

Bird predation on hatchery reared Atlantic salmon smolts, *Salmo salar* L., released in the River Eira, Norway.

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Carlin-tagged Atlantic salmon smolts have been released in the River Eira in western Norway during the period 1961—1980. Just after release birds were observed as smolt predators. Each year the river bank was searched for tags and pellets containing tags. This recovery rate varied between 0.0—10.8% in a total of 46 smolt releases during 20 years. Predation of smolts was positively correlated with the water discharge in the river, and negatively correlated with the recapture rate of adult salmon, accounting for 14% of the variation in adult recapture rates.

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INTRODUCTION

Migrating smolts of Atlantic salmon *Salmo salar* L. are exposed to many predators. In rivers and estuaries several species of birds, mammals and fishes are potential predators. Some authors have studied the relationship between juvenile salmonids and mergansers *Mergus* spp. in rivers and lakes (Huntsman 1941, Lindroth 1955, White 1957, Elson 1962, Mills 1962, Moen 1983). Mace (1983) and Ruggerone (1986) have estimated bird predation on juvenile Pacific salmonids in some North American rivers. However, data on predation by birds and mammals on migrating Atlantic salmon smolts are almost unknown.

Hatchery reared smolts are released in many rivers in Norway, and they are subject to heavy mortality (Hansen 1983). In order to improve survival of released smolts it is important to recognize the predators involved and estimate their significance on adult return rate. In River Eira it has been observed that birds, and especially gulls *Larus* spp., prey on released salmon smolts. In this paper we analyse bird predation on Carlin-tagged salmon smolts released in this river.

MATERIAL AND METHODS

River Eira runs out in Romsdalsfjord, western Norway. The river system is heavily re-

gulated and about 70% of its catchment area is transferred to neighbouring rivers. The salmon stock consists of grilse, 2 and 3 sea-winter-fish and the annual reported catch varies between 200 and 1000 kgs.

Compensatory releases of salmon smolts have been carried out since 1961. Tagged smolts were released in River Eira during the period 1961—1980 (Table 1). A total of 46 batches of smolts were released, 27 in the river and 19 in the estuary. The same areas of the riverbanks and estuary were searched by local people each summer for Carlin-tags and pellets containing tags. A reward of Nkr 20, was paid for each tag recovered.

We regarded the tags recovered as smolts preyed upon mainly by birds, but also by mammals, and this predation was analysed in relation to water flow, mean length of stocked smolts and recapture rate of adult salmon. Recaptures of tagged adult salmon were reported by fishermen, and recapture rates were expressed in % of number of smolts released in each group.

RESULTS

The recovery of Carlin-tags reported from birds/mammals of 46 smolt releases during 20 years varied between 0.0—10.8% (Table 1). In most cases the recovery rates were below 4.0%. The bird/mammal predation ex-

Table 1. Carlin-tagged smolts released in the River Eira. R = released in river, E = released in estuary.

Date		Number released	Length (cm)		% recovered
			Mean	Min.- max.	from birds/ mammals
1961.04.27.	R	699	14.9	13 - 19	2.43
1961.05.19.	R	700	15.4	13 - 22	0.71
1961.06.07.	R	700	15.8	13 - 20	1.43
1962.04.12.	R	1000	14.9	14 - 25	0.70
1962.05.08.	R	1000	15.0	14 - 25	0.80
1962.06.06.	R	1000	14.6	14 - 18	0.60
1963.04.25.	R	1000	13.9	13 - 18	1.00
1963.05.22.	R	999	13.7	13 - 18	1.40
1963.06.12.	R	995	14.2	13 - 18	0.30
1964.04.30.	R	997	14.1	13 - 18	0.30
1964.05.21.	R	1000	14.9	13 - 21	1.80
1964.06.10.	R	997	16.1	14 - 19	1.50
1965.05.15.	R	1000	15.9	13 - 26	0.80
1966.05.06.	R	1000	15.7	13 - 26	1.50
1966.06.08.	R	999	17.1	13 - 28	2.30
1967.05.08.	R	2000	19.5	13 - 30	0.70
1968.05.14.	R	2000	17.9	14 - 29	2.00
1969.05.06.	R	1000	16.6	14 - 27	0.20
1969.05.22.	R	1000	16.9	14 - 26	0.00
1970.05.05.	R	2000	16.0	14 - 30	3.10
1971.05.29.	R	1989	15.5	12 - 19	3.82
1972.05.15.	R	1000	15.0	14 - 17	0.30
1973.05.22.	R	1000	15.5	14 - 21	0.20
1974.04.25.	R	1000	20.1	14 - 29	0.10
1974.05.20.	R	1000	20.0	14 - 27	0.30
1975.05.22.	R	990	16.4	13 - 26	3.13
1976.06.02.	R	1955	15.4	13 - 23	10.03
1976.06.02.	E	1981	15.3	13 - 21	9.09
1976.06.02.	E	962	15.6	13 - 21	10.81
1977.05.31.	E	1969	15.2	13 - 24	3.30
1977.05.31.	E	970	15.6	13 - 24	0.00
1977.05.31.	E	956	15.1	13 - 24	0.00
1977.06.15.	E	941	14.6	13 - 21	0.52
1977.06.29.	E	957	15.3	13 - 26	0.00
1978.05.31.	E	1972	16.0	14 - 23	1.06
1978.05.31.	E	985	15.1	14 - 24	0.41
1978.05.31.	E	990	14.9	14 - 20	0.61
1978.06.28.	E	931	15.0	14 - 21	0.21
1978.06.28.	E	975	15.3	14 - 25	0.31
1979.05.29.	E	998	16.8	14 - 25	0.40
1979.05.29.	E	995	16.6	14 - 24	0.40
1979.05.29.	E	997	15.8	24 - 27	0.90
1979.06.13.	E	996	16.7	14 - 25	1.31
1980.06.02.	E	996	14.9	13 - 20	4.65
1980.06.02.	E	998	14.8	13 - 20	3.95
1980.06.02.	E	993	14.7	13 - 20	3.63

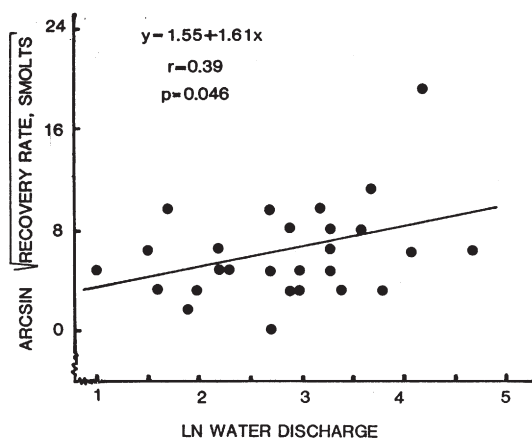


Fig. 1. Relation between water flow the first day after smolt release and tag recovery rate from birds/mammals. Only releases in the river are considered. N = 27 cases.

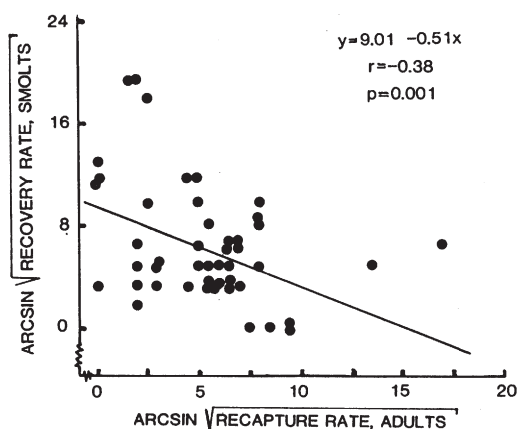


Fig. 2. Relation between recovery rate of Carlin tags reported from birds/mammals and recapture rate of adult salmon.

pressed by recovery rates of smolt tags, from river releases only, was positively correlated with the water discharge in the river ($r = 0.39$, $p = 0.046$, Fig. 1). This was also the case for the smolts released in the estuary ($r = 0.70$, $p = 0.001$, Table 2).

There was no relationship between average size of the released smolts and tag recovery rate from birds/mammals ($p > 0.05$, Table 2). There was a negative correlation between tag recovery rate from birds/mammals and recapture rate of adults ($r = -0.38$, $p = 0.001$). The recorded recovery rate thus accounts for 14% of the variation in adult recapture rates (Fig. 2).

DISCUSSION

Predation on hatchery reared salmon smolts by birds, and to a lesser extent, by mammals is of significant importance in River Eira and

Table 2. Correlation between recovery rates of tags from birds/mammals and water flow the first day after release, mean size of the released smolts and recapture rate of adult salmon. * = $p < 0.05$.

	Waterflow	Mean smolt length	Recapture of adult salmon
River releases	0.39*	-0.17	-0.12
Estuary releases	0.70*	-0.14	-0.68*
All releases	0.36*	-0.14	-0.38*

its estuary. Hatchery reared smolts start their migration immediately after release (Hansen & Jonsson 1985) and are therefore vulnerable to such predation for a short period.

Bird predators regurgitate the indigestible and hard parts of the food in pellets (Brown et al. 1985) and this occurs mainly at the birds' resting places, nests and foraging sites (Bang & Dahlström 1973). Mammal predators drop the indigestible parts in the food as excrements on special places in their territory (e.g. Brown et al. 1985). Carlin-tags found along the riverside and in the estuary might originate from bird pellets regurgitated on land, mammal excrements dropped on land, or tags, pellets and excrements washed ashore after deposition above or in the water. The present data are underestimates of predation rates as most of the bird pellets regurgitated in water or in high vegetation, and the mammal excrements placed outside the riverside and estuary, probably are not found.

Two species of mammals are potential predators on smolts in River Eira, otter *Lutra lutra* and American mink *Mustela vison*. We believe that the predation from these mammals is small. In general there are few data on mammal predation on salmon smolts available (Ruggles 1980). Among potential smolt predatory birds present in the area, mergansers *Mergus merganser* and *M. serra-tor*, Grey Heron *Ardea cinerea* and several species of gulls *Larus* spp. are suggested to be the most important. In the River Surna, north-

east of River Eira, the fishing activity on hatchery-reared salmon smolts was highest by Common Gull *Larus canus*, in addition the mergansers preyed on many smolts (Reitan unpubl.).

These species are probably the most important predators in River Eira too. Common Gull regurgitate pellets mainly at special places as e.g. resting sites, and the pellets are easy to find. Most of the tags found at River Eira are assumed to be from smolts preyed upon by this species.

In rivers with generally higher water flow, e.g. River Surna, predation seems to be highest at low water flows (Reitan unpubl.), which contradicts the results in the present study. At low water discharges in River Eira the water is drained through the main river, which is deep. In the lower parts of the river there are large areas which are overflowed by freshwater at high water discharges. Thus, the smolts may be more vulnerable to bird predation in these shallow areas.

Bird predation was not correlated with mean smolt size. However, these data do not disprove that birds select small smolts or feed on low quality smolts. Bird predation on smolts is influenced by the activity of both smolts and birds. For example, birds are more effective predators during daylight (Ruggerone 1986). In addition, bird activity along rivers and estuaries is dependent on bird activity on the surrounding cultivated land (Reitan unpubl.).

Atlantic salmon are subject to high predation both by birds and freshwater and marine fish species. Hvidsten & Møkkelgjerd (1987) estimated that 24.8% of Carlin-tagged hatchery reared smolts released in River Surna were preyed upon by cod *Gadus morhua* within the first week after release.

In the present study, bird predation explained 14% of the variation in adult recapture rate. Significant improvements in adult returns of salmon could therefore be obtained by release of smolts when environmental factors are optimal to the fish, and when the risk of predation is small.

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