

# THE INFLUENCE OF CHANGES TO ABIOTIC PARAMETERS ON THE FISH ASSEMBLAGE STRUCTURE OF A LOWLAND STREAM

T. Vítek, R. Kopp, J. Mareš, T. Brabec, P. Spurný

**Received: February 6, 2012**

## Abstract

VÍTEK, T., KOPP, R., MAREŠ, J., BRABEC, T., SPURNÝ, P.: *The influence of changes to abiotic parameters on the fish assemblage structure of a lowland stream*. Acta univ. agric. et silvic. Mendel. Brun., 2012, LX, No. 3, pp. 207–216

Ichthyological monitoring and the assessment of 16 physical and chemical parameters of the water environment were conducted at two localities on the Dyje River, Czech Republic, at different distances downstream from the Znojmo Reservoir (at 12 and 31 km) to reveal habitat alterations. Canonical correspondence analysis confirmed that differences in fish abundance between localities were influenced by different hydrological regimes characterized by discharge and flow velocities and also by water conductivity, which increased with the distance from the reservoir. The influence of chemical parameters of water related to water quality on fish assemblage structure was insignificant. The second locality (further from the reservoir) was characterised by substantial water shortage during the vegetation season. Changes in hydrological regime and the loss of connectivity in the Dyje River both connected with dam building and water shortage for irrigation have led to dramatic changes in the fish assemblage structure since the 1950s and the complete loss of common nase.

dam-reservoir, river continuity, water shortage, fish assemblage, habitat, diversity, common nase

Human alterations to rivers, especially the construction of dams, fundamentally influence fish communities (Rice, 2005; Hladík *et al.*, 2008), as in the case of the important Czech river, the Dyje, which used to be a typical lowland stream with a barbel zone-based ichthyocenosis gradating to a bream zone in the area of southern Moravia (Hochman & Jirásek, 1958). Dam-reservoir building (Vranov in 1934, Znojmo in 1966 and Nové Mlýny from 1978 to 1989) had a significant effect on fish assemblage along the river course. As is typical for the Czech Republic, deep dam-reservoirs were built on most of the larger rivers. The release of water from near the bottom of the reservoir affects the river fauna, mainly due to the cooling effect in summer and the non-freezing effect in winter (Čech *et al.*, 2007). Furthermore, fragmentation of the river prevents fish migrations, which are necessary for successful spawning in rheophilous fish species (Horký *et al.*, 2007; Ovidio & Philippart, 2008). The benthic fauna

is also affected and its biodiversity declines, which can cause deterioration of the feeding grounds for fish (Horsák *et al.*, 2009).

Another important factor affecting fish communities of the altered rivers is water shortage. It is widely acknowledged that alterations to the flow regime impact riverine ecosystems (Halls & Welcomme, 2004; Acreman *et al.*, 2008; Riley *et al.*, 2009). To achieve sustainability, the water framework directive (WFD) covering hydrological regimes was established. In areas of intensive agriculture, the demand for water is enhanced due to its use for irrigation during the vegetation season. To offset the deficit, additional water should be released from the reservoir (Gippel & Stewardson, 1995).

The portions of rivers below dam-reservoirs in the Czech Republic, most often classified as secondary trout zones, have been widely studied (Peňáz *et al.*, 2002, 2003; Prokeš *et al.*, 2006; Jurajda *et al.*, 2010a). The Dyje River was ichthyologically

monitored in the 1950s by Hochman & Jirásek (1958). Many research results were published later (Lusk *et al.*, 1997, 2001, 2003, 2005), but no studies were undertaken on the stretch of the river between Znojmo and Nové Mlýny.

The main aims of this study were 1) to evaluate changes in fish fauna in the above-mentioned stretch by comparing the recent situation from 2007 to 2008 with the situation from the 1950s and 2) to relate these changes to changes in abiotic parameters with respect to the distance from the dam.

## MATERIALS AND METHODS

### Study area

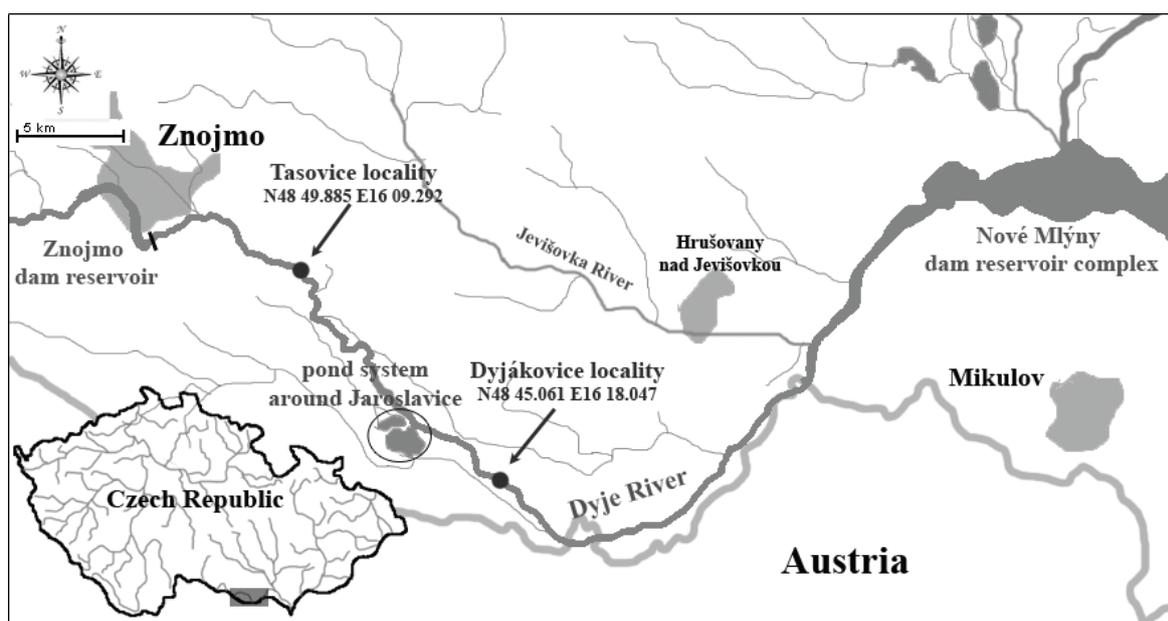
The Dyje River constitutes an important right side tributary of the Morava River with a length of 305.6 km, a drainage area of 13,419 km<sup>2</sup> and a mean annual discharge at the stream mouth of 43.8 m<sup>3</sup>/s. It flows near the Czech–Austrian border crossing it several times in the upper part. The study was conducted on the middle part of the river between two dam reservoirs: Znojmo (with a surface area of 53.3 ha, a dam height of 17 m, and a mean annual discharge of 10.25 m<sup>3</sup>/s, river km 132.5) and Nové Mlýny (a complex of three reservoirs of total surface area 3,296 ha, a dam height from 5 to 6.7 m, river km 46–58). The observation was conducted at two localities, each at a different distance from the Znojmo reservoir (Tasovice 12 km, Dyjákovice 31 km; Fig. 1). The Tasovice locality (river km 120.5) represents a relatively straight stretch. The bottom substrate consists of pebbles and larger solitary boulders. In parts characterized by low flow velocity (near the banks), sand appears. Both banks are partially shaded by riparian vegetation (herbs, salix,

oak, maple, black locust). During the vegetation season, huge river crowfoot *Batrachium fluitans* herbage is typically seen in this locality, offering shelter for fish and macroinvertebrates. The depth is mostly up to 0.85 m (with the exception of rare 1.5 m deep pools), the stream channel is approximately 20 m wide, and the mean flow velocity is between 0.4–0.8 m/s. The Dyjákovice locality (river km 101.5) also represents a straight part, but the river bed here is quite flat, formed by gravel and fine muddy sediment. The only shelters are found in undermined banks. Both banks are firmed by trees (alder, salix, black locust) partially shading the water course. Shallow parts with a depth of about 0.4 m alternate with deeper ones with a depth of up to 1 m, especially near the banks. Flow velocity is mostly up to 0.5 m/s.

### Fish sampling and parameter measurement

The research was based on repeated electro-fishing (pulsating DC, 240–300 V, 2.5 A, frequency 50 Hz) at both localities, which was carried out in October 2007, and June and October 2008, using a double passage (the second with a delay of at least 30 min) of approximately 100 m in length, which is enough for collecting evidence of species richness (Humpl & Lusk, 2006). Caught fish were carefully identified, measured and released back into the river.

In addition, measurement of the following physical and chemical parameters of the water environment using WTW portable instruments was undertaken: temperature (in °C), oxygen saturation of water (in %), and pH and conductivity (in mS/m). To assess flow velocities (in m/s) and discharge (in m<sup>3</sup>/s; assessed according to EN ISO 748), an ADC (acoustic current digital meter) by OTT



1: Map of the study area showing the locations of sampling sites (geographical co-ordinates in WGS-84)

(Kempton, Germany) was used. Measurements in both localities were carried out in October 2007 and monthly from June to October 2008, together with water sampling. Both localities were sampled on the same six days, three of which were also the days on which electrofishing was conducted. Water samples were kept in a cooling box for further laboratory analyses.

### Laboratory analyses

The following parameters (in mg/l) were assessed in water samples (applied analytic methods according to APHA 1998 are given in parentheses): Ammonia nitrogen (the indophenols method), nitrite nitrogen (a method using N-(1-naphthyl)-ethylenediamine), nitrate nitrogen (a method using sodium salicylate), total phosphorus and orthophosphate phosphorus (a method using ascorbic acid and ammonium molybdenate), total nitrogen (a method based on dimethylphenol after the transformation of all nitrogen compounds into nitrate by Koroleff's method), total organic carbon (a method based on digestion with sulphuric acid and peroxydisulphate, and transformation into carbon dioxide), chemical oxygen demand (a method using potassium dichromate) and the biological oxygen demand (the standard diluting method).

### Data processing and statistical analyses

Field data from electro-fishing were processed as population abundance and the biomass related to unit of area. The estimation of abundance was assessed according to Zippin (1958) on the basis of the linear regression model of fish counts from the first and second passage and cumulative fish counts. The diversity index ( $H'$ ) according to Shannon and Weaver (1963) and the equitability index ( $E$ ) according to Sheldon (1969) were also calculated.

The measured physical and chemical parameters of water and also data from the laboratory analyses of water were processed as a small sample analysis according to Horn (1983) using QC-Expert software (TriloByte Ltd., Czech Republic). The influence of environmental parameters on fish occurrence was evaluated statistically by canonical correspondence analysis (CCA; Ter Braak 1986). Two source matrices, a species matrix and an environmental matrix, were used. The species matrix contained fish species abundance data in six rows accordant with samples (two localities electrofished in three dates). To reduce the number of environmental parameters, a principle component analysis (PCA) was applied. The source matrix for the PCA consisted of 16 variables such as water temperature ( $t$ ), oxygen saturation ( $oxy$ ), pH, conductivity ( $cond$ ), mean flow velocity ( $fvel$ ), discharge ( $disch$ ), ammonia nitrogen ( $NH_4$ ), nitrite nitrogen ( $NO_2$ ), nitrate nitrogen ( $NO_3$ ), total phosphorus ( $P$ ), orthophosphate phosphorus ( $PO_4$ ), total nitrogen ( $N$ ) total organic carbon ( $TOC$ ), chemical oxygen demand ( $COD$ ), biological oxygen demand ( $BOD$ ) and distance from the Znojmo

reservoir ( $dis$ ) in columns, and 12 samples (two localities sampled at six dates) in rows. According to the PCA results, appropriate (weakly correlated) environmental variables were chosen as columns of the environmental CCA matrix. In addition, the date of the electrofishing (term), scaled as 1 for October 2007, 1.6 for June 2008 and 2 for October 2008, was added as another environmental variable to evaluate the effect of fish occurrence changes over time. Step-wise forward selection in CCA was used to identify the most influential environmental variables. The significance of each environmental factor as well as the significance of the ordination axes was assessed using Mote Carlo permutation tests (Lepš & Šmilauer, 2003). Both PCA and CCA were performed according to Ter Braak & Šmilauer (2002) using CANOCO for Windows 4.5 software.

## RESULTS

Looking at the water analyses results (Table I), we did not find extreme values exceeding the limits for surface waters given by Government Decree No. 61/2003 Coll. as amended by Government Decree No. 229/2007 Coll. and Government Decree No. 23/2011 Coll. Most of the variability among the samples with respect to the analysed abiotic factors can be explained by the first two ordination axes (53.9%) of PCA (Fig. 2). As the ordination diagram revealed, many variables were strongly correlated. Positive correlations were found between flow velocity and discharge and also between distance from the dam and water conductivity. The next positive correlations were identified among ammonia, phosphates and BOD. These three parameters were negatively correlated with oxygen saturation. The strong negative correlation between pH and a group of positively correlated parameters – temperature, phosphorus, nitrogen, nitrates and nitrites – was also confirmed. COD decreased with the distance from the dam and water conductivity.

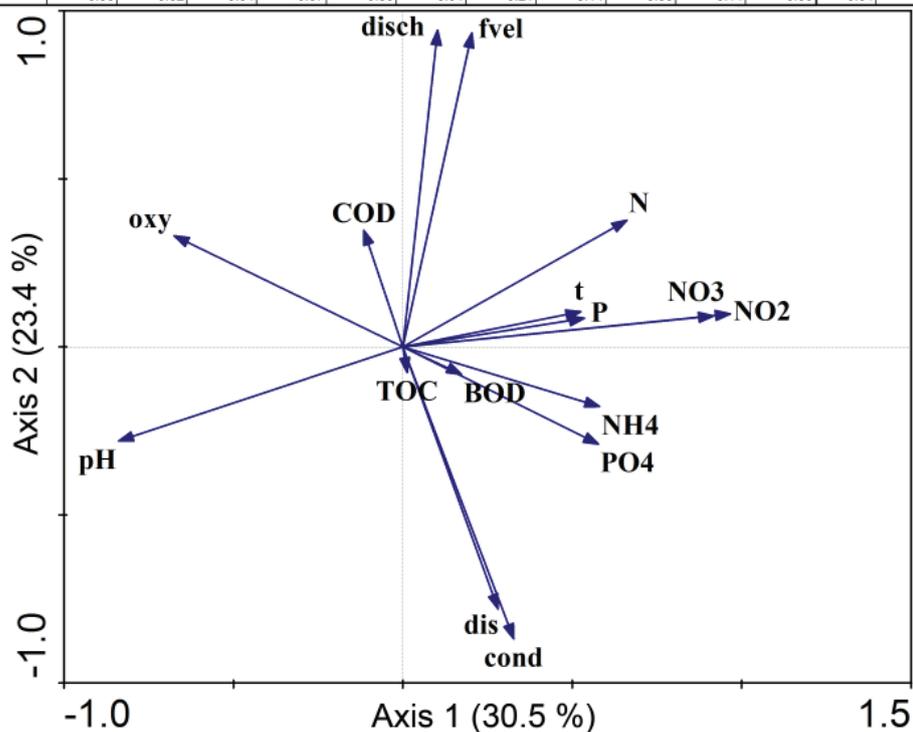
The most important difference between the localities was found in the discharge (Fig. 3). The difference was greatest in June 2008, when the discharge at Tasovice was more than three times higher than the discharge at Dyjákovice. However, the Tasovice discharge decreased towards October 2008, when it was only 23% greater than the Dyjákovice discharge.

Ichthyological research confirmed the occurrence of 17 fish species of seven families (Table II), eight of which appeared at both localities. Fish diversity and equitability calculated from particular electrofishing data were repeatedly higher in Tasovice, although the number of fish species was similar to the number found at Dyjákovice. Total fish abundance and biomass were also higher in Tasovice than in Dyjákovice. The most abundant species in Tasovice were barbel *Barbus barbus* (L.), chub *Squalius cephalus* (L.), dace *Leuciscus leuciscus* (L.) and gudgeon *Gobio* sp. (L.), representing together always more than three quarters of the total abundance. In Dyjákovice there

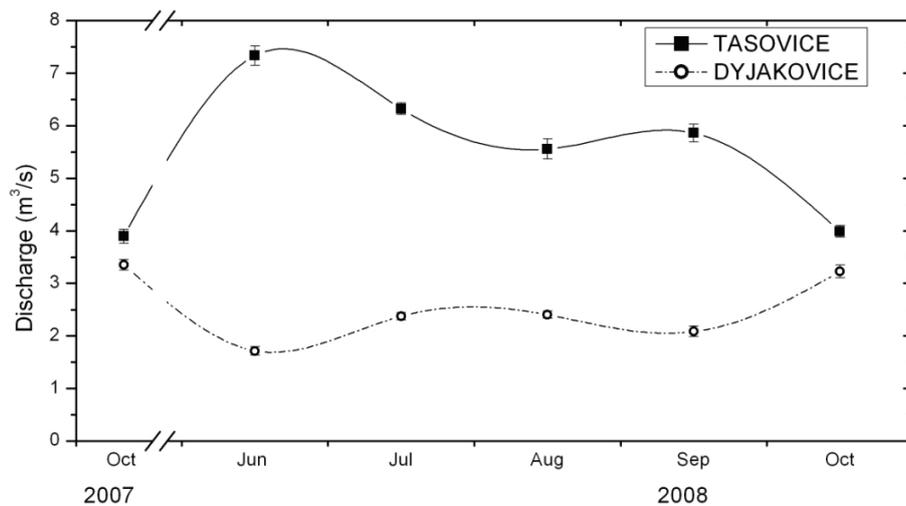
I: Physico-chemical parameters of water in the monitored localities of the Dyje River during 2007–2008 (mean values and 95% confidence limits according to Horn 1983 for  $n = 6$ )

parameter	Tasovice			Dyjákovice		
fvel (m/s)	0.12	0.49	0.86	0.16	0.26	0.36
disch (m <sup>3</sup> /s)	4.89	5.94	6.99	1.81	2.25	2.68
t (°C)	16.42	17.7	18.9	15.26	18.0	20.7
pH	6.12	7.65	9.18	6.66	7.65	8.64
O <sub>2</sub> (%)	78.9	88.5	98.1	69.6	86.0	102.4
cond (mS/m)	29.7	32.7	35.7	36.4	39.7	43.0
NH <sub>4</sub> (mg/l)	0.00	0.08	0.21	0.00	0.07	0.23
NO <sub>2</sub> (mg/l)	0.00	0.04	0.08	0.00	0.04	0.07
PO <sub>4</sub> (mg/l)	0.00	0.04	0.07	0.02	0.06	0.10
NO <sub>3</sub> (mg/l)	4.68	5.50	6.32	4.63	4.90	5.17
COD (mg/l)	0.00	18.0	37.2	0.43	15.5	30.6
N (mg/l)	4.63	6.00	7.37	4.29	5.25	6.21
P (mg/l)	0.00	0.08	0.21	0.00	0.10	0.20
TOC (mg/l)	12.7	16.2	19.6	12.1	17.3	22.5
BOD (mg/l)	0.05	1.55	3.04	0.63	1.69	2.74

variable	fvel	disch	t	pH	oxy	cond	NH4	NO2	PO4	NO3	COD	N	P	TOC	BOD	dis
fvel																
disch	0.96															
t	0.19	0.13														
pH	-0.45	-0.30	-0.60													
oxy	0.24	0.29	-0.47	0.55												
cond	-0.70	-0.72	0.01	-0.06	-0.44											
NH4	-0.04	-0.08	-0.16	-0.19	-0.22	0.28										
NO2	0.27	0.19	0.36	-0.78	-0.56	0.21	0.71									
PO4	-0.06	-0.19	0.02	-0.34	-0.16	0.39	0.73	0.63								
NO3	0.19	0.13	0.65	-0.81	-0.72	0.19	0.36	0.86	0.26							
COD	0.37	0.36	-0.53	0.08	0.50	-0.14	0.25	0.00	-0.05	-0.23						
N	0.42	0.35	0.33	-0.68	-0.38	-0.06	0.09	0.63	0.08	0.75	0.09					
P	0.30	0.28	-0.09	-0.26	-0.01	0.17	0.86	0.65	0.62	0.27	0.48	0.07				
TOC	0.07	0.02	0.22	0.20	0.11	0.01	0.25	-0.03	0.26	-0.15	0.05	-0.26	0.37			
BOD	-0.11	-0.01	0.28	0.00	-0.12	0.12	-0.13	0.11	-0.08	0.29	-0.28	0.31	-0.16	-0.19		
dis	-0.56	-0.62	0.04	-0.07	-0.30	0.94	0.21	0.14	0.35	0.14	-0.00	-0.04	0.20	0.14	0.12	



2: Relations among environmental variables of the Dyje River during 2007–2008 (PCA ordination diagram and pair-wise correlation coefficients between variables)



3: Mean discharge dynamics of the sampling sites on the Dyje River in 2008 (in m³/s, SD in whiskers)

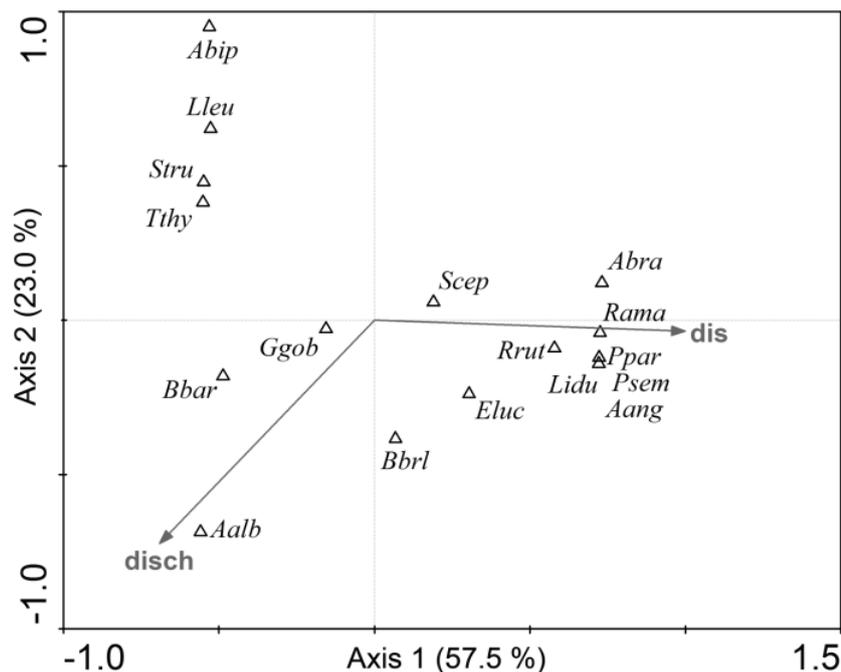
II: Ichthyological parameters and fish species participation (relative abundance in %) in the monitored localities of the Dyje River

species/parameter	Abbr.	Tasovice			Dyjákovice		
		Oct 07	Jun 08	Oct 08	Oct 07	Jun 08	Oct 08
<i>Salmo trutta m. fario</i> L.	Stru	1.23	0.50	1.61	-	-	-
<i>Thymallus thymallus</i> (L.)	Tthy	0.62	0.25	0.54	-	-	-
<i>Leuciscus leuciscus</i> (L.)	Lleu	21.0	3.97	19.4	-	0.44	-
<i>Squalius cephalus</i> (L.)	Scep	48.8	25.6	29.0	72.2	52.4	54.1
<i>Leuciscus idus</i> (L.)	Lidu	-	-	-	2.53	-	-
<i>Rutilus rutilus</i> (L.)	Rrut	1.23	3.72	0.54	15.2	20.4	30.8
<i>Alburnus alburnus</i> (L.)	Aalb	-	10.2	0.54	-	0.44	-
<i>Alburnoides bipunctatus</i> (Bloch, 1782)	Abip	-	-	1.08	-	-	-
<i>Barbus barbus</i> (L.)	Bbar	19.8	28.3	14.5	2.53	0.89	2.98
<i>Abramis brama</i> (L.)	Abra	-	-	-	-	0.44	-
<i>Gobio</i> sp. (L.)	Ggob	7.41	26.1	32.8	6.33	23.1	9.14
<i>Pseudorasbora parva</i> (Temminck & Schlegel, 1846)	Ppar	-	-	-	-	-	0.37
<i>Rhodeus amarus</i> (Pallas, 1776)	Rama	-	-	-	-	0.44	0.76
<i>Barbatula barbatula</i> (L.)	Bbrl	-	1.24	-	-	0.89	1.12
<i>Esox lucius</i> L.	Eluc	-	0.25	-	-	0.44	0.38
<i>Proterorhinus semilunaris</i> (Heckel, 1837)	Psem	-	-	-	-	-	0.37
<i>Anguilla anguilla</i> (L.)	Aang	-	-	-	1.27	-	-
<b>No. of fish caught</b>		162	403	186	79	226	263
<b>No. of species</b>		7	10	9	6	10	9
<b>Abundance (fish/ha)</b>		1 344	3 762	1 736	670	2147	2498
<b>Biomass (kg/ha)</b>		167	350.4	126.3	151.3	112.4	98.5
<b>Diversity index (H')</b>		1.92	2.38	2.2	1.35	1.74	1.69
<b>Equitability index (E)</b>		0.68	0.72	0.69	0.52	0.52	0.53

were only three eudominant species: chub, roach *Rutilus rutilus* (L.) and gudgeon.

With respect to the PCA results, only five environmental variables (discharge, distance from the dam, NO<sub>2</sub>, NH<sub>4</sub> and date of electrofishing) were analysed under CCA to attempt to explain the variability in fish species as influenced by abiotic factors. Step-wise forward selection confirmed only

two statistically significant factors, distance from the dam ( $p = 0.001$ ) and discharge ( $p = 0.021$ ), each individually explaining 46.1%, and 19.3% of the fish assemblage variability respectively. The remaining variables (NH<sub>4</sub>, date of electrofishing and NO<sub>2</sub>) were not significant ( $p = 0.411, 0.392$  and  $1.000$ ). The CCA model with the two most influential variables was statistically significant ( $p = 0.001$  for all the canonical



4: Relations between environmental variables and fish species abundance of the Dyje River during

axes and  $p = 0.006$  for the first axis), and the first two ordination axes of this model explained 80.5% of species variability (Fig. 4). Gudgeon and chub were not affected by environmental variables (situated near zero), whereas other species were distributed according to the influence of these factors. The group including pike *Esox lucius* L., roach, common bream *Abramis brama* (L.), bitterling *Rhodeus amarus* (Pallas 1776), topmouth gudgeon *Pseudorasbora parva* (Temminck & Schlegel, 1846), orfe *Leuciscus idus* (L.), tubenose goby *Proterorhinus semilunaris* (Heckel, 1837) and eel *Anguilla anguilla* (L.) found optimal conditions at a greater distance from the reservoir, where the discharge was lower. Dace, brown trout *Salmo trutta* m. *fario* L., grayling *Thymallus thymallus* (L.) and spiralin *Alburnoides bipunctatus* (Bloch, 1782) formed a cluster in the opposite part of the diagram (lower distance from the dam), predestining them to occur in conditions of higher discharge together with bleak *Alburnus alburnus* (L.), and barbel.

## DISCUSSION

Whereas the Tasovice locality was characterised by markedly higher discharges and flow velocities, the Dyjákovice locality was, contrariwise, characterised by higher water conductivity. These factors, which were confirmed as the most important environmental variables affecting the fish assemblage structure of the monitored localities, should be understood in their complexity as influenced by, and related to many other factors.

The influence of the release of deep water from the dam-reservoir into the river water below often leads to temperature and discharge stabilisation. In our survey, the decrease in water discharge at

a distance of 31 km from the reservoir was greater than expected. It was caused by the drainage of water to irrigate the surrounding vegetable fields and also to supply the fishpond system around Jaroslavice. It might be the case that below the reservoirs water shortage may cause serious problems for fish assemblages with respect to the increasing amount of water needed during dry and hot summers. The discharge measured at such a time (in June and July) at Dyjákovice constituted respectively only 14% and 19% of the annual mean flow (Fig. 3). Such flow regime conditions are completely unsatisfactory for maintaining the ecological status of the river. Acreman *et al.* (2008) recommend, even for the least ecologically sensitive of rivers, maximum abstractions in the range of 15–35% of the natural flow. Long-term critically low discharges are connected with adult fish migrations to deeper pools (Fischer & Kummer, 2000) and also increased mortality among juvenile fish, namely due to increased vulnerability to predation and the loss of stream margins as preferred habitat under conditions of low flow (Riley *et al.*, 2009). These conditions substantially disadvantage more demanding fishes such as salmonids, common nase *Chondrostoma nasus* (L.) and barbel compared with the more widespread and tolerant chub, gudgeon and roach, as documented in the comparison of Dyjákovice and Tasovice (Table II). Finally, a decline in diversity and equitability should be expected in affected localities.

Fish diversity also often corresponds to saprobity assessed according to zoobenthos, as described by Jurajda *et al.* (2010a) in the case of the Bílina River. In localities with a saprobity index in the range 2.06–2.58, they found chub, gudgeon and roach as

the most abundant species. Bleak, roach and chub formed the majority of the fish community in the Elbe River (Jurajda *et al.*, 2010b), where Adámek *et al.* (2010) reported a saprobity index in the range 1.97–2.46. In the Dyje River the index of saprobity was more favourable, as both localities exhibited better betamesosaprobity (1.70–1.80; Sukop *et al.*, 2010), thus enabling barbel to be eudominant in Tasovice.

The number of fish species inhabiting the monitored part of the river is higher than indicated in this study, as documented in anglers' capture evidence. Common carp *Cyprinus carpio* L., tench *Tinca tinca* (L.), pikeperch *Sander lucioperca* (L.), european catfish *Silurus glanis* L., rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), grass carp *Ctenopharyngodon idella* (Valenciennes, 1844), asp *Aspius aspius* (L.), and very sporadically also common nase appear there. Most anglers specialize in carp inhabiting deeper pools, whereas the fish assemblage in the present study was assessed in riffle areas where not all species could be documented. Compared to the situation in the 1950s, before the Znojmo reservoir was built, the number of species has decreased. Hochmann & Jirásek (1958) documented 25 fish species, 16 of which corresponded to our data (Table II). In contrast to this study and related evidence from anglers' capture, they found an abundant population of common nase and confirmed the occurrence of vimba bream *Vimba vimba* (L.) and burbot *Lota lota* (L.). They did not reveal the tubenose goby. This invasive species, originally spreading from the Danube River (Koščo *et al.*, 2010), colonised the Nové Mlýny reservoir complex and started to expand from it in the 1990s (Lusk & Halačka, 1995), becoming the dominant littoral species in the lower parts of the Dyje River (Prášek & Jurajda, 2005). Recently Vašek *et al.* (2011) provided evidence of the occurrence of tubenose goby in both littoral and pelagic habitats of the Vranov Reservoir.

Greater differences in temperature between the localities were expected but not found. It might be that the distance of 19 km between the localities was not enough to reflect the influence of temperature. Water quality, characterized by the analysed chemical parameters, could be considered as sufficiently high, not limiting even the most demanding salmonids. Pivnička *et al.* (2005) and also Humpl *et al.* (2009) documented the negative influence of ammonia ions on fish occurrence in the Berounka River and its tributaries, but concentrations higher than 1 mg/l were measured, which were more than five times higher than those in the Dyje. In this study the influence of chemical parameters of water including ammonia concentrations was not confirmed. The situation is better than in the 1950s, when Hochman & Jirásek (1958) observed problems in fish health caused by the toxicity of the water.

Discharge and flow velocity, together with the type of substratum, form the distinct types of habitat, to which fish occurrence and abundance

are often related (Doughty & Maitland, 1994; Pires *et al.*, 1999; Humpl & Pivnička, 2006). Thus, the fish assemblage structure often changes with the longitudinal profile of the river (Eros *et al.*, 2003), as documented in this study. Although our localities were situated below the dam-reservoir, the position of the locality along the watercourse expressed by the distance from the dam reservoir significantly influenced fish assemblage. In the river parts below dams the channel is often altered, which could affect fish abundance (Lyons, 1996; Angermeier & Davideanu, 2004). The chub and gudgeon, as species exhibiting great tolerance to the mentioned variables, predominated at both localities in this survey. These were accompanied by barbel, bleak and dace in the better conditions for rheophilous fishes in the Tasovice locality, and by roach in the less favourable conditions in the Dyjákovice locality. The fragmentation of the river caused by dam-reservoirs might play the most important role in the vanishing of the common nase, as it is prevented from migrating. In such streams, populations of the common nase are very vulnerable (Ovidio & Philippart, 2008). The situation with the barbel is substantially different, as it can maintain, to a certain extent, sustainable resident populations in fragmented river parts below reservoirs, where it finds suitable conditions for all phases of the life cycle, as confirmed by Peňáz *et al.* (2002) in the Jihlava River.

Aside from the influence of abiotic factors, differences in fish assemblage structures between the localities reflected also differences in fish stocking. Fish stocking takes place at both localities, each managed as a non-salmonid River Fishery by the Moravian Anglers Union. A total of seven species (common carp, asp, common nase, barbel, brown trout, rainbow trout and grayling) are stocked in Tasovice (Dyje 11 River Fishery) every year; the Dyjákovice locality (Dyje 9 River Fishery) is stocked with four species (common carp, common nase, barbel, and chub). The occurrence of brown trout and grayling in Tasovice could be the result of fish stocking, whereas in the case of barbel a natural population with functional reproduction must exist as both adults and 0+ juveniles were captured. The common nase has become extinct in the monitored part of the Dyje River in recent years, although it is stocked every year to the amount of 200 fish/ha. This amount is insufficient and the stock is inappropriate in age. The yearlings can serve as prey for abundant chub.

## CONCLUSIONS

Ichthyological monitoring of the stretch of the Dyje River between Znojmo and Nové Mlýny Reservoirs, Czech Republic, which was performed in 2007–2008, confirmed dramatic changes in the fish assemblage structure, mainly the complete loss of common nase, in comparison with the situation in the 1950s, before the Znojmo reservoir was built.

These changes were related to changes in abiotic parameters with respect to the distance from the dam. Differences in fish assemblage structure and population abundances between localities were influenced by different hydrological regimes

characterized by discharge and flow velocities and also by water conductivity, which increased with the distance from the reservoir. The influence of other chemical parameters of water related to water quality on fish assemblage structure was insignificant.

## SUMMARY

Ichthyological monitoring and the assessment of 16 physical and chemical parameters of the water environment were conducted at two localities on the Dyje River, Czech Republic, at different distances downstream from the Znojmo Reservoir (at 12 and 31 km) to evaluate changes in fish fauna and to relate these changes to changes in abiotic parameters with respect to the distance from the dam. Both localities were electro-fished in October 2007 and June and October 2008. The water was sampled in October 2007 and monthly from June to October 2008 together with flow velocity measurements.

Compared to the situation in the 1950s, before the Znojmo reservoir was built, the number of species in the monitored stretch of the Dyje River has decreased. Common nase *Chondrostoma nasus* (L.), vimba bream *Vimba vimba* (L.) and burbot *Lota lota* (L.) have vanished, whereas the invasive species tubenose goby *Proterorhinus semilunaris* (Heckel 1837) was newly revealed. Both monitored localities also differed in fish assemblage structure. Barbel *Barbus barbus* (L.) (up to 1064 fish/ha, 28.3%), chub *Squalius cephalus* (L.) (962 fish/ha, 48.8%), dace *Leuciscus leuciscus* (L.) (336 fish/ha, 21%) and gudgeon *Gobio* sp. (L.) (980 fish/ha, 26.1%) constituted the main part of the ichthyocenosis of the first locality, whilst in the fish assemblage of the second site, chub were unambiguously predominant (up to 1355 fish/ha, 72.2%) attended by roach *Rutilus rutilus* (L.) (773 fish/ha, 30.8%). Brown trout *Salmo trutta* m. *fario* L. (17–28 fish/ha) and grayling *Thymallus thymallus* (L.) (8–9 fish/ha) sporadically occurred in the first locality.

Principal component analysis and subsequent Canonical correspondence analysis confirmed that differences in fish abundance between localities were influenced mainly by different hydrological regimes. Whereas the first locality (closer to the reservoir) was characterised by sufficient discharge and flow velocities during the vegetation season, the second was, contrariwise, determined by substantial water shortage and also by higher water conductivity. The influence of other chemical parameters of water related to water quality on fish assemblage structure was insignificant.

Changes in hydrological regime and the loss of connectivity in the Dyje River both connected with dam building and water shortage for irrigation have led to dramatic changes in the fish assemblage structure since the 1950s and the complete loss of common nase, which used to be abundant there.

## Acknowledgment

This study was supported by Research Plan No. MSM6215648905 “Biological and technological aspects of the sustainability of controlled ecosystems and their adaptability to climate change“, which is financed by the Ministry of Education, Youth and Sports of the Czech Republic. We also thank the Moravian Anglers Union (namely V. Habán) for data from anglers' capture evidence and M. Nicholls for language revision.

## REFERENCES

- ACREMAN, M., DUNBAR, M., HANNAFORD, J., MOUNTFORD, O., WOOD, P., HOLMES, N., COWX, I., NOBLE, R., EXTENCE, C., ALDRICK, J., KING, J., BLACK, A. & CROOKALL, D., 2008: Developing environmental standards for abstractions from UK rivers to implement the EU Water Framework Directive. *Hydrological Sciences Journal – Journal Des Sciences Hydrologiques*, 53: 1105–1120. ISSN 0262-6667.
- ADÁMEK, Z., ORENDT, C., WOLFRAM, G. & SYCHRA, J., 2010: Macrozoobenthos response to environmental degradation in a heavily modified stream: Case study the Upper Elbe River, Czech Republic. *Biologia*, 65: 527–536. ISSN 0006-3088.
- ANGERMEIER, P. L. & DAVIDEANU, G., 2004: Using fish communities to assess streams in Romania: initial development of an index of biotic integrity. *Hydrobiologia*, 511: 65–78. ISSN 0018-8158.
- APHA, 1998: *Standard methods for the examination of water and wastewater*. American Public Health Association Inc., Washington D.C.
- ČECH, M., KUBEČKA, J., FROUZOVÁ, J., DRAŠTÍK, V., KRATOCHVÍL, M., MATĚNA, J. & HEJZLAR, J., 2007: Distribution of the bathypelagic perch fry layer along the longitudinal profile of two large canyon-shaped reservoirs. *J.Fish Biol.*, 70: 141–154. ISSN 0022-1112.
- DOUGHTY, C. R. & MAITLAND, P. S., 1994: The ecology of the river Endrick – present status and changes since 1960. *Hydrobiologia*, 290: 139–151. ISSN 0018-8158.
- EROS, T., BOTTA-DUKAT, Z. & GROSSMAN, G.D., 2003: Assemblage structure and habitat use of fishes in a Central European submontane stream:

- a patch-based approach. *Ecol. Freshw. Fish*, 12: 141–150. ISSN 0906-6691.
- FISCHER, S. & KUMMER, H., 2000: Effects of residual flow and habitat fragmentation on distribution and movement of bullhead (*Cottus gobio* L.) in an alpine stream. *Hydrobiologia*, 422: 305–317. ISSN 0018-8158.
- GIPPEL, C. J. & STEWARDSON, M. J., 1995: Development of an environmental flow management strategy for the Thomson River, Victoria, Australia. *Regulated Rivers-Research & Management*, 10: 121–135. ISSN 0906-6691.
- GOVERNMENT DECREE 61/2003 COLL. AS AMENDED BY GOVERNMENT DECREE No. 229/2007 COLL. AND GOVERNMENT DECREE No. 23/2011 COLL. *On the indicators and values of admissible pollution of surface waters and wastewaters, mandatory elements of the permit for discharge of wastewaters into surface waters and sewerage system, and on sensitive areas.*
- HALLS, A. S. & WELCOMME, R. L., 2004: Dynamics of river fish populations in response to hydrological conditions: A simulation study. *River Res. and Appl.*, 20: 985–1000. ISSN 1535-1459.
- HLADÍK, M., KUBEČKA, J., MRKVIČKA, T., ČECH, M., DRAŠTÍK, V., FROUZOVÁ, J., HOHAUSOVÁ, E., MATĚNA, J., MATĚNOVÁ, V., KRATOCHVÍL, M., PETERKA, J., PRCHALOVÁ, M. & VAŠEK, M., 2008: Effects of the construction of a reservoir on the fish assemblage in an inflow river. *Czech J. Anim. Sci.* 53: 537–547. ISSN 1212-1819.
- HOCHMAN, L. & JIRÁSEK, J., 1958: Příspěvek k současnému stavu zarybnění řeky Dyje [Contribution to present status of stocking rate of the Dyje River]. *Acta Univ. Agric. et Silv. Mendel. Brunen.*, 6: 245–265. ISSN 1211-8516.
- HORKÝ, P., SLAVÍK, O., BARTOŠ, L., KOLÁŘOVÁ, J. & RANDÁK, T., 2007: Behavioural pattern in cyprinid fish below a weir as detected by radio telemetry. *J. Appl. Ichthyol.*, 23: 679–683. ISSN 0175-8659.
- HORN, P. S., 1983: Some easy t-statistics. *Journal of the American Statistical Association*, 78: 930–936. ISSN 0162-1459.
- HORSÁK, M., BOJKOVÁ, J., ZAHŘÁDKOVÁ, S., OMEŠOVÁ, M. & HELEŠIC, J., 2009: Impact of reservoirs and channelization on lowland river macroinvertebrates: A case study from Central Europe. *Limnologica*, 39: 140–151. ISSN 0075-9511.
- HUMPL, M. & LUSK, S., 2006: Effect of multiple electro-fishing on determining the structure of fish communities in small streams. *Folia Zool.*, 55: 315–322. ISSN 0139-7893.
- HUMPL, M. & PIVNIČKA, K., 2006: Fish assemblages as influenced by environmental factors in streams in protected areas of the Czech Republic. *Ecol. Freshw. Fish*, 15: 96–103. ISSN 0906-6691.
- HUMPL, M., PIVNIČKA, K. & JANKOVSKÝ, M., 2009: Sport fishery statistics, water quality, and fish assemblages in the Berounka River in 1975–2005. *Folia Zool.*, 58: 457–465. ISSN 0139-7893.
- JURAJDA, P., ADÁMEK, Z., JANÁČ, M. & VALOVÁ, Z., 2010a: Longitudinal patterns in fish and macrozoobenthos assemblages reflect degradation of water quality and physical habitat in the Bílina river basin. *Czech J. Anim. Sci.*, 55: 123–136. ISSN 1212-1819.
- JURAJDA, P., JANÁČ, M., VALOVÁ, Z. & STRECK, G., 2010b: Fish community in the chronically polluted middle Elbe River. *Folia Zool.*, 59: 157–168. ISSN 0139-7893.
- KOŠČO, J., KOŠUTHOVÁ, L., KOŠUTH, P. & PEKÁRIK, L., 2010: Non-native fish species in Slovak waters: origins and present status. *Biologia*, 65: 1057–1063. ISSN 0006-3088.
- LEPŠ, J. & ŠMILAUER, P., 2003: *Multivariate analysis of ecological data using CANOCO*. Cambridge University Press, New York, 269 pp. ISBN 978-0-521-81409-6.
- LUSK, S. & HALAČKA, K., 1995: The first finding of the tubenose goby, *Proterorhinus marmoratus*, in the Czech Republic. *Folia Zool.*, 44: 90–92. ISSN 0139-7893.
- LUSK, S., HALAČKA, K. & LUSKOVÁ, V., 2003: Rehabilitating the floodplain of the lower River Dyje for fish. *River Res. Appl.*, 19: 281–288. ISSN 1535-1459.
- LUSK, S., HALAČKA, K., JURAJDA, P., LUSKOVÁ, V. & PEŇÁZ, M., 1997: Diversity of fish communities in the waters of the Podyji National Park. *Czech J. Anim. Sci.*, 42: 269–275. ISSN 1212-1819.
- LUSK, S., HALAČKA, K., LUSKOVÁ, V. & HORÁK, V., 2001: Annual dynamics of the fish stock in a backwater of the River Dyje. *Regulated Rivers-Research & Management*, 17: 571–581. ISSN 0886-9375.
- LUSK, S., LUSKOVÁ, V., HALAČKA, K., ŠLECHTOVÁ, V. & ŠLECHTA, V., 2005: Characteristics of the remnant *Vimba vimba* population in the upper part of the Dyje River. *Folia Zool.* 54: 389–404. ISSN 0139-7893.
- LYONS, J., 1996: Patterns in the species composition of fish assemblages among Wisconsin streams. *Environ. Biol. Fish.*, 45: 329–341. ISSN 0378-1909.
- OVIDIO, M. & PHILIPPART, J.C., 2008: Movement patterns and spawning activity of individual nase *Chondrostoma nasus* (L.) in flow-regulated and weir-fragmented rivers. *J. Appl. Ichthyol.*, 24: 256–262. ISSN 0175-8659.
- PEŇÁZ, M., BARUŠ, V., PROKEŠ, M. & HOMOLKA, M., 2002: Movements of barbel, *Barbus barbus* (Pisces: Cyprinidae). *Folia Zool.*, 51: 55–66. ISSN 0139-7893.
- PEŇÁZ, M., PIVNIČKA, K., BARUŠ, V. & PROKEŠ, M., 2003: Temporal changes in the abundance of barbel, *Barbus barbus* in the Jihlava River, Czech Republic. *Folia Zool.*, 52: 441–448. ISSN 0139-7893.
- PIRES, A. M., COWX, I. G. & COELHO, M. M., 1999: Seasonal changes in fish community structure of intermittent streams in the middle reaches of the Guadiana basin, Portugal. *J. Fish Biol.*, 54: 235–249. ISSN 0022-1112.

- PIVNIČKA, K., ŠVÁTORA, M., KŘÍŽEK, J., HUMPL, M. & SÝKORA, P., 2005: Fish Assemblages in the Berounka River and its Tributaries (Úhlava and Mže) in 1975–2004 – Environmental Parameters, Fishery Statistics, and Electroshocker Data. *Acta Universitatis Carolinae Environmentalica*, 19: 33–89. ISSN 0862-6529.
- PRÁŠEK, V. & JURAJDA, P., 2005: Expansion of *Proterorhinus marmoratus* in the Morava River basin (Czech Republic, Danube R. watershed). *Folia Zool.*, 54: 189–192. ISSN 0139-7893.
- PROKEŠ, M., ŠOVČÍK, P., PEŇÁZ, M., BARUŠ, V., SPURNÝ, P. & VILIZZI, L., 2006: Growth of barbel, *Barbus barbus*, in the River Jihlava following major habitat alteration and estimated by two methods. *Folia Zool.*, 55: 86–96. ISSN 0139-7893.
- RICE, J. C., 2005: Understanding fish habitat ecology to achieve conservation. *J. Fish Biol.*, 67: 1–22. ISSN 0022-1112.
- RILEY, W. D., MAXWELL, D. L., PAWSON, M. G. & IVES, M. J., 2009: The effects of low summer flow on wild salmon (*Salmo salar*), trout (*Salmo trutta*) and grayling (*Thymallus thymallus*) in a small stream. *Freshwater Biol.*, 54: 2581–2599. ISSN 2581-2599.
- SHANNON, C.E. & WEAVER, W., 1963: *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.
- SHELDON, A. L., 1969: Equitability indices – dependence on species count. *Ecology*, 50: 466–471. ISSN 0012-9658.
- SUKOP, I., ŠŤASTNÝ, J., VÍTEK, T. & BRABEC, T., 2010: Roční cyklus zoobentosu středního toku řeky Dyje. [Annual development of the zoobenthos of the middle course of the Dyje River]. *Acta Univ. Agric. et Silv. Mendel. Brunen.*, 58: 195–203. ISSN 1211-8516.
- TER BRAAK, C. J. F. & ŠMILAUER, P., 2002: *CANOCO Reference manual and CanoDraw for Windows User's guide: Software for Canonical Community Ordination (version 4.5)*. Microcomputer Power, Ithaca, NY, USA, 500 pp.
- TERBRAAK, C.J.F., 1986: Canonical correspondence analysis – a new eigenvector technique for multivariate direct gradient analysis. *Ecology* 67: 1167–1179. ISSN 0012-9658.
- VAŠEK, M., JŮZA, T., ČECH, M., KRATOCHVÍL, M., PRCHALOVÁ, M., FROUZOVÁ, J., ŘÍHA, M., TUŠER, M., SEĎA, J. & KUBEČKA, J., 2011: The occurrence of non-native tubenose goby *Proterorhinus semilunaris* in the pelagic 0+ year fish assemblage of a central European reservoir. *J. Fish Biol.*, 78: 953–961. ISSN 0022-1112.
- ZIPPIN, C., 1958: The removal method of population estimation. *J. Wildlife Management*, 22: 82–90. ISSN 0022-541X.

#### Address

Ing. Tomáš Vítek, Ph. D., Ústav zoologie, rybářství, hydrobiologie a včelařství, Mendelova univerzita v Brně, Zemědělská 1, 613 00, Brno, Česká republika, e-mail: gabon@centrum.cz