

Atlantic salmon ranching: past problems and future management

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Straying of ranched salmon into rivers in Iceland has given cause for concern because of ecological, genetic, and disease effects on wild stocks. More than 96% of returning Icelandic ranched salmon are harvested at ranching stations. Over 80% of the strays into salmon rivers occurs on the west coast in the area where most of the ranching stations have been located. In that area the ranched component in rivers ranged from <1% to >20% (average 4.4%) of the population, depending on proximity to the ranching sites. Combined strays from river enhancement and from the west coast rivers into the ranching stations averaged 2.5% (97.5% recovered in rivers), which corresponds to 1.0% of the total harvest at ranching stations. Strays of enhanced populations were at least three times more numerous in ranching stations than strays of wild salmon. Eighty-nine to ninety-seven percent of the ranched salmon returning to ranching stations were recaptured in the station of release. Strayers from other ranching stations in the catches of individual ranching stations comprised 2–13% of the catch with the extent of straying being more related to harvest methods and the location of the ranching station than to homing accuracy. Biological and social concerns regarding the harvesting methods at ranching stations, increased illegal fishing effort as a result of ranching and a put-and-take fishery for ranched salmon, which has been developing in Iceland since the late 1980s are discussed. The management implications of these practices are considered as well as possible solutions to the problems associated with ranching.

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Key words: Atlantic salmon management, Atlantic salmon ranching, interaction of salmon, ocean ranching, straying of salmon.

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Introduction

Enhancement of wild Atlantic salmon (*Salmo salar* L.) populations through smolt releases has been conducted in various countries bordering the North Atlantic for decades. In the absence of a local sea fishery, commercial ranching of Atlantic salmon has been developed in Iceland based on terminal fisheries utilizing traps in ranching stations. This has led to concern for the integrity of wild salmon stocks and considerable information has been gathered over the last ten years on the straying of salmon from ranching stations into rivers, from rivers into ranching stations and between ranching stations. This paper

summarizes some of this information and examines the biological and social implications of salmon ranching.

Principles and problems

Definition of ranching

Ocean or sea ranching is the practice of releasing young fish into the marine environment and allowing them to roam and grow in the wild until maturation and harvest (Thorpe, 1980). Usually it refers to the release of salmon smolts which migrate to sea and subsequently return after one or more years as mature fish to the same

freshwater location. Returning Atlantic salmon are usually grilse or 1-sea-winter (1SW) and 2-sea-winter (2SW) fish with older salmon being observed infrequently in ranching operations. There are two types of salmon ranching (Isaksson, 1995). Private ranching is defined as large-scale releases of salmon smolts by private companies with the intent of harvesting all the salmon upon return at the release site. This activity is currently confined to Iceland and is dealt with in this paper. Semi-private ranching is conducted in Japan and Alaska with Pacific salmon, where cooperative companies of fishermen release salmon to enhance local fisheries. All other releases by the public and private sectors for mitigation or restoration purposes are considered to be enhancement activities.

Definition of strayers

Most salmon return to their home stream or place of release after their oceanic feeding migration. Those that are captured elsewhere are termed strayers, irrespective of whether they are there intentionally or accidentally, e.g. due to estuarine trapping operations. This definition ignores the possibility that some strayers might have returned to their home stream or place of release if they had not been caught.

Possible implications of salmon ranching for wild salmon

Salmon ranching could influence wild stocks through genetic, disease, and ecological interactions and as a result of harvest in mixed-stock fisheries, which also has social implications. Ranched salmon straying into rivers might breed with the wild populations with potential adverse effects if the genetic make-up of the two populations were greatly different. Similarly, the ranched population could be a carrier of disease, particularly if it had been selected for disease resistance or had been vaccinated. Large-scale ranching could attract marine as well as avian predators, especially at the time of release, leading to a high level of mortality during the wild smolt migrations as has been observed in Norway (Hvidsten and Mökkelgierd, 1987; Hvidsten and Lund, 1988). Competition for food in the estuarine areas or ocean could also reduce survival as well as growth of wild post-smolts, as described for sockeye salmon (*Oncorhynchus nerka*) in Alaska (Peterman, 1984).

In many places the only way to harvest surplus ranched or enhanced salmon is to increase the fishing pressure in mixed stock fisheries in coastal areas during the spawning migration. This may result in overfishing of wild salmon populations, particularly where the populations are small, as occurred in Pacific salmon fisheries and in the Baltic, where salmon (*Salmo salar* L.)

are harvested on the feeding grounds in the main basin (Larsson, 1980).

Ranching in Iceland

Since 1932, the Icelandic laws have prohibited fishing for salmon in the sea with any type of gear. This has been the main catalyst for the development of private ranching in Iceland and the main reason for the healthy status of Icelandic salmon populations. The advent of ranching, however, increased the incidence of illegal salmon fishing in the sea and required greater enforcement activity in coastal areas. It has also resulted in increased fishing effort and catches in a small number of legal coastal nets.

Local river owners and sports fishermen in Iceland have blamed ranching stations for reduced angling catches within a specific geographical area, sometimes without scientific justification. This view has been supported by the large quantities of salmon returning to a ranching facility (50 000–100 000 salmon) compared with the small runs into individual rivers (500–2000 salmon). Non-traditional harvesting methods developed by the ranching stations in the upper estuarine areas to ensure the quality of their product have compounded the dispute and it has been argued that these methods represent a harvest in sea water, contrary to legislation.

In Iceland, the fishing rights in rivers and lakes are privately owned and are not separable from the ownership of the adjoining land. The law requires the fair sharing of the resource between the river owners, who must form an association, with an elected board, to administer all fisheries matters as well as enhancement activities and river improvements. The Directorate of Freshwater Fisheries is responsible for overall management of the resource, including angling, net fisheries, enhancement, farming, and ranching. The Directorate is also responsible for the enforcement of the salmon legislation, e.g. with respect to illegal fishing of salmon in the sea.

Private ranching in Iceland has created some disputes between interest groups. The most important problems have been related to the harvest strategy employed at ranching stations, an increase in the legal and illegal coastal harvest of salmon, and the development of a put-and-take fishery for ranched salmon as well as the genetic and ecological concerns. Private ranching of Atlantic salmon developed in Iceland in the late 1980s, with total annual releases of more than six million smolts in the early 1990s. The expansion of ranching was experimental and showed that private ranching was not commercially viable due to low return rates and to the decline in the price of salmon internationally, although ranched salmon achieved 20–30% higher prices than did farmed salmon. In spite of the economic difficulties, the

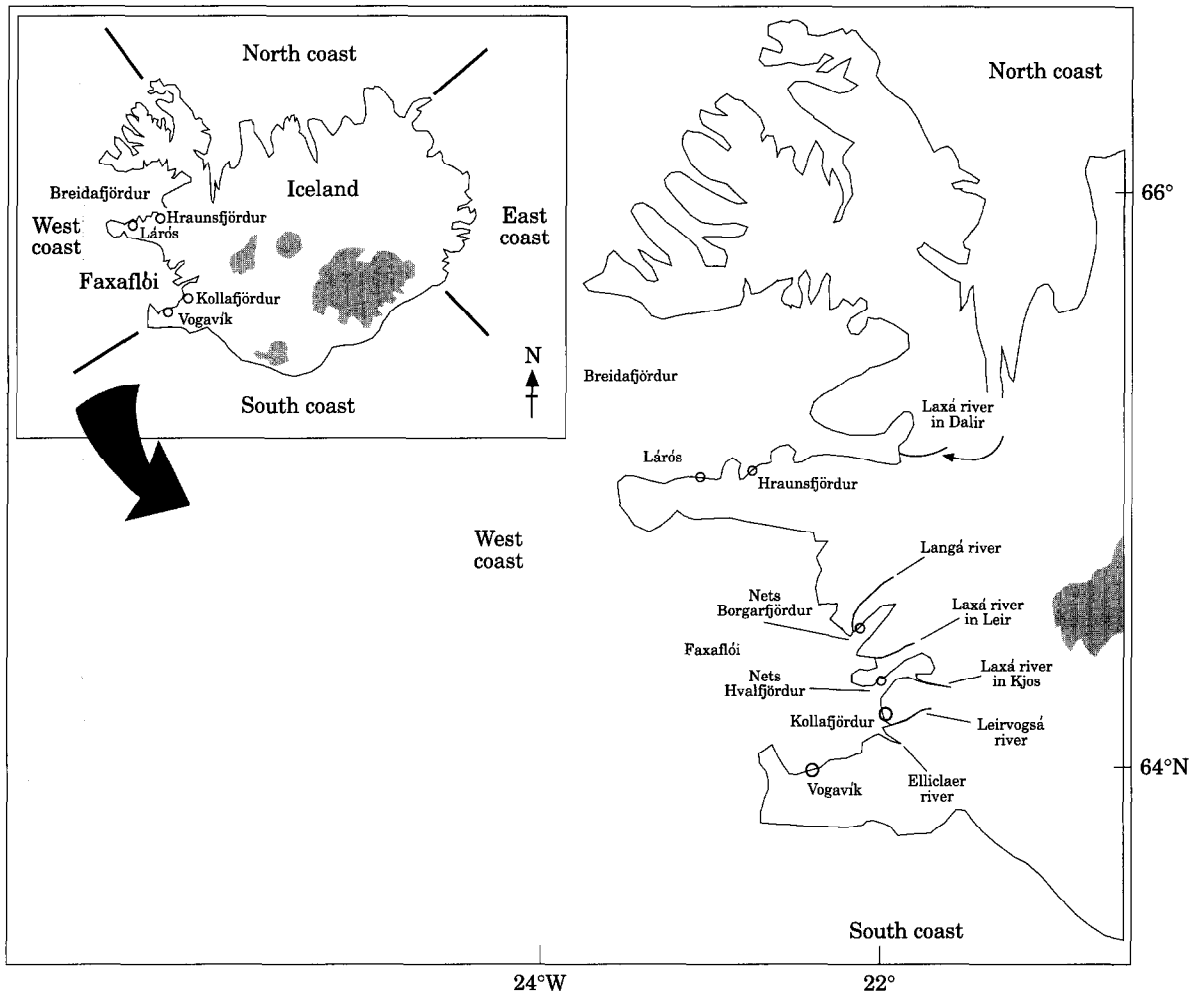


Figure 1. Geographical location of the ranching stations and rivers in Iceland referred to in the text.

ranching contribution to the catches increased rapidly from 1984 (comprising 60–80% of the Icelandic salmon catch during 1989–93) creating various biological and sociological problems.

Tagging

It was anticipated that straying of ranching salmon into salmon rivers would pose the greatest threat to the wild stocks. Although strays occur, sometimes in large numbers, the straying of wild salmon into ranching stations has been of equal or greater concern to the river owners, especially in western Iceland (Fig. 1). Ranching stations may be harvesting wild salmon from various rivers, and this is currently the most critical issue facing Icelandic managers with respect to salmon ranching. Tagging has provided a good insight into these interactions of ranching and wild populations.

Smolts are tagged solely by the Institute of Freshwater Fisheries, which maintains a database on the numbers tagged and recovered. The tagging costs are borne entirely by those requesting tagging (i.e. ranching stations), but the decoding of the tags and analysis of the data have been financed by the Institute of Freshwater Fisheries, which pays tag rewards and operates a lottery to encourage tag returns.

Smolts have been tagged and released in ranching experiments since the early 1960s (Gudjonsson, 1973). Coded wire tags have been used since 1974 (Isaksson and Bergman, 1978) and their benign nature and the efficiency of the process has improved the assessment of the survival and the extent of straying of ranching salmon. The adipose fin is clipped at the time of tagging and the Institute of Freshwater Fisheries collects the snouts of adipose clipped salmon from ranching stations, river associations, and individual sports fishermen. The reporting of tags is high (95%) from the

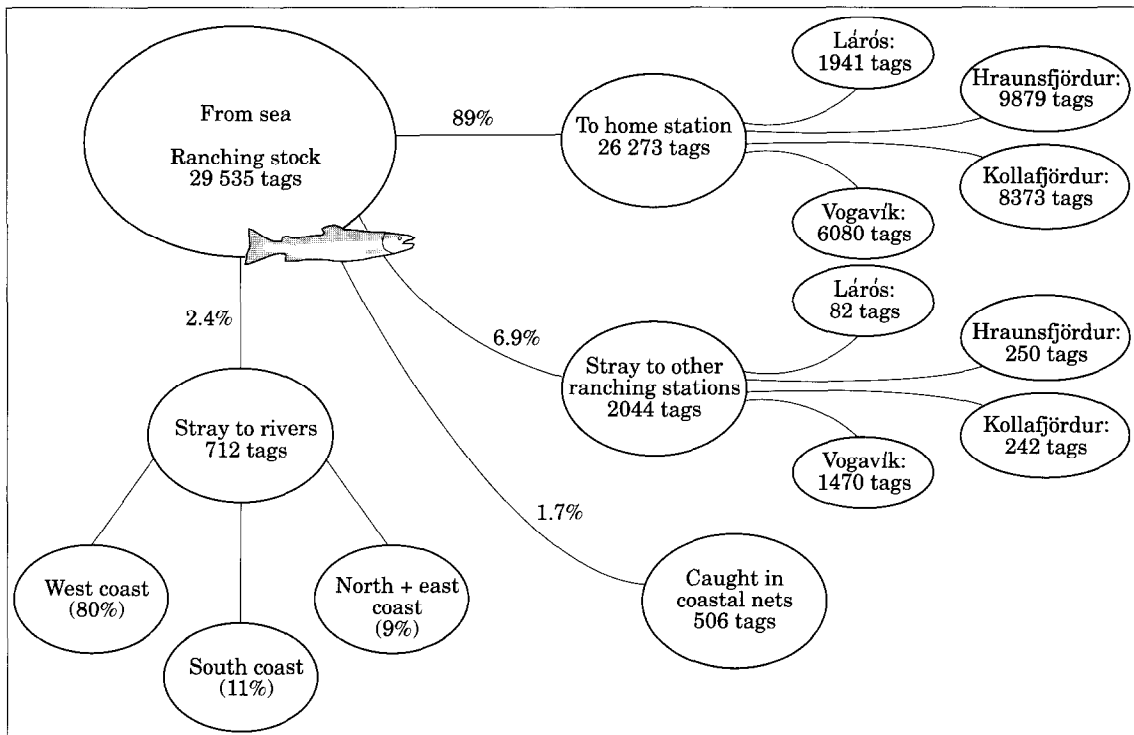


Figure 2. Recaptures of tagged ranched salmon and percent straying to salmon rivers, other ranching stations, and coastal nets 1988–1995.

ranching stations and from a few monitored rivers. Reporting from other salmon rivers is less complete and provides only qualitative information.

During 1987–1994, approximately 1.3 million smolts were microtagged and released in Icelandic ranching stations out of a total of 28 million smolts released. Total recoveries from these releases amounted to 29 500 salmon (28 300 at the ranching stations) with total returns to ranching stations of 770 000 salmon. Wild smolts have been tagged for a number of years in the Ellidaar river in western Iceland, the Midfjardara river in northern Iceland, and the Vesturdalsa river in north-eastern Iceland (Antonsson, 1996; ICES, 1997). Data for straying of wild smolts in western Iceland into ranching stations were only available for the Ellidaar stock.

Straying

Straying of ranched salmon into rivers and between ranching stations was estimated from the Icelandic tagging database. The relative proportions of salmon of wild and enhanced origin in the catches of the ranching stations were also estimated and compared on an area basis. To facilitate this, the total numbers of strayers (tagged and untagged) from individual ranching stations were corrected for the proportion of tags in the total releases from, and recaptures in, the stations. The tags

recovered from the catches in salmon rivers were multiplied by a factor of two to derive the quantity of tags in the escapement (50% harvest ratio).

Straying into rivers

The straying of ranched salmon into rivers is presented as a proportion of the total returns of ranched salmon in Figure 2 and as the ranched component of the total run to the rivers in Figures 3 and 4. The ranched component in salmon rivers on the west coast of Iceland was estimated using both the overall ranched component in the rivers and the component in monitored streams (Fig. 3, Table 1) to reflect the variability between areas and account for the non-reporting of tags in some rivers.

Almost 90% of returning ranched salmon were caught in the ranching station from which they were released (Fig. 2) with 6.9% returning to other stations, 1.7% being caught in coastal nets (mostly from the Kollafjörður ranching station) and 2.4% being reported from salmon rivers (1.7% in west coast rivers (Fig. 1)). Strays from ranching operations have only minor effects (<10% of total strays) on north and east coast salmon populations, since most of the ranching stations are located in the Faxafloi and Breidafjörður areas on the west coast. Further analysis was thus confined to rivers in that area (Fig. 1).

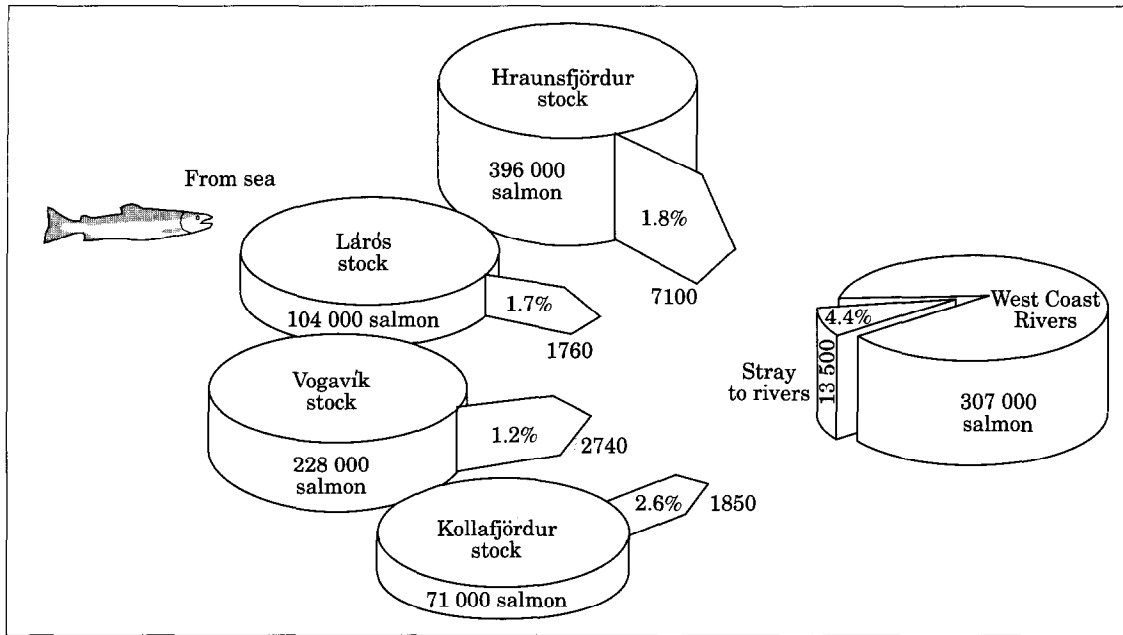


Figure 3. Estimated numbers of ranched salmon and percent straying from the four ranching stations into west coast salmon rivers during 1988–1995. Also shown is the ranched component in the salmon rivers both in numbers and as a percentage of the runs.

Table 1. Estimated catch and proportion of ranched component in monitored rivers and nets in Faxaflói bay (west coast) 1988–1995.

Place of recovery	Vogavík MPC=32		Kollafjörður MPC=6		Laros MPC=40		Hraunsfjörður MPC=34		Total strays from ranching stations Σobs.	Estimated total strays from ranching stations in catches or gear Σest.	Total catch in river or gear	Proportion of ranched salmon in river or gear
	obs.	est.	obs.	est.	obs.	est.	obs.	est.				
Ellidaar	16	512	44	264	6	240	26	884	92	1900	10 205	19%
Leirvogsa	11	352	53	318	2	80	2	68	68	818	3913	21%
Laxa í Kjos*	1	32	7	42	0	0	1	34	9	108	10 778	1.0%
Langa river	3	96	0	0	1	40	7	238	11	374	8502	4.4%
Nets in Hvalfjörður	66	2112	265	1590	22	880	144	4896	497	9478	20 983	45%

MPC=Mean proportional correction coefficient from tagging and harvesting ratio of microtags for each ranching station 1987–1995.

est.: Estimated number=Observed X MPC.

Overall, the ranched salmon component in rivers was variable depending on location. Approximately 13 500 ranched salmon strayed into west coast salmon rivers over the 8-year period, averaging 1600 salmon per annum, or 4.4% of the total population of 307 000 salmon in those rivers during this period (Fig. 4). This was estimated by multiplying the total angling catch during the period (Gudbergsson, 1997) by a factor of 2 (50% harvest ratio). Due to some shortcomings in microtag surveillance, this average figure should be

considered minimal and the ranched component in rivers is thus likely to be underestimated. Comparison with ratios observed in monitored streams is thus of vital importance (Table 1).

The ranching contribution in the Ellidaar and Leirvogsa rivers, close to two ranching stations, was almost 20% (Table 1). Due to the complete sampling of tags in these rivers and their proximity to ranching stations, the figures are probably maximal for Icelandic salmon rivers. In the Langa river, at a greater distance

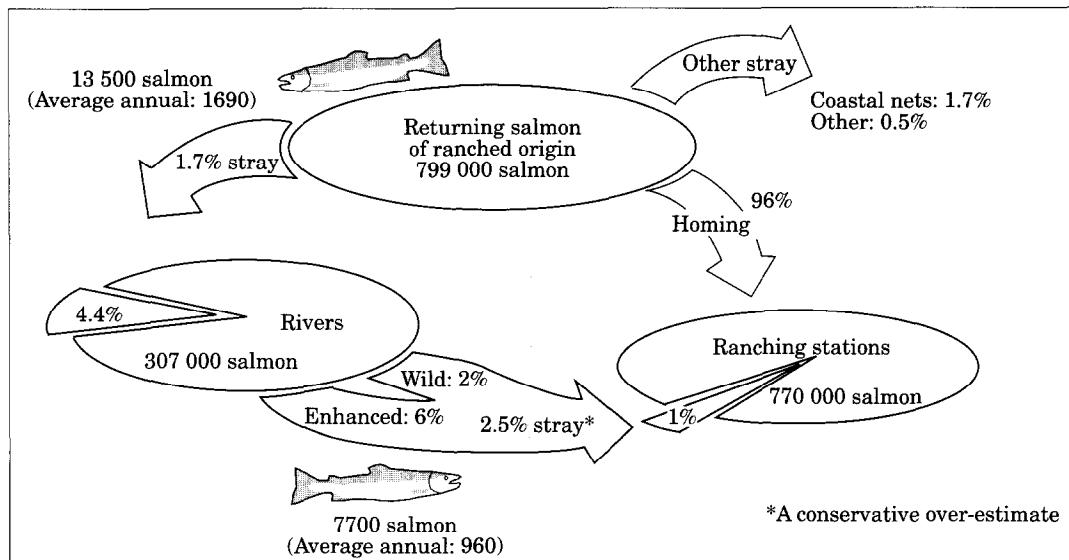


Figure 4. Overview of reciprocal straying into ranching stations and rivers on Iceland's west coast 1988–1995 expressed as numbers and percent. Also shown is the ranched component in rivers and wild/enhanced component in ranching stations.

from the ranching stations, the ranched component was much lower (4.4%), as was the case in the Borgarfjörður coastal nets. Ranching contributed over 45% of the catches in the Hvalfjörður coastal nets during the same period (Table 1).

Gudjonsson (1991) analysed the reared and ranched component in Icelandic salmon rivers with an emphasis on fish farm escapees, which were abundant in Icelandic salmon rivers in the late 1980s, and showed that the effects of rearing and ranching facilities were most pronounced in rivers close to the facilities but decreased with increased distance from the centre of activity. Strays of ranched salmon comprise insignificant proportions of the total stocks in tributaries of complex river systems on Iceland's west coast, but are very significant in smaller rivers flowing directly into the sea. Strays into Icelandic rivers are small in number compared with the strays of farmed salmon into Norwegian rivers, where the numbers of farmed fish frequently exceeded those of wild salmon (Heggberget *et al.*, 1993). It is likely, however, that the spawning success of the ranched salmon is higher than for farmed fish.

Straying into ranching stations

In addition to straying into rivers, ranched and wild salmon have strayed into ranching stations (Table 2). It is suspected that these strays occur because of the harvesting methods at the stations. The main findings are as follows:

- During the 8-year period, 244 tags from salmon tagged in rivers were recovered at ranching stations, which corresponds to 2% straying if the total

estimated riverine recoveries in all parts of Iceland are used (98% returning to home rivers) (Table 2).

- The straying rate was highest (4.9%) from rivers in the Faxaflói area. In this area, salmon from enhancement programmes strayed seven times more frequently (mean 7%, range 1–18%) than wild salmon (1%). Because of the long time series and high quality monitoring the Ellidaar data are the most reliable and a straying ratio of three enhanced to one wild salmon is used in further analysis (Table 2). The straying rates for enhanced salmon into ranching stations (6%) are comparable to those between ranching stations in western Iceland (Fig. 5).
- Straying into ranching stations from other areas in Iceland ranged from 0.3 to 1.5% (Table 2). As straying from Breidafjörður rivers into ranching stations could not be estimated, Faxaflói rates have been used (Table 2).

In order to present a conservative evaluation in the study, the Ellidaar estimate for wild strayers (1%) was multiplied by a factor of 2 to present an overall stray of wild salmon (2%) (Fig. 4).

Recoveries of microtags in the ranching stations are in most cases complete, whereas microtag recoveries from the recreational fisheries in the rivers are often incomplete. So riverine recoveries were, therefore, multiplied by 2 as a minimal correction to account for tagged salmon in the escapement as well as incomplete tag reporting (Table 2). Straying into ranching stations from wild and enhanced populations is thus likely to be overestimated.

The total harvest of microtagged salmon of wild and enhanced origin from the Faxaflói area in the

Table 2. Observed recaptures and estimated proportion of microtagged Atlantic salmon of wild and enhanced origin from various parts of Iceland recovered from coastal nets and in the catches.

Origin	Area of recapture		Area of release (rivers)										Total
			West coast										
			Faxaflói					Breiðafjörður					
			Wild + Enh. control		Enhanced control			Langa í Leir.		Laxa í Kjos		Laxa í Leir.	
		Overall	Ellidaar	Leirvogsa	i Kjos	Laxa í Leir.	Laxa í Leir.	Breiðafjörður	North coast	East coast	South coast		
Wild+ enhanced	Nets in Hvalfjörður	155						6	9	1	2	173	
	Ranching station	46						3	4	2	9	64	
	Faxaflói	69						4	1	0	4	78	
	Breiðafjörður	10						2	0	0	0	12	
	Hraunsfjörður	21						23	13	3	8	68	
	Total strays to ranching stations:	146	22					32	18	5	21	244	
Wild	Estimated tag recoveries to rivers (obs. × 2)	2806	1456					70*	5676	340	1344	11 622	
	Total strays from rivers to ranching stations (%)	4.9%	1.5%					*	0.3%	1.4%	1.5%	2.1%	
	Strays to ranching stations:	11	11					5					
	Estimated tag recoveries to rivers (Obs. × 2)	1100	1100										
	Proportional strays from rivers to ranching stations	1.0%	1.0%										
Enhanced	Strays to ranching stations:	135	11					27					
	Estimated tag recoveries to rivers (obs. × 2)	1706	356					52	41	7	7		
	Strays from rivers to ranching stations (%)	7.3%	3.0%					18.3%	13.4%	2.8%	1.0%		

* Insufficient data.

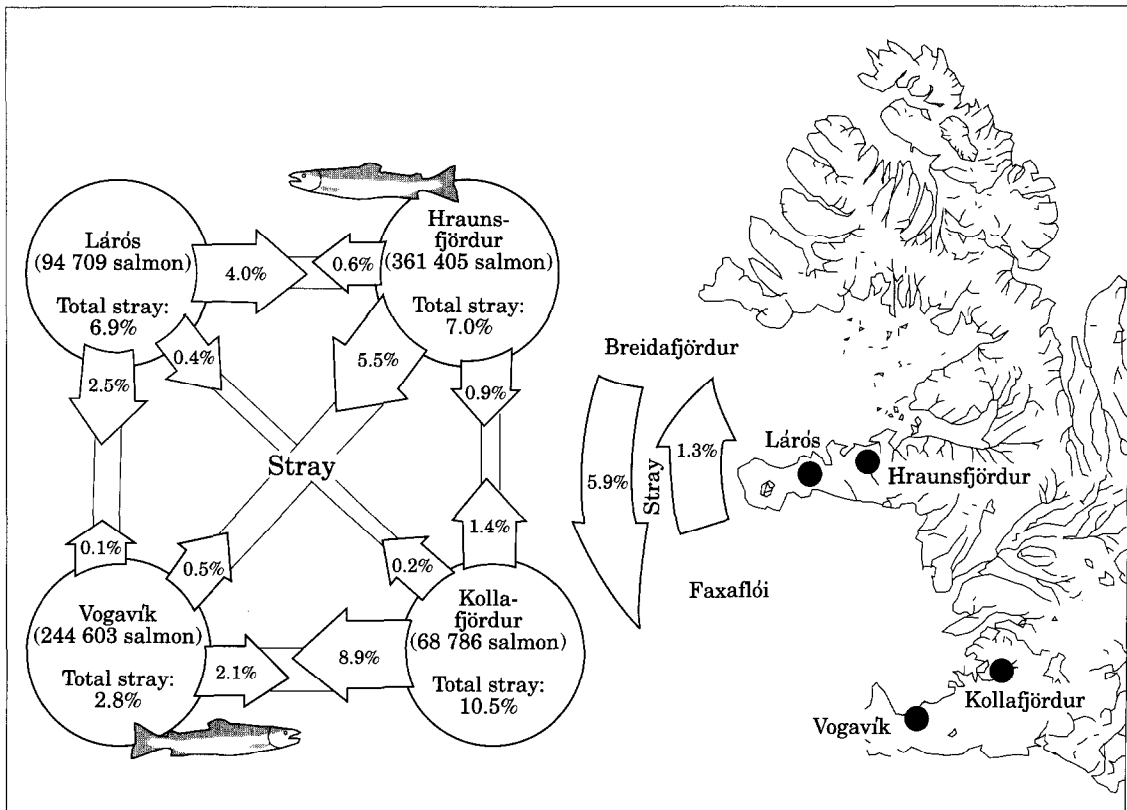


Figure 5. Proportion of microtagged salmon straying between ranching stations and between the Breidafjörður and Faxaflói areas on Iceland's west coast 1988–1995. Also shown are the total catches of salmon at each ranching station during this period.

Hvalfjörður coastal nets was of a similar magnitude as the strays of salmon from rivers in the same area into ranching stations (Table 2).

There were twice as many salmon (13 500) straying from ranching stations into rivers as strayed from rivers into ranching stations (7700). Wild and enhanced components in the harvests at ranching stations were close to 1%, but the ranched component in rivers was close to 4.4% (Fig. 4).

Scale analysis has shown that 1.4% (1200 salmon annually) of the salmon harvest at the Hraunsfjörður ranching station during 1994–1996 was of wild origin (S. M. Einarsson, Institute of Freshwater Fisheries, Borganes, Iceland, unpublished data) which is somewhat higher than the figure (1%) presented in this paper. One reason for this difference might be that this review does not include data for 1996, a year of high straying.

Salmon ranching requires explicit strategies for smolt production, release and harvest (Hansen and Jonsson, 1994; Isaksson, 1994). The ranching stations in Iceland all harvest salmon by seine nets or traps located in estuaries or in fresh water close to the sea (Isaksson, 1994). Salmon tagged in the estuary of the river Ölfusa in south Iceland and in the Blanda River, were recaptured later in several other rivers (Gudjonsson, 1977;

Vidarsson and Gudjonsson, 1994). This suggests that salmon may explore estuaries or lower parts of other rivers prior to entering their home river, a pattern of behaviour which has been confirmed using data storage tags (Sturlaugsson, 1995). Ranched and enhanced salmon populations have a higher degree of such exploratory migrations than do wild salmon and are thus more vulnerable to estuarine netting at ranching stations. This partly explains the higher straying of enhanced salmon into ranching stations.

Straying between ranching stations

With an increase in the number of ranching facilities in the 1980s, a reduction in the distance between facilities and greater numbers of microtagged smolts released and recovered, it became clear that there was considerable straying between ranching stations. It was anticipated that straying between stations might be highly variable depending on the location of stations with respect to the migratory route of the ranched salmon as well as the harvesting methods. The main findings, presented in Figure 5, are as follows:

- Over 97% of the salmon released at the Vogavík ranching station returned there and less than 3%

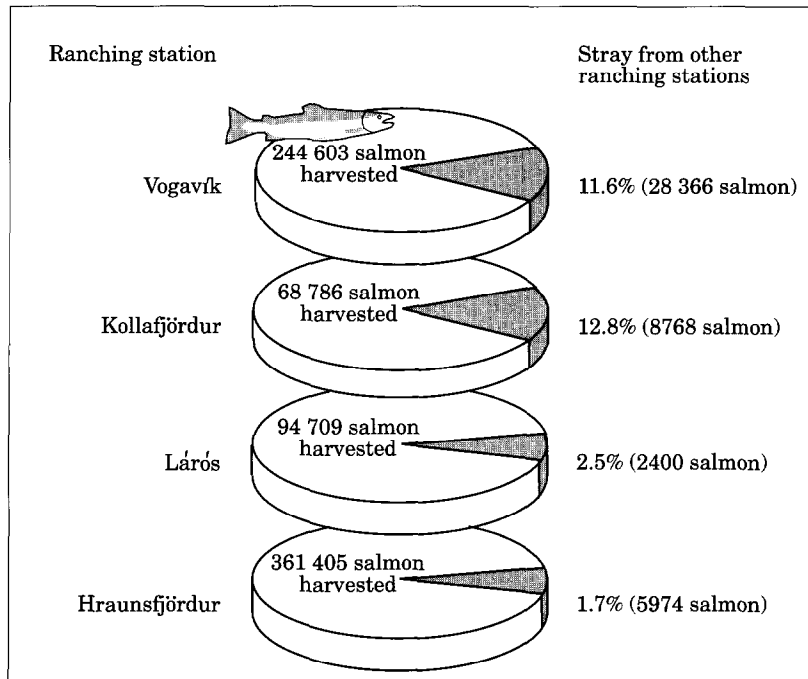


Figure 6. Total harvest and composition of the salmon catch at each ranching station between 1988 and 1995, showing the contribution from other stations expressed as numbers and percentage of the catch.

strayed to other stations, mostly to the Kollafjörður ranching station within 50 km of Vogavík at the south of Faxafloi bay.

- About 90% of the smolts released at Kollafjörður were recovered there and about 10% at other stations, primarily Vogavík (9%) within 50 km.
- Over 93% of the tagged salmon released at the Laros ranching station returned there and about 7% strayed to other stations, primarily to the Hraunsfjörður station (4%) within 30 km, but also to Vogavík (2.5%).
- About 93% of the salmon released at the Hraunsfjörður facility were harvested there and 7% strayed to other stations, mostly to Vogavík (5.5%) and <1% each to Kollafjörður and Laros.
- The cumulative harvest of microtagged strays from other stations was highest (1500 fish) at Vogavík. Kollafjörður and Hraunsfjörður accumulated about 250 microtagged salmon strays each and Laros about 80 (Fig. 2).

Strays from ranching stations in the Breidafjörður area to stations in the Faxafloi area were four times more numerous than strays in the other direction (Fig. 5). Cumulative catches at each station suggest that a small proportion of straying from the larger stations to the smaller ones can contribute significantly to the catch of those stations. To estimate the real impact of this it is necessary to use the tagged/untagged ratio in the releases

to assess the total number of salmon straying between ranching facilities.

The main observations, presented in Figure 6, are as follows:

- Almost 12% of the catches at Vogavík were strayers from other stations, primarily from Kollafjörður and Hraunsfjörður.
- About 13% of the catches at Kollafjörður were strayers from other stations, mostly from Vogavík and Hraunsfjörður where a small proportion of the large releases was tagged. Each percent of straying identified from those stations was thus contributing large quantities of salmon.
- The proportions of strayers from other stations at Laros and Hraunsfjörður were low, ranging from 1.5 to 2.5%.

Vogavík ranching station was harvesting by far the highest number of strayers from other stations in absolute terms, almost 30 000 salmon during the 8-year period, while Hraunsfjörður and Kollafjörður harvested approximately 6000 and 9000 salmon respectively; Laros harvested only 2400 (Fig. 6). The high numbers at Vogavík were probably due to its location at the mouth of Faxafloi Bay, apparently on a major migratory route of ranched salmon bound for other facilities in the Faxafloi and Breidafjörður area. The high proportion, but lower numbers, of strayers at Kollafjörður confirms a high harvest rate of ranched salmon bound

for Breidafjörður in the Faxaflói region, suggesting a major migratory route along the southern coast of Faxaflói.

In the period 1978–1982, over 99% of the ranched salmon that were recaptured at three ranching stations had been released at these facilities. Only 91% of the recaptures of salmon released at the Vogavík ranching station were made at this facility, which is non-river based and adapted smolts to sea-water prior to release (Isaksson and Oskarsson, 1986). Similar release methods were used later at the Hraunsfjörður station, which also harvested the returning salmon through estuarine seine netting (93%). It seems clear that such release practices promote straying, and seine netting operations increase the catch of strayers both from natural rivers and other ranching stations.

With higher quality requirements for colour and condition of farmed and ranched salmon on the international market, there has been an increasing tendency towards estuarine harvest at all Icelandic ranching stations, which partly explains the increase in straying. Ranched salmon that are allowed to linger in estuaries for a week or more become discoloured and are unfit for sale as a prime product. It is likely that estuarine harvesting reduces straying of ranched salmon into neighbouring rivers, which often occurs in late summer. The resources manager must, therefore, consider the odds carefully and decide whether such harvesting methods are preferable to the conventional method of harvesting in fresh water, which would increase straying to rivers.

Hansen and Jonsson (1994) suggested that straying would be less serious in large rivers. This has been demonstrated in the Ranga river enhancement programme on Iceland's south coast (Johannsson *et al.*, 1996). There are, however, few large rivers in Iceland and these are mostly salmon-producing and have not been available for commercial ranching operations.

In recent years most Icelandic ranching stations have used the Kollafjörður stock, adapted to ranching since the mid-1960s. Its performance in both fresh water and the sea is better than that of any wild stocks when used in ranching (Jonasson, 1993). Hence salmon bound for different ranching stations would not have stock specific cues to aid them in homing with unknown effects on straying.

Harvesting methods

It is thought that the occurrence of wild salmon at ranching stations is related to the harvest strategy employed and to the location of the stations in relation to major salmon rivers. Estuarine traps may catch more strayers from wild salmon rivers than would freshwater traps and a ranching station in a migration path would catch more wild salmon than would a station at the head

of a long fjord. However, experience has shown that ranched salmon are reluctant to enter fresh water except during freshets, which can be infrequent in summer. Such salmon become coloured as maturation advances, and become unfit for sale. Delays often result in greater strays from the ranching site to neighbouring rivers. Estuarine traps are thus of great importance, providing a steady supply of bright salmon throughout the season and reducing late-summer straying into rivers, possibly preventing genetic interactions with wild fish (Isaksson, 1994). Straying of wild salmon into ranching stations has caused controversy between ranchers and river owners. A successful solution to this controversy is the greatest challenge facing the freshwater fisheries managers in Iceland today.

Coastal Fishing

Traditionally, there has been commercial fishing for salmon at five locations on Iceland's west coast, which were exempted from the prohibition of salmon fishing in the sea under the Salmon Act of 1932. This fishing has been controlled strictly by gear and time limitations and the catches in the period 1950–1980 were <3 t (Einarsson, 1996). When ranching commenced, these catches rose to 10–15 t annually and although approximately 50% of the salmon are of ranched origin, the harvest of salmon of wild origin, especially from neighbouring rivers, has also increased. Due to the existence of heritable rights, the fishery can only be eliminated through an annual renting agreement or a permanent buy-out financed by those affected by the fishery. With ranching activity currently decreasing, the value of the netting rights has fallen and, in early 1997, the remaining heritable netting rights were permanently purchased by river owners in south-western Iceland. Some illegal netting in nets ostensibly used for charr fishing has been observed in key locations, but schooling salmon may also be targeted from small boats fishing for other marine species. These additional harvest pressures are due to the increased abundance of ranched salmon along the coast during a short period of the year. Patrol and surveillance of the coastline in June and July during the period of peak migration has been a high priority for managers, river-owners, and ranchers.

Genetic problems

Genetic distance between wild Icelandic salmon populations within the same region is lower than that between populations in different regions and genetic mixing of ranched stocks with wild populations should be prevented to avoid breakdown of stock integrity (A. K. Danielsdóttir, Institute of Marine Research, Reykjavík, Iceland, pers. comm.).

Isaksson (1992) reviewed genetic resource management related to salmon ranching in various parts of the world with the intent of formulating a policy for Iceland. He found no clear guidelines to follow on this issue but many countries have adopted conservative policies in accordance with the precautionary principle. Ranched salmon should, therefore, be harvested in a terminal fishery and local stocks should be used to improve homing and reduce straying. A workshop on biological interactions of natural and enhanced stocks of salmon in Alaska concluded that it was of the utmost importance to maintain genetic diversity within and between natural populations of salmon to sustain productivity of both wild and enhanced stocks (Thomas and Mathisen, 1993). Ecological concerns are linked closely to genetic issues.

Put-and-take fishery

Salmon caught by angling are 10–15 times more valuable than ranched salmon sold for consumption, so release of ranched salmon into under-utilized rivers could create considerable income and benefits for local river owners through the sale of fishing licences and accommodation. The first put-and-take fishery for ranched salmon was established in 1976 in the Kalfa river, a tributary of the Thjorsa river on the south coast of Iceland. Approximately 140 salmon were transported to the area (Isaksson, 1980) and a high proportion were angled, but as some were injured by a fence crossing the river the method was discontinued.

With the great increase in ranching activity in 1988 and the availability of ranched salmon throughout the summer, ranched salmon have been transported into several rivers for angling purposes. To minimize risk, transport of ranched salmon has only been permitted to rivers with a small or absent salmon population and in addition the ranched salmon must be prevented from leaving the river by a fence. Most of the salmon have been tagged to detect straying and most spawners are netted out of the river at the end of the fishing season. More recent measures include inspection of all salmon for major diseases. The disease concerns increased in 1995, when furunculosis was diagnosed for the first time in Iceland and no transport of ranched salmon was permitted in 1996. As there were no further outbreaks in 1996 some permission to transport ranched salmon will be granted in 1997 under strict conditions. It seems likely that put-and-take fisheries for ranched salmon in small streams flowing directly into the sea could create considerable income for the river owners and benefit the local economy through tourism in some rural areas. Releases of ranched salmon into complex river systems, however, will always be debated and create conflicts between different interest groups and fishery experts.

The practicality of put-and-take ranching in large rivers is, therefore, questionable.

Future management

The complex issues which have emerged in Iceland were not easily addressed within the framework of Icelandic law. As a result the law was revised in 1994 to encompass ranching and ranching licences. The information presented here provides some guidelines for future management of ranching to avoid reciprocal straying and other complicating issues. The most important points are as follows:

- Ranching stations should be situated away from major salmon rivers and should preferably be located inland.
- Ranching stations should not be situated close to each other.
- Estuarine harvesting should be avoided with harvesting in freshwater traps being encouraged. This might, however, affect the quality of the harvest and increase straying into rivers, especially during dry summers.
- Large-scale ranching leads to increased illegal fishing, which demands greater enforcement effort.
- Put-and-take fisheries for ranched salmon should only be conducted in under-utilized rivers, which preferably flow directly into the sea.

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