International Council for the Exploration of the Sea *CM 1997/AA:05*

Origin and migration of wild and escaped farmed Atlantic salmon, *Salmo salar* L., tagged and released north of the Faroe Islands

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Abstract

A total of 5,448 Atlantic salmon (3,811 wild and 1,637 fish farm escapees) were caught by long-lines, individually tagged and released back into the sea in Faroese waters between November 1992 and March 1995. In total 106 fish (87 wild and 19 farmed) have been reported recaptured. The recapture rate of wild salmon (2.3 %) were significantly higher than of farmed salmon (1.2 %). Tagged wild salmon were reported from large areas in the north Atlantic, both from marine fisheries and in freshwater. No tagged fish were reported from Faroes nor from West Greenland. Tags of wild fish were reported from homewaters in nine countries, the majority in Norway, but in significant numbers also from Scotland. Tags were also recovered in Russia, Ireland, Sweden, Denmark, England, Iceland and Spain. Furthermore, four tags of wild fish were reported from Canada, three from River Miramichi and one in a river close to the Miramichi, all in the same year when they were tagged. This shows that adult Atlantic salmon can cross the north Atlantic ocean in at least 5 months. Of the farmed fish recovered 18 were reported from Norway and one from the west coast of Sweden. We suggest therefore that the majority of farmed salmon in Faroese waters originates from Norwegian salmon farms.

Introduction

Atlantic salmon are distributed over large areas in the Northeast Atlantic, and inside the Faroes EEZ salmon have been exploited for a relatively long period of time. This fishery exploits mainly 2 SW fish, although some 1 and 3 SW fish are also caught. Recaptures at Faroes of salmon tagged as smolts in different countries has revealed that salmon from many countries are present in the area. However, the majority of salmon has been suggested to be of Norwegian origin (Anon. 1996). A tagging experiment at sea around the Faroes, particularly south of the islands was carried out during the period 1969 to 1976 (Jákupsstovu 1988). Because the fish had to be bought from the fishermen, it is expected that the 1SW fish were over represented among the tagged fish due to its lower weight (cost). Most recaptures of the tagged fish were reported from Scotland and Norway, and there were also several fish recovered from Ireland.

In recent years large numbers of farmed salmon have been observed at Faroes (Hansen *et al*. 1993), accounting for a significant proportion of the Faroese salmon catch (Hansen *et al*. 1997). There is direct evidence that farmed salmon escaping from net pens in Norway enter this area (Hansen *et al*. 1987), but there is no information about their performance in the ocean.

The main goal of this paper is to examine the origin and migration of wild and escaped farmed salmon using the Faroese area during parts of their oceanic feeding phase. We also aimed to examine the proportion of fish that were maturing and of those that remained for an additional year in the sea before returning to their home river.

Material and methods

As a part of a salmon research project in the Faroese area in the period 1992 to 1995, wild and farmed Atlantic salmon caught on long-lines were tagged and released back into the sea. The salmon were caught north of the Faroe Islands using commercial floating long-lines that were baited with sprats. The lines were usually set early in the morning, hauling started

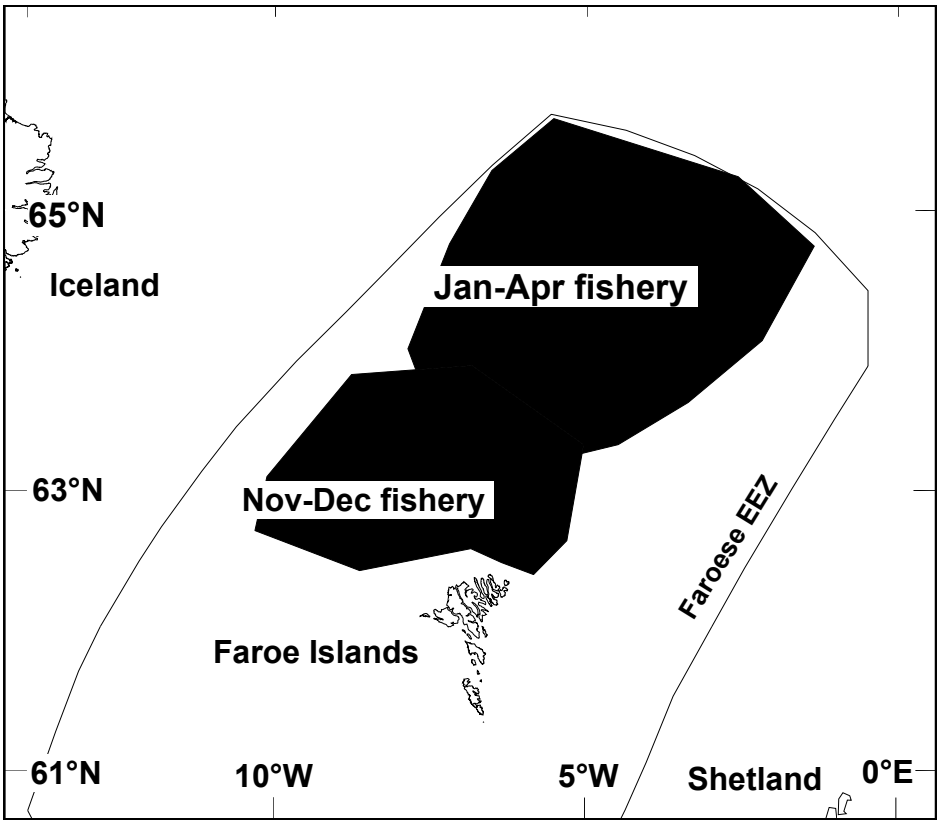

Figure 1. *Areas of tagging north of the Faroes. The autumn fishery is located closer to the isles and as the season progresses the fishery moves in a northeastern direction farther into the Norwegian Sea.*

approximately at noon and were completed between 5 and 10 hours later, dependent on the weather conditions and other complications that might occur. The average number of hooks in each set was about 2000. The fishing took place between November and March during the

Table 1. *Number of wild and escaped farmed salmon tagged by month in Faroese waters November 1992 to March 1995.*

Month	No wild salmon	No farmed salmon	Total
November 1992	469	212	681
December 1992	204	62	266
March 1993	1311	793	2104
November 1993	126	50	176
December 1993	102	41	143
February 1994	80	26	106
March 1994	132	57	189
November 1994	392	106	498
December 1994	149	36	185
February 1995	311	100	411
March 1995	535	154	689
Total	3811	1637	5448

three fishing seasons 1992/93, 1993/94 and 1994/95. The area fished during the autumn part (November-December) was closer to the Faroes than the area fished in the winter (February-March) (Figure 1).

Immediately after capture the salmon that were judged to have a fair probability of survival were individually tagged with numbered Lea tags. The fish were measured (fork length) and a few scales were removed from the dorso-lateral area as recommended by Shearer (1992 ed.). If possible the hook was removed, but in cases where removal could seriously damage the fish, the hook was left in the fish. The salmon were kept in a tank with a continuous inflow of sea water onboard the vessel for some time allowing the fish to recover after handling and tagging. If the fish seemed fit by visual inspection, the decision to release the fish was taken.

All fish were determined to be of wild or farmed origin by examining whether the fish showed external characters like e.g. fin erosion which is common on reared salmon (Lund *et al*. 1989), and by analysis of scales (Lund & Hansen 1991). The number of wild and farmed salmon tagged by month is shown in Table 1, and Figure 2 shows the length distribution per half season of both groups. The sea age of wild salmon was estimated by splitting the length frequencies into sea age cohorts (see e.g. Anon. 1996), i.e. fish less than 57 cm forklength were taken to be one sea winter (1SW), fish between 57 to 82 cm forklength were taken to be 2SW, and fish larger than 82 cm were 3SW. The sea age cohort can be readily seen from the length frequency data of wild fish (Figure 2), with 2SW fish as the dominating sea year class. It should be noted that the incidence of 1SW fish is more pronounced in the autumn than in the winter. It can also be observed that the length distribution of wild and farmed salmon is similar.

Tags were reported from commercial fishermen operating in home waters, and from anglers in rivers, and they submitted information about date, time and site of recapture, the size of the fish and the gear used for catching the fish. To estimate the proportion of wild fish originating from the different countries we corrected the observed distribution by country with their respective mean exploitation rates in homewaters (Anon. 1996) plus and minus

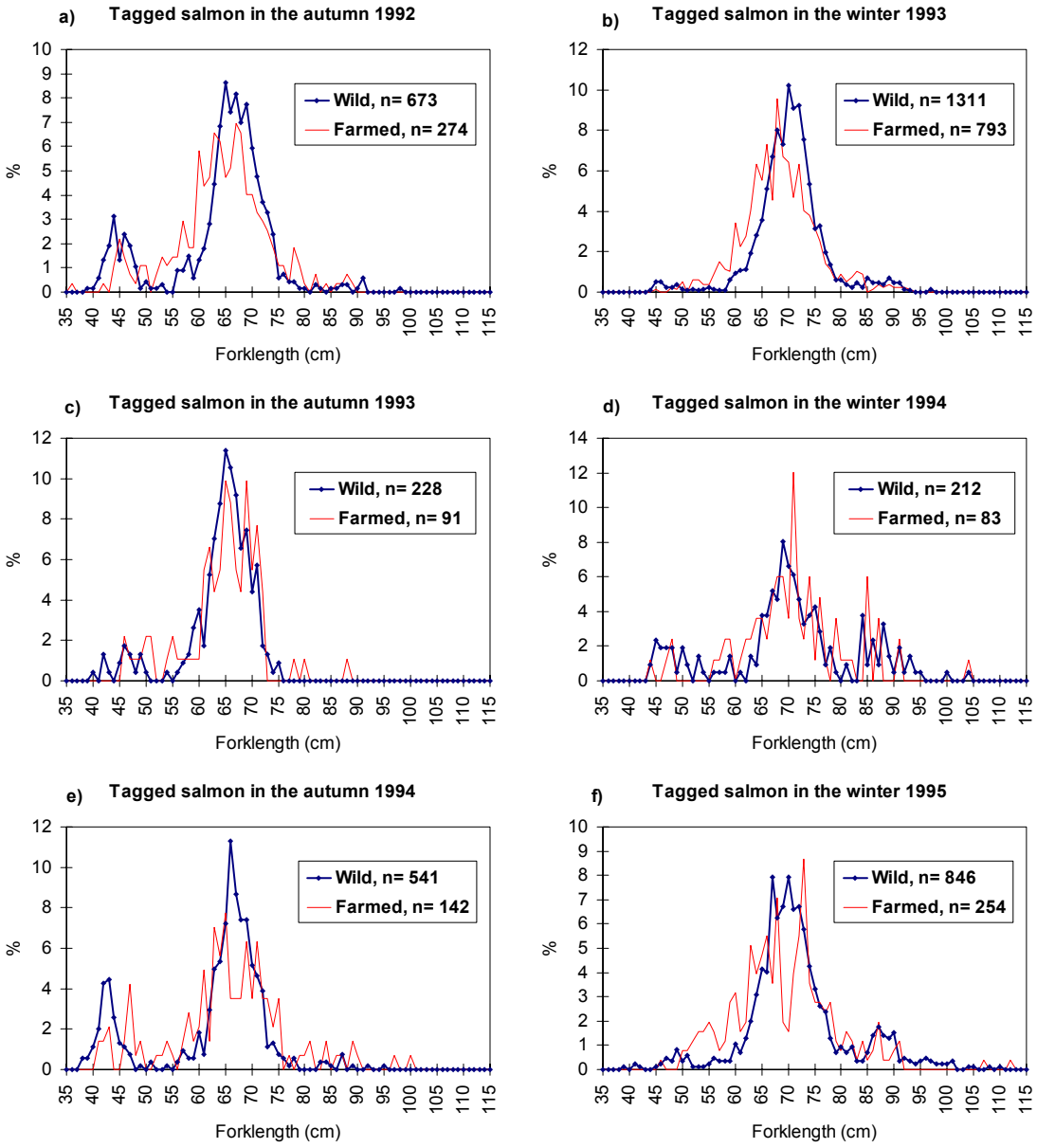

Figure 2. *Length distributions of wild and farmed salmon tagged north of the Faroes in three fishing seasons (1992/93, 1993/94, and 1994/95). The fishing season is divided into Now-Dec period (autumn) and Feb-Mar period (winter).*

10% error. Furthermore, the recaptures from each country were adjusted for their respective homewater tag reporting rates (ICES North Atlantic Salmon Working Group members, 1997, personal communications). The error due to sampling size of the estimated proportions of salmon recaptured by country was estimated using a binominal model. Monte Carlo simulations ('At Risk') were used to introduce error estimates (95% confidence limits) on the estimated proportion of fish returning to different countries. Farmed or reared salmon were not included in this analysis.

Table 2. *Overall recapture rates of salmon in number (% in brackets) tagged at Faroes by period of tagging (autumn: Nov-Dec and winter: Feb-Mar).*

Season	Wild	Farmed	Total
Autumn 1992	11 (1.6)	1 (0.4)	12 (1.3)
Winter 1993	36 (2.7)	8 (1.0)	44 (2.1)
Autumn 1993	3 (1.3)	1 (1.1)	4 (1.3)
Winter 1994	5 (2.4)	2 (2.4)	7 (2.4)
Autumn 1994	7 (1.3)	1 (0.7)	8 (1.2)
Winter 1995	24 (3.0)	6 (2.4)	31 (2.8)
Total	87 (2.3)	19 (1.2)	106 (1.9)

Results

The overall recapture-rate of the number of salmon tagged was small, until the end of 1996 only 106 fish were recovered which is 1.9% of the number of salmon tagged. Of wild fish 87 individuals (2.3% of the number tagged) were recaptured, whereas 19 (1.2%) of the fish identified as fish farm escapees were recovered (Table 2). The recapture rate of fish of farmed origin is significantly lower than for wild fish (χ^2= 6.8, df= 1, P= 0.009). For both wild and farmed salmon, the recapture rates were lower of fish tagged in the autumn than in winter (Table 2) (χ^2= 7.3, df= 1, P= 0.007). Tags were reported from large areas in the North Atlantic, both from marine fisheries and in freshwater. No tags were recovered from the research fishery at Faroes nor from West Greenland.

Table 3. *Recaptures in number of wild salmon in different countries tagged at Faroes during the 1992/1993, 1993/1994 and 1994/1995 fishing seasons.*

Country	Tagged 1992/1993		Tagged 1993/1994		Tagged 1994/1995		Total	
	Rec.93	Rec.94	Rec.94	Rec.95	Rec.95	Rec.96	No	%
Norway	22	3	2		17	3	47	54.0
Scotland	8		1		3		12	13.8
Ireland	3		2		4		9	10.3
Sweden	2	1			1		4	4.6
Russia	1	1	3		1		6	6.9
Canada	1				3		4	4.6
Denmark	2						2	2.3
England	1						1	1.1
Iceland	1						1	1.1
Spain	1						1	1.1
Total	42	5	8	0	29	3	87	99.8

In wild fish the majority of the tags were reported from Norway, but there were relatively large numbers from Scotland and Ireland (Table 3). The geographic distribution of recaptures of fish tagged the three respective fishing seasons is shown in Figures 3, 4 and 5. Tag returns were scattered over large areas of Norway, and Scotland suggesting that fish from large areas of these countries were present in the same areas at Faroes. It is interesting to note, however, that 4 recaptures were reported from Canada, one tagged in March 1993 and recaptured in Miramichi River September 1993, three tagged in February/March 1995 and

two subsequently recaptured in the Miramichi in September 1995 and one in Kouchibouguac River (close to Miramichi) in October 1995. It is also evident that salmon from distant areas, such as northeast Russia and Spain were present at Faroes. Of fish recaptured relatively close to the tagging site there was no apparent difference in the distribution of salmon that was tagged in the autumn or in the winter. This does not seem to be the case of fish that were recaptured relatively far away from the tagging sites. They were all tagged in the winter. This may suggest that salmon of distant origin are not present in the Faroese area in the autumn.

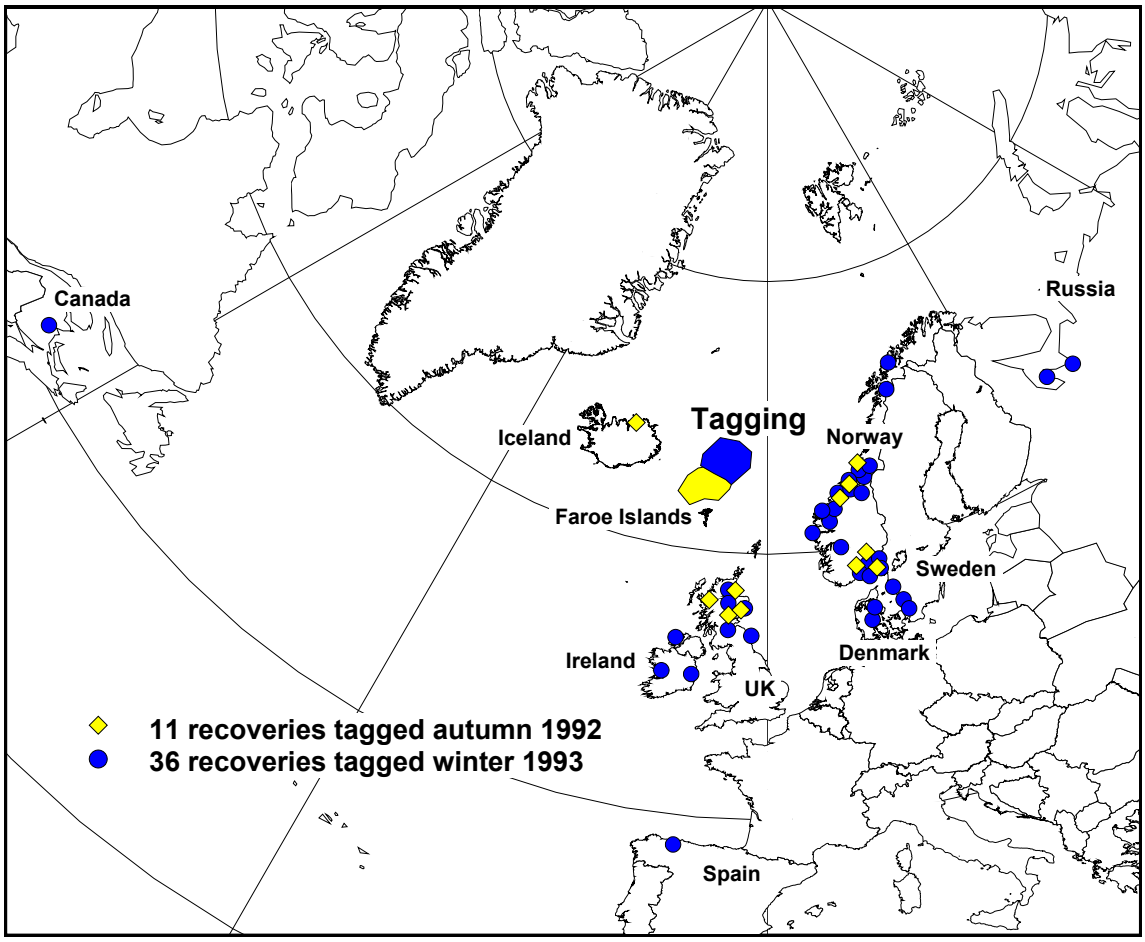

Figure 3. *Recoveries of wild Atlantic salmon tagged in the 1992/93 fishing seasons. Fish were tagged during autumn (Nov-Dec: light shading) and winter (Feb-Mar: dark shading). Recoveries from each tagging period are shown as light diamonds (autumn tagging) and dark circles (winter tagging).*

Of the 19 fish farm escapees recaptured, 18 were recovered from Norway, and one from the west coast of Sweden, at Ugglarp (Table 4), and a detailed geographic distribution of the recaptures shows that the fish were distributed over large areas of coastal Norway (Figure 6).

The recapture rate of salmon increased significantly with sea age (Figure 7) ($G= 13.9$, $df= 2$, $P= 0.001$). However, the power of the test might be questioned, as only two 1SW fish was recovered.

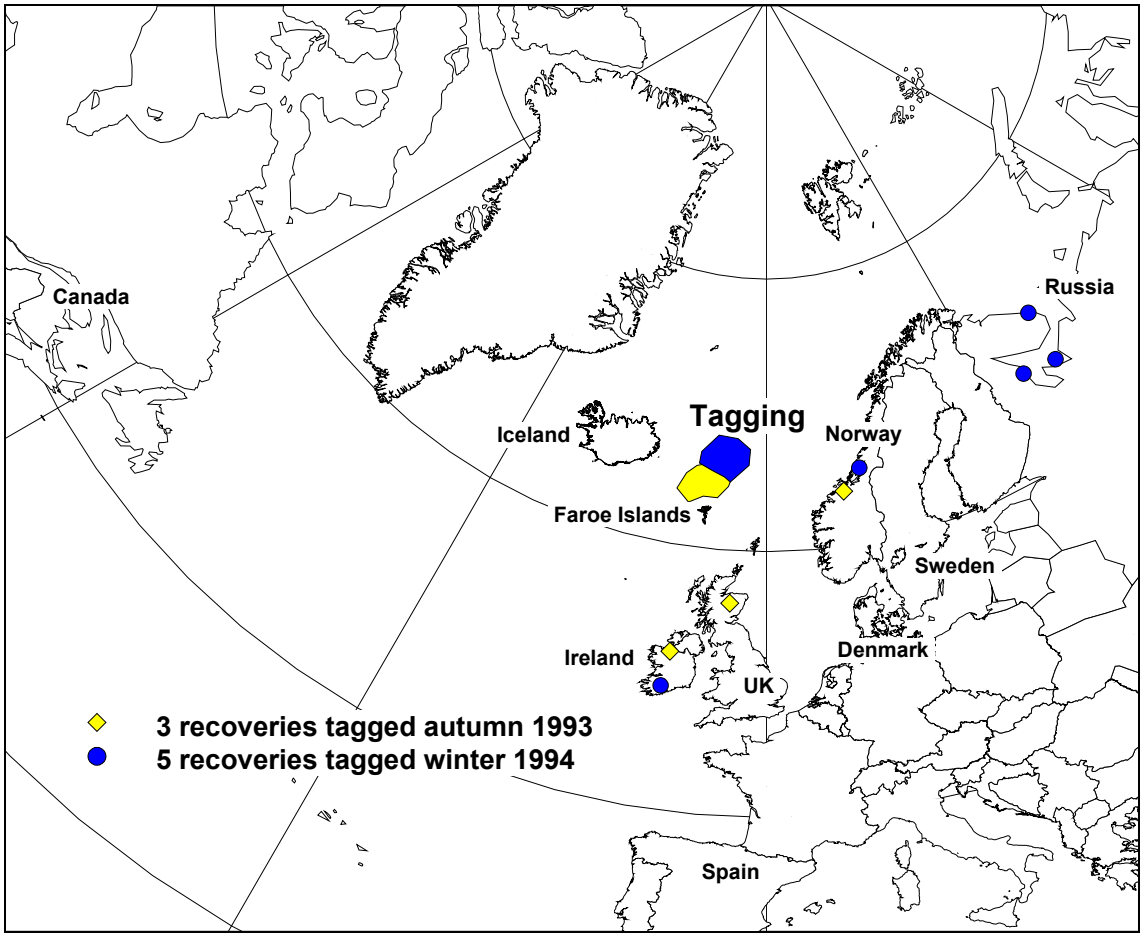

Figure 4. *Recoveries of wild Atlantic salmon tagged in the 1993/94 fishing season. Fish were tagged during autumn (Nov-Dec: light shading) and winter (Feb-Mar: dark shading). Recoveries from each tagging period are shown as light diamonds (autumn tagging) and dark circles (winter tagging).*

Of the wild fish, 8 individuals of a total of 87 fish recaptured (9.2 %), appeared to stay for an additional year in the sea before returning to home waters (Table 3). Probably all these fish stayed in the ocean for the whole period of time as inferred by their growth, which were as expected for salmon staying that time period in the ocean.

The overall estimates of the proportion of wild salmon originating from different countries in the research fishery during these three fishing seasons are presented in Table 5 together with assumptions and approximation made. It is not surprising that Norway accounts for the major proportion (41%), whereas the mean estimated proportion of salmon from Scotland and Russia is close to 20 %. For the other countries there are only a relatively small number of fish in the area (Figure 8).

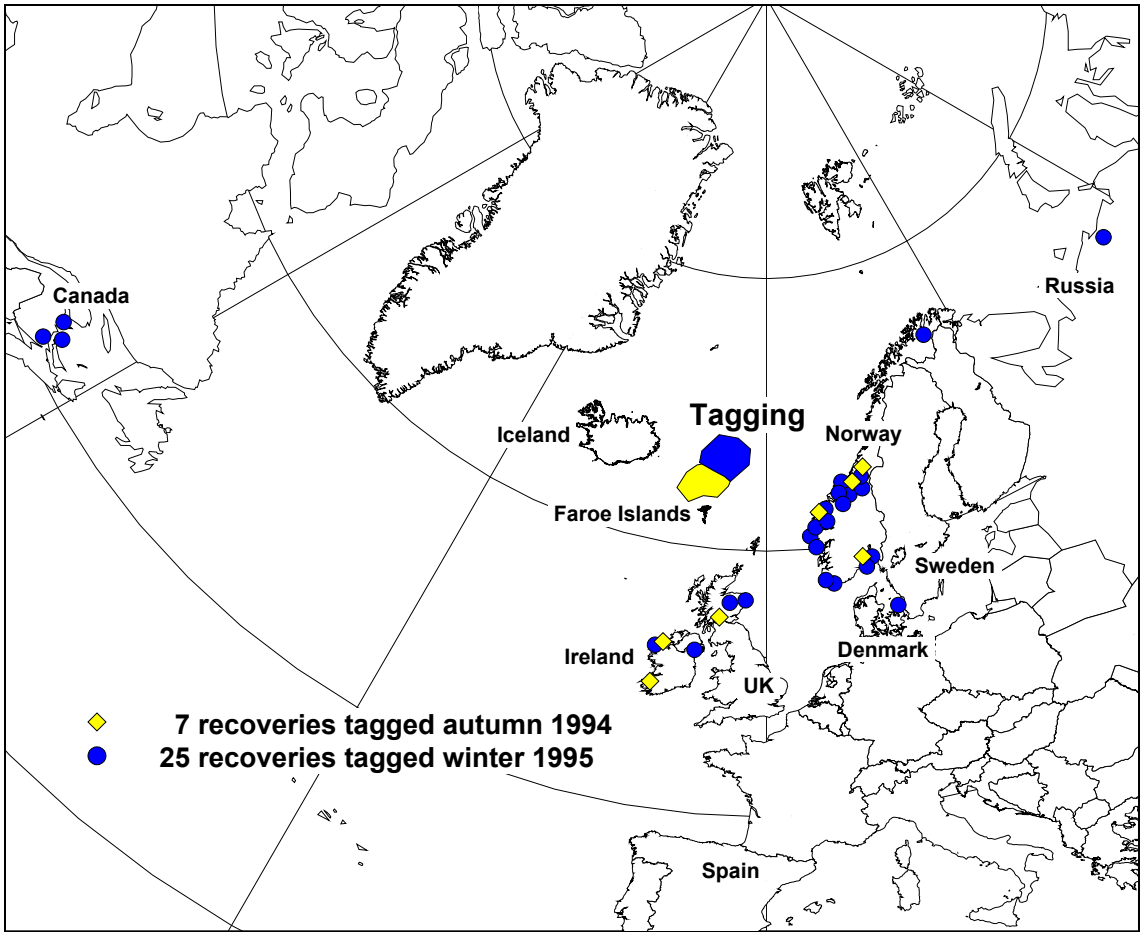

Figure 5. *Recoveries of wild Atlantic salmon tagged in the 1994/95 fishing season. Fish were tagged during autumn (Nov-Dec: light shading) and winter (Feb-Mar: dark shading). Recoveries from each tagging period are shown as light diamonds (autumn tagging) and dark circles (winter tagging).*

Table 4. *Recaptures in number of salmon in different countries of escaped farmed fish tagged at Faroes during the 1992/93, 1993/94 and 1994/95 fishing seasons.*

Country	Tagged 1992/1993		Tagged 1993/1994		Tagged 1994/1995		Total	
	Rec.93	Rec.94	Rec.94	Rec.95	Rec.95	Rec.96	No	%
Norway	8	0	3	0	5	2	18	94.7
Sweden	1	0	0	0	0	0	1	5.3
Total	9	0	3	0	5	2	19	100.0

Discussion

The overall recapture rate of salmon from this tagging experiment is low, suggesting that the survival of the tagged fish is small. In general, handling prior to release is known to stress

salmonids, and the effects of this are suggested to be more serious when the fish are in salt water (e.g. Saunders & Allen 1967; Bouck & Smith 1979; Rosseland et al. 1982; Hansen 1988). It is obvious that the sampling and handling of salmon in this study pose a threat to the

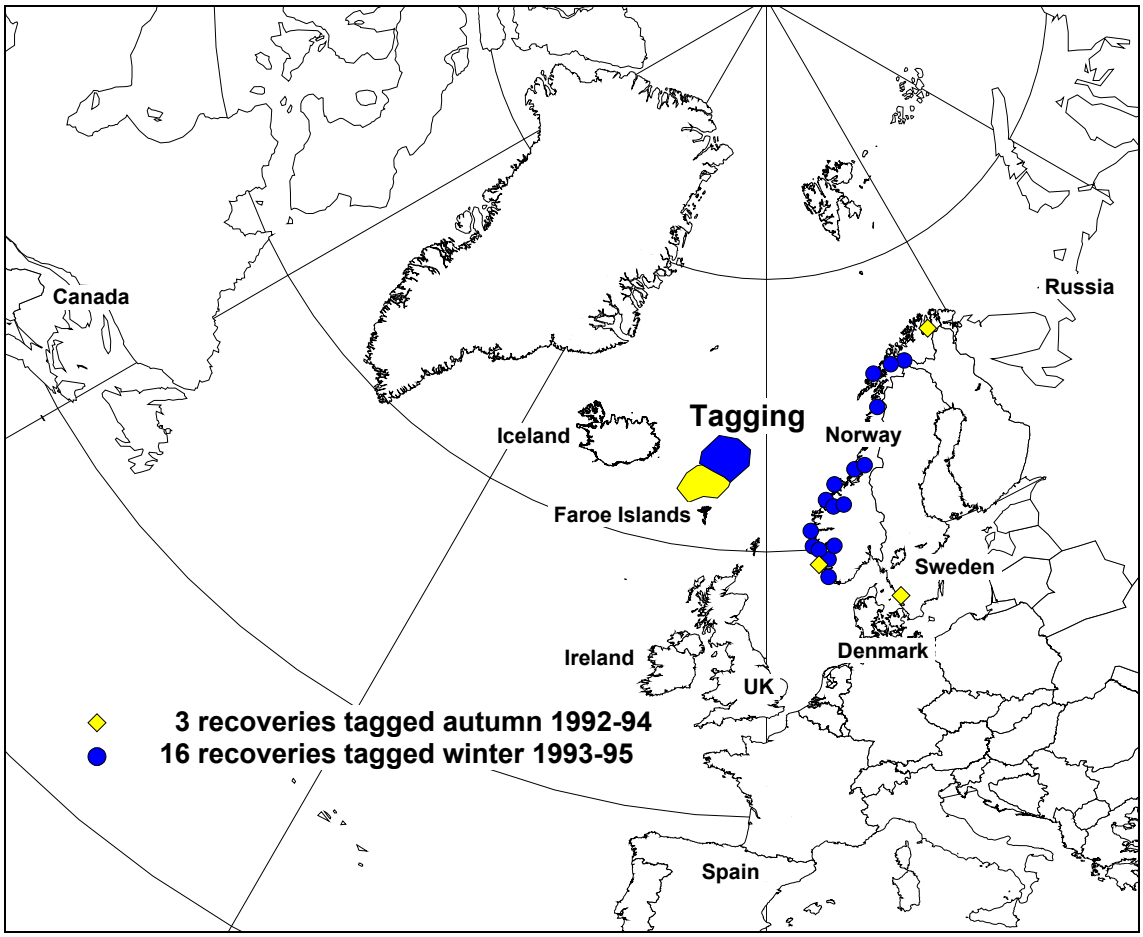

Figure 6. *Recoveries of escaped farmed Atlantic salmon tagged in the 1992/93-1994/95 fishing seasons north of the Faroes. Fish were tagged during autumn (Nov-Dec: light shading) and winter (Feb-Mar: dark shading). Recoveries from each tagging period are shown as light diamonds (autumn tagging) and dark circles (winter tagging).*

fish, and because decisions to release the fish had to be taken on visual judgement of the external performance of the fish in a saltwater tank onboard the vessel, we probably released many fish that were unable to survive. One important factor is loss of scales. When the fish are in saltwater a heavy scale loss will give the fish severe osmotic problems which may result in death or increased stress making the fish vulnerable to predation or different pathogens (Bouck & Smith 1979; Rosseland et al. 1982). Scale loss appeared to be more frequent among small than large salmon, so this may at least partly explain the low recapture rate observed in small salmon. Presumably the small salmon in general suffers higher predation after release than the larger salmon. Furthermore, an alternative explanation can be that 1SW fish are less vulnerable to homewater exploitation than larger salmon.

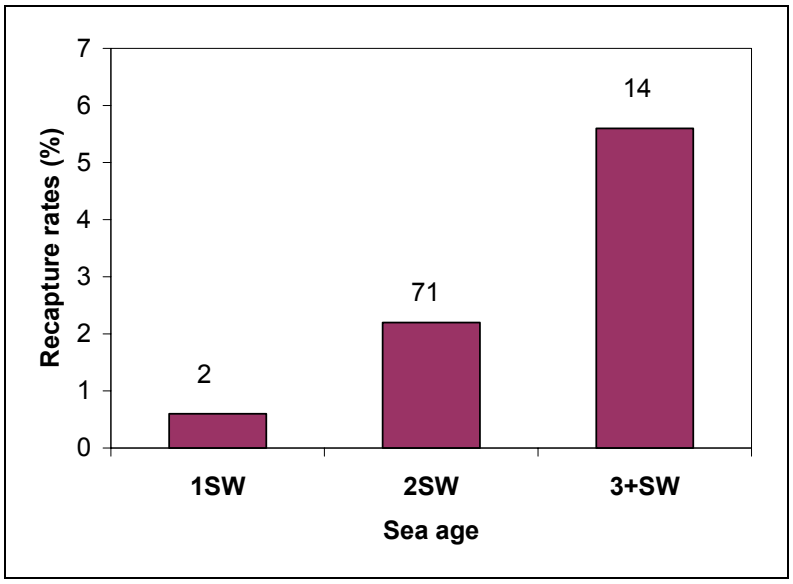

Figure 7. *Recapture of salmon tagged at different sea age at Faroes. The figures give the actual numbers of recapture.*

Table 5. *Results of 'At Risk' simulation to estimate proportion (%) of fish tagged at Faroes returning to different countries. Confidence limits (95%) were applied based on 1000 simulations. Recoveries were adjusted for homewater exploitation rates and tag reporting rates as provided by the North Atlantic Salmon Working Group members, 1997.*

Country	No.	Tag reporting rate		Exploitation rate		Estimated	Simulation		
	recapt.	min	max	min	max	recapt.	'-5%	Mean(%)	'+95%
Norway	47	0.40	0.60	0.50	0.80	144.6	28.6	41.1	55.3
Scotland	12	0.80	1.00	0.10	0.30	66.7	9.1	19.9	34.3
Russia	6	0.60	0.80	0.10	0.15	57.1	8.2	18.9	31.0
Ireland	9	0.60	0.80	0.50	0.75	20.6	2.7	5.8	9.7
Denmark	2	0.40	0.60	0.14	0.34	16.7	0.0	4.9	12.3
Canada	4	0.65	0.85	0.35	0.55	11.9	0.8	3.4	6.8
England	1	0.40	0.60	0.15	0.35	8.0	0.0	2.4	7.2
Sweden	4	0.55	0.75	0.55	0.90	8.5	0.6	2.4	4.9
Spain	1	0.60	0.80	0.55	0.85	2.0	0.0	0.6	1.7
Iceland	1	0.80	1.00	0.40	0.60	2.2	0.0	0.6	1.9
Total	87					338.3		100	

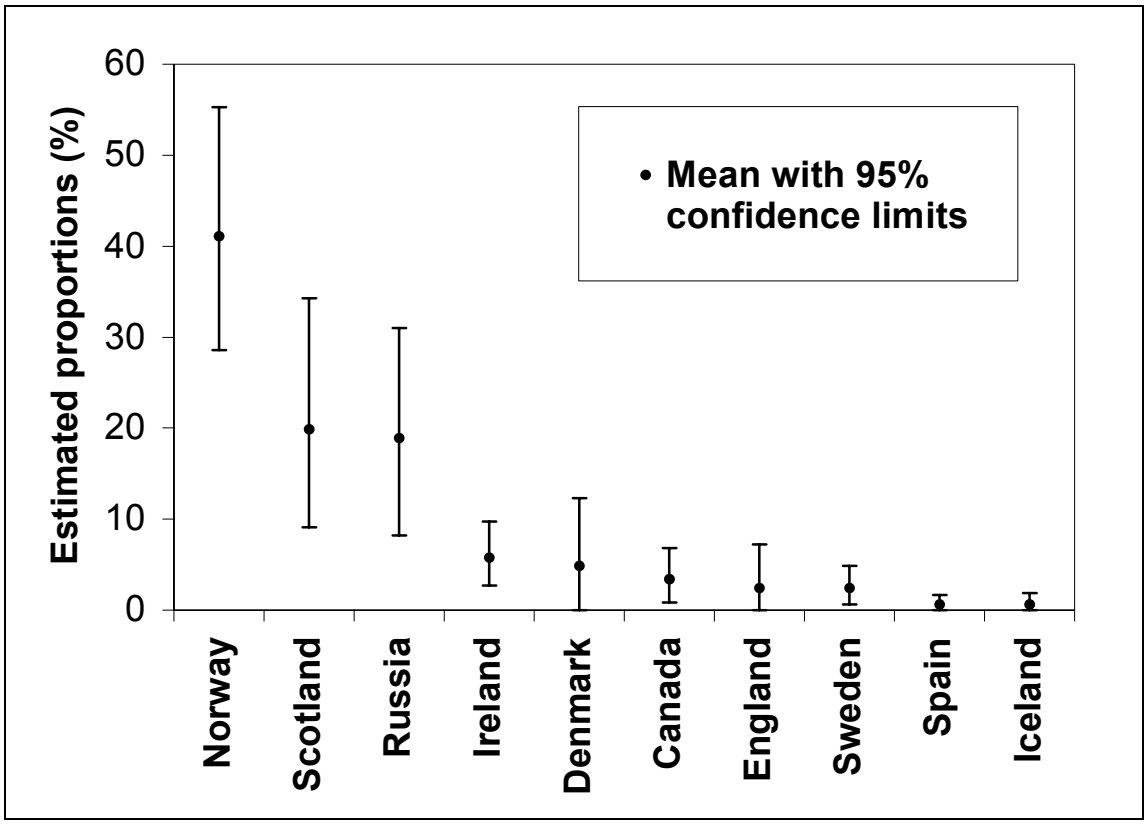

Figure 8. *Estimated proportions at Faroes (mean with 95 % confidence limits) of salmon from different countries.*

Fish that were tagged in the winter seem to survive better than fish tagged in the autumn. There may be several explanations for this. First the fish that were tagged in the autumn were smaller than those tagged in the winter, and may thus be more vulnerable to handling and tagging stress and predation. Second, these fish will spend longer time in the sea than fish tagged in the winter, and may be exposed to different marine mortality factors for a longer period of time. Third, Jacobsen & Hansen (1996) showed that the feeding intensity of salmon in the Faroese area was much lower during autumn than winter, indicating that the autumn period is relatively stressful for the fish. Furthermore, based on smolt age and sea age distribution of salmon, Jacobsen et. al (1997) suggested that fish originating from stocks in southern Europe were more abundant in the autumn than in winter. If this holds true, we can not rule out the possibility that the differences in survival may reflect recent observations made by the North Atlantic Salmon Working Group (Anon. 1997) that marine mortality of salmon stocks from southern Europe has increased more quickly than for salmon from Scandinavia and Russia.

The estimated proportions of salmon from different countries in the research fishery the three fishing seasons show that Norway accounts for the major part of the stock complex, although there are also significant abundance of salmon from Scotland, Russia and Ireland. Because 1SW accounts for most of Irish salmon runs, it is reasonable to assume that the proportion of Irish salmon north of the Faroes is underestimated. The reason for this is the apparent high mortality of tagged 1 SW salmon. This is further supported by previous occurrence of many microtagged 1 SW salmon of Irish origin reported from the Faroes fishery (Anon. 1996).

All in all, the geographical distribution of recaptured wild fish in homewaters, strongly suggests that fish from most areas of the distribution range of Atlantic salmon are at some life stage present in the area in the Norwegian Sea north of the Faroe Island. This is supported by the fact that tagged wild fish have been recovered in north America, in Spain and eastern part of European Russia, as well as in all major salmon producing countries in Europe. This does not mean that all stocks are systematically abundant in the area, but some of them may pass through occasionally, or that components of stocks systematically use the area for feeding.

Almost 90 % of the fish recaptured were reported from home waters the same year as the were tagged. This shows that a large proportion of the salmon were sexually maturing. Estimates of the incidence of maturity of salmon (based on hormone analyses) caught in the Faroes fishery in 1982 and 1983 suggested that between 70 and 80 % of the fish were maturing (Anon. 1984).

The distribution of salmon at Faroes has earlier been assessed from sampling the fishery for a number of years. Some of the results have been reported by Jákupsstovu (1988), and he also reported on a tagging program during the period 1969 to 1976 where in total 1,946 salmon caught on long line were tagged and released back into the sea. The fish were tagged in more southerly areas of the Faroes, and because the fish had to be bought from the fishermen, 1SW fish were probably highly over represented in the material released. In total 90 fish were recovered, 33 in Scotland, 31 in Norway, 15 in Ireland, 8 in other European countries, and 3 at West Greenland. Total recapture rate was 4.6%. This result is somewhat different of the observations reported in the present paper, and the difference may be due to selection of the fish for tagging, or that the tagging took place in more southern areas than the present experiment. The great majority of the tags were reported the same year as they were tagged, suggesting that many fish were sexually maturing. However, it is interesting to note that some fish in the area may have been on their way westwards, as they were reported from West Greenland later the same the year. In the present experiment no fish were recaptured at West Greenland. However, this may be due to the fact that the fishing effort in this area has been very small in recent years.

Of the total number of salmon tagged and released 30.0% were estimated to be of farmed origin. This figure is of slightly higher than reported by Hansen *et al*. (1997) in random samples from whole catches during the same period. Not all fish captured are tagged, so the difference between the groups may be due to the possibility that a higher proportion of farmed than wild fish are tagged and released. The reason for this may be that fish farm escapees are used to be handled, and may thus be less vulnerable than wild fish to capture and tagging procedure. Hansen & Jonsson (1991) showed that reared salmon kept in saltwater, tagged and released into a Norwegian fjord every month throughout a year, tended to return to the geographical area of release except when released in late winter. Then they tended to stray far away from the release site. When the fish were released in the summer and autumn, their survival appeared to be very poor (Hansen & Jonsson 1989). This performance of reared fish has recently been confirmed by sequential releases of individually tagged large farmed salmon from two fish farms in Norway (L.P. Hansen in preparation). Thus this may help to explain the observed difference in the survival between wild and farmed salmon. Our observation that most of the tagged farmed salmon in the present experiment were recaptured in Norway, may suggest that these fish escaped from Norwegian fish farms.

Acknowledgements

We sincerely thank the crews on "Hvítiklettur" and "Polarlaks", and the staff at Faroes Fisheries Laboratory for carrying out the sampling. We are also much indebted to Leidulf Fløystad, Gunnell Østborg and Roar A. Lund for excellent assistance in the laboratory. Furthermore, we are greatly indebted to Ted Potter and the members of ICES Salmon Working Group for helpful discussions. The Faroese Government, the Nordic Council of Ministers, the Norwegian Research Council and the Directorate for Nature Management in Norway provided financial support. One of the authgors (JAJ) is in receipt of a personal grant from NORFA (Nordic Academy for Advanced Study) during 1996/97.

References

Anon. 1984: Report of the meeting of the working group on north Atlantic salmon. *ICES CM 1984/Assess:16*

Anon. 1996: Report of the Working Group on North Atlantic salmon. *ICES CM 1996/Assess:11*, 227 pp.

Anon. 1997: Report of the Working Group on North Atlantic salmon. *ICES CM 1997/Assess:10,* 242 pp.

Bouck. G.R. & S.D. Smith 1979: Mortality of experimentally descaled smolts of coho salmon (*Oncorhynchus kisutch*) in fresh and salt water. *Transactions of the American Fisheries Society* **108:** 67-69.

Hansen, L.P. 1988: Effects of Carlin tagging and fin clipping on survival of Atlantic salmon (*Salmo salar* L.) released as smolts. *Aquaculture* **70:** 391-394.

Hansen, L.P. & B. Jonsson 1989: Salmon ranching experiments in the River Imsa: Effect of timing of Atlantic salmon (*Salmo salar*) smolt migration on survival to adults. *Aquaculture* **82:** 367-373.

Hansen, L.P. & B. Jonsson 1991: The effect of timing of Atlantic salmon smolt and post-smolt release on the distribution of adult return. *Aquaculture* **98:** 61-67.

Hansen, L.P., Døving, K.B. & Jonsson, B. 1987: Migration of farmed adult Atlantic salmon with and without olfactory sense, released on the Norwegian coast. *Journal of Fish Biology* **30:** 713-721.

Hansen, L.P., Jacobsen, J.A. & Lund, R.A. 1993: High number of farmed Atlantic salmon, *Salmo salar* L., observed in oceanic waters north of the Faroe Islands. *Aquaculture and Fisheries Management* **24:** 777-781.

Hansen, L.P., J.A. Jacobsen & R.A. Lund 1997: The incidence of escaped farmed Atlantic salmon, *Salmo salar* L., in the Faroese fishery and estimates of catches of wild salmon. *ICES CM 1997/AA:04,* 8 pp.

Jacobsen, J.A., R.A. Lund & L.P. Hansen 1997: Smolt age and sea age distributions of Atlantic salmon (*Salmo salar* L.) in the sea north of the Faroe Islands during 1991 to 1995. *ICES CM 1997/BB:08,* 8 pp.

Jákupsstovu, H. i. 1988: Exploitation and migration of salmon in Faroese waters. In: *Atlantic Salmon: Planning for the Future* (ed. by D.H. Mills & D.J. Piggins), pp. 458-482. Croom Helm, London & Sydney.

Lund, R.A. & Hansen, L.P. 1991: Identification of wild and reared Atlantic salmon, *Salmo salar* L., using scale characters. *Aquaculture and Fisheries Management* **22:** 499-508.

Lund, R.A., L.P. Hansen, & T. Järvi. 1989: Identification of reared and wild salmon by external morphology, size of fins and scale characteristics. *NINA Research Report* **1:** 1-54 (In Norwegian with English summary).

Lund, R.A., G.M. Østborg & L.P. Hansen 1996: Rømt oppdrettslaks i sjø- og elvefisket i årene 1989-1995. *NINA Oppdragsmelding* **411:** 1-16.

Rosseland, B.O., T.B. Lea & L.P. Hansen 1982: Physiological effects and survival of Carlin tagged and descaled Atlantic salmon, Salmo salar L., in different water salinities. *ICES CM 1982/M:30,* 23 pp.

Saunders, R.L. & K.R. Allen 1967: Effects of tagging and fin-clipping on the survival and growth of Atlantic salmon between smolt and adult stages. *Journal of the Fisheries Research Board of Canada* **24:** 2595-2611.

Shearer, W.M. 1992 (ed.): Atlantic salmon scale reading guidelines. *ICES Coop. Res. Rep.* **188:** 1-46.