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Primary Research Paper

The impact of the extreme floods in July 1997 on the ichthyocenosis of the Oder Catchment area (Czech Republic)

Bohumír Lojkásek[1,*], Stanislav Lusk[2], Karel Halačka[2], Věra Lusková[2] & Pavel Drozd[1]
[1]*Department of Biology and Ecology, Faculty of Natural Sciences, University of Ostrava, Chitussiho 10, 710 00, Slezská Ostrava, Czech Republic*
[2]*Institute of the Vertebrate Biology, Czech Academy of Sciences, Kvetná 8, 603 65Brno, Czech Republic*
*(*Author for correspondence: E-mail lojkasek@osu.cz)*

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Abstract

Changes in the ichthyocenosis of five smaller streams of 2nd to 4th order existing in the spring section of the River Odra (Oder) catchment area, in the territory of the Czech Republic, were observed before and after the catastrophic floods of July 1997. Quantitative catches using electro-fishing were performed in June, August, and September 1997, i.e. a month before and 2 months after the floods. The maximum flow of water in the examined sites usually reached or exceeded the limit of the so-called 'once in a century high water'. Extreme floods did not influence statistically the proven average readings of species diversity of ichthyocenosis in the examined sites ($p = 0.5625$), species variety ($p = 0.7316$), abundance per hectare ($p = 0.3125$), and biomass per hectare ($p = 0.4375$). A distinctive decline in abundance and also in the biomass of the ichthyocenosis took place in geomorphic reaches. Significant incisions and alterations in the routes of the streams were also observed. Statistical data of catches of key reophilous fish species from the River Oder catchment basin, all of which were affected by the floods, in the periods 1995–1996, 1997, and 1998–1999, were evaluated. Catches of the species of *Salmo trutta* and *Thymallus thymallus* in 1997 considerably increased. Only *Thymallus thymallus* experienced a more pronounced decrease in the years after the floods, when compared with the average readings made in the period 1995–1996. The readings of the adult abundance of *Barbus barbus* and *Chondrostoma nasus* did not prove a negative impact of the floods on the adult population of both species in the assessed years. Our findings suggest that the original fish communities may be naturally well adapted to culmination flows.

Introduction

The oscillation of a hydrologic regime is a phenomenon, which is not only natural, but probably also necessary for the prosperity of the particular watercourse ecosystem, and also for the preservation of its biological diversity. Experience gathered over many years show that extreme fluctuation in stream flows towards the minimum readings has a more devastating impact on fish than the extremely high flows. The impact of the extremely high flows seems to be more positive. These findings led to the formulation of 'The Flood Pulse Concept in River Floodplain Systems' (Junk et al., 1989), which followed the concept of a river continuum (Vannote et al., 1980). Flood flows play an irreplaceable role in maintaining and increasing the morphological diversity of river ecosystems. Further, they also seem to have a positive impact on the biodiversity. Our research shows that the resistance of stream ecosystems to destructive effects caused by floods increases from upper stream sections towards the lower ones with developed floodplains. The flood phenomena are of a strong character, but are also usually seasonally predictable. It can be presumed that repeatedly occurring high flows in lower parts of streams generated many biological adaptations through the course of the fish phylogenesis. These allow the fish to 'utilise' flood situations in an optimal way (reproduction, production) as reported, for example, by Holčík (1996), Holčík & Bastl (1976, 1977), and Fernandes (1997).

The data available on the impact and influences of extreme flood flows on fish in streams are based mostly on information from North America. Seegrist & Gard (1972) evaluated the impacts of a flood on the population of *Salvelinus fontinalis* and *Oncorhynchus mykiss* in the Sagehen Creek. Hoopes (1975) found a drastic reduction mainly in the yearling population of *Salvelinus fontinalis* after the summer flood caused by the hurricane Agnes. As far as other sources are concerned, studies by Paloumpis (1958), Hanson & Waters (1974), Harrell (1978), Ross & Baker (1983), Matthews (1986), and also Bain & Bolz (1989) can be listed. Studies of the impact of high flows on Salmon-type fish in the North American Pacific Coast are well researched by Harvey (1987), Harvey et al., (1999), and Bell et al. (2001). On the other hand, findings related to the impact of a catastrophic typhoon on the fish-fauna structure in a mountain stream were published by Tew et al. (2002). In European conditions, actual findings related to the impact of floods on fish in small streams have been only sporadic (Čihař, 1976, Lusk et al., 1998).

The impact of floods on fish is of interest to professionals, anglers, and also to laymen. However, there is usually a lack of necessary resource materials and data to evaluate the impact of floods in an objective way. The chance to assess the impact of the so-called 'once in a century high water' on fish communities in smaller streams occurs only very rarely. We took advantage of such an opportunity in July 1997, when we obtained qualitative and quantitative data on the fish population from the areas affected by extreme floods. Just prior to the catastrophic floods, we performed ichtyological research of six sites in smaller streams (the details are given below). Follow-up research after the floods enabled us to assess the impact of the flood flows on the fish communities in specific profiles.

Description of the study sites

The River Oder has its spring section in a catchment basin of the total area of 5820 km^2. It is in the territory of the Czech Republic. The length of the River Oder itself, measured from its springs in the Oder Hills at an altitude of 632 m to the border profile of Kopytov, where the river enters the Polish territory, is 131.4 km. The average annual flow, measured at the border profile, is 55.8 m^3 s^{-1}. The River Oder flows into the Baltic Sea. Its total catchment basin has got the area of 118,600 km^2; the total length of the flow, from the springs to its inlet to the sea, is 861 km. The average annual flow, measured in the inlet, is 610 m^3 s^{-1}.

The researched sites were situated in the River Oder tributaries in the Czech territory (North Moravia and Silesia). These can be described as smaller streams of 2nd to 4th order (Strahler, 1957). All researched streams are used for recreational angling.

Description of the study sites prior to the floods

The Černý potok is a 2nd order stream with the catchment basin area of 109.2 km^2 and the length of 24.3 km. The stream springs, at the altitude of 740 m, flow into the Moravice River at the altitude of 475 m. The average flow in the inlet is 1.01 m^3 s^{-1}. The researched part was 110 m long and is located at the river kilometre 4.1; the geographic coordinates are 49° 57′ 15.60″, E = 17 29′ 27.51″. The riverbed in the examined site was altered in the past; both banks have been reinforced with a rough stone levee. The average width of the riverbed was 5 m; the maximum depth was 0.5 m. The bottom had a natural structure with alternating cobble and boulder sediments.

The River Olše is a stream of 4th order with the catchment basin area of 1120 km^2. The length of the stream is 89 km, and the spring area, 15.4 km long, is situated in Poland. The springs are located at the altitude of 820 m. The River Olše flows into the River Oder at the altitude of 192 m; the average annual flow at its inlet is 12.5 m^3 s^{-1}.

There were two sites in the middle part of the stream examined, where the average annual flow is 4.70 $m^3 s^{-1}$.

Site 1 can be found at river kilometre 55.3 beneath the inlet of the Hluchová rivulet having the geographic coordinates N = 49° 37′ 54.37″, E = 18° 42′ 56.67″. This was 145 m long unaltered section, on average 14 m wide and, in the deepest places, the water level reached up to 0.8 m. The section consisted of 45 m long rapids followed by approximately 50 m long stretch of a slower stream, which was followed by just another 50 m long part with slow flowing waters above a passage with rapids. The natural bed of the rivulet comprised alternating pebble, cobble, and boulder sediments.

Site 2 is situated at the river kilometre 53.0 of the coordinates N = 49° 38′ 26.877″, E = 18° 42′ 04.70″. The left bank alongside the entire stretch was reinforced with a rough stone levee. The length of the stretch was 100 m, the width of the stream was 10 m, and the maximum depth of water there reached 1 m. The bottom sediments alongside the entire stretch were of the cobble and boulder character.

The Střední Opava is 2nd order stream with the catchment basin area of 83.7 km^2. Its length is 12.4 km. The springs are located at the altitude of 1195 m. The stream flows into the Černá Opava (Black Opava River) at the altitude of 540 m. The average annual flow in its inlet is 1.37 $m^3 s^{-1}$. The examined site is at the river kilometre 1.6 with the coordinates N = 50° 07′ 33.03″, E = 17° 21′ 48.52″. The section was 110 m long, the width of the riverbed was 10 m, and the maximum depth of water was 0.7 m. The examined stretch was modified in the past and the right bank was reinforced with a 2 m high and 20 m long stone wall. The structure of the river bottom, formed by cobble and boulders, and the structure of the left bank, including tree vegetation, was quite close to natural conditions.

The river Opava is constituted by the confluence of the Černá Opava (Black Opava) and the Střední Opava (Middle Opava) at the altitude of 540 m. It is a stream of 4th order. The total catchment basin area is 2089 km^2. The length of the waterway is 118.6 km and the average flow in the inlet to the River Oder, at the altitude of 210 m, is 15.01 $m^3 s^{-1}$. The investigated stretch was located in the 107 km river section of the coordinates N = 50° 06′ 29.84″, E = 17° 25′ 42.53″. The investigated stretch was 120 m long with the average width of 13 m and water depth of 0.6 m. The bottom comprised gravel and boulder material. The bottom consisted of cobble and boulder sediments.

The river Osoblaha is a stream of 3rd order with the catchment basin area of 1008 km^2. The total length of the watercourse is 58 km. Its upper stream has got the length of 34.7 km. It is located in the Czech territory. The average annual flow in the border profile is 2.08 $m^3 s^{-1}$. The Osoblaha river springs are at the altitude of 715 m and the river flows into the River Oder in Poland at the altitude of 205 m. The investigated site is situated at the river kilometre 31.2 – the coordinates are N = 50° 14′ 37.52″, E = 17° 42′ 48.51″ in the centre of the village of Bohušov. The research was performed on 8 June 1997. The average width of the riverbed was 8 m at the site and the maximum depth of water was 0.6 m. Bottom sediments had a natural structure with alternating coarse sand, pebble, and cobble areas.

The flood

In July 1997, an extremely high amount of precipitation fell down on the territory of the Czech Republic (Moravia, Silesia, and Eastern Bohemia). Consequently, extreme floods were experienced in most streams in the catchment basin areas of the River Oder, the River Morava, and the upper part of the River Elbe. These extreme flows exceeded, in most cases, the level of the so-called 'once in a century high water'. The first and the biggest precipitation wave took place between 4 and 8 July. In the span of 4–5 days, approximately 300 mm of precipitations fell down in the spring area of the River Oder in the Czech Republic, whilst the precipitation level reached between 400 and 500 mm in the mountain areas. Extreme readings were measured in the catchment basin of the River Oder on the Lysá Hora (Bold Mountain) station – 585 mm, at the Šance Dam station on the River Ostravice – 616 mm (Munzar et al., 1997; Soukalová et al., 1997, Opperman & Lauschke, 1998). The course of the floods on the observed streams of 1st to 3rd class was characteristic for streams with small catchment basins that do not have any extensive floodplains. A considerably fast start of the maximal flows was observed. The flow peak was reached within several hours, or several tens of hours. This was followed by a gradual decline, while the peak flow was maintained only for a short period (Figs. 2–5).

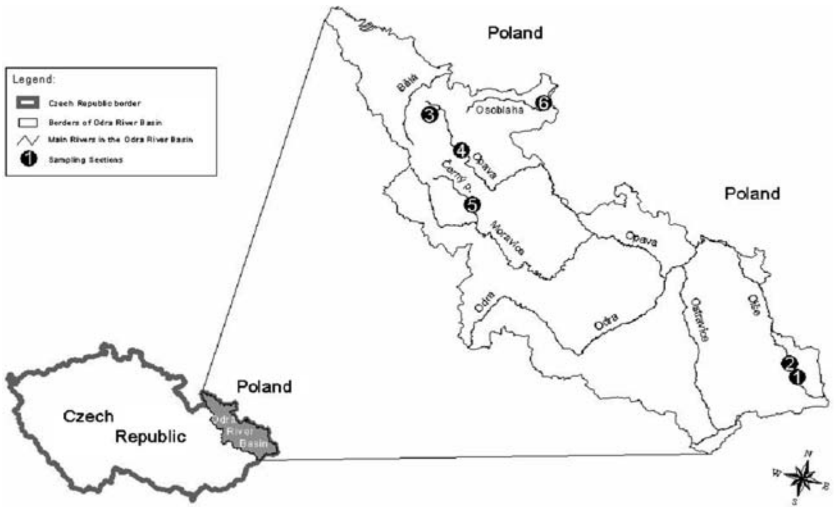

Figure 1. The Oder catchment basin in the territory of the Czech Republic with the marked location of 6 research sites .

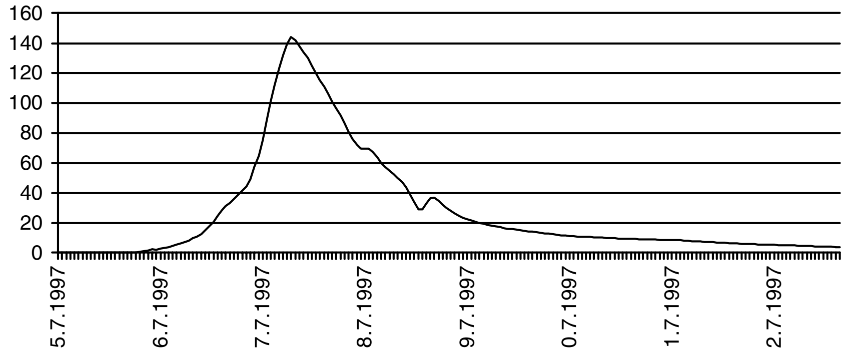

Figure 2. The hydrograph of the River Osoblaha in the profile Bohušov (r. km 31.2).

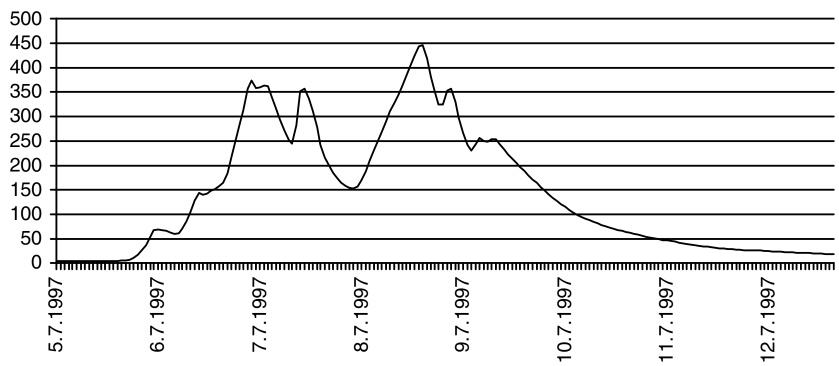

Figure 3. The hydrograph of the River Olše in the profile Ropice (r. km 43).

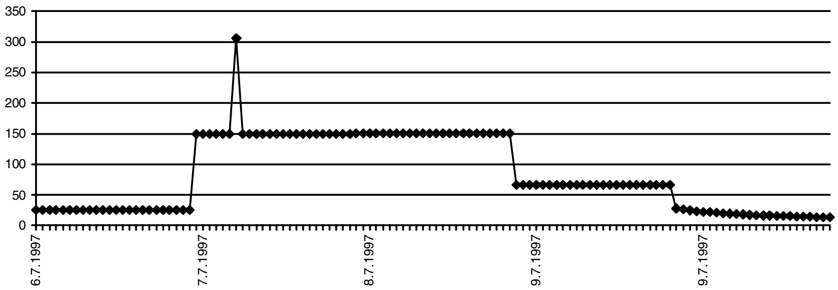

Figure 4. The estimated hydrograph of the River Opava in the profile Karlovice (r. km 107). The estimate was performed by the Hydro-meteorological Institute in Ostrava.

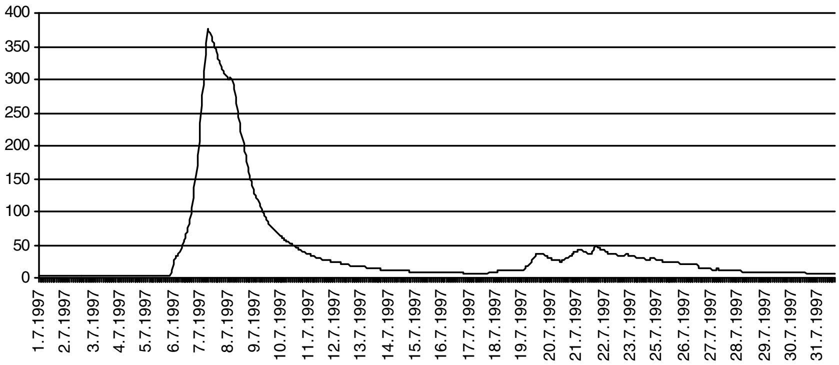

Figure 5. The hydrograph of the River Opava in the profile Krnov (r. km 43).

Methodology

The species composition of the ichthyocenosis and the quantitative parameters (the abundance and biomass) of the populations of fish identified in the defined sites were estimated by the use of 2-pass electro fishing (the direct current [160–220 V, 0.4–1.6 A] produced by the ZB6 electric transformer unit made in the Czech Republic). The investigated site was defined at the lower and upper ends with nets with a mesh 1.5×1.5 cm, which prevented the fish from escaping. The site was searched twice with the in between minimal interval of 90 min. The species composition, abundance, and the weights of fish were recorded separately after each search. The final estimate of the fish population in the investigated site was done in accordance with the Seber & LeCren method (1967). The diversity index (H') was calculated, according to Shannon & Weaver (1949), with a logarithm of 2. The Wilcoxon's double-selection pair test was chosen for the evaluation of possible changes in the number of species, total abundance, biomass, and diversity of fish in individual sites before and after the floods. The order of the stream was set in accordance with Strahler (1957). The river kilometres are given in the direction against the streams, from their inlets. Data on water flows existing during the floods were obtained from the Czech Hydro-Meteorological Institute. Data on the catches by recreational anglers were provided by the Czech Angling Association in the City of Ostrava.

In June 1997, we estimated the ichthyocenosis population abundance at six sites (see Fig. 1). Following the catastrophic floods of July 1997, we carried out the following estimates in the identical sites in August and September 1997.

Results

We did not find any substantial changes in the number of fish species in the investigated sites before and after the floods. Disappearance or appearance of new species, in connection with the floods, mostly affected those species, the occurrence of which was either less frequent or only random. There were two sources of the newly found species. They were either flooded out ponds, situated higher in the catchment basins, or higher located parts of the stream themselves. For instance, a trout farm in the catchment area of the River Oder was flooded out and *Oncorhynchus mykiss* individuals later appeared in the examined sites.

More prominent changes resulting from the floods were noted in the abundance and biomass of individual species. Changes in species that formed a substantial part of the fish population are commented on in more detail. The identified changes in the specific fish community resulted on one hand from the flood course (the spread of water, duration, and intensity) and on the other hand from habitat changes (the structure of riverbeds, structure of banks, movements of sediments, etc.), which took place in individual research sites.

Statistical evaluation of possible changes in the number of species, total abundance, biomass and fish diversity in individual locations before and after the floods (the Wilcoxon's two-selection pair test) did not prove any significant difference (the number of species: $p = 0.731601$, Shannon's index: $p = 0.5625$, the equitability: $p = 0.5625$, the abundance per hectare: $p = 0.3125$, the weight per hectare: $p = 0.4375$, where p is the relevant level of importance for the test (p indicates the probability that the test statistics will take a value at least as extreme as the actually observed value, assuming that the null hypothesis is true). This result, however, was probably affected also by a small number of study sites.

The Černý potok

The research prior to the floods was performed on 8 June 1997. The quantitative parameters (the abundance and biomass) of the populations of fish after the floods were researched in the corresponding site on 14 August 1997.

On 7 July 1997, the flood flow in this area reached its culmination level of $79 m^3 s^{-1}$, which was 107% of the theoretical flow Q_{100}. Conditions in the microhabitat at the site, where our research was conducted, were not considerably changed by the flood flows.

The species composition of the fish community in the researched site was not changed by the floods. The ichthyocenosis comprised species *Salmo trutta*, *Thymallus thymallus*, *Phoxinus phoxinus*, and *Barbatula baratula*. Following the floods, one specimen of *Rutilus rutilus* was also caught that came from the ponds higher in the catchment basin. After the floods, we estimated the increase in the total abundance to stand at 72.4%. The estimated reduction in the total biomass was 21.7%. Significant increases in the abundance were recorded in *Barbatula barbatula* (by 72.4%), *Thymallus thymallus* (even by 124.7%), and *Phoxinus phoxinus* (by 78%). In the case of *Salmo trutta*, a reduction in the abundance by 11% and the reduction in biomass by 37.2% were noted. The values of species diversity and equitability indexes show that the floods did not substantially change the character of the fish community in the examined location (see Table 1).

The River Olše

The research prior to the floods in both sites was carried out on 28 June 1997 and the situation after the floods was assessed on 3 September 1997.

The flood characteristics were identical for both sites. During the floods, on 7 July 1997, the maximum flows reached the level of $316 m^3 s^{-1}$, which represented 73% of the theoretical Q_{100} for this part of the river. As a result of the floods, the microhabitat in Site 1 was considerably changed. The riverbed was incised down to 10 m. Sediments were flooded away from the central part of the riverbed. The bottom, where the main line of the flow was situated, was formed by bare sandstone rock protrusions. Most fish were hidden under two alluvial tree trunks, which lay along the bank.

Nine fish species: *Salmo trutta*, *Thymallus thymallus*, *Rutilus rutilus*, *Leuciscus leuciscus*, *Leuciscus cephalus*, *Phoxinus phoxinus*, *Chondrostoma nasus*, *Gobio gobio*, and *Barbatula barbatula* were recorded in this site prior to the floods. After the floods, no *Leuciscus leuciscus* and *Chondrostoma nasus* species were recorded there in spite of their presence there before the floods, even if as few isolated cases only. Despite a prominent change in the microhabitat of the examined site, taking place

Table 1. Species composition and ichthyocenosis characteristics in the researched sites

Sampling sections	1		2		3		4		5		6	
	b n/kg	a n/kg	b n/kg	A n/kg	b n/kg	a n/kg	b n/kg	a n/kg	b n/kg	a n/kg	b n/kg	a n/kg
Salmo trutta	995/68.7	1374/77.5	389/39	1021/92	922/110.6	247/27.7	985/173.1	212/21.8	82/23.4	73/14.7	333/17.1	233/25
Oncorhynchus mykiss+				21/2.5								
Thymallus thymallus	177/18.4	253/17.6	231/18.7	333/34.2			77/21.5	121/28.3	73/8.8	164/5.6	21/7.3	17/1
Rutilus rutilus +	25/2.4	61/2.7								18/0.2	1313/40	925/25.4
Leuciscus leuciscus	10/0.7										63/8.7	25/1.9
Leuciscus cephalus	256/47.3	596/73	185/22.4	417/35.4							1750/30.8	975/67.5
Chondrostoma nasus	39/25.9											
Barbus barbus			120/6.6									
Phoxinus phoxinus	719/3.9	485/3.2	1343/8.3	1000/6.7					218/0.7	382/0.7		417/2.1
Gobio gobio	138/1.6	81/2.4		104/2.9							438/14.2	467/16.5
Carassius auratus+											83/8.4	17/2.3
Tinca tinca+											21/3.3	
Pseudoras parva+			28/0.2									8/0.1
Barbatula barbatula	872/13.3	242/1.8	5204/24.9	208/2.7						1255/ 6.5	104/2.5	492/7.3
Cottus poecilopus					233/1.8	49/0.5	246/3.8	379/3.4	729/3.8			
Perca fluviatilis+											167/7.9	8/1
Number of species	9	7	7	7	2	2	3	3	4	5	10	11
Abundance n. ha^{-1}	3232	3091	7500	3104	1155	296	1308	712	1102	1891	4292	3583
Biomass kg ha^{-1}	182.8	178.2	120.1	176.6	112.4	28.2	198.4	53.5	36.7	27.7	140.2	150.2
index of sp. div. H'	2.39253	2.22908	1.4439	2.263	0.73243	0.65002	0.98355	1.44247	1.3943	1.41129	2.25408	2.57081
Equitability	0.75476	0.79401	0.5143	0.8061	0.73243	0.65002	0.62055	0.91009	0.6972	0.60781	0.67855	0.74313

The Olše (1, 2), the Střední Opava (3), the Opava (4), the Černý potok (5), the Osoblaha (6) b, before the floods; a, after the floods; +, Non-original fish species, which entered the ichthyocenosis in the researched sites from ponds or fish farms in the catchment area.

during the floods, the estimates of total abundance and the total biomass did not change significantly. A more prominent growth in abundance was noted in *Salmo trutta* (38.6%), *Thymallus thymallus* (37.2%), and *Leuciscus cephalus* (132%). On the other hand, the abundance of the smaller species *Phoxinus phoxinus* (33.8%), *Barbatula* barbatula (72.1%) was reduced; more detailed data, including the changes in biomass, can be found in Table 1.

Conditions in the microhabitat in Site 2, located 2.3 km lower down the stream, were not significantly altered by the floods.

The fish population in Site 2 comprised 7 species prior to the floods: *Salmo trutta*, *Thymallus thymallus*, *Leuciscus cephalus*, *Phoxinus phoxinus*, *Pseudorasbora parva*, *Barbus barbus*, and *Barbatula barbatula*. The species composition of the fish population did not experience any fundamental changes resulting from the floods. Only the presence of *Pseudorasbora parva*, which used to appear at random, was not recorded and *Oncorhynchus mykiss* appeared only sporadically. However, this site experienced considerable changes in the estimated quantitative levels of ichthyocenosis resulting from the flood wave course.

The total abundance of fish was reduced by 58.6%. It was the reduction in *Barbatula barbatula* by 96% that had the most significant impact on the decrease of the abundance. *Salmo trutta* increased its abundance by 162.5%. Total biomass of the community had increased by 47.2%. The increase in the biomass of *Salmo trutta* by 136.6% had a significant impact on the growth of the total biomass of the ichthyocenosis. The increase was also recorded in *Thymallus thymallus* as its abundance increased by 44% and the biomass by 82.7%. These changes meant that the index of species diversity and equitability increased considerably (see Table 1).

The Střední Opava

The research prior to the floods was carried out on 8 June 1997 and after the floods on 14 August 1997. The calculated so-called 'once in a century high water flow' for the investigated stretch is 87 $m^3\ s^{-1}$. The actual peak occurred on 7 July 1997 and it reached 63.7 $m^3\ s^{-1}$, i.e. 73% of Q_{100}. The original riverbed was blocked by gravel in the course of the flood. The stream created a new parallel riverbed 30–40 m to the right of the original route. This was found in gravel deposition, which filled up the entire width of the valley (approximately 150 m). The new part of the riverbed, filled with water, was 9 m wide, and the maximum depth was 0.4 m. The structure of sediments consisted of pebble, cobble, and boulder with the grain size range of 5–30 cm.

This mountain stream was inhabited only by *Salmo trutta* and *Cottus poecilopus*, which were recorded there prior to and also after the floods. The abundance and biomass of both species decreased significantly in the new riverbed (see Table 1). The estimated level of the total abundance of the fish community was reduced down to 25.6% of the abundance existing there before the floods. Following the floods, the estimated biomass was reduced down to 25.1%. Both fish species, *Salmo trutta* and *Cottus poecilopus*, contributed to the reduction in both readings equally. The abundance of *Salmo trutta* dropped down to 25% and the biomass down to 26.9% of the situation existing there prior to the floods.

The river Opava

The research prior to the floods was carried out on 8 June 1997 and again after the floods on 14 August 1997. In the course of the floods, the culmination flow reached two peaks in this location. It was on 7 and 8 July, when the readings were 150–151 m^3s^{-1}. These readings made up 92% of the calculated $Q_{100.}$ In the morning on 8 August, the readings reached during a short period of time 306 $m^3\ s^{-1}$, i.e. 188% of the theoretical flow Q_{100}. The original riverbed, approximately 1.5 km long, was completely filled up with tree trunks, stumps, gravel and stones after the floods. The river has created a new riverbed.

The fish population of this sub-mountain stream comprised *Salmo trutta*, *Thymallus thymallus*, and *Cottus poecilopus*. The same species composition was identified in the 400 m long stretch higher up the stream after the floods; the original stretch was completely blocked by alluvial material. The presence of *Oncorhynchus mykiss*, which came from a flooded trout farm, was newly recorded. Considerable changes took place in the abundance and biomass of the caught fish. The estimated numbers show that the abundance of trout decreased by 78.4%. The biomass of this species had decreased by 82.8%. On the contrary, the abundance of *Thymallus thymallus* increased by 78.3%. However, the biomass in the species grew only by 31%. This resulted from the fact that individuals from younger age groups, which were washed down with the flood wave from higher locations, were present in the site.

The river Osoblaha

The research before the flood took place on 8 June 1997 and after the flood on 15 August 1997. The peak flow reached 144 $m^3 s^{-1}$ on 7 July 1997. That represents 140% of the theoretical flow Q_{100}. The previously altered riverbed in the researched site allowed for flood flows without any recorded substantial changes to the riverbed microhabitat. Individuals of the higher located *Salmo* community as well as the lower located *Barbus* community, together with species that came from ponds in the catchment basin, were recorded in the ichthyocenosis of the site. Prior to the floods, species *Salmo trutta*, *Thymallus thymallus*, *Rutilus rutilus*, *Leuciscus leuciscus*, *Leuciscus cephalus*, *Gobio gobio*, *Carassius auratus*, *Tinca tinca*, *Barbatula barbatula*, and *Perca fluviatilis* were caught. Following the floods, larvae of *Lampetra planeri* and also *Phoxinus phoxinus*, brought from higher locations of the watercourse, appeared. Also, *Pseudo*-rasbora parva was recorded. No *Tinca tinca* was found, which had been occasionally present before the floods. Appearance of the species *Carassius* auratus, *Tinca tinca*, and *Pseudorasbora parva* resulted from the situation, when they were washed into the river from several ponds in the catchment basin positioned above the researched site.

No large changes in ichthyocenosis were found in this location during the flood flows. The estimated total abundance decreased by 16%. The biomass increased by 7.1%. A decrease in abundance by 30.6% and a simultaneous increase in biomass by 46% were registered in *Salmo trutta*. No significant changes in the abundance of *Thymallus thymallus* were reported, however, the biomass decreased considerably by 86.3%. These findings show that the flood wave transported individuals from younger age groups of *Thymallus thymallus* from the higher located sections of the river down to the researched site.

Anglers' catches

All watercourses in the Oder catchment basin, including the study sites, are subjected to active fish management and are used for recreational angling purposes. Because the floods in July 1997 affected the entire Oder catchment basin, we attempted to assess the potential influence of the floods on the population of the main species in trout streams on the grounds of the catches reported by anglers. Data from the anglers' catch statistics from the years prior to the floods (1995 and 1996), the year affected by the floods (1997), and the years after the floods (1998 and 1999) were used. Recreational angling for brown trout, *Salmo trutta*, is permitted in the period between 16 April and 31 August and for grayling, *Thymallus thymallus*, between 16 April and 30 November. An interesting conclusion can be drawn from the presented data (see Table 2): The highest numbers of catches were reported both in brown trout and in grayling in 1997, even though recreational angling was made impossible for most of July due to the floods. The catches of brown trout dropped down to the average level in the following years. The catches of grayling over two years after the flood year demonstrated a considerable reduction (37%), when compared with the two years prior to the floods. To allow for comparisons, also catches of characteristic species of the so-called Barbell Zone – *Barbus barbus* and *Chondrostoma nasus*, are presented. These also suggest that the adult part of the population was not significantly devastated as a result of the floods. The presented statistical data on fish catches show that floods might not have a devastating effect on the population of river fish species, as many anglers presume.

Table 2. Catches of selected fish species (in pcs.) in years before the floods (1995–1996) in 1997, and in the years after the floods (1998–1999)

Species	Average 1995–1996	Flood July 1997	Average 1998–1999
Salmo trutta m fario	16837	19567	16253
Thymallus thymallus	6125	7094	3846
Barbus barbus	753	1019	1160
Chondrostoma nasus	4744	2654	5937

Discussion

Findings on the effects of extreme flood flows obtained by examining shorter reaches of the riverbed have only a limited value, when applied to the entire stream. The flow situation and the impacts of floods vary in individual parts of streams.

The negative impacts of floods mostly affect the smallest individuals and the youngest development stages. Adult individuals of river fish species usually overcome the flood flows and mostly remain in original locations (Gerking, 1950; Lusk et al., 1997). Extreme flows, mostly in mountain and submountain streams, cause extensive transfers of bottom sediments across the whole size range. This results in an impact on organisms connected to the bottom substrate. It is the potential of the banks overflowing and spreading flood flows into the surrounding lea, which has a decisive impact on the transport of the sediments. If a considerable part of the flood flow spreads out of the riverbed, the potential destruction of fish communities in the given stretch is usually less drastic. An almost complete destruction of *Lampetra planeri* larvae in several reaches of the River Tichá Orlice was detected in our conditions (Lusk et al., 1998). The floods resulted in the reduction in numbers of *Cottus gobio* and *Barbatula barbatula*. The only exception was the reach, where a substantial part of the flood discharge overflowed and bypassed the original riverbed. The original bottom was maintained in that area. The same fish population, including a high abundance of *Lampetra planeri*, was reported there after the floods.

Considerable changes in the structure of the river bottom were experienced in both stretches of the River Olše. We detected a major reduction in the abundance of *Barbatula barbatula* following the floods in those reaches, where the bottom had been altered. Seegrist & Gard (1972) proved with several years of observation that the destruction of *Salvelinus fontinalis* and *Salmo gairdnerii* spawn, after spawning in the Sahegen stream in California, resulted from large flooding. Onodera & Ueno (1961) reported the almost total reduction of the fish fry of *Oncorhynchus mykiss* and *Salvelinus fontinalis* in an investigated reach that resulted from floods. However, they admitted that this situation was not necessarily caused by mortality, but rather by washing of that part of the fish fry down to lower parts of the stream. Similar devastating effects of floods on benthic invertebrates were also reported (Hynes, 1970).

Allen (1951) stated that massive floods on the Horokiwi stream, in New Zealand, had reduced the numbers of *Salmo trutta* of all age categories by between a quarter and a half of the total. Hoopes (1975) detected almost the total reduction (96%) in the yearling population of *Salvelinus fontinalis* in a stream in Pennsylvania, which resulted from floods. The effect on the abundance and biomass of larger individuals was only minor. An interesting conclusion was drawn – a considerable part of marked bigger size individuals was detected in an examined site or at its vicinity also after the floods.

We can agree with the statement that the impact of floods on adult (bigger) individuals is usually not as devastating as on small individuals. This corresponds with our partial findings, from which we can presume that the population of *Salmo trutta* in trout waters overcomes flood situations without considerable damage, if the whole riverbed was not destroyed. Based on previous investigations of brown trout behaviour in increased flows (Lusk, 1979), we presume that this species, when particular levels of the flow have been reached, leaves the original site. Subsequently, it overcomes the high flow in quieter parts of the stream away from the main flow. Similar behaviour by many other species has been detected also by other authors, e.g. Ross & Baker (1983) and Matthews (1986). Species variety did not change considerably in the sites our team researched, apart from the species connected to the bottom substrate (*Barbatula barbatula*). Also, the dominance remained largely unchanged as dominant species remained the most abundant even after the floods. This is in agreement with findings published by Harrell (1978), Matthews (1986), and Kwee et al. (2002).

The flood flows may have a positive impact on the reproduction effect of the brown trout population in the following year, if the floods take place before the reproduction period (October–November). In 1998, this finding was drawn in the Osoblaha stream, where high quantities of 0+ populations were found (the result of spawning in the autumn of 1997). One of the reasons might be the positive impact of flood flows on the quality of bottom sediments and also on the consequent higher survival rate of spawned eggs. Also Matthews (1986) drew attention to the increased abundance of the fish fry after the floods. In connection with the July 1997 floods, we detected the extremely high concentration of some cyprinid fish fry (*Cyprinus carpio*, *Tinca tinca*, *Carassius auratus*) in the bottom reaches of the River Morava and the River Dyje, for which the flooded floodplain provided optimal conditions for spawning.

The impact of the floods on *Thymallus thymallus* is rather negative, primarily on bigger individuals. We presume that grayling leave the actual riverbed during floods and swim into the flooded alluvium. When the water drops, grayling presumably do not return to the riverbed immediately and die. Balon (1952) reports on the devastating impacts of floods on the grayling population in the River Olše. Also findings from the River Orlice catchment basin support it (Lusk et al., 1998). We assume that the significant reduction in *Thymallus thymallus* catches in the River Oder catchment basin in the years after the flood could be seen as a result of the negative impact of the culmination flows on the adult part of its population. A high correlation between the records of anglers' catches and the abundance of the population was found, for instance for *Barbus barbus* and *Chondrostoma nasus* (Lusk et al., 2002). The fact that no statistically distinctive differences in the abundance parameters of grayling prior to the floods and after the floods were shown in the researched sites could have been affected by the small number of researched sites.

Our findings indicate that the typical species of *Salmo* and *Barbus* communities may be adapted to overcome high (i.e. flood) flows without being washed away. Changes in the species composition of the fish population were not recorded in the researched sites. Changes in the abundance were conditioned by geomorphologic changes in the riverbed. The findings obtained by us correspond to a large extent with the published information on highland streams regardless of the type of fish community, for instance Harrell (1978) or Matthews (1986). Our results cannot confirm the anglers' outlasting opinion on the devastating impacts on fish communities in streams caused by floods.

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