Immediate Impact of an Extensive Summer Flood on the Adult Fish Assemblage of a Channelized Lowland River

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ABSTRACT

The fish community of a channelized stretch of a lowland floodplain River Morava (Danube basin) was surveyed before and after an exceptionally extensive flood in July 1997. Water discharge peaked at 2,000% of long-term average and discharge >1,000 % lasted for 20 days. Electrofishing survey along the bank in three inter-weir reaches revealed 26 species, with the same species (chub *Leuciscus cephalus*, gudgeon *Gobio gobio*) dominating before and after the flood. The flood had a minor effect on the assemblage structure. The total density of fish was not significantly different before and immediately after the flood. The largest decline was observed for pelagic species (e.g. bleak *Alburnus alburnus*, roach *Rutilus rutilus*) and benthic species (e.g. barbel *Barbus barbus*). The overall gudgeon abundance did not decrease significantly after the flood, though length-frequency distribution revealed a decrease in abundance of one-year-old individuals. The flood had no effect on abundance of chub and burbot (*Lota lota*) but increased the abundance of perch (*Perca fluviatilis*).

INTRODUCTION

Periodic flooding is critical for maintaining ecological integrity and biological productivity of floodplain rivers (Rasmussen 1996, Poff et al. 1997). In river systems, extensive floods are primary sources of environmental variability and disturbance. Disturbances arise from a broad array of physical and biological effects which vary in their size, frequency and intensity (Michener 1998). An important dichotomy exists between nonerosive (laterally expansive) and erosive floods and their effects on stream fishes (Mathews 1998). Erosive floods are characterized by fast-moving, turbulent water with the power to entrain and move substrates, often with dramatic destructive impacts on the physical habitat of the channel and riparian zone (Ward and Stanford 1955, Grimm and Fischer 1989, Matthews 1998). Erosive floods can reduce the density of fish populations (Seegrist and Gard 1972). Nonerosive floods in lowland rivers typically inundate large areas of terrestrial habitat enabling fish to move into flooded areas to feed, with some species showing greater reproductive output in flood years (Ross and Baker 1983, Mathews 1998). The immediate effect of floods on individual fish seem largely to depend on fish size, life stage and on habitat complexity (Pearsons et al. 1992, Lobón-Cervia 1996). Floods can wash out larval and juvenile fish (Harvey 1987, Bishoff and Wolter 2001), while having little impact on adults (John 1964, Hoopes 1975), particularly in complex habitats (Pearsons et al. 1992, Mathews 1998). There is evidence that both the timing of floods and the type of river habitat affected can influence the impact on fish assemblages (Kushlan 1976, Schlosser 1982, Mathews 1998).

The importance of nonerosive floods for fish populations is well documented for tropical regions (e.g., Lowe-McConnell 1975, Goulding 1980, Welcomme 1985) but less documented in temperate zones (Ross and Baker 1983, Reimer 1991, Knight and Bain 1993). Most information regarding the immediate impact of floods on fish in temperate

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zones comes from small coldwater streams (e.g., Gerking 1950, Seegrist and Gard 1972, Hoopes 1975, Lobón-Cervia 1996) and, more rarely, from lowland medium-sized streams (Ross and Baker 1983, Mathews 1986). Historically, spring floods have played an important role for fish reproduction in lowland temperate rivers (Kux 1956), where fish migrate into inundated meadows to spawn.

In this study, we used an exceptional opportunity to quantify the effects of a long-term summer flood on the fish assemblage in a strongly channelized stretch of a lowland river that naturally flooded a large inundation area in the past. In early July 1997, discharge of the lower River Morava increased rapidly and exceeded 2,000% of the long-term average (about 45 m^3/s). This rapid increase was due to widespread precipitation and the complete isolation of the flood plain from the river channel, with flood-protection dikes having been constructed close to the channel banks. The flood was the most extensive flood ever recorded in the River Morava (Soukalová 1998) and occurred at a time when the seasonal minimum discharge normally occurs. A discharge of more than 1,000% of the long-term average lasted for 20 days. However, dikes were not overtopped in the study stretch and the flood had an erosive character rather than non-erosive. The fast-moving water had the power to entrain and move sand, although no dramatic destruction of the channel or riparian zone was observed.

The study area was a 19 km stretch of the River Morava, a large tributary of the River Danube, from a concrete weir at river km 74.1 (distance from the confluence with the River Danube) to a sleeve weir at river km 92.8 (Fig. 1). Within this stretch of the river there are two additional weirs that separate the river into three similar and uniform habitats (Matějíček 1981), which we identified as reaches I, II , and III. The river bottom was uniformly flat and predominately of sand and gravel, with silting taking place in some areas, particularly above the weirs. In this study, we compared species richness, assemblage structure, fish size and the relative density of adult fish (one-year-old and older) in the littoral zone before and immediately after the flood event.

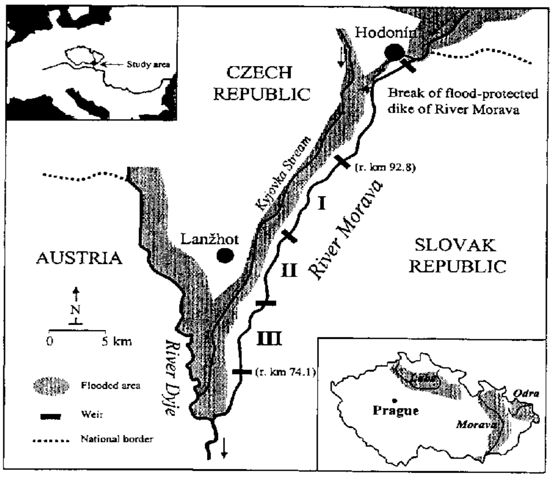

Figure 1. Map of the lower course of the River Morava with the study stretch (river km 74.1- 92.8) and study reaches (I, II, III) indicated. Map of the Czech Republic with flooded areas in Morava, Odra and Labe basins in summer 1997 (bottom right). Flooded areas outside the Czech Republic are not indicated.

METHODS AND MATERIAL

Fish were collected during daylight hours in the first half of June (before the flood) and in the middle of October (after the flood), during periods of comparable discharge. Sampling was undertaken by continuous electrofishing (220 V, 1.5-2 A, 1000 W, 100 Hz) from a boat along the shoreline, and focused on the near-shore zone where most fish occurred (Mann and Penczak 1984) and where our sampling method was most efficient.

A section of about 150-200 m was sampled upstream at every river km marker within the study stretch. The same eighteen sites were sampled before and after the flood if possible. Captured fish were stored in a large container in the boat. After sampling was completed at each section, all fish were identified, measured (SL), and released. The relative density (catch-per-unit-effort, CPUE), was expressed as the number of individuals per 100 m of sampled shoreline, with a standard width (3.5 m) of the sampled area.

The adult (one-year-old and older) fish assemblage did not change seasonally in the study stretches separated by weirs in years without a flood (Jurajda and Peňáz 1994, Jurajda et al. 1998). Interannual changes in fish community in the study river are mainly influenced by the efficiency of natural reproduction in a particular year (Jurajda 1995). Thus, 0+ juvenile fish were not included in analyses of the October sampling in the present study.

The rarefaction method was used to compare species richness before and following the flood, because sampling effort varied between seasons. This method standardizes samples by estimating the number of species expected in a sub-sample of individuals randomly selected from a larger sample. As the relationship between species richness and sampling effort is not linear, this method compares samples of unequal sampling effort better than comparison of the number of species per number of individuals and other indices (Magurran 1983). A Kendall coefficient of rank correlation was used to compare similarity in community structure before and after the flood. The fourteen most dominant species were used in the analysis to eliminate the effects of rare species with our unequal sampling design. Quantitative data (CPUE) were ln (x+1) transformed and subjected to two-way factorial ANOVA, with season (pre-flood, post-flood) and river stretch (I, II, and III) as effects.

RESULTS

A total of 986 and 423 fish belonging to 26 species from six families were collected in spring and autumn respectively (Table 1). The total number of fish species caught was higher in the spring (22 before flood) than in autumn (18 after flood). However, when sampling effort was taken into account, species richness was not different before and after the flood (rarefaction method, $P > 0.05$, Fig. 2). After the flood we did not catch common bream (*Abramis brama*), nor seven other species (dace *Leuciscus leuciscus*, asp *Aspius aspius*, tench *Tinca tinca*, nase *Chondrostoma nasus*, carp *Cyprinus carpio*, stone loach *Barbatula barbatula* and spined loach *Cobitis elongatoides*) with low abundance before the flood. However, four new species were collected following the flood (pike *Esox lucius*, blue bream *Abramis ballerus*, zander *Stizostedion lucioperca*, and ruffe *Gymnocephalus cernuus*), although at low abundance.

Community structure was not significantly different before and after the flood on the basis of the 14 dominant species (Kendal τ, $\tau = 0.402$, $P < 0.045$). Chub (*Leuciscus cephalus*) and gudgeon (*Gobio gobio*) were the most abundant species both before and after the flood (Fig. 3).

The relative density (CPUE) of all fishes pooled was not significantly different before (mean $\pm$ SD = 29.625.7 inds/100m, n = 18) and after the flood (mean $\pm$ SD = 18.0 $\pm$ 14.4, n = 18) (ANOVA, F=2.5, *df* = 1.30, P = 0.125). However, a significant interaction between season and reach (F = 6.8, *df* = 2.30, P = 0.004) showed that a decrease in CPUE occurred in reach I (Fig. 4). Relative densities of the dominant species (chub and gudgeon) did not decrease following the flood, though the interaction effect on their density was similar to that for the total catch, with chub density decreasing in reach I (Fig. 5). Perch was the only species whose density increased after the flood. In contrast, the density of barbel (*Barbus barbus*) and bitterling (*Rhodeus amarus*) decreased following the flood, and the abundance of bleak (*Alburnus alburnus*) and roach both decreased substantially.

The mean body size of chub in all study stretches before the flood was significantly smaller (mean = 83.8 mm, n = 258) than after the flood (mean = 111.6 mm, n = 164; Kolmogorov-Smirnov test, Z = 6.08, P < 0.001). Similarly, the mean body size of gudgeon before the flood was significantly smaller (mean = 51.7 mm, n = 254) than after the flood (mean = 85.4 mm, n = 83; Z = 6.47, P <0.001).

Table 1. Relative abundance (%) of fish species recorded in the channelized stretch of the River Morava in June (before flooding) and October (after flooding) 1997.

Scientific name	Common name	Before flooding	After flooding
Esocidae			
Esox lucius	pike	-	0.5
Cyprinidae			
Rutilus rutilus	roach	9.1	0.9
Leuciscus leuciscus	dace	0.4	-
Leuciscus cephalus	chub	26.5	41.4
Leuciscus idus	ide	0.2	0.2
Aspius aspius	asp	0.1	-
Tinca tinca	tench	0.1	-
Chondrostoma nasus	nase	0.2	-
Pseudorasbora parva	Japanese minnow	1.9	1.2
Gobio gobio	gudgeon	25.9	20.3
Gobio albipinnatus	whitefin gudgeon	1.8	5.4
Barbus barbus	barbel	5.2	1.2
Alburnus alburnus	bleak	11.0	0.9
Blicca bjoerkna	white bream	1.1	0.2
Abramis brama	common bream	1.6	-
Abramis ballerus	blue bream	-	0.5
Rhodeus amarus	bitterling	7.9	5.0
Carassius auratus gibelio	goldfish	1.4	3.1
Cyprinus carpio	common carp	0.2	-
Balitoridae			
Barbatula barbatula	stone loach	0.1	-
Cobitidae			
Cobitis elongatoides	spined loach	0.2	-
Siluridae			
Silurus glanis	wells	0.3	0.2
Gadidae			
Lota lota	burbot	2.7	4.7
Percidae			
Perca fluviatilis	perch	2.0	11.3
Stizostedion lucioperca	zander	-	2.1
Gymnocephalus cernuus	ruffe	-	0.7

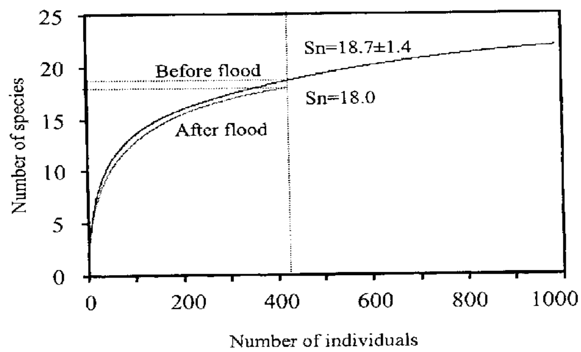

Figure 2. Rarefaction curves of fish species richness in the littoral zone of the River Morava before and after the flood. Expected number of species (Sn ± standard deviation) for 423 individuals caught before the flood are shown.

DISCUSSION

The extensive summer flood on the River Morava offered a unique opportunity to evaluate the immediate response of a fish assemblage in a channelized lowland river to a substantial disturbance. Our results show that the species richness of the fish assemblage did not decrease significantly following the flood. The differences in individual species occurrence before and after the flood were almost exclusively caused by rare fish species. The capture of more rare fish species before the flood was affected by unequal sampling effort rather than the flood itself, as confirmed by the results of the rarefaction analysis.

Although the flood in our study stretch was not of an erosive character, with a bank structure damage (Grimm and Fisher 1989, Ward and Stanford 1955, Matthews 1998), large quantities of sand from the river bottom were displaced and the main channel habitat was heavily impacted by a high current velocity. These effects may decrease fish

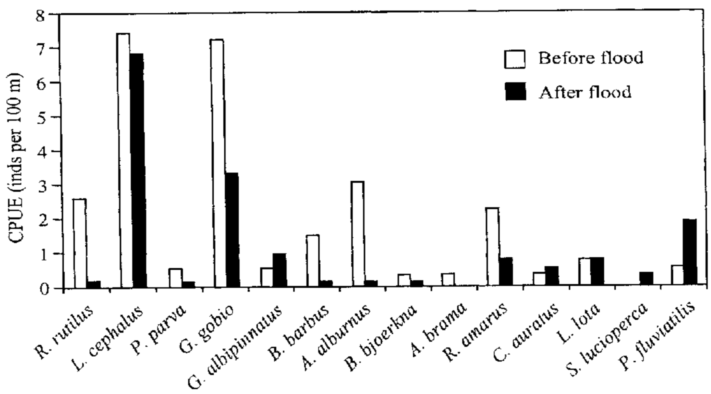

Figure 3. Comparison of CPUE of fish species before and after the flood in the channelized study stretch of the River Morava in 1997.

abundance, especially in channel sections without backwaters or tributaries, which is the case for the study stretch. Fish in flash-flood prone streams have behavioral responses that facilitate survival. During erosive floods with high discharges, fish remain close to submerged structures (Meffe 1984), seek low-velocity stream margins (Minckley and Meffe 1987, Scrimgeour and Winterbourn 1987, Matheney and Rabeni 1995, Matthews 1998), tributaries (Paloumpis 1958), or backwater pools (Scrimgeour and Winterbourn 1987), and are able to remain in a given reach of river even during a major flood (Matthews 1998). In the present study, fish probably used submerged refuges along the channel margin and spaces between boulders on the submerged shoreline, since no tributary or backwaters were present.

It has been documented that high river flow rates can initiate upstream migration in fishes (Gerking 1950, Trépanier et al. 1996). Potentially, Danubian fishes were able to use high water levels (more than 4 m above the top of the weirs) to move upstream. However, of the four species caught exclusively after the flood, only blue bream is a typical Danubian migrant that originated from downstream (Jurajda et al. 1998). During fish sampling two weeks after post-flood sampling for the present study, another Danubian migrant, yellow pope (*Gymnocephalus schraetser*) was recorded in the study stretch upstream of the two lowermost weirs. However, in general, we did not recognize significant upstream movement.

Fish assemblage structure was not significantly different before and after the flood and largely corresponded with previous studies (e.g., Jurajda and Peňáz 1994). Harrell (1978) found that the species dominant before a flood also dominated after the flood and he hypothesized that successful species were well adapted to the flood-prone environment. He suggested that the long-term effect of floods on structuring fish assemblages might be minimal. Similarly, Gerking (1950) observed that most individuals may remain in place during flood events in small streams, with floods having only a marginal effect on the fish assemblage as a whole. The fish assemblage in the study river is expected to be adapted to floods, but it is notable that they seem able to cope with high discharges even after the river had been heavily channelized.

The mean body size of dominant fishes significantly increased after the flood, but it is difficult to separate the effects of the flood from the effect of fish growth during to four-months between sampling periods. However, the difference in the mean body size of gudgeon (34 mm) appeared too large for a four month growth increment, compared to the

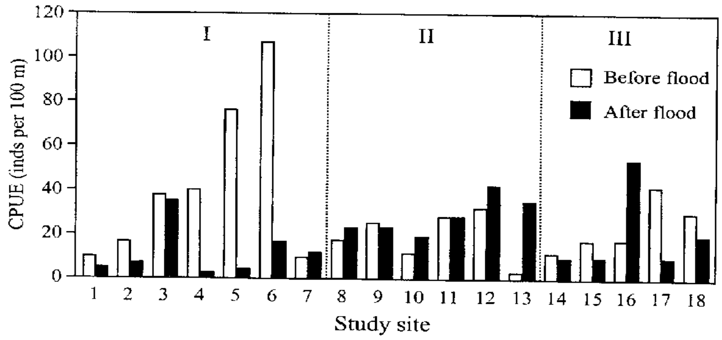

Figure 4. Comparison of CPUE of all fish species at 18 sites before and after the flood within the three reaches between weirs (indicated by dotted lines) in the study stretch of the River Morava in 1997.

mean annual growth increment of 30 mm in comparable habitats across the Czech Republic (Hanel 1992). This result suggests that smaller one-year-old fish may have been partly eliminated by the flood.

Overall abundance of fish from all sites was not different before and after the flood. Comparing the three study reaches before and after flooding, we found higher CPUE before the flood only in the first reach. We believe this result was influenced by high fish density (mainly of gudgeon) at two sites within this stretch. The abundance of fish in other reaches was not different. Whether the similarity of the assemblage before and after the flood was due to fish remaining in place (Gerking 1950, Harrell 1978, Matthews 1998), or if fish swept downstream were replaced by fish in the study stretches, remains unclear.

It appears that fish that use shelters (e.g., perch, chub, burbot) were less affected by the flood, compared with open water species (e.g., bleak, roach). The immediate effect of the flood on individual fish may largely depend on habitat complexity (Matthews 1998). In this case, the structured boulder bank may provide complex hydraulic conditions even during extensive flooding which may faciliate the retention of fish (Pearsons et al. 1992, Lobón-Cervia 1996).

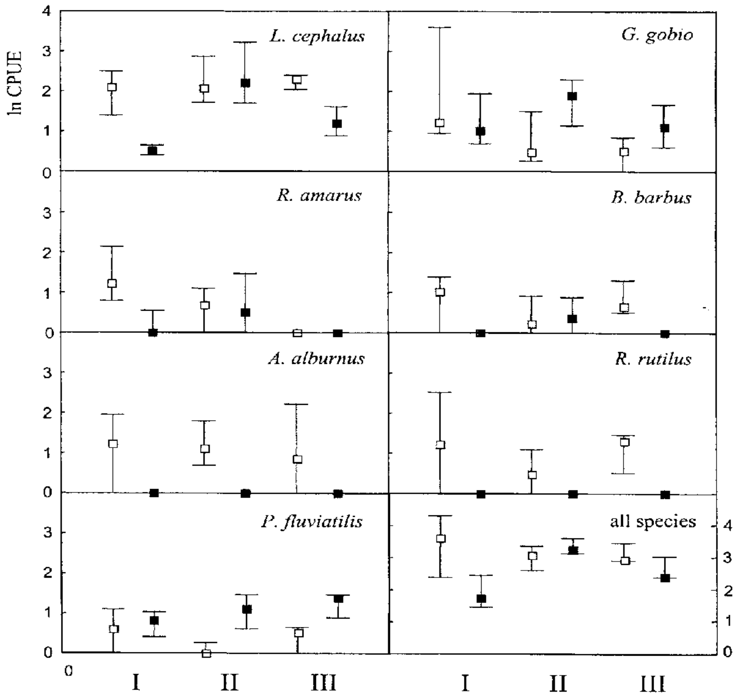

Figure 5. CPUE (median ± quartiles) of the seven dominant fish species in three reaches separated by weirs before and after the flood in the channelized study stretch of the River Morava in 1997.

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