

Species diversity (H') was calculated according to Shannon-Weaver using Past Statistical software, version 1.75b (Hammer, Harper and Ryan 2001). The calculated parameters included: mean density ($D = [\sum(n_i a)^{-1}] M^{-1}$, with n_i , number of specimens per sample; a , area sampled; M , total number of samples); dominance ($D_m = 100 (n N^{-1})$, with n , total number of specimens of given species; N , total number of specimens of all species) and frequency ($F = (m M^{-1})$, with m number of samples containing a given species; M , total number of samples). Correlations between environmental parameters and abundance of Oligochaeta species were determined by Pearson's correlation coefficients (Hair *et al.* 1995, Tabachnick and Fidell 1996, Sharma 1996).

RESULTS

Oligochaete potamofauna in Porsuk Stream was represented by 15 species of Naididae, 8 species of Tubificidae, one species of Haplotaxidae and 2 species of Lumbriculidae (Table 1). The density varied between 72 and 34,800 ind. m⁻². Number of species varied between 6 and 13, and the diversity ranged from 0.95 to 2.16. Although this study revealed 30 taxa of oligochaetes, only 26 (8 tubificid, 14 naidid, 2 lumbriculid, 1 haplotaxid and 1 lubricid) have been determined to the species level (Table 2) and included in the analysis. Among the determined twenty-six taxa, ten species, (*Tubifex tubifex* (Müller 1774), *Limnodrilus hoffmeisteri* 1862, *Limnodrilus udekemianus* Claparède 1862, *Psammoryctides albicola* (Michaelsen 1901), *Potamothrix hammoniensis* (Michaelsen 1901), *Nais pardalis* Piguet 1906, *Nais elinguis* Müller 1773, *Pristinella jenkiniae* (Stephenson 1931), *Ophidonais serpentina* (Muller 1773) and *Lumbriculus variegatus* (Muller 1773)) were widely distributed in the study area (being found at four or more sites), whereas other species (*Limnodrilus claparedianus* Ratzel 1868, *Haber speciosus* (Hrabě 1931), *Rhyacodrilus coccineus* (Vejdovský 1876), *Chaetogaster diaphanus* (Gruithuisen 1828), *Pristina aequiseta* Bourne 1891, *Pristina longiseta* Ehrenberg 1828, *Stylaria lacustris* (Linnaeus 1767), *Nais communis* Piguet 1906, *Nais variabilis* Piguet 1906, *Nais pseudobtusa* Piguet 1906, *Nais barbata* Müller 1774, *Nais bretscheri* Michaelsen 1899, *Pristinella rosea* (Piguet 1906), *Haplotaxis gordioides* (Hartmann 1821), *Rhynchelmis* sp. And *Eiseniella tetraedra* (Savigny 1826) had a more limited distribution (Table 1).

The total densities of oligochaetes in each of the nine sampling sites showed considerable fluctuations during the study period; the lowest total density of specimens (72 ind m⁻²) was recorded at site 3 in spring, whereas the highest total density of specimens (34,800 ind m⁻²) was recorded at site 5 in winter (Fig. 2).

Table 1. List of Oligochaeta with their frequency of occurrence.

	Taxa	Frequency (%)	Sampling sites
1	Tubificidae juvenile with hair setae*	34	All
2	Tubificidae juvenile without hair setae*	21	All
3	<i>Tubifex tubifex</i> (Müller, 1774)	5.2	1, 2, 4, 5, 6, 8, 9
4	<i>Limnodrilus hoffmeisteri</i> Claparède, 1862	19.6	1, 2, 4, 6, 7, 8, 9
5	<i>Limnodrilus udekemianus</i> Claparède, 1862	0.9	2, 4, 5, 6
6	<i>Limnodrilus claparedianus</i> Ratzel, 1868	0.12	6
7	<i>Haber speciosus</i> (Hrabě, 1931)	0.008	7
8	<i>Potamothrix hammoniensis</i> (Michaelsen, 1901)	10.9	1, 5, 6, 7
9	<i>Psammoryctides albicola</i> (Michaelsen, 1901)	12.3	1, 3, 5, 6, 7
10	<i>Rhyacodrilus coccineus</i> (Vejdovský, 1876)	0.11	7, 8
11	<i>Chaetogaster diaphanus</i> (Gruithuisen, 1828)	0.6	5
12	<i>Stylaria lacustris</i> (Linnaeus, 1767)	12.3	5, 8, 9
13	<i>Ophidonais serpentina</i> (Müller, 1774)	9.1	2, 6, 7, 9
14	<i>Nais elinguis</i> Müller, 1774	7.5	2, 4, 8, 9
15	<i>Nais communis</i> Piguët, 1906	3.2	3, 5, 6
16	<i>Nais variabilis</i> Piguët, 1906	0.11	3, 9
17	<i>Nais pardalis</i> Piguët, 1906	5.9	1, 2, 3, 5, 6, 9
18	<i>Nais pseudobtusa</i> Piguët, 1906	0.2	3, 5
19	<i>Nais barbata</i> Müller, 1774	2	7, 8
20	<i>Nais bretscheri</i> Michaelsen, 1899	1.6	7, 8
21	<i>Pristina aequiseta</i> Bourne, 1891	0.3	4
22	<i>Pristinella rosea</i> (Piguët, 1906)	0.03	2, 6
23	<i>Pristina longiseta</i> Ehrenberg, 1828	0.09	6
24	<i>Pristinella jenkiniae</i> (Stephenson, 1931)	4.8	1, 2, 6, 9
25	<i>Haplotaxis gordioides</i> (Hartmann, 1821)	0.01	3
26	Lumbriculidae*	1.8	1, 2, 3, 6, 9
27	<i>Rhynchelmis</i> sp.	1.8	3
28	<i>Lumbriculus variegatus</i> (Müller, 1774)	0.2	1, 3, 4, 6
29	<i>Eiseniella tetraedra</i> (Savigny, 1826)	0.1	1, 5, 7
30	Enchytraeidae*	3.2	1, 3, 5, 7, 8, 9

* means excluded from analysis.

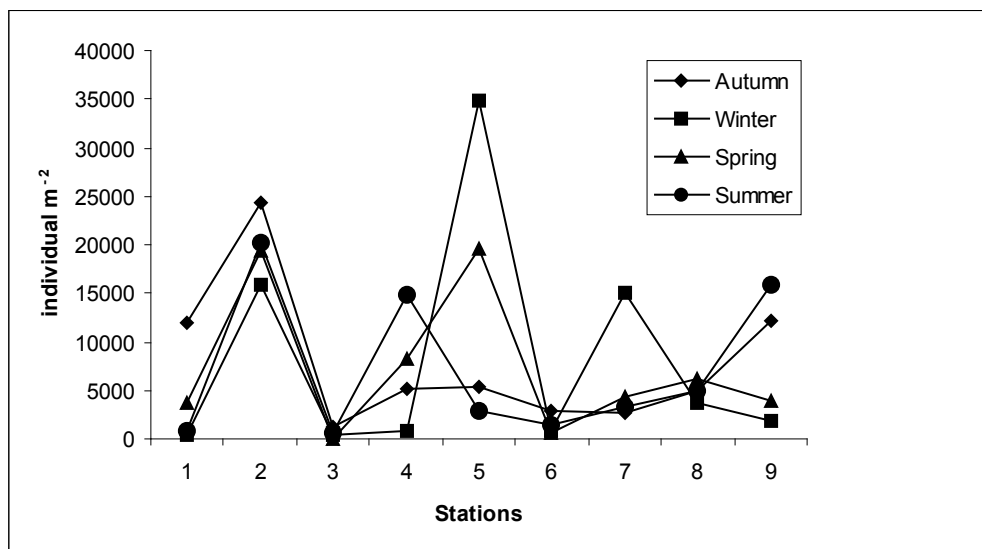


Figure 2. Seasonal abundances of the total Oligochaeta population at the sampling sites during the study.

Table 2. The highest and lowest values of physical, chemical and microbiological parameters of the bottom water, and classes of the water quality at the stations from September 1998 to August 1999.

Sn	T (°C)	pH	DO (mg l ⁻¹)	BOD ₅ (mg l ⁻¹)	NH ₄ ⁺ -N (mg l ⁻¹)	NO ₃ ⁻ -N (mg l ⁻¹)	NO ₂ ⁻ -N (mg l ⁻¹)	F.c (number of cell/100 ml)
1	9,2-19,4 (I)*	7,7-8 (I)	6,2-8,2 (II-I)	1,4-2,8 (I)	0,18-0,83 (I-II)	4,82-9,38 (I-II)	t-0,29 (I-IV)	400-11 000 (III-IV)
2	11,9-19 (I)	7,4-7,8 (I)	0,5-8,9 (IV-I)	5-11 (II)	0,83-3,36 (I-IV)	7,89-18,82 (II-III)	0,13-0,5 (IV)	23 000-230 000 (IV)
3	8,3-16,8 (I)	7,9-8,1 (I)	5,5-9,1 (II-I)	1,6-4 (I)	0,28-0,94 (I)	5,2-9,57 (II)	0,02-0,08 (II-IV)	0-46 000 (I-IV)
4	9,1-16,7 (I)	7,3-7,7 (I)	1-7,54 (IV-II)	3,7-34 (I-IV)	1,18-7,75 (II-IV)	4,3-8,41 (I-II)	0,16-1,08 (IV)	46 000-2 300 000 (IV)
5	8,5-16,5 (I)	7,5-7,6 (I)	2,9-6,9 (IV-II)	2-18 (I-III)	1,37-4,18 (II-IV)	3,23-11,11 (I-III)	0,34-4,14 (V)	0-110 000 (I-IV)
6	5,9-13,6 (I)	8,2-8,5 (I)	8,7-13,3 (I)	1,3-3 (I)	0,08-0,51 (I)	5,97-8,16 (II)	0,02-0,1 (II-IV)	390-4 300 (III-IV)
7	5,5-13,1 (I)	8,2-8,3 (I)	8,1-9,5 (I)	3-5,5 (I)	0,25-1,43 (I-III)	3,02-7,25 (I-II)	0,03-0,23 (II-IV)	0-1 200 (I-III)
8	5,7-13 (I)	8-8,1 (I)	7-10 (II-I)	2,8-5 (I-II)	0,028-1,2 (I-II)	3,15-7,75 (I-II)	0,02-0,23 (II-IV)	0-24 000 (I-IV)
9	8,4-12,9 (I)	7,2-7,5 (I)	5,5-7,6 (II-III)	3-9,4 (I-III)	0,21-7,32 (I-IV)	10,85-15,80 (II)	0,15-0,19 (IV)	0-9 300 (I-IV)

Sn: Station number; T: temperature; F.c: Fecal coliforms; t: traces;

* Roman numbers given in parentheses indicate classes of water quality.

Environmental parameters of the sampling sites are shown in Table 2. Correlations between environmental parameters and abundance of oligochaetes were determined by Pearson's correlation coefficients. The abundance of aquatic Oligochaeta correlated directly with pH, dissolved oxygen, biochemical oxygen demand and nitrate levels of the water.

Diversity (H') varied between 0.95 at site 3 and 2.16 at site 6 (Table 3) and species number varied from 6 (site 4) to 13 (site 6). Abundances of the most relevant species recorded at the sampling sites during the study are shown in Figure 3.

Correlations of oligochaete abundance with physical and chemical parameters of sampling sites are presented in Table 4. All species of oligochaetes were responding different to these parameters.

Table 3. Mean density, diversity and species number of the total Oligochaeta population at the sampling sites.

site	Mean density (m ⁻² ind.)	Diversity (H')	Species number
1	4 214	1.55	8
2	19 966	1.33	8
3	591	0.95	8
4	7 309	1.06	6
5	15 695	1.86	10
6	1 363	2.16	13
7	6 330	1.61	8
8	4 955	1.53	7
9	8 438	1.70	8

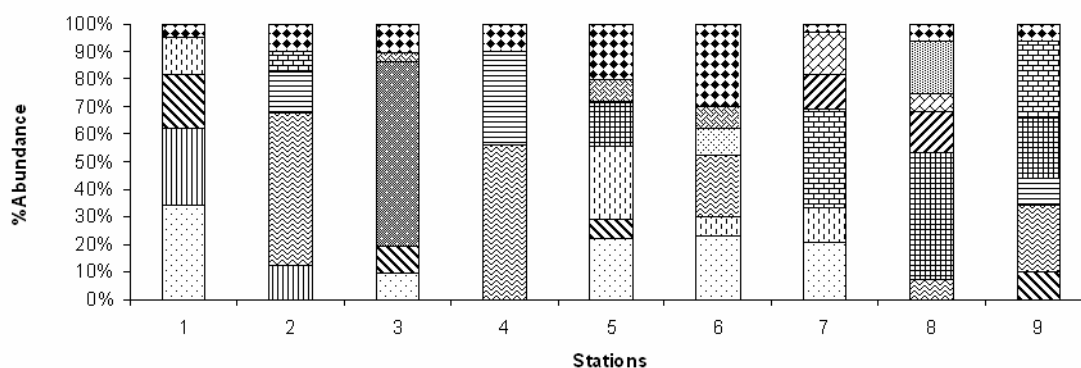


Figure 3. Abundances of the most relevant species recorded at each sampling site.

DISCUSSION

Normal seasonal variations of temperature were observed at all sites at suitable conditions (Table 2). pH varied between 7.2 and 8.5. Because of the lack of extreme variations temperature and pH were not considered as a decisive factor for oligochaete composition. Abundances of *Nais barbata* and *N. bretscheri* were correlated with pH but only to a moderate extent. However, *N. elinguis* was the only species whose abundance was negatively correlated with pH. *Potamothrix hammoniensis*, *Psammoryctides albicola*, *Tubifex tubifex*, *N. communis* and *N. pardalis* were the species whose abundances were significant positively correlated with the NO₂⁻-N levels of the water (Table 4). BOD levels of the water showed significant positive correlations with the abundances of *Limnodrilus hoffmeisteri* and *N. elinguis*. In addition, the abundance of *L. hoffmeisteri* was also significant positively correlated with NO₃⁻-N levels. It is known that *L. hoffmeisteri* is very resistant to environmental pollution (Brinhurst and Cook, 1974) and our result supports this knowledge.

Table 4. Pearson's correlation coefficients for abundant oligochaete species and physical and chemical variables at sites 1-9 in Porsuk Stream.

Species	Variables						
	pH	Temp.	DO	BOD ₅	NO ₃ ⁻ -N	NO ₂ ⁻ -N	NH ₄ ⁺ -N
<i>Tubifex tubifex</i>	-.250	.028	-.283	.288	-.188	.833**	.270
<i>Limnodrilus hoffmeisteri</i>	-.583	.387	-.491	.637*	.907**	.026	.598
<i>Limnodrilus udekemianus</i>	-.170	-.031	-.099	.314	-.169	.822	.319
<i>Potamothrix hammoniensis</i>	.269	.079	-.288	.285	-.229	.935**	.316
<i>Psammoryctides albicola</i>	.143	.061	-.152	.158	-.289	.860**	.184
<i>Stylaria lacustris</i>	-.359	-.276	-.220	.171	.137	.637	.307
<i>Ophidonais serpentina</i>	-.219	-.363	.034	-.116	.649	-.201	.106
<i>Nais elinguis</i>	-.674*	.328	-.673*	.727*	.508	.024	.762
<i>Nais communis</i>	-.257	.032	-.230	.282	-.189	.924**	.316
<i>Nais pardalis</i>	-.553	.170	-.341	.149	.299	.775*	.356
<i>Nais barbata</i>	.622*	-.597	.379	-.228	-.568	-.241	-.395
<i>Nais bretscheri</i>	.611*	-.549	.362	-.212	-.535	-.223	-.357
<i>Pristinella jenkinae</i>	-.368	.559	-.176	-.167	.690*	-.191	-.032
<i>Rhynchelmis</i> spp.	.128	.125	.083	-.254	-.065	-.235	-.277
<i>Lumbriculus variegatus</i>	-.071	.520	-.215	.032	-.148	-.241	-.017

* Correlation is significant at the 0.05 levels.

** Correlation is significant at the 0.01 levels.

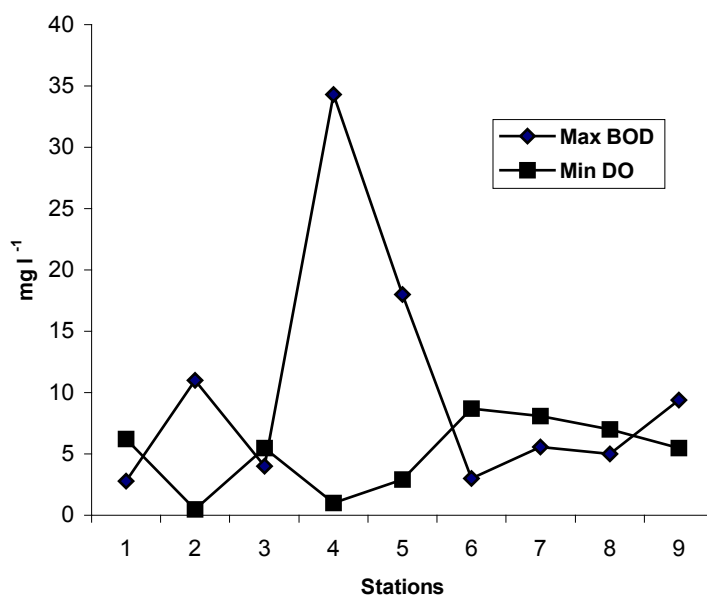


Figure 4. Variations in the minimum concentrations of dissolved oxygen and maximum values of biochemical oxygen demand in the Porsuk Stream.

In the measurement of DO in the field in Porsuk Stream minimum values were determined in site 2 (at summer, 0.5 mg l⁻¹) and site 4 (in autumn, 1 mg l⁻¹). Low DO in sites 2 and 4 can be related to frequent industrial wastewater discharges in this area (Fig. 1). Maximum DO value was measured in the site 6 in spring (13.3 mg l⁻¹). Site 6 is inflow of Porsuk Stream and for this reason it could not be affected by industrial pollution. The highest species number (13 taxa) and species diversity (2.6) were determined namely there (Table 3).

DO and BOD₅ values, which were determined at sampling sites 2, 4 and 5, supported that there was an extreme discharge in organic pollution (Fig. 4). High values of fecal coliforms support this result. Furthermore, this sampling site was the poorest in species number.

In the study area, *Limnodrilus hoffmeisteri* was often found together with *Tubifex tubifex*. *L. hoffmeisteri* was the dominant species in sites 2 and 4; 55% and 56%, respectively, and it was the second dominant species in site 9 after *Ophidonais serpentina* (Fig. 3). High abundances of *L. hoffmeisteri* reflect organic enrichment associated with fecal contamination. In Porsuk Stream, maximum fecal coliform concentrations were measured in sites 4 and 9. This result indicated that there was a high fecal pollution in these two sites. The species found in high numbers there, are tolerant against fecal

pollution. It is known that *L. hoffmeisteri* and *T. tubifex* can be very abundant in polluted waters (Brinkhurst and Jamieson 1971, Mason 1996). Our findings support this result. In addition, *N. elinguis* accompanying *L. hoffmeisteri* as the second dominant species in sites 2 and 4, is known also as very abundant in some British polluted but rapidly flowing, stony streams and even filter-beds (Learner, Lochhead and Hughes 1978).

Limnodrilus claparedianus, *Haber speciosus*, *Chaetogaster diaphanus*, *Pristina aequisetata*, *Pristina longiseta*, *Haplotaxis gordioides* and *Rhynchelmis* sp. had a limited distribution. Numbers of these seven species were also lower than the other species except *Rhynchelmis* sp. (Table 2 and Fig. 3). Lumbriculidae are mostly a Palaearctic and Baikalian family. Timm (1980) indicated that the lumbriculids are especially diverse and abundant in cool habitats. According to seasonal temperature of sampling sites, site 3, where *Rhynchelmis* sp., was found, was the second coolest sampling station in winter.

As a result of study it can be concluded that the oligochaete fauna of Porsuk Stream mainly consists of widely distributed naidid and tubificid species. Most of the species found in the study sites are cosmopolitan and have been associated with diverse aquatic environments.

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