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Did the management of the recreational fishery, water quality and flow of water modify the assemblage of fish in the lower part of the River Rokytná (Czech Republic) over the period 1968–2006?

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Abstract. In 39 samples of fish collected in autumn 1968–2006 in the River Rokytná using electric fishing there were a total of 26 species of fish, with the average number per sample increasing from 11 to 15. Of the nine native species eight were present in all the samples and stone loach (*Barbatula barbatula* Linnaeus, 1758) in 31 samples. Five species were in more than 50% of the samples and the frequency of the remaining species was between 3–29%. The abundance of fish decreased from 5000 to 3300 and biomass from 320 to 180 kg×ha^{-1}. The anglers caught 30 to 290 kg×ha^{-1}× year^{-1} of carp, *Cyprinus carpio* (Linnaeus, 1758), over the period 1950–2006 and the catches of native nase, *Chondrostoma nasus* (Linnaeus, 1758), chub, *Leuciscus cephalus* (Linnaeus, 1758), and barbel, *Barbus barbus* (Linnaeus, 1758), were greatest in 1965 to 1967 with catches of 40.7, 31.8 and 8.7 kg×ha^{-1}, respectively, and then gradually decreased both in terms of the biomass caught by anglers and in the samples. The four significant RDA models confirmed that the environmental factors selected had an effect on the biomass of the different species in the the whole assemblage. High values of BOD and N NH_3 negatively affected dace and bitterling and high water flow positively that of barbel, chub, nase and schneider, and negatively gudgeon, dace, bitterling and stone loach. In addition nase, schneider, dace and bitterling were negatively affected by the number of carp stocked that were recorded as caught. Changes in the environment and management of recreational fishing significantly altered the number of species of fish and the abundance and biomass of the individual species in the assemblage.

Key words. Ichthyology, fishery, number of species, abundance, biomass, environmental parameters, RDA models.

INTRODUCTION

Decline in stream water quality and its influence on the assemblages of fish in streams has been repeatedly documented by Lusk & Halačka (1995), Lusk (1996), Eklöv et al. (1998), Penczak et al. (2004), Kruk (2007), Humpl et al. (2009) and simultaneous changes in fish communities by Wolter & Vilcinkas (1997), Gevrey et al. (2005) and Lusk & Pivnička (2009). That the hydrological regime can affect the abundance of fish in Moravian streams was confirmed by Vítek et al. (2012). Evidence that fish assemblages are strongly affected by the way recreational fishing is managed is published by Penczak & Sirakowska (2003), Pivnička et al. (2005) and Jankovský et al. (2011). Over the last two decades the water quality has improved and many streams have been restored as part of the aim to improve damaged habitats (Pretty et al. 2003). All these changes are often analyzed using multivariate statistical methods (Godinho et al. 2000, Humpl & Pivnička 2006, Morán-Lopez et al. 2006, Mesquita et al. 2006).

Information on the abundance and biomass of species in assemblage of fish and the management of recreational fishing in the Rokytná River collected since the end of the 1950s'has been

Table 1. Frequency of species: *regularly stocked species, **species stocked up to 1980s', ***since 1980s', + since 1990s', ++ invasive species, and +++ species probably coming from further upstream in the Rokytná River or from the Jihlava River

species	common name	family
frequency (100–81%)		
Rutilus rutilus (Linnaeus, 1758)	roach	Cyprinidae
Leuciscus leuciscus (Linnaeus, 1758)	dace	Cyprinidae
Leuciscus cephalus (Linnaeus, 1758)	chub***	Cyprinidae
Alburnoides bipunctatus (Bloch, 1782)	schneider	Cyprinidae
Gobio gobio (Linnaeus, 1758)	gudgeon	Cyprinidae
Chondrostoma nasus (Linnaeus, 1758)	nase***	Cyprinidae
Alburnus alburnus (Linnaeus, 1758)	bleak	Cyprinidae
Barbus barbus (Linnaeus, 1758)	barbel+	Cyprinidae
Barbatula barbatula (Linnaeus, 1758)	stone loach	Balitoridae
frequency (80–50%)		
Cyprinus carpio (Linnaeus, 1758)	carp*	Cyprinidae
Romanogobio albipinnatus (Lukasch, 1933)	white gudgeon	Cyprinidae
Anguilla anguilla (Linnaeus, 1758)	eel*	Anguillidae
Tinca tinca (Linnaeus, 1758)	tench*	Cyprinidae
Esox lucius (Linnaeus, 1758)	pike*	Esocidae
frequency (<33%)		
Vimba vimba (Linnaeus, 1758)	zährte+	Cyprinidae
Rhodeus amarus (Bloch, 1782)	bitterling	Cyprinidae
Carassius auratus (Linnaeus, 1758)	goldfish++	Cyprinidae
Abramis brama (Linnaeus, 1758)	bream+	Cyprinidae
Perca fluviatilis (Linnaeus, 1758)	perch+++	Percidae
Pseudorasbora parva (Temminck et Schlegel, 1846)	stone moroko++	Cyprinidae
Carassius carassius (Linnaeus, 1758)	crucian carp+++	Cyprinidae
Scardinius erythrophthalmus (Linnaeus,1758)	rudd+++	Cyprinidae
Salmo trutta (Linnaeus, 1758)	brown trout+++	Salmonidae
Blicca bjoerkna (Linnaeus, 1758)	white bream+++	Cyprinidae
Sander lucioperca (Linnaeus, 1758)	pikeperch**	Percidae
Ctenopharyngodon idella (Valenciennes,1842)	grass carp***	Cyprinidae

previously summarized (Lelek 1959, 1963, Lusk 1967, 1970, 1973, Libosvárský 1977, Humpl & Lusk 2006 and unpublished data). In this paper we summarize other data on fish, water quality and flow together with data on fishery management and assess how they contributed to the change recorded in the assemblage.

MATERIAL AND METHODS

River Rokytná arises in the southeastern part of the Bohemian-Moravian Higlands at an altitude of about 580 m a. s. l. The length of the river is 89 km, it has a drainage area of 584 km^2 and an average discharge of 1.28 m^3×s^{-1}. The stretch of river fished is located near the village of Budkovice, 5.6 km upstream from where this river joins the River Jihlava and is 225 m long and has a surface area of 1724 m^2. The fish were caught by wading through the area twice with an electrofishing apparatus that emitted a pulsed DC output of between 1–3 kW, 230 V and 2–4 A, which was always operated by experienced ichthyologists.

The Latin and common names of all the fish caught in the River Rokytná over the period 1968–2006 are given in Table 1. In the following text and figures we use the common names of the fish.

Of the native species we recorded the numbers of roach, dace, chub, schneider, gudgeon, nase, bleak, barbel, stone loach, zährte and bitterling. Whitefin gudgeon were not distinguished from gudgeon from 1968 to 1973 and therefore not

included in the RDA models. The abundance was assessed using Zippin's method (Zippin 1951) and the biomass was the sum of the weights of all the fish in kg. Both parameters are expressed per ha.

A total of 66 samples were collected during the course of the 39 years (1968–2006). Up to 1979 two to four samples were collected annually and two per year over the period 1988–1989. In all years at least one autumn (August–October) sample was collected.

Data on the quality of the water and average monthly water flow recorded at Ivančice, one km upstream of where the River Rokytná joins the River Jihlava, were acquired from the web pages of the Czech Hydrometeorological Institute (CHMI), and the recreational fishing statistics for a stretch the River Rokytná (Stretch Rokytná 1) upstream from the site studied were kindly provided by the Angling Association at Moravský Krumlov. This particular stretch of the river has an area of 16.4 ha and extends from the weir in Moravský Krumlov and ends 18.7 km from where the River Rokytná joins the River Jihlava. At the end of the 1960s' the fishery changed from a trout to a carp fishery and the numbers of fish stocked and species markedly increased. On this stretch of the River Rokytná there is the Týnský pond (20 ha), which is managed by the Fishery Organization in Pohořelice for rearing carp of up to one kg in weight. The site "Budkovice" is located in the centre of this stretch of the river near Budkovice. Downstream to the confluence of the River Rokytná with the River Jihlava there are no weirs or other types of barrier, whereas upstream there are three weirs that are overpassed by fish in both directions during flooding.

Figures 1–6 and all the simple linear regressions were done in Exel and the 95% predictive limits in Figure 1 were calculated using the program TableCurve 2D, version 3. Multivariate statistical analyses used for estimating the effect of environmental factors on changes in the assemblage of fish, were done using the program CANOCO ver. 4.5. (ter Braak & Šmilauer, 2002). Since the length of all the gradients of the environmental factors varied between 0.6–2.3, we also used a linear direct gradient analysis (Redundancy Analysis, RDA). As species data we used the biomass of eleven native species of fish or that of all 26 species caught by electrofishing in 1968–2006 (Table 1) and for environmental data (1) BOD in mg of O_2 l^{-1}, (2) N NH_3 in mg of N l^{-1}, (3) the number of months when the discharge was >0.5 $m^3 \times s^{-1}$ in a given year, and (4) catch of carp in kg ha^{-1} $year^{-1}$ in the section Rokytná 1. In reality the number of fish in the "species data" was affected by the number of carp stocked, but this data was not available for most years. The first two factors characterize the water quality, the third the fluctuations in water level, the numbers of carp stocked (measured in terms of carp caught) the affect of the management of the fishery on the native species and the whole assemblage of fish,

The strongest gradient in the four RDA models was detected using DCA, and due to its shortness, RDA was then used. Models differed in the number of species (11 native or all 26) and samples (39 or 66). We expected that a greater percentage of the variability would be accounted for by the models of native species caught in the 39 autumn samples. We also assume that the environmental factors affect mainly the first age group of all the species and therefore we coupled the values of biomass in the species data with the corresponding values of the environmental data recorded three years before. In all the models the statistical significance of the first and all canonical axes was tested. In the next step we used forward selection and tested the marginal effects of individual environmental variables i.e. the variance they each account for.

RESULTS

There were a total of 26 species in 39 autumnal samples and no other species were recorded in the 27 spring and summer samples (Fig. 1).

From the linear relationship (years – number of species) it is obvious that the number of species increased by 0.11 per year or by 4.2 species over the period of this study. In 1968 we predicted an average of 11 species (7–14) and in 2006 15 species (11–18). Moving average analysis reveals maximum values in 1980 (15), 1990 (17) and 2000 (17 species).

The number of species in the samples was influenced by the carp, pike, eel and tench that were regularly stocked up to the 1980s' (pikeperch), and since the 1980s' (grass carp, nase, chub) and 1990s' (bream, barbel, zährte), and the arrival of invasive species (goldfish, stone moroko) and of brown trout from further up the River Rokytná or white bream, rudd and crucian carp from the River Jihlava. We do not have evidence of stocking with asp (*Aspius aspius* Linnaeus, 1758), wells (*Silurus glanis* Linnaeus, 1758) and silver carp (*Hypophthalmichthys molithrix* Valenciennes, 1844). Burbot (*Lota lota* Linnaeus, 1758) was stocked only twice after 2000. However, these four species were not present in samples collected at Budkovice.

Of the 26 species, eight had a frequency of 100% and stone loach a frequency of 81% and are native species. Of the five species with a frequency 50–80%, four were stocked and only one, whitefin gudgeon, is a native species.

Table 2. Average abundance, biomass and number of species (Coeff. of Variance % in brackets) in some Bohemian and Moravian streams, 60–100 km from the source, compared to that recorded in the River Rokytná at Budkovice (data from Křížek et al. 2000, Lusk 1978a, 1978b, 1980, Lojkásek et al. 2001, Pivnička et al. 2005)

river	Bohemia one sweep Úhlava, L. Nisa Blanice	Bohemia two sweeps	Moravia two sweeps Jevišovka, Kyjovka, Odra, Ostravice, Oslava, Svratka, Svitava, Vsetínská Bečva	Moravia two sweeps Rokytná Budkovice Rokytná
column	1	2	3	4
samples	23	23	56	39
A ha^{-1}	804 (79%)	1343	4120 (64%)	4140 (44%)
B ha^{-1}	60 (68%)	100	329 (68%)	252 (40%)
species	11.2 (19%)	12	11.1 (26%)	13.4 (17%)

The last group of fish with a frequency of less than 33% contains 12 species of which zährte (stocked since 1990s') and bitterling are native and the incidence of all the other species are influenced by fishery management. The gradual increase in the number of species over the years is mainly due to these fish (Fig. 2), with zährte caught 13 times in the 39 samples and rudd 3 times. The last three species, white bream, pikeperch and grass carp, were each caught only once. Crucian carp, brown trout and rudd were caught in the first half, bitterling during the whole period and the other species in the second half of the period studied.

Eight native species were recorded in the samples, in particular, stone loach were present in 31 of the samples. Of the other native species the frequency of occurrence in the samples of whitefin

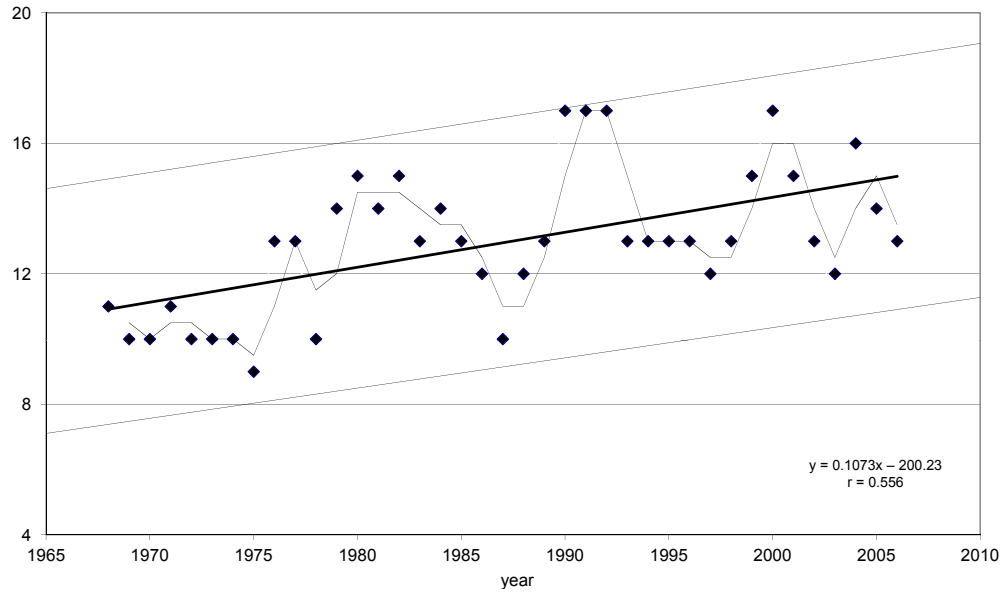


Fig. 1. Number of species in 39 samples collected from 1968 to 2006, the linear relationship and predicted upper and lower limits and the curve based on two year moving averages.

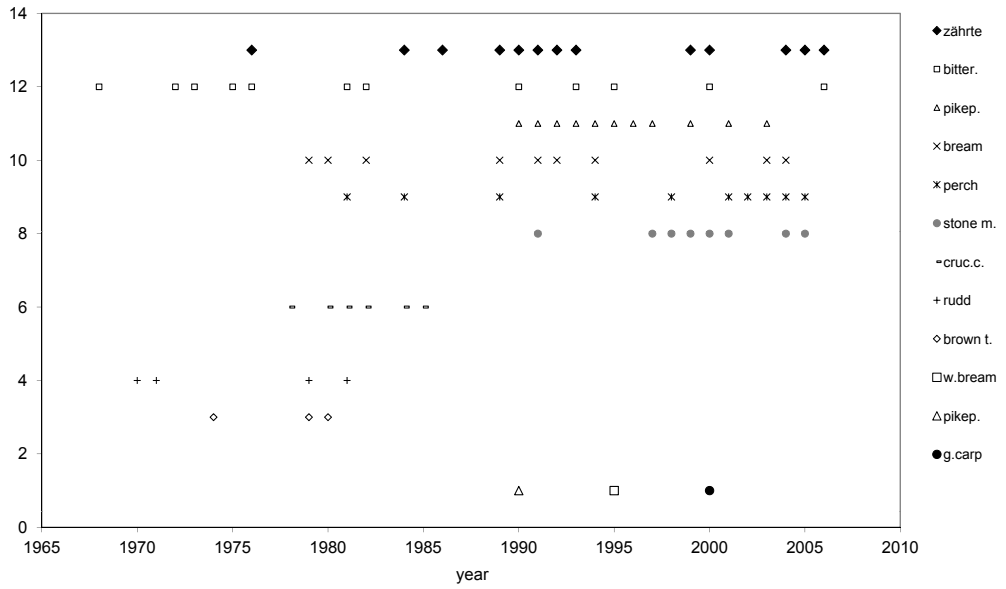


Fig. 2. Species that occurred in catches with a frequency ≤33% in each of the years sampled.

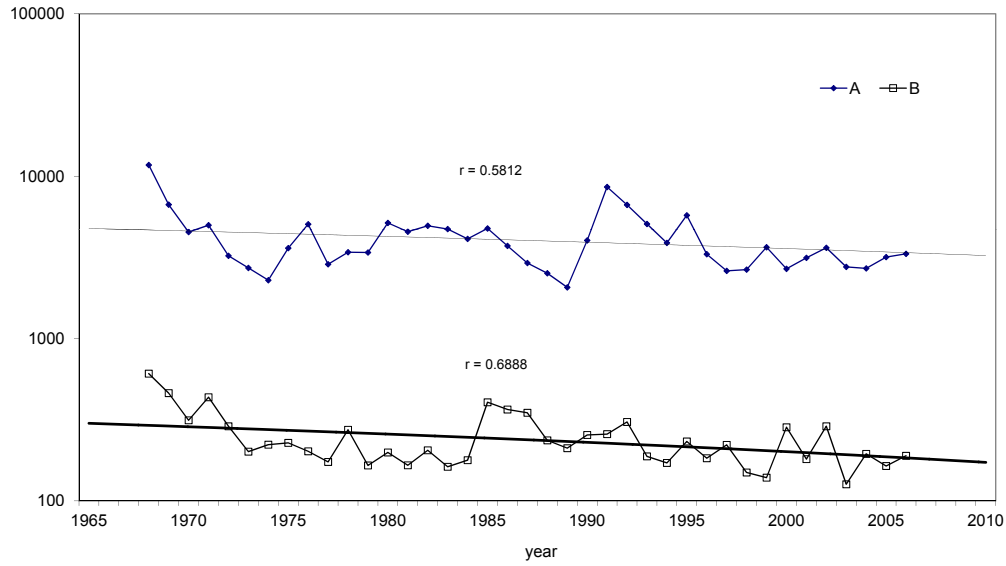


Fig. 3. Values of the abundance (A) in terms of fish per ha and biomass (B) in kg×ha^{-1} recorded in the 39 samples.

Table 3. Details of the four RDA models, first axis (eigenvalue) and all canonical axes (trace) and their statistical significance P

eigenvalue	trace	P	eigenvalue	trace	P
	11 sp. 4 env. 39 samples			11 sp. 4 env. 66 samples	
0.315	0.378	0.001	0.307	0.327	0.001
	26 sp. 4 env. 39 samples			26 sp. 4 env. 66 samples	
0.285	0.342	0.001	0.280	0.301	0.001

gudgeon, bitterling and zährte was 56, 31 and 33%, respectively. Each sample contained 1 or 2 of these species. Four regularly stocked species, carp, pike, eel and tench, occurred in samples with frequencies of from 49 to 56%. Adding these species to the "average sample" the number of species caught increased by 12 or 13. The rest of the species occurred mostly in the samples collected since the 1980s'. On average 13.4±2.3 species were caught and numbers ranged from 10 to 17 species.

The abundance and biomass of fish in samples significantly decreased from 5000 to 3300 fish×ha^{-1} and from 320 to 180 kg×ha^{-1} (r = –0.58 and –0.69 respectively; Fig. 3).

The numbers of fish caught were highest in 1968–1972, and the next highest values were recorded in the 1980s' and at the beginning of the 1990s'. Biomass fluctuated less markedly, with the highest values recorded in 1968–1971. The biomass of the native species nase and chub decreased significantly (P<0.1), but not that of barbel (Fig. 4).

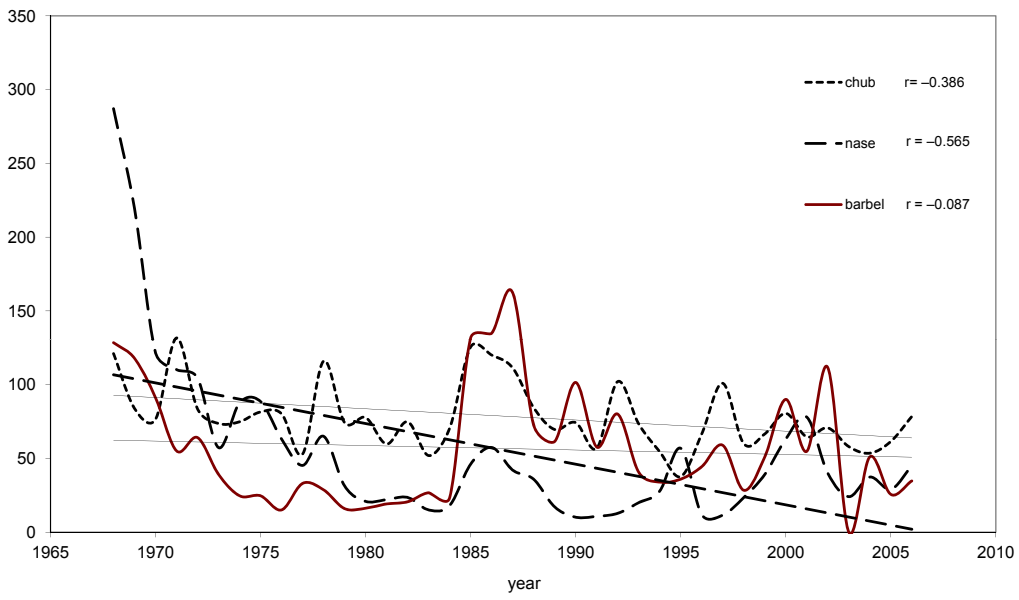


Fig. 4. Changes in the biomass in kg×ha^{-1} of chub, nase and barbel recorded in the 39 samples.

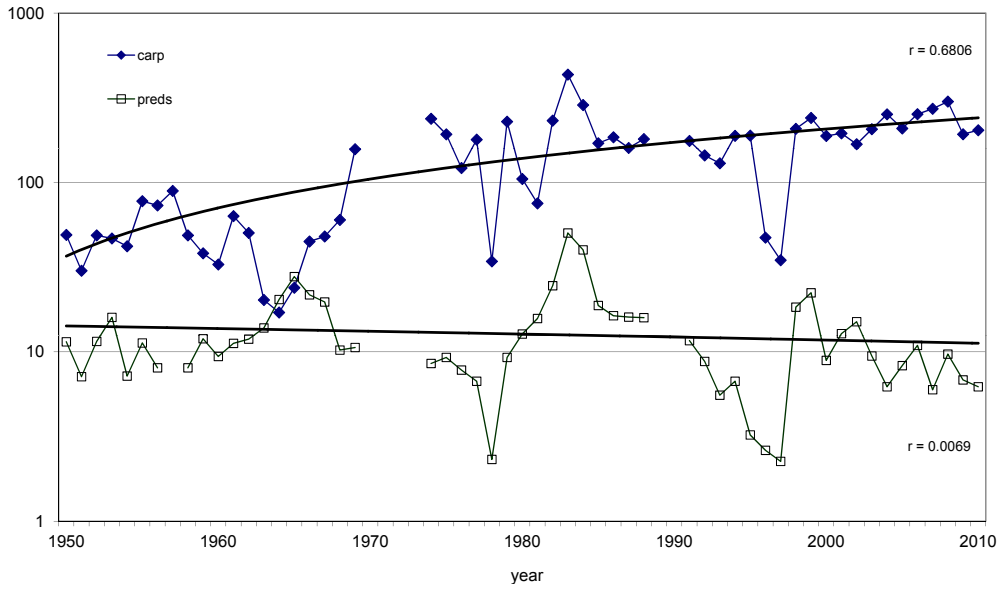


Fig. 5. The kg×ha^{-1} of carp and predators (pike, pikeperch and eel) caught by anglers over the period of the study.

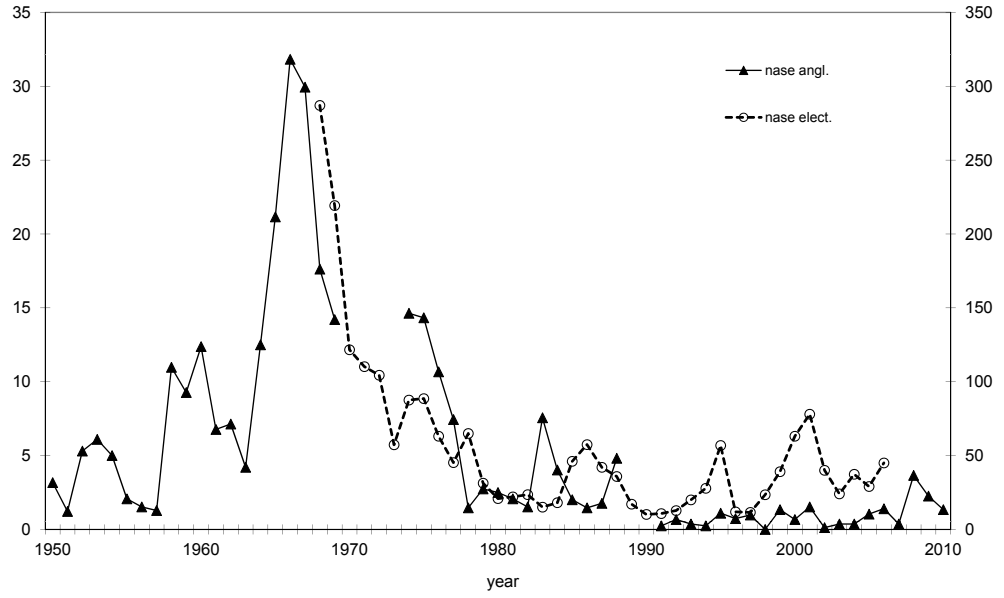


Fig. 6. The quantity in kg×ha^{-1} of nase caught by anglers (▲, scale left Y axis) and by electrofishing (○, scale right Y axis).

Table 4. Marginal effect of environmental factors (in %) and their P values

	26 sp. 39 samples		11 sp. 39 samples		26 sp. 66 samples		11 sp. 66 samples	
	ME (%)	P	ME (%)	P	ME (%)	P	ME (%)	P
BOD	14	0.006	15	0.007	15	0.002	16	0.001
N NH3	13	0.010	14	0.012	8	0.010	9	0.005
>0.5m^3	6	0.060	7	0.063	8	0.003	8	0.006
carp catch	7	0.060	8	0.073	6	0.020	7	0.011

For a comparison of abundance, biomass and number of species in the River Rokytná with that in other streams see data in Table 2. In Moravian streams the fish were caught using two sweeps of an electrofishing apparatus as in the River Rokytná, whereas in the Czech streams only one sweep was used, which results in a catch that is about 60% in terms of abundance and biomass and 94% in terms of number of species caught using two sweeps. The comparable enlarged values for the Czech sites are in column 2 of Table 2.

Data on anglers' catches are for 1950–2010, with the exceptions of 1970–1973 and 1989–1990. The catches of carp and predators (pike, eel, and pikeperch) are shown in Fig. 5. Up to 1968 the average catch of carp was 48 kg (range 20–89 kg) or 52% of the total. Since 1969 the catch has increased more than three times to 183 kg (range 34–286 kg) or 83% of the total. The increase in catches over the whole period is significant (r=0.681). The average catch of predators was 12.7 kg, the lowest 2.3 kg and the highest 50.3 kg in 1983. Over the whole period the catch of predators decreased slightly with maximum catches of 28 kg in 1965 and 22 kg in 1999 (Fig. 5).

Of the native species, those preferred by fishermen in the 1960s' were chub, nase and barbel. The catches of these species were highest from 1965 to 1967 (chub 40.7 kg, nase 31.8 and barbel 8.7 kg×ha^{-1}) and decreased in the 1970s' to 15.4, 14.3 and 3.4 kg, respectively. The continuous decrease in the catches of nase, chub and barbel since 1968 is associated with the high catches of

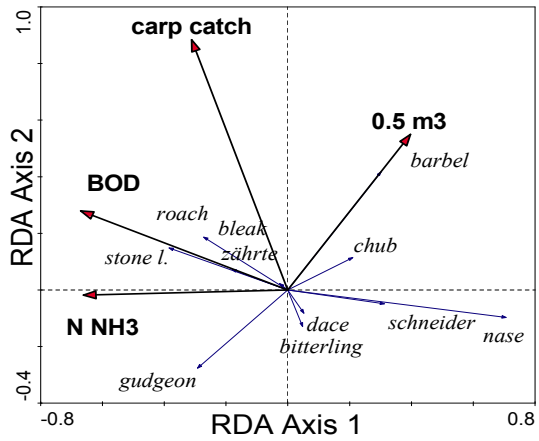
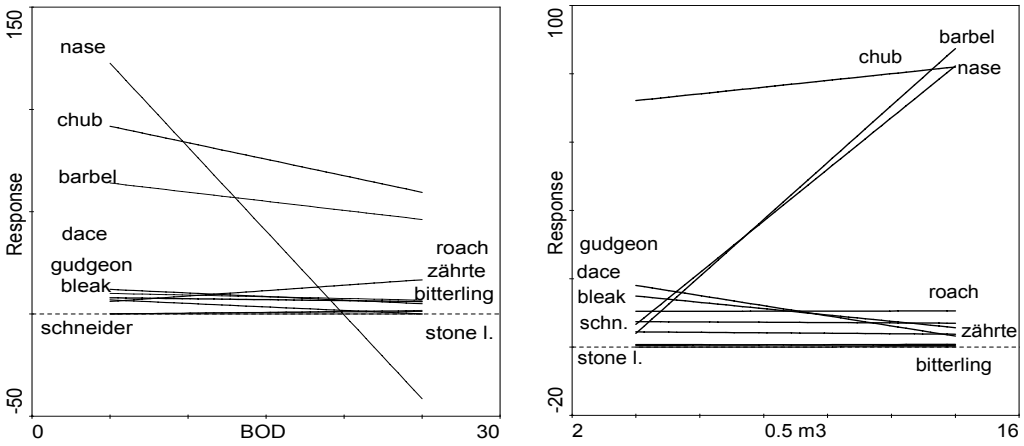


Fig. 7. RDA ordination diagram distinguishing the effects of the environmental variables measured on the different species of fish.



Figs. 8, 9. Species response curves. 8 (left) – species response curves to BOD. Generalized linear model with statistically negatively significant correlation coefficients for schneider and nase. 9 – (right) species response curves to water flow> 0.5 $m^3 \times s^{-1}$. Generalized linear models in which the correlation coefficients for barbell and roach are both positive and significant, and those for bleak and gudgeon are negative and significant.

carp that followed the massive stocking with carp. In our samples the decrease in the catches of nase showed a similar trend (Fig. 6).

In addition, we used linear direct gradient analysis, RDA, to estimate the effect of environmental factors on changes in the fish assemblage. The eigenvalues, traces and the significance of the first axis and of all canonical axes are summarized in the Table 3, marginal effect of individual environmental factors in Table 4.

For 11 and 26 species in the 39 autumn samples the first axis and all canonical axes explain 32 and 38%, and 29 and 34% of the variability associated with environmental factors. For the 66 samples the corresponding results for 11 and 26 species are 31 and 33%, and 28 and 30%, respectively.

Marginal effects of both chemical factors (BOD and N NH_3) on the catches of 11 and 26 species, respectively, in the 39 and 66 samples were highly significant and the statistical significance of the effect of the number of months when water flow was >0.5m^3 on the carp catch slightly exceeded the 0.05 value in models based on the results for the 39 samples and was significant for those based on the results of the 66 samples.

The ordination diagram (Fig. 7) shows the relationships between the biomass of eleven native species and environmental factors in 1968–2006. The biomass of nase, schneider, chub, barbel, dace and bitterling caught was negatively associated with water quality (BOD and N NH_3) and for nase, schneider, dace and bitterling also with the number of carp stocked (measured in terms of the catch of carp). The barbel, chub, schneider and nase were positively influenced by a flow of >0.5$m^3 \times s^{-1}$, gudgeon, dace, bitterling and stone loach negatively so. As an example of the linear relationships among biomass of native species and environmental factors we present the generalized linear models for BOD and water flows >0.5 m^3 for 11 native species caught in 39 samples in Fig. 8 and 9.

DISCUSSION

Before 1968, 24 species were caught using electrofishing in the lower part of the River Rokytná (sites near the villages Vémyslice and Budkovice; Lusk 1970). Between 1968 and 2006 invasive stone moroko and goldfish were recorded and occasionally stocked grass carp. Carp, tench, pike, eel and asp were regularly, and bream, grass carp, pikeperch, burbot, wels and silver carp occasionally stocked. Brown trout was stocked only in 1960s'. Some species (perch, rudd) entered the river from the Týnský pond, white bream together with stocked bream.

From 1950 to 2010 anglers caught a total of 21 species of fish in the section Rokytná 1. Of these species, wels, silver carp, asp, orfe, burbot, rainbow trout, burbot and grayling have not been caught by electrofishing since 1968. The total number of species caught by anglers and electrofishing is 34.

The number of species of fish at a given river site depends on its distance from the source, number of ponds in the watershed, water flow and on the number of suitable habitats (Oberdorff et al. 1993, Angermaier & Winston 1999, Oberdorff et al. 2002). For predicting the number of species of fish in a section of a stream, a simple semilogarithmic relationship (distance from the source – number of species) is frequently used (Oberdorff et al. 1993, Pivnička 1996, Lusk & Pivnička 2009). Using such an equation, the average expected number of species for the site at Budkovice, which is 83 km from the source, was assessed to be 10 with a predicted range of 6 to 15.

The number of species is further dependent on stream width, the number of hiding places, and the effectiveness of the electrofishing. An average of 95.4% (range 71–100% of the species) was caught during the first sweep in the Loučka and Rokytná streams based on two sweeps (Humpl & Lusk 2006). For streams in Pennsylvania the equivalent values are 67–100% (Kimmel & Argent 2006). In 171 samples of fish caught using two sweeps in Moravian streams Lusk & Pivnička (2009) recorded 89.6% of the different species recorded using three sweeps. At Budkovice the fish were caught using two sweeps, so the error in the number of species recorded in one sample is about one species.

Of the 26 species the management of the recreational fishery affected 12 of which four species were stocked along with carp (crucian carp, goldfish) or "white fish" (white bream, rudd). Therefore the "native" assemblage of fish is likely to be quite different from its assumed original structure. The high number of species in the Rokytná River 1 section is due to the change in the management of the sport fishery from brown trout to carp and the regular or occasional stocking of 18 species of fish.

Up to 1968 anglers caught on average 93 kg of fish and during 1969–2010 it increased to 212 kg (40–319 kg×ha^{-1}×year^{-1}). Of the native species they preferred nase, chub and barbel. The catches of these species were highest in 1965–1967 (81 kg×ha^{-1}) and in the 1970s' it first decreased to 33 kg×ha^{-1} and then down to 5–10 kg. A similar trend in the catches of native species of fish is recorded in reservoirs (Pivnička & Rybář 2001, Jankovský et al. 2011).

The values for BOD and N NH_3 in Czech and Moravian streams were highest at the end of the 1980s' and then at the beginning of this century they decreased to even lower values than those recorded at the beginning of the 1960s'(Pivnička et al. 2005). A comparable improvement in water quality is recorded at the end of the last century (Eklöv et al. 1998, Humpl et al. 2009) and is associated with the rehabilitation of these streams (Pretty et al. 2003). It is known that physical restoration is most effective in increasing fish populations if associated with improvements in water quality and habitat management (Pretty et al. 2003). The environmental requirements of fish are sine qua non (Mann 1996).

The decrease in abundance of native nase and barbel in Moravian streams is already recorded by Libosvárský (1977) and Lusk (1996). They indicate that the main factors determining this

decline in abundance is water pollution and canalization of the streams. The results presented here indicate that decline in the abundance of nase is to a some degree due to the management of the fishery. The negative effect of intensive stocking with brown trout on the diversity of fish in small streams is reported by Pivnička et al. (1996).

A preliminary evaluation of the effect of environmental factors on the fish assemblage confirmed that values for the biomass of the different species of fish are more useful than measures of their abundance. This is because the importance of the very numerous young age groups is better represented by their biomass than their numbers. Of the four RDA models that include the eleven native and all 26 species of fish, and 39 and 66 samples, the model based only on native species and 39 samples accounted for most of the variability.

The marginal effect of environmental factors, i.e. the variance they individually account for, in the case of BOD and N NH_3 is highly significant, whereas the statistical significances of the carp stocked (measured in terms of carp caught) and number of months when the flow of water was >0.5 m^3 slightly exceeded the 0.05 value in the models based on 39 samples and is significant for those based on 66 samples. Changes in the environment and management of the fishery over the last fifty years have significantly affected the fish assemblage in the lower part of the River Rokytná.

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