

Restocking the River Akerselv, Oslo with Atlantic salmon smolts *Salmo salar* L. of different stocks

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Sea ranched hatchery-reared smolts of Atlantic salmon originating from the Rivers Imsa and Lone in Norway and Neva in USSR were released in the River Akerselv, in 1985 and 1987. Both 1+ and 2+ smolts were released into the river which had been empty of fish due to heavy pollution from the middle of the 19th century to the beginning of the 1980ies. The Norwegian salmon migrated to sea and left the Oslofjord shortly after release. The Neva salmon, on the other hand, stayed in the Oslofjord during the summer after release, and many turned up as maturing adults the first autumn after release. Few recaptures were made the following summer as grilse. The reported recapture-rate varied between 7.1 and 19.1% of the number of smolts released. Few fish strayed to other rivers; those that did entered nearby rivers. Mean weight of grilse produced from 2+ smolts, reflecting differences in size at release. Reported yields per 1000 smolts released varied between 77.5 and 138.4 kg, it was lowest for 2+ Lone smolts and highest for 2+ Neva smolts. These figures are gross underestimates when taking tagging and handling mortality and non-reported tags into consideration.

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INTRODUCTION

The River Akerselv in Oslo, the capital city of Norway, has been heavily polluted for more than 100 years. This resulted in a complete loss of all fish species, except for a small area in the uppermost river. In recent years, however, the water quality has been significantly improved, and the diversity of the freshwater fauna has increased in the lowermost reaches (Brittain & Saltveit 1985). However, episodic pollution by the industry along the river, have caused fish kill (Brittain & Saltveit 1988).

The first attempt to reintroduce Atlantic salmon (*Salmo salar* L.) to the river took place in 1981, when two groups of smolts were released (Hansen 1986). The first adult fish returned in 1982, and the result of the first experiment was promising. Therefore these releases were followed up by new experiments in 1984 (Hansen 1986), 1985 and 1987.

This paper summarizes migration, growth and yields of smolts released in 1985 and 1987, and discusses smolt releases as a possible method to introduce Atlantic salmon into habitats where the local salmon population has been extinct for a long time.

STUDY AREA

The River Akerselv (catchment area ≈ 250 km²) runs out of the Lake Maridalsvann, which is a main reservoir for drinking water in Oslo, and empties into the Oslofjord. From the outlet of the lake to the river mouth in the center of Oslo, the distance is about 8 km. Anadromous fish may ascend the river up to the first waterfall at Nedre Foss, a distance of about 1.5 km.

The river is regulated, and the minimum water discharge has been set to 1.5 m³s⁻¹. In periods with heavy rain, the water discharge may increase, but large natural floods are rare.

The heavy pollution of the river has since the middle of the 19th century consisted of sewage and effluents from local industry. Even though the water quality has improved considerably during recent years, episodes with heavy pollution from the industry are from time to time causing mortality of the fauna (Brittain & Saltveit 1988)

MATERIAL AND METHODS

In 1985, Atlantic salmon from two stocks, 1+ smolts from the River Lone, and 2+ smolts

Table 1. Survey of the different smolt groups released in the River Akerselv.

Stock	Smolt age	Time of release	No. released	Average smolt size (mm)	Range (mm)
R. Lone	1+	9 May 1985	941	150	130—177
R. Neva	2+	9 May 1985	987	325	159—394
R. Imsa	2+	23 May 1987	1922	222	135—402
R. Lone	2+	23 May 1987	983	217	135—396

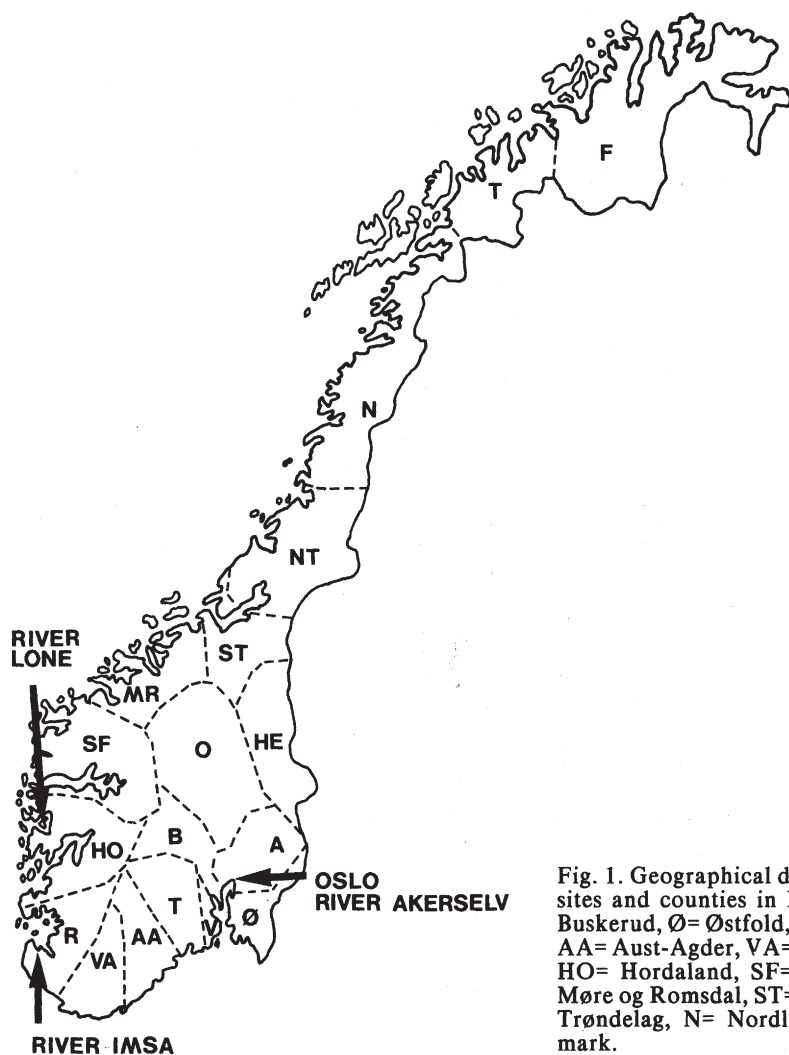


Fig. 1. Geographical distribution of experimental sites and counties in Norway. A= Akershus, B= Buskerud, Ø= Østfold, V= Vestfold, T= Telemark, AA= Aust-Agder, VA= Vest-Agder, R= Rogaland, HO= Hordaland, SF= Sogn og Fjordane, MR= Møre og Romsdal, ST= Sør Trøndelag, NT= Nord Trøndelag, N= Nordland, T= Troms, F= Finnmark.

from the River Neva, and in 1987 2+ smolts from the Rivers Lone and Imsa were released in the River Akerselva, about 1 km upstream of the river mouth (Table 1).

River Imsa is situated in Sandnes, near Stavanger, SW Norway, River Lone drains into the Osterfjord, north of Bergen (Fig. 1), whereas River Neva is running through Leningrad in the USSR and empties in the Baltic Sea. Most of the salmon of the River Imsa stock mature after spending one year in the ocean (grilse), but there is also a significant component of salmon that return as 2 sea-winter fish. The River Lone salmon is a grilse stock, where multi-sea-winter salmon are rare. The salmon from the River Neva consists of several sea age groups (Kallio-Nyberg & Ikonen 1989).

Fish of the River Imsa and Lone stocks were hatched from eggs taken directly from wild parent fish. Five parents of each sex were used in the crosses. The Neva stock was derived from three groups of fish (hatched 1972, 1974, 1976) at the Laukaa Central Hatchery Station, Finland, originally imported from the Neva Hatchery Station, USSR, taken from wild salmon caught in the River Neva. In March 1983, eyed eggs from Finland were imported and hatched at the Research Station for Freshwater Fish at Ims, where all groups were reared to smolts.

All smolts were anaesthetized with chlorobutanol, tagged individually with numbered Carlin tags (Carlin 1955) and measured (total length in mm). After this treatment, the fish were allowed to recover for at least two

weeks. Then, the fish were trucked in tanks for about 12 hours and subsequently released directly into the River Akerselv in the evening just before dark. Recaptures were reported both from freshwater and the sea by fishermen, and by systematic sampling in the River Akerselv.

RESULTS

The sea-ranched hatchery salmon originating from the Rivers Imsa and Lone migrated out of the Oslofjord soon after release.

However, this was not the case with the salmon originating from the River Neva. They fed in the Oslofjord during summer and autumn. Some smolts did not leave the river, and stayed there for spawning in the autumn (Table 2). Most salmon of the two Norwegian stocks returned as grilse, whereas most Neva salmon were recaptured the year of release. The great majority (84.4%) of the marine recaptures were reported from the Oslofjord (Table 3). However, recaptures were reported from all counties along the Norwegian coast, except Nordland and Troms.

Total reported recapture-rate of the different releases varied between 7.1 and 19.1% of the number of smolts released (Table 4). Relative to the 1+ smolts a large proportion of the Norwegian 2+ smolts were captured a short time after release. The great majority entered the river of release, when mature (Table 5). The few strayers (n=5) were captured in rivers nearby the River Akerselv, viz.

Table 2. Number of salmon recaptured at different stages and fisheries.

Stage at recapture	Smolt group			
	R. Lone-85	R. Neva-85	R. Imsa-87	R. Lone-87
Smolts/post-smolts freshwater	0	86	57	61
Smolts/post-smolts sea	2	93	7	5
Ocean 0+	0	3	0	0
Norw. home water 1+	34	5	17	9
River of release 1+	46	0	51	10
Other rivers 1+	0	0	1	1
Ocean 1+	0	1	1	0
Norw. home water 2+	3	1	1	2
River of release 2+	0	0	2	0
Other rivers 2+	0	0	0	0
Total number recaptured	85	189	137	88
Recapture-rate (%)	9.0	19.1	7.1	9.0

Table 3. Number and proportion of salmon caught in the marine salmon fisheries in different counties. *= counties within the Oslofjord.

County	Smolt group				Total	%
	R. Lone-85	R. Neva-85	R. Imsa-87	R. Lone-87		
Oslo*	2	4	0	1	7	3.9
Akershus*	3	25	4	3	35	19.6
Buskerud*	2	15	2	1	20	11.2
Østfold*	2	3	2	1	8	4.5
Vestfold*	21	44	10	5	80	44.7
Telemark*	1	0	0	0	1	0.6
A. Agder	0	1	0	1	2	1.1
V. Agder	2	3	1	0	6	3.4
Rogaland	2	0	0	0	2	1.1
Hordaland	1	0	3	0	4	2.2
S. og Fjordane	0	0	2	1	3	1.7
M. og Romsdal	0	0	1	0	1	0.6
S. Trøndelag	0	0	0	1	1	0.6
N. Trøndelag	0	1	0	0	1	0.6
Finnmark	0	2	0	1	3	1.7
Unknown	3	1	0	1	5	2.8

Table 4. Recapture-rates at different sea-ages of the different groups of salmon released.

Stock	Smolt age	Year of release	0	Sea age 1	2	Total recapture (%)
R. Lone	1+	1985	0.2	8.5	0.3	9.0
R. Neva	2+	1985	18.4	0.6	0.1	19.1
R. Imsa	2+	1987	3.3	3.6	0.2	7.1
R. Lone	2+	1985	6.7	2.0	0.2	8.9

Table 5. Straying (percent of the total number of recaptures in other rivers/total number of returns from freshwater) of the different groups released.

Stock	Smolt age	Year of release	0	Sea age ≥ 1	Total
R. Lone	1+	1985	—	0.0	0.0
R. Neva	2+	1985	1.2	—	1.2
R. Imsa	2+	1987	0.0	1.9	0.9
R. Lone	2+	1987	3.3	9.1	4.2

Table 6. Mean weight (kg) of grilse and 2 sea-winter salmon from the different releases. Sample sizes are given in brackets.

Stock	Smolt age	Year of release	0	Sea age 1	2
R. Lone	1+	1985	0.05 (2)	1.51 (60)	3.10 (2)
R. Neva	2+	1985	0.59 (160)	3.01 (7)	—
R. Imsa	2+	1987	0.29 (39)	2.12 (66)	4.35 (2)
R. Lone	2+	1987	0.44 (31)	2.09 (19)	2.70 (2)

Table 7. Total yield (kg) of the different sea age groups and total yield per 1000 salmon smolts released. One Neva salmon with sea age 2 had no reported weight and is pooled with fish of sea age 1.

Stock	Smolt age	Year of release	0	Sea age 1	2	Total per 1000
R. Lone	1+	1985	0.1	120.8	9.3	138.4
R. Neva	2+	1985	107.4	21.1	0.0	130.2
R. Imsa	2+	1987	18.6	148.4	13.1	93.7
R. Lone	2+	1987	29.0	41.8	5.4	77.5

the Rivers Lysakerelv (3), Gjersjøelv (1) and Sandvikselv (1).

The mean weight of the different sea ages varied among stocks (Table 6), the 2+ smolts developed larger post-smolts and grilse than did 1+ smolts. This reflects the difference in size among the smolt groups.

Total reported yield per 1000 smolts released was highest for the River Neva stock, and yields were generally lower for smolts released in 1987 than in 1985 (Table 7).

DISCUSSION

Salmon from the Rivers Imsa and Neva were caught in the ocean at the feeding areas. Salmon from all stocks were recaptured in the Norwegian home water fishery, and in the River Akerselv. In general, when released as smolts (1+ and 2+ and 3+) Norwegian salmon stocks leave the river and fjord area within a short time after release, as has been observed in River Akerselv (Hansen 1986) as well as in the River Imsa (Hansen et al. 1987). On the other hand, most Neva salmon were caught in the Oslofjord as post-smolts. The fact that 2+ smolts of the River Neva stock tended to stay in the Oslofjord the following summer and autumn is consistent with results obtained from releases of comparable groups of smolts in the River Imsa (Hansen & Jonsson, in manus), and suggests that salmon from this Baltic salmon stock is different from Atlantic salmon in migratory behaviour.

Some smolts became resident after release. This was more pronounced for 2+ than for 1+ smolts, and could be due to parr male maturation at age 1+, which is very common and is partly a result of advanced development in hatcheries (Thorpe 1989). Maturation among 0+ males in the Ims rearing station is not very common, but has been observed in some tanks with fast growing fish (Hansen & Jons-

son pers. obs.). In experiments performed in the River Imsa, we have demonstrated that males maturing as parr smolted at a lower rate than immatures of corresponding age (Hansen et al. 1989), and consequently results in reduced returns of adults as observed in the Baltic Sea (Lundqvist et al. 1988).

Among all groups of 2+ smolts, some fish returned to the River Akerselv to spawn the year of release, after having spent the summer in the sea. Such behaviour is relatively rare, but may occur among large 2+ or 3+ smolts that also smolted a year earlier (e.g. Piggins & Mills 1985, Hansen et al. 1987, Hansen & Jonsson, in manus).

The salmon homed with high precision to the River Akerselv. Compared with data from the smolts released in 1981 and 1984, the straying to other rivers has decreased. Hansen (1986) suggested that the relatively high straying rates of the returning adults released as smolts in 1981 and 1984, could be due to the fact that the water quality in the river at that time still was very poor. In the last half of the 80-ies the water quality has improved successively (S. J. Saltveit pers. comm), which may have caused the improved homing. Furthermore, the fishing effort in the river has increased, resulting in a higher number of returning adults being recaptured. Also the presence of salmon parr in the watercourse may have attracted the adult salmon.

Tagging, the use of anaesthesia, handling and transport prior to release are known to stress salmonids (e.g. Soivio et al. 1977, Barton et al. 1980, Pickering et al. 1982, Soivio & Virtanen 1984). In the present experiments the source of stress that probably has had the most serious effect on the fish released was the long transport of the smolts. Furthermore, all fish were tagged with external tags. However, the fish were allowed to recover at Ims for two weeks before transport and re-

lease. Experiments carried out in the River Imsa Research Station have demonstrated that stress caused by handling and a 4 hr transport seriously reduced the survival of salmon released as 1+ smolts relative to similar groups of 2+ smolts (Hansen & Jonsson 1988). In the present experiment the smolts were transported for 12 hrs, and it seems likely that this has reduced their performance considerably.

Not all external Carlin tags are reported, and Rosseland (1973) suggested that the tag reporting-rate from the Norwegian home water salmon fishery was in the order of magnitude of 0.5—0.7. It is difficult to extrapolate these figures to the present experiments, but taking unreported tags and handling mortality into consideration, it is clear that the reported recapture-rates and yield are gross underestimates of the true data. Hansen (1986) found it reasonable to double the reported yields to obtain estimates of the total yield of untagged salmon released without a high stress level. If the yield data presented in Table 7 is doubled, a total of 277 and 260 kgs of salmon of the Rivers Lone og Neva stocks released as smolts in 1985 were harvested per 1000 smolts released. Similarly, of the smolts from the Rivers Imsa and Lone released in 1987, 187 and 155 kgs per 1000 smolts released were recaptured. These estimates are within the same range as for smolts released in the River Akerselv in 1981 and 1984 (Hansen 1986).

To choose the best strategy for restocking salmon rivers where the local population has been completely lost raises many difficult questions. It is important to have historical data of life history of the indigenous stock in order to select similar stocks. Salmon from nearby rivers may be closely related, provided that the environment is similar. Because small rivers usually are inhabited by grilse stocks, River Akerselv should be restocked with grilse stocks from similar rivers in the same climatic regime. Of the stocks tested, salmon from Rivers Lone and Imsa have yielded the best returns to the river. However, we have no information of the spawning success of the different groups. When the conditions in the river is good for parr production, the main emphasis should be at releasing fry and fed fry. However, if conditions in the river are less suitable for parr production, with episodes of fish kill, smolts should be released.

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