Strategies for re-establishing Atlantic salmon *(Salmo salar)* in two limed rivers in southern Norway

Directorate for **Nature Management**

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INTRODUCTION

A total of seven large salmon rivers are found in southernmost Norway. However, during the early 1900s, acidification led to a steep decline in salmon stocks in these rivers. By the late 1960s these stocks were extinct, including those in the rivers Tovdalselva and Mandalselva (***Figure 1***). Liming in these two rivers began in 1996 and 1997, respectively, a measure that has substantially improved water quality (***Figure 2***). In 1998, a research programme on these rivers was launched, with the aim of studying various aspects of the re-establishment process of salmon. Development of fry and older parr densities and angling catches have also been assessed.

STRATEGIES TO RE-ESTABLISH SALMON

Stockings

Migrating mature salmon are able to ascend both rivers from the sea, which offers a potential basis for natural re-establishment. However, an alternative strategy based on re-stocking has also been implemented, using brood stocks from geographically nearby rivers; salmon from River Bjerkreimselva into River Mandalselva, and from River Storelva into River Tovdalselva (***Figure 3***) Eyed eggs, fry and smolts have all been stocked (***Table 1***). River Mandalselva has been stocked with large numbers of fry and smolts, which are raised in a local hatchery. No hatchery has been built to produce salmon for re-stockings in River Tovdalselva, and eyed eggs from a hatchery near Storelva were therefore released into the river bed. Fish of all stages were marked; eyed eggs with fluorescent marks, fry by fin-clipping and smolts with external marks.

Comparative studies

The genetics, physiology, survival and growth of offspring of salmon caught in River Mandalselva will be compared with those of salmon from River Bjerkreimselva. The new salmon stock in River Mandalselva has recently been established, probably based on different strains. Comparison will be made by stocking individuals of the two strains in the same year, including both fry (2004-05), smolts (2005-6) and eyed eggs (2006-07). In River Tovdalselva, comparison will be made between naturally produced salmon and individuals stocked as eyed eggs in the river bed.

RESULTS

The present salmon from River Tovdalselva is genetically different from the stock that was wiped. This finding is based on analyses of salmon scales from 1910, 1955 and 1999-2001.

Eyed eggs and fry stocked into the rivers Mandalselva and Tovdalselva showed a normal survival rate.

The concentration of aluminium on gills of pre-smolts/smolts from the two rivers, suggests that the level may have affected post-smolt survival in some years, especially for salmon in River Tovdalselva.

In Mandalselva, salmon re-established themselves quite rapidly after liming, as the fry density has reached 64 individuals 100 m^{-2} and the annual catch of adults has exceeded 10 tonnes (***Figures 4 & 5***). In River Tovdalselva, re-establishment has been slower, however, fry density reached 33 individuals 100 m^{-2} in 2003.

On the basis of scale readings and external marks on adult fish, the fraction of naturally produced salmon in the rivers Tovdalselva and Mandalselva was determined. The proportion of wild salmon in these two rivers was found to be 0 and 42% in 1998, respectively, increasing to 50 and 91% in 2004.

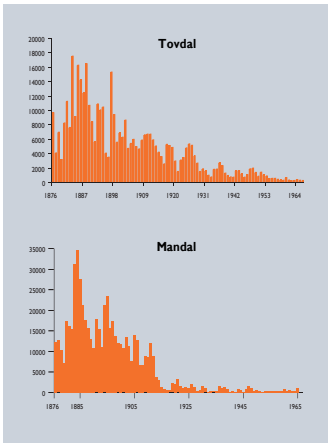

Figure 1. Angling statistics (tonnes) of Atlantic salmon in the rivers Mandalselva and Tovdalselva, 1876-1965.

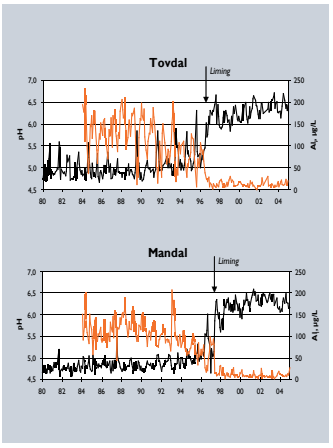

Figure 2. Before liming started, the pH in the rivers Tovdalselva and Mandalselva typically ranged between 4.6-5.5, as opposed to 6.0-6.5 after liming. While labile Al has been reduced from 100 to 200 µeq L^{-1} to levels below 15 µeq L^{-1}.

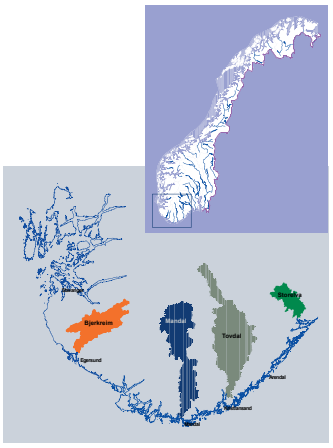

Figure 3. Outline of the catchment areas of the two rivers where salmon are re-established, Mandalselva and Tovdalselva, and their source rivers for brood stock; Bjerkreimselva and Storelva.

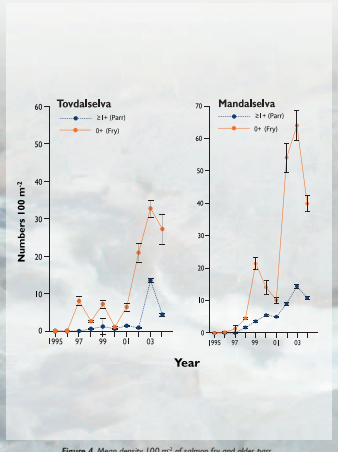

Figure 4. Mean density 100 m^{-2} of salmon fry and older parr in the rivers Mandalselva and Tovdalselva, 1995-2004

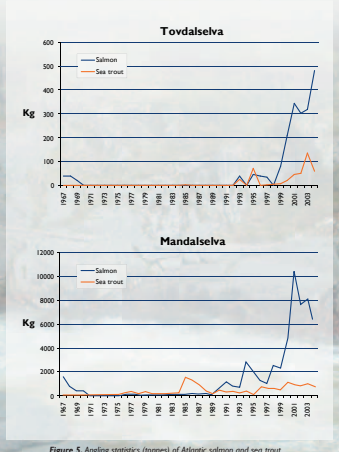

Figure 5. Angling statistics (tonnes) of Atlantic salmon and sea trout in the rivers Mandalselva and Tovdalselva, 1967-2004.

	River Mandalselva		River Tovdalselva	
	Numbers	Period	Numbers	Period
Eyed eggs	431.000	2003-2004	1.346.000	2000-2004*
Fry	1.667.702	1997-2004	0	-
Smolts	29.416	1997-2003	6.750	1997

*Table 1. Number of eyed eggs, fry (age 0+) and smolts stocked in the rivers Mandalselva and Tovdalselva, 1997-2004. *Only 18.000 eyed eggs in 2000.*

CONCLUSION

* The more rapid development in River Mandalselva than in River Tovdalselva is thought to be due to the large numbers of stocked fish, giving rise to a larger spawning stock.
* At present, however, natural reproduction in River Mandalselva is overshadowing the quantity of stocked fish.
* New stocks of salmon are re-established in both rivers after liming.
* In Tovdalselva natural reproduction has been low so far, and the rate of re-establishment will probably correlate with the amount of stocked eyed eggs. However, this measure was first initiated in a large scale in 2001, i.e. five year after liming began.

Liming of salmon rivers in Norway; success depends on sophisticated strategy and organisation.

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INTRODUCTION

The rivers Mandalselva and Tovdalselva in southernmost Norway were formerly among the best Atlantic salmon rivers in the country. However, in the 1960s acidification wiped out the salmon populations of both rivers. Liming programmes in these two rivers began in1996-97 with the aim of improving water quality to a level that would allow Atlantic salmon to reproduce successfully. The two rivers are quite similar in size; their catchment areas are approximately 1800 km^2, with mean annual flows of 70-90 m^3/sec. The geographical extent of both rivers involve several municipalities and counties.

Salmon, which is extremely sensitive to acid and aluminium-rich water, is the main target species for the mitigation projects. Climatic conditions in Norway typically produce rapid changes in water flow rates, which in turn affect the water chemistry. Thus, liming is a complex task in terms of achieving an optimized and stable water quality. A total of 21 salmon rivers are currently being limed in southern and south-western Norway.

LIMING STRATEGIES

The strategy for improving water quality involves continuous liming with 0-0.2 mm calcite powder from dispensers, controlled by water flow and down stream pH in a feed back system. In the rivers Mandalselva and Tovdalselva, a total of nine and six dispensers, respectively, have been installed. The annual consumption of limestone powder in these rivers ranged between 6000-12000 and 4000-9000 tonnes, respectively, depending on the prevailing water flow each year.

These dispensers should always give the correct dose, never become empty, and never stop working. This is necessary in order to avoid lethal or sub-lethal water quality for salmon on one hand, and to avoid waste of resources on the other hand. Liming aimed to create a pH of about 6.2-6.4 during the critical period for pre-smolt/smolts in spring (1 April to 31 May) and between 6.0-6.2 during the rest of the year.

Atlantic salmon are now reproducing naturally in all the limed rivers, and densities of salmon fry have increased significantly over years since the first treatment.

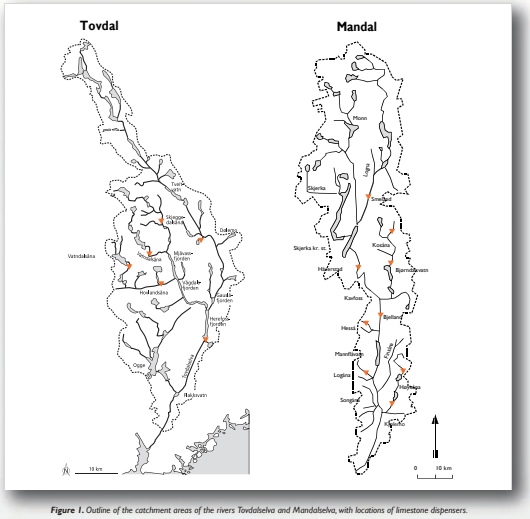

Figure 1. *Outline of the catchment areas of the rivers Tovdalselva and Mandalselva, with locations of limestone dispensers.*

LIMING ORGANISATION

The Directorate for Nature Management is responsible for the Norwegian Liming Programme, and administers the contracts for transport, purchase of limestone powder and monitoring programmes to assess the effects of these mitigation activities, in cooperation with the County Governors.

The County Governor coordinates national and local liming activities. In both rivers, several municipalities are involved in planning and implementing the liming programmes. Cooperation is ensured through contracts between the County Governor and relevant municipalities and local organisations. These contracts establish the responsibilities at regional and local level, according to funding and management of the mitigation activities.

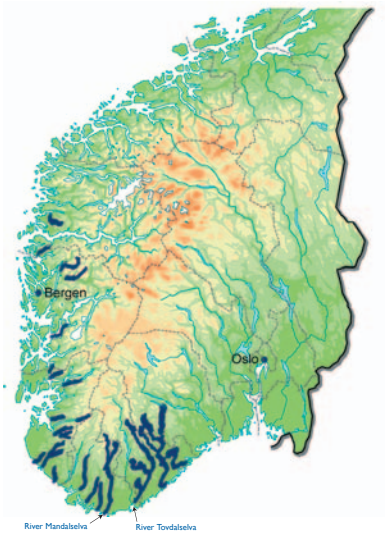

Figure 2. *The 21 limed rivers with Atlantic salmon in Norway.*

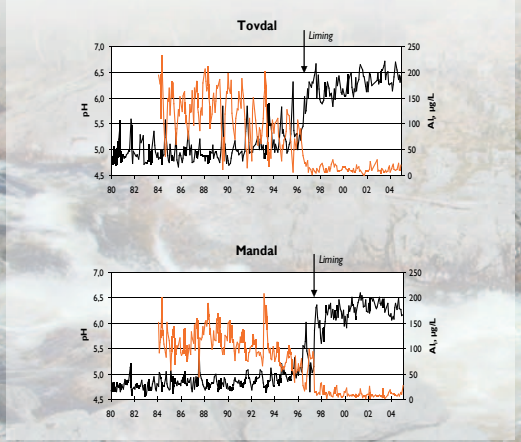

Figure 3. *Before liming started, the pH in the rivers Tovdalselva and Mandalselva typically ranged between 4.6-5.5, as opposed to 6.0-6.5 after liming. Thus, the target water quality in terms of higher pH, and subsequent reduction in toxic aluminium during spring snow melt as well, is now largely being achieved in most limed rivers.*

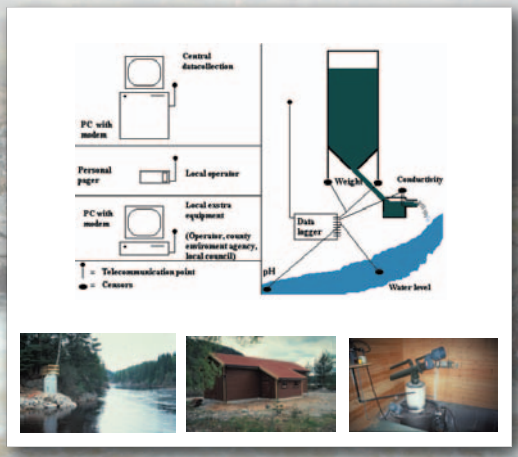

Figure 4. *A typical lime dispenser, showing water inlet, building and water-lime mixing equipment. The diagram shows a specific dose-control system.*

CONCLUSION

The liming strategy for the rivers Mandalselva and Tovdalselva demands an effective adjustment of dose according to water flow and water quality (pH). This gives a water quality which ensures healthy salmon stocks. The success of the liming programmes has been achieved through cooperation between local organisations, municipalities and the environmental administration in each county and at a national level.