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Sport fishery statistics, water quality, and fish assemblages in the Berounka River in 1975–2005

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A b s t r a c t . In 1975–2005, we utilized data on water quality (N-NH_4^+, O_2, Cl^-) and number of carp caught (CC) as environmental data, and sport fishery statistics as species data, from three fishing stretches of the Berounka River, Czech Republic. An indirect gradient analysis (DCA) for calculating the strongest gradient affecting the species data, and direct linear gradient analysis (RDA) were used for assessing the relationships among environmental and species data. All RDA models were significant and consecutively explained 45.5, 39.6, and 39.7% of the variability of species data. The strength of environmental variables was evaluated by partial RDA. In the first stretch below the City of Plzeň, with the poor water quality and low carp yields, all environmental variables were significant and the CC data alone explained 26.2% variability of species data. In the second stretch, with intermediate water quality and carps yields, only two environmental variables (O_2 and Cl^-) were significant and in the third stretch near the city of Prague, with the same water quality and exceptionally high yields, the environmental variables did not significantly influence the species data. These results indicate that sport fishery statistics can be used as at least one source of information for studies of fish assemblages in streams where other data is lacking.

Key words: environmental data, species data, DCA, RDA

Introduction

A decline in stream water quality during the second half of the last century caused a decrease in fish diversity (G a t z & H a r i g 1993), and altered the proportions of fish species as well as of key species abundance (P h i l i p p a r t et al. 1987, T u r n p e n n y et al. 1987, L u s k 1995, 1996, M a n n 1996). Recent studies dealing with fish assemblages in running waters are steadily confronted with changes in the diversity of habitats, water quality, and human activities in the watersheds, as well as the impact of fishery management on ichthyocenoses (K a r r 1999, A l l a n 2004). In some cases, stream rehabilitation efforts have been undertaken with the aim of documenting their positive effects on species diversity, abundance and biomass (P r e t t y et al. 2003). On the other hand, sport fishery statistics often provide the only information available for long term studies of fish assemblages (C o w x & B r o u g h t o n 1986, S m u t n ý & P i v n i č k a 2001, P e n c z a k & S i e r a k o w s k a 2003, P i v n i č k a et al. 2005, W o l t e r & M e n z e l 2005). Considering the complexity of these problems, multivariate statistical methods are often used (B r o w n 2000, P e n c z a k et al. 2004, H u m p l & P i v n i č k a 2006).

In this paper we utilized data on water quality and carp yields as environmental data, and sport fishery statistics as species data, from three fishing stretches in the upper, middle, and lower part of the Berounka River. The aim was to assess the contribution of given environmental factors to changes in species data.

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Material and Methods

Water quality data from three localities on the Berounka River – Bukovec 5 km downstream of Plzeň (average stream flow 20 m^3), Liblín 45 km downstream of Plzeň (30 m^3), and Lahovice 2 km upstream from the confluence with the Vltava River (36 m^3) – are available on the Czech Hydrometeorological Institute (CHMI) web page http://www.chmi.cz/. For the period 1962–2005, mean values from 12 monthly measurements were calculated for each year; for the DCA and RDA analysis, we were limited by fishery statistics which are available for 1975–2005. The following water quality data were used: $N\text{-}NH_4^+$, O_2, Cl^-, all in $mg.l^{-1}$. As the fourth environmental factor we used the number of caught $carps.ha^{-1}$, for it is generally accepted that the stocked carps are often responsible for changes in the fish assemblages caught by anglers.

Sport fishery statistics for carp and other nine fish species in the period 1975–2005 from the fish stretches B10, B7, and B1, corresponding to the above water quality data sites, were provided by the West-Bohemian and Capital of Prague Fishing Unions in Plzeň and Praha, Fig. 1.

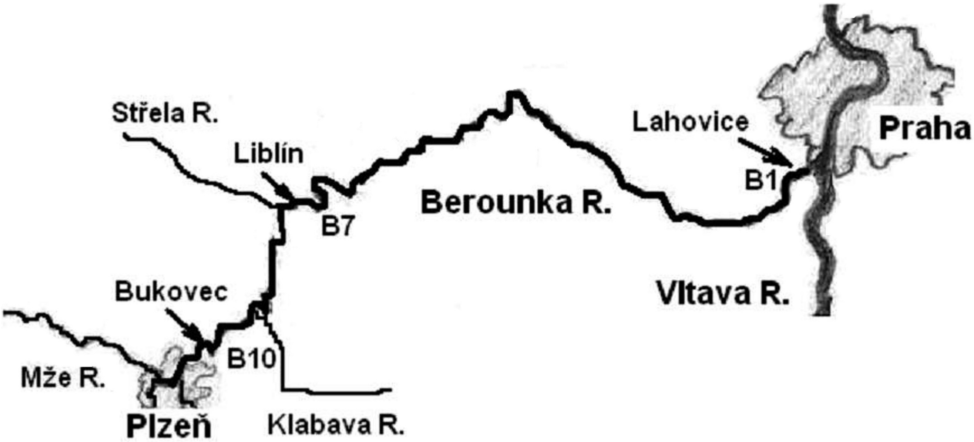

Fig. 1. Map of the Berounka River, Bukovec, Liblín, and Lahovice – sites of the water quality measurements, B10, B7, and B1 investigated stretches.

The species data file ($fish.ha^{-1}.year^{-1}$) contains the following species: bream (*Abramis brama*), chub (*Leuciscus cephalus*), perch (*Perca fluviatilis*), barbel (*Barbus barbus*), zarte (*Vimba vimba*), pike (*Esox lucius*), eel (*Anguilla anguilla*) and pikeperch (*Stizostedion lucioperca*). In addition, we defined an „other coarse fish“ (OCF) category, consisting of roach (*Rutilus rutilus*), dace (*Leuciscus leuciscus*) and white bream (*Blicca bjoerkna*). From these species only pike, eel, and pikeperch are stocked, so we expected that proportions of the other species would vary according to changes in water quality and number of carp caught. Pike, eel, and pikeperch are stocked as fingerlings and are therefore affected by environmental factors similarly to the other non-stocked species. Carp are stocked when having individual weights of 0.6–1 kg (28–152 $fish.ha^{-1}$ $year^{-1}$ on average), and are therefore less dependent on water quality.

To assess the strongest gradient affecting the species data structure, we used indirect gradient analysis (detrended correspondence analysis, DCA). Since the length of the longest gradients in all cases varied from 0.5–2, we further used linear direct gradient analysis

(Redundancy Analysis, RDA) for assessing the relationships among environmental and species data. The strength of each type of environmental data on the fish assemblage was assessed by partial RDA. All calculations were performed in CANOCO version 4.5 (t e r B r a a k & Š m i l a u e r 2002).

B e r o u n k a R i v e r w a t e r s h e d

The Berounka River originates in the City of Plzeň as the confluence of four rivers, and discharges into the Vltava River in Prague (V l č e k et al. 1984), with an the average flow rate of 36 m^3 and catchment area of 8 861 km^2. The fishing stretch Berounka 10 (B10; 23 km long with an area of 65 ha) originates just below the City of Plzeň (160 000 inhabitants), and has been characterized by the lowest angler catches, low habitat diversity, and poor water quality. About 8 km downstream of the village Liblín, the fishing stretch B7 starts (8 km, 45 ha) with average yields, higher habitat diversity and better water quality. The fishing stretch B1 (10 km, 55 ha), with exceptionally high angler catches ends in the village Lahovice near the confluence of the Berounka with the Vltava River. The small towns lying on the lower part of the Berounka River do not significantly influence the water quality (Fig. 1).

Results

At the Bukovec and Liblín, values of ammonium nitrogen increased up to end of the 1970s then decreased to the present; short term maxima ranged between 2–4 $mg.l^{-1}$. The highest values, however, are consistently measured at Lahovice, where average values since 1962 decreased only from 5 to 4 $mg.l^{-1}$, with maxima over 12 $mg.l^{-1}$. Concentrations of dissolved oxygen steadily increased since 1962 in Bukovec and Liblín, while in Lahovice they remained

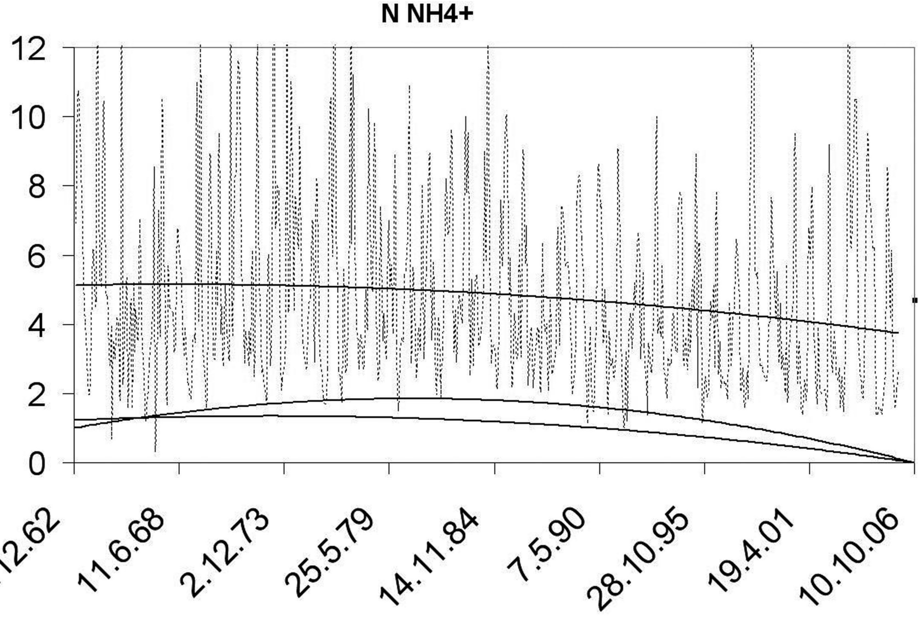

Fig. 2a. Changes in N $NH4^+$ concentration (mg/l), polynoms of the second order. From above Lahovice R^2=0.024, Bukovec R^2=0.0232, and Liblín R^2=0.169. Monthly variability is valid for Lahovice.

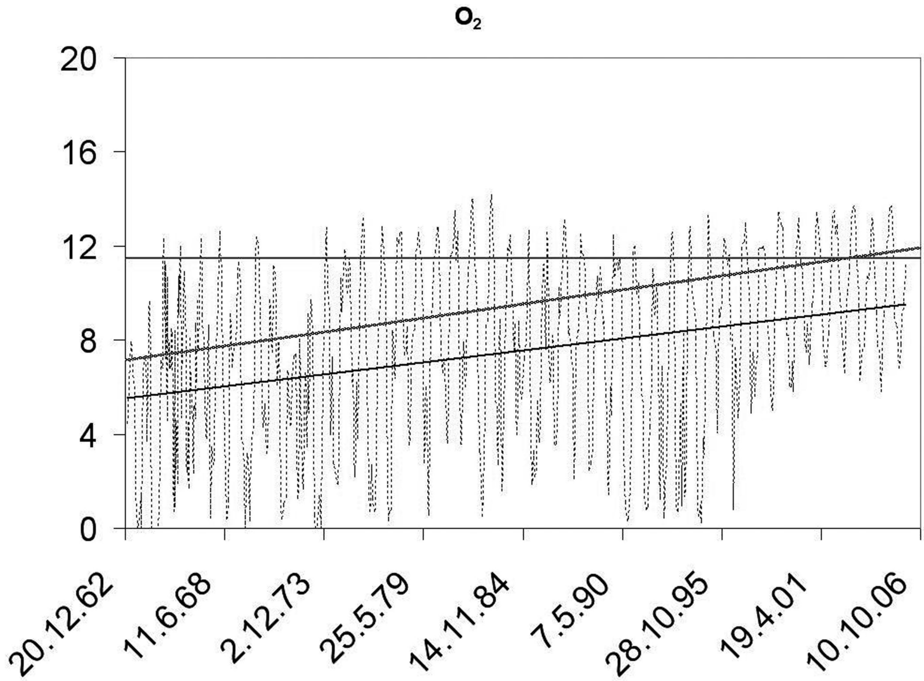

Fig. 2b. Changes in O_2 concentration (mg/l), straight lines. From above localities Lahovice R^2=0.003, Liblín R^2=0.236, and Bukovec R^2=0.098. Monthly variability is valid for Bukovec.

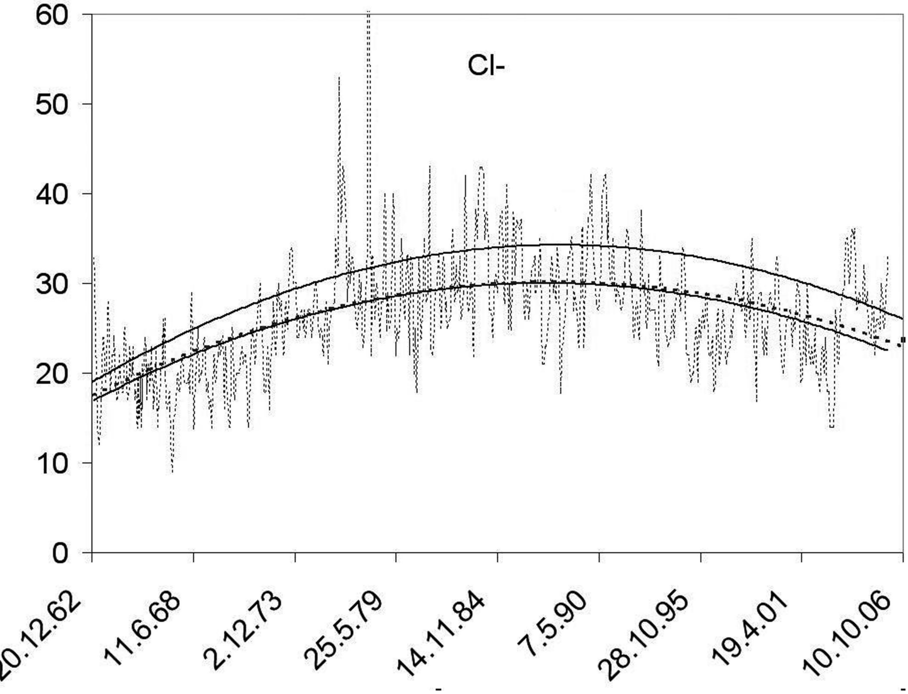

Fig. 2c. Changes in Cl^- concentration (mg/l), polynoms of the second order. From above Lahovice R^2=0.207, Bukovec dotted line R^2=0.267, and Liblín R^2=0.305. Monthly variability is valid for Liblín.

Table 1. RDA analysis for B10, B7, and B1, sum of all eigenvalues, values of partial ordination (PO) in %, and their significance (P). Significant values in bold.

NH4, O2, Cl, CC								
B10	%	P	B7	%	P	B1	%	P
total RDA	45.5	**0.0001**	total RDA	39.6	**0.0008**	total RDA	39.7	**0.0420**
	PO			PO			PO	
NH4	17.3	**0.0018**	NH4	3.8	0.1802	NH4	0.7	0.7192
O_2	7.4	**0.0312**	O_2	5	**0.0390**	O_2	1.8	0.4172
Cl	9.3	**0.0194**	Cl	5.2	**0.0308**	Cl	5.9	0.1109
CC	26.5	**0.0003**	CC	1.3	0.6634	CC	6.8	0.0775

consistently high and had the lowest monthly variability. Chlorides increased at all localities from the beginning of 1960s until the end of the 1980s, then decreased until present; maxima reached 60 mg .l^{-1}, and minima 10–15 mg.l^{-1} (Fig. 2a-c). Carp catches from 1975–2005 were

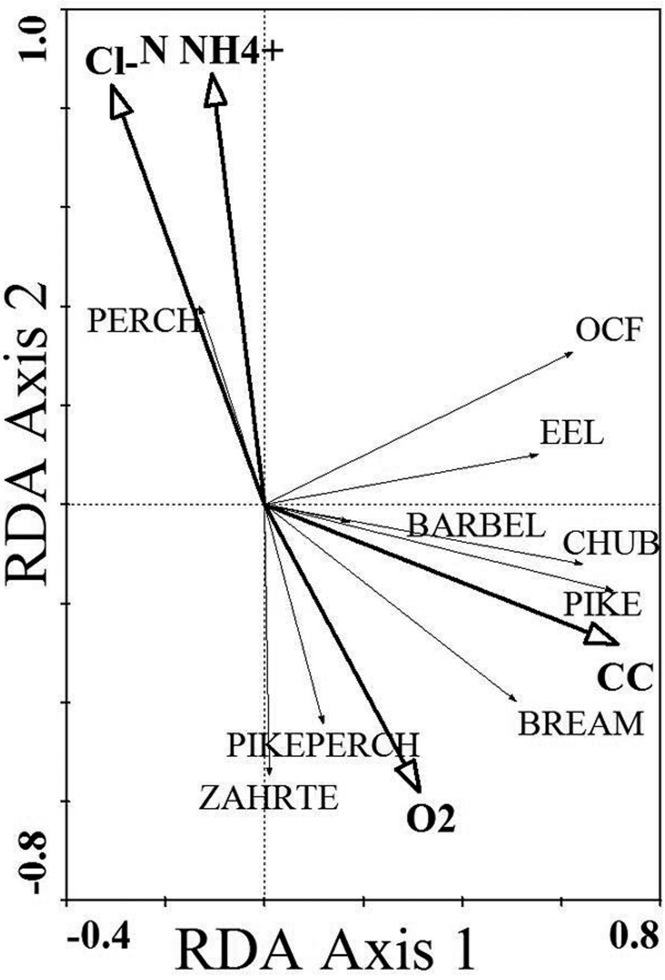

Fig. 3. Redundancy Analysis (RDA) showing the effect of environmental factors (N-NH_4^+, O_2, Cl^- , and CC) on the structure of fish assemblages (relative abundance data caught by anglers in B10).

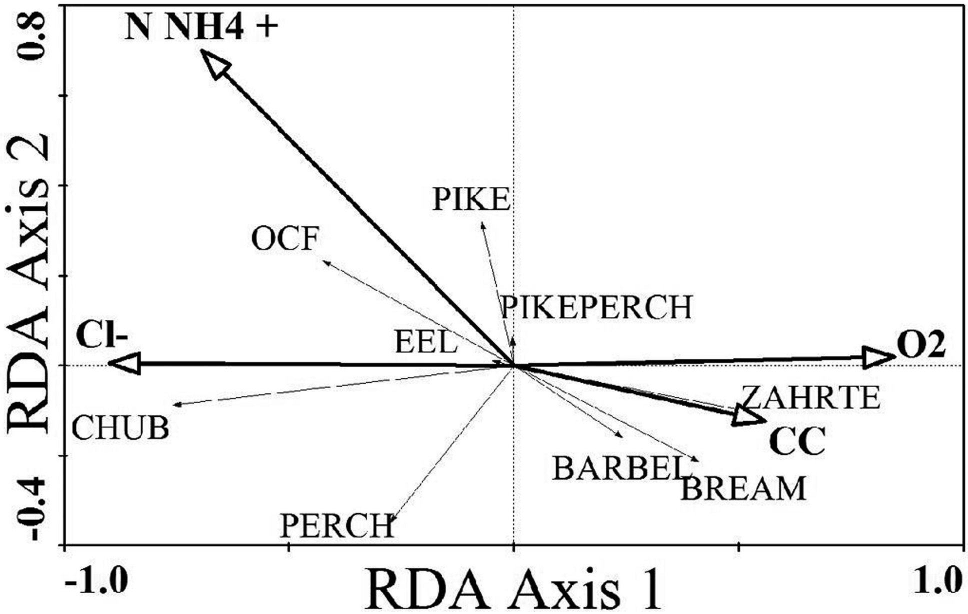

Fig. 4. The same as in Fig.3. for B7.

between 5–10 kg ha^{-1}year^{-1} in the B10, between 10 to 20 kg.ha^{-1}year^{-1} in B7, and between 40 to 120 kg.ha^{-1}year^{-1} in B1.

The first axis in the DCA analysis (9 species, 31 seasons) explained 12% of the variability in species data at B10 and the second axis 5.8%; no trend in yields could be demonstrated. For B7, the first axis explained 14.7% of variability and well reflected the gradient of time, and the second explained 4%. At B1 the first axis explained 6.6%, the second 1.6%. Though the effect of increasing fishing pressure connected with the first axis seemed important at this stretch, it was statistically non-significant.

In the B10, B7, and B1, the relationships among species and environmental data were assessed by three RDA models, all of which were significant. These models explained 45.5% of the variability of species data in the first case, 39.6% in the second, and 39.7% in the third. In partial RDA all environmental factors were shown to be significant at B10, NH_4^+ and O_2 were significant at B7, while no environmental factors were significant at B1 (Table 1, Fig. 3–5).

The number of caught carps significantly influenced the species data only at B10, explaining 26.2% of their variability, while in the other two stretches caught carp did not influence the species data.

Discussion

Unionized ammonia (NH_3) is toxic to fish and its fraction rises with pH and water temperature (Eddy 2005, Fairchild et al. 2005). However, its toxicity to fish can be mitigated when chloride compounds are present (Duangsawasdi & Sripoomun 1981). At B7 N NH_4+ explained 3.8 % of the variability, and even 17.3% of the variability at the B10 below the City of Plzeň. At the B1, with the highest values of N NH_4+, the NH_3 values

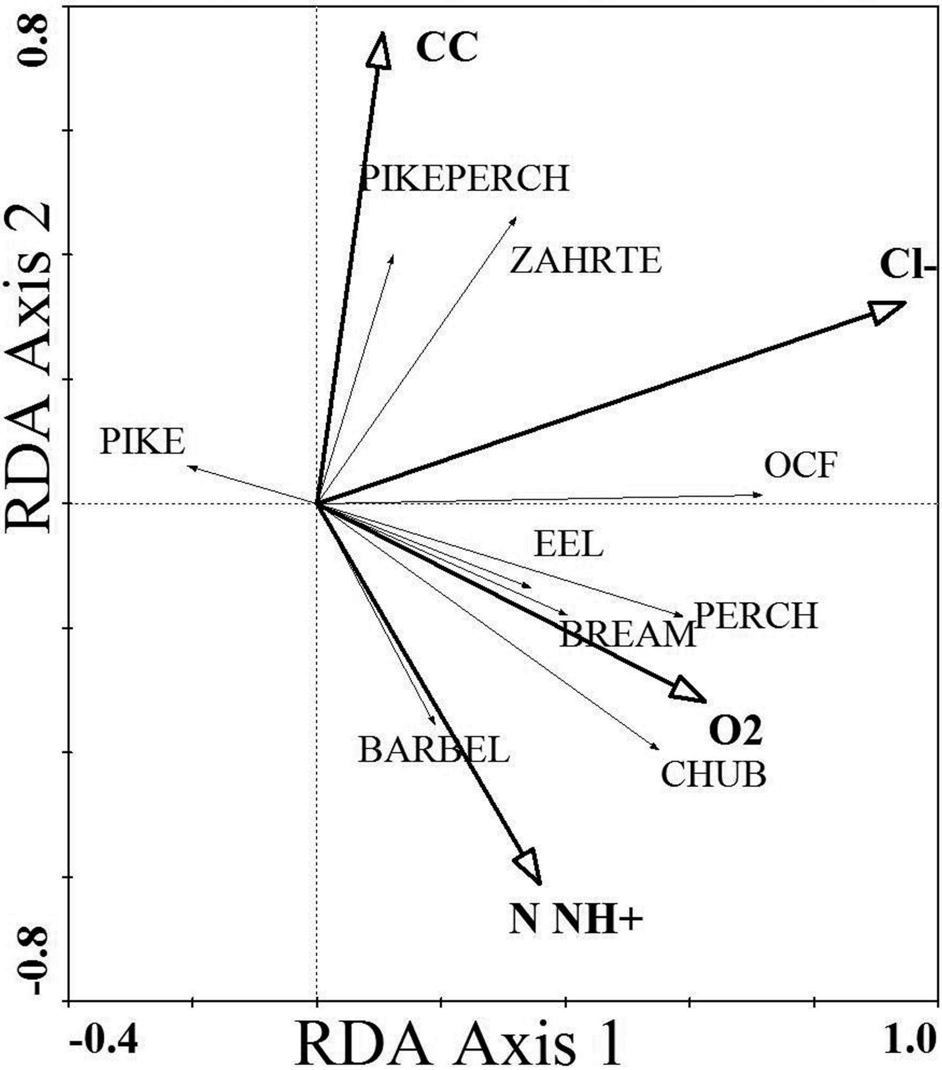

Fig. 5. The same as in Fig 3. for B1.

regularly reached the levels of 1.5–2.0 mg.l^{-1}. Even though NH_3 concentrations above 0.6 mg are capable of killing fish in ponds (D u r b o r o w et al. 1997), in B1 the N NH_4+ itself explained only 0.7% of the variability of the species data.

Safe concentrations of dissolved oxygen for fish, allowing them free motion, food intake, and reproduction, ranges according to water temperature between 5–8.5 mg O_2.l^{-1} (D o b í h a l & B l a ž k a 1974, M a n n 1996). In B10 and B7, where minima of O_2 were up to the mid 1990s often near zero, a negative effect on the structure and number of species caught was generally expected. Oxygen concentration was a significant environmental factor at B10 and B7, explaining 7.4% and 5% of the variability in species data, respectively. At B1, where average values of oxygen were always close to 11mg.l^{-1}, the effect of O_2 on species data was non-significant.

Concentrations of chlorides at all sites had distinctive dynamics, with mean values up to 20–40 $mg.l^{-1}$ and maxima up to 60–70 $mg.l^{-1}$. As values up to 100 $mg.l^{-1}$ are not considered dangerous for freshwater fish, a negative influence on the fish assemblages was not expected; rather, a positive effect was observed due to interactions with unionized ammonia. Chlorides were significant at B10 and B7, explaining 9.3% and 5.2% of the variability in species data, respectively.

Due to the fact we used sport fishery statistics to represent species data, we had to assume that the "fish assemblage" caught by sport fishermen did not differ from the actual assemblage in a given water (C o w x & B r o u g h t o n 1986, L u s k et al. 2003). This was documented by C o o p e r & W h e a t l e y (1981) for fish longer then 12 cm, who had found that proportions of these fish obtained from sport fishery statistics are comparable to those from any other fish sampling technique. A comparison of fish assemblages caught by electric shock and by anglers in the B7 fishing stretch from 1998–2004 showed that this is true at least for comparable habitats – in that case stream reaches below weirs (P i v n i č k a el al. 2005).

The significant influence of CC on species data was confirmed only in the B10, which had poor water quality and where mortality of mature fish has been repeatedly reported. The pure effect of CC was highest at this site, explaining 26.5% of the species data variability.

The structure of caught fish assemblages was not significantly affected by carp yields in either the B7 or B1, with better water quality, higher habitat diversity, and carp catches at a level of about 10–20 $fish.ha^{-1}$ and 40–120 $fish.ha^{-1}$, respectively. Out of ten fishing stretches in the Berounka River, we classify B10 and B9 as having poor water quality and low habitat diversity, and B3–B8 as having better water quality, habitat diversity, and average or high fish yields. In eight of the ten stretches of the Berounka River, the fish assemblages were not influenced by the expected angler preferences for carp.

In our opinion, sport fishery statistics can be used as at least one source of information for long-term studies of fish assemblages in streams where other data are lacking.

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