Restoration of a river backwater and its influence on fish assemblage

E. Hohausová[1], P. Jurajda[2]

[1]Hydrobiological Institute of the ASCR, České Budějovice, Czech Republic
[2]Institute of Vertebrate Biology of the ASCR, Brno, Czech Republic

ABSTRACT: The development of fish assemblage in a restored river backwater (Kurfürst backwater, Morava River, Czech Republic) was monitored over a six-year period from its restoration. The structure of fish assemblage remained similar throughout the years. Species richness of adult fish increased from twelve species during the restoration to 20 after it. Initially steady fish abundance (mean 52.3–98.1 inds/ha) and biomass (mean 5.8–7.6 kg/ha) increased significantly in 1999 five years after restoration (576.9 inds/ha and 23.3 kg/ha, respectively). The main resident species were pike *Esox lucius*, roach *Rutilus rutilus*, rudd *Scardinius erythrophthalmus* and perch *Perca fluviatilis*. High abundance of bleak *Alburnus alburnus* and chub *Leuciscus cephalus* was related to their spring spawning period. The structure of the 0+ fish assemblage was similar throughout the years, with chub and bleak prevailing during the restoration, and roach, chub and rudd after it. The number of 0+ species increased from seven to 17. The monitoring documented that the restoration could be considered as beneficial for the fish assemblage. Habitat development of the backwater is likely to influence its current value as a refuge, spawning site and nursery for local fish populations.

Keywords: rehabilitation; monitoring; colonisation; floodplain; Morava River; assemblage development; adult fish; 0+ fish; freshwater

Every newly created biotope undergoes the process of succession, beginning with colonisation and following with changes in the assemblages of organisms occurring at the locality. Changes in fish assemblages were recorded for large man-made reservoirs (Kubečka, 1993; Lojkásek, 1996) but not for smaller waters such as oxbows and floodplain backwaters. Although these water bodies are known for their importance for fish assemblages in rivers (Reimer, 1991; Schiemer, 1999), long-term studies, particularly from the beginning of their 'life', are missing. Similarly, references to the results and/or long-term observations of restoration projects are scarce (Eiseltová and Biggs, 1995; Grift et al., 2003).

When the upper Morava River was canalised in the 1970's, numerous meanders were cut off from the main river. They became abandoned oxbows or partly connected backwaters in the river floodplain and many of them underwent terrestrialisation. The local Protected Landscape Area (PLA) Authority at Litovelské Pomoraví promoted the restoration of parts of the local floodplain (Rybka, 1995) including the terrestrialised, partly connected backwater (the Kurfürst backwater). The main reason for the restoration of this backwater was to re-create a habitat formerly attractive for fish (Machar, 1996) as this type of lentic habitat is rare in the area. The River Authority of the Morava River Ltd. and the Litovelské Pomoraví PLA Authority were principally responsible for the works carried out in 1993–1994.

The aim of the study was to assess the effect of restoration measures on fish assemblage in the

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Kurfürst backwater and to review the restoration efficiency. We predicted that fish abundance and biomass would increase after restoration as a result of the increased area and improved habitat conditions. We expected that assemblage composition and species number would develop with improved habitat conditions in the backwater. Restoration indices for fish assemblage development may be critical for decision making in future restoration projects.

Study area

The Kurfürst backwater is a former left-side meander of the Morava River (Danube River tributary, Figure 1), north of the Olomouc town. It is included in the Litovelské Pomoraví PLA with the status of a protected location where the angling activity is prohibited. The meander was cut off during the river regulation in the early 1970's, and following the isolation from the main channel a large part of the meander underwent terrestrialisation. In the years 1985–1986 some sediments were removed from the backwater and a concrete pipe was installed into the connection with the river (removed in 1994). The backwater restoration in 1993–1994 was based on the removal of sediment deposits and reconnection to the river.

The backwater now consists of a series of five pools: P1, P2 (P2A + P2B), P3, P4 and P5. In addition to the pools already existing in the backwater area (P1 – a remnant of the terrestrialised backwater, 0.45 ha, and P3 – a water spring area, 0.02 ha), four new pools were created during the restoration (Figure 1). The restoration steps went as follows: pool P5 (0.05 ha) was created by the sediment removal in December 1993 and was left as a separate pool. Pools P4 (0.03 ha), P2A and P2B (0.32 ha each) were created during August 1994. The deepening of pool P1, its connection to new pools and reconnection to the river by the removal of stabilising concrete pipes from the river-backwater connection were carried out in November 1994. The pools are connected to each other by narrow channels also created during the restoration. The connection between the backwater and the river now remains open throughout the year. Except the periods of flooding, the mean depth of the backwater is around 1.3 m. After all, the area of permanent water increased to 1.2 ha. A detailed description of the backwater character is given in Hohausova et al. (2003).

In the restoration period aquatic vegetation existed in pool P1, while in pool P5 developed it during 1994. No vegetation succeeded to appear in pools P2 and P4; these pools mostly comprised a

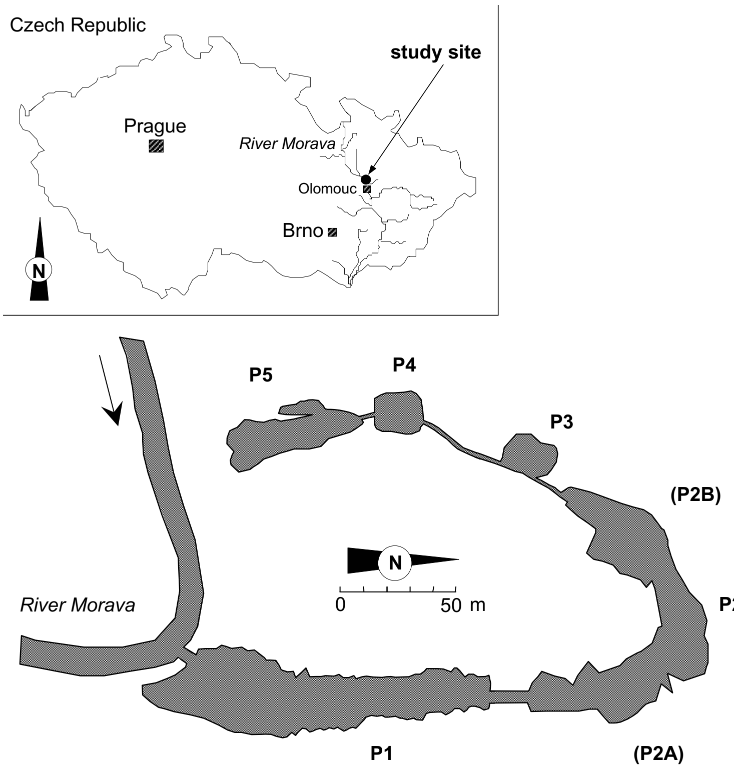

Figure 1. Map of the studied Kurfürst backwater (1.2 ha) with pools P1–P5 connected to the Morava River. The inset map gives a position of the study area in the Czech Republic

naked gravel substrate when the fish entered them for the first time in 1994. In 1995–1999 the vegetation cover in all pools increased, being represented mainly by *Batrachium aquatile*, *Ceratophyllum submersum* and *Callitriche verna*. The vegetation cover ranged annually between 66% and 86% of the water area.

Water characteristics, such as temperature (°C), pH, conductivity (mS/m) and dissolved oxygen (mg/l) differed only slightly from year to year and were within the range normally found for similar water bodies within the Morava River system (Jurajda and Hohausová, unpublished).

The river adjacent to the Kurfürst backwater is about 10 m wide, with silt in pools and gravel in riffles and with partly reinforced riverbanks. A discharge in the river is regulated by the Hynkov weir, 5 km upstream (Krejčí, 1998). By September 1996, the minimum discharge was kept at 1.5 m^3/s, and since then it has been increased to 2.5 m^3/s. Discharges smaller than 4 m^3/s caused the lack of water in pool P3 (access of fish to pools P4 and P5 was possible as the channel along pool P3 has permanent water) and discharges of 10 m^3/s and higher caused the fusion of pools, initially pools P2A and P2B into P2. For more details see Hohausova et al. (2003).

MATERIAL AND METHODS

This study was conducted in the years 1994 to 1996 and 1999. The backwater was sampled for fish quarterly in 1994 and 1999 and monthly in 1995–1996 (Table 1). On each sampling date all pools were sampled, except the June and September of 1994 when only pool P1 was sampled.

Adult fish (≥1+ years old) were regularly sampled by electrofishing (CPUE); each pool was sampled twice according to the removal method of Zippin (1958) allowing the population estimation according to Seber and LeCren estimation (Seber and LeCren, 1967; Cowx, 1983). A full description of these methods is available in Hohausova (2000).

Samplings of 0+ fish were carried out on the dates of adult fish samplings, except in 1996 when the sampling effort increased to a biweekly interval. Point abundance sampling by electrofishing (PASE) (Persat and Copp, 1989) was used to sample 0+ fish. In every sampling run on the backwater, a standard number of sample points (a total of 110–115) was taken and divided among the pools according to their surface area. The total number of points varied due to the temporal drying up of pool P3 (5 points taken). Samples were taken as described in Copp (1993).

Indices of diversity H' (Shannon and Weaver, 1949) and evenness E (Sheldon, 1969) were calculated from the data. These indices, number of species and fish abundance were compared by analysis of variance among years to reveal possible trends. The diversity index was arcsin-transformed and species data were log-transformed. Tukey's HSD test was used for post-hoc comparisons. Simple regression described the relation between mean fish number per year, mean biomass per year and backwater area (in 1994, data from each sampling were used instead of the yearly mean because the area differed at each sampling, Table 1). The fish assemblage was also assessed on the basis of ecological (Schiemer and Weidbacher, 1992) and reproduction (Balon, 1975) guilds of the species (Table 2). To assess the balance of fish assemblage (*sensu* Swingle, 1950), the F/C coefficient – a ratio of predatory to non-predatory fish in an assemblage based on fish weights was calculated (Balon, 1966; Holčík and Hensel, 1972). The values of F/C between 1.4 and 10 (with optimum between 3.0 and 6.0) characterise a balanced assemblage. F/C < 2 shows prevalence of predatory fish, F/C > 6 prevalence of non-predatory fish (Holčík and Hensel, 1972). Despite the suggestions of Balon (1966), 0+ fish were not included in the calculation because of missing weight data of 0+ fish in 1999.

RESULTS

Adult fish (fish ≥1+) assemblage development

The colonisation of the backwater by adult fish already occurred during the restoration in 1994. Fish were always present in P1 because this pool was occasionally connected to the river. In spring 1994 the whole backwater area was flooded and fish were apparently trapped in the separated pool P5. From here fish possibly colonised the new pools created later in the year. In the November sampling, following a few days after connecting the new pools to pool P1 and thus to the river, 10 species were found compared to 5 to 8 in previous samplings (Table 1). Overall, 12 species were found in 1994, eight of them before the restoration was completed.

Table 1. Summary of estimated abundance (n; inds/ha) and biomass (b; kg/ha) and number of species (s), index of diversity (H') and evenness (E) for all samplings in the Kurfürst backwater in 1994–1999. The area of the backwater has been ca 1.2 ha since 1995. Results of ANOVA for comparison of diversity, evenness and number of species between years and post-hoc testing

Date	1994						1995					1996					1999				
(month)	*n*	b	s	H'	E	area (ha)	*n*	b	s	H'	E	*n*	b	s	H'	E	*n*	b	s	H'	E
III.							19	2.2	5	1.57	0.68										
IV.	42.2	4.7	8	2.45	0.82	1.00	51	6.6	8	2.44	0.81						724	15.1	13	2.18	0.59
V.							71	4.4	9	2.42	0.76	78.1	6.9	10	2.48	0.75					
VI.	44.1	11.9	5	1.82	0.78	0.45	172	8.9	12	2,28	0.64	40.6	4.8	9	2.93	0.93	1015	43.4	13	2.41	0.65
VII.							144	10.2	10	2.13	0.64	59.6	10.3	9	2.67	0.84					
VIII.							182	14.2	8	1.85	0.62	66.5	8.2	8	2.34	0.78					
IX.	93.2	9.2	5	1.69	0.73	0.45	81	10.1	8	2.07	0.69	66.9	5.7	7	2.23	0.79	367	21.6	9	1.69	0.53
X.	restoration completed						73	6.2	8	2.07	0.69	22.5	2.9	4	1.35	0.68					
XI.	48.3	4.6	10	2.71	0.81	1.20	89	5.7	7	1.85	0.66	31.9	2.1	4	0.92	0.46	201	13.1	9	1.98	0.62
Sum			12						14					13					17		
Mean	57.0	7.6	6.0	2.0	0.8		98.1	7.6	8.6	2.1	0.7	52.3	5.8	7.3	2.1	0.7	576.9	23.3	11.7	2.1	0.6
SD	24.3	3.6	1.7	0.4	0.05		55.7	3.6	2.1	0.3	0.1	20.7	2.9	2.4	0.7	0.1	364.6	13.9	2.3	0.4	0.1

Diversity (arcsin-transformed)					
	SS	df	MS	*F*	*P*
Abs. term	13.4	1	13.37	703.19	
Var1	0.2	3	0.06	3.31	0.04111
post hoc (Tukey's HSD)					
Var1	{1} .9046	{2} .7619	{3} .8673	{4} .6415	
1	–	0.34	0.97	0.06	
2	0.34	–	0.45	0.48	
3	0.97	0.45	–	0.07	
4	0.06	0.48	0.07	–	
Number of species (log-transformed)					
	SS	df	MS	*F*	*P*
Abs. term	91.47	1	91.47	984.43	
Var1	0.65	3	0.22	2.32	0.1057

Evenness					
	SS	df	MS	*F*	*P*
Abs. term	10.53	1	10.53	1 204.08	
Var1	0.09	3	0.03	3.31	0.04096
post hoc (Tukey's HSD)					
Var1	{1} .7850	{2} .6878	{3} .7471	{4} .5975	
1	–	0.34	0.92	0.05	
2	0.34	–	0.60	0.40	
3	0.92	0.60	–	0.08	
4	0.05	0.40	0.08	–	

In the following years the species number increased (Table 2), although not significantly (ANOVA, F = 2.32, df = 3, P = 0.106).

In the six-year study period (1994–1999), 20 species representing 3 families (Esocidae, Cyprinidae and Percidae) occurred in the backwater (Table 2). Their occurrence varied seasonally and between years. Roach *Rutilus rutilus* and pike *Esox lucius* remained dominant species of the assemblage during the restoration and after it, accounting for 9–65% (roach) and 3–64% (pike) of the assemblage. Other common species were perch *Perca fluviatilis* (2–15%) and rudd *Scardinius erythrophthalmus* (2–27%). Tench *Tinca tinca*, bream *Abramis brama,* crucian carp *Carassius carassius* and Prussian carp *Carassius auratus* were less abundant but they were also a stable part of the assemblage (Figure 2). The relative proportion of rudd slightly increased and bream slightly decreased after restoration. Adult chub *Leuciscus cephalus* and bleak *Alburnus alburnus* regularly increased in abundance during April and May (spawning time).

Mean estimated abundance and biomass (Table 1) were not significantly related to the increase of the water area after restoration (R^2 = 0.08, P = 0.53; R^2 = 0.001, P = 0.93). ANOVA showed significant differences in abundance (F = 13.6, df = 20, P < 0.01) and biomass (F = 9.11, df = 20, P < 0.01) between the years, caused mainly by a major increase of fish occurrence in 1999 (Tukey's HSD test, P < 0.01). The abundance increased mainly due to high occurrence of 1+ and 2+ fish in the assemblage. In 1999 the abundance and biomass were 3–4 times higher than in previous years (Table 1), suggesting possible changes of environmental conditions in the backwater or in the adjacent river stretch. Pike, perch and occasionally bleak dominated in biomass in 1994. In subsequent years, pike always accounted for a larger part of the assemblage biomass (from 19.5 to 72.8%) (Figure 2). The contribution of roach (1.2–48.9%) was always higher by the end of each year. The contribution of chub (6.5–44.8%) and bleak (0.1–25.6%) was linked with their spring occurrence.

Diversity and evenness showed marginally significant differences between the years (ANOVA,

Table 2. List of species recorded in the Kurfürst backwater and their membership to reproductive (Balon, 1975) and ecological (Schiemer and Weidbacher, 1992) groups

No.	Scientific name	English name	Reproductive group	Ecological group
1	*Esox lucius*	pike	phytophils	eurytopic
2	*Rutilus rutilus*	roach	phyto-lithophils	eurytopic
3	*Leuciscus leuciscus*	dace	phyto-lithophils	rheophilic A
4	*Leuciscus cephalus*	chub	lithophils	rheophilic A
5	*Phoxinus phoxinus*	minnow	lithophils	rheophilic A
6	*Scardinius erythophthalmus*	rudd	phytophils	limnophilic
7	*Aspius aspius*	asp	lithophils	rheophilic B
8	*Tinca tinca*	tench	phytophils	limnophilic
9	*Leucaspius delineatus*	sunbleak	phytophils	limnophilic
10	*Gobio gobio*	gudgeon	psammophilis	rheophilic B
11	*Pseudorasbora parva*	–	phyto-lithophils	eurytopic
12	*Alburnus alburnus*	bleak	phyto-lithophils	eurytopic
13	*Abramis (Blicca) bjoerkna*	silver bream	phytophils	eurytopic
14	*Abramis brama*	bream	phyto-lithophils	eurytopic
15	*Rhodeus sericeus*	bitterling	ostracophils	limnophilic
16	*Carassius carassius*	crucian carp	phytophils	limnophilic
17	*Carassius auratus*	Prussian carp	phytophils	eurytopic
18	*Cyprinus carpio*	carp	phytophils	eurytopic
19	*Perca fluviatilis*	perch	phyto-lithophils	eurytopic
20	*Stizostedion lucioperca* hybrid (cyprinid fish)	pike-perch	phytophils	eurytopic

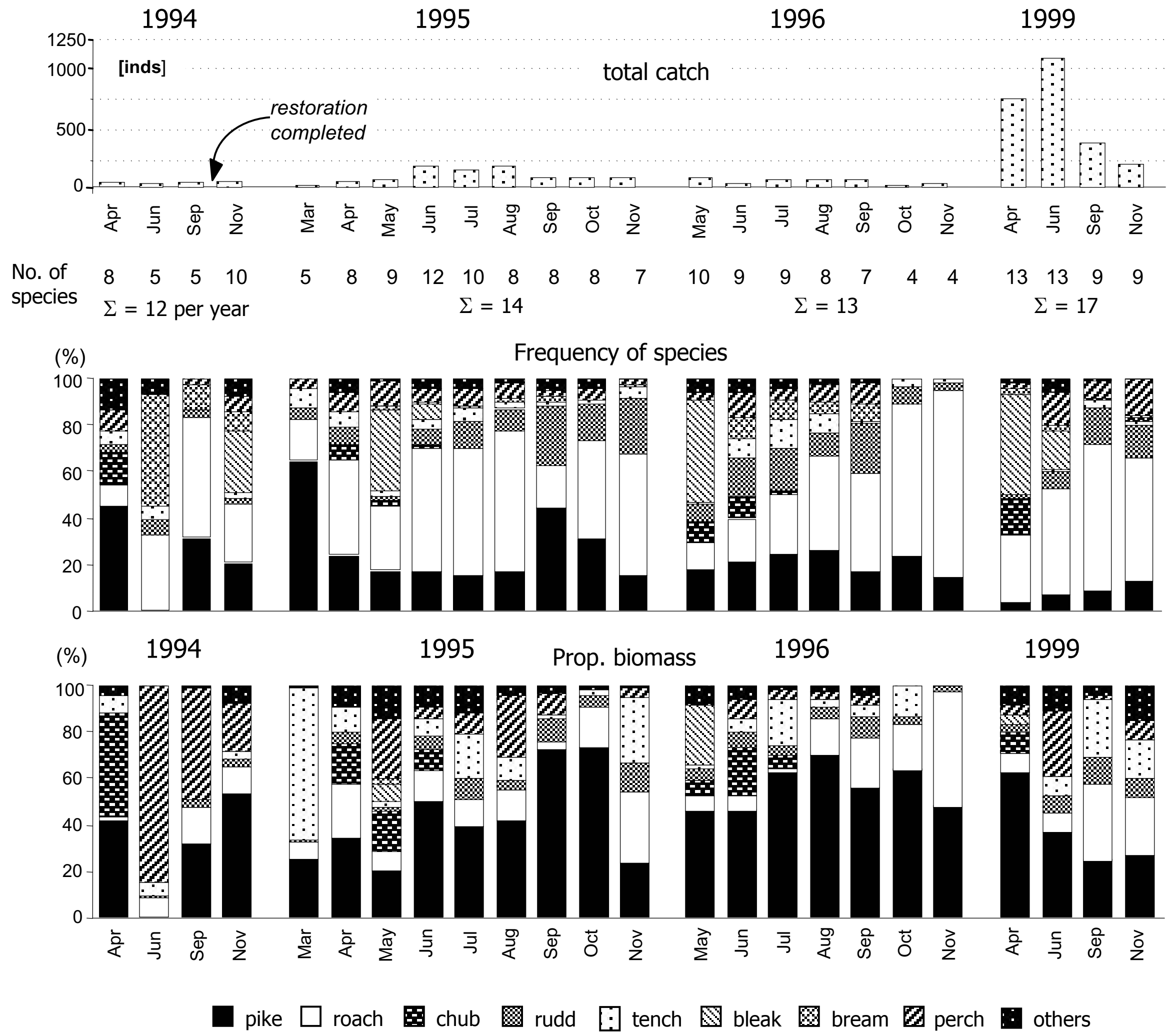

Figure 2. A review of absolute catches of adult fish per sampling, frequency of species in abundance and biomass of the assemblage, and number of species in the Kurfürst backwater in the 1994–1999 period

H': $F = 3.31$, df = 3, $P = 0.041$, E: $F = 3.31$, df = 3, $P = 0.041$). Post-hoc comparison (Tukey's test) showed marginally significant differences between 1994 and 1999 ($P = 0.06$), and 1995 and 1996 ($P = 0.07$) for diversity, and a significant difference between 1994 and 1999 ($P = 0.05$) for evenness. As the *P*-values are marginal, the results might differ with a higher number of samplings. Higher values of the indices were often found in spring and/or early summer, when various species visited the backwater, however, one of the highest values of diversity (2.71) was recorded just after restoration (Table 1).

There was no significant shift in the composition of ecological groups throughout the years among which eurytopic species always prevailed (Figure 3). In reproductive groups, no trend was visible in 1994–1996, however in 1999 a proportional decrease of phytophils occurred, namely of pike and tench (Figure 3).

F/*C* coefficient revealed the values of 1.3 for 1994, 0.6 for 1995, 0.5 for 1996 and 2.2 for 1999, indicating an assemblage with prevalence of predatory fish in 1994–1996 and a balanced assemblage in 1999. The dominant predator was pike.

0+ fishes

In total, 17 species of 0+ fish were recorded in the backwater, with the number slightly increasing after restoration (Figure 4). In 1994, chub prevailed (55%), followed by bleak (22%) and roach (18%). In 1995, rudd and perch dominated (39% and 18%, respectively). In 1996, roach prevailed (48%), followed by chub (24%) and in 1999 chub dominated (57%),

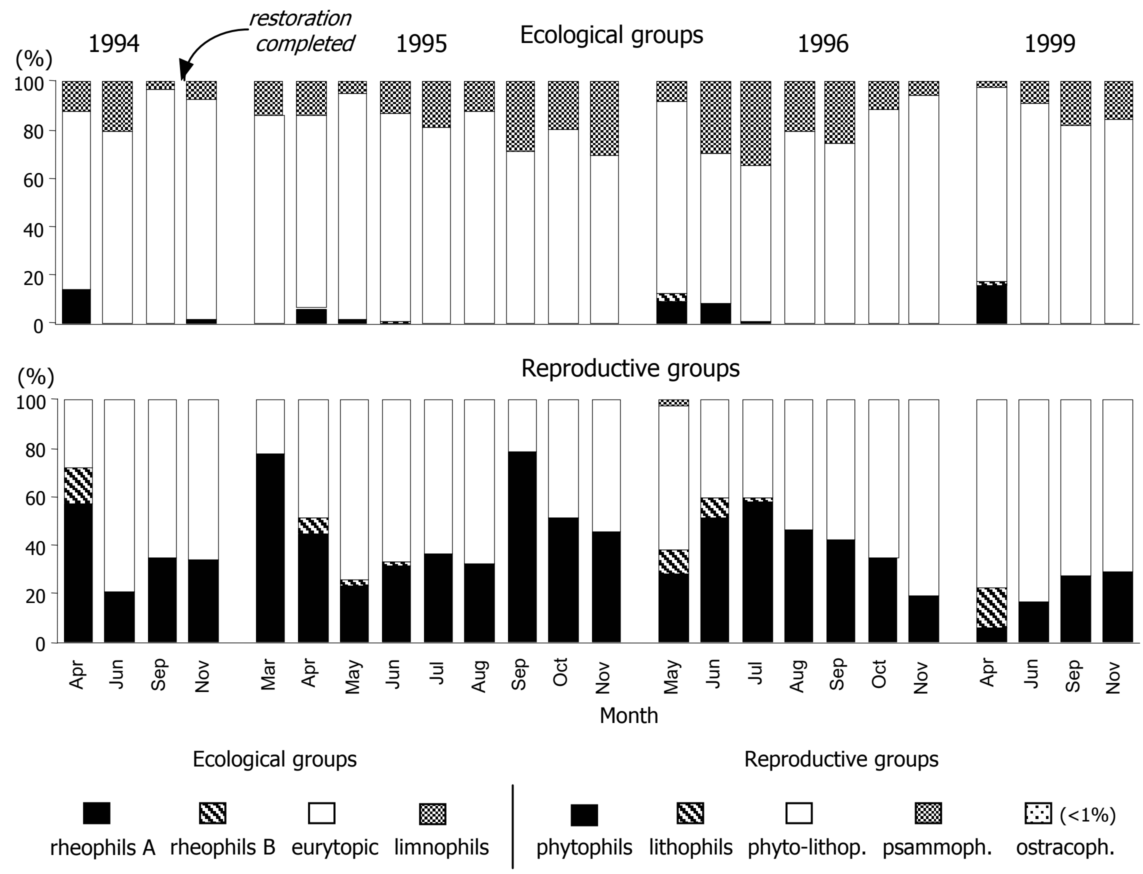

Figure 3. A review of the proportions of ecological and reproductive groups of adult fish in the Kurfürst backwater in 1994–1999

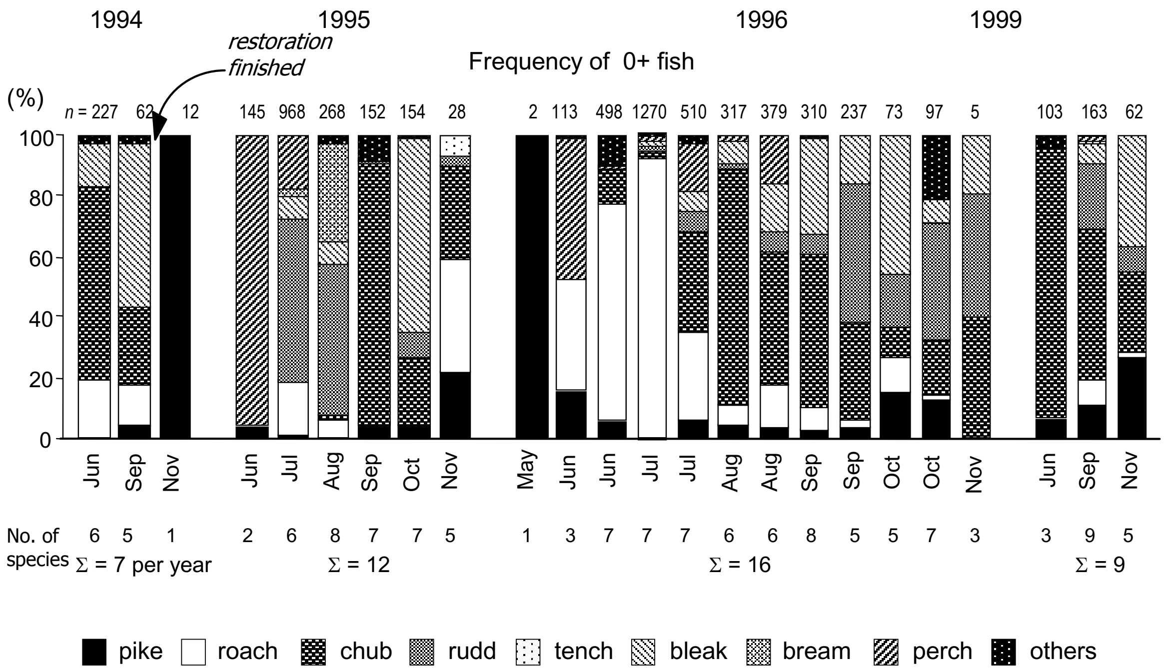

Figure 4. A review of species frequency and number of species of 0+ fish in the Kurfürst backwater in 1994–1999

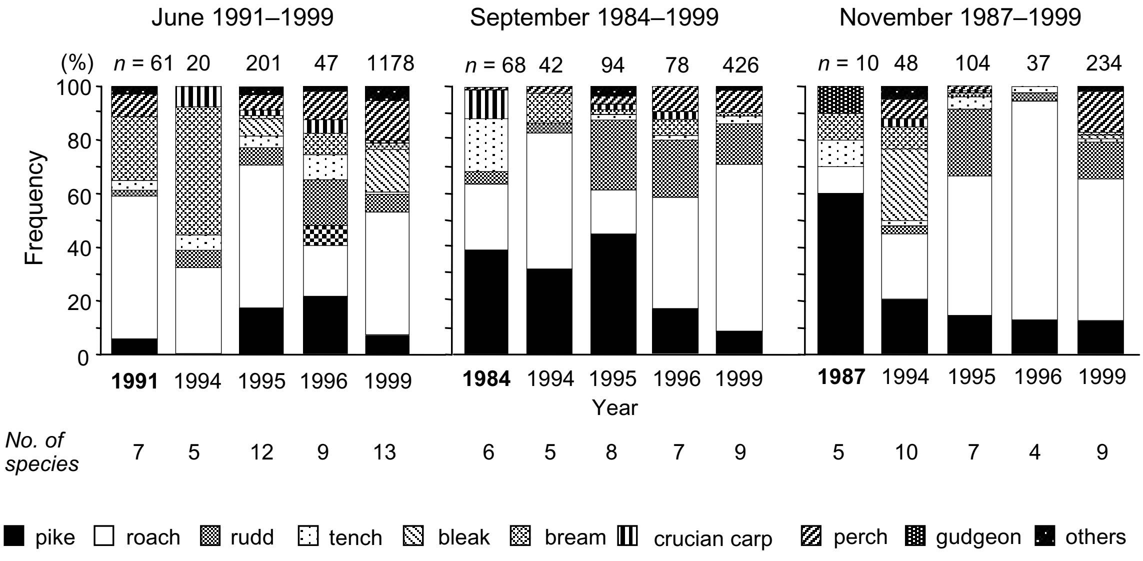

Figure 5. Comparison of adult fish assemblage composition available as cross-sections over months common for the current and previous studies performed before the restoration of the backwater (1984–1991 – in bold; Peňáz and Jurajda, 1993, 1994; Loyka, 1993). *n* gives an absolute catch of fish per sampling (above bars)

followed by pike (13%), rudd (12%) and bleak (11%). Changing proportions of ecological groups occurred during the years, without clear pattern even during seasons. No obvious change in the assemblage after restoration can be pointed out. In reproductive groups, the same unstable pattern was observed. Before restoration a higher proportion of psammophils was found than in any later samplings.

DISCUSSION

The study showed that the conditions established in the backwater as a result of restoration supported the development of fish assemblage similar to that found in the backwater before restoration (Peňáz and Jurajda, 1993, 1994; Loyka, 1993) (Figure 5). The goal of the restoration of the fish habitat (Machar, 1996) has been successfully achieved. Increased area and wider spectrum of habitats enhanced the fish assemblage in terms of abundance. Additionally, more species were found out after restoration than before it (9 species recorded by Peňáz and Jurajda, 1993, 1994), which, besides the improved conditions, could partly be caused by the higher intensity of sampling. However, some of the newly recorded species did not become a stable part of the assemblage during the study. We can only hypothesise about the reasons for the shift in fish composition, abundance and biomass in 1999, five years after restoration. It could be the beginning of a new trend in the assemblage development or a delayed consequence of the huge flood in 1997. Fish might also use the backwater to a larger extent as an overwintering (Freyhof, 1997), feeding or other type of habitat/refuge (Allouche et al., 1999). Similarly, Černý et al. (1997) recorded an increase in the fish abundance in backwaters of the lower Morava River within three years after their restoration, however, it was probably caused by the increase of their area.

A limited comparison with the previous studies of the backwater (Peňáz and Jurajda, 1993, 1994; Loyka, 1993) (Figure 5) revealed a decrease of tench in autumn months, and an increase of perch, rudd and roach. A subsequent decrease of formerly abundant phytophils (1984 and 1987) might indicate the suitability of conditions in the overgrown and silted remnant of the backwater for phytophilic species before its restoration. A lower ratio of phytophils in 1999 (mainly in April and June) was partly caused by increased occurrence of 1+ phyto-lithophils and lithophils which did not occur in such amounts in previous years.

On the other hand, pike was always abundant in the backwater, which is not always typical (Hohausová and Jurajda, 1996; Penczak et al., 2004) of similar locations. For this phytophilic species preferring lentic and vegetated habitats (Balon, 1975) limited in this reach of the Morava River, sites such as Kurfürst backwaters are important locations. Limited availability of habitats may then result in aggregation of pike causing a high predation pressure on other fish (Hohausová, 2000). A High proportion of predators was also revealed by the F/C coefficient, which indicates a less frequent case of balance in fish assemblage (Balon, 1966; Holčík and Hensel, 1972).

Limited data on 0+ fish prior to restoration (Peňáz and Jurajda, 1993, 1994; Loyka, 1993) also showed variations in dominating species. Roach prevailed (83.6%) among the 5 species in 1991, and bleak (80.5%) among the 8 species in 1992. On top of the nine species found in 1991–1992, further eight species were recorded during 1994–1999 (total of 17 species). In 1994–1999, the sampling intensity was higher. A fluctuation in the 0+ fish assemblage composition within and between seasons is a common feature of 0+ communities influenced by many environmental variables (Schlosser, 1985). In general, the occurrence of 0+ fishes in all studied years confirms the importance of the backwater environment as nurseries critical for many fishes in the river systems (Schiemer, 1999).

The fish community in the backwater was interconnected with the fish assemblage in the river. Fish migrated between the river and the backwater frequently (Hohausova, 2000; Hohausova et al., 2003). The species common for the backwater and the adjacent river stretch were roach, pike, bleak, chub, and perch. Dace (*Leuciscus leuciscus*) and gudgeon (*Gobio gobio*), common in the river, occurred occasionally in the backwater. Overall, 20 species found in the Kurfürst backwater represented about 70% of all the species documented for the Morava River in the area during 1994–1997 (Peňáz and Jurajda, 1994; Hohausová and Jurajda, 1996; Prokeš and Baruš, 1998), indicating the importance of the backwater. The study of a similar restored backwater nearby (Čepovo backwater, Morava River; Zapletal et al., 2000) found a high use by a fish assemblage similar to the Kurfürst backwater, and both showed similar initial development of fish assemblages after restoration.

After the six-year period of monitoring, the restoration of the Kurfürst backwater can be considered as beneficial for fish. The assemblage developed successfully, becoming richer in both species and abundance. Now the following development of environmental conditions in the backwater and its treatment will be crucial to that it can further and successfully serve its purpose. During the study, initial terrestrialisation and overgrowing of aquatic macrophytes limiting fish movement and migration were observed. As the development of such new habitats is restricted in the regulated floodplain, the above-mentioned natural processes have to be slowed down in the backwater to maintain the required function. The regular treatment should include at least keeping all the connections accessible for fish at any water level. Data from the previous studies of the Kurfürst backwater can partly document the possible course of its succession if not treated.

This study confirmed that restoration provided new opportunities and enriched the habitat scale of the river system for local populations (Schiemer and Weidbacher, 1992). Further long-term studies are critical for future successful planning in the river system management and restoration.

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REFERENCES

Allouche S., Thevenet A., Gaudin P. (1999): Habitat use by chub (*Leuciscus cephalus* L. 1766) in a large river, the French Upper Rhone, as determined by radiotelemetry. Arch. Hydrobiol., *145,* 219–236.

Balon E.K. (1966): Príspevok k vyváženosti rybích spoločenstiev v inundačných vodách Dunaja. Biológia, *21,* 865–884.

Balon E.K. (1975): Reproductive guilds of fishes: A proposal and definition. J. Fish. Res. Board Can., *32,* 821–864.

Copp G.H. (1993): Microhabitat use of fish larvae and 0+ juveniles in a small abandoned channel of the Upper River Rhône, France. Folia Zool., *42,* 153–164.

Cowx I.G. (1983): A review of the methods for estimating fish population size from survey removal data. Fish. Mgmt., *14,* 67–82.

Černý J., Hensel K., Jurajda P., Kováč V., Hohausová E., Thick L. Reichard M. (1997): Úvodné riešenie renaturácie rieky Moravy v úseku Tvrdonice-Devín. [Záverečná správa.] Ústav zoológie SAV, Bratislava, 6 pp.

Eiseltová M., Biggs J. (1995): Restoration of stream ecosystems – an integrated catchment approach. Eiseltová M., Biggs J. (eds.): IWRB Publ. 37, Slimbridge. 170 pp.

Freyhof J. (1997): Age-related longitudinal distribution of nase, *Chondrostoma nasus* in the River Sieg, Germany. Folia Zool., *46* (Suppl. 1), 89–96.

Grift R.E., Buijse A.D., Van Densen W.L.T., Machiels M.A.M., Kranenbarg J, Breteler J.P.K., Backx J.J.G.M. (2003): Suitable habitats for 0+ group fish in rehabilitated floodplain along the lower River Rhine. River Res. Appl., *19*, 353–374.

Hohausová E. (2000): Exchange rate and small-scale movements of fish between a river and its backwater. Arch. Hydrobiol., *147*, 485–504.

Hohausová E., Jurajda P. (1996): Společenstva horního toku Moravy v oblasti Mohelnické brázdy a některých vybraných přítoků a ramen. Čas. Slez. Muz. Opava (A), *45*, 211–222.

Hohausová E., Copp G.H., Jankovský P. (2003): Movement of fish between a river and its backwater: diel activity and relation to environmental gradients. Ecol. Freshwater Fish, *12*, 107–117

Holčík J., Hensel K. (1972): Ichtyologická príručka. Obzor, Bratislava. 22 pp.

Krejčí M. (1998): Manipulační řád pro jez Hynkov na řece Moravě. Povodí Moravy, s.p., Brno. 22 pp.

Kubečka J. (1993): Succession of fish communities in reservoirs of Central and Eastern Europe. In: Straškraba M., Tundisi J.G., Duncan A. (eds.): Comparative Reservoir Limnology and Water Quality Management. Kluver Academic Publisher, Dordrecht. 153–168.

Lojkásek B. (1996): Vývoj druhové diversity ichtyocenózy v údolní nádrži Morávka v průběhu 30 let. Biodiversita ichtyofauny České republiky I. ÚBO AV ČR, Brno. 50–56.

Loyka P. (1993): Složení a funkce společenstev juvenilních ryb v říčním systému Moravy na území CHKO Litovelské Pomoraví. [Thesis.] Palacky University. Olomouc.

Machar I. (1996): Revitalizace říčních systémů v Litovelském Pomoraví. Ochr. Přírod., *6,* 167–168.

Peňáz M., Jurajda P. (1993): Fish assemblages of the Morava River: Longitudinal zonation and protection. Folia Zool., *42,* 317–328.

Peňáz M., Jurajda P. (1994): Složení a funkce rybích společenstev řeky Moravy. [Průběžná zpráva.] Ústav ekologie krajiny, Brno. 17 pp.

Penczak T., Galicka W., Glowacki L., Koszalinski H., Kruk A., Zieba G., Kostrzewa J., Marszal L. (2004): Fish assemblage changes relative to environmental factors and time in the Warta River, Poland, and its oxbow lakes. J. Fish. Biol., *64*, 483–501.

Persat H., Copp G.H. (1989): Electrofishing and point abundance sampling for the ichthyology of large rivers. In: Cowx I.G. (ed.): Developments in Electrofishing. Fishing New Books, Oxford. 205–215.

Prokeš M., Baruš V. (1998): Structure of the fish assemblage in a stream section of the Morava River (locality Vitošov) after the flood in 1997. Čas. Slez. Muz. Opava (A), *47*, 151–157.

Reimer G. (1991): The ecological importance of floodplains for fish at the River March (Austria). Arch. Hydrobiol., *121*, 355–363.

Rybka V. (1995): Restoration of the Morava River and its floodplain, Czech Republic. In: Eiseltová M., Biggs J. (eds.): Restoration of stream ecosystems. an integrated catchment approach. IWRB Publication 37, Slimbridge. 132–138.

Schiemer F. (1999): Conservation of biodiversity in floodplain rivers. Large Rivers 11/3, Suppl. 115/3: 423–438.

Schiemer F., Waidbacher H. (1992): Strategies for conservation of Danubian fish fauna. In: Boon P.J. Calow P., Petts G.J. (eds.): River Conservation and Management. John Wiley Sons Ltd., Chichester. 363–382.

Schlosser I.J. (1985): Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology, *66*, 1484–1490.

Seber G.A.F., LeCren E.D. (1967): Estimating population parameters from catches large relative to the population. J. Anim. Ecol., *36*, 631–643.

Shannon C.E., Weaver W. (1949): The mathematical theory of communication. University Illinois Press, Urbana.

Sheldon A.L. (1969): Equitability indices: dependence on the species count. Ecology, *50*, 466–467.

Swingle H.S. (1950): Relationship and dynamics of balanced and unbalanced fish populations. Bull. Agr. Exp. St. Alabama Polytech. Inst., *374,* 1–74.

Zapletal J., Peňáz M., Baruš V., Prokeš M., Vojtásek S. (2000): Druhová diversita společenstva ryb Čepova ramene (řeka Morava). In: Lusk S., Halačka K. (ed.): Biodiverzita ichtyofauny České republiky (3). ÚBO AV ČR, Brno. 171–174.

Zippin C. (1958): The removal method of population estimation. J. Wildl. Mgmt., *22*, 82–90.

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Corresponding Author

Eva Hohausová, PhD., Hydrobiological Institute of the ASCR, Na sádkách 7, 370 05 České Budějovice, Czech Republic
Tel. +420 387 775 874, e-mail: ehoh@centrum.cz