

Perch, *Perca fluviatilis* L. migrations in the drainage area of the mountainous Solina Dam Reservoir, Poland

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Abstract - The ranges of occurrence of perch *Perca fluviatilis* L. were determined in the upper River San and its main tributaries above the Solina Dam Reservoir. In the years 1994 - 2000 perch was caught by electrofishing at 12 out of 50 sites. Its participation in the total number and biomass usually amounted to a few percentages of fish caught in a given year. The relationship between the water level in the dam reservoir and the number of perch in the tributaries of the upper San was stated. Perch migrated upstream from the dam reservoir, however it did not reach streams divided by waterfalls and water steps.

Key words: river impoundment, water level, fish migrations, perch.

1. Introduction

River impounding causes changes, sometimes significant ones, in the ichthyofauna (Neves and Angermeier 1990, Peñáz and Wohlgemuth 1992, Lusk 1995). Above a dam the extinction of migratory fish can be observed (Backiel 1985). Some native species can disappear, while new ones appear (Penczak et al. 1984). Research conducted in the drainage area of the Carpathian dam reservoirs showed that apart from the disappearance of salmon *Salmo salar* L. and trout *S. trutta* m. *trutta* L., the appearance of new species such as roach *Rutilus rutilus* (L.) and perch *Perca fluviatilis* L., rare in mountainous waters, could be found there. The fish were migrating upstream from the dams (Skóra and Włodek 1988, 1989, Starmach 1998, Kukuła 2003).

On the basis of the material collected by electrofishing 16 species of fish were recorded in the drainage area of the upper San in recent years (Kukuła 1999, 2003). Siberian sculpin *Cottus poecilopus* Heck., minnow *Phoxinus phoxinus* (L.), brown trout *Salmo trutta* m. *fario* L. and chub *Leuciscus cephalus* (L.) occurring most abundantly. Chub and brown trout predominated in terms of biomass (Kukuła 1999). According to the findings in the Solina Reservoir drainage basin in the 1990s, the abundance varied within species (e.g. bleak *Alburnus alburnus* (L.), roach, perch) migrating from the reservoir in different years and in different seasons (Kukuła 2003). Among the species migrating upstream perch was most numerous (Kukuła 1999).

The aim of the present study was to determine the range of perch, as well as the reasons for their migration up the drainage area of the Solina Reservoir.

2. Study area

The impoundment in Solina was built on the River San, the biggest tributary of the upper River Vistula (443.4 km, 16861 km² of the drainage area). The drainage basin of the reservoir covers 1189 km². The dam is 58 m in height, and the average depth of the reservoir being 22.4 m. Total capacity is 0.506 km³ and the total area 22 km². It is the largest reservoir by volume in Poland (Hennig et al. 1991).

The Solina Reservoir is a mountainous reservoir (the mean water level 420 m above sea level, the mean altitude of the reservoir basin 750 m). The major rivers and streams of the area are: the Solinka and the Wetlina (48 km long, 377 km² drainage area), and the Wolosaty Stream called the Wolosatka in its upper part (28 km, 118 km² of the drainage area). The shores of the Solina Reservoir are very steep and the littoral zone is very narrow. The drainage area is heavily forested (above 70%; mostly by deciduous forest). The water in the reservoir is clean with a large amount of dissolved oxygen and a small amount of nitrates and phosphates (Table I). Sewage discharge appears locally close to holiday resorts in the vicinity of the reservoir.

Table I. Meteorological data and physico-chemical parameters of water in the Solina Reservoir and the River San. Average values of each parameter designated by the same letter are not significantly different; Tukey test, * - $p < 0.05$; ** - $p < 0.001$.

Parameter	Year		
	1994	1995	1996
Mean temperature in Lesko (°C)	8.50a	7.56a	6.41a
Annual precipitation in Lesko (mm)	736.1	803.0	906.3
Mean flow in San River (m ³ s ⁻¹) *	11.8a	13.9a	25.9b
Mean water temperature in San River (°C)	14.1a	13.2a	13.4a
Mean water level in Solina Reservoir (m) **	414.4a	416.5b	417.5c
Mean water temperature in Solina Reservoir (°C)	16.5a	14.7a	13.4a
Dissolved oxygen in Solina Reservoir (mg dm ⁻³)	10.1a	9.8a	10.5a
Nitrate in Solina Reservoir (g N-NO ₃ dm ⁻³)	<5	<5	<5
Phosphate in Solina Reservoir (mg PO ₄ dm ⁻³)	<0.2	<0.2	<0.2

3. Materials and methods

The investigation covered the River San and its main tributaries (Fig. 1, Table II). The material used in the present study was collected by electrofishing as well as by carrying out surveys among anglers. Fish were collected using electric fishing gear (350 V, 3.5 A, 20-100 Hz). The investigations were carried out in the years 1994–2000. At most sites fish were caught at least three times every year – in spring, summer and autumn. Initially, data were only collected in the area of the Bieszczady National Park; then in the whole drainage area. In 1997 and 1999-2000 fish were caught at some sites only in summer (Table III). Each time the site of electrofishing was measured and its area calculated. The abundance of the caught fish was standardised for 100 m².

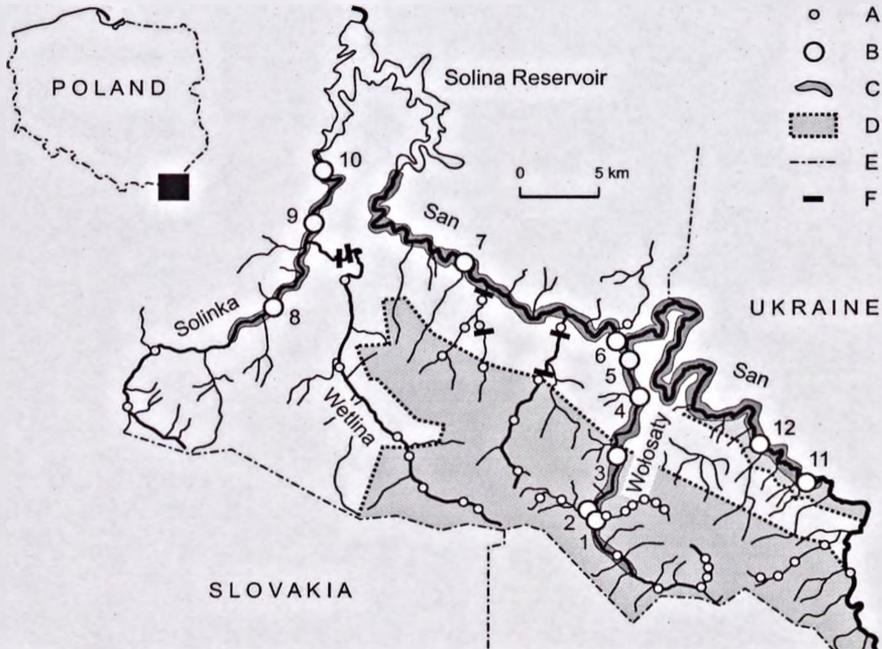


Fig. 1. Geographical ranges of occurrence of perch *P. fluviatilis* in the Solina Reservoir drainage basin. A – electrofishing sites, B – electrofishing sites where perch were caught, C – range of perch, D – border of Bieszczady National Park, E – state boundary, F – waterfalls and water steps.

Mean temperature values, flow in the San, the water temperature in the river and in the Solina Reservoir, as well as the amount of dissolved oxygen were calculated on the basis of the data collected from May to the end of October each year. Statistical analysis of the data was carried out by using one – way ANOVA (Table I).

Table II. Characteristics of sites in the upper San River drainage basin. r – rocks, bs – big stones, s – stones, g – gravel.

Name of stream	Site number	Altitude (m)	Gradient (%)	Width (m)	Mean depth (max.) (m)	Type of bottom
Wolosatka	1	640	13.8	3-7	0.2 (0.7)	bs, s, r
Rzeczyca	2	650	25.5	2-6	0.2 (0.7)	bs, s, g
Wolosaty	3	613	7.6	4-10	0.3 (0.9)	r, bs, s
	4	560	8.5	4-6	0.3 (1.0)	bs, r, s
	5	541	6.1	5-10	0.3 (1.0)	r, bs, s
San	6	536	3.1	8-20	0.3 (1.0)	bs, r, s, g
	7	485	3.8	20-40	0.3 (1.0)	bs, r, s, g
Solinka	8	515	10.7	4-10	0.2 (0.8)	bs, r, s
	9	445	8.5	8-20	0.2 (0.7)	bs, r, s, g
	10	420	6.3	8-30	0.2 (0.7)	bs, r, s, g
San	11	664	4.1	5-8	0.2 (0.7)	bs, s, g
	12	650	2.5	6-8	0.3 (0.8)	r, bs, s

Table III. Percentage of perch *P. fluviatilis* in the total abundance (%N) and total biomass (%B) of the material collected by electrofishing. * - a single catch in summer.

Site	Year	Dominant species				<i>P. fluviatilis</i>	
		N%		B%		N%	B%
1	1994	<i>C. poecilopus</i>	36.7	<i>S. trutta m. fario</i>	78.3	13.0	6.5
	1995	<i>C. poecilopus</i>	47.1	<i>S. trutta m. fario</i>	70.8	0.5	0.8
	1996	<i>C. poecilopus</i>	45.4	<i>S. trutta m. fario</i>	37.3	no perch	no perch
	1999*	<i>P. phoxinus</i>	39.5	<i>S. trutta m. fario</i>	60.7	1.3	0.3
	2000*	<i>P. phoxinus</i>	41.6	<i>S. trutta m. fario</i>	45.6	no perch	no perch
2	1994	<i>P. phoxinus</i>	65.1	<i>S. trutta m. fario</i>	65.1	0.5	0.8
	1995	<i>P. phoxinus</i>	64.0	<i>S. trutta m. fario</i>	55.0	no perch	no perch
	1999*	<i>P. phoxinus</i>	48.9	<i>P. phoxinus</i>	37.4	no perch	no perch
	2000*	<i>C. poecilopus</i>	64.7	<i>C. poecilopus</i>	78.7	no perch	no perch
3	1994	<i>C. poecilopus</i>	34.3	<i>S. trutta m. fario</i>	50.6	8.4	6.1
	1995	<i>P. phoxinus</i>	38.3	<i>S. trutta m. fario</i>	56.2	3.6	4.7
	1996	<i>P. phoxinus</i>	44.0	<i>S. trutta m. fario</i>	45.9	no perch	no perch
	1999*	<i>C. poecilopus</i>	56.2	<i>S. trutta m. fario</i>	43.7	3.9	2.3
4	1996	<i>C. poecilopus</i>	36.2	<i>S. trutta m. fario</i>	31.5	no perch	no perch
	1996	<i>P. phoxinus</i>	29.1	<i>L. cephalus</i>	28.7	5.5	8.4
6	1996	<i>L. cephalus</i>	19.4	<i>L. cephalus</i>	41.0	7.4	6.4
	1997*	<i>A. alburnus</i>	22.0	<i>L. cephalus</i>	33.1	4.9	4.2
7	1996	<i>B. barbatula</i>	27.5	<i>L. cephalus</i>	29.9	7.3	8.7
	1997*	<i>A. alburnus</i>	18.8	<i>L. cephalus</i>	36.4	4.1	3.6
8	1997	<i>P. phoxinus</i>	20.9	<i>L. cephalus</i>	39.6	5.0	2.5
9	1997	<i>L. cephalus</i>	16.3	<i>L. cephalus</i>	60.5	8.0	2.8
10	1997	<i>L. cephalus</i>	22.1	<i>L. cephalus</i>	52.1	6.3	5.0
11	1997*	<i>P. phoxinus</i>	36.6	<i>S. trutta m. fario</i>	29.3	1.2	2.0
12	1997*	<i>P. phoxinus</i>	29.3	<i>L. cephalus</i>	33.7	1.5	1.6

The relationship (Spearman's rank correlation) between the quantity of perch and the mean water level in the dam reservoir one month before electrofishing was analysed. The data collected at sites 1 and 3 fulfilled the conditions of analysis.

Meteorological data and physico-chemical parameters of water in the Solina Reservoir and the San River were obtained from the Institute of Meteorology and Water Management in Kraków, Regional Inspectorate of Environmental Protection in Rzeszów and the Solina-Myczkowce Power Station.

4. Results

The range of occurrence of perch in the upper San drainage area reached 650 m a. s. l. The limits occurred in the River San as well as in the Wołosaty Stream, and the lower part of the Rzczyca Stream. Perch was also found in the Solinka River. In 2003 perch was observed also in the Wołosatka Stream, above site 1, 750 m a. s. l. (Fig. 1).

In electrofishing perch were caught at 12 sites (Fig. 1, Table II). Its participation in the total number and biomass was usually a few percentages of all the fish caught in the given year (Table III). The individuals caught were from 8.7 cm to 16.7 cm in total length. Their average weight ranged from 10.0 to 50.6 g. The largest perch caught by anglers was 23.5 cm length and 182 g in weight. Most fish were 2+ and 3+ years old. Only few were 0+ or older than 3+.

According to the data collected in 1990s by means of angling, perch were found in the River San as far as the Wołosaty stream confluence and in the Solinka as far as the Wetlina confluence between June and September each year. There were years when perch were caught also in the lower part of the Wołosaty and in the middle part of the Solinka (Fig. 1, Table III).

In smaller streams (sites 1-5 and 11-12), *C. poecilopus* or *P. phoxinus* dominated in numbers whereas the greatest biomass of *S. trutta* m. *fario* was recorded. In the San and the Solinka (sites 6-10) *L. cephalus* predominated (Table III).

In the years 1994-1996 the mean values of most parameters of waters in the Solina Reservoir and in the River San did not significantly differ ($p < 0.05$). The only exception was the mean flow in the San, which in 1996 significantly differed from the mean flow in the remaining two years. Differences between mean water levels in the Solina Reservoir were also significant (Fig. 2, Table I).

In the years 1994-1996 analyses of changes in the number of perch at sites 1 and 3 showed some differences between particular years and seasons (Table III). In spring 1994 no perch were recorded at sites 1 and 3. In the middle of July they were scarce at site 3, whereas in August they were among the most abundant species at sites 1 and 3. In autumn their numbers fell. Perch was less abundant in the material collected by electrofishing at sites 1 and 3 in summer 1995 than in the preceding year. In 1996 the species did not occur at these two sites at all (Table IV). Throughout the period under analysis perch was caught by anglers in the San, the Solinka, and the lower part of the Wołosaty stream (sites 4-10) from the middle of June to the middle of September.

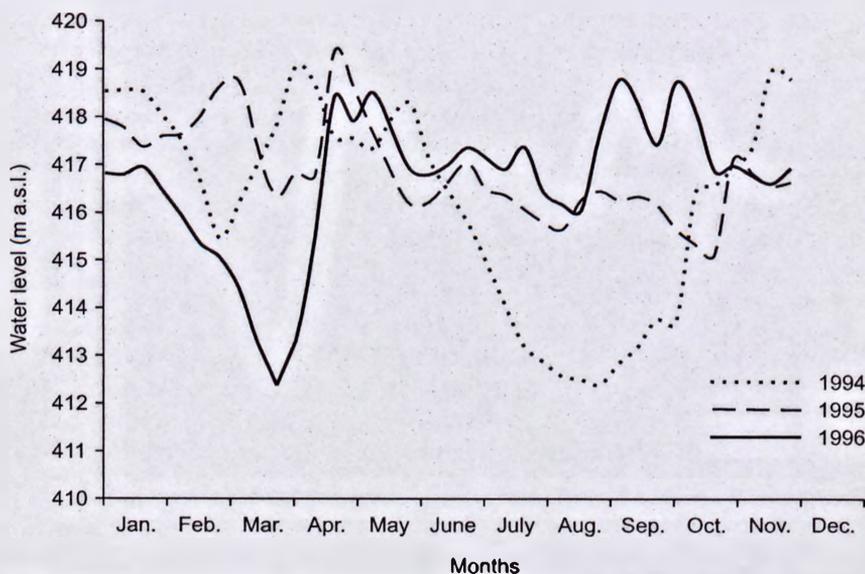


Fig. 2. Water level in the Solina Reservoir in 1994–1996.

Table IV. Abundance of perch at sites 1 and 3. R – correlation coefficient for the relationship between mean water level in the Solina Reservoir and the abundance of perch at sites 1 and 3.

Date of electrofishing	Site number	
	1	3
29.05 - 3.6.1994	0	0
15 - 16.07.1994	0	0.18
19 - 22.08.1994	7.40	2.57
30.09.1994	0.27	1.61
27.05.1995	0	0
17.08.1995	0.29	1.29
7.10.1995	0	0
20.05.1996	0	0
22 - 23.08.1996	0	0
11.10.1996	0	0
28.07.1999	0.17	0.60
2.08.2000	0	0.12
	R = - 0.722 p<0.01	R = - 0.811 p<0.001

The relationship between the mean water level in the Solina Reservoir and the number of perch at sites 1 and 3 was ascertained. There was a high correlation between these values (Table IV).

5. Discussion

The Solina Dam Reservoir was established as a result of impounding a narrow valley of two mountain rivers. The lake formed in this way has very steep banks and great depth. A large number of sunken trees and bushes on the bottom offered ideal conditions for perch reproduction. In the upper San drainage area above the present dam reservoir perch was not previously observed. Single individuals appeared in the zone of the present reservoir. The species was not abundant in the lower part of the River San either (Rolik 1971). For the first few years after the reservoir was built perch and chub fry predominated in the ichthyofauna (Wajdowicz 1979). Currently perch is the third species most frequently caught by anglers (Bieniarz and Epler 1993). In a similar mountain dam reservoir on the Czarna Orawa River (Slovakia), perch temporarily constituted over 50% of all fish caught (Holčík 1966).

The littoral zone in the Solina Reservoir is poorly developed. The water level undergoes big fluctuations related with rainfall. In dry years the water level falls significantly, this resulting in a dramatic reduction in the area and desiccation of the shallow parts of the reservoir. In the warm and dry summer of 1994 there was a considerable drop in the water level in the reservoir (by more than 7 m) as compared with the spring (Fig. 2, Table I). Smaller individuals of fish usually staying in shallow water probably moved to the places where the rivers San and Solinka discharge waters to the reservoir. An increase in fish density leading to a decrease in available food as well as predation could be the cause of fish migration and appearance of perch in the upper tributaries of the San. In 1995 the fall in the water level in the reservoir was not so dramatic (about 2 m) and the number of migrating fish could be smaller. In the following year because of heavier rainfall the amount of water accumulated in the reservoir was maintained at a relatively high level and perch was less abundant in the tributaries of the Solina Reservoir.

Migration intensity probably had nothing to do with the higher water temperature in the Reservoir since fairly high water temperatures were noted also in the reservoir drainage area. Furthermore, the amount of oxygen dissolved in the water was high in the reservoir throughout the whole period under analysis (Table I).

The relationship between the number of perch in a dam reservoir and water level was determined by Prokeš (1995). He observed that a fall in the water level resulted in a decrease in perch density and fish translocation within the reservoir (Prokeš 1995). In dam reservoirs the translocation of perch can also result from the pressure of predators, e.g. pikeperch, *Stizostedion lucioperca* (L.) (Flesch et al. 1995). There is some evidence of perch translocation outside dam reservoirs even to mountain streams. In the Carpathian dam reservoirs upstream migration of some limnophilic species, especially perch and roach (Skóra and

Włodek 1989, Starmach 1998), was observed. In the drainage area of the Czarna Orawa a distinctive increase in the quantity of perch migrating there from the Orawa Dam Reservoir (Slovakia) was recorded (Skóra and Włodek 1989).

Perch migrates from the Solina Reservoir upstream, not reaching the streams divided by waterfalls and water steps (Fig. 1). Such natural obstacles are especially difficult to cross at a low water level. In 19th century shad *Alosa sapidissima* (Wilson) was introduced to North American rivers flowing into the Pacific Ocean. It lived only in the lower part of the Columbia River until water steps, that prevented migration upstream, existed. After a dam reservoir was built, the obstacles disappeared and shad rapidly penetrated the middle part of the river (Hinrichsen and Ebbesmeyer 1998). There were years of a relatively great participation of perch in the quantity and biomass in some sectors of the Bieszczady rivers penetrated by this species (Table III).

Migrating upstream, perch reaches streams in the Bieszczady National Park. In the very hot and dry summer of 2003 perch was observed at a site at 750 m a. s. l. (Fig. 1). Like shad to salmon (Hinrichsen and Ebbesmeyer 1998), perch may be a rival to native species of fish (Kukuła 1995). Great numbers of perch can contribute to the extinction of native species (Penczak et al. 1984, Neves and Angermeier 1990) as it is observed in drainage areas of dam reservoirs.

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