The impact of methods of fishery management on the diet of otters (*Lutra lutra*)

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A b s t r a c t . The diet of the otter (*Lutra lutra* L.) was assessed through spraint analysis at three different streams in the Beskydy Mountains (north-east Czech Republic) and compared with fish availability and river management procedures. The remains of 3 478 prey items were recorded in 894 spraints, collected between May 2000 and May 2002. Fish were the dominant species taken (90%), followed by amphibians (50%). The most frequently occurring species of fish were the Carpathian sculpin *Cottus poecilopus* (71%) and brown trout *Salmo trutta* m. *fario* (65%). The composition of the otter's diet tended to reflect the fish availability (biomass) in streams. Despite the general similarity of the different streams studied, diet composition differed significantly. The differences in diet could be explained by differences in fishery management (stocking) together with the location of migration barriers.

Introduction

Over recent decades, the diet of otters has been studied in many western and northern European countries (e.g. E r l i n g e 1967, C h a n i n 1981, A d r i a n & D e l i b e s 1987, K r u u k & M o o r h o u s e 1990, B e j a 1991), and also in Central and Eastern Europe (e.g. K e m e n e s & N e c h a y 1990, B r z e z i n s k i et al. 1992) see also reviews in M a s o n & M a c d o n a l d (1986) and C a r s s (1995). Only a few studies, however, have simultaneously compared otter diet with food availability (e.g. K o ž e n á et al. 1992, D u r b i n 1997, C a r s s et al. 1998, R o c h e 2001 for lowland sites). These studies tend to confirm an opportunistic feeding style for otters. With increasing otter populations in Central Europe, there is an increasing conflict arising between fisheries, angling, and species conservation. Otters are blamed for considerable losses of commercial fish stocks in different habitats, including trout streams. However, the fish assemblages in many rivers and streams of Central Europe, and other areas, are strongly influenced through fishery and riverine management. Despite this, the impact of different forms of management on otter diet has not yet been studied. This paper presents results from the Beskydy Mts (north-east Czech Republic) on the diet of otters, as indicated by spraint (faeces) analysis, and compares this with the availability of fish as affected by differing forms of river and fisheries management.

Study Area

The Beskydy Mountains form the outer part of the western Carpathian mountain range and are located on the border between the Czech Republic, Poland and the Slovak Republic. Otters living in this area form the eastern edge of the large Eastern European population, overlapping from Slovakia and Poland into the Czech Republic, and are presently separated from other otter populations in the Czech Republic (K u č e r o v á et al. 2001). The population in the Beskydy Mountains is estimated at around 15 to 20 adult individuals (G r e n d z i o k & L o j k á s e k 1995) and the population density at around 1-2 ind/100 km^2; the reproduction rate is believed to be low (G r e n d z i o k et al. 1998).

Otter spraints were collected from the banks of three medium-sized rivers belonging to the River Olše catchment in the eastern part of the Beskydy Mts. All three rivers are permanently inhabited by otters and form the core area of otter distribution in the Czech part
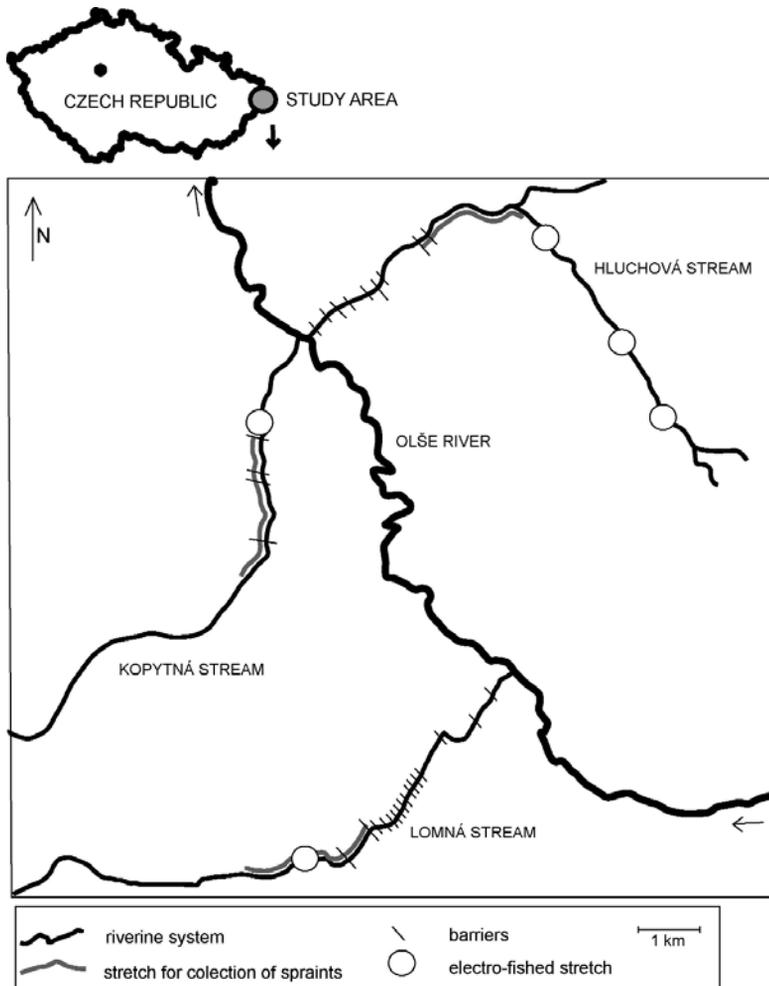
Fig. 1. Map of the study area with location of spraint collection sites, electro-fished stretches, and barriers for migration of fish.

Table 1. The size of artificial gradient drops (weirs) as found along the studied streams (left downstream end). For location of individual barriers see in Fig. 1.

stream	Height of weirs (cm)															
Hluchová	140	90	110	150	130	130	150	150	600							
Kopytná	180	130	170	240												
Lomná	130	150	200	40	130	50	90	70	40	70	80	110	60	40	30	50

of the Beskydy Mts, with reproduction repeatedly recorded (W r ó b e l 1993, G r e n d z i o k & L o j k á s e k 1995).

The Hluchová Stream arises at 840 m a.s.l. and joins the River Olše near the village of Bystřice (330 m a.s.l.; 49° 38' N, 18° 43'E). It has a drainage basin of 37.9 km^2, a total length of 12.3 km and an average discharge at its confluence of 0.78 m^{3}s^{-1}. The Lomná Stream arises at 870 m a.s.l. and joins the River Olše at the village of Jablunkov (380 m a.s.l.; 49° 35'N, 18° 45'E). It has a catchment area of 70.9 km^2, a total length of 17.6 km and an average discharge of 1.49 m^{3}s^{-1}. The Kopytná Stream arises at 920 m a.s.l. and joins the River Olše near the village of Bystřice (328 m a.s.l.; 49° 38' N, 18° 43'E). It has a total length of 9.1 km. The streams have a mountainous character with average slope of 4.2%. The bottom deposit in riffle areas is of gravely substrate of 0.5 to 0.2 m, whereas in pools gravels of 0.05 to 0.1 m prevail. Fluctuating precipitation in the area causes high differences in water flows throughout the year and continuous reshaping of riverbeds. The banks are partially improved and widths vary between 2 to 10 m.

Several artificial gradient drops (weirs) interrupt the course of the streams and the height of weirs affects the possibility of upstream migration of fish (Table 1). Only a few allow upstream migration of brown trout, and none one allow migration of other bottom dwelling fish. The location of weirs differs amongst the streams studied (Fig. 1), thereby significantly affecting local fish communities.

Local angling associations presently manage the fish assemblages within the Hluchová and Lomná streams, however, no fisheries management has been carried out on the Kopytná stream since 1997. The tributaries of the Hluchová and Lomná streams are used for breeding (no angling allowed). These are stocked in spring with 0+ fry of brown trout (*Salmo trutta* m. *fario*) and grayling (*Thymallus thymallus*) and 1+ fish are harvested by electro-fishing in the following spring. The Hluchová and Lomná streams are stocked with brown trout of 10–20 cm in size for angling purposes, with angling allowed between 16th April and 30th November. The fish are stocked at several randomly chosen points along all the course of the streams. The average stocking density of brown trout for the Hluchová stream is about 650 ind/ha, and only about 400 ind/ha for the Lomná stream. The annual fish harvest (fish caught by angling) varies between 25–125 ind/ha (5–25 kg/ha) of brown trout for both streams.

Methods

S p r a i n t a n a l y s i s

Fresh spraints were collected from the banks of the three study localities at one-monthly intervals between May 2000 and May 2002 (Fig. 1).

Before analysis, the spraints were soaked for several hours in detergent and then washed through a sieve (0.5 mm pore diameter). Fish species were identified according to the keys of

Libois et al. 1987, Libois & Hallet-Libois 1988, Conroy et al. 1993, Knollseisen 1996 and by comparison of the hard remains (jaw bones, pharyngeal teeth, vertebrae, and scales) with a reference collection. Other vertebrates were determined from skeletal remains, teeth, hair and feathers. Invertebrates were identified from their integuments.

The diet composition is presented as relative frequency of occurrence (RFO – number of occurrences of a prey category divided by the number of occurrences of all prey categories) and frequency of occurrence (FO – number of occurrences of a prey category divided by the total number of spraints). Despite several problems associated with this method, it generally gives a reasonable estimate of the 'relative importance' of various dietary elements in the diet (Erlinge 1968, Jacobsen & Hansen 1996, Carss & Parkinson 1996).

Both fish and amphibians have single and paired bone structures around the head (e.g. dentary, maxillary, premaxillary bones, and pharyngeal or jaw structures) that allow an assessment of the minimum number of individuals in a collection through the pairing of left and right sided bones of the same size. Therefore, the importance of prey categories in the diet of otters is also presented as relative abundance (RA – number of individuals of a prey category divided by the total number of individuals of all prey categories). The minimum number of individuals was scored either on the basis of the number of left and right-sided unpaired head bones and paired bones of the same size found in a spraint or, where these were not available, vertebrae of clearly differing sizes or scales from different age groups. When vertebrae or scales of the same size or age were found in a sample, the number of individuals of a particular species was scored as one. For comparison of diet and fish availability, only those spraint samples were used which were collected six weeks before and six weeks after electro-fishing. In the case of the Lomná stream, the spraint samples collected in August, September and October were used.

Electro-fishing

Three 100 m long stretches of river were electro-fished in the spring and autumn of 2000 and 2001 respectively on the Hluchová stream, and one 100 m stretch in the autumn of 2000 on the Kopytná stream (Fig. 1). Each stretch was always electro-fished twice, following the standard procedure of Seber & LeCren (1967). All fish of both runs were determined to species level, the number of individuals counted, and the total biomass for each species calculated. For each stretch, both the total abundance and biomass, and abundance and biomass of each species, were estimated according to Seber & LeCren (1967). No electro-fishing was carried out on the Lomná stream due to bank and bottom improvements; the data on fish abundance and biomass being obtained from Hartvich (1997).

Statistical analysis

All invertebrates occurring in the diet, except crayfish, were excluded from statistical analysis due to the possibility of secondary ingestion.

The diversity of the otters' diet, and that of the fish assemblages on the electro-fished stretches, was calculated using the Shannon-Wiener index of diversity (log base 2; Krebs 1998).

All other statistical tests were implemented only on those prey categories exceeding 5% of RFO in at least one season. The overall diet (number of individuals) at all three streams was compared using the log-likelihood ratio test (Zar 1999). The Kruskal-Wallis test,

nonparametric multiple comparison, or the Mann-Whitney test (Z a r 1999) were used to test for significant differences in the number of individuals of the main prey categories in the diet between sites. Spearman's rank order correlation test (Z a r 1999) was used to compare the diet (expressed as FO) with fish biomass available in the streams (C a r s s & P a r k i n s o n 1996) whenever possible. The log-likelihood ratio test (Z a r 1999) was used to compare fish abundance between the Hluchová and Lomná streams.

Results

Assessment of otter diet was based upon the analysis of 894 spraints (Table 2), yielding 3 478 prey items from 27 prey categories (Table 3).

Differences were found in numbers of spraints collected in different seasons at different streams. Whereas at Kopytná the seasonal peak was found in autumn, two peaks were found at Hluchová and Lomná streams – in spring and autumn.

Table 2. Number of otter spraints collected and analysed from the three streams in the study area.

Stream	Spring	Summer	Autumn	Winter	Total
Hluchová	126	81	97	54	358
Lomná	120	96	120	64	400
Kopytná	22	39	61	14	136
Total	268	216	278	132	894

Overall diet

Fish dominated the diet of otters, followed by amphibians, and invertebrates (FO = 94 %, 50 %, 21 % respectively). Other vertebrates were not important, with mammals occurring in 1.7 %, reptiles (grass snake - *Natrix natrix*) in 0.6 % and birds in 0.1 % of spraints. Apart

Table 3. Overall diet of otters at different streams; FO – frequency of occurrence, RFO - relative frequency of occurrence, RA – relative abundance. All results above 5 % marked in bold.

	Kopytná			Hluchová			Lomná		
	FO	RFO	RA	FO	RFO	RA	FO	RFO	RA
Salmonidae	**57.4**	**21.5**	**20.6**	**72.1**	**30.6**	**37.0**	**60.3**	**27.5**	**19.1**
Thymallus thymallus	**12.5**	4.7	4.2	2.5	1.1	0.8	0.8	0.3	0.2
Gobio gobio	2.2	0.8	0.8	1.4	0.6	0.6	-	-	-
Leuciscus sp.	1.5	0.6	0.4	1.7	0.7	0.7	0.3	0.1	0.1
Chondrostoma nasus	0.7	0.3	0.4	-	-	-	-	-	-
Phoxinus phoxinus	**14.0**	**5.2**	**5.6**	0.6	0.2	0.3	-	-	-
Rutilus rutilus	1.5	0.6	0.4	1.4	0.6	1.3	-	-	-
Tinca tinca	-	-	-	0.6	0.2	0.2	-	-	-
Other Cyprinidae	4.4	1.7	1.2	4.5	1.9	1.7	1.5	0.7	0.4
Barbatula barbatula	**33.8**	**12.7**	**12.8**	7.5	3.2	2.7	1.0	0.5	0.2
Cottus poecilopus	**72.1**	**27.0**	**33.8**	**48.6**	**20.6**	**20.6**	**90.0**	**41.1**	**63.3**
Unidentified fish	-	-	-	1.1	0.5	0.3	-	-	-
Mammalia	1.5	0.6	0.4	1.1	0.5	0.3	2.3	1.0	0.5
Aves	-	-	-	0.3	0.1	0.1	-	-	-
Reptilia	-	-	-	-	-	-	1.3	0.6	0.3
Anura	**46.3**	**17.4**	**12.6**	**70.7**	**30.0**	**22.9**	**33.8**	**15.4**	**7.5**
Invertebrata	**19.1**	**7.1**	**6.8**	**21.5**	**9.1**	**10.6**	**27.8**	**12.7**	**8.5**

from the larvae of Trichoptera, occurring in 9.4 % of spraints, remains of molluscs (Mollusca; FO = 2.8 %), crayfish (*Astacus astacus*; FO = 1.8 %), larvae of water beetles (*Dytiscus* sp.; FO = 1.9 %) and low numbers of a further seven taxa of invertebrates were found in spraints.

The Carpathian sculpin (*Cottus poecilopus*) and brown trout were the most important fish species (together RA = 70 %), with a further eight fish species identified in low numbers (Table 3).

Comparison of streams

A comparison of the main prey categories revealed significant differences in the overall diet at all three streams (G = 749.2, df = 8, p < 0.001). The diversity of prey categories within the diet was highest at the Kopytná stream (H'= 2.5), with five main prey categories, followed by the Hluchová stream (H'= 2.2), and the Lomná stream (H'= 1.3) with only three main prey categories. Brown trout was the most important prey at the Hluchová stream, whilst sculpin was the most important prey species at the Lomná and Kopytná streams. Amphibians were third most important prey category at all three streams. The proportion of grayling in the diet did not differ between all three streams, nor did the proportion of brown trout and frogs between the Lomná and the Kopytná streams and the proportion of stone loach (*Barbatula barbatula*) between the Hluchová and the Lomná streams. In all other cases, the comparison between different prey categories and between streams revealed significant differences (Table 4).

Table 4. Statistical comparison of otter diet between different streams (H = Hluchová, K = Kopytná, L = Lomná). G =log-likelihood ratio test; Hc = Kruskal-Wallis test; Q = nonparametric multiple comparison; Z = Mann-Whitney test; NS = no significant difference; *** p < 0.001.

	H x K x L		H x K		H x L		K x L	
All species	G = 749.2	***	G= 151.7	***	G= 54.9	***	G= 292.3	***
Salmonidae	Hc= 26.3	***	Q= 4.1	***	Q= 4.4	***	Q= 1.0	NS
Cottus poecilopus	Hc= 257.6	***	Q= 4.5	***	Q= 16.0	***	Q= 7.1	***
Anura	Hc= 82.7	***	Q= 4.4	***	Q= 9.0	***	Q= 2.1	NS
Barbatula barbatula	Hc= 33.4	***	Q= 4.6	***	Q= 1.6	NS	Q= 5.8	***
Thymallus thymallus	Hc= 4.3	NS	--		--		--	
Phoxinus phoxinus	--		Z= 6.6	***	--		--	

Fish availability in streams compared with otter diet

The most diverse fish composition was found at the Kopytná stream, with brown trout, sculpin, stone loach, minnow and grayling (H' = 1.98). Only two fish species occurred in the electro-fished catches at the Hluchová stream, brown trout and sculpin (H' = 0.93). The same also holds true for the Lomná stream (H a r t v i c h 1997). A comparison of fish composition between the Hluchová and Lomná streams revealed significant differences between both streams (G = 8.7, df = 1, p < 0,01), brown trout constituting a higher proportion of total fish abundance at the Hluchová stream than at Lomná (Table 5).

A positive correlation between FO of fish species in spraints and biomass of fish species in the stream was found at Kopytná in autumn 2000 (r_s = 0.93, df = 7, p < 0.05), and at Hluchová in spring 2000 (r_s = 1, df = 6, p < 0.01) and autumn 2001 (r_s = 0.74, df = 9, p < 0.05), though no correlation was found at the Hluchová stream in spring 2001. No statistical test was possible for autumn 2000 at the Hluchová and the Lomná Streams.

Table 5. Summary of results of electro-fishing of each stream (data for the Lomná stream from H a r t v i c h 1997), the number of individuals and the biomass are expressed per hectare of water surface.

Stream	Period	Salmo trutta		Cottus poecilopus		Barbatula barbatula		Phoxinus phoxinus		Thymallus thymallus	
		ind.	kg	ind.	kg	ind.	kg	ind.	kg	ind.	kg
Kopytná	Autumn 2000	3409	220	5514	47	544	24	4752	21	1134	14
Hluchová	Spring 2000	1247	66	2957	25						
Hluchová	Autumn 2000	1858	76	5315	65						
Hluchová	Spring 2001	1209	45	1770	22						
Hluchová	Autumn 2001	1587	113	2366	19						
Lomná	Autumn 1997	305	20	1087	9						

In three cases at the Hluchová Stream (spring 2000, 2001 and autumn 2000), the rank order of sculpin and brown trout in the stream and in the diet were the same; only in autumn 2001 was the rank order reversed. At the Lomná stream, the rank order of sculpin and brown trout in the stream and in the diet was also reversed. (Fig. 2)
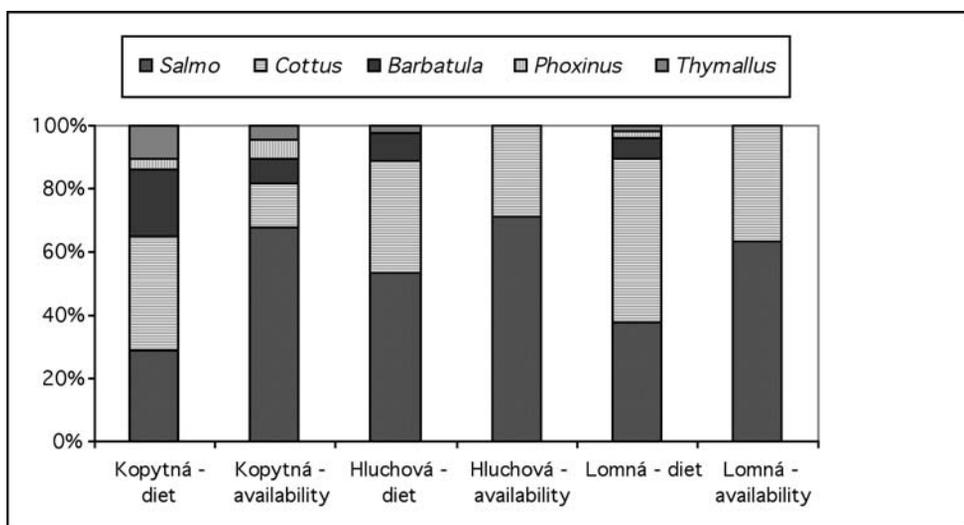
Fig. 2. Comparison of main fish species in otter diet (RFO; 364 spraints) and fish availability (biomass) at the different streams.

Discussion

The results of spraint analysis, showing fish as the most frequent prey of the otter, followed by amphibians, and other prey categories taken in low quantities, generally agrees with a number of earlier findings (e.g. E r l i n g e 1967, C h a n i n 1981, B e j a 1991). The present study also showed a fish species composition in the diet in concordance with other studies from the Carpathians Mountains, where brown trout and sculpin dominate the diet (e.g. K o ž e n á et al. 1992, H a r n a 1993, G r e n d z i o k & L o j k á s e k 1994).

Despite the broad similarity of the streams studied, both in general appearance and main features, otter diet composition varied significantly. This may be explained through differences

in fish abundance, diversity, and biomass. In all three streams, the diet of otters tended to reflect these differences, with fish species occurring in the diet in relative proportion to their availability, although with sculpin taken slightly more often than availability would suggest, and trout slightly less, especially at the Kopytná stream (Fig. 2). This latter fact could be explained as an artefact caused by under- or over-estimation of prey items when using the spraint analysis method (see C a r s s & P a r k i n s o n 1996). Another explanation, however, could be a preference for feeding on the slower moving sculpin.

The main factors causing the differences in fish assemblages at the streams are the management practices of the local angling association and the location of migration barriers (Fig. 1). A lack of fishery management, together with an absence of migration barriers, in the lower stretch of the Kopytná stream results in a more 'natural' fish community, with free migration of smaller species in particular (Table 5). At the Hluchová stream, in three out of four samplings, the diet of otters corresponded to availability. However, the results for spring 2001, and the rank order of brown trout and sculpin at the Lomná stream, did not follow this pattern. In the case of the Lomná stream, however, the data on fish availability used were four years old and changes in fish composition could have occurred between 1997 and 2000. The explanation of this discrepancy for the Hluchová stream remains unclear. A difference in stocking density of brown trout at the Hluchová and Lomná streams also results in a difference in predation pressure on sculpin. Sculpin occur in higher numbers and biomass in the Lomná stream, where stocking of trout is lower. Here again, the diet of otters followed availability and sculpin occurred in the diet in higher numbers at the Lomná stream than at the Hluchová stream.

The regular stocking of high densities of brown trout in the Hluchová and Lomná streams imposes a high predation pressure on small fish species, causing local depletion of their populations and, consequently, a relative 'increase' in the availability of trout to the otter. Due to the migration barriers downstream, no immigration of new individuals from the River Olše is possible and the populations are slowly driven to extinction. Thus the fish community in these two streams is composed almost entirely of brown trout and sculpin (see Table 5 and H a r t v i c h 1997). Despite trout not having been stocked in the Kopytná stream since 1997, higher numbers of trout and sculpin were found in this stream than the others (Table 5). It is possible that, as smaller fish disappear from the latter streams, older trout turn to cannibalism to supplement sculpin in their diet. Unfortunately, no stomach contents were analysed to prove or disprove this. Alternatively, spraint sampling indicated two peaks at both the Hluchová and Lomná streams (spring and autumn), unlike the Kopytná stream where there was only one peak in autumn, as observed in other studies (e.g. M a c d o n a l d & M a s o n 1987). The high annual stocking of trout, and their higher relative abundance to other species, at the former sites may be encouraging otters to feed heavily on these fish in spring; conversely, the wider diversity of slower prey at the Kopytná, and the lack of downstream migration barriers, allowing free movement of trout and other species in and out of the river, may reduce such predation and allow trout populations to grow.

The fish composition in the diet, therefore, generally corresponds to fish availability in the streams. These results support earlier assumptions (e.g. M a s o n & M a c d o n a l d 1986, C a r s s 1995) as well as findings stating that otters take prey species in proportion to their availability in the environment (K e m e n e s & N e c h a y 1990, K o ž e n á et al 1992, D u r b i n 1997, C a r s s et al. 1998). The occasional presence of other fish species in

the diet at these streams, in low numbers, can be explained either by the inefficiency of electro-fishing for small and/or bottom living species, or as a result of the otter eating an item caught at another site and later sprainting in the study area. Otters are able to move over considerable distances, often within short periods (G r e e n et al. 1984, D u r b i n 1993, own unpublished data), and the distances between the study localities and the River Olše is short enough to explain this effect.

There is evidence; therefore, to show that recent fisheries management, consisting of the stocking of high densities of brown trout, together with habitat fragmentation, can affect non-target fish species. Such management decreases the overall availability of these fish species in streams and, because otters tend to eat prey in proportions similar to those available in the environment, they are forced to feed mostly on commercial fish species. Further, migration barriers and high densities of 'enclosed' prey may actually encourage otters (and other predators, including piscivorous fish) to increase their predation beyond what might be termed a 'normal' level. A change in management practices, to include the protection or restocking of non-target species, spreading the stocking of trout over a wider area or time period, together with habitat restoration (e.g. fish passes), could increase local populations of non-target species. Such additional food may result in a reduction of otter predation on commercial fish, resulting in a decrease in economic damage and the resulting conflict.

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