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Otter (*Lutra lutra*) predation on stocked brown trout (*Salmo trutta*) in two Danish lowland rivers

Jacobsen L. Otter (*Lutra lutra*) predation on stocked brown trout (*Salmo trutta*) in two Danish lowland rivers.
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Abstract – This study aimed to evaluate otter predation on stocked trout. Large hatchery-reared trout (16–30 cm) were stocked into two Danish rivers with different fish populations. Otter diet before and after trout stocking was determined by analysing 685 spraints, collected regularly during the 35-day study period. Fish composition in the rivers before stocking was assessed by electrofishing. In River Trend, a typical trout river, the proportion of trout in the otter diet increased from 8% before stocking to 33% a few days after stocking. Moreover, trout lengths in the diet changed significantly towards the lengths of stocked trout, indicating that newly stocked trout were preferred to wild trout. In River Skals, dominated by cyprinids, there was no change in otter diet after stocking of hatchery trout, i.e., these were ignored by otter. Otter predation should be taken into account together with fish and bird predation, when stocking is used as a measure for conserving endangered salmonid populations.

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Key words: diet preference; electrofishing; hatchery-reared trout; length distribution; management implication; spraint analysis

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Un resumen en español se incluye detrás del texto principal de este artículo.

Introduction

Predation is an important mortality factor for salmonid fishes (*Salmonidae*) in running waters (Alexander 1977). Piscivorous fish and birds can not only pose a considerable predation threat (e.g., Jepsen et al. 1998, 2000) but also mammals can contribute to predation on trout (*Salmo trutta* L.) and salmon (*S. salar* L.) (Alexander 1977; Heggenes & Borgstrøm 1988; Kruuk et al. 1993). The main fish-eating mammal in north European fresh waters is the European otter (*Lutra lutra* L.) in its area of distribution. Mink (*Mustela vison* Schreber) also feed upon fish, but to a smaller extent and of smaller sizes than otters (Wise et al. 1981; Dunstone 1993).

Otters are opportunistic feeders in that they feed upon whatever available prey (Mason & Macdonald 1986; Taastrøm & Jacobsen 1999). They show a preference for cyprinids and slower moving fish. But if available, they prey on brown trout and Atlantic salmon (Carss et al. 1990; Kruuk et al. 1993), although these might demand more energy to catch.

Danish rivers have been stocked with trout for almost a century (Larsen 1972; Rasmussen & Geertz-Hansen 1998). Enhancement of recreational fisheries was the purpose of the stockings. However, in recent years stocking has been increasingly used as a conservation tool, both to support native populations by stocking offspring of local wild fish and for the re-establishing of populations where the native populations have been extirpated (Rasmussen & Geertz-Hansen 1998). Stocking has typically been conducted with hatchery-reared trout at the fry stage or as 1-year-old fish. In addition, stocking with older trout, such as smolts (i.e., trout ready to metamorphose to anadromous trout) and larger 1–2-year-old trout (17–30 cm) has been conducted. The latter was mainly performed because of requests from anglers to stock almost legal-sized fish (Rasmussen & Geertz-Hansen 1998).

It has been demonstrated that the mortality of stocked hatchery-reared trout is higher than for wild trout (e.g., Bachman 1984; Berg & Jørgensen 1991). This difference is more distinct the longer the fish has remained in the hatchery, i.e., mortality increases for

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fish stocked at older life stages than fry (Näslund 1992). Thus, mortality of 1 and 2-year-old stocked trout (17–30 cm) is higher (Näslund 1992; Pedersen et al. 2003).

Differences in behaviour may explain differential mortality between wild and hatchery-reared trout. Hatchery-reared trout exhibit reduced ability to capture prey and to hold their feeding positions (Bachman 1984). In addition, anti-predator behaviour may be poorly developed in hatchery-reared fish (Maynard et al. 1995) and they have been shown to be more vulnerable to predation by birds (Eklöv & Greenberg 1998).

As yet, the predation risk to stocked fish from mammals has not been examined, this study estimates the vulnerability of newly stocked large-sized hatchery-reared trout to otter predation. This was achieved by comparing a trout river and a river dominated by coarse fish in order to incorporate the effect of preceding dietary habits. This study was carried out in the river Trend and the river Skals (Denmark). The present study comprises an estimation of otter diet before and after stocking of large hatchery-reared trout in the two rivers by means of spraint analysis. Otter diet was compared with the fish population, as assessed by electrofishing and change in otter diet was monitored at short time intervals for 5 weeks after stocking. I hypothesised that following releases of hatchery-reared trout, otters will change their prey preferences and disproportionately predate on the newly stocked trout, because they are easy to catch immediately after stocking.

Materials and methods

Study areas

River Trend

River Trend is situated in the northern part of Jutland, Denmark. The study section of the river represents a 7-km section in the lower reaches of the river, approximately 3 km above the mouth into the Limfiord. In the study area the river was partly regulated, but with some meandering sections. The river is 4.2–7.0 m wide and 0.5–2.0 m deep with variable speed of current. The substratum is mainly sand and silt, and more than 50% of the river bottom was covered by vegetation during summer, mainly *Sparghanium* spp. and *Elodea canadiensis*. The fish species consist of resident and anadromous brown trout, three-spined stickleback (*Gasterosteus aculeatus* L.), eel (*Anguilla anguilla* L.), flounder [*Platichthys flesus* (L.)], rainbow trout [*Oncorhynchus mykiss* (Walbaum)], and brook lamprey [*Lampetra planeri* (Bloch 1784)]. The riverbanks vary from overgrown with willow scrubs to open areas of cultivated fields. There is some angling activity in the area.

River Skals

Rivers Skals is situated in northern Jutland, approximately 30 km south of River Trend. The study area comprised 5.5 km of stream 50 km from the mouth. In this study area, the river is 7–12 m wide and 1–2 m deep with small pools along the turns. The river flows slowly with a uniform speed. The fish species were dominated by roach [*Rutilus rutilus* (L.)] and perch (*Perca fluviatilis* L.) with pike (*Esox lucius* L.), eel, gudgeon [*Gobio gobio* (L.)], three-spined stickleback, bream (*Abramis brama* L.), rudd [*Scardinius erythrophthalmus* (L.)], resident and anadromous brown trout and brook lamprey occurring as well. In the study area there is very little angling activity, compared with River Trend.

Stocking

Two size groups of hatchery-reared trout from Egebæk Fish Farm were transported to holding facilities. Total length (TL) and weight were measured and trout classified as ‘small’ or ‘large’. All trout were dye marked with alcian blue by a panjet inoculator, small trout on the left and large trout right side of the abdomen.

Trout were stocked in equal densities in the two rivers. In total 937 trout were stocked in River Skals and 483 trout in River Trend: On 7 October 1998, 470 ‘small’ trout [mean length 21.1 cm ± 1.4 (range 16–23.9), mean weight 94 g ± 17 (range 38–116)] and 449 ‘large’ trout [mean length 27.2 cm ± 0.9 (range 26–30.4), mean weight 202 g ± 20.5 (range 158–248)] were stocked in River Skals. On 8 October 1998, 240 ‘small’ trout [mean length 21.3 cm ± 1.3 (range 18.0–23.9), mean weight 97 g ± 17 (range 41–123) and 243 ‘large’ trout (mean length 27.6 cm ± 0.8 (range 26.5–30.4), mean weight 210 g ± 18 (range 162–245)] were stocked in River Trend. In both study sites all trout were stocked from a boat and distributed in homogenous densities along a 4-km stretch in the study section of the river.

On 11 and 12 November, four 500-m stretches in both stocking areas were electrofished to estimate the survival rate of previously stocked individuals. All recaptured fish were measured and weighed.

Population estimates of fish

Fish density and composition in the rivers were assessed by electrofishing in the study sites during the day before stocking.

In River Trend 10, 100-m stretches with 500-m intervals and one 500-m stretch of the river were electrofished from a boat by use of 4500 W generator. In River Skals eight 100-m stretches with 500-m intervals and one 500 m stretch were electrofished. All fish were identified, counted, measured (±0.5 cm) and released back to the water. In both study areas, two 100-m stretches were electrofished twice. Catch efficiency was estimated for each species separately and for two size groups of trout. For some species too few individuals were caught to estimate catch efficiency. This was carried out to estimate the total number of fish in the study areas using the catch depletion method according to Bohlin et al. (1989). Biomass of fish in the study areas was estimated from key length–weight relationships for eel (Rasmussen & Terkildsen 1979), stickleback (Wooton 1976), roach (Kleanthidis et al. 2000) and perch (Huusko 1990). For River Trend, trout equations were derived from length–weight measures from previous captures of wild trout (own data). The relative distribution of fish species, based on biomass, was calculated to compare it with the distribution of fish species in the otter diet. Trout length distributions were compared with trout length distributions estimated from otter diets.

Brown trout and rainbow trout were pooled (hereafter categorized as *trout*) as they were not distinguishable in the otter spraints. Instead, trout in the river were divided into groups ≤ or >40 cm because otters did not predate on trout >40 cm in the present study.

Otter diet

Otter spraints were collected in both study areas the day before trout stocking and on days 2, 5, 8, 14, 26 and 33 after stocking. During all samplings both banks were searched thoroughly in the study areas, including an approximately 0.7–1.5 km stretch (depending on accessibility) of the river before and after the stocking areas, likely to be visited by an otter. On day 14 after stocking, the banks of River Trend were flooded because of heavy rainfall, preventing spraint collection. Spraints were frozen and stored for later analysis.

In the laboratory, spraints were dissolved in a detergent solution for a week, and then washed through a 1-mm sieve and the remains analysed in a Petri dish containing water. Then the analysed spraints were dried and weighed.

Otter spraints contain the hard, indigestible remains of their prey. Fish remains were identified to species or family by use of vertebrae and scales and occasionally by use of jawbones or otholiths, accomplished by key literature (Webb 1976; Conroy et al. 1993). Remains of other prey such as frogs and mammals were identified from bones, hair or teeth. The importance of each prey item in one spraint was assessed using a bulk estimate, giving each item a score from 1 to 10 (Wise 1980). All bulks were multiplied by spraint dry weight and the bulk score was summed for each prey item in all spraints to give the final food composition. This method has been shown to provide accurate estimates of diet composition (Jacobsen & Hansen 1996).

In order to determine length distributions of trout in the otter diet, the length of all trout vertebrae in the spraints were measured using a digital slide calliper. These vertebrae lengths were back calculated to fork length (FL) of fish using the mean equations by Wise (1980) for either caudal or abdominal vertebrae. By use of minimum and maximum equations given by Wise (1980), each vertebra was assigned to a fish length interval. The lengths of fish represented in one spraint were assessed by pooling all vertebrae, which could possibly come from the same fish, i.e., that were assigned to overlapping fish length intervals and record these as one fish. This represents a minimum because two fish or more of the same length, appearing in one spraint, would be recorded as one (Carss & Elston 1996). However, this is preferred instead of scoring each vertebra as a separate fish. FL of trout in the diet was recalculated to TL using length relationships (Sigler 1951). All trout lengths were grouped in 3-cm intervals.

Statistics

Differences in diet composition before stocking and subsequent sampling dates were analysed by chi-square tests. For River Trend, the chi-square test was run on number of occurrence data in a 6×4 contingency table. All minor groups of prey (eel, other fish, mammals, birds, insects and unidentified) were pooled to avoid <5 numbers (Siegel & Castellan 1988). For River Skals the chi-square test was run on number of occurrence in a 5×2 contingency table, with sampling dates after stocking pooled. Minor groups of fish prey (eel and pike) were pooled and frogs were pooled with other prey items (mammals, birds and crustaceans).

Trout lengths in the otter diet in River Trend before stocking were compared with the five sampling dates after stocking (day 8 and 14 were pooled because of insufficient data on day 14) through Kolmogorov–Smirnov tests.

Trout length distributions in River Trend were compared with otter diet through Jacobs Index of Preference (*D*) (Jacobs 1974). This was applied to the proportions of fish of each length group. Jacobs Index varies from −1 to 1, with −1 being total avoidance, 1 being total preference and 0 being neutral. This index was estimated for the trout length distributions in River Trend before and after stocking. The two series of indices were tested (Sokal & Rohlf 1995) to determine trends in preferences, if any.

Results

River Trend

Fish populations

A total of 967 fish were caught by electrofishing 1500 m (7910 m^2) of the River Trend at the onset of the study period. Trout (brown trout and a few

Table 1. Fish population of River Trend.

	Trout				
	≤40 cm	>40 cm	Sticklebacks	Eel	Flounder
Number of fish caught	635	13	300	18	1
Catch efficiency *p*	0.86–0.90	0.86	0.63	–	–
Estimated biomass in the area (kg)	266.4	65.9	1.76	6.16	
Fish biomass before stocking (%)	78.3	19.4	0.5	1.8	
Stocking of trout (kg)	74.4				
Fish biomass after stocking (%)	82.2	15.9	0.4	1.5	

Biomass in the study area was estimated by electrofishing, incorporating catch efficiency factors. All salmonid fishes (brown trout and rainbow trout) were pooled as trout (see Materials and methods).

rainbow trout) were the dominating fish (Table 1). Trout represented 97.7% of the estimated fish biomass, with 78.2% of trout ≤40 cm and 19.4% of trout >40 cm. Other fish species, eel, stickleback and one individual of flounder only represented 2.3% of the biomass, but 31% in numbers (mainly sticklebacks) (Table 1).

The stocking of 483 trout, in total 74.4 kg, increased the total biomass of trout ≤40 cm by 28%, but made only minor changes in the per cent of trout compared with other fish species. Hence, trout ≤40 cm then represented 82.2% of the fish biomass (Table 1).

Otter diet

A total of 365 spraints were analysed from River Trend: 108 spraints before stocking and 248 spraints after stocking. The number of spraints varied during the sampling period (Table 2). Before trout stocking, the otter consumed a variety of food items with a large proportion made up by sticklebacks (65%). Frogs represented 16% and trout only 8% of the food composition. There was a significant change in diet composition during the study period ($\chi^2 = 46.8$; $P < 0.001$). There was only a slight, nonsignificant increase in the proportion of trout in the diet 2 days after stocking (Table 2). Five days after stocking, the proportion of trout in the diet had increased significantly along with a significant decrease in stickleback ($\chi^2 = 19.1$; $P < 0.001$). This increase remained for the rest of the study period. The proportion of frogs in the diet also varied; a significant increase in the proportion of frogs compared with trout and stickleback occurred on the third sampling date after stocking ($\chi^2 = 4.25$, $P < 0.05$) (Table 2).

Proportions and lengths of trout in the diet before and after stocking

Comparing the proportion of fish species in the river with the proportion in the otter diet (Fig. 1) revealed that the otter retained a preference for sticklebacks, however, the preference for trout increased and trout constituted a mean of 48.6% of the fish in the diet (33.3% of the total diet) after stocking (Fig. 1).

Length frequency distributions of trout before and after stocking were based on measurement of 553 vertebrae. The length distribution before stocking is shown in Fig. 2a along with the length distribution of trout remains in the otter diet, as estimated from the spraints. 1+ trout, especially the group of 9–12 cm fish, dominated trout numbers in the river, followed by 21–24 cm trout. Occasionally, trout >42 cm also occurred in the river but are not shown in the figure. The otter preferred 9–18 cm trout that constituted 63% of diet trout (Fig. 2a).

Stocking of 483 hatchery trout into the river increased the number of trout by 7.9%. This did not change trout length distribution in the river; the increase was distributed with 0.6–3.5% among each of the length groups 18–21, 21–24, 24–27 and 27–30 cm (Fig. 2b).

The trout length distributions in the otter diet changed significantly after stocking (Kolmogorov–Smirnov: DN = 0.31, $P < 0.01$), towards most trout being preyed upon in the 15–27 cm length groups, with 18–24 cm trout being most represented in the diet (Fig. 2b). Fewer 9–15 cm trout were preyed upon. Jacobs index (Fig. 3) changed significantly after stocking (runs test; $N = 12$, $P = 0.01$) and revealed a large increase in the preference of 18–21 cm trout

Table 2. The proportion of prey items (%) in otter diet in River Trend.

Day	*n*	Trout	Stickleback	Eel	Other fish	Frog	Mammal	Insect	Unident.
Before stocking	108	8.4	64.8	4.4	0.5	16.2	5.3	0.1	0.3
Day 2	34	14.5	57.9		1.3	26.3			
Day 5	58	49.9	16.6	3.6		30.0			
Day 8	39	28.9	21.5	5.1	5.3	39.3			
Day 14	3								
Day 26	64	43.6	31.8	0.1	0.01	22.0		2.3	0.3
Day 33	50	21.9	24.8	9.2		31.4	12.7		

Before stocking, the diet composition before trout stocking, followed by the diet on the subsequent sampling dates. Other fish were rare occurrences of northern pike (*Esox lucius*), cyprinids (*Cyprinidae*) and percids (*Percidae*); unident., unidentified items refer to unknown fish bones; *N*, number of spraints. On day 14 the number of collected spraints ($n = 3$) was too low because of flooding.

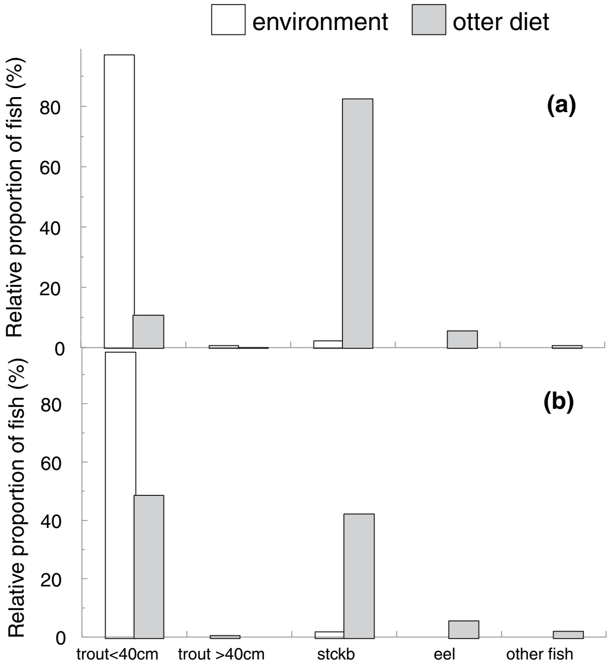

Fig. 1. River Trend. The relative proportion of fish species in otter diet and in the environment, estimated by electrofishing. (a) Before stocking and (b) after stocking. ☐ Fish in the river; ▩ fish in the otter diet. *Stckb*, stickleback. Other fish were pike, cyprinids and percids.

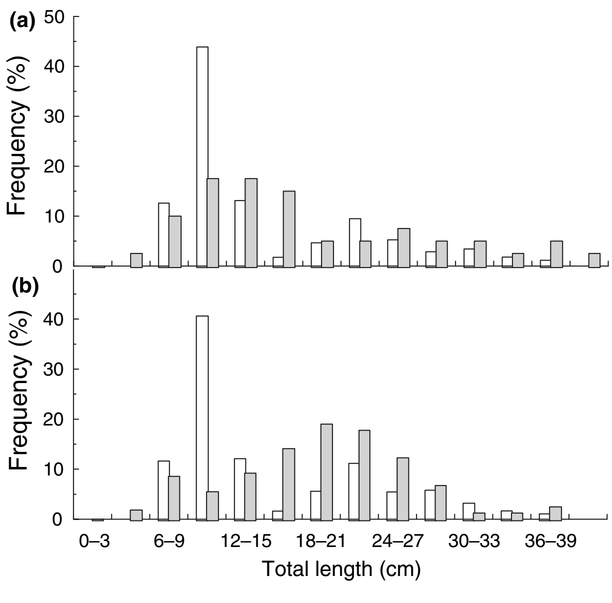

Fig. 2. Trout length distribution in River Trend and in the otter diet, before (a) and after (b) stocking of trout. ☐ Trout in the river; ▩ trout in the otter diet.

(from $D = 0.05$ to 0.46), 21–24 cm trout (from $D = -0.31$ to 0.29) and 24–27 cm trout (from $D = 0.19$ to 0.56). No shift in the 15–18 cm length group was noted, but in the of 12–15 cm group a shift from positive to negative preference was noted (from $D = 0.17$ to -0.38).

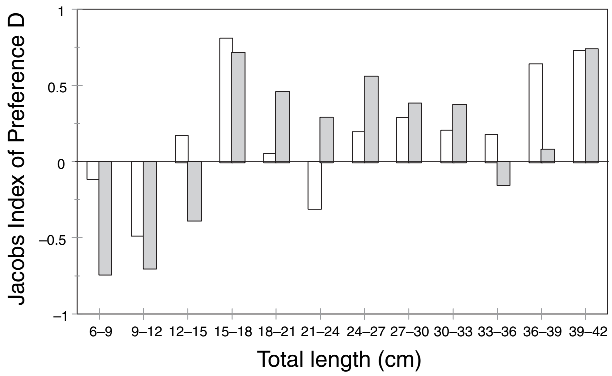

Fig. 3. Preferences of trout lengths before and after stocking River Trend. Jacobs Index of Preference (*D*) is described in Materials and methods. ☐ Before stocking; ▩ after stocking.

The trout length distribution in the otter's diet on each sampling date after stocking changed significantly from before stocking to the second sampling date (day 5) (DN $= 0.37$, $P < 0.01$). This represents a change towards the length groups of stocked trout (Fig. 4). Some variation appeared during the sampling period, but still 26 days after stocking the lengths of consumed trout were significantly larger than those before stocking (DN $= 0.36$, $P < 0.01$; Fig. 4).

Survival of stocked trout

Five weeks after stocking (after the sampling period ended) 278 stocked trout were estimated from electrofishing to remain in the stocking area. Most fish had disappeared from the 24–30 cm length group (an estimated number of 131 individuals). Seventy-four trout were missing in the 18–24 cm length group.

River Skals

Fish population

In the beginning of the study period a total of 1872 fish were caught by electrofishing 1300 m (8615 m^2) of River Skals. Cyprinids (mainly roach plus a few rudd, gudgeon and bream) were the dominating group by number and constituted 40.9% of the estimated biomass, whereas perch constituted 36.4% of the biomass (Table 3). Catch efficiency was quite low for cyprinids and perch (Table 3). Trout only represented 1.1% of the biomass (Table 3). The stocking of 929 trout, in total 135.0 kg, changed the relative fish composition, and increased trout biomass from 1.1 to 34.9% (Table 3).

Otter diet

A total of 307 spraints were analysed: 65 spraints before stocking and 242 spraints after stocking. Numbers of spraints varied during the sampling period (Table 4). Before trout stocking the otter consumed a variety of food items with a main constitution by cyprinids (67%).

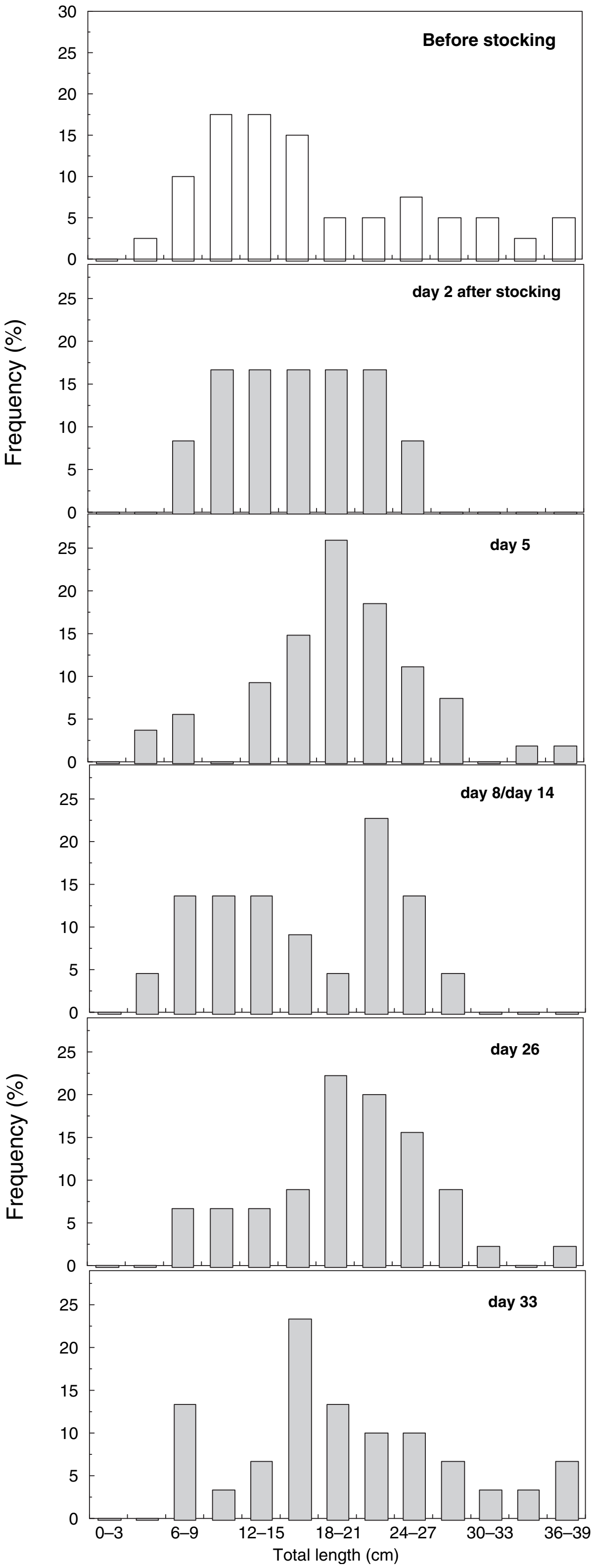

Fig. 4. River Trend. The length distribution of trout in the otter diet before stocking (☐) and on subsequent sampling dates (■). Days 8 and 14 are pooled because of low numbers of estimated trout in the diet on day 14.

There were only small variations in diet after stocking, cyprinids continued to be the main prey item (67–99%), whereas perch and sticklebacks decreased in the diet. Occasionally, frogs were a major item as well. There was a significant difference in diet composition before and after stocking based on number of occurrences ($\chi^2 = 66.21$; d.f. = 5; $P < 0.001$), but there was no significant difference in trout proportion ($\chi^2 = 1.00$; d.f. = 1; $P = 0.32$), and trout seldom appeared in the diet after stocking (Table 4).

Comparing the proportion of fish in the river with the proportion of fish in the otter diet (Tables 3 and 4) revealed a preference by otters for cyprinids and a negative preference for percids both before and after stocking. The increased proportion of trout in the river after stocking was not reflected in the diet, suggesting a negative selection for stocked trout.

Survival of stocked trout

Five weeks after stocking, 238 (26%) of the stocked trout remained in the study area in River Skals, as estimated from electrofishing. Similar numbers of trout were left from both groups: 130 individuals were left from the 24–30 cm length group, and 108 fish were left in the smaller group (18–24 cm).

A simultaneous study of the fate of the stocked trout in this river by use of radio tracking, revealed that 35 of 50 radio tagged trout left the study area during the study period, mainly because of downstream migration (K. Aarestrup, unpublished data).

Discussion

Predation by otter and mink on wild salmonid populations has been previously assessed: otters have been shown to prey upon Atlantic salmon in Scottish rivers during the spawning season (Carss et al. 1990). This study concluded that otter predation did not contribute significantly to the mortality of adult salmon in autumn/winter. Kruuk et al. (1993) found that otters in Scottish rivers may consume up to 60% of the annual production of juvenile salmon and trout. Heggenes & Borgstrøm (1988) assessed the effect of mink predation on trout and salmon parr in Norwegian rivers, and found a strong correspondence between declines in trout/salmon density as well as injured fish and the presence of mink. Recently, otters have been shown to feed on trout farms and on trout in rivers with stocking (Ludwig et al. 2002). So far, no studies have explicitly focused on predation impact by otters on stocked hatchery-reared salmonids.

Composition of otter diet

The two study areas represented different otter habitats, River Trend being a typical trout river and River

Table 3. Fish population of River Skals.

	Trout ≤40 cm	>40 cm	Cyprinids	Perch	Pike	Eel	Stickleback
Number of fish caught	3	5	1536	269	19	16	24
Catch efficiency p	–	–	0.49	0.33	–	–	–
Estimated biomass in the area (kg)	2.75	21.54	106.4	94.5	28.97	5.82	0.054
Fish biomass before stocking (%)	1.1	8.3	40.9	36.4	11.1	2.2	0.02
Stocking of trout total (kg)	134.98						
Fish biomass after stocking (%)	34.85	5.45	26.93	23.94	7.33	1.47	0.01

Biomass in the study area was estimated by electrofishing, incorporating catch efficiency factors. Brown trout, sea trout, and rainbow trout were pooled as trout (see Materials and methods), all cyprinids (mainly roach, and a few rudd, gudgeon and bream) were pooled as well.

Table 4. The proportion of prey (%) in otter diet in River Skals.

Day	n	Cyprinids	Perch	Stickleback	Eel	Pike	Trout	Frog	Mammal	Bird	Crustacean
Before stocking	65	66.7	7.4	5.2	1.2		0.9	7.5		11.1	
Day 2	43	78.6	8.7	0.7	7.7		0.1				1.4
Day 5	38	95.6	1.4	0.3	1.1			1.1	0.4		
Day 8	29	69.9		0.8	7.4			21.9			
Day 14	23	66.2		0.3				32.7	0.9		
Day 26	54	99.3	0.2	0.02				0.5			
Day 33	55	67.3			6.0	15.3	5.5	5.9			

Before stocking, the diet composition before trout stocking, followed by the diet on the subsequent sampling dates; n, number of spraints.

Skals with a cyprinid-perch dominated fish assemblage typical of slow flowing rivers.

In River Trend, the diet resembled the diet reported for other areas where brown trout was present (reviewed in Mason & Macdonald 1986 and Kruuk 1995), including the Danish River Karup, where sticklebacks also contributed a substantial amount to the diet (Taastrøm & Jacobsen 1999). There was an evident preference for sticklebacks before stocking, when the diet was compared with the fish composition in the river.

Trout is a fast swimming fish, and otters should spend more energy to capture them compared with other species. Therefore, otters are often seen to show negative preferences for trout, if alternative prey resources are present (Erlinge 1968).

Preponderance for sticklebacks and accordingly less preference for trout could be the result of bias from methodological problems in spraint analysis, overestimating sticklebacks and underestimating trout (see Mason & Macdonald 1986; Carss & Parkinson 1996; Jacobsen & Hansen 1996). Moreover, the number of sticklebacks in the river might have been underestimated from electrofishing. Hence, the preference for sticklebacks in River Trend is believed to be somewhat overestimated, and the trout proportion concomitantly underestimated. Nevertheless, the results might show similar bias before and after stocking.

In River Skals the preference for cyprinids compared with percids, resembled otter diet in rivers and lake-habitats in northern Europe (Mason & Macdonald 1986; Taastrøm & Jacobsen 1999). Cyprinids are also preferred over the spiny-rayed percids by other piscivores, e.g., pike (Eklöv & Hamrin 1989), as they are easier to swallow.

Predation on stocked trout

In River Trend, the proportion of trout in the otters diet increased after trout stocking. The increase was not apparent in the first but on the second sampling, i.e., in the spraints defecated on the third or fourth night after stocking. Trout can pass through otter guts in 1–5 h depending on activity level (Carss et al. 1998), so trout remains will occur in spraints the following day. Thus, it seems that the otter started exploring this new resource after a few days, supposedly having discovered the possibility of easier available prey. There was some variation in the diet composition after stocking, but the increment in the proportion of trout persisted to the end of the study period.

Before stocking the otter took most trout in the length interval 9–18 cm and avoided smaller trout between 3–9 cm in correspondence with previous found size preferences (e.g., Kyne et al. 1989; Taastrøm & Jacobsen 1999).

Concurrently, with the increase in trout proportion in the otter diet there was a significant shift in length distribution in the diet. There was clearly not only a disproportional raise in the otter intake of trout in the stocked trout length groups, especially the smaller trout of 18–24 cm, but also an increase in preference of the 24–30 cm trout. Thus, the otter increased the consumption of the length groups representing the stocked fish to a significantly larger extent than could be explained by the overall increase of fish in these length groups because of stocking.

This sudden change in size preference, simultaneously with the significant increase in proportion of trout in the diet compared with other prey items, suggests that the increased consumption of trout was caused mainly by the newly stocked trout. The fact that otters took larger fish than they usually prefer, emphasize the vulnerability of the stocked trout, especially the 18–24 cm group.

The use of vertebrae to back calculate fish length in dietary studies has been disputed as the equations are subject to some error because of the large variation in vertebrae along the column. Carss & Elston (1996) showed trout length (12.5 and 21.3 cm) to be underestimated by 9–16% (i.e., 2–3 cm) by use of vertebrae-fish length equations by Wise (1980). Jacobsen & Hansen (1996) also showed some deviations for trout. Some authors (Feltham & Marquiss 1989; Carss & Elston 1996) have recommended to use the atlas vertebrae of salmonids, these provide better correlation. However, this method depends on the appearance of this single key bone in the spraint. In the present study, there were very few occurrences of atlas vertebrae, so it was decided to use all vertebrae, despite the uncertainties. Considering the reported underestimation by Carss & Elston (1996), the group of 18–21 cm fish should be converted to 21–24 cm fish and so forth, resulting in an even higher proportion of the stocked fish length groups appearing in the diet after stocking, but now with a higher proportion of 'larger trout' in the diet (see Fig. 2b). Thus, this methodological bias does not seem to interfere with the interpretation of the results.

In River Skals there seemed to be almost no otter predation on the newly stocked trout. Although trout stocking increased fish biomass in the study area, otters continued feeding on cyprinids and percids. Hence, the assertion that otters prefer cyprinids over salmonids (Erlinge 1968) seemed to include hatchery reared trout. Plausibly, otters, which are inexperienced with trout predation, are unlikely to change to this food source despite the conspicuous behaviour of hatchery trout, if there are sufficient alternative food resources. Other parameters such as water turbidity and river morphology varied between the two rivers and this may influence the predatory behaviour of otters as well.

Fate of the stocked trout

After 5 weeks, 74% trout were estimated to have disappeared from the study area in River Skals. This was mainly the result of downstream migration, according to a radio telemetry study, that was carried out at the same time, to evaluate the fate of the stocked trout. Seventy per cent (35 of 50) of the radio tagged trout left the area during the study period, and were recorded passing on automatic listening stations located above and below the study area. The downstream migration was not recorded until 9 days after stocking, but after 2 weeks half of the radio tagged trout had left the study area. Thus, the fact that otters did not prey on these stocked trout could not be the result of immediate trout migration out of the study site. Although there was no or very little predation on stocked trout, some trout might have been eaten by otters further down the stream. Two of the 50 radio tagged trout, migrating downstream, were probably preyed upon by otters, as the transmitters were found with chewing marks left, on the banks.

In River Trend, 42% of the stocked trout had disappeared from the study area, corresponding to the low survival found in a previous study in this river (Pedersen et al. 2003). This is not likely to be explained by downstream migration as in River Skals because a previous radio telemetry study in River Trend had shown that only 8% (four of 50) of radio tagged newly stocked trout moved out of the area during 5 weeks (Aarestrup et al. in press). Instead, it is made obvious, that in this river, mammal predation is one of the operating mortality factors. This confirms that otters were responsible for a large number of radio transmitters with carnivore chewing marks, which were left on the River Trend banks, in the radio telemetry study by Aarestrup et al. (in press). Thus, the hypothesis that hatchery reared trout, stocked in natural rivers, are more vulnerable to predation than wild trout, not only from fish and birds, but also from mammals, seemed to be confirmed.

The fact that relatively more fish from the larger group 25–30 cm had disappeared, is inconsistent with the otters preying upon most 18–24 cm trout. This could partly be the result of underestimation of trout length in otter spraints (see Materials and methods). However, it is also consistent with the general lower survival of 'larger' trout compared with 'smaller' stocked trout, found by Pedersen et al. (2003), and further indicates that other mortality factors or migratory behaviour is more important with the larger size group of stocked trout.

Conclusions

In conclusion, the present study shows that otters can be important predators on newly stocked trout. It became obvious that the food regime of otters in the local area of stocking might be determinant of the levels of otter predation on stocked trout. Thus, hatchery reared trout stocked in rivers with sufficient amounts of other fish species, preferred by otters, were not as vulnerable to otter predation, as those stocked in a typical trout river. Nevertheless, most compensatory stockings are carried out in rivers that already hold a trout population.

The results from River Trend showed some implications for the use of stocking in management and conservation of salmonid fishes. First, in conservation programmes for endangered salmonid fishes it is important to recognize the increased mortality, including mammal predation, of stocked fish that have become adapted to hatchery environments. This mortality is lower for trout, stocked at younger life stages (Näslund 1992). However, otter predation might still be considerable, if younger trout of 9–15 cm sizes are used in stocking programmes, because this is in general the preferred fish size for otters (Mason & Macdonald 1986). Otter predation on stocked trout fry and yearlings warrant further research. Secondly, the fact that otters are the most endangered mammals in temperate Europe and hence protected in most of Europe may complicate management in areas where stocking of large hatchery reared trout is an option. A critical assessment of stocking activities in areas inhabited by otters would therefore be beneficial not only to the populations of salmonid fishes, but also to otters, because potential conflicts of interests between otter conservation and conservation and enhancement of salmonid populations could be avoided.

Resumen

1. La predación puede ser un factor importante de mortalidad en salmónidos de río. La mortalidad inducida por predación ha mostrado ser mayor en truchas de repoblación criadas en piscifactoría que en truchas naturales debido a un menor ajuste al sistema natural. Esta diferencia se hace mayor cuanto más tiempo hayan permanecido las truchas en piscifactoría. Este estudio tiene como fin evaluar la predación de las nutrias (*Lutra lutra* L.) sobre ejemplares de repoblación de trucha *Salmo trutta* L. criadas en piscifactoría, sobre la hipótesis de que, tras la repoblación, las nutrias cambian la preferencia dietética para predar desproporcionadamente sobre las nuevas truchas en el río.

2. Trucha criadas en piscifactoría de tamaños comprendidos entre 16 y 30 cm. de longitud fueron repobladas en dos ríos daneses con diferentes poblaciones de peces. La dieta de las nutrias fue estudiada antes y después de la repoblación sobre análisis de 685 excrementos colectados regularmente durante un período de 35 días. Antes de la repoblación también determinamos la composición de la fauna de peces en los dos ríos con pesca eléctrica.

3. En el Río Trend, un río típicamente truchero (Tabla 1), la proporción de truchas en la dieta de las nutrias aumentó de un 8% antes de la repoblación hasta un 33%, unos pocos días después de la repoblación (Tabla 2). Además, las longitudes de las truchas en la dieta cambiaron significativamente hacia los grupos de tamaño de las truchas repobladas, lo que indica que las truchas repobladas fueron preferidas sobre las truchas del río (Fig. 2). Este cambio también ocurrió unos días después de la repoblación indicando que a las nutrias las llevó varios días descubrir la presencia de este nuevo recurso disponible de presas (Fig. 4). En el Río Skals, dominado por ciprínidos (Tabla 3), no aparecieron cambios en la dieta de las nutrias después de la repoblación lo que supone que éstas fueron ignoradas por las nutrias (Tabla 4). Concluimos en que el régimen alimenticio de las nutrias a escala local puede ser determinante de los niveles de predación de las nutrias sobre las truchas repobladas.

4. El efecto de la predación sobre truchas de gran tamaño criadas en piscifactoría no ha sido previamente documentado para las nutrias. Sin embargo, la predación de las nutrias debería ser considerada junto a la predación por peces piscívoros y por aves cuando las repoblaciones se utilicen como medida para conservar populaciones de salmónidos en peligro. Una evaluación crítica de las actividades de repoblación en áreas habitadas por nutrias seria beneficioso para evitar conflictos de interés potenciales entre la conservación de las nutrias y la mejora de las poblaciones de salmónidos.

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