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# Dam reservoir affects diet of otters inhabiting mountain river in SE Poland

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**Abstract.** The diet of otters was studied by the means of spraint analysis in the Bieszczady Mountains, in southeastern Poland. The study area extended over 25 km long stretch of the River San, about 1 km above Solina dam reservoir. Spraints were collected on seven 2 km long sections in 1993, and on three sections in 2010. In both study periods, otter spraints were collected in August, when the weather conditions were similar. The study revealed high contribution of mountain fish species such as *Phoxinus phoxinus*, *Cottus* spp., and *Barbatula barbatula* in otter diet. Diet composition along the River San showed little variation in 1993, except from the section closest to dam reservoir where it was characterised by the highest frequency of occurrence of perch *Perca fluviatilis*, cyprinids and amphibians. The share of perch in otter diet decreased, while that of noble crayfish *Astacus astacus* increased with the distance from Solina reservoir. Changes in otter diet between 1993-2010 were characterized by an increase of the consumption of perch and cyprinids on the one hand, and a decrease of the consumption of crayfish, on the other. Both spatial and temporal changes in otter diet reflected the effect of Solina reservoir on the river community and the availability of prey to otters. The results indicate the ongoing changes in fish community influenced by the construction of Solina reservoir.

**Key words:** diet stability, Eurasian otter, *Lutra lutra*, fish community, Solina reservoir

## Introduction

The feeding habits of otter *Lutra lutra* have been studied for many decades across Europe in a variety of habitats. In most of them, fish constitute the staple food of otters, however, the feeding plasticity of otters is also well documented (Jędrzejewska et al. 2001, Clavero et al. 2003, Remonti et al. 2008, Ruiz-Olmo & Jiménez 2009). Although otters may select prey species from fish community, in general, their diet reflects the availability of a particular prey (including other than fish) in a certain habitat. For example, in rivers with low fish abundance, otters feed extensively on anurans (Brzeziński et al. 1993, Pagacz & Witczuk 2010, Krawczyk et al. 2011) and in small unstable waterbodies they hunt almost exclusively crayfish and water beetles (Román 2011).

In aquatic habitats, due to many different biotic and abiotic factors, prey availability undergoes temporal changes. Fish communities in mountain rivers are composed of a relatively small number of species as compared to lowland aquatic habitats, and despite some year-to-year changes in fish abundance, they

are considered to be stable, if not disturbed by human activities. One of the most serious human impacts to the mountain habitats is the construction of dams and reservoirs. Dams affect considerably fish migrations (Collares-Pereira et al. 2000, Kruk 2004) while reservoirs create unnatural aquatic habitats which undergo eutrophication and are inhabited by specific fish communities (Wołos & Wiśniewolski 2009). In the mountains, reservoirs are being colonised by species absent from fast flowing mountain rivers.

The Solina reservoir was built on the River San in 1968 and covers an area of about 22 km<sup>2</sup>. The long-term monitoring of fish communities in selected sites in the Bieszczady Mountains revealed the ongoing expansion of several fish species from the reservoir to the upper reach of the River San and its tributaries (Kukuła 1999, 2003).

The aim of this study was to assess whether the diet of otters inhabiting the River San differs according to the distance from the reservoir and whether it has changed during 17 year-long period as a reaction to the observed changes in the ichthyofauna community.

## Material and Methods

The study area extends over about a 25 km long stretch of the River San in the Bieszczady Mountains, in southeastern Poland, between the villages of Dwernik (49.20° N, 22.62° E) and Rajskie (49.32° N, 22.48° E) (Fig. 1) and is protected within the Natura 2000 Networking Programme. The source of the River San is located at the Polish-Ukrainian border at an altitude of 889 m. In the study area, the river is up to 80 m wide. The river bed is rocky and the steep banks are covered by beech *Fagus sylvatica* forest, while the flat riverside terraces are overgrown with grey alder *Alnus incana*, willow *Salix* sp., hazel *Corylus avellana* and other riparian vegetation.

In 1993, otter spraints were collected along the River San during the experiments on otter sprainting activity (see Brzeziński & Romanowski 2006), but not analysed until present study. The material was collected along seven 2 km long sections, located about 2 km away from one another. Section 1 was located in the downstream reach of the river, close to the Solina reservoir (about 1 km apart from the reservoir), whereas section 7 was located in the upper part of the river (about 25 km apart from the reservoir). In 2010, a study was undertaken on three of these sections (section 4, 5 and 6) (Fig. 1). In both study periods otter spraints were collected in August. Weather conditions were similar, no heavy rainfall was recorded prior to collecting the spraints, therefore the water level in the river was relatively low. Spraints were collected from stones, boulders and rocks along both banks of the study sections. Altogether 207 spraints were collected in 1993 and 186 in 2010. They were washed through a sieve with 1 mm mesh and oven-dried at 50 °C. Prey remains were identified according to the publications of Horoszewicz (1960), Hájková et



Fig. 1. Distribution of study sections along the River San in the Bieszczady Mountains.

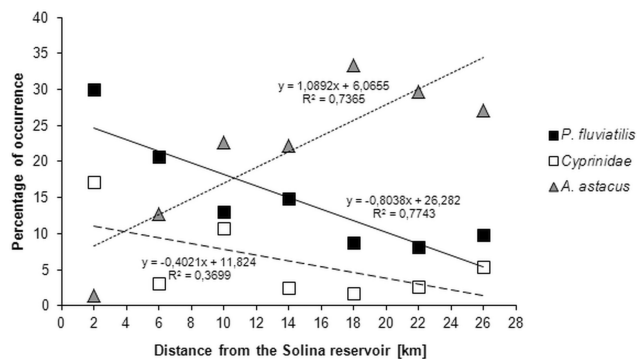
al. (2003) and collections of comparative bones and scales. Prey items were identified to the species or higher taxonomic levels. Results are presented as the percentage of occurrence of a particular prey item in relation to the total number of occurrences of all items in the sample (relative frequency of occurrence).

## Results

On each of the seven sections studied in 1993, the otter diet was predominated by the same main groups of prey, however, their contribution differed significantly ( $\chi^2 = 161.8$ ,  $p < 0.001$ ) (Table 1). Otter diet at section 1 was characterised by the highest

Table 1. The relative frequency of occurrence of main prey items in otter spraints collected along seven 2 km long sections of the River San in 1993.

Species	Section						
	1	2	3	4	5	6	7
<i>Cottus</i> spp.	15.7	38.1	29.8	25.9	24.5	36.5	30.4
<i>Phoxinus phoxinus</i>	4.3	7.9	11.9	16.0	12.3	6.8	11.9
<i>Barbatula barbatula</i>	0	6.3	1.2	2.5	1.8	1.4	3.3
<i>Salmo trutta</i>	1.4	3.2	2.4	2.5	1.8	0	2.2
<i>Thymallus thymallus</i>	2.9	0	1.2	0	3.5	2.7	0
<i>Perca fluviatilis</i>	30.0	20.6	13.1	14.8	8.7	8.1	9.8
<i>Cyprinidae</i> undet.	17.1	3.2	10.7	2.5	1.8	2.7	5.4
Fish undet.	1.4	0	0	0	1.8	2.7	3.3
<i>Astacus astacus</i>	1.4	12.7	22.6	22.2	33.3	29.7	27.2
<i>Amphibia</i>	12.9	4.8	7.1	6.2	3.5	8.1	5.4
Other prey	12.9	3.2	0	7.4	7.0	1.4	1.1
Number of spraints	27	25	31	33	22	34	35
Number of items	70	63	84	81	57	74	92



**Fig. 2.** The occurrence of perch, cyprinids and crayfish in otter diet on the River San in relation to the distance to the Solina dam reservoir.

frequency of occurrence of perch *Perca fluviatilis*, cyprinids and amphibians. The share of perch and cyprinids in otter diet decreased, while that of noble crayfish *Astacus astacus* increased in relation with the distance from Solina reservoir (Fig. 2). In 1993, the diet of otters on section 4, 5 and 6 was similar ( $\chi^2 = 22.4$ ,  $p > 0.05$ ) and also in 2010 we did not record significant differences in food composition between these sections ( $\chi^2 = 27.1$ ,  $p > 0.05$ ). However, the comparison of the prey hunted by otters in 1993 and 2010 on the three sections (pooled data for each year) showed significant changes ( $\chi^2 = 78.5$ ,  $p < 0.001$ ) (Table 2). It was mainly characterized by the decrease in the consumption of crayfish (from 27.8 % in 1993 to 6.6 % in 2010), and by the increase in predation on perch (from 10.9 % to 19.6 %) and cyprinids (from 2.4 % to 13.0 %). Brook minnow *Phoxinus phoxinus* and *Cottus* spp. remained important prey and contributed equally to the diet in both years. Other fish species, such as trout *Salmo trutta*, grayling *Thymallus thymallus* and loach *Barbatula barbatula* were of

**Table 2.** Comparison of the relative frequency of occurrence of main prey items in otter spraints collected in 1993 and 2010 on the River San, for the sections 4, 5 and 6 (pooled for the three sections).

Species	Year	
	1993	2010
<i>Cottus</i> spp.	29.2	24.8
<i>Phoxinus phoxinus</i>	11.8	14.1
<i>Barbatula barbatula</i>	1.9	1.4
<i>Salmo trutta</i>	1.4	3.5
<i>Thymallus thymallus</i>	1.9	4.9
<i>Perca fluviatilis</i>	10.9	19.6
Cyprinidae undet.	2.4	13.0
Fish undet.	1.4	2.6
<i>Astacus astacus</i>	27.8	6.6
Amphibia	6.1	5.8
Other prey	5.2	3.7
Number of spraints	89	186
Number of items	212	347

minor importance. Amphibians, birds and mammals represented together about 10 % of prey occurrences in both study periods.

## Discussion

The diet of otters inhabiting the Bieszczady Mountains has been well described on the basis of studies conducted by Harna (1993), on the Oślawa, Oślawica, Solinka and Wetlinka rivers and Brzeziński et al. (2006) on the River San. All these studies revealed high seasonal stability of the otter diet and high contribution of typical mountain river species, such as *Phoxinus phoxinus*, *Cottus* spp., and *Barbatula barbatula*. Additionally otters hunted other fish species including various cyprinids, *Thymallus thymallus*, *Salmo trutta*, and *Perca fluviatilis*. However, all these fish, except from cyprinids in the study of Harna (1993), were of minor importance and their contribution to the otter diet did not exceed 10 % of prey frequency of occurrence.

In the upper River San, 13 fish species have been recorded. Two species, brook minnow and Siberian sculpin *Cottus poecilopus* are the most numerous and constitute over 50 % of the fish community (Kukuła 1999). The contribution of brook minnow and *Cottus* spp. to the otter diet was high in both study periods and has not changed significantly from 1993 to 2010. In general, it reflected high availability of these fish in the River San.

The construction of dam and reservoir on the River San in 1968 created new aquatic habitats which have successfully been colonized by fish species not typical for rapidly flowing mountain rivers. The results of ichthyological studies conducted on Solina reservoir showed three most abundant species: roach *Rutilus rutilus* (45.9 %), perch (34.5 %) and bleak *Alburnus alburnus* (10.9 %) (Wiśniewolski 2002). Some of the species (with broad environmental plasticity) recorded in Solina reservoir consecutively enlarged their range by migration to the upper flow of the River San. Such expansion has been documented for perch and roach (Kukuła 2003). Perch is the most numerous species migrating upstream from Solina reservoir. Small perches tend to migrate from upstream to tributaries mainly during dry summers, at low water level (Kukuła 2006).

Changes in otter diet were characterized by an increase of the consumption of perch and cyprinids on the one hand, and in a decrease of the consumption of crayfish, on the other. Otters may select some prey species and avoid hunting others but in general, they exploit food resources according to their availability in the habitat.

Therefore, the obtained results indirectly confirm the expansion of perch towards the upper flow of the River San and its tributaries in the Bieszczady Mountains. The increase of the contribution of perch to the otter diet reveals changes in time, however, it is worth noting that in 1993 we recorded significant differences in the proportion of perch remains in otter spraints on particular study sections. It was the highest at section 1 and decreased towards section 7. Ichthyological studies from the Bieszczady Mountains based on electrofishing showed that perch abundance and total biomass decreased with the distance from Solina reservoir (Kukuła 2006), thus, the species was less available to otters in the upper flow of the river. Aquatic food resources usually differ significantly between reservoirs and their tributaries, both in the composition of fish communities and the total fish and other prey biomass, which is poorer in tributaries (Pedroso et al. 2007, Sales-Luís et al. 2007). Therefore, otters which inhabit reservoirs and their vicinities often feed along reservoir banks and look for shelters on better preserved rivers and streams (Sales-Luís et al. 2007). In the Bieszczady Mountains we cannot exclude that some otter individuals inhabiting the River San exploited occasionally food resources from Solina reservoir, as the distance of the first study section to the reservoir was relatively short (1 km). However, the following sections were more and more distant and thus the probability of otters visiting the reservoir declined with the distance. In habitats where crayfish are abundant they always constitute important food for otters (see Jędrzejewska et

al. 2001 for review). No data on long-term population dynamics of noble crayfish is available from the Bieszczady Mountains, however, this species suffered drastic decline in Poland and in many other areas of its natural range (Hessen et al. 2004, Krzywosz & Śmietana 2004, Medar et al. 2006, Bohman & Edsman 2011). There are several causes of this decline, including crayfish plague, habitat destruction, water pollution, overfishing, introduction of alien invasive species and predation. Predatory fish may have strong effects on crayfish numbers (Englund 1999), and the expansion of perch recorded in the River San could also cause the decline of the species, as the perch is an effective predator feeding on juvenile crustaceans (Tulonen et al. 2010).

In general, the most significant changes in the fish community of the River San in the Bieszczady Mountains were due to the establishing of the dam and reservoir (Kukuła 2003). The diet of otters along the River San showed little variation in 1993, however, on the river section 1 closest to Solina reservoir, it differed from the remaining six sections, reflecting the effect of Solina reservoir on the river community and availability of prey to otters. Seventeen years later, a similar diet composition to this recorded on section 1 in 1993 was noted on more remote sections of the River San, indicating ongoing changes in fish community influenced by the construction of Solina reservoir.

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