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Hydrobiology of the Dyje River in the National Park Podyjí, Czech Republic

Jan Helešic & František Kubíček
(Editors)

Masaryk University
Brno, Czech Republic, 1999

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Cover drawing: *Gammarus fossarum* – the dominant taxon in secondary trout zone of the Dyje River downstream the Vranov Reservoir

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FOREWORD

The Dyje River is the most important landscape and ecological part of the National Park Podyji in the southern Moravia of the Czech Republic on the border with Austria. The main geomorphologic feature of river is a canyon valley with many meanders. The river creates a natural bio-corridor and surroundings of river – floodplain meadows and forests and rocky canyons are very important natural bio-centres. The river flows in the first protection zone of the National Park, where the first management priority is natural protection.

The Dyje River is strongly influenced by the Vranov reservoir hydropower station operation. The reservoir Vranov was constructed in 1934 three kilometres upstream from the border of National Park. Down part of the river in the Park is influenced by inflow part of the Znojmo reservoir.

These experiences and features were the basis for application to carry out complex hydrobiologic research of the Dyje River. The research has been started in years 1991 – 1992, when the Authority of the National Park Podyjí sponsored it. In years 1993 - 1995, the research was supported by the Grant Agency of ČR, No. 204/93/2051 (applicant F. Kubíček). Final evaluation and publication has been supported by Grant No. PG 97126 of the Ministry of Education of the Czech Republic (applicant R. Rozkošný) with additional supporting by grant of GA ČR č. 206/99/1522 (applicant J. Helešic).

This work is a part of common project of Department of Zoology and Ecology called "Spatiotemporal Biodiversity Dynamics in Ecosystems of Central Europe" supported by grant of Ministry of Education No. J07/98:143100010.

The hydrobiologic problemacy of the Dyje River is very large, and therefore this publication consists of three separate articles. Contributions covered all studied problems especially impact of artificial hydrological and thermal regime on bottom biota and fishes.

Jan Helešic & František Kubíček
Editors

This issue is dedicated to the memory of

JIŘÍ HELAN
(29. 4. 1942 – 17. 6. 1990)

JAROSLAV ROSOL
(18. 1. 1932 – 3. 5. 1992)

MICHAL FIALA
(23. 8. 1965 – 17. 6. 1995)

prominent Czech hydrobiologists,
our colleagues, collaborates
and best friends

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THE IMPACT OF THE VRANOV RESERVOIR HYDROPOWER STATION OPERATION ON THE BOTTOM BIOTA OF THE DYJE RIVER (CZECH REPUBLIC)

František Kubíček, Jan Helešic, Denisa Vojtíšková & Světlana Zahrádková
Department of Zoology and Ecology, Faculty of Science, Masaryk University Brno, Kotlářská 2, 611 37 Brno, Czech Republic

ABSTRACT

In this work, the abundances, species composition and trophic structures of the river bottom community in a part of the River Dyje upstream and downstream a reservoir of the National Park Podyji are described. Results obtained from the study of communities of the river were compared with the general model of the river continuum concept (RCC). Altogether 15 species of aquatic macrophytes, more than 260 species of aquatic invertebrates and 32 species of fish were determined.

The influence of controlled discharges and dependent environmental variables (especially flow velocity, temperature and concentration of dissolved oxygen) in the river downstream the reservoir creates a specific resilient bottom community that is different from the model of the river continuum concept.

We consider the sharp shape of the discharge wave in the river closest to the reservoir and altered temperature regime to be the main stress factors. An absence of equalizing reservoir as well as a small capacity of the weir impoundment downstream does not ensure ecologically negligible minimal discharge, which is only 1.2 $m^3.s^{-1}$, sometimes declining only to 0.8 $m^3.s^{-1}$. In times of minimal discharge, about 30% and more of the bottom area are exposed in certain parts of the river below the reservoir. The peak discharge depends on the number of working turbines (one turbine capacity - 15 $m^3.s^{-1}$, two - 30 $m^3.s^{-1}$, and three - 45 $m^3.s^{-1}$); long-term maximal discharges are around 60 $m^3.s^{-1}$.

Changed discharges have strongly altered the substrate and bottom permeability. In profiles below the reservoir, the bottom is encrusted by iron and manganese hydroxides. Cobbles and gravel are relatively strongly attached. The hyporheic zone of the bottom is completely different downstream the reservoir than upstream not only in substrate granulometry, but in bottom permeability and biota as well.

There is a completely different community of organisms in the River Dyje than it might be expected in this type of a river. There is a secondary trout zone (epi-metarhithral) with some features typical for barbell zone (epipotamal). Tributaries are influenced especially by increased carrying capacity, increased amount of suspended matter and bed-load (significant erosion in the upper parts of the drainage area) as well as built reservoirs. None the less, there is a lot of species typical for submountain as well as mountain streams (Alps-Carpathian species); on the other side, occurrence of individuals of pannonian fauna was marked. Some remedial measure esp. for minimalizing of negative effects of hydropeaking and minimal flow stress on bottom community was recommended.

INTRODUCTION

The management of the National Park Podyjí initiated research of the Dyje River to allow the study of fauna and flora as well as other ecological factors that might be used for nature preservation in the part of the river flowing through the most important part of the protected area.

Before the Vranov reservoir was built in 1934, the part of the river flowing through the current National Park had been a typical barbell zone - epipotamal (HOCHMAN & JIRÁSEK 1960). In the part of the National Park with the highest level of protection, this type of the stream should be preserved or its basic ecological parameters should be very close to it. Two valley reservoirs, Vranov and Znojmo interrupted the natural river continuum; the stream between these two reservoirs has different environmental features. Currently, the hydrological and temperature regime created a brand new type of zone - secondary trout zone (epi-metarhithral) with several features of a barbell zone (epipotamal).

Research of the river and its main tributaries has been started in 1991 (research was supported by the Ministry of Environment of the Czech Republic through the National Park Podyji Authority), but the main part of the research was carried out in 1993 - 1995. Research was supposed to answer several questions:

- What are the environmental conditions in the stretches of the river above and below the valley reservoir Vranov, and what important changes have occurred between these river sections?
- What is the answer of the river biota on these changes?
- At what distance downstream of the reservoir are the natural conditions restored?
- To what degree is the studied part of the Dyje a natural range of the river continuum?
- What measures should be taken to lessen the impact of the reservoir on the river and its biota?

Another aim of this research was to map the occurrence of algae and blue-green algae, aquatic macrophyts, aquatic invertebrates and fish in the stretch of the Dyje situated in the National Park.

The main project was supported by a grant of the GA CR 204/93/2051. The manuscript was prepared with the help of the Ministry of Education, Youth and Physical Education of the CR PG 97126 and the Ministry of Environment PPŽP No. 610/3/98. This work is a part of common project of the Department of Zoology and Ecology called "Spatio-temporal Biodiversity Dynamics in Ecosystems of Central Europe" supported by grant of the Ministry of Education No. J07/98: 143100010 and final preparation of manuscript was supported by the grant of the Czech Grant Agency No. 206/99/1522.

The first results were published in papers by KUBÍČEK (1994), HELEŠIC & KUBÍČEK (1997) and HELEŠIC, KUBÍČEK & ZAHRÁDKOVÁ (1998). This work summarizes and evaluates all gathered data; new original results as well as lists of organisms living in the Dyje River are published here.

BACKGROUND

WARD & STANFORD (1983) and WARD & STANFORD respectively (1995) who used the serial river discontinuity concept elaborated the influence of reservoirs in connection with the river continuum concept (VANNOTE et al 1980). Other scientists such as ZWICK (1992) use the term fragmentation of ecosystem of running waters. There are a lot of studies on reservoir influence on the biology of streams, for example in Europe: OBR (1956, 1963, and 1972), PEŇÁZ et al (1968), REHFELDT (1987), BRETSCHKO & MOOG (1990), BRETSCHKO (1992), MOOG (1993), HELEŠIC & SEDLÁK (1995) and others. A lot of information was compiled in monographs (WARD & STANFORD 1979, LILLEHAMMER & SALTVEIT 1984, CRAIG & KEMPER 1987, PRACH (ed.) 1995) or special studies (PETTS 1984, LIGON, DIETRICH & TRUSH 1995).

However, all information is very heterogeneous in its content and extend; scientists did not always reach the same conclusions. The degree of influence of the discharge by a reservoir depends on the size, type and age of the reservoir, on water manipulation, on presence or absence of an equalizing reservoir and technical changes of the channel downstream a reservoir. That is why it is necessary to judge all these influences case to case.

Generally, water released from a deep reservoir differs from water from a tributary in several basic characteristics (WARD & STANFORD 1979, YEAGER 1993, LIGON et al. 1995):

1. in hydrological and sediments discharge regime, changes of geomorphology of the stream and substratum
2. in temperature regime
3. in concentration of dissolved gases
4. in input of nutrients
5. in drifting activity of organisms and migration movements of animals

(1) Water may be released from the reservoir in several ways: the releases of overfall, the releases of base dam outlet or the releases of the hydropower station. The most frequent form of outlet in the case of the Vranov reservoir is discharge through a turbine from the hypolimnium of the reservoir. In the tailwater below the reservoir, discharge oscillations are caused by seasonal changes of the hydrological regime of the reservoir and operation frequency and capacity of the turbines.

Regulated discharge in rivers below reservoirs gradually erodes the channel width as well as depth differently from natural streams (SIMONS in WARD & STANFORD 1979, PETTS & PRATTS 1983, PETTS 1984). LIGON et al. (1995) proved vast geomorphological changes in the entire flooded area of an influenced river and disturbance of the natural ecological integrity. When a reservoir is built, the sediment discharge regime changes in the stream below the reservoir since all heavier bed-loads carried by the tributaries sediment in the upper part of the stream while the finer bed-loads flow through the reservoir often all the way to the discharge. From the reservoir, organic matter formed of living and dead organisms and their remains keep getting into the stream. This phenomenon was proved on a relatively small weir impoundment on gravel streams (PEHOFER & SOSSAU 1995).

In the transport of water, these substances behave as organic suspended matter but since they have a different shape and a lower weight, they are susceptible to different hydraulic forces (SMITH 1975). All suspended and dissolved matters can influence the light regime in the river as well as a development of primary production. In most cases, turbidity in streams below reservoirs is markedly decreased by hypolimnic water discharge. Gradual sedimentation of solid organic matters in the stream below the reservoir creates an important substrate for bottom organisms.

The velocity of the current influences the size of substrate particles and their distribution on riverbed (GORDON et al. 1992). While studying a real part of a river, SEAR (1995) proved that main morphological adjustments are identified as degradation of riffle spewing grounds, the development of the fine sediment berms along channel margin, the aggregation of pools, vegetation of former gravel shoals and the growth of tributary confluence bars.

Water velocity and associated physical forces collectively represent perhaps the most important environmental factors affecting organisms of running waters (HYNES 1970, ALLAN 1995). Influence of substrate characteristic and its physical state was analyzed in detail by HILDREW et al. (1991), MOOG & JANECEK (1991), COBB et al. (1992), LANCASTER & HILDREW (1993) BRETSCHKO (1995) etc. They confirmed the importance of flow and substrate diversity on the macroinvertebrate community; moreover, they clarified the significance of the so-called microrefugium for keeping and normal functioning of riverbed community.

In a detailed review, STATZNER et al. (1988) analyzed the influence of stream conditions on the river biota. They summarized up-to-date knowledge of the influence of physical forces on population and communities. REICE (1984) published a study on disturbance in flows, and RESH et al. (1988) then explained the role of disturbance on stream ecology and made a clear conclusion that the changes of flow conditions or artificial occurrence of minimal or maximal flows function are typical disturbances. POFF (1992) gave several good examples. TOWNSEND (1989) argued that in the patch dynamic concept, the character of the substrate of the riverbed and the flow conditions play a key role.

(2) Water temperature in deep reservoir shows vertical stratification; if water is released from deeper levels, from hypolimnium, it is colder in summer and warmer in winter than in the tributary (KRATOCHVÍL 1944, PEŇÁZ et al. 1968, STRAŠKRABA 1973). Seasonal development of the temperature peak is 2 months delayed behind the development in the reservoir (BRATRÁNEK 1953).

In the stream below the reservoir, the water temperature is less changeable than above the reservoir even during the day. The total temperature balance in the stream below the reservoir is one of the selective factors of zoobenthos species composition. Species adapted to small and predictable changes have an advantage in these conditions. As a first, LEHMKUHL (1972) compiled the influence of water temperature conditions on benthic communities. This study was later followed by studies by WARD (1974), WARD & STANFORD (1979) and others and later published in monograph by WARD (1992).

(3) In the reservoir, concentration of dissolved oxygen is decreasing with depth. That is why water released from deeper levels is usually poor in oxygen. The oxygen deficit is, however, quickly equalized by a physical as well as biological way. During water discharge through a turbine, situation of quicker warming of water and decrease of hydrostatic pressure can lead to a transient oversaturation of gases (nitrogen and oxygen) and formation of gas bubbles in water. This may lead to death of invertebrates and especially fish of so-called bubble disease (PETTS 1984, PETTERSEN & MELLQUIST 1984, REHFELDT 1987). This unfavorable situation usually turns into saturation equilibrium within several hundred meters; however, in special cases, it can last up to several km below the reservoirs.

(4) Reservoir wall disrupts the natural transport of matter and nutrients by inflow and changes the river nutrient regime (nutrient spiraling concept) to a lake – limnetic nutrient regime (STRAŠKRABA & TUNDISI 1999). Then, the bed-load and nutrient trap is formed. In reservoirs, a lot of matters, organic as well as inorganic, are kept inside together with vegetation-limiting nutrients, nitrogen and phosphorus. A part of nutrients found in sediments and deeper water levels (hypolimnion) gets into the stream above the reservoir and is involved in the production of algal growth, macrovegetation and in stream bank vegetations. This characteristic is typical for reservoirs with outlet in hypolimnium but in other reservoirs with outlet from higher levels, it happens only twice in mixing of the reservoir in the Temperate Zone.

Nutrient allocation of water leaving the reservoir together with organic matter comprises a major trophic source for biota downstream the reservoir.

(5) Passive transport of plankton and other limnetic organisms in tailwater is a continuous feature of river discontinuum (WARD & STANFORD 1983). Amount and composition of drifting organisms is based on the height of water discharge equipment in the body of the reservoir, on the duration of water retention and season of the year. Further fate of limnoplankton had been described before (for example CHANDLER 1937, CHUTTER 1963) as well as in other works (PEŇÁZ et al. 1968, KUBÍČEK 1968, 1968a, ARMITAGE & CAPPER 1976, SHIEL & WALKER 1984). Amount and species composition of the river plankton is significantly higher than in the tributary to the reservoir.

Real lotic organisms become a part of the drifting bed-loads. Drifting rheobionts are a major part of the colonizing cycle and the trophic web of the stream (BISHOP & HYNES 1969, MÜLLER 1974, KUBÍČEK 1978, ALLAN 1995). Drifting in the stream below the reservoir is usually more intense than in the tributary where there are no major daily changes of flows and hydraulic parameters. Reservoirs are usually a barrier of upstream and downstream migration of fish and some invertebrates, for example crustaceans (PRINGLE 1997) and cause so-called fragmentation of ecosystem (ZWICK 1992).

MATERIAL AND METHODS

Study area

The beginning of protection of a large area of the central part of the Dyje River dates back to 1978 when the Protected Landscape Area Podyji was established covering 103 km^2. Most of its area is close to the border, and therefore it was inaccessible to the public. After the change of political situation in 1989, preparations for establishing a National Park (NP) were started for high natural qualities of this area. The park was founded on May 5th 1991 by a ruling of the Government of the Czech Republic 164/1991. The NP Podyjí is the smallest national park covering only 63 km^2; area of the protected zone is only 29 km^2. The NP Podyjí is situated between Znojmo and Vranov on the Dyje close to the border with Austria. On January 1st 2000, the National Park Thayatal was established even on the right Austrian bank of the Dyje thus creating a unique bilateral area of European importance.

Rugged area of Podyjí is a territory of the uplands of the southeastern part of the Czech-Moravian Highlands; only its eastern headland reaches to the Dyje-Svratka Valley. Geological base is created mostly of acidic rocks of the Moravicum of the Dyje vault and the Dyje massif.

The National Park represents a uniquely preserved countryside of a river valley in a highland area of central Europe. The Dyje canyon forms a unique river phenomenon with many meanders, deep valleys of side tributaries, different rock formations, rock seas and rock cliffs. In this country, a majority of similar river valleys was changed by construction of reservoirs, roads and holiday huts. The area is known for high richness of flora and fauna communities caused by changing exposition of slopes in the Dyje valley (CHYTRÝ & VICHEREK 1995). The Dyje forms a natural axis of this area a canyon valley creating on a 40 km distance from Vranov to Znojmo with depth up to 220 m.

The Dyje River flows from two completely separated source areas. The Moravian Dyje branch springs from the area of Velké Javořice in the Czech-Moravian Highlands, while the Austrian Dyje (Thaya) springs from the foothills of Weinsberger Wald; their confluence is situated near the village Raabs. It enters the Czech Republic again on the 209th river km. Near the village Vranov nad Dyjí, a dam reservoir was built in 1934 (Fig. 1). The reservoir drowned a part of a deep valley from the village Podhradí to the 195th river km. In 1966, a smaller water-works and equalizing reservoir Znojmo was built. Then the river leaves the Jevišovice highland and as a typical potamal stream flows through the Dyje-Svratka ravine where new tributaries flow into it (Jevišovka, Jihlava, Svratka and Kyjovka) and system of Nové Mlýny Reservoirs are situated there. At the border with Slovakia, close to Lanžhot, it empties into the river Morava. The Dyje belongs to the Morava catchment area and the upper drainage area of the Danube River.

The studied area is situated between the 140th and 208th river kilometers, and with the exception of the site Podhradí, it is situated in the National Park. There are several tributaries in the studied area. On the right side, there are Fugnitzbach, Kajabach and Tifenbach. For hydrograph, the most important is Fugnitzbach. The left side tributaries have an unimportant discharge, but they participate in the total hydrological and geomorphological (side canyons) characteristics of the area (Klaperův, Žlebský Mašovický, Lukovský and Gránický brooks). Naturally, the river Dyje was epipotamal-barbell zone (classification ILLIES & BOTOSANEANU 1963).

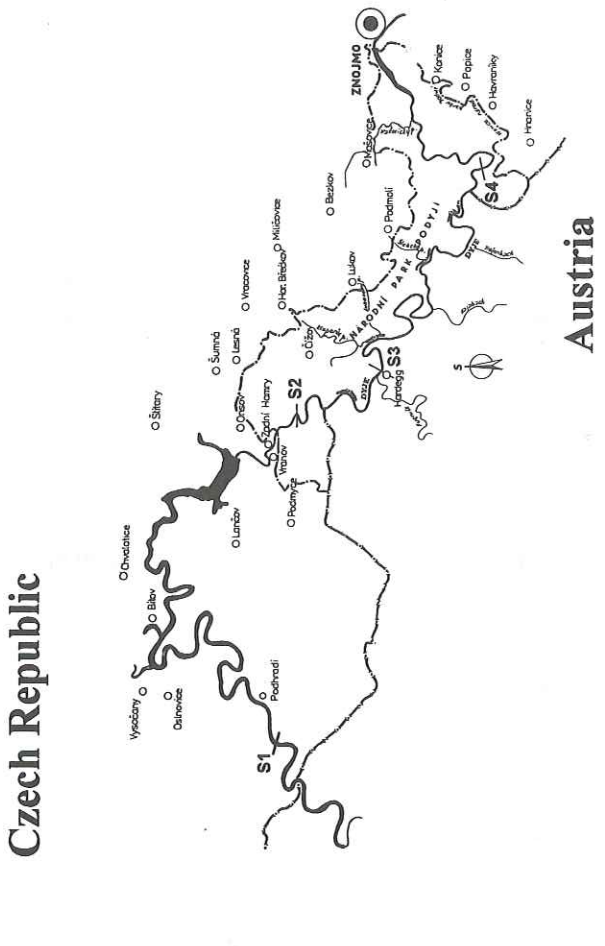


Fig. 1. Map of the Dyje River and reservoirs in the National Park Podyjí

Tab. 1. The base characteristic of the Dyje River

Total length (km)	305.6
Length of stretch between Vranov and Znojmo reservoirs (km)	33.5
Total river basin area (km^2)	13418.7
Average discharge at the mouth ($m^3.s^{-1}$)	43.89
Average discharge at profile Vranov ($m^3.s^{-1}$)	9.74
Average discharge at profile Hardegg ($m^3.s^{-1}$)	9.75
Average discharge at profile Znojmo ($m^3.s^{-1}$)	10.42

Tab. 2. The base characteristic of the Vranov and Znojmo reservoirs

	Vranov	Znojmo
Assessing the interests of reservoirs	Power plant, irrigation, drinking water	Drinking water, irrigation
Altitude (m above sea level)	350	227
Max. depth (m)	58	13.4
Width of the wall (m)	292	15
Max. width (m)	1300	600
Length of reservoir (km)	29.8	5.5
Catchment area (km^2)	2221	2477.1
Capacity of reservoir (m^3)	132.6 mil.	4.29 mil.
Area of reservoirs (km^2)	7.65	0.537
Max. capacity of turbine ($m^3.s^{-1}$)	45	-
Min. capacity of turbine ($m^3.s^{-1}$)	15	-
Avg. time of retention (days)	156	3.8

Sampling sites

S1 - PODHRADÍ

Sampling profile is localized on the 207[th] river kilometer above the village Podhradí nad Dyjí. A relatively natural section was chosen; last regulation was done 35 years ago. On average, the channel is 30m wide, during times of flow above 20 $m^3.s^{-1}$, the width is up to 47 m. Average depth is 0.4 m, max. 0.6 m. Average annual flow on the profile is 8.5 $m^3.s^{-1}$ with current velocity from 0.4 do 1.0 $m.s^{-1}$.

The bottom substrate has a character of cobbles and gravel, close to the bank there are clay up to silt deposits (1:3:1). The left bank is covered with grass of genus *Baldingera,* and the right side is sludge with growth of different evergreens. In the streambed, obstacles formed of fallen trees, branches and other material are often found.

S2 - HAMRY - STŘELNICE

The sampling site is situated near a former shooting ground about 1 km above the village Hamry about 4 km from the dam and 2.5 km below the equalizing weir Formoza in Vranov on the 170[th] river km. The stream possesses a native character; no regulation measures are visible. The maximal width of the channel is 32 m, and on the right bank there is gravel bar. The depth ranges from 5 to 45 cm and during peaks it increases to 85 cm. The current velocity ranges from 0.18 až 1.44 $m.s^{-1}$. The bottom is formed of cobbles with a mixture of gravel and sandy bars close to the bank (5:1:1). Cobbles are bound to the bottom by iron-manganese incrustations. In the vegetation season, about 75% of the bottom are covered by macrophytes (mosses and *Batrachium* sp.), and in the exposed parts, there is a strong growth of filamentous algae. The right bank is rocky with roots of alder-trees and pines. Left bank is sludgy with grass and shrub growth.

S3 - HARDEGG

Sampling site is situated about 500 m below an Austrian hydrograph measuring station and about 700 m below the second weir Hardegg on the 163[rd] river km. The channel was kept in its natural state. The maximal width of the channel is 25 m with depth ranging from 20 to 60 cm and during peaks up to 100 cm. Average discharge in the profile is 9.8 $m^3.s^{-1}$ with speed velocities from 0.3 to 1 $m.s^{-1}$. The bottom is cobble with gravel-sandy bars (5:4:1). During the vegetation season, up to 60% of the bottom is covered by macrophytes and algal growth. The right bank is rocky, and the left is sandy-silt with growths of *Baldingera* sp. and *Phragmites communis.*

S4 - PAPÍRNA

This site was chosen below the last weir in the area of the Nine Mills about 32 km downstream the reservoir on the 141[st] river km. This part of the stream is in native state as well. The channel is 28 m wide with 40 – 60 cm of depth, and during peaks the depth increases to 1m. Average discharge is 10.4 $m^3.s^{-1}$. Current velocities are different according to the bottom substrate diversity and range from 0.4 to 1.5 $m.s^{-1}$. Bottom is formed of boulders, cobbles, and gravel with smaller sandy parts (3:2:1:2). Moss growth

Moss growth was found on about 30% of the total area. Banks are formed of cobbles, sandy-silt bar, growth of grass (Baldingera sp.), and other herb vegetation. Left bank is covered by vegetation of trees - alder-trees, willow-trees and ash-trees.

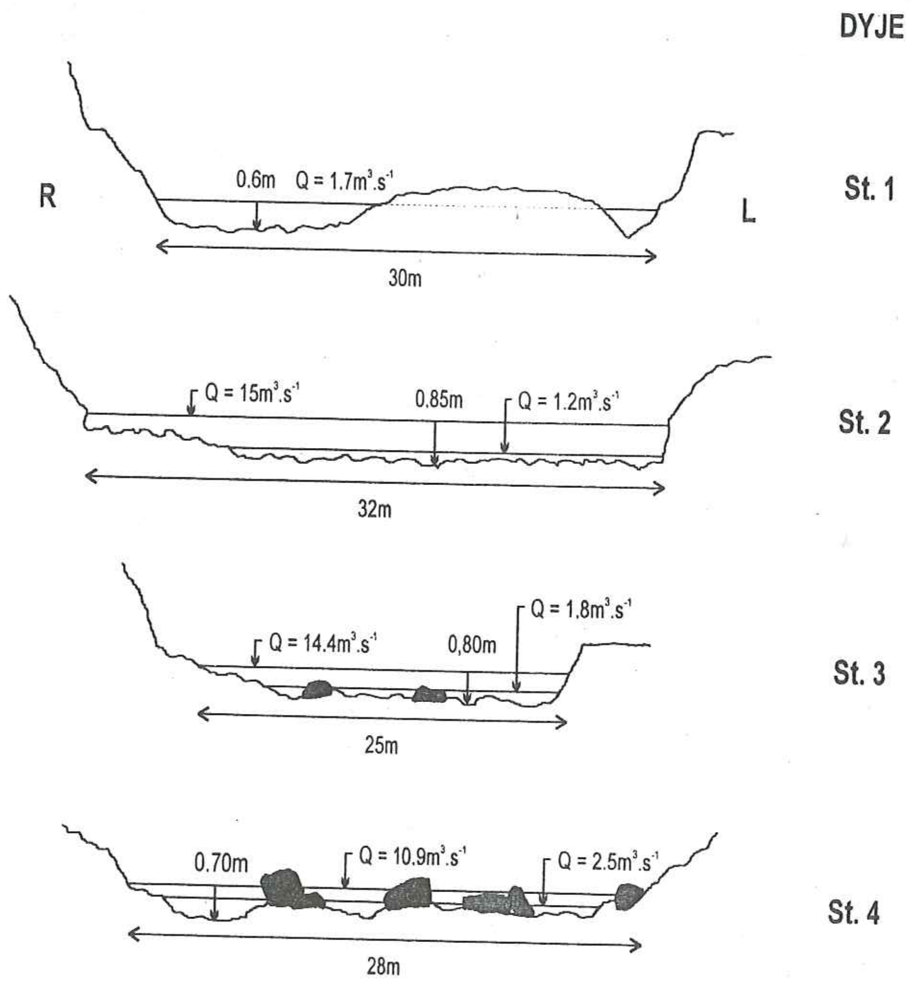
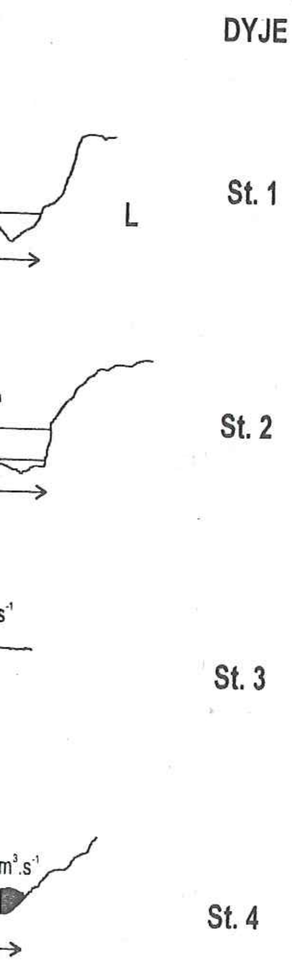


Fig. 2. Cross-section of profiles in the sampling sites

a. Banks are formed of cobbles, ...er herb vegetation. Left bank is ... and ash-trees.



Sampling methods

The research was carried out between 1991 and 1995. At all sampling sites, basic hydrological and hydrochemical parameters were measured; conductivity, pH and oxygen contents were measured by portable multimeter HORIBA U10. Samples of water were collected to special polyethylene flasks. Nutrients were analyzed in laboratory by standard ISO methods. Hydrological parameters were measured by a Czech authorized organization - the Czech Hydrometeorological Institute. The Institute carried out two complete measurements, and all other data were evaluated according to official hydrological model and/or according to running measurements of flows at the hydrological stations Podhradí (S1), Hamry (S2), Hardegg (S2) and Papírna (S4).

Bentic fauna as a main group of the bottom community was gathered by net with a mesh size 0.4-0.5 mm manufactured according to ISO and CSN norms. Quantitative samples of zoobenthos were gathered at different habitats of the bottom by an original benthometer with a sampling area of 0.5 m^2 (according to KUBÍČEK in HELAN et al. 1973, ČSN 75 7713) in parallel samples. It had been previously verified that samples from the area of 0.3 m^2 are sufficient for recording 100% of dominant and 50% of other species at the studied part of the section (TRNKOVÁ 1972). At the same time, semiquantitative samples of zoobenthos were gathered using hand net (according to ISO Norm) roughly for the same amount of time (1 min at each detected habitat of the profile). Biota from samples was partially picked on the spot and the rest was quantitatively moved to sample flasks and fixed with formalin solution on spot. Quantitative samples (benthometer) were analyzed and counted in the laboratory. On the basis of our experience, we suppose that the combination of both methods allowed for detection of all dominant species and more than 90% of other species. Sampling was not aimed at gathering data for construction of life cycles nor for biomass and production assessment.

Organism drifting was evaluated only during the light part of the day. Drifting zooplankton was caught by plankton net with a 25 cm diameter of entry and mesh density around 100 μm. Drifting zoobenthos was gathered with nets of size 25 . 40 cm and mesh size of 0.5 mm. Amount of filtrated water was 2 - 4 m^3 and for zoobenthos drift 8 - 10 m^3.

Sampling procedures of periphyton and meiobenthos were described in other parts of this monograph - KOMÁREK & MARVAN (1999) and OPRAVILOVÁ & KOMÁREK (1999). Macrophyts were gathered using frame method from the bottom area of 1 m^2 so that all main habitats in the stream were recorded; biomass was evaluated as dry matter by standard procedures. Four season samplings were carried out between 1992 and 1994.

Sampling of hyporheic zone was carried out in the part of the Dyje above and below the dam reservoir (S1, S2) by freezing core method (BRETSCHKO & KLEMENS 1986, KLEMENS 1991, BRETSCHKO 1995). This method uses liquid nitrogen to freeze and fix a sediment sample with a strictly defined volume and space around a metal corer installed in the bottom. To prevent evasion of fauna once around a metal corer installed in the bottom. To prevent evasion of fauna once the sediment freezes, fauna was immobilized by a 10 min. impact of electricity (650 V, 50 Hz). Installation of metal corers into the river bottom was done on May 4th, 1995. The sampling of bottom sediment 60 cm deep was carried out on May 11th, 1995 after 7 days of exposition of corers in the stream. Distribution of corers is depicted at Fig.3. For biological analysis, samples from the right and left bank zone as well as streamline were used (S1a, S1d, S1e, S2a, S2c, S2e); for granulometric analysis including the total organic carbon content analysis we used samples of corers situated at the streamline (S1b, S1c, S2b, S2d). Core samples were determined by standard procedures and granulometric analyses and C org. measurements (LEICHTFRIED 1995) were carried out. At each sampling point, 3 corers were hammered to the depth of 60 cm in the streamline, in the drying zone and in the area of shallows.

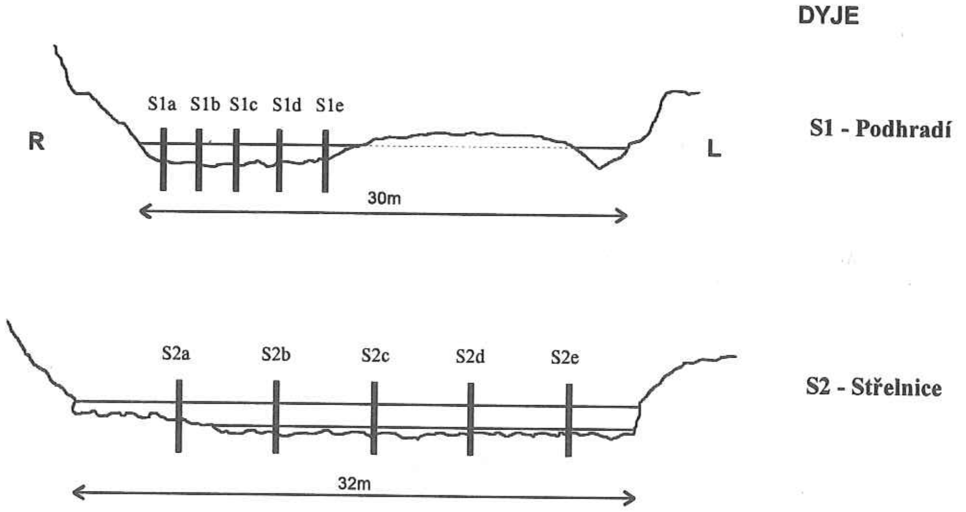


Fig. 3. Localization of sampling points for freezing corer in S1 and S2

Fish were studied using semiquantitative electrofishing (pulsed current 220-260 V; 0.6 – 1.0 A). They were caught by the system of a line with 6 m diameter at one passage. Altogether 12 line catchings were carried out, the length of the lines was 80 - 260 m. Then, bottom tenant nets were used with mesh size 17 - 60 mm, in weir reservoirs and optionally in pools under dam and bigger weirs. Overall, 5 catchings at 3 profiles between 1991 and 1994 were done.

Sampling and other observations were carried out between 1993 and 1995 so that the spring, summer and autumn conditions of the bottom biota at individual sections of the stream were observed. Samples of benthos and fish could be gathered only during low flow during the operation break of the hydropower station.

Evaluations methods

Quantitative data on abundance of zoobenthos at sections of the stream below the dam was considered as specific or ecological density (ODUM 1977) since sampling was not carried out during high discharge (that is over 45 cm depth). Ecological indexes were evaluated according to basic textbook of ecology (ODUM 1977) and methodical monographs (BOWER et al. 1990).

Higher plants, macrozoobenthos and fish were determined up to the species level if possible. Only in specified cases (impossible determination of larval stages), determination was carried out only to the level of genera or families. All results were recorded in absolute numbers of found species.

The results were analyzed by software ECOLSTAT (LUDWIG & REYNOLDS, 1988), TWINSPAN (HILL 1979) and CANOCO (TER BRAAK 1988, TER BRAAK & ŠMILAUER 1998) and SPSS 7.0 (1998).

Remarks

In the next chapter "Results", you can find results that had not been complexly published in the paper by HELEŠIC et al. (1998). Groups of phytobenthos and meiobenthos are evaluated in different parts of this monograph.

RESULTS

Hydrological conditions

The flow regime downstream the reservoir (S1-Podhradí) is natural, this means that it is influenced by actual hydrological flow and meteorological situation. The primary sign of regime below reservoirs is smaller differences between minimal and maximal flows. The flow regime of 1991-1994 is depicted on Fig 4.

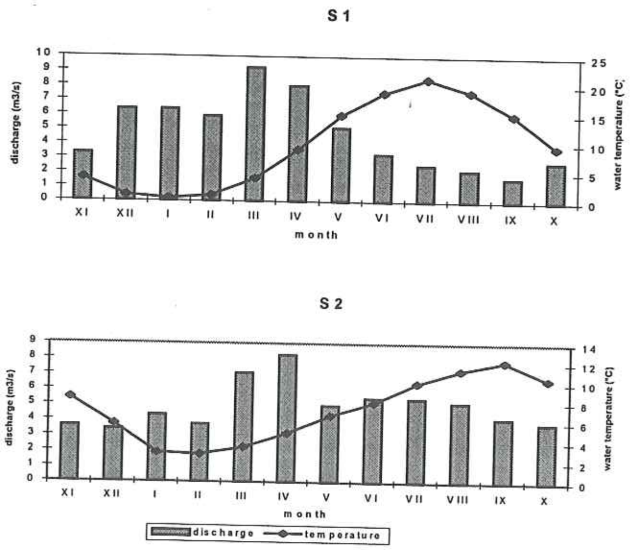


Fig. 4. Mean monthly discharges and water temperature at the sites above (S1) and below (S2) the Vranov Reservoir

The main characteristics of the flow regime in the studied profile S2 (4 km below the dam) are shown in Tab 3. The hydropower plant peaking regime lasts from 6 to 10 a.m. and 6 to 10 p.m. This regime is typical for most of the hydrological year.

Tab. 3. Regulated flow in the influenced stretch of the Dyje River - profile S2

Duration of minimal flow (acc. 1.2 $m^3.s^{-1}$)	11 – 12 hrs.
Duration of maximal flow (16 - 46 $m^3.s^{-1}$)	3 - 4 hrs.
Duration of increasing of water level	- 1 turbine .... 50 - 60 min.
	- 2 turbine .... 30 min.
Duration of decreasing of water level	- 1 turbine .... 150 min.
	- 2 turbine .... 170 min.

During time with sufficient amount of water and higher flows, the plant operates in the regime of 2 or 3 turbines (Figs. 5, 6, 7, 8) with different combinations during the year. During extremely high flows (snow melting and high rainfall), the plant works in a regime with 3 turbines for longer periods of time (typically 24 hrs altogether) exceptionally several days in a row. Maximal flows are then up to 50 $m^3.s^{-1}$.

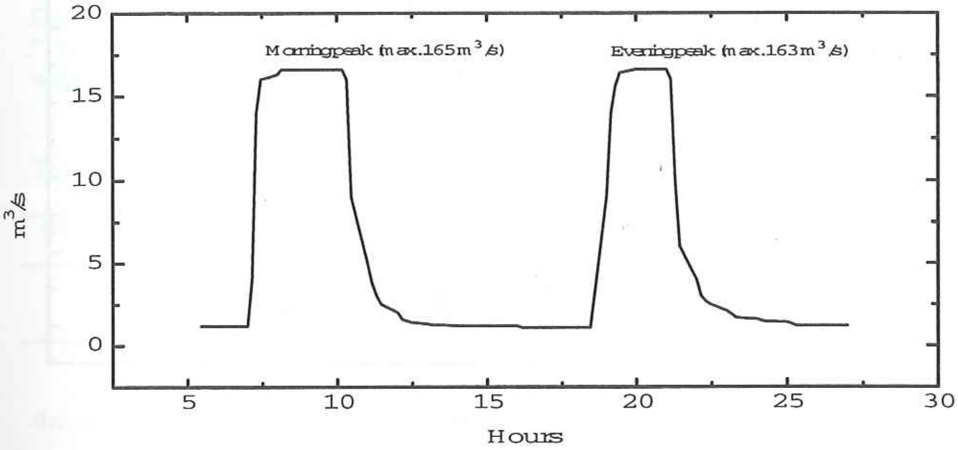


Fig. 5. One day flow regime in S2 – one turbine processing (autumn).

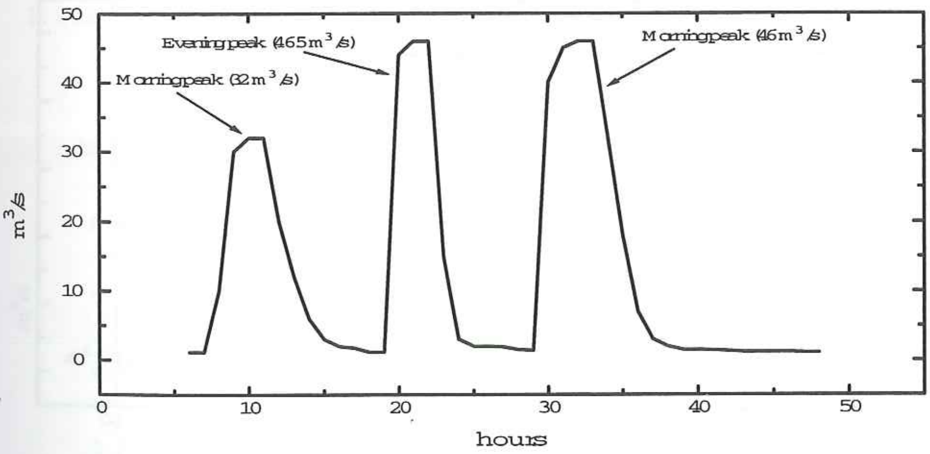


Fig. 6. Two days flow regime in S2 – two and three turbine processing (spring).

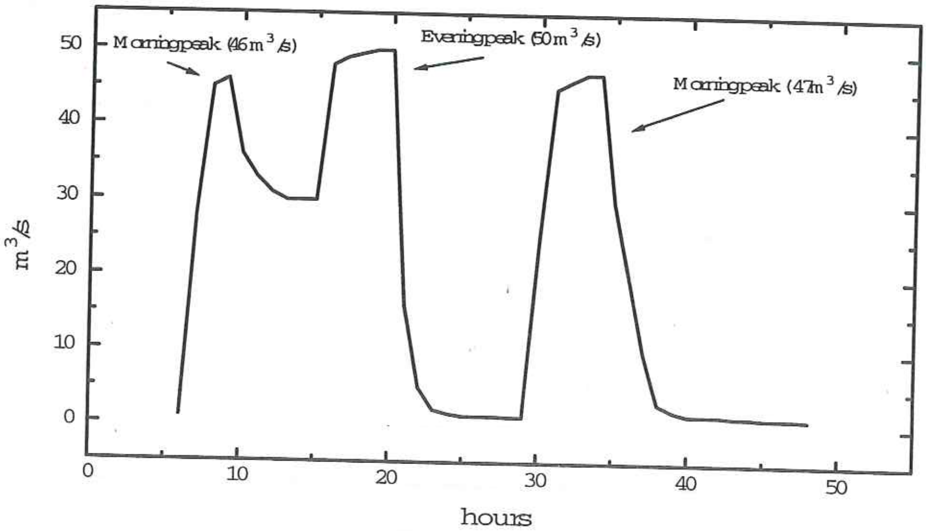


Fig. 7. Two days regime in S2 – three and two turbine processing (spring)

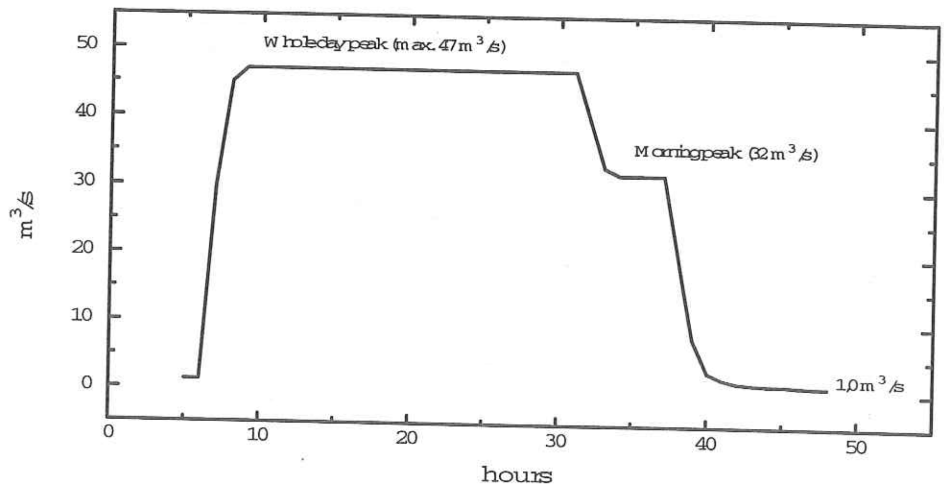
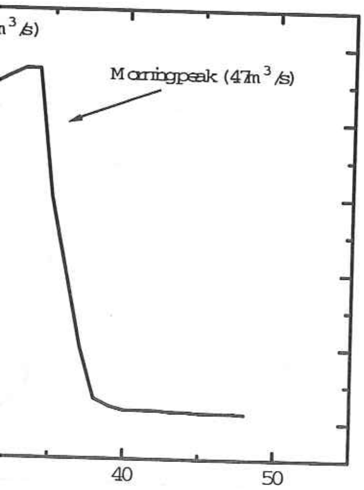
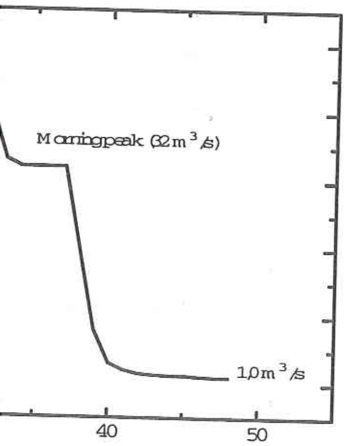


Fig. 8. Two days flow regime in S2 – whole day three turbine processing (spring- extremely high discharge)



processing (spring)



ree turbine processing (spring-

Water for the turbines supplying is collected from the depth of 40 m, which is from hypolimnion. The discharge from the reservoir is completely closed between peaks. The Formoza weir, with a capacity of 60.000 m^3 with a regulated discharge of 1.0 $m^3.s^{-1}$, was built in Vranov to partially equalize the peaking wave and to maintain a minimal flow in the river between the peaks. The volume of the empty weir is filled up within 60 min from the time of flow renewal. After the weir is filled, water spills over the top and the peaking wave travels all the way to the Znojmo reservoir. If the flows are increased, there are visible changes in average flow velocities and other hydraulic parameters (Tab. 4). From the table it is clear that erosion abilities of water (shear stress) as well as water turbulence increase.

Tab. 4. The main hydrological and hydraulical parameters in profile S2

No. of turbine	Rel. depth (cm)	Discharge ($m^3.s^{-1}$)	Current velocity ($m.s^{-1}$)	Boundary Reynolds No.	Shear stress ($dyn.cm^{-2}$)
0	15	1.2	0.3	10.5	413
1	55	16	0.9	21.8	1515
2-3	70	31-46	1.5	34.8	1928

It takes 60 min. for the peaking wave to reach site S3-Hardegg when the discharge is 16 $m^3.s^{-1}$, and decrease of the flow to 1,8 $m^3.s^{-1}$ takes about 450 min.

It takes between 60 to 90 min. for the wave to reach site S4 – Papírna. At the profile S4, the wave flattens and its time duration and maximal discharge depends on the length of operation and the number of turbines. During regular operation of one turbine, the maximal flow is up to 10 $m^3.s^{-1}$ (Fig. 9). During longer operation of more turbines, the peaks are elongating and maximal flows are 28 $m^3.s^{-1}$ to 47 $m^3.s^{-1}$(Figs. 10, 11). Minimal flow between the peaks decreases to 2.2 and even 1.8 $m^3.s^{-1}$.

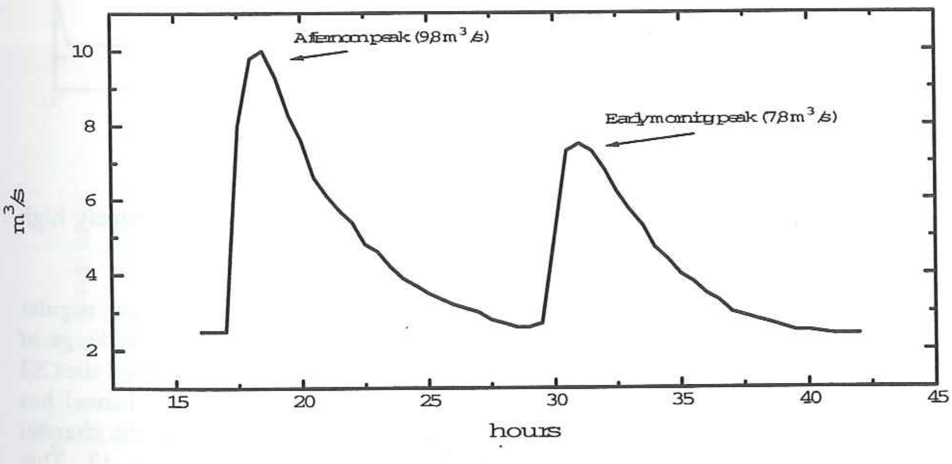


Fig. 9. One day flow regime in S4 – one turbine processing (autumn)

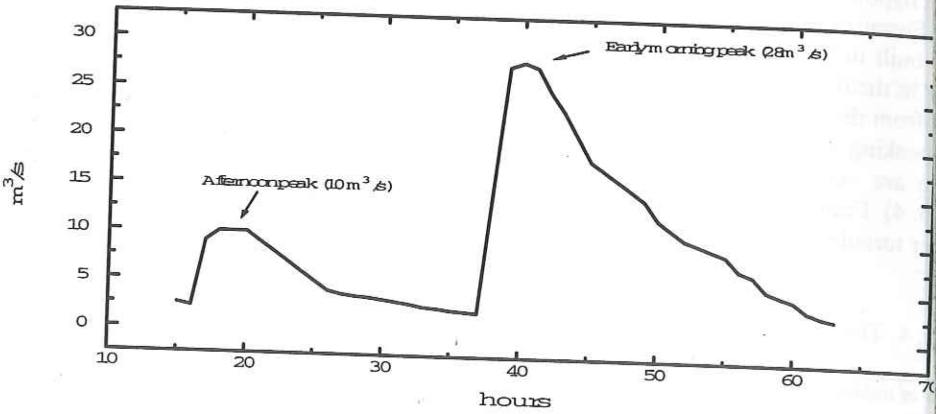


Fig. 10. Two days flow regime in S4 – one and two turbine processing (spring).

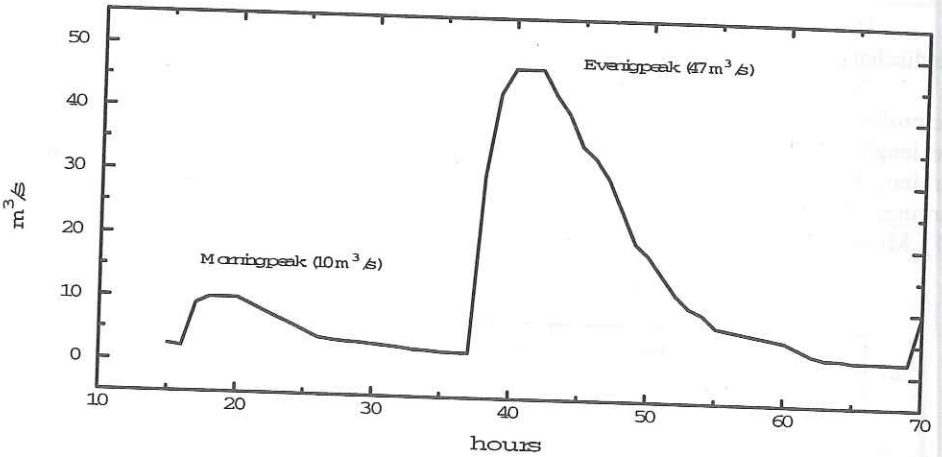
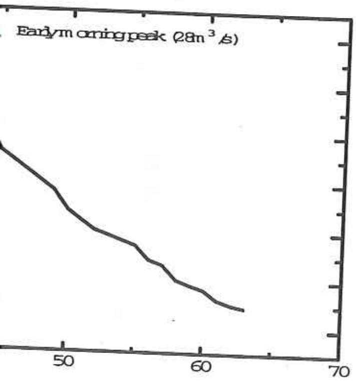


Fig. 11. Two days flow regime S4 – one and three turbine processing (extremely high discharge in spring)

Comparison of time course of the waves and maximal flows during regular operation is depicted at Fig .12. Wave flattening and successive filling and discharge of water cause a decrease of maximal flows from the river basin and weirs between sites S3 and S4. At this part of the channel, there are several older weirs and the channel has a larger volume capacity than at the site S2. However, total volume flow in the channel is kept what can be extracted from the areas of individual peaks at Fig. 12. This unnatural flow regime influences over 30 km of the river downstream the dam.



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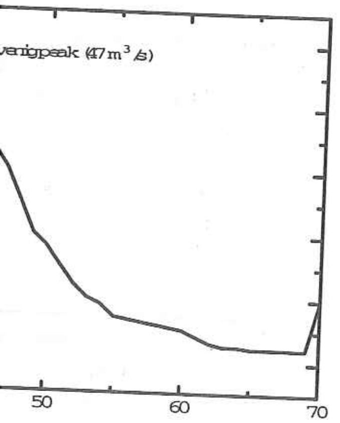

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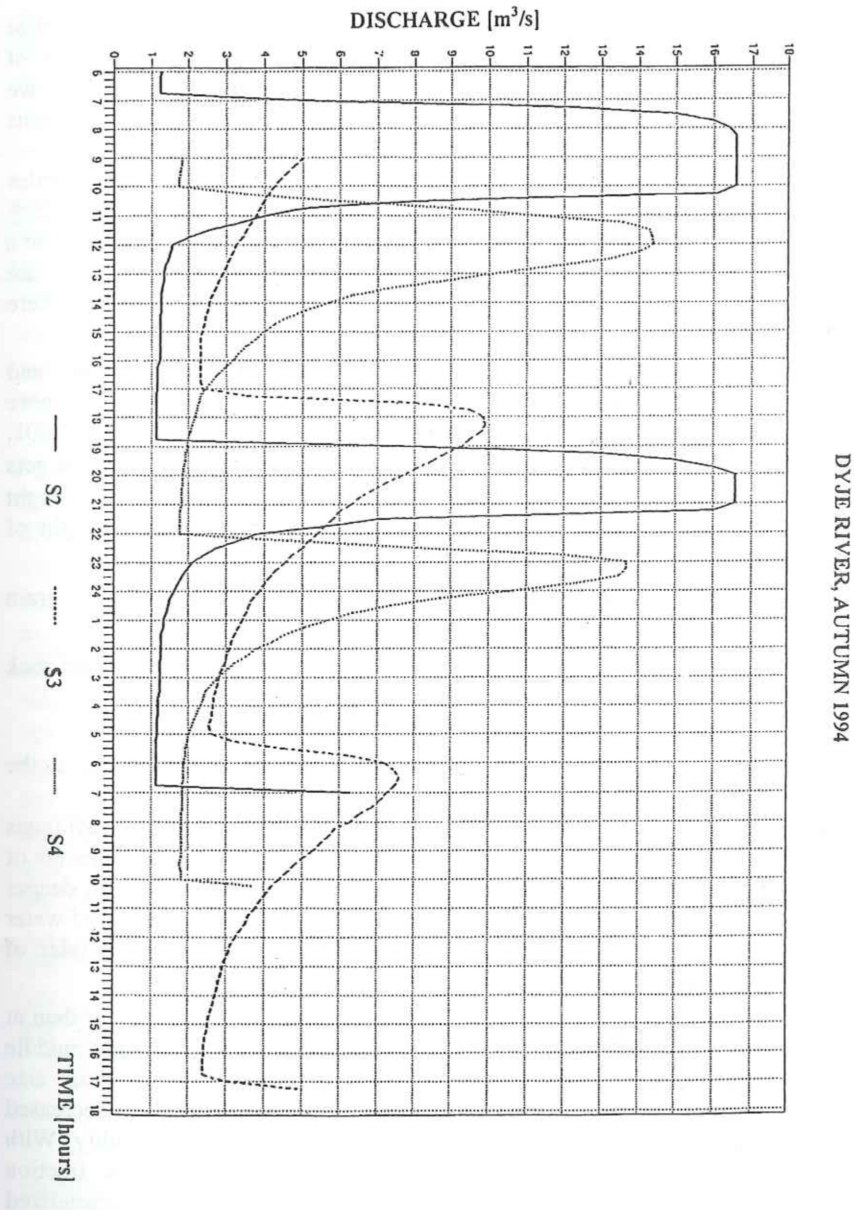


Fig. 12. Daily wave – movement variation at downstream sites S2 – S4

Bottom substrate conditions

Granulometry is a basic measurement that lets us to assume several properties of the sediment. The most common representation of the granulometry is a curve of grain size structure of the bottom material. From the position and shape of the curve, we can detect the porosity, grain parity and also the prevailing size fraction of the grains (HYNIE 1961).

Another characteristics of sediments are quartiles (MÜLLER 1964). Quartiles are points on the grain size curve: quartile 25% (Q_{25}) is a point on the curve where 25% of the total is smaller than the size of the grains found at this point, median (Md) is a value of average size of the grains where 50 % of the grains are coarser and 50% are finer than the size of the grains at this point, and quartile 75% (Q_{75}) is a point where 75% of total are smaller than the size of the grains at this point.

Sorting coefficient So is a statistical parameter coming from quartiles and expressing the rate of the number of grain size classes found in the sediment. The more grain size classes there are in the mixture, the higher the value of So is. So = Q3/Q1. Humidity of sediment ω is a momentary content of liquid water in the sediment that gets out when the temperature is raised to 105 ^{0}C ω = Gv/Go * 100%, where Gv is the weight of water (Gv = Gs - Go), Go is the weight of dry sediment and Gs is a weight of naturally watered sediment (HYNIE 1961).

% > 1 mm is % ratio of the weight of a fraction of the sediment with the grain size smaller than 1 mm to the total weight of the sediment Go.

Porosity is a ratio of the volume of the hollows to the total volume of the rock expressed in % .

Porosity = (Gv/1g.cm^{-3}) / (Go/2,6g.cm^{-3} + Gv/1g.cm^{-3}) * 100%

Grain curves of individual layers of the bottom at both profiles are at the Fig. 13 a-b. Results of granulometric analyses are at Tab. 5.

From the graphs of grain size curves it is obvious that at the site Podhradí (sites S1b and S1c) there is a sandy up to gravel-sandy bottom. Higher layers of sediments of the bottom 0 - 10 (20) cm are formed by 65% of fine gravel and 20% sand. In deeper layers of the bottom (20-60 cm), porosity increases (up to 95%) and the amount of water in sediment (up to 88%) in connection to the high amount of fine sediments (size of grain up to 1 mm) form about 70-90% of dry matter weight.

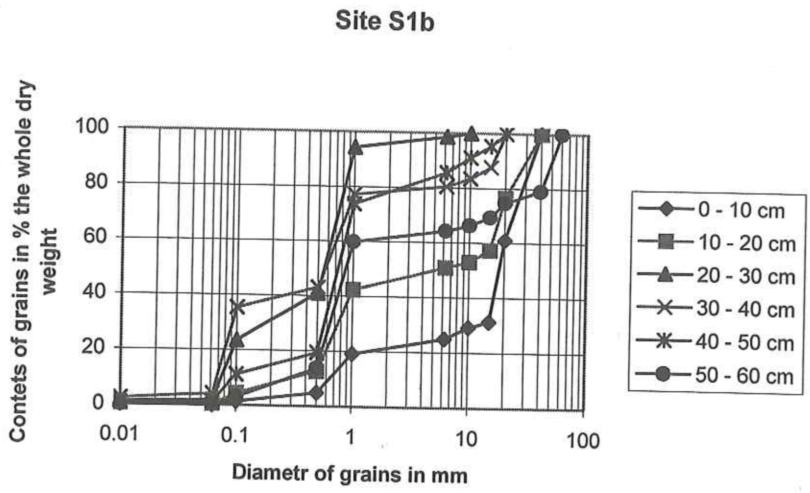
At the site Střelnice (sites S2b and S2d), the sediment is clearly coarser than at the site Podhradí. It is formed by coarser sand, but there are also finer and middle fractions of gravel and cobbles over 10 cm in diameter. Presence of this grain size (above 100 mm) in several layers influenced the shape of the grain size curve, decreased the value of the sorting coefficient as well as the value of porosity or humidity. With increasing depth, even at this site the sediments gets finer (the volume of the fraction below 1mm increases). Overall, at the site S2, the bottom sediments can be characterized as heterogeneous and sufficiently porous.

Statistical comparison of the bottom substrates (when median of the grain size and porosity were considered) showed a significant difference for the periodically flooded river bottom of the above the reservoir and below the reservoir (particle size $t = 3.06$, $p = 0.028$; porosity: $t = 4.54$, $p = 0.006$). In the streamline, there was a statistically significant difference between the porosity of the substrate in both followed sections ($t = 4.18$, $p = 0.009$). In the median of the particle size, the difference was insignificant ($t = -1.65$, $p = 0.16$).

Tab. 5. Basic characteristic of bottom sediments

Site	Depth Layer cm	Q_{25}	Md	Q_{75}	So	% > 1 mm [%]	Max. grain size [mm]	Gs [g]	Go [g]	Gv [g]	w [%]	Porosity [%]
S1b	0 - 10	6.40	18.00	28.00	4.4	19.12	40	575.3	439.3	136.0	23.64	44.60
S1b	10 - 20	0.67	5.30	26.00	38.8	42.28	40	891.0	712.0	179.0	20.09	39.53
S1b	20 - 30	0.12	0.57	0.78	6.7	94.48	10	602.0	292.0	310.0	51.50	73.41
S1b	30 - 40	0.09	0.58	0.95	11.0	77.37	20	333.0	84.0	249.0	74.77	88.52
S1b	40 - 50	0.32	0.69	1.20	3.8	73.86	20	563.0	403.0	160.0	28.42	50.79
S1b	50 - 60	0.59	0.87	21.00	35.6	59.93	60	1444.0	1183.0	261.0	18.07	36.45
S1c	0 - 10	0.98	19.00	28.00	28.6	26.05	40	478.0	360.0	118.0	24.69	46.01
S1c	10 - 20	0.56	0.72	0.92	1.6	83.81	15	502.0	364.0	138.0	27.49	49.64
S1c	20 - 30	0.55	0.73	0.95	1.7	80.47	20	374.0	236.0	138.0	36.90	60.32
S1c	30 - 40	0.13	0.54	0.75	5.8	96.55	10	182.0	73.7	108.3	59.51	79.26
S1c	40 - 50	0.20	0.57	0.77	3.9	96.01	15	342.5	205.2	137.3	40.09	63.50
S1c	50 - 60	0.26	0.62	0.81	3.1	93.61	15	438.4	119.7	318.7	72.70	87.38
S1c	60 - 70	0.54	0.70	0.91	1.7	80.44	10	367.0	45.0	322.0	87.74	94.90
S2b	0 - 10	11.00	18.80	45.00	4.1	6.00	60	2175.0	1751.0	424.0	19.49	38.63
S2b	10 - 20	19.00	44.00	51.00	2.7	12.85	100	5853.0	5444.0	409.0	6.99	16.34
S2b	20 - 30	0.84	16.50	42.00	50.0	29.79	60	2275.0	1954.0	321.0	14.11	29.93
S2b	30 - 40	32.00	70.00	83.00	2.6	11.07	100	6157.0	5781.0	376.0	6.11	14.46
S2b	40 - 50	0.85	18.70	75.00	88.2	29.07	100	4877.0	4414.0	463.0	9.49	21.43
S2b	50 - 60	13.30	62.00	85.00	6.4	18.30	100	2335.0	2077.0	258.0	11.05	24.41
S2d	0 - 10	7.75	18.70	27.50	3.5	18.74	40	499.5	399.9	99.6	19.94	39.30
S2d	10 - 20	44.00	57.00	76.00	1.7	8.07	100	4359.0	4122.0	237.0	5.44	13.00
S2d	20 - 30	0.59	1.70	17.00	28.8	47.95	40	1225.0	977.0	248.0	20.24	39.76
S2d	30 - 40	0.52	1.15	16.00	30.8	49.50	40	1272.0	1020.0	252.0	19.81	39.11
S2d	40 - 50	0.40	1.20	17.50	43.8	49.44	40	1938.0	1623.0	315.0	16.25	33.54
S2d	50 - 60	19.50	52.00	72.00	3.7	12.94	100	3445.0	3231.0	214.0	6.21	14.69

Composition of substrate is influenced not only by physical impacts such as porosity, heterogeneity, current velocity, but also substrate composition is effected by accumulation of particulated matter (LEICHTFRIED 1985, 1995). From the point of view of physical interactions, granulometric composition of sediments is important especially for macrozoobenthos (UVÍRA 1997). Many scientists agree that sand is least suitable for macrozoobenthos, while fine gravel is the most suitable (UVÍRA 1997, HYNES 1970, KUBÍČEK et al. 1971).



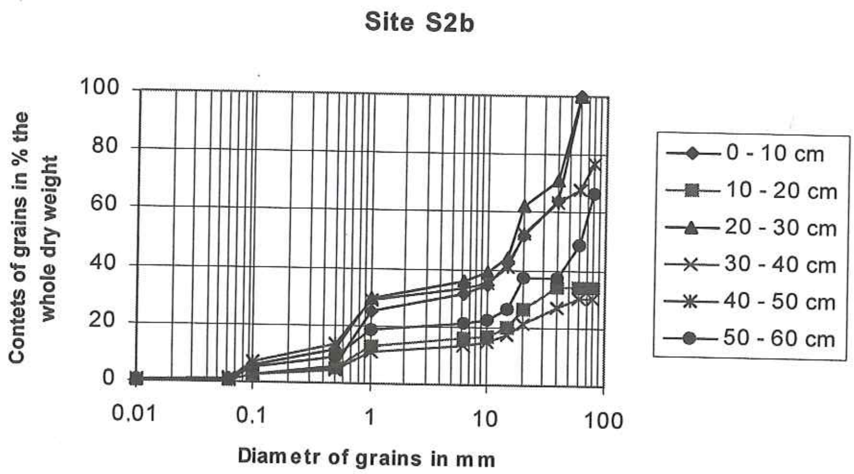


Fig. 13. a,b. The curve of grain size in sampling layers in river channel zone

Total organic carbon (C org.) has a different content and vertical distribution at both sites (Fig. 14).

Site Podhradí is localized in a natural slowly flowing lower part of the stream where sedimentation of fine detritus, branches as well as fine inorganic particles. Higher amount of C org. in the layer 30 - 40 cm of site S1b and in the deepest layer S1c is connected to the higher accumulation of detritus and woody debris. The reason is a slower decay in anaerobic conditions and a very low density up to absence of consumers.

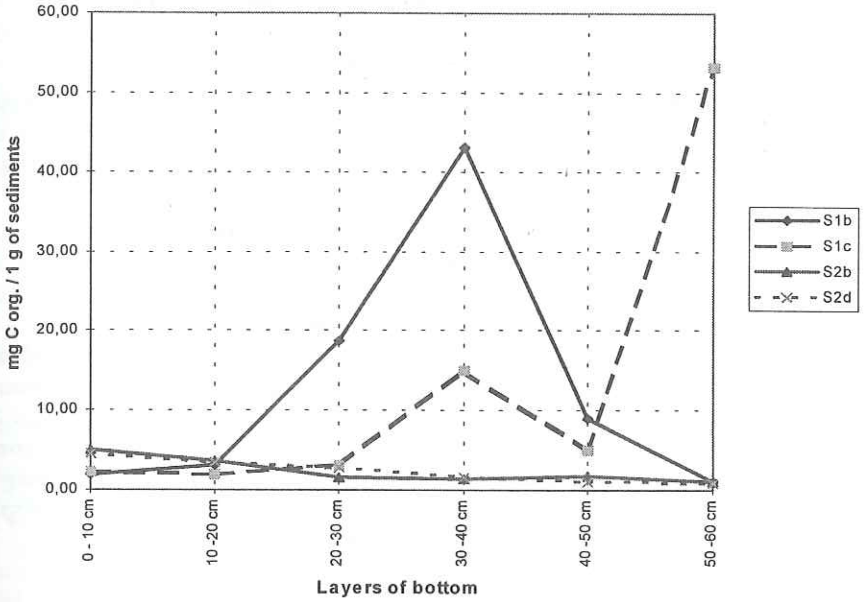


Fig. 14. Total contents of C org. in bottom layers in sampling site S1 (Podhradí) and S2 (Hamry – Střelnice)

At the site Střelnice, the amount of total organic carbon is lower. Maximal amount of C org. was described in the layer 0 - 10 cm; it decreases with depth. Rich tufts of the moss *Fontinalis antipyretica* and filamentous algae (*Cladophora* sp.) cover the upper layer of sediment. It is possible to assume that the amount of C org. in the upper layer is mostly caused by sampled growth of mosses and detritus caught in the tufts of macrophyts.

Thermal and hydrochemical regime

The temperature regime below the dam is very different (Fig. 4). There was a change of average year temperature and also a decrease of the amplitude of maximal and minimal temperatures. Above the reservoir, the water temperature fluctuates from 0 to 23°C near the water surface, while below the reservoir at the site S2 it is 2 to 14°C. The first ice scouring events occur solely at the site S4 and only during extremely cold winters. The temperature oscillates between 0 to 16°C here. In the most influenced part of the river (S2), the average water temperature is 1 to 1.5°C lower.

The hydrochemical parameters were partially obtained from the Water Research Institute TGM, branch Brno (KOČKOVÁ 1993) and our measurements were added (Tab. 6. to 9.). At the influenced part of the river, the hydrochemical regime is very different particularly in the parameters of oxygen and nutrition content.

At the site Podhradí (S1), the water showed high oxygen content. Lower ranges of dissolved oxygen concentrations were found in January 1992 and May 1994, while the highest values were found in July and August, but also in March 1994. The values of BOD and COD were obtained only in 1992. They varied from 1.4 to 9.44 $mg.l^{-1}$, while balanced values ranged from 0.25 - 14.61 $kg.d^{-1}$. The values of COD showed scatter from 4.2 to 16.2 $mg.l^{-1}$. Organic pollution level calculated according to these parameters was at the worse site of beta-mesosaprobity. The ammonium ion content ($N\text{-}NH_4^-$) ranged from 0.05 to 0.45 $mg.l^{-1}$ in 1992 and 0.21 to 0.26 $mg.l^{-1}$ in 1994; it is good for cleaner saprobic degrees. The nitrate concentration ($N\text{-}NO_3^-$) was higher ranging from 0.88 to 11.65 in 1992 and 2.75 to 7.5 $mg.l^{-1}$ in 1994. The total inorganic phosphorus content varied from 4 to 94 $\mu g.l^{-1}$, respectively from 55 to 127 $\mu g.l^{-1}$.

Tab. 6. The basic hydrochemical variables of water - Podhradí (S1)

Variable/Year	1992			1994		
	min.	median	Max.	min.	median	max.
pH	7.37	7.67	9.21	7.47	8.39	9.60
Conductivity ($\mu S.cm^{-1}$)	229	294	373	278	313	318
Oxygen ($mg.l^{-1}$)	9.17	11.05	13.66	6.90	13.56	17.35
Saturation (%)	87.7	96.8	110.5	66.4	78.5	107.7
$N\text{-}NH_4^-$ ($mg.l^{-1}$)	0.05	0.19	0.45	0.21	0.26	0.3
$N\text{-}NO_3^-$ ($mg.l^{-1}$)	0.88	2.94	11.65	2.75	4.63	7.5
P inorg. ($\mu g.l^{-1}$)	40.0	94.0	280.0	55.0	127.5	250.0
BOD (mg $O_2.l^{-1}$)	1.44	3.98	9.44	-	-	-
COD (mg $O_2.l^{-1}$)	4.2	7.05	16.6	-	-	-

Site S2 Střelnice is influenced by water outflow from the hypolimnion of the reservoir. In lower layers of saturation, the influence of this water is obvious (52.9 %). Oversaturation was found in period of intensive growth of submerged plants (*Fontinalis antipyretica, Batrachium fluitans).* The BOD values ranged from 1.39 to 4.03 $mg.l^{-1}$, and COD values from 2.9 to 6.8 $mg.l^{-1}$. The BOD balanced values varied from 0.72 to 3.89 $kg.d^{-1}$; they were at the level of beta-mesosaprobity to oligosaprobity.

The dissolved ammonia ions content in nutrients decreased, while the nitrogen content in nitrates increased. Inorganic phosphorus content as well as the scatter of values decreased.

Profile Hardegg (S3) is situated below the confluence with Fugnitzbach that carries a higher amount of particulate matter to the River Dyje. The hypolimnic water here less influences the oxygen regime of the Dyje; saturation ranged from 58.9 to 108.4 % what are usual values for this river order. Oversaturation is caused by massive growth of filamentous algae on the crest of weir and intensive growth of macrophyta (*Fontinalis antipyretica, Batrachium fluitans*). Nitrogen in ammonia is present in lower concentrations than at the previous profile, while the nitrogen in nitrate increases, and the phosphorus concentration is the same. The BOD values slightly increased what might be caused by higher pollution of the Dyje from the confluence or pollution from the village.

Tab. 7. The basic hydrochemical variables of water – Hamry Střelnice (S2)

Variable/Year	1992			1994		
	min.	median	max.	min.	median	max.
oH	6.97	7.56	7.95	7.0	7.98	8.57
Conductivity ($\mu S.cm^{-1}$)	259	305.5	327	326	337	350
Oxygen ($mg.l^{-1}$)	7.4	10.59	13.48	5.65	7.69	13.98
Saturation (%)	65.2	90.2	102.6	52.9	66.37	106.1
$N\text{-}NH_4^-$ ($mg.l^{-1}$)	0.08	0.18	0.54	0.10	0.16	8.0
$N\text{-}NO_3^-$ ($mg.l^{-1}$)	1.74	6.72	9.08	0.12	5.13	8.0
P inorg. ($\mu g.l^{-1}$)	9	58.5	136	50	85	245
BOD ($mg\ O_2.l^{-1}$)	1.39	2.19	4.03	-	-	-
COD ($mg\ O_2.l^{-1}$)	2.9	4.75	6.8	-	-	-

Tab. 8. The basic hydrochemical variables of water – Hardegg (S3)

Variable/Year	1992			1994		
	min.	median	max.	min.	median	max.
pH	7.22	7.7	7.89	7.25	8.07	8.3
Conductivity ($\mu S.cm^{-1}$)	261	295.5	324	325	345	403
Oxygen ($mg.l^{-1}$)	9.29	11.83	9.29	6.82	9.3	13.78
Saturation (%)	79.4	99.4	108.4	58.97	81.29	104.95
$N\text{-}NH_4^-$ ($mg.l^{-1}$)	0.05	0.12	0.28	0.10	0.14	0.19
$N\text{-}NO_3^-$ ($mg.l^{-1}$)	2.89	6.40	9.35	4.0	6.75	8.0
P inorg. ($\mu g.l^{-1}$)	13	56.5	91	50	85	245
BOD ($mg\ O_2.l^{-1}$)	1.21	2.56	4.10	-	-	-
COD ($mg\ O_2.l^{-1}$)	2.9	5.15	6.00	-	-	-

The last followed profile Papírna (S4) is characterized by a standard oxygen regime. Nutrients are decreased of primary production utilization. The weir reservoirs are covered with rich growth of *Elodea canadensis* and other higher plants, while in the stretches of running water there is a rich growth of *Cladophora glomerata* and *Fontinalis antipyretica.*

Tab. 9. The basic hydrochemical variables of water – Papírna (S4)

Variable/Year	1992			1994		
	min.	median	max.	min.	median	max.
pH	7.39	7.79	7.93	7.75	7.90	8.28
Conductivity ($\mu S.cm^{-1}$)	275	307.5	327	323	342	354
Oxygen ($mg.l^{-1}$)	9.40	11.26	13.81	6.70	8.00	13.96
Saturation (%)	78.4	95.5	102.2	58.7	74.62	108.3
$N-NH_4^-$ ($mg.l^{-1}$)	0.07	0.10	0.23	0.10	0.14	0.19
$N-NO_3^-$ ($mg.l^{-1}$)	2.76	6.07	9.06	4.0	6.75	8.0
P inorg. ($\mu g.l^{-1}$)	6	65	143	50	85	245
BOD ($mg\ O_2.l^{-1}$)	1.21	2.30	4.61	-	-	-
COD ($mg\ O_2.l^{-1}$)	3.0	5.05	7.20	-	-	-

The course of median of temperature in the longitudinal profile (Fig. 15) was different in 1992 and 1994. Overalls, 1994 was a warmer year with longer time of minimal flows above the reservoir. So, there was a marked change of median of temperatures to higher values. Decrease of temperatures was considerably steeper and from the site, S3 there was a warming of water. In colder year of 1992, the temperature medians at the sites S3 and S4 were very similar.

The course of pH values in the longitudinal profile of the river was stable. A slight increase was found at the site S3. Water is contained in the weirs of Hardegg and especially the influence of the right-sided tributary Fugnitzbach is obvious.

Medians of water conductivity in the longitudinal profile show an expected trend. However, higher differences at the site S3 were found caused by above-mentioned influences of the weirs and the tributary Fugnitzbach.

Water saturation by oxygen significantly decreases below the reservoir at the site S2 (Fig. 16). At the site S3, there is a profound increase of oxygenated water caused by assimilation activity of autotrophs in the vegetation season (see above site S3). We measured the oxygen content twice at the site from the reservoir dam to the site S3. The entire part of the stream up to the site S3 is influenced by a different oxygen regime. In the pools under dam, we detected only 35 – 50% oxygen saturation of water. At the beginning of the vegetation season, when the algal growths at the bottom have not fully colonized free niches, the oxygen saturation is gradual. However, in June, during the full assimilation activity of the growth, especially of the filamentous algae, the oxygen saturation is quicker and in about 3.5 km, the situation is more or less normal.

The course of medians of COD and BOD values in 1992 is depicted in graphs - Fig 17. COD values decrease over the stream of the followed longitudinal profile with a clear jump between sites S3 and S4. The value of median BOD has a similar trend with rowth of *Cladophora glomerata* and

– Papírna (S4)

	1994	
min.	median	max.
7.75	7.90	8.28
323	342	354
6.70	8.00	13.96
58.7	74.62	108.3
0.10	0.14	0.19
4.0	6.75	8.0
50	85	245
-	-	-
-	-	-

e longitudinal profile (Fig. 15) was
warmer year with longer time of
s a marked change of median of
tures was considerably steeper and
older year of 1992, the temperature

al profile of the river was stable.
contained in the weirs of Hardegg
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itudinal profile show an expected
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m the reservoir dam to the site S3.
nced by a different oxygen regime.
% oxygen saturation of water. At
al growths at the bottom have not
gradual. However, in June, during
cially of the filamentous algae,
m, the situation is more or less

es in 1992 is depicted in graphs -
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a slight increase of values at the site S3 caused by Fugnitzbach tributary, while the decrease at the site S4 is more evident.

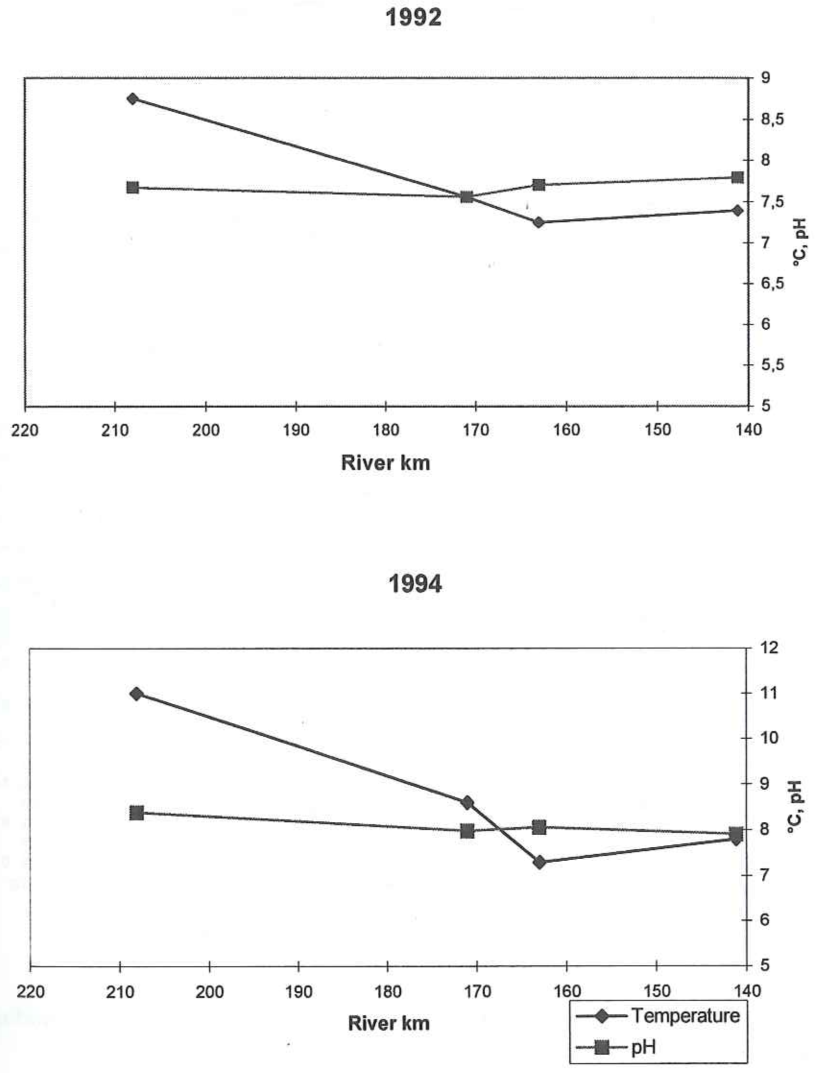

Fig. 15. Water temperature and pH in the longitudinal profile of the Dyje River

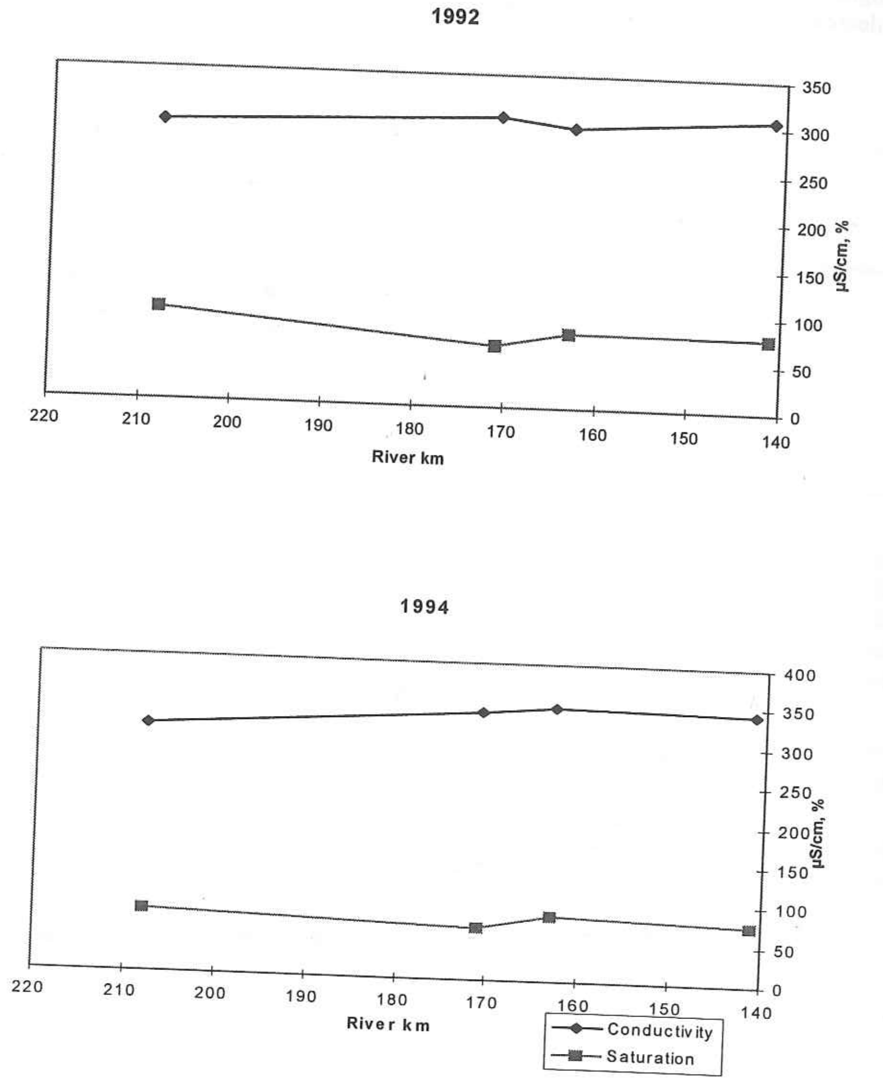

Fig. 16. Specific conductivity and oxygen saturation of water in the longitudinal profile of the Dyje River

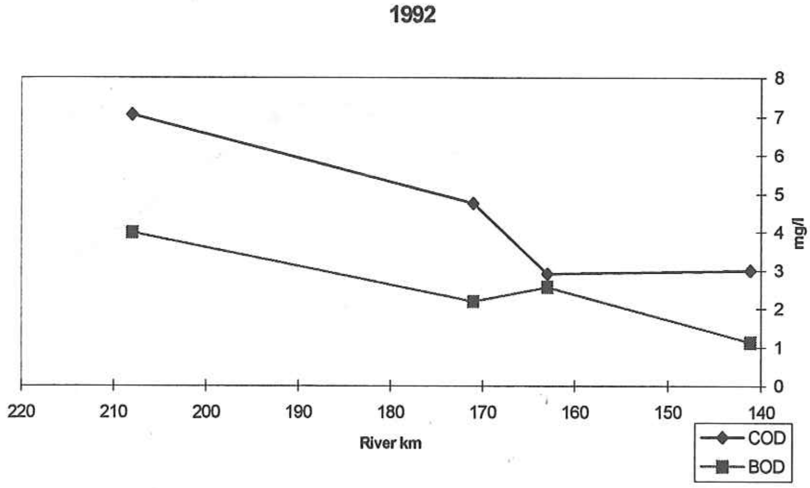

Fig. 17. COD and BOD of water in the longitudinal profile of the Dyje River

Concentration of ammonium nitrogen in water of the river Dyje in the followed part declines from the site above the reservoir up to the profile Papírna S4. More significant changes of concentration and faster decreases were found especially at the sites S2 and S3 where the 1994 curve copies the course of the temperature curve very well ($t = 7.56$; $F = 57.18$, $p = 0.017$). Nitrate nitrogen does not show such a clear trend. In 1992, the curve of the median is (statistically insignificant) inverted to the curve of medians of concentrations $N\text{-}NH_4^-$ ($t = -1.018$; $F = 1.035$; $p = 0.416$). In 1994, the highest concentrations of $N\text{-}NO_3^-$ were found at the site S3 and gradually decreased. Above the reservoir, there were lower concentrations.

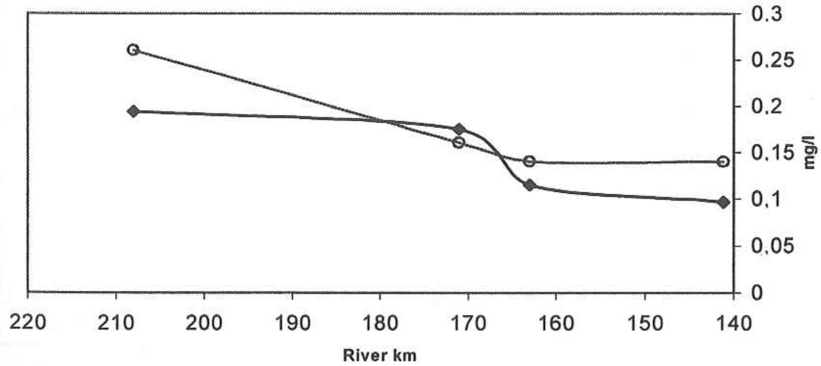

Fig 18. $N\text{-}NH_4^-$ contents in water in the longitudinal profile of the Dyje River (black box 1992, shadow circle 1994)

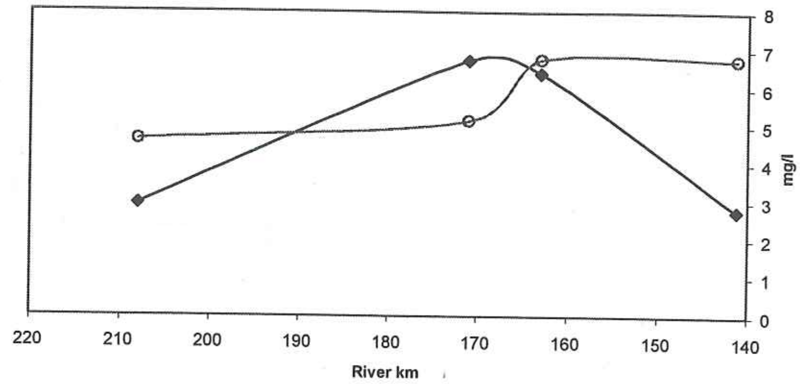

Fig.19. N-NO_3 contents in water in the longitudinal profile of the Dyje River (black box 1992, shadow circle 1994)

The velocity of change of physical-chemical parameters of water at the beginning and end of the peaking wave is a very specific problem. Measurements were done at the site S2, and they were related to the relative depth measured by the watermeter and time. Four measurements of the beginning and one of the end of the wave were carried out. Fig. 20. shows the trends of measured parameters of the morning peaking wave (around 7 a.m. at the studied profile). The graphs show visible changes between values of dissolved oxygen and pH.

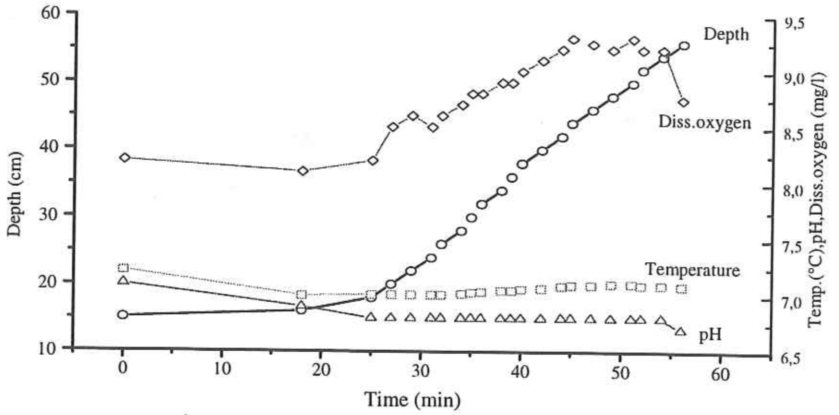

Fig. 20. Variations of some parameters with flow stage changes (increasing discharge) 7 – 8 a.m. – June 1994 – S2

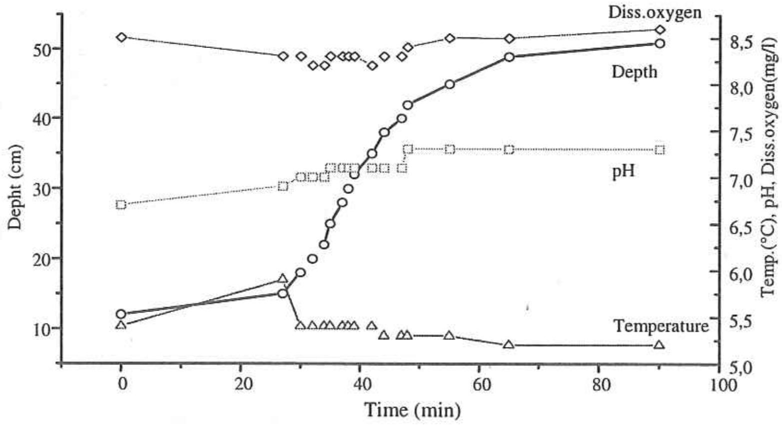

Fig. 21. Variations of some parameters with flow stage changes (increasing discharge) 7 – 8 p.m. – April – S2

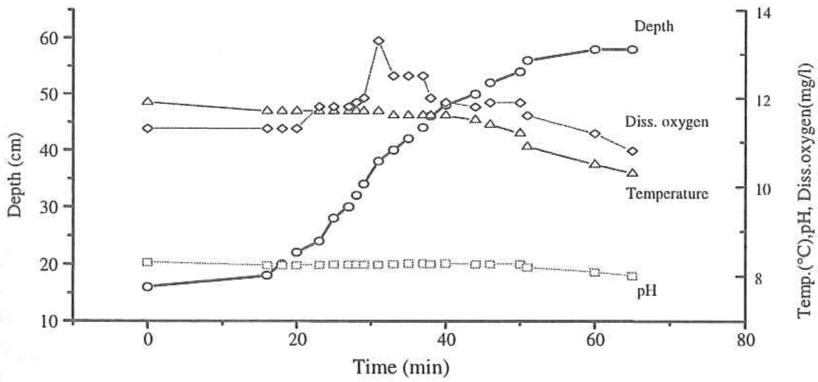

Fig. 22. Variations of some parameters with flow stage changes (increasing discharge) 7 – 8 p.m. – June – S2

Figs 21., 22., 23. show the same trends for the evening peaking wave (usually around 7 p.m.). Especially June values show a very different concentration curve of dissolved oxygen caused by relatively well oxygen-filled water in the hypolimnium of the reservoir, particularly the photosynthetic activity of primary producers in the Formoza weir and in the pools of the downstream profile. On contrary, in September, the hypolimnic water is strongly undersaturated, and the oxygen appropriation from the weir and the pools does not have an obvious influence.

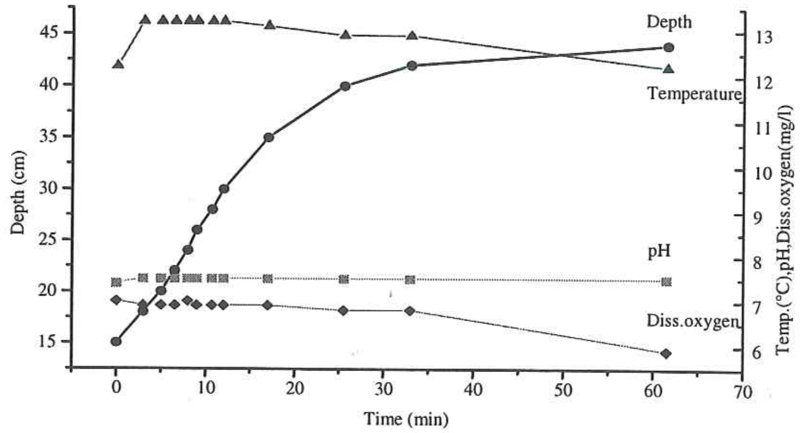

Fig. 23. Variations of some parameters with flow stage changes (increasing discharge) 7 – 8 p.m. – September, S2

The course of the decrease of the flow can be seen in Fig. 24. Slow warming of water and increase of oxygen concentration by more than 2.2 $mg.l^{-1}$ is apparent.

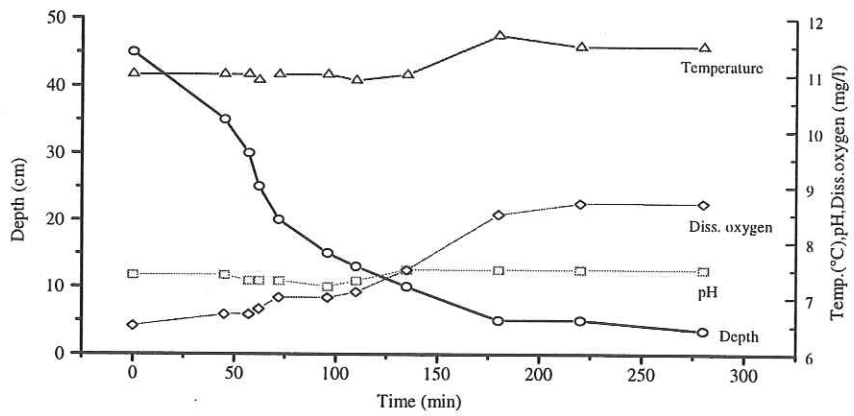

Fig. 24. Variations of some parameters with flow stage changes (decreasing discharge) 11 – 15 a.m. – September, S2

Aquatic macrophyts

(evaluated with the use of data and preliminary results of Š. Husák, Inst. Botany, CAS, České Budějovice).

In a natural barbell zone of the river upstream the Vranov reservoir, there are mostly *Potomageton crispus* and *Myriophyllum spicatum*. In the entire part of the flow below the reservoir, *Batrachium fluitans*, *Fontinalis antipyretica* and other species of moss were dominant. In winter and springtime, moss growth were dominant, while in summertime, tufts of *Batrachium fluitans* were found. In the cross section of the channel, the moss growths were localized in the permanently flooded part of the bottom (medial), while *Batrachium fluitans* colonized the daily drying part of the riverbed.

Species composition and distribution of macrophyts correspond to the environmental influences of the followed parts. In the Dyje upstream the reservoir (S1), rocky bottom with sandy substrate dominates; less fluctuating parts with finer sediments allow rooting of *Myriophyllum spicatum* and *Potamogeton crispus*, as their single island-like growth did not change during the studied period.

The part of the river downstream the reservoir (S2) is the most strongly influenced by short-term discharge changes; it is distinct by its high cover of growths of *Batrachium fluitans* and moss. Covering of *Batrachium* showed a decline from 25 % - 30 % to 10 - 15 % of the total area of the bottom throughout the year. This submerged species propagates only vegetatively because of annual low water temperature.

Higher covering of bottom was proved for moss (up to 50 % of the bottom) in the following range based on abundance: *Fontinalis antipyretica*, *Leptodictium riparium*, *Rhynchostegium riparioides* and *Chiloscyphus polyanthos*. Since the flow is changing, moss *Fontinalis* does not create typical long thallus but only very short accessions.

Phalaris arundinacea, *Veronica beccabunga* and *Cardamina amara* were also found in lower abundance especially in periodically drying parts of the channel.

The Dyje in Hardegg (S3). Natural high cover of the bottom by the genus *Batrachium* (40 - 50 %) declined throughout the study to 15 %. Next, relatively high abundances of moss *Fontinalis antipyretica* were found as well (up to 45 % of the total area of the bottom).

The last studied part of the Dyje downstream the reservoir (S4) showed a levelled cover of macrophyts permanently covering 15 - 30 % of the total bottom area. This condition testifies a somewhat declining impact of the reservoir on the flow.

At the bottom of the stream, submerged vegetation is an important space trap for suspended solids, a shelter place and also food source for benthic organisms.

Macroinvertebrates

Species structure, dominance and frequency of found species and the trophic affinity was studied in detail in work by HELEŠIC et al. (1998). In the present paper, we will concentrate only on characteristic groups and indicator species that had been found at the studied profiles of the river Dyje using standard methods as found in the chapter Material and Methods.

In the macroinvertebrates of the entire studied area, altogether 260 taxa were determined; found species and the frequency of their occurrence are listed in Appendix 1. Majority of taxa, 157 items, was found upstream the reservoir near Podhradí – S1 using the same sampling method and the same number of samples. This part of the river corresponds to the change from hyporhithral and epipotamal. Dominant groups of benthic species *Tubificidae*, *Ancylus fluviatis*, *Potamanthus luteus*, *Caenidae*, *Hydropsychidae* and *Orthocladiinae* also verified this change. Typical individuals from potamal parts of rivers were found as well, such as mussels *Anodonta anatina*, *Unio tumidus* and *Unio pictorum*, hemipterans *Aphelocheirus aestivalis* and caddisflies (*Athripsodes albifrons*, *Ceraclea dissimilis*, *Mystacides nigra* and *Neureclipsis bimaculata*).

At the sampling site about 4 km downstream the Vranov reservoir (S2), we identified 136 taxa. This part of the river was classified as epirhitral, that is a repetition of the upper parts of the river, for different water quality released from the reservoir. Population of *Gammarus fossarum* (35%) was dominant as well as *Naididae* bound to epilithic algae, rheophilic chironomids and blackflies (*Odagmia ornata*) catching planktonic organisms drifted from the reservoir into the river. At this site, larvae of mayflies of the family *Heptageniidae* (with the exception of *Heptagenia sulphurea*) and stoneflies (just one finding of *Leuctra fusca*) were missing completely.

A prospering population of *Gammarus fossarum* is characteristic by high density of individuals, good reproductive capacity and a favorable age classes structure. As it is clear from graph of age (size) pyramids (Fig. 25.), that the age structure of the S2 population is the most complete, while at the site S4 it is influenced by a competition of another species *Gammarus roeselii* (see in HELEŠIC et al. 1998).

In conditions of extreme flow oscillation below the reservoir, *Gammarus fossarum* is very well adapted. From the strategy point of view, it represents an r - strategist (BLANDIN et al. 1976) or even better an A – strategist according to GREENSLADE 1983 and SOUTHWOOD 1988, for it was able to hold its optimal reproduction and competition position even in unfavorable conditions.

On the other hand, a species just as demanding in trophic and habitat conditions, *Asellus aquaticus*, represents a population on the margin of survival at the site S2. It did occur but in very small numbers. Average size of individuals of this population was 5 mm in cohort. Maximal size around 9 mm was found in 2 individuals of the total gathered data file of a 4-year research. Females reached their sexual size in cohort of 5 mm, and the number of eggs was around 30 per individual. When compared with populations at the last locality (S4) or at the Podhradí (S1) site where the maximal size of individuals over 10 mm and sexually mature females produced eggs of 7 mm size (76 eggs per female), the population at the site S2 is

ncy of found species and the trophic
et al. (1998). In the present paper, we
indicator species that had been found
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porhithral and epipotamal. Dominant
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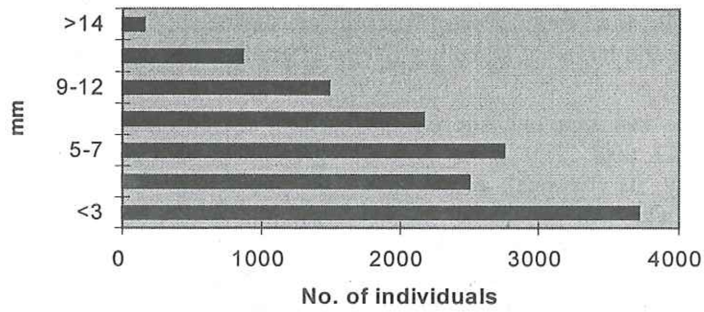
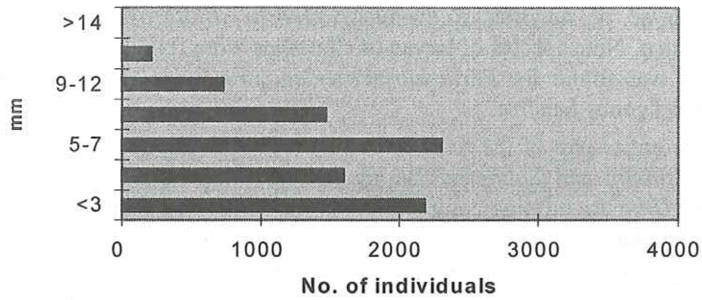
(S4) or at the Podhradí (S1) site
m and sexually mature females
the population at the site S2 is

markedly different. We consider the steady low water temperature to be the main destructive factor of this population as it does not allow for optimal growth of individuals. On contrary, water level fluctuation and discharge are not considered to be main factors for this species.

S2



S3



S4

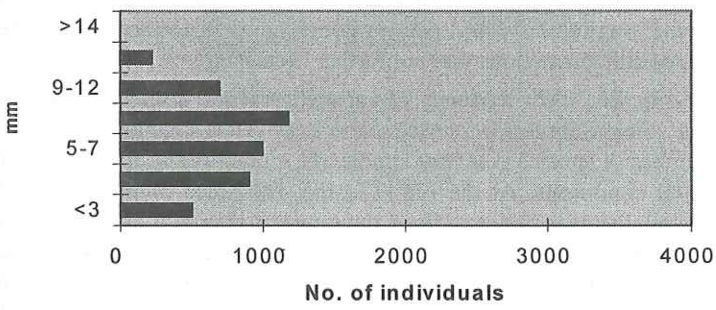


Fig. 25. Age (size) structure of *Gammarus fossarum* population at the site S2 – S4, Number of specimens from all quantitative samples

At the site S3, 9.5 km downstream the reservoir, altogether 138 taxa were determined in the part of the stream identified as epiritral. Dominant populations were found *Gammarus fossarum* and then *Oligoplectrum maculatum, Orthocladius wetterensis, Tvetenia bavarica, Odagmia ornata* and *Elmis aenea.* At this site, the proportion of dominant species is markedly changing; moreover, other epi-metapotamal species were found as well: *Gammarus roeselii* or *Hydracarina* and others. Very occasionally, in low frequency of occurrence, larvae of mayflies of the family *Heptageniidae* and larvae of stoneflies (*Isoperla grammatica* and *Leuctra albida*) were found.

At the last sampling site S4 on the 32nd km downstream the reservoir, we determined 149 taxa. This river section represents a change from hyporhitral to epipotamal by its physical conditions, fish population and several species of invertebrates. The end of another reservoir Znojmo makes a clearer distinction of this stretch. A high dominant population of caddisfly *Oligoplectrum maculatum* (more than 23%) was found there, a species of clear flowing streams (meta – hyporitral). A relatively strong population of *Gammarus fossarum* was found together with another species *Gammarus roeselii.* A strong representation of mayflies of the genus *Baetis*, especially *B. rhodani* and *Ephemerella ignita* were found as well as several species of chironomids, blackflies *(Odagmia ornata)* and beetles (*Elmis aenea*). At this site, we also found larvae of mayflies *Ecdyonurus venosus*, *Rhithrogena semicolorata* and *Ephemera danica.* Nine species of larvae of stoneflies were found; the highest frequency of occurrence was found for *Perla burmeisteriana*, *Perlodes microcephalus*, *Isoperla grammatica* and genus *Leuctra*.

In the entire part of the river below the reservoir, the population of bivalves of the genera *Pisidium* and *Sphaerium* is significantly impoverished; species of genera *Anodonta* and *Unio* are missing completely, but they were found above the reservoir in a relatively native part of the stream. A similar situation was found for hemipterans; in the influenced part of the river, only two species probably drifted from the tributary Fugnitz were found once. In the entire section of the river below the reservoir, larvae of Odonata, individuals of Porifera (*Ephydatia fluviatilis*) and Bryozoa (*Plumatella repens*) have disappeared from this part of the river.

If data obtained by analysis of macroinvertebrate communities are graphically represented to the longitudinal profile of the river according to the studied sites, we will obtain several possible formations that are further presented.

At the Fig. 26., clear tendency of variability of the number of taxa and species diversity of macroinvertebrates in consequence to physical changes of the environment is obvious. Number of species is a very simple yet a functioning indicator of the change of environmental conditions. At the Fig. 27., the difference of medians of number of species at individual sites is obvious. Even the range of maximal and minimal number of species is significant, especially at the most stressed sites (S2 and S3) there were the highest differences and the lowest number of species. From Tab. 10., the statistically significant difference in the number of species between the sites S1 and S2, S3 and S4 is clear. On the other hand, there is a high similarity between the site S2 and S3, S1 and S4 as seen in Fig. 28.

reservoir, altogether 138 taxa were
epiritral. Dominant populations were
plectrum maculatum, Orthocladius
and *Elmis aenea*. At this site, the
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Perlodes microcephalus, Isoperla

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impoverished; species of genera
were found above the reservoir in a
was found for hemipterans; in the
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w the reservoir, larvae of Odonata,
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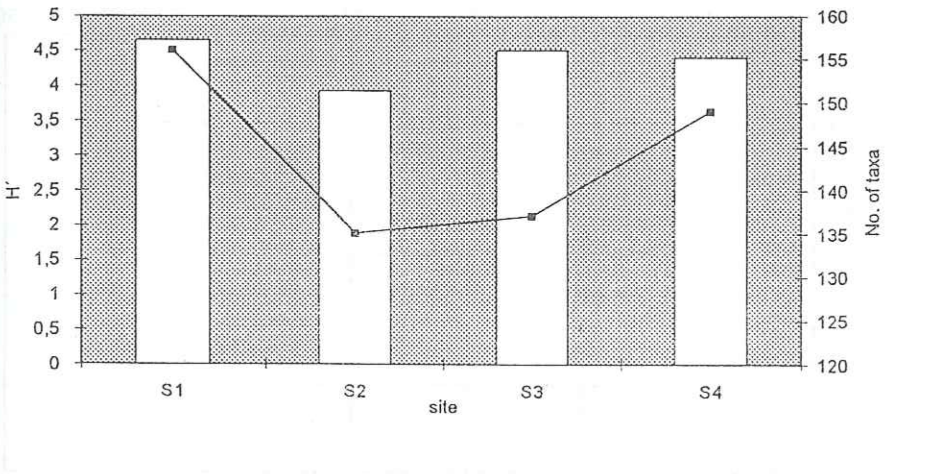


Fig. 26. Species diversity (Shannon index) of benthic macroinvertebrates and number of taxa at the Dyje River sites (column – species diversity, line – number of macroinvertebrate taxa)

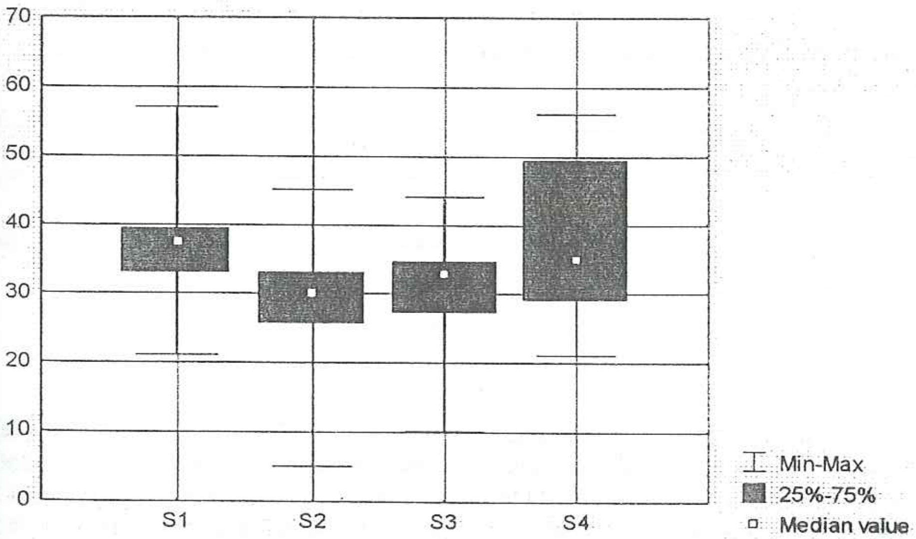


Fig. 27. Box and whisker plot of median of number of taxa in the Dyje River

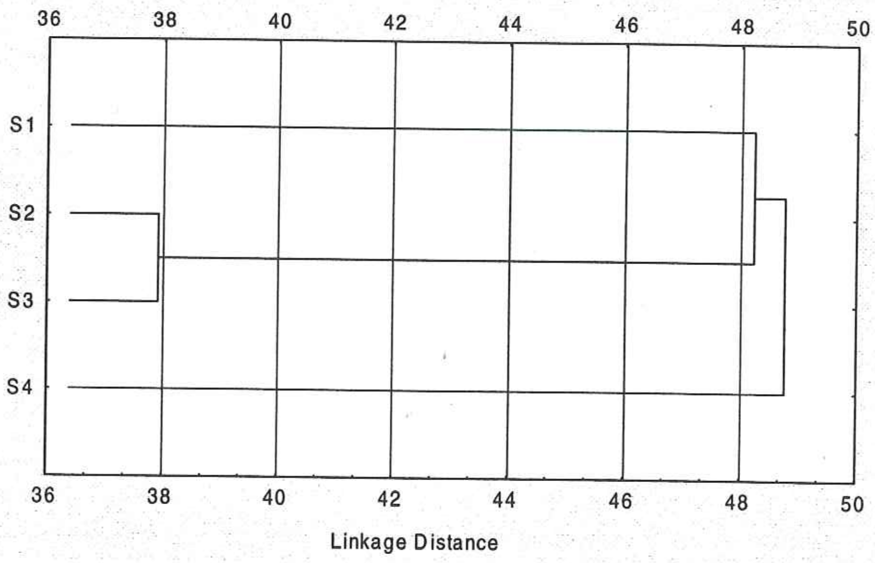


Fig. 28. Tree diagram for number of taxa at sampling sites in the Dyje River (Single linkage, Euclidean distance). Sampling sites S1, S2, S3 and S4.

Tab. 10. Statistical similarities of communities at sampling sites – number of taxa

Sampling sites	Value of t- test	P
S1 - S2	2.33	0.04
S2 - S3	- 0.62	0.55
S3 - S4	- 2.24	0.04
S1 - S4	- 0.24	0.82

In the graph Fig. 29., we present the variability of the total density and species diversity. If number of all individuals of macroinvertebrates found in quantitative samples at all sites are equal to 100 %, then higher values of density were found at the site below the reservoir (S2-S4) when compared to the natural part of the river above the reservoir (S1).

The high density corresponds well with lower values of species diversity. High density of individuals is caused by share of the *Gammarus fossarum* population.

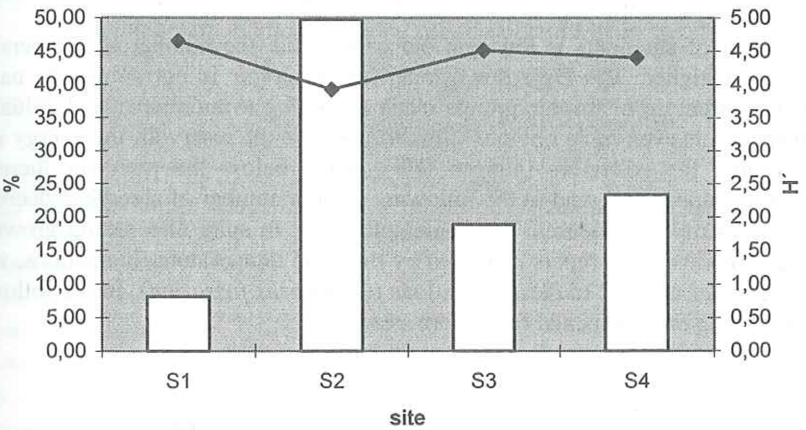


Fig. 29. Relative dominance of macroinvertebrate density at stations S1 – S4. Number of specimens from all quantitative samples (column), species diversity (line)

Average density as an indicator of the similarity of the sites was used when evaluating data in HELEŠIC et al.(1998). From this paper, we are presenting only the table of similarities (Tab. 11.) showing that density was significantly similar at the sites above and below the reservoir. However, above the reservoir, mayflies were numerically dominant populations, while below the reservoir it was only *Gammarus fosarum*. Based on this indicator, other sites had insignificant similarity, see Tab. 11.

Tab. 11. Statistical similarities of communities at the sampling sites - density

Sampling sites	Value of t - test	p
S1 - S2	2.39	0.04
S2 - S3	2.03	0.07
S3 - S4	1.27	0.23

Mutual ratio of trophic groups of zoobenthos is the indicator of the situation of the river continuum concept (RCC). In our case, it is epipotamal (S1) that was changed into lower RCC epirithral (S2-S4). The temperature regime and the fish community confirm this.

The analysis of trophic groups of zoobenthos showed that the natural barbel zone stretch above the reservoir (S1) is very close to the general RCC model. While the stretches below the reservoir correspond to the natural RCC only in numbers of collectors and predators, while numbers of shredders, scrapers and grazers are very different. Parasites are not mentioned in the RCC model.

Number of shredders is lower in our case, while the number of scrapers and grazers is much higher. The Dyje downstream the reservoir is not similar to natural epirhitral. The structure of trophic groups made according to number of individuals of individual species is even more obvious (Fig. 30.). Above the reservoir, the energy input is made through the collectors (almost 85%), while below the reservoir there are shredders and scrapers (S2), and in the following section number of shredders decreases and number of scrapers increases. We contemplate that in spite of a strong growth of epilithic algae, number of scrapers is limited by flow and temperature fluctuations, while shredders are better adapted to these conditions (*Gammarus fossarum*). In the following sections, the strong environmental factors are steadier.

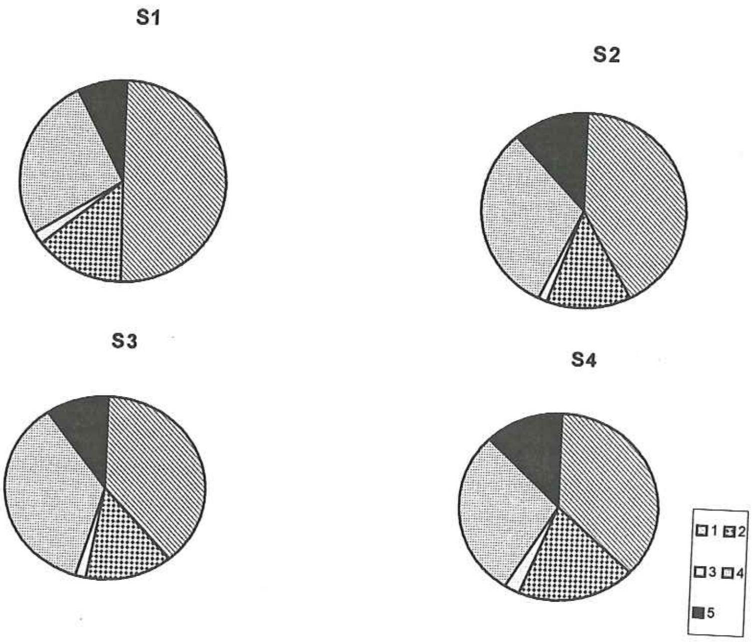


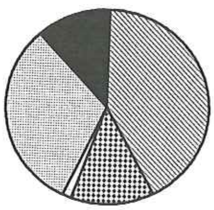
Fig. 30. Trophic guilds in sampling sites (1 – collectors, 2 – predators, 3 – parasites, 4 – scrapers, 5 – shredders)

ature regime and the fish community

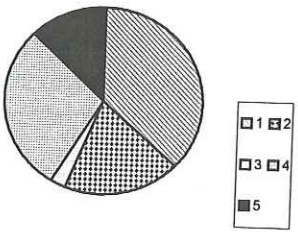
enthos showed that the natural barbel : to the general RCC model. While the e natural RCC only in numbers of edders, scrapers and grazers are very model.

se, while the number of scrapers and he reservoir is not similar to natural ccording to number of individuals of Above the reservoir, the energy input while below the reservoir there are ection number of shredders decreases e that in spite of a strong growth of w and temperature fluctuations, while *ammarus fossarum*). In the following er.

S2



S4



rs, 2 – predators, 3 – parasites, 4 –

Drift

A part of the drifting living individuals was reservoir zooplankton as well as river zoobenthos. Zooplankton in the river above the reservoir was as for the number of species and abundance very poor and contained also species of litoral zone usually existing in river conditions (weirs, pools).

Drifting zooplankton taxa and their relative abundance is listed in next tables.

Tab. 12. Relative abundance of drift zooplankton (alphabetical order, rel. abund. + - 5)

Taxa/Stations	S1	S2	S3	S4
Acanthocyclops vernalis		+ - 3	+- 2	
Acroperus harpae				+
Alona costata	+			
Alona quadrangularis			+	
Alona rectangula			+	
Asplanchna sp.		+ - 2		
Bosmina coregoni		+ - 3	+ - 2	+ - 2
Bosmina longirostris		+ - 3	+ - 3	+ - 3
Brachionus calyciflorus		+ - 3		
Candona candida	+ - 2	+ - 1	+	+
Conochilus unicornis		+ - 1		
Cyclops strenuus		+ - 4	+ - 3	+ - 3
Cyclops vicinus		+ - 3	+ - 3	+ - 2
Cypridopsis vidua	+ - 1	+ - 1	+	+
Daphnia galeata		+ - 4	+ - 3	+ - 2
Daphnia longispina		+ - 3	+ - 2	+ - 2
Diacyclops bicuspidatus	+ - 2	+ - 2		
Diaphanosoma brachyurum		+ - 1	+	+
Eudiaptomus gracilis		+ - 3	+ - 1	
Gastropus stylifer		+		
Harpacticidae	+	+ - 1	+ - 1	+
Chydorus sphaericus		+		
Ilyocryptus acutifrons	+			
Keratella cochlearis		+ - 3	+ - 2	+
Keratella quadrata		+ - 2	+ - 1	
Mesocyclops leuckarti		+ - 2		
Megacyclops viridis		+ - 1		
Polyarthra dolichoptera		+ - 2		+ - 1
Polyarthra vulgaris		+ - 2	+	
Synchaeta sp.		+ - 3	+ - 2	+

Taxa of drifting zoobenthos were *Gammarus fossarum*, *Simuliidae*, *Orthocladiinae*, Hydrozoa, *Baetis*, *Ephemerella*, *Naididae* and other less frequent species.

A list of the number of drifting individuals and species is comprised in Tab. 13. Median abundance of drifting individuals per 1 m^3 of discharge is relatively low (higher values in ARMITAGE & CAPPER 1976, KUBÍČEK 1968). In the first part of the Dyje downstream the reservoir (S2), the values of both components are the highest.

Tab.13. The basic values of drift abundance in the Dyje River

Stations	No. of	Zooplankton $n.m^{-3}$			Zoobenthos $n.m^{-3}$			No. of taxa	
	samples	min.	max.	median	min.	max.	median	zooplankton	zoobenthos
S1	5	0.3	4.3	1.7	0.25	6.15	2.76	2 - 5	4 - 8
S2	16	25.1	1206	179	0.5	26.4	6.1	2 - 9	1 - 11
S3	8	0.6	233	32.5	0.4	12.3	2.75	1 - 7	2 - 12
S4	7	0.04	270	55	0.15	12.5	3	2 - 10	6 - 14

Species and numerical changes of drifting organisms are connected to daily changes of discharge as well as the presence of weirs where zooplankton can cumulate and breed. It is obvious that nocturnal drifting activity would give different, probably higher values.

Several samplings of drift during the rise and decline of discharge did not bring sufficient data for course of drifting model construction in connection to the discharge variability. When abundance of drifting organisms is calculated according to the total amount of discharge water at the present time, we get an almost fluent rising or declining lines of values. When abundance is calculated based on 1 m^3, an unsteady line of values is created (Fig. 19.) that can be explained only by speculative hypothesis of hydraulic variables (STATZNER 1992).

It is obvious that the amount of zooplankton 18 min. after the discharge increases at the site after the start of the power station operation (Fig. 31.) and is connected to drifting of zooplanton gathered at the weir Formoza upstream the profile S2. Another increase noted about 55 min after the start of the plant operation is caused by zooplankton from the reservoir Vranov.

Higher values of drifting individuals of zoobenthos in 45th and 55th min. are caused by increased drifting activity when periodically flooded areas are flooded again.

After the stop of the plant operation, when discharge declines (Fig. 32.), it is obvious that the amount of zooplankton in the drift visibly declines only during low discharge (about 3 hrs after the discharge is stopped). The amount of drifting zoobenthos remains the same during the entire low discharge period even after 3 and more hours.

This fact is connected to the effort of macroinvertebrates to actively leave the drying parts of the channel into permanently flooded parts.

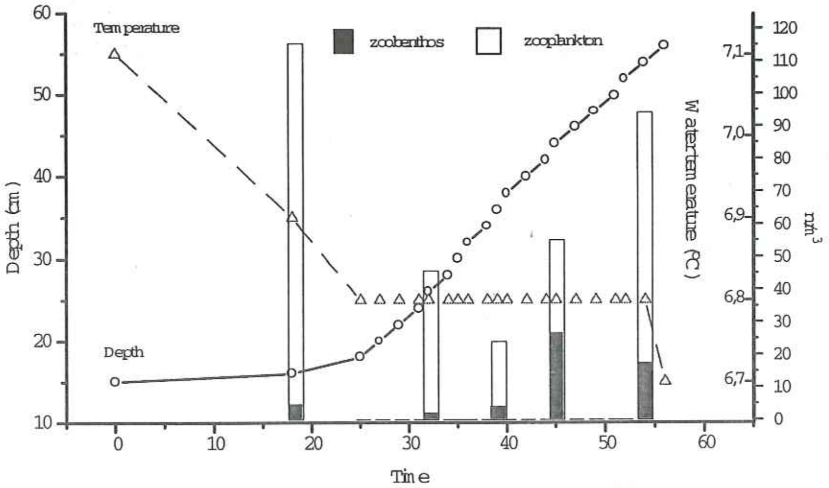


Fig. 31. Drift activity in course of increased flow. S2 – 23.6.1994

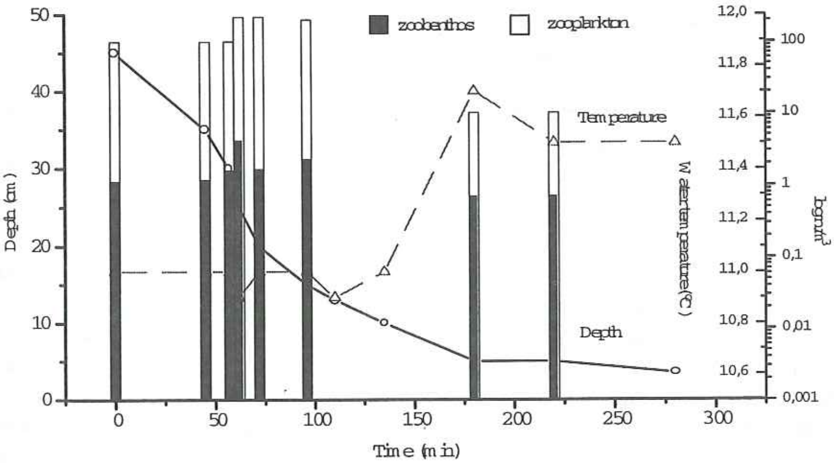


Fig. 32. Drift activity in course of decreased flow – S2 – 1.9.1994

There are clear time differences of the changes that in the first case (Fig. 31.) happen within an hour (discharge increase), and in the second case during discharge decrease (Fig. 32.) they last for several hours.

A part of the drift has always been composed of terrestrial organisms that invaded the dried bottom during low discharge and that were moved by the next discharge wave. The most common were terrestrial species that actively moved to the bottom, for example spiders, ants, beetles (*Carabidae*, *Staphylinidae*), flies, springtails, or that were passively moved from the bank vegetation, such as aphids, thysanopterans, small hymenopterans.

Exuvie of aquatic invertebrates (*Chironomidae*, Ephemeroptera) as well as chitin remains of aquatic and terrestrial insect were a regular part of drift as well. Often, bits of leaves, moss, filamentous algae, bluegreen algae and other aquatic vegetation were found in the drift. This matter formed an irregular part of the total drift and had not been quantified. It was regularly found in the gut content of the *Gammarus fossarum*.

It is obvious that all alochtonous and autochtonous matters create a source of energy (in the form of CPOM) for the existence of the bottom community in the river below the reservoir.

An accidental part of the drift was formed of adult aquatic insects, cocoons of turbellarians and oligochaets and eggs of mites (*Hydrachnellae*).

Hyporheic biota

The difference between the sites upstream and downstream the reservoir is also in the qualitative and quantitative composition of organisms of the meio - and macroinvertebrates in the hyporheic zone of the riverbed. Total abundance of organisms is showed in Fig. 33.

At the site Podhradí (S1), in the upper 10 cm of the bottom, there were found 13 to 85% of the fauna probably in connection with the granulometric composition of the sediment and with the flow conditions above and in the bottom. Communities of meio- and macroinvertebrates was found up to 30 cm below the bottom top, where 99% of taxa was found caught in the vertical profile - Oligochaeta, Ephemeroptera and *Chironomidae*. Occasionally, individuals of the taxa of Nematoda, Oligochaeta, Cladocera and *Chironomidae* were found deeper.

At the site Střelnice (S2), the first 10 cm of the bottom, 88% of fauna was concentrated in the periodically flooded area (S2a) or 95% of fauna at the steadily flooded parts. In the epirheic level (0 - 10 cm), the most abundant were the following taxonomical groups Rotatoria, Oligochaeta, Cyclopoida, Harpacticoida and *Chironomidae*. In depth of up to 20 cm below the bottom surface, in all cases we found 99% of all fauna that had been found in the vertical profile (up to 60 cm). In deeper layers (20 - 60 cm), we found occasionally individuals of Nematoda, Oligochaeta, Cyclopoida, Harpacticoida, Amphipoda and *Chironomidae*. Amount of individuals was roughly ten of thousands, while lower number of individuals was found at the right bank site (S2a). This site was regularly affected by water decrease to the total drying of the bottom.

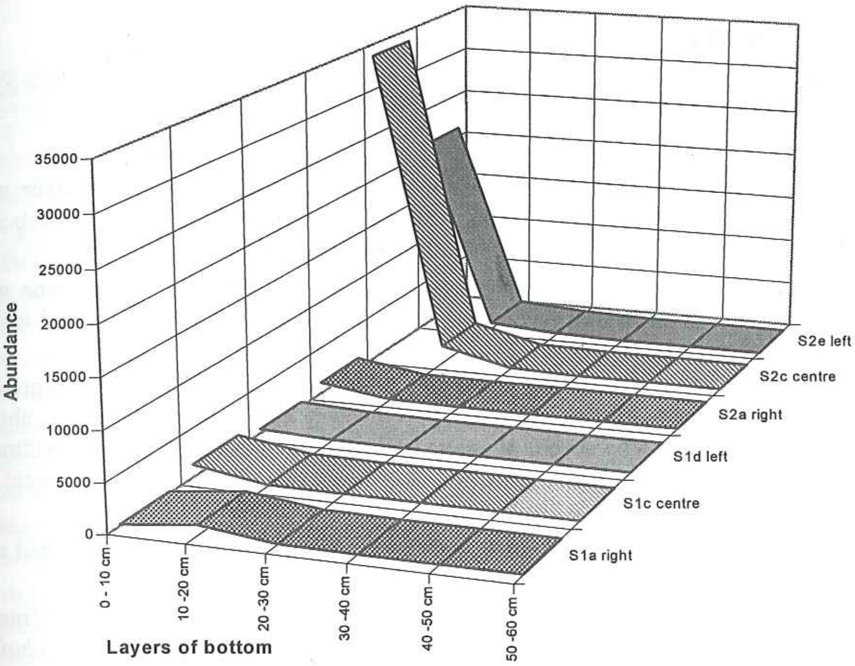


Fig. 33. Total abundance of macroinvertebrates in bottom layers in sampling sites S1, S2

As obvious from above and the graph, at both sites the upper layers of sediments were colonized by invertebrates. This finding is similar to other research by HYNES (1974), HYNES et al. (1976), MARCHANT (1988) and UVÍRA (1997). They all agree that the most animated are layers up to 30 to 40 cm, while in deeper layers the abundance of macroinvertebrates rapidly decrease.

Despite different environmental conditions in the part of the river above and below the reservoir, hyporheal fulfills its refugial and trophic function for a large scale of bottom and drifting organisms. Differing physical conditions of hyporheal of both sections (especially the grain size composition and space distribution of the grains in the substrate layers and the organic matter content) are probably (together with different water temperature and flow conditions in the bottom) responsible for invertebrate colonization of this ecologically important part of the river. It is obvious that hyporheal allows for existence of resilient bottom community in the river below the reservoir; this community is exposed to stress conditions caused by regulated discharge from the reservoir. Presented results also demonstrate the changes that happen concerning the discontinuum of the hyporheic corridor in the river (STANFORD & WARD 1993).

We are aware that from a simple sampling it is not possible to deduce any more concrete conclusions. However, we found significant changes, and we cannot assume that they are accidental based on other data (DANIELOPOL 1978, RULÍK 1994, RULÍK 1995, LEICHTFRIED 1995, UVÍRA 1997).

Fish community

(evaluated with the use of data and preliminary results of S. Lusk, P. Jurajda, Inst. Syst. Ecol. Vertebtatology, CAS, Brno)

In the followed part of the stream, the natural part of the Dyje River was stocked with a wide spectrum of carp fish, with the dominance of barbel, nase, chub and vimba bream, as it is obvious from catching above the reservoir (Tab. 14., S1).

After building of the valley reservoir Vranov, the typically barbel zone was moved below the city of Znojmo while the part of the Dyje River was changed into a trout-grayling zone.

Building of the Znojmo reservoir definitively interrupted the migration possibilities of the natural fish community; however, the part of the river above the reservoir was enriched by several limnetic species (Tab. 14., S4). This impoundment together with a steady low water temperature reduces the chance of development of autochtonous population of *Chondrostoma nasus*.

Between 1991 and 1994, 26 fish species belonging to two fish zones (barbel and trout) were found (Tab. 14.).

Typically barbel zone was preserved in the Dyje River upstream the Vranov valley reservoir (S1) and 70 - 80 % of stock is formed by species: *Leuciscus cephalus, Barbus barbus, Chondrostoma nasus, Vimba vimba* and *Alburnus alburnus*.

Stock of the trout zone in the Dyje between the two reservoirs (S2, S3, S4) is formed by basic species: *Salmo trutta* m. *fario*, *Oncorhynchus mikkis*, *Salvelinus fontinalis*, *Thymallus thymallus* and *Cottus gobio*. In the last studied profile (S4), barbel was found to occur as well, so the barbel zone continues downstream the Znojmo reservoir.

From Tab.14., it is obvious that the species diversity of fish in the part of the Dyje River downstraem the reservoir Vranov is lower than above the reservoir. In the list of fish from sites S2 and S4, there are more species found as accidental or rare finding; some of them come from the larger tributaries (for example Fugnitz at the site Hardegg S 3-4) or they are of limnetic origin.

Although trout and grayling breed in the studied parts of the Dyje River, the population of the brown trout strengthened by stocking, and the population of the rainbow trout and brook trout are maintained only through artificial stocking. (Tab.14., see notes).

Relatively high productivity of fish (Fig. 34.) in the trout zone of the Dyje is about 110 $kg.ha^{-1}$ downstream the Vranov reservoir (S2), about 72 $kg.ha^{-1}$ at the Hardegg site (S3) and almost 190 $kg.ha^{-1}$ at the site Papírna (S4).

Biomass of fish in the upstream the Vranov reservoir was estimated at 350 $kg.ha^{-1}$ (LUSK 1993, 1994 unpublished data).

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lts of S. Lusk, P. Jurajda, Inst. Syst.

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about 72 kg.ha^{-1} at the Hardegg

reservoir was estimated at 350

Tab. 14. Relative abundance of fishes in the Dyje River

Taxa/Stations	S1	S2	S3	S4	Notes
Salmo trutta m. *fario*	R	D	D	A	NR + AR
Oncorhynchus mikiss		A	A	C	AR
Salvelinus fontinalis		C	R	R	AR
Coregonus lavaretus		O			
Thymalus thymalus		C	C	C	NR
Esox lucius		R	R		
Rutilus rutilus	C	R		C	ALS
Leuciscus leuciscus	R			R	NR
Leuciscus cephalus	D			R	
Phoxinus phoxinus			O		ALS
Chondrostoma nasus	R	R		R	NR
Gobio gobio	R		O		
Gobio albipinnatus			O		ALS
Pseudorasbora parva				O	
Barbus barbus	D		R	A	NR
Alburnus alburnus	C				
Alburnoides bipunctatus	R				
Abramis brama		R		R	ALS
Rhodeus sericeus	O				ALS
Vimba vimba	A				NR
Noemacheilus barbatulus	O			O	ALS
Anguila anguila	O	O		O	ALS
Perca fluviatilis	R	R	R	R	ALS
Stizostedion lucioperca		R		O	ALS
Cottus gobio			A	A	NR
No. of taxa 24	14	12	11	16	

D - dominant, A - abundant, C - common, R - rare, O - occasional,
NR - natural reproduction, AR - artificial reproduction, ALS - allochtonous species

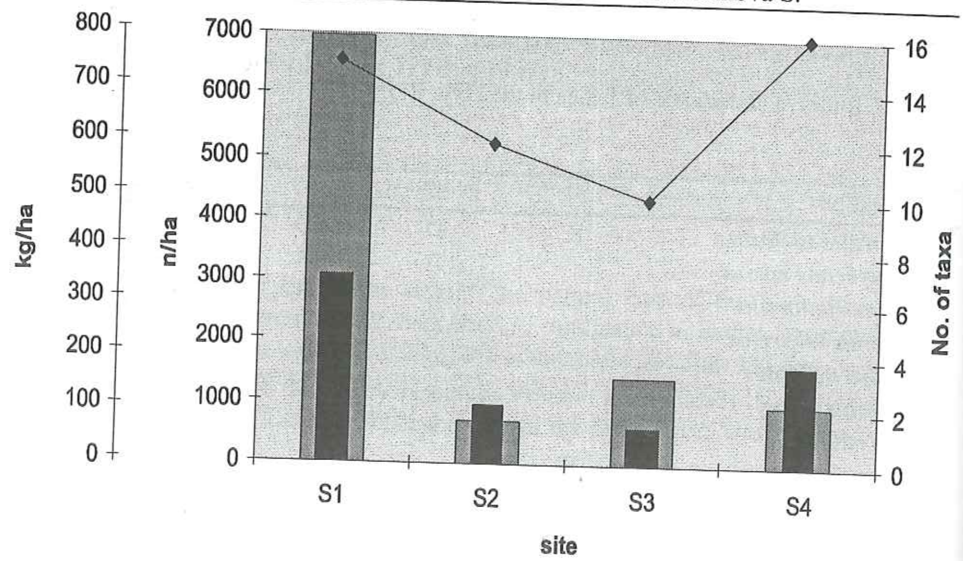


Fig. 34. Relative fishes abundance (gray column), biomass (black column) and number of species (line) at the stations S1 – S4 (1991 – 1994)

Response of communities to environmental changes in downstream stretch of river

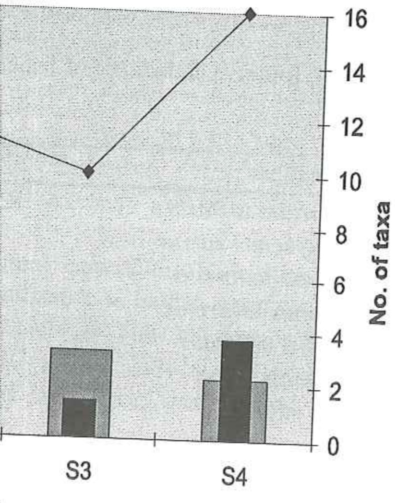
Benthic community as well as fish reacts to the river discontinuum. Epilithic community upstream the reservoir is characterized by development of filamentous algae, diatoms and planktonic coccal algae. In the stretch below the reservoir, there is a majority of epilithic algae with oligostenotherm species and species preferring more lotic parts of the stream or tolerating frequent flooding and drying of the bottom.

Macrophytes react similarly by different presentation of species in flooded parts of periodically drying parts of the channel. Differences of macroinvertebrate density and species structure and preference of several species for the followed parts of the Dyje are depicted in Fig. 26.

Hierarchic divisive classification of samples

For further analysis of samples, TWINSPAN (HILL 1979) classification method was used to evaluate the species data from quantitative sampling of zoobenthos

TWINSPAN classification had eigenvalue higher than 0.3 in the division of the 1st and 2nd level (Fig 35). The first division classified samples into two groups. All samples from the locality S1 (above the reservoir) were detached on the positive side of the dichotomy (group *1). An indicator taxon of this group was midge *Orthocladius* sp.



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her than 0.3 in the division of the
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detached on the positive side of
oup was midge *Orthocladius* sp.

On the negative side of the dichotomy (group *0) all samples gathered below the reservoir were situated. Further division divided them into 2 groups: (i) *00 with indicator species caddisfly *Oligoplectrum maculatum* (all samples from the locality S4, one from S2 and three samples from S3) and (ii) *01 where majority of the samples from the localities S2 and S3 was found.

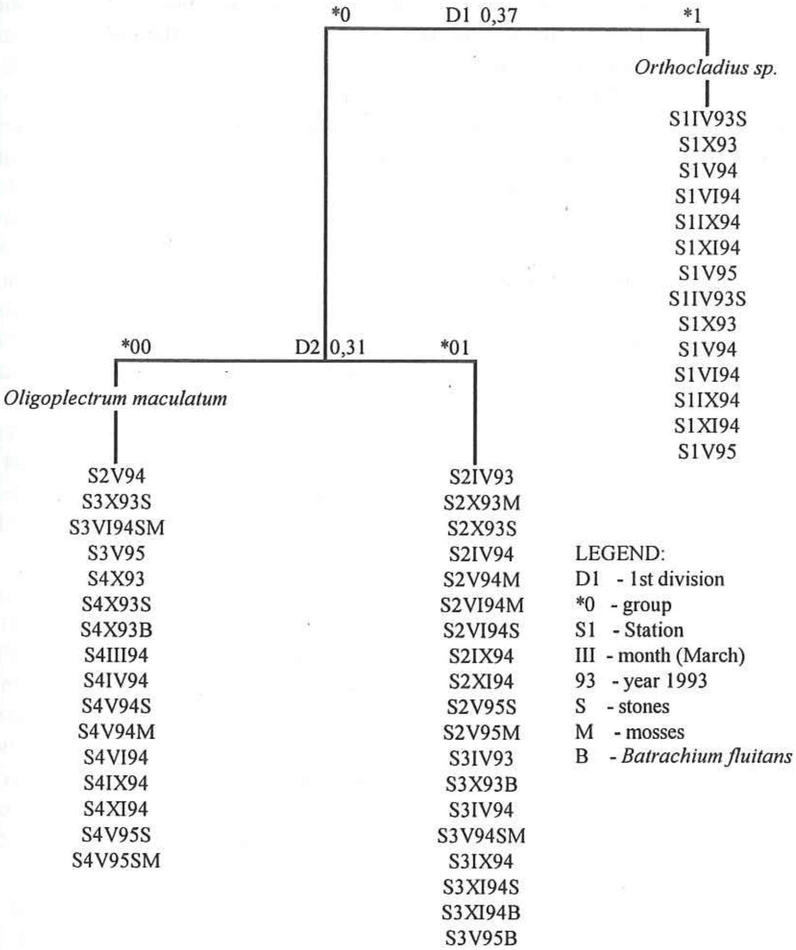

Fig. 35. Results of TWINSPAN classification of macroinvertebrate quantitative samples

Detrended correspondence analysis of communities

Data were gathered by detrended correspondence analysis (Fig. 36). The sum of all eigenvalues is 3.54. The eigenvalue of the 1st ordination axis is 0.40, that of the second axis is 0.24. Cumulative percentage variance of the species data explained on the 1st axis is 11.3 %, that on the second axis is 18.1 %. Axes in the ordination analyses usually present cumulated environmental factors. Here, we explain 1st axes as water temperature regime: in the side the normal annual water temperature regime occurs, the left side is characterized by temperature regime nearly without seasonal fluctuations. The 2nd axis presents discharge regime. In the positive direction of this the fluctuation of discharge decreases (discharge pulses are flattening). After all samples were depicted using envelopes (Fig. 36), it is obvious that in the right part of the ordination space (seasonal temperature differences, natural discharge) there are all samples from S1 and only one sample from autumn sampling of S2 (close to the center of the ordination). This exception happened because of occurrence of a typically potamal species *Potamanthus luteus*; its larvae hatched below the reservoir in autumn; however, they were unable to complete their life cycle. In the left part (stable temperatures) in the lower quadrant (highly fluctuating discharge) there is a majority of S2 samples. In the left upper quadrant (smaller fluctuation of discharge) there are S4 samples. Envelopes for samples of S1, S2 and S4 do not overlap, while the S3 envelope overlaps with S2 and S4 and it reaches to the upper and lower left quadrant. The graph well documents the difference of S1 and a gradual longitudinal zonation of benthic community as well as a differing character of S3 site.

For TWINSPAN site classification, the group *1 corresponds with S1. Samples taken below the reservoir divided into group *01 situated predominantly in the left lower quadrant and the group *00 predominantly in the left upper quadrant (Fig.37). The display of abundance of indicator species from TWINSPAN in the ordination space (Fig. 38): *Heptagenia sulphurea* and *Orthocladius* only upstream the reservoir; *Oligoplectrum maculatum* only downstream the reservoir in places of less influenced sites by discharge fluctuation with the S4 site; *Gammarus fossarum* with a rapid development downstream the reservoir at S2 site. Fig. 38 also showing the occurrence of *Baetis fuscatus* and *Baetis lutheri* seem to show that there is a approximation of S4 and S1 communities.

The results document the principal difference of community in the river above the reservoir when compared to the community at any site of the river below the reservoir. Cumulating of points presenting individual samplings of S1 shows leveled conditions at this site. On contrary, a large scatter of other points with regard to the second ordination axis is caused by differing discharge conditions below the reservoir. If there are taxa found at all sites, they are euryvalent species and usually there are large differences of abundance values above and below the reservoir.

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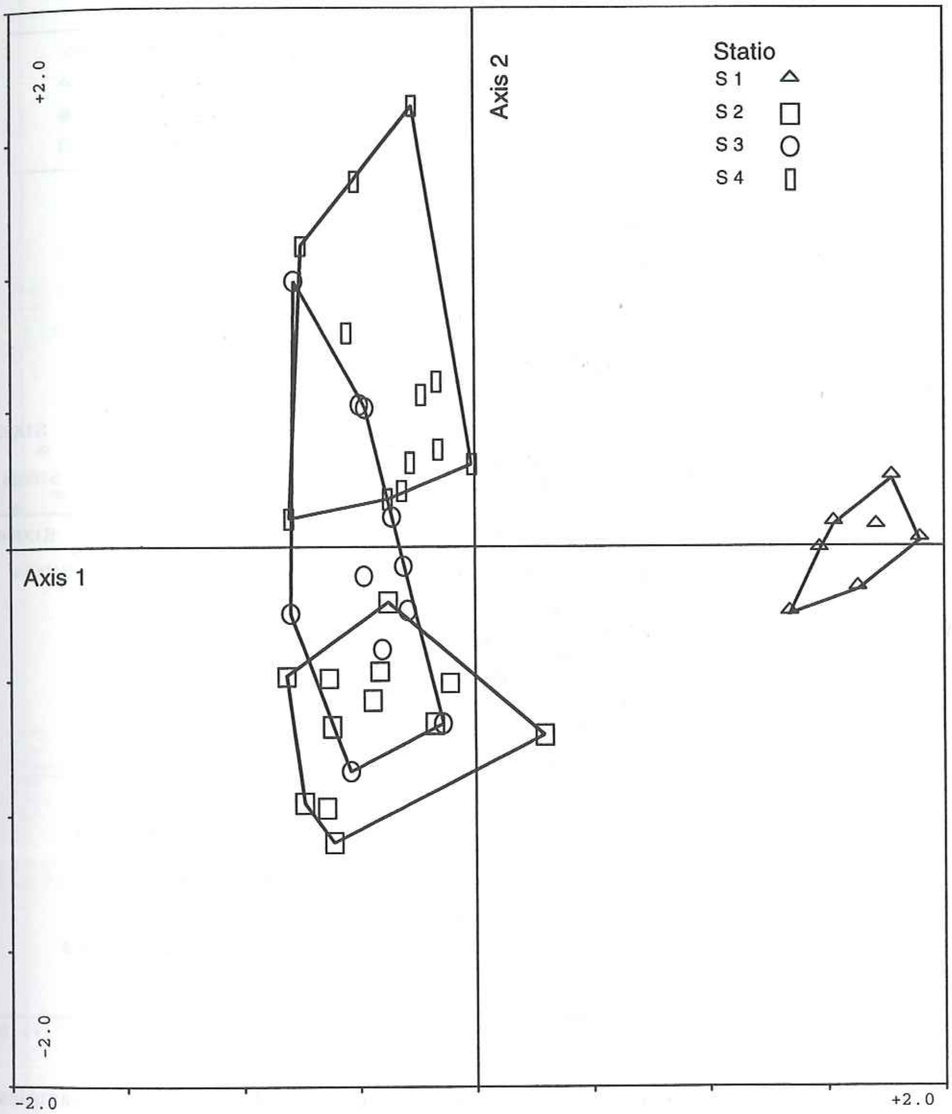


Fig. 36. DCA ordination diagram of benthic macroinvertebrates quantitative samples. Station S1 – S4.

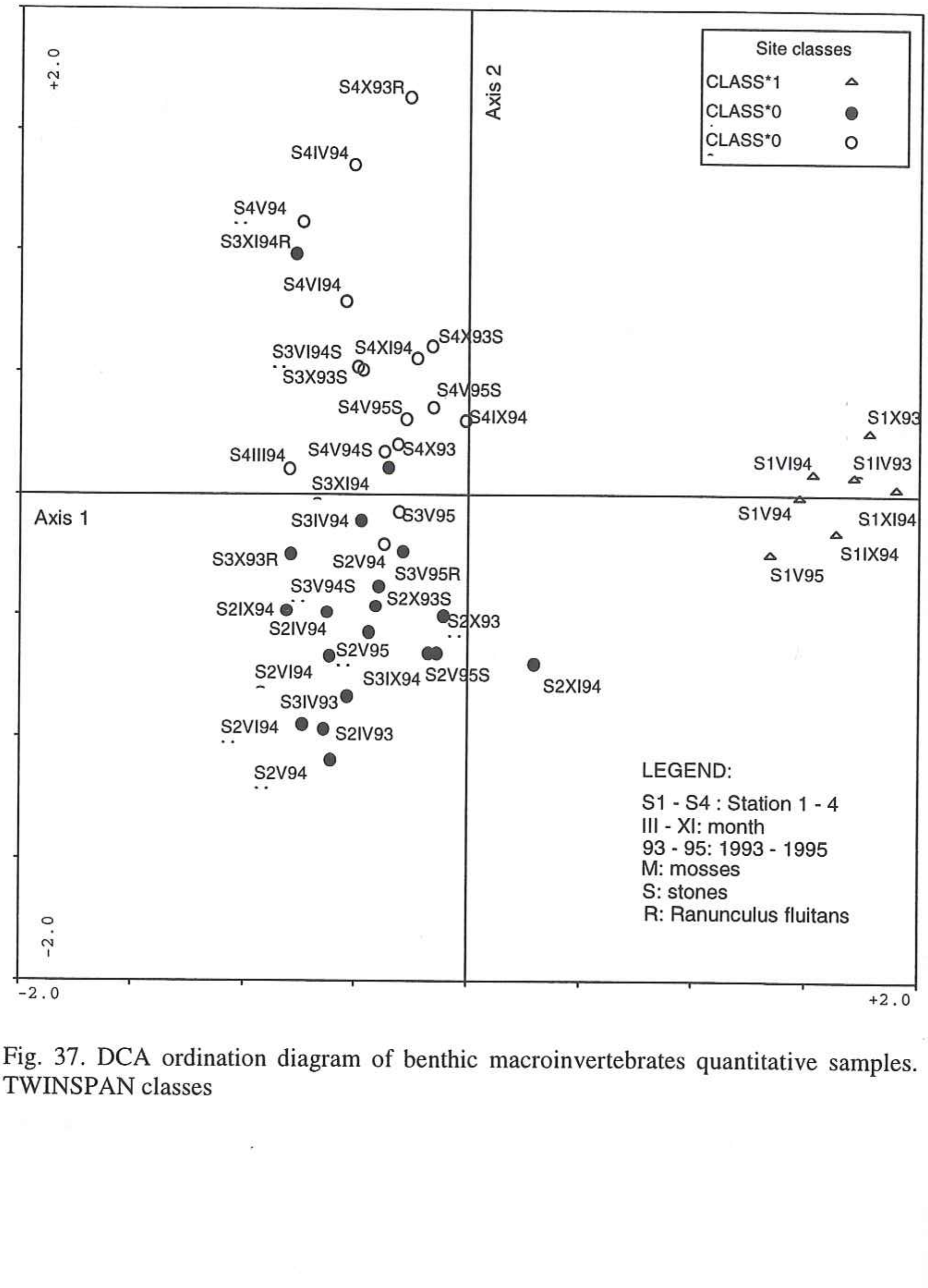
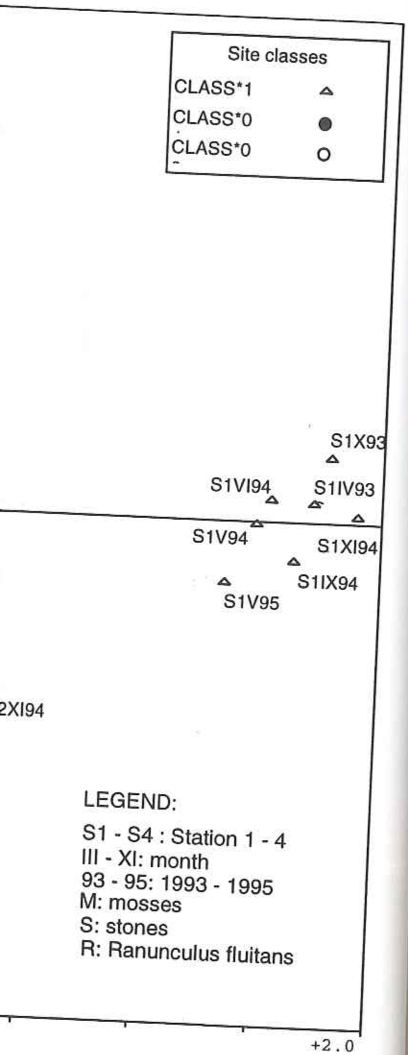


Fig. 37. DCA ordination diagram of benthic macroinvertebrates quantitative samples. TWINSPAN classes



vertebrates quantitative samples.

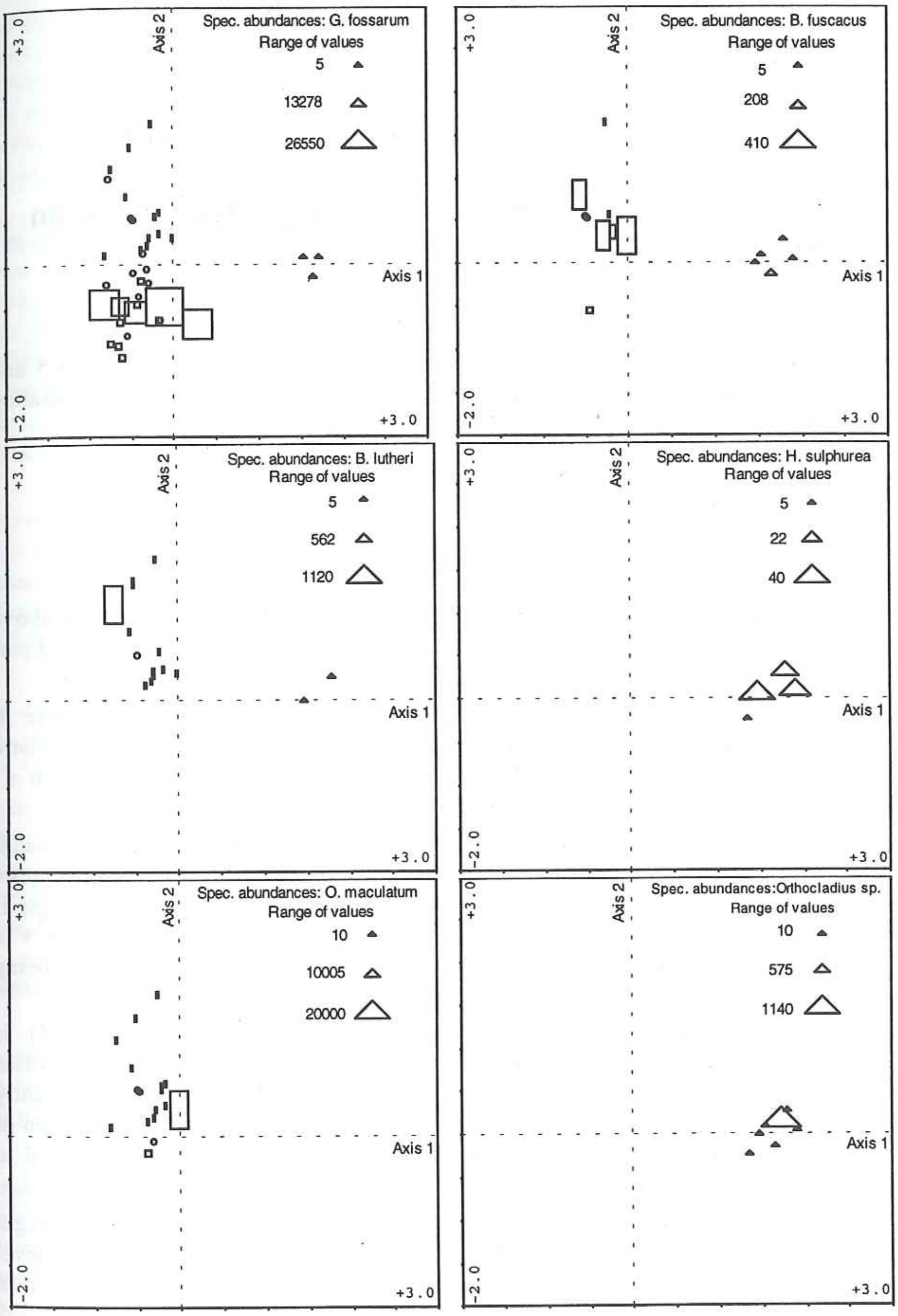


Fig. 38 DCA – abundance of macroinvertebrate taxa. (symbols of sites in Fig. 36)

Discussion

Discussion is in the same order as the five questions at the beginning.

Environmental differences in the Dyje River upstream and downstream the reservoir

Discharge regime and bottom substrate conditions

Average annual discharge at both sites (S1 a S2) is almost the same, 8.5 and 9.7 $m^3.s^{-1}$ (five-year-average). Also, high monthly discharges are very similar in duration and volume, and in both cases occur in March (M) and April (A):

	S1		S2	
	M	A	M	A
$m^3.s^{-1}$	9.3	8.0	7.1	8.4

There are differences in monthly minimal flows. In the unregulated part above the reservoir (S1), it is 1.7 $m^3.s^{-1}$ occurring in August or September, in the regulated part below the reservoir (S2) it is around 3.4 $m^3.s^{-1}$ occurring in November or December.

Overall, the hydrograph below the reservoir is more levelled than above it. The main difference is in the daily discharge variability below the reservoir where the minimal discharge increases from the theoretical value of 1.2 $m^3.s^{-1}$ to 15.3 -45 $m^3.s^{-1}$ depending on the number of working turbines.

In consequence of these oscillations, changes of the size of the wetted perimeter occur as well as creation of permanently and periodically flooded parts of the bottom. The share of the periodically flooded part is about 60% based on our findings; if the residual flow was lower (0.8 $m^3.s^{-1}$) than the officially accepted (about 1.2 $m^3.s^{-1}$), the size of the exposed bottom increased almost to 70% with the residual flow being concentrated to a couple brooklets streams only.

Short-term fluctuation in further sections of the river (S3 and S4) is characteristic by smaller height amplitude and a wider base of the discharge wave as well as higher residual flow from 1.8 to more than 2 $m^3.s^{-1}$. The size of the recurrently flooded part of the bottom is therefore smaller than at the site S2. With the exception of the higher residual flow, half shorten duration of the minimal flow when compared to the site S2 (about 2 times 2 hrs).

The steep rise of the discharge wave is an unfavourable factor as its height amplitude is the highest at the site S2. According to our measurements, the water level increase happens within 30 min or even shorter time from the basic depth of 15 cm to 85 cm.

Discharge variability are also followed by changes in values of current velocity, shear stress and complex Reynolds·number. LAKE (1990) called these rapid changes in the current velocity in a river predictable flow disturbance. However, that is valid for natural changes of the flow. Hydrological changes detected in the Dyje River downstream the reservoir never happen in natural sections of rivers; in our case above the reservoir where the changes of the wetted perimeter occur during the spring and storm torrent gradually, in longer period and in a differently shaped cross-section of the channel.

Only a limited number of species can adapt to this situation. That is why we consider the time and space distribution of the discharge wave as well as the low residual flow to be strong ecological factors responsible for further changes in the daily temperature and oxygen regime, erosion and driving activity of water. Generalisation of this problem may be found in works of FISCHER & LAVOY (1972), WARD (1986), GORE (1977) and ARMITAGE (1984). GASCHIGNARD & BERLY (1987) studied a similar discharge regime of the river Rhone in France. The effect was obvious especially in occurrence and abundance of caddis caddisflies and in increase of catastrophic drift frequency.

PETTS et al. (1985) reported an attempt to change this situation in the English reservoir Kielder on the river Nord Tyne. Working regime of the turbines was divided into two phases so that a less steep and longer beginning of the discharge wave was gained as well as its flattening at the 10 km downstream the reservoir. The initial discharge was 25 $m^3.s^{-1}$. The total start of the turbine regime was distributed to about 150 min.

LIGON et al. (1995) stresses that it is necessary to individually assess the adjustments of the discharge regime downstream the reservoir. He suggests that the change of the river channel geometry and of the operation regime is important.

In the suggestions of STANFORD et al. (1996), they relate the regulation of hydrograph in the river below a reservoir with precautions for the entire floodplain. Model originating from concrete data of the river Columbia (U.S.A.) contained a lot of variables that should ensure not all-natural but ecologically sufficient conditions for simulation of hydrograph curve that would copy the natural flow oscillations in the river below a reservoir as well as flooded valley area. Regulation of hydrograph invokes further favourable consequences in the physical and biological spheres of the entire river corridor.

Shape and time change of the discharge wave is possible through a sufficiently large equalizing reservoir as in the case of other reservoirs in the CR, such as the Vír reservoir on the Svratka River (PEŇÁZ et al. 1968) or the Dalešice – Mohelno reservoirs on the Jihlava River (HELEŠIC & SEDLÁK 1995).

Another important effect of the changed flow conditions is the bottom substratum change. First of all, the size structure of the coarse inorganic matter and individual cobbles and boulders is changed and they are attached to the bottom by iron encrustation. The upper layer of the bed sediments is intensively washed by water and thus the content of the particulate organic matter is different at sites above and below the reservoir. GORDON et al. (1992) summarised the influence of the changed discharge conditions on the bottom substratum. SEAR (1995) proved very similar changes in the bottom substratum structure on a well-defined part of a river with similar sudden changes of the flow. Based on these changes, there occurred a clear change of the bottom habitat, especially in the different spatial distribution of the stream and hyporheic refugium. As LANCASTER & HILDREW (1993) proved these spaces are absolutely necessary for maintenance of microdistribution of lotic macroinvertebrates and for community or the entire ecosystem stability. COBB et al. (1992) studied the situation of the bottom substrate change below the reservoir and proved a significant influence on species composition and density of water insect larvae.

Water temperature regime

There is a completely different temperature regime upstream and downstream the reservoir on the Dyje River. In consequence of the short-term daily changes of discharge, there are changes of water temperature in connection with the depth of water released from the reservoir as well as the retention in the weirs throughout the year. These changes are very visible during the increase and decrease of the discharge wave when the temperature gradient is up to 2°C within 1-3 hr.

At the start of the discharge wave, the water temperature is increased for a short time (release of warmer weir water) and then decreased for the entire time of the higher discharge (lower temperature of water from hypolimnion). After the decrease of the wave, the temperature is kept at the lower level and then, after decline of the water level, it increases to a certain level until a new change of the discharge occurs.

LEHMKUHL (1972) and GORE (1977) were one of the firsts to identify this phenomenon, and they deduced that temperature is an important fact in the course and completion of life cycles and for reproduction of the bottom organisms and fish. The total sum of temperatures is very important as well as the high daily temperature gradient that correlates with the species diversity according to the river continuum concept (VANNOTE et al. 1980) and zonation-spatial concept (ILLIES & BOTOSANEANU 1963).

The daily temperature gradient in the range of 1 or 2 degrees does not have a significant effect on these phenomena (WARD & STANFORD 1979). In the longitudinal profile of the Dyje River, the water temperature is similar to the Svratka River downstream the Vír reservoir (PEŇÁZ et al. 1968) or to the Jihlava River below Dalešice (HELEŠIC & SEDLÁK 1995). However, the temperature decrease is more obvious in the Dyje River, as well as differences upstream and downstream the reservoir. From spring to autumn, the temperatures are generally rising, while in winter they are decreasing. Neither the lowest nor the highest temperatures of the Dyje River downstream the reservoir ever reach the values above the reservoir.

Oxygen saturation regime

At the studied sites, the percentile oxygen saturation of water reaches values of natural conditions, organic matter load and intensity of primary production (Tab. 6. - 9.):

Sites	Min.	Max.
S1	66.4 %	110.5 %
S2	52.9 %	106.1 %
S3	58.9 %	108.9 %
S4	58.7 %	108.3 %

The lowest value at S2 is caused by discharge of hypolimnic water. High saturation is complemented by primary production, at S1 especially from the river phytoplankton, in the parts of the section below the reservoir from epilithic algae and macrovegetation.

MACKIE et al. (1983) added to the knowledge of oxygen regime in rivers influenced by water discharge from hypolimnion. The situation in the first two kilometres below the dam was similar in the Dyje River. Especially YEAGER (1993) and LIGON et al. (1995) studied the problem of undersaturation of water by dissolved oxygen below reservoirs releasing hypolimnic water. Technically, this problem is solved by artificial airing of hypolimnium zone of reservoirs or discharge through turbines or building of weirs with a longer crest length and increased turbulence of water (YEAGER 1993).

Organic pollution (COD and BOD)

In the longitudinal profile, the parameters of the organic pollution analysed as BOD and COD are decreasing. Organic matter pollution of the river upstream the reservoir is improved to lower saprobic levels by passing through the reservoir. Also, a slightly increased pollution at Hardegg (S3) is completely gone about 20 km downstream (S4). In this case, the reservoir has a positive role in water quality improvement. At the same time, generally valid conclusions of WARD & STANFORD (1983) were verified.

Dissolved nutrients regime

The majority of data about nutrients in the longitudinal profile come from 1992 and 1994. The highest expected concentrations of ammonium nitrogen and total phosphorus were found in the Dyje River upstream the reservoir; at the studied sites below the reservoir they were lower because of utilisation of the reservoir and river primary production. In the longitudinal profile, nitrate nitrogen showed lower values at sites above the reservoir and higher values at sites below the reservoir. For more detailed analysis of the nutrient regime we do not have sufficient information; however, we can claim that the limnetic cycle of the nutrients in the reservoir is changing its character and acts as a nutrient trap (STRAŠKRABA 1973, STRAŠKRABA & TUNDISI 1999). These conclusions agree with the general theory of the river discontinuum (WARD & STANFORD 1983).

River biota response to environmental changes in the river downstream a reservoir

Benthic community and fish react to the river discontinuum. Epilithic community in the riverine above the reservoir is characteristic by filamentous algae growths, epilithic diatoms and planktonic coccal algae. In the section below the reservoir, there is a majority of epilithic algae with oligostenotherms species and species preferring more lotic and less lenitic parts of the channel, or tolerating recurrent flooding and drying of the bottom.

Similarly, macrophyts are characteristic by various richness of species in the stable flowing or periodically flooded parts of the bottom. Relatively constant low temperature causes slower growth (*Fontinalis*) or blocks sexual reproduction (*Batrachium*).

Changes in macroinvertebrates community were not followed in the Dyje River after the building of the Vranov reservoir (1934). Thus, we do not know their development since the time of filling the reservoir; however, we do consider the flow situation to be relatively stable lasting for several tens of years. Of the total number of species in the followed part of the Dyje River (260), 33 taxa of all were found only at the site upstream the reservoir (S1). In sites downstream the reservoir (S2 - S4) 73 taxa were found only there. The rest of taxa numbers was common for all parts of river.

Taxa belonging to the warmer parts of the barbell zone were Porifera, Bryozoa, *Helobdella*, the majority of species of the family *Chironomidae* and the genus *Pisidium*, Odonata, several mayflies (*Caenis*, *Ecdyonurus*, *Ephoron*, *Heptagenia*), some caddisflies (*Leptoceridae*, *Lype*, *Mystacides* etc.). On the other hand, in this section the following species were missing completely: Turbellaria, Gastropoda, *Gammarus roeselii*, majority of the genus *Baetis*, all found species of Plecoptera, several species of caddisflies of the family *Limnephillidae* and *Sericostomatidae*, majority of species of the genus *Eukiefferiella*, majority of *Simuliidae* and Coleoptera (see Appendix).

Of the 136 found taxa at the site S2, some may be considered to be surviving in extreme conditions, such as *Asellus aquaticus*, *Gammarus roeselii*, *Potamanthus luteus*, *Heptagenia sulphurea*, species of the genus *Caenis*, *Cheumatopsyche lepida*; these species do not have the optimal conditions for their development. List of typical species listed by their dominance is in Appendix.

On contrary, at the last site downstream the reservoir (S4) we found species that did not occur at the previous sites or that were present in large quantities. We consider them to be signal species that reflect the lessening of the impact of the reservoir in this section as well as a transfer to another zone of the RCC (see also DCA results). At S4, the following species are considered signal: *Rhithrogena semicolorata*, *Baetis lutheri*, *Baetis fuscatus*, *Perla burmeisteriana*, *Isoperla grammatica*, *Oligoplectrum maculatum*, *Rhyacophila nubila*, *Glossosoma* sp., *Antocha vitripennis*, *Eusimulium costatum*.

In the longitudinal profile of the Dyje River, there are important changes of the trophic structure in relation with the substrate, discharge and temperature conditions and variety of nutritional sources. Species number of gatherers remained quite high in the entire followed part of the Dyje River; however, at the Dyje downstream the reservoir, gatherers are represented by worms especially, larvae of net-spinning caddisflies (*Hydropsychidae*) and larvae of mayflies of the genus *Potamanthus* and *Caenis*; in the section below the reservoir there were mostly larvae of blackflies, some species of chironomids, predatory caddiesflies *Polycentropus flavomaculatus*.

At both sites S1 and S2 we found also high numbers of scrapers and grazers with different species of mayflies, caddisflies and chironomids. In the section below the reservoir, the shredders were very abundant, especially both species of *Gammarus*, caddisflies larvae of *Limnephilus*, *Potamophylax*, *Sericostoma*, *Chaetopteryx* and chironomids of the genus *Brillia*, *Cricotopus*.

Sizeable differences between the sites upstream and downstream the reservoir was found also in the quantitative and species structure of hyporheic community. In the stretch below the reservoir, there were almost 10 times more individuals and a higher number of taxa than above the reservoir. In the deeper bottom layers below the reservoir, there was a higher representation of planktonic species and active species of macroinvertebrates. Upstream the reservoir, we found also additional larvae of soil species. It is obvious that hyporheal below the reservoir creates an important refugium for the true zoobenthic species that undergo short-term stress discharge oscillations.

Hydrological regime, especially hydropower peaking, frequency and value of minimal flow are major factors found in many studies. For example, FISHER & LAVOY (1972) showed the influence of these factors on litoral fauna. They proved that in the zone with the highest flow fluctuation, the fauna is changed in biomass and species diversity. Our results showed that the littoral zone is recolonized by species capable of migrating to the hyporheal, that is *Chironomidae* and small amphipods.

In his case study, GORE (1977) reported influence of the changed temperature regime and established the minimal flow for the influenced part of the river. In our results, the character of the canyon-shaped river valley affected possible warming of water in minimal flow conditions. Only short stretches of the river were exposed to sunshine all day long. In many places, direct light lasted only for several minutes. The canyon exhibited all parameters of deep canyons including the temperature and vegetation inversion effects.

GISLASON (1985) demonstrated migration of macroinvertebrates in the deeper parts of the river. In the studied part of the river, this migration was true for amphipods.

ARMITAGE (1987) summarized the results of studies of impounded rivers in Great Britain. To analyze the results, he used TWINSPAN methods and biotic indexes (BMWP Score and ASPT Score). The number of families was statistically correlated with the age of the reservoir, distance from the source of the stream, altitude, water velocity and pH. Ordination analysis showed similar results to ours. Since his data ranges were larger, the author could have better interpreted axes in the ordination space. In our conditions, the situation was simpler since only two main factors were changing-flow regime and temperature.

To analyze the influence of peaking regime of hydropower stations, GORE et al. (1989) used the IFIM method (Instream Flow Incremental Methodology). The authors confirmed that the main factor was the difference between minimal and maximal flows and the duration of these events.

WEISBERG et al. (1990) were interested in the factor of minimal flows from a hydroelectric dam. They confirmed that dewatering and minimal flow had main effect on species composition and density of macroinvertebrates. Another more detailed factor was current velocity what corresponds to our results. Gore (1994) then summarized the influence of hydraulic conditions on habitat and on the character and distribution of bottom substrate. He quantified the influence on plants, macroinvertebrates and fishes.

BRETSCHKO & MOOG (1990) and MOOG (1993) compiled the results from regulated stretches of rivers in Austria affected by daily hydropower peaking. They showed that the decrease of biomass of macroinvertebrates was in the range of 40 - 60 % when compared to other stretches. However, in our case we obtained different results. We found that downstream of the reservoir, there was lower species diversity but higher abundance of macroinvertebrates, apparently caused by a different hydrochemical situation. In the studied stretch of the river, we found high nutrients concentrations (N, P), a situation completely different from the rivers in Austria. In the studied profiles, we observed massive growth of submerged angiosperms on riffles. On the stones and weir crest spill, we found growth of filamentous algae forming a 15 cm wide habitat for amphipods (*Gammarus fossarum*), euryvalent mayflies (*Baetis rhodani*) and midges.

MORGAN et al. (1991) analyzed the results of changes of flow regime on reviving the bottom. They confirmed that changes in frequency of maximal and minimal flows influenced the density and number of taxa. Densities increased especially for midges and net-spinning caddisflies.

VALENTIN et al. (1995) studied a river influenced by hydropower peaking. Minimal and maximal flow was about the same as in our case. In the influenced stretch of the river, higher densities and lower diversity were found as in the Dyje. However, there is a different situation for trophic guilds. VALENTIN et al. (1995) found dominance of scrapers in the influenced stretch, while we found a clear dominance of shredders. High abundance and dominance of amphipods caused this difference. *Gammarus fossarum* adapted to different food source and the mass of moss have become its main food. We found the identical situation in the Dyje, where the nutrition of *Gammarus fossarum* was formed by moss of genus *Fontinalis*. This situation is probably a long - term adaptation of this species to changed conditions and actual food offer.

MALMQVIST & ENGLUND (1996) studied the influence of changed discharge in tailwater on the population of mayflies larvae. They proved that only *Baetis rhodani* was capable of adaptation to different unnatural discharge fluctuations. On the other hand, species of the family *Heptageniidae* reacted by a significant change of abundance and species composition in the influenced part of the river. The main factors are especially the operation length and duration of the minimal discharge. This conclusion corresponds well with our finding that at the site S2 with the highest impact the species of this family were found only occasionally

In a monograph, EIE et al. (1997) summarized knowledge on ecology of influenced flows in Norway. They assume that the main factors influencing the composition and biomass biota changes in water flow, in water temperature and in sediment transport. They also study the possibilities of restoration of regulated rivers. In Norway, weir building to increase the minimal flows solves this situation.

ULRICH et al. (1998) studied the rare case of a complete release of a reservoir and its refilling on macrozoobenthos of downstream part of river. There were vast changes in amounts of dissolved Fe, Mn and Al and amounts of POM and PIM in water. The most influenced species were larvae of stoneflies and crustaceans, especially *Gammarus fossarum*. They decreased from 52 % to 10 %, 19 % to 9 % respectively. Total abundance, however, increased almost twice; larvae of Diptera (*Chironomidae*)

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covered up to 68 % of all individuals. This case proved a very clear ability of adaptation of larvae of *Chironomidae;* they were abundant even in the Dyje River downstream the reservoir, and even in the Svratka River downstream the Vír reservoir as was found by BRABEC (1998).

CAMARGO & VOELZ (1998) summarized results of two rivers influenced by reservoirs of the Colorado River in the USA and Duratón in Spain. As for the Colorado River, the main influence was decrease and different changes during the year of the water temperature; in Spain, there were short-term changes of discharge. In both cases, with increasing distance from the reservoir, the number of shredders and scrapers increased. In both cases, larvae of *Chironomidae* were very tolerant, while water beetles of the genus *Elmis* and caddisflies of the family *Psychomyidae* were the least tolerant. Similarly to the river Dyje at the site S2, the larvae of *Psychomyia pusila* were found only occasionally while above the reservoir they were very dominant.

Below the reservoir, the community of water mussels was very reduced. VAUGH et al. (1999) found this effect in the Little River, USA. About the same situation was found in the Dyje River, where mussels of genus *Unio* and *Anodonta* completely disappeared.

The influence of regulated thermal regime is also significant. Oligostenothermal organisms occurred in the impacted stretch of river. This situation, influence of deep release outlet, was described by many authors e.g. (PEŇÁZ et al. 1968, WARD 1974, WARD & STANFORD 1979, etc.). Our results are very similar to those published by SPENCE & HYNES (1971) and LEHMKUHL (1972).

In the regulated stretch of the Dyje, there is a distinct fragmentation of the river continuum and a secondary zone of rhithral was formed with several typical species. This result corresponds very well with the river discontinuum concept (WARD & STANFORD 1979, 1995). In the influenced part, there originated a specific community of organisms adapted to massive growth of moss, which covered up to 99% of the bottom. A large production of shredders, especially *Gammarus fossarum,* was a specific feature of this river. Also, several species of caddisflies (*Potamophylax* sp., *Sericostoma* sp. etc.) were found while shredder stoneflies were missing completely. Scrapers were found as several species of midges (*Cricotopus* sp., *Brillia* sp.) and mayflies (*Baetis* sp.), but in lower abundances and biomass than amphipods.

The temperature regime and higher concentrations of basic nutrients from the mineralisation processes in the reservoir enabled huge growths of moss, algae and a specific community of macroinvertebrates. This situation may be specific for intensively agricultural regions of central Europe where the flows are burdened with huge amounts of nutrients as found in the Jihlava River in the Czech Republic (ZELINKA 1984, HELEŠIC & SEDLÁK 1995). Eutrophication and high quantities of organic material inputting to the Vranov reservoir and their utilization and mineralisation to the bioavailable nutrients are the main factors of this specific situation.

What distance from reservoir enables the renewal of the natural character of the river?

Changes in the number of taxa and individuals of macroinvertebrates in the longitudinal course of the Dyje River and the occurrence of signal species at the site S4 suggest that there begins the intermediate zone (hyporhithral/epipotamal) to a lowland river. There are more often occurrences of populations of *Gammarus roeselii*, *Tubificidae*, several species of stoneflies (*Perla*, *Perlodes*, *Isoperla*), increased number of species *Hydropsychidae* as well as presence of Barbel and Nase.

Differences in the structure of fish in the longitudinal course of the Dyje River are very clear. Variability of abundance and fish biomass in the sites downstream the reservoir is caused by species and numerical composition of the fish stock. For example, a large share of bullheads at the site S3 increases abundance but decreases biomass. When compared to other parts of the section below the reservoir, the biomass of fish at the site S4 is increased by large species of fish (Barbel, Chub).

The total trophic composition of zoobenthos does not show optimal conditions even at the furthest site S4 of the barbel zone nor the common model RCC. We suppose that the temperature and discharge regime influenced by the reservoir are the main factors even 32 km below the reservoir, and they change up to a shallow and instantaneous reservoir Znojmo (ZELINKA & HELAN 1989).

Shortly below the small reservoir Znojmo, the Dyje River leaves the highlands, and it changes into a typical potamal river with summer temperatures of over 20°C. At the same time, there occurs another flattening of the discharge wave (DUB 1957) so that the high daily water surface and discharge gradient is ecologically unimportant. Return to natural temperature regime in the river and decrease of daily discharge oscillations to a minimum is thought to happen around the 45th km (river km 154th) from the Vranov reservoir.

Suggested remedial measures

We consider the daily oscillation of discharges (cyclic daily dwatering/rewatering) to be the strongest stress factor responsible for the macroinvertebrates community structure changes in the channel below the reservoir at the site S2. Swift increase and decrease of the discharge wave and low values of the residual flow are features unknown in nature. During the work of the turbines, the discharge is about 16 – 46 $m^3.s^{-1}$ for more than two hrs, while during the break, the discharge is only 1.2 $m^3.s^{-1}$ for about 6 hrs. During minimal discharge, more than 30 % of the bottom are dried. When discharge drops below 1 $m^3.s^{-1}$, in some stretches of the river more than 50 % of the bottom is dried.

Another negative factor is permanently low temperature with minimal fluctuations during the year, so that only a few species of the bottom community are capable of finishing their life cycles (WARD & STANFORD 1979, WARD 1992).

Increase of temperature gradient could be possible by releasing surface layers from the reservoir. However, because of hydrological assessment and the size of usable volume of the reservoir, this regime is not possible. In the operation procedure, there is an obvious priority given to sufficient amount of water for hydroelectric station and for the water supply. Water, warming up during the break in directly releasing weir Formoza in Vranov, will gain, during a sunny day, temperature 2°C higher than the water temperature of the hypolimnic layer in the reservoir in the depth of the turbine release. In other parts of the stream, this increase is even lower. In that case, water temperature cannot be influenced.

More possibilities are offered in remediation of discharge regime especially peaking regime and volume and duration of minimal flow (Qmin). Next to international experience we have mentioned before, we rely on our experience (HELEŠIC & KUBÍČEK 1997) of minimal discharge as well. From our observations it is obvious that the residual minimum in the break of the hydropower station should be higher, at least during the monthly minimum discharge in this part of the Dyje that is $1.8\ m^3.s^{-1}$, optimally based on the geometry of the channel, temperature regime of $2.4\ m^3.s^{-1}$. That means that there is a need to gain an increase of discharge by $1.2\ m^3.s^{-1}$ 2 x 4 hrs daily. It is necessary to add that independently from us, for example PETTS & MADDOCK (1994) used the principle of determining Qmin from the half of the average monthly flow. Our recommendation is based on a thought that zoobenthos is formed in connection with long-term repetition discharge variability and is capable of surviving disturbance with 50 % (so called "acceptable loss" PETTS, 1996) tolerance just as other scientist suggest (GORDON et al., 1992).

Minimum ecological discharge or ecologically acceptable flow regimes and volumes (PETTS 1996) should be determined so that they are suitable for fish and the river bottom community or especially protected species. So, the conditions must be suggested with regard to velocity and migration activity of organisms, to spatial and flow refugia, reproductive and nutritional habitats (STATZNER 1992).

Technically, the problem of increasing discharge can be solved by a change of the water discharge of the station. There is a possibility of adding water from the weir Formoza in Vranov nad Dyjí; another peak in lasting and volume of released water so that the discharge would not decrease below $2.4\ m^3.s^{-1}$ exceptionally $1.8\ m^3.s^{-1}$.

Another possibility is increasing water capacity of the weir Formoza or addition of another weir in the part below the reservoir. The new weir may be placed above the weir Formoza as well as below it on the 171[st] river km. Downstream in the First Protection Zone of the NP, all manipulations with the geometry of the channel are strictly prohibited. Legal conditions of the NP Podyjí do not allow for any exceptions. Weir building in the village Vranov might cause problems since there is a possibility of increasing the groundwater level and permanent flooding of cellars and buildings. Building of the weir below the reservoir is technically possible; however, static influence of the dam and the decrease of turbine discharge must be taken into consideration.

Based on international experience (GORDON et al. 1992, HEY 1994 and LARSEN 1994), there is also the possibility of two changes of the channel close to natural changes: building of a series of smaller discharge weirs - boulders bars and a series of left and right-sided spur dikes or wing dams of the natural material of the river bottom in the entire part of the flow from the reservoir to the borders of the natural park. These types of improvements would increase the morphological diversity of the bottom and so even the discharge and habitat diversity and they would not cause any difficulties for fish migration. It would be a simulation of classical river sequence pool – riffle. These buildings should slow down the steep start of the peaks and prolong the time of water discharge from the channel in times of the breaks of the station. Pools originating from these weirs and the spur dike would have stable deeper water levels. In the pools and stony benches, many species including fish could survive that nowadays react to the flow changes by escape to further parts of the river. However, there is a worry that since the space is limited (only 0.8 km), the gained volume of water in serial constructions would not cover the increase of the residual minimum to the required value in the next part of the channel in the NP.

The management of the NP Podyjí demands a change of the hydrological regime by law; minimal discharge between the peaks must be 2.4 $m^3.s^{-1}$ long-term with acceptable absolute minimum up to 1.8 $m^3.s^{-1}$. Of all the technical, organizational and economic view points, the most acceptable change of the discharge regime for the future would be addition of another peak around midday or at midnight. The length of the peak and volume of released water must be a topic of a special hydrological-technical study.

Souhrn a závěry

(Summary and Conclusions in Czech)

Výzkum řeky Dyje byl iniciován Správou Národního parku Podyjí, která má zájem na tom, aby úsek toku protékající chráněným územím nejvyššího významu byl co nejvíce prozkoumán z hlediska výskytu fauny a flory a obecných ekologických poznatků, které by mohly sloužit k řízení ochrany přírody.

Před výstavbou údolní nádrže Vranov byl úsek řeky v nynějším NP typickým parmovým pásmem - epipotamalem (HOCHMAN & JIRÁSEK 1960), které by mělo být v národním parku zachováno, nebo by se mu mělo v základních ekologických ukazatelích přibližovat. Původní říční kontinuum bylo přerušeno dvěma údolními nádržemi Vranov a Znojmo a tok ležící mezi nimi má jiné enviromentální vlastnosti než v období před výstavbou přehrad. V současné době hydrologický a teplotní režim vytvořil zcela nový typ pásma jakési druhotné pstruhové pásmo (epi-metarhithral) s některými prvky parmového (epipotamal).

Výzkum říčního úseku a hlavních přítoků začal v roce 1991 a hlavní těžiště prací bylo v letech 1993 – 1995.

Studovaný úsek Dyje se nachází mezi 140 až 208 říčním kilometrem a kromě odběrného profilu Podhradí a údolní nádrže Vranov je součástí Národního parku Podyjí.

Ve studovaném úseku je několik přítoků. Na pravé straně jsou významné přítoky Fugnitzbach, Kajabach a Tifenbach. Z hydrologického hlediska je nejdůležitější prvně jmenovaný. Levostranné přítoky mají z hlediska hlavního toku nevýznamnou vodnatost, jejich význam je však v celkové hydrologické a geomorfologické (postranní kaňony) charakteristice oblasti (Klaperův, Žlebský Mašovický, Lukovský a Gránický potok).

Pro výzkum vlivu nádrže Vranov byly zvoleny tři profily pod nádrží a jeden tzv. pozaďový nad přehradou (S1 – Podhradí, 207 říční km), který reprezentoval původní charakter řeky. Pod přehradou byl sledován profil Hamry – Střelnice (S2, ř. km 172,5) asi 4 km pod přehradou, dále pak profil Hardegg (S3, 163 říční km) a profil Papírna (S 4, 141 říční km) těsně nad vzdutím přehradní nádrže Znojmo.

Hlavní cíle a výsledky jsou stručně uvedeny v následujícím textu. Podstatné informace jsou však především uvedeny v výše.

Enviromentální rozdíly v řece Dyji nad a pod přehradou

Průtok a substrát dna

Průměrný roční průtok na obou úsecích (S1 a S2) je přibližně stejný 8,5 a 9,7 $m^3.s^{-1}$ (průměr za 5 let). Také vysoké měsíční průtoky jsou časově a kvantitativně velmi shodné a v obou případech se vyskytují v měsících březnu a dubnu .

Více rozdílné jsou měsíční minimální průtoky. V neřízeném úseku nad přehradou (S1) činí 1,7 $m^3.s^{-1}$ a spadají do měsíce srpna nebo září , v řízeném úseku pod přehradou (S2) jsou minimální měsíční průtoky v listopadu nebo prosinci okolo 3,4 $m^3.s^{-1}$.

Celkově je čára průtoků pod přehradou vyrovnanější než nad přehradou. Hlavní rozdíl je v denní průtokové variabilitě pod přehradou, kde minimální průtok z teoretické hodnoty 1,2 $m^3.s^{-1}$ narůstá denně na 15,3 až 45 $m^3.s^{-1}$ podle počtu pracujících turbín.

V důsledku těchto oscilací dochází ke změnám velikosti plochy omočeného obvodu a k vytváření trvale a periodicky zaplavovaných částí dna. Podíl periodicky zaplavované části dna je podle našich pozorování až 60 % a v případech, kdy dotokový průtok byl menší (0,8 $m^3.s^{-1}$) než oficiálně stanovený (asi 1,2 $m^3.s^{-1}$), zvětšila se obnažená plocha dna téměř na 70 % a zbytkový průtok se asi po dobu 2 hodin soustředil pouze do několika stružek v korytě.

Krátkodobé kolísání průtoku v dalších úsecích toku pod přehradou (S3 a S4) se vyznačují menší výškovou amplitudou a širší základnou postupové vlny a také vyšším dotokovým průtokem od 1,8 do více než 2 $m^3.s^{-1}$. Velikost střídavě zaplavované plochy dna je proto menší než na lokalitě S2. Kromě vyššího dotokového průtoku je na těchto lokalitách zkrácena doba minimálního průtoku na polovinu (asi 2 x 2 hod denně) oproti kritické lokalitě S2.

Nepříznivým faktorem je strmý nárůst průtokové vlny, jejíž výšková amplituda je na S2 největší. Podle našich měření docházelo ke zvýšení hladiny od základní hloubky 15 cm do 85 cm během 30 minut, někdy ještě během kratší doby.

Průtokové změny samozřejmě provázejí změny v hodnotách rychlosti proudu, smykového stresu a komplexního Reynoldsova čísla. LAKE (1990) nazval tyto prudké změny v rychlosti proudění vody v korytě řeky jako předpovídatelé průtokové disturbance. To ovšem platí pro přirozené změny průtoku. Hydrologické změny detekované na příkladu řeky Dyje pod přehradou nikdy nenastávají v přirozených úsecích toků, v našem případě nad přehradou, kde změny omočeného obvodu probíhají kromě jarních a bouřkových přívalů pozvolna, v delším časovém úseku a ve tvarově jiném příčném profilu koryta.

Na takové situace se může adaptovat jen omezený počet druhů. Proto vidíme v časovém a výškovém rozložení této postupové vlny a v nízkém dotokovém průtoku silný ekologický faktor odpovědný za další změny v denním teplotním a kyslíkovém režimu a v erosní a unášecí práci vody. Zobecnění tohoto problému podali ve svých pracích především FISCHER & LAVOY (1972), WARD (1974), GORE (1977) a ARMITAGE (1984). GASCHIGNARD & BERLY (1987) studovali podobný průtokový režim na řece Rhône ve Francii. Jeho vliv se projevil především na výskytu a abundanci schránkatých chrostíků a ve zvýšení frekvence výskytu katastrofického driftu.

Dalším významným efektem změněných průtokových poměrů je změna substrátu dna. Především se mění velikostní struktura hrubé anorganické hmoty a jednotlivé balvany a kameny jsou železitými inkrustacemi pevně přichyceny do dna. Svrchní vrstva dnových sedimentů je intenzivně promývána vodou a tak i obsah partikulované organické hmoty je rozdílný na profilech nad a pod přehradou.

Teplotní režim vody

Teplotní režim úseku Dyje nad a pod přehradou je zcela rozdílný. V důsledku krátkodobých změn denních průtoků dochází ke změnám teploty vody v závislosti na hloubce vody vypouštěné z nádrže a na délce zadržení v jezových zdržích v průběhu roku. Tyto změny jsou dobře sledovatelné při nástupu a poklesu postupové vlny a teplotní gradient činí až 2 °C v časovém průběhu 1 - 3 hodin.

Při nástupu postupové vlny se nejčastěji teplota vody v létě nejdříve krátkodobě zvýší (odtok teplejší vody z jezových zdrží) a pak se sníží po celou dobu zvýšeného průtoku (vliv nízké teploty vody z přehradního hypolimnia). Při poklesu vlny se nejdříve udržuje příslušná nízká teplota, která se po snížení hladiny postupně zvýší na určitou úroveň až do nové průtokové změny.

LEHMKUHL (1972) a GORE (1977) jako jedni z prvních kvantifikovali tento jev a odvodili, že teplota je významným faktorem pro průběh a dokončení vývojových cyklů a pro reprodukci dnových organismů a ryb. Důležitá je nejen určitá celková suma teplot, ale také vysoký teplotní denní gradient, který koreluje kladně s druhovou rozmanitostí dle koncepce říční návaznosti (VANNOTTE et al. 1980) a podélně-prostorového členění toků (ILLIES & BOTOSANEANU 1963).

Denní teplotní gradient v rozsahu pouze 1 - 2 °C nemá na tyto děje podstatný vliv (WARD & STANFORD 1979). Teplota vody v podélném profilu Dyje pod přehradou se vyvíjí podobně jako ve Svratce pod Vírskou nádrží (PEŇÁZ et al. 1968) nebo v řece Jihlavě pod Dalešicemi (HELEŠIC & SEDLÁK 1995). Na řece Dyji je ovšem pokles teplot výraznější, stejně tak jako rozdíly mezi úsekem nad a pod nádrží. Od jara do podzimu se obecně teploty vody postupně zvyšují, v zimním období se snižují. Nejnižší a ani nejvyšší teploty vody v části Dyje pod přehradou nedosahují nikdy teploty vody nad přehradou.

Množství rozpuštěného kyslíku ve vodě

Procentuální nasycení vody kyslíkem dosahuje na sledovaných úsecích hodnot odpovídajících přirozené saturaci, organickému zatížení a intenzitě primární produkce :

Nejnižší hodnota na S2 je dána odtokem vody z hypolimnia. Vysoké saturace jsou doplňovány z primární produkce, na S1 převážně z říčního fytoplanktonu, v úsecích pod přehradou z epilitických řasových nárostů a z porostů makrovegetace.

Technicky se problém nízké saturace vody pod nádržemi řeší provzdušňováním hypolimia, aerací výtoku z turbín a nebo výstavbou speciálně upravených jezů se zvětšenou délkou koruny jezu a se zvýšenou turbulencí (YEAGER 1993).

Organické znečištění

Parametry organického znečištění zjišťované jako BSK a CHSK mají v podélném profilu klesající tendenci. Organicky středně znečištěná část Dyje nad přehradou se průtokem údolní nádrží a v další části toku zřetelně zlepšuje na úroveň nižších saprobních stupňů. Také mírné zvýšení znečištění v Hardeggu (S3) je asi po 20 km toku (S4) zcela odbouráno.V tomto případě nádrž Vranov působí kladně na zlepšení kvality vody, což potvrzuje obecně platné závěry WARD & STANFORD (1983).

Živiny

Nejvíce údajů o živinách v podélném profilu pochází z let 1992 a 1994. Nejvyšší očekávané koncentrace amoniakálního dusíku a celkového fosforu byly v úseku Dyje nad přehradou, na sledovaných úsecích pod přehradou byly nižší v důsledku utilizace přehradní a říční primární produkcí. Dusičnanový dusík vykazoval v podélném profilu nižší hodnoty v úseku nad přehradou a variabilní, většinou vyšší hodnoty v úsecích pod přehradou. Pro podrobnější vyhodnocení živinového režimu nemáme dostatek dat. Přesto můžeme tvrdit, že limneticky cyklus živin v nádrži významně mění jejich charakter a působí na ně jako past – zadržuje velké množství v nádrži (STRAŠKRABA 1973, STRAŠKRABA & TUNDISI 1999). Tyto závěry souhlasí s obecnými tezemi teorie říčního diskontinua (WARD & STANFORD 1983).

Odpověď říční bioty na enviromentální změny v řece pod přehradou

Na říční diskontinuitu reaguje především bentické společenstvo a rybí obsádka. Epilitické nárosty se v úseku nad přehradou vyznačují rozvojem vláknitých řas, epilitických rozsivek a planktonních kokálních řas. V úseku pod přehradou je převaha epilitických řasových nárostů se studenomilnými druhy a druhy preferujícími více lotické nebo více lenitické části toku, případně tolerujícími střídavé zaplavování a obnažování dna.

Podobně reagují makrofyta různě silnou prezencí druhů na stabilně proudivých nebo periodicky obnažovaných částech dna. Relativně konstantní nízká teplota vyvolává pomalejší růst (*Fontinalis*) nebo blokuje pohlavní reprodukci (*Batrachium*).

Změny ve společenstvech zoobentosu nebyly v řece Dyji po postavení Vranovské přehrady (1934) sledovány. Neznáme tedy jejich vývoj od doby napuštění nádrže, přesto považujeme současný stav za relativně stabilizovaný, přetrvávající již několik desítek let. Z celkového počtu druhů sledované části Dyje (260) bylo jen v úseku nad přehradou (S1) zjištěno 33 taxonů a výhradně v úsecích pod přehradou (S2 - S4) 73 taxonů.

Do taxonů, které byly pouze v teplejší části parmového pásma Dyje patřili především zástupci Porifera, Bryozoa, *Helobdella*, většina druhů čeledi Chironomidae a rodu *Pisidium*, Odonata, některé jepice (*Caenis*, *Ecdyonurus*, *Ephoron*, *Heptagenia*), někteří chrostíci (*Leptoceridae, Lype, Mystacides*) a další. Naopak v tomto úseku zcela chyběli zástupci taxonů Turbellaria, Gastropoda, *Gammarus roeselii*, většina rodu *Baetis*, všechny zjištěné druhy Plecoptera, řada druhů chrostíků čeledi *Limnephilidae* a *Sericostomatidae*, většina druhů rodu *Eukiefferiella*, většina *Simuliidae* a Coleoptera (viz Apppendix).

Z celkového počtu taxonů 136 na lokalitě S2 pod přehradou musíme některé považovat za přežívající v mezních podmínkách. Týká se to např. *Asellus aquaticus*, *Gammarus roeselii*, *Potamanthus luteus*, *Heptagenia sulphurea*, druhy rodu *Caenis*, *Cheumatopsyche lepida*, které nemají na této lokalitě podmínky k optimálnímu vývoji. Seznam typických druhů dle dominancí je uveden v Appendixu.

Na poslední lokalitě pod přehradou (S4) se naopak vyskytly druhy, které na předešlých lokalitách nebyly, nebo se pouze na S4 prezentovaly ve větším množství. Považujeme je za signální druhy, které vypovídají o tom, že v tomto úseku dochází k tlumení enviromentálních vlivů přehrady a k přechodu do dalšího pásma RCC (viz také výsledky DCA). Za signální druhy na S4 považujeme: taxony *Rhithrogena semicolorata*, *Baetis lutheri*, *Baetis fuscatus*, *Perla burmeisteriana*, *Isoperla grammatica*, *Oligoplectrum maculatum*, *Rhyacophila nubila*, *Glossosoma* sp., *Antocha vitripennis*, *Eusimulium costatum*.

K podstatným změnám dochází v podélném profilu Dyje v trofické struktuře v závislosti na substrátových, průtokových a teplotních podmínkách a na různosti potravních zdrojů. Druhový počet sběračů zůstal v celé sledované části Dyje relativně vysoký, ale v Dyji nad přehradou jsou sběrači reprezentováni hlavně nitěnkami (*Tubificidae*), larvami chrostíků se sítěmi (*Hydropsychidae*) a larvami jepic rodu *Potamanthus* a *Caenis*, v úsecích pod přehradou jsou to převážně larvy muchniček a některé druhy pakomárů, a dravých chrostíků (*Polycentropus flavomaculatus*).

Na obou lokalitách S1 a S2 byly také ve vysokém podílu škrabačů a spásačů vždy jiné druhy jepic, chrostíků a pakomárů. V úsecích pod přehradou byli velmi silně zastoupeni kouskovači, hlavně oba druhy rodu *Gammarus*, larvy chrostíků rodu *Limnephilus*, *Potamophylax*, *Sericostoma*, *Chaetopteryx* a pakomárů rodu *Brillia*, *Cricotopus*.

Velké rozdíly mezi úseky Dyje nad a pod přehradou byly také v početním i druhovém osídlení hyporhealu. V úseku pod přehradou bylo téměř 10x více jedinců a také vyšší počet taxonů než nad přehradou. V hlubších vrstvách dna pod přehradou bylo větší zastoupení planktonních druhů a mobilních druhů zoobentosu než nad přehradou, kde byly navíc druhy terestrické. Je zřejmé, že hyporheal pod přehradou plní důležitou refugiální funkci pro pravé zoobentonty, kteří jsou vystavováni krátkodobým stresovým průtokovým oscilacím.

V jaké vzdálenosti pod přehradou se začíná obnovovat přirozený charakter toku

Změny v počtu taxonů a jedinců zoobentosu v podélném profilu Dyje a výskyt signálních druhů na lokalitě S4 naznačují, že zde začíná přechodná zóna (hyporhithral/epipotamal) do nížinného toku. Jsou zde častější výskyty populace *Gammarus roeselii*, *Tubificidae*, některé druhy pošvatek (*Perla*, *Perlodes*, *Isoperla*), zvýšený počet druhů *Hydropsychidae* a také prezence parmy a ostroretky.

Rozdíly ve struktuře rybí obsádky v podélném profilu Dyje jsou jednoznačné. Variabilita abundance a biomasy ryb na lokalitách pod přehradou je dána druhovým a velikostním složením rybí obsádky. Např. velký podíl vranky na S3 zvyšuje abundanci ale snižuje biomasu. Biomasa ryb na S4 je oproti ostatním úsekům pod přehradou zvýšena velkými druhy ryb.

Celkové trofické složení zoobentosu ani ve vzdáleném úseku S4 neodpovídá optimálním podmínkám parmového pásma ani obecnému modelu RCC. Domníváme se, že teplotní a průtokový režim ovlivňovaný nádrží je i po 32 km toku od hráze pro zoobentos stále řídícím faktorem a upravuje se v Dyji až dále pod mělkou a průtočnou nádrží Znojmo (ZELINKA & HELAN 1989).

Brzy pod malou vodárenskou nádrží Znojmo opouští řeka Dyje vrchovinu a stává se typickým potamálním tokem s letními teplotami vody přesahujícími hranici 20 °C. Zároveň zde dochází k dalšímu zploštťování průtokové křivky (DUB 1957), takže denní výškový gradient hladiny a průtoků je ekologicky zcela nevýznamný. Návrat původních teplotních poměrů v řece a snížení denních průtokových oscilací na minimum předpokládáme asi okolo 45 km (říční km 154) od nádrže Vranov.

Návrh nápravných opatření

Za nejsilnější stresující faktor odpovědný za změnu struktury dnového společenstva vodních bezobratlých v úseku toku pod přehradní nádrží na lokalitě S2 považujeme silné denní oscilace průtoků vyvolané činností hydroelektrárny. Rychlý nástup a pokles postupové vlny a nízká hodnota zbytkového průtoku jsou jevy v přírodě neznámé. Při práci turbin protéká korytem okolo 16 – 46 $m^3.s^{-1}$ po dobu více jak 2 hodiny a v přestávce zbytkový průtok okolo 1,2 $m^3.s^{-1}$ po dobu asi 6 hod. V minimech průtoku zůstává obnaženo asi 30 a více procent plochy dna řeky. V průtocích menších než 1 $m^3.s^{-1}$ bývá obnažena plocha dna v některých úsecích toku větší než 50%.

Dalším negativním faktorem je trvale nízká teplota vody s minimálním kolísáním během roku, která z možného druhového spektra dnového společenstva umožňuje dokončení životních cyklů jen málo druhům (WARD & STRANFORD 1976, WARD 1993). Zvýšení teplotního gradientu by bylo možné vypouštěním hladinové vrstvy z nádrže. Vzhledem k hydrologickým bilancím a velikosti využitelného objemu nádrže tento režim není možný. V manipulačním řádu dostává jednoznačně přednost dostatek vody pro hydroelektrárnu a pro vodárenský zdroj. Voda, která se v době pracovní přestávky ohřeje v řízeně vypouštěné jezové zdrži Formoza ve Vranově dosáhne asi za 6 h slunného dne v létě teplotu vody jen o 2°C vyšší než má voda v hypolimnické vrstvě nádrže v hloubce nátoku na turbiny. V jiných částech roku je toto zvýšení ještě nižší. Teplotu vody nemůžeme v tomto případě výrazně ovlivnit.

Více možností se nabízí v nápravě průtokového režimu zvláště pak v úpravě špičkování a v omezení nebo zvýšení minimálních průtoků. Kromě zahraničních zkušeností uvedených již dříve, vycházíme i z vlastních zkušeností (HELEŠIC & KUBÍČEK 1997) o minimálních průtocích. Z našich pozorování vyplývá, že dotokové minimum v pracovní přestávce hydroelektrárny by mělo byt podstatně vyšší, minimálně v hodnotě měsíčního minima v tomto úseku řeky Dyje tj. 1,8 $m^3.s^{-1}$, optimálně, vzhledem ke geometrii koryta, teplotnímu režimu 2,4 $m^3.s^{-1}$. To znamená, že je potřeba získat nadlepšení průtoku o 1,2 $m^3.s^{-1}$ po dobu 2x4 hod denně. Je třeba připomenout, že nezávisle na nás uplatnili princip poloviny průměrného měsíčního průtoku pro stanovení Qmin např. PETTS & MADDOCK (1994). Naše doporučení vychází z úvahy, že zoobenthos se formuje v závislosti na dlouhodobém opakování průtokové variability a že je schopen přežít disturbance s 50% tolerancí, jak kalkulují i jiní autoři (GORDON et al. 1992).

Minimální ekologické průtoky nebo lépe ekologicky akceptovatelné průtokové režimy (PETTS 1996) mají být stanovovány tak, aby vyhovovaly rybám i společenstvu říčního dna, příp. zvlášť chráněným druhům. Musí být tedy navrhovány s ohledem na pohybovou a migrační aktivitu organismů, na zachování prostorových a proudových refugií, reprodukčních a potravních habitatů (STATZNER 1992).

Technicky lze problém navýšení průtoků řešit především změnou vypouštěcího režimu vodní elektrárny. Je možnost přidat v době dotoku vody ze zásobního prostoru jezu Formoza ve Vranově nad Dyjí, další špičku v trvání a objemu vypouštěné vody tak, aby průtok nepoklesl pod hranici 2,4 $m^3.s^{-1}$, výjimečně pak 1,8 $m^3.s^{-1}$.

Další možností je zvýšení objemu jezové zdrže Formoza nebo přidání dalšího jezu v úseku toku pod přehradou. Nový jez je možné umístit jak nad jezem Formoza, tak pod ním do říčního km 171. Níže po proudu v I. ochranné zoně NP je jakákoliv manipulace s geometrií koryta, případně stavební činnost zcela nepřípustná. Zákonné podmínky vyhlášení NP Podyjí neumožňují žádné výjimky. Výstavba jezu v zástavbě obce Vranov je problematická, vzhledem k možnému zvýšení hladin podzemních vod a trvalému zatopení základů staveb a sklepů. Výstavba jezu pod přehradní nádrží je technicky možná, s tím, že se musí vzít v úvahu možné statické ovlivnění přehrady a snížení výkonu turbin.

Podle zahraničních zkušeností (GORDON et al. 1992, HEY 1994 a LARSEN 1994) se ještě pro naše účely nabízí možnost dvou přírodě blízkých úprav koryta: výstavba série nižších průtočných jezů – balvanitých valů (skluzů) a série střídavě levo- a pravobřežních výhonů z původního materiálu říčního dna v celém úseku toku od nádrže až k hranici NP. Tyto typy úprav by zvýšily morfologickou rozmanitost dna řeky a tedy i průtokovou a habitatovou diverzitu a nebyly by překážkou v migraci ryb. Jednalo by se o simulaci klasické říční sekvence tůň – peřej. Tyto stavby by měly zpomalit strmý nástup průtokové špičky a prodloužily by dobu vytékání vody z koryta v době přestávky v činnosti hydroektrárny. Tůně, které by vznikly u těchto jezů a výhonů, by měly trvale vyšší hloubky vody. V tůních a balvanitých lavicích by přežívala řada druhů včetně ryb, které dnes reagují na průtoková oscilace unikem do vzdálenějších úseků řeky. Při této úpravě koryta řeky je ovšem oprávněná obava, že vzhledem k omezenému prostoru (asi jen 0,8 km), získaný objem vody nepokryje zvýšení dotokového minima na požadovanou hodnotu v další části koryta v prostoru NP.

Správa NP Podyjí požaduje ze zákona nápravu hydrologického režimu, s tím, že minimální průtok mezi špičkami musí být dlouhodobě 2,4 $m^3.s^{-1}$, s přípustnými mimi do 1,8 $m^3.s^{-1}$. Ze všech technických, organizačních a ekonomických hledisek je do budoucna pravděpodobně nejvýhodnější změna odtokového režimu hydroelektrány, v první fázi přidání další špičky v době kolem poledne, resp. půlnoci. Délka trvání špičky a objem vypouštěné vody a musí být předmětem zvláštní hydrologicko – technické studie.

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Appendix 1

Complete list of taxa with dominance (D) and frequency of occurrence (F) in sampling sites from the year 1991 – 1994 (FC – filtering collectors, GC – gathering collectors, SC – scrapers, SH – shredders, P – predators, Pa – parasites)

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
PORIFERA									
Ephydatia fluviatilis (LINNÉ)	FC	0,008	8,33	-	-	-	-	-	-
HYDROZOA	P	0,024	8,33	-		0,371	7,7	-	-
Hydra attenuata (PALLAS)	P	-	-	0,177	15,4	0,302	30,8	-	-
Pelmatohydra oligactis (PALLAS)	P	0,005	8,33	-	-	-	-	-	-
TURBELLARIA									
Dugesia gonocephala (DUGES)	P	-	-	0,554	100,0	0,240	69,2	0,071	69,2
Dugesia lugubris (SCHMIDT)	P	-	-	-	-	0,021	15,4	0,014	23,1
Polycelis nigra (MÜLLER)	P	-	-	0,070	53,8	0,015	15,4	0,004	23,1
NEMATODA									
Mermithidae (indet.)	Pa	0,133	33,33	0,151	53,8	0,007	7,7	0,106	30,8
NEMATOMORPHA									
Gordionus scaber MÜLLER	Pa	-	-	-	-	-	-	0,001	7,7
Gordionus sp.	Pa	-	-	< 0,001	7,7	-	-	-	-
OLIGOCHAETA									
Bothrioneurum vejdovskyanum ŠTOLC	GC	0,016	8,33	< 0,001	7,7	-	-	-	-
Chaetogaster crystallinus VEJDOVSKÝ	P	-	-	0,190	7,7	-	-	-	-
Chaetogaster diaphanus (GRUITHUISEN)	P	0,007	16,67	0,013	15,4	0,168	15,4	-	-
Criodrilus lacuum HOFFMEISTER	GC	0,098	16,67	0,042	7,7	0,011	15,4	0,173	7,7
Eiseniella tetraedra (SAVIGNY)	GC	0,039	33,33	0,017	46,2	-	-	0,104	53,8
Enchytraeus sp.	GC	-	-	0,002	15,4	0,007	7,7	0,006	7,7
Enchytraeidae (indet.)	GC	0,003	8,33	0,085	53,8	0,059	15,4	0,014	7,7
Haplotaxis gordioides (HARTMANN)	GC	0,311	16,67	0,011	15,4	0,063	7,7	0,089	7,7
Limnodrilus hoffmeisteri CLAPAREDE	GC	**3,019**	16,67	0,004	7,7	0,001	-	-	-
Lumbriculus variegatus GRUBE	GC	0,003	8,33	0,003	15,4	-	-	-	-
Mesenchytraeus sp.	GC	-	-	0,009	7,7	-	-	-	-
Nais alpina SPERBER	GC	**2,067**	25,00	**1,120**	30,8	0,664	15,4	0,223	15,4
Nais communis PIGUET	GC	0,013	25,00	-	-	0,004	7,7	0,001	7,7
Nais elinguis MÜLLER	GC	**2,433**	41,67	**2,858**	30,8	0,505	38,5	0,695	46,2
Nais sp.	GC	0,122	8,33	0,019	15,4	-	-	0,039	7,7
Naididae (indet.)	GC	0,024	8,33	0,013	23,1	0,017	7,7	0,006	7,7
Ophidonais serpentina (MÜLLER)	GC	0,002	8,33	-	-	-	-	-	-
Peloscolex ferox (EISEN)	GC	-	-	0,021	15,4	0,014	7,7	0,095	15,4

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
Potamothrix hammoniensis (MICHAELSEN)	GC	0,060	25,00	0,003	7,7	0,050	15,4	0,023	15,4
Propappus volki (MICHAELSEN)	GC	0,036	8,33	-	-	0,112	23,1	-	-
Psammoryctides barbatus (GRUBE)	GC	-	-	0,011	7,7	-	-	0,056	7,7
Rhyacodrilus coccineus (VEJDOVSKÝ)	GC	0,130	8,33	-	-	-	-	-	-
Stylaria lacustris (LINNÉ)	GC	0,013	16,67	-	-	0,169	15,4	0,022	7,7
Stylodrilus heringianus CLAPAREDE	GC	**2,215**	66,67	0,481	61,5	**2,039**	69,2	**1,023**	76,9
Trichodrilus sp.	GC	0,016	8,33	-	-	0,014	7,7	-	-
Tubifex tubifex (O.F.MÜLER)	GC	**10,704**	50,00	0,001	7,7	-	-	0,001	7,7
Tubificidae (indet.)	GC	**18,234**	16,67	0,017	7,7	0,001	7,7	0,084	7,7
HIRUDINEA									
Erpobdella monostriata (GEDR.)	P	0,005	8,33	-	-	-	-	0,002	23,1
Erpobdella octoculata (LINNÉ)	P	0,295	66,67	0,004	23,1	0,003	7,7	0,100	76,9
Glossiphonia complanata (LINNÉ)	P	0,015	16,67	0,013	15,4	0,008	7,7	0,006	30,8
Helobdella stagnalis (LINNÉ)	P	0,098	25,00	-	-	-	-	-	-
Piscicola geometra (LINNÉ)	Pa	0,037	25,00	-	-	0,021	7,7	0,001	15,4
BRYOZOA									
Plumatella repens (LINNÉ)	FC	-	16,67	-	-	-	-	-	-
MOLLUSCA									
Ancylus fluviatilis MÜLLER	SC	**4,108**	83,33	0,118	61,5	0,921	84,6	0,268	69,2
Bythinella austriaca (v. FRAUENFELD)	SC	-	-	-	-	0,001	7,7	-	-
Bithynia tentaculata (LINNÉ)	SC	-	-	-	-	0,042	15,4	-	-
Gyraulus albus (MÜLLER)	SC	0,016	8,33	-	-	-	-	0,028	7,7
Lymnaea peregra (MÜLLER)	SC	-	-	0,016	30,8	0,017	38,5	0,043	76,9
Lymnaea truncatula (MÜLLER)	SC	-	-	0,002	15,4	0,014	15,4	-	-
Pisidum amnicum (MÜLLER)	FC	0,041	8,33	-	-	0,001	7,7	-	-
Pisidium casertanum (POLI)	FC	0,057	25,00	-	-	-	-	-	-
Pisidium milium HELD	FC	0,065	8,33	-	-	-	-	-	-
Pisidium cf. obtusale (LAMARCK)	FC	0,002	8,33	-	-	-	-	-	-
Pisidium subtruncatum MALM	FC	0,007	16,67	-	-	-	-	-	-
Pisidium supinum A. SCHMIDT	FC	0,685	66,67	-	-	0,028	15,4	-	-
Pisidium sp.	FC	0,018	16,67	0,001	7,7	0,007	15,4	0,006	7,7
Sphaerium rivicola (LAMARCK)	FC	0,005	16,67	-	-	0,003	7,7	-	-
Sphaerium sp.	FC	-	-	0,127	7,7	-	-	-	-
Unio pictorum (LINNE)	FC	Not account		-	-	-	-	-	-
Unio tumidus PHILIPSSON	FC	Not account		-	-	-	-	-	-
Anodonta anatina (LINNE)	FC	Not account		-	-	-	-	-	-
CRUSTACEA									
Asellus aquaticus LINNÉ	GC	0,042	41,67	0,121	76,9	0,018	38,5	0,033	30,8
Gammarus fossarum KOCH	SH	0,090	33,33	**34,881**	92,3	**9,460**	92,3	**2,802**	100,0
Gammarus roeselii GERVAIS	SH	-	-	< 0,001	7,7	0,048	46,2	0,131	76,9

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
HYDRACARINA									
		0,016	8,33	-	-	-	-	-	-
Hydracarina (indet.)	P	0,008	8,33	0,078	46,2	**1,627**	92,3	0,288	76,9
EPHEMEROPTERA									
Baetis buceratus EATON	SC	-	-	0,001	7,7	0,095	23,1	0,143	30,8
Baetis fuscatus (LINNÉ)	SC	0,526	58,33	0,003	7,7	0,067	15,4	0,763	53,8
Baetis lutheri MÜLLER-LIEBENAU	SC	0,046	33,33	-	-	0,007	7,7	**1,487**	76,9
Baetis muticus (LINNÉ)	SC	-	-	< 0,001	7,7	-	-	-	-
Baetis rhodani (PICTET)	SC	0,216	58,33	**1,476**	100,0	**1,043**	84,6	**3,173**	100,0
Baetis vernus CURTIS	SC	0,072	25,00	< 0,001	7,7	0,016	7,7	0,020	15,4
Baetis sp. juv.	SC	0,231	58,33	0,102	30,8	0,338	30,8	**2,776**	61,5
Caenis horaria (LINNÉ)	GC	0,008	8,33	-	-	-	-	-	-
Caenis luctuosa (BURMEISTER)	GC	0,617	25,00	-	-	-	-	-	-
Caenis macrura STEPHENS	GC	0,832	41,67	0,003	7,7	-	-	-	-
Caenis pseudorivulorum KEFFERMÜLLER	GC	0,031	8,33	-	-	-	-	-	-
Caenis sp. juv.	GC	**4,800**	58,33	0,082	23,1	-	-	0,006	7,7
Centroptilum luteolum (MÜLLER)	GC	-	-	-	-	0,001	7,7	0,007	7,7
Cloeon dipterum (LINNÉ)	GC	-	-	-	-	0,003	7,7	-	-
Ecdyonurus dispar (CURTIS)	SC	0,005	8,33	-	-	-	-	-	-
Ecdyonurus insignis (EATON)	SC	0,002	8,33	-	-	-	-	-	-
Ecdyonurus venosus (FABRICIUS)	SC	0,008	16,67	-	-	0,003	23,1	0,002	7,7
Ephoron virgo (OLIVIER)	FC	0,049	8,33	-	-	-	-	-	-
Ephemera danica MÜLLER	FC	0,052	33,33	-	-	0,004	15,4	0,013	30,8
Ephemerella ignita (PODA)	SC	0,085	16,67	0,334	53,8	**1,287**	69,2	**1,523**	69,2
Ephemerella mucronata BENGTSSON	GC	-	-	-	-	-	-	0,004	7,7
Habrophlebia lauta EATON	GC	-	-	-	-	-	-	0,002	15,4
Heptagenia flava ROSTOCK	GC	0,003	8,33	-	-	-	-	-	-
Heptagenia sulphurea (MÜLLER)	GC	0,195	66,67	0,001	7,7	-	-	-	-
Heptagenia sp. juv.	GC	0,003	8,33	-	-	-	-	-	-
Potamanthus luteus (LINNÉ)	FC	**14,646**	100,00	0,073	30,8	-	-	-	-
Procloeon bifidum (BENGTSSON)	SC	0,018	16,67	-	-	-	-	-	-
Rhithrogena semicolorata (CURTIS)	SC	-	-	-	-	0,003	7,7	0,062	30,8
ODONATA									
Platycnemis pennipes (PALLAS)	P	0,002	8,33	-	-	-	-	-	-
PLECOPTERA									
Isoperla grammatica (PODA)	P	-	-	-	-	0,004	15,4	0,021	23,1
Isoperla obscura (ZETTERSTEDT)	P	-	-	-	-	-	-	0,003	7,7
Isoperla rivulorum (PICTET)	P	-	-	-	-	-	-	0,007	7,7
Isoperla tripartita ILLIES	P	-	-	-	-	-	-	0,001	7,7
Isoperla sp. juv.	P	-	-	-	-	-	-	0,028	7,7
Leuctra albida KEMPNY	GC	-	-	-	-	0,003	7,7	-	-
Leuctra fusca (LINNÉ)	GC	-	-	< 0,001	7,7	-	-	0,002	15,4
Leuctra sp.	SH	-	-	-	-	-	-	0,126	23,1
Perla burmeisteriana CLAASSEN	P	-	-	-	-	-	-	0,017	46,2
Perlodes microcephalus (PICTET)	P	-	-	-	-	-	-	0,009	23,1

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
HETEROPTERA									
Aphelocheirus aestivalis (FABRICIUS)	P	**1,021**	75,00	-	-	0,021	7,7	-	-
Micronecta minutissima (LINNÉ)	P	0,018	8,33	-	-	-	-	-	-
Sigara falleni (FIEBER)		-	-	-	-	0,001	7,7	-	-
MEGALOPTERA									
Sialis fuliginosa PICTET	P	-	-	-	-	0,001	7,7	0,001	7,7
Sialis lutaria (LINNÉ)	P	-	-	-	-	-	-	0,002	15,4
TRICHOPTERA									
Agapetus fuscipes CURTIS	SC	-	-	0,116	46,2	0,025	38,5	0,020	30,8
Anabolia furcata BRAUER	GC	0,018	16,67	0,005	23,1	0,011	15,4	0,017	46,2
Anabolia sp.	GC	0,002	8,33	0,001	7,7	0,004	7,7	0,003	7,7
Athripsodes albifrons (LINNÉ)	GC	0,062	16,67	-	-	-	-	-	-
Athripsodes cinereus (CURTIS)	SC	0,213	33,33	-	-	-	-	-	-
Ceraclea dissimilis (STEPHENS)	Pa	0,067	41,67	-	-	-	-	-	-
Chaetopteryx villosa (FABRICIUS)	SH	-	-	0,132	46,2	0,004	7,7	0,004	30,8
Chaetopteryx villosa juv.	SH	-	-	0,098	15,4	-	-	-	-
Chaetopteryx cf. *villosa*	SH	-	-	0,006	7,7	-	-	-	-
Chaetopteryx sp.	SH	0,049	8,33	0,014	15,4	0,036	15,4	0,013	15,4
Cheumatopsyche lepida (PICTET)	FC	**1,890**	91,67	0,011	7,7	-	-	0,011	7,7
Cyrnus trimaculatus (CURTIS)	FC	0,003	16,67	-	-	-	-	0,001	7,7
Glossosoma sp.	SC	-	-	-	-	0,003	7,7	0,007	15,4
Glossosomatidae (indet.)	SC	-	-	-	-	-	-	0,056	7,7
Goera pilosa (FABRICIUS)	GC	0,007	8,33	-	-	-	-	0,007	23,1
Halesus radiatus (CURTIS)	SH	-	-	-	-	0,010	7,7	0,014	15,4
Halesus sp.	SH	0,337	25,00	-	-	-	-	0,004	30,8
Hydropsyche contubernalis MCLACHLAN	FC	**1,813**	66,67	0,004	15,4	-	-	-	-
Hydropsyche instabilis (CURTIS)	FC	0,002	8,33	-	-	0,002	7,7	-	-
Hydropsyche pellucidula (CURTIS)	FC	**1,989**	100,00	0,009	23,1	0,007	7,7	0,344	76,9
Hydropsyche saxonica MCLACHLAN	FC	-	-	-	-	-	-	-	-
Hydropsyche siltalai DÖHLER	FC	0,042	16,67	0,037	7,7	0,003	7,7	0,264	61,5
Hydropsyche sp. juv.	FC	**2,560**	41,67	0,201	23,1	0,049	15,4	0,146	38,5
Hydroptila forcipata (EATON)	GC	-	-	0,063	7,7	-	-	0,117	23,1
Hydroptila sp.	GC	-	-	-	-	-	-	0,001	7,7
Ithytrichia lamellaris EATON	GC	0,016	8,33	-	-	-	-	-	-
Lasiocephala basalis (KOLENATI)	SC	-	-	0,053	7,7	0,287	69,2	0,437	84,6
Lepidostoma hirtum (FABRICIUS)	SC	0,016	8,33	-	-	0,016	15,4	0,007	23,1
Lepidostomatidae (indet.)	SC	-	-	-	-	0,161	15,4	0,128	15,4
Leptoceridae (indet.)	GC	0,049	8,33	-	-	-	-	-	-
Limnephilus lunatus CURTIS	SH	-	-	0,013	23,1	0,002	15,4	-	-
Limnephilus rhombicus (LINNÉ)	SH	-	-	-	46,2	-	-	0,003	7,7
Limnephilidae (indet.)	SH	-	-	0,152	-	0,035	30,8	0,067	15,4
Lype phaeopa (STEPHENS)	P	0,005	8,33	-	-	-	-	-	-
Mystacides nigra (LINNÉ)	SC	0,008	8,33	-	-	-	-	-	-
Neureclipsis bimaculata LINNÉ	P	0,007	-	-		-			
Oligoplectrum maculatum MCLACHLAN	SC	0,002	8,33	0,687	7,7	**3,023**	30,8	**23,250**	100,0

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
Polycentropus flavomaculatus (PICTET)	P	0,034	33,33	0,021	7,7	0,066	30,8	0,955	92,3
Potamophylax latipennis (CURTIS)	SH	0,007	8,33	0,004	15,4	0,010	23,1	0,003	7,7
Psychomyia pusilla (FABRICIUS)	P	**1,457**	75,00	0,005	7,7	0,096	38,5	0,258	76,9
Rhyacophila nubila (ZETTERSTEDT)	P	0,186	66,67	0,075	84,6	0,630	92,3	**1,144**	92,3
Sericostoma flavicorne SCHNEIDER	SH	-	-	0,015	38,5	0,108	84,6	0,085	76,9
Silo piceus (BRAUER)	SC	-	-	0,001	7,7	0,014	7,7	0,045	30,8
Tinodes roztocki MCLACHLAN	GC	-	-	-	-	0,015	15,4	-	-
Tinodes waeneri LINNÉ		-	-	0,001	7,7	-			
DIPTERA									
DIPTERA – MUSCIDAE									
Limnophora riparia (FALLÉN)	P	-	-	-	-	-	-	0,001	7,7
DIPTERA – TIPULIDAE									
Tipula benesignata MANNHEIMS	SH	0,011	8,33	-	-	-	-	-	-
Tipula lateralis MEIGEN	SH	0,003	8,33	-	-	-	-	0,001	7,7
Tipula luna WESTHOFF	SH	0,007	8,33	-	-	-	-	-	-
Tipula sp.	SH	-	-	-	-	0,007	7,7	-	-
DIPTERA - LIMONIIDAE									
Antocha vitripennis (MEIGEN)	SH	0,098	25,00	0,143	7,7	0,044	30,8	0,571	46,2
Dicranota sp.	P	0,020	33,33	0,020	53,8	0,480	46,2	0,106	15,4
Limnophila submarmorata (VERRALL)	P	-	-	-	-	-	-	0,033	7,7
Dicranomyia didyma (Meigen)	SH	-	-	-	-	0,001	7,7	-	-
Dicranomyia modesta (MEIGEN)	SH	-	-	-	-	-	-	0,050	7,7
Pedicia straminea MEIGEN	SH	0,033	8,33	0,024	7,7	-	-	0,195	7,7
Pedicia immaculata (MEIGEN)	SH	-	-	0,001	7,7	-	-	-	-
Pedicia sp.	SH	-	-	-	-	-	-	0,017	7,7
DIPTERA - PSYCHODIDAE									
Pericoma diversa TONNOIR	SC	0,002	8,33	-	-	0,007	7,7	-	-
Pericoma fallax EATON	SC	-	-	0,003	7,7	0,007	7,7	-	-
Pericoma sp.	SC	0,024	8,33	-	-	0,007	7,7	-	-
DIPTERA - BLEPHARICERIDAE									
Liponeura decipiens + vimmeri	SC	-	-	-	-	-	-	0,006	7,7
DIPTERA - CERATOPOGONIDAE	SC	0,057	8,33	-	-	-	-	-	-
Atrichopogon sp.	SC	-	-	0,001	7,7	-	-	-	-
Bezzia sp.	SC	**1,136**	66,67	-	-	0,001	7,7	0,011	7,7
Bezzia + Palpomyia sp.	SC	0,003	8,33	0,001	7,7	0,008	7,7	0,090	30,8
DIPTERA - CHIRONOMIDAE									
Brillia longifurca KIEFFER	SH	0,007	16,67	0,001	7,7	-	-	-	-
Brillia modesta (MEIGEN)	SH	-	-	0,003	23,1	-	-	-	-
Cardiocladius fuscus KIEFFER	P	0,015	16,67	-	-	-	-	-	-
Chironomus thummi (KIEFFER)	GC	0,002	8,33	-	-	-	-	-	-
Chironomidae - larvae et pupae	GC	-	-	**5,536**	15,4	0,629	-	-	-
Chaetocladius sp. juv.	FC	-	-	0,001	7,7	-	-	0,017	7,7

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
Cladotanytarsus mancus (WALKER)	FC	**1,424**	33,33	0,310	7,7	0,717	23,1	0,432	15,4
Corynoneura celeripes WINNERTZ	GC	-	-	-	-	0,061	23,1	0,006	7,7
Cricotopus sylvestris (FABRICIUS)	SH	**1,341**	16,67	0,007	23,1	0,385	30,8	0,102	23,1
Cricotopus trifasciatus EDWARDS	SH	0,002	8,33	-	-	0,013	15,4	0,047	38,5
Cricotopus sp. juv.	SH	-	-	-	-	-	-	0,039	7,7
Cryptochironomus defectus (KIEFFER)	P	0,005	25,00	-	-	-	-	-	-
Diamesa tonsa (HALIDAY)	SC	0,220	25,00	**6,119**	100,0	**2,179**	84,6	**8,029**	84,6
Eukiefferiella brevicalcar (KIEFFER)	SC	-	-	-	-	0,005	7,7	0,030	7,7
Eukiefferiella clypeata (KIEFFER)	SC	0,013	16,67	0,001	7,7	-	-	-	-
Eukiefferiella coerulesces (KIEFFER)	SC	-	-	-	-	0,210	7,7	-	-
Eukiefferiella cyanea THIENEMANN	SC	-	-	0,110	15,4	**2,023**	15,4	-	-
Eukiefferiella devonica (EDWARDS)	SC	-	-	0,056	7,7	-	-	0,285	7,7
Eukiefferiella gracei (EDWARDS)	SC	0,220	25,00	0,978	7,7	0,867	23,1	0,022	7,7
Eukiefferiella hospita (EDWARDS)	SC	-	-	0,719	7,7	-	-	-	-
Eukiefferiella ilkleyensis (EDWARDS)	SC	0,146	8,33	0,077	7,7	-	-	-	-
Eukiefferiella lobifera GOETGHEBUER	SC	0,155	16,67	-	-	0,857	15,4	-	-
Eukiefferiella longicalcar POTTHAST	SC	-	-	0,143	15,4	0,004	7,7	0,352	23,1
Eukiefferiella minor (EDWARDS)	SC	-	-	0,063	7,7	-	-	0,547	15,4
Eukiefferiella similis GOETGHEBUER	SC	0,114	8,33	**4,001**	38,5	**2,511**	46,2	0,392	38,5
Eukiefferiella veralli	SC	-	-	0,037	7,7	-	-	-	-
Eukiefferiella sp. juv.	SC	-	-	-	-	0,002	7,7	0,022	7,7
Eukiefferiella sp.	SC	0,003	8,33	0,005	7,7	0,094	7,7	-	-
Glyptotendipes gripekoveni (KIEFFER)	GC	0,285	50,00	0,003	15,4	-	-	-	-
Hydrobaenus distylus (KIEFFER)	SC	-	-	-	-	-	-	0,003	7,7
Macropelopia nebulosa (MEIGEN)	P	-	-	0,001	7,7	-	-	-	-
Micropsectra curvicornis CHERNOVSKIJ	GC	0,138	33,33	0,001	15,4	-	-	0,114	15,4
Micropsectra junci (MEIGEN)	GC	0,490	83,33	0,277	92,3	**6,106**	76,9	**3,039**	92,3
Microtendipes chloris (MEIGEN)	SC	**1,782**	58,33	0,001	7,7	-	-	0,269	46,2
Nanocladius bicolor (ZETTERSTEDT)	SC	0,080	25,00	0,410	7,7	-	-	-	-
Orthocladius (*Euo.*) *thienemanni* KIEFFER	SC	0,049	8,33	0,673	30,8	0,718	23,1	0,050	7,7
Orthocladius (*Eud.*) sp.	SC	0,073	16,67	0,323	15,4	0,066	7,7	-	-
Orthocladius (*Ort.*) *wetterensis* BRUNDIN	SC	0,418	25,00	**5,676**	30,8	**11,362**	38,5	**1,269**	30,8
Orthocladius (*Ort.*) sp. juv.	SC	-	-	**5,554**	38,5	**6,342**	61,5	**8,744**	61,5
Orthocladius (*Ort.*) sp.	SC	**3,233**	58,33	-		-		-	
Orthocladius sp.	SC	0,109	33,33	0,513	38,5	0,320	46,2	**2,179**	30,8
Orthocladiinae (indet.)	SC	0,171	16,67	**4,552**	38,5	**2,493**	30,8	**1,089**	23,1
Parachironomus cryptotomus (KIEFFER)	FC	0,002	8,33	-	-	-	-	-	-

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
Paracricotopus niger (KIEFFER)	GC	0,376	16,67	0,294	30,8	0,019	23,1	0,033	15,4
Paratanytarsus sk. *lauterborni* KIEFFER	FC	-	-	0,001	7,7	-	-	-	23,1
Polypedilum breviantennatum CHERNOVSKIJ	FC	0,018	16,67	0,001	15,4	0,001	7,7	0,028	23,1
Polypedilum convictum (WALKER)	FC	0,002	8,33	-	-	0,021	7,7	0,001	7,7
Polypedilum (*Pentapedilum*) *exsectum* (KIEFFER)	FC	0,008	8,33	-	-	-	-	-	-
Polypedilum nubeculosum (MEIGEN)	FC	0,002	8,33	-	-	-	-	-	-
Polypedilum pedestre (MEIGEN)	FC	0,067	33,33	**1,366**	30,8	0,786	61,5	0,986	30,8
Potthastia longimana (KIEFFER)	GC	-	-	0,203	53,8	0,210	30,8	0,408	38,5
Procladius sp.	P	0,059	25,00	-	-	0,001	7,7	-	-
Prodiamesa olivacea (MEIGEN)	SC	-	-	< 0,001	7,7	0,001	7,7	-	-
Rheocricotopus atripes (KIEFFER)	SC	0,008	8,33	-	-	0,004	7,7	-	-
Rheocricotopus effusus (WALKER)	SC	0,075	25,00	0,224	30,8	0,041	15,4	0,179	15,4
Rheocricotopus fuscipes (KIEFFER)	SC	0,350	16,67	**1,906**	7,7	0,231	15,4	0,943	23,1
Rheotanytarsus sk. *exiguus* BAUSE	FC	**2,419**	33,33	-	-	0,014	7,7	-	-
Synorthocladius semivirens (KIEFFER)	SC	0,915	58,33	**1,749**	53,8	0,988	30,8	0,844	38,5
Tanypodinae (indet.)	P	-	-	0,028	7,7	-	-	0,126	7,7
Tanytarsus sp.	GC	-	-	0,007	7,7	-	-	-	-
Tanytarsini - pupae	GC	-	-	0,019	7,7	0,052	1,4	-	-
Thienemannimyia sp.	FC	0,868	75,00	0,062	38,5	**1,313**	76,9	0,748	61,5
Tvetenia bavarica (GOETGHEBUER)	SC	0,951	75,00	**4,071**	92,3	**6,181**	92,3	**2,966**	92,3
DIPTERA - SIMULIIDAE									
Eusimulium costatum (FRIEDERICHS)	FC	-	-	-	-	-	-	**1,251**	7,7
Odagmia ornata (MEIGEN)	FC	**1,867**	75,00	**7,452**	92,3	**17,624**	92,3	**15,114**	100,0
Odagmia variegata (MEIGEN)	FC	-	-	0,001	7,7	-	-	0,832	7,7
Wilhelmia lineata MEIGEN	FC	0,008	8,33	0,007	7,7	0,019	30,8	0,013	7,7
Simulium reptans (LINNÉ)	FC	-	-	-	-	0,003	7,7	-	-
Simuliidae (indet.)	FC	-	-	0,211	23,1	**5,154**	15,4	0,001	7,7
DIPTERA - EMPIDIDAE									
Clinocera nigra MEIGEN	P	-	-	0,005	7,7	0,049	7,7	0,011	7,7
Wiedemannia oedorum (VAILLANT)	P	-	-	0,003	7,7	-	-	0,006	7,7
Wiedemannia sp.	P	-	-	0,265	53,8	0,254	61,5	0,386	61,5
DIPTERA - RHAGIONIDAE									
Chrysopilus sp.	P	0,003	8,33	-	-	-	-	-	-
DIPTERA - ATHERICIDAE									
Atherix ibis (FABRICIUS)	P	0,090	16,67	0,001	7,7	-	-	-	-

TAXA\SITES		S1 D	S1 F	S2 D	S2 F	S3 D	S3 F	S4 D	S4 F
COLEOPTERA									
Acilius sulcatus (LINNÉ)	P	-	-	-	-	-	-	0,018	15,4
Brychius sp.	Pa	-	-	-	-	-	-	0,028	7,7
Elmis aenea (MÜLLER)	GC	0,052	58,33	0,727	61,5	**3,886**	92,3	**2,065**	84,6
Elmis sp. larva		-	-	-		-	-	0,008	7,7
Esolus angustatus (MÜLLER)	GC	0,002	8,33	-	-	0,021	7,7	-	-
Esolus parallelepipedus (MÜLLER)	GC	0,260	25,00	0,021	23,1	-	-	0,045	15,4
Gyrinus sp.	P	-	-	-	-	-	-	0,014	7,7
Helodes minuta (LINNÉ)	GC	0,002	8,33	-	-	-	-	-	7,7
Limnius volkmari	GC	0,041	25,00	0,232	23,1		53,8	0,553	53,8
Orectochilus villosus (MÜLLER)	FC	0,002	8,33	-	-	-	-	0,024	38,5
Oulimnius tuberculatus (MÜLLER)	GC	0,041	8,33	-	-	0,001	-	-	-
Platambus maculatus (LINNÉ)	P	-	-	-	-	0,007	7,7	-	-
Potamophilus acuminatus (FABRICIUS)	GC	-	-	-	-	-		-	-
Shannon diversity index		**4,66**		**3,93**		**4,52**		**4,43**	
Equitability		**2,12**		**1,84**		**2,11**		**2,04**	
Number of taxa		**160**		**135**		**138**		**149**	

ech Republic)

S3 F	S4 D	S4 F
-	0,018	15,4
-	0,028	7,7
2,3	**2,065**	84,6
-	0,008	7,7
,7	-	-
-	0,045	15,4
-	0,014	7,7
-	-	7,7
3,8	0,553	53,8
-	0,024	38,5
-	-	-
,7	-	-
	-	-
	4,43	
	2,04	
	149	

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THE INFLUENCE OF THE VRANOV RESERVOIR HYDROPOWER STATION OPERATION ON PHYTOBENTHOS IN THE DYJE RIVER (CZECH REPUBLIC).

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ABSTRACT

The influence of the Vranov hydropower plant operation on phytobentos diversity and dynamics was studied between 1991 and 1994. Four localities were examined. The uppermost site lies in the shallow, fairly eutrophicated stretch of the Dyje River in a flat valley upstream the Vranov Reservoir with relatively poor diversity of bottom vegetation but well developed phytoplankton. The dominants were *Cladophora glomerata* (L.) KÜTZ and other filamentous green algae. The three other sampling points represent a river stretch situated in a deep narrow canyon below the reservoir exposed to considerable water level fluctuation and changed water temperature, turbidity and nutrients regime. Strong development of macrophytes (*Phalaroides arundinacea* (L.) DUMORT. and benthic algae (with predominating *Cladophora glomerata* (L.) KÜTZ), low occurrence of free-living benthic species and complete absence of planktic algae characterise this downstream stretch with relatively cold water. *Cladophora glomerata* (L.) KÜTZ was often accompanied by red alga *Audouinella chalybea* (LYNGB.) FRIES. In comparison with the Dyje above the Vranov reservoir, algal assemblages occurring in the river below the reservoir show a certain decrease of species diversity (measured by Shannon-Weaver's or Brillouin's index), but, on contrary, a wider spectrum of ecotypes with different ecological requirements. The species occurring in highly disturbed places was *Fontinalis antipyretica* L. on the big steady stones, *Cladophora glomerata* (L.) KÜTZ. on the surfaces of smaller but yet stable stones, and the rhodophytes in shadowed shallow sites and specific microflora inhabiting periodically flooded areas.

INTRODUCTION

The basic information about the influence of the reservoirs on the river biota can be found in CUMMINS (1974, 1979), VANNOTE et al. (1980), CUSHING et al. (1983), PETTS (1984). ARMITAGE (1984), KUBÍČEK et al. (1999). The stream stretches below the dams exhibit many modifications of chemical and physical parameters that influence phytobenthic communities. Physical controlling factors include temperature, substrate, flow and turbidity. Chemical factors include mainly nutrients (LOWE 1979).

Below a reservoir with a power plant operating in hydropeaking regime it is the diurnal water level fluctuation which may be considered the most important factor influencing the structure and function of river phototrophic communities (PETTS 1984, KOMÁREK 1998). Flow regime changes daily from steady minimal to highest water level. Diurnal flow variability increases the spectrum of microhabitats in comparison with localities situated above the reservoir (KOMÁREK 1998). The artificial flood has a high cleaning force hindering deposition of bottom sediments. In the streamline it creates highly resistant algal community (PETERSON 1996 Cyanobacteria and other microphytes surviving drying up between floods occur in periodically flooded bank zones (KOMÁREK 1998). Thus, species diversity can substantially increase due to existence of periodically flooded and dried bottom microhabitats; but only firmly attached algae are able to survive the high flow periods.

The goal of this papar is to describe the influence of the Vranov reservoir on the structure of phytobenthos in the subsequent Dyje River stretch. In the Czech Republic, only little attention was paid to phototrophic biota in regulated stretches of rivers below dam reservoirs, and only several recent articles deal with this topic (PEŇÁZ et al. 1968, BRABEC 1997, KOMÁREK 1998, MARVAN 1998, KOUDELKOVÁ 1999).

MATERIAL AND METHODS

The Vranov Reservoir is a typical stratified valley reservoir with maximal depth 58 m, max. capacity 132.6 million m^3, length 29.6 km, and area of 7.7 km^2 and average time of retention 156 days (VLČEK et al. 1984). The peaking wave influences 35 km of the river (HELEŠIC et al. 1998).

There is high dynamics of the water flow changes within twenty-four hours at the localities below the reservoir as was described in KUBÍČEK et al. (1999). The flow regime is based on an increased power supply twice a day (morning and evening). The hydropower plant works and uses possibly one, two or three turbines for electricity generating. The discharge varies between 16, 31 and 46 $m^3.s^{-1}$, respectively; current velocity at the Hamry profile (S2) is 0.9 up to 1.5 $m.s^{-1}$. The Boundary Reynolds No. is 21.8 for one turbine and 34.8 for two up to three turbine; corresponding share stress is 1512 and 1928 $dyn.cm^{-2}$, respectively. This situation lasts for four or five hours twice a day. Break between peeks is filled by discharge of about 1.2 $m^3.s^{-1}$, current velocity 0.3 $m.s^{-1}$ in relative depth of about 15 cm which correspond to the Boundary Reynolds No. 10.5 and Shear stress 413 $dyn.cm^{-2}$. This conditions lasts for seven hours.

Benthic flora of the river above and below the reservoir was studied at 4 sampling sites. First site, Podhradí (S1 - profile) is situated 28 km upstream the reservoirs dam (about 3 km above the uppermost part of lake). The second one, Hamry (S2 – profile) is situated 4 km below the dam, the third site, Hardegg (S3 - profile) 12 km downstream the reservoir and the forth one, Papírna (S4 – profile) 33 km below the reservoir (see KUBÍČEK et al. 1999 for detailed description of localities). All sites were sampled in 1991-1994 three times a year. In most cases, three or more parallel subsamples representing different riverine microhabitats were taken in each sampling site for microscopic determination to species level.

For quantitative phytobenthos analyses the sampling method DOUGLAS (1958, ex SCHWOERBEL 1966) was used. The samples were fixed by formaldehyde to 4 % concentration and stored in 100ml PVC bottles. Qualitative samples were analysed *in vivo* the day following the sampling date or fixed by formaldehyde up to the 4 %

concentration and stored in 3 ml tubs. Following determination keys were used: STARMACH (1966, 1972), HINDÁK (1978), SIEMIŃSKA (1964) and KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a, 1991b).

Statistical methods

Semiquantitative data on algal communities were analysed by Detrended Correspondence Analysis (TER BRAAK & PRENTICE 1988) in CANOCO program (TER BRAAK & ŠMILAUER 1998) and TWINSPAN (HILL 1979). Graphical output of CANODRAW (ver.3.1) was improved by CANOPOST ver 1.0 (ŠMILAUER 1990 - 3). These methods were used for description of possible gradients of species and groups of species living together in similar conditions. This method was used also for sample clustering due to their similar properties.

RESULTS

Altogether 219 species of algae and cyanobacteria and 6 species of macrophytes were recorded during the years 1992 - 1994. The list of taxa (see Appendix 1) includes 28 Cyanoprokaryota, 119 Bacillariophyta, 42 Chlorophyta, 5 Rhodophyta and 6 other algae. The majority of them are typical benthic organisms. Algal flora of all localities strongly resembles benthic algae flora of other rivers (Oslava, Jihlava, Rokytná) draining south-eastern slopes of the Czech-Moravian Highlands. Its prevailing components are ± alkaliphilous species prefering waters with medium up to slightly increased concentration of electrolytes. Acidophilous algae such as species of genera *Pinnularia* and *Eunotia* were extremely rare.

In Podhradí (the upstream locality S1 above the Vranov Reservoir) the dominant of epilithon in the streamline is *Cladophora glomerata*, in spring and autumn regularly associated with diatoms *Melosira varians* BORY and *Diatoma vulgaris* var. *Vulgaris* BORY, and with a thin bottom layer formed by cyanobacteria (*Homoeothrix, Chamaesiphon* spp.). Green filamentous algae (*Cladophora* cf. *Globulina* KÜTZ., *Rhizoclonium hieroglyphicum* (AG.)KÜTZ and *Oedogonium* spp.) occupy microhabitats in stagnant water. Free living diatoms are represented by a broad spectrum of species in both types of habitats. The same holds true for typically planktonic species of diatoms and green coccal algae drifting in this stretch of the Dyje River in rather high concentrations (cf. HETEŠA & MARVAN 1998) from the ponds above the locality.

Bottom flora of the Dyje River stretch below the Vranov Reservoir (sites S2, S3, S4) differs markedly from that on the above locality. Like at the Podhradí (site S1), the most important alga of the streamline remains *Cladophora glomerata* and yet quite abundant is *Diatoma vulgaris*, but some further rheophilous species such as *Ulothrix zonata* (WEB. et MOHR.) KÜTZ, *Microspora amoena* (KÜTZ) RABENH., *Audouinella chalybaea* and. *Batrachospermum moniliforme* (L.) ROTH accede, whereas *Melosira varians* (MOORE)CRAWFORD retreats. Very characteristic, though not even abundant, is *Ellerbeckia arenaria* (sporadically occurring also above the reservoir), a very rare species in Czech rivers at present. Both named representatives of red algae occupy more shadowed sites near the littoral zone of *Phalaroides arundinacea*(L.)DUMORT.

As for further differences against the first sampling site, the following are worth mentioning:

Almost complete absence of green coccal algae and other plankton elements (their transient occurrence cannot be, of course, excluded on more protected sites during the period of the spring and autumn reservoir water circulation),

Very low occurrence of free-living elements of microflora accompanying epilithic communities; this holds true especially for Hamry (S2) and Hardegg (S3).

Existence of periodically flooded and naked sites with specific microflora. The most characteristic dominants of such habitats are *Prasiola crispa* (LIGHTF.) MENEGH. and *Vaucheria sp.* together with *Cladophora* cf. *globulina* (known from the first locality, too). The thick layer of filamentous algae helps benthic animals to survive phases of discharge decrease.

Big stones with tops exceeding maximal water level represent other periodically flooded type of specific microhabitat with a species-poor community (*Prasiola* stages with uniseriate filaments, *Nitzschia brevissima* (GRUNOW IN WAN HEURCK) and *Phormidium autumnale* GOM.). It occurs only on site S4 (Papírna) and S3 (Hardegg S3).

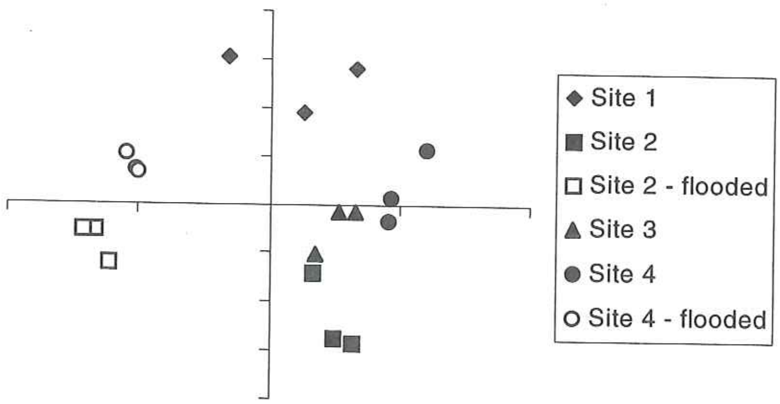


Fig. 1. The distribution of the samples in ordination diagram of correspondence analysis. The classification is made according to dominant species.

A preliminary comparison of sampling sites 1 through 4 according to floristic data from the 3 first samplings (June and September 1991, June 1992) brings Fig. 1. The evaluation is based on values of relative abundance (expressed in degrees of an estimation scale 1, 2,...7 ; see SLÁDEČKOVÁ & MARVAN in HINDÁK 1978). The position of sampling sites in the plane of the 1st and 2nd principal axis was derived on the basis of the covariance matrix. Both first axes covered about 54 % of variance. Samples from periodically flooded microbiotops appeared at negative values of the 1st axis, those from permanently flooded microbiotops at positive values of the same axis.

Samples from different localities were distributed along the 2nd axis. The highest values reached samples from S1 (Podhradí), the lowest samples from site S2, most influenced by the hydropeaking. The differences in the species composition of micro-phytobenthos below and above the reservoir appeared so to be gradually wiped off in the longitudinal profile of the river.

Shannon-Weaver`s and Brillouin`s indexes (calculated with natural logarithms) are based on the same set of data (see Tab. 1) as the preceding evaluation. They illustrate a certain decrease of species diversity for sampling sites S2 - S4 with lowest values for S3.

Tab. 1. Brillouin and Shannon species diversity index at four studied localities. Abbreviation Per. means periodically flooded / naked areas.

	Podhradí	Hamry	Hamry Per.	Hardegg	Papírna	Papírna Per.
Brillouin	2.4368	2.2761	1.4002	1.7051	2.3798	0.9407
Shannon	2.9967	2.8041	1.7590	2.2061	2.9322	1.2689

Assemblages of algae and differences between localities according to DCA

We used DCA to recognise different assemblages of algae and to see the variability of these assemblages within localities.

Points of all samples from Podhradí (S1; see Fig. 2.) are concentrated near the beginning of axes, thus showing a rather low variability in species composition. This seems to be in concordance with lower variability of microhabitats. The river above the reservoir shows distinct marks of man-made eutrophication but has a quite natural flow regime. In relatively small flow speed (0.4 – 1.0 $m.s^{-1}$) throw wide channel the sedimentation of fine particles in area of the S1 locality take place (MORISAWA 1968 in ALLAN 1996). Relatively constant flow without disturbances enables the sedimentation of fine particles and leads to a rather stable algae assemblage with minimum variability and heterogeneity of species composition.

In contrast to S1 (locality above the reservoir) the sample points representing locality S2 below the reservoir are dispersed not only around the beginning of the axes but also along the right part of the 1st axis and positive part of the 2nd axis. Position of points indicates so a distinctly broader spectrum of microhabitats.

The next locality Hardegg (S3) shows also the broader distribution of sample points along the positive part of the 2nd axis. Data from the last locality, S4, appear again (like S2) to be extremely diverse with respect to both axes. Both these localities have a rather similar species composition. Their spectrum of microhabitats involves stable places exposed to alternation of fast flow during the flood and low water level phases during break of power plant operation, with *Cladophora glomerata* as dominant species. On shadowed places around banks red algae occur in higher abundance. Stable places open to air during flood break are inhabited partly by cyanobacteria (*Phormidium autumnale*), partly by *Vaucheria*, *Prasiola crispa* and other green algae as dominant species. *Fontinalis antipyretica* occurs on border between flooded and not flooded zone during the break of hydro-power-station operation.

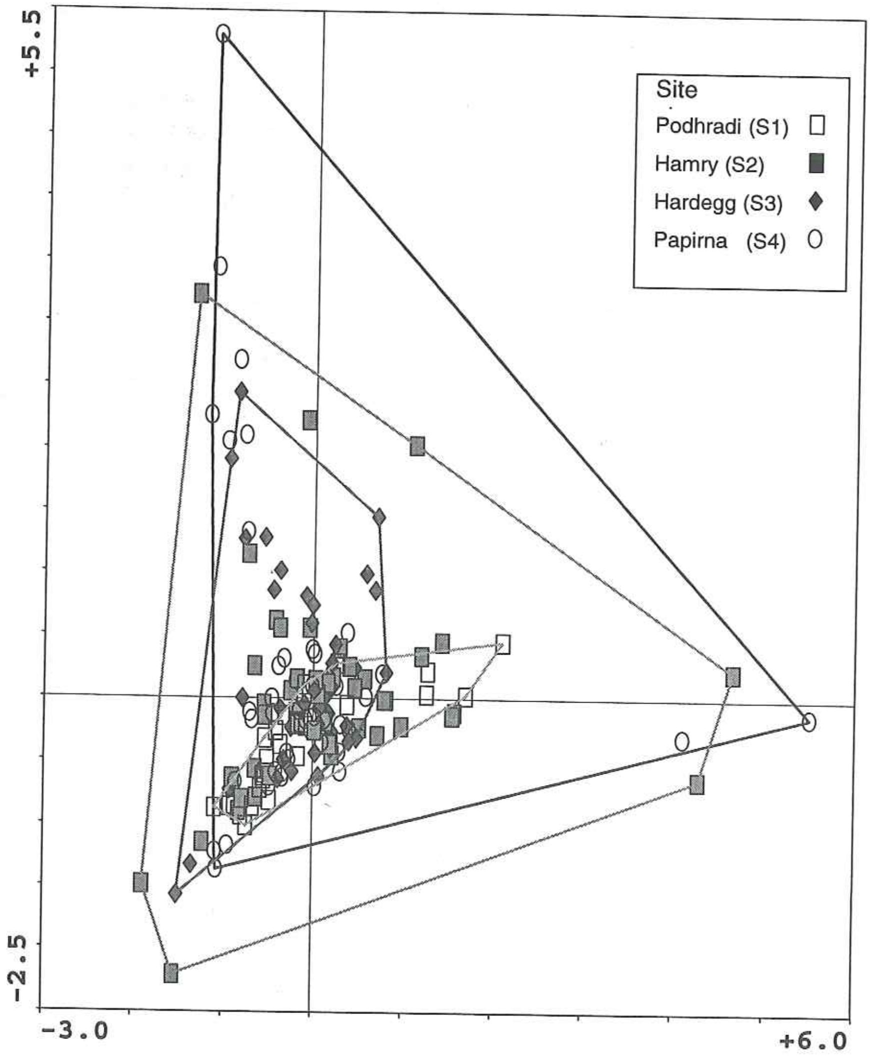
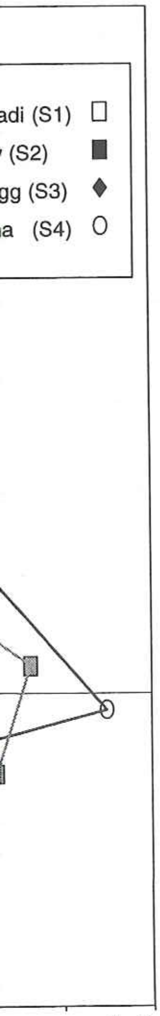


Fig. 2. The DCA ordination diagram of samples from investigated localities S1 - S4. Manual classification is done for the four studied localities.

not flooded zone



localities S1 - S4.

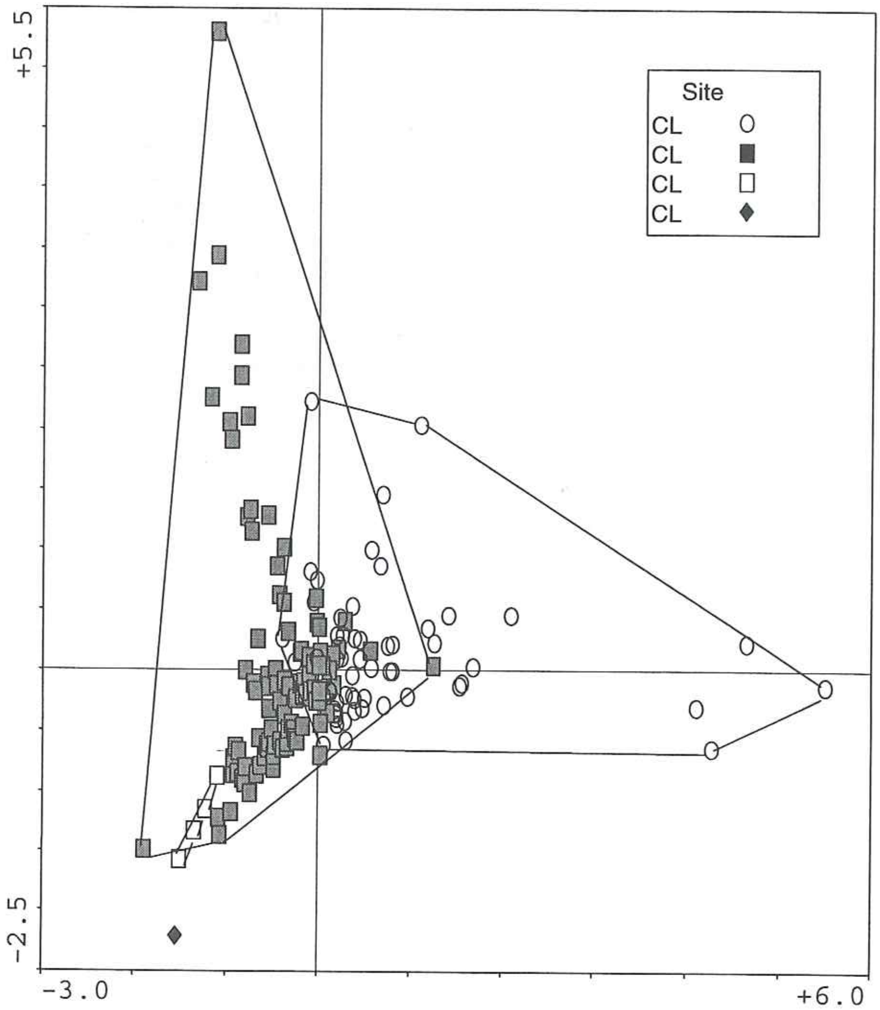


Fig. 3. Distribution of the samples in the DCA ordination diagram of the first and second ordination axis. The classification was done by TWINSPAN.

Classification by TWINSPAN

Classification by TWINSPAN divides the samples into two main groups. The samples of the 00 group are connected with the gradient of the first axis. The second large group 01 is distributed along the second axis. This suggests existence of two complex factors influencing the species composition in the spectrum of the studied conditions.

We suppose that the first axis is connected to the narrow valley and dense bank vegetation of the Dyje River below the reservoir. The vegetation leaves cover leads to development of rhodophytes in the shadowed parts of a relatively cold river. The second axis is tied to the spectra of the filamentous green algae. *Spirogyra* sp. on the negative part of second axis of diagram and the *Prasiola crispa* on the positive part of the second axis represent extremes of this algae occurrence gradient. Both of them occupy special biotops and require special flow conditions. While *Prasiola crispa* can survive semiaerophytic conditions, *Spirogyra* develops in slow flowing shallow waters. Their occurrence describes wideness of the conditions below reservoir.

The classification of algal species by TWINSPAN (see Fig. 4) is almost the same as the classification of samples (see Fig.3). This will help with the interpretation of the axes due to the species composition. The first axis corresponds to the red algae gradient, and the second axis to the green algae and cyanobacteria gradient of occurrence.

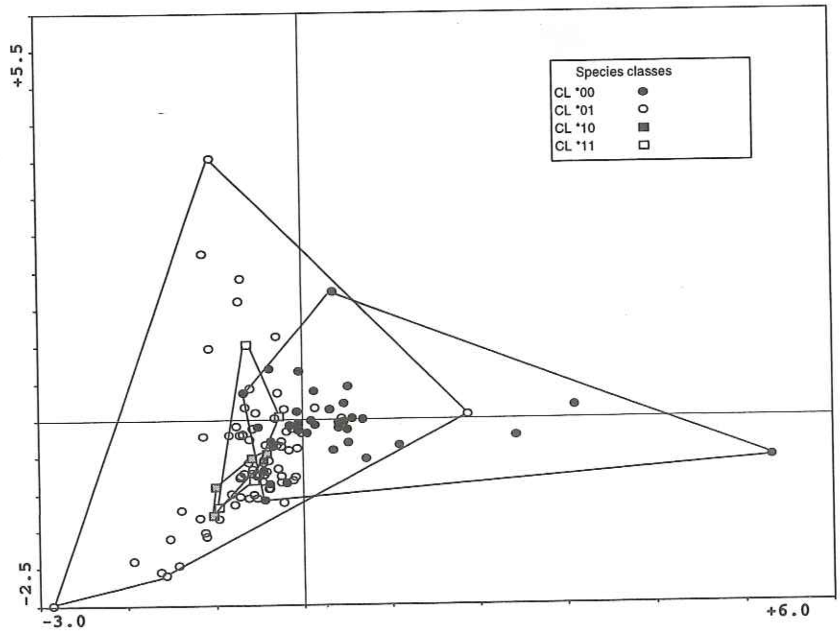


Fig. 4. Distribution of species in the DCA ordination diagram. The classification into four groups was done by TWINSPAN.

The species that distinguish the Podhradí (S1) sample site from the other localities, is well seen on Fig. 5, which explains species distribution in ordination diagram of first and second axes of Fig. 4 with TWINSPAN classification. Several noteworthy conclusions follow from the diagram. There are several species (*Lemanea* sp., *Spirogyra* sp., *Prasiola crispa*) occupying extreme microbiotops where other algae do not find convenient conditions for life.

The description of groups of tied species at Fig. 5.:

GROUP 1 = Nav crt, Syn par, Gyr att, Amp ova, Gom par, Mel var, Vau sp., Nit sig

GROUP 2 = Mel are, Coc ped, Cha noc, Oed sp

GROUP 3 = Cym cym, Nit dis, Nit pal, Nav crc, Gom tru, Gyr acu

GROUP 4 = Nav pup, Nit fon, Cla sp., Osc sp.,

GROUP 5 = Nav ave, Sce acu, Pin sp, Nav rhy,

GROUP 6 = Nei aff, Cyn gra, Nit par, Nav gre, Ste dub, Nit sga, Cyc cf., Nit sin, Cam hyb, Cym lan, Aul sp., Chlgl sp., Cym lib, Nit cap, Hetersp, Nav cap, Syn vau.

GROUP 7 = Cym eli, Elo can, Sur ele, Cym tum, Gom acu, Nev sem

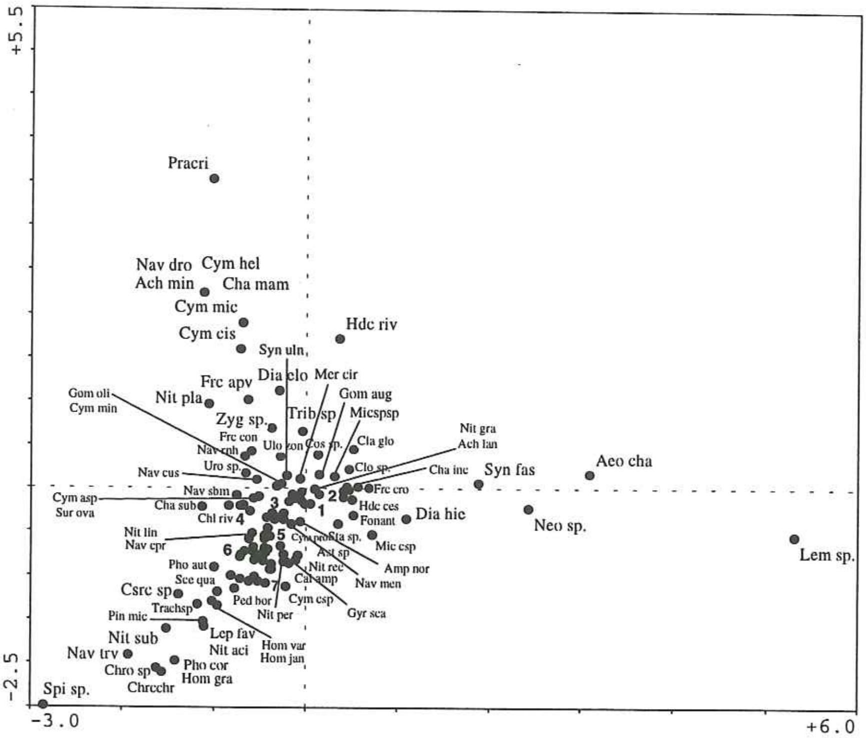


Fig. 5. Distribution of algal species in the DCA ordination space of the first and second axis.

DISCUSSION

Several authors (LOW 1979, PEŇÁZ et al. 1968) discussed the influence of power plant hydropeaking and river regulation on benthic algae. Main factors influencing phytobenthos below reservoir were temperature, flow, turbidity and nutrients.

Regulated streams below reservoirs, with deep release dams, generally have lower summer temperatures and higher winter temperatures than unregulated streams in the same region (SPENCE, & HYNES 1971, WARD 1974, 1976a in PETTS 1974, 1976b; NEEL 1963, KOMÁREK 1998). This effect can increase densities of benthic algae and change the species composition (WARD 1976b). In addition, shallow regions of deep lakes and streams generally have a greater seasonal temperature variation than deep-water areas (WARD 1974). In case of the Dyje river, the reservoir equalise the temperature variability during the year, but the density and species composition of microphytes is influenced also by other factors (light, substrate structure, depth etc.). The water temperature of the deep outflow may be kept on the same level for a long distance from the reservoir in deep narrow valleys covered by vegetation (LYNCH et al., 1984 WEATHERLEY & ORMEROD 1990). It is influenced mainly by differences in stratification of the reservoir, surrounding water sources and tributaries temperatures. There is also usually a lack of ice during the wintertime. This is just the case of Vranov reservoir.

The fluctuation of water is the next factor influencing distribution of algae. Flow regime of reservoirs usually makes seasonal flow below reservoir more constant (NEEL 1963, WARD 1976a in PETTS 1984, 1976b). The relatively steady current regime in streams regulated by hydropeaking is one of the contributing factors that leads to increased densities of phytobenthos. The main influence to algae assemblages cause the stratification of the channel due to duration of the water cower during the day. Tile-water below the Vranov reservoir possesses high daily fluctuation. Hydropeaking creates zones with different depth and regime of artificial flooding in river channel. These zones differ in many aspects. The most radical difference is between flooded and not flooded zones during the break of power station operation. Rise of this stage takes some time. Water flows out from weir impoundment to minimal water level for several hours. Nevertheless, there is a four or five-hour-break with minimal water level and naked parts of upper zone of tile water channel. The upper zone seems to be drying up during this time or is exposed to freezing, but the rate depends on temperature, relative air humidity and light penetration. The conditions of naked surfaces of stones shaded by vegetation are similar to wet rock biotopes. On these places, cyanobacteria (*Phormidium autumnale*, *Homeothrix varians* and *Leptolyngbya* sp. but possibly also other species) dominate. The mosses (*Fontinalis antipyretica*) occur on the border of permanently submersed zone. Another aspect that had not been studied but could possibly influence algae mats in the river is the interaction of water forces with the topography of the bottom. However, this aspect would be in correlation with changes found in the both zones. Reservoir power station operation and dam influence corresponds with other geomorphologic conditions of river localities around the reservoir. The geomorphologic situation complicates the interpretation of DCA axes in the case of Vranov reservoir.

Changes in turbidity of water are dependent on hydrological stage of the original river and type of reservoir as well as on seasonal changes in the phytoplankton development. Turbidity influences light penetration to river bottom affecting primary production of. algae. The river Dyje above the reservoir is rich of phytoplankton and fine particles of organic matter drifting to reservoir from ponds situated in river stretch. Reservoir body usually changes drift quality and quantity (LOWE 1979). The Vranov reservoir phytoplankton and drift outflow to regulated part of the river is minimised by deep outlet of the reservoir. Hydropeaking leads to more intensive cleaning of channel from sediments down the reservoir and ranks this part of river to erosive one but high frequency of spates cause that the rest of sediment is more stable from the long-term point of view.

Nutrient concentration changes within river channel goes hand in hand with reservoir role in the river system of conditions participating in water quality development. The reservoir can increase or decrease nutrient contents in river (LOWE 1979, WETZEL 1975a). The Vranov reservoir body is quite long, deep and narrow and so relatively cold. Development of water blooms in such type of should not have such extension as in other water bodies (shallow, wide and eutrophic reservoirs used for recreation or fish production; cf. REYNOLDS et al 1975). Nevertheless, in the case of Vranov reservoir, phases of strong development of waterbloom-forming cyanobacteria are well known since 50s.

Geomorphologic differences between the area above and below the reservoir could hide the influence of the reservoir (the changes in temperature, turbidity and flow) on biomass and species composition of phytobentos below the dam. Relatively low light intensity in deep valley together with correspondingly higher humidity in shadowed places can mild conditions for breaking mats below the reservoir as well as conditions for extremely high growth of biomass below the reservoir.

The Detrended Correspondence Analysis showed wider spectra of the species composition below the reservoir. Increase of flooding variability due to hydrological conditions below the reservoir leads generally to higher heterogeneity of bottom vegetation see (KOMÁREK 1998, KOUDELKOVÁ 1999). Below the reservoir, the fluctuation of water due to the daily discharge regime is creating zonation on the channel bottom. Zones correspond to the duration of flooding at specific places and also to disturbance caused by water during flooding. The influence of the first feature on the biodiversity is positive, while of the second is negative. Analyses of phytobenthos samples from the Dyje River stretch below the dam of Vranov reservoir proved considerable differences between particular sampling sites. Differences occur also on the level of the samples within localities below the reservoir. The increased spectrum of microhabitats in the bottom mosaic of phytobenthos in a river influenced by hydropeaking and corresponding algae assemblages is the main contribution of this study. A quite similar phenomenon was observed already in Svratka River below the Kníničky reservoir (KOMÁREK 1998, KOUDELKOVÁ 1999). Further studies of reactions of particular species of phytobenthos to fluctuating discharge below power plants with hydropeaking are necessary.

In spite of different flow regime, there were always several samples at influenced localities where species composition corresponded to the locality Podhradí (S1). They stem from areas possessing corresponding (similar) conditions to S1 locality. In such cases, the disturbing influence of hydropeaking affect algal community in such a way that the DCA results could be moderated by morphology of the channel, by vegetation of the channel banks or even by valley slopes.

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Appendix 1:

The list of species with their abbreviations

Species	Abbrew.	Podhradi	Hamry	Hardegg	Papirna
		S1	S2	S3	S4
Higher plants and mosses					
Batrachium fluitans	Batracsp	-	+	+	+
Phalaroides arundinacea	Bald sp	-	-	+	+
Hygrohypnum sp.	-	-	+	-	-
Elodea canadensis	Elo can	+	-	+	+
Fontinalis antipyretica	Fontant	-	+	+	-
Platyhypnidium rusciforme	-	-	-	+	+
Cyanobacteria					
Aphanocapsa incerta	-	+	-	-	-
Aphanocapsa sp.	Aph sp.	-	-	+	-
Cyanosarcina sp.	Csrc sp	-	-	+	-
Geitlerinema splendidum	-	-	-	-	+
Gomphosphaeria compacta	-	+	-	-	-
Heteroleibleinia sp.	Heter sp.	+	+	+	-
Heteroleibleinia kuetzingii	-	+	-	+	+
Homoeothrix gracilis	Hom gra	-	-	-	+
Homoeothrix janthina	Hom jan	+	+	+	+
Homoeothrix varians	Hom var	+	+	-	+
Hydrococcus cesatii	Hdc ces	+	+	-	+
Hydrococcus rivularis	Hdc riv	+	+	+	+
Chamaesiphon confervicola	Chacon	+	+	+	+
Chamaesiphon subglobosus	Cha sub	+	+	-	-
Chamaesiphon ametystinus	Chamam	-	-	-	+
Chamaesiphon incrustans	Cha inc	+	-	+	+
Chamaesiphon sp.	-	-	-	+	+
Chlorogloea sp.	Chlglsp	-	-	-	+
Chroococcopsis chroococcoides	Chrc chr	-	-	-	+
Leptolyngbya foveolarum	Lep fav	+	-	-	+
Leptolyngbya sp.	Lep sp.	+	+	+	+
Lyngbya cf. *nordhaagii*	-	+	-	-	-
Lyngbya sp.	-	+	-	-	-
Microcystis sp.	Mic sp.	-	-	+	-

Appendix 1 (continued)

Species	**Abbrew.**	**Podhradi** S1	**Hamry** S2	**Hardegg** S3	**Papirna** S4
Oscillatoria limosa	Osc lim	+	+	-	-
Oscillatoria sp.	Osc sp.	+	+	+	+
Phormidium autumnale	Pho aut	+	+	+	+
Phormidium corium	Pho cor	-	-	-	+
Cryptophyceae					
Cryptomonas curvata	-	+	-	-	-
Bacilariophyceae					
Achnanthes clevei	-	+	-	-	-
Achnanthes lanceolata	Ach lan	-	+	+	+
Achnanthes minutissima	Ach min	+	+	-	+
Amphora normanii	Amp nor	+	+	+	+
Amphora ovalis	Amp ova	+	+	+	+
Asterionella formosa	Ast for	+	-	-	+
Aulacosira sp.	Aul. sp.	+	+	+	-
Aulacosira cf.ambigua	-	+	-	-	-
Aulacosira distans s.l.	-	+	-	-	-
Aulacosira granulata	-	+	-	-	-
Caloneis amphisbaena	Cal amp	-	-	-	+
Caloneis silicula	-	-	-	-	+
Campylodiscus hibernicus	Camhyb	-	-	-	+
Cocconeis pediculus	Coc ped	+	+	+	+
Cocconeis placentula	Coc pla	+	+	+	+
Cyclostephanos dubius	Ste dub	+	-	-	-
Cyclotella meneghiniana	Cyc cf.	+	-	-	-
Cymatopleura elliptica	Cym eli	+	-	-	-
Cymatopleura librilis	Cym lib	+	-	-	+
Cymbella aspera	Cym asp	+	-	+	-
Cymbella cf. *helvetica*	Cym hel	-	-	-	+
Cymbella cf. *microcephala*	Cymmcrc	-	-	-	+
Cymbella cistula	Cym cis	-	+	-	+
Cymbella cymbiformis	Cym cym	-	+	+	-
Cymbella gracilis	Cym gra	-	-	+	-
Cymbella lanceolata	Cym lan	-	-	-	+
Cymbella minuta	Cym min	+	+	+	+
Cymbella minuta v.minuta	-	+	+	+	+
Cymbella minuta v.silesiaca	-	-	+	-	+
Cymbella prostrata v.prostrata	Cym pro	+	+	+	-
Cymbella prostrata v.auerswaldii	-	-	+	+	-
Cymbella tumida	Cymtum	+	+	-	+
Denticula tenuis	-	-	+	-	-
Diatoma hiemalis	Dia hie	-	+	-	-

Appendix 1 (continued)

Species	Abbrew.	Podhradi S1	Hamry S2	Hardegg S3	Papirna S4
Diatoma tenuis	Dia elo	-	+	+	+
Diatoma vulgaris	Dia vul	+	+	+	+
Ellerbeckia arenaria	Mel are	+	+	+	+
Eunotia curvata	-	-	+	-	-
Fragilaria capucina s.l.	-	+	+	-	+
Fragilaria capucina v. *vaucheriae*	Frccpv	-	+	+	-
Fragilaria construens	Frccon	-	+	+	+
Fragilaria crotonensis	Frc cro	+	+	+	+
Fragilaria pinnata	-	-	-	-	+
Fragilaria rumpens	-	-	-	-	+
Gomphonema acuminatum	Gom acu	-	-	+	+
Gomphonema angustum	-	+	-	-	+
Gomphonema augur	Gom aug	+	-	-	-
Gomphonema olivaceum	Gom oli	-	+	+	+
Gomphonema parvulum	Gom par	+	+	-	+
Gomphonema pumilum	-	+	-	-	+
Gomphonema truncatum	Gom tru	+	-	-	-
Gomphonema sp.	-	-	-	+	-
Gyrosigma acuminatum	Gyr acu	+	+	-	+
Gyrosigma attenuatum	Gyr att	-	+	+	+
Gyrosigma scalproides	Gyr sca	+	+	+	+
Gyrosigma spenceri v.*nodiferum*	-	+	+	+	+
Hantzschia amphioxys	-	+	-	-	-
Melosira varians	Mel var	+	+	+	+
Meridion circulare	Mer cir	+	+	-	-
Navicula avenacea	Nav ave	+	+	+	+
Navicula capitata	Nav cap	+	+	+	+
Navicula capitatoradiata	Nav cpr	+	+	-	-
Navicula cf.*placentula*	-	-	-	-	+
Navicula cf.*rostellata*	-	+	-	-	-
Navicula cryptocephalsa	Nav crc	+	-	-	-
Navicula cryptotenella	Nav crt	-	-	+	-
Navicula cuspidata	Nav cus	+	-	+	+
Navicula gregaria	Nav gre	+	+	+	+
Navicula menisculus	Nav men	+	+	+	+
Navicula mutica	-	-	-	-	+
Navicula pupula	Nav pup	-	-	-	+
Navicula reinhardtii	Nav rnh	-	+	-	+
Navicula rhynchocephala	Nav rhy	-	+	+	+
Navicula seminulum	Nav sem	-	-	-	+

Appendix 1 (continued)

Species	**Abbrew.**	**Podhradi** S1	**Hamry** S2	**Hardegg** S3	**Papirna** S4
Navicula slesvicensis	-	+	-	-	-
Navicula sp	Nav dro				
Navicula subminuscula	Nav sbm	+	+	-	+
Navicula tripunctata	Nav tri	+	+	+	+
Navicula trivialis	Nav trv	+	-	-	+
Navicula veneta	-	+	-	-	-
Neidium affine var. *longiceps*	Nei aff	-	+	-	+
Nitzschia acicularis	Nit aci	+	-	-	-
Nitzschia brevissima	-	-	-	-	+
Nitzschia calida	-	+	-	-	-
Nitzschia capitellata	Nit cap	+	+	+	+
Nitzschia cf. *paleacea*	Nit pla	+	+	+	-
Nitzschia dissipata	Nit dis	-	-	-	+
Nitzschia fonticola	Nit fon	-	+	+	+
Nitzschia gracilis	Nit gra	+	+	+	-
Nitzschia hungarica	-	-	-	-	+
Nitzschia levidensis	-	+	-	-	-
Nitzschia linearis	Nit lin	-	+	+	+
Nitzschia palea	Nit pal	+	-	-	+
Nitzschia paleacea	-	+	+	+	-
Nitzschia parvula	Nit par	+	+	+	+
Nitzschia perminuta	Nit per	+	+	+	+
Nitzschia perpusilla	-	-	+	-	-
Nitzschia recta	Nit rec	+	+	-	+
Nitzschia sigma	Nit sig	-	-	+	+
Nitzschia sigmoidea	Nit sga	-	-	+	+
Nitzschia sinuata	Nit sin	+	+	+	+
Nitzschia subtilis	Nit sub	+	+	-	-
Nitzschia cf. *subcapitellata*	-	-	-	-	+
Nitzschia vermicularis	-	-	+	-	+
Pinnularia microstauron	Pin mic	-	+	-	-
Pinnularia sp.	Pin sp.	+	+	-	-
Rhoicosphenia abbreviata	Rho abb	+	+	+	+
Skeletonema potamos	-	+	-	-	-
Stephanodiscus hantzschii	-	+	+	-	-
Surirella angusta	Sur ang	-	-	-	+
Surirella elegans	Sur ele	+	-	-	-
Surirella ovata	Sur ova	+	+	+	+
Synedra acus	-	+	+	-	-
Synedra fasciculata	Synfasc	+	-	-	-
Synedra parasitica	Syn par	-	-	-	+

Appendix 1 (continued)

Species	Abbrew.	Podhradi S1	Hamry S2	Hardegg S3	Papirna S4
Synedra tenera	-	+	-	-	-
Synedra ulna	Synuln	+	+	+	+
Xanthophyceae					
Characiopsis sp.	-	+	-	-	-
Characiopsis cf.*subulata*	-	+	-	-	-
Goniochloris mutica	-	+	-	-	-
Tribonema sp.	Trib sp	-	+	-	-
Vaucheria sp.	Vau sp.	-	+	-	-
Euglenophyceae					
Phacus parvulus	-	+	-	-	-
Trachelomonas planctonica	-	+	-	-	-
Trachelomonas volvocina	-	+	-	-	+
Trachelomonas sp.	Trachsp	-	+	-	-
Rhodophyceae					
Audouinella chalybaea	Aeo cha	-	+	+	-
Lemanea sp.	Lem sp.	-	+	-	+
Hildebrandia rivularis	Hdc riv	-	+	-	+
Batrachospermum moniliforme	-	-	-	+	-
Pophyridium sp.	-	-	+	-	-
Chlorophyceae					
Actinastrum hantzschii	-	+	-	-	-
Cladophora cf.*globulina*	Cla sp.	+	+	-	-
Cladophora glomerata	Cla glo	+	+	+	+
Coelastrum astroideum	-	+	-	-	-
Crucigeniella apiculata	-	+	-	-	-
Dicellula planctonica	-	+	-	-	-
Dictyosphaerium pulchellum	-	+	-	-	-
Gongrosira sp.	-	+	+	-	-
Chlorhormidium rivulare	Chl riv	+	+	+	-
Chlorhormidium sp.	-	-	+	+	-
Microspora amoena	-	-	+	+	+
Microspora sp.	Micrspsp	-	-	+	-
Monoraphidium arcuatum	-	+	-	-	-
Monoraphidium contortum	-	+	-	-	-
Neodesmus danubialis	-	+	-	-	-
Neonema sp.	Neo sp.	+	-	-	+
Nephroselmis olivacea	-	+	-	-	-
Oedogonium sp.	Oed sp	+	+	-	+
Pandorina morum	-	+	-	-	-
Pediastrum boryanum	Ped bor	+	-	-	-

Appendix 1 (continued)

Species	**Abbrew.**	**Podhradi** S1	**Hamry** S2	**Hardegg** S3	**Papirna** S4
Pediastrum duplex	-	+	-	-	-
Pediastrum tetras	-	+	-	-	-
Pedinomonas sp.	-	+	-	-	-
Prasiola crispa	Pra cri	-	+	+	+
Pseudodictyosphaerium jurisii	-	+	-	-	-
Scenedesmus abundans	-	+	-	-	-
Scenedesmus acuminatus	Sce acu	+	-	-	-
Scenedesmus cf. *bicaudatus*	-	+	-	-	-
Scenedesmus cf.*dimorphus*	-	+	-	-	-
Scenedesmus disciformis	-	+	-	-	-
Scenedesmus opoliensis	-	+	-	-	-
Scenedesmus quadricauda	Sce qua	+	-	-	-
Scenedesmus sp.	-	+	-	-	-
Stichococcus sp.	-	-	+	-	-
Stigeoclonium sp.	-	-	+	-	-
Tetrastrum cf.*glabrum*	-	+	-	-	-
Tetrastrum triangulare	-	+	-	-	-
Ulothrix zonata	Ulo zon	-	+	+	+
Uronema sp.	Uro sp.	-	-	+	-
Zygnematophyceae					
Closterium acerosum	-	+	+	-	+
Closterium sp.	Clo sp.	+	-	-	-
Cosmarium sp.	Cos sp.	+	-	--	-
Mougeotia	-	-	+	--	-
Staurastrum sp.	Sta sp.	+	+	+	+
Staurastrum pingue	-	-	-	+	-
Spirogyra sp.	Spi sp.	+	+	-	-
Zygnema sp.	Zyg sp.	-	+	-	-
Number of species		133	99	78	105

ardegg	Papirna
S3	S4
-	-
-	-
-	-
+	+
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
+	+
+	-
-	+
-	-
--	-
--	-
+	+
+	-
-	-
-	-
78	105

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THE MICRO - MEIOZOOBENTHIC COMMUNITIES IN TORRENTIAL ZONE OF THE DYJE RIVER INFLUENCED BY HYDROPEAKING

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ABSTRACT

Four localities situated on the Dyje River in the National Park Podyjí in Southern Moravia were sampled during 1994. The micro-meiobenthos and algae were determined to find out the relationship between the micro-meiobenthic taxa and different algae microhabitats. Altogether 172 taxa of micro-meiobenthic organisms were studied for comparison of algae microhabitats. Detrended Correspondence Analysis and Canonical Correspondence Analysis was used for processing the data. Significant differences of micro-meiobenthic diversity and algae microhabitat were found. The tested plant were moss *Fontinalis antipyretica* L., and all determined taxa of algae. The algal taxa were tested by Monte Carlo permutation test. The dominants significantly determining microhabitat were *Fontinalis antipyretica* L., *Oedogonium* sp., *Navicula avenacea* GRUN. and *Synedra ulna* (NITZSCH) EHRENB. We found that in extreme daily water level fluctuation, the exposed algae and plants (*Fontinalis antipyretica* L. and *Oedogonium* sp. had reduced taxa richness, lower diversity of other algal species as well as micro - meiobenthic taxa. In deeper water, the microhabitats with *Cladophora glomerata* (L.) Kütz.. allow many taxa of other algae and micro-meiobenthos to survive in microhabitat. The highest diversity and spectrum of micro-meiobenthic organisms were found in diatoms assemblages with dominant species *Navicula avenacea* GRUN. and *Synedra ulna* (NITZSCH) EHRENB.

INTRODUCTION

The importance of micro-meiobenthic component of running waters bottom community for decomposition is known (CUMMINS 1992, ALLAN 1995). ERTL (1970) also pointed the importance of this component for secondary production of organic matter and its function in trophic chain of ecosystem in his periphyton study of the Slovak part of the Danube River.

Micro-meiobenthos as well as the whole community of river depends on several physical variables of the environment, i.e. type of substrate, depth, water discharge and seasonal changes of these factors, which directly or indirectly influence production of micro-meiobenthic component (SCHÖNBORN 1998, TIRJÁKOVÁ & DEGMA 1996). There are papers about the influence of flow regimes and regulated discharges below reservoirs and other water works on river biota (e.g. BERECZKY 1978-1979, OPRAVILOVÁ 1990, OPRAVILOVÁ & KOMÁREK 1995).

The bottom biota, macro- and micro - meiobenthos, are highly influenced by changes in the discharge regime in rivers below reservoirs. OPRAVILOVA (1990) studied this problemacy of the water work Dalesice situated on the river Jihlava on this group of organisms. She followed several microhabitats; of them, the most influenced was the microhabitat of the submerged macrovegetation in the torrentile part of the river. After the building of the water work, several changes in the species composition of the community occurred what resulted in a lower value of diversity. Also BERECZKY (1978 - 1979) found changes in planktonic population of ciliates and testate amoebae in the Hungarian part of the Danube; building of several water works there led to a water level fluctuation and changes in the discharge regime. Torrential part of the rivers is the most influenced by discharge changes. The most common microhabitat in this part is periphyton. Higher discharge negatively influences development of the micro-meiozoobentos (OPRAVILOVÁ & KOMÁREK 1995).

Close interaction between autotrophic and heterotrophic component of periphyton and their changes under pressure of daily fluctuation of discharge in tailewater below reservoir were estimated in this study.

Presented results are the part of a grant project, which is described closely in KUBÍČEK et al. (1999) and in KOMÁREK & MARVAN (1999). All data and measured chemical - physical data can be found in KUBÍČEK et al. (1999).

The micro-meiobenthos in epilithic algal mats at four localities was evaluated. The algal species composition include mainly diatoms, filamentous green algae, cyanobacteria and some higher plants (*Fontinalis antipyretica* L., *Batrachium fluitans* (L.)) were determined and used for habitat analysis of micro-meiobenthos.

METHODS

The Vranov Reservoir is a typical stratified valley reservoir with maximum depth 58 m, maximum capacity 132.6 million m^3, length ca. 29.6 km, and area of ca 7.7 km^2 and average time of retention ca.156 days (VLČEK et al. 1984). The peaking wave influences 35 km of the river (HELEŠIC et al. 1998). Micromeiobenthos and algae of 4 usual sampling sites were studied. Podhradí (S1 - profile) is situated 28 km upstream the reservoir ca. 3 km above the end of lake. The second one, Hamry (S2 – profile) is situated 4 km below the dam. The third Hardegg (S3 - profile) is situated 12 km downstream the reservoir, and the fourth one Papírna (S4 – profile) is situated 33 km below the reservoir (KUBÍČEK et al. 1999)

Sampling of material

Periphyton sampling, including *Fontinalis antipyretica* L., was a part of a complex research at the studied sites. Hydrological characteristics of the studied area, chemical and physical measurements and a description of sites are written in KUBÍČEK et al. (1999). Sampling was carried out in 1994 in the following months: March, April, May, June, September and November.

The sampling of algae and micro-meiobenthos was done according to the Douglas method (ex SCHWOERBEL, 1966): epilithic periphyton was scraped from the surface of the neck of polyethylene bottle (5.7 cm^2) with a string brush.

Algae were determined native (Chlorophyceae) or fixed in formaldehyde 4% solution (Cyanobacteria) or burned in H_2O_2 solution and prepared to the Pleurax media slide for exact visualization of diatoms structures.

The material of micro-meiobenthos was processed alive. For counting and preliminary identification of taxa, subsample of 0.3 ml was transferred into a Sedgwick-Rafter counting cell. The majority of taxa required or native (Gymnamoebae, Heliozoa, Ciliophora) or permanent slides in glycerol-gelatin (testate amoebae, Rotifera, Gastrotricha, Oligochaeta, Crustacea). Others item are also permanent in Liquido-Faure (Nematoda, Tardigrada).

Micro-meiobentic organisms were converted for an area of 1 cm^2:

$$M\ (n.cm^{2}) = 10n\frac{x}{p}$$

where: M = number of individuals per cm^2, n = number of individuals found, x= sediment sample volume in ml, p= sample area.

Dominance

Dominance of the most represented taxa was expressed in % of the relative abundacne of individuals of the taxa in the superior group (Rhizopoda, Ciliophora, Rotifera, Nematoda), see Fig. 1. Dominance of the main groups was expressed as a relative abundance of individuals of the group from the found individuals total number, see Fig. 2.

Index diversity H'

List of the micro- meiobenthic taxa and its abbreviations completed by Shannon – Weawer index of diversity (BROWER et al. 1989) for each locality is in Appendix 1.

$$H' = -\sum Pi \ln \sum Pi$$

Statistical methods

Ordination methods were used for statistical estimation of the micro-meiobenthic interactions as well as interactions with the algal dominants. Determination of the main micro - meiobenthos infracommunities was done by Detrended Correspondence Analysis (DCA) (TER BRAAK & PRENTICE 1998) in CANOCO ver. 4.0 program (TER BRAAK & ŠMILAUER 1998). The comparison of micro-meiobenthos with the algal (microhabitat) dominants was done by the Canonical Correspondence Analysis. Algae determining the most important assemblages for micro-meiobenthos were analysed by the Monte Carlo permutation test (10000 permutations). Graphical output of CANODRAW (ver. 3.1) was improved by CANOPOST ver. 1.0 ŠMILAUER 1990 – 3).

These specialists identified some groups of meiozoobenthos: Nematoda - L. Háněl, Institute of Soil Biology, Academy of Sciences, České Budějovice; Oligochaeta, Ostracoda - F. Kubíček - Department of Zoology and Ecology, Faculty of Sciences, Masaryk University, Brno; Harpacticoidea - D. Vojtíšková – T.G.Masaryk Water Research Institute; revision of identification of Rotifera was done by F. Kubíček.

RESULTS AND DISCUSSION

Occurence of micro-meiobenthic organisms in the studied localities during the sampling period

Micro-meiozoobenthos in epilitic algal mats was studied at four localities. Diatoms were predominant at samples. Next dominants were filamentous green algae (*Cladophora, Oedogonium, Ulothrix*), cyanophytes and moss *Fontinalis antipyretica.* We found 172 taxa of micro-meiozoobenthos, 103 taxa of Protozoa and 69 of Metazoa.

Dyje - Podhradí (S1)

The lowest number of individuals was found at this locality - 927 belonging to 95 taxa.

The maximum amount of gymnamoebae, testate amoebae and heliozoans was found in autumn (XI). The highest density of testate amoebae have these taxa: *Pseudodifflugia fulva* (D = 27.72%), *Pamphagus granulatus* (D = 21.44%), *Chlamydophrys stercorea* (D = 17.83%) and *Cochliopodium bilimbosum* (D = 13.54%). High density of these taxa was found also in other rivers of the Czech Republic (OPRAVILOVÁ 1974, 1980, 1983).

The Ciliophora reached maxima in spring and autumn. The highest density was found for *Chilodonella uncinata* and members of the family *Oxytrichidae.*

The most abundant Rotifera were members of the class Bdelloidea (D = 70.13 %), which occurred during the whole time of study; however, the highest values of abundance were achieved in March. Species of the *Cephalodella* genus occurred quite often (D = 13.17%).

Genus *Eumonhystera* was the most abundant of nematods (D = 67.44%).

Mentioned abundant species of testate amoebae: *Pseudodifflugia fulva, Pamphagus granulatus, Chlamydophrys stercorea* and *Cochliopodium bilimbosum* belong to typical representatives of algal mats formed mainly of diatoms. The significant increase of abundance at this locality occurred in the autumn samples. ERTL (1970) described the similar taxa composition during the study of microflora in periphyton of the Danube River on an artificial substrate (microscopic slides).

The moss *Fontinalis antipyretica* was also sampled. As for Rotifers, abundant occurrence of the class Bdelloidea was found, and sporadic occurrence of species *Keratella quadrata* and *Colurella adriatica* were found. As for other species, we found Crustacea – Ostracoda and Harpacticoidea.

Mostly species of the class Bdelloidea and testate amoebae *(Centropyxis aculeata)* occurred in microhabitat of filamentous green algae *Cladophora glomerata.*

Dyje – Hamry (S2)

This locality was quite rich of the micro - meiobenthic taxa. 1747 individuals were studied. The number of taxa was the smallest in comparison with the other localities - 78, but very close to the Papírna locality (S4) with 80 taxa.

Gymnamoebae occurred only sporadically. *Pseudodifflugia fulva* (D = 40.36%) of testate amoebae was a taxon of the highest density. *Centropyxis aculeata* (D = 13.85%) was quite abundant and common species. Samples from June showed the highest richness of *Centropyxis aculeata* together with *Pseudodifflugia fulva.*

The most abundant species of Ciliophora was *Vorticella campanula* (D = 58.64%), mainly in autumn months - September and November. The family *Oxytrichidae* was less abundant (D = 10.10%).

The most abundant of rotifers was the class Bdelloidea (D = 80.68%). The highest density we found in September and November.

Nematods were abundantly represented by 14 taxa all together. The most abundant genus was *Eumonhystera* (D = 67.79 %).

Samples of the moss *Fontinalis antipyretica* mats were also taken. The Bdelloidea were the most abundant group, while we found no adult individuals of nematods. Also, larger amount of tardigrads of the species *Dactylobiotus dispar* was found. Samples of *Rhodophyceae* algal community contain genus *Vorticella* in larger density together with species *Actinophrys sol.*

The filamentous green algae samples included mainly Ciliophora, the representatives of Hypotrichida: *Aspidisca lynceus* and *Oxytrichidae.* From Cyrtophorida, there were found: *Chilodonella uncinata* and *Dysteria fluviatilis.*

Dyje - Hardegg (S3)

At this locality, 1241 individuals and 104 taxa were found. This locality was the most taxonomically rich locality.

Five taxa of Gymnamoebae were found most abundant in autumn months (IX, XI). The testate amoebae was represented by species *Arcella discoides* (D = 13.92%), which achieved the highest density in the sample of *Fontinalis antipyretica* in June. The other abundant species was *Centropyxis aculeata* (D = 18.84%), with highest values in June. Also species *Pseudodifllugia fulva* occured on this locality although less than on other localities. Its highest density was observed in June.

Ciliophora were mainly represented by *Aspidisca lynceus* (D = 15.82%), *Oxytrichidae* (D = 14.12%) and *Vorticella campanula* (D = 11.86 %) Ciliophora was mostly present in March due to the density of the representatives from Peritrichida and Hypotrichida.

As for rotifers, the highest density was achieved by the class Bdelloidea, although the values of density were lower than at other localities (D = 13.18%). The highest abundances were achieved in March. As for other species, the higher density was found for the species *Colurella adriatica* (D = 14.66 %), which occurred nearly at all samples: 8 of 10. MEUCHE (1939) found this species often in algae mats in lake sediments, although it is characteristic for running waters. It was found also in algal mats in other streams of the Czech Republic (OPRAVILOVÁ 1990, 1996). Species *Proales theodora* achieved also high values in May. It occurred on submerse vegetation (*Batrachium fluitans* (L.), *Myriophyllum spicatum* (L.)) mainly in torrential zone (D = 9.58 %) of the river Jihlava (OPRAVILOVÁ 1990). This species live also epizoic on gammarids. The food of *Proales theodora* is diatoms, often big specimens, which gobble with sand (BARTOŠ 1959)

Nematods occurred in small numbers, and only about half of all findings were juvenile individuals.

Arcella discoides, *Actinophyrs sol* and genus *Vorticella* were mostly abundant in samples of the moss *Fontinalis antipyretica.*

Bdelloidea and Nematoda were abundant in samples of Cyanobacteria.

Dyje - Papírna (S4)

The highest number of individuals was found at this locality -1875 of 80 taxa.

Rhizopods (Gymnamoebae, testate amoebae and heliozoans) were mostly abundant in November. The "periphytic species": *Pamphagus granulatus* and *Pseudodifflugia fulva* had the extra high density.

The species *Vorticella campanula* was the most abundant in Ciliophora. Mass development was noted in October and November. The family *Oxytrichidae* occurs also quite often. ERTL (1970) mentioned also abundant occurrence of the genus *Vorticella* in periphyton in accesoric branch channel of Danube River mainly in autumn months.

Of the rotifers, the class Bdelloidea was abundant (D = 81.73%) in May and June. Monogonont rotifers were represented by the *Colurella adriatica*, which was also found in every microhabitats of the River Jihlava (OPRAVILOVÁ 1990) and in algal mats in experimental brooks in Dalečín (OPRAVILOVÁ 1996).

Of nematods, 7 taxa were found. The genus *Eumonhystera,* prevailed on all the other localities, and the highest density was found for *Eumonhystera vulgaris* (D = 44.17 %).

The family *Naididae - Nais, Chaetogaster* and *Tubificidae - Peloscolex ferox* from Oligochaeta were more abundant at this site than on other localities.

Several samples of moss *Fontinalis antipyretica* L. were found at this locality (III,V, VI, XI). In November, higher abundance of "periphytic species": *Chlamydophrys stercorea*, *Pamphagus granulatus*, *Pseudodifflugia fulva* were found; beside this group, also species *Euglypha acathophora* was gathered. In each month, species *Vorticella campanula* (mostly at V, VI) was highly abundant, the family *Oxytrichidae* was next (mostly at V) and also *Aspidisca lynceus* at one sample (III). The Bdeloidea (mostly VI), next *Colurella adriatica* (V, VI) and in lower amount *Cephalodella* ssp. (XI) were the most abundant taxa of rotifers.

Within sample of the filamentous algae, *Centropyxis aculeata* was abundant species, Bdelloidea and genus *Eumonhystera.* Individuals of the *Hydrachnellae* (Acari) were found in small numbers.

Thė sample of *Elodea canadensis* (Richard) Michaux. was inhabited by the *Vorticella campanula* species (was significantly dominant), the family *Oxytrichidae,* Bdelloidea and genus *Eumonhystera* (was less abundant).

Comparison the communities of micro-meiobentic organisms in the studied localities.

Percentile piecharts of the micro-meiobenthic main taxa composition at four studied localities show similarity of the Podhradi (S1) and Hardegg (S3) locality as well as similarity of the Hamry (S2) and the Papirna (S4) localities. At the site S1, a typically growth community formed of testate amoebae and Rotifera was found with an abundant group Bdelloidea. At the site S2, testate amoebae were prevalent, but species composition was different. Species *Centropyxis aculeata* were relatively abundant. At both sites, there was a high index of diversity (S1 - H' = 3.48; S3 - H' =3.77). At the community of sites S2 and S4, Ciliophora, especially *Vorticella campanula,* and of Rotifer Bdelloidea were abundant. That is why the indices were lower than at the above mentioned sites (S2 - H' = 2.94; S4 - H' = 2.20).

We suppose that this difference is the result of the tributary above the Harddeg locality equalizing the drifting conditions to the Podhradi locality. The inlet of drifting organisms and POM is missing at the Hamry and Papirna localities.

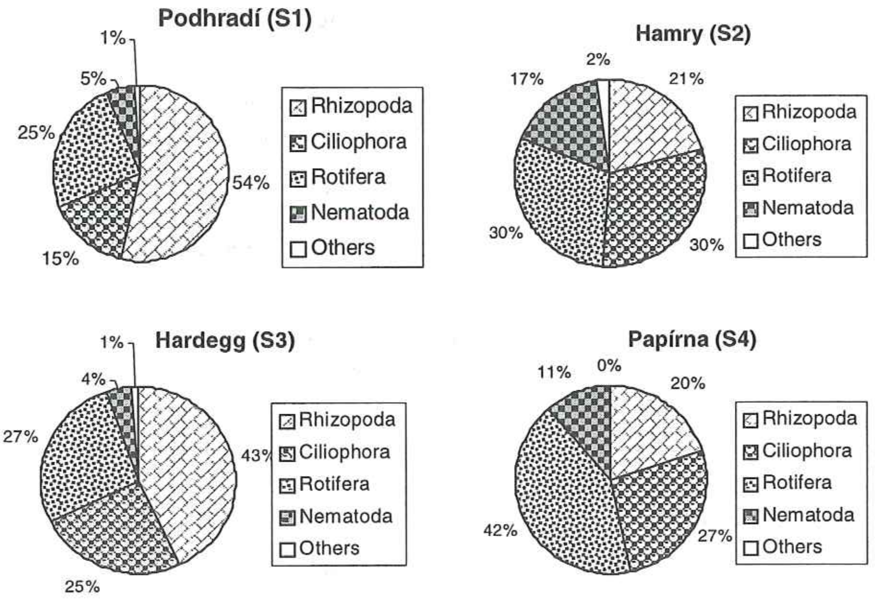

Fig. 1. Perceptual composition per cm^2 of the most abundant groups of micro-meiobenthos at four studied localities. Others see Appendix 1

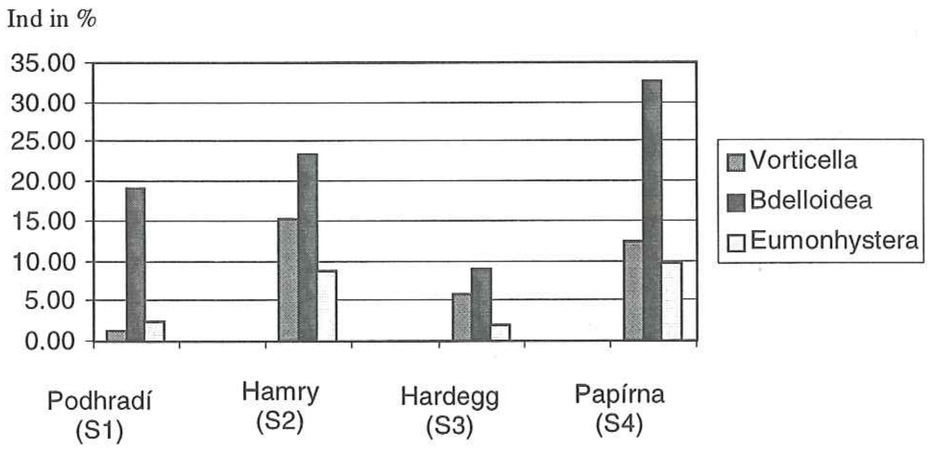

Fig. 2. The distribution of dominant taxa (in %): *Vorticela*, Bdeloidea, *Eumonhystera* within groups Ciliophora, Rotifera, Nematoda at four localities.

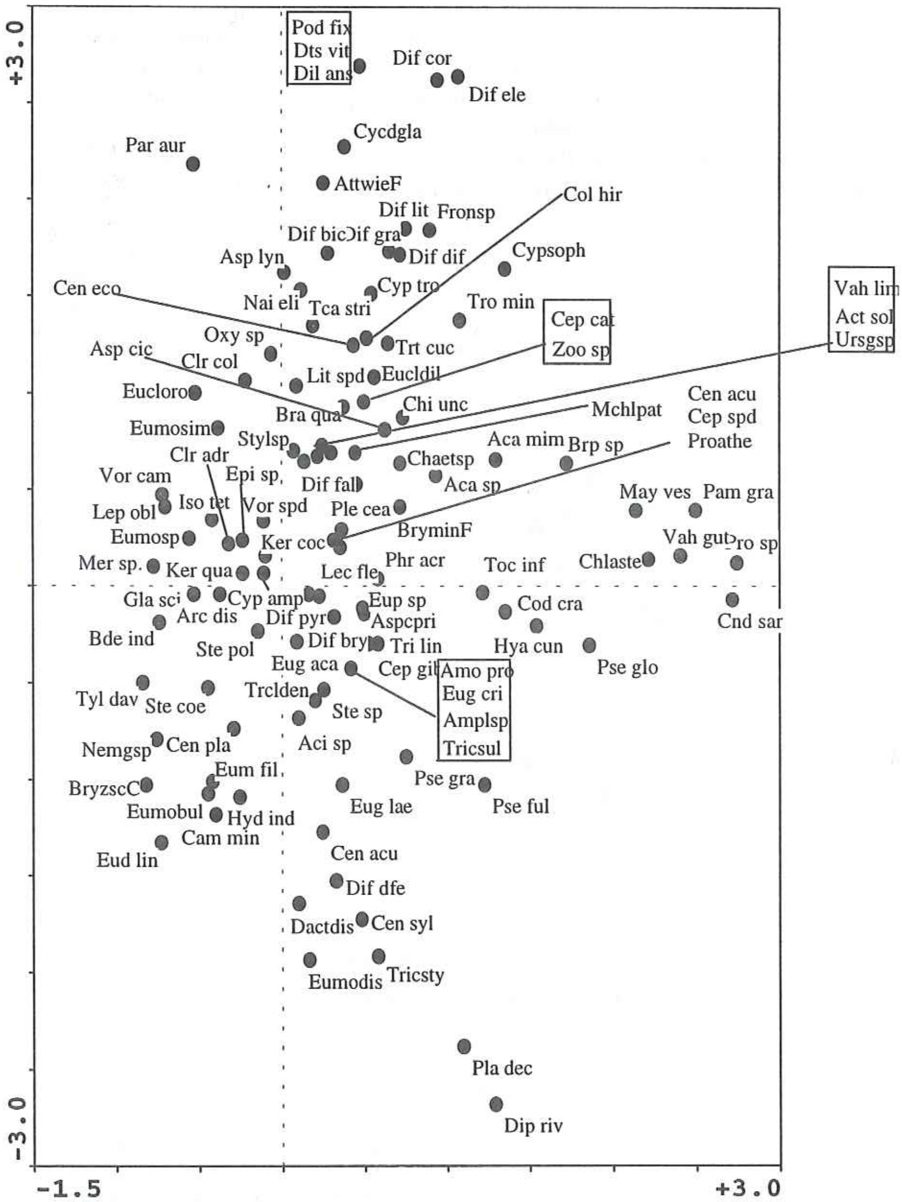

Fig. 3. The DCA diagram of the species of the micro-meiobenthos. The rare species (abundance = 2 and smaller) occurrences are omitted.

We suppose that there are several groups connected to the special substrates. At this diagram, we can find many species living in infracommunities (assemblages of species with tide occurrence). Extremely tide species create one point in the diagram, which means they occur together in all the samples with the same occurrence. Such groups of species are *Amoeba proteus* (Amo pro), *Euglypha cristata* (Eug cri), *Amphileptus* sp. (Amp lsp), *Trichocerca sulcata* (Tric sul) and *Cephalodella catellina* (Cep cat), *Zoothamnium* sp. (Zoo sp.) see Tab1.

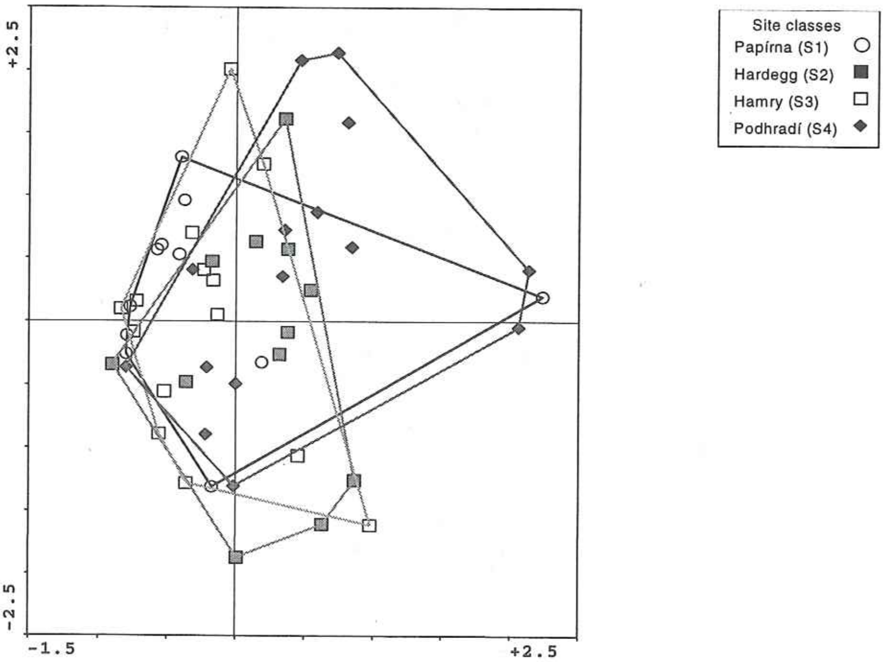

Fig. 4. The distribution of the samples in the ordination space of the first and second axes of DCA. Manual classification due to localities.

Relatively high spreads of the samples from the less influenced localities can bee seen at Fig. 4. The possible reason is a decreased influence of the reservoir on the localities, particularly by normal seasonal changes in temperature, which are equalized by hypolimnion reservoir water release (outflow) on influenced localities.

The positive part of the first axes corresponds with the extraordinary species composition (see Fig. 4. and Fig. 5.). The water fluctuation and daily flooding influences also decrease of the organic substrate and debris in the channel. This eccentricity can be possibly caused by influence of debris at the first locality Podhradi (S1) and the last locality Papirna (S4). Papirna locality is far enough from reservoir to be in area with available sedimentation of debris. On the other hand, localities S2 and S3 are cleaned by hydropeaking.

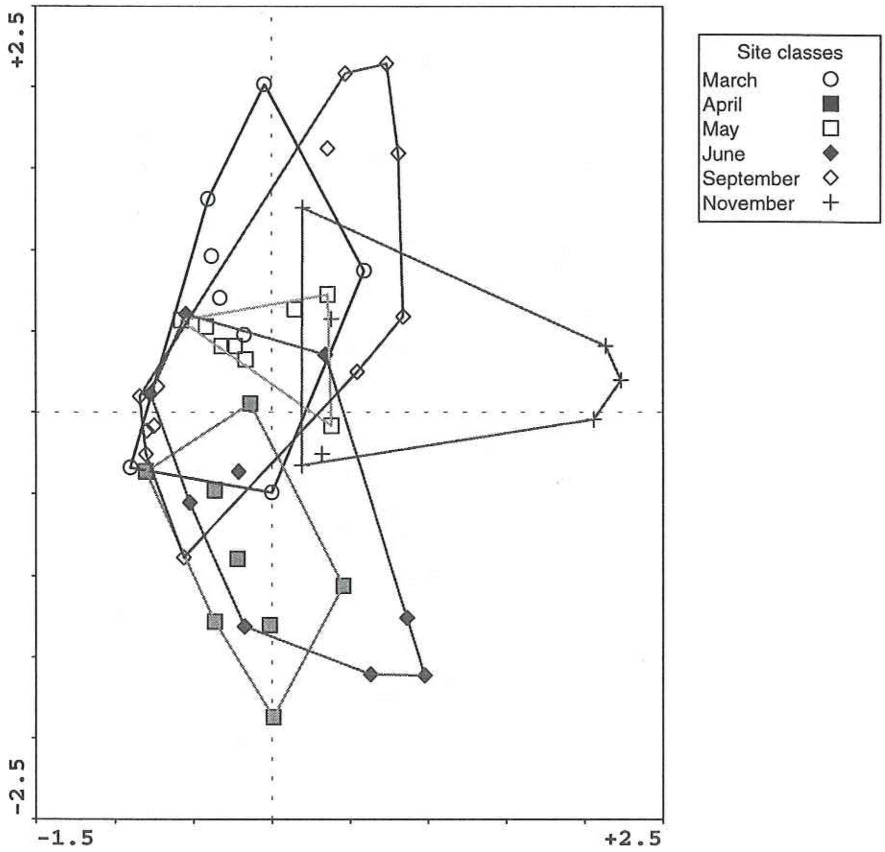

Fig. 5. This is the diagram of DCA of samples classified manually according to seasonal changes in months.

The month classification distributed species occurrence due to the first axis gradient and changes from left to right part see Fig. 5. The important change within the season occurs in November (debris). The second axis is hard to interpret as month clusters. Samples change its position alternatively in the upper and lower part of the axis due to the season. Nevertheless, the second axis is with highest probability the inverse gradient of temperature as the summer samples are at the lower part of the second axis, and March and September samples occur at the higher positions of the axis. Conditions bellow reservoir was narrowed by lack of debris during the season. Changes were mainly at S2 and S4 localities where discharge conditions influenced substrate composition and debris amount at November. Higher POM input from catchment area (S1 case) and tributary of the Fugnitz (S3 case) characterized S1 and S3. This causes the differences in gradient of the first axis-influencing occurrence of micro-meiobenthic taxa.

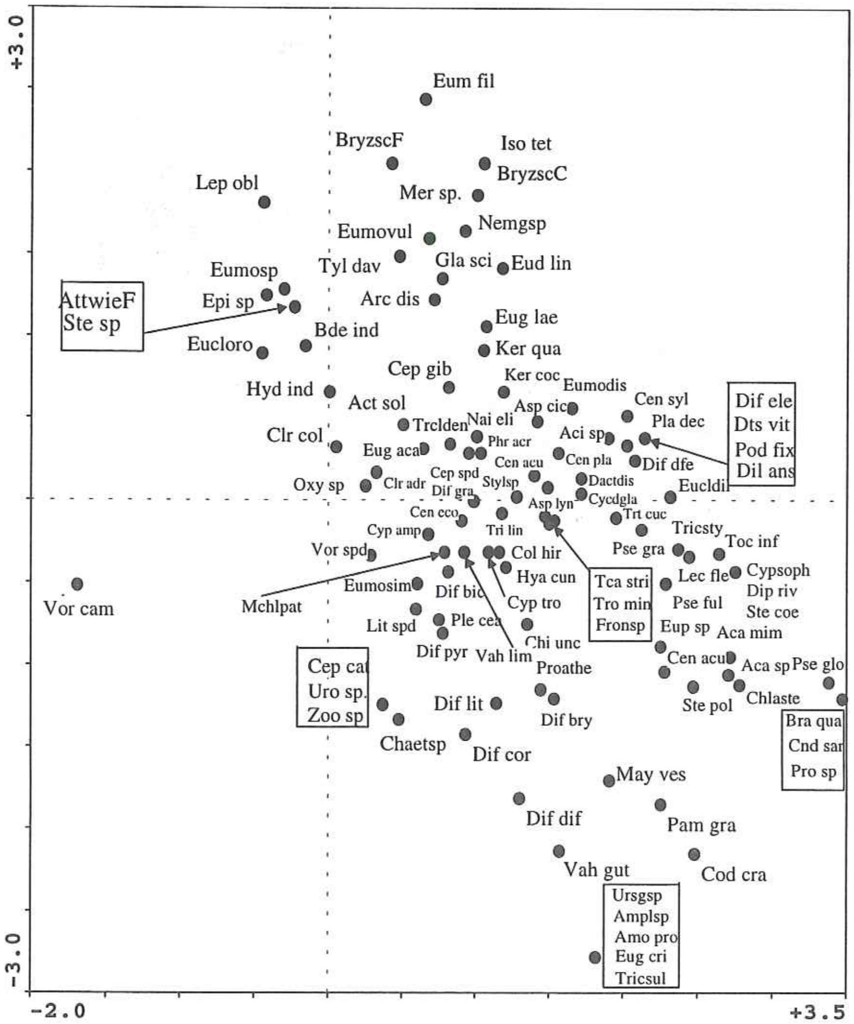

Fig. 6. The micro-meiobenthic taxa distribution in the CCA diagram of the first and second ordination axes. The graph is free of the rare taxa, which can be seen on the graph with the factors. (Abbreviations see – Appendix 1.)

The diagram (Fig. 6.) is a nice demonstration of the infracommunity of micro-meiobenthos, which arise in the hydropeaking flow of the Vranov reservoir in connection to the algal microhabitat.

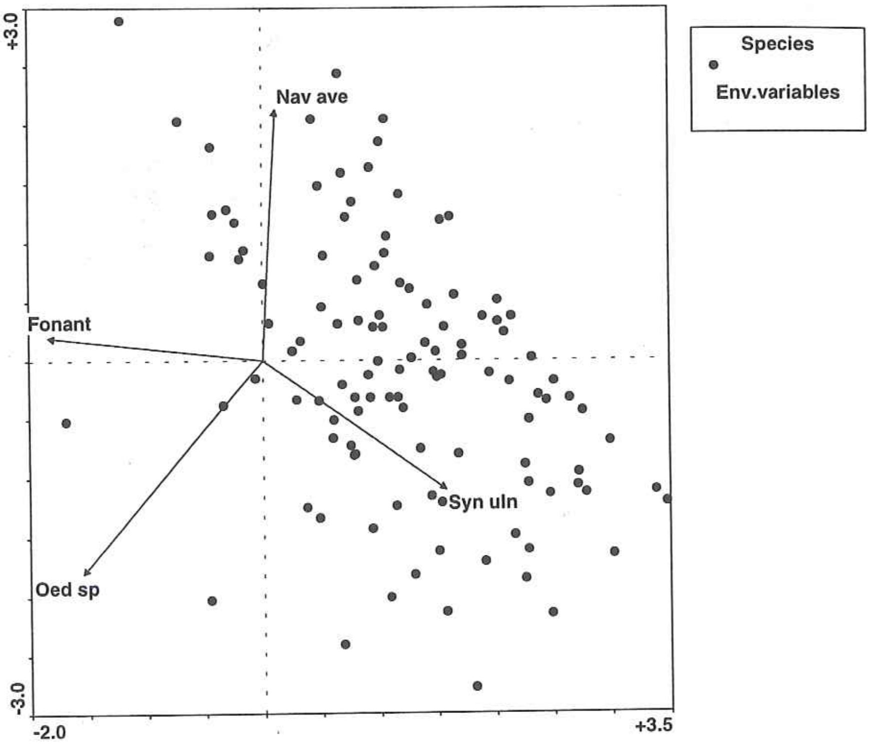

Fig. 7. The distribution of the statistically significant algal species in the CCA analysis biplot of species and factors. Nav ave = *Navicula avenacea*, Fon ant = *Fontinalis antipyretica*, Oed sp = *Oedogonium* sp., Syn uln = *Synedra ulna*.

The algal composition creates the reference set of factors (see arrows) for the micro - meiobenthos as a suitable habitat. The statistical significance was tested by the Monte Carlo permutation test. Only four species were significant due to MC permutation test with 1000 permutations under full model as well as under partial model on the significant level ($P < 0.05$).

The biplot shows that the highest species diversity was in the area with lack of moss *Fontinalis* as the *Fontinalis* occurs usually in the area highly exposed to the hydropeaking operation flow and was under pressure of flow disturbance. Also habitat of green filamentous alga *Oedogonium* sp. was relatively poor with low micro-meiobenthos species number (but these samples were rare). The highest number of micro-meiobenthic species occurs in assemblage of diatoms. The reason is that diatoms as microalgae are the energetic source for many species of micro-meiobenthos (SCHÖNBORN 1998).

The comparable distribution of the micro-meiobenthos can be seen in Fig 7. The comparison of these graphs can show the each micro-meiobenthic taxa connection to the habitat of dominant algae species.

The moss habitat of *Fontinalis antipyretica* is connected to the occurrence of *Vorticella campanula*, which is only species able to survive in this fast flow microhabitat. Also *Oedogonium* sp. habitat was quite poor of micro-meiobenthic species.

On the other hand, we can see occurrence of many species in the gradient of *Synedra ulna* (NITZSCH) EHRENB. and *Navicula avenacea* GRUN. as dominants of assemblages. These species of algae represent rich community of other diatom species.

Tab. 1. List of micro-meiobenthic taxa occurring in *Naviculla avenacea* GRUN. and *Synedra ulna* (NITZSCH) EHRENB. microhabitat. ...... - dominant species; Rh – Rhizopoda, Rh (Am) – Gymnoamoebae, Rh.(Hel.) – Heliozoa, C – Ciliophora, N – Nemathoda, Tar. – Tardigrada, Har. – Harpacticoidea,.

1. NAVICULA: Nematoda dominance

Arcella discoides (Arc dis – Rh); *Glaucoma scintillans* (Gla sci – C); *Eudorylaimus lindbergi* (Eud lin – N); *Nematoda* g.sp. (Nemgsp – N); *Tylenchus davainei* (Tyl dav – N); *Eumonhystera vulgaris* (Eumovul – N); *Mesodorylaimus bastiani* (Mer sp – N); - *Eumonhystera filiformis* (Eum fil – N); - *Bryocamptus minutus* – (female BryzscF – Har); *Isohypsibius tetradactyloides* (Iso tet – Tar); *Bryocamptus minutus* (BryzscC – Har);

Lepadella oblonga (Lep obl – R); *Eumonhystera* sp. (Eumosp – N); *Epistylis* sp. (Epi sp – C); *Atteyella wierzejski* (AttwieF – Har); *Stentor* sp. (Ste sp – C)

2. SYNEDRA - Rhizopoda - dominance

Trichocerca stylata (Tristy – R); *Lecane flexilis* (Lec fle – R); *Tocophrya infusionum* (Toc inf - C); *Pseudodifflugia fulva* (Pse ful – Rh); *Euplotes* sp. (Eup sp – C); *Centropyxis aculeata* (Cen acu – Rh); *Acanthocystis mimetica* (Aca mim - Rh (Hel)); *Acanthocystis* sp. (Aca sp. Rh (Hel)); *Pseudodifflugia globulosa* (Pse glo – Rh); *Stentor polymorphus* (Ste pol – C); *Chlamydophrys stercorea* (Chlaste – Rh) ; *Proales theodora* (Proathe *a* – R); *Difflugia lithophila* (Dif lit – Rh); *Difflugia bryophila* (Dif bry –Rh); *Difflugia corona* (Dif cor – Rh); *Mayorella vespertilio* (May ves - Rh (Am)); *Pamphagus granulatus* (Pam gra – Rh); *Difflugia difficilis* (Dif dif *s* – Rh); *Vahlkampfia guttula* (Vah gut - Rh (Am)); *Codonella cratera* (Cod cra – C);

Cypris ophathalmica (Cypaoph – Ostr); *Diplogaster rivalis* (Dip riv – A); *Stentor coeruleus* (Ste coe – C);

Brachionus quadridentatus (Bra qua – R); *Candona sarsi* (Cnd sar – Ostr); *Prorodon* sp. (Pro sp - C);

Urostylidae (Ursgsp – C); *Amphileptus* sp. (Amplsp – C); *Amoeba proteus* (Amo pro - Rh (Am)); *Euglypha cristata* (Eug cri – Rh); *Trichocerca sulcata* (Tricsul - R).

Cephalodella catellina (Cep cat – R);*Uroleptus* sp. (Uro sp - C); *Zoothamnium* sp. (Zoo sp - C)

Quite significant is the fact that several species of micro-meiobenthos is occurring "tide" together on similar habitats. The Monte Carlo permutation test showed us the four main algal dominants connected with the micro-meiobenthic assemblage. We can denote that micro-meiobenthos depends on substrate structure and character. Smallest diversity was observed at *Fontinalis antipyretica* growing on the exposed but stabile places - big stones in the bottom. Similar situation was at the *Oedogonium* sp. community, which also occur on the stones. On the other hand, relatively high diversity of micromeiobenthic species occurred in diatoms community and there where smooth crossing between *Naviculla avenacea* and *Synedra ulna* assemblages in micromeiobenthic species composition. Both algae dominate species posses its micromeiobenthic specialists. Micromeiobenthic species tied to *Navicula avenacea* – *Lepadella oblonga*, *Bryocamptus* (B.) *zschokkei*, *Eumonhystera filiformis*, *Isohypsibius tetradactyloides*, *Bryocamptus zschokkei* copepodit, *Nematoda* g. sp. We expect the occurence of the *Cladophora glomerata* in connection with *Navicula avenacea* on very similar vector (Fig. 7.) *Synedra ulna* microhabitat is also very rich by micromeiobenthic species see Tab 1.

Food relations of micro-meiobenthos and algae

In the water environment, protozoons are at the beginning of the food web followed by micrometazoa, macrometazoa (water insect larvae etc.) and vertebrates; that is why the protozoons are very important for the energy flow in the environment. Majority of protozoons feed on bacteria, detritus and algae, while predators are rare.

Diatoms can be found at feeding vacuoles of the protozoa in diatom mats. It is known that gymnoamoebae often swallow diatoms, and many species of testate amoebae feed on diatoms. SCHÖNBORN (1981) found several species from the river Saale (*Arcella rotundata* Playfair, *Centropyxis aculeata, Centropyxis discoides* (Penard), *Centropyxis ecornis* and *Centropyxis hirsuta* Deflandre) where diatoms were found in the vacuoles; he also found them *Chlorococales*, microspors of *Ulothrix.* Even the species *Trinema lineare* contained not only bacteria but also diatoms as well in their vacuoles. ERTL (1954) also noticed diatoms in the cell of *Pamphagus granulatus*. In our material, we found diatoms in cells of species *Cochliopodium bilimbosum* and *Pamphagus granulatus.*

From Ciliophora, the species *Trithigmostoma cucullulus* is considered to be algivorous and feeding especially on diatoms (NOLAND 1925, FOISSNER et al. 1991). Also the genus *Frontonia* is considered to be algivorous (NOLAND 1925, MADONI 1989), while FOISSNER et al. (1994) classify it to omnivorous organisms. For members of the family *Oxytrichidae*, diatoms are considered to be the main food source, while bacteria only to a smaller degree (NOLAND 1925, FOISSNER et al. 1991).

In our material, the above mentioned Ciliophora contained diatoms as well. Other protozoon's species are considered to be bacteriovorous, detritovorus and algivorous feeding on single-cell algae with the exception of diatoms. We have found the following predatory species of Ciliophora: *Amphileptus* sp., *Dileptus margaritifer*, genus *Litonotus*, *Loxophyllum meleagris*, *Suctoria* (MADONI 1989, TIRJÁKOVÁ 1993, FOISNER et al. 1995).

According to POURRIOT (1977), the food intake of rotifers depends on the size of the mastax and the body size. For example, large species feed on desmids and diatoms, small bacterial strains and detritus. Species of the genus *Cephalodella* feed on single cell algae sucking out their content (LELLÁK et al. 1985).

It is known that nematods are often found in algal growths. PREJS (1970) found a positive relation between the amount of algae and the number of herbivorous nematods. Nematod species belonging to the genus *Eumonhystera* were abundant; ANDRÁSSY (1984) consideres them to be detritovorous occasionally feeding on algae. Also genera *Plectus* and *Diplogaster* are considered detritovorous (PREJS 1970). Genus *Chromadorita*, also found in our material, is included in herbivorous species feeding on small green algae, anabaena and diatoms (PREJS 1970).

An indispensable habitat of flowing waters is the moss *Fontinalis antipyretica* as well as filamentous green algae, that is caught detritus noticed by TIRJÁKOVÁ (1993) while studying Ciliophora on the river Turiec. In our material, in the detritus on *Fontinalis antipyretica* , the genus *Vorticella* was found the most abundant, especially *V. campanula* and Bdelloidea of rotifers. These are organisms satisfied with the stronger current bringing sufficient amount of nutrients.

In detritus of the filamentous *Cladophora glomerata*, the community was more diverse containing not only Bdelloidea but also testate amoebae (*Arcella discoides, Centropyxis aculeata),* of Ciliophora: Cyrtophorida and Hypotrichida as well as individuals of other groups.

CONCLUSIONS

Highest species diversity is connected to the diatoms species dominants *Navicula avenacea* and *Synedra ulna* . This evokes the idea that the occurrence of the most of the micro - meiobenthos species with in extreme range of the water discharges due to the hydropeaking of the reservoir is significantly correlated to the character of sediments over channel bottom. The *Fontinalis* microcommunity was quite poor for species. *Vorticella campanula* was only one species which occured within *Fontinalis* moss.

The community of the filamentous algae (*Cladophora glomerata*), was more diverse as there occured (*Arcella discoides*, *Centropyxis aculeata*) Testate amoebae, (Cyrtophorida, Hypotrichida) from ciliates and representatives of next groups instead of Bdelloidea.

The moss *Fontinalis antipyretica* and green filamentous algae create important habitat in flowing waters causing better conditions for catching the detritus. This phenomenon describes TIRJÁKOVÁ (1993) in study of Ciliophora from the Turiec river. *Vorticella campanula* and Bdelloidea were the dominants in our detritus material *antipyretica*. These organisms live in conditions with higher flow rate, which enable the higher food input and exchange.

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Appendix 1

Taxa	Locality Abbrev.	Podhradí S1	Hamry S2	Hardegg S3	Papírna S4
Gymnamoebae					
Amoeba bothryllis Penard	*Amo bot*	-	-	-	+
Astramoeba radiosa Dujardin	*Amo rad*	+	-	+	-
Amoeba proteus Leidy	*Amo pro*		+	+	-
Amoeba sp.	*Amo sp*	+	-	-	-
Dactylosphaerium vitraeum Hertwig & Lesser	*Dts vit*	-	-	+	-
Mayorella vespertilio (Penard)	*May ves*	+	-	+	+
Thecamoeba striata (Penard)	*Tca stri*	+	+	+	+
Thecamoeba verrucosa (Ehrenberg)	*Tca ver*	-	-	-	+
Vahlkampfia guttula gr.	*Vah gut*	+	-	+	+
Vahlkampfia limax gr.	*Vah lim*	+	+	+	-
Testate amoebae					
Cochliopodium bilimbosum Auerbach	*Cochbil*	+	-	-	+
Cochliopodium minutum West	*Cochmin*	-	-	-	+
Microchlamys patella Claparède & Lachmann	*Mchlpat*	+	+	+	+
Arcella discoides Ehrenberg	*Arc dis*	+	+	+	+
Centropyxis aculeata (Ehrenberg) Stein	*Cen acu*	+	+	+	+
Centropyxis aculeata oblonga Deflandre	*Cen aco*	+	+	+	-
Centropyxis aerophila sphagnicola Deflandre	*Cen aer*	-	-	+	-

(Appendix 1 continued)

Taxa	Locality Abbrev.	Podhradí S1	Hamry S2	Hardegg S3	Papírna S4
Centropyxis cassis Deflandre	*Cen cas*	+	-	+	-
Centropyxis ecornis (Ehrenberg) Leidy	*Cen eco*	+	+	+	-
Centropyxis minuta Deflandre	*Cen min*	-	-	-	+
Centropyxis orbicularis Deflandre	*Cen orb*	+	-	-	-
Centropyxis platystoma (Penard) Deflandre	*Cen pla*	+	+	+	+
Centropyxis sylvatica (Deflandre) Bonnet & Thomas	*Cen syl*	+	-	+	+
Cyclopyxis eurystoma parvula Bonnet & Thomas	*Cyc eur*	+	-	-	-
Plagiopyxis declivis Bonnet & Thomas	*Pla dec*	-	+	+	-
Plagiopyxis oblonga Bonnet & Thomas	*Pla obl*	+	-	-	-
Difflugia avellana Penard	*Dif ave*	+	-	-	-
Difflugia bryophila (Penard) Jung	*Dif bry*	-	-	+	+
Difflugia corona Taránek	*Dif cor*	+	-	-	-
Difflugia difficilis Thomas	*Dif dif*	+	-	+	-
Difflugia difficilis ecornis Chardez	*Dif dfe*	-	+	+	+
Difflugia elegans Penard	*Dif ele*	+	-	-	-
Difflugia elegans bicornis Jung	*Dif bic*	+	-	-	+
Difflugia fallax Penard	*Dif fal*	+	-	+	-
Difflugia globularis (Wallich) Leidy	*Dif glo*	-	-	+	-
Difflugia gramen Penard	*Dif gra*	+	-	-	-
Difflugia lithophila (Penard) Gauthier-Lièvre & Thomas	*Dif lit*	+	-	+	-
Difflugia lobostoma Leidy	*Dif lob*	+	-	-	-
Difflugia mammilaris Penard	*Dif mam*	+	-	-	-
Difflugia minuta Rampi	*Dif min*	-	-	-	+
Difflugia penardi Hopkinson	*Dif pen*	-	-	+	-
Difflugia pulex Penard	*Dif pul*	+	-	-	-
Difflugia pyriformis Perty	*Dif pyr*	+	+	+	-
Difflugia pyriformis incondita Gauthier -Lièvre & Thomas	*Dif pri*	+	-	-	-
Difflugia pyriformis lata Jung	*Dif prl*	-	+	+	-
Hyalosphenia cuneata Stein	*Hya cun*	+	-	-	+
Phryganella acropodia (Hertwig & Lesser)	*Phr acr*	+	+	+	+
Euglypha acanthophora (Ehrenberg)	*Eug aca*	+	+	+	+
Euglypha brachiata Leidy	*Eug bra*	-	-	+	-
Euglypha cristata Leidy	*Eug cri*	-	-	+	-
Euglypha laevis Perty	*Eug lae*	-	+	+	+
Sphenoderia lenta Schlumberger	*Spndlen*	-	-	+	
Tracheleugpyha dentata (Vejdovský) Deflandre	*Trclden*	+	+	+	+
Trinema lineare Penard	*Tri lin*	+	+	+	+

(Appendix 1 continued)

Taxa	Locality Abbrev.	Podhradí S1	Hamry S2	Hardegg S3	Papírna S4
Campascus minutus Penard	*Cam min*	-	+	+	+
Cyphoderia ampulla (Ehrenberg)	*Cyp amp*	+	+	+	+
Cyphoderia trochus Penard	*Cyp tro*	+	-	+	+
Chlamydophrys stercorea Cienkowski	*Chlaste*	+	-	+	+
Pamphagus granulatus Schulze	*Pam gra*	+	+	+	+
Pseudodifflugia fulva (Archer)	*Pse ful*	+	+	+	+
Pseudodufflugia globulosa Štěpánek	*Pse glo*	+	+	+	-
Pseudodifflugia gracilis Schlumberger	*Pse gra*	+	+	+	+
Pseudodifflugia senartensis Couteaux	*Pse sen*	-	+	+	-
Heliozoa					
Acanthocystis mimetica Penard	*Aca mim*	+	-	+	-
Acanthocystis sp.	*Aca sp*	+	+	+	-
Actinophrys sol Ehrenberg	*Act sol*	+	+	+	+
Ciliophora					
Coleps hirtus (O.F.Müller) Nitzsch	*Col hir*	+	+	+	-
Prorodon sp.	*Pro sp*	+	-	-	-
Bryophyllum sp.	*Brp sp*	-	-	+	+
Amphileptus sp.	*Amplsp*	-	-	+	-
Dileptus margaritifer (Ehrenberg) Dujardin	*Dil ans*	-	-	+	-
Litonotus sp. div.	*Lit spd*	+	+	+	+
Loxophyllum meleagris Dujardin	*Lox mel*	+	-	+	-
Bursaria sp.	*Bur sp*	-	-	-	+
Dysteria fluviatilis Stein	*Dys flu*	-	+	-	-
Chilodonella uncinata (Ehrenberg) Strand	*Chi unc*	+	+	+	+
Trithigmostoma cucullulus (O. F. Müller) Jankowski	*Trt cuc*	+	+	-	+
Trochilia minuta (Roux) Kahl	*Tro min*	+	+	+	+
Acineta sp.	*Aci sp*	+	+	+	-
Podophrya fixa O.F.Müller	*Pod fix*	-	-	+	-
Tocophrya infusionum (Stein) Bütschli	*Toc inf*	+	-	-	-
Frontonia sp.	*Fronsp*	+	+	+	-
Glaucoma scintillans Ehrenberg	*Gla sci*	-	+	+	+
Paramecium aurelia - komplex	*Par aur*	-	-	-	+
Cyclidium glaucoma O.F.Müller	*Cycdgla*	+	+	+	+
Pleuronema crassum Dujardin	*Ple cea*	-	+	+	-
Cothurnia annulata Stokes	*Cot ann*	-	-	-	+
Epistylis sp.	*Epi sp*	-	-	-	+
Vorticella campanula Ehrenberg	*Vor cam*	+	+	+	+

(Appendix 1 continued)

Taxa	Locality / Abbrev.	Podhradí S1	Hamry S2	Hardegg S3	Papírna S4
Vorticella sp. div.	*Vor spd*	+	+	+	+
Zoothamnium sp.	*Zoo sp*	-	-	+	-
Stentor coeruleus (Pallas) Ehrenberg	*Ste coe*	-	-	+	-
Stentor polymorphus (O.F.Müller) Ehrenberg	*Ste pol*	-	-	+	-
Stentor sp.	*Ste sp*	-	-	-	+
Codonella cratera (Leidy) Imhof	*Cod cra*	+	-	+	-
Strombidium sp.	*Strbsp*	+	-	-	-
Aspidisca cicada (O.F.Müller) Claparède	*Asp cic*	+	+	+	+
Aspidisca lynceus (O.F.Müller) Ehrenberg	*Asp lyn*	+	+	+	+
Euplotes patella (O. F. Müller) Ehrenberg	*Eup pat*	+	-	+	-
Euplotes sp.	*Eup sp*	+	-	+	+
Oxytrichidae g. sp.	*Oxy sp*	+	+	+	+
Uroleptus sp.	*Uro sp.*	+	-	+	-
Urostylidae g.sp.	*Ursgsp*	+	-	+	-
Turbellaria					
Neorhabdocoela (indet.)	*Neo ind*	-	-	+	-
Rotifera					
Bdelloidea (indet.)	*Bde ind*	+	+	+	+
Brachionus angularis Gosse	*Bra ang*	-	-	+	-
Brachionus calyciflorus Pallas	*Bra cal*	-	+	-	-
Brachionus quadridentatus Hermann	*Bra qua*	+	-	-	-
Brachionus sp.	*Bra sp*	-	-	-	+
Keratella cochlearis (Gosse)	*Ker coc*	+	+	+	+
Keratella quadrata (O. F. Müller)	*Ker qua*	+	+	+	+
Euchlanis dilatata Ehrenberg	*Eucldil*	+	-	+	-
Euchlanis lucksiana Hauer	*Euclluc*	-	-	+	-
Euchlanis oropha Gosse	*Eucloro*	-	-	+	+
Euchlanis parva Rousselet	*Euclpar*	+	-	-	-
Mytilina ventralis (Ehrenberg)	*Myt ven*	+	-	-	-
Notholca squamula (O. F. Müller)	*Not squ*	-	+	-	-
Colurella adriatica Ehrenberg	*Clr adr*	+	+	+	+
Colurella colurus (Ehrenberg)	*Clr col*	+	+	+	+
Lepadella oblonga (Ehrenberg)	*Lep obl*	+	+	+	-
Lecane (*L.*) *flexilis* (Gosse)	*Lec fle*	+	-	-	+
Lecane (*M.*) *closterocerca* (Schmarda)	*Lec clo*	-	-	+	-
Lecane (*M.*) *quadridentata* (Ehrenberg)	*Lec qua*	+	-	-	-
Lecane (*M.*) *subulata* (Harring & Myers)	*Lec sub*	-	-	-	+

(Appendix 1 continued)

Taxa	Locality Abbrev.	Podhradí S1	Hamry S2	Hardegg S3	Papírna S4
Lecane sp.	*Lec sp*	-	-	-	+
Cephalodella gibba (Ehrenberg)	*Cep gib*	+	-	+	+
Cephalodella cf. *catellina* Müller	*Cep cat*	-	-	+	-
Cephalodella sp. div.	*Cep spd*	+	+	+	+
Proales theodora (Gosse)	*Proathe*	-	+	+	+
Trichocerca collaris (Rousselet)	*Triccol*	+	-	-	-
Trichocerca longiseta (Schrank)	*Tri lon*	-	+	-	-
Trichocerca stylata (Gosse)	*Tricsty*	+	-	-	-
Trichocerca sulcata (Jennings)	*Tricsul*	-	+	+	-
Encentrum sp.	*Enc sp*	-	+	-	-
Asplancha priodonta Gosse	*Aspcpri*	-	-	+	-
Polyarthra dolichoptera Idelson	*Pol dol*	-	-	+	-
Conochilus unicornis Rousselet	*Con uni*	-	-	+	-
Gastrotricha					
Chaetonotus sp. div.	*Chaetsp*	+	-	+	+
Nematoda					
Eumonhystera dispar (Bastian)	*Eumodis*	-	+	-	+
Eumonhystera longicaudatula (Gerlach & Riemann)	*Eumolon*	-	+	-	-
Eumonhystera simplex (de Man)	*Eumosm*	-	+	-	+
Eumonhystera vulgaris de Man	*Eumovul*	+	+	-	+
Eumonhystera cf. *filiformis* (Bastian)	*Eum fil*	+	+	-	-
Eumonhystera sp.	*Eumosp*	+	+	+	+
Hofmaenneria sp.	*Hof sp.*	-	+	-	-
Chromadorita leuckarti (de Man)	*Chr leu*	-	-	-	+
Diplogaster rivalis (Leydig)	*Dip riv*	-	+	-	-
Tylenchus davainei Bastian	*Tyl dav*	-	+	-	+
Aphelenchoides saprophilus Franklin	*Aph sap*		+	-	-
Dorylaimus stagnalis Dujardin	*Dor sta*	+	-	-	-
Eudorylaimus lindbergi Andrássy	*Eud lin*	-	+	-	-
Mesodorylaimus bastiani (Bütschli)	*Mes bas*	-	-	-	+
Mermis sp. larvae	*Mer sp.*	-	-	+	+
Plectus aquatilis Andrássy	*Plc aqu*	-	+	-	-
Plectus parvus Bastian	*Plc par*	-	+	-	-
Plectus sp.	*Plc sp*	-	-	+	-
Nematoda g.sp. larvae	*Nemgsp*	+	+	+	+

(Appendix 1 continued)

Taxa	Locality / Abbrev.	Podhradí S1	Hamry S2	Hardegg S3	Papírna S4
Oligochaeta					
Aelosoma sp.	*Aeol sp*	-	-	+	-
Nais alpina Sperber	*Nai alp*	-	-	-	+
Nais elinguis O. F. Müller	*Nai eli*	+	+	-	+
Chaetogaster diastrophus (Gruithuisen)	*Chg dia*	+	-	-	-
Chaetogaster sp.	*Chg sp*	-	-	-	+
Peloscolex ferox juv. (Eisen)	*Pelx fer*	-	-	+	+
Tardigrada					
Dactylobiotus dispar (Murray)	*Dactdis*	-	+	+	+
Isohypsibius tetradactyloides (Richters)	*Iso tet*	-	+	+	-
Isohypsibius sp.		-	-	-	+
Acari					
Hydrachnellae (indet.)	Hyd ind	-	-	-	+
Ostracoda					
Candona sarsi Hartwig	*Cnd sar*	+	-	-	-
Cypria ophthalmica (Jurine)	*Cypaoph*	-	-	+	+
Cypris pubera O. F. Müller	*Cypspub*	+	-	-	-
Harpacticoidea					
Atteyella (*A.*) *wierzejskii* (Mrázek) female	AttwieF	-	+	-	-
Bryocamptus B. minutus (Claus)	*BryminF*			+	
Bryocamptus (B.) *zschokkei* (Schmeil) female	BryzscF	-	+		-
Bryocamptus (B.) *zschokkei* (Schmeil) male	BryzscM	-	+	-	-
Bryocamptus (B.) *zschokkei* (Schmeil) copepodit	BryzscC	-	+	-	-
Camptocamptidae					
Camptocamptidae copepodit st.	CantaeC	+	+	-	-
Total number of taxa		95	78	104	80
Diversity index		3.48	2.94	3.77	2.2

Hardegg S3	Papírna S4
+	-
-	+
-	+
-	-
-	+
+	+
+	+
+	-
-	+
-	+
-	-
+	+
-	-
-	-
+	
	-
-	-
-	-
-	-
104	80
3.77	2.2

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