Spatial distribution of 0+ juvenile fish in differently modified lowland rivers

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A b s t r a c t . Juvenile 0+ fish communities in three adjacent stretches of two lowland rivers with different degrees of habitat modification were surveyed using electrofishing and evaluated as indicators of fish assemblage reproductive success and spatial distribution. Both rivers originally meandered through large flood plains, however both have been regulated and channelised, to a varying extent, during the last century. The first study stretch, the Czech stretch of the Morava River (69.4 – 92.8 r. km), was regulated by five weirs and completely separated from its floodplain. The second and third study stretches, the Slovak stretch of the Morava River (33.5 – 69.4 r. km) and the Dyje River (0 – 26.7 r. km), were not interrupted by weirs and their floodplain areas remain connected, though partially modified. The total number of 0+ fish species in all of the stretches recorded over three years was similar (22, 23 and 25 spp. resp.). The lowest value of the Shannon index of species diversity and the highest value of total relative density (CPUE) were documented in the Czech regulated-channelised stretch. Significant differences in species richness and relative density were documented among habitats.

Key words: 0+ juvenile fish, regulation and channelisation, habitat utilisation, Danube basin

Introduction

Many European floodplain rivers have been regulated and channelised during the previous century, which has led to reduced habitat diversity (S c h i e m e r & W a i d b a c h e r 1992). These rivers often lack off-channel habitats that represent major spawning and nursery areas for fluvial fishes and which increase habitat diversity, and provide a food supply and shelters (C o p p & P e ň á z 1988). Without off-channel habitat available only bank-side habitat along the main channel, often artificially stabilised by boulders, may be used as spawning and nursery areas. As a consequence, the reproductive success of many fish species depends largely on the availability of suitable spawning and nursery habitats within the river channel (S c h l o s s e r 1982, L o b b & O r t h 1991).

Considering their specific habitat requirements, their high physical habitat dependence and their sensitivity to habitat changes, 0+ juvenile fish have been recognised as a reliable indicator of the reproduction success and recruitment during individual years (e.g. S c h i e m e r & S p i n d l e r 1989, C o p p et al. 1991, J u r a j d a 1995). The seasonal succession of the 0+ fish assemblages indicates that most species remain in their spawning area and also use it as their nursery (C o p p 1989, but see R e i c h a r d et al. 2002).

The Morava River and its tributary, the Dyje River (Fig. 1), are two of the most important Czech rivers. Their main channels have been embanked by levees, regulated by weirs and isolated from their flood plains to different extents. Even though they have been the subject

of ichthyological interest over the past century (e.g. J u r a j d a 1995, J u r a j d a et al. 1998b, L u s k et al. 2001), there are only a few studies of their 0+ fish assemblages based on reach and habitat characteristics (J u r a j d a 1999, J u r a j d a et al. 2001). The main aim of this study was to find: 1) differences in the 0+ fish assemblages in the regulated reach versus floodplain reaches; 2) what effect river regulation has on the longitudinal pattern of fish communities along a river; and 3) what habitat features determine fish communities in this drainage.

Study Area

The lower stretches of the Morava and Dyje rivers (Danube basin) were used in this study as their direct connection and the same geographical environment provide ideal conditions for their comparison. The Morava River is 351 km long. The mean annual discharge upstream of the confluence with the Dyje River is 65 m^3s^{-1} and at the confluence of the Danube River is 120 m^3s^{-1} (V l č e k et al. 1984). Originally, this lower reach of the Morava River comprised a river system with a large flood plain that was inundated up to five times every year (K u x 1956).

The first study section of the Morava River comprises a stretch from the confluence with the Dyje River (69.4 r. km), upstream to a weir at 92.8 river km (Fig. 1). In this section the River Morava forms a border between the Czech and the Slovak Republics. For simplicity we used the title "Czech" study stretch. During channelisation (1968–1982), meanders were disconnected from the main channel by levees and now exist as isolated oxbow lakes (Fig. 1). Four weirs (r. km 74.2, 76.9, 79.5, 92.8, max. height 1.4 m) and one rocky chute (r. km 85.4, height 3.1 m) serve to regulate the study stretch of river (23.4 km long). Levees on both banks of the river (max. 20 m from the main channel) isolate the river from its flood plain. The channel width in the study section was 50–60 m, the depth about 1 m during mean discharge (M a t ě j í č e k 1990). The channel shoreline was stabilised by boulders (30–80 cm in diameter), which were partially covered with silt. The river bed comprised sand and gravel. During low summer discharges, shallow gravel-sand bars were exposed along the inner bends of the river, and shallow riffles below weirs. During high discharge, water levels reached bank-side vegetation. Submerged vegetation was completely absent from the main channel, but woody debris and tree roots were relatively dense in some sections.

The second study stretch of the Morava River was investigated from the town of Suchohrad (33.5 r. km) upstream to the River Dyje confluence (69.4 r. km) (Fig. 1). In this section the River Morava forms a border between the Slovak Republic and Austria. For simplification we used the title "Slovak" study stretch. This reach was partially channelised and meanders were isolated during 1837–1964 (H o l č í k 1996), however this river stretch was not interrupted by weirs. A large floodplain area with several backwaters still exists, although partially modified (Fig. 1), as levees were constructed further from the main channel. The channel width varied between 50–60 m with a variable depth (max. 2 m) depending on the discharge. The minimum discharge is controlled by the water power station Nové Mlýny on the Dyje River (40 km upstream of the confluence). Lower summer discharges formed shallow sand-gravel beaches along inner bends though to a lesser extent than in the Czech stretch. The river banks, bed, riparian cover and absence of submergent vegetation were similar to the Czech regulated-channelised stretch.

The Dyje River is the largest tributary of the Morava River (length 209 km). The mean annual discharge above the confluence is 43.8 m^3s^{-1} (M a t ě j í č e k 1990). The study
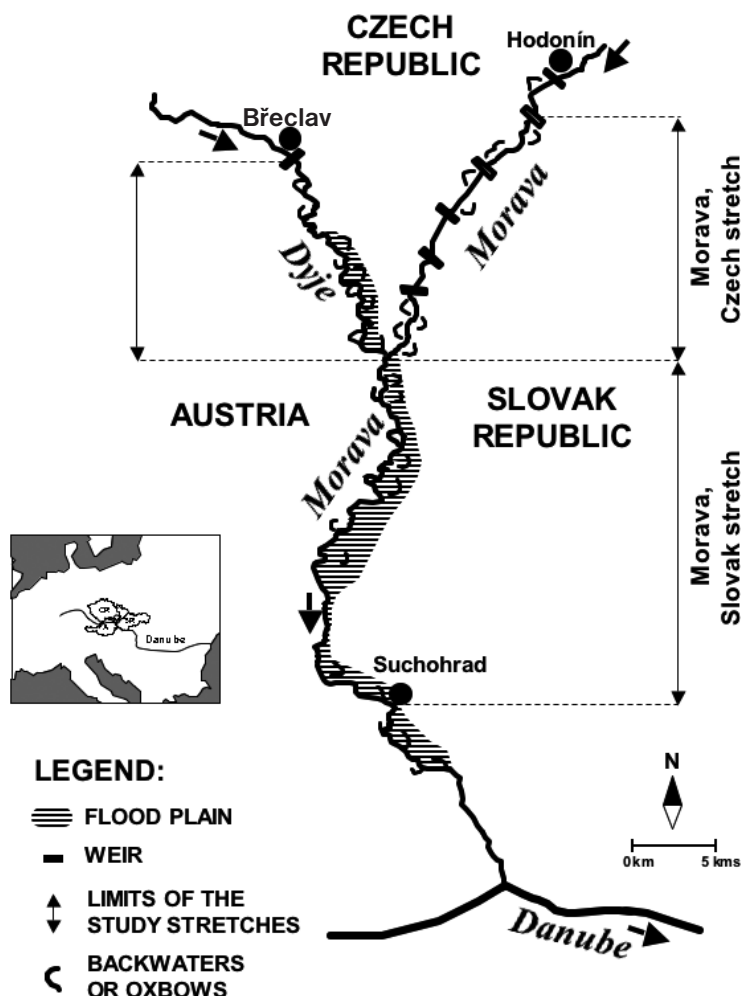
Fig. 1. Map of the study area indicating study stretches of the Morava and Dyje rivers sampled from 2002–2004.

section of the Dyje River (26.7 km long) stretches from the confluence with the Morava River (0 r. km) upstream to the first weir in Břeclav (26.7 r. km) (Fig. 1). The first 18 km of this river forms a border between the Czech Republic and Austria. This section was channelised in 1969–1973, with all meanders isolated, except for remaining two backwaters on the Czech side (Fig. 1) and five on the Austrian side of the river. Levees of the Dyje River were built 200–600 m from the main channel and the area inside the dykes was covered by alluvial meadows and floodplain forest, which are inundated approximately twice each year (discharges exceeding 80–100 m^3s^{-1}). The river has a trapezoidal stream cross-section and is 40 m wide. The shoreline has been stabilised by boulders that were smaller (15–25 cm in diameter) than those in the Morava River. The river banks, bed, riparian cover and absence of submergent vegetation were otherwise similar to the previous stretches.

The main difference between the three adjacent study stretches were as follows: The Czech stretch of the Morava River is completely isolated from its flood plain and fragmented

by five weirs, whereas flood plain and several backwaters remained connected to the Slovak stretch of the Morava River and the Dyje River.

Material and Methods

Juvenile 0+ fish were sampled during daylight in August from 2002–2004. Late summer is the best time of the year for a sampling as the density of 0+ juveniles is relatively stable after high mortalities suffered during the first few months after hatching (M a t h e w s 1971, H o l l a n d 1986), and juveniles have not yet moved to deeper waters for overwintering (S c h l o s s e r & A n g e r m e i e r 1990). In addition, during their first summer, the 0+ fishes of most species use the channel shoreline as a nursery (M i l l s & M a n n 1985), and can be sampled readily. Sampling was carried out by electrofishing (220–240 V, 1.5–2 A, 100 Hz) using the point abundance sampling strategy (P e r s a t & C o p p 1989). This approach was chosen because it provides comparable unit point samples and can be used in a wide range of habitats, especially along stony banks where seining is ineffective (C o p p & P e ň á z 1988). Sampling was carried out using a stratified random method (C o p p 1989) with a total of 20 sampling points at each site. A sampling point is an area around the sampling anode (40 cm in diameter, personal observation), where the electrotaxis and anaesthesia of 0+ juvenile fishes occurs. Each sampling point was approached with care to avoid any fish disturbance. The distance between sampling points was at least 2 m to avoid bias. The activated anode was swiftly immersed into the water at each sampling point and all the fish visually affected were collected immediately with a separate dip net (C o p p & G a r n e r 1995). The 0+ juvenile fish that were caught were overdosed with anaesthetic and fixed in 4% formaldehyde for subsequent analysis in the laboratory. All fish 1+ and older were released back into the river. In the laboratory, fishes were identified to species and categorised into reproductive guilds according to B a l o n (1975) and into ecological guilds according to S c h i e m e r & W a i d b a c h e r (1992).

The study stretches of each river were sampled along the shoreline at 63 sites (Czech stretch of the Morava River), 44 sites (Slovak stretch of the Morava River) and 57 sites (Dyje River) throughout all three years in which the study was conducted. Each site comprised a stretch of approximately 100 m of shoreline with the same representative habitat type. All of the mesohabitat types that were present during the study were randomly sampled, and included boulder bank (rip-rap), sand-gravel beach, steep clay eroded bank, vegetation sites and backwaters. The sites selected for sampling corresponded with the total frequency of each mesohabitat type in the study stretch. According to environmental characteristics, the study sites were divided into particular mesohabitat types using correspondence analysis (CA) (Fig. 2). Un-typical sites (A03 and C03 in the Czech stretch of the Morava River and 21B in the Dyje River) were excluded from subsequent analyses. The list of individual mesohabitat types that were sampled during our study are summarized in Tables 1–3. The beaches were gently sloped; they were formed along the inner bends of the rivers and were visible only during low summer discharges. Beach sites in all the study stretches were characterised by a low occurrence of vegetation and woody debris (Table 1–3). The man-made boulder bank was an uniform bank type that occurred along the shoreline at most of the study stretches. Its only structural variation was the presence of stones and boulders of different sizes and the presence or absence of woody debris. Eroded bank was typified by a steep slope and clay substrate. A relatively high frequency of woody debris was found

along the eroded bank sites in the Czech stretch of the Morava River (Table 1) and woody debris and flooded bank vegetation in the Dyje stretch (Table 3). During periods of elevated discharge, the water level reached the bank-side vegetation above the boulder bank. These sites were designated as vegetation sites. Data from different mesohabitats were analysed
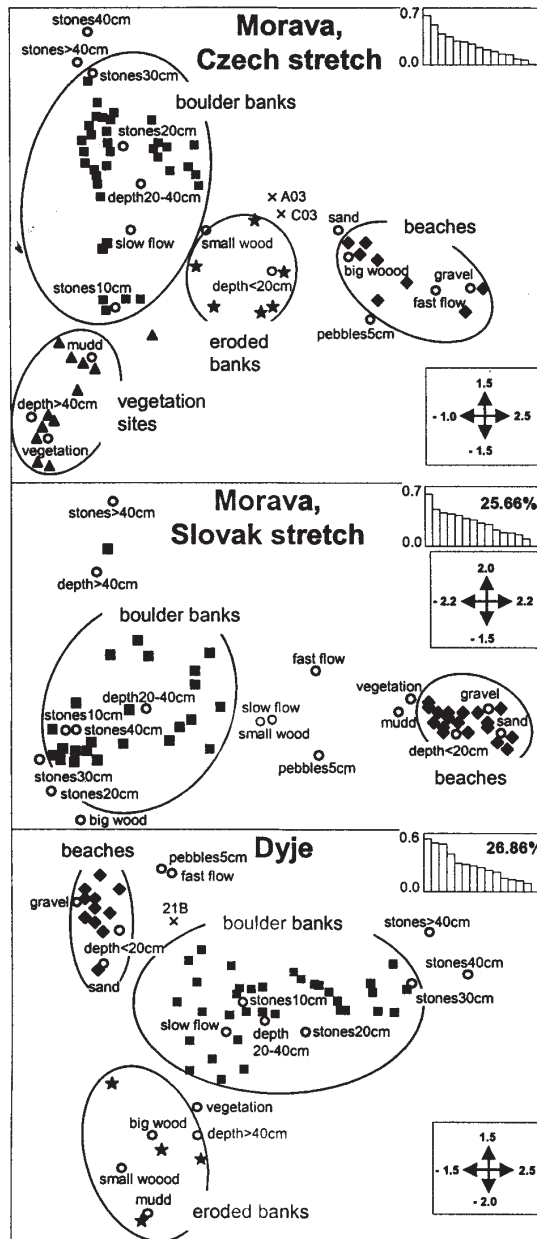

Fig. 2. Correspondence analysis showing the division of individual locations into mesohabitat groups based on their substrate composition and environmental variables (square - boulder bank, diamond - beach, star - eroded bank, triangle - vegetation sites, circle - environmental characteristic, cross - excluded localities).

separately and the data from backwaters were not included in the analyses due to insufficient number of sampled sites. At each sampling point, a series of environmental variables were recorded (water velocity, bottom substrate, water depth, presence of physical structures – macrophytes, branches) and are indicated in Tables 1–3. Each current velocity was given a score according to C o p p (1991): 0 = no current, 1 = slow current, 2 = middle current, 3 = fast current. Each final current velocity was calculated as the mean of these scores and is shown in Tables 1–3.

Statistical analysis

The relative fish abundance (in %), the total relative density (catch per unit effort, CPUE) – the number of individuals per sampling site and the Shannon species diversity index (H´) were calculated. Kendall tau correlation (Kendall τ) was used to compare the similarity of the 0+ juvenile assemblage structure among years (S o k a l & R o h l f 1995). Only species that occurred in two or three seasons in each river were used for comparison of the fish assemblages (no null-null comparison was performed in this data set). Analysis of variance (ANOVA) was used to detect significant differences in fish density and species richness among individual sampling stretches and particular types of habitat. The fish density data were $\log_e$ transformed. Both $\log_e$ transformed fish density and species richness corresponded with a normal (Student) distribution and met the assumptions of ANOVA. An unequal n HSD

Table 1. The characteristics and number of particular mesohabitat types in the Czech study stretch of the Morava River sampled from 2002-2004 (SE=standard error, VEG=percentage of points with flooded bank-side vegetation and woody debris (WD), n=number of localities).

mesohabitat type	mean depth±SE (cm)	mean current±SE (score)	VEG (%)	WD (%)	n
boulder bank	24.38±0.35	0.33±0.02	10.29	8.86	35
beach	15.09±0.69	1.45±0.10	1.25	12.50	8
eroded bank	26.03±0.91	0.90±0.08	6.67	35.00	6
vegetation sites	48.87±1.90	0±0	100.00	0.42	12

Table 2. The characteristics and number of particular mesohabitat types in the Slovak study stretch of the Morava River sampled from 2002-2004 (SE=standard error, VEG= percentage of points with flooded bank-side vegetation and woody debris (WD), n=number of localities).

mesohabitat type	mean depth±SE (cm)	mean current±SE (score)	VEG (%)	WD (%)	n
boulder bank	26.74±0.42	0.72±0.03	2.29	16.25	24
beach	13.62±0.39	0.87±0.04	5.56	8.61	18

Table 3. The characteristics and number of particular mesohabitat types in the study stretch of the Dyje River sampled from 2002-2004 (SE=standard error, VEG= percentage of points with flooded bank-side vegetation and woody debris (WD), n=number of localities).

mesohabitat type	mean depth±SE (cm)	mean current±SE (score)	VEG (%)	WD (%)	n
boulder bank	26.59±0.49	0.53±0.03	29.56	6.03	34
beach	13.76±0.44	1.31±0.07	5.91	6.36	11
eroded bank	59.44±1.37	0.14±0.04	72.50	25.00	4

test was used for *post hoc* comparisons. GLM-b ANOVA (logit link) with *a priori* contrasts were used to find significant differences between the proportion of a particular reproductive and ecological guilds within the study stretches. Data analyses and plots were performed using Statistica 6 and R 2.0.1.

Results

0+ fish composition

A total of 5165 0+ juvenile fishes, comprising 23 species (18–21 among years), were caught in the Czech stretch of the Morava River during three years (Table 4). Altogether, 1232 0+ fish specimens, comprising 22 species (16–18 in individual years), were caught in the Slovak stretch of the Morava River during three sampling seasons (Table 4). A total of 1924 0+ juvenile fish, including 25 species (16–21 in individual years), were collected in the Dyje River (Table 4). The mean number of species at all sites in the Czech stretch of the Morava River (mean = 6.56 species, S.E. = 0.29, n = 63) was significantly higher (ANOVA, $df_{2,16}$, P<0.001, unequal n HSD tests for *post hoc* comparisons) than in the other two study stretches (mean = 4.70 and 5.11 species, S.E. = 0.36 and 0.41, n = 56 and 44 in Dyje River and Slovak stretch of the Morava River, respectively). The assemblage structure did not differ among years in all three study stretches (Czech stretch of the Morava River: $\tau = 0.50$–0.63, P<0.005; Slovak stretch of the Morava River: $\tau = 0.35$–0.49, P<0.05; Dyje River: $\tau = 0.37$–0.52, P<0.01); data for all the three years were subsequently pooled for further analyses.

The Shannon index of species diversity ranged from 1.41 to 1.83 among the years in the Czech stretch of the Morava River. In this stretch, the total catch was dominated by bitterling *Rhodeus sericeus* (Pallas), roach *Rutilus rutilus* (L.), chub *Leuciscus cephalus* (L.) and bleak *Alburnus alburnus* (L.), which formed more than 80% of the total catch in the three years (Table 4). In the Slovak stretch of the Morava River bleak, barbel *Barbus barbus* (L.) and roach formed >50% of the 0+ fish assemblage and asp *Aspius aspius* (L.), chub, dace *Leuciscus leuciscus* (L.), ide *Leuciscus idus* (L.) and tubenose goby *Proterorhinus marmoratus* (Pallas) represented >5% (Table 4). The Shannon index of species diversity ranged from 2.06 to 2.23 over the study. In the Dyje River, the Shannon diversity indices were similar among years (range 2.02–2.08) and four dominant species, ide, bleak, tubenose goby and roach formed >60% of the total catch (Table 4).

When comparing particular mesohabitat types of the floodplain stretches (Dyje River and Slovak stretch of the Morava River, respectively), the species richness was significantly higher (ANOVA, $df_{2,46}$, P<0.05 and $df_{2,46}$, P<0.05) at the beach sites (mean = 5.91 and 6.83 species, S.E. = 0.52 and 0.51, n = 11 and 18) than at the boulder bank sites (mean = 3.68 and 3.79 species, S.E. = 0.46 and 0.46, n = 34 and 24) (Fig. 3). In the regulated-channelised stretch, the number of species was significantly higher (ANOVA, $df_{3,57}$, P = 0.57) at the vegetation sites (mean = 8.08 species, S.E. = 0.80, n = 12) than at the eroded bank sites (mean = 5.50 species, S.E. = 0.61, n = 6) (Fig. 3), no significant differences were found among other mesohabitat types.

Relative density

The total relative density of 0+ fish from all sites was significantly higher (ANOVA, $F_{2,161}$, P<0.001) in the regulated-channelised stretch of the Morava River (mean = 81.98 individuals;

Table 4. List of 0+ fish species caught and their relative abundance (%) in the study stretches of the rivers Morava (CM=Czech stretch, SM=Slovak stretch) and Dyje (D) sampled from 2002–2004. Reproductive guilds (R.G.) after B a l o n (1975) and ecological guilds (E.G.) after S c h i e m e r & W a i d b a c h e r (1992) are indicated (Ph=phytophilic, Ph-Li=phyto-lithophilic, Li=lithophilic, Ps=psammophilic, Li-Pe=litho-pelagophilic, Os=ostracophilic and Sp=speleophilic species; E=eurytopic, L=limnophilic, R-A=rheophilic A and R-B=rheophilic B species).

Scientific name	R.G.	E.G.	CM02	CM03	CM04	SM02	SM03	SM04	D02	D03	D04	CM02-04	SM02-04	D02-04
Esocidae														
Esox lucius	Ph	E	0.1	0	0	0	0	1.9	0	0.5	0.2	<0.1	0.5	0.3
Cyprinidae														
Rutilus rutilus	Ph-Li	E	36.5	18.4	3.3	19.1	7.0	4.3	32.7	8.7	1.4	19.7	10.6	13.3
Leuciscus leuciscus	Ph-Li	R-A	1.6	1.0	0.1	12.1	7.9	2.2	0.5	0.1	0	0.9	7.8	0.2
Leuciscus cephalus	Li	R-A	13.9	15.9	12.5	10.5	7.7	4.0	2.9	2.6	2.1	13.9	7.7	2.3
Leuciscus idus	Ph-Li	R-B	0.1	0.4	0.1	2.7	14.3	0.3	6.8	36.6	3.3	0.2	6.5	17.1
Scardinius erythrophthalmus	Ph	L	0	0	0	0.7	0	0	0.7	0.7	3.2	0	0.2	1.5
Aspius aspius	Li	R-B	3.1	2.0	0.5	4.6	14.3	1.2	5.7	2.2	0.6	1.8	7.4	2.7
Tinca tinca	Ph	L	0	0	0	0	0	0	0	0.1	0	0	0	0.1
Chondrostoma nasus	Li	R-A	1.9	0.8	1.5	1.6	7.9	0	0	0	0.2	1.5	3.6	0.1
Pseudorasbora parva	Ph-Li	E	0.7	0.4	0	1.6	0	0.6	0	0.3	0	0.4	0.7	0.1
Gobio gobio	Ps	R-B	1.0	1.3	3.1	0	0	0.3	0	0	0	1.9	0.1	0
Gobio albipinnatus	Ps	R-A	0.9	1.5	0.8	0	0	0	0	0	0.2	1.0	0	0.1
Barbus barbus	Li	R-A	2.5	4.5	9.7	8.0	6.2	24.2	0.2	1.5	18.4	5.7	11.5	6.7
Alburnus alburnus	Ph-Li	E	25.2	1.9	4.2	33.0	23.9	27.9	7.3	11.3	29.6	11.6	28.2	16.1
Abramis bjoerkna	Ph	E	0.4	0.1	0.7	1.4	0.4	8.7	5.6	1.0	16.9	0.4	2.9	7.5
Abramis brama	Ph-Li	E	0.6	0.2	0.1	0.2	0.2	0	0.7	0.4	0.3	0.3	0.2	0.5
Rhodeus sericeus	Os	L	10.4	48.1	61.6	1.4	0.6	11.8	4.8	9.7	12.7	38.8	3.8	9.3
Carassius gibelio	Ph	E	0.1	0.1	0	0	0.9	0.9	0.2	5.0	0.5	<0.1	0.6	2.1
Cyprinus carpio	Ph	E	0.1	0	0.1	0	0.2	0	0	0.3	0	0.1	0.1	0.1
Balitoridae														
Barbatula barbatula	Ps	R-A	0	0	0.1	0	0	0	0	0	0	<0.1	0	0
Cobitidae														
Cobitis elongatoides	Ph	R-A	0	0	0	0	0	0	0	0	0.2	0	0	0.1
Siluridae														
Silurus glanis	Ph	E	0.1	0.2	0.2	0.5	0	0	0.4	0.3	0.5	0.1	0.2	0.4

	Guild 1	Guild 2												
Gadidae														
Lota lota	Li-Pe	R-B	0	0	0	0.2	0	0	0	0.3	0	0	0.1	0.1
Percidae														
Sander lucioperca	Ph	E	0.2	0	0	0.7	0.2	0.3	11.1	0	0	0.1	0.4	3.2
Perca fluviatilis	Ph-Li	E	0.4	0	0.1	0.7	0.9	1.2	1.8	2.0	1.4	0.2	0.9	1.8
Zingel streber	Li	R-A	0	0.2	0	0	0	0	0	0.1	0	0.1	0	0.1
Gobiidae														
Proterorhinus marmoratus	Sp	E	0.5	3.2	1.6	1.4	7.5	10.2	18.6	16.4	8.3	1.6	6.0	14.4
Total number of species			21	18	18	18	16	16	16	21	18	23	22	25
CPUE (ind./site)			93.57	70.83	91.71	31.43	31.27	21.53	34.94	35.05	31.45	81.98	28.00	34.36
H`			1.83	1.65	1.41	2.08	2.23	2.06	2.08	2.04	2.02	1.85	2.34	2.37

S.E. = 8.42; n = 63) than in the other two study stretches (mean = 34.36 and 28.00 individuals; S.E. = 4.20 and 4.11; n = 56 and 44).

When comparing mesohabitat types of the floodplain stretches of the Dyje River and Slovak stretch of the Morava River, respectively, the total relative density was significantly higher (ANOVA, $df_{2,46}$, $P<0.05$ and $df_{1,40}$, $P<0.001$) at the beaches (mean = 46.45 and 49.94 individuals, S.E. = 6.58 and 6.69, n = 11 and 18) than along the boulder banks (mean = 24.10 and 11.92 individuals, S.E. = 4.76 and 1.77, n = 34 and 24) (Fig. 4). In the Czech stretch of the Morava River, the total relative density of fish was significantly higher (ANOVA, $df_{3,57}$, $P<0.001$) at the vegetation sites (mean = 144.25 individuals, S.E. = 22.99, n = 12) than at the eroded bank sites (mean = 22.00 ind., S.E. = 3.06, n = 6) (Fig. 4). No significant differences were found among other mesohabitat types.

Reproductive and ecological guilds

In the Czech stretch of the Morava River, ostracophilic (represented by bitterling), phyto-lithophilic and lithophilic species dominated significantly (GLM-b ANOVA, $P<0.05$) (Fig. 5). Phyto-lithophilic and lithophilic species dominated significantly ($P<0.05$) in the Slovak part of the Morava River. Other reproductive guilds in these two study stretches were present in low numbers. In the Dyje River, phyto-lithophils dominated significantly ($P<0.05$). The lowest proportion of lithophilic species and the highest proportion of speleophilic (represented by the tubenose goby) and phytophilic species was recorded in this stretch when compared to the other two study stretches ($P<0.05$) (Fig. 5). Psammophils (represented by the gudgeons, *Gobio gobio* (L.) and *Gobio albipinnatus* Lukasch) were present in the regulated-channelised stretch and almost absent in the other two study stretches.

In ecological terms, eurytopic species dominated (GLM-b ANOVA, $P<0.05$) in the Dyje River and in the Slovak part of the Morava River (Fig. 6). Limnophilic species were presented rarely in these two stretches in comparison with the Czech part of the Morava River.
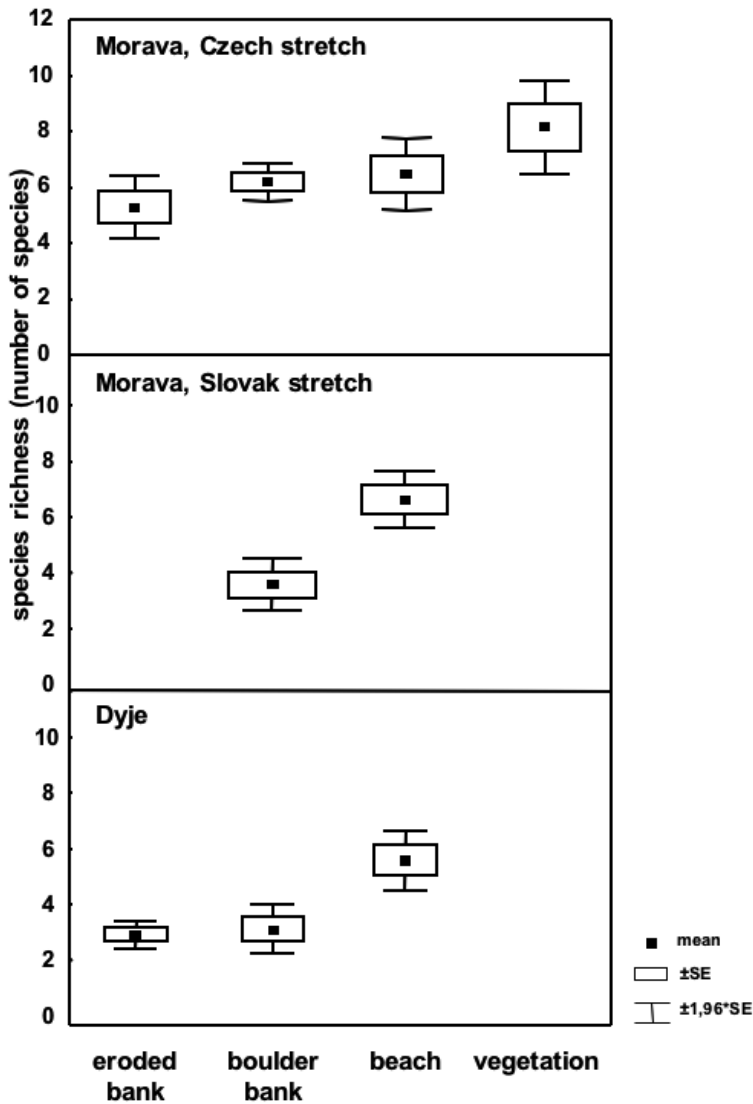
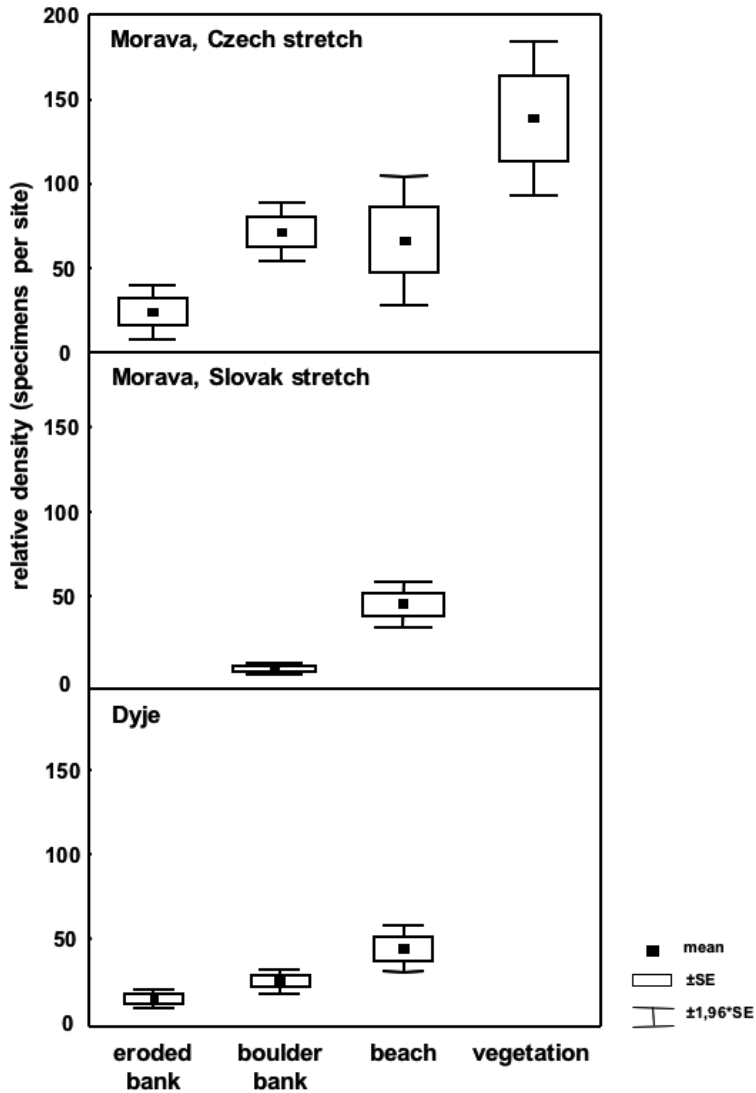**Fig. 3.** Number of 0+ fish species (median, quartiles, range) caught at the study sites (according to nursery habitat type) in three study stretches of the Morava and Dyje rivers from 2002–2004.

Discussion

The results of this study indicate the successful natural reproduction of 27 species from a total of 44 occurring in the study area (J u r a j d a & P e ň á z 1994, L u s k et al. 2001). The composition of the ichthyofauna of the River Morava has changed considerably during the last century. K u x (1956), investigating the adult fish assemblages in the Morava River before its regulation and channelisation, mentioned a high abundance of barbel, nase *Chondrostoma nasus* L., vimba *Vimba vimba* (L.), riffle minnow *Alburnoides bipunctatus* (Bloch) and ide. The populations of these previously common rheophils have severely declined along

Fig. 4. Total relative density of 0+ fish species (median, quartiles, range) caught at the study sites (according to nursery habitat type) in three study stretches of the Morava and Dyje rivers from 2002–2004.

the entire course of the river (J u r a j d a & P e ň á z 1994). At present, only barbel and chub successfully reproduce there. Populations of these two species seem to have been less affected by river modification than other rheophilic species (nase, vimba, riffle minnow). In contrast to other highly modified rivers in Europe (e.g. B i s c h o f f & W o l t e r 2001, A r l i n g h a u s et al. 2002), the studied regulated-channelised stretch is not used for navigation and during the summer low discharges, shallow, slow-flowing nurseries suitable for rheophils are formed. Differently modified rivers with a steep bank slope, stable high depth and negligible flow velocity provide only a limited number of suitable nursery habitats for fish, and in that case the 0+ assemblages are dominated by roach and perch *Perca fluviatilis* L.

Fig. 5. Relative proportion (mean, S.E., in %) of reproductive guilds of 0+ juvenile fish in the study stretches of the Morava and Dyje rivers from 2002–2004.

(B i s c h o f f & W o l t e r 2001, A r l i n g h a u s et al. 2002). It is not clear, why in the free flowing floodplain stretches the proportion of rheophilic species was not higher than in the regulated-channelised stretch. In the case of nase and vimba, it could be influenced by a low density of the parental generation (S p i n d l e r et al. 1992, L u s k 1995).

The absence of phytophilous 0+ fishes in the regulated stretch clearly reflects the absence of inundation that is important during reproduction for these species. Adult pike *Esox lucius* L., carp *Cyprinus carpio* L. and tench *Tinca tinca* (L.) do inhabit the regulated channel, though only due to intensive stocking by angling clubs, since natural reproduction does not occur. Rare occurrence of 0+ fish of some species could originate from upstream sites or the floodplain waterbodies and their accidental or passive transport (drift) to the main channel. For example, common bream *Abramis brama* (L.) and silver bream *Abramis bjoerkna* (L.) spawn and successfully develop during their first year of life in floodplain lentic waterbodies (N e u m a n n et al. 1996, F r e y h o f 1998) and in the following years move to the main channel during the flood. In the case of the Slovak floodplain stretch of the Morava River these two species form up to 75% of the adult fish assemblages (S p i n d l e r et al. 1992) but they are poorly represented in the 0+ fish assemblage. Common bream also spawn in the Czech stretch of the Morava River and in Dyje River, but drift downstream during their larval stages (R e i c h a r d et al. 2002, 2004) and it was almost absent in the 0+ fish assemblages in the summer samples. Also, other phytophilic and phyto-lithophilic species use floodplain waters, if available, as their nursery and their occurrence in the main channel is rare (J u r a j d a et al. 2004, Table 4).
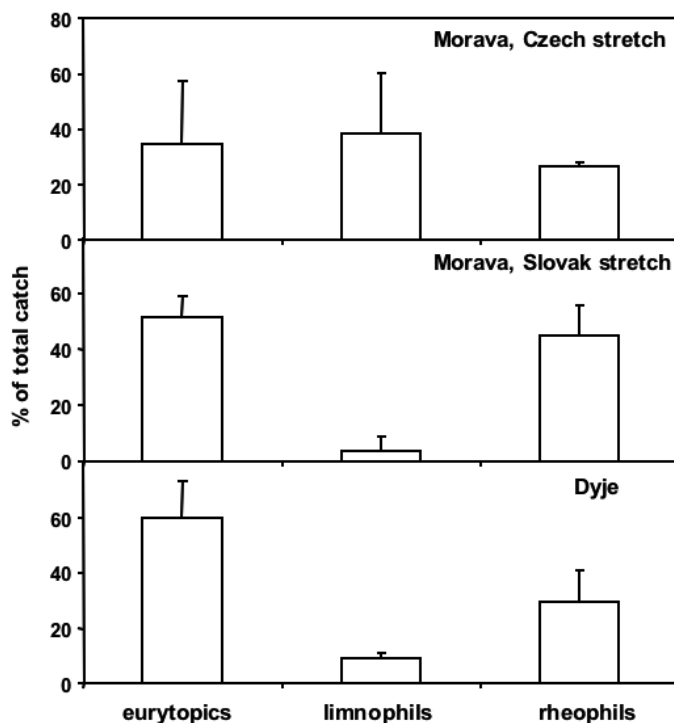
Fig. 6. Relative proportion (mean, S.E., in %) of ecological guilds of 0+ juvenile fish in the study stretches of the Morava and Dyje rivers from 2002–2004.

The introduction of submergent macrophytes could have beneficial effect for phytophils in the main channel. L a n g l e r & S m i t h (2001) demonstrated that introduction of shallow water areas combined with macrophytes significantly increased the abundance and diversity of 0+ phytophlic spawners. The importance of refugia to 0+ group fishes in lotic environment stems largely from protection against high current velocities (S c h e a f e r & N i c k u m 1986, 1997).

Some species have adapted to the conditions following river modification and form abundant and stable populations. These species reproduce successfully and form a major part of the 0+ fish community. A species composition characterised by high densities of a small number of species and low densities of specialist species is known also from other regulated lowland rivers (C o p p 1990, B i s c h o f f & W o l t e r 2001, A r l i n g h a u s et al. 2002). A dominance of tolerant species suggests a disadvantage to specialist species in the modified stretches, in terms of their reproductive success and recruitment.

The high abundance of 0+ bitterling was noted in previous studies (J u r a j d a 1995) and it is probably supported by slower current velocity in the regulated-channelised stretch and abundance of mussels. The reason for a lower abundance of chub and almost absence of gudgeons in the non-regulated stretches is not so clear. In the case of the Dyje River, we suppose that the small size of boulders, used for bank stabilisation, are not a suitable shelter for these fishes, except for small specimens of the bottom dwelling tubenose goby. Other common species in the Dyje River inhabited the beach sites (bleak, ide and roach) rather than the boulder bank sites.

The relative composition of the 0+ assemblages in any particular stretch did not differ throughout the three years of study. As expected, the lowest variability was documented in the most uniform regulated-channelised stretch of the Morava River compared with the floodplain stretches with more heterogeneous habitat. On the other hand, the highest density was recorded in the regulated-channelised stretch. One explanation could be that the 0+ fish may not use oxbows (J u r a j d a et al. 1998a, J u r a j d a et al. 2001) as their nursery and, therefore, are concentrated only in the main channel margin. In spite of all the habitat river modifications, the Czech stretch of the Morava River appears to provide sufficient mesohabitat and adequate conditions for fish recruitment.

B a i n & F i n n (1988) found that water depth and current velocity are the most important habitat variables affecting fish distribution, and that shallow and slow-flowing habitat was used only by small and young fish. This finding also corresponds to the present study and to the observation of S c h i e m e r et al. (1991) who also showed that high population densities and high species diversity of 0+ fishes is found along shallow sand-gravel beaches and that low fish densities are associated with linear rip-rap, constructed from large rock blocks. In the present study, the relative density in the Czech regulated-channelised stretch was almost the same as those at the beach sites. The 0+ fish assemblage was more abundant at the boulder bank sites of the regulated-channelised stretch than in the Slovak floodplain stretch, even though the stone size of rip-rap was identical. The eroded steep bank sites appeared to be avoided by most of the 0+ fishes in both stretches.

In contrast, a high density of 0+ fish was registered along the vegetated sites of the channel, where the water level reached the bank-side vegetation (mainly grass *Phalaris arundinacea*) during periods of high discharge. During these periods, shallow areas are not affected much by the rapid water flow and, therefore, may serve as refuges for young fish (L o b b & O r t h 1991).

Despite the proximity of the study stretches, pronounced differences in the 0+ fish assemblages were documented. The recruitment of fishes in the regulated-channelised Morava River was less variable and indicated successful reproduction for only a limited number of species, but with the highest values of CPUE. Reproduction of fish in floodplain stretches took place mainly in the floodplain waterbodies and the 0+ phytophils and phyto-lithophils remained there during their first year of life and entered the main river channel only rarely (J u r a j d a et al. 2001). The relatively low proportion of rheophils in the 0+ assemblage, even in the free-flowing stretches, remains unanswered.

Both Morava and Dyje rivers are not used for navigation and, therefore, a variable water discharge is allowed to occur, which creates more habitat variability. Where bank-side vegetation is flooded during high discharges, and a low water level uncovers sand-gravel beaches, our results suggest these habitats are suitable for, and to a large extent utilized by, the 0+ juvenile fish assemblage.

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