Longitudinal patterns in fish and macrozoobenthos assemblages reflect degradation of water quality and physical habitat in the Bílina river basin

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ABSTRACT: The aim of this study was to provide the first account of fish and macroinvertebrate communities in a heavily degraded river basin in the Czech Republic. Fish and macrozoobenthos were surveyed at 18 sites in the Bílina River and 11 sites in tributary streams during June–July 2007. Fish were sampled by electrofishing and macrozoobenthos were collected by kick-sampling using a sweep net. The composition of macroinvertebrate assemblages in headwater and reference sites in the upper Bílina River indicated clean water with saprobic index (SI) 1.31–1.43 followed by a transitional stretch downstream the Kyjická reservoir (SI 2.05–2.32) and dramatic decline of water quality to SI 3.18 in the river stretch downstream of industrial and municipal pollution at Litvínov-Záluží. Despite several minor pollution sources on the subsequent downstream river stretch until its mouth into the Elbe River, the water quality indicators fluctuated in the range of lower betamesosaprobity (SI 2.06–2.58). Species richness and biodiversity indices followed a similar pattern as river saprobity. Twenty-three fish species were documented in the Bílina River basin. Chub (*Leuciscus cephalus*), gudgeon (*Gobio gobio*) and roach (*Rutilus rutilus*) were the most frequent species at the Bílina sites. Chub was the most numerous fish in the tributaries. Fish species richness in the longitudinal profile did not increase downstream in the Bílina mainstem, most likely because the presence of reservoirs and water pollution interrupted the river continuum pattern. Qualitative data on fish assemblages corresponded to the course of environmental stress. A sustainable fish community was documented only in the lowermost site in Ústí nad Labem near the confluence with the Elbe River. The Bílina River tributaries constitute potential refuges for fish in this basin.

Keywords: fish community; macroinvertebrates; pollution; channelization; Elbe basin

According to the EU Water Framework Directive (WFD), Member States are obliged to protect, enhance and restore all surface waters with the aim of achieving the good ecological status by 2015 (Pont et al., 2006). Fish and macrozoobenthos are two of four biological indicators that have been used for the ecological status assessment (Simon, 1999). Several hydrobiological or ichthyological surveys were conducted in smaller or larger drainage areas in the Czech Republic (Hohausová and Jurajda, 1998; Lojkásek et al., 2000, 2004), but only rarely they covered a complex limnological survey (Jurajda et al., 2007). Many basins still remain devoid of hydrobiological and ichthyological surveys.

Even though there exists a nation-wide monitoring program, many river basins in the CR are underrepresented. Smaller basins such as the Bílina River have not been intensively surveyed

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for logistical reasons. Our knowledge of the natural biota of the Bílina River basin is quite limited, especially because this basin has suffered severe pollution impacts since the Second World War (M. Urych in litt.). No published historical data are available on fish and macroinvertebrate communities from this degraded river basin. Two exceptions, though limited in their sampling extent and not representing the characterization of river biota along a continuum, are the occurrences of fish mentioned in a fish toxicological study in the upper and lowermost part of the Bílina River for body burden analyses (Svobodová et al., 1993; Kružíková et al., 2008).

Generally, the higher level responses (at population and community levels) which can be attributed to either single stressor or multiple stressors have been defined well for invertebrates but less satisfactorily for fishes (Elliott, 1994; Walker et al., 1996; Elliott and Hemingway, 2002). In communities exposed to chronic environmental stress, the abundance of tolerant species is expected to increase. If the stress persists, then a new equilibrium is likely to develop. Ecosystems where the stress is subsequently eliminated or reduced recover through recruitment, recolonisation and/or immigration, although the recovery stages may be transient until a stable system is regained. With regard to fish, the effects of stress may be manifested at one or more of several levels of biological organization (Whitfield and Elliot, 2002; Lawrence and Hemingway, 2003).

The objective of this study was to describe for the first time the fish and macrozoobenthos communities that exist under multiple stressors in the Bílina River basin (excluding standing water bodies) and to examine how responses to environmental stressors are reflected in the fish and macrozoobenthos community composition.

MATERIAL AND METHODS

Study area

The study area is situated in North Bohemia, Czech Republic. The Bílina stream, together with its tributaries, drains the Czech-German border section of the Krušné hory Mts. and is a tributary to the Elbe River (Figure 1). The drainage area of the Bílina stream (watershed area 1 070.9 km^2) has been affected at least since the Second World War by a high concentration of heavy industry, brown coal mining, and associated energetic and chemical industries. Although during the 1990s most of the above-mentioned industrial activities were reduced (especially mining), the Bílina River is very likely the most polluted stream in the Czech Republic and possibly in Central Europe.

Aside from chemical and municipal pollution, the geomorphology and hydrology of the stream were strongly affected during the last century. The stream channel was displaced several times to make space for opencast coal mining activity. At present, 3 km of the stream are displaced into two pipes (2 m in diameter) for protection of the adjacent brown coal mining activity. In the longitudinal profile of the main channel, two reservoirs and one small pond were constructed. Because the annual discharge of the Bílina River was limited, a man-made inlet canal (called Podkrušnohorský přivaděč) from the Ohře River to the Bílina River was built 50 years ago. A small pond in the town of Jirkov is the site of the junction of the canal and the Bílina River.

The Bílina River originates from springs in the Krušné hory Mountains at the altitude of 785 m a.s.l. and its length is 84.2 km. The upper torrential section having the trout zone character of habitat (and management) is interrupted by the Jirkov drinking water reservoir (river km 72.7, area 16 ha), followed by a small pond (Jirkov pond, < 1 ha) mentioned above, and then by the Kyjická reservoir (Újezd reservoir) at river km 66.8 (area 152 ha) (Vlček et al., 1984) (Figure 1).

The stretch between the reservoir and the inlet to pipes has been canalised with boulder bank or concrete stabilisation. The following 3 km of the river are displaced into two pipes (2 m diameter) for protection of the adjacent brown coal mining activity (Figure 1).

At river km 54, the stream is impacted by an outlet from the waste water treatment plant (WWTP) from the Litvínov town and refinery Chemopetrol Litvínov Co. Downstream the town of Most (river km 46.8), the stream stretch has no barriers to fish migration. At the altitude of 132 m a.s.l., the Bílina River flows into the Elbe River at the town of Ústí nad Labem (Figure 1).

Macroinvertebrates

In total, 16 sites in the longitudinal profile of the Bílina stream and 11 sites in 7 tributaries were

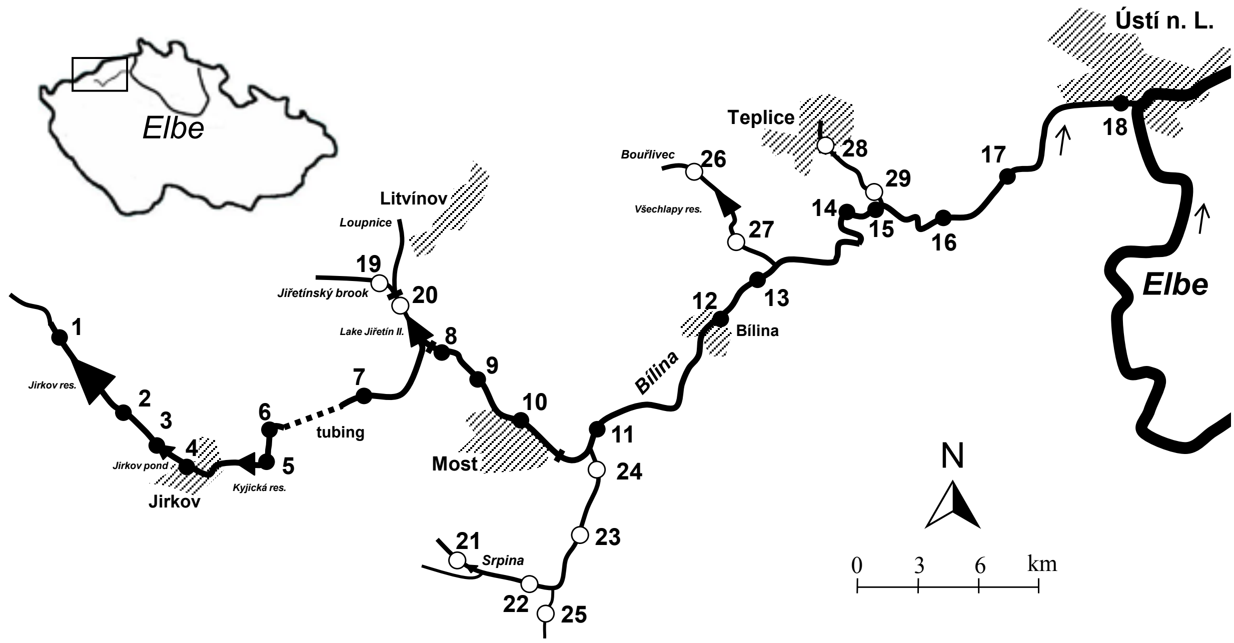

Figure 1. Map of the Bílina basin with the study sites indicated (full rings – sites in the mainstem of the Bílina River; open rings – sites in tributaries)

sampled in June–July 2007 (Table 1, Figure 1). Macrozoobenthos samples were collected with a hand sweep net (25 × 25 cm, 250 µm) using a 3-minute kick sampling procedure. Individual habitats (stones, gravel, sand, mud, macrophytes and wooden debris) present at the sampling site were surveyed proportionally for the time period corresponding to their share in the site area. In habitats where the stream bottom was not completely covered by sand or gravel substrate enabling kick sampling, the macrozoobenthos were collected by sweeping of the net (in mud, submersed/emersed macrophytes and wooden debris habitats). Macroinvertebrates were preserved in 4% formaldehyde solution, transported to the laboratory, separated from the debris (sediments, gravel, sand etc.) and counted using a microscope (25–40 times magnification). As much as possible, the identification was done to the species level for all major benthic groups.

Fish assemblages

In total, 18 sites in the longitudinal profile of the Bílina River and 11 sites in 7 streams in its basin were sampled at the same time as macroinvertebrates (Table 1, Figure 1). Fish were sampled using single-pass continual electrofishing (backpack type SEN, 220–240 V, 1.5–2 A, 80–90 Hz) throughout the entire channel profile of each study site. Two anodes were used in river stretches wider than 5 m. Study sites were limited upstream by natural (shallow riffles, boulder ramp) or artificial (weir, stop net) transversal barriers. The depths of the Bílina stream (maximum 0.8 m) typically allowed electrofishing by wading. One exception to these procedures was that site 8, downstream of the Jiřetín weir, was sampled from a small boat because the higher layer of soft sediment on the bottom hampered wading.

Site 3, Jirkov industrial pond, was sampled by beach seine (50 m length, 4 m depth, 10 mm mesh size) only, with the aim to collect a sample of target fish species for chemical analyses from a reference site and as a measure of species richness. Data from this selective sampling was not used for other community analyses. At all sites the fish were identified immediately on the bank, measured (standard length to the nearest 1 mm) and released back into the water.

Data analyses

Species richness, relative community structure (dominance in %), density and size population structure (in dominant species) were analysed.

Table 1. List of localities in the mainstem and tributaries of the Bílina River surveyed in 2007 for fish communities

No.	Name of locality	r. km	**Coordinates**
1	Bílina – Orasín	75.8	50°31'59"N 13°23'58"E
2	Bílina – Jirkov – upstream Jirkov reservoir	72.0	50°30'04"N 13°25'21"E
3	Bílina – Jirkov – small industrial pond	70.5	50°29'48"N 13°25'49"E
4	Bílina – Jirkov – downstream small industrial pond	70.3	50°29'43"N 13°26'06"E
5	Bílina – downstream Kyjická reservoir	66.6	50°30‘33"N 13°29'22"E
6	Bílina – upstream tubing	65.2	50°30'45"N 13°29'18"E
7	Bílina – Komořany	59.0	50°31'51"N 13°33'35"E
8	Bílina – Jiřetín downstream weir	55.4	50°32'52"N 13°35'34"E
9	Bílina – Litvínov – Záluží	53.2	50°32'33"N 13°37'00"E
10	Bílina – Most	49.3	50°30'55"N 13°38'59"E
11	Bílina – České Zlatníky	45.1	50°30'49"N 13°41'54"E
12	Bílina – Bílina	35.4	50°33'16"N 13°46'24"E
13	Bílina – Hostomice	28.6	50°34'44"N 13°48'15"E
14	Bílina – Lbín	22.5	50°36'23"N 13°51'29"E
15	Bílina – Velvěty	18.5	50°36'21"N 13°53'39"E
16	Bílina – Brozánky	12.9	50°36'35"N 13°56'24"E
17	Bílina – Stadice	9.7	50°37'12"N 13°58'26"E
18	Bílina – Ústí n. Labem	0.2	50°39'24"N 14°02'18"E
19	Jiřetínský brook – Dolní Jiřetín	0.1	50°33'53"N 13°33'25"E
20	Loupnice – Dolní Jiřetín, downstream weir	2.9	50°33'84"N 13°33'65"E
21	Luční brook – upstream Nemilkovský pond	1.7	50°27'94"N 13°36'64"E
22	Srpina – Polerady	10.8	50°26'56"N 13°40'14"E
23	Srpina – Stránce	7.8	50°27'99"N 13°41'27"E
24	Srpina – Patokryje	1.4	50°30'00"N 13°42'14"E
25	Počeradský brook – upstream mouth to Srpina	0.7	50°26'19"N 13°40'87"E
26	Loučenský brook – Lahošť	1.3	50°37'07"N 13°45'16"E
27	Bouřlivec – Želénky	3.3	50°36'09"N 13°46'70"E
28	Sviní brook (Bystřice) – Bystřany	3.3	50°37'75"N 13°51'35"E
29	Sviní brook (Bystřice) – Kozlíky	0.5	50°36'75"N 13°53'18"E

Shannon diversity indices (H´; Begon et al., 1990) were calculated for all sites on macroinvertebrate data. Fish ecological guilds were classified according to Balon (1975) and Schiemer and Waidbacher (1992). Saprobiological index (SI) of macrozoobenthos was determined according to the Czech National Standard ČSN 75 7716 (1998).

Detrended correspondence analysis (DCA; using CANOCO v 4.5 software) was used to ordinate localities with respect to (a) fish abundance (expressed as CPUE) and (b) number of species in particular macroinvertebrate groups (Oligochaeta, Hirudinea, Isopoda, Amphipoda, Ephemeroptera, Plecoptera and Trichoptera) (Kruskal and Wish, 1978).

RESULTS

Macroinvertebrates

Bílina mainstem

Altogether, 190 taxa of benthic macroinvertebrates were recorded in 16 sites of the Bílina mainstem River. Sensitive species, for example stonefly nymphs (mainly *Leuctra*) and some caddis fly larvae (*Sericostoma*, *Rhyacophila*, *Halesus digitatus*, *Philopotamus montanus* and others), occurred only in the headwater sites (Orasín – Jirkov). This stretch of sensitive species occurrence was followed by a transitional section influenced by outlets from seve-ral standing water bodies with oligochetes (*Stylaria lacustris*), molluscs (*Potamopyrgus antipodarum*), some mayfly nymphs (*Baetis rhodani*), caddis fly larvae (*Hydropsyche* sp.div.) and dominance of various chironomid species. A dramatic change in macrozoobenthos assemblage was recorded downstream of the Záluží outlets (site 9) where only three benthic macroinvertebrate species (*Dero digitata*, *Limnodrilus claparedeanus* and *Chironomus* ex gr. *thummi*) were recorded (Figure 2). The next downstream sampling site (Most) showed an increase in the number of species dominated by small oligochetes (*Ophidonais serpentina*, *Stylaria lacustris*, *Chaetogaster diaphanus*) and black flies (Simuliidae g. sp. div.) larvae and pupae. The lower part of the Bílina River (České Zlatníky – Ústí nad Labem) proved more or less uniform water quality parameters with the number of taxa ranging between 24 and 32 (Figure 2). In this river section, the macroinvertebrate benthic community consisted mainly of numerous black flies (at least four *Simulium* species), chironomids (28 species) and caddis fly (*Hydropsyche* g. sp. div.) larvae, water mites (Hydrachnellae g.sp.), molluscs (*Sphaerium corneum*, *Pisidium* g. sp. div.), isopod *Asellus aquaticus*, leeches (*Erpobdella* g. sp. div. and others), oligochetes (*Limnodrilus* g. sp. div. and *Tubifex* sp.).

Shannon's biodiversity (H´) and saprobic indices (SI) of macrozoobenthos followed a qualitative pattern as expressed in taxa numbers (Figure 2). The best values were found in the headwater section (H´ = 2.41–2.67 and SI = 1.31–1.43, respectively). In the downstream transitional zone, the biodiversity and saprobic indices amounted to H´ = 2.00–3.09 and SI = 2.05–2.32, respectively, followed by a dramatic decline downstream of the Záluží outlets to H´ = 0.83 and SI = 3.18, respectively. The subsequent downstream sampling site (Most) exhibited slightly improved values of water quality determinants with H´ = 0.95 and SI = 2.58. These determinants were evenly distributed with H´ and SI between 2.06–2.33 and 2.1–2.7, respectively, in the lower 47 km Bílina River stretch until its mouth at the Elbe River.

The DCA (Figure 3) revealed a different composition of macroinvertebrate fauna at sites directly impacted by sewage outlets (Záluží – Most) and also in headwater sites. The headwater reference sites, represented by a higher number of EPT taxa, were separated from others at the first ordination axis representing what we termed the "mountain-lowland gradient". Impacted sites were represented by a higher number of oligochete and isopod taxa and/or absence of other macroinvertebrate groups. They were separated from other localities

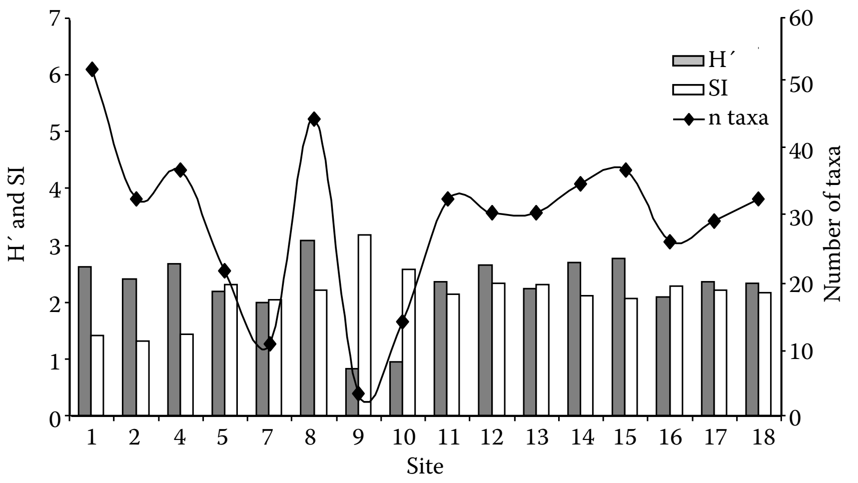

Figure 2. Shannon species diversity index (H´), saprobiological index (SI) and number of taxa of macroinvertebrates in study sites of the Bílina River mainstem surveyed in 2007

on the second ordination axis representing what we termed the "pollution gradient".

Bílina tributaries

The number of macroinvertebrates in Bílina tributaries amounted to values of over 50 taxa in the Bouřlivec (Lahošť), Srpina (Patokryje) and Loupnice brooks; while the lowest values were less than 30 taxa in the Počeradský, Luční and Sviní brooks with 24–28 taxa per site. The dominant taxa were nematodes (Nematoda g. sp.) in the Sviní and Luční brooks, oligochetes (*Stylaria lacustris*, *Nais elinguis*, *N. barbata*, *Ophidonais serpentina*, *Tubifex* sp., *Limnodrilus* sp. div.) in all tributaries, molluscs (*Radix ovata*, *Potamopyrgus antipodarum*, *Sphaerium* sp. div.) in the Bouřlivec (Želenky), Srpina (Patokryje), Počeradský, Luční and Loupnice brooks, mayflies (*Baetis vernus*, *B. fuscatus*) in the Bouřlivec (Lahošť), Srpina (Polerady) and Luční brooks, caddis flies (*Hydroptila* sp.) in the Bouřlivec (Lahošť) brook, numerous dipteran larvae such as *Tinearia* (*Psychoda*) *alternata* in the Sviní brook (Bystřany) and blackfly larvae (at least eight *Simulium* species) and chironomids (37 taxa) in all tributaries.

The biodiversity indices were lowest in the Luční and Sviní brooks (H´ 0.79 and 1.71–2.11, respectively). Their values in the other sites under study were quite similar, ranging from H´ = 2.34–3.11 in the lower (Želenky) and upper (Lahošť) Bouřlivec brook sampling sites, respectively. Saprobic indices of macrozoobenthos were almost identical in all tributaries, ranging from SI = 2.04 (Bouřlivec – Lahošť) to 2.46 (Sviní brook – Kozlíky).

Fish assemblage

In total, 23 fish species from seven families were registered in the whole Bílina River basin (Table 2).

Bílina mainstem

A total of 416 fishes (1+ and older), belonging to 19 species, were recorded at 17 sites in the mainstem of Bílina (beach seine sample in the Jirkov reservoir excluded). Species richness in the longitudinal profile indicated visible changes in the fish assemblage structure (Table 3), however, both fish

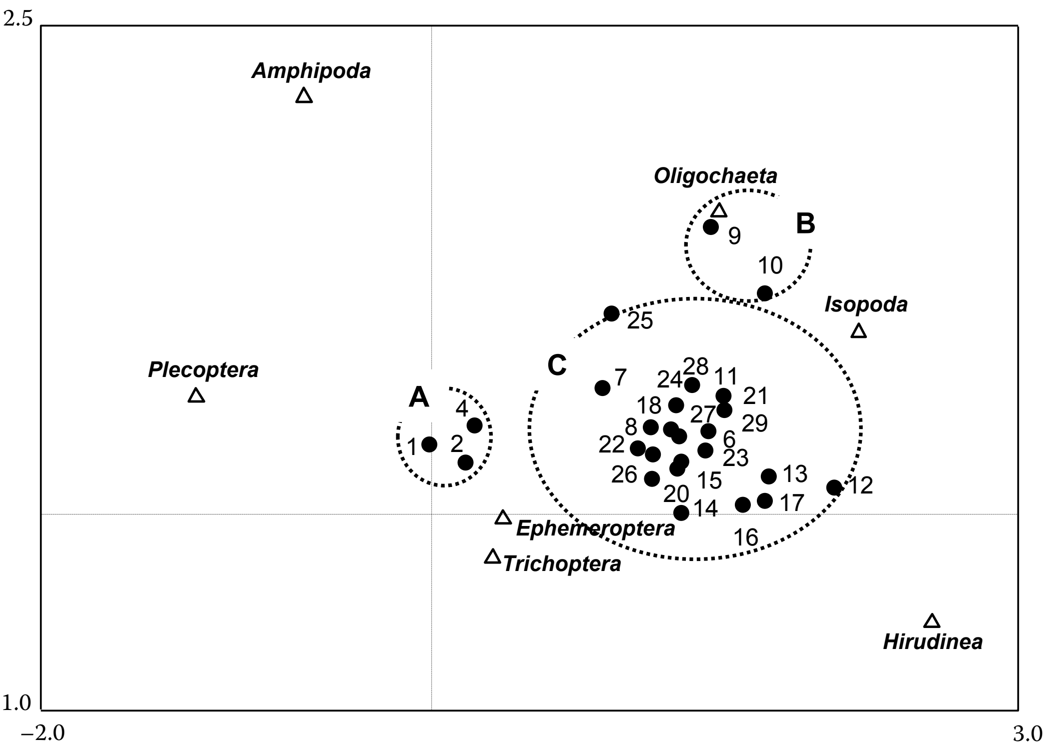

Figure 3. DCA graph based on macroinvertebrate assemblages (number of taxa in particular groups) of streams in the Bílina basin in the Czech Republic during surveys in 2007 (A – headwater sites, B – zone of heavy industrial pollution, C – zone of the mainstem (Bílina) recuperation and indifferent zone on tributaries)

Table 2. List of fish species caught in the studied Bílina catchment in 2007

Scientific name	Abbr.	Ecological guild	Reproductive guild
Salmonidae			
Salmo trutta m. *fario*	ST	rheophilic	lithophilic
Esocidae			
Esox lucius	EL	eurytopic	phytophilic
Cyprinidae			
Rutilus rutilus	RR	eurytopic	phyto-lithophilic
Leuciscus leuciscus	LL	rheophilic	lithophilic
Leuciscus cephalus	LC	rheophilic	lithophilic
Leuciscus idus	LI	rheophilic	phyto-lithophilic
Scardinius erythrophthalmus	SE	limnophilic	phytophilic
Tinca tinca	TT	limnophilic	phytophilic
Gobio gobio	GG	rheophilic	psammophilic
Gobio belingi	GL	rheophilic	psammophilic
Barbus barbus	BB	rheophilic	lithophilic
Alburnus alburnus	AA	eurytopic	phyto-lithophilic
Abramis bjoerkna	BJ	eurytopic	phytophilic
Abramis brama	AB	eurytopic	phyto-lithophilic
Carassius carassius	CC	limnophilic	phytophilic
Carassius gibelio	CA	eurytopic	phytophilic
Cyprinus carpio	CY	eurytopic	phytophilic
Balitoridae			
Barbatula barbatula	NB	rheophilic	psammophilic
Ictaluridae			
Ictalurus nebulosus	IN	eurytopic	speleophilic
Gadidae			
Lota lota	LT	rheophilic	litho-pelagophilic
Percidae			
Perca fluviatilis	PF	eurytopic	phyto-lithophilic
Gymnocephalus cernuus	GC	eurytopic	phyto-lithophilic
Sander lucioperca	SL	eurytopic	phytophilic

reproductive guilds according to Balon (1975) and ecological guilds according to Schiemer and Waidbacher (1992) are indicated

species richness and fish densities did not correlate with a distance from the source (Spearman $R = 0.03$ and -0.33, respectively, both $P > 0.05$).

The headwater stretch up to the Kyjická reservoir (sites 1, 2 and 4) was inhabited mainly by brown trout (*Salmo trutta* m. *fario*) (Figure 4). In the industrial pond Jirkov (site 3), the presence of 8 fish species: chub, roach, tench (*Tinca tinca*), pike (*Esox lucius*), perch (*Perca fluviatilis*), common carp (*Cyprinus carpio*), ruffe (*Gymnocephalus* *cernuus*), and gudgeon was detected but not in the downstream river site (Table 3). The presence of the lowland Kyjická reservoir significantly affected the downstream fish assemblage structure. In a short stretch between the Kyjická reservoir and tubing (length of stream stretch 1 300 m) the highest fish density was detected (2 643 inds/ha), with roach and perch as the dominant species (Table 3). Downstream from the tubing in the village of Komořany (site 7; Figure 1), the fish density was six times lower than upstream of the tubing (Table 3). Downstream of the site Litvínov – Záluží (site 9), water conductivity increased considerably (1 132 μS/cm) and the concentration of dissolved oxygen dramatically decreased (0.4 mg/l). No typical fish assemblage was detected, only a few individuals of some species (range 3–5 species) were found in sites 9–17 (Table 3). Only at the site immediately above the mouth to the Elbe River in the town of Ústí nad Labem (site 18) was a rich fish assemblage (8 fish species) detected, dominated by chub, gudgeon and roach with more age classes present than at upstream locations (Table 3).

Eight and ten species of the total 19 species registered in the Bílina mainstem represented rheophilic and eurytopic ecological guilds, respectively (Table 2). According to reproductive guilds, only 3 species represented the fluvial lithophilic group.

DCA revealed different composition of fish fauna among headwaters (reference sites 1, 2, 4, and 26), the sites influenced by the reservoirs (5, 6, 7, 8, 19, 20), and the remainder of sites (mainly tributaries and main Bílina stream influenced by the tributaries) (Figure 4). The most obvious "mountain-lowland" gradient was revealed by the first ordination axis, where brown trout (and partly stone loach) sites were separated from others, followed by a large group of sites from tributaries and mainstem, with dominance of chub and partial dominance of gudgeon. The last group on the gradient is represented by the sites on the middle Bílina stream (and two tributaries) influenced by reservoirs and formed mostly by roach-perch-bream assemblages (Figure 4).

Bílina tributaries

Fish species richness in all tributaries amounted to 19 species (Table 4). Chub was the most frequently occurring species (100% occurrence in sites), followed by gudgeon (64%) and perch (55%) in all of 11 tributary sites. Species richness in individual tributaries was 7.8 species on average (range 3–11). The density of fish assemblages varied considerably from 22 inds/ha to 6 457 inds/ha (Table 4). Out of 19 fish species registered in tributaries, only 5 species represented the rheophilic ecological guild and only one species (chub) represented the lithophilic reproductive guild. Most of the species in the Bílina basin originate from standing water bodies, represented by the eurytopic and phytophilic or phytolithophilic guild (Table 2).

DISCUSSION

The Bílina River catchment has been highly influenced by anthropic activities since the Second World War and consequentially, poor water quality has appeared to be a crucial environmental factor for river biota in the Bílina mainstem until now. Based on macrozoobenthos analyses, water quality in the Bílina mainstem determines three diversified stretches colonized by different macroinvertebrate and fish communities (Figures 3 and 4). Good water quality corresponding to oligosaprobity according to the Czech National Standard (ČSN 757716, 1998) was demonstrated only in the upper part of the river (Orasín – Jirkov) having low to negligible levels of physical habitat degradation. Subsequent parts of the river (downstream of the Kyjická reservoir to the Jiřetín weir) were already channelized and their water quality was affected by a reservoir and standing water bodies in the basin. Downstream of this section, several outlets from the petrochemical industry including municipal wastes resulted in dramatic deterioration of water quality according to parameters of alpha-mesosaprobity (Záluží – Most). Besides the outlets, the extremely poor physical river habitat (an artificial long and straight channel) also contributed to a sudden decline in macroinvertebrate and fish assemblage quality (very low number of macroinvertebrate species and near absence of fish) which is a well known phenomenon associated with severe physical river habitat degradation (Adámek and Jurajda, 2001). The lowest river stretch (from České Zlatníky to river mouth) downstream was characterized by self-purification processes; but due to numerous small sources of municipal pollution and high stream water trophic level, water quality was unable to recover in terms of beta-mesosaprobity levels. The saprobic indices remain in higher alpha-mesosaprobity for the whole 47 km river stretch as far as the mouth to the Elbe River.

Table 3. Relative abundance (%) of fish in the studied sites of the main stream of the Bílina River in 2007

Scientific name	Locality No.																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Salmo trutta m. *fario*	100.0	100.0		84.8														
Esox lucius			x												12.5			
Rutilus rutilus			x		36.6	71.6	65.9	59.3							12.5			3.7
Leuciscus leuciscus																		11.2
Leuciscus cephalus			x				7.3	1.9			55.6		100.0	62.5		100.0	77.8	43.9
Leuciscus idus														12.5				
Tinca tinca			x					3.7										
Gobio gobio			x					1.9			33.3			25.0	12.5		22.2	25.2
Gobio belingi																		3.7
Barbus barbus																		0.9
Alburnus alburnus																		8.4
Abramis bjoerkna											11.1							
Abramis brama					29.3	6.8	7.3	3.7										
Carassius gibelio															50.0			2.8
Cyprinus carpio			x												12.5			
Barbatula barbatula				15.2														
Perca fluviatilis			x		34.1	14.9	19.5	25.9										
Gymnocephalus cernuus			x			6.8												
Sander lucioperca								3.7										
Total catch	18	10	–	33	41	74	41	54	0	0	9	0	1	8	8	3	9	107
Species richness	1	1	8	2	3	4	4	7	0	0	3	0	1	3	5	1	2	8
Density (inds/ha)	2 000	1 429	–	1 844	1 708	2 643	432	360	–	–	918	–	16	74	147	77	94	1 338

x = occurrence of fish investigated by means of a seine net

Table 4. Relative abundance of fish in the studied tributaries of the Bílina River in 2007

Scientific name	Locality No.										
	19	20	21	22	23	24	25	26	27	28	29
Esox lucius				0.9	9.1						
Rutilus rutilus	10.8	32.6		0.9					10.3		
Leuciscus leuciscus											21.1
Leuciscus cephalus	33.7	22.0	44.4	54.1	63.6	30.3	40.0	0.9	15.4	100.0	68.4
Scardinius erythrophthalmus					18.2						
Tinca tinca		3.0									
Gobio gobio		4.5		39.4		6.1	60.0	21.8	25.6		10.5
Alburnus alburnus				2.8							
Abramis bjoerkna					9.1	33.3					
Abramis brama		4.5									
Carassius carassius									2.6		
Carassius gibelio									25.6		
Cyprinus carpio	2.4	5.3									
Barbatula barbatula		0.8		0.9				77.3	17.9		
Ictalurus nebulosus	2.4										
Lota lota		0.8									
Perca fluviatilis	50.6	25.0	55.6	0.9		30.3					
Gymnocephalus cernuus		1.5									
Sander lucioperca									2.6		
Total catch	83	132	9	109	11	33	15	226	39	1	38
Species richness	5	10	2	7	4	4	2	4	7	1	3
Density (inds/ha)	1 345	5 500	744	4 844	81	1 320	429	6 457	1 573	22	1 551

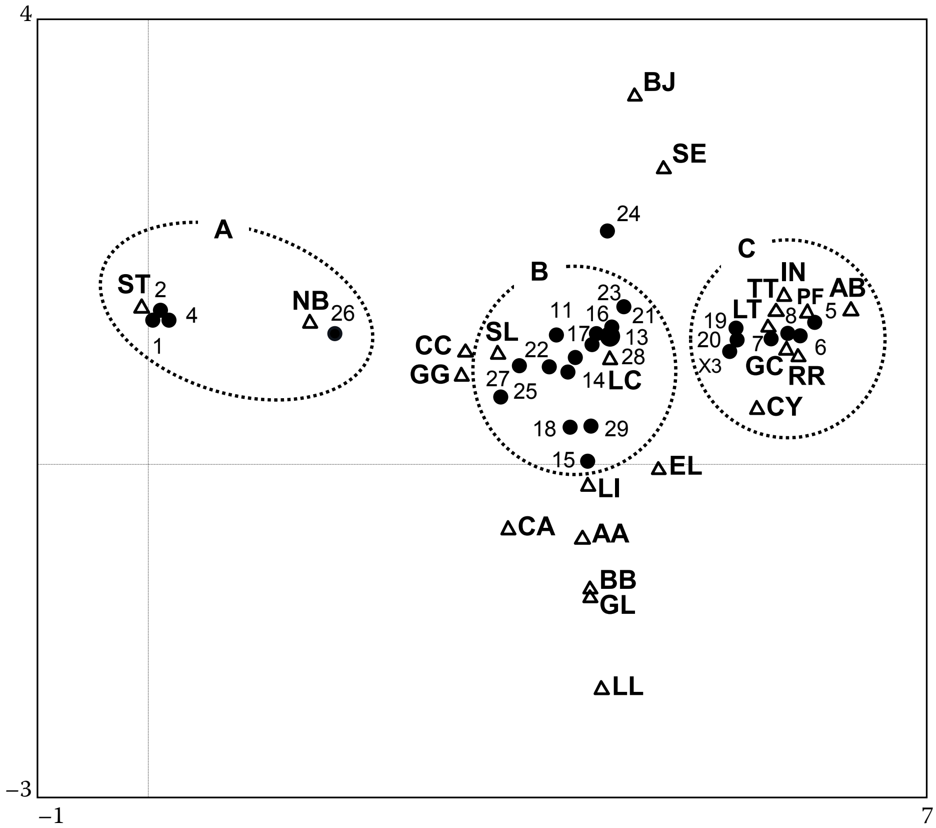

Figure 4. DCA graph based on fish assemblages (CPUE of individual species) of the Bílina basin in the Czech Republic during surveys in 2007

A – headwater sites, B – zone of the Bílina recuperation and tributaries, C – sites upstream of the WWTP outlet, affected by reservoirs (for fish code see Table 2), X3 site (reservoir sampled with beach seine) was treated as supplementary site (i.e. not used for calculation)

The Bílina River tributaries reflected low values of beta-mesosaprobity (SI 2.04–2.46) despite their small sizes and corresponding discharges. The occurrence of several highly sensitive species in the Bílina tributaries, for example *Pisidium henslowanum* in the Bouřlivec brook (Lahošť), *Gammarus pulex* in the Počeradský brook, *Baetis alpinus* in the Sviní brook and *Atherix ibis* in the Loupnice brook, indicate a high potential of these habitats for restoration if pollution sources are eliminated in future. For example, an abundant population of *Baetis alpinus* (SI 0.3) occurred in the Sviní potok brook (Kozlíky), where water quality corresponds to beta-alpha-mesosaprobity of 2.46 according to macrozoobenthos analyses. Appropriate oxygenation and riffle stream habitat are known to serve as driving elements of the occurrence of highly sensitive species in streams with high organic pollution but cold torrential habitat (Adámek, 1977).

Present fish assemblages in the stream system originate mainly from natural reproduction and/or escape from the numerous standing water bodies in the basin. Because of the high risk of acute pollution, very limited fish stocking is performed by the local Anglers Association in the Bílina mainstem (T. Kava, M. Urych in litt.). In the Czech Republic where fisheries management of natural water bodies has a long-standing tradition, the absence of fish stocking in a river of the Bílina size is quite exceptional. Total registered species richness in the whole basin was high (23 species); however, not many species formed sustainable populations in the river system (main channel of Bílina and tributaries). In addition, asp (*Aspius aspius*), vimba (*Vimba vimba*) and eel (*Anguilla anguilla*) were recorded in the Bílina mainstem during a pilot study in 2006, and grass carp (*Ctenopharyngodon idella*) were recorded in anglers‘ protocols in the Bílina basin (M. Urych, in litt.). Among the typically fluvial species, only chub and gudgeon were common. However, in many sites younger age classes were scarce. Stone loach was registered in 5 sites in the catchment but only in one site was it common. Many eurytopic and limnophilic species were registered in the basin (Table 2). However, only roach, perch and bream were common in several sites (Tables 3 and 4). These species are known to reproduce successfully in adjacent standing waters and probably are dominant there as well.

Environmental stressors are reflected in the fish community composition along the longitudinal river profile. The submountain trout zone has a rather natural character with the occurrence of brown trout (Figure 4) and did not change considerably during the last 20 years (Svobodová et al., 1993). Nevertheless, this stretch is managed as a fishery and is supported by stocking. The presence of a small (< 1 ha) pond (site 3) in the trout zone did not impact the fish community in the downstream stretch of the Bílina River. In the pond, the presence of 8 fish species was detected (Table 3) with a predominance of roach. Svobodová et al. (1993) also documented the presence of bleak (*Alburnus alburnus*) in the pond. However, no eurytopic species from the pond were registered in the downstream site. This corresponds with a low probability of fish escapement from the pond and their short-term occurrence in the fast current of the channel.

However, the presence of the lowland Kyjická reservoir (152 ha) significantly shifted the fish assemblage structure downstream the reservoir to cyprinid and percid fishes. The highest fish density was recorded (2 643 inds/ha) in sites downstream of the reservoir with roach and perch as dominant species (Table 3). These fish most likely originate from the upstream reservoir. In order to escape downstream from the reservoir, fish would need to pass through the reservoir outlet turbine of a small hydropower plant, a hypothesis supported by the dominance of small-size classes of roach, bream and perch at sites 5 and 6, with SL median of 110 mm for roach, 100 mm for bream and 115 mm for perch. Disruptions to the longitudinal pattern of fish assemblage adjacent to reservoirs are often anecdotally observed by researchers or fisheries managers, but most studies fail to detect a statistically significant effect based on limited sampling along the longitudinal profile (Stanford and Ward, 2001). The present study was able to demonstrate this "serial discontinuity" (*sensu* Ward and Stanford, 1983) in the fish assemblage due to likely fish recruitment in an adjacent reservoir.

Fish passability through the 3 km tubing with the turbine in its outlet is questionable. These pipes represent yet another environmental stressor. In each case, downstream of the pipes in the village of Komořany (site 7; Figure 1) the fish density was six times lower than upstream of the tubing (Table 3). Nevertheless, fish could have originated from a small adjacent retention lake Jiřetín II, which is connected with the main channel of the Bílina River.

The main anthropogenic impact in the Bílina River basin appears to be the outlet of WWTP in Litvínov – Záluží. Dissolved oxygen did not reach the levels allowing for fish occurrence in a stretch of several kilometres and the pollution reduced the fish density in nearly the entire remainder of the river downstream to the confluence. Only rare occurrences of fish were registered in the Bílina River nearby the tributary mouths (Table 3). Other small pollution sources were not reflected by changes in the fish community, despite the likely contribution of diffuse pollution sources to water quality deterioration.

Despite the high levels of pollution by organic compounds (Stachel et al., 2005), only at the site immediately above the mouth to the Elbe River in the town of Ústí nad Labem could a typical fluvial fish assemblage be detected. It is highly probable that fish species richness at this site is supported by fish originating from the Elbe River. Nevertheless, the geomorphological character of the habitat at this site seems to be highly important. In 1994, chub, roach, gudgeon, crucian carp (*Carassius carassius*), Prussian carp (*Carassius gibelio*) and white bream (*Abramis bjoerkna*) of a total density of 10 146 inds/ha were documented in this site (J. Poupě in litt.).

Compared to the Bílina mainstem, all study sites in the tributaries harbour fish assemblages. Nevertheless, none of the assemblages could be classified as natural type-specific self-sustainable fish community (Table 4). Populations in most tributaries were subsidized by fish from standing waters in the basin. Of the typical fluvial fish species, only chub occurred frequently (in 100% of sites). Gudgeon and stone loach were common only in a few sites.

Fish assemblages in the Loupnice and Jiřetínský brooks were represented by a mix of typical rheophilic species (gudgeon, chub, stone loach, burbot) and fish originating from the adjacent lake Jiřetín II (roach, tench, common bream, perch). The Loupnice brook has a typical torrential character with the clear gravel bottom, preferred by fish as documented by the high fish density in those locations. These tributaries including adjacent mining pits could be a potential natural source of fish for the degraded stretch downstream of the WWTP in Litvínov – Záluží in the case of future water quality improvement. The streams of the Srpina and Bouřlivec brooks could be potential sources of fish for the Bílina River in the currently polluted middle stretch downstream of the town of Most, as indicated by fish occurrence, e.g. in České Zlatníky (Table 3). In any case, all tributaries of the Bílina stream could serve as potential sources of fish for the Bílina mainstem recolonisation in the case of future habitat improvements.

The Bílina River and its tributaries are illustrative examples of undesirable habitat destruction and water quality deterioration impacts. Revitalising measures in the middle course of the Bílina and its tributaries with the aim of increasing habitat diversity would support the higher diversity of fish and other aquatic organisms. The presently impoverished fish community in the Bílina basin could be a measuring stick of future management seeking to facilitate the stream recovery.

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