Otter, *Lutra lutra*, feeding pattern in the Kamenice River (Czech Republic) with newly established Atlantic salmon, *Salmo salar*, population

David KORTAN[1], Zdeněk ADÁMEK[1]* and Pavel VRÁNA[2]

[1] *University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters, South Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, Zátiší 728/II, 389 25 Vodňany, Czech Republic; e-mail: adamek@ivb.cz*
[2] *Czech Anglers´ Union, Vyšehradská 49, 128 00 Praha 2, Czech Republic*

Abstract. Food composition of otter, *Lutra lutra,* was studied by the analysis of 349 spraints found during one year period (2003–2004) at the River Kamenice (Czech Republic), where Atlantic salmon, *Salmo salar,* fry have been stocked regularly since 1998 in a reintroduction programme for the species. Brown trout, *Salmo trutta* m. *fario*, dominated otter diet and formed 29% of all prey items and 62% of biomass of all fish eaten. The second most abundant prey (27%) was common sculpin, *Cottus gobio*, followed by Atlantic salmon, and grayling, *Thymallus thymallus*. The proportion of salmon in the diet of otters amounted to 14.5% in numerical abundance of all prey items taken and 2% in biomass of fish component of the diet. The majority (71.5%) of fish eaten by otters had a total length between 61 to 200 mm.

Key words: fish predator, diet composition, prey fish

Introduction

The Eurasian otter, *Lutra lutra*, and Atlantic salmon, *Salmo salar*, were, until the second half of 19th century, common species inhabiting many riverine habitats in the territory of current Czech Republic (Frič 1893). Overfishing caused a rapid decline in the salmon population at the end of 19th century and the construction of the Střekov weir (Ústí nad Labem, Czech Republic) on the Labe (Elbe) River completely closed the access to Czech rivers for adult salmon returning for spawning and led to their extinction in Czech rivers. In 1998, the Czech Anglers´ Union initiated a stocking program of salmon fry (yolk sac stage) into the three rivers formerly inhabited by salmon and, together with Agency for Nature Conservation and Landscape Protection and the Ministry of Environment of the Czech Republic, began a reintroduction programme under the framework of the "Salmon 2000" project (Benda & Šmíd 2002). The aim was to re-establish salmon population in these rivers, allowing returning adult fish to enter

via fish passes. The Kamenice River in the National Park Bohemian Switzerland is one of the three rivers where salmon fry have been stocked regularly. Over 100 thousand salmon fry have been released regularly every year in spring at suitable sections of the river since 1998, and the first four adult salmon returning to spawn were recorded there by electrofishing in autumn 2002. In addition, migrating adult salmon have been observed regularly by environmental agencies and one to two salmon (78–104 cm TL) have been caught (and released) by anglers every year during 2001–2006 (Urych 2007).

The area of the National Park is also one of a few localities where an otter population persisted during the dramatic decline and near extinction of this species across most of central Europe during the last century (Riebe 1994, Hájková et al. 2007). Problems associated with damage caused by otter predation on fish assemblages, especially in artificially stocked waters, increased as numbers of otters in the Czech Republic raised in recent years (Adámek et al. 2003,

Kortan et al. 2007). Information about the impact of otters on fish assemblages and stocks (particularly of species of high conservation concern like the Atlantic salmon) is therefore of considerable interest especially to ichthyologists and nature conservationists. This paper investigates the food composition of otters in an environment with "natural" fish population, where juvenile salmon occur as a newly reintroduced species. Its aim is to contribute to the evaluation of the success of salmon reintroduction process and its possible threats.
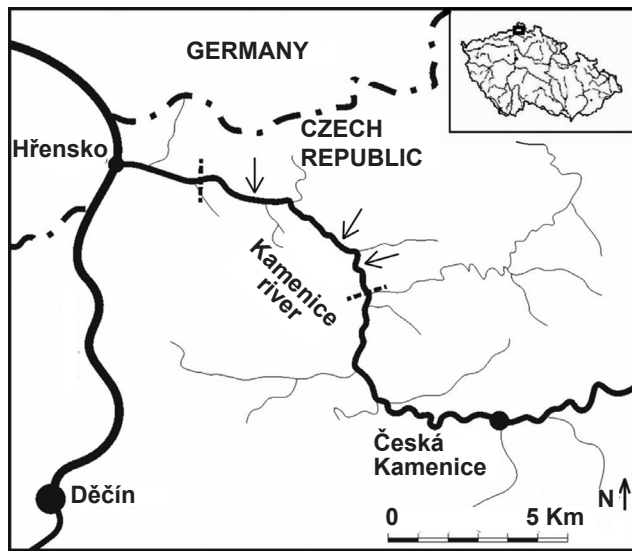

Fig. 1. *Location of the study area and section of the Kamenice River searched for otter spraints (dashed line) and position of electrofished sites (arrows).*

Study Area

National Park Bohemian Switzerland is located in North Bohemia (Czech Republic) on the border with Germany. The Kamenice River is a fast-flowing torrentile river running, in its lower part, through the territory of the National Park in a deep, narrow sandstone canyon before ultimately flowing into the Labe River (50°52′27.47′′ N; 14°14′9.98′′ E). In total, an 8 km river stretch was monitored for otter spraints. The upper boundary of the section was located 11 km upstream from the confluence with the Labe River and one kilometre upstream from the site of regular salmon fry release. The lower boundary of the study stretch was situated 3 km upstream of the confluence with the Labe River (Fig. 1). Average width of the river at this part was about 10 m, water depth varied between 0.1–0.9 m although pools (up to 2 m deep and several metres long) are formed

under big boulders in the watercourse or below rocks surrounding banks.

Juvenile Atlantic salmon have occurred in the river since stocking began in 1998. The native fish assemblage comprised brown trout, *Salmo trutta* m. *fario*, common sculpin, *Cottus gobio*, grayling, *Thymallus thymallus,* and eel, *Anguilla anguilla*. Recreational fishing has been prohibited on the territory of the National Park since its establishment in 2000. Apart from salmon, no other fish species have been stocked into the river within the study area.

Methods

Otter diet was studied by faeces (spraint) analysis. Spraints were collected at monthly intervals for one year, from April 2003 until March 2004. A special attention was given to thorough searching for fish remains partly consumed and left by otters but none were found.

Spraints were prepared for analysis by soaking in a solution of enzymatic preparation Golem Bio (Druchema Prague, CR) for three days before being washed through a 0.5 mm mesh sieve and dried on filter paper. The remains recovered from spraints were used for the determination of prey species, including the assessment of a minimum number of consumed individuals, their total length (TL) and weight (W). Non-fish prey were identified and categorised to class, as being insect, amphibian, bird or mammal. Results are presented as relative abundance of individual prey species (or category) for all spraints collected. Relative biomass was counted only for fish component of the diet. Data for fish species with relative abundance < 3% were combined and presented as a separate category ("other fishes").

Prey fish species were determined using diagnostic bones and scales according to published keys (Webb 1980, Libois et al. 1987, Libois & Hallet-Libois 1988, Conroy et al. 1993) and by comparison with a reference collection of fish bones and scales. Brown trout and salmon were distinguished by the differences in the structure of the first "atlas" vertebra, following Feltham & Marquiss (1989). The proportion of brown trout to salmon was first calculated on the basis of species identification from atlases found in spraints and this proportion was then applied to all salmonid remains, including the samples where no atlases were found. This computation enabled the estimation of relative abundance and biomass of particular species in the diet. Minimum number of individuals was estimated from the number of atlases, pair bones and from differences in size of bones. Original length

(TL) was calculated on basis of published correlations between bone and fish length (Libois et al. 1987, Libois & Hallet-Libois 1988, Feltham & Marquiss 1989, Conroy et al. 1993). When the key bone was impossible to measure, fish preys were classified into 50 mm length categories according to comparison with appropriate bones from the reference collection. Several individuals of each species in 50 mm length categories were elaborated for this purpose. Original weight of prey was calculated from the total length; exponential length to weight relationships being computed from measurements (TL and W) of fish caught by electrofishing in the study area. Mean weight of particular 50 mm TL categories was used for weight reconstruction in those cases when exact TL was impossible to measure.

Single electrofishing (National Park status did not enable repeated monitoring) was carried out in June 2003 to estimate the fish assemblage composition in the study area. Three 100 m long sections of the river were chosen as representative with respect to accessibility and were monitored by standard electrofishing methods CEN 14011 standards (CEN 2003) in one run only. Fish were measured (TL) and weighed and results presented as relative abundance and biomass of particular fish species from all fish caught.

Using data about fish food supply composition, Ivlev´s selectivity coefficient (Jacobs 1974) was applied for the evaluation of food electivity: $E = (r - p)/(r + p)$, where r = percentage of certain food item taken by otter, p = percentage of that prey item available in the environment. Thus a value of $E = 0.00$ means that consumption of a particular food item corresponds to its occurrence, whilst $-1 < E < -0.01$ and $0.01 < E < 1$ indicate negative (lesser consumption than expected from estimates of food item abundance) and/or *vice versa* positive selectivity for a particular food item, respectively.

Statistical evaluation of otter diet and fish assemblage relationships was performed by two sided t-test for independent samples in Statistica 6.0 (StatSoft Inc. 2000).

Results

Altogether, 1042 prey individuals were identified in 349 faecal samples found during the whole year. Fish formed 83.9% of otter diet in terms of relative abundance. Overall nine fish species were found in spraints, of these only four species were registered as a frequent prey: brown trout, common sculpin, Atlantic salmon, and grayling (Table 1).

Salmonids (brown trout and salmon) together formed 43.5% (453 individuals) of all prey individuals. The atlas vertebra was found in 57 individuals (12.5% of all possible cases). According to the structure of atlas vertebrae, 19 individuals were identified as salmon and 38 as brown trout, corresponding to their relative proportions of 33.3 and 66.7% for salmon and brown trout, respectively. This ratio was thus used for subsequent estimation of the proportions of salmon and brown trout proportion for all prey consumed.

Brown trout and common sculpin were the most commonly consumed prey, with 29.0 and 27.2% relative prey abundance, respectively. Salmon comprised 14.5% of all prey taken, grayling (7.3%) and perch, *Perca fluviatilis*, (3.2%) were also found at a greater extent in spraints. "Other fishes" recorded in spraints were eel, roach, *Rutilus rutilus*, carp, *Cyprinus carpio*, and pike, *Esox lucius*, and together they formed 2.8% of prey recorded. Otter spraints contained relatively high number of invertebrate remains (10.9% of total abundance). The remains of amphibians, mammals and birds constituted the non-fish prey recorded in otter diet with 2.9, 1.7 and 0.6% proportion, respectively.

Brown trout dominated the fish component of the diet in terms of biomass (62.1% of the total biomass of fish), followed by grayling (16.3%) and common sculpin (8.7%). Although salmon was the third most commonly recorded prey by numbers, its contribution to the total biomass of fish component of the diet was only 2.0%. Relative abundance and biomass of main prey items are presented in Fig. 2.

The proportion of salmonids in the river fish community was relatively high with 82.9 and 83.0% relative abundance and biomass, respectively, in comparison with their proportion in the fish component of the otter diet (43.7 and 55.5% of abundance and biomass, respectively). The ratio of brown trout to salmon estimated in the fish assemblage (74.7 to 25.3%) did not differ significantly from the proportion found in the otter diet, where this ratio was 66.7 to 33.3% (p = 0.21). Proportions of brown trout and salmon in terms of biomass were almost identical (p = 0.96) in the otter diet and in the estimates of fish stock.

The Ivlev´s coefficient of selectivity (Table 1) was slightly negative for salmonids (E = -0.28 and -0.11 for brown trout and salmon, respectively), whilst positive values were proved for the other species (E = +0.48, 0.33 and 0.85 for common sculpin, grayling and perch, respectively).

The majority (71.5%) of fish eaten by otters had a total length between 61 to 200 mm. The most abundant (35.7% of fish) size category in otter diet was 61–100 mm, whereas the most numerous (34.1%) size category in the sampled river fish assemblage was 101–150 mm (Fig. 3).
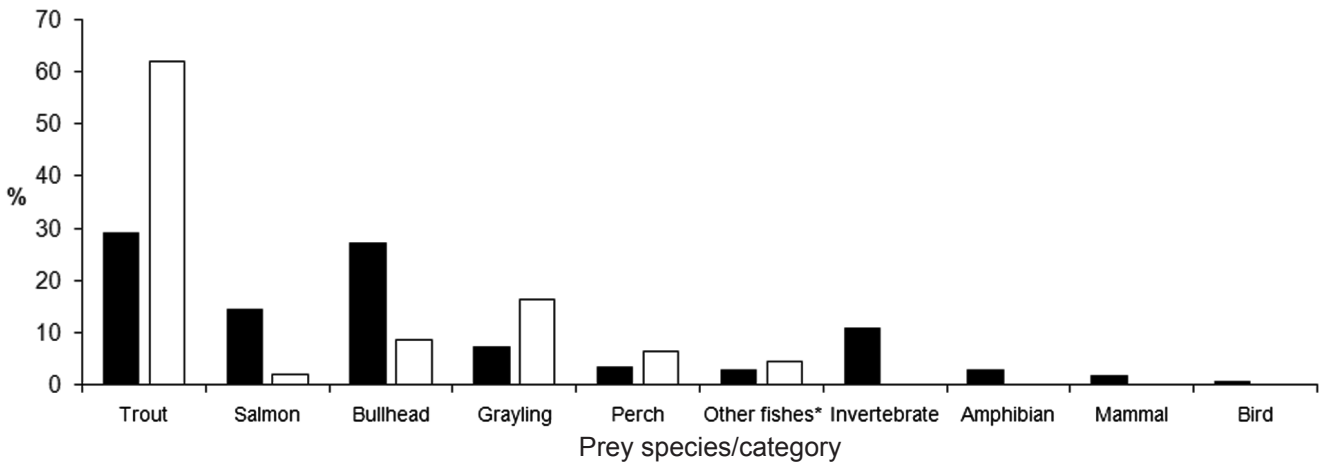
*Fig. 2. Relative abundance (■) and estimated biomass** (□) of particular prey items found in otter spraints. Explanations: *, other fish species (eel, roach, carp, pike), **, biomass of fish only.*

The distribution of all size categories from 61 to 250 mm differed significantly between the diet and fish assemblage estimates. Brown trout of all size classes appeared to be captured by otters in similar proportions to their abundance as estimated by electrofishing. Common sculpin was recorded in a relatively high number of small fish because this small species never exceeds 150 mm. On the other hand, grayling and eel were represented mostly in the larger size categories with 62% of grayling and and 82% of eel exceeding 150 mm and 300 mm, respectively. Small salmon were found predominantly in spraints, 68.4% of consumed salmon were 61 to 100 mm (TL) long.

Discussion

Otter diet has been studied in many freshwater habitats throughout the Europe. The common conclusion of these studies is that otter diet consists predominantly of fish and the main factors influencing the food composition are above all the prey availability and vulnerability (e.g. Erlinge 1968, Jenkins et al. 1979,

Mason & Macdonald 1986, Kožená et al. 1992, Carss et al. 1998). This conclusion integrates many ecological issues, where prey availability is influenced by the day time, season, antipredatory behaviour of prey and distribution of food resources, as well as the energetic demand of feeding otters (Carss 1995, Kruuk 1995, Roche 2001). Although Carss (1995) concluded that current spraint analysis techniques are probably not sufficiently rigorous to accurately assess the diet of otters (at least to the level required for some analyses), it is generally accepted that spraint analysis can at least provide useful information on the prey consumed and their rank order in otter diet (Carss & Parkinson 1996). Possible sources of errors must therefore be considered in the interpretation of results of the present study.

Brown trout and common sculpin were registered as dominant prey items. These species dominated in other otter diet studies carried out at the similar riverine habitats. Kožená et al. (1992) in the study of otter diet at streams in the Slovenské rudohorie

*Table 1. Proportion (%) of particular fish species in the diet of otters as estimated from spraint analysis and in the local fish assemblage as estimated by electrofishing and the Ivlev´s selectivity coefficient (E). Explanations: *, other fish species (eel, roach, carp, pike).*

Fish species	Diet n = 874	Fish assemblage n = 367	E
Brown trout	34.6	61.9	-0.28
Salmon	17.3	21.0	-0.11
Common sculpin	32.4	11.4	0.48
Grayling	8.7	4.4	0.33
Perch	3.8	0.3	0.85
Other fish species*	3.3	1.1	0.50

Mountains (Slovak Republic) found Carpathian sculpin, *Cottus poecilopus*, as the most abundant prey species (38.8% relative abundance) followed by brown trout (36.0%), grayling (11.3%) and perch (3.9%). Poledník et al. (2004) studied otter diet at three different streams at the Beskydy Mountains (Czech Republic). Major components of the diet here were Carpathian sculpin and brown trout, but overall diet composition varied significantly according to different fish availability. This was explained by differences in fishery stocking management and the location of migration barriers. Also Harna (1993) found the highest biomass of brown trout and sculpin (42%) in the diet of otters at the Bieszczady Mountains in Poland.

The rank order of fish species in the otter diet corresponded quite closely to their estimated proportion in the assemblage. The only difference in order involved common sculpin and salmon - sculpin was the second most commonly recorded prey of otters, whilst electrofishing revealed salmon as the second most abundant species in fish assemblage. Common sculpin was preyed upon considerably more often than would be suggested according to their occurrence in the river, as revealed by the electrofishing (see Ivlev´s selectivity coefficient in Table 1). This fact may be a consequence of specific anti-predatory reactions of this species and may be explained by two ways. Sculpin is a slow moving fish, which, rather than burst-swimming to avoid a predator, seeks shelters and hides under boulders on the bottom when in danger. Sculpin, therefore, can become a very easy prey for an otter when an individual learns where and how to find this prey. On the other hand, the abundance of sculpin may be underestimated by electrofishing for the same reason, as it may remain under boulders when affected

by electric current. As shown by Kořínek (2006), the success in Carpathian sculpin capture in repeated electrofishing runs was quite high and corresponded to the ratio of 45.5, 32.8, and 21.7% in the first, second and third run respectively. This suggestion of variable species-specific capture efficiency by electrofishing could also affect the estimated proportions of fish species in the assemblage.

According to the regional Czech Anglers´ Union, the high abundance of perch in the diet of otters in the study section of the river can be most likely explained by predation on perch in the water reservoir in the vicinity of the river, where this species occurs in high abundance (T. Kava, pers. comm.). Similarly, pike and cyprinid fishes could penetrate into the river from the ponds upstream of the study sites, or they could be caught by otters feeding either there or several kilometres downstream in the Labe River where these species occur. Invertebrates found in spraints may come from stomachs of preyed fish and some authors exclude them from the total evaluation of diet composition (Jenkins & Harper 1980, Poledník et al. 2004). The majority of invertebrates found in the samples were beetles or caddis fly larvae. As broken parts of them (beetle wing cases in particular) were often recorded on the boulders at sprainting sites, the invertebrates were therefore considered as otter prey as well.

Small fish between 61–100 mm TL were by far the most abundant size category in otter diet, whereas the fish assemblage was dominated by the 101–150 mm category. Nearly half of fish recorded in the diet in the 61–100 mm category were common sculpin. Such great differences between the representation of this size class in estimates of otter diet and of fish in the environment may be a result of underestimation
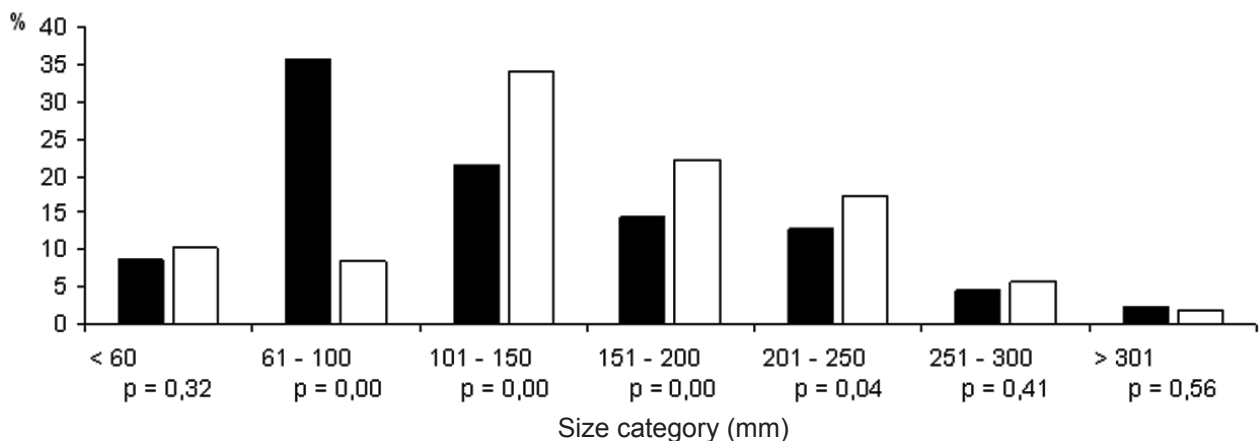

Fig. 3. The occurrence of fish (regardless the species) size categories in otter diet (■) and in the river environment (□).

of sculpin numbers in electrofishing data, or its preference by otters due to increased availability. The size class distribution of fish preyed by otters and the predominance of fish up to 150 mm is in accordance with findings of almost all authors who studied otter diet from spraints (e.g. Jenkins & Harper 1980, Mason & Macdonald 1986, Kruuk et al. 1993, Roche 2001). This phenomenon is thought to be related to the higher abundance and availability of small fish in the environment (Jurajda et al. 1996). Some authors mention that otters may take very small fish (< 50 mm) less frequently, as they are probably not too attractive as prey in terms of energy balance (Erlinge 1968, Kožená et al. 1992). Kruuk et al. (1993) found that otters take mostly fish in the 70–90 mm range, appearing to ignore the smaller fry, despite its very high abundance in the studied stream. However, Carss & Elston (1996) reported that small fish may be preyed upon in proportion to their availability but may not be identified in spraints due to the complete digestion of their hard parts. These authors carried out feeding trials with captive otters and found under-representation of first vertebrae of small fish (< 40 mm) in spraints. Also a proportion of bigger fish can be under-represented, as the bone remains of big fish are often missing in the spraints (Adámek et al. 2003).

Based on estimates of the minimum numbers of fish recovered from spraints, a relatively low percentage (12.5%) of atlases was found from bone remains of salmonid fish (brown trout and salmon) for distinguishing between species. Feeding trials with captive otters showed that proportion of ingested atlases recovered from spraints was only 44%, with recoveries varying between 30 and 77% in separate trials (Carss & Elston 1996). Their conclusions were based on an assumption that all spraints were collected from the enclosure. However, the proportion of collected spraints from the wild is unknown. Many spraints may be washed out after rain when water levels arise, many sprint sites are at rock-bound inaccessible places and large proportion of spraints may be deposited in the water (Kruuk 1992). The joint proportion of salmon and brown trout identified from salmonid bone remains in spraints was almost identical with the proportion of these two species in the fish community. The salmon percentage was slightly higher in otter diet than in fish community, being 33.3 and 25.3% respectively, but with respect to very low numbers of identified individuals, this conclusion must be considered with certain caution. A similar study carried out in the small Scottish stream, the Beltie Burn, revealed that young salmon were probably more vulnerable to otter predation than brown trout. Over the whole year, 17.7% of salmonids caught by otter were salmon and 82.3% trout, in comparison with 6.5% of salmon and 93.5% of trout present in the stream (Kruuk et al. 1993). Bremset & Heggenes (2001) report that despite general ecological similarities, juvenile salmon preferably occupy faster-flowing habitats at longer distances from the riverbank and seem to use mid-river areas to a greater extent than brown trout do. This behavioural pattern may also contribute to their higher vulnerability to otter predation in comparison with brown trout. Most of salmon preyed upon by otters were small individuals (61–100 mm). This phenomenon could be the result of lower anti-predation reaction of young fish in their first year of life. After release into the river, the sac fry are probably not threatened by otter predation due to their size and due to the fact that they hide in the substrate until the yolk sac is depleted. The size of fish taken by otters may vary during the year and a more detailed study would be needed to resolve the size distribution of preyed salmon more accurately.

With the successful reintroduction of salmon, it is now expected that adult fish will come back regularly for spawning into the Kamenice River and otter predation on adult individuals can also be expected. Carss et al. (1990) described seasonal predation on adult Atlantic salmon by otters during the spawning season on the Scottish River Dee and its tributaries, where particularly male fish were often found killed by otters. Males migrate up and down the stream much more than the females do and are therefore more available to otters, particularly when they cross shallow riffles.

As the majority of the adult salmon captured by otters were males, due to their higher availability during the spawning season, it was suggested that otter predation was unlikely to affect the breeding success of the Dee salmon population (Carss et al. 1990). Although otters take salmon – like other prey fishes – in relation to their availability and primarily abundance in the river, they are certainly significant predators of adult salmon under certain circumstances (Carss et al. 1990). This means that even under conditions of relatively low numbers of Atlantic salmon, otters may be able to prey upon them. Hence in the next few years of this reintroduction programme, as the numbers of returning adults have been low, otter predation may be an important potential source of salmon mortality and certain threat to the return success. However although a certain proportion of stocked juvenile salmon is

taken out by otters, it does not appear likely on the study reported here that otters will have a significant negative effect on the overall reintroduction process.

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