

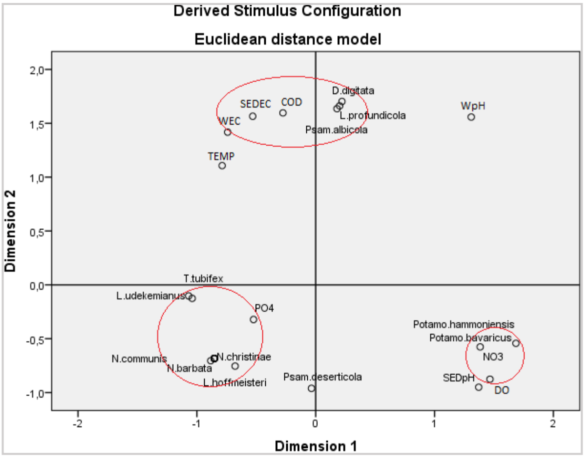

Figure 5. The relationships between the physicochemical variables anf Oligochaeta species detected in Kocabaş Stream.

Environmental Parameters

Temperature values of the surface water showed typical temporal differences. While dissolved oxygen ranged between 2.55 mgL^{-1} and 15.9 mgL^{-1}, pH values fluctuated between 6 and 9. COD values showed seasonal fluctuations between 3.24 and 137 mgL^{-1}.

Table 6. The Dominancy and Frequency values of the Oligochaeta Fauna detected in the Kocabaş Stream (S:Sand, St:Stone, P:Plant, M:Muddy, S+St:Sand+Stone, P+S:Plant+Sand)

KOCABAŞ	AUTUMN (26.11.2008)				WINTER (18.02.2009)				SPRING (04.05.2009)				SUMMER (13.08.2009)							
Stations	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	TOTAL	%D	F	%F
Habitat Type	S,S+St	St,M,P+St	S,P	S+P,S,M	St,S	S	S	S	St,S	S+St,S	S+St,St	M,P,P+S	St,S	S	St,S	P,St,M				
Family: Naididae																				
Subfamily:Naidinae																				
Stylaria lacustris	0	0	0	0	0	0	0	0	1587	3219	466	7526	0	0	0	78	12876	34.14	5	31.25
Dero digitata	0	0	133	22	0	0	0	0	0	0	0	0	0	11	0	0	167	0.44	3	18.75
Nais barbata	0	0	0	0	0	0	0	0	222	0	178	0	0	0	0	0	400	1.06	2	12.5
Nais pardalis	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	11	0.03	1	6.25
Nais elinguis	0	0	0	0	0	0	0	0	100	799	0	200	0	0	0	0	1099	2.91	3	18.75
Nais christinae	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	11	0.03	1	6.25
Nais variabilis	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	11	0.03	1	6.25
Nais communis	0	0	0	0	0	0	0	0	89	1021	0	0	0	0	0	0	1110	2.94	2	12.5
Subfamily: Tubificinae																				
Tubifex tubifex	0	333	2054	189	67	500	33	611	89	1798	233	1776	33	244	200	555	8714	23.10	15	93.75
Psammoryctides albicola	0	544	0	0	0	0	0	0	0	0	0	0	0	0	0	0	544	1.44	1	6.25
Psammoryctides moravicus	0	0	0	0	0	0	0	0	0	0	0	111	0	0	0	0	111	0.29	1	6.25
P. deserticola	0	278	0	0	0	0	0	355	0	22	0	422	0	0	0	0	1077	2.85	4	25
Potamothrix bavaricus	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	44	0.12	1	6.25
Potamothrix hammoniensis	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0	33	0.09	1	6.25
Limnodrilus udekemianus	33	655	0	0	22	111	0	0	56	144	0	1032	0	0	56	78	2187	5.80	9	56.25
Limnodrilus profundicola	0	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0.15	1	6.25
Limnodrilus hoffmeisteri	0	178	500	0	11	666	0	22	33	555	255	988	0	0	11	78	3297	8.74	11	68.75
Juvenil Tubificinae	155	899	178	0	133	633	56	244	56	1310	433	944	67	167	244	455	5972	15.83	15	93.75
TOTAL	**189**	**2886**	**2919**	**211**	**233**	**1954**	**89**	**1265**	**2253**	**8869**	**1576**	**12999**	**100**	**422**	**511**	**1243**	**37718**			
Shannon Index (H')	0.465	1.661	0.937	0.3344	1.045	1.329	0.659	1.191	1.166	1.695	1.574	1.392	0.634	0.779	1.045	1.249				

In the present study, all Oligochaeta taxa identified in Tuzla and Kocabaş Streams were recorded for the first time (Table 5, 6). In addition, *B. vejdovskyanum* Stolc, 1886 in Karamenderes Stream, *Mesenchytraeus sanguineus* Nielsen & Christensen, 1959 and *E. christenseni* Dozsa-Farkas, 1992 in Tuzla Stream are new records for the Oligochaeta fauna of Turkey.

The highest values measured in Station 3 in Sarıçay (S3) indicated that this station was classified as Class IV with regard to water quality. Seasonal COD values of Karamenderes Stream in stations 2 and 4 (Km2 and Km4) in autumn were 66.8 mgL^{-1} and 66.6 mgL^{-1}, respectively and therefore are classified as Class III with respect to water quality. The vicinity of

Karamenderes Stream is characterized by extensive agriculture activities particularly olive production. The increased COD values in the autumn are therefore caused by the discharge of the waste water from olive oil production. COD values of Tuzla Stream, seasonally measured in all stations (except the station 3 (T3) in autumn), generally remained below 20 mgL^{-1}. However, COD parameter of the station 3 (T3) in autumn was found to be 214 mgL^{-1} an therefore can be classified as Class IV (Table 6). The surface water in all sampling stations of Kocabaş Stream were of Class I quality with regard to COD values.

BOD_5 values showed differences both between the streams and the seasons; Karamenderes Stream can be classified at Class I quality of surface water except the values measured in spring in the stations 3 and 4 (Km3 and Km4) (in the values of 4.62 and 4.125 mgL^{-1} respectively). It was also observed that Tuzla Stream at the Class I quality in respect to BOD_5 values; similarly, the Kocabaş Stream, was found at Class I quality surface water characteristics, except from value measured in the station 2 (T2) in spring as being 8.91 mgL^{-1} (Table 7).

There is no significant difference observed in NO_3-N values in all sampling localities. However, in autumn, at the 3rd station of Tuzla Stream (T3), nitrate-nitrogen was measured as 6.7 mgL^{-1} and it showed at Class II water quality. It was determined that the water quality of all streams diminished according to PO_4-P values. In Sarıçay Stream, it was observed that according to PO_4-P values, water quality at Class III in all sampling stations. While the highest value measured in Karamenderes Stream was determined as 8.34 mgL^{-1} in the station 2 (Km2), in spring; the lowest value was determined as 0.014 mgL^{-1} in the station 1 (Km1), in summer. It was identified that according to ortho-phosphate values measured especially in the stations 1st, 2nd and 3rd of Karamenderes Stream, water quality at Class III and IV. Measured as 0.88 mgL^{-1} in the station 2, Tuzla Stream in winter, the lowest value of ortho-phosphate was identified as 0 mgL^{-1} in the station 4, in autumn. It was observed that phosphate values were high in all the stations of Tuzla Stream; and especially in the stations 2nd and 3rd, water quality at Class III. The results of PO_4-P measurement recorded in the streams indicate that there are domestic or agricultural wastes (Table 7).

Table 7. Minimum, maximum and average values of the environmental parameters of streams during the period of investigations from Autumn 2008 and Summer 2009 (number in parentheses and roman numbers indicate average value and class of water quality for Anonymus, 2012).

		Parameters								
STREAM	St.	E.C. (μScm^{-1})	pH	Temp. (°C)	NO_3-N (mgL^{-1})	PO_4-P (mgL^{-1})	DO (O_2 mgL^{-1})	%DO	COD (mgL^{-1})	BOD_5 (mgL^{-1})
SARIÇAY	1	(250.48-448)	(6.41-7.15)	(10.38-13.73)	(0.3-0.6)	(0.009-0.33)	(6.86-12.48)	(71.53-109.63)	(3.24-21.6)	(1.2-3.72)
		315.93(I.)	6.8225(I.)	12.1(I.)	0.4 (I.)	0.172 (III.)	10.1 (I.)	94.7 (I.)	3.24 (I.)	2.38 (I.)
	2	(280.5-666.25)	(6.89-7.66)	(8.05-21.65)	(0.3-0.5)	(0.02-0.36)	(4.41-12.62)	(58.17-107)	(9.2-15.82)	(1.2-7.5)
		526.69 (II.)	7.25 (I.)	13.87 (I.)	0.4 (I.)	0.175 (III.)	7.73 (II.)	75.26 (II.)	12.28 (I.)	3.58 (I.)
	3	(31.57-33057)	(7.58-8.89)	(9.2-26.2)	(0.1-1.7)	(0-0.44)	(7.75-10.64)	(79.29-109.5)	(42.2-137)	(1.4-13.4)
		19589 (IV.)	7.97 (I.)	16.22 (I.)	0.8 (I.)	0.21 (III.)	8.92 (I.)	90.41 (I.)	88.25 (IV.)	6.07 (II.)
KARAMENDERES	1	(188.3-463.8)	(6.17-8.06)	(9.87-20.91)	(0.3-0.5)	(0.014-4.32)	(8.86-12.72)	(95.73-117.8)	(5-12.9)	(0.6-1.32)
		290.77 (I.)	7.27 (I.)	15.54 (I.)	0.4 (I.)	1.2(IV.)	10.99 (I.)	105.78 (I.)	8.7 (I.)	0.91 (I.)
	2	(267-638.67)	(6.76-7.83)	(6.94-24.96)	(0.3-0.4)	(0.041-8.34)	(2.55-12.98)	(24.9-108.55)	(8.77-66.8)	(0.2-2.64)
		448.34 (II.)	7.3(I.)	15.80 (I.)	0.35 (I.)	2.39 (IV.)	8.42 (I.)	83.38 (II.)	24.69 (I.)	1.32 (I.)
	3	(266.5-850)	(6.82-8.03)	(6.45-24.61)	(0.2-1.3)	(0.063-1.07)	(8.48-12.89)	(85.8-133.8)	(7.44-25.8)	(0.84-4.62)
		536.33(II.)	7.58 (I.)	15.58 (I.)	0.5 (I.)	0.37 (III.)	10.75 (I.)	108.63 (I.)	15.14 (I.)	2.69(I.)
	4	(567.8-11226)	(7.43-7.95)	(7.04-24.21)	(0-0.9)	(0.05-0.231)	(8.7-11.55)	(93.15-105.5)	(9.21-66.6)	(1-4.125)
		3329.06(IV.)	7.71 (I.)	15.81 (I.)	0.3 (I.)	0.156 (II.)	9.70 (I.)	99.28 (I.)	26.08 (II.)	2.37 (I.)
TUZLA	1	(270.33-538.25)	(6.71-8.43)	(8.92-20.68)	(0.2-1.7)	(0.01-0.187)	(9.12-15.07)	(99.5-144.2)	(6.77-18.76)	(0.045-1.67)
		355.67 (I.)	7.34 (I.)	15.42 (I.)	0.68 (I.)	0.067 (II.)	11.65 (I.)	115.69 (I.)	13.56 (I.)	0.638 (I.)
	2	(302.17-594)	(7.53-8.74)	(8.85-28.18)	(0.2-1.3)	(0.03-0.88)	(9.27-15.73)	(113.72-188.58)	(9.36-16.08)	(0-1.65)
		419.95 (I.)	8.13 (I.)	18.77 (I.)	0.575 (I.)	0.294 (III.)	13.46 (I.)	143.57 (I.)	12.84 (I.)	1.083 (I.)
	3	(302.25-549.67)	(7.38-8.03)	(9.27-27.62)	(0-6.7)	(0.019-0.39)	(4.5-15.37)	(11.15-181.63)	(7.66-214)	(0.6-1.62)
		425.66 (I.)	7.66 (I.)	18.51 (I.)	1.88 (I.)	0.184 (III.)	10.88 (I.)	93.82 (I.)	61.42 (III.)	1.103 (I.)
	4	(290.25-466.33)	(7.47-8.48)	(10.11-27.3)	(0.3-3.8)	(0-0.221)	(12.09-15.9)	(107.8-263.7)	(3.6-9.57)	(0.4-1.24)
		390.59 (I.)	7.84 (I.)	10.24 (I.)	1.4 (I.)	0.068 (II.)	15.56 (I.)	167.39 (I.)	6.57 (I.)	0.69 (I.)
KOCABAŞ	1	(198.75-344)	(6.75-7.65)	(9.45-21.25)	(0.4-0.9)	(0-0.196)	(6.53-12.47)	(101.07-111.13)	(5.5-9.94)	(0.19-2.685)
		290.65 (I.)	7.38 (I.)	14.86 (I.)	0.65 (I.)	0.11 (II.)	10.17 (I.)	107.1 (I.)	7.64 (I.)	1.258 (I.)
	2	(280-1627)	(7.04-7.66)	(6.83-27.38)	(0.3-1.9)	(0.371-0.96)	(6.2-13.79)	(59.97-113.25)	(15.3-25.6)	(0.7-8.91)
		889.23 (II.)	7.3 (I.)	16.57 (I.)	0.98 (I.)	0.66 (IV.)	9.44 (I.)	93.92 (I.)	18.8 (I.)	3.60 (I.)
	3	(286-887)	(6.7-7.76)	(6.64-24.88)	(0.3-2.4)	(0-0.465)	(9.4-13.41)	(91.23-110.6)	(19.8-24)	(0.2-1.89)
		665.79 (II.)	7.21 (I.)	15.8 (I.)	1.18 (I.)	0.254 (III.)	11.37 (I.)	103.83 (I.)	21.78 (I.)	0.86 (I.)
	4	(311.5-738.33)	(6.86-7.53)	(7.29-22.35)	(0-2.8)	(0.131-0.52)	(5.62-13.47)	(50.9-111.65)	(13.7-22)	(0.12-3.7)
		569.58 (II.)	7.19 (I.)	15.08 (I.)	1.23 (I.)	0.395 (II.)	9.1 (I.)	83.68 (I.)	17.93 (I.)	1.89 (I.)

Discussion

In this study, *Bothrioneurum vejdovskyanum* Stolc, 1886, *Mesenchytraeus sanguineus* Nielsen & Christensen, 1959 and *Enchytraeus christenseni* Dozsa-Farkas, 1992 were recorded for the first time in Oligochaeta Fauna for Turkish freshwaters. In previous studies carried out in Sarıçay and Karamenderes streams by Türkkan (2008) and Akbulut et al., (2009), respectively, the number of Oligochaeta species reported were less than those reported in the present study. In this study, 23 new taxa were reported for the first time for this region and updates the Oligochaeta fauna in Biga Peninsula.

With respect to aquatic Oligochaeta biodiversity, the highest taxa number identified was from Tuzla Stream with a total of 26 taxa. On the other hand, the least number of taxa were detected from Kocabaş Stream represented by 17 taxa. The number of taxa identified from both Sarıçay and Karamenderes Streams were 20. Biodiversity and Shannon Index (SI) values were in accordance with high species richness corresponding to higher SI values. For example, Tuzla Stream which had the highest biodiversity had also the highest SI values and Kocabaş Stream, had the lowest biodiversity corresponding to lowest SI values. The SI index of Sarıçay ranged between 0 to 1.792; the SI value of 0 corresponded to only one species identified in the sampling station. The higher biodiversity of Tuzla Stream can be explained by the pristine nature of the area which is sparsely populated (Anonymous, 2011) that promotes higher water quality. In contrast, Kocabaş Stream flows through densely populated rural area with heavy agricultural activities which promotes poor water quality and resulted in lowest oligochaeta biodiversity.

Distribution and density of Oligochaeta species depend on many factors such as temperature of water, environmental factors, bottom microflora and aquatic plants (Grigelis et al., 1981). Water temperature alone effects distributions of aquatic Oligochaeta widely. For example, Yıldız et al., (2010) showed positive correlation between distribution of *Dero digitata* and temperature. Our results supported those of others reported in the literature.

S. lacustris was reported as a salt tolerant species (Chekanovskaya, 1962). Our results are in accordance with this as high numbers of this species were observed in the downstream regions of Kocabaş Stream (station 4), where the effects of seawater penetration is pronounced.

Considering the reported wide ecological tolerance of the genera *Potamothrix*, *Tubifex* and *Limnodrilus* (Wetzel et al., 2000; Brinkhurst & Jamieson, 1971; Hare & Shooner, 1995), to environmental parameters such as NO_3-N, PO_4-P, BOD_5 and COD, in the present study, the presence of high densities of these species were expected (Figure 3). Arslan & İlhan (2010) found a positive relationship between *L. hoffmeisteri*, *P. hammoniensis* and NO_3 levels. According to Milbrink (1973; 1980) and Rodriguez & Reynoldson, (2011), *P. hammoniensis* had a high tolerance to water quality parameters that are indicative of eutrophication and organic pollution such as COD and PO_4-P levels. Similarly, *N. elinguis* was reported to be abundant in algal waters and reported to have a high tolerance against organic pollution (Brinkhurst, 1971) and high nutrient concentrations (Polatdemir-Arslan & Şahin, 2003; Yıldız et al., 2007). Overall, our findings are in accordance with those reported in the literature. For example, in spring and summer, when PO_4-P levels were high dense populations of *N. elinguis* in planted habitat were detected.

In this study, environmental parameters and faunistic data were in accordance. With respect to PO_4-P and COD values, Karamenderes, Sarıçay and Kocabaş Streams are considered to have Class III and IV water quality (Table 7). The Oligochaeta diversity of these streams are characterized by a dominancy of pollution tolerant species. Species such as *Tubifex*, *Potamothrix* and *Limnodrilus* are frequently attributed to organic pollution of aquatic environments and based on the results of this study these 3 streams are under stress of organic pollution.

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