

Research Paper

Water Quality and Biotic Community of a Highland Stream under the Influence of a Eutrophic Fishpond

key words: phytobenthos, macrozoobenthos, fish, pond, chemical analyses

Abstract

The influence of the fishpond on the chemical composition of the stream was mainly demonstrated by a higher concentration of organic matter and total phosphorus. Altogether, 128 species of algae and cyanobacteria were recorded in the stream. The species richness of phytobenthos per site was very similar. We observed the presence of typical phytoplankton species among the phytobenthos assemblages. Cyanobacteria species (*Woronichinia naegeliana*) were particularly dominant in the phytoplankton of the fishpond in autumn. Altogether, we identified 164 taxa of benthic macroinvertebrates in running waters of the stream. The structure of macrozoobenthos communities from all localities of the stream indicated good water quality and a low influence of environmental stressors with no negative effects of the fishpond. In total, six fish species were registered in all profiles. The condition of the fish population was mainly influenced by the fishery management of the stream (stocking, angling). Generally, the influence of the discharge water from the fishpond was recognizable in small changes in both chemical and biological variables of the stream.

1. Introduction

Streams and rivers are the first and often the principal recipients of many anthropogenic influences and eutrophication is often caused by organic sewage (PETTS and CALOW, 1996). Organic enrichment and eutrophication of aquatic ecosystems induced by urbanization and agricultural activities are the oldest and well documented forms of pollution. The organic enrichment of streams and rivers comprises two aspects: trophism and saprobity. Whereas trophism is the extent and intensity of organic primary production, saprobity is characterized by the communities of organisms reflecting the extent and intensity of organic matter decomposition. In practice, however, these two factors are difficult to separate (BRABEC *et al.*, 2004). The characterization of stream conditions requires the assessment of physical and chemical characteristics, as well as the composition and structure of biotic communities. Various methods for evaluating pollution exist, mostly based on a list of indicator organisms. These methods have been used on plankton, periphyton, macrophytes, fish and benthic macroinvertebrates (ROSENBERG and RESH, 1993).

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The European Water Framework Directive (EC, 2000) outlines a legal structure for the assessment of all types of water bodies in Europe. A main focus of the WFD is the use of biotic indicators (macrobenthic fauna, fish and aquatic flora) in stream assessment, which is a new concept for many European countries. The directive defines 'surface water status' as the general expression of a water body, determined by its ecological and its chemical status. 'Ecological status' refers to the quality of the structure and functioning of an aquatic ecosystem. Ecological water quality is defined by biological parameters because the composition of aquatic communities is reflected by the sum of all influencing or disturbing factors. The implementation of the WFD specifies a stream-type specific assessment composed of modules which reflect the impact of three different factors: general degradation, acid impact and organic pollution. Several methods are available for the assessment of organic pollution, for example single metrics such as biotic indices and scores, as well as the saprobic index and multimetric approach (e.g., Biological Monitoring Working Party, average score per taxon, saprobic index, trophic diatom index, integrated assessment system for the ecological quality of streams and rivers) (BIRK and HERING, 2006; HERING *et al.*, 2004).

Fishponds are dynamic ecosystems characterized by shallowness and continuous water flow which directly affect both limnological variables throughout the day. A water outlet from the pond is important for the transport of nutrients and microorganisms, in addition to supplying oxygen to the outlet water and organic materials. The maximum amount of material leaving a fishpond occurs when fish are netted (BOYD, 2003). The abundance and composition of benthic micro-organisms can be very useful indicators of effluent water quality, since they reflect environmental conditions in the recent past. The benthos community is often the most abundant compartment of primary production in running waters in temperate regions. Any environmental change within the ecosystem can, therefore, have major repercussions on this community (MASSERET *et al.*, 1998). Two approaches are usually adopted for assessing the impact of pollution on the benthic community. The first consist of studying changes in the population structure by measuring variables that are representative of the biomass or of the species composition by measuring the species richness or diversity of the communities (WELCH *et al.*, 1992). Macrozoobenthos and diatoms have been recognized as being the best bioindicators, they are very useful for studying the impact of various forms of pollution such as the discharge of eutrophic water, treated sewage effluents and organic and inorganic nutrients (JURAJDA *et al.*, 2010; HÜRLIMANN and SCHANZ, 1993). The aim of this study was to evaluate the influence of fishery management in a fishpond on water quality, benthos and fish diversity and structure in a selected stream in the Czech-Moravian Highlands.

2. Methods

2.1. Characteristics of the Drainage Area

The Fryšávka Stream is a right tributary of the Svatka River into which it empties at the town Jimramov. In the official intercalibration exercise for the Water Framework Directive, this stream type was named as a small stream in the lower mountainous areas of Central Europe (HERING *et al.*, 2004). The spring of the stream is near the hill of Hradecká skalka at an elevation of 740 m; its mouth into the Svatka River lies at 490 m; the average slope of the stream is 11.06‰. The main stream and its tributaries have characteristics of speed running water. The drainage area of the Fryšávka Stream is elongated in the West-East direction. The main stream is 22.6 km long and the surface of the drainage area is 66.58 km². The Fryšávka Stream receives a total of 21 registered tributaries, of which only 2 have major drainage areas: the Medlovka (17.1 km long with a drainage surface area of 10.3 km²) and the Bílý potok (13.1 km long with a drainage surface area of 6.4 km²) streams. In the drainage area of the Fryšávka Stream there are several fishponds. The biggest one, Medlov (28.47 ha with $V = 600\,000$ m³ of accumulated water, average depth 2.1 m), lies in the drainage region of the right

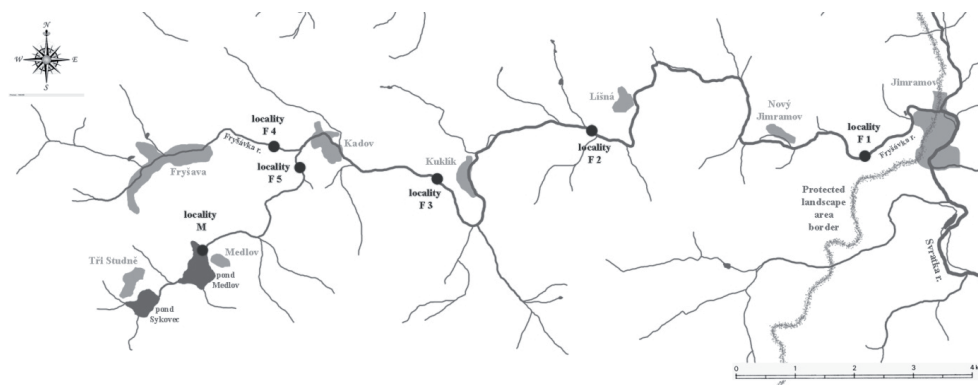


Fig. 1. Map of the Fryšávka basin with the study sites indicated. (F5-F1) – Fryšávka Stream, (M) – fishpond Medlov.

Medlovka tributary of the Fryšávka Stream. The characteristics and positions of the selected localities are given in Table 1 and Figure 1.

The drainage area of the Fryšávka Stream is covered by woodland (53%), mostly Norway spruce monocultures, with the original beach stands only occurring in places. There is a large share of meadows and pastures which amounts to 37% of the total farmland. The whole surrounding of the Fryšávka Stream has got natural character; its bed is fringed with bank vegetation, alder and willow trees and shrubs. The Fryšávka Stream is located on crystalline bedrock, with mainly gneiss, mica schists and hornblende schists. Organic pollution mainly comes from point sources, usually from sewage waters from villages, recreation enterprises and small factories. The Fryšávka Stream, which shows a high self-purification capacity, can usually cope with these scattered pollution sources without showing any marked changes.

Medlov pond is primarily used for rearing market carp and whitefish. The fish stock is composed of common carp (*Cyprinus carpio*), northern whitefish (*Coregonus peled*), maraena whitefish (*Coregonus maraena*) and in small quantities is bred also tench (*Tinca tinca*) and pike-perch (*Sander lucioperca*). The average annual production is 360–520 kg ha⁻¹. Most of the increase in weight is made up of natural feed, supplementary feeding is by 15–17 tons per year. No fertilisers or other harmful substances were applied to the pond.

Table 1. Characteristics of the selected localities in the Fryšávka Stream (Mean $\pm$ standard deviation).

Locality	GPS localization	Average width of stream (m)	Average depth of stream (m)	Average flow velocity (m s ⁻¹)	Average discharge (m ³ s ⁻¹)	Distance from pond (km)
F1	N49 37.906 E16 04.372	6.26 $\pm$ 0.87	0.143 $\pm$ 0.01	0.243 $\pm$ 0.10	0.23 $\pm$ 0.12	18.7
F2	N49 37.566 E16 06.562	4.85 $\pm$ 0.53	0.124 $\pm$ 0.01	0.346 $\pm$ 0.11	0.22 $\pm$ 0.13	11.0
F3	N49 38.133 E16 08.582	3.59 $\pm$ 0.25	0.230 $\pm$ 0.02	0.185 $\pm$ 0.07	0.15 $\pm$ 0.07	6.3
F4	N49 37.938 E16 12.375	3.22 $\pm$ 0.20	0.168 $\pm$ 0.03	0.128 $\pm$ 0.03	0.07 $\pm$ 0.03	–
F5	N49 37.790 E16 04.435	2.73 $\pm$ 0.08	0.153 $\pm$ 0.01	0.133 $\pm$ 0.05	0.06 $\pm$ 0.03	3.0

2.2. Chemical and Hydrobiological Methods

Samples for chemical analyses were collected in plastic bottles from a depth of 10–20 cm. Water oxygen saturation (oxy), temperature (tem), pH, conductivity (cond) and water transparency were immediately measured at the locality. Basic physico-chemical parameters (oxygen saturation of water, pH, temperature and conductivity) were measured using a CyberScan PCD 650 (Eutech Instruments, Illinois, USA). The transparency of the water was assessed using a Secchi disc. Ammonium ions (N–NH₄) were determined using the indophenols method, nitrite nitrogen (N–NO₂) by a method using N–(1-naphthyl)-ethylenediamine and nitrate nitrogen (N–NO₃) by a method using sodium salicylate. Total nitrogen (NT) was measured with dimethylphenol after the transformation of all nitrogen compounds into nitrate by Koroleff's method. Total phosphorus (PT) and orthophosphate (P–PO₄) were measured using ascorbic acid and ammonium molybdenate. The acid neutralization capacity (ANC) was measured by a method using hydrochloric acid, iron ions (Fe) were reduced by ascorbic acid and determined with triazine, sulphate ions (S–SO₄) were measured using a turbidimetric method with barium, potassium (K) levels were measured by the photometric turbidity method as potassium tetraphenylborate, calcium (Ca) levels were determined by EDTA titration and chlorine ions (Cl[–]) were measured by the reaction with mercury thiocyanate to form mercury chloride. Total organic carbon (TOC) was determined by digestion with sulphuric acid and peroxodisulphate and transformation into carbon dioxide. Chemical oxygen demand (COD) was measured by a method using potassium dichromate (CODCr) and a method using potash (CODMn), and the biological oxygen demand (BOD) was determined by the standard diluting method. All the chemical parameters were measured by the standards methods (APHA, 1998). Algal and diatom biomass was evaluated by chlorophyll-*a* concentrations using heated ethanol extraction (LORENZEN, 1967). Values of total inorganic carbon (TIC) were determined by arithmetic operation at utilization values of water temperature, alkalinity and pH (ŽALUD, 2008). The flow velocities were measured using an acoustic digital current meter (ADC, OTT Inc., Kempen, Germany) and the discharge was assessed according to EN ISO 748. The physico-chemical parameters of the selected localities are given in Table 2.

Qualitative samples of zoobenthos were collected with a hand net (25 × 25 cm aperture, mesh size 0.5 mm, sack length 75 cm). Quantitative samples of zoobenthos were collected using a Surber sampler (sampling area 1225 cm²). Qualitative and quantitative samples were collected at each of the sites under at each study site. Zoobenthos samples were preserved in 4% formaldehyde. The biomass of the zoobenthos was determined by weighing the preserved samples after a standard period of three months. Epilithic samples were taken following the European protocol by brushing the surface of 3–5 submerged stones (KELLY *et al.*, 1998) and suspending these samples in 100 ml of water. The samples were stored alive in an insulated cooler box and transported to the laboratory. The most common species of cyanobacteria and algae (except the diatoms) were determined within 24 hours. The Lugol's iodine was added for short-term storage. Diatom frustules were cleaned by boiling with hydrogen peroxide to eliminate the organic matter, then they were washed and mounted in Pleurax (FOTT, 1954); at least 300 undamaged valves per sample were counted using 1000 × magnification to estimate the relative abundance of each taxon in the samples (CEN, 2004). Final estimated abundance was calculated according to standard methodology (CEN, 2010). Phytobenthos abundance values according to five-point scale are in brackets behind the relevant taxon.

The fish community was sampled via a standard method of electro-fishing using the BMA PLUS electroshocker (Bednar Inc., Czech Republic) with Honda Eu 20i gear (pulsating output DC 240–300 V, 2.5 A, frequency of pulses 50 Hz). The sampling dates were 24–25. 10. 2007 and 12–13. 6. 2008. Each selected stream section (F1–F5) was electro-fished twice, with a minimum time lapse of one hour between the two runs. The captured fish were collected with a geogrid bag. After each second run of electro-fishing the species were determined, counted carefully and immediately released back into the water.

2.3. Statistical Analysis

Statistical significance of various abiotic and biotic parameters between localities was evaluated using the analysis of variance, ANOVA in Statistica 8.0 software (StatSoft, Tulsa, OK, USA). Field data were statistically processed using canonical correspondence analysis (CCA), Canoco for Windows 4.5 (TER BRAAK and SMILAUER, 2002). The relative abundance of macrozoobenthos and phytobenthos specimens

scaled as classes according to KELLY (2000) were input into the model as species data. Logarithmically transformed values of the parameters in Table 2 were input as environmental variables; a correlation matrix was used. The outputs are presented as biplots (species and environmental variables) to explain the variability of the first two ordination axes.

3. Results

3.1. Water Quality

Table 2 shows the average and standard deviations of monthly measurements of the physical and chemical characteristics at the sampled sites (M, F1–F5) in the Frysavka Stream and in the Medlov fishpond between March and September 2008. Analysis of variance didn't show any statistically significant differences among monitored areas of Frysavka stream. Statistically significant differences ($P \leq 0.05$) were found in chemical parameters between areas Medlov and Frysavka. The value of nitrate nitrogen in the pond was dramatically lower than the value in the Frysavka stream and conversely some values of organic substances (COD_{Cr} , COD_{Mn} , TOC) were significantly lower in the stream. The pH and conductivity ranges in the investigated stream were similar to those in the fishpond, without extreme fluctuations. Typically, these parameters slightly increased along the stream set. The water in all localities under study was characterized by a high dissolved oxygen concentration. On the other hand, the concentration of ions was very low in all of the sites, which induced low values of alkalinity in the fishpond and in the Frysavka Stream. The influence of the fishpond on the chemical composition of the stream was mainly demonstrated by a higher concentration of organic matter (COD, BOD, TOC). Domestic sewage from the villages and agriculture around the Frysavka Stream caused an increase of nitrates and organic matter in the water and caused a slight increase in their concentrations for all the drainage areas of the Frysavka Stream. A higher concentration of TOC was also caused by the presence of humic acid in the water. Most of the physical and chemical composition parameters examined in the river did not show any major seasonal variations; only a slight decrease in pH was noted during the spring. This was caused by the affluent that poured a high volume of acidic snow-melt water causing lower alkalinity of the Frysavka Stream. The results indicating a correlation between the selected chemical values and the benthos community are shown in Figures 2 and 3.

3.2. Phytobenthos

In total, we found 128 species of algae and cyanobacteria (Table 3); the most common were Bacillariophyceae (99 species). The species richness of the phytobenthos per site was very similar and we only observed small differences when compared to the discharge of the fishpond. The dominant species in all of the sites without specification (F5) was *Audouiniella chalybea* (Rhodophyta) (3–4). At the upper sites (F5, F4), the dominant species of Bacillariophyceae were *Achnanthes lanceolata* (3–4), *A. pyrenaica* agg. (3), *Fragilaria capucina* (3), *Gomphonema parvulum* (2–3) and *Aulacoseira granulata* (3). Downstream (F3–F1), the dominant genera were also *Achnanthes lanceolata* (3), *A. pyrenaica* agg. (2–3), *Fragilaria capucina* (3), and *Cocconeis placentula* (4–5), *Cymbella minuta* (2–3) and *Navicula avenacea* (3) were also highly abundant.

An influence of the Medlov fishpond was observed on the structure of phytobenthos mainly in autumn after catching the fish, when a large quantity of water drains from the fishpond into the Frysavka Stream. We observed the presence of typical phytoplankton species among

Table 2. Physical and chemical characteristics of the sites in the Frysavka Stream (F5-F1) and the Medlov (M) fishpond every month from March to September (Mean $\pm$ standard deviation).

Variables	Unit	M	F5	F4	F3	F2	F1
Temperature	°C	14.7 $\pm$ 6.7	9.7 $\pm$ 5.0	8.9 $\pm$ 4.4	9.2 $\pm$ 4.7	9.8 $\pm$ 5.1	10.2 $\pm$ 5.2
pH		7.2 $\pm$ 1.0	7.1 $\pm$ 0.6	7.1 $\pm$ 0.6	7.2 $\pm$ 0.6	7.3 $\pm$ 0.5	7.4 $\pm$ 0.5
Conductivity	mS m ⁻¹	10.6 $\pm$ 1.1	12.0 $\pm$ 2.1	12.9 $\pm$ 2.5	11.7 $\pm$ 2.6	11.8 $\pm$ 2.6	13.0 $\pm$ 2.0
O ₂ saturation	%	90 $\pm$ 15	92 $\pm$ 11	89 $\pm$ 11	92 $\pm$ 12	93 $\pm$ 12	95 $\pm$ 11
N-NH ⁴	mg l ⁻¹	0.17 $\pm$ 0.17	0.12 $\pm$ 0.16	0.17 $\pm$ 0.22	0.12 $\pm$ 0.17	0.15 $\pm$ 0.26	0.11 $\pm$ 0.13
N-NO ₂	mg l ⁻¹	> 0.01	0.01 $\pm$ 0.01	0.01 $\pm$ 0.01	> 0.01	> 0.01	> 0.01
N-NO ₃	mg l ⁻¹	0.43 $\pm$ 0.5	2.36 $\pm$ 2.1	3.57 $\pm$ 1.9	2.89 $\pm$ 1.6	3.42 $\pm$ 1.8	3.79 $\pm$ 1.8
NT	mg l ⁻¹	1.83 $\pm$ 0.7	2.58 $\pm$ 0.3	4.28 $\pm$ 0.9	3.44 $\pm$ 1.0	4.03 $\pm$ 1.4	4.54 $\pm$ 1.7
P-PO ₄	mg l ⁻¹	0.03 $\pm$ 0.02	0.05 $\pm$ 0.02	0.04 $\pm$ 0.02	0.04 $\pm$ 0.02	0.04 $\pm$ 0.01	0.04 $\pm$ 0.02
P _T	mg l ⁻¹	0.13 $\pm$ 0.06	0.10 $\pm$ 0.03	0.10 $\pm$ 0.06	0.08 $\pm$ 0.02	0.08 $\pm$ 0.04	0.08 $\pm$ 0.03
Ca ²⁺	mg l ⁻¹	11.2 $\pm$ 2.7	12.1 $\pm$ 1.9	12.8 $\pm$ 2.6	11.6 $\pm$ 2.3	12.3 $\pm$ 2.7	12.6 $\pm$ 1.6
K ⁺	mg l ⁻¹	> 2	> 2	> 2	> 2	2.08 $\pm$ 0.4	2.08 $\pm$ 0.4
Cl ⁻	mg l ⁻¹	7.0 $\pm$ 1.0	6.4 $\pm$ 0.4	6.4 $\pm$ 0.9	6.9 $\pm$ 0.8	6.8 $\pm$ 0.6	7.5 $\pm$ 0.6
Fe	mg l ⁻¹	0.11 $\pm$ 0.07	0.17 $\pm$ 0.06	0.09 $\pm$ 0.04	0.13 $\pm$ 0.05	0.11 $\pm$ 0.08	0.08 $\pm$ 0.06
S-SO ₄	mg l ⁻¹	8.5 $\pm$ 1.0	8.7 $\pm$ 0.7	9.0 $\pm$ 0.5	8.9 $\pm$ 0.7	9.2 $\pm$ 0.7	9.7 $\pm$ 0.8
ANC	mmol l ⁻¹	0.58 $\pm$ 0.2	0.59 $\pm$ 0.1	0.55 $\pm$ 0.1	0.50 $\pm$ 0.1	0.52 $\pm$ 0.1	0.53 $\pm$ 0.1
TOC	mg l ⁻¹	23.5 $\pm$ 6.2	17.9 $\pm$ 2.7	16.5 $\pm$ 4.5	16.6 $\pm$ 4.1	16.6 $\pm$ 3.7	14.7 $\pm$ 2.2
TIC	mg l ⁻¹	14.5 $\pm$ 11.9	9.2 $\pm$ 3.5	10.8 $\pm$ 5.4	8.5 $\pm$ 2.9	7.9 $\pm$ 1.7	7.6 $\pm$ 1.4
COD _{Mn}	mg l ⁻¹	15.1 $\pm$ 3.6	8.1 $\pm$ 2.3	7.3 $\pm$ 3.4	8.0 $\pm$ 2.8	7.3 $\pm$ 2.2	7.2 $\pm$ 2.1
COD _{Cr}	mg l ⁻¹	46.0 $\pm$ 5.5	32.9 $\pm$ 13.7	26.8 $\pm$ 16.1	27.6 $\pm$ 10.3	30.0 $\pm$ 12.3	20.1 $\pm$ 9.3
BOD ₅	mg l ⁻¹	5.5 $\pm$ 4.4	2.2 $\pm$ 0.8	1.7 $\pm$ 0.4	1.7 $\pm$ 0.3	1.8 $\pm$ 0.3	2.2 $\pm$ 0.3
Chlorophyll <i>a</i>	µg cm ⁻²	75.8 $\pm$ 44.7*	1.1 $\pm$ 0.8	1.5 $\pm$ 0.4	1.3 $\pm$ 0.1	2.9 $\pm$ 0.8	2.2 $\pm$ 1.6
Transparency	cm	89.5 $\pm$ 28					

* µg l⁻¹

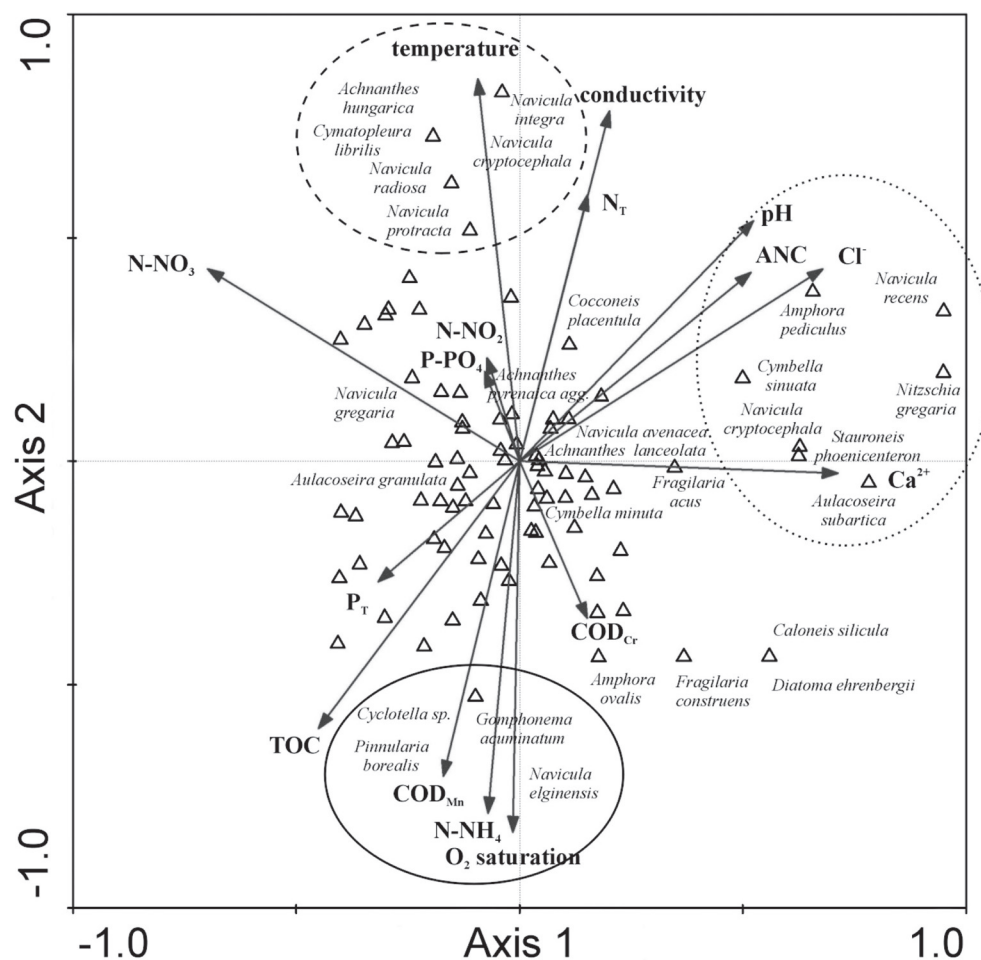


Fig. 2. The CCA ordination biplot with samples and investigated physico-chemical factors performed on phytoplankton taxa. For chemical codes see chapter “Methods”.

the phytoplankton communities. The dominant species from the phytoplankton communities of the Medlov fishpond, *Woronichinia naegeliana* (Cyanobacteria), occurred in all of the monitored sites (except F4) at a high abundance (3–4) during autumn and also in locality F3 in spring (1). We observed the presence of other phytoplankton species at the sites in the Frysavka Stream which mainly included the groups Chlorophyta (*Chlorella* sp. 1, *Pediastrum boryanum* 1, *Desmodesmus communis* 1) and Bacillariophyceae (*Cyclotella meneghiniana* 1, *Cyclotella dubius* 1), and also the genus *Trachelomonas* sp. (1) (Euglenophyta), although this occurred at a low abundance and only during autumn.

The canonical correspondence analysis separated the diatom species into several distinct groups depending on the influence of physical and chemical parameters as shown in Figure 2. The structure of the first group (full line) was due to the higher concentrations of ammonium, organic matter and oxygen, represented by species with a higher trophic index.

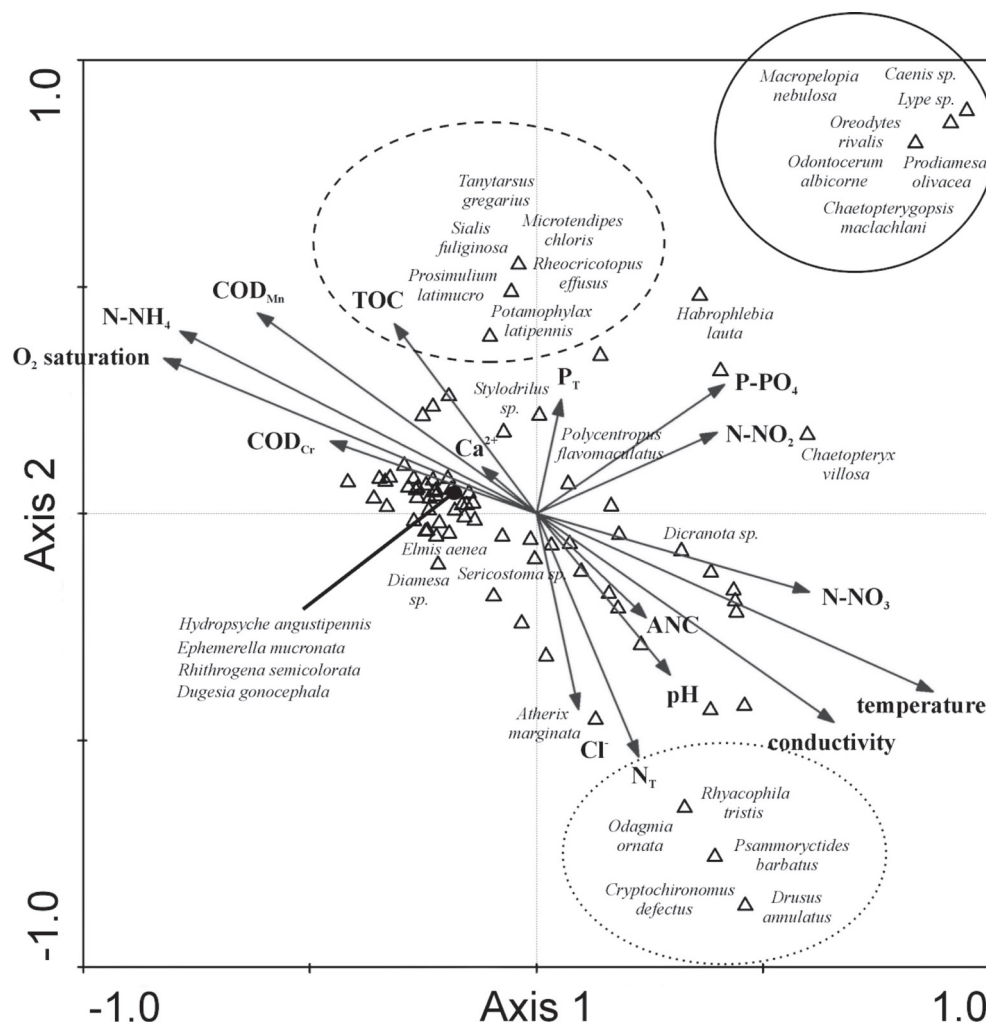


Fig. 3. The CCA ordination biplot with samples and investigated physico-chemical factors performed on macrozoobenthos taxa. For chemical codes see chapter "Methods".

This effect was only found in the locality below the fishpond (F5) in spring. These species occurred at a low abundance and did not affect the trophic index at the locality.

Different communities of the second group (dashed line) were represented by diatom species (mainly *Navicula*) which occurred at the localities toward the mouth of the Frysavka Stream (F1, F2) in summer. This group was mainly characterized by their dependence on higher temperatures. The last group (dotted line) was represented by phytobenthos species occurring at the locality at the lower part of the Frysavka Stream (F1, F2) in autumn. This species, in conjunction with higher concentrations of calcium, chloride, ANC and pH, were represented by species with a higher trophic index. The species *Amphora pediculus* (2–3) and *Nitzschia gregaria* (2) occurred at higher abundances and affected the trophic indices at the locality at the lower part of the Frysavka Stream.

Table 3. Taxonomic composition of the benthos and number of taxa present in the Frysavka Stream.

Group of macrozoobenthos	Number of taxa	Group of algae and cyanobacteria	Number of taxa	Genus of Bacillariophyceae	Number of taxa
Coelenterata	1	Cyanobacteria	8	<i>Achnanthes</i>	6
Turbellaria	1	Euglenophyta	2	<i>Amphora</i>	3
Oligochaeta	7	Cryptophyta	1	<i>Asterionella</i>	1
Hirudinea	1	Chromophyta	100	<i>Aulacoseira</i>	4
Gastropoda	1	Rhodophyta	1	<i>Caloneis</i>	1
Bivalvia	3	Chlorophyta	16	<i>Cocconeis</i>	2
Amphipoda	2			<i>Cyclostephanos</i>	1
Isopoda	1			<i>Cyclotella</i>	3
Decapoda	1			<i>Cymatopleura</i>	1
Hydracarina	1			<i>Cymbella</i>	3
Ephemeroptera	20			<i>Diatoma</i>	2
Plecoptera	9			<i>Diploneis</i>	2
Heteroptera	1			<i>Eunotia</i>	7
Megaloptera	1			<i>Fragilaria</i>	9
Planipennia	1			<i>Frustulia</i>	1
Trichoptera	45			<i>Gomphonema</i>	5
Coleoptera	7			<i>Melosira</i>	1
Diptera	61			<i>Meridion</i>	1
				<i>Navicula</i>	16
				<i>Nitzschia</i>	12
				<i>Pinnularia</i>	7
				<i>Stauroneis</i>	4
				<i>Stephanodiscus</i>	2
				<i>Surirella</i>	3
				<i>Tabellaria</i>	2

3.3. Macrozoobenthos

Altogether, 164 taxa of benthic macroinvertebrates were recorded in the running waters of the Frysavka Stream. The main component of the bottom fauna in the Frysavka Stream were water insects represented by two important groups: caddisfly larvae (Trichoptera) and mayfly nymphs (Ephemeroptera). Caddisfly larvae occupied 35% of the bottom fauna in the Frysavka Stream and were represented mainly genus *Sericostoma*, *Hydropsyche* and *Polycentropus*. Mayfly nymphs were represented by genus *Ephemerella* and *Rhithrogena* in particular and constituted 11% of the total fauna. Larvae of dipterans (Diptera) were represented by the genus of *Atherix*, *Diamesa* and *Dicranota*, in particular, and made up 19% of the total fauna. Oligochaetes (Oligochaeta) constituted 14% of the total fauna and were mainly represented by genus *Stylodrilus*. Turbellarian (Turbellaria) and coleopteran (Coleoptera) were represented mainly by genus *Dugesia* and *Elmis* in particular and constituted 8% and 7% of the total fauna, respectively. Other groups of macroinvertebrates were occasionally found, although their share in the entire bottom fauna did not exceed 5%.

We did not observe the presence of any species of zooplankton or the macrozoobenthos community from the Medlov fishpond in the Frysavka Stream. Canonical correspondence analysis separated the macrozoobenthos species into several distinct groups depending on the influence of physical and chemical parameters are shown in Figures 3. The first group (full line) favoured higher concentrations of phosphorus and was represented by macro-

zoobenthos species (mainly from Trichoptera) occurring in the locality below the fishpond (F5) in summer. There were higher concentrations of phosphorus outflow from the fishpond mainly in summer due to increasing recreational activity. The second group (dashed line) was represented by macrozoobenthos species (mainly from Diptera) which occurred in the locality not influenced by the fishpond (F4), in spring. This group was not characterized by any physical or chemical parameters. The last group (dotted line) was represented by macrozoobenthos species (mainly from Diptera) that occurred at the locality at the bottom of the Frysavka Stream (F1, F2) throughout the whole year. This group were mainly characterized by its dependence on higher pH and total nitrogen values. Most of the other macrozoobenthos species were located around the axes of oxygen saturation and COD. Dependence of the individual groups on physical and chemical parameters was not high; differences in physical and chemical parameters between the localities were small during year.

3.4. Fish

Over the course of the years 2007 and 2008, only six species of fish were recorded in the study area of the Frysavka Stream. The dominant species that occurred in the Frysavka Stream were brown trout (*Salmo trutta* m. *fario*), with an abundance varying from 312 to 6143 ind. ha⁻¹, and the alpine bullhead (*Cottus poecilopus*), with an abundance varying from 399 to 3260 ind. ha⁻¹, which represented the rheophilic ecological guild. The grayling (*Thymallus thymallus*), with an abundance varying from 18 to 110 ind. ha⁻¹, occurred in the lower part of the Frysavka Stream and its size structure and numbers were influenced by fishery management. The population of burbot (*Lota lota*), with an abundance varying from 25 to 49 ind. ha⁻¹, is indigenous, but occasionally it was found in the Medlov fishpond. The last two species of fish, roach (*Rutilus rutilus*) and ruffe (*Gymnocephalus cernuus*), represented the eurytopic ecological guild that occasionally occurred in the Frysavka Stream (with an abundance varying from 14 to 68 ind. ha⁻¹) when it escaped with water from the Medlov fishpond, especially during fish harvest.

4. Discussion

To a certain extent, the chemical composition of the stream water depends on bedrock composition (LUKAVSKÝ *et al.*, 2006). The Frysavka Stream is located on siliceous substrate that is why concentration of both organic and inorganic chemical compounds is low. On the basis of what has been said, it can be asserted that the investigated fishpond exerts a mild negative influence on the water quality of the Frysavka Stream. The analogous influence of the fish farm on the chemical composition of the stream recorded ŽIVIČ *et al.* (2009). Generally, the water of the Frysavka stream can be classified as clean water, even though it had high contents of organic matter and nitrates. In fact the values of the monitored physical and chemical parameters when compared to the water quality standards (LAWA, 1998) were classified as classes I or I–II, except for the values of nitrates and TOC. On the other hand, in accordance with the classification of stream trophic status by P_T and N_T variables, the water of the Frysavka Stream is eutrophic (DODDS *et al.*, 1998).

Total species richness of phytobenthos in the Frysavka stream is comparable with analogous studies from highland streams (KAWECKA 1980; LUKAVSKÝ *et al.*, 2004, 2006). Similar diatom structures have been observed in other streams and rivers (ATAZADEH *et al.*, 2007; LUKAVSKÝ *et al.*, 2004). Generally, species belonging to genera such as *Navicula* and *Nitzschia* are predominant in the lower streams and thrive in nutrient-rich water. This is an indicator of medium-to-low water quality (KELLY and WHITTON, 1995). Species belong-

Table 4. Indices at the sites in the Frysavka Stream (F5-F1) and Medlov (M) fishpond. (Mean $\pm$ standard deviation).

Index	M	F5	F4	F3	F2	F1
<i>Phytobenthos</i>						
Saprobic index CZ (ZELINKA and MARVAN, 1961)	1.81 $\pm$ 0.06*	1.29 $\pm$ 0.08	1.29 $\pm$ 0.06	1.36 $\pm$ 0.08	1.52 $\pm$ 0.13	1.39 $\pm$ 0.06
Saprobic index AT (ROTT <i>et al.</i> , 1997)	–	1.56 $\pm$ 0.12	1.54 $\pm$ 0.09	1.63 $\pm$ 0.17	1.88 $\pm$ 0.06	1.83 $\pm$ 0.10
Trophic index AT (ROTT <i>et al.</i> , 1999)	–	2.38 $\pm$ 0.32	2.47 $\pm$ 0.25	2.52 $\pm$ 0.18	2.74 $\pm$ 0.23	2.59 $\pm$ 0.10
Trophic diatom index TDI (KELLY, 1998)	–	52.41 $\pm$ 4.21	50.35 $\pm$ 3.35	51.05 $\pm$ 4.18	58.48 $\pm$ 2.16	61.26 $\pm$ 3.67
% tolerant taxa to organic pollution (KELLY and WHITTON, 1995)	–	13.63 $\pm$ 2.12	17.25 $\pm$ 4.24	16.59 $\pm$ 3.59	17.35 $\pm$ 5.22	17.91 $\pm$ 4.52
Diversity index H' (SHANNON and WEAVER, 1949)	2.44 $\pm$ 0.08*	2.92 $\pm$ 1.11	2.90 $\pm$ 1.22	3.17 $\pm$ 0.39	2.90 $\pm$ 0.69	3.03 $\pm$ 0.95
Evenness	0.54 $\pm$ 0.03*	0.62 $\pm$ 0.01	0.59 $\pm$ 0.02	0.64 $\pm$ 0.02	0.58 $\pm$ 0.01	0.60 $\pm$ 0.05
<i>Macrozoobenthos</i>						
Saprobic index CZ (ZELINKA and MARVAN, 1961)	1.52 $\pm$ 0.16#	1.41 $\pm$ 0.29	1.29 $\pm$ 0.26	1.24 $\pm$ 0.30	1.25 $\pm$ 0.25	1.18 $\pm$ 0.21
Average score per taxon ASPT (ARMITAGE <i>et al.</i> , 1983)	–	5.48 $\pm$ 0.58	5.33 $\pm$ 0.62	5.67 $\pm$ 0.67	5.74 $\pm$ 0.69	5.75 $\pm$ 0.73
EPT number of taxa (PLAFKIN <i>et al.</i> , 1989)	–	12.2 $\pm$ 2.5	12.8 $\pm$ 2.4	13.5 $\pm$ 4.1	13.5 $\pm$ 4.3	12.9 $\pm$ 2.5
Diversity index H' (SHANNON and WEAVER, 1949)	2.77 $\pm$ 0.08#	2.01 $\pm$ 0.36	1.93 $\pm$ 0.36	2.31 $\pm$ 0.37	2.13 $\pm$ 0.62	2.28 $\pm$ 0.42
Evenness	0.58 $\pm$ 0.07#	0.25 $\pm$ 0.05	0.25 $\pm$ 0.06	0.30 $\pm$ 0.05	0.27 $\pm$ 0.08	0.28 $\pm$ 0.06

* phytoplankton, # zooplankton

ing to genera such as *Achnanthes*, *Cymbella* and *Fragilaria* were more abundant in the cleaner headwater sites. This structure of Bacillariophyceae from the Frysavka stream is in agreement with the results of other authors (ATAZADEH *et al.*, 2007; CENTIS *et al.*, 2010; HOLLINGSWORTH and VIS, 2010). The concentration of benthic chlorophyll ranged between 0.5 and 4.3 mg m⁻², which correspond to oligotrophic conditions according to the classification scheme proposed by DODDS *et al.* (1998). We observed an increase of Chl-*a* in the downstream samples, reflecting increased pH levels and nutrient concentrations, especially nitrates from agricultural landscape. Similar trends were shown by the saprobic and trophic indices (Table 4), indicating a slight decline in water quality in the sites downstream.

The changes in nutrient contents and organic matter in the stream were probably too slight to induce significant changes in species diversity of the phytoplankton. All monitored sites were ranked as eutrophic by the trophic index (ROTT *et al.*, 1999) and by the trophic diatom index (KELLY, 1998), *i.e.*, as a stream with middle nutrient concentrations but free from significant organic pollution. The values of these indices slightly increased downstream and were more affected by sewage waters from villages and farming than by the eutrophic fishpond.

Total species richness of the macrozoobenthos is comparable with analogous studies from highland streams (JURAJDA, 2007; DRATNAL and KASPRZAK, 1980). Good and poor water qualities were perfectly indicated by numerous occurrences of *Gammarus sp.* (Amphipoda) and *Assellus aquaticus* (Isopoda), respectively (JURAJDA *et al.*, 2007). The genus *Gammarus* only occurred occasionally in the Frysavka Stream throughout the whole monitored period. The reasons for its scarcity probably include the unfavourable conditions (low pH and calcium values) of the Frysavka Stream and not the quality of the stream, which was not too poor. The indicator of pollution, *Assellus aquaticus*, only occurred once, at a low abundance, during the whole monitoring period and confirmed the good water quality of the Frysavka Stream by its absence. A similar situation also applied to the other indicator organisms, such as the clean water *Rhitrogena* (Ephemeroptera), *Agapetus*, *Sericostoma* (Trichoptera) and Plecoptera species inhabiting sites with low values on the saprobic index and which occurred in the Frysavka Stream at a high abundance, while polluted sites are preferred by *Tubifex* (Oligochaeta), *Erpobdella octoculata* (Hirudinea) and *Chironomus* species (Diptera), which inhabit sites with high values on the saprobic index and only occurred in the Frysavka Stream occasionally. Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa have been widely used as indicators of environmental disturbances, organic enrichment and exposure to toxic chemicals because of their general sensitivity to anthropogenic stressors. The EPT group richness decreases with increasing environmental stress (GRIFFITH *et al.*, 2005). High numbers of EPT taxa from all localities in the Frysavka Stream indicated good water quality and a low influence of environmental stressors. These indicated that the habitats of the basin were diverse and that anthropogenic disturbance was not serious problem in these areas (JIANG *et al.*, 2010).

The species diversity of macrozoobenthos in a highland stream was shown to decline with a decrease in water quality and physical stream habitat (ADÁMEK and JURAJDA, 2001). A decline in the number of the taxa below the influx of organic matter as a result of the elimination of less resistant species is a widely known phenomenon (BRABEC *et al.*, 2004; JURAJDA *et al.*, 2010). Our results showed only small differences in diversity of the macrozoobenthos between the individual localities in the Frysavka Stream. Shannon's biodiversity index ranged from 2.77 to 3.32, corresponding on the saprobic index (CZ) to oligosaprobity (1.18–1.41), which is a class of high or good ecological status for the all monitored localities (Table 4). In comparison with the evolution of phytobenthos index we can observe an opposite trend for macrozoobenthos and therefore, a slight improve of water quality in the areas which are more distant from the eutrophic pond. Higher intake of organic matters from the pond has a bigger impact on the quality of zoobenthos then quality of phytobenthos. Also lower flow in pond, especially in summer time, can cause decrease of diversity on area F5 due to water deficiency. Impact of drying on biodiversity of macrozoobenthos and degradation of water environment described ŘEZNIČKOVÁ *et al.*, (2007).

From the ichthyological point of view, the Frysavka Stream is a river with low species richness and the dominance of native fish species, alpine bullhead (*Cottus poecilopus*) together with the brown trout (*Salmo trutta m. fario*). The same dominant species were mentioned by LUSK (1993) from the period of 1972 to 1991 in the Frysavka Stream. The main breeding fish in the Medlov fishpond (*Cyprinus carpio*, *Tinca tinca*, *Coregonus peled*, *Coregonus maraena* and Sander lucioperca) were not detected in the Frysavka Stream. Fish stocks in the pond were not affected by the fish population in the Frysavka Stream; the fish population was mainly influenced by the fishery management of the stream (stocking, angling).

The influence of water discharge from the fishpond was recognizable from some changes in both chemical and biological variables. The influence of the fishpond on the chemical composition of the stream was mainly demonstrated by higher concentrations of organic matter and phosphorus. Total species richness of fish and the phytobenthos community were not markedly affected by the concentration of physical and chemical variables. Zoobenthos

population shows less biodiversity and worse ecological quality of the river due to the inflow of organic matter from the pond, but the changes in water environment are insignificant and statistically inconclusive. The largest impact on the population of the stream has an autumn draining of the pond, when water contains more phytoplankton, especially cyanobacteria. In some cases can cyanobacteria (*e.g.*, *Woronichinia naegeliana*) and other similar strains hibernate in benthos until the spring season.

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