ISSN 1643-3157

KAROL STARMACH INSTITUTE OF FRESHWATER BIOLOGY
POLISH ACADEMY OF SCIENCES

ZAKŁAD BIOLOGII WÓD im. KAROLA STARMACHA
POLSKA AKADEMIA NAUK

SUPPLEMENTA ad ACTA HYDROBIOLOGICA

Volumen 4

Krzysztof Kukuła

Structural changes in the ichthyofauna of the Carpathian tributaries of the River Vistula caused by anthropogenic factors

KRAKÓW 2003

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A journal devoted to the study of water biology

SUPPLEMENTA ad ACTA HYDROBIOLOGICA is published by the Karol Starmach Institute of Freshwater Biology, Polish Academy of Sciences, ul. Sławkowska 17, 31–016 Kraków, Poland. The journal is fully financed by the authors of submitted papers and issued when the number of accepted papers has been completed. Orders for subscription, exchange, back issues, offprints or advertising space should be sent to the publisher.

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ISSN 1643-3157

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Supplementa ad Acta Hydrobiologica, **4** (2003), 1–63. Cracow, May 2003

Structural changes in the ichthyofauna of the Carpathian tributaries of the River Vistula caused by anthropogenic factors

Krzysztof KUKUŁA

Abstract – Analyses concerned the chief Carpathian tributaries of the upper course of the River Vistula. In the years 1993–2002 over 21 thousand fish of 21 species were caught. In the collected material *Phoxinus phoxinus* L., *Cottus poecilopus* Heck, and *Leuciscus cephalus* (L.), were most abundantly represented with *L. cephalus*, *Salmo trutta* m. *fario* L., and *Chondrostoma nasus* L. dominating in the biomass. The current materials were compared with data from the 1960s and 1970s, and also from earlier years, basic changes being observed in the ichthyofauna. *Acipenser sturio* L., *Salmo salar* L., and *S. trutta* m. *trutta* L. became extinct. *Alburnoides bipunctatus* (Bloch), *Barbus barbus* (L.), *C. nasus*, *Cottus gobio* (L.), and *Vimba vimba* (L.), characteristic of mountain and submontane river sectors, were found in the group of endangered species. Pollution and the construction of water dams had the most pronounced impact. The effects of pollution were distinctly visible in the River Skawa and the San middle course, where a dramatic decrease was noted in the percentages of *C. nasus*, *B. barbus*, and *A. bipunctatus*. At the same time, the numbers of *L. cephalus* and *Gobio gobio* (L.) increased and *Rutilus rutilus* (L.) widened the area of its occurrence. In most dam reservoirs fish assemblages were formed with a great share of *R. rutilus* and *Perca fluviatilis* L. These species previously not recorded, e.g. in the upper San, occurred fairly abundantly. In the River Wisłok significant changes in the ichthyofauna composition occurred both above and below the dam reservoir. Above the reservoir the numbers of *P. fluviatilis* distinctly increased. Directly below the reservoir a greater share of *L. cephalus* and *P. phoxinus* was observed. The abundance of *B. barbus* and *B. carpathicus* (Kotlík et al.) decreased, while *C. nasus* was absent. The devastation of stream beds in the course of forest works caused a decreased abundance and lower condition coefficient of fish. Angling and, above all, poaching (a common occurrence) contributed to a disturbed age structure in the population of *S. trutta* m. *fario*. In the drainage basin of the upper San, significantly higher mean body weights and total lengths of *S. trutta* m. *fario* were observed at sites where no visible signs of poaching could be found. In the upper Wisłoka the poachers' ways of fishing brought about significant differences between assemblages at the stations compared. Of the introduced fish species, none appears numerously in the discussed catchment areas. *Thymallus thymallus* (L.), introduced in the basin of the Wisłoka and San, was more frequently encountered, although it is endangered in the areas of its natural occurrence.

Key words: fish, mountain streams, threatened species, dam reservoirs, pollution, poaching.

1. Introduction

The ichthyofauna assemblages of running waters show considerable qualitative and quantitative variability caused by natural and anthropogenic factors (Penczak 1989, Grossman et al. 1990, Przybylski et al. 1993, Przybylski 1994, Penczak et al. 1996, Witkowski et al. 2000*b*, Kruk et al. 2001). The changes could be determined by comparing materials collected at intervals of several or more years, and also by analyses of data from different seasons of the year (Grossman et al. 1990, Zalewski et al. 1990). In running waters, changes in hydrological conditions frequently have a disastrous character (Strange et al. 1992, Allan 1995), but even in the case of great floods fish assemblages return fairly rapidly to their previous condition (Lusk et al. 1998, Lojkásek et al. 2000). In an undisturbed ecosystem native species are adapted to varying environmental conditions and their populations are sustained in spite of distinct reductions of abundance which frequently occur (Noakes and Grant 1986). However, owing to human activity, water ecosystems are currently subjected to pronounced abiotic and biotic stresses, which disturb the biology of many species (Welcomme et al. 1989).

In the previous century anthropogenic factors had increasingly important effects on changes occurring in aquatic ecosystems, bringing about considerable transformations of the environment, particularly of running waters (Backiel 1993). The most important factors were the pollution of waters, changes in the management of catchment areas, running water engineering, and also in the exploitation of fish populations (Backiel 1983, Schiemer and Waidbacher 1992, Allan and Flecker 1993, Heese 2001*a*, Danilkiewicz 2001). The discharge of industrial wastes and increases in the amount of domestic sewage in Poland have also caused deep changes in the ichthyofauna composition of inland waters (Backiel and Penczak 1989, Bieniarz and Epler 1991, Witkowski et al. 1992, 2000*b*, Przybylski 1993). Apart from point pollution, the surface contamination caused by runoff from agricultural areas had the greatest effect (Grabarczyk and Niewiadomski 1983, Chełmicki 2001). These factors contributed to the increased turbidity of the waters and their eutrophication (Wróbel 1983). Additionally, the extension of cropland, causing deforestation, particularly in the mountains, could have considerably deteriorated the water quality (Rees and Ribbens 1995). Energy, navigational, and agricultural needs have brought about considerable changes in the course of numerous rivers (Chełmicki 2001). Their beds have been straightened and dammed. Hydrological changes were observed in the drainage basins of rivers (Pierzgalski 1993, Żelazo 1993), leading to the decline of habitats indispensable for the reproduction and growth of fry, and reduced numbers of accessible hiding places. Large dams had a decisive effect on the extinction or drastic reduction in abundance of anadromous fish, and also contributed to changes in the composition of fish assemblages both below and above the dam reservoirs (Penczak et al. 1984, 1994, 1998, Backiel 1985, Neves and Angermeier 1990, Lusk 1995*a*, Głowacki and Penczak 2000). The place of the receding species was occupied by those better adapted to the new conditions; frequently by strange species (Peňáz and Wohlgemuth 1990, Persson 1994, Lusk 1995*a*, Kukuła 2003*b*).

During the last hundred and more years similar changes were observed in the ichthyofauna of the Carpathian affluents of the River Vistula. From the nineteenth century a gradual decline in anadromous fish occurred. In the first place a drastic reduction was observed in the abundance of Atlantic sturgeon *Acipenser sturio* L., leading to its total extinction. Formerly this species was encountered in the rivers San and Dunajec (Byliński and Kolman 2000, Dyduch-Falniowska 2001). After

World War II more and more rapid changes took place. The Atlantic salmon *Salmo trutta* L. and the sea trout *Salmo trutta* m. *trutta* L. ceased to reach the Carpathian affluents of the Vistula. These two species had their spawning grounds in drainage basins of the Soła, Skawa, Dunajec, Wisłoka, and San (Bartel 1988, 2000*a*, 2000*b*, Sych 1996, Bartel et al. 2001). Later decreases in the numbers of great predatory fishes such as pike *Esox lucius* (L.), pikeperch *Stizostedion lucioperca* (L.), and wels *Silurus glanis* (L.) were more and more frequently observed as a typical situation for numerous Polish rivers (Witkowski 1984*a*, 1984*b*, Penczak 1989, Penczak et al. 1990). Some of the previously abundant species were to be found on the list of endangered species whose number increased every year (Witkowski 1992, 2001, Witkowski et al. 1999, 2000*a*). Signals of the decreasing abundance of Cyprinidae species commonly occurring in the mountain and submontane rivers of the region, were shown. This concerned, among other species, the barbel *Barbus barbus* (L.) and nase *Chondrostoma nasus* (L.) (Skóra and Włodek 1988, 1991, Włodek and Skóra 1999, Amirowicz 2001, Kukuła 2001).

The extinction of Atlantic salmon and Atlantic sturgeon and the decreasing numbers of – among other species – the barbel and nase was accompanied by the appearance of new fish species introduced by stocking or migration from various basins (Witkowski 1996*a*, 1996*b*). Moreover, some autochthonous species with smaller requirements began to be recorded in places where they had not previously been found (Starmach 1998, Kukuła 1999).

The aim of the work was to evaluate the changes observed in the ichthyofauna of the Carpathian part of the upper Vistula in the 20th century. Analysis concerned the chief anthropogenic factors affecting to the greatest degree fish communities. Tendencies in the changing distribution ranges of the species most characteristic of the ichthyofauna in the Carpathian tributaries of the Vistula were estimated. Seasonal changes in the drainage basins of mountain rivers were analysed following the example of the upper San.

2. Study area

Selected tributaries of the upper Vistula were analysed (Fig. 1). The Carpathian sectors of the rivers were taken into consideration, accepting the border of the Carpathian Mts as delimited by Kondracki (1978). Fishes were caught in the basin of the upper San and some affluents of that river middle course (Osława, Hoczewka, Baryczka, Stupnica, and Wiar), in the upper Wisłok, in the upper Wisłoka basin, in the River Jasiołka, in streams of Mount Babia Góra, in the mid- and lower course of the Skawa and its affluents, and in headwater streams of the Vistula. A total of 91 sites were investigated (Tables I and II).

The Carpathian part of the River San is about 280 km in length from its sources to the town of Przemyśl. The catchment area covers about 4500 km^2. In the basin of the upper San the investigation was carried out at 50 sites (Fig. 2). The drainage basin covers an area of 1189 km^2 above the Solina dam reservoir. A 50-kilometre long border sector of the San resembles a submontane river, while a further sector, up to the Solina reservoir, shows traits of a mountain river. The tributaries of the upper San are typical mountain streams with a rapid water current and stony bottom. The river-beds of most water courses show traits of a natural character, smaller brooks only having been changed in the past when used as roads for wood transport (Kukuła and Szczęsny 2000). The waters of streams and rivers are pure in the investigated catchment area. The problem of

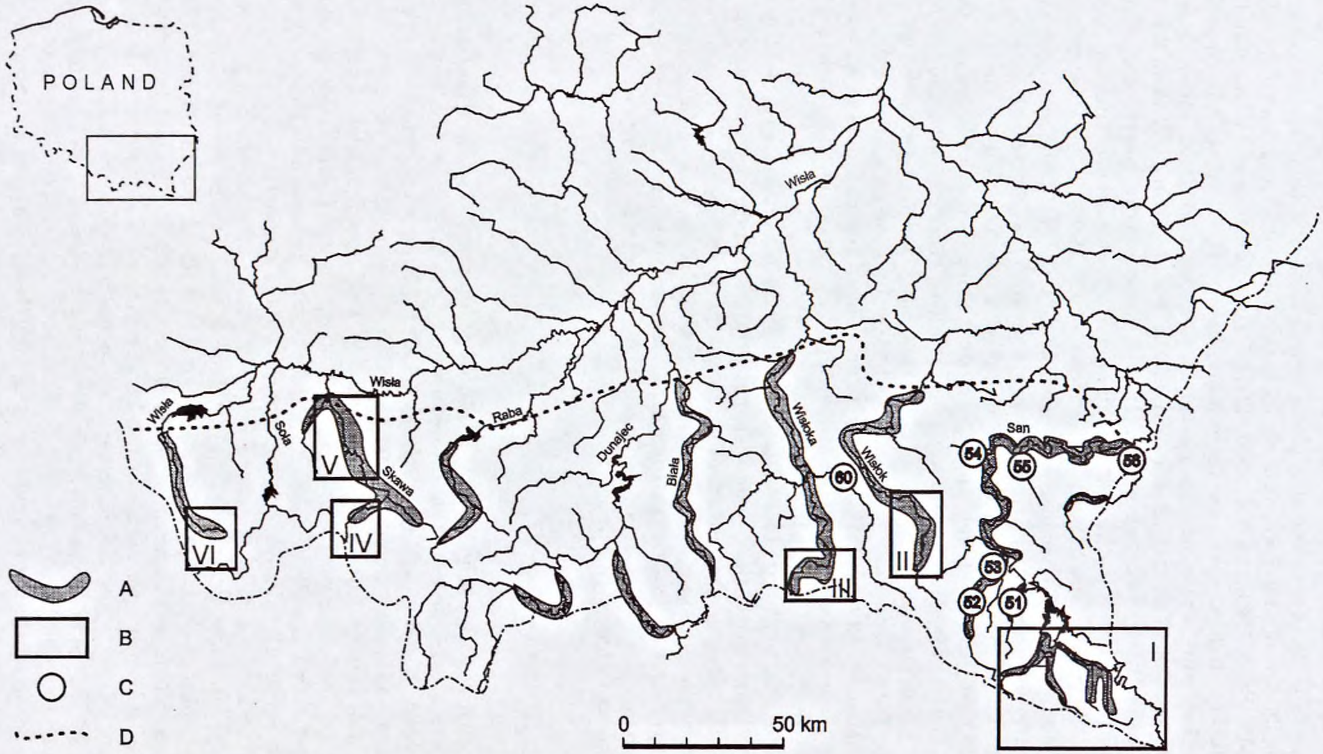

Fig. 1. Area of investigation in Carpathian affluents of the River Vistula. A – watercourses taken into consideration in comparative analyses; B – areas (I–VI) and sites (C) included in detailed studies; D – borderline of the Carpathian Mts according to Kondracki 1978.

Table I. Characteristics of sites in the upper San drainage basin (diameter of substratum [cm]: r – rocks, >50; ls – large stones, 15–50; s – stones, 2–15; g – gravel, 0.5–2; sa – sand, <0.5).

River	Site	Altitude [m]	Gradient [‰]	Width [m]	Mean depth (max.) [m]	Type of bottom	Cover (in 4 grade scale)	Shading (in 3 grade scale)
Wołosatka	1	904	146.7	1–2	0.1 (0.3)	r, ls	1	3
	2	885	34.5	1–2	0.1 (0.2)	r, ls	1	3
	3	860	50.0	2–5	0.2 (0.3)	r, ls, s	2	3
	4	820	39.0	2–5	0.2 (0.5)	r, ls, s	4	3
	5	768	26.3	3–5	0.3 (0.6)	r, ls	4	3
	6	689	14.3	3–6	0.2 (0.7)	ls, s, r	3	2
	7	640	13.8	3–7	0.2 (0.7)	ls, s, r	4	2
Wołosaty	8	613	7.6	4–10	0.3 (0.9)	r, ls, s	3	1
	9	560	8.5	4–6	0.3 (1.0)	ls, r, s	2	2
	10	541	6.1	5–10	0.3 (1.0)	r, ls, s	3	1
San	11	719	13.8	2–6	0.1 (0.4)	ls, s, g	1	2
	12	664	4.1	5–8	0.2 (0.7)	ls, s, g	2	2
	13	650	2.5	6–8	0.3 (0.8)	r, ls, s	2	2
	14	536	3.1	8–20	0.3 (1.0)	ls, r, s, g	2	1
	15	485	3.8	20–40	0.3 (1.0)	ls, r, s, g	4	1
Górna	16	801	85.0	2–3	0.2 (0.5)	r, ls	2	2
Solinka	17	775	26.0	2–6	0.2 (0.5)	r, ls, s	3	2
	18	714	24.2	3–6	0.2 (0.5)	r, ls	3	2
	19	650	22.3	4–7	0.3 (0.7)	r, ls, s	3	2
Wetlina	20	640	6.7	4–7	0.2 (0.6)	r, ls, s	3	2
	21	575	9.7	4–12	0.3 (1.2)	ls, r, s, g	2	1
	22	540	5.8	6–12	0.3 (0.7)	ls, r, s	2	1
Solinka	23	670	36.7	2–4	0.1 (0.3)	r, ls	2	3
	24	630	12.8	2–4	0.1 (0.6)	r, ls, s	1	3
	25	515	10.7	4–10	0.2 (0.8)	ls, r, s	2	2
	26	445	8.5	8–20	0.2 (0.7)	ls, r, s, g	2	1
	27	420	6.3	8–30	0.2 (0.7)	ls, r, s, g	1	1
Terebowiec	28	885	177.8	1–2	0.2 (0.4)	r, ls	1	3
	29	835	71.4	1–2	0.1 (0.4)	ls, s, r	1	3
	30	790	35.3	2–3	0.2 (0.5)	r, ls	2	2
	31	740	34.5	3–5	0.2 (0.4)	ls, s, r	1	3
	32	722	40.0	3–6	0.3 (0.8)	r, ls	3	3
	33	675	26.5	2–6	0.2 (0.7)	ls, s, g	4	3
Halicz	34	845	119.6	1–2	0.1 (0.4)	ls, r, s	3	3
	35	820	53.3	2–5	0.1 (0.4)	r, ls, s	2	3
	36	800	26.7	2–5	0.2 (0.5)	r, s, ls	3	3
	37	755	20.0	3–5	0.2 (0.4)	ls, r, s	2	3
Rzeczyca	38	755	168.0	1–2	0.1 (0.3)	ls, s	1	3
	39	720	50.0	2–5	0.2 (0.4)	ls, s	2	2
	40	650	25.5	2–6	0.2 (0.7)	ls, s, g	2	2

Table I. *continued*

River	Site	Altitude [m]	Gradient [‰]	Width [m]	Mean depth (max.) [m]	Type of bottom	Cover (in 4 grade scale)	Shading (in 3 grade scale)
Nasicznianński	41	785	160.4	1–2	0.1 (0.2)	ls, s	1	1
	42	693	26.7	2–4	0.3 (0.6)	r, ls	4	2
	43	625	27.2	2–6	0.3 (1.0)	r, ls, s	4	3
	44	525	15.1	3–8	0.2 (1.0)	r, ls, s, g	2	2
Hylaty	45	675	155.7	2–4	0.1 (0.6)	r, ls	2	3
	46	560	35.1	2–4	0.2 (0.7)	r, ls, s	3	3
Rzeka	47	645	142.0	1–2	0.1 (0.3)	r, ls	3	3
	48	575	26.7	2–3	0.2 (0.4)	r, ls	2	3
Głeboki	49	510	25.3	2–5	0.2 (0.4)	r, ls, s	2	3
Smolnik	50	535	19.5	2–4	0.2 (0.5)	ls, s, g, sa	3	2

Table II. Characteristics of sites in the drainage basins of the rivers Skawa, Czarna and Biała Wisełka, upper Wisłok, upper Wisłoka, and tributaries of the River San middle course (diameter of substratum [cm]: r – rocks, >50; ls – large stones, 15–50; s – stones, 2–15; g – gravel, 0.5–2; sa – sand, <0.5; m – mud).

River	Site	Altitude [m]	Width [m]	Mean depth (max.) [m]	Type of bottom	Cover (in 4 grade scale)	Shading (in 3 grade scale)
Hoczewka	51	380	10–15	0.2 (0.7)	r, ls, s	3	2
Osława	52	460	15–30	0.1 (1.0)	r, ls, s	3	1
	53	306	25–35	0.2 (0.8)	ls, r, s, g	2	1
Baryczka	54	250	4–7	0.2 (1.0)	s, g, sa, m	3	3
Stupnica	55	220	6–15	0.2 (0.6)	s, g	2	2
Wiar	56	195	18–20	0.4 (1.0)	g, s, sa	2	1
Wisłok	57	360	12–20	0.2 (1.0)	ls, r, s	3	2
	58	280	5–12	0.2 (0.8)	s, g, ls	3	3
	59	260	8–15	0.2 (0.6)	s, g, sa	2	2
Jasiołka	60	254	10–20	0.3 (0.7)	r, ls, s	2	2
Ryjak	61	520	1–2	0.1 (0.5)	s, g, sa	1	2
	62	470	2–4	0.2 (0.7)	ls, s, g	4	3
	63	440	3–4	0.2 (0.4)	ls, s	2	3

Table II. *continued*

River	Site	Altitude [m]	Width [m]	Mean depth (max.) [m]	Type of bottom	Cover (in 4 grade scale)	Shading (in 3 grade scale)
Wisłoka	64	465	4–5	0.3 (0.9)	s, g, sa	4	3
	65	430	4–6	0.4 (1.2)	ls, s, g	2	2
	66	400	4–8	0.3 (0.7)	ls, s	2	2
	67	380	6–15	0.3 (1.5)	s, ls, g	3	1
	68	340	8–15	0.3 (1.5)	r, ls ,s, g	3	2
Krempna	69	480	1–2	0.1 (0.3)	ls, s	1	2
	70	400	2–4	0.1 (0.4)	ls, s, g	4	3
Baranie	71	440	2–3.5	0.2 (0.4)	ls, s	2	3
Hucianka	72	430	2–5	0.2 (0.6)	ls, s	3	3
Wilsznia	73	345	3–5	0.3 (1.0)	s, ls, g	3	2
Reszówka	74	430	1–2.5	0.1 (0.5)	s, ls	2	3
Świerzówka	75	470	1–2	0.1 (0.3)	ls, s	2	3
Rybny Potok	76	825	1–4	0.2 (0.5)	ls, s	4	3
	77	700	4–6	0.2 (0.8)	r, ls	2	2
Jaworzyna	78	720	4–7	0.2 (0.4)	ls, s	2	1
Jałowiec	79	730	2–6	0.2 (0.7)	ls, s	3	3
Skawa	80	315	9–15	0.3 (0.6)	ls, s, g	2	1
	81	295	8–25	0.4 (1.0)	ls, r, g	3	1
	82	280	12–20	0.3 (0.7)	ls, r	2	2
	83	265	10–20	0.3 (0.8)	s, g	2	1
	84	245	10–30	0.3 (1.0)	s, ls, g	2	1
	85	215	10–40	0.3 (1.2)	s, ls, g, sa	1	1
Paleczka	86	320	2–10	0.2 (0.6)	ls, g	2	2
Stryszówka	87	320	2–5	0.2 (0.5)	s, g	2	2
Tarnawka	88	325	2–4	0.2 (0.4)	ls, s	2	3
Jaszczurówka	89	280	2–5	0.3 (0.8)	g, s, sa, m	2	3
Czarna Wisełka	90	580	4–8	0.1 (0.5)	ls, s	2	3
Biała Wisełka	91	600	4–10	0.2 (1.0)	ls, s, r	3	2

water pollution has appeared only in some villages owing to intensified tourism (Kukuła 1997*b*).

On the Osława (65 km in length) and Hoczewka (28 km in length) three sites (51–53) were located. The two rivers flowing into the San below the Solina reservoir have a natural riverbed character but the effects of eutrophication are manifested in their lower sectors. The lower sectors of the tributaries of middle San (Fig.1) were also investigated. The small Baryczka stream (station 54) is marked

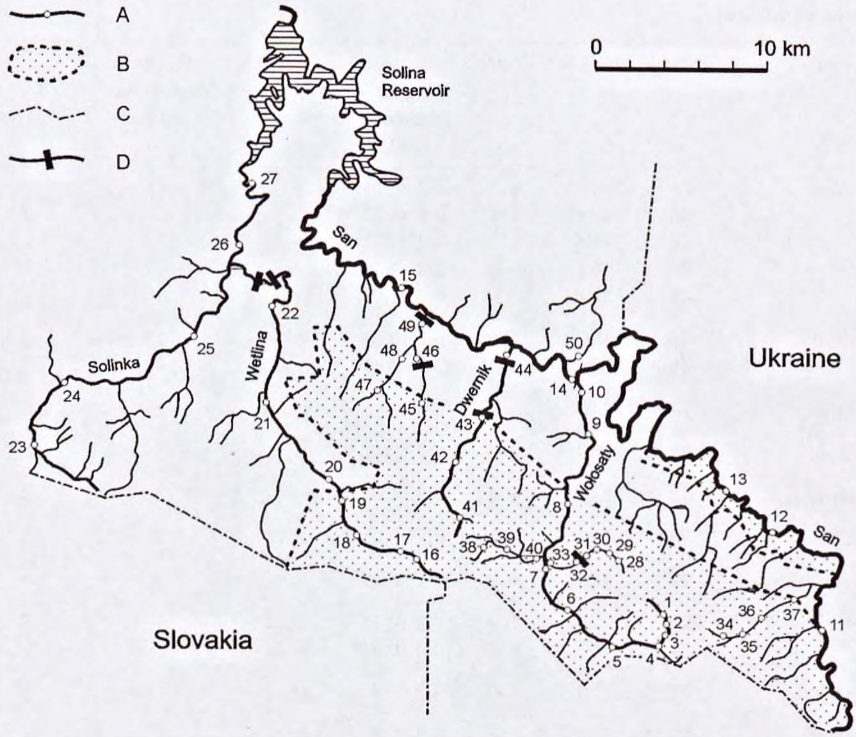

Fig. 2. Location of sampling sites on the upper San drainage basin. A – sites; B – Bieszczady National Park; C – state borders; D – water bars and waterfalls.

with distinct anthropogenic changes in its whole course, and in the investigated sector the effect of domestic wastes was observed. The lower course of the Stupnica stream (26 km in length) has slightly changed and in this sector the quantities of pollution inflow are not great (site 55). The River Wiar (70 km in length) at site 56 up to the inflow to the San flows between embanked and strengthened banks and in the physicochemical aspect, its waters fall outside purity class III (Suchy 2001).

In the upper part of the largest San affluent – the River Wisłok (205 km in length) – catches were made at three sites (Fig. 3). Site 57 lies above the Besko reservoir. The Wisłok here is a pure mountain river, with a natural riverbed pattern. The other two stations were located below the dam. The river is partly regulated and fairly pure there.

In the catchment area of the Wisłoka the investigation included the Wisłoka (164 km in length) and seven of its affluents (Fig. 4). The rivers and streams of this area have the character of mountain watercourses with a fairly pronounced bed gradient and a stony bottom. With respect to physicochemical parameters, the waters of this area belong to purity class I (Suchy 2001).

In the River Skawa (96 km in length and a drainage basin of 1160 km^2) catches were conducted at four sites in the Skawica catchment where the investigation included the most important streams of Babia Góra National Park (Fig. 5). In the middle and lower part of the Skawa basin 10 stations were located (Fig. 6). Catches were made in a sector of the Skawa from the village of Zembrzyce to that of

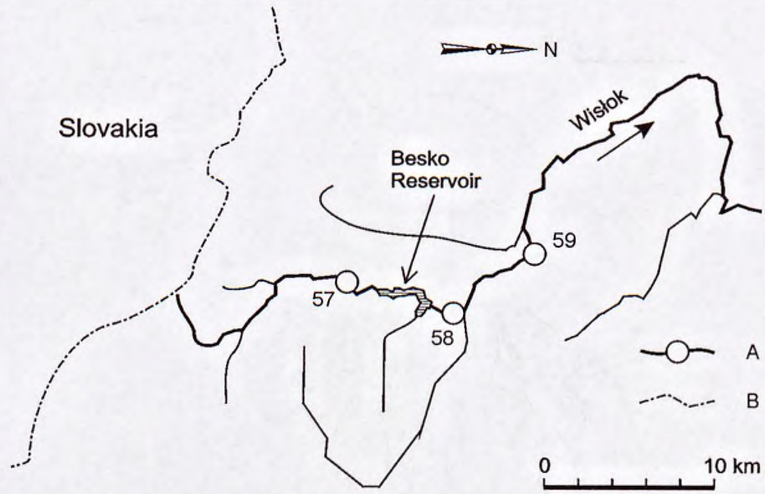

Fig. 3. Sampling sites in the upper Wisłok. A – sites; B – state border.

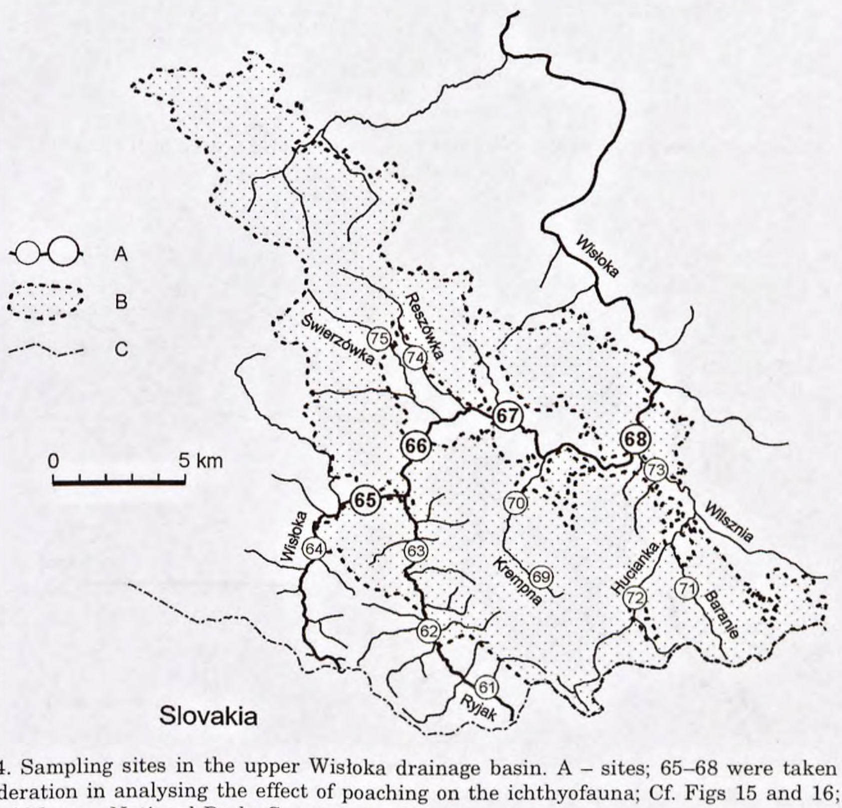

Fig. 4. Sampling sites in the upper Wisłoka drainage basin. A – sites; 65–68 were taken into consideration in analysing the effect of poaching on the ichthyofauna; Cf. Figs 15 and 16; B – area of Magura National Park; C – state border.

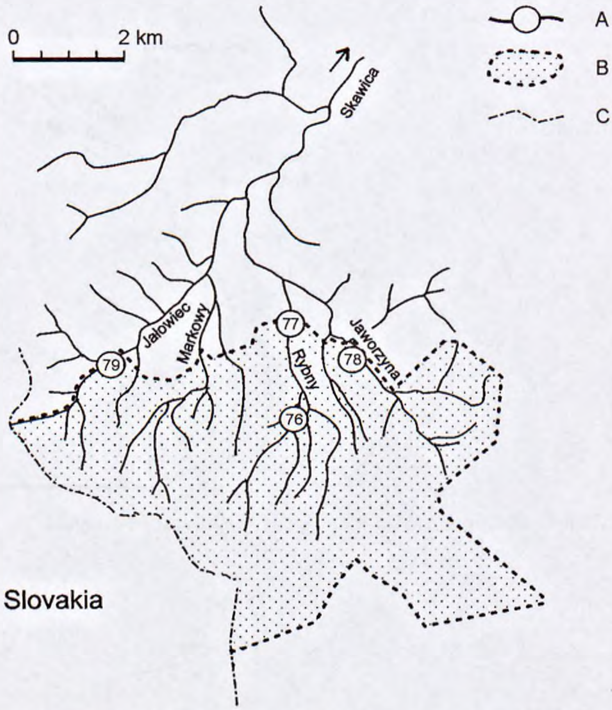

Fig. 5. Sampling sites in Babia Góra National Park. A – sites; B – area of the Park; C – state border.

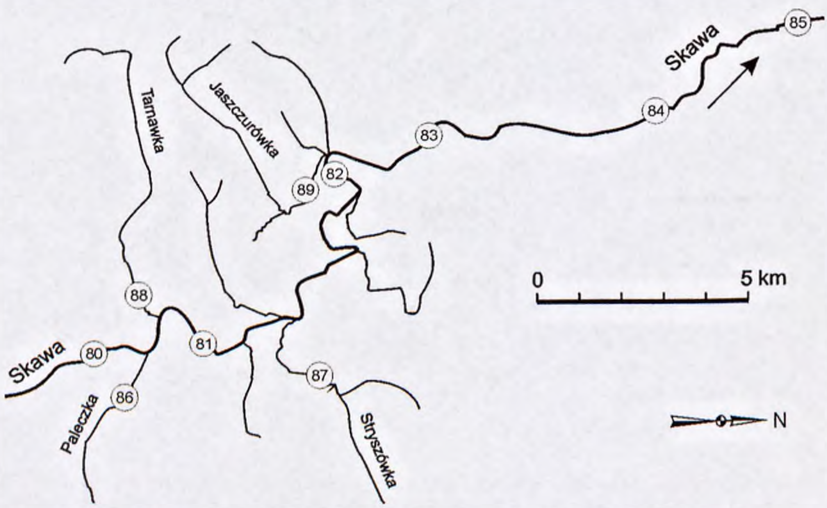

Fig. 6. Sampling sites in the middle and lower course of the River Skawa.

Graboszyce and in mouth sectors of its greater tributaries. In this sector the Skawa waters are in places contaminated with domestic sewage, being in purity class III with respect to physicochemical parameters (Gałaś 1998).

Catches were also made in the headwater part of the Vistula drainage basin (Fig. 7). One site in the Biała Wisełka (site 91) was selected; fish were also sought

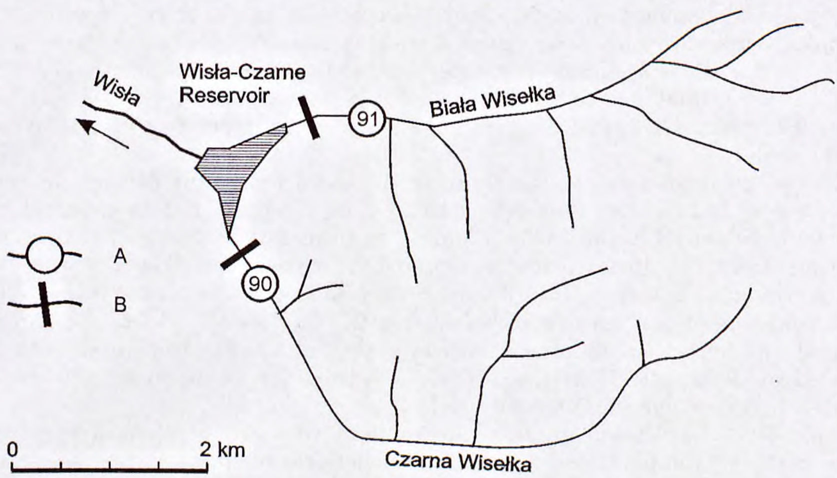

Fig. 7. Sampling sites in headwaters of the River Vistula. A – sites; B – water bar.

for in two sectors of the Czarna Wisełka (site 90). The two sectors investigated are fairly similar from the morphometric aspect, distinctly differing by the chemical composition of the water (Wróbel 1995).

3. Material and methods

The material was collected by electrofishing carried out in 1993–2002 with the use of IUP-12 (350 V; 3.5 A; 20–100 Hz) electric impulse equipment. The catches were carried out using the method of once-over passage. Owing to a fairly shallow depth, the fishing was conducted by wading in the water. The length of sectors where the fishing occurred was from about 100 m in the smallest streams to about 250 m in larger rivers. The numbers and weight of caught fish were calculated per 100 m^2. After catches the fish were identified, counted, and weighed, and then released into the water.

Morphometric traits were evaluated on site whose description was given in Tables I and II. The traits were standardized and used for grouping the sites in the basins of the upper San and upper Wisłoka by cluster analysis (Gauch 1982).

At most sites on the upper San fishing was carried out at least three times: in spring, summer, and autumn, except for stations 11–13 and 50 where one fishing took place in summer. The density of fish at different sites was calculated as the percentage of maximum density of the given species in the entire catchment area, the assumptions presented by Przybylski (1993) being accepted. These values were also used in grouping species by cluster analysis.

For comparison of fish assemblages from the different groups of stations, the number of species at the sites was determined (species abundance – S), diversity indices being applied:

$$H' = -\Sigma p_i \ln p_i$$

$$D = 1/\Sigma(p_i^2)$$

where p_1 is the proportion of the abundance of species i – of this species in the assemblage. The two indices are used since the index H' is a better characteristic of rare species while D applies a greater weight to common species (Krebs 1994).

Of the identified fishes the brown trout *Salmo trutta* m. *fario* L. as a key species (Głowaciński 1994) in the drainage basin of the upper San was analysed on a wider scale.

Changes in biomass and abundance of the more important fish species in the middle course of the River San were estimated on the basis of data collected above the town of Przemyśl in the 1960s (Bieniarz and Epler 1972, Kołder 1973), and also materials from the 1990s made available by the Regional Board of the Polish Angling Union at Rzeszów. In affluents of the San below dam reservoirs, changes in the numbers of fish species were investigated at sites 51, 53–56, the materials collected in 2002 (Kukuła and Amirowicz unpubl.) being compared with data obtained by Rolik (1971) in the 1960s. In estimating abundance the categories accepted by the above author were used.

The effect of pollution on the ichthyofauna was investigated in the Vistula upper course by comparing sites differing in chemical composition and above all by the pH value of the water (Wróbel 1995). In these studies the Skawa was also taken into consideration as the last important affluent of the upper Vistula, where no dam reservoir had yet been constructed. Here the changes in the ichthyofauna composition could have been above all induced by water pollution, particularly distinct in the 1980s and 1990s (Turzański 1999). The data obtained from the Skawa basin in 1995–1998 (Kukuła 2000*b*) were compared with materials collected in the same sectors in the 1970s and 1980s (Skóra and Włodek 1991).

The problems of poaching were considered, using as examples the streams flowing across three national parks (Babia Góra National Park – BgNP, Bieszczady National Park – BdNP, and Magura National Park – MNP). In all three parks fishing is absolutely forbidden. In estimating the intensity of poaching attention was paid to all traces of fishing (such as fishing lines, remaining remnants of bait, or characteristic trodden places on river banks). At some of these places poachers were observed. The general estimate of poaching intensity was based on information supplied by workers in the parks. Their opinion helped to determine that within protected areas the pressure of poaching, particularly in the zones of strict protection of nature, was less than outside them. In BgNP out of four analysed sites only station 76 did not suffer from poaching (Kukuła 2003*a*). In BdNP two pairs of similar sites were elected (stations 32 and 33, and 42 and 43). In the period of investigation sites 33 and 43 were within the reach of the poachers' activity, while the corresponding sites 32 and 42 were not subject to such pressure. In MNP the selection of sites was based on similar principles. At stations 65 and 67 poachers' catches were recorded while at stations 66 and 68 no signs of poaching, or only sporadic events were noted (Kukuła 2002).

The effect of dam reservoirs on the ichthyofauna was estimated by analysing the situation in the drainage basin of the Solina reservoir and in the Wisłok sector in the region of the Besko dam reservoir. In the above dams no fish-passes had been installed.

A great part of the upper Vistula catchment is afforested (Fabijanowski and Jaworski 1995) and forest management was frequently damaging to water ecosystems. Here sites 38 and 41 in the Bieszczady Mts can be quoted as examples. Up to the early 1990s, before the BdNP was enlarged, forest works were conducted in this region using streams as roads for wood transport (Kukuła unpubl.). The hydrological and morphological conditions of the two sites were very similar. On the basis of interviews with foresters and the author's own observation site 38 was estimated as strongly devastated while station 41 was not changed in the course of forest works. The Fulton (K) condition coefficient was calculated for Siberian sculpin individuals caught there (Opuszyński 1983).

Analysis of changes in the distribution range of the most important fish species for Carpathian rivers and streams was based on the occurrence of fish at 125 sites located on those rivers (Fig. 1). There electrofishing was conducted in the 1960s and 1970s and repeated in the late 1980s or later (Rolik 1971, Skóra 1972, Bieniarz and Epler 1972, Kołder 1973, Kołder et al. 1974, Skóra and Włodek 1989*a*, 1991, Starmach et al. 1988, Włodek and Skóra 1992, Skóra et al. 1994, Augustyn and Bieniarz 1995, Augustyn et al. 1996, 1998, Starmach 1998, Kukuła 1999, 2003*a*, Kukuła unpubl., Kukuła and Amirowicz unpubl.). The waters investigated in the two periods mentioned above were taken into consideration, the data concerning the presence or absence of species at the sites being compared by the Eklöv et al. (1998) method based on contingency table analysis. The same statistical method was used in comparing fish communities in the middle course of the San, Wisłok, and Wisłoka.

The mean values of density and biomass of fish for the different groups of stations in the drainage basin of the upper San and the mean densities and biomass of species occurring in all the groups of watercourses were statistically verified using one way analysis of variance, the t-test or the Kruskal-Wallis test and the U-test. For the grouping of means the Tukey test was used. Differences between the mean density values in various seasons of the year within the groups of sites for species occurring in at least half the stations in the group were estimated using the Friedman test and by calculating the Kendall's coefficient of concordance W (Zar 1984).

Data concerning the condition of the ichthyofauna were supplemented by polling and interviewing anglers. This method of gathering data was used with respect to the upper Vistula, streams of the Silesian Beskid Range, and drainage basins of the Soła, Skawa, Wisłoka, and San. The materials obtained were used for supplementing the chapter "Results" with sections dealing with Poaching and Degree of threat to the ichthyofauna. The presented general estimate of the degree of threat to fish species and lampreys in the Carpathian affluents of the River Vistula was based on the classification of threats elaborated by the International Union of Nature Protection (Głowaciński 1997, Witkowski et al. 1999).

4. Results

In the course of the investigation carried out in the Carpathian affluents of the River Vistula from 1993–2002 over 21 thousand fish of 688 kg body weight representing 21 species were caught (Table III). In the collected material the minnow *Phoxinus phoxinus* L., Siberian sculpin *Cottus poecilopus* Heck, and chub *Leuciscus cephalus* (L.) were most abundantly represented. In the biomass chub, brown trout, and nase prevailed. The highest occurrence stability was found for the brown trout, Siberian sculpin, and minnow.

Table III. Species composition, relative numbers (N), biomass (B), and stability of occurrence (C) of the ichthyofauna in Carpathian tributaries of the River Vistula in the years 1993–2002.

Species	N		B		C
	[ind.]	%	[g]	%	
Alburnoides bipunctatus	455	2.10	4781	0.70	21.1
Alburnus alburnus	561	2.59	16074	2.34	18.9
Barbatula barbatula	1438	6.65	16136	2.35	53.3
Barbus barbus	128	0.59	16511	2.40	7.8
Barbus carpathicus	1629	7.53	62170	9.04	38.9
Chondrostoma nasus	243	1.12	83519	12.15	12.2
Cottus gobio	88	0.41	978	0.14	13.3
Cottus poecilopus	4004	18.51	32033	4.66	77.8
Esox lucius	5	0.02	286	0.04	3.3
Gobio gobio	805	3.72	10468	1.52	22.2
Gobio albipinnatus	5	0.02	40	0.01	1.1
Gymnocephalus cernuus	2	0.01	43	0.01	2.2
Hucho hucho	1	0.01	1200	0.17	1.1
Leuciscus cephalus	2505	11.58	219226	31.89	38.9
Leuciscus leuciscus	209	0.97	12574	1.83	27.8
Oncorhynchus mykiss	4	0.02	596	0.09	3.3
Perca fluviatilis	412	1.90	11329	1.65	25.6
Phoxinus phoxinus	6697	30.96	36169	5.26	63.3
Rutilus rutilus	358	1.65	12969	1.89	18.9
Salmo trutta m. *fario*	1841	8.51	132245	19.24	88.9
Thymallus thymallus	242	1.12	18136	2.64	25.6
Total	21632	100	687483	100	

4.1. Fish assemblages in the River San catchment

On the basis of morphometric traits, the stations located in the upper San drainage basin were divided into five groups (Fig. 8). Group A was composed of the upper courses of streams with a great bed gradient and a small width and depth. The streams in group B were characterized by a smaller gradient and a slightly greater number of hadeaways accessible to fish. Group C included the middle courses of larger streams and lower courses of small brooks. In group D the width of watercourses reached 12 m while the gradients did not exceed 16‰. Group E included rivers with a considerable width of riverbed. In numerous sectors the bottom was covered with small stones and gravel (Table I).

In different seasons of the year differences were observed in the abundance of fish species occurring in the catchment area. In spring, 13, in summer, 16, and in autumn 14 species were recorded. Differences were found in the density of fish at the sites and between the groups of sites (Fig. 9). At the sites of group A two species at the most occurred throughout the year – the Siberian scuplin and brown trout. In group B apart from the above species the minnow was found in a few sites. In spring the spawners of the roach *Rutilus rutilus* (L.) were observed. In summer and autumn the minnow occurred in most sites of group C. Some other species such as grayling *Thymallus thymallus* (L.) and perch *Perca fluviatilis* L. were also observed in a few places. At the sites of group D the number of occurring

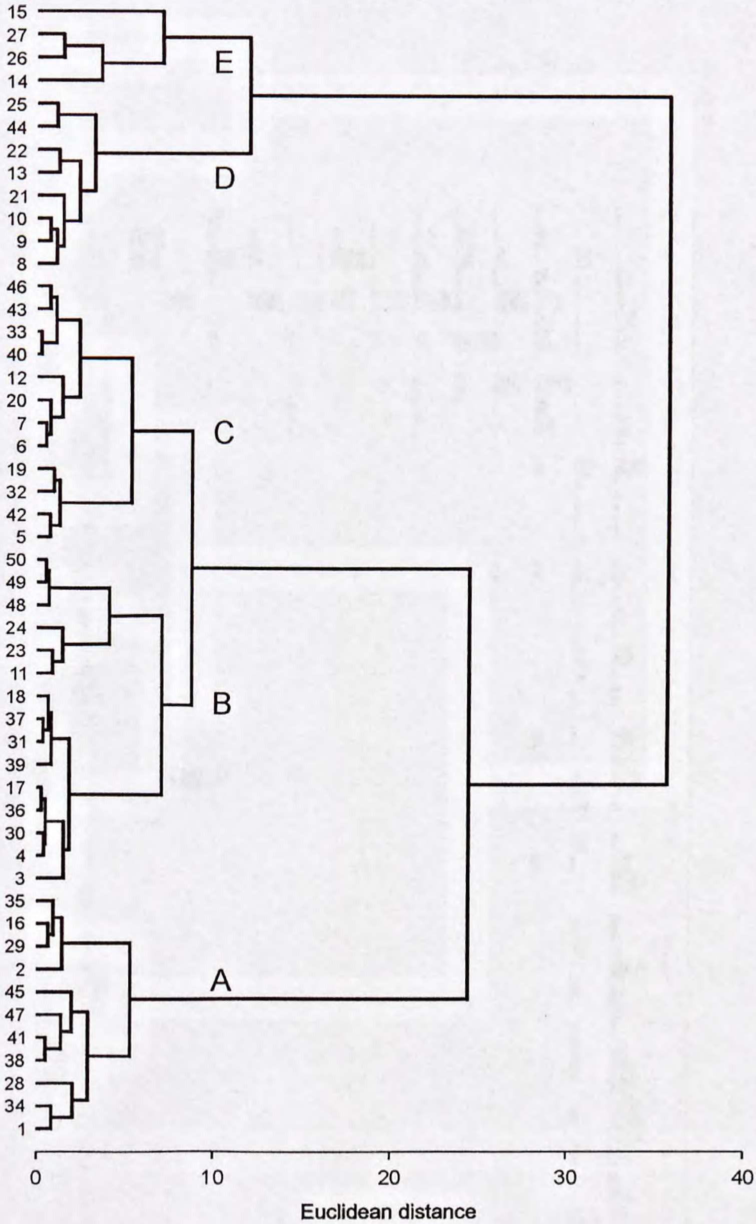

Fig. 8. Dendrogram of 50 sampling sites in the upper San basin formed by cluster analysis based on morphometric characteristics. A–E – groups of sites.

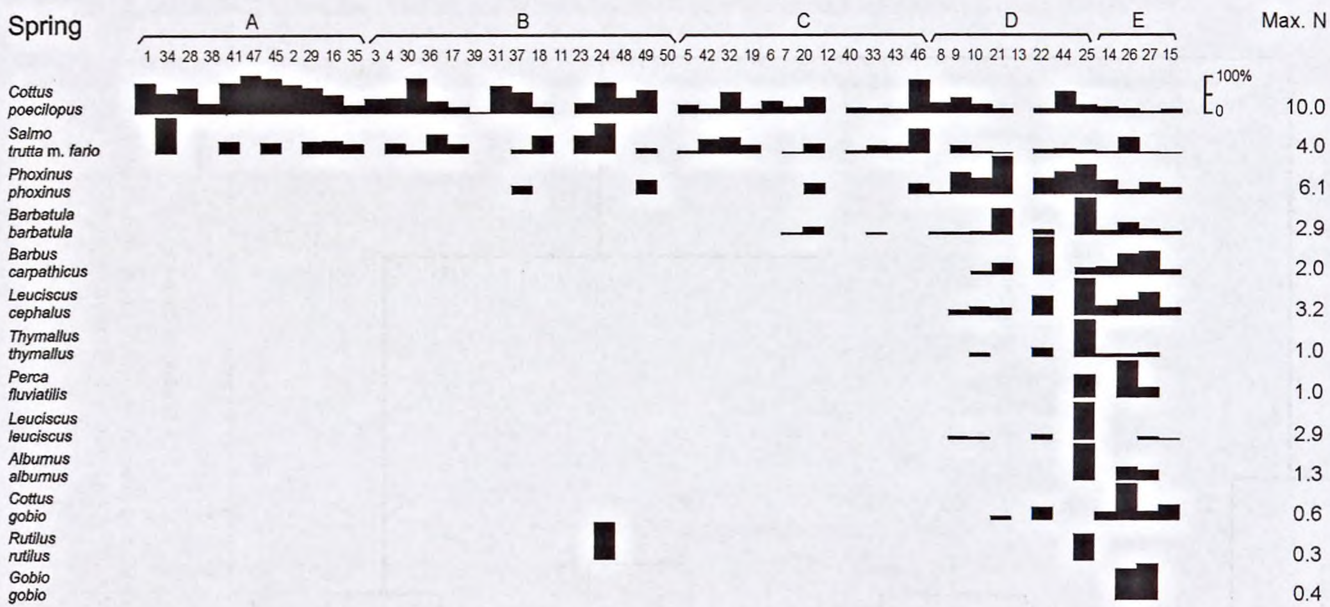

Fig. 9. Density of fish at different sites in the upper San basin calculated as percentages of the maximum density of a given species in the entire river catchment. A–E – groups of sites.

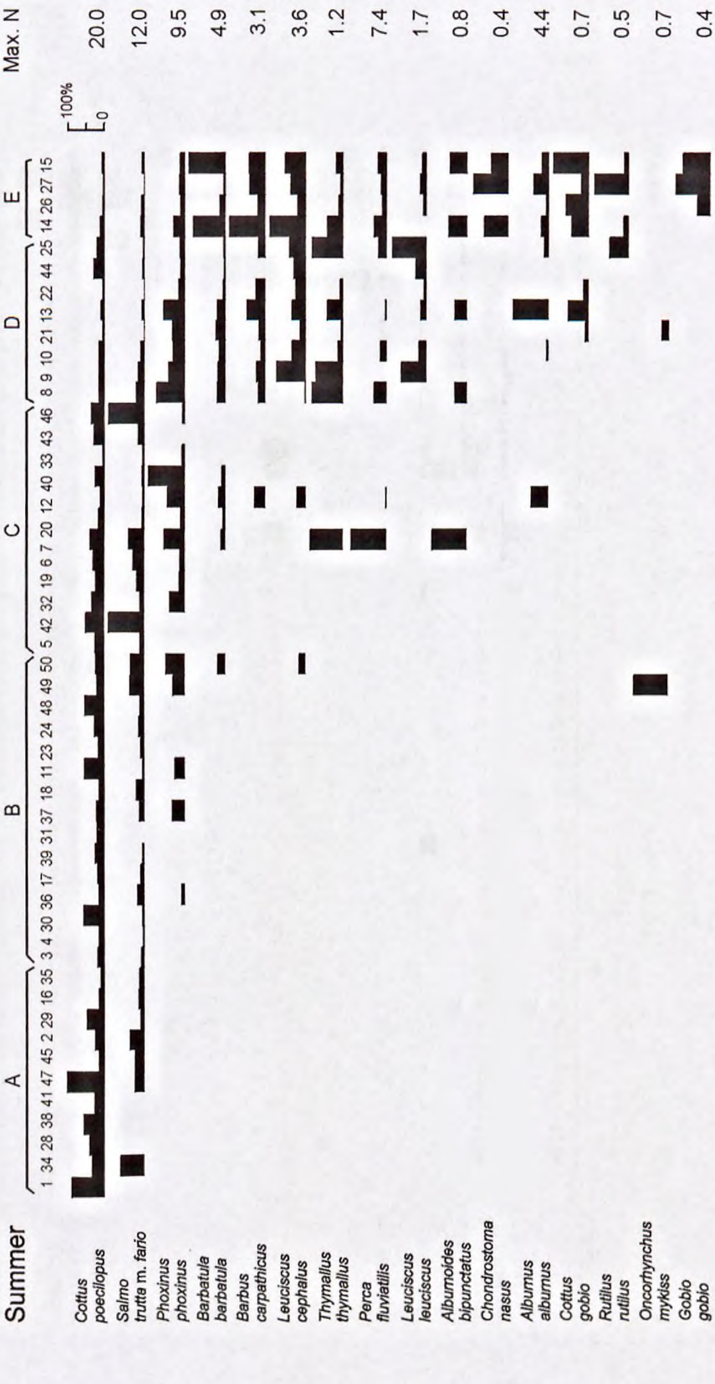

Fig. 9. Continued

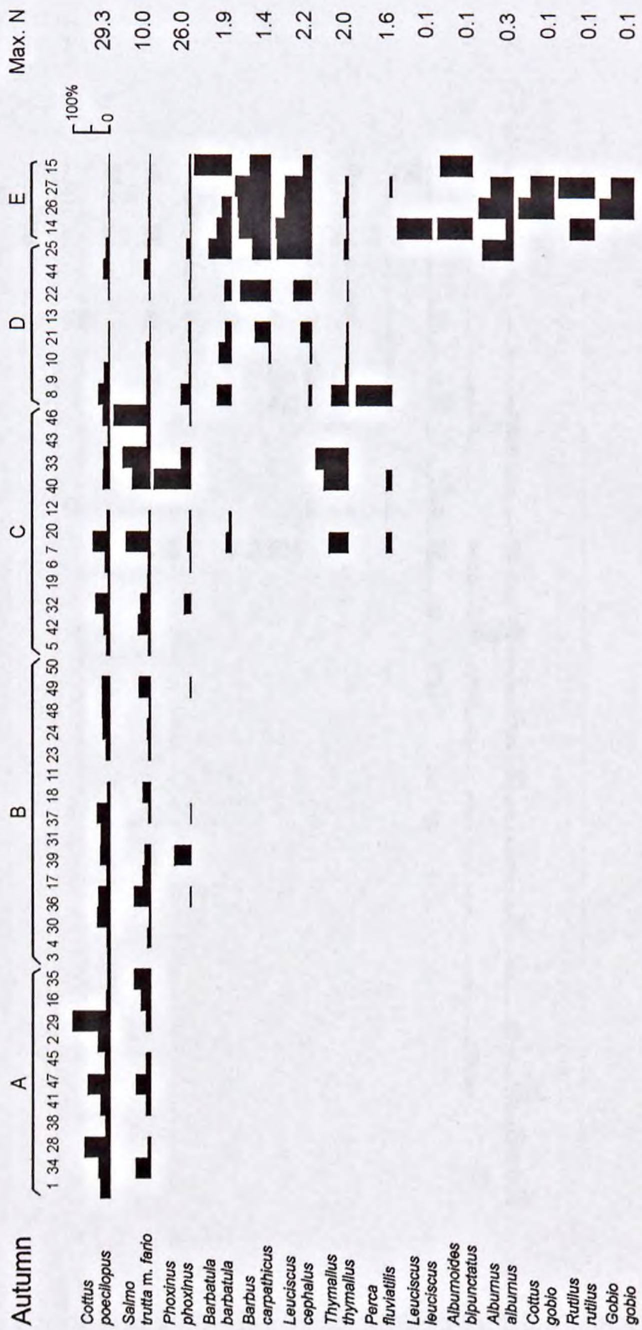

Fig. 9. Continued

species ranged from 9 in autumn to 13 in summer. In the rivers of group E, 15 fish species were recorded. In this zone only the occurrence of the gudgeon *Gobio gobio* (L.) and nase were determined, the latter being found only in summer.

Among the more numerous species of the upper course of the San, statistically significant differences appeared in mean density and mean biomass in the individual groups of sites (Table IV). The greatest density and biomass of Siberian sculpin was observed in the highest sectors of streams (group A) throughout the year. A similar density was recorded only in zone C in summer and with respect to biomass in zone B in autumn. The density and biomass of the minnow, abundantly occurring in the catchment of the upper San, showed significant differences only in spring. Significant differences in density and biomass were found for stone loach *Barbatula barbatula* (L.). This species preferred larger watercourses (groups D and E), most abundantly occurring there. In the remaining groups, except for the grayling, significant differences in density and/or biomass were noted only in summer.

Of the investigated fish species the Siberian sculpin showed the greatest stability and, apart from group C (CV=60.3), the coefficient of variation for this species (CV 30.9–43.9) varied in the range determined by Freeman et al. (1988) as moderately stable. The brown trout which, like the Siberian sculpin, occurs in all the groups of stations, was characterized by a medium or high fluctuation in abundance at all sites. In zone D high coefficients of variation were found for the chub and spotted barbel, while in group E the coefficients for these species were fairly low. Out of 15 species found at the sites of group E most were characterized by high coefficients of variation (Table V). The highest mean coefficient of variation for the abundance of species was obtained in group E and the lowest in group B. For the species which occurred at least at half the sites of the given group, significant differences were found between mean densities in various seasons of the year in places where high coefficients of variation were determined, i.e. in groups C–E (Table VI).

Statistical analysis showed no significant differences between the mean values of biodiversity indices in groups A or B. However, the mean values of the D coefficient at the sites of group C, the species abundance (S) in group D, and all the indices in group E were significantly higher in summer ($P<0.05$; Fig. 10).

In each season of the year three cenological groups of species were determined. In spring the first group was composed of the brown trout and Siberian sculpin (Fig. 11), the second of the minnow with grayling and stone loach; besides these there occurred the chub, dace *Leuciscus leuciscus* (L.), bleak *Alburnus alburnus* (L.), and roach *Rutilus rutilus* (L.). The third group contained the spotted barbel *Barbus carpathicus* (Kotlík et al.) with the perch, gudgeon, and bullhead *Cottus gobio* L. Three groups could have been identified also in summer. The composition of the second and third groups changed and in the case of the second group the minnow and grayling were accompanied by the dace, perch, and the spirlin *Alburnoides bipunctatus* (Bloch). In autumn, in the first group the brown trout and Siberian sculpin were found with minnow, grayling, and perch (Fig. 11).

The brown trout commonly occurring in the San basin did not show statistically significant differences either with respect to density or biomass between the groups of sites A–E (Table IV). However, in the groups of sites the mean body weight of individuals differed significantly (Table VII). In the upper course of streams (sites of group A), small, chiefly individuals of brown trout were caught, their abundance being somewhat low (Fig. 12). In large rivers (group E) this species was fairly rare and individuals of various length classes were encountered. At the sites of group C

Table IV. Mean density (N) and biomass (B) of the more abundant fish species in the upper San drainage basin in various seasons of the year (A–B – groups of sites distinguished on the basis of morphometric parameters; *** – P<0.001; ** – P<0.01; * – P<0.05; NS – non-significant differences; subgroups underlined).

Species		Spring					Summer					Autumn				
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Cottus poecilopus	N	64.5	43.9	28.1	27.0	10.5	41.2	26.3	26.8	13.8	6.1	35.9	20.4	17.5	11.4	2.0
		*** A BCD CDE					** AC BCD DE					** A BCDE				
	B	50.5	29.3	26.2	22.9	13.0	31.2	16.7	17.1	9.3	5.9	39.5	23.9	20.0	15.4	3.6
		* A BCDE					** A BCDE					* AB BCDE				
Salmo trutta m. *fario*	N	23.7	25.3	23.8	9.4	14.1	18.7	14.6	30.8	9.4	7.3	18.3	14.0	35.0	8.3	2.7
		NS					NS					NS				
	B	8.5	15.9	23.0	12.5	17.3	14.0	13.6	32.8	14.1	12.9	8.9	6.0	24.0	8.8	4.0
		NS					NS					NS				
Phoxinus phoxinus	N	–	4.6	5.2	55.4	24.9	–	10.6	25.5	37.0	19.0	–	3.9	14.9	8.2	3.7
		*** BC CE D					NS					NS				
	B	–	2.1	3.0	49.1	14.5	–	13.9	28.0	45.3	19.6	–	4.5	15.1	19.1	3.4
		*** BCE D					NS					NS				
Barbatula barbatula	N	–	–	2.9	29.6	17.5	–	1.4	4.0	15.9	52.3	–	–	1.9	23.9	41.0
		** CE DE					*** BC CD E					* C DE				
	B	–	–	1.1	20.0	10.1	–	1.2	5.0	17.5	53.1	–	–	2.5	26.4	43.7
		** CE DE					*** BC CD E					* C DE				

Barbus carpathicus	N	–	–	–	22.6	38.4	–	–	2.5	21.2	52.7	–	–	–	27.1	85.0
		NS					*** C D E					*				
	B	–	–	–	31.8	49.1	–	–	1.5	28.5	54.7	–	–	–	29.2	58.8
		NS					*** C D E					NS				
Leuciscus cephalus	N	–	–	–	29.6	37.9	–	1.2	2.1	36.4	56.5	–	–	–	27.2	68.3
		NS					*** BC D E					NS				
	B	–	–	–	23.4	39.9	–	1.4	2.2	42.6	81.2	–	–	–	19.4	61.3
		NS					*** BC D E					*				
Thymallus thymallus	N	–	–	–	18.9	6.7	–	–	8.3	43.8	23.0	–	–	21.4	14.1	8.4
		NS					NS					NS				
	B	–	–	–	19.4	7.8	–	–	0.4	32.2	26.5	–	–	6.4	46.4	31.4
		NS					*** CE DE					*** CE D				
Perca fluviatilis	N	–	–	–	8.9	31.9	–	–	8.5	9.8	22.0	–	–	2.9	14.3	1.6
		NS					NS					NS				
	B	–	–	–	14.3	28.8	–	–	8.8	17.7	64.7	–	–	3.7	14.3	2.7
		NS					** CD E					NS				

Table V. Mean coefficients of variation of the species determined in at least half of sites in a given group.

Species	Group of stream									
	A		B		C		D		E	
	CV	*SD*	CV	*SD*	CV	*SD*	CV	*SD*	CV	*SD*
Cottus poecilopus	43.9	*24.2*	35.5	*22.4*	60.3	*28.4*	30.9	*21.5*	36.4	*18.7*
Salmo trutta m. *fario*	66.7	*62.3*	62.0	*46.0*	82.6	*36.7*	56.5	*27.5*	77.1	*35.2*
Phoxinus phoxinus					73.5	*61.7*	65.5	*20.7*	33.6	*26.7*
Barbatula barbatula							85.3	*53.2*	86.1	*38.0*
Barbus carpathicus							70.8	*73.4*	48.2	*36.6*
Leuciscus cephalus							81.0	*62.5*	46.5	*30.1*
Thymallus thymallus							64.8	*44.6*	96.3	*56.9*
Perca fluviatilis									135.6	*44.4*
Leuciscus leuciscus							89.1	*66.2*	138.2	*41.5*
Alburnus alburnus									116.4	*66.2*
Cottus gobio									85.2	*29.7*
Rutilus rutilus									98.0	*74.3*
Gobio gobio									77.4	*71.5*
Alburnoides bipunctatus									77.7	*90.9*
Chondrostoma nasus									129.9	*86.6*

Table VI. Evaluation of differences in the mean density of the species occurring in at least half of sites in groups (A–E) in various seasons of the year.

Group of stream	CV	SD	W	Friedman's test	
				χ^2	P
A	55	47.6	0.750	3.00	>0.05
B	49	37.9	0.246	2.95	>0.05
C	72	44.0	0.633	12.67	<0.01
D	68	50.1	0.531	14.86	<0.001
E	86	58.3	0.767	23.06	<0.0001

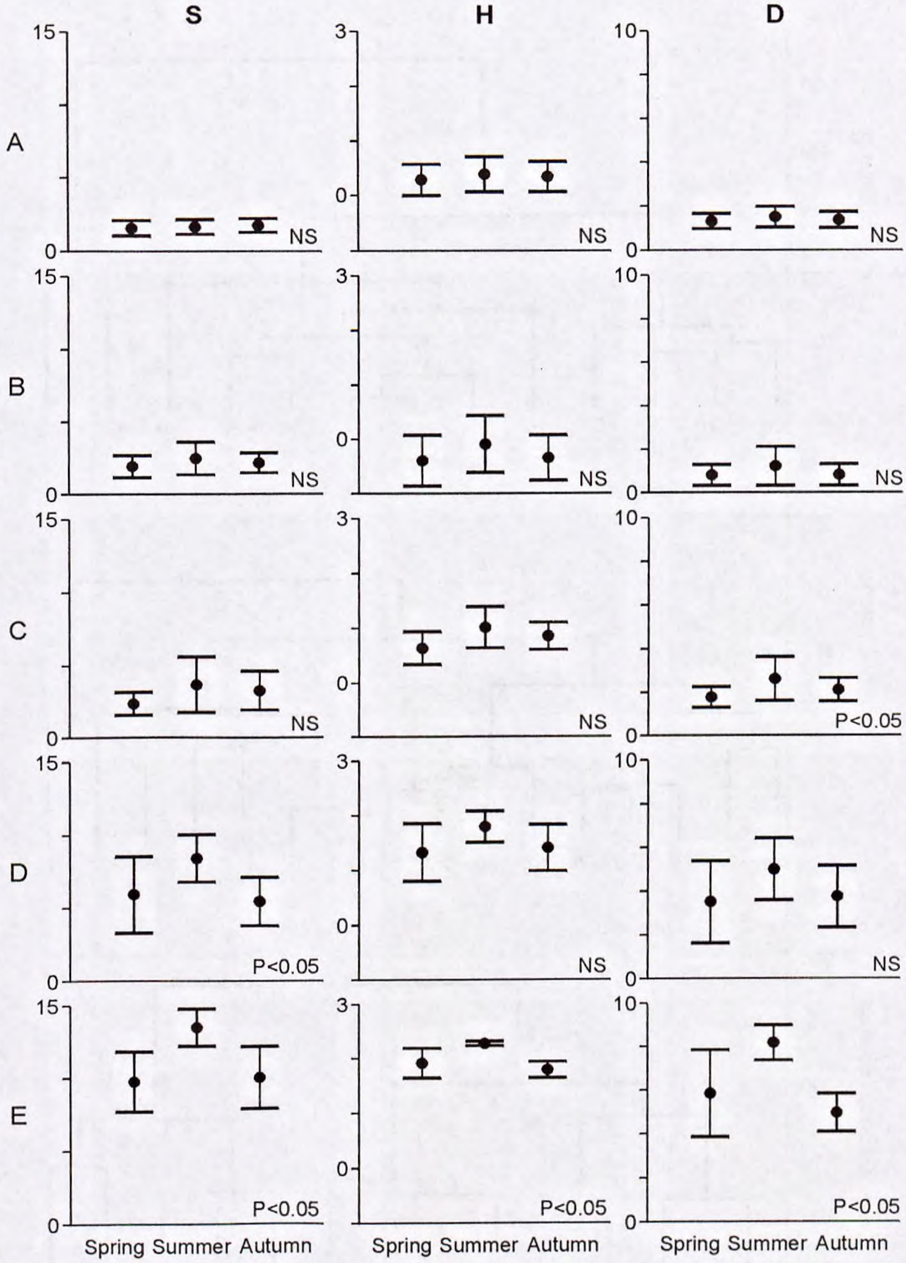

Fig. 10. Biodiversity coefficients (S – species abundance, H – Shannon-Wiener index of diversity, D – Simpson index of diversity) in groups of streams in the upper San basin. A–E – groups of sites; NS – non-significant differences.

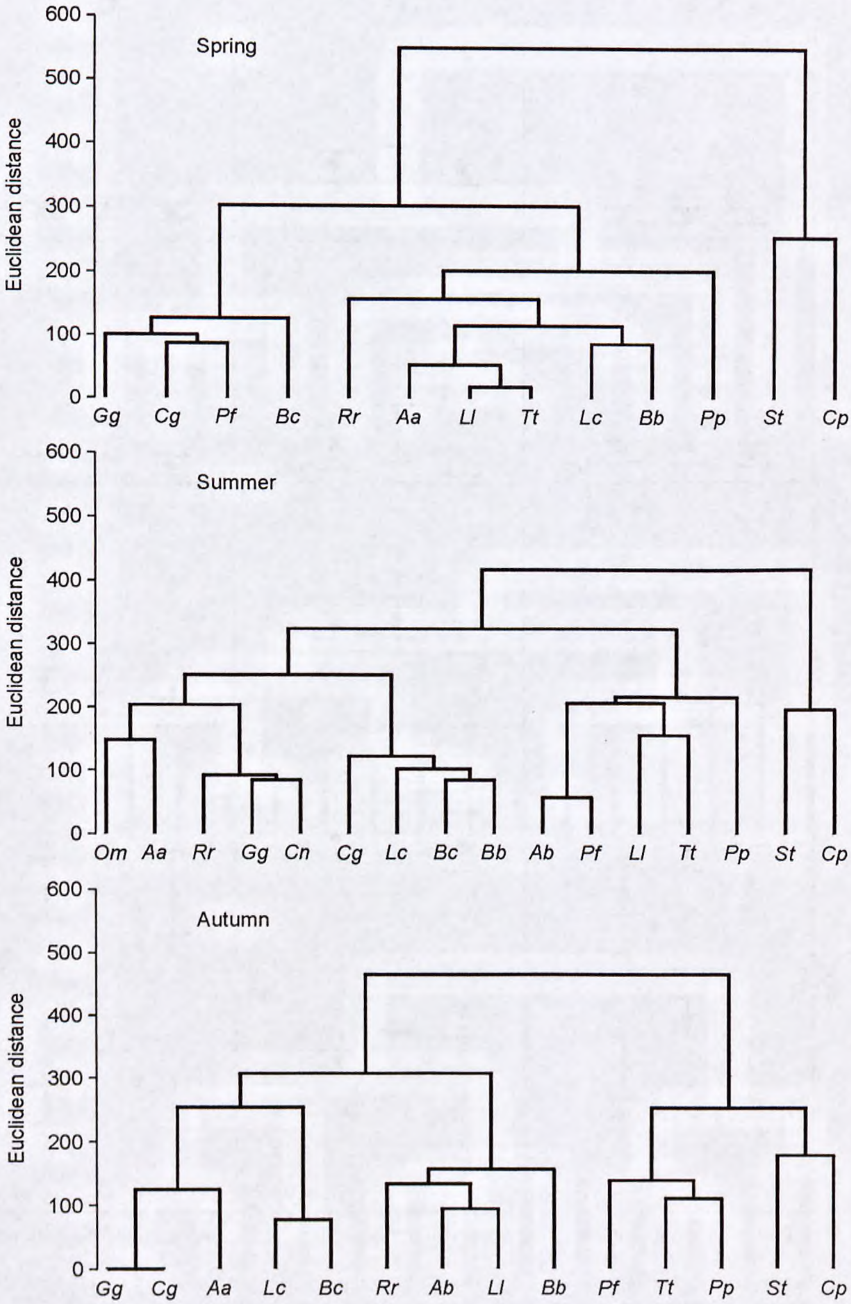

Fig. 11. Cenologic communities of fish in the upper San basin. *Pp* – *P. phoxinus*; *St* – *S. trutta* m. *fario*; *Bb* – *B. barbatula*; *Cp* – *C. poecilopus*; *Cg* – *C. gobio*; *Lc* – *L. cephalus*; *Ll* – *L. leuciscus*; *Bc* – *B. carpathicus*; *Tt* – *T. thymallus*; *Pf* – *P. fluviatilis*; *Rr* – *R. rutilus*; *Om* – *O. mykiss*; *Cn* – *C. nasus*; *Ab* – *A. bipunctatus*; *Gg* – *G. gobio*; *Aa* – *A. alburnus*.

Table VII. Body weight (g) of brown trout in the basin of the San upper course (means for groups significantly differing in the seasons of the year; $P<0.0001$; the Kruskal-Wallis test; the Tukey test – subgroups underlined).

Group of stream	Spring					Summer					Autumn				
	n	min	max	mean	SD	n	min	max	mean	SD	n	min	max	mean	SD
A	14	7.9	60.1	30.4	17.8	35	4.7	258.0	45.8	51.8	26	6.5	116.0	44.0	39.6
B	41	9.9	155.1	52.9	38.9	67	0.6	188.5	58.6	39.4	54	4.8	170.0	43.1	33.7
C	57	6.5	162.9	70.9	43.6	141	1.3	321.0	77.8	61.1	147	3.7	805.0	66.0	93.3
D	23	27.0	343.0	108.1	60.5	67	7.6	352.0	108.7	78.5	41	7.0	285.0	108.1	86.1
E	30	50.0	154.3	100.8	31.1	51	3.0	451.0	122.2	65.2	14	89.5	300.0	148.0	62.9
				H=45.76 ABC CD DE					H=64.43 ABC CD DE					H=39.14 ABD C DE	

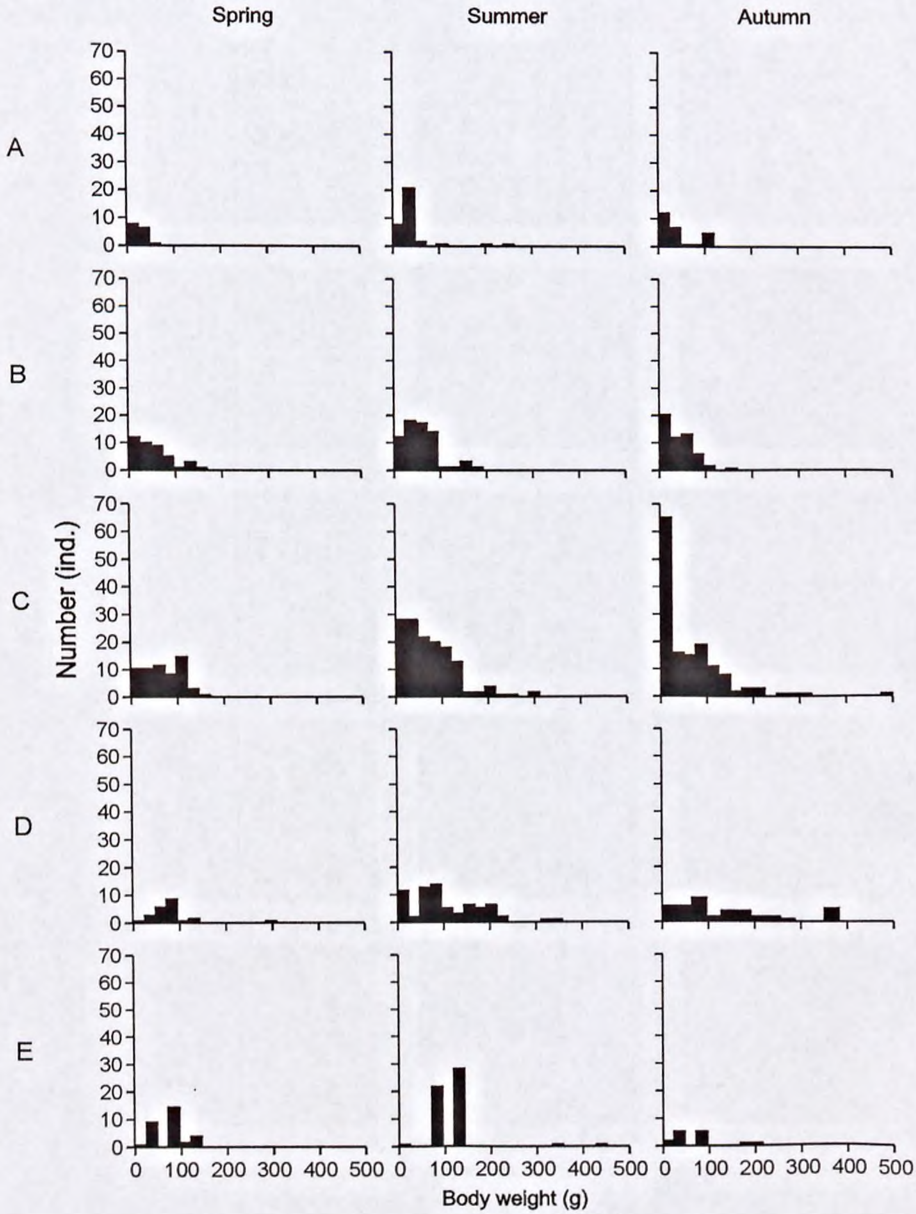

Fig. 12. Histogram of the brown trout *S. trutta* m. *fario* body weight in groups of sites in the upper San basin. A–E – groups of sites.

the brown trout appeared most abundantly. They were both of the youngest age class and also older individuals, while in autumn the spawners and that-year fry were most frequently found in this part of the drainage basin (Fig. 12).

In the investigation of the ichthyofauna of the San and its affluents below the Solina reservoir changes were observed in the participation of the more important fish species (Fig. 13, Table VIII). In the River San middle course, differences between the fish assemblage found in 1960 (Bieniarz and Epler 1972, Kołder 1973) and those from 1993 (data supplied by the Polish Angling Union) were significant (for the biomass: $\chi^2 = 41.55$, $P<0.001$; for numbers $\chi^2 = 387.26$; $P<0.001$). A significant decrease in numbers concerned the nase ($\chi^2 = 169.354$, $P<0.001$), barbel ($\chi^2 = 8.534$, $P<0.01$), spirlin ($\chi^2 = 42.998$, $P<0.001$), and spotted barbel ($\chi^2 = 14.726$, $P<0.001$). A decrease in biomass concerned the nase ($\chi^2 = 24.641$, $P<0.001$) and vimba *Vimba vimba* (L.) ($\chi^2 = 6.913$, $P<0.01$). Increases were found in the share of the chub ($\chi^2 = 8.786$, $P<0.01$) and barbel ($\chi^2 = 18.475$, $P<0.001$) in biomass, and of gudgeon ($\chi^2 = 288.041$, $P<0.001$) in abundance. In the San tributaries a decrease in the share of the nase, barbel, and chub was most pronounced. The abundance of minnow increased. At station 55 the grayling and huchen *Hucho hucho* (L.) were observed (Table VIII).

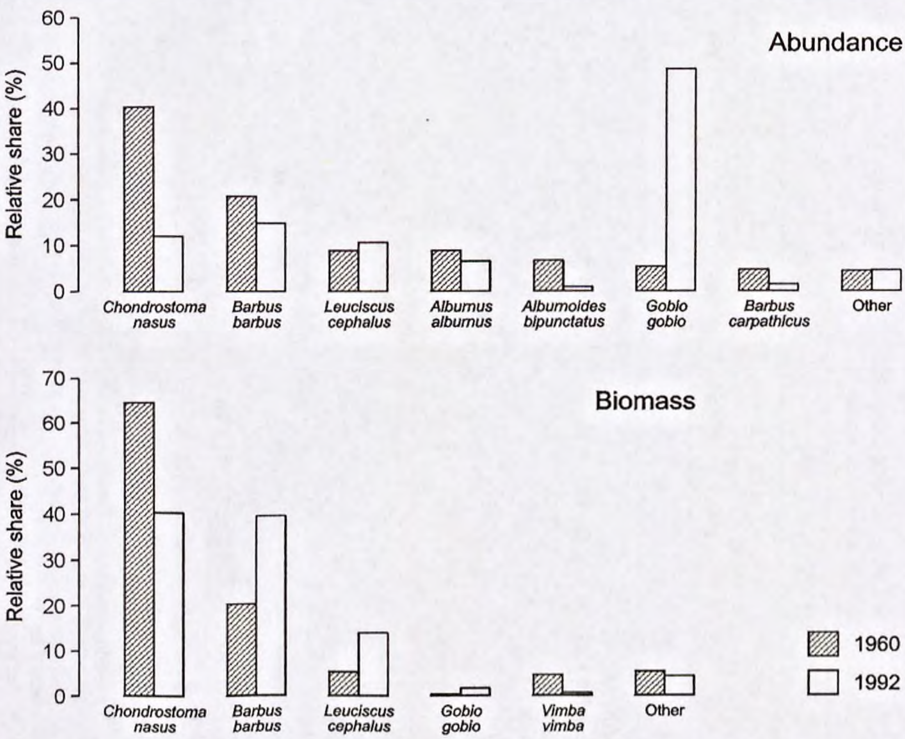

Fig. 13. Percentage share of fish species in numbers and biomass in the River San middle course.

Table VIII. Changes in the ichthyofauna composition in the tributaries of the River San middle course (* data according to Rolik (1971); 2002 – data according to Kukuła and Amirowicz unpubl.).

Species	River (site)									
	Hoczewka (51)		Osława (53)		Baryczka (54)		Stupnica (55)		Wiar (56)	
	1968*	2002	1968*	2002	1968*	2002	1968*	2002	1968*	2002
Abramis bjoerkna	–	–	–	–	–	–	–	–	<5	–
Alburnoides bipunctatus	5–10	5–10	5–10	20–25	15–20	–	15–20	15–20	10–15	<5
Alburnus alburnus	–	–	–	–	–	–	5–10	–	<5	>25
Barbatula barbatula	20–25	10–15	10–15	10–15	5–10	10–15	<5	<5	–	–
Barbus barbus	<5	–	10–15	–	–	–	5–10	–	<5	<5
Barbus cyclolepis	<5	–	10–15	–	<5	–	<5	–	<5	–
Barbus carpathicus	15–20	20–25	15–20	5–10	5–10	–	–	–	5–10	–
Carassius auratus gibelio	–	–	<5	–	–	–	–	–	–	–
Chondrostoma nasus	<5	–	5–10	–	<5	–	5–10	<5	>25	5–10
Cottus gobio	<5	<5	<5	–	<5	–	–	–	–	–
Gobio gobio	<5	–	5–10	15–20	>25	<5	15–20	10–15	10–15	<5
Gobio albipinnatus	–	–	–	–	–	–	–	–	–	<5
Gymnocephalus cernuus	–	–	<5	–	–	–	–	–	–	–
Hucho hucho	–	–	–	–	–	–	–	<5	–	–
Leuciscus cephalus	10–15	–	10–15	<5	15–20	10–15	>25	20–25	20–25	5–10
Leuciscus leuciscus	<5	–	–	<5	5–10	–	–	5–10	–	<5
Phoxinus phoxinus	>25	>25	5–10	>25	5–10	>25	<5	15–20	–	<5
Rhodeus sericeus	–	–	<5	–	–	–	–	–	–	–
Rutilus rutilus	–	–	–	<5	<5	–	–	–	–	<5
Salmo trutta m. *fario*	–	<5	–	–	<5	5–10	–	5–10	–	–
Thymallus thymallus	–	–	–	–	–	–	–	5–10	–	–
Tinca tinca	–	–	<5	–	–	–	–	–	–	–
Number of species	11	6	14	8	12	5	9	10	9	11

4.2. Pollution of waters

In the 1970s and 1980s pollution of the Vistula headwaters caused a considerable decrease in pH value of the waters in the Czarna Wisełka – periodically even below 5. In the Biała Wisełka the reaction was maintained at a level of about 6.5–7 (Wróbel 1995). In 1993 fish were found only in the Biała Wisełka (Table IX) with brown trout as the dominant. No fish were caught in any of the investigated sectors of the Czarna Wisełka.

Table IX. Fish densities in headwater streams of the River Vistula (ind. 100 m^{-2}).

Stream	Site	Year	Species		
			S. trutta m. *fario*	*C. poecilopus*	*P. phoxinus*
Biała Wisełka	91	1958	6.9	0.14	present
		1993	10.7	8.0	–
Czarna Wisełka	90	1958	present	present	–
		1993	–	–	–

In the 1980s and 1990s in relation to the earlier condition a distinct worsening of water quality was determined in the Skawa drainage basin (Turzański 1999). In relation to earlier studies by Skóra and Włodek (1991) on the River Skawa, a very distinct decrease in the percentage of nase with respect to abundance and biomass was found on five sites (Tables X and XI). A similar regress appeared in the case of the barbel. Only in site 80 was an increase noted in the occurrence of these species. A reverse tendency was found with the chub and in all six sites investigated its percentage share in abundance and, except site 80, in biomass, increased. With respect to abundance, a significant increase in the share of the roach was everywhere determined, apart from the lower river sector (station 85). In almost the entire investigated river sector the occurrence of the stone loach increased (Table X).

Table X. Participation of selected species in materials sampled in the River Skawa in 1970s and 1980s. A – according to figures given by Skóra and Włodek (1989) and late 1990s. B – according to Kukuła (1999) in percentage of numbers of the caught fish.

Species	Site											
	80		81		82		83		84		85	
	A	B	A	B	A	B	A	B	A	B	A	B
Barbatula barbatula	22.4	29.6	0.7	5.4	6.0	12.2	3.0	9.6	4.5	3.1	0.7	1.8
Barbus barbus	1.5	4.3	23.9	0.9	11.9	5.2	11.9	9.0	22.4	2.1	11.9	1.2
Barbus carpathicus	19.4	21.7	14.9	14.8	10.4	28.0	26.1	24.4	10.4	5.2	10.4	0.6
Chondrostoma nasus	6.7	14.8	38.8	6.7	16.4	6.1	29.9	2.6	36.6	2.1	38.1	2.1
Gobio gobio	4.5	0.8	4.5	6.7	10.4	2.4	4.5	2.6	11.9	6.2	3.7	7.6
Leuciscus cephalus	2.2	14.6	6.0	38.1	19.4	22.2	19.4	30.5	6.0	43.1	9.0	60.8
Phoxinus phoxinus	37.3	5.9	6.0	4.9	11.9	12.2	1.5	13.7	2.2		0.7	
Rutilus rutilus		2.4		15.3		7.0		2.9		8.6	17.9	16.7
Salmo trutta m. *fario*	1.5	0.6	0.7	0.9	10.4	2.1	0.7	3.2	+			
others	4.5	5.3	4.5	6.3	3.2	2.6	3.0	1.5	6.0	29.6	7.6	9.2
	100	100	100	100	100	100	100	100	100	100	100	100

Table XI. Participation of selected species in the material sampled in the Skawa in 1970s and 1980s. A – (according to figures given by Skóra and Włodek 1989) and late 1990s. B – (according to Kukuła 1999) in percentage of biomass of caught fish.

Species	Site											
	80		81		82		83		84		85	
	A	B	A	B	A	B	A	B	A	B	A	B
Barbatula barbatula	3.0	3.1	1.5	0.9	+	1.8	+	1.8	+	0.8	+	0.4
Barbus barbus	7.5	9.3	25.4	2.3	13.4	7.4	18.7	19.8	19.4	4.4	10.4	4.1
Barbus carpathicus	13.4	9.9	5.2	11.7	4.5	15.6	9.0	19.8	3.0	4.2	3.0	0.5
Chondrostoma nasus	50.7	60.3	59.7	25.8	56.7	38.6	49.3	8.2	70.9	28.9	70.1	3.2
Leuciscus cephalus	14.9	11.2	4.5	43.2	16.4	23.3	17.9	40.3	2.2	40.4	7.5	73.8
Phoxinus phoxinus	3.0	0.5	+	0.2	+	0.6	+	1.0	+		+	
Salmo trutta m. *fario*	1.5	1.6	0.7	2.0	4.5	4.9	0.7	4.2	+			
others	6.0	4.1	3.0	13.9	4.5	7.8	4.5	5.0	4.5	21.3	9.0	18.0
	100	100	100	100	100	100	100	100	100	100	100	100

4.3. Poaching

In the streams of BgNP the brown trout occurred in four sites (Table XII). Significant differences in average weight (H=9.337, $P<0.05$) and average length (H=10.167, $P<0.05$) were recorded in various sites. The decidedly greatest density of the brown trout was noted in site 76 lying deep inside the Park.

Table XII. Mean weight (g), total length (mm), and biomass (g 100 m^{-2}) of brown trout *S. trutta* m. *fario* from streams of the Babia Góra National Park (August 19, 1998).

Site	n	Mean body weight [g]	Mean total length [mm]	Density [ind. 100 m^{-2}]	Biomass [g 100 m^{-2}]
76	22	38.57	147.4	22.2	856.3
77	22	27.15	109.4	8.0	217.2
78	28	30.54	119.3	13.5	412.3
79	15	53.60	154.9	8.8	471.7

In the upper San basin in two streams analysed, significantly higher average body weights (df=108, $P<0.001$) and total lengths (df=108, $P<0.05$) were recorded in sites which, on the basis of collected information, could have been regarded as not subject to poaching (stations 32 and 42) – in comparison with sites 33 and 43 where the poaching was fairly frequent (Fig. 14).

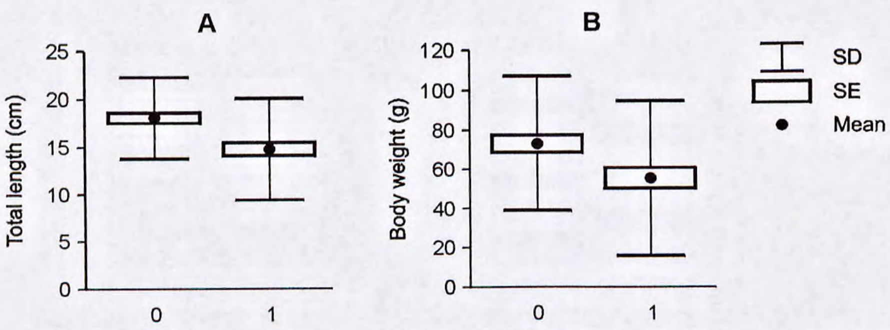

Fig. 14. Mean total length (A) and body weight (B) of the brown trout *S. trutta* m. *fario* in the upper San basin at sites with no traces of poaching (0) and with poaching damage (1).

Two pairs of sites (65–66 and 67–68) similar with respect to their morphometric traits but differing in the intensity of poaching were compared in MNP (Fig. 15). Significant differences were found between fish assemblages in these two pairs of sites both with respect to abundance and biomass (Fig. 16).

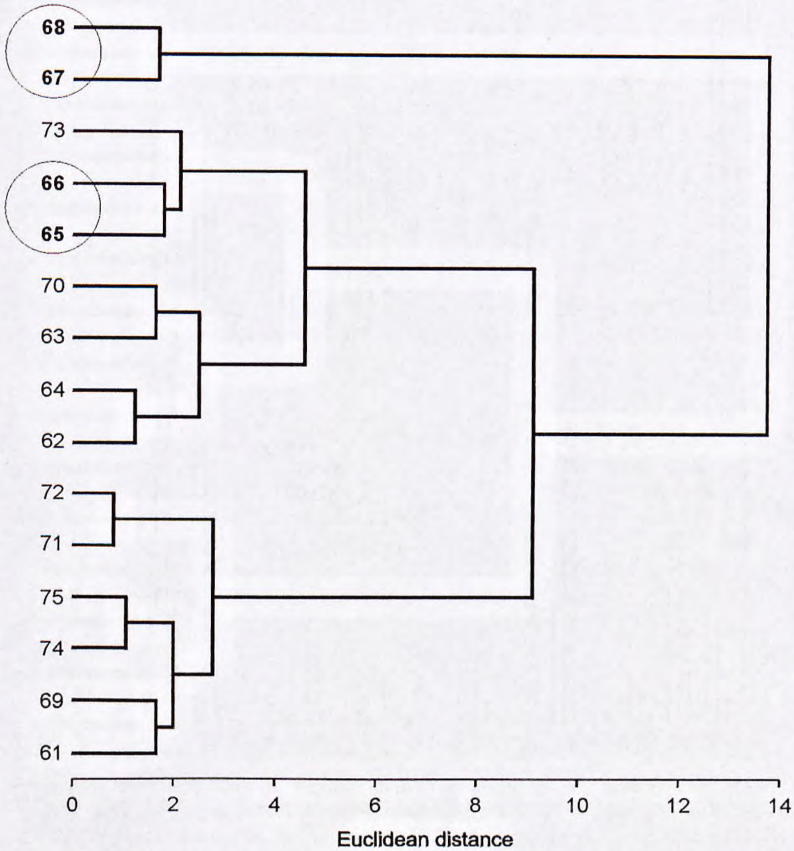

Fig. 15. Dendrogram of 15 sites of fish catches in the upper Wisłoka basin formed by cluster analysis on the basis of morphometric traits (the distinguished sites were compared on account of poaching).

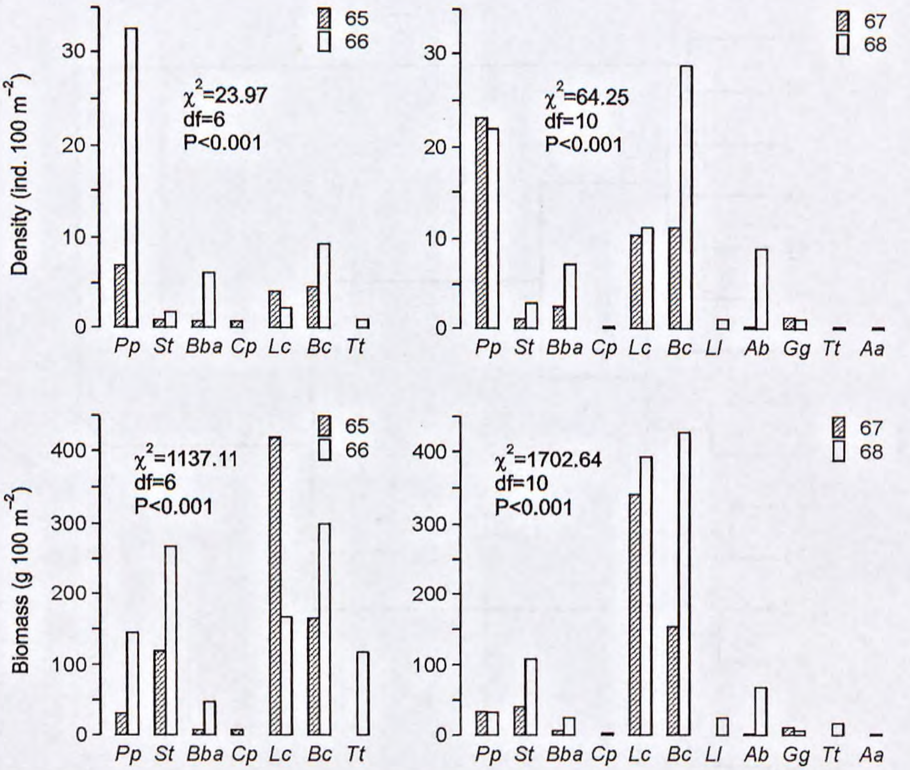

Fig. 16. Mean density and mean biomass of fish caught in the upper Wisłoka (July, 20–21, 1998). 65–68 sites of catches; *Pp* – *P. phoxinus*; *St* – *S. trutta* m. *fario*; *Bba* – *B. barbatula*; *Cp* – *C. poecilopus*; *Lc* – *L. cephalus*; *Ll* – *L. leuciscus*; *Bc* – *B. carpathicus*; *Tt* – *T. thymallus*; *Ab* – *A. bipunctatus*; *Gg* – *G. gobio*; *Aa* – *A. alburnus*.

4.4. Dam reservoirs

Of 50 sites investigated in the upper San basin above the Solina reservoir, the occurrence of the perch and/or the roach was noted in 13 in 1993–2002 (Fig. 17). These species were encountered in the San and Solinka and in the Wołosaty stream. Their mean density and mean biomass were high at some stations, this particularly concerning the perch (Fig. 18).

In the sector of the River Wisłok directly affected by the dam reservoir at Besko significant changes in the composition of ichthyofauna were determined in site 57 above the reservoir and site 58 below it (Fig. 19). In relation to data from 1977 (Pasternak and Wajdowicz 1983), the number of occurring species had increased from four to seven. At the same time, a decrease in the abundance of minnow and a pronounced share of perch were observed. Above the reservoir in site 58 the ichthyofauna composition also considerably changed, with a greater share of the chub and minnow, appearance of the roach and bleak, and a decrease in the abundance of the barbel and spotted barbel (Fig. 19). In relation to data collected by Rolik (1971) in the Wisłok above the reservoir in 1968, the percentage of the minnow, barbel, and the spirlin had distinctly decreased and that of the perch and

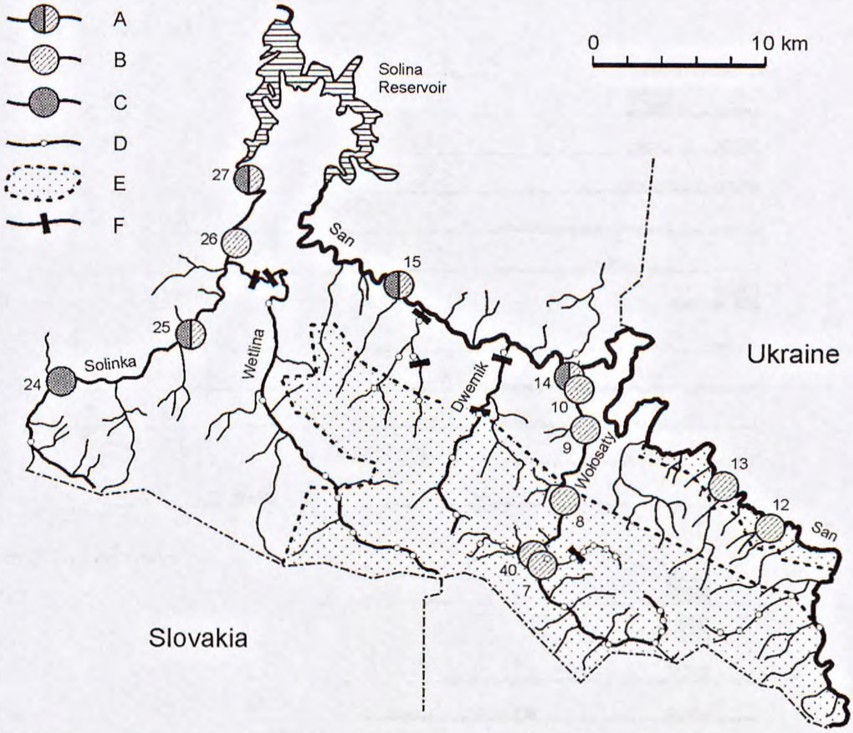

Fig. 17. Occurrence of the perch *P. fluviatilis* and roach *R. rutilus* in the upper San basin. A – occurrence of perch and roach; B – occurrence of perch; C – occurrence of roach; D – both species absent; E – area of Bieszczady National Park; F – water bars and waterfalls.

gudgeon increased (Table XIII). Below the reservoir in site 58 numbers of the chub, minnow, bleak, and roach increased while a regress was noted in the case of the nase, barbel, and spirlin. In site 59 the absence of the barbel in catches was most pronounced.

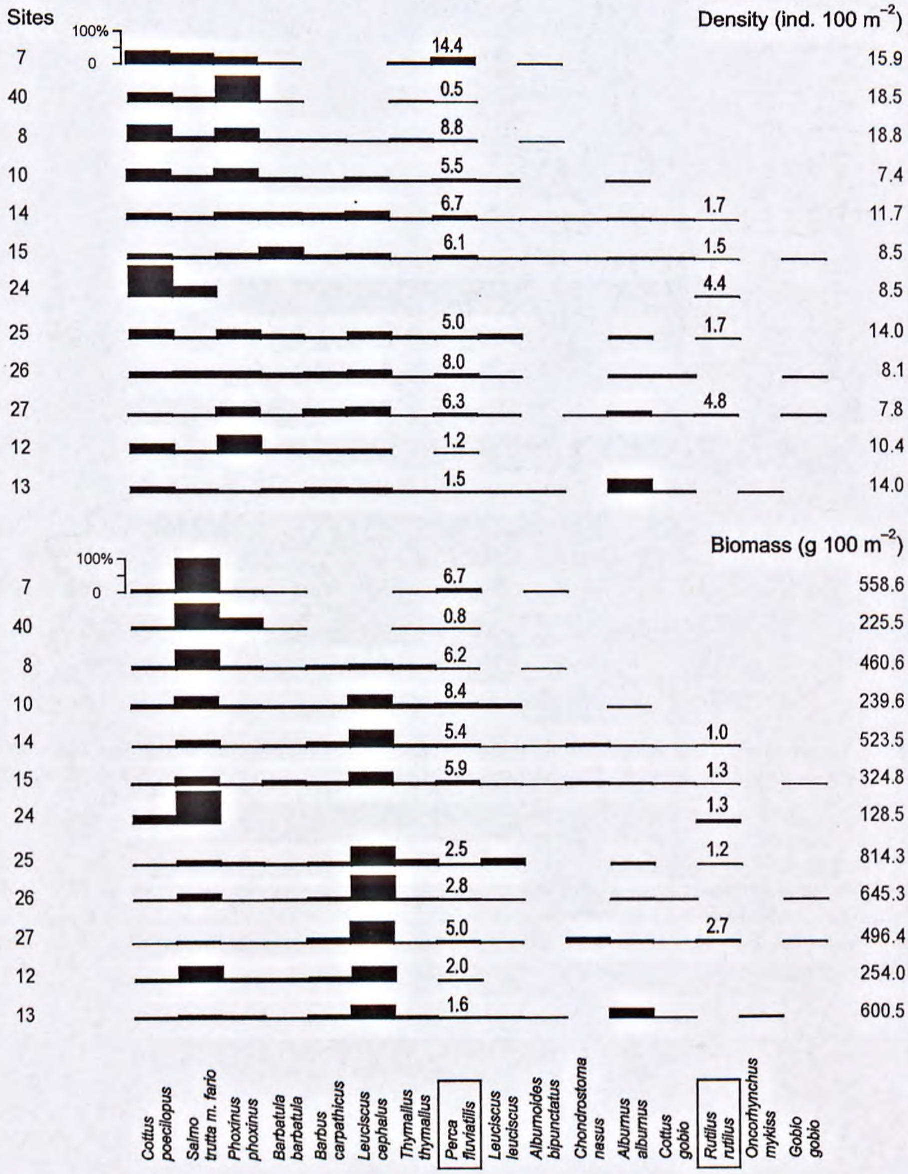

Fig. 18. Percentage of fish species caught in electrofishing in the upper San basin at sites where the perch or roach were recorded.

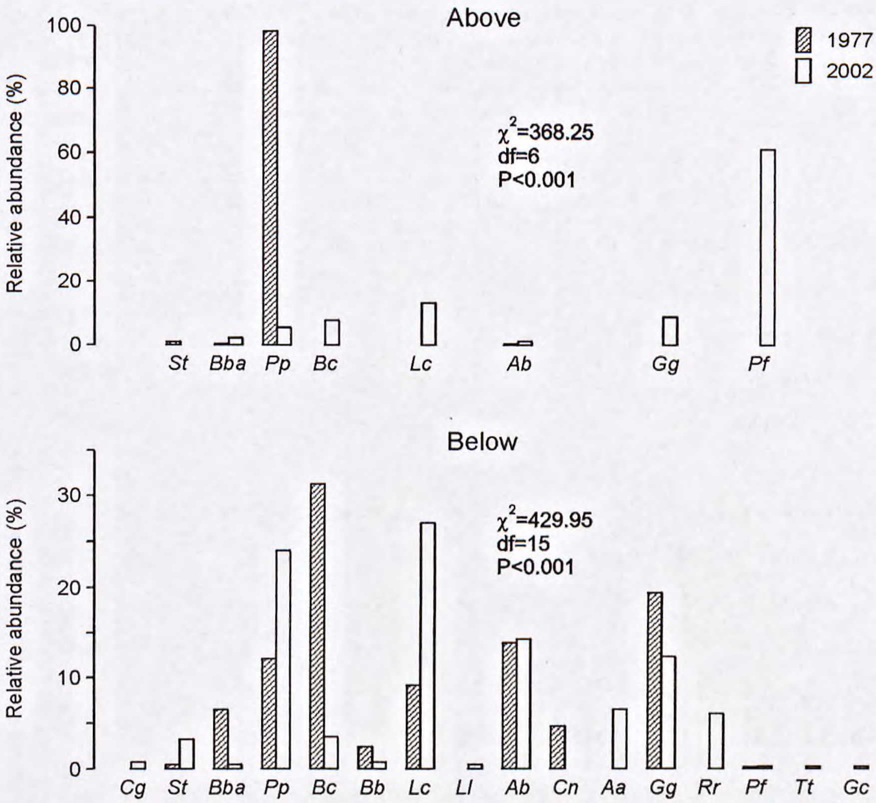

Fig. 19. Changes in the ichthyofauna composition at sites above (site 57) and below (site 58) the Besko dam reservoir on the River Wisłok. *Pp* – *P. phoxinus*; *St* – *S. trutta* m. *fario*; *Bba* – *B. barbatula*; *Bb* – *B. barbus*; *Bc* – *B. carpathicus*; *Cp* – *C. poecilopus*; *Cg* – *C. gobio*; *Lc* – *L. cephalus*; *Gc* – *G. cernuus*; *Ll* – *L. leuciscus*; *Tt* – *T. thymallus*; *Pf* – *P. fluviatilis*; *Rr* – *R. rutilus*; *Cn* – *C. nasus*; *Ab* – *A. bipunctatus*; *Gg* – *G. gobio*; *Aa* – *A. alburnus*.

Table XIII. Changes in the ichthyofauna composition of the River Wisłok on the basis of percentages of different species in electrofishing catches (* – according to Rolik 1971; 2002 – data according to Kukuła and Amirowicz unpubl.)

Species	Site number					
	57		58		59	
	1968*	2002	1968*	2002	1968*	2002
Alburnoides bipunctatus	10–15	<5	20–25	10–15	15–20	<5
Alburnus alburnus	–	–	–	5–10	<5	<5
Barbatula barbatula	5–10	<5	<5	<5	–	<5
Barbus barbus	–	–	10–15	<5	20–25	–
Barbus cyclolepis	–	–	<5	–	5–10	–
Barbus carpathicus	>25	–	15–20	<5	–	<5
Chondrostoma nasus	–	–	20–25	–	<5	<5
Cottus gobio	–	–	–	<5	10–15	20–25
Gobio gobio	–	10–15	5–10	10–15	20–25	20–25
Gobio kessleri			<5	–	<5	
Gymnocephalus cernuus	–	–	–	<5	–	–
Leuciscus cephalus	20–25	10–15	<5	>25	5–10	10–15
Leuciscus leuciscus	–	–	–	<5	<5	10–15
Perca fluviatilis	–	>25	–	<5	–	–
Phoxinus phoxinus	10–15	<5	5–10	20–25	<5	–
Rutilus rutilus	–	–	–	5–10	<5	5–10
Salmo trutta m. *fario*	<5	–	<5	<5	–	–
Thymallus thymallus	–	–	–	<5	–	–
Number of species	6	6	11	15	12	9

4.5. Forest works

In a stream whose bed was devastated in the course of forestry works (site 38) only the occurrence of the Siberian sculpin was determined. Its average biomass and length were much lower than in site 41 where the riverbed preserved its natural character (Table XIV). The condition coefficient for the Siberian sculpin was significantly lower in site 38 than in site 41 (the t-test = -2.833, df = 38, $P<0.01$) (Fig. 20).

Table XIV. Mean density (ind. 100 m^{-2}) and biomass of fish (g 100 m^{-2}) at sites in the streams Nasiczniański (41) and Rzeczyca (38).

Species	Site			
	41		38	
	Abundance	Biomass	Abundance	Biomass
Cottus poecilopus	21.5	156.4	12.7	67.3
Salmo trutta m. *fario*	2.4	29.1	–	–

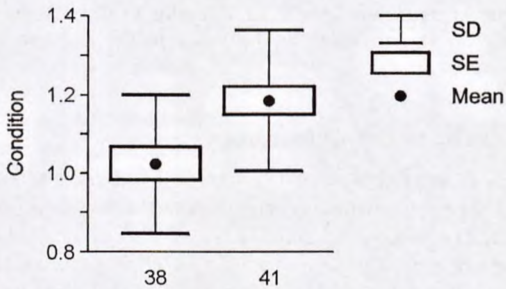

Fig. 20. Condition coefficient (K) of the Siberian sculpin *C. peocilopus* from the streams Rzeczyca (site 38) and Nasiczniański (site 41).

4.6. Temporary changes in the distribution of species in the catchment area

Analysis of changes in the occurrence of species in 125 sites located in the Carpathian affluents of the River Vistula showed significant differences ($\chi^2 = 33.67$, $P<0.01$) in the number of sites where these species were found in the two periods compared (Fig. 21). Statistically significant differences were determined in the case of the perch ($\chi^2 = 7.771$, $P<0.01$) and roach ($\chi^2 = 4.209$, $P<0.05$), which occurred in a greater number of sites. With respect to the barbel ($\chi^2 = 3.842$, $P<0.05$) and spirlin ($\chi^2 = 10.492$, $P<0.01$), a significant decrease was recorded.

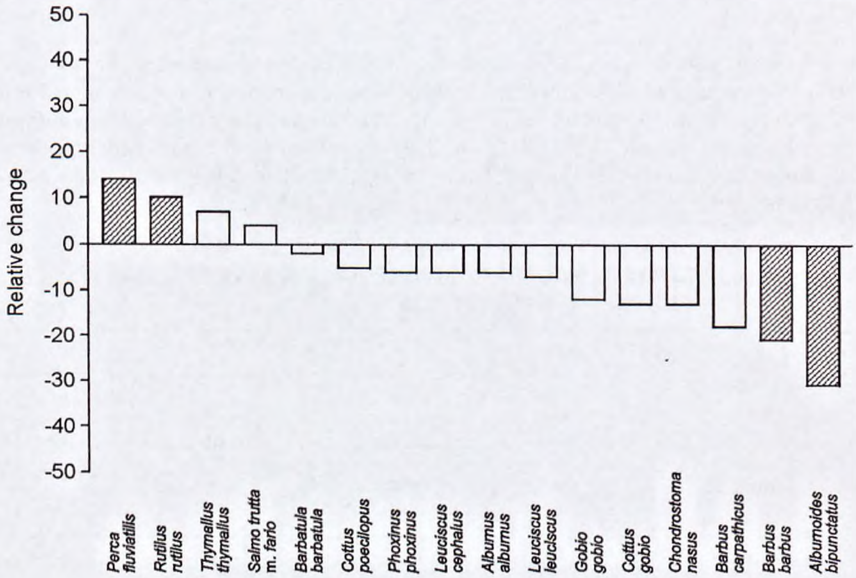

Fig. 21. Changes in the occurrence of species at 125 sites in Carpathian affluents of the River Vistula (statistically significant increases or decreases in the number of sites were found for highlighted species).

4.7. The degree of threat to the ichthyofauna

Among the species encountered in the Carpathian part of some affluents of the Vistula (Table XV) three (the Atlantic sturgeon, Atlantic salmon, and sea trout) are classed as extinct in the entire or some part of the discussed area. The first two species have not occurred in the investigated catchment basin for several decades. Sporadic information about catches of the sea trout by anglers should be verified. However, it is possible that attempts during the last two years to restore the Atlantic salmon and sea trout in the Carpathians will be successful.

In the group of threatened species are fish characteristic of mountain and submontane sectors of rivers, i.e., the spirlin, barbel, nose, bullhead, and vimba. The author's studies showed a decrease in the abundance and distribution area of these species. The critically threatened spirlin still forms fairly abundant populations only in some affluents of the San, in the Wisłoka, and Jasiołka. The species is rarely encountered in the remaining basins. The barbel and nase, which used to prevail in the middle sectors of the Carpathian affluents of the Vistula (Kołder 1961, Włodek 1975), now rarely appear more abundantly in the catches (Tables X and XI) and their numbers are smaller than in previous years. Vimba is also endangered to a great degree. The latter species is found sligtly more frequently in the submontane part of the River San, in the vicinity of the towns of Dynów and Przemyśl.

A distinct regress is also observed in the case of the brook lamprey *Lampetra planeri* (Bloch), bitterling *Rhodeus sericeus* (Pall.), and burbot *Lota lota* (L.). In the catches of 1993–2002 no fishes of the above species were recorded (Table III) but the verified polling data showed their occurrence in some places. The bitterling was found in the Wisłoka above Jasło, burbot in the Wisłok above Rzeszów and in the

Table XV. Species composition and categories of threat to the ichthyofauna (according to IUCN/WCU in: Głowaciński 1997) within the selected basins of the River Vistula affluents (symbols of species: EXP – extinct in Poland, CE – critically endangered; EN – endangered; VU – vulnerable; CD – conservation dependent; NT – near threatened; LC – least concern; DD – data deficient; NE – not evaluated; IN – introduced).

Species	Upper Vistula	Skawa	Wisłoka	Wisłok	San
Abramis bjoerkna (L.)	LC	LC	LC	LC	LC
Abramis brama (L.)	LC	LC	LC	LC	LC
Acipenser sturio L.	EXP		EXP	EXP	EXP
Alburnoides bipunctatus (Bloch)	CE	CE	VU	CE	VU
Alburnus alburnus (L.)	LC	LC	LC	LC	LC
Anguilla anguilla (L.)	CD	CD	CD	CD	CD
Aspius aspius (L.)	EN	VU	NT	NT	NT
Barbatula barbatula (L.)	LC	LC	LC	LC	LC
Barbus barbus (L.)	EN	VU	VU	EN	VU
Barbus carpathicus Kotlík et al.	NT	LC	LC	VU	LC
Barbus cyclolepis Heck.			NE	NE	NE
Carassius auratus gibelio (Bloch)	IN		IN	IN	IN
Carassius carassius (L.)	LC	LC	LC	LC	LC
Chondrostoma nasus (L.)	EN	VU	EN	CE	VU
Cobitis taenia L.	DD	DD	DD	DD	DD
Cottus gobio L.	EN	VU	VU	EN	VU
Cottus poecilopus Heck.	NT	NT	NT	NT	LC
Cyprinus carpio L.	IN	IN	IN	IN	IN
Esox lucius L.	NT	NT	NT	NT	NT
Eudontomyzon mariae Berg		EN			
Gobio albipinnatus Lukasch					DD
Gobio gobio (L.)	LC	LC	LC	LC	LC
Gobio kessleri Dyb.					DD
Gymnocephalus cernuus (L.)	LC	LC	LC	LC	LC
Hucho hucho (L.)					IN
Lampetra planeri (Bloch)	EN	EN	EN	EN	EN
Leucaspius delineatus (Heck.)	DD			DD	DD
Leuciscus cephalus (L.)	LC	LC	LC	LC	LC
Leuciscus idus (L.)	VU	VU	NT	VU	VU
Leuciscus leuciscus (L.)	LC	LC	LC	LC	LC
Lota lota (L.)	VU	VU	VU	NT	VU
Oncorhynchus mykiss Walb.	IN	IN	IN	IN	IN
Perca fluviatilis L.	LC	LC	LC	LC	LC
Phoxinus phoxinus (L.)	LC	LC	LC	LC	LC
Rhodeus sericeus (Pall.)	EN	EN	EN	EN	EN
Rutilus rutilus (L.)	LC	LC	LC	LC	LC
Sabanejewia aurata (Fil.)					DD
Salmo salar L.	EXP	EXP	EXP	EXP	EXP
Salmo trutta m. *fario* L.	CD	CD	CD	CD	CD
Salmo trutta m. *trutta* L.	EXP	EXP	CE	CE	CE
Salmo trutta m. *lacustris* L.			IN	IN	IN
Scardinius erythrophtalmus (L.)	LC		LC	LC	LC
Silurus glanis L.			VU	CE	VU
Stizostedion lucioperca (L.)			VU	VU	VU
Thymallus thymallus L.	VU	VU	IN	IN	IN
Tinca tinca L.	LC		LC	LC	LC
Vimba vimba (L.)	CE	CE	CE	CE	EN

San above Przemyśl, and the brook lamprey in some small tributaries of the rivers Wisłok and San.

Great predators are also endangered, particularly the wels, pikeperch, and asp *Aspius aspius* (L.). They were never numerous in submontane rivers but decreases in their numbers were visible in the analysed waters.

In five analysed catchment areas only 12 autochthonous species are not threatened (Table XV). Among them the chub, dace, minnow, or gudgeon were above all recorded as constant, locally numerous, elements of the ichthyofauna in this part of the drainage basin. The remaining species of the not endangered group, e.g. the roach, perch, or common bream *Abramis brama* (L.) have recently occurred more abundantly in many mountain and submontane sectors of the Carpathian tributaries of the Vistula.

Of the introduced fish species none are numerous in the discussed catchment areas. Only the grayling transferred to the Wisłoka and San basins occur more frequently, often being found in the San and its affluents. However, it is endangered in the regions of its natural occurrence, e.g. in the River Skawa.

5. Discussion

Life in running waters necessitates suitable adaptations on the part of the organisms occurring there, while important geomorphologic and hydrologic elements change with the river course (Morin and Naiman 1990, Allan 1995). In this continuous system the communities of producers and consumers are in a state of dynamic balance in every sector of the river (Vannote et al. 1980) and the abiotic factors changing with the stream flow determine the amounts of available resources (Zalewski and Naiman 1985, Starmach et al. 1991). Mountain sectors of rivers and streams are a particularly difficult environment and only a few fish species are adapted to life in high mountain streams (Opuszyński 1983, Heese and Przybyszewski 1993, Brylińska 2000). In high mountain brooks the typical steep gradient, and hence the rapid water current, low temperatures, and frequent freezing-up of shallow streams to the bottom, significantly affect the animals living there and are decisive for the growth and development of fish (Beecher et al. 1988, Elliott 1994, Kownacki 1996). The natural variability of environmental agents in running waters to which the living organisms have adapted is often, and to a high degree, disturbed by human activity (Allen and Flecker 1993, Lelek 1996). This frequently concerns even those drainage basins which are regarded as "natural", such as the River San catchment.

In the Carpathian Mts the upper sectors of streams unfavourable for numerous fish species are colonized only by the Siberian sculpin and brown trout (Starmach 1956, Starmach 1972, 1983/1984, Augustyn et al. 1996, Skóra and Włodek 1988, 1989*c*, 1991, Kukuła 1999, 2003*a*). It was found that in the upper San catchment the occurrence of the brown trout and Siberian sculpin was most strongly correlated with the high gradient of the riverbed, shading, and altitude above sea level. The conditions that develop with the increasing width and depth of a stream and the lessening gradient, favour the occurrence of other fish species (Kukuła 2003*b*). This is due to increased water temperatures, particularly in summer, in the middle and lower sectors of mountain streams, to their greater depth and the more varied substrate (Allan 1995). In the River Nysa Kłodzka the abundance of such species as the brown trout or minnow decreased from the upper course down river while that of the chub and gudgeon increased (Błachuta and Witkowski 1990).

Owing to the great variability of abiotic factors throughout the year different fragments of mountain streams can be only periodically colonized by some species. Hence in the middle course of the investigated streams species appearing in summer were rarely encountered in cooler seasons of the year (Fig. 9).

In the upper course of streams the Siberian sculpin was the only constantly occurring species, and in this part of the catchment area its highest mean biomass and mean density were noted (Table IV). The seasonal variability of the most important abiotic factors caused a varied composition of ichthyofauna assemblages in the different parts of the watercourses (Fig. 9). In the upper course the community of fish was stable while in the streams of medium size distinct differences were found in the composition of assemblages in different seasons of the year. In summer some species arrived from the San and even from the Solina dam reservoir, retreating down river in early autumn (Kukuła 1997*a*). This type of migration of river fish permits them to avoid dangers resulting from the instability of important environmental elements (Northcote 1978, Mahon 1984). In upland rivers the seasonal migrations of species are observed in the spawning period and also in connection with changes in oxygen conditions (Zalewski et al. 1990). The migrations allow the fish to escape the pressure of abiotic and biotic factors whose impact changes along the river course (Zalewski and Naiman 1985).

In a given stream fragment the stability of a fish assemblage depends to a great degree on the stability of conditions significant for various species in the association. Here a good index is the coefficient of variation (Grossman et al. 1990). In running waters the main variability factor of fish assemblages is the instability of hydrological factors. According to Grossman et al. (1990) they are decisive in causing the pronounced variability of the assemblages with the passage of years. Hydrological conditions most important for fish can change distinctly even in the period of one year. During the present study, in the area of the upper San, very low water levels accompanied by high temperatures were noted in summer (Kukuła and Szczęsny 2000). Most species showed high coefficients of variation (Table V). The Siberian sculpin seemed to be the most stable species and with the high (zone A) and low (zone E) densities did not manifest any pronounced variation of abundance. In the entire range of occurrence the brown trout showed a high variability coefficient. However, the highest variability was found with species that appeared periodically and not at all stations, e.g. the perch or nase (Table V). The migration of some species along the stream course brought about significant differences between the seasons of the year in the mean density and mean values of biodiversity coefficients in the middle and lower zones of streams (Fig. 10, Table VI). No significant differences were found between the mean values of coefficients calculated for fish assemblages in small streams owing to the distinct dominance of two or three species (Siberian sculpin, brown trout, and minnow) throughout the year at almost all sites (Fig. 9).

It was possible to distinguish cenological associations among the identified fish species (Fig. 10). As in the rivers of England (Penczak et al. 1991*b*), in the River San and upland running waters of central Poland (Zalewski et al. 1990) the composition of assemblages results from environmental changes occurring with the river course, and also from fish migrations connected with their life cycle. In spring Cyprinid species (the chub, dace, and roach) gathering for spawning in a similar zone of streams were found in one assemblage (Fig. 11). In autumn the occurrence of perch in one group with the brown trout was also striking. The appearance of perch in the basin of the upper San is associated with the construction of the Solina reservoir (Kukuła 1997*a*, 2000*a*). The abundance of this species above dam reservoirs has frequently been (Kołder 1964, Penczak 1989), and could present a threat to the autochthonous ichthyofauna, including the brown trout.

The brown trout, a key species for the water ecosystems of the Bieszczady region (Głowaciński 1994), was encountered throughout the catchment area (Fig. 9). In the upper course of streams (sites of group A) the numbers of brown trout caught were low, small individuals prevailing (Fig. 12, Table VII). The species was most numerous in the middle course of streams and it was there that the individuals of greater body size were most frequently caught. With respect to abiotic factors the highest requirements of the brown trout at spawning time are associated with a suitable composition of the substrate, depth of water corresponding with the size of spawning fish, the temperature and oxygenation of the water, and also its purity. The accessibility of hiding places and the occurrence of natural or artificial obstacles making migration difficult, are also of consequence (Binns and Eiserman 1979, Milner et al. 1993, Elliott 1994, Haury et al. 1995, Crisp 1996, Lamouroux and Capra 2002). These factors have been disturbed to a varied degree in many rivers and streams of the upper Vistula catchment, considerably affecting the abundance of fish, among them the brown trout (Pasternak and Skóra 1982, Augustyn 1999). In Bieszczady the local disturbances of abiotic factors are fairly rare, chiefly concerning changes caused by forest works and municipal wastes below tourist resorts.

The most important anthropogenic factors bringing about rapid changes in freshwater fish communities are hydro constructions, excessive exploitation of some species, introduction of foreign species, and above all the pollution of waters (Penczak 1992, Allan and Flecker 1993, Penczak and Mann 1993, Witkowski 1996*a*, 1996*b*). The most drastic effect of anthropogenic agents is the extinction of species. In recent decades the decline or pronounced threat to a great many species of the ichthyofauna have been noted in numerous regions of the world (Warren and Burr 1994, Povž 1996, Holčik 1996, Lusk and Hanel 1996). A similar situation is observed in Poland (Witkowski et al. 1999, Głowaciński 2001). In the course of the present study 21 species were found in the tributaries of the Vistula (Table III). If the species recorded by other authors in the 1990s and the verified polling data are taken into consideration, about 40 species of fish and lampreys live in the Carpathian affluents of the Vistula. From the time of investigations conducted in previous years (Żarnecki and Kołder 1955, 1956, Schramm 1957, Jokiel and Backiel 1960, Kołder 1961, 1964, 1973, Solewski 1960*a*, 1960*b*, 1964, 1965, Klimczyk 1965, Bontemps 1971, Rembiszewski 1971, Rolik 1971, Skóra 1972, Bieniarz i Epler 1972, 1991, Klimczyk-Janikowska 1973, Kołder et al. 1974, Włodek 1975, Łysak and Bieniarz 1975, Gertychowa 1976, Wajdowicz 1979, Pasternak and Skóra 1982, Pasternak and Wajdowicz 1983, Skóra and Włodek 1988, Włodek and Skóra 1992) qualitative and quantitative changes occurred in the entire catchment area. The Atlantic sturgeon which in the old days occurred in the San up to Przemyśl, in the Wisłok, Wisłoka, Raba and upper Vistula, was the first to disappear. The last records of its occurrence in the investigated waters come from the 1950s (Bryliński and Kolman 2000, Dyduch-Falniowska 2001). Atlantic salmon had been noted in the rivers San, Wisłok, Wisłoka, Skawa, and upper Vistula (Żarnecki and Kołder 1956, Sych 1996, Bartel 2000*a*, Bartel et al. 2001). In the River San it reached its Bieszczady sectors (Schramm 1957). In the upper Vistula drainage basin the last individuals of Atlantic salmon probably occurred as late as the early 1950s (Łysak and Bieniarz 1975). It seems that the sea trout still noted in the San, Wisłoka, and Dunajec in the 1950s and 1960s (Jokiel and Backiel 1960, Bartel 1988, Amirowicz 2001) also disappeared. Distinct decreases in the abundance of many species were also observed, and further names entered the list of endangered species (Table XV).

Of the species occurring in the waters of this part of the Vistula drainage basin the spirlin, bitterling, vimba, grayling, nase, and barbel may be quoted (Witkowski et al. 1999, Głowaciński 2001).

In the entire catchment area of the upper Vistula, the condition of aquatic fauna is to the greatest degree affected by pollution. According to the current criteria, the waters of large Carpathian tributaries of the Vistula and of the main part of this river were of purity class I up to World War II (Kamiński and Wróbel 1991). Then, however, the quality of these waters very rapidly deteriorated and in the early 1980s only the upper sectors of the main affluents of the Vistula had waters of this class of purity. The remaining parts were even evaluated as outside any class of purity (Dynowska 1995).

The River Skawa is the affluent of the Vistula where changes in fish associations could above all be caused by pollution. At the same time, this is the last large tributary with no greater hydro construction in its drainage area (Hennig et al. 1991). Since the middle of the 1970s the inflow of wastes has rapidly increased. Now the quality of waters in the Skawa is low – in purity class III, and even worse below the town of Wadowice (Gałaś 1998), hence species that occurred abundantly in the middle and lower course of this river (Skóra and Włodek 1991) in the past, are now disappearing.

The effects of pollution are most evident in the middle and lower courses of the Skawa, where a drastic decrease has occurred in the share of the nase (Tables X and XI). This species constituted even 99% of biomass in the catches of the 1960s (Kołder 1961). A similar regress was noted in the case of the barbel. At the same time the abundance of the chub distinctly increased while the roach from the lower sectors broadened its range up river (Table X). An increase in the share of the chub in the assemblage and the widening of its range also occurred in other Carpathian rivers (Augustyn and Bieniarz 1995, Starmach 1998, Włodek and Skóra 1999), and was usually associated with decreases in the abundance of the nase and barbel. Nevertheless in many drainage basins of lowland rivers the chub is more and more frequently regarded as an endangered species (Przybylski et al. 1993, Penczak 1996*a*, Kruk et al. 2001). In the ichthyofauna of the Skawa an increase in the participation of stone loach was also noted (Table X). In strongly polluted rivers, this species begins to dominate (Kotusz 1996).

In the 1970s, in the River San below the Solina dam reservoir and in some of its tributaries, decreases in water quality were also recorded (Kamiński and Wróbel 1991), causing significant changes in the ichthyofauna assemblage. The participation of the barbel and nase in abundance and biomass was reduced, this also applying to the spirlin, spotted barbel, and vimba (Fig. 13, Table VIII). A characteristic increase in the share of the gudgeon, another species, besides the stone loach, that frequently increases its occurrence when other species disappear (Witkowski et al. 1992), was also observed.

The deterioration of the quality of surface waters in the entire catchment is effected by numerous sources of pollution. The point pollution associated with industrial production chiefly concerns the western part of the upper Vistula drainage basin (Kamiński and Wróbel 1991). The towns lying along the rivers and characterized by inadequate sewage management and surface runoff contamination from agricultural areas, also significantly contribute to the pollution (Bombówna 1975). Owing to the development of tourism many rivers are polluted almost from their sources (Bombówna 1977).

It also happens that in unfavourable soil conditions, i.e. in the case of a low content of calcium in the soil (Wróbel 1995), airborne pollution can destroy aquatic ecosystems not burdened with wastes (Szczęsny 1995). In the headwaters of the Vistula, decreased values of pH in the Czarna Wisełka stream brought about the extinction of the ichthyofauna (Table IX). A negative effect of water acidity on the ichthyofauna has been observed in Scandinavian countries (among others by Gjedrem 1981, Hesthagen 1986) and in the Sudeten Mts (Witkowski et al. 1995).

Hydro constructions present a particular threat to the ichthyofauna. Disturbances in the composition of fish assemblages, observed in numerous catchment areas, were caused by technical obstacles in riverbeds (Neves and Angermeier 1990, Lusk 1995*a*, Nicola et al. 1996, Penczak 1989, 1992, 1999, Penczak et al. 1993, 1994, 1998, Penczak and Kruk 1999, 2000, Głowacki and Penczak 2000). In the Carpathian part of the River Vistula basin, distinct changes observed in fish assemblages were to a great measure caused by the construction of several water dams (Skóra and Włodek 1988, Starmach 1998), the greatest of them being the Solina dam reservoir (Hennig et al. 1991). Most frequently, these constructions have no facilities – or of very poor utility – for fish migration (Backiel 1993). The existence of dam reservoirs is accompanied by changes in the ichthyofauna composition both below and above them (Penczak et al. 1984, Backiel 1985, Lusk 1995*a*, Cowx and Gould 1985, Vehanen 1997, Penczak 1999, Cowx 2002) caused by changes in water temperatures, the chemical composition of waters, and the size of water flow (Baxter 1977, Cowx and Gould 1985).

Apart from anadromous migratory fish (the Atlantic salmon, sea trout, and vimba), whose decline in the tributaries of the upper Vistula coincided with the construction of the Włocławek dam (Backiel 1983, Bartel 1988), dam reservoirs also affect other fish species (Backiel 1983). Among other effects the dams are a very important factor in the limitation of abundance of rheophilous Cyprinids (Lusk 1995a, Penczak and Kruk 2000).

In comparing the materials sampled in the San drainage basin above the Solina reservoir (Fig. 9) with those from the 1950s and 1960s (Solewski 1964, Rembiszewski 1971, Rolik 1971, Skóra 1972, Wajdowicz 1979), considerable changes are observed in the ichthyofauna composition (Kukuła 2003*b*). Above all, in the present investigation no catches contained barbel. Before the river was dammed, barbel occurred abundantly in the zone from the now existing reservoir down river, while in the upper catchment of the San it constituted a few percentages of catches (Rolik 1971). The absence of this species in the collected material is in agreement with the tendency observed in many drainage basins, chiefly due to pollution and constructions on the rivers (Penczak 1996*b*, Penczak et al. 1998). This could be observed even in those river sectors where the barbel had previously found optimum living conditions (Lusk 1996). In the River Jihlava, below a dam reservoir, the fall in water temperature changed the natural fish assemblage, with the barbel and nase prevailing, into that of brown trout and grayling (Peňáz and Wohlgemuth 1990). In the River San below the Solina-Myczkowce dam, reservoir changes in the thermal conditions considerably shifted down the zone of a greater abundance of the barbel. The population which colonized the area at the upper line of its longitudinal range of occurrence, cut off by the dam, gradually declined. This was caused by weirs and dikes breaking the continuity of the river system while the too short sectors of rivers could not meet all the requirements of fish biology (Lusk 1996). In the upper San catchment the nase, like the barbel, occurred only in a few sectors of the San and Solinka, but now the abundance of this species is now distinctly smaller in the same sites. The reason for decreases in nase is similar to that of the barbel (Lusk 1995b, Peňáz 1996, Povž 1996, Kukuła 2003*b*).

In other tributaries of the Vistula, distinct decreases were also observed in the numbers of species formerly occurring in rivers above and below dam reservoirs (Kołder 1964, Skóra and Włodek 1988, Starmach 1998). This was, at least in part, caused by the difficulties in, or impossibility, of passing dams. It also sometimes happens in spite of the existing fish pass. The poor construction of fish passes usually hampers their use by the fish (Żarnecki and Kołder 1955, Backiel 1983).

The dam reservoirs affect the ichthyofauna of the catchment not only as a hydro construction preventing fish migration but also by the formation of fish assemblages in the reservoir. Such an assemblage of fish here formed partly of river species that colonized the dammed river, and also of species introduced by man (Holčik 1966, Mastyński 1985, Jelonek and Amirowicz 1987, Skóra and Włodek 1988, 1989*c*, Penczak 1989, Witkowski and Błachuta 1992, Starmach 1998, Lojkásek et al. 2001). The range of influence of a dam reservoir on fish assemblages in a drainage basin can be wide. In the upper San the effect of the Solina reservoir is observed even in the mountain streams of the Bieszczady National Park (Kukuła 1995).

In the Carpathian Mts in most dam reservoirs, slowly occurring succession has led to the formation of a lake fish assemblage with a great percentage of the common bream and roach (Mastyński 1985, Jelonek and Amirowicz 1987, Epler and Sych 1997, Łysak and Ligaszewski 1998). In the Solina reservoir the introduction of lake trout was initially successful owing to the prevailing conditions (Wajdowicz 1976). As in the Myczkowce reservoir, in the first years of existence of the Solina reservoir a great abundance of perch and chub fry were noted in the ichthyofauna (Wajdowicz 1966, 1979). The parallel stocking included the pikeperch, pike, and the Cyprinids (Mastyński 1985). Currently, the lake trout is only sporadically encountered there (Kukuła 1999). Anglers chiefly catch common bream, roach, and perch (Bieniarz and Epler 1993). The perch and roach, having been unrecorded earlier in the upper San, appeared fairly abundantly in the fish assemblage of some streams (Fig. 18). These species reached as high as 640 m above sea level. Their expansion up stream is probably limited by waterfalls and natural and artificial bars. This is documented by the absence of the roach and perch in the upper and middle course of the River Wetlina (Fig. 17). In spring 1980 a landslide took place on a mountain slope (Luboński and Swianiewicz 1992) and a few kilometres above the River Wetlina mouth another obstacle for fish was formed on the river. Before 1980 numerous roach spawners appeared in this river in spring, and in summer the perch was fairly frequent (Kukuła unpubl.). The occurrence of these two expansive species in the upper San changes in successive years (Kukuła 1997*a*) and seasons of the year (Fig. 9). In spring, the roach arrive to spawn in the San and in some of its tributaries. They then probably return to the reservoir and only a part of the population still remains in some streams in summer. The perch appears early in summer and in some places remains until autumn. A similar tendency of the perch and roach to migrate from dam reservoirs up river was observed in the Soła (Skóra and Włodek 1988), Dunajec (Starmach 1998), Pilica (Peńczak 1989), and in the Starina reservoir in Slovakia (Koščo and Košuth 1995). In a mountain dam reservoir on the River Czarna Orawa (the Danube catchment), the perch periodically constituted over 50% of all fish caught (Holčik 1966) and in the catchment of this river the abundance of this species migrating from the reservoir distinctly increased (Skóra and Włodek 1989*c*).

The lake trout (Mastyński 1985) and European whitefish (Falkowski 1999) were introduced in a small dam reservoir on the River Wisłok at Besko. Other fish species, including the Cyprinids, were also introduced, chiefly on account of anglers

(Mastyński 1985). The perch is common here (Kukuła unpubl.). In the sector of the Wisłok directly affected by the dam reservoir, significant changes in the composition of the ichthyofauna occurred both above and below the dam (Fig. 18, Table XII). In relation to earlier data (Rolik 1971, Pasternak and Wajdowicz 1983) the occurrence of some species decreased with a simultaneous distinct increase in the abundance of the perch. Directly below the reservoir the ichthyofauna assemblage also changed considerably and the share of the chub and minnow increased. The abundance of the barbel and spotted barbel was distinctly smaller and the nase was not recorded. A few kilometres below the reservoir the most striking absence of the barbel and a distinct reduction in the abundance of the nase and spirlin were observed.

The threats appearing below the dams chiefly result from changes in the regime of water flow, in water temperatures, and in the chemical composition (Baxter 1977, Neves and Angermeier 1990, Penczak et al. 1993, 1998, Elvira et al. 1998). The natural cycles of high and low water levels, characteristic of rivers, are equalized, affecting the pattern of life cycles of the entire water fauna (Welcomme et al. 1989, Szczęsny 1991). It has sometimes happened that a rapid fall in water level below a dam has devastated the entire ecosystem. Such an event occurred in the reservoir at Myczkowce on December 2, 2002, when a drastic fall in water flow caused massive fish kills in the River San. A similar situation occurred in March 1996 when, after a rapid rise and then fall in the water level, dead fish were observed in a long sector of this river (Kukuła unpubl.). Even small damming bars can bring about significant changes in the environment by affecting the size of flow or impeding fish migration (Lusk et al. 1995, Buras and Gasiński 1998, Lojkásek et al. 2001). Such was the case of a bar on the River San above the town of Przemyśl (Kukuła unpubl.) or some tributaries of the rivers Dunajec and Poprad (Pasternak and Skóra 1982, Augustyn 1999).

The degradation of water ecosystems can also be caused by other factors – not associated with wastes or hydro constructions. Massive afforestation of the catchment area was positively correlated with the occurrence of the brown trout (Maret 1999). However, an important issue is to associate the management of forests with the protection of flowing waters. In the Carpathian part of the Vistula basin the timberland ranges from 18% in the Upland to about 70% in the Bieszczady and Tatra Mts (Fabijanowski and Jaworski 1995), hence the forest economy plays an important role in the economy of this region of Poland. In the difficult local conditions of the mountains, cut timber was also transported through midforest streams. In Bieszczady the beds of numerous streams were devastated by the removal of rock bars and boulders with heavy equipment and explosives. The inundated trees, so important for the functioning of ecosystems, were also removed (Wallace et al. 1995). The rock debris and organic matter covering stream beds were reduced to a pronounced degree. Currently in numerous sectors the streambeds are composed of solid rock. The transport through streambeds caused a mass devastation of the ichthyofauna and invertebrate animals by damaging the natural hiding places of fish and the habitats of invertebrates that are the food of fish (Kukuła and Szczęsny 2000). Changes in the state of these streams caused decreases in the abundance of fish and reduced the fish condition coefficient (Fig. 20, Table XIV). Intensive silviculture is frequently associated with increased erosion, and changes in stream bed gradient, or with the chemical composition of the waters (Harr and Nichols 1993, Rees and Ribbens 1995). The erosion and resulting water turbidity and siltation of streams increase fish mortality, particularly at the youngest developmental stages (Berkman and Rabeni 1987).

Like badly conducted silviculture, the frequent exploitation of gravel out of mountain riverbeds causes unfavourable changes in rivers (Punzet 1994, Punzet and Czulak 1993). The degradation of streambeds connected with the mining of crushed stone aggregate or the regulation of the watercourse, bring about quantitative and qualitative changes in the communities of aquatic invertebrates. A decrease in the amount of food available for fish, damage to eggs and fry, and the degradation of hiding places indispensable for fish survival follow (Bieniarz and Epler 1991, Szczęsny 1991, Penczak et al. 1992). It was determined that the abundance of the brown trout depended to a high degree on the number of accessible hidings (Crisp 1996), e.g. in some investigated Danish streams, bed dredging led to distinct decreases in the abundance and productivity of this species (Nielsen 1986).

For many fish species a very important factor is the exploitation of the population by man (Penczak et al. 1991*a*, 1999, Allan and Flecker 1993). In some cases this is an agent affecting the abundance of species in a given river to a greater degree than the inflow of pollution or the river regulation (Penczak 1996*b*). In the entire catchment, widespread poaching (Skóra and Włodek 1991, Kukuła 2001) and a great pressure from angling are noted. As in all waters, the interest of anglers is directed to some species only. Owing to the character of waters these are the brown trout and grayling (Leopold et al. 1989). In many mountain brooks the so-called sport angling of salmonids is so intensive that some control and limitation to catches becomes necessary (Almodóvar and Nicola 1998). In the catchment of the upper Vistula great interest is traditionally paid, by anglers, to catches of rheophilous Cyprinids and also to large predatory fish (Leopold et al. 1989). Increasingly advanced angling techniques permit the catches of great numbers of fish. Włodek (1978) claims that people removed 75% of fish biomass from the Skawica stream, 25% of this value being poachers' catches.

Among other factors, angling, and above all widespread poaching, contributed to the disturbance of age structure in the brown trout populations (Włodek 1975, Skóra and Włodek 1988, 1989*b*, 1991, Augustyn et al. 1998). In the upper San this is the cause of the poor abundance of older generations of brown trout (Fig. 12, Table VII). The activity of poachers probably led to the breakdown of the lake trout population in the Solina reservoir (Bartel et al. 1996, Kukuła 2001). In the middle and lower San and in the Wisłoka a disproportionately small abundance of large predators (pike, wels, or pikeperch) was found in the ichthyofauna assemblages (Włodek and Skóra 1999, Kukuła 2001). The main reason for this situation – as in numerous other rivers – may be poaching (Penczak and Mann 1993, Penczak and Koszalińska 1993, Penczak et al. 1996, Błachuta and Witkowski 1997, Penczak and Kruk 1999).

The effects of poaching were evident when the ichthyofauna from sites under the pressure of poaching was compared with that found in watercourses similar as to habitat conditions, though under much more efficient protection (Kukuła 1996, 2003*a*). Of the streams of Babia Góra National Park the greatest density of the brown trout was found in a site located in the depth of the Park (Table XII). In the upper San basin significantly higher average body weights and total length of the brown trout were found in sites where no traces of poaching were visible (Fig. 14). In the upper Wisłoka, fishing with the use of chemicals caused a pronounced decrease in the numbers of fish and significant differences between assemblages at the sites compared (Fig. 16). Hence, the abundance of the minnow commonly occurring in the entire drainage basin was very low here.

The composition of fish communities to a great degree depends on the local traits of the environment (Schlosser 1991, Maret 1999). This dependence being taken into consideration, zones characterized by a specific ichthyofauna composition were distinguished (Starmach 1956). Two zones were separated in the Carpathian tributaries of the River Vistula: that of the brown trout and that of the barbel. However, the application of this division was greatly impeded by rapidly occurring anthropogenic changes (Penczak 1972). The changes in physical and chemical attributes of the ecosystem induced by human activity usually change the distribution and structure of fish assemblages (Allan and Flecker 1993).

This is evident in the Carpathian affluents of the Vistula, which, as far as ichthyology is concerned, are among the better-investigated regions of Poland. In some flowing waters investigations were repeated, sometimes in the same river sectors (Blachuta and Witkowski 1997). A general tendency towards the extinction of numerous species, observed in the investigation of 125 river sectors (Fig. 21), is in agreement with observations recorded in various catchment areas (Neves and Angermeier 1990, Przybylski 1993, Peňáz and Jurajda 1993, Nicola et al. 1996, Eklöv et al. 1998). In the Carpathian tributaries of the Vistula, eurytopic species, i.e. the perch and roach, widen their distribution range, other species being in distinct regress. With a lesser pressure from competitors, the former species increase their abundance also in other catchment areas (Penczak and Koszalińska 1993, Penczak et al. 1995). Their increasing share is very distinct in rivers under a strong anthropopressure (Persson 1994, Wolter and Vilcinskas 1997, 1998).

The extinction of migratory fish occurred first. In the Carpathian tributaries of the Vistula the last sea trout individuals were caught for obtaining eggs in 1968 (Łysak and Bieniarz 1975). The migratory form of the vimba, formerly abundant in the rivers Dunajec and San, ceased flowing in for the spawning period to the Carpathian rivers and now occurs only locally as a residential form of this species (Bontemps 1960, 1971, Sych 1996). In the case of these species the construction of dams was decisive (Backiel and Penczak 1989).

In the first half of the 20th century, before a dramatic increase in the quantities of industrial wastes, great numbers of the barbel and nase were caught by anglers in the upper Vistula in the region of Cracow (Backiel 1983). A similar situation was noted in the main tributaries of the Vistula where these species still prevailed in the 1960s (Kołder 1961, Klimczyk-Janikowska 1973, Kołder et al. 1974). The nase and barbel are now threatened species and fast disappearing from numerous rivers (Lusk 1995*b*, 1996, Danilkiewicz 1994, 1996, Penczak 1996*a*, Marszał and Przybylski 1996). Currently, in the "barbel zone" of the Carpathians Mts the leading species is distinctly less abundant and the nase do not form such numerous shoals as before, while the chub begin to dominate (Włodek and Skóra 1999). A dramatic decrease in the abundance of the spirlin also seems symptomatic. This species, found in most flowing waters of the catchment until recently, is now on the list of critically endangered fish (Witkowski et al. 1999, Heese 2001*b*, Kukuła 2001).

The most serious threat to the ichthyofauna is the pollution of waters. This can effect changes in the composition of entire fish assemblages (Przybylski 1993). It is true that currently the quantities of wastes discharged from towns and industrial plants are decreasing, but the quantities of sewage produced by rural areas are increasing (Suchy 2001). Their joint effect, the run-off from fields and the regulation of riverbeds, intensify a rapid degradation of smaller streams. The usual result is a decline of fish and lampreys in these watercourses (Penczak et al. 1991*a*, 1992, Witkowski 1995).

In popular opinion the drainage basin of the upper San, depopulated after World War II, is a region in a state of "wild" nature (Luboński and Swianiewicz 1992). However, in spite of the fairly natural condition of water ecosystems in the

Bieszczady area, particularly distinct with respect to invertebrates (Kukuła and Szczęsny 2000), the composition of the ichthyofauna has changed distinctly, the turning point being the barring of the River San with the Solina dam (Kukuła 2003*b*). The results of other harmful activities are also locally manifested – such as poaching, and the devastation of natural streambeds.

As stressed in the studies conducted in rivers of the Danube catchment, hydro constructions sometimes cause even a twenty-time decreases in the abundance of certain species, including the nase, barbel, or chub (Lusk 1995*a*). Changes in water discharges – differing from the natural ones and frequently of catastrophic character – below retention reservoirs – negatively affect the youngest fish as well as adult individuals (Penczak et al. 1998, Cattaneo et al. 2002, Kukuła unpubl.).

The unfavourable changes in natural fish assemblages are frequently the introduction by man of alien species. They present a serious danger to autochthonous populations, sometimes inducing catastrophic transformations (Almaça 1983, Ross 1991, Kaufman 1992, Swales 1994, Elvira 1995, Levêque 1996, Cowx 2002). In the flowing waters of the Carpathian part of the Vistula catchment, the number of species alien to the fauna of Poland is low. In some Tatra lakes the occurrence of the brook trout *Salvelinus fontinalis* (Mitchill) was recorded (Amirowicz 2001) while the rainbow trout *Onchorhynchus mykiss* Walbaum is sometimes encountered (Kukuła 1999). However, the introduction of three species – the grayling, huchen, and lake trout *Salmo trutta* m. *lacustris* L. – into new catchment areas was more significant. The reason for the translocation was that these species were threatened or extinct in their natural sites of occurrence (Witkowski et al. 1999). The grayling was introduced to the Wisłoka and San basin (Witkowski et al. 1984). This species, characteristic of numerous upper and middle sectors of formerly pure Carpathian rivers which are now strongly polluted in some places, is declining in its natural sites (Skóra and Włodek 1988, 1991, Skóra et al. 1994). Currently, it forms stable populations in the San catchment (Kukuła 2001). The huchen, which disappeared in Poland in the area of its natural occurrence, was saved as a species (Witkowski 1996*c*, Witkowski et al. 2001). It is now found in the Dunajec, Poprad, and San. The third translocated species is the lake trout, which currently occurs in three dam reservoirs (Solina, Besko, and Klimkówka), although in the first two of them as vestigial populations (Bartel et al. 1996).

The populations which usually occur in the lower river course, which – after it was dammed – frequently form large populations in the new dam reservoir and migrate up river, present a serious problem. They were often found to occur abundantly above dam reservoirs (Penczak et al. 1984, Elvira et al. 1998, Kukuła 2003*b*). This is frequently observed above the reservoirs on the Dunajec (Starmach 1998, Augustyn and Bieniarz 1995), San and Wisłok. It has happend that the reproductive success of a species in the impoundment has led to its numerous appearance below the reservoir (Penczak 1994).

Changes in the composition of a fish assemblage can also be caused by excessive exploitation (Allan and Flecker 1993). With respect to the barbel, nase, or large predators this is due to angling (Leopold and Bnińska 1987, Backiel and Penczak 1989) and poaching (Witkowski 1984*a*, 1984*b*, Penczak and Koszalińska 1993).

Of the agents significantly affecting the natural character of fish assemblages, the intensification of agriculture in the catchment area and the devastation of the ecotone zone may be quoted (Hughes and Noss 1992, Schlosser 1995, Lammert and Allan 1999). The number of endangered species was smaller when the riverbed and banks were more natural, the differentiation of depth greater, and the ecotone zone well developed (Kirchhofer 1995). The regulation of watercourses usually results in a considerable impoverishment of the ichthyofauna (Crisp et al. 1983, Witkowski et al. 1991). Unfortunately, in the Vistula catchment a great many of sectors of large tributaries and small streams were greatly changed by the regulation of riverbeds, construction of bars, stone and gravel exploitation etc. (Pasternak and Skóra 1982, Hennig 1991*a*, 1991*b*, Punzet 1994, Punzet and Czulak 1993).

In recapitulating it may be postulated that the ichthyofauna of the Carpathian tributaries of the Vistula basically and unfavourably changed in the second half of the last century. It is impossible to reconstruct the natural systems of the riverine environment still encountered several decades ago (Backiel 1993, Lelek 1996). The structural changes that have taken place in riverbeds are too serious and current economic and social circumstances do not permit the recovery. However, there is a chance of improving the situation at least partially. The first step in this direction could be the improvement of the water quality. However, this is not enough. The process of ecosystem reconstruction will be long, even though it is not certain that the final effect will be fish assemblages similar to the natural ones. In spite of the reduced amounts of pollution, the barbel or nase population have not reappeard in the Wisłok below Rzeszów (Kukuła 2001). A similar situation was noted in the Bzura (Penczak et al. 2000) where, in spite of a distinct improvement in water quality, some formerly occurring species did not return. Investigations conducted in Sweden suggest that the improved quality of water can contribute to positive changes in the ichthyofauna (Eklöv et al. 1998). However, the examples of pure waters of the upper San, Wisłok, and Wisłoka catchment areas show that this is an insufficient element and the effects of different anthropogenic factors, above all of large hydro constructions, could make any improvement impossible. The data discussed in the present work, and also those reported by other authors, suggest that the extinction of the vimba, nase or barbel was to the greatest degree caused by the construction of bars on the rivers (Bontemps 1971, Kirchhofer 1996, Penczak et al. 1998) and the devastation of spawning grounds (Keckeis et al. 1996). In the River Kwisa positive changes in the ichthyofauna, following a distinct improvement in water quality, were noted in the 1990s; however the hydro construction on the River Bóbr is a hindrance to the reappearance of large rheophilous Cyprinids, including the barbel (Witkowski et al. 2000*a*). Even small damming bars can present an obstacle to the return of fish to their previous sites (Pasternak and Skóra 1982, Szczęsny and Kukuła 1998) and disturb the regular pattern of life cycles and the associated migration of different age groups (Backiel 1985, Zalewski et al. 1990, Axford 1991, Lusk et al. 1995, Penczak et al. 1998). It seems that in Carpathian rivers the key to improvement of the state of the ichthyofauna is the building of fish ladders which would permit the migratory species to pass through artificial bars and dams. The necessity for any further construction of dam reservoirs should be carefully analysed, and in the case of larger objects their development should be relinquished (Kukuła 2001).

Acknowledgements

The writing of this monograph was possible thanks to the kindness and support of a number of people whom I would like to thank for their help.

In particular, Prof. dr hab. Andrzej Witkowski, Dean of the Faculty of Natural Sciences, Wrocław University, for his thoughtful comments on the work in progress. Discussions with Prof. Witkowski contributed to the increasing of my knowledge and helped shape the material.

I am grateful to the reviewers – Prof. dr hab. Janusz Starmach from the Karol Starmach Institute of Freshwater Biology Polish Academy of Sciences, Kraków, and Prof. dr hab. Jerzy

Mastyński from August Cieszkowski Agricultural University, Poznań for their kindness and valuable comments which allowed me to introduce some corrections.

I wish to thank Prof. dr hab. Zbigniew Głowaciński from the Institute of Nature Conservation Polish Academy of Sciences, Kraków and Prof. dr hab. Andrzej Górecki from the Faculty of Biology and Earth Sciences, Jagiellonian University for his commitment, support, and stimulating me to work, that was especially important in the initial stage of my research.

A big thank you to my colleagues Drs Antoni Amirowicz from the Karol Starmach Institute of Freshwater Biology Polish Academy of Sciences, Józef Mitka from the Jagiellonian University and Mirosław Przybylski from the Łódź University for their help in reaching some lacking source material and for a constant opportunity to discuss any emerging problems.

The comparative research into ichthyofauna of a few rivers was possible thanks to the sources made available by M. Sc. Stanisław Prokuski, The Polish Angling Union in Rzeszów. I wish to thank him for this.

Much of the presented materials could be collected thanks to the help of a number of people and institutions. In particular, I would like to thank Dr Tomasz Winnicki from the Bieszczady National Park, Doc. dr hab. Bronisław Szczęsny Institute of Nature Conservation Polish Academy of Sciences, Kraków and the directors of the Magura National Park and Babia Góra National Park. The fish catches would not have been possible without the favour of the Polish Angling Union in Krosno and Bielsko-Biała.

Similarly, I would like to thank those who offered me their help in the field studies, in particular M. Sc. Andrzej Sokołowicz from Rzeszów.

And finally, the greatest thanks to my wife, Ewa, for her understanding, support, and buoying me up in moments of pessimism.

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