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Distribution of escaped farmed salmon and rainbow trout in the sea and possible effects of salmon lice on wild stocks

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The aims and first results of a recently started project are presented. The geographical and seasonal distribution of the catch and catch per unit effort of escaped farmed salmon and rainbow trout are studied in an area in western Norway characterized by dense farming activity. The general condition of the escapees during the year is monitored by various parameters. The migration behaviour of the escapees is studied by tagging experiments. Possible effects of salmon lice on wild salmon populations is estimated by the number of adult female sea lice parasitasing escaped farmed fish during the period of the natural smolt run, and by release of smolts treated/untreated with slice (an oral anti lice drug). In addition, the sea survival and incidence of male parr maturity (precocious maturation) of river stocked family groups is estimated.

Keywords: salmon, rainbow trout, escapees, salmon lice, sea survival, precocious maturation

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Introduction

From the late eighty's there has been a growing concern for the negative impact of fish farming on wild populations of salmon. Under the assumption of local adaptation the main problem is though to be the genetic influence of escaped farmed fish entering the river to spawn. The fish farming industry has continued to grow, and the numbers of farmed salmon in Norway totally outnumbers the wild in many regions. If there is a large farming activity in a region, one may ask whether, or to what degree, the industry and natural populations of salmon can coexist. The present report does not deal with the genetic impact on wild populations, but describe a project that point towards other aspects of the wild-farmed fish interaction. Consideration of the different scenarios of interaction between fish farming and conservation of natural populations should also be done on the basis of an improved knowledge of the "biology" of escaped farmed fish, such as the distribution of the escaped fish in the sea and with time the of the year, the general condition of the escapees (including consideration of their welfare) and their role as carriers of the salmon louse.

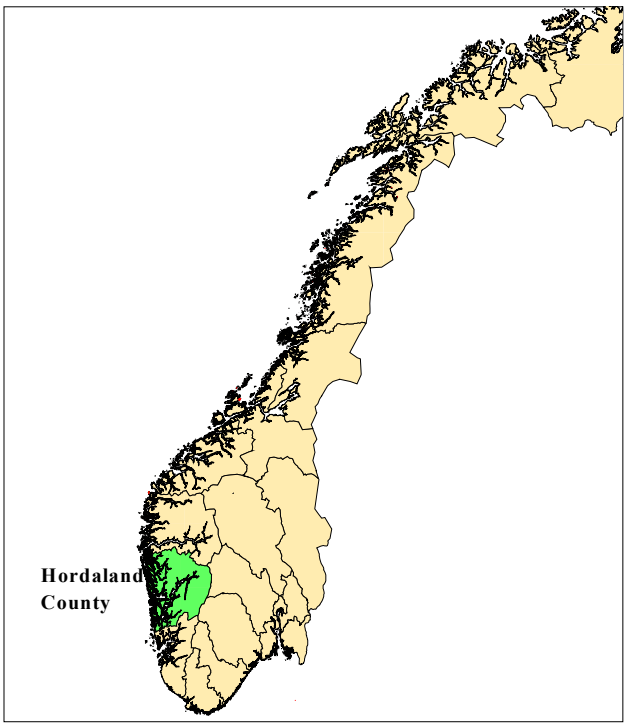


Figure 1. Map showing location of Hordaland County.

The study is performed in Hordaland County (see Figure 1). Several of the pioneers in salmon and rainbow culture in Norway built fish farms in this area in the early seventies, and a large aquaculture industry is located in Hordaland today. More than 100 fish farms are permitted to use 300 local sites in the sea for farming. The production from the region in 2000 was 80.000 tons of salmon and 14.000 tons of rainbow trout, approximately 20 % of the total Norwegian production of salmon and trout. The wild salmon populations in the area have declined to low levels, especially since 1990, and do not seem to have been significantly affected by the general improvement seen in other parts of Norway during the last two-three years. Among them is the River Vosso, which was known for its large salmon exceeding 10 kg in mean weights. The reason(s) for the recent collapse in this population remains unsolved.

The project was started in 2001. Few results are available at this stage, and there is a need to look at variation between years when using the described approaches. The focus of this paper will be to present the objectives of the following activities:

1) Geographical distribution of catches of escaped salmon and rainbow trout
2) Catch, tagging and release of wild and farmed salmon
3) General condition of escaped farmed fish
4) Interactions between salmonids culture, salmon lice and wild populations
    4a) Escaped farmed fish as carriers of adult sea lice
    4b) Return rates of released smolts treated against salmon lice
    4c) Possible influence of high adult marine mortality on the population structure in a salmon river

1) Geographical distribution of catches of escaped salmon and rainbow trout

From 1997 the County Governor of Hordaland, Department of Environmental Affairs, has opened for a public fishery for salmonids in the sea during late autumn and winter (Figure 2). The rationale is to reduce the number of escaped fish in the sea at a time of the season when most wild fish have already entered fresh water. From this fishery, the numbers and total weights of the catch of salmon and rainbow trout have been reported from each fisherman. The aim of the present study was to gather more specific information from the fishery to improve the knowledge of the distribution of escaped fish. Local fishermen participating in the fishery were therefore contacted by the Institute of Marine Research (IMR) before the 2001/2002 season and asked for information about fishing effort and individual data for each fish. In return there are paid for collecting scales from the fish. Forty fishermen returned the catch data shown in figures 3-6.

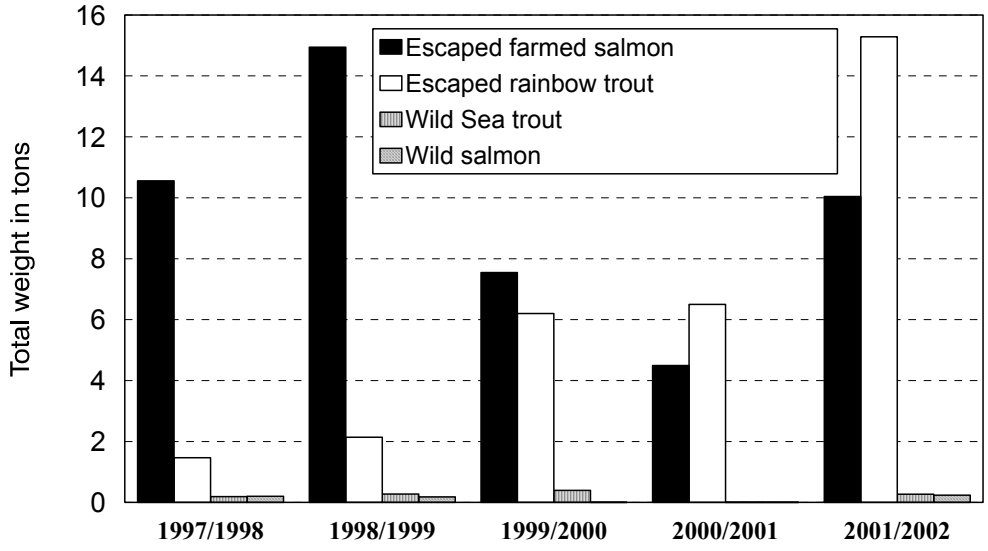


Figure 2. Total catches reported to the during the autumn/winter fishery for escapees since 1997. Source: A. Kambestad and G. Lehmann, Governor of Hordaland, Department of Environmental Affairs. The catch of wild salmon during the 2001/2002 is estimated from the individual scale readings done by the present project.

IMR received individual data for 389 salmon and 803 rainbow trout of the total of the 3700 salmon and 4564 rainbow trout reportedly caught during autumn/winter 2001/2002, which

correspond to 10.6 % and 17.6% of the totals, respectively (plus fishing effort data for additional 510 rainbow trout). Mean weights of rainbow trout and escaped salmon were 3.1 and 3.6 kg, respectively.

The catch of rainbow trout was high immediately after the opening of the fishery for salmonids on October 1, and dropped sharply during the next 4-5 weeks (Figure 3). The reduction in catch is partly a consequence of a reduction in fishing effort during autumn (no of nets; Figure 4). In addition, there was a clear reduction in catch per effort (trout per net per day, Figure 5) with season that matches the drop in total catch.

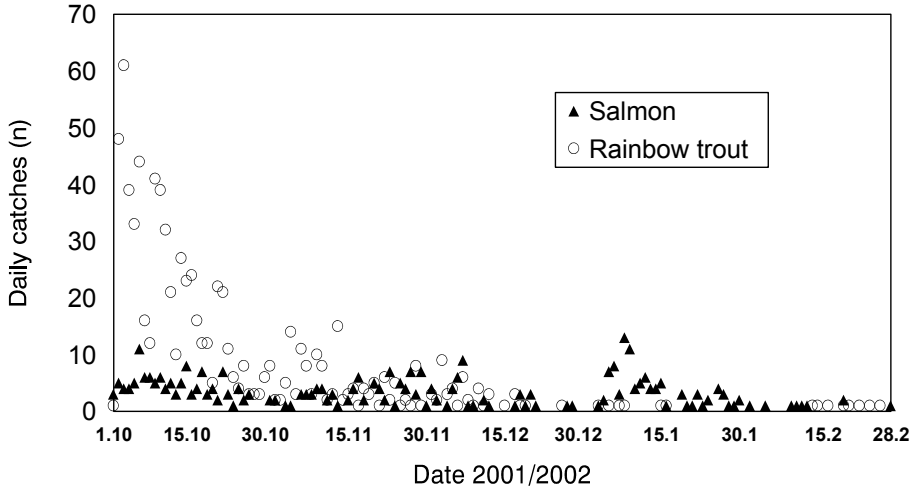


Figure 3. Summarised daily catches of escaped farmed salmon and rainbow trout during the fishery for escapees from 1. October 2001 to 28. February 2002. The figure is based on individual fish data reported to the Institute of Marine Research, which corresponds to 25 % of total catch reported to the authorities.

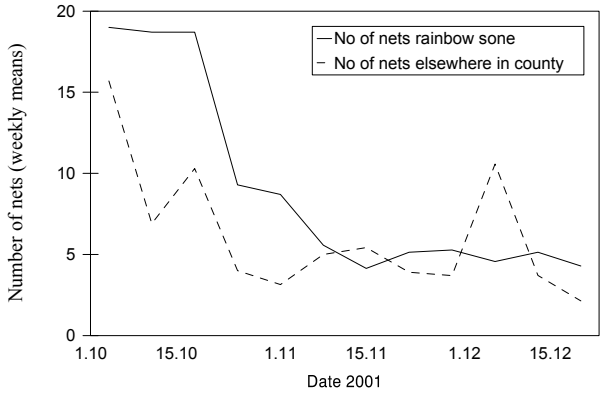


Figure 4. The numbers of gill nets (weekly means) in, and outside, the Osterøy area (). Mesh size 63-70 mm.

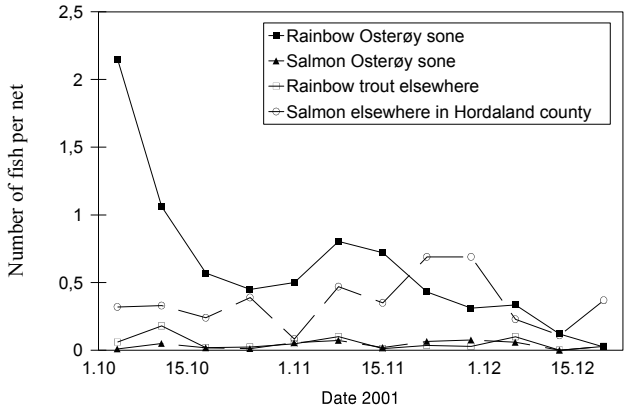


Figure 5. Catch per effort. Weekly mean of the number of salmon and rainbow trout per day per net in and outside the Osterøy area from October 1 to December 20. Mesh size 63-70 mm.

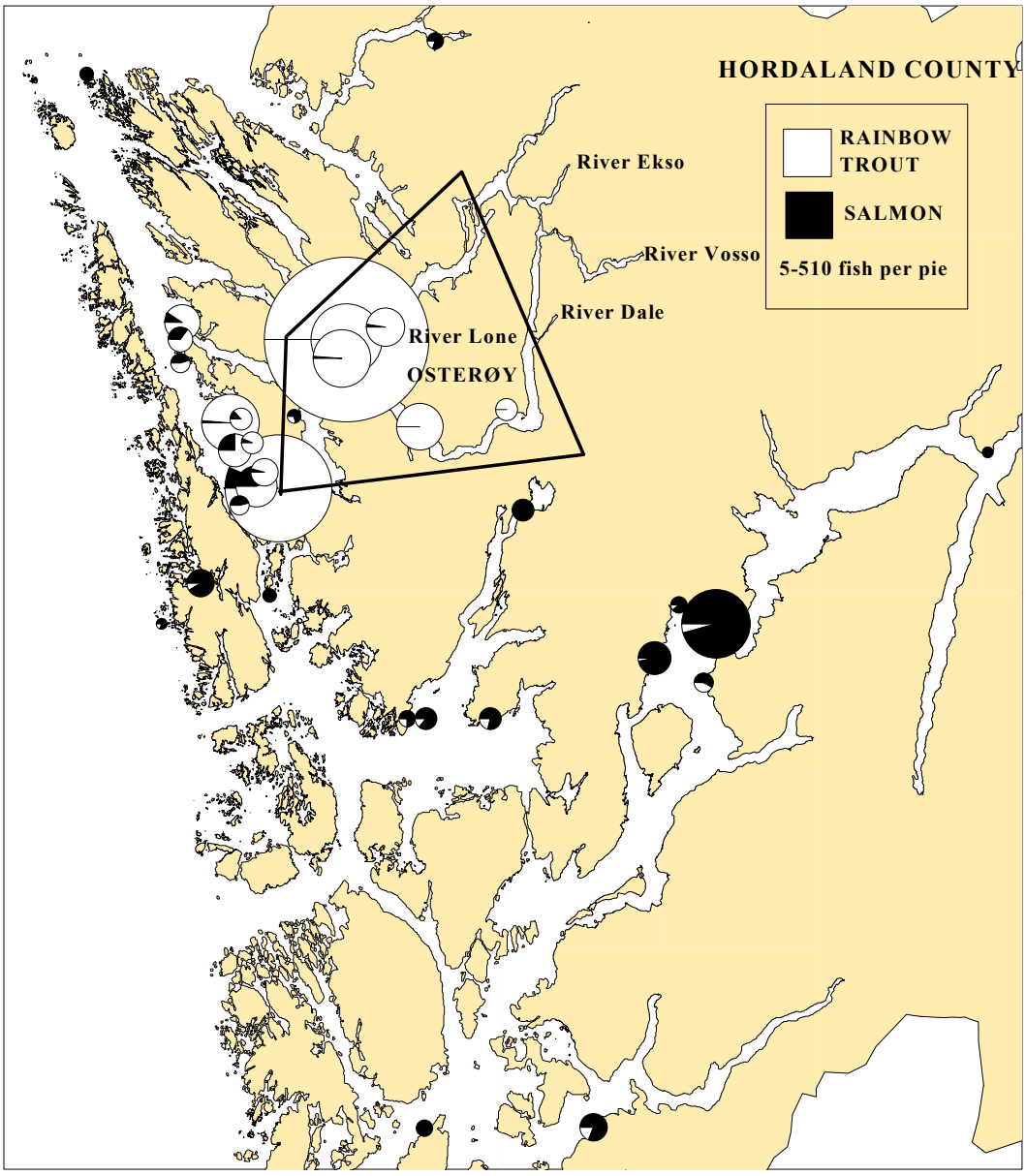


Figure 6. Geographical localisation and size of catches of escaped farmed salmon and rainbow trout in Hordaland county October 2001-February 2002. The region where most

rainbow trout, and no salmon, are held in catches is enclosed. There are no net pens in the inner part of the Osterøy fjord system. Mesh size 63-70 mm.

2) Catch, tagging and release of wild and farmed salmon

To monitor the movements of wild and escaped farmed salmon in the Osterøy fjord system a bag net was at Trengereid (se Figure 8 for location) was used from July 1 to September 9 for sampling and tag and release experiments.

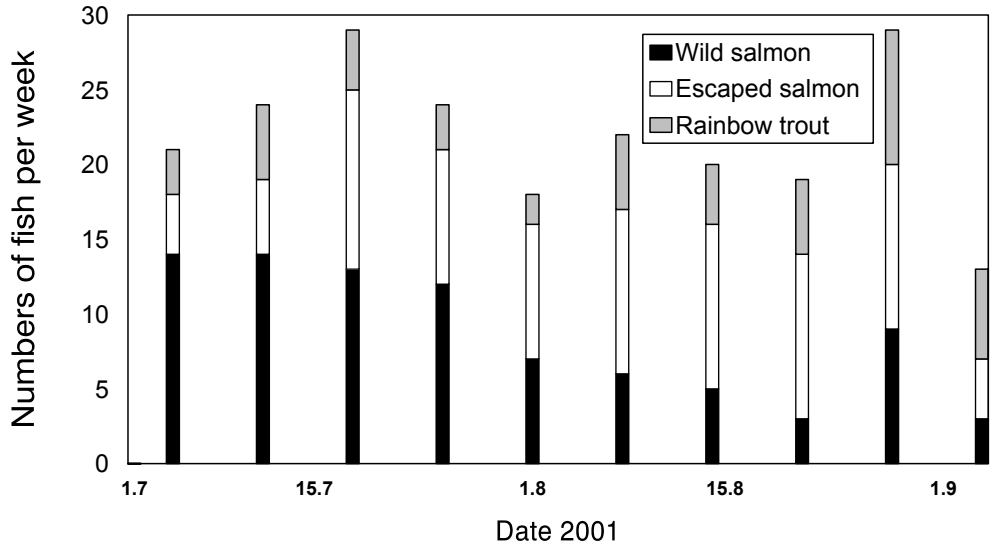


Figure 7. Weekly catches of wild salmon and escaped farmed salmon and rainbow trout in bag-net at Trengereid (see figure 8 for geographical location).

The dominance of wild salmon in the catch in the bag net at Trengereid early in the season was succeeded by higher numbers of escaped farmed salmon later in the season (Figure 7). Salmon fit for tagging were tagged with Anchor T-tags and released immediately. Of a total catch of 192 salmon, 41 escaped farmed and 60 wild salmon were tagged. The recapture rate was 32.4 %, all recaptures during summer and autumn. The escaped salmon evidently entered salmon rivers in the fjord system (Figure 8). In a sample of 14 escaped untagged salmon all stomachs were empty and the gonads were developing. These results are therefore in accordance with earlier experiences showing delayed spawning migration of escapees towards fresh water.

Seven out of nineteen tagged rainbow trout were recaptured, all of them in the fjord system.

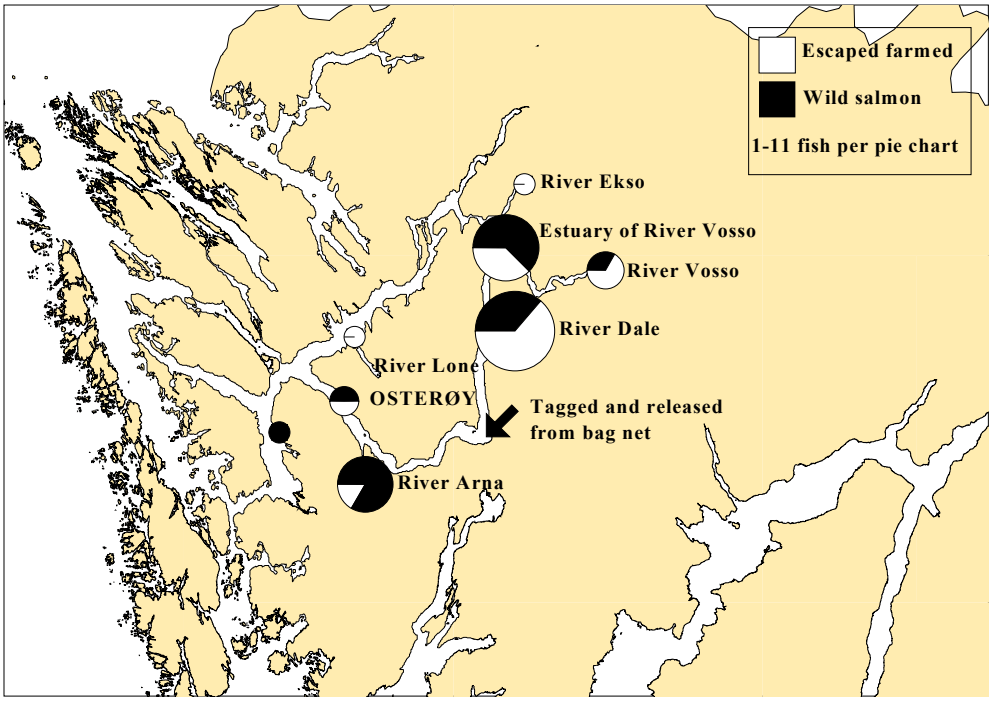


Figure 8. Recaptures of adult salmon that were caught, tagged and released from bag-net during juli-september 2001. Based on analysis of scales the salmon are classified as wild, escaped farmed or stocked as juveniles.

3) General condition of escaped farmed fish

The total yearly reported catch of escaped farmed salmon in the sea in Hordaland County of 4-15 tons must be assumed to be clearly lower than the total biomass of escapees. In spite of this, there is a poor correlation between the catch of escapees in the sea and the estimated yearly weight of escapees entering the rivers of approximately 2 tons (according to A. Kambestad, Governor of Hordaland, Department of Environmental Affairs). Apart from migration out the area, one reason may be poor survival from time of escape to maturation. The aim of the study is therefore to describe the general condition of escaped fish throughout the year. This subject is also of interest for consideration of the welfare of cultured animals, which should also include escaped as well as fish held in captivity.

Gill nets that are used each month at two sites to cover the depth range from 0-40 meter. For each individual the following samples are collected: Number of adult female salmon lice, external wounds/fin erosion, scale sample, sex and weight of gonads, weight of guts vs. total weight, weight of milt, stomach, sample from liver and muscle for fatty acid analysis.

Data collection is still in progress.

4) Interactions between salmonids culture, salmon lice and wild populations

During the nineties premature returns to fresh water by sea trout (Salmo trutta) infested with the salmon louse (Lepeophtheirus salmonis Kroyer) were observed (Birkeland 1996; Birkeland and Jakobsen, 1997). The phenomenon seem to correlated with the distance to salmon farms (Tully et al. 1999; Bjørn and Finstad 2002). If migrating salmon smolts are heavily infested with lice, as observed by Finstad et al. (2000), then the results may be

serious mechanical damage to the skin, reduced capacity to osmoregulate, loss of body fluids and finally death if infestation intensity are high enough (Pike and Wadsworth 1999).

4a) Escaped farmed fish as carriers of adult sea lice

According to Pike and Wadsworth (1999) there is a need for data to understand the dynamics between wild salmon, culture of salmon and salmon lice. Heuch and Mo (2000) have looked into different scenarios, and propose that the relative contribution of salmon lice due to escaped farmed salmon serving as hosts may increase as disease control is improved in the net pens.

The presence of escaped farmed salmon and rainbow trout carrying adult salmon lice during spring may increase the mortality of wild smolts if there is geographical overlap between migration routes and distribution of escapees. This situation may easily occur if escaped farmed fish stay in fjords and coastal regions during winter and spring.

Escaped farmed fish were gill-netted at several locations April-May 2002 for measurements of adult female sea lice. The catch was too low in 2002 to give a general picture (partly due to algae's reducing the catchability), and should be optimised the next year. However, in one of the locations it was demonstrated that the presence of escapees in the vicinity of a salmon river imply that female sea lice are also present during the smolt run in April-May (Figure 9).

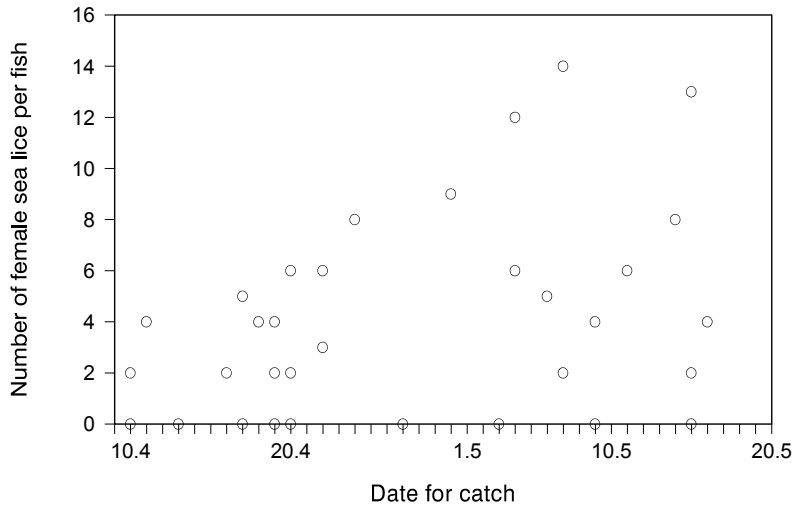


Figure 9. The number of adult female sea lice parasitazing individual escaped farmed salmon caught in gill net in the Samnanger fjord 1 km from the River Tysse during spring 2002.

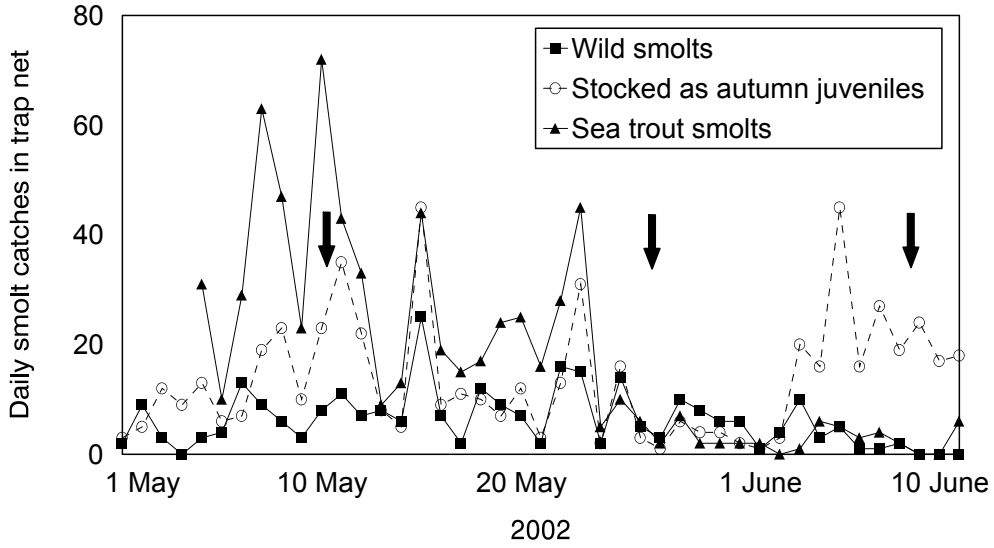
4b) Return rates of released smolts treated against salmon lice

The decline of the wild salmon population in the River Vosso during the last decade has stimulated research activity in the region. Because of the neighbourhood to the River Dale, which is located in the same fjord system (see Figure 6 for location), and the availability of juveniles and smolts produced for stocking in the Dale River release experiments are performed in Dale. To estimate the mortality of smolts caused by salmon lice smolts are treated with slice, an oral anti lice drug, prior to release. The overlap between the migration routes of smolts outward the fjord system and the aggregation of escaped farmed rainbow trout in that area is one important reason for choosing this release site.

The 1+ smolts are cultured offspring of wild salmon from the River Dale (see 4c for details). Returns rates have been observed to vary widely between family groups originating from the River Dale (Skilbrei et al. 1998). Family groups are therefore mixed equally between treated and untreated release groups. All fish are microtagged (Northwest Marine Technology) and adipose fin-clipped.

The migration speed of released and wild smolts may differ, and the natural smolt run takes some weeks. Additionally, if the probability of being infested with salmon lice changes during the period of the natural smolt run, then there are three reasons for not releasing all smolts on one particular day. In 2002 the smolts were therefore released over a period of one month according to the catches in a trap net for smolts (Figure 11).

In 2001 and 2002 8.000 and 10.000 smolts were released, respectively. (Anglers in the River Dale have caught 0.5% of the 2001 release during July-August 2002.)



Figur 11. Daily catches of salmon and sea trout smolts during spring 2002 in smolt trap net in the River Dale. Arrows show dates for releases of cultured smolts treated/untreated with oral anti lice drug.

4c) Possible influence of high adult marine mortality on the population structure in a salmon river

The principal objectives are to increase our understanding of the role of precocious maturation for population structure, maintenance and restoration. A comprehensive survey in 33 rivers in western Norway from the early nineties has shown that 10 - 40 percent of parr mature precociously (pers. com. Harald Sægrov, Rådgivende Biologer). While there has been relatively little effort to study the significance of precocious maturation in Norwegian populations, a number of studies have been performed in other regions. It has been observed that male mature parr participate during spawning (Hutchings and Myers 1988, Erkinaro et al. 1994), and that they may successfully fertilize a considerable proportion of the eggs (40 % in a Scottish study; Youngson and Hay 1996).

The significance of precocious mature males may be of special interest in endangered populations. They may increase the effective population size when the number of adult salmon returning from the sea is low (Martinez et al. 2000; L'Abbe Lund, 1989). Low return

rates may be a consequence of high post-smolt mortality due to heavy infestation of sea lice. Both successful participation of precocious mature males during spawning and their possible influence on the frequencies of life-history alternatives among their offspring will reduce the generation time cycle, and should be taken into account when modeling the genetic effects on natural populations of successful spawning of escaped cultured salmon entering the river, and when looking for causes for the decline in large sized multi-sea-winter stocks.

The significance of precociously mature males is tested by their use as brood fish in cultivation/stocking of Atlantic salmon by studying the performance of their offspring. Their growth rates, smolt age, age at maturity in fresh water and sea age are compared with the performance of half-sibling groups. Gene-environment interaction is included as the river performance of families stocked as 0+juveniles in autumn is compared with the development of their hatchery-reared siblings.

All brood fish are collected in the River Dale. Three year-classes of offspring have been produced. In autumn 1999, 2000 and 2001 five large males and 5-9 precocious mature males were used to fertilize egg batches of five females. Half of the eggs from each female were fertilised by one large male, while one (occasionally 2-3) precociously mature male were used for the other half. The resulting 10-14 family groups were reared in tanks until September-October (2000-2002), when approximately half of the 0+ juveniles have been stocked in the river. The 1+ smolts of the remaining are microtagged and released in spring. The slowest growing fish are held until the next autumn for recording of precocious maturation. Tanks and river are sampled twice a year for measurements of growth and precocious maturation. A small piece of one pelvic fin of all sampled fish are cut for identification to family by use of microsatellite analysis. The anglers association in Dale collects tissue samples of returned salmon.

The first results do not indicate that precocious mature males did produce high percentages of mature male parr among their offspring. The individual fish have not yet been identified to family (microsatellites), but the maturation during the first year in culture would still be low if all mature male parr originated from eggs fertilized by a small male (Table 1). Besides, two thirds of the mature male parr of the 1999 year class could be traced back to the two half sibling offspring groups of one single female resulting in 5.4% precocious maturation in these two groups and 0.4 % for the rest of the material. However, precocious maturation is more common among the potential 2+ smolts (also seen in Table 1). Family variation can be more easily detected at this stage, or later stages for the stocked juveniles that are supposed to stay in the river for several years.

Tagged precociously mature males that smolted as 1+ smolts are included in the release groups. It is of special interest to study their age at maturity in the sea (and that of their family), as an earlier study showed that their returned rate as grilse was clearly higher than that of their siblings (Skilbrei et al. 1998).

Table 1. Percentage of 1+ smolts and precociously mature males reared in tanks or stocked in the River Dale.

Brood fish Collection	% 1+ smolts		% Precocious mature males			
	Culture	River	Culture		River	
			1+	2+	1+	2+
1999	92.9	60-80	0.8	38.0	0.4	17.1
2000	93.6		5.2			

General remarks

The total reported catch of escaped farmed salmon was only 0.02% of the yearly production of farmed salmon in the region. The number was also low compared to several known episodes where 20-30.000 individuals escaped from single net pens during the last years. The incoming results on the welfare of escaped fish may hopefully tell a story about the life-after-escape of escapees. According to the experiences from these mass escapements, high numbers of salmon are caught during the first few weeks, thereafter they seem to disappear. Because of the high degree of geographical dispersion of escaped salmon (as seen in sea ranching operations; Skilbrei and Holm 1998) local management of fish farming activity is difficult. In the present study this was exemplified in the Osterøy area. Although there are no net pens for salmon in the fjord, a high percentage of escaped farmed salmon was caught in the bag-net fishing for migrating salmon during summer. Spawning migration of escaped farmed salmon is delayed compared with wild salmon. A shifting in the period for the sea/fjord fishery for salmon towards the end of the season will most probably reduce the proportion of escapes at the spawning grounds. Despite the conflict with late-running wild salmon, a fishery targeted for catching escaped salmon may during late summer /autumn should be considered as a management tool in regions where escapees are numerous compared with wild salmon. However, in some regions, trapping of adult salmon in the estuary and removal of escapees may be the only way to maintain local populations if escapement is not lowered to almost zero.

Although the aquaculture production of salmon in the region is approximately five times that of rainbow trout, more trout was caught in the fishery for escapees. In spite of this, the total reported catch of rainbow trout corresponded to approximately 0.1 % of the yearly production in the county of rainbow trout. This low number may indicate that the escape rate is low. From the decline in the catch of trout per effort, the possibility seem to exist that the stock of escaped rainbow can be significantly reduced by a fishery targeted for escapees The most potent negative influence of escaped rainbow trout on the wild populations seems to be their potential for producing salmon lice. The production of rainbow trout has shown a larger relative increase in Norway than salmon during the last 10 years, many net-pens are located in fjord regions, the escaped rainbow trout tend to stay in the area after escaping (at least in fjord). This development may be of concern if we assume that the escaped trout is the cause of an enlarged production of sea lice in fjord areas during spring, when wild smolts migrate. The present study will hopefully produce result to look into this subject. In addition, we hope to improve our understanding of the significance, and possible use of precocious mature males in conservation of endangered populations.

Acknowledgement
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