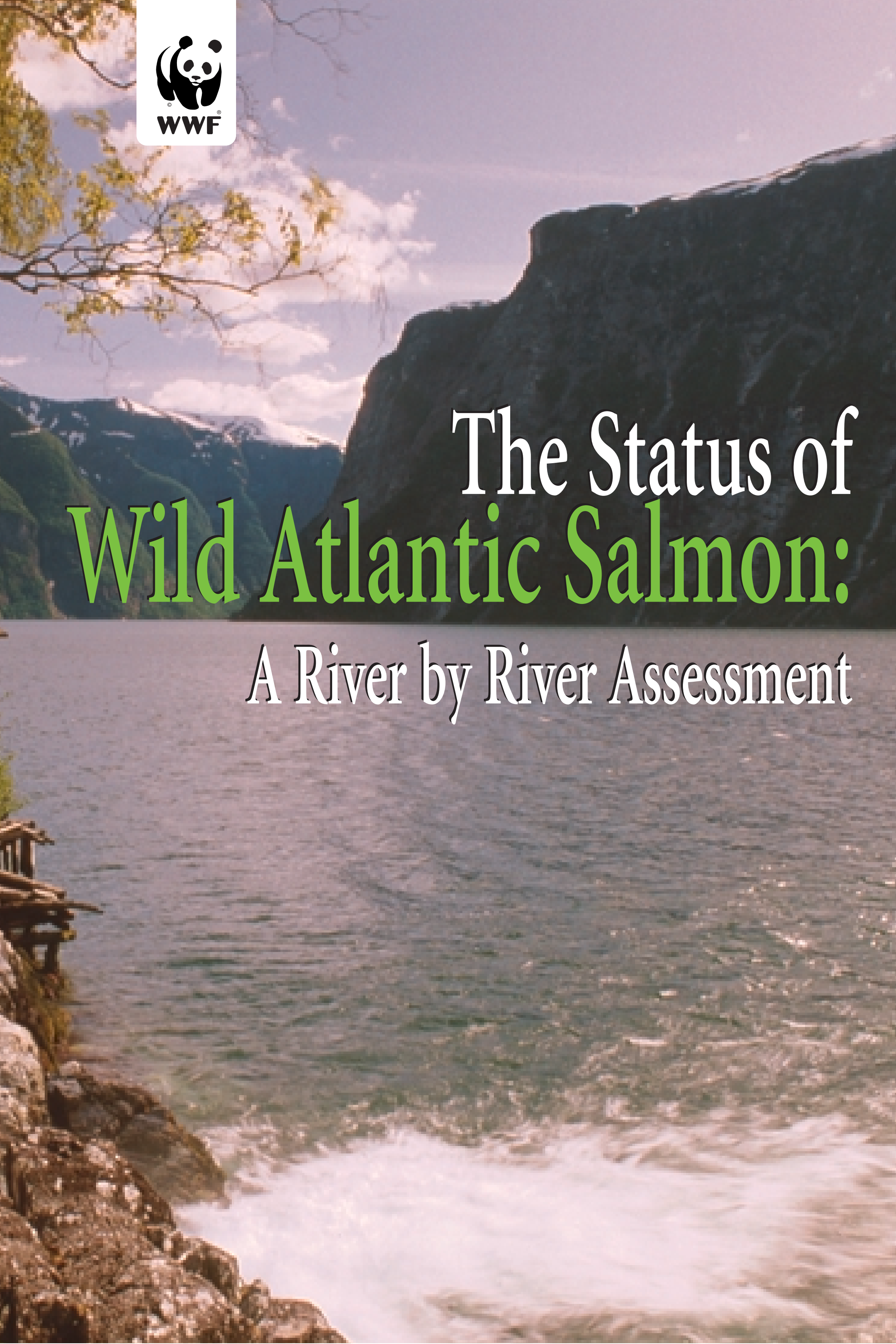


The Status of Wild Atlantic Salmon:

A River by River Assessment

The Status of Wild Atlantic Salmon:

A River by River Assessment

Table of contents

List of Figures and Tables

Foreword

WWF is committed to preserving the World's biological diversity with a particular emphasis on the protection and restoration of vulnerable and endangered species. The following report represents the collective effort of many individuals within WWF and its partners in the conservation, scientific and angling communities and is an attempt to help bridge the gap in public knowledge of the status of Atlantic salmon across it's range.

Conducting our research we learned that, in many instances, not enough information was available to formulate an appropriate assessment of a particular river's population of wild Atlantic salmon. Where sufficient information existed we were able to make the proper assessment and categorization based on readily available government data. In other circumstances, when information was more difficult to discern, every effort was made to apply precautionary standards and conservative analysis to our review and assessment.

WWF submits this report to all those interested in helping to protect and restore this magnificent species and we sincerely hope that it better informs the international community of the salmon's plight and begins a dynamic discussion of ways to restore populations of wild Atlantic salmon to health in all their native rivers.

WWF, May 2001

Acknowledgements

This Status of Wild Atlantic Salmon report started as an initiative of WWF's Norway office. It evolved into a collaboration among numerous WWF offices, in particular WWF-U.S.'s Marine Conservation Program and WWF's European Freshwater Programme. WWF also collaborated with government agencies, academic institutions and other NGO's. We are grateful to the Norwegian Ministry of Agriculture for intial funding and to WWF-U.S., WWF-Norway and WWF's European Freshwater Programme for additional funding and support.

Henning Røed, of WWF Norway, coordinated and analyzed the majority of the research and was the main editor during a four-year process. Gareth Porter, Jim Gourlay and Richard DeVitre edited and researched several sections of the report. The freshwater sections were the result of extensive research by Hanne Christiansen, Kjell Moe, Mark Vanderbeeken and Jane Madgwick. Our special thanks to Bill Taylor, president, and researchers Stephen Tinker and Fred Whoriskey as well as Sue Scott of the Atlantic Salmon Federation and Ed Baum, former Senior Scientist for the Atlantic Salmon Commission, Maine.

In addition, we would like to thank our in-country contributors, who did excellent work. In Norway: Kjetil Hindar, Mai Britt Knoph, Øystein Aas, Arne Sivertsen, Steinar Sandøy, Stig Hvoslef, Erik Steineger, and Rasmus Hansson. In Sweden: Cathy Hill, Lennart Nyman, Niki Sporong, Lennart Henrikson (WWF), Christina Rappe (Swedish Environmental Protection Agency), Hans Ackerfors, and Lars Karlson (Swedish Salmon Research Institute). In Finland: Dr. Timo Makinen (Finnish Game and Fisheries Research Institute for Helsinki) and Anita Makinen (WWF). In Iceland: Thorolfur Antonsson (Institute of Freshwater Fisheries in Reykjavik), Arni Finnsson (INCA), Gorm Rasmussen (Danish Institute for Fisheries Research), and Michael Brinch Pedersen (WWF).

In Scotland, we would like to thank the following for their research and support: R.I.G. Morgan (WWF) who prepared the report with the help of Andrew Wallace (Association of Salmon Fishery Boards), James Butler (Wester

Ross Fisheries Trust), Jon Watt (Lochaber Fisheries Trust), Callum Sinclair (West Galloway Fisheries Trust), Shona Marshall (North West Fisheries Trust), Mark Bilsby (Western Isles Fisheries Trust), Andrew Black (Dundee University), Elizabeth Leighton and Becky Wills (WWF). [*Note*: The views expressed in the Scotland section are not necessarily representative of all experts mentioned in this paragraph.] In the rest of the U.K.: Dr. Lynda M. Warren (University of Wales), John Browne and Martin O'Grady.

In Russia, special thanks go to: Dmitry Lajus (Zoological Institute Russian Academy of Sciences Universitetskaya), Sergey Titov (State Research Institute on Lake and River Fisheries), and Vassily Spiridonov (WWF). In France, Dr. Frederic Mazeaud (AIDSA), Gaele Roussau (ERN), and from WWF, Martin Arnauld, Jean-Chriostopher Poupet, and Vincent Graffin. In Spain: Cesare Rodrigues Ruiz and Guido Schmidt (WWF). In Portugal, thanks to Torres de Noronha. In Belgium, J.C. Philippart and Phillippe Weiler (WWF). In Germany: Anna Schulte-Wulwer-Leidig (Internationale Kommission zum Schutze des Rheins). Thanks also to Kirsty Overberg, Gunda Marianne Ruud, Erwin Meissner Schau, Nils Gjerstad, Chris Poupard (Salmon & Trout Association) and Orri Vigfuson (North Atlantic Salmon Fund).

We would especially like to thank Dr. Malcolm Windsor and Dr. Peter Hutchinson, both of the NASCO secretariat, and Kjetil Hindar, who was a very valuable scientific advisor.

WWF, May 2001

1

Introduction

A species on the brink

The anadromous Atlantic Salmon *(Salmo salar)* is among the most revered species on the planet. Its ability to navigate the ocean, to return to its natal stream, to leap over seemingly impassable obstacles, and to detect through its olfactory senses the very gravel of its origin, has amazed and inspired humans for thousands of years.

Dubbed the "King of Fish" more than three centuries ago by the English writer Izaak Walton, the spectacular wild Atlantic salmon is today at risk of disappearing altogether.

Through millennia, this amazing animal has chosen only the most pristine river systems as its habitat. It became the magnificent centrepiece for thriving ecosystems – but more recently has been

Atlantic salmon can leap vertical distances of 12 feet in order to surmount obstacles. However dams and other man-made barriers have had a major impact on numbers through the years. Atlantic Salmon Federation likened to a canary in the mine, an early detection system warning us, with its widening demise, that that we are threatening the planet and every living thing.

After two centuries of a slow and steady decline that coincided, both geographically and chronologically, with human industrial development, wild Atlantic salmon populations have plummeted precipitously over the past three decades. Salmon catches in the entire North Atlantic fell by more than 80 percent between 1970 and the end of the 20th century. Today they stand at the lowest levels in known history, with wild Atlantic salmon completely extirpated from much of their original range, and hanging by a thread in many other locations.

Wild Atlantic salmon have disappeared in Germany, Switzerland, the Netherlands, Belgium, the Czech Republic and Slovakia; they currently teeter on the brink of extinction in the United States and parts of southern Canada. Salmon are in a precarious state in many other North Atlantic countries to the point where anadromous Atlantic salmon are plentiful today in only a handful of rivers. Atlantic salmon populations are known to be comparatively healthy in only four countries – Norway, Ireland, Iceland and Scotland. Common population sizes range from 20 to 2,000 individuals, and few rivers have more than 10,000 spawners. This contrasts dramatically with historic levels, and with several species of Pacific salmon (*Oncorhynchus* spp.), which may have population sizes on the order of millions (Hindar & Jonsson, 1995).

NASCO

The North Atlantic Salmon Conservation Organization (NASCO) – the treaty organization responsible for the international management of Atlantic salmon – has described the gravity of the situation thus:

> *Many populations are threatened, despite the major sacrifices resulting from the increasingly stringent management measures which have been implemented in the last decade. Very strong conservation measures have been taken but the salmon are still not responding in the way that had been hoped. (NASCO, 1999)*

Through the International Council for the Exploration of the Sea (ICES), emphasis has been placed on managing salmon stocks on a river-by-river basis. In its advice to NASCO, ICES states:

> *Management of salmon stocks in the whole of the Atlantic should be based on local assessments of the status of river and sub-river stocks (NASCO, 2000).*

But until now, only Norway has followed the advice from NASCO and undertaken a comprehensive assessment of the status of salmon rivers on a river-by-river basis.

This report is intended to fill a critical gap in knowledge about wild Atlantic salmon. It includes a series of analyses of the status of salmon in each country in its entire range and details factors influencing salmon population declines in each country, followed by a general analysis of the major threats to wild Atlantic salmon throughout what remains of their range.

In the 18 years since NASCO was first formed, Atlantic salmon stocks have declined more than 75 per cent and despite the advice of ICES, the NASCO member states have refused or failed to manage Atlantic salmon on a river-specific basis in recognition of the fact that each river system hosts a strain of salmon uniquely adapted to its particular ecology. Consequently, the accumulated knowledge base has remained limited at a time when many of these unique strains are at risk of extinction.

Methodology[1]

Each nation study is based on the best available data on the status of Atlantic salmon populations, whether from published literature, official data, or unpublished data collected directly by a salmon specialist commissioned by WWF.

In order to present data that are analogous among all salmon-bearing regions, the report employs a system of six categories based upon The World Conservation Union (IUCN) Red List for species (IUCN, 2000) and upon work by scientists specializing in Atlantic salmon (Frankel and Soulé, 1981; Allendorf *et al.*, 1997; More *et al.*, 1999; Fleming *et al.*, 2000). Those six categories are:

1. Extinct
2. Critical
3. Endangered
4. Vulnerable
5. Healthy
6. Unknown status

---

[1] See Appendix 1 for a detailed explanation of the categorization methodology.

2

Summary of findings

Based on nation-by-nation reports from the remaining 19 countries still hosting populations of wild Atlantic salmon, this study finds that:

- Wild Atlantic salmon populations in one third of the rivers of North America and Europe are endangered.
- Wild Atlantic salmon stocks have already disappeared completely from at least 309 river systems in Europe and North America.
- Wild Atlantic salmon are on the brink of extinction in Portugal, Estonia, Poland, the United States and adjoining parts of southern Canada.
- Nearly 90 percent of the known healthy populations of wild salmon are found in only four countries – Norway, Iceland, Scotland and Ireland.
- In the remainder of the range, 85 percent of wild Atlantic salmon populations are categorized as either *Vulnerable, Endangered* or *Critical.*
- The production of farmed salmon in the North Atlantic is 600,000 tonnes annually – which is 300 times greater than the annual catch of wild salmon. This means that for every wild salmon caught, one tonne of farmed salmon is produced.

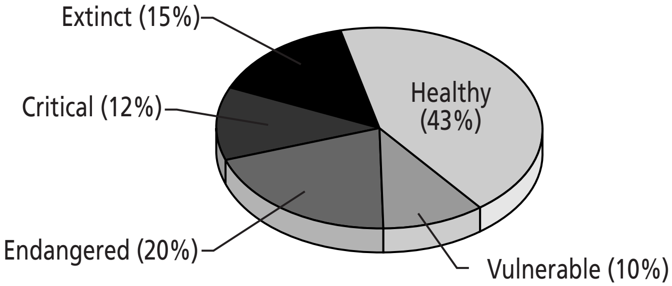


Figure 1. In 2000, wild salmon populations occur in the rivers of 19 countries. This study found that: (1) the status of salmon populations in 610 rivers is unknown due to insufficient data, and (2) It was possible to categorized the status in 2,005 rivers. The overall categorization for 2,005 salmon-bearing rivers in 19 countries is shown above.

The status of salmon stocks country-by-country

The reports on individual countries in this study reveal that of 2615 historical salmon-bearing rivers, 2,005 can be categorized, whereas insufficient data exists to categorize 610 rivers. Of the total of the 2,005 salmon-bearing rivers that can be categorized (see Figure 1), 294 (15 percent) have lost their salmon populations completely. 403 (20 percent) have populations that are endangered, and 236 (12 percent) are in critical condition (meaning very close to extinction). Another 205 (10 percent) of the rivers have populations that are vulnerable, whereas the populations in 867 rivers (43 percent) are healthy.

Approximately 90 percent of the Atlantic salmon populations known to be healthy are in four countries – Norway, Ireland, Iceland and Scotland. When the rivers of those four countries are subtracted from the totals, the global condition of the species appears dramatically worse.

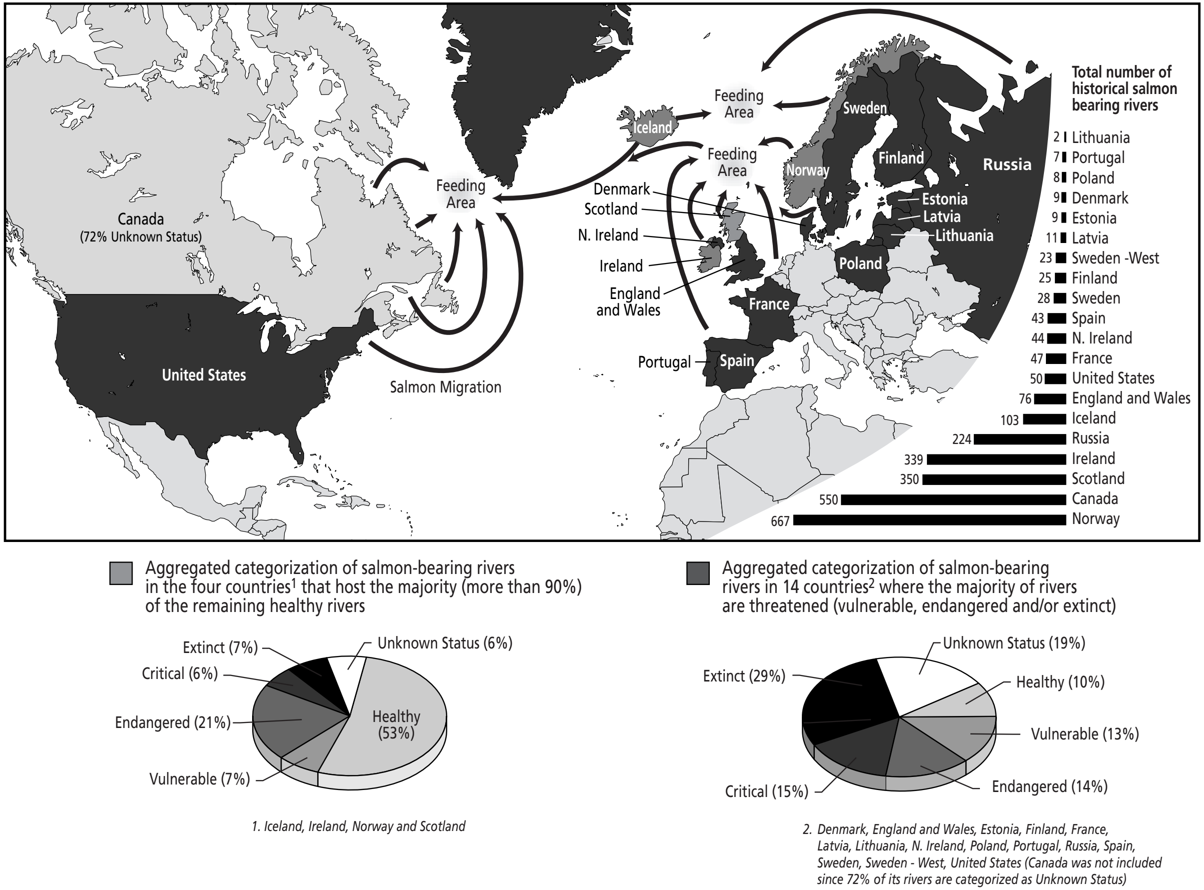
Throughout the remainder of Europe and North America, of the 642 historic rivers that can be categorized, 30 percent (191 rivers) have already lost their wild salmon stocks completely. No less than 25 percent of the categorizable rivers (153) have populations in critical condition, and a further 15 percent (99 rivers) are endangered. Another 15 percent (100 rivers) are categorized as vulnerable to factors that could eventually cause extinction – so that only 15 percent (99) of the historic salmon rivers are considered as still healthy.

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %

Figure 2a. Categorization of salmon-bearing rivers in 19 countries. The countries are classified by alphabetical order and the status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country). Raw data is given in Appendix 2.

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %

Figure 2b. Categorization of salmon-bearing rivers in 19 countries. The countries are sorted using the extinct category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country). Appendix 2 also includes tables sorted according to the other 5 categories.



1. Iceland, Ireland, Norway and Scotland

2. Denmark, England and Wales, Estonia, Finland, France, Latvia, Lithuania, N. Ireland, Poland, Portugal, Russia, Spain, Sweden, Sweden - West, United States (Canada was not included since 72% of its rivers are categorized as Unknown Status)

Figure 3. Map showing the wild Atlantic salmon's range in 2000 and its known migration routes. Aggregated categorization data on a country-by-country basis as reported in this study is also shown.

Major impacts on wild Atlantic salmon

This study finds that the major threats to wild Atlantic salmon populations are:

- *Overfishing* in the sea, estuaries and rivers reduces the stock size to below a critical level
- *Hydropower dams and other man-made river obstructions* form severe obstacles to upstream and downstream migration of salmon, so reducing population viability
- *River engineering schemes* (e.g. for flood defence or navigation), result in direct habitat loss (e.g. through channel deepening) and disconnection of the main river from the complex of floodplain habitats (e.g. ox bow lakes, channels and islands). Habitat degradation also occurs through the resulting changes in ecological processes such as nutrient cycling, sedimentation and flooding.
- *Pollution* (from industry, urban settlements and agriculture) resulting in acid rain, inputs of excessive nutrients and upstream sediments, heavy metals and other toxic substances, including endocrine disruptors. These pollutants degrade the salmon habitats and some have direct impacts on species mortality and behaviour.
- *Salmon aquaculture* results in erosion of the natural gene pool through interbreeding with escapees, resulting in a competitive disadvantage to the wild stock. Diseases and sea lice transferred from caged salmon to wild salmon are a severe hazard to juveniles in countries where salmon farming is predominant. In countries with major salmon aquaculture industries (Norway, Scotland, Ireland, Canada and the United States), which impact upon nearly two-thirds of the salmon rivers in the Atlantic salmon's range, salmon aquaculture now constitutes a major threat to wild salmon stocks – if not *the* major threat.

References

Allendorf, F.W., Bayles, D, Bottom, D. L., Currens, K. P., Frissell, C. A., Hankin, D, Lichatowich, J. A., Nehlsen, W., Trotter, P.C. and Williams, T. H. (1997). Prioritizing Pacific salmon stocks for conservation. *Conservation Biology* 11: 140-152.

Fleming, I. A., Hindar, K., Mjølnerød, I. B., Jonsson, B., Balstad, T. and Lamberg, A. (2000). Lifetime success and interactions of farm salmon invading a native population. *Proc. R. Soc. Lond.* B 267: 1517-1524.

Frankel, O. H. and Soulé, M.E. (1981). *Conservation and Evolution*. Cambridge, UK: Cambridge University Press.

Hindar, K. & B. Jonsson (1995). Impacts of aquaculture and hatcheries on wild, fish, pp. 70-87. In D. P. Philipp, J. M. Epifanio, J. E. Marsden & J. E.

Claussen (Eds) Protection of Aquatic Biodiversity. Proceedings of the World Fisheries Congress, Theme 3. Oxford and IBH Publishing, New Delhi.

IUCN (2000). http://www.redlist.org/categories_criteria.html

Mork, J., Bentsen, H.B., Hindar, K, and Skaala, Ø. (1999). Genetiske interaksjoner mellom oppdrettslaks og vill laks (Genetic interactions between farmed Atlantic salmon and wild salmon). Appendix 4. *In. Til laks åt alle kan ingen gjera?(“Not enough salmon for all?*”). *Norges offentlige utredninger.* Oslo,: Statens forvaltningstjeneste. pp. 181-200.

NASCO (North Atlantic Salmon Conservation Organization). (2000). *Report of the annual meeting of the council. Seventeenth annual meeting*. Miramichi, Canada, CNL (00)57, Edinburgh, NASCO.

3

Scenarios for the future

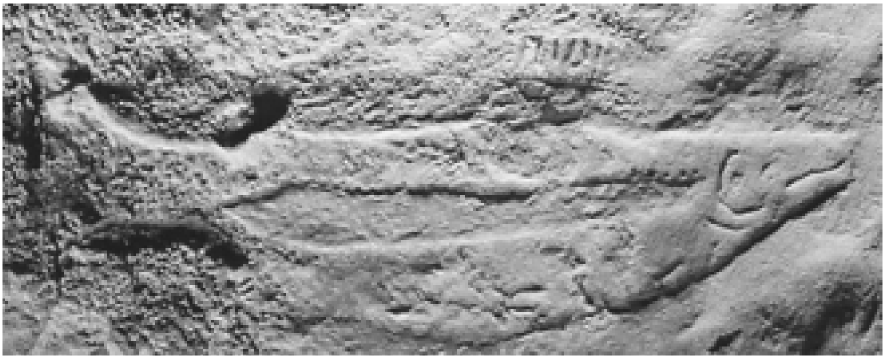
In this chapter three scenarios are offered for the future of Atlantic salmon: one pessimistic, one realistic and one optimistic.

Each of these scenarios will be significantly influenced by our handling of (1) salmon aquaculture (2) pollution, (3) harvest of salmon and other fish species, (4) river restoration, (5) international agreements, (6) large-scale environmental changes, (7) stocking and enhancement programs and (8) governmental protection of endangered stocks.

The future of wild salmon populations depends on different critical issues in each part of the North Atlantic range. However, research into salmon mortality in the sea as well as overall action will be needed on fishing, salmon aquaculture and river management:

- In Ireland, Scotland, southern Canada and in the Gulf of Maine (USA) and Norway, the future management of the salmon aquaculture industry is the most critical issue.
- In Portugal, Spain, France and most of central Europe, the impact of habitat protection and restoration measures on riverine production of salmon is the most important problem to address.

- In the Baltic Sea basin, the management of stocking and sea ranching is the most urgent concern.



A 25, 000 old relief of a salmon from the cave Gorge d´Enfer in Les Eyzies de Tayac in France. The worlds oldest known reproduction of a fish.

Jacqueline Angot-Westin, Musée National de la Préhistoire, Les Eyzies de Tayac, France

Table 1

Possible scenarios for the future of wild Atlantic salmon *(Salmo salar)*

	Pessimistic scenario	Realistic scenario	Optimistic scenario
Assumptions			
Protection of endangered stocks	Governments do not categorize salmon stocks according to their conservation status and protect threatened stocks. No laws to protect endangered salmon stocks.	More governments categorize salmon stocks according to their conservation status. Some enforcement and funding for protection for specific salmon stocks or rivers.	All governments categorize salmon populations according to their conservation status and most governments follow this up with designation, enforcement and funding for protection.
Control of harvest	No reduction in salmon fisheries. Increased fishing pressure on species used as food by wild salmon to feed farmed salmon.	Reduction in salmon fisheries that affect endangered salmon stocks.	Strong reduction in salmon fisheries that affect endangered stocks. All fisheries on river or sub-river stocks are regulated and based on the size of the stocks to ensure a large enough spawning stock.
Evaluate stocking	No critical evaluation of stocking programs and no reduction of non-sustainable stocking.	Better understanding of negative effects of such programs. Existing programs are either improved or halted.	Non-sustainable stocking programs are halted and populations are enhanced by sustainable methods for stocking and habitat restoration. Guidelines to protect and enhance wild populations are implemented throughout the species' range.
Fish passes and dam management	No improvement in efficiency of existing fish passes; existing obstructions remain and new structures have poor design for critical fish species, including salmon.	Removal of some impediments to salmon migration and improvement in the design of fish passes for new dams and existing structures.	All governments commit to alternate energy sources instead of installing new hydro dams on wild Atlantic salmon rivers, removal of dams (especially those that are no longer operating or operating inefficiently) and implementation of state-of-the-art upstream and downstream fish passage on all other dams.

	Pessimistic scenario	Realistic scenario	Optimistic scenario
Assumptions			
River restoration	Unabated river alterations and no effective restoration.	No further large-scale river alteration. Targeted restoration measures where salmon rivers can most readily be restored Effective implementation of EU Water Framework Directive in some countries results in improved passage for migratory fish and improved "water status".	No further large-scale river alteration. Effective restoration measures facilitated through a coordinated legal framework and guidelines that require improved conditions for migratory fish, as an integral part of water management in river basins.
Controls on salmon farming	Continued growth based on only profit considerations in existing regions and in new countries. Few measures to reduce escapes and control sea lice in fish farms. Genetically modified farmed salmon introduced.	Continued growth but some measures taken (e.g. better physical containment, measures to reduce disease and parasite transmission, microtagging, GM salmon not in use). Threats to wild salmon remain due to disease transmission and ecological and genetic interactions with escaped farmed fish.	Much improved physical containment and handling methods. Optimal localisation of units. Strong reduction in the number of escaped salmon. Efficient and environmentally safe measures to control fish diseases and parasites. All farmed salmon are microtagged. Methods of "biological containment" of farmed fish are implemented. Good husbandry pratices for a wider healthy marine environment.
International agreements	No regulations on fisheries, aquaculture and transfer of fish among continents.	International regulation of fisheries and aquaculture. International certification schemes to make aquaculture more sustainable.	Strong international regulation of fisheries and aquaculture. International certification schemes and market forces push all salmon farming to become sustainable. Governments use precautionary principle and achieve binding agreements through NASCO.

Pollution control	Little change in waterborne pollution or acidification. Increased levels of greenhouse gases.	Reduced acidification and other industrial and domestic pollution. Little control over greenhouse gases. Effective implementation of EU Water Framework Directive in some countries results in improved water quality.	Significantly reduced acidification and industrial and domestic pollution. Control over greenhouse gases but continued negative impact on some salmon stocks.
Large-scale environmental changes	No measures to control climate change and protect salmon populations from unfavourable environmental conditions.	Better understanding of the causes of environmental change and the effects on salmon. Few measures taken to reduce the impact on threatened populations.	Effective mitigation efforts for those wild salmon populations threatened by unfavourable environmental conditions.
Consequences for wild salmon	Current negative trends for natural populations will be reinforced and even reach populations currently not at risk. Native populations will eventually be composed of individuals that have all descended from farmed fish in some regions. Southern Atlantic: majority of salmon rivers lose their wild salmon populations. Northern Atlantic: many more salmon stocks will be endangered Baltic and other areas with salmon aquaculture and/or sea ranching: descendants of cultured stocks (feral salmon) will replace wild salmon populations. Native salmon populations only persist in a few areas and rivers. Total catch of wild salmon in rivers and in the ocean further reduced. Recreational fisheries lose their economic importance for local communities.	Overall negative trend will continue for the wild Atlantic salmon, especially because of the negative impacts from aquaculture. Populations will change genetically in the direction of farmed fish. Stocks may also diminish because of lack of regulations and protection in the rivers and unfavourable conditions in the North Atlantic. More rivers will lose their wild salmon populations and more populations will become endangered. Some southern stocks will receive improved protection and certain stocks will improve to become non-endangered. Improved management of salmon in the Baltic will strengthen the remaining wild salmon stocks in this region. Recreational fisheries regain their economic importance only in some areas.	Existing salmon stocks strengthened across the whole range of the species and catch of wild salmon increased over the whole of the North Atlantic. Recreational fisheries recover and re-emerge as an important economic factor in many more areas.

Salmon conservation: constraints and opportunities

Constraints

1. *Information gaps* ignore: the influence of specific aspects of river management schemes, assessment of river conditions as they affect fisheries, poor and inconsistent monitoring of the impact of river management on salmon populations, and the potential for restoration given the multiple-use of rivers in North America and Europe.
2. *Plans for river management don't address* and integrate fishery conservation needs like flood defence, navigation, and hydo-power schemes. This lack of planning has resulted in malfunctioning fish passes.
3. *The exclusion of the potential benefits of fisheries improvement in cost-benefit analyses* for river management schemes – for example, linked with economic benefits from commercial and recreational fisheries.
4. *The focus of fisheries management on the productivity of commercial species* rather than on conservation of the native fish fauna of particular rivers – leading to an emphasis on salmon stocking programmes rather than on protecting and restoring ecological processes within rivers, which may be more cost-effective.
5. *The lack of clear international policy framework* for fisheries management, that takes full account of threatened species, prevents proactive steps from being taken to protect the wild Atlantic salmon.
6. *There is* a *lack of coherent legal framework* for coordinating river management to benefit the Atlantic salmon across its range, with competing pieces of legislation country by country canceling out effectiveness (e.g., seven different Acts regulate river management in Denmark alone).

It is apparent that relatively little attention has been given to the role of river management and restoration and that most efforts have been on trade, fishing and stocking of salmon. The continued loss of "river connectivity" puts increasing pressure on the remaining fish stocks.

Opportunities

1. *The new EU Water Framework Directive* offers a promising basis for restoring Europe's rivers using a whole catchment approach to decision-making. Member states are now required to take action to improve water quality and this will also benefit migratory fish.

2. *There are existing commitments under the EU Habitats Directive* concerning species conservation and the development of functioning ecological networks, which can be used to promote action plans for migratory fish conservation. The Atlantic salmon is listed as a *species of Community* interest under the EU Habitats Directive, providing further obligations to governments to adopt measures to ensure a *"favorable conservation status"* for the listed species.

3. *The establishment of many transboundary commissions and expert groups* for river basin management (e.g., Danube, Elbe, and Rhine) that develop and propose measures to restore migratory fish, building on efforts to improve water quality, and navigational and flood management.

4. *Existing commitments by international commissions and conventions* such as HELCOM and the Danube River Fisheries Commission relative to certain specific species (salmon and sturgeon for instance) are encouraging.

5. M*any organisations concerned with migratory fish conservation* – including research institutes, government departments, angling societies and a range of NGOs – could work effectively in new partnerships to facilitate actions for migratory fish conservation.

6. *EU, GEF/World Bank and private sources* have funds available for research and development of action plans, toward meeting species conservation goals.

7. *Development of a series of sanctuaries or protected areas* to safeguard wild salmon populations in highly sensitive or fragile feeding or migrating areas i.e. Greenland and Faroe Islands

4

The biology of Atlantic salmon

The Atlantic salmon is an anadromous species periods of the juvenile and the adult stages are spent in the sea, while spawning and nursery take place in freshwater. Spawning and hatching success depend upon favorable substrate and water quality. Food and predation pressure tend to be limiting factors for growth and survival at subsequent stages that, in turn, add biological attributes to the habitat requirements. For migratory species like the Atlantic salmon, reduced water-quality, physical disturbance and man-made barriers may be crucial for survival of both the juvenille and the adult. This section forms a brief outline of the biology of the Atlantic salmon. The requirements for the limnetic habitat of each development stage are identified as the basis for the man-made impact factors identified in other sections of this report.

Distribution

The Atlantic salmon comprises a significant number of reproductive strains belonging to watercourses emptying into the Atlantic Ocean. In Europe, Atlantic salmon are found in most of the large rivers from Portugal to Northwest Russia. Salmon populations are also found in United Kingdom (U.K.), Iceland and Greenland. Greenland has only one spawning river however Southwest

Greenland is an important wintering/feeding area for salmon from other areas. In North America, the species occurs from Ungava Bay in Canada and southwards to New England.

The species is divided into four genetic main groups: Baltic salmon in the Baltic Sea, East Atlantic salmon in Europe, West Atlantic salmon in North America and Northern Atlantic salmon in the Barents region.

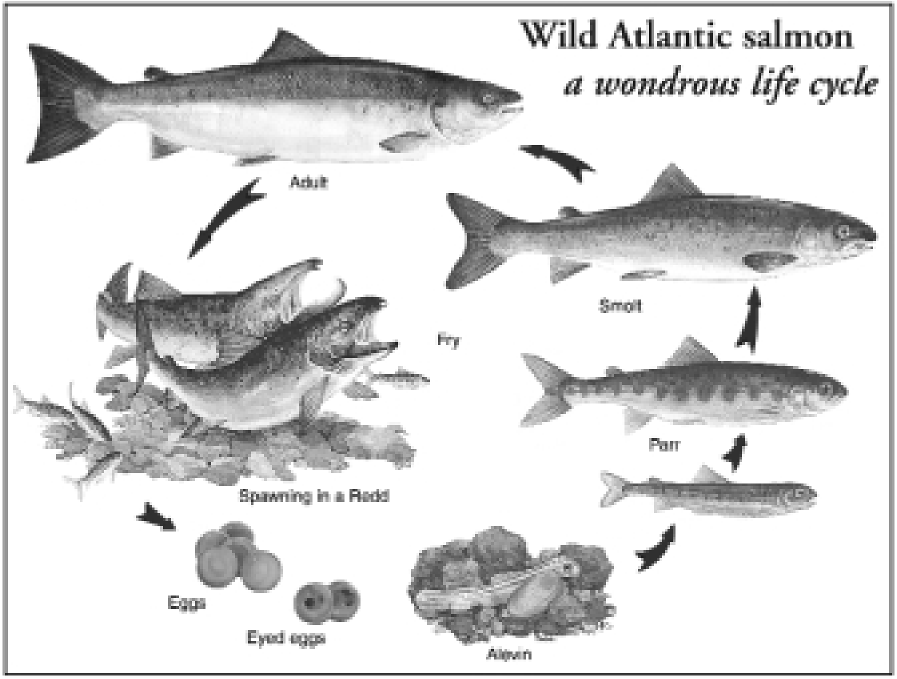
The marine environment of the distribution area is fairly homogenous. The freshwater conditions, however, where temperature and ice formation, dissolved oxygen, and favourable sediments for spawning, are considered among the limiting factors, and appear to be very important to the species' distribution. In this respect, the northern and southern parts of the distribution range can be considered marginal.

Industrialization during the 18th and 19th centuries contributed greatly to the depletion of several salmon strains in southern areas on both sides of the Atlantic. Major European rivers like the Rhine in Germany, the Seine in France, and the Thames in England, were among the first to lose their salmon populations because of the construction of dams and the discharge of industrial waste and sewage.

On the European continent today, only remnant populations are found in a few rivers of France and on the northern coast of Spain. Atlantic salmon have also been lost in the southern part of the former distribution range in the United States, and are currently found **only** as an endangered status population in the northern State of Maine.

Life history

As already indicated salmon are anadromous: the young migrate from the river to the sea for feeding and sexual maturing before they return to the natal river to spawn as adults. Once the salmon have entered the river, they migrate upwards until a suitable spawning site is reached. This homing instinct brings the salmon back not only to the correct river but also to the same place where born. After spawning and the subsequent period of incubation, the alevins develop to fry and parr. When the nursery period is completed, after one to six years and a body length of 10-20 cm, the salmon migrate to the sea as a smolt. The total life-cycle ranges from four and eight years.



Life Cycle diagram for Atlantic salmon.
Atlantic Salmon Federation, J. O. Pennanen

Habitat

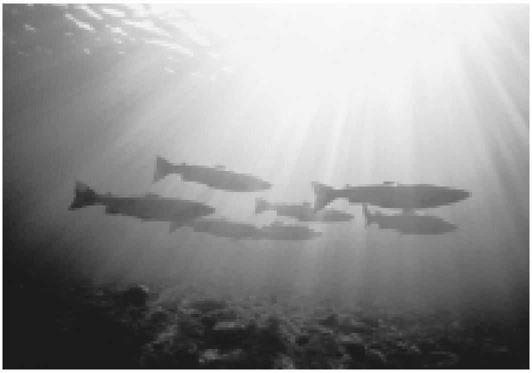
The physical habitat requirements of the Atlantic salmon vary from stage to stage. In this section of the report, the freshwater phase of the life cycle is divided in three successive stages:

- spawning and incubation
- juvenile stages in freshwater
- return of mature adult

General habitat requirements

Rivers hosting Atlantic salmon range from waterways with low flow rates, such as the chalk streams of southern England, to rivers with steeper gradients, like those draining the Scottish Highlands. The relative proportions of habitat required by salmon may vary in quantity and quality, and, in turn, these factors influence the size of the population in a given river.

During upstream freshwater migration, the Atlantic salmon must navigate the various reaches of a river, and confront contrasting conditions due to geology, relief, channel morphology, flow types, channel features and bedloads. The wide variety of salmon habitat; from upland rivers, often with small channels and waterfalls exposed to erosive processes – to broad, calm, less oxygenated lowland rivers where sedimentation and estuarine conditions prevail – renders any analysis of habitat conditions complex.


Atlantic salmon on their way upstream.
Gilbert Van Ryckevorsel, ASF

In general terms, the biophysical habitat requirements of Atlantic salmon include well-oxygenated water, absence of organic and inorganic pollution, fine gravel bottom for spawning, combined with suitable juvenile nursery sections and cover for migrating adults.

Habitat requirement for spawning and incubation

Mills (1989) suggests that favourable spawning locations for salmon are likely to occur if the gradient of a river is 3 percent or less. The preferred spawning site is a transitional area between pool and riffle where the flow is accelerating and the depth decreasing, and where gravel of a certain coarseness is present (Petersen, 1978; Bjorn & Reiser, 1991). In such a location, downwelling water fluxes through the gravel are typical, providing a certain level of dissolved oxygen in the immediate vicinity of the eggs. However, wide ranges of water flow and depths are reported. Areas with upwelling groundwater may also be selected as spawning sites.

The particle size distribution of the sediments at the spawning sites varies from river to river. Petersen (1978) presents a breakdown of the composition of spawning gravel in nine rivers, based on the proportion of cobbles, pebbles, and sand (cf. Table 2). Stratification was found in the gravel beds, with a higher proportion of coarse material at the top and more sand in the lower strata. For artificial spawning channels, 80 percent of the particle size distribution within the range of 1.3 to 3.8 cm, and a balance of sizes up to 10.2 cm, is recommended.

Table 2

The composition of gravel at salmon spawning sites

Particle size (mm)	Percent dry weight
Cobble (22.2-256)	40-60
Pebble (2.2-22.2)	40-50
Coarse Sand (0.5-2.2)	10-15
Fine Sand (< 0.5)	0-3

Data aggregated from nine rivers. After Petersen (1978)

During the incubation of ova and the emergence of fry, the intergravel physio-chemical environment is critical, and adequate flow of water through the gravel is especially important. The proportion of fine material in the gravel must therefore be relatively low. Petersen (1978) found that if the content of sand (i.e. grain size less than 2 mm) exceeded 20 percent by weight, the permeability was reduced to zero. Other authors state that productive, good quality spawning gravel contains less than 5 percent fines (grain size less than 0.8 mm), while unproductive gravel sites are characterised by more than 30 percent fines.

(A summary of physical requirements for spawning and incubation is outlined in Table 3.)

Table 3

Summary of requirements for spawning and incubation

Flow		Gravel		Incubation	
Velocity	Depth	Mean grain size	Percent fines by weight	Minimum permeability	Sand content
25-90 cm/s	17-76 cm	11.3 cm	< 8.2	1,000 cm/h	< 20%

Compiled from U.K. Environment Agency (1998)

Juvenile habitat

Heggenes (1990) considered water depth, water velocity, and streambed substratum cover to be the principal physical variables for juvenile salmon *in situ*. Most relevant studies refer to one or more of these variables in discussions of habitat characteristics.

Fry densities vary considerably in natural streams. The availability of suitable habitat is often considered the limiting factor. The highest reported density of fry is more than 86 per 100 m^2, whereas the corresponding density of parr is more than 19 per 100 m^2. These values come from salmon habitat of highest quality. Conversely, poor habitats are suspected of supporting fewer than 9 fry and 3 parr per 100 m^2.

Fry and underyearling parr have been found to occupy locations other than those occupied by older and larger parr. For some areas, significant differences between summer and winter micro-habitats have been reported.

Juvenile salmon have been observed in water flow velocities from 20 to 75 cm/s, with the highest densities in areas of 60-75 cm/s velocity. Pebbly riffles without boulders are considered to be prime nursery habitat for salmon less than 7 cm long.

The proportion of 0+ to 1+ age group fish decreases as depth increases between 20 and 40 cm; yearling or older parr are rarely observed in riffles of less than 20 cm depth and without boulders (particle size > 256 mm). Experiments indicate that during an underyearling's growth, preference is shown for deeper and swifter parts of the riffles. At 8-9 cm in length, 80-90 percent of the underyearlings prefer cobble/boulder habitats (particle size > 6.4 cm) of more than 30 cm depth.

In general, juvenile salmon occupy shallow, fast-flowing water, with a moderately coarse substrate combined with overhead cover provided by surface turbulence. In summer, fry occupy shallower and faster flowing sections of river with slightly smaller sized gravel than that selected by parr.

Most studies on the microhabitats of juvenile salmon describe the distribution and location of the fish during the summer months. However, the habitat utilization changes when the water temperature falls in the autumn. In Scottish rivers, juvenile salmon tend to leave the shallow riffle habitats during the autumn and move to deeper water in pools, re-appearing in the shallow water when the temperature rises to 6-7° C in spring (Mills, 1989). Bjorn & Reiser (1991) state that juvenile salmon move into deeper water and hide when the temperature drops below 10° C.

Several studies indicate that the juvenile fish disappear from their "home stone" in the streambed surface in autumn and hide in chambers beneath cobbles and boulders at the streambed. However, the overall distribution of the fish between riffles, runs and pools remains the same as in summer. The proportional distribution has been estimated for the Sevogle River in New Brunswick, Canada, counting 76.8 percent in the runs, 19.1 percent in the riffles and 4.2 percent in the pools. The "home stones" tend to be larger in winter than in summer, typically 20-30 cm, compared to 6.4-6.7 cm in summer. In parallel, the focal "nose" velocity (i.e. the water velocity around the body of the fish), is less than 10 cm/s in winter, while a summer range of 10 to 50 cm/s is observed.

(A summary of typical characteristics of juvenile salmon habitat is presented in Table 4.)

Table 4

Typical characteristics of juvenile salmon habitats

Fry and Underyearling Parr			Yearling and Older Parr		
Water depth	Velocity	Substrate a) summer b) winter	Water depth	Velocity	Substrate
< 20 cm	50-65 cm/s	a) Gravel and cobble b) Cobble to boulder	20-40 cm	60-75 cm/s	Cobble to boulder

The table is a synopsis of data from the literature review of U.K. Environmental Agency (1998), but excludes extreme values from rivers outside the U.K. Gravel and cobble refer to the particle fractions of 16-256 mm, while cobble to boulder refer to the fractions of 64-256 mm.

To improve autumn and winter habitat suitability, Rimmer et al. (1984) recommend that the substrate in unsilted areas with a certain water depth (24-36 cm) and flow velocity (10-60 cm/s) should be roughened by the application of large (> 20 cm), angular stones.

Adult habitat requirement

The major requirement for adult salmon is accessible spawning area, which should be of a certain size and provide a safe location for these large fish.

Obstacles to upstream migration should not exceed a vertical height of 3 m. In order to pass an obstacle of vertical height of Y m, the plunge pool directly below the obstacle should be deeper than 1.25 x Y m.

For a 2.8 kg female salmon, the average size of a redd is about 3 x 1 m. The average space required to avoid interference with other spawners is 9.5 m^2. Shelter for salmon waiting to spawn, e.g. undercut banks, overhanging and submerged vegetation, submerged objects like logs and rocks, floating debris, deep water, turbulence and turbidity, are also important (Bjorn & Reiser, 1991).

References

Bjorn, T.C. and Reiser, D.W. (1991). Habitat Requirements of Salmonids in Streams. In; Influences of forest management on salmonid fishes and their habitats. Meehan, W.R. (ed.), Bethesda: American Fisheries Society.

Environmental Agency (1998). Restoration of Riverine Salmon Habitats – A guidance Manual. Fisheries Technical Manual 4. R&D Technical Report W44. Research Contractor: APEM Ltd. Version 1.0/07-97.

Heggesnes, J. (1990). Habitat Utilisation and Preferences in Juvenile Atlantic Salmon (*Salmo salar*) in streams. Regulated Rivers Research and Management, 5; 341-354.

Mills, D. (1989). Ecology and Management of Atlantic Salmon. Department of Forestry and Natural Resources, University of Edinburgh, London: Chapman and Hall.

Peterson, R.H. (1978). Physical Characteristics of Atlantic Spawning Salmon Gravel in Some New Brunswick Streams. Fisheries and Marine Service Technical Report, 785. St. Andrews, Canada; Fisheries and Environment.

Rimmer, D.M., Saunders, R.L. and Paim, U. (1985). Effects of Temperature and Season on the Holding performance of Juvenile Atlantic Salmon *Salmo salar*. Canadian Journal of Zoology, 63: 92-96.

5

Threats to salmon populations

During the last century, the freshwater habitat of Atlantic salmon was significantly impacted by industrial development as well as agricultural and forestry practices. The changes in land and water use resulted in effects ranging from a dramatic decline of salmon in many river systems, to outright extinction in others. Although natural climatic-aquatic factors may, from time to time, negatively impact the population dynamics of Atlantic salmon, the most severe impacts have been caused by human activities: water pollution, disruption of natural watersheds, hydroelectric development, forestry and agricultural activities, and the secondary impacts of aquaculture.

The nature of impact factors

While habitat degradation may adversely affect migration, spawning and hatching success,

The pristine Alta river in Northern Norway before a highly controversial dam destroyed the river and its salmon stocks.
Tom Schandy, Norway

population sustenance and growth, the situation can be rather more complex than a simple cause and effect relationship. A given impact factor may generate adverse effects directly, by its chemo-toxicity or by mechanical stress when the habitat is chemically or physically disturbed or altered so that its vital functions are inhibited. Other parts of the ecosystem, however, may be much less directly subjected to impact by changes in co-existence dynamics – predator-prey interactions, for instance. This means that many inter-related factors may generate similar effects; other effects may be additive and even synergistic, while some effects only appear long after the in situ exposure. Thus, in order to tailor effective remedial action, each factor must be assessed both individually and holistically.

5.1. Pollution

Pollution of freshwater is perhaps the single most significant factor in the decline of Atlantic salmon populations (Maitland *et al.*, 1994). Most pollution comes from domestic, agricultural or industrial wastes and can be lethal to fish. Even at sub-lethal levels, pollutants can raise the susceptibility threshold of fish to other threats, such as thermal pollution. Fertilizers can cause over-enrichment of nutrients (eutrophication) in aquatic systems with resultant loss of fish productivity. In the worst cases, salmon stocks may be totally lost.

Pollution from industrial and domestic sources and from agriculture remains a major problem in many countries, although, for example in Europe, there is a significant improvement in wastewater treatment in the northern, western and southerly countries. Pollution remains most problematic in small rivers close to densely populated areas (Iversen *et al.,* 2000). Many "salmon rivers" are shared between a number of countries and in both North America and Europe many river watersheds receive long range airborne inputs from industrial complexes.

Silt and chemical pollution can have major impacts on Atlantic salmon populations. This river is on Prince Edward Island.
Atlantic Salmon Federation

Water chemistry

Eutrophication

The extensive use of fertilizers in forestry and agriculture has increased the input of phosphate and nitrate to rivers both directly by initial site fertilization and indirectly during clear-cutting operations when soils are disturbed. The risk is enhanced if operations coincide with heavy precipitation or winter thaw. The upland drainage produced by foresters and farmers can increase soil erosion. Peat and bog drainage may be especially harmful because acidity and toxicity are increased by the release of compounds naturally bound to such wetlands.

Historically, increased urbanization and industrialization have reduced or exterminated the Atlantic salmon populations in many rivers. Many of the impacts that exist today (raw sewage discharge, industrial effluents, discharged hydrocarbons, elevated concentrations of phosphates and nitrogen) were first observed more than 100 years ago and have continued, or worsened.

Oxygen

Although adult salmon can accept concentrations of dissolved oxygen down to 5 to 6.5 mg/l, it is generally recognized that concentrations below a single-day mean of 8 mg/l O_2 may be harmful to spawning fish (Binkley & Brown, 1995). Critical conditions can be observed in degradation processes of large quantities of fine organic sediments or logging-debris.

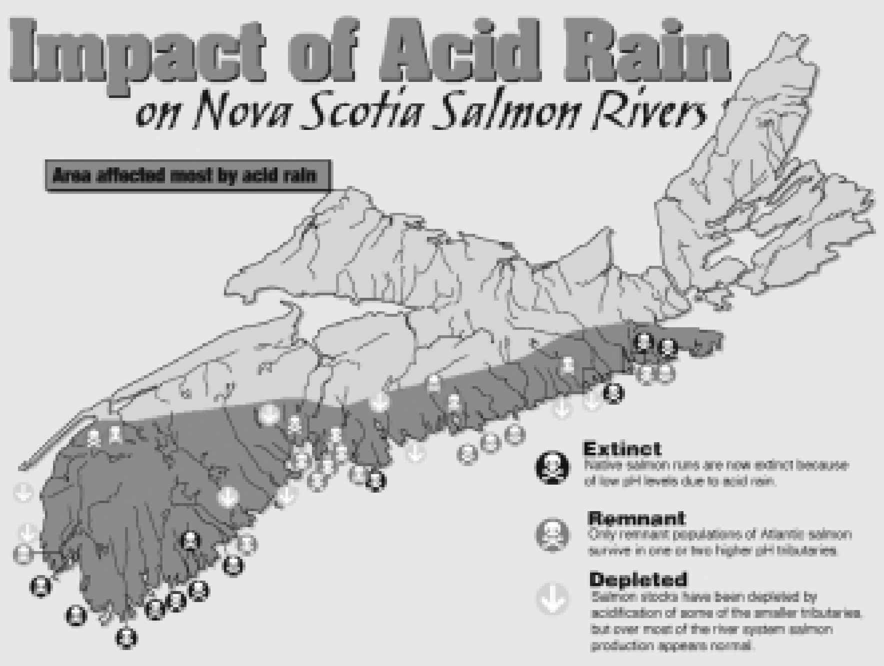
Temperature

The affects of water temperature changes on salmonids have been discussed by Crisp (1995); Jensen (1990); Jensen *et al.* (1989). The temperature influences both the period of incubation of eggs and thus the time of emergence, as well as the subsequent development rate of alevins. The temperature within spawning beds is mediated by the porosity and the hydraulic conductivity of the gravel. Consequently, physical disturbance of the porosity, including compaction and long-term changes in water flow regimes, are among the main causes of intergravel temperature changes.

Watercourse alternation may raise river temperature and produce earlier emergence of alevins. Although this could sometimes be beneficial, premature hatching may be lethal if the timing mis-matches the corresponding growth, or migration, of predatory species.

Acid rain

Acid precipitation has, for many years, reduced the pH levels of aquatic environments to toxic levels where the geological buffering capacity of the watershed is poor. In addition, heavy metals in the soil, notably aluminium, are released into the watercourses. Because of their sensitivity to changes in pH, and in particular to aluminium, salmon alevins and smolt are among the first organisms affected, altering the ion exchange balance through the gills. Ultimately, when pH is reduced below 5.4, conditions may prove lethal to salmon. The stage transforming the smolt from a freshwater to a saltwater fish seems to represent the most sensitive period. Salmon smolt exposed to quite low concentrations of labile inorganic aluminum (< 25 mg/l) have suffered physiological disturbances and even death in subsequent exposure to salt. Mortality of smolt in the marine environment after running from moderately acidified water is therefore expected. A three-fold increase in catches of salmon grilse the first year after liming in Bjerkreim River, Norway, supports the hypothesis (Langåker and Sandøy, 2000).



Although the release of acidic gases from industrial plants has been reduced at source during the last 10 years, the damage will remain for decades due to the loss of natural buffering agents. Consequently, freshwater fish populations in systems so affected, can only be preserved by mitigation measures which include the introduction of neutralizing agents, usually limestone.

Atlantic salmon are exposed to, and damaged by, a wide variety of pollution sources, but acidification is the single factor causing the most negative effects on salmon in areas of Canada, Norway and Sweden which receive wet deposition of airborne pollutants from industrial complexes downwind. The extreme sensitivity of Atlantic salmon to pH levels renders them particularly vulnerable to this water chemistry-altering pollution source. The first reports of acidification affecting fish are from around 1910, when episodic killing of Atlantic salmon (*Salmo salar*) began to occur in some of the southernmost rivers of Norway. From 1885 to 1920, official Norwegian salmon catch statistics showed a decline in catches in rivers in the two southernmost counties, Aust-Agder and Vest-Agder, of about 80 percent. Sporadic catches of salmon were reported up to the late 1960s, but the natural salmon stocks in this region were virtually extinct by 1960 (Langåker and Sandøy, 2000).

In 1995 officials of the Environment Ministry (Norwegian Ministry of Environment, 1999) stated that 18 Norwegian salmon populations had become extinct due to acidification, 11 in the southern Agder counties, seven in the southwestern counties Rogaland and Hordaland. In the late-1990s, 10 salmon stocks were classified as threatened by acidification and 26 as vulnerable (Norwegian Ministry of Environment, 1999). The total annual loss of salmon production of Norwegian stocks due to acidification is estimated to range between 345 and 1150 tons (Hesthagen and Hansen, 1991).

In 1983 the Norwegian government initiated a liming program to neutralize the acidity. The funding has increased year by year, and from 1996 yearly budgets have been around NKr 110 million (US$13 million). Several salmon rivers were limed with good effect from the middle of 1990s, and in 2000 the number is 20 rivers (Langåker and Sandøy, 2000).

Similar initiatives has been taken in Sweden, more than 7,000 lakes and watercourses are currently being treated for acidification by liming, either directly in the water or on adjoining wetlands. Roughly one-third of 300,000 km watercourses in Sweden is affected during high-flood periods by such noticeable acid surges as to limit the survival prospects of fish and benthic fauna (see e.g.

Henrikson and Brodin, 1995; EPA 2001). It is estimated that approximately 75% of the natural salmon smolt production on the Swedish west coast would be lost without liming (Fiskeriverket, 1999).

ICES scientists have estimated that the loss of salmon from acidification of the freshwater environment in Norway is between 100,000 and 330,000 adult salmon per year (ICES, 1989).

In Canada, the prevailing geology in much of southern and eastern Nova Scotia contains almost no buffering capacity against acid precipitation. The damage to Nova Scotia rivers attributable to acidification was first detected in the 1970s when 11 rivers were reported to be affected with noticeably declining populations of salmon.

Unlike the Norwegian experience, the Canadian Government has not acted effectively to mitigate the problem by applying known technology such as liming. While some research was initially conducted, and a token amount of liming undertaken (mainly by spreading powdered lime on headwater lake ice during the winter months), more recently both the monitoring program and the liming program were simply abandoned.

A modeling exercise suggested that: “55 percent of the salmon stocks in the Southern Uplands rivers are already extirpated, a further 36 percent are at risk of extirpation (produce fewer than three recruits per spawning fish), and that only 8 percent of the rivers are capable of sustaining salmon populations at 10 percent marine survival” (DFO 2000/2E).

(Additional details on this situation are provided in the Canadian section of this report.)

Hormone disrupters

Hormone disrupters Atrazine is an organochlorine herbicide previously used as a weed-killer on non-agricultural land such as roadsides, railways and industrial areas. However, due to drinking water contamination its usage in non-agricultural application was banned in the U.K. Despite this, it is still widely used to control weeds in maize and sweet corn crops in the U.K. and Europe.

Atrazine is extremely persistent and can be present in the water column for more than a year (WWF, 2000). The high mobility and persistence of this herbicide means it can be found in many estuaries and coastal waters throughout Europe. Continued distribution of this herbicide give cause for concern due to its endocrine disrupting properties, such as changes in testis and disturbances in sperm production in mammals, and reduced reproductive success in common amphibians. Atrazine is also a suspected human carcinogen and concerns arise from the potential role of atrazine in breast cancer in humans.

A striking example of the effects of atrazine occurs in salmon. At low concentrations of atrazine, water regulation (osmoregulation 1) capabilities are disrupted which means the fish may be adversely affected during migrations due to decreasing ability to move between fresh and salt water.

Researchers have now linked environmentally realistic levels of atrazine with the negative affect on osmo-regulatory processes in salmon. This has far reaching consequences since it will limit the ability of the salmon to migrate. This is of particular relevance when one considers that the first migration of the salmon from fresh to sea water (smoltification) is an essential part of the salmon's life cycle and this could be severely disrupted. The research described showed significant mortality of salmon smolts exposed to environmentally relevant levels of atrazine when they were exposed to seawater, hence highlighting the disruption in salmon migration (Waring and Moore, 1996).

The same researchers have also carried out experiments showing that atrazine also has a negative impact on olfactory systems in salmon. Inhibition of olfactory detection of female pheromones occurs in male salmon exposed to environmentally relevant levels of atrazine. This impairs breeding, because the male salmon will not be ready for breeding at the same time as the females (Waring and Moore, 1998).

These findings suggest that conventional toxicity testing used to set environmentally safe levels of endocrine disrupters for marine organisms are inadequate. These subtle effects occur at low concentrations, and therefore are not detected by standard toxicological methods, but they have potential interactive effects when exposure to several substances and other stresses occurs. These effects could have severe consequences especially at a population level. Hence, these findings highlight the need to eliminate exposure of fish to such chemicals irrespective of data gained from conventional toxicity testing.

Pesticides

There is ongoing research in Canada into suspected widespread damage in the recent past from forest insecticide spraying against spruce budworm infestations, especially in New Brunswick and Newfoundland. Nonylphenols, found in such chemical spray solutions, are suspected of having been a factor in massive losses of juvenile salmon. Investigation began as early as 1977 following major losses in New Brunswick's Restgouche River. The evidence gradually began to point to a pesticide. Researchers have noted a close correlation between watersheds where pesticide containing nonyphenols was aerially sprayed and the observed decrease in the numbers of salmon returning to those rivers in subsequent years.

There is some evidence that the impact has manifested in an inability of juvenile salmon to survive the physiological transformation required to move from fresh to salt water. (Fairchild *et al.*, 1999).

Nonylphenols are thought to imitate the female hormone system and interfere with the reproduction capability of a wide variety of animals. Usually they cause fish to lay eggs that do not hatch or contain defective embryos. The salmon may look healthy, but salmon from streams in which nonylphenols were present died soon after entering the ocean (Fairchild *et al.*, 1999).

Although the pesticide containing nonylphenols has not been used since 1985, a key ingredient is still used in a wide variety of cleaning chemicals and industrial processes, and still enters rivers in high levels. And other chemicals with a similar ability to imitate estrogen, including the waste from pulp mills, are still in use (Ottawa Citizen, 1999).

References

DFO 2000/2E. The effects of Acid rain on the Atlantic salmon of the Southern Upland of Nova Scotia. DFO Maritimes Regional Status Report 2000/2E.

EPA 2001. Swedish Environmental Protection Agency (Naturvårdsverkets). http://www.internat.environ.se/documents/pollutants/kalka/forsur/kalkrese.html

Fairchild, W. L., E. O. Swansburg, J. T. Arsenault and S. B. Brown 1999. Does an association between pesticide use and subsequent declines in catch of Atlantic salmon (*Salmo salar*) represent a case of endocrine disruption? Environmental Health Perspectives 107(5):349-357.

Fiskeriverket. (1999). Plan för bevarande av Västkustlaxen [Plan for conservation of salmon on the Swedish West Coast]. Working group for west-coast salmon, Swedish National Board of Fisheries. Fiskeriverket information 1999:9. 1-156

Henrikson, L. & Brodin, Y.W. 1995. Liming of acidified surface waters: a Swedish synthesis. Springer-Verlag Berlin Heidelberg. (ISBN 3-540-58505-2).

Hesthagen, T. and L. P. Hansen. (1991). Estimates of the annual loss of Atlantic salmon, *Salmo salar* L., in Norway due to acidification. *Aquacult. Fish. Manage.* 22: 85-91.

ICES (1989). Report of the study group of toxicological mechanisms involved in the impact of Acid rain and its effects on salmon. Copenhagen. C.M. 1989/M:4

Iversen, T.M., Madsen, B.L. and Bøgestrand, J. (2000) River conservation in the European Community, including Scandinavia, global perspectives on River Conservation: science, policy and Practice. Ed. P.J. Boon, B.R. Davies and G.E. Petts, Wiley & Sons Ltd.; Chapter 3: 80-103.

Langåker, R. and Sandøy, S. (2000). (in prep)

Maitland, P.S. (1994). Fish. In Maitland, P. S., Boon, P. J. and McLusky, D. S. (eds), *The freshwater of Scotland: A National Resource of International Significance*. New York: John Wiley. Pp. 191-208

Ottawa Citizen. (1999). Pesticides linked to mass kill of salmon: federal scientists name “gender-bender” chemicals as prime suspect in decline. 14 May 1999. In NASCO Council paper CNL (00)16 *Review of International Salmon-Related Literature Published in 1999*. Edinburgh, UK:NASCO,

Waring, C.P. and Moore, A. (1996.). Environmental atrazine: Physiological effects on Atlantic Salmon (*Salmo salar*) smolts in freshwater and after seawater exposure. Presented at International Congress on the Biology of Fishes, San Francisco, July.

Waring, C.P. and Moore, A. (1998). Mechanistic effects of a triazine pesticide on reproductive endocrine function in mature male Atlantic salmon (*Salmo salar*) parr. *Pestic Biochem Physiol*. 62: 41-50.

World Wide Fund For Nature. (2000). Atrazine in Proposed additions to the OSPAR List of chemicals for Priority Action. Submitted to OSPAR Commission Meeting,

Copenhagen (document OSPAR 00/5/0-E). WWF North-East Atlantic Program, Bremen. http://www.ngo.grida.no/wwfneap/ 00/5/0-E

5.2 River infrastructure and engineering

For more than two centuries, people have altered rivers to harness their power and to use their biological richness and fertile floodplains for various social and economic purposes. Rivers have been regulated primarily for the generation of hydro power (mills in the past, electricity today), but also for the supply of water for domestic, agricultural and industrial use, for flood control, for the transportation of timber, and for marine navigation.

River regulation can alter water quality, either by affecting water flow or by changing the morphology of the riverbed itself.

Hydrological manipulation

Deepening and straightening river channels has been the traditional flood control technique intended to direct floodplain drainage and reduce of bank erosion. Reservoirs may inundate spawning gravel and reduce oxygen levels; interbasin transfers may affect river water quality and natural runoff and temperature regimes may be altered. Such changes may reduce salmon reproduction and survival in the river. In addition, the drying out of spawning grounds, stranding of juveniles during rapid reductions of runoff and sedimentation of spawning grounds due to the absence of high flows, often have had adverse affects. Engineering works during the construction of hydropower plants have led to local habitat destruction, and increased siltation (Førde *et al.,* 1999; Mills, 1991; Maitland, 1994).

These activities have been shown to degrade channel diversity, with a corresponding loss of critical habitat such as riffles and pools. Straightening river channels increases water velocity, thus facilitating transportation of sediments from the swift upper areas to be deposited in the lower reaches. The result may be a homogenous channel that is no longer suitable as salmon habitat.

Barriers to migration

Structures such as dams, weirs, fords and culverts may form insurmountable barriers for the upstream spawning migration of adult salmon and for downstream juvenile migration. In many cases, this factor is considered the major cause of Atlantic salmon population declines. Hydro-electric dams are chief among obstructions to vital spawning grounds, whereby anadromous salmonid populations are denied passage over spillways, through turbines and impoundments. Smolts are vulnerable to the impacts of dams on downstream migrations. Dams alter the flow patterns of rivers, creating head pond reservoirs


Dams create major problems for Atlantic salmon migration upstream and down.
Atlantic Salmon Federation

which increase water temperature and trap pollutants, thereby adversely impacting resident parr and migratory smolts.

Where dams exist, effective upstream and downstream fish passage facilities are critical to restoration success. For example, Munro (1965) has reported 55 percent mortality of smolts due to turbine loss in Scotland. In Norway it is estimated that 185 out of 640 (the total number of salmon rivers) rivers are negatively affected by watercourse regulations. Annual natural production of juvenile salmon (smolt) in Norway is 6 million in 5,000 kilometres of rivers. Hydropower development causes a net loss of 20 percent of the total, or about 1 million, smolts. Fish ladders have opened up 2,036 kilometers of river habitat previously obstructed, adding another estimated 600,000 smolts (juveniles) to the production (Førde et al., 1999).

The technology of fish pass design and other means of mitigating the impact of dams have improved in recent years. However, the World Commission on Dams reports that a major effort is needed globally to design and test more efficient fish passes. In the case of the Pollan dam in Ireland, the EIA resulted in design modifications for the concrete dam, spillway and downstream channel, increasing the cost of the project by 30%. These costs are offset by the maintenance of the recreational fishery (WCD, 2000)

Disruption of substrate

Gravel composition is of vital importance to eggs and alevins. Consequently, gravel extraction and river engineering works upstream may alter flood dynamics and natural gravel compositions downstream with catastrophic results. Similar damage can be caused by periodic releases of large volumes of water from power plants and other man-made structures.

Siltation

Erosion and siltation can be induced by forestry, agriculture, mining and other human activity involving the use of heavy equipment. (Herbert *et al.*, 1961). Most natural spawning rivers hold concentrations of suspended sand, silt and clay of less than 5 mg/l during low flows, while the concentration during high flows is about 100 mg/l. The primary affect of increased concentrations of suspended matter is the clogging of the gills, which ultimately can be lethal. Foraging may also be reduced if such conditions become protracted.

Clearcut area in Quebec. Clearcuts can have major impacts on siltation and rates of river flow.
Atlantic Salmon Federation

Flow alteration

Watercourse alteration, water extraction or diversion for agricultural, industrial or domestic uses, and interference with natural catchment areas drainage can seriously impede flow rates. If low flows are maintained over periods of time, elevated water temperatures and deoxygenation may become evident. Such conditions have been shown to be lethal to most river organisms, including fish. Low flow may also reduce the availability of spawning grounds for adult salmon, and ultimately, the eggs may be fatally exposed to air or ice. The movement of gravel during sudden flow fluctuations (e.g. from dams) can cause erosion of spawning beds and downstream drift of salmon eggs and alevins that are usually accompanied by high mortality.

Riparian land use

Urbanization, agriculture, logging and other human activities impacting riverbanks all serve to reduce or denude riparian vegetation. The soil-binding function of streamside plant life is thereby lost, and riverbank instability becomes evident. Ultimately, the riverbanks may be undercut and collapse into the river with detrimental affect.

In addition to siltation damage to spawning areas, invertebrate densities may be reduced, with a corresponding reduction in habitat quality. The widening of channels by such bank collapses can reduce water velocity leading to insufficient flow through the spawning beds. Loss of streamside vegetation can also serve to increase mean summer water temperatures, especially in the upper reaches, and to reduce the natural supply of invertebrate food sources into the ecosystem.

River restoration

Since the 1960's, the main focus of river conservation and restoration has been on measures to improve water quality. During the last 15 years, physical rehabilitation of rivers has taken place especially in the Nordic and Western countries of Europe (a review of practical examples and techniques is given by Brookes and Shields 81996), Hansen (1996), Holmes (1997), Environment Agency (1998), Christensen (in prep.) and Zockler (2000)). This work has, for example involved the re-connection of old river meanders, changing steep and deep stream profiles to a more natural shape, removing stream obstacles and re-creation of in-stream river structures. These measures have often resulted in increased fish diversity, density and biomass. When salmon are the main target species, specific measures such as the improvement of spawning grounds and modification of fish ladders is combined with experimental stocking with under-yearlings.

However, river restoration is no simple matter. The challenges are multi-faceted, involving various inter-related factors. Obviously, the benefits of river restoration depend on the pressure on salmon in the estuarine and marine environment. River restoration is rarely justified for one species and should take account of multiple use of the whole river system. The success or otherwise of restoration projects can only be properly assessed after the entire life cycle of the salmon has been completed – usually requiring about 10 years. The Environment Agency (England and Wales) has set out a process for screening and developing river restoration projects for the wild salmon (Environment Agency, 1998).

References

Baum, E. T. 1997. Maine Atlantic Salmon: A national treasure. Atlantic Salmon Unlimited, Hermon, Maine.

Brookes, A. and Shields, D. (1996) River Channel Restoration: Guiding principles for Sustainable Projects. John Wiley, Chichester.

Christensen, H. (in prep.) The Atlantic Salmon: Restoration of Freshwater Habitats. Prepared for the WWF European Freshwater Programme.

Environment Agency (1998). Restoration of Riverine Salmon Habitats – A Guidance Manual. Fisheries Technical Manual 4. R & D Technical Report W44. Research Contractor: APEM Ltd. Version 1.0/07-97.

Førde E., L'Abée Lund, J.H., Erlandsen, A., Myklebust, N., Heggberget T. and Skurdal, J. (1999). *Vurdering av fysiske inngrep i lakseførende vasdrag.* (A review of physical interventions in salmon rivers). Appendix 10. In. Norwegian Ministry of Environment, Oslo, Norway. 1999. NOU 1999:9. *Til laks åt alle kan ingen gjera?* ("Not enough salmon for all?"). Pp. 249-255

Hansen, H.O. (ed.) (1996). River Restoration – Danish Experience and Examples. Ministry of Environment and Energy, National Environmental Research Institute, Silkeborg, Denmark.

Holmes, N.T.H. (1997) The UK experiences on river restoration. In: Hansen, H.O. and Madsen, B.L. (eds.) River Restoration 96-plenary lectures. International conference of the European Centre for River Restoration, 57-84

Maitland, P.S. (1994). Fish. In Maitland, P. S., Boon, P. J. and McLusky, D. S. (eds), *The freshwater of Scotland: A National Resource of International Significance*. New York: John Wiley. Pp. 191-208

Mills, D. (1991). *Ecology and Management of Atlantic Salmon*. London: Chapman and Hall.

Munro, W.R. (1965). *Fish migration in Scotland.* Pitlochry, UK: Freshwater Fisheries Laboratory

World Commission on Dams (2000). Dams and Development. A new framework for decision-making, Novmber 2000, Earthscan Publications Ltd.

Zockler, C (compiler) (2000) Wise Use of Floodplains – LIFE Environment Project: A Review of 12 WWF River Restoration Projects Across Europe. WWF European Freshwater Programme, Copenhagen, Denmark.

5.3 The effect of fisheries on wild Atlantic salmon stocks

The wild Atlantic salmon has coexisted with humans for millennia, and has been a valuable resource throughout this period. Some of the earliest legislation suggests that salmon have been overharvested in various locations at various times in the past. In Norway during the 13th century, for instance, a law required that the salmon should be permitted to ascend as far upstream as they would do naturally, without being obstructed by humans. We appear to have regressed steadily from there.

In the 1970s and 1980s huge interceptory fisheries existed in the open sea around the coasts of Greenland and the Faeroes. Mixed stock fisheries also operated in the coastal waters of Canada, Norway, the U.K. and Ireland.

In Canada, the Atlantic Salmon Federation (ASF) led a fight to remove 10,000 nets from Canadian territorial waters during the 1980s and 1990s. Persistent effort finally led, by 1998, to the complete elimination of commercial Atlantic salmon fishing along the Canadian coast. Where more than 400,000 wild salmon were killed annually in the 1970s, only very small subsistence aboriginal fisheries now remain. Since the inception of NASCO in 1984, harvests at West Greenland and the Faeroe Islands have been subject to steadily diminishing quotas. NASCO was successful in reducing harvests from an uncontrolled 2,700 mt in the mid-70s (about a million maturing salmon) off West Greenland to 201 mt (122,000 maturing salmon) in 1993.

The North Atlantic Salmon Fund (NASF) was launched in Iceland in 1989, to help fight for the salmon's survival. In co-operation with conservation organizations located in specific countries and sometimes with governmental assistance, NASF pioneered the concept of purchasing intergovernmental open seas fisheries quotas. All such agreements have included compensation for the displaced salmon fishermen and NASF has concerned itself with finding alternative employment through the sponsorship of sustainable development projects. NASF's success included the co-operative buyouts of commercial salmon quotas of West Greenland and the Faeroe Islands in the early 1990s. In collaboration with the Atlantic Salmon Federation, which donated $500,000; the U.S. National Fish and Wildlife Foundation, which donated $250,000; and the U.S. State Department, which donated $150,000 – NASF bought out the Greenland fishery in 1993 and 1994 at an annual cost of $400,000 U.S. The agreement permitted a subsistence fishery of 12 mt in each of these years. The contract called for a three-year renewal, starting in 1995, but this was never achieved.

Since then, NASCO has negotiated with Denmark, on behalf of Greenland, a subsistence fishery of not more than 20 mt (7,500 salmon), for 1998, 1999 and 2000 at Southwest Greenland.

Within the Icelandic fishery zone, NASF successfully led a campaign to purchase and close netting rights.

The combination of continued declines in wild salmon numbers, the advocacy and buy-out campaigns of co-operating conservation partners, and persistent scientific advice for reduced exploitation, has helped NASCO reduce quotas for the high seas fisheries and contain the Greenland activity to a small subsistence fishery for the past three years. Although the Faeroes quota is still considered too high, good sense prevails and fishing is restricted to a small research fishery.

In response to the Atlantic Salmon Federation's call for fair compensation for retired commercial fishermen, the Canadian government spent more than $72 million (Cdn.) buying out coastal salmon nets. In Norway, drift net fisheries were phased out by the government in the late 1980s.

Today, mixed stock commercial salmon fishing is conducted only in the coastal waters of the U.K. and Ireland. The Irish drift net fishery is the most damaging, taking more than 150,000 wild salmon a year from a wide range of European stocks. A Salmon Commission has now been set up in Ireland, but remedial action is slow in coming. However, recently NASF and its partner conservation organizations are making some progress with the Irish government and fishermen.

In England and Wales the north-east coast drift net fishery (average catch 30,000 fish) is being phased out and there are hopeful signs of a changed attitude from the British Government. The Salmon and Trout Association and the Atlantic Salmon Trust of the U.K., the Atlantic Salmon Federation and NASF, have been providing submissions advising on the future management and funding of salmon and freshwater fisheries. The British Review Group has now advised its Government to close the mixed stock fisheries as soon as possible and to make a pump-priming contribution towards compensation for netsmen. This recommendation has been accepted by the UK government and they have provided 750,000£ matching funds. Northern Ireland has also provided funding to buy out nets. A new Migratory Salmon Foundation has been set up to raise matching funds.

With NASF assistance, the Welsh mixed stock fisheries off the Rivers Usk and Wye have been bought out permanently by the private sector and there is encouraging movement in Northern Ireland. Thanks to organizations such as NASF and ASF, the serious plight of wild Atlantic salmon is now widely acknowledged by governments. There is an now a need for a concerted effort to capitalize on the progress made so far to ensure first, the survival, and then the restoration of wild Atlantic salmon to abundance.

The 2000 NASCO meetings demonstrated that a broader non-governmental organization (NGO) alliance to save wild salmon stocks is gathering momentum. The recruitment to the cause of major organisations like WWF had added significant strength to the ongoing work of volunteer organizations.

Today, influential groups compete for access to exploit Atlantic salmon, either in oceanic or coastal commercial fisheries, or in rivers by sport fishing. Based on advice from ICES, the high seas fisheries for wild Atlantic salmon are regulated by NASCO, and are under better control than fisheries for comparable species.

Nevertheless, the remaining mixed stock fisheries continue to indiscriminately harvest wild Atlantic salmon populations from river systems under severe stress and the remarkably high numbers of escaped farmed Atlantic salmon in the ocean may be masking downward trends in the actual abundance of wild salmon by showing up as part of these commercial catches.

The trend towards more stringent regulation of river fisheries for wild Atlantic salmon is welcomed since, ultimately, the size of the spawning populations is central to maintenance of genetic variation and recruitment of new generations. There is an urgent need, however, to improve our knowledge of the numbers of wild fish entering each river in order to manage this important species with a view to correcting the serious population decline.

References

Anonymous 1999. Report of the Working Group on North Atlantic Salmon. Int. Counc. Explor. Sea CM 1999/ACFM:14.

FAO. 1989. Review of the state of world fishery resources. FAO Fisheries Circular 710, Rev. 6, Food and Agriculture Organisation, Rome.

Nelson, K. & Soulé, M. 1987. Genetical conservation of exploited fishes, pp. 345-368. *In* N. Ryman & F. Utter (eds) *Population Genetics and Fishery Management*. University of Washington Press, Seattle, WA.

Poupard, Christopher (pers com) of the Salmon & Trout Association, London, UK.

Ricker, W. E. 1981. Changes in the average size and average age of Pacific salmon. Can. J. Fish. Aquat. Sci. 38: 1636-1656.

Scott, Sue (pers. com) of the Atlantic Salmon Federation (ASF), Canada and USA.

Taylor, Bill (pers. com) of the Atlantic Salmon Federation (ASF), Canada and USA.

Vigfusson, Orri.(pers com) The North Atlantic Salmon Fund (NASF), Iceland.

5.4 Salmon aquaculture industry

Aquaculture of the Atlantic salmon (*Salmo salar*) has expanded exponentially since its inception in the 1960s, and now dwarfs wild salmon fisheries. In 1999, the total farmed production of Atlantic salmon was 600,000 tonnes, or more than 300 times the wild salmon caught in all the rivers in the North Atlantic – one tonne of farmed salmon for each individual wild salmon caught (NASCO, 2000). Reports from countries such as Canada, Ireland, Scotland and

Norway have shown that large numbers of escapes from fish farms have contributed to the reduction in wild salmon stocks in these countries.

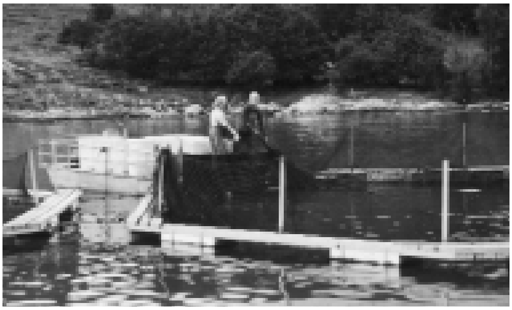
Only small numbers of salmon were being farmed in any country at the start of the 1980s. In 1980, Norway led world production with a total of 4,153 mt, followed by Scotland (598 mt), Ireland (21 mt), Canada (11 mt) and there was no production in the USA. By 1999, the year for which the most recent production figures are available, dramatic increases had occurred, with Norway producing 415,399 mt, Scotland 111,918 mt, Ireland 18,000 mt, Canada 22,537 mt, and the USA 12,194 mt. (ICES 2000, p. 28, Table 2.2.1.1).

Norway, Scotland and Canada have seen drastic (and chronologically and geographically co-incident) declines in wild salmon returns to their rivers (ICES, 2000). This report presents evidence that impacts from salmon farming have contributed to these declines. Wild salmon populations have declined most noticeably in these three countries where intensive salmon farming is underway. Ireland, which is now a major salmon farming nation, has witnessed declines in its wild salmon returns, they have been less dramatic than in the other three nations.

Escapes

Norway

The production of farmed salmon in Norway in 1997 totalled more than 330,000 tonnes (Norwegian Ministry of Environment, 1999), which is more than 500 times greater than that nation's wild salmon catch. In 1998 the production of salmon was 360,000 tonnes, while production of Rainbow trout was 46,000 tonnes. And the industry is expected to grow 8-10 percent a year according to official sources (Norwegian Directorate of Fisheries, 2000). Worse, escaped farmed salmon far outnumber the wild salmon spawning in Norwegian rivers, which have been estimated at 100,000 to 250,000 individuals (Norwegian Ministry of the Environment, 1999).



Changing of nets on a fish farm in Rogaland county in south-western Norway. During such operations farmed salmon may often escape.
Henning Røed, WWF-Norway

At least half a million farmed salmon escape annually and mix with the wild salmon in the sea, along the coast and in the rivers. Escaped fish, together with unnaturally severe sea lice infestations, are regarded by fisheries authorities as the biggest environmental problem connected with salmon aquaculture. Between 30 and 50 percent of the coastal catch may be farmed fish. The percentage of farmed fish as a percentage of the total salmon in rivers varied between 15 and 34 percent during the period 1989-1999 (Norwegian Directorate of Nature Management, 2000), but was as high as 70-90 percent in some rivers (Norwegian Ministry of Environment, 1999).

In the period 1993-1999, the official number given for escaped farmed salmon in Norway is 2,626,000 (Norwegian Directorate of Nature Management, 2000). In the same period, the numbers of smolts in the farms grew from 67 million to twice that number. The Norwegian Ministry of Environment, (1999) has estimated that in the 1988-1992 period and average of 1.6 million farmed fish escaped annually. That would mean that a total of approximately 10.6 million salmon escaped from Norwegian salmon aquaculture operations in the period from 1988 to 1999. (The actual number of escapees may be somewhat higher than the official figures, however, because of unregistered escapes.)

The Norwegian Directorate of Fisheries, which gathers the data on escapes in Norway, has also published statistics since 1997, based on information received from salmon farmers. In 1999, the salmon farmers themselves reported the loss of more than 20 million fish due to diseases, escapes, predators and other causes. However the farmers could not account for 5,700 000 missing farmed salmon. In 1998, moreover, the industry was unable to account for 3,700,000 (Norwegian Directorate of Fisheries, 2000). The numbers of farmed salmon that have escaped from Norwegian fish farms since 1988 is therefore probably much higher than the 10.6 million officially reported.

Elsewhere

Unfortunately, only Norway has published official statistics on the numbers of escaped farmed salmon. However, recent figures on escaped farmed salmon from Scotland confirm that this is not only a Norwegian problem. The Salmon and Trout Association (STA) and Friends of the Earth Scotland (FOE) recently made public a detailed list of escapes from salmon farms in Scotland since 1997 (FOE, 2000). This came in response to the refusal by the Scottish Executive to provide detailed statistics on grounds of commercial confidentiality. According to those figures, farmed escapes now outnumber catches of wild salmon by more than four to one in Scotland. The data show that farmed salmon escapes have increased from 95,000 in 1998 to 395,000 for the first five months of 2000. Of the 31 reported incidents since August 1997, most related to salmon in marine water and were concentrated in Wester Ross, Lochaber, Sutherland, Outer Hebrides, Shetland and Orkney (FOE, 2000).

> Farmed salmon escapes now outnumber catches of wild salmon by more than four to one in Scotland.

In Canada, reports to the Department of Fisheries and Oceans of escapes of farmed Atlantic salmon are not presently required, but many escapes are known to have occurred. In November 1999, 50,000 farmed Atlantic salmon escaped into the Bay of Fundy, and in December 2000 a further estimated 100,000 fish escaped into the bay from a farm in the adjacent State of Maine, perhaps spelling the end for the handful of wild salmon left in the whole of the United States.

In raw numbers of escapees, this is far greater than all the 2SW salmon (salmon that have spent more than one year in the ocean) returning to the coast of Nova Scotia and the Bay of Fundy Rivers (Scott, pers comm.). In 1994, 20,000 to 40,000 farmed salmon escaped in southwest New Brunswick, and many entered rivers in the region (Scott, pers comm.).

It is difficult to obtain official data on total numbers of salmon that have escaped from fish farms in the North Atlantic. The official total number of escaped farmed salmon in Norway is more than 10 million since 1988 and the total number of escaped farmed salmon in all affected countries in the same period may be more than 20 million.

Escapees far outnumber the wild salmon returning to Maine, the coast of Nova Scotia and the Bay of Fundy Rivers (Scott, pers. Comm) There are two distinct lineages of salmon in the rivers draining into the Bay, termed respectively inner and outer Bay fish. The inner Bay salmon are not believed to undertake a migration to the North Atlantic Ocean, whereas the outer Bay fish have been traced to Greenland.

Starting in about 1983, populations of inner and outer Bay fish began to decline. In an effort to stop the declines, fishing was closed on inner Bay in 1991, but recoveries did not materialize. In the outer Bay of Fundy's Magaguadavic river, which has served as a reference river for the interactions between escaped farmed salmon and wild salmon, farmed escapees have been detected in the river in every year since monitoring began in 1992 (Carr et al. 1997, Whoriskey 2000). Escapees have outnumbered wild salmon by as many as 10 to one, and the wild population of the river has fallen from a high in the 1980s of about 1,000 fish, to only 14 fish in 2000. Canada's Department of Fisheries and Oceans is very concerned about the situation (DFO 2000).

Ecological effects

The salmon aquaculture industry tends to officially deny that escapes have any negative effect on wild salmon populations. At a recent meeting between NASCO and the Fish farmers associations from around the North Atlantic, a representative of the Canadian salmon farmers stated that "this industry does not accept that farmed salmon cause any problems for wild salmon" (NASCO, 2000).

A typical salmon farm from Rogaland in south-western Norway.
Henning Røed, WWF-Norway

However, the scientific literature suggests that escaped farmed salmon may indeed be causing serious problem for wild Atlantic salmon. Once they enter salmon rivers, farmed progeny compete with wild salmon for access to spawning partners and sites. Successful spawning of farmed Atlantic salmon that had escaped to Norwegian and Scottish rivers has been documented on the basis of observations of distinct pigmentation differences between the eggs of wild and farmed fish. (Lura and Sægrov, 1991a; Lura and Saegrov, 1991b) Experiments suggest that the reproductive success of farmed salmon is considerably lower than that of wild salmon, especially for males. In rivers with low density of spawners, escaped farmed females may spawn with as high success as wild female (Lura, 1995).

Superimposition of redds (i.e., digging up of eggs of early-spawning fish by late spawning fish), which is common among salmonids, especially when the density of spawners is high, lowers reproductive success. It has been observed that farmed females often destroy the redds of wild salmon in nature. Thus, even though farmed salmon have low spawning success themselves, they can reduce the success of local wild fish (Lura and Sægrov, 1991b).

Experiments with progeny of farmed and local wild fish suggest that the former compete with, and in some cases, dominate, the latter. In hatchery experiments, farmed progeny were more aggressive, and more risk prone, than the progeny from two wild parents. Farmed fish also showed a higher growth rate (Einum and Fleming, 1997). In the wild, observations of habitat use and diet suggest that farmed and wild offspring compete for territories and food, and that both farmed progeny and farmed/wild crosses have higher growth rates than native fish (Einum and Fleming, 1997). An experiment in Ireland showed offspring of farmed salmon will displace offspring of wild salmon (McGinnity *et al.*, 1997).

It is likely that competition between farmed and wild fish in rivers results in lower production of native populations (and perhaps even lower total production). Release of genetically marked farmed and wild salmon into the River Imsa, Norway, in autumn 1993, resulted in a total number of smolts approximately 30 percent lower than the population in this river usually produces from the same number of eggs. This was the second largest depression in 16 years of monitoring, and occurred even though these cage-reared fish faced no competition from older salmon, a factor which is known to increase smolt productivity generally (Fleming *et al.*, 2000).

Little, if anything, is known about interactions between farmed and wild fish in the open ocean. Farmed salmon make up about 20 percent of the salmon caught in the Faroese fishery, and if not accounted for, may mask the size and status of wild stocks in the ocean (Hansen *et al.*, 1997).

Genetic effects

Interbreeding between farmed and wild Atlantic salmon will result in homogenization of the genetic structure of the species and erosion of genetic adaptations to local environmental conditions. At current levels of invasion by farmed fish of the habitats of wild salmon populations, this may be a rapid process.

Atlantic salmon is a genetically sub-structured species, for which genetic differences have been demonstrated between populations in protein-coding genes, nuclear and mitochondrial DNA markers and genetically-based performance traits. Farmed Atlantic salmon represent a mixture of wild populations that have been selected for adaptation to a captive environment since the early 1970s. It has been shown that farmed salmon now differ genetically from the wild populations from which they were derived. This difference includes change in allele frequencies, loss of alleles and loss of total genetic variability (Mjølnerød *et al.*, 1997; Norris *et al.*, 1999), and changes in behavioral and ecological traits (Fleming and Einum, 1997).

A large-scale experiment was recently undertaken in the Norwegian River Imsa to quantify the lifetime reproductive success of farm salmon compared with that of wild salmon. It showed that the lifetime reproductive success (adult-to-adult) of farm fish was only 16 percent of that of native wild salmon (Fleming et al., 2000). With farmed fish representing 55 percent of all spawners, the gene flow from farm to native salmon that occurred during one generation in this experiment was m = 0.19. This means that the genetic difference between the donor (farm) and recipient (native) population is halved every 3.3 generations, depending on the fitness of hybrids during subsequent generations (Hedrick, 1983). The native population will eventually be composed of individuals that have all descended from the migrants, and this situation is approaching rapidly for selectively neutral traits.

This genetic impact comes on top of the potential effects of competition on productivity (e.g., smolt production) and calls into question the long-term viability of many salmon populations (Hindar *et al.*, 1991; Fleming *et al.*, 2000).

The Research Council of Norway, through the National Research Ethics Committee for Natural Sciences and Technology (NENT), has undertaken a case study of the potential genetic interactions between escaped cultivated fish and wild salmon (Kaiser and Storvik, 1997). The authors concluded that the precautionary principle must be applied in developing a strategy to solve the problem. Possible ecological and disease-related interactions were not considered.

Interspecific hybridization

Evidence from Scotland and Norway suggests that the rate of hybridization between Atlantic salmon and Brown trout (*S. trutta*) is increasing, and that escaped farmed salmon may be partly responsible for this increase (Youngson *et al.*, 1993; Hindar and Balstad, 1994). The average proportion of interspecific hybrids is low (1 percent) but reaches 7.5 percent in certain rivers.

Hybrids survive well but rarely reproduce, and thus may lower the productivity of local populations – and in rare cases lead to incorporation of the genetic material of one species into the genome of the other.

Salmon farming and communicable diseases

One of the ways in which salmon aquaculture causes the reduction and loss of salmon populations is through diseases. In particular, transfer of Atlantic salmon between regions has led to fish populations coming in contact with pathogens and parasites to which they were not adapted. These new host-parasite or host-pathogen confrontations have in some cases led to unnaturally high fish mortality.

The small parasitic Salmon lice may kill both small and large salmon in the ocean.
Jan Johansson, Sweden

In Norway, Atlantic salmon populations in more than 35 Norwegian rivers have been severely reduced since 1975 following introductions of fish from hatcheries infected by the parasite *Gyrodactylus salaris*. This parasite does not appear to be native to Norway, and was probably first imported to a central hatchery with salmonid eggs or juveniles from the Baltic in the 1970s. From the central hatchery, the parasite spread to other hatcheries and rivers by intentional transport and releases for stock enhancement, and also with unintentional releases in salmon aquaculture operations. Support for the hypothesis that *G. salaris* is an introduced species has come from experiments showing much higher resistance to the parasite in Baltic salmon than in Norwegian Atlantic salmon (Bakke *et al.*, 1990).

Furunculosis, caused by the bacterium *Aeromonas salmonicida salmonicida* was introduced to Norwegian fish farms with infected smolts from Scotland in 1985, and spread rapidly from the first few infected farms to reach 550 fish farms (70 percent of the total) by the end of 1992. Of the 1.2 million salmon that escaped from fish farms during the winter of 1988-1989, more than 250,000 fish were from farms infected with furunculosis. The spread of furunculosis in Norwegian rivers clearly implicates salmon aquaculture as the main cause. Furunculosis was registered in cultured Rainbow trout and on wild Atlantic salmon in only one Norwegian river from 1965 until the 1970s. When furunculosis appeared in Norwegian fish farms in 1985, it spread rapidly through the whole industry and to wild salmon over a large area. The disease was found among spawning salmon in the autumn of 1989, first among farmed escapees and later among wild fish. By 1992, furunculosis had been detected in 74 Norwegian rivers. In four rivers, the disease reached epidemic proportions (Johnsen and Jensen, 1994). This sequence of developments shows the enormous potential that salmon aquaculture activities have for disease transmission.

Salmon farming and parasites

Salmon lice (*Lepeophtheirus salmonis, Caligus* sp.) have been a problem in aquaculture since the mid 1970s, and have been recognized as a problem on wild Brown trout and Atlantic salmon since 1989 (Tully *et al.*, 1993a; Tully *et al.*, 1993b). Salmon lice have been shown in experimental studies to transfer the infectious virus salmon anemia between fish (Nylund *et al.*, 1993). Salmon lice have caused the premature return of anadromous Brown trout (sea trout) to freshwater and reduced sea-water growth (Tully *et al.*, 1993a; Tully *et al.*, 1993b; Birjkeland, 1996; Birkeland and Jakobsen, 1997). Heavily infested sea trout and Atlantic salmon smolts have increased sea-water mortality (Grimnes and Jakobsen, 1996; Finstad *et al.*, 2000).

To what extent salmon lice are implicated as a cause for the recent unexplained high mortality of Norwegian salmon in the ocean is not yet clear. According to the Marine Research Institute in Bergen, up to 86 percent of juvenile salmon leaving the rivers are killed by sea lice and never make it into the open ocean (Marine Research Institute, 1999). According to Tulley and others (1993), the worst infections of sea lice on wild salmon are in areas with salmon farming. Because of the large numbers of farmed salmon compared to wild salmon, it is likely that the incidence of salmon lice on farmed fish is much more substantial than the incidence on wild salmon. In Ireland it has been estimated that 95 percent of the sea lice come from farmed salmon (Tulley and Whelan, 1993).

In Norway, approximately 200 million farmed salmon now exist in Norwegian fish farms. The total number of wild spawners, meanwhile, is estimated to be between 100,000 and 250,000. (Norwegian Ministry of Environment,

Genetic modification

The potential threat from the escape of farmed fish has been heightened by the recent experimental production of genetically modified fish. Development of transgenetic salmon was pioneered in Canada, where genes form other fish species were inserted into the DNA of salmon to increase growth rates. No transgenic fish have been given clearance for commercial production in Europe yet. However, between 1995 adn 1997, a land-based salmon farm in Scotland reared transgenic salmon on an experimental basis using the Canadian DNA construct (Ross, 1997). Media reports confirm that similar experiements with transgenic fish have been undertaken recently in both Canada and the USA. In July 2000 an article in Nature (Reichhardt, 2000) reported that a Massachusetts aquaculture company was in the process of applying for a license to start farming genetically modified salmon.

The most obvious danger, preceding genetically modified salmon, arises from the transmission of inserted alien genes to wild fish if the transgenic fish escape and breed in the wild. It has been noted that the transmission of such genes to wild fish could lead to physiological and behavioural changes and that traits other than those targeted by the inserted genes are likely to be affected. Clearly the outcome of such an event would be highly unpredictable (Kapuscinski & Hallerman, 1990). Ecological impacts are also unpredictable, but faster growing fish are likely to out-compete their wild counterparts for food or mates and other artificially introduced traits such as cold-tolerance could affect geographic distribution of the species with profound ecological effects.

Transgenic fish would ultimately find their way into wild salmon runs. The number of accidentally-released fish from aquaculture operations is considerable; in Norway, the biomass of escaped fish surpasses the annual yield of wild fish in the sea and rivers combined.

It has therefore been proposed that any use of transgenic fish should be contained, either physically in secure units and/or biologically using sterile fish. However, physical containment is argued not to be viable in an industry dominated by cage culture, and sterilisation methods are not considered to be 100% safe. NASCO (2000) in its annual meeting stated that "there should be a strong presumption against any activity which would risk the introduction of transgenic salmonids to the wild".

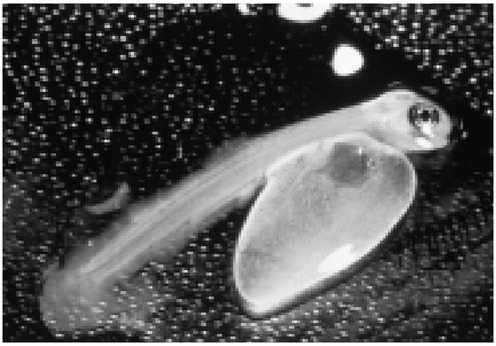
1999). The wild salmon are out in the open ocean (Faeroe Island and the North Atlantic) most of the time, while the salmon farms and farmed salmon are in the net pens in the fjords, which wild salmon smolts must pass on their way to the open ocean. According to a recent Norwegian study (Nilson, 2000), if each farmed salmon has one female louse carrying eggs the pressure on the wild salmon will be 200 times higher than it was before salmon farming existed.

In Hordaland, the main salmon aquaculture county in Norway, the maximum number of individual female lice on individual farmed salmon varied between 3 and 100 (Norwegian Animal Health Authority, 1999). In salmon fisheries in Norwegian fjords in the winter escaped farmed salmon have been observed 1,256 times more often than wild salmon (Norwegian Ministry of Environment, 1999). Because of the escaped farmed salmon with sea lice in the coastal waters of Norway, the sea lice populations in those waters threaten the migrating salmon which leave the rivers in mid-May (Norwegian Ministry of Environment, 1999). Salmon farmers and the authorities are aware of this and have carried out co-ordinated delousing in many areas with good results. In future, such operations are planned in all salmon farming areas in Norway.

Other aquacultured fish

The Rainbow trout (*Oncorhynchus mykiss*) has been transferred from western North America to Europe for use in aquaculture, and for stocking. Establishment of this species in the wild is extremely rare in Europe, despite more than a century of introductions. In Norway, Rainbow trout have established only in a few lakes and dams without native fish communities. However, Rainbows have reproduced successfully in one stream having both native Atlantic salmon and Brown trout, following an escape of farmed Rainbow trout to that stream. It is not yet known whether this is a one-off event; young Rainbow trout have not been seen in the stream after being recorded there twice as age 0+ fish in 1994 (Hindar *et al.*, 1996; Sægrov et *al.,* 1996).

Rainbow trout are known to compete with native European salmonids, and will suppress Atlantic salmon populations where they establish self-sustaining populations. Even if they do not establish such populations, escaped (or stocked)



An egg yolke larvae of salmon, recently hatched from the egg.
Jan Johansson, Sweden

Rainbow trout may compete with native Atlantic salmon in rivers and in estuaries (Hindar *et al.*, 1996).

In eastern Canada, where introduced Rainbows have successfully established colonies in the past, escaped farmed Rainbow trout are currently showing up in increasing numbers of salmon streams in insular Newfoundland. The actual risk of colonization by these animals is not known at this time.

References

Bakke, T. A., Jansen, P. A. and Hansen, L. P. (1990). Differences in host resistance of Atlantic salmon, *Salmo salar* L., stocks to the monogenean *Gyrodactylus salaris* Malmberg, 1957. *J. Fish Biol.* 37: 577-587.

Birkeland, K. & Jakobsen, P. J. (1997). Salmon lice, *Lepeophtheirus salmonis,* infestation as a causal agent of premature return to rivers and estuaries by sea trout, *Salmo trutta*, post smolts. *Env. Biol. Fish*. 49: 129-137.

Birkeland, K. (1996). Consequences of premature return by sea trout (*Salmo trutta* L.) infested with the salmon louse (*Lepeophtheirus salmonis* Krøyer): migration, growth and mortality. *Can. J. Fish. Aquat. Sci*. 53: 2808-2813.

Carr, J. W., J. M. Anderson, F. G. Whoriskey and T. Dilworth 1997. The occurrence and spawning of culture Atlantic salmon (Salmo salar) in a Canadian river. I.CES Journal of Mar. Science 54:1064-1073.

DFO 1999/ Interaction between wild and farmed Atlantic salmon in the Maritime provinces. DFO Maritimes Regional Habitat Status Report 99/1 E.

Directorate for Nature Management, Government of Norway. (1999). *Bestandssituasjonen for laks* (The situation for salmon stocks) Trondheim: Directorate for Nature Management.

Directorate of Nature Management. (2000). *Miljømål for norsk oppdrettsnæring* (Environmental goals for Norwegian Aquaculture). Trondheim: Directorate for Nature Management.

Einum, S. and Fleming, I.A. (1997). Genetic divergence and interactions in the wild among native, farmed and hybrid Atlantic salmon. *J. Fish Biol.* 50: 634-651.

Finstad, B., Bjørn, P. A. and Hvidsten, N. A. (2000). Laboratory and field investigations of salmon lice (*Lepeophtheirus salmonis* Krøyer) infestation on Atlantic salmon (*Salmo salar* L.) post-smolts. Aquaculture Research 31: in press

Friends of the Earth (FOE). (2000). Press Release. Edinburgh, Scotland. June 6.

Grimnes, A. and Jakobsen, P. J. (1996). The physiological effects of salmon lice (*Lepeophtheirus salmonis*) infection on post smolt of Atlantic salmon (*Salmo salar*). J. Fish Biol. 48: 1179-1194.

Fleming, I.A., Jonsson, B., Gross, M.R., and Lamberg, A. 1996. An experimental study of the reproductive behaviour and success of farmed and wild Atlantic salmon (*Salmo salar*). *Journal of Applied Ecology,* 33: 893-905.

Fleming, I. A. and Einum, S. (1997). Experimental tests of genetic divergence of farmed from wild Atlantic salmon due to domestication. *ICES J. Mar. Sci.* 54: 1051-1063.

Fleming, I. A., K. Hindar, Mjølnerød, I. B., Jonsson, B., Balstad, T. and Lamberg, A. (2000). Lifetime success and interactions of farm salmon invading a native population. *Proc. R. Soc. Lond.* B 267: 1517-1524.

Fleming, I.A., Lamberg, A. and Jonsson, B. 1997. Effects of early experience on the reproductive performance of Atlantic salmon. *Behav. Ecol.,* 8: 470-480.

Hansen, L. P., Jacobsen, J. A. and Lund, R. A. (1997). The incidence of escaped farmed Atlantic salmon, *Salmo salar* L. In *The Faroese fishery and estimates of catches of wild salmon*. ICES working paper. Copenhagen: North Atlantic Salmon Working Group.

Hedrick, P. W. (1983). *Genetics of Populations*. Boston: Science Books International.

Hindar K. (2000). Pers comm.

Hindar, K. and Balstad, T. (1994). Salmonid culture and interspecific hybridization. *Conservation Biology* 8: 881-882

Hindar, K., I., Fleming, A., Jonsson, N., Breistein, J., Sægrov, H., Karlsbakk, E., Gammelsæter, M., and Dønnum, B. O. (1996). Rainbow trout in Norway: occurrence, reproduction and establishment. *NINA Oppdragsmelding* 454: 1-32. (In Norwegian, English summary).

Johnsen, B. O. and Jensen, A. J. (1994). The spread of furunculosis in salmonids in Norwegian rivers. *J. Fish Biol.* 45: 47-55.

Kaiser, M. and Storvik, H. (1997). *The precautionary principle between research and politics,* (in Norwegian). *The National Research Ethics Committee for Natural Science and Technology.* NENT publication no. 11.

Kapuscinski A.R & Hallerman E.M (1990). Transgenic Fishes. American Fisheries Society Position Statement. Fisheries 15(4): 2-5.

Lura, H. and Sægrov, H. (1991a). A method of separating offspring from farmed and wild Atlantic salmon (*Salmo salar*) based on different ratios of optical isomers of astaxanthin. *Can. J. Fish. Aquat. Sc*i. 48: 429-433.

Lura, H. and Sægrov, H. (1991b). Documentation of successful spawning of escaped farmed female Atlantic salmon, *Salmo salar*, in Norwegian rivers. *Aquaculture* 98: 151-159.

Lura, H. (1995). Domesticated female Atlantic salmon in the wild: spawning success and contribution to local populations. Doctoral thesis, University of Bergen.

Marine Research Institute (1999). Lice infection: Press release from the Marine Research Institute (havforskningsinstituttet) in norwegian: http://www.imr.no/info/pm/1999/pm19990813.htm

McGinnity, P., Stone, C., Taggart, J. B., Cooke, D., Cotter, D., Hynes, R., McCamley, C., Cross, T. & Ferguson, A. (1997). Genetic impact of escaped farmed Atlantic salmon (Salmo salar L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment. ICES J. Mar. Sci. 54: 998-1008.

Mjølnerød, I. B.,. Refseth, U. H., Karlsen, E., Balstad, T., Jakobsen, K. S., and Hindar, K. (1997). Genetic differences between two wild and one farmed population of Atlantic salmon (*Salmo salar*) revealed by three classes of genetic markers. Hereditas 127: 239-248.

NASCO (North Atlantic Salmon Conservation Organization). (2000). Report to the Annual Meeting of the Council. Seventeenth Annual Meeting. Miramichi. Canada. Edinburgh. NASCO.

Nilsen, F. (2000). *9 Millioner til luseforskning. Fiskets Gang* (9 million NOK for the study of salmon lice) Bergen. The Directorate of fisheries. Pp. 49-50

Norris, A. T., Bradley, D. G. and Cunningham, E. P. (1999. Microsatellite genetic variation between and within farmed and wild Atlantic salmon (*Salmo salar*) populations. *Aquaculture* 180: 247-264.

Norwegian Animal Health Authority (1999). *Nasjonal handlingsplan mot lakselus* (National action plan against lice). Oslo-. Statens Dyrehelsetilsyn.

Norwegian Directorate for Nature Management (2000) *Nasjonal tiltaksplan mot rømming*:(Norwegian National plan for measures to prevent escapes). Trondheim. Directorate for Nature Management.

Norwegian Directorate of Fisheries (1999*), Fiskeridirektoratet, Statistikk for fiskeoppdrett* (Fish farming Statistics from the Directorate of fisheries). Bergen. Directorate of Fisheries.

Norwegian Directorate of Fisheries. (2000a). *Nøkkeltall fra norsk havbruksnæring 1999.* (Key figures from Norwegian aquaculture) Bergen. Directorate of fisheries.

Norwegian Directorate of Fisheries. (2000b). *Statistikk fra norsk havbruksnæring 2000* (Statistics from Norwegian aquaculture). Bergen. Directorate of Fisheries.

Norwegian Ministry of Environment. (1999). *Til laks åt alle kan ingen gjera*? ("Not enough salmon for all?") http://balder.dep.no/nou/1999-9/innhold.htm

Nylund, A., Wallace, C. and Hovland, T. (1993). The possible role of *Lepeophtheirus salmonis* (Krøyer) in the transmission of infectious salmon anemia, pp. 367-373. *In* G. A. Boxshall & D. Defaye (eds) *Pathogens of Wild and Farmed Fish: Sea Lice.* New York: Ellis Horwood.

Reichhardt T. (2000). Will souped up salmon sink or swim? Nature 406, pp 10-12.

Ross A. (1997). Leaping in the Dark. A review of the environmental impacts of marine salmon farming in Scotland and proposals for change. A report for Scottish Wildlife and Countryside Link, Perth. 92 p.

Scott, S. Pers comm. (2000). Sue Scott, Atlantic Salmon Federation (ASF). St. Andrews, Canada.

Sægrov, H., Hindar, K. and Urdal, K. (1996). Natural reproduction of anadromous Rainbow trout in Norway. *J. Fish Biol.* 48: 292-294.

Tully, O. and Whelan, K. R. (1993). Production of nauplii of *Lepeophtheirus salmonis* (Krøyer) (Copepoda: Caligidae) from farmed and wild salmon and its relation to the infestation of wild sea trout (*Salmo trutta* L.) off the west coast of Ireland in 1991. *Fish. Res.* 17: 187-200.

Tully, O., Poole, W. R. and Whelan, K. R. (1993a). Infestation parameters for *Lepeophtheirus salmonis* (Krøyer) (Copepoda: Caligidae) parasitic on sea trout, *Salmo trutta* L., off the west coast of Ireland during 1990 and 1991. *Aquacult. Fish. Manage.* 24: 545-555.

Tully, O., Poole, W. R., Whelan, K. R and Merigoux, S. (1993b). Parameters and possible causes of epizootics of *Lepeophtheirus salmonis* (Krøyer) infesting sea trout (*Salmo trutta* L.) off the west coast of Ireland, pp. 202-213. *In* G. A. Boxshall and Defaye, D. (eds) *Pathogens of Wild and Farmed Fish: Sea Lice*. Ellis Horwood, New York.

Youngson, A. F., Webb, J. H., Thompson, C.E. and Knox, D. (1993). Spawning of Escaped Farmed Salmon (*Salmo Salar*) by hybridisation of Female with brown trout (*Salmo trutta*). *Can J. Fish Aquat Sci* 50: 1986-1990.

5.5 Stocking and sea-ranching

Atlantic salmon and other salmonid fishes have been artificially propagated and released into the wild on a large scale for more than a century. Releases are carried out for a variety of reasons – conservation of endangered populations, augmentation of non-endangered populations, compensation for human-mediated loss of production, re-establishment of extinct populations, and increased catch.

An Atlantic Salmon Federation researcher returns an Atlantic salmon to its river in late autumn, after measuring it and taking a scale sample for analysis.
Atlantic Salmon Federation

The artificial reproduction of Brown trout was mastered in Germany in the middle of the 18th century. From the 1850s onwards, this technique was used to supplement populations of several species of salmonid fishes all over the northern hemisphere. Initially, the young were released as unfed fry, and as rearing techniques improved, also as summer-old juveniles, out-migrating smolts, and eventually all life stages. Currently, releases involve millions of Atlantic salmon and Rainbow and Brown trout, and billions of Pacific salmon (genus Oncorhynchus) (Isaksson, 1988).

In some regions, such as the rivers draining into the Baltic Sea, artificially propagated Atlantic salmon account for 80-90 percent of the outmigrating smolts (Hindar and Jonsson, 1995). This sea-ranching of Atlantic salmon frequently involves a technique known as "delayed release" whereby outmigrating post-smolts are released directly into salt water, instead of rivers. The technique improves survival – but it also increases straying to other rivers. Large-scale release programs carried out in this manner will overcome the natural population dynamics and, eventually, the natural genetics of the species over broad areas. Such an eventuality would constitute a serious threat to the future of wild populations (Ryman and Utter, 1987).

In the Baltic, extraordinarily high rates of interspecific hybridization between Atlantic salmon and Brown trout have been found in some rivers. This phenomenon is probably related to release programs in this region (Laikre *et al.*, 1999).

Releases of artificially propagated individuals may have both ecological and genetic consequences. It is disturbing, therefore, that most release programs have been carried out without any pre-existing assessment of their impact on natural populations (Cowx, 1994). The ecological consequences relate primarily to competition between released and wild fish, which may involve displacement of wild fish by the released fish, especially directly after release when hatchery-reared fish enjoy a competitive advantage due to a larger body size. While hatchery-reared fish demonstrate poorer survival rates, they can still register a substantial impact if released in large numbers (Waples, 1991; Grant, 1997).

The potential genetic effects of released fish are substantial. If releases are based on local population only, the genetic impacts relate to inbreeding and domestication in the artificially propagated part of the population. Several studies have shown genetic changes in hatchery populations, such as loss of genetic variation within the hatchery and genetic divergence from the populations from which they originated. Mass releases of hatchery-reared fish may therefore reduce the genetic variation even in the recipient natural population. (Ryman, 1991). If, however, releases are based on non-native stocks, several genetic concerns are posed, in addition to loss of variability in the hatchery. These include loss of local adaptations through interbreeding and erosion of the genetic structure of the species (Ryman et al., 1995).

A review of the genetic effects on native populations of releases of non-native salmonid populations (Hindar et al., 1991) came to two broad conclusions:

- The genetic effects of (intentionally or accidentally) released salmonids on natural populations are typically unpredictable; they vary from no detectable effect to complete introgression or displacement.
- Where genetic effects on performance traits have been detected, they appear always to be negative in comparison with the unaffected native populations. For example, reduced total population size has been observed following introductions of non-native populations, along with reduced performance in a number of traits which would explain such population declines (e.g. lower survival in freshwater and marine environments).

The typically negative effects of releases of non-native populations of salmonid species are not unexpected. Salmonid populations have been shown to demonstrate adaptations to their local environments, and introduced populations (or crosses involving introduced populations) should be expected to perform less well than native populations. (Taylor, 1991).

In some instances, stocking of salmonid fishes has involved exotic species, such as Brown trout released into North America and Rainbow trout released into Europe. Brown trout releases into eastern Canada and the USA have led to interspecific hybridization with Atlantic salmon at rates that are higher than those occurring where the two species coexist naturally. Moreover, adding an exotic salmonid species leads to more intense competition, and very often the introduction of exotic pathogens and parasites which may have detrimental effects on local populations (Krueger and May, 1991).

References

Cowx, I. (1994). Stocking Strategies. *Fish. Manage. Ecol.* 1: 15-30.

Grant, W. S. (ed.) (1997). *Genetic effects of straying of non-native hatchery fish into natural populations: proceedings of the workshop.* US Dep. Commer., NOAA Tech. Memo., NMFS-NWFSC-30, Seattle, WA.

Hindar, K., Ryman, N. and Utter, F. (1991). Genetic effects of cultured fish on natural fish populations. *Can. J. Fish. Aquat. Sci.* 48: 945-957.

Hindar, K. and Jonsson, B. (1995). Impacts of aquaculture and hatcheries on wild fish, pp. 70-87. *In* D. P. Philipp, J. M. Epifanio, J. E. Marsden and Claussen, J. E. (eds) *Protection of Aquatic Biodiversity. Proceedings of the World Fisheries Congress, Theme 3.* Oxford and IBH Publishing, New Delhi.

Isaksson, A. (1988). Salmon ranching: a world review. *Aquaculture* 75: 1-33.

Krueger, C. C. and May, B. (1991). Ecological and genetic effects of salmonid introductions in North America. *Can. J. Fish. Aquat. Sci*. 48 (Suppl. 1): 66-77.

Laikre, L. (ed.). (1999). *Conservation genetic management of brown* trout (Salmo trutta) *in Europe.* Report by the "TROUTCONCERT". CED Contract FAIR CT97 3882. Silkeborg, Denmark: Danish Institute for Fisheries Research.

Ryman, N. (1991). Conservation genetics considerations in fishery management. *J. Fish Biol.* 39 (Supp. A): 211-224.

Ryman, N. and Utter, F. (eds.) (1987). *Population Genetics and Fishery Management*. University of Washington Press, Seattle, WA.

Taylor, E. B. (1991). A review of local adaptation in Salmonidae, with particular referencew to Pacific and Atlantic salmon. *Aquaculture* 98: 185-207.

Waples, R. S. (1991). Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. *Can. J. Fish. Aquat. Sci.* 48 (Suppl. 1): 124-133.

5.6 Climate change

Future climate scenarios for the northern hemisphere suggest a temperature increase of 1-5 ^{o}C, mainly due to changes in winter temperature, particularly in inland areas.

Precipitation is expected to increase by seven to eight percent so that winter runoff will increase markedly, while the summer runoff will decrease. In the colder regions of Atlantic salmon distribution, milder, wetter winters will result in heavier accumulation of snow and higher spring floods. Here, where rivers are ice-covered during winter, no change in winter water temperature is anticipated. Elsewhere, however, winter water temperatures will increase and spring floods will be considerably reduced (Jensen, 1992).

If climate does change in accordance with this scenario, hatching of salmon eggs will be accelerated in the southern portion of salmon distribution, and juveniles will need to start feeding earlier in spring. This initial feeding is a critical point in the life of salmon. It is likely that several food organisms will be available, as they will also develop more rapidly at higher water temperatures.

However, altered flood regimes may present a harsher environment to juvenile salmon, especially in the coldest rivers where the spring flood is likely to increase (Jensen, 1992). Human activity, including river regulation and the channelization of floodplains, will exacerbate the severity of floods.

Growth conditions in northern rivers are likely to improve, and so will the productivity of salmon smolts. In contrast, rivers in the southern part of the distribution range are likely to present salmon juveniles with warmer water at a lower runoff, which may reduce productivity (Jensen, 1992). Altered flow regimes are likely to influence the timing of the outmigration of the smolt, as well as the timing of ascending adults.

Since different salmon populations will be affected differently by climate change, it is difficult to predict changes for the species as a whole. Moreover, changes in the marine environment may be so predominant that they mask variation in individual rivers. Research on the North Atlantic during the last 30 years, has shown that temperature changes in the ocean affect both the survival and growth of Atlantic salmon. River populations in distant locations have shown parallel variations in sea survival and growth. This appears to improve for post-smolts (i.e. fish which have recently left the rivers as smolts) during warm ocean years.

Similar to predictions for pacific salmonids, Atlantic salmon distributions will shift to the areas where the habitat is most suitable. If the most suitable habitat shifts north due to global warming, that is where the salmon will go. (Welch et al., 1999)

This research has also indicated that some of the large-scale variations in salmon populations in the past may have co-incided with a general cooling of the North Atlantic (Friedland et al., 2000). The North Atlantic temperatures depend on major current patterns to a larger extent than global mean temperatures. It is, therefore, premature to say whether marine habitats for salmon will improve or be degraded by global warming.

It is likely, however, that the more extreme climatic conditions become, the more vulnerable salmon populations will become to co-occurring human-related environmental impacts.

References

Jensen, A. J. (1992). Effects of climate change on Atlantic salmon in Norway. NINA (Trondheim) Research Report 36: 1-21 (In Norwegian, English summary)

Welch, D. W. B. R. Ward and B. D. Smith. In press. Temporal and spatial responses of British Columbia Steelhead (*Oncorhynchus mykiss*) populations to ocean climate shifts. Fisheries Oceanogr.

Friedland, K.D., Hansen, L. P., Dunkley, D. A. and MacLean, J. (2000). Linkage between ocean climate, post-smolt growth, and survival of Atlantic salmon (Salmo salar L.) in the North Sea area. ICES Journal of Marine Science 57: 419-429.

6

The economic value of wild salmon stocks

The value of the salmon farming industry to national and local economies has been the subject of much media coverage and political posturing in recent years. The inherent value of the wild salmon stocks and of the economic revenue wild salmon generate for those same mainly rural economies has not received equal emphasis. Conservation of wild Atlantic salmon will yield larger economic benefits than is commonly believed.

Polls in the United States suggest the general public has a strong preference for helping endangered wild salmon stocks, but often fear the necessary steps may impose severe economic consequences. Niemi and Whitelaw (2000) reported on recent studies in Oregon and Washington States showing that 137 businesses had saved $42 million by taking steps to help Pacific salmon stocks. The study also estimated the average value of a salmon in recreational fisheries at $200 per fish, while the per-fish value in Pacific coast commercial fisheries could be between $5 and $70. Recreational fisheries would create an estimated 2.5 times more jobs than commercially caught fish.

The net economic value of an activity or service is the total sum of the individual's willingness to pay for it, minus the opportunity cost of the resource used in providing it. In 1991 an economic evaluation of salmon fisheries in

Great Britain (Radford *et al.*, 1991) was published by Portsmouth Polytechnic's Centre for Marine Resource Economics (CEMARE). Radford *et al.* (1991) estimated that the net economic value of rod fisheries in Scotland in 1988 lay within the range £198 million to £300 million, with a best estimate of £255 million. Updating this estimate based on the change in rental values between 1988 and 1995, the Scottish Salmon Strategy Task Force (Mclay and Gordon-Rogers, 1997) estimated the net economic value for rod fisheries in Scotland in 1995 at £350 million, with a possible range of £270 million to £430 million.

The economic benefits of angling extend well beyond the fishery owners. In addition to their direct expenditure on the rental of fishing, anglers also require additional service, for example rods, reels and other tackle, accommodation, food, drink, and clothing. In 1988, the gross expenditure by salmon anglers in Scotland was £34 million and that angling generated about 3,400 full-time equivalent (FTE) jobs. The total expenditure, including indirect effects, was estimated as £50.4 million a year. Updating this estimate in line with the Retail Price Index, the total expenditure by salmon anglers in Scotland is now more than £70 million a year (Mclay and Gordon-Rogers, 1997).

The economic value of Scotland's rod fisheries might also be expressed in terms of the capital value of purchases on the open market. On the major Scottish salmon rivers, where the great majority of fish are caught, revenues from fishing fees currently range from £6,000 to £8,000 per fish, based on the average catch per year for each licence. Over the last five years, the total rod catch in Scotland has averaged 75,000 fish. On this basis, the total market value of Scotland's salmon angling today might be in excess of £400 million per year (Mclay and Gordon-Rogers, 1997).


Floor Water in River Tweed, one of the most famous Scottish salmon rivers. In the background the magnificent Floors castle.
Jan Johansson, Sweden

Studies have also been undertaken to establish the local economic impact of salmon angling in Scotland. In 1995, it was estimated that salmon angling on the River Dee contributed between £5 and £6 million a year to the economy of the Grampian region. A study commissioned by the Tweed Foundation in 1996 revealed that the Tweed salmon fisheries brought £12.5 million a year to the Border region's economy and that angling supported more than 500 jobs (McLay and Gordon-Rogers, 1997).

The value of wild salmon in Norway and Sweden

A recent research project in Norway evaluating the profitability of treating salmon rivers infected with *Gyrodactylus salaris* with rotenone, estimated the annual economic revenue of the wild salmon in the watercourses around the Trondheimsfjord at NKr 87-160 million (approximately US$10-18 million). The total value of the wild salmon in the rivers in this area was estimated to be NKr 1.25 billion, or approximately US$140 million. (Mørkved and Krokan, 2000).

The Norwegian Wild Salmon Committee (Ministry of Environment, 1999) analyzed five different studies of the sports fishing revenues earned from salmon fisheries in Norwegian and Swedish rivers. These studies showed that caught salmon had a value ranging from NKr 465 per kilo in 1989 to NKr 2,608 per kilo in 1996 in Norwegian rivers, and ranging from SKr 875 per kilo in 1983 to SKr 1,979 per kilo in 1989 in Swedish rivers. Thus, the value of wild salmon caught in recreational fisheries in this region has been estimated at between US$200-280 per kilo in recent years.

The river Surna in mid Norway.
Jan Johansson, Sweden

If wild salmon resources in Norway were restored and utilized in a sustainable manner, salmon catches in rivers could easily be around 1,000 to 2,000 tonnes annually (according to annual catch statistics published by NASCO (2000)). Using a mid-range estimate of NOK 2000 per kilo, the economic value of wild salmon stocks could thus be at least between NOK 2 – 4 billion (US$220 – 440 million) annually. The value of the wild salmon catch in Norway would then be of the same order of magnitude as the value of salmon farming, which had a 1999 export value of approximately 11 billion NOK (US$1.2 billion). (And the value of salmon farming should be discounted appropriately in order to take into account the environmental costs associated with the industry.)

It should also be noted, that without the wild salmon, there would be no salmon farming industry in countries like Norway, Scotland, Ireland, Canada and the USA. The genes of wild salmon stocks contain information that the salmon farming industry may need to solve future problems. Therefore, any calculation of the full economic value of wild salmon to any nation in which salmon farming is an important industry, should take into account the contingent value of wild salmon to the salmon farming industry.

The value of wild salmon in Canada

Whoriskey and Glebe (in press) reviewed the literature available on the economic value of the recreational Atlantic salmon fishing industry in Canada. They focused in particular in the provinces of Quebec and New Brunswick where salmon populations are relatively well monitored, where large recreational angling fisheries occur, and where more economic information available. They drew on a variety of sources including the Canadian Government's most recent survey of the value of the recreational angling industry (Economic and Policy Analysis Directorate, 1997), and studies of the New Brunswick (Tuomi 1987, 1980) and Quebec (Michaud, 1990) Atlantic sport fishing industries.

Direct annual spending for salmon fishing was estimated at about $166 million (all figures in Canadian dollars), and the capital value of salmon waters in New Brunswick may be approaching $194.4 million. In recent years, Canadian Federal and Provincial governments, together with private sector partners, have spent more than $150 million to attempt to expand recreational fishing. Angling licence sales, though declining, have declined much more slowly than the salmon populations. Thus the economic benefits of the recreational salmon fishery have remained relatively high. However, efforts to garner additional revenues from salmon angling have been only partially successful because of the poor salmon returns to rivers.

Additionally, difficult to quantify benefits from wild Atlantic salmon come from the species' contribution to aboriginal fisheries and traditions, its use as a source of genetic material for the salmon aquaculture industry, and its aesthetic appeal.

The cost of reintroducing salmon stocks

Many programs have been established to reintroduce salmon into former salmon rivers. The salmon-introduction program for the Rhine has cost the bordering nations and the European Commission (part of the EU-LIFE-Program) about EMU 8-10 million for habitat improvements. These measures consist of reducing effluents, building fish ladders or other means of facilitating fish migration, spawning materials, research etc. A further EMU 7.5 million has also been expended for building a new fish passage at the weir at Iffezheim, and EMU 7.5 million more is planned used on another fish passage at the weir at Gambsheim (Schulte-Wülwer-Leidig, 2000).

However, even if only a small fraction of the half million salmon that once filled the Rhine a century ago could be restored to the river, as experts now anticipate (Chichester, 1999), these relatively modest costs could be recovered in only a few years by the expenditures of sports fisherman in the river.

The Rhine bordering countries, Switzerland, France, Germany, Luxembourg and the Netherlands have also spent roughly EMU 50 billion to clean up the Rhine and for construction of sewage water plants for cities and industries on the river during the past 25 years (Schulte-Wülwer-Leidig, 2000). But the Rhine cleanup provides far broader ecosystem services and amenities than just the possible restoration of wild salmon stocks (ICPR, 2000).

References

Canadian Department of Fisheries and Oceans. (1990). *1988 Survey of Atlantic Salmon Anglers in Canada*. Economic Analysis and Statistics Division Economic and Commercial Analysis Directorate. Economic and Commercial Analysis Report No. 63.

Chichester, P. (1999). Resurrection on the Rhine. *International Wildlife*. September-October. http://www.nwf.org/intlwild/salmon.html

ICPR (International Commission for the Protection of the Rhine). (2000). "Salmon 2000: The Rhine, a salmon river again?" www.iksr.org./icpr/welcome.html

McLay, A. and Gorden-Rogers, K. (Eds.). (1997). *Report of the Scottish Salmon Strategy Task Force*. Edinburgh. The Scottish Office.

Ministry of Environment. (1999). *Til laks åt alle kan ingen gjera?* ("Not enough salmon for all?" Oslo. Norwegian Governmental report NOU: 9 1999, 297 p. http://balder.dep.no/nou/1999-9/innhold.htm

Mørkved, O. J. and Krokan, P. S. (2000). *Nytte – kostnadsanalyse av prosjektet rotenonbehandling av Steinkjærvassdragene, Utredning for DN 2000-3* (Cost-benefit analysis of use of Rotenon to treat the Steinkjær rivers) (with English summary). Trondheim, Directorate for Nature Management. 38 p.

Niemi, E. and Whitelaw, E. (2000). Salmon and the Economy. *Conservation Biology in Practice*. 1: 20-21.

Radford, A.F., A.Hatcher and Whitmarsh, D. (1991). An economic evaluation of salmon fisheries in Great Britain, volume 1: principles, methodology and results for England and Wales. CEMARE Report, no 16, 1991. 292 p.

Schulte-Wülwer-Leidig. A. (2000). Pers. comm. Internationale Kommission zum Schutze des Rheins. P.O. Box 309, D-56003 Koblenz, Germany.

Michaud, L. 1990. Évauluation de la valeur economique du saumon Phase II. Estimation des valeurs reliées aux utilisations directes. Rapport préparé pour la vice-presidence Environnement d'Hydro-Québec. Décembre 1990. 2 volumes: rapport final 70 pages; résumé 6 pages.

Tuomi, A. L. W. 1980. Canada's Atlantic salmon: an economic evaluation of the New Brunswick sport fishery. The International Atlantic Salmon Foundation Special Publication Series, No. 8.

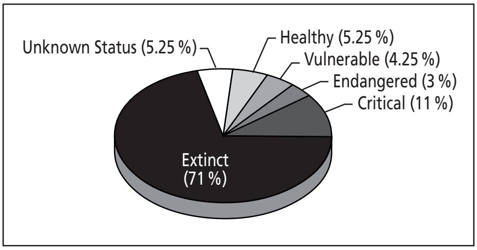
Tuomi, A. L. W. 1987. Canada's Atlantic salmon recreational fisheries and their future: An economic overview. Atlantic Salmon Federation Special Publication Series, No. 14.

Whoriskey, F. G. and J. Glebe. In press. The Atlantic salmon recreational angling industry: economic benefits. In: Sustaining North American Salmon: Perspectives across regions and disciplines.

7

Status of salmon rivers by country or region

7.1 The Baltic



Categorization (%) of non-Russian salmon-bearing rivers in the Baltic.

Populations of Atlantic salmon in the Baltic Sea have been isolated from those in the Atlantic Ocean for thousands of years. The Baltic populations are therefore genetically distinct from the western Atlantic and other European populations. There is further genetic differentiation among Baltic salmon from different rivers. Most Baltic Sea salmon migrate in the post-smolt stage to the main feeding areas in the Baltic proper and return to their home rivers after 2-4 years. In the Baltic Sea, the salmon feed mainly on sprat and herring.

The state of wild Atlantic salmon populations in the Baltic region appears extremely serious. At the beginning of the 20th Century, 60 or so Baltic rivers produced an estimated 7-10 million smolts annually; but it is estimated that only about 400,000 wild salmon smolt migrated to the Baltic Sea each year in the mid-1990s (IBSFC, 2000). Thus, the annual production of smolt in the Baltic has declined by about 95 percent in the past century.

In the Baltic today fewer than 10 percent of the young salmon fry are the offspring of "wild" salmon, while 90 percent of the offspring are produced in hatcheries (International Baltic Sea Fisheries Commission (IBSFC), 2000). The percentage of "wild" offspring dropped from more than 30 percent in 1979 to below 20 percent in 1985. Thus the recruitment to the total Baltic salmon stock is nearly completely dominated by farmed salmon smolt, which are released mainly by Swedish and Finnish hatcheries. These mass releases of smolt are intended to compensate for the loss of natural salmon production in the impounded rivers (Ackefors *et al.*, 1991; Rappe *et al.*, 1999).

About 5.5 million reared salmon smolt are released annually into the Baltic Sea. Of this total, 3.5 million smolt are released according to legal obligations, as a compensatory measure for lost salmon production in rivers that have been dammed for hydroelectricity. After release, reared smolt exhibit the same behavioural patterns in the sea as wild smolt. In most rivers the farming of smolt is based on eggs collected from migrating spawners that have returned to the river of release. In Finland, the annual production of about 2 million salmon smolt is based on broodstocks held in hatcheries (IBSFC, 2000).

The genetic variation within hatchery stocks of Finnish and Swedish salmon is in general lower than in natural populations, probably due to the small number of parent fish that have been used in the breeding programs. However, the Baltic salmon populations reared for compensatory purposes still carry unique and valuable genetic characteristics (IBSFC, 2000).

The genetic diversity of wild salmon may also be diminished through interbreeding with escaped farmed salmon that stray to "wild" rivers. Hybridisation between salmon and Baltic sea trout (*Salmo trutta*) presents an additional threat to wild salmon along the Swedish coast of the Baltic Sea. Interbreeding between salmon and trout takes place when ascending broodfish crowd in the fish ladders that bypass hydroelectricity dams. The salmon-sea trout hybrids normally produce non-viable offspring that die at the fry stage (Jansson and Öst, 1997).

Earlier wild salmon populations are believed to have spawned in 120 rivers. Other estimates refer to approximately 100 rivers (E.Degerman/pers.comm.) around the Baltic Sea, and the status of six additional rivers is unknown. Of these, six are in Russia and are dealt with separately in the section on Russia. Today natural salmon populations occur in only 34 Baltic rivers (plus three Russian rivers dealt with in the chapter on Russian rivers). Of these 34 rivers, 13 are Swedish, one is Swedish-Finnish, one is Finnish, one is Polish, one is Lithuanian, seven are Estonian, and 10 are Latvian. Based on the information given by Rappe *et al.* (1999) only 10 of these 34 rivers appear to have substantial natural populations of wild salmon without major input of supplementary stocked fish.

The categorization of the 114 non-Russian salmon rivers in the Baltic is based on the estimates by Rappe *et al.* (1999) of smolt production in the rivers in the Baltic and the fact that only about 2 percent of smolts survive until spawning in the Baltic area (Ackefors *et al.*, 1991). Of the 114 rivers, the condition of salmon populations in six is unknown. Of the remaining 108 systems, salmon populations in 81 rivers are Extinct; 12 (11 percent) are Critical; four are Endangered, five are Vulnerable. Only in six Baltic rivers do the stocks seem to be in a Healthy condition. The main reason for the favourable status of these six populations may be the lack of dams (Rappe *et al.*, 1999) obstructing the salmon in these rivers.

Causes of salmon decline

Overexploitation by offshore fisheries

Most of the remaining wild salmon populations of the Baltic are endangered or vulnerable, in large part because intensive offshore fisheries that harvest farmed salmon populations and simultaneously overexploit wild salmon. Baltic salmon are exploited in the offshore fishery by the use of drift nets and long lines. In the coastal areas the most common gear used are trap nets and there is also a non-commercial fishery with gill nets. In rivers, seine nets and sport fishing are the most common methods used. (IBSFC, 2000).

The structure and pattern of the salmon fishery in the Baltic Sea has changed substantially during the 20th Century. Total annual catch levels were about 1,500 tonnes in the 1920s and 1930s, when salmon were caught in rivers, in estuaries and offshore. Before World War II, only about one third of the fishery took place offshore. After the war, the offshore fishery expanded, due to development in fisheries techniques (both boats and gear), and by the late 1980s the offshore fisheries accounted for about 85 percent of the total catch (IBSFC, 2000).

The total catch increased to around 5,000 tonnes in the 1980s. The bigger catches were based on the increased smolt releases that began in the 1950s and escalated from the 1960s to the 1980s. This expansion in fisheries could take place because the reared part of the stock was less sensitive to exploitation than the wild component of the stock (IBSFC, 2000).

Wild salmon populations are particularly at risk from overexploitation in the offshore fishery in the Baltic Sea which indiscriminately exploits mixed stocks of wild (naturally reproducing) and farmed salmon, as they migrate. Despite the European Union regulation of 1991 that limits the maximum length of drift nets to 2.5 km per boat, salmon fisheries in the Baltic Sea use extremely long drift nets. Present regulations for the salmon fishery in the Baltic Sea allow the use of drift nets up to a total length of 21 km (IBSFC, 2000).

The drift-net fishery also causes considerable bycatch of seabirds and marine mammals (Grey seals and Harbour porpoises). A recent Swedish report shows that of the common guillemots (*Uria aalge*) that were ringed in the Baltic Sea during the 1900s, half the recovered birds were found in fishing gear, mainly drift nets for salmon (Olsson *et al.*, 2000).

The establishment of the International Baltic Sea Fisheries Commission (IBSFC) in 1974 provided for more effective international management of Baltic salmon. The IBSFC now manages Baltic salmon as two units: salmon in the Gulf of Bothnia and the Baltic proper as one unit; and salmon in the Gulf of Finland as the second. The management decisions are normally based on advice given by the International Council for Exploration of the Seas (ICES). Since the early 1990s the most effective element of salmon regulations is a Total Allowable Catch (TAC), based on the need to sustain the wild salmon populations. Besides the measures adopted by IBSFC to protect the wild populations, additional national regulations are implemented to redirect the fishery towards harvesting reared populations. A detailed "Salmon Action Plan (1997-2010)" was adopted by the International Baltic Sea Fisheries Commission in February 1997. This plan will monitor the development of Baltic salmon and create even more specific rules for the management of the populations (IBSFC, 1997).

Hydroelectric projects

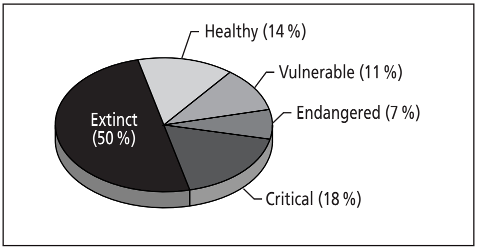
Most Baltic rivers are blocked by hydroelectricity projects, which restrict the spawning migration of salmon. These projects divert the rivers into a chain of water reservoirs and thus compromise the suitability of the habitat for wild salmon populations. In some of the rivers that are not dammed, water pollution prevents full utilization of the potential spawning capacity (Rappe *et al.*, 1999).

Disease

A disease known as M74 has caused a major reduction in the production of salmon smolt. The disease is an environmentally related syndrome that kills newly-hatched salmon alevins at the yolk-sac stage. The disease has been known since 1974, and reached a peak in 1993, when it killed an estimated 80 percent of salmon broods in Swedish hatcheries along the Baltic Sea. M74 results from a deficiency of thiamine (vitamin B_1) in the broodstock. The thiamine deficiency is related to the diet of salmon in the Baltic Sea (salmon feed mainly on sprat and herring) but the ultimate cause is still unknown. In hatcheries, M74 syndrome can be treated by bathing salmon eggs and fry in a solution of thiamine, but there is no practical way of treating wild salmon. (Bengtsson *et al.*, 1999).

Baltic country status reports

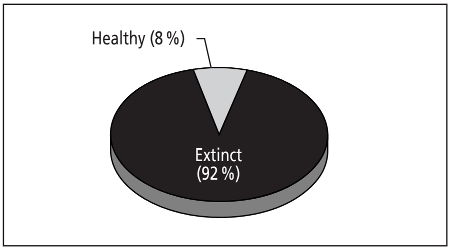
Sweden



Categorization (%) of salmon-bearing rivers in Sweden.

Fewer than 10 percent of the salmon in Swedish rivers that drain into the Baltic Sea are the offspring of wild, naturally spawning animals. The remainder are farmed salmon stocked as smolt in rivers of low productivity, usually to compensate for the negative effects of hydroelectric power plants on natural salmon production. Of the 28 Swedish rivers along the Baltic coast considered by Rappe *et al.* (1999), only 14 now have natural self-reproducing stocks of salmon. Based on information given by Rappe *et al.* (1999) and Ackefors (1991), salmon stocks in five of these rivers are categorized as Critical, stocks in two rivers are categorized as Endangered, and those in three rivers as Vulnerable. Only in four rivers are the salmon populations considered Healthy.

Finland



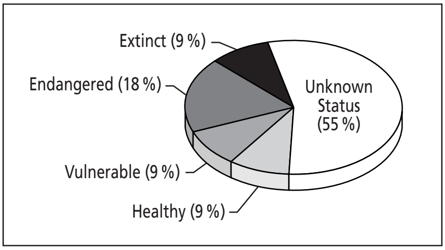
Categorization (%) of salmon-bearing rivers in Finland.

A salmon river inventory (Jantunen *et al.*, 1997), counts the number of Finnish rivers that have had salmon populations historically as 25. By 1900, the impact of dams had caused the extinction of salmon populations in the small southern rivers of Ähtävänjoki, Kyrönjoki, Lapuanjoki, Paimionjoki, and Mustionjoki which formerly produced an estimated 70,000 smolts per year. By 1931 and 1938, respectively, salmon fishing in the western and eastern arms of the Kymijoki River on the Gulf of Finland had been adversely affected. Construction of a power station at the Pirilä Rapids (Harjavalta) on the Kokemäenjoki in 1940 prevented salmon access to upriver nursery areas. By the middle of the 20th century, salmon had also disappeared from the Uskelanjoki, Aurajoki and the Eurajoki rivers of south east Finland because of dams and pollution. Similarly in northern Finland, power dam construction on the Oulujoki beginning in 1945 and on the Kemijoki beginning in 1948 eliminated salmon populations by blocking spawning migrations. Salmon ceased to spawn in the Iijoki in 1971. Gulf of Bothnia tributaries still supporting salmon runs in the end of the 1970s were the Tornionjoki (at the Swedish border), Simojoki, Kuivanjoki, Kiiminkijoki, Siikajoki, Pyhäjoki, Kalajoki, and Lestijoki. (Rappe *et al.*, 1999).

Today, however, only the Tornionjoki and Simojoki contain wild Atlantic salmon populations (Rappe *et al.*, 1999). Thus, the number of salmon rivers in Finland has been reduced by 92 percent since the 18th century. Both the Torniojoki and Simomoke are without power stations, although in the latter river, canalization of rapids for timber transport has reduced salmon numbers. Based on the information about smolt production given by Rappe *et al.* (1999), salmon populations in both rivers appear to be self-sustaining at this time.

Of the 25 historic salmon rivers in Finland, therefore, 23 are categorized as Extinct, and two as Healthy. The Tornejoki is a border river between Sweden and Finland but we have chosen only to mention it under Finland.

Latvia



Categorization (%) of salmon-bearing rivers in Latvia.

Rappe *et al.* (1999) report that 11 rivers had salmon populations in Latvia historically, but the population in the river Lielupe is Extinct. Based on information given by Rappe *et al.* (1999) and Ackefors (1991) salmon stocks in the remaining 10 rivers can be categorized as follows:

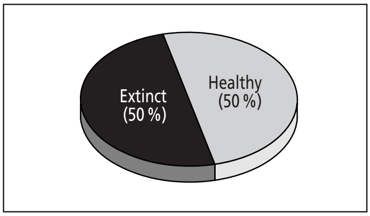
Two rivers have populations that are Endangered, one is categorized as Vulnerable and one is Healthy. Insufficient data are available on the remaining six rivers to categorize them.

Latvia has large stocking programs and annually releases 840,000 smolts into its salmon rivers. In the Daugava River alone are more than 500,000 smolts are released annually (Rappe *et al.*, 1999).

The river Salacea is the most important wild salmon river in Latvia and probably also in all of the Baltic republics. Unfortunately, an old unused dam partly blocks the river about 40 kilometres from the river mouth. On the other hand, it is forbidden to fish salmon and sea trout in the river, and the whole catchment area of the river is situated within the North Vidzeme Biosphere Reserve (Rappe *et al.*, 1999). The Salacea population has been reinforced using its own brood stock. Until 1996, fisheries authorities released 150,000 smolts into the Salacea annually, but the program was halted in an attempt to increase the numbers of wild spawners. The number of wild smolts in the Salacea has since fluctuated between 9,000 and 30,000 annually (Rappe *et al.*, 1999).

The wild Atlantic salmon population of the Salacea is thus categorized as Healthy.

Lithuania



Categorization (%) of salmon-bearing rivers in Lithuania.

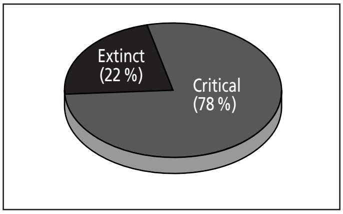
According to Rappe *et al.* (1999), salmon have disappeared entirely from the Sventoji. Salmon populations have also disappeared from several of the tributaries to the Nemunas River, and only in the Neris and the Zeimena branch of the Nemunas is there any substantial spawning of wild salmon. Nevertheless, based on the information about smolt production in Rappe *et al.* (1999) salmon are categorized as in healthy condition in the Nemunas.

The Zeimena branch is said to have the largest salmon population in the country, with an annual spawning that results in 5,000 smolts. Rappe *et al.* (1999) estimate that the river has a potential annual production of 30,000 smolts. Half of the Neris branch of the river Nemunas is in Belarus, where the building of a hydroelectric power station in 1973 reduced the water flow of the river.

Thus one salmon population in Lithuania s categorized as Extinct, and one as Healthy.

Estonia

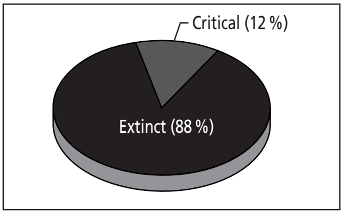
Estonia has historically hosted wild Atlantic salmon in nine systems. Today, the populations are Critical in seven, Extinct in the other two (Rappe *et al.*, 1999). The salmon rivers in Estonia all contain weak salmon stocks, with few salmonids observed annually. The river Kunda, where recent production estimates are as low as between 1,000 and 2,000 smolts, is a good example. None of the three hydro electric dams on the river is equipped with a fish ladder.



Categorization (%) of salmon-bearing rivers in Estonia.

Poland

Rappe et al. (1999) note that Atlantic salmon are virtually extinct in all eight historic salmon rivers in Poland. The Vistula River is the “ecological backbone” of Poland and the only large river remaining in Central Europe with natural water dynamics in a large part of its 186 km long course, unlike the Odra whose channel has been dredged to accommodate shipping traffic. A national decision to re-introduce an Atlantic salmon population in the Vistula is still pending (Rappe et al., 1999).



Categorization (%) of salmon-bearing rivers in Poland.

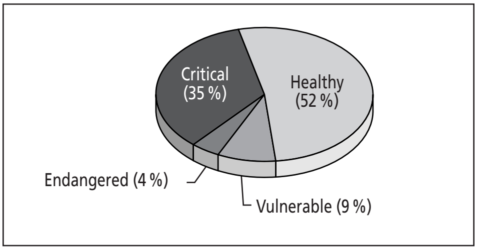
Wild salmon now occur only in small numbers in the Drweca and Odra tributaries of the Vistula, supported by stocking programs. Continued severe pollution problems due to untreated sewage and industrial waste discharges are the main threat to salmon and all other forms of aquatic life. Although Poland accounts for just 12 percent of the Baltic catchment area, it contributes more than a third of the nitrogen being dumped into the Baltic Sea (the main cause of coastal eutrophication leading to the decline of fisheries). In addition, the Wloclawek dam contributed to the severe reduction in salmon populations (Rappe *et al.*, 1999).

However, the survival of *Salmo trutta* in the Vistula, albeit supported by restocking, indicates that *Salmo salar* populations might be restored in the Vistula river. The lack of significant alterations in the Lower and Middle Vistula has permitted the retention of an abundance of microhabitats which lend themselves to a diversity of fish species.

Poland has historically hosted Atlantic salmon populations in eight rivers. The species is now Extinct in seven, and Critical in the remaining river (Rappe *et al.*, 1999).

Non-Baltic Swedish Rivers

Natural stocks of Atlantic salmon exist in 23 rivers on the Swedish West Coast (Fiskeriverket, 1999). These salmon populations spend their oceanic phase in the same areas as the other Atlantic salmon populations in the North Atlantic. At the beginning of the 20th century, hydroelectric power schemes soon limited the habitat available for wild salmon spawning. In the 1970s, acid rain increased pH levels and further limited the survival of wild salmon. The exploitation of mixed salmon fisheries in the North Atlantic has also reduced salmon stocks on Sweden's West coast. The situation is further exacerbated by escaped farmed salmon (Fiskeriverket, 1999).



Categorization (%) of salmon-bearing rivers on the west coast of Sweden.

The catch of salmon on the Swedish West Coast dropped from around 90 tonnes annually (Fiskeriverket, 1999) in the 19th century to about 10 tonnes at the beginning of the 1980s (NASCO, 1999). Active liming measures in rivers and stock enhancement (habitat restoration and releases of farmed smolt) helped to partially restore the salmon stocks in this area. By the mid-1990s the catches had increased to between 30 and 55 tonnes a year, but since then, there has been a dramatic reduction in the catches of salmon on the Swedish West Coast (NASCO, 1999). This reduction in salmon stocks has created a very grave situation for many wild salmon on the Swedish West Coast.

Based on smolt estimates in the Swedish report by Fiskeriverket (1999), the rivers of Sweden's west coast can be categorized as follows:

Salmon stocks in eight rivers (35 percent) are in Critical condition; stocks in one river (4 percent) are Endangered; stocks in two rivers (8 percent) are Vulnerable, and stocks in 12 rivers (53 percent) are considered to be Healthy.

References

Ackefors, H., Johansson,N. and Wahlberg, B. (1991). The Swedish compensatory program for salmon in the Baltic: an action plan with biological and economic implications. *ICES Mar. Sci. Symp*. 192:109-119.

Bengtsson, B. –E., Hill, C., Bergmann, Å., Brandt, I., Johansson, N., Magnhagen, K., Södergren, A. and Thulin, J. (1999). Reproductive Disturbances in Baltic Fish: An International Perspective. *Ambio* 28: 2-8.

Fiskeriverket. (1999). Plan för bevarande av Västkustlaxen [Plan for conservation of salmon on the Swedish West Coast]. Working group for west-coast salmon, Swedish National Board of Fisheries. Fiskeriverket information 1999:9. 1-156

International Baltic Sea Fisheries Commission (IBSFC). (1997). Salmon Action Plan 1997-2010. http://www.ibsfc.org/baltic/WS-5-0.htm

IBSFC. (2000). "Salmon: Salmo salar" http://www.ibsfc.org/

Jansson, H. & Öst, T. 1997. Hybridization between Atlantic salmon (Salmo salar) and brown trout (S. trutta) in a restored section of the River Dalälven, Sweden. Can. J. Fish. Aquat. Sci. 54:2033-2039.

Jantunen, K., Jutila, E., Ikonen, E., and Jokikokko, E. (1997). Salmon river Inventory, Finland (unpublished report, August 21, 1997). Finnish Game and Fisheries Research Institute, Helsinki, Finland.

North Atlantic Salmon Conservation Organization (NASCO). (1999). *Report of the annual meeting of the council. Sixteenth annual meeting*. Westport, Ireland. NASCO.

Olsson, O., Nilsson, T. and Fransson, T. (2000). *Long-term study of mortality in the common guillemot in the Baltic Sea. Analysis of 80 years of ringing data*. Swedish Environmental Protection Agency, Report 5057.

Rappe, C., Ranke, W., Soler, T., Funegård, F., Karlson, L. and Thorell, L. (Eds.). (1999). *Baltic salmon rivers: status in the late 1990s as reported by the countries in the Baltic region*. Stockholm: Swedish Environmental Protection Agency and Swedish National Board of Fisheries.

7.2 Belgium, Netherlands, Germany, Switzerland, the Czech Republic and Slovakia

In Belgium, Netherlands, Germany and Switzerland, historic salmon rivers had entirely lost their wild salmon populations by 1960. The last known captured salmon in the Meuse Basin of Belgium and Netherlands was reported in 1942, and Dutch salmon fisheries had completely died out by the 1950s. The last reported salmon catch in Swiss waters was in 1958. Salmon were present in Bohemian streams until 1935, and in the Vistula basin of Slovakia until 1958 (MacCrimmon and Gots, 1979). Germany's Rhine had lost its salmon population by 1958 (Chicester, 1997).

Efforts have been under way since 1987 to reintroduce salmon to both the Meuse and Rhine rivers, and both rehabilitation programs had began to produce results by the late 1990s.

Causes of salmon decline

The Rhine River in Germany was once the largest and most important salmon river in Europe, and probably in the entire North Atlantic region. In 1885, according to official statistics, 250,000 wild salmon were caught from in the Rhine (ICPR, 2000). This represents almost half of the total catch (2,218 tonnes) of salmon in all rivers and in the North Atlantic in 1999. But salmon spawning grounds in the Rhine were destroyed in the 18th century by the use of its tributaries to float wood. Excessive exploitation of salmon began to deplete salmon stocks in the late 19th century. In addition, 11 hydroelectric power stations were built along the Rhine between 1895 and 1966, turning the river into a series of slow flow, or even stagnant, bodies of water. The weirs disrupted fish migration, excessive damming destroyed spawning grounds, and the smolts were torn to pieces in the turbines of the power plants. (Macrimmon and Gots, 1979). The rapid decline in the water quality of the Rhine, particularly after World War II, reached a point where it became known as the "sewer of Europe", and many fish species wee extirpated. (Chicester, 1997).

In the case of the Meuse in Netherlands and Belgium, the construction of navigation locks at the beginning of the 19th century has been identified as the main cause of the disappearance of salmon (MacCrimmon and Gots, 1979). Swiss salmon declined precipitously on the Rhine and Aar rivers between 1898 and 1920 after the placement of hydroelectric dams with no effective fish passes. But it was the increasing pollution in the upper Rhine that ultimately spelled the end for wild salmon in Swiss rivers (MacCrimmon and Gots, 1979).

By 1877, Atlantic salmon runs in Czechoslovakia were limited by dams and by pollution to the Vlatava (Moldau), Otava (Wottawa), Orlice (Adler), Divoka Orlice (Wilde Adler), and Kamenice (Kamnitzbach) streams in the headwaters of the River Labe (Elbe) in Bohemia. Spawning continued until 1928 when the erection of a floodgate at Strekov blocked fish passage. Attempts to restore spawning runs through the use of fish ladders proved unsuccessful (MacCrimmon and Gots, 1979).

Reintroduction of salmon to the Meuse and Rhine rivers

A program to reintroduce Atlantic salmon in Belgium was launched in 1987. This involved restocking six tributaries of the Meuse with eggs, parr and presmolts obtained from foreign eggs. By 1998, nearly 1 million juvenile salmon had been released into the Meuse tributaries. Meanwhile, the restoration project saw dams and power stations equipped with effective fish ladders, and water quality was improved by a reduction in pollutants. However, the last lock in the Meuse before the North Sea still lacks a fish ladder, and the area around Liege still lacks the oxygen concentration required for salmon survival. (Prignon *et al.*, 1999).

The first Atlantic salmon known to have returned to the Meuse was caught and kept for observation in the Netherlands in 1993. Between 1994 and 1998, 48 salmon were found in Dutch rivers (Prignon *et al.*, 1999). These initial results raise some hope for the return of wild self-reproducing salmon populations to the Meuse.

After the catastrophic 1986 spill of 30 tonnes of toxic chemicals into the Rhine near Basel, killing an estimated 500,000 fish, the International Commission for the Protection of the Rhine (ICPR) formed in 1950, adopted a plan to introduce a self-sustaining population of salmon into the Rhine by the year 2000. It identified and eliminated the main sources of pollution and removed or mitigated dams and other obstacles to fish migration. Millions of salmon were released into the Rhine or its tributaries (Chicester, 1997).

The Sieg River, a tributary of the Rhine, which was once the most important spawning and nursery stream for the Rhine's salmon population, was choked with pollution in the 1980s – but by the late 1990s, it was almost devoid of sewage and other organic pollutants. The first known Atlantic salmon to reappear in the Sieg was spotted in 1990; and in 1994, researchers found recently hatched salmon in the Sieg, indicating that natural salmon reproduction was occurring in the Rhine basin for the first time in decades. More than 50 adult salmon have returned to Sieg since 1990. Restocking of the Sieg was to be ended after 1999 (Chichester, 1997).

References

Chicester, P. (1997). Resurrection on the Rhine. *International Wildlife*. September-October. http://www.nwf.org/intlwild/salmon.html

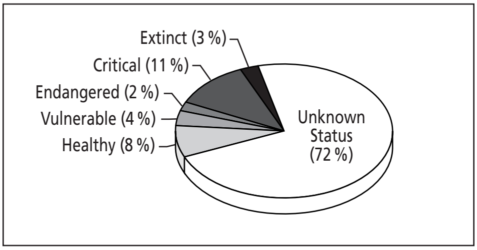
ICPR (International Commission for the Protection of the Rhine). (2000). “Salmon 2000: The Rhine, a salmon river again?” http://www.iksr.org./icpr/welcome.html

MacCrimmon, H. and Gots, B. L. (1979). World distribution of Atlantic salmon (*Salmo salar*). *J. of Fish. Res. Board Can.* 36: 422-547.

Prignon, C., Micha, J.C., Rimbaud, G and Philppart, J.C. (1999). Rehabilitation efforts for Atlantic salmon in the Meuse basin area: Synthesis 1983-1998. *Hyrologia* 410: 69-77.

7.3 North America

Canada



Categorization (%) of salmon-bearing rivers in Canada.

During the past three decades wild Atlantic salmon populations in their natural range in eastern Canada have declined by more than 75 percent. In the 1970s, about 1.5 million small and large Atlantic salmon returned to Canadian rivers (Marshal *et al.*, 1988). Now, however, only about 350,000 return to those same streams. Moreover, the proportion of grilse has increased from about 45 percent in the 1970s to about 75 percent today (Anderson *et al.*, 2000).

This decline has continued despite restrictions, partial closures, and finally a complete ban on commercial salmon netting. Canada banned commercial fishing for salmon in Nova Scotia, New Brunswick and the Gaspé region in 1972 (Anderson *et al.*, 2000). Salmon fishing was closed around Newfoundland under a moratorium in 1992 (Friedland and Kocik, 2000). By 1998, there were no net fisheries for salmon in Canada, with the exception of small, localized aboriginal food fisheries, mainly in Labrador.

Recreational salmon fishing has been strictly regulated since the mid-1980s in most areas, employing the use of a strict tag system and a ban on the killing of multi sea-winter fish in most areas. Mandatory catch-and-release had been imposed in rivers showing consistently poor returns by the mid-1980s, and a complete ban on salmon angling was imposed on salmon rivers consistently falling far below minimum required spawning escapement, mainly in Nova Scotia and southern New Brunswick (Anderson *et al.*, 2000).

Although Canada still has river systems with healthy populations, mainly in remote locations where human activity is minimal, most Canadian salmon stocks appear to be in various stages of decline.

Nowhere is this decline so pronounced as in the Bay of Fundy, a unique marine ecosystem lying between New Brunswick and Nova Scotia, where salmon runs to about 50 streams have declined to dangerously low levels and appear to face extinction.

Unlike all other Atlantic salmon populations in Canada, fish native to rivers emptying into the inner Bay of Fundy do not migrate to West Greenland. Instead, they spend the entire marine portion of their life cycle in the Bay of Fundy. One and two sea-winter fish tend to be distinctly smaller than their ocean-going cousins, and the spawning run is usually late in the year.

Two distinct salmon areas are found in the Bay of Fundy. The first is the Outer Bay, which includes rivers from the St. John River westward to the Saint Croix River, bordering the state of Maine. The second is the Inner Bay of Fundy (IBOF), which includes 33 rivers, extending clockwise from, but not including, the Saint John River in New Brunswick to the Annapolis River in Nova Scotia.

The IBOF area salmon rivers, where the total combined run has declined from an estimated 40,000 fish 15 years ago to a few hundred today (Atlantic Salmon Federation, 2000; Kenchington, 1999), are being targeted for listing as endangered by the Committee on the Status of Endangered Wildlife in Canada. In October 1999, the federal Department of Fisheries & Oceans recommended that the Atlantic salmon in IBOF rivers be listed as endangered. In May 2001, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) announced that they consider the salmon of the 33 inner Bay of Fundy rivers to be endangered. Unfortunately, the Government of Canada still has no formal endangered species legislation. Although New Brunswick and Nova Scotia have such legislation, provincial governments have rarely acted to save endangered species. An act (Species at Risk Act) was before the

Canadian Parliament in 2001 that would provide the federal government with regulatory powers in regard to endangered species (Anderson *et al.*, 2000).

On the Atlantic coast of Nova Scotia the Atlantic salmon runs to approximately 30 additional rivers have been devastated by the effects of wet deposition of airborne acid pollution originating mainly in the mid-western United States. In recent years, all of these rivers have been closed to angling and minimum spawning escapement has not been met for several consecutive years.

Canadian stock evaluations

There are about 550 Atlantic salmon rivers in Canada (ICES 2000). The Canadian approach to balancing available resources with the need to monitor the health of salmon runs in individual rivers has consisted of working with “indicator” rivers. These “indicators” are believed to be representative of the run trends for the other rivers in the surrounding area. The data they provide are used to develop regional management strategies. Where resources permit, supplementary information may be obtained from additional rivers in a region. This can include catch and effort data from fisheries, and electrofishing information on the densities of juvenile salmon. Conservation thresholds have been established for most Canadian rivers.

A brief description of the salmon rivers in Canadian regions is given below, along with the criteria which were used to assign river specific status for this report. In general, rivers in the north of Canada are relatively healthy, whereas those in the south (Bay of Fundy and Eastern Shore (Southern Uplands) of Nova Scotia) are in very serious trouble.

Newfoundland and Labrador

There are about 200 Atlantic salmon rivers in Newfoundland and Labrador (DFO 2000 (D2-01)). Annual estimates of returns and of the estimated egg depositions in relation to their conservation thresholds are available for 19 rivers.

Quebec

Quebec has 116 salmon rivers (Tremblay *et al.*, 2000). Those which are believed to naturally generate annual salmon runs of fewer than 100 fish are closed to fishing. These number about seven (four in the Gaspé/lower St. Lawrence region (zones Q1-3) and three in the North Shore region (zones Q5-

Q9). It is the opinion of the province's salmon biologists that in the medium term, there is no threat to the salmon's survival in its range in Quebec. Nor is there reason to anticipate a dramatic turnaround towards historic high abundance (Tremblay *et al.*, 2000). Quebec biologists have fishing statistics for virtually all of the rivers that are open for fishing. In addition, they use fishways, counting fences, diver (swim) counts, and at one site an acoustic counter to count the adult runs annually in a suite of rivers (Caron et Fontaine, 1998). Thus, managers in Quebec have at least some information on virtually every salmon river in their province. Conservation thresholds for egg depositions have been established for all of the province's rivers, although estimates of the annual egg depositions relative to these thresholds have not been obtained for all rivers. For this document, the status of Quebec's rivers has been determined for those rivers where two-year average egg depositions relative to conservation can be calculated (data from 1999 and 1998; these are the most recent data published).

Maritimes (Scotia-Fundy)

There are 234 rivers in the Maritimes (Provinces of Prince Edward Island, New Brunswick and Nova Scotia), which includes the southernmost distributions of Atlantic salmon in Canada. The two largest and most productive rivers in the region are the Restigouche and Miramichi rivers. Most of the salmon returning to the region enter these two systems. Salmon populations in the rivers draining into the Bay of Fundy, and along the Eastern Shore (Southern Uplands) of Nova Scotia are in serious trouble. Returns to rivers on Prince Edward Island probably could not continue to exist without supportive hatchery rearing. The situation in the more northern rivers, including the Miramichi and Restigouche systems is better, but returns have been declining and even those famous systems are now struggling to meet conservation thresholds.

Bay of Fundy

Thirty-three rivers in the inner Bay of Fundy contain a genetically distinct lineage of salmon that are also morphologically and behaviorally different from the rest of the North American salmon complex. Among other things, their ocean migration is believed to be restricted largely to the Bay of Fundy and its environs. The unique salmon populations in all of these rivers are believed to be on the brink of biological extinction, if not extinct already (Kenchington 1999, DFO 2000 (D3-14)). They have been submitted to Canada's Committee on the Status of Endangered Wildlife (COSEWIC) as a group with a recommendation for listing as endangered. Sampling for juvenile salmon in the region has confirmed the severely depressed status of salmon populations. All indications are that at best these rivers can be considered as critical. Here they have been classified as such. In May 2001, COSEWIC officially announced that they consider the salmon of the 33 inner Bay of Fundy rivers to be endangered.

Eastern shore (Southern Uplands) of Nova Scotia

Sixty-six salmon rivers occur in this region (DFO 2000/2E). Most of the area has poor natural buffering capacity, and rivers are impacted by acid precipitation. While information on populations of salmon in the region is lacking, water chemistry analyses coupled with sampling of salmon rivers have indicated that there are 14 rivers that cannot support salmon given current pH conditions. Populations in these rivers have here been classified as extinct. Another 20 rivers have annual pH values in the 4.7 – 5.1 range and are expected to be heavily impacted by acid conditions. The rivers in this category have been assigned a critical status for this analysis. Rivers with pH values above 5.1 but less than 5.4 should be able to reproduce naturally, but at reduced levels. In the absence of other information on their salmon populations, the status of salmon in these rivers has been classified as unknown. Thirteen rivers are not believed to be acid impacted. In the absence of information about their salmon populations, their status has also been classified as unknown.

The evaluation presented here is the best case scenario. A modeling exercise suggested that "55 percent of the salmon stocks in the Southern Uplands rivers are already extirpated, a further 36 percent are at risk of extirpation (produce fewer than three recruits per spawning fish), and that only 8 percent of the rivers are capable of sustaining salmon populations at 10 percent marine survival" (DFO 2000/2E).

Prince Edward Island

Atlantic salmon runs on PEI are largely maintained in six rivers with hatchery support programs (Cairns, 1999). Runs with vestiges of wild fish occur in the Morrell, Mill, Trout, Dunk, West, Montague, and Valleyfield rivers. The Morrell River has served as an indicator for the other rivers on the island.

Should the supportive rearing be discontinued there is little reason to believe that salmon could persevere on the island. Hence, for this report all these rivers have been considered critical. Historically, Atlantic salmon occurred in other rivers on the island, but these populations are now extinct.

Remainder of the region

All other rivers in this region which have a status assigned to them were classified by determining the average of the conservation threshold achieved in the two most recent years for which published data were available (1999 and 1998). A variety of methods were used to make these determinations, including mark-recapture experiments, diver counts, counting fences or fishways, and redd counts previously calibrated to the number of spawners. For historical reasons, conservation levels in this area can be reported in terms of fish, and/or eggs (Cameron *et al.*, 1999; Chaput, 1999; DFO 1999 (D3-14), 2000 (D3-14); Douglas and Swasson, 2000; Marshall *et al.*, 1998, 1999; O'Neill *et al.*, 1999). Where they are reported only in terms of fish, there are frequently separate conservation levels for grilse and large salmon. In virtually all cases, the large fish are the most important because they provide the bulk of the egg supply. In this analysis, conservation was preferably evaluated in terms of egg supply. Where values were reported in fish, the large fish values were used. Figures for the Miramichi River in 1999 and 1998 are slight overestimates of the levels of conservation achieved, because the angler removals could not be subtracted from the estimates of returns to the river.

Causes of salmon decline

The critical condition of salmon stocks in many rivers in the Bay of Fundy appears to be the result of a combination of factors, including overfishing, river obstructions and poor success of hatchery populations. Along the Atlantic coast of Nova Scotia, rivers have been particularly affected by acidification which, in the worst cases has totally eliminated Atlantic salmon populations.

Parasites and disease from aquaculture operations have also become serious problems for Canadian salmon. Infectious salmon anaemia (ISA), first discovered in Norway in the 1980s, appeared in New Brunswick and has spread through the Bay of Fundy, despite the introduction of ISA vaccine (Anderson, 2000).

There is also increasing evidence (Hawkins, 1999) of increased mortality in the marine phase of the salmon's development affecting both Canadian and U.S. Salmon populations. This trend toward increased salmon mortality at sea remains unexplained and both the Canadian and the US government has declined to provide the resources to research the problem.

Summary

Number of rivers in various classifications

Region	No. rivers	Healthy	Vulnerable	Endangered	Critical	Extinct	Unknown
Newf.	200	11	3	5	0	0	181
Quebec	116	23	9	6	1	0	77
Mar.	234	8	8	1	62	15	140
Canada	550	42	20	12	63	15	398

Considering only rivers whose status could be classified: Percentages of the sample of rivers in the different classification categories.

Region	No. rivers	%Healthy	%Vulnerable	%Endangered	%Critical	%Extinct
Newf.	19	58	16	26	0	0
Quebec	39	59	23	15	3	0
Mar.	94	8.5	8.5	1	66	16
Canada	152	28	13	8	41	10

Newf. = Newfoundland, Mar. = Maritimes (Provinces of Prince Edward Island, New Brunswick and Nova Scotia), Canada = totals or percentages for all regions

References

Atlantic Salmon Federation: Historical and Current Status of the Wild Atlantic Salmon in North America, prepared for the World Wildlife Fund Norway by S.H. Tinker and F.G. Whoriskey, 1999.

Atlantic Salmon Federation: Atlantic Salmon on the Brink, the University of Michigan, School of Natural Resources and Environment, J. Anderson, F.G. Whoriskey and A. Goode, 2000.

Cairns, D. K. 1999. An update on the status of Atlantic salmon on Prince Edward Island in 1999. Canadian Stock Assessment Secretariat Working Paper 99/95.

Cameron, P., B. Baker and G. Chaput. 1999. Update of the stocks status of Atlantic salmon (*Salmon salar*) in the Nepisiguit and Jacquet rivers, 1999. Canadian Stock Assessment Secretariat Working Paper 99/91.

Caron. F. et P. M. Fontaine 1998. Ré-évaluation du nombre de saumons géniteurs et du nombre de saumons de retour au Québec, 1979-1997. Conseil International pour l'exploration de la mer, Groupe de travail sur le saumon de l'Atlantique nord Document de travail 98/23.

Chaput, G., R. Pickard, M. Arsenault and P. D'Amours 1999. Stock status of Atlant salmon (Salmo salar) in the Restigouche River, 1998. Canadian Stock Assessment Secretariat Research Document.

DFO 1999 (D3-14). Atlantic Salmon Maritimes Provinces Overview for 1998. DFO Science Stock Status Report D3-14 (1999).

DFO 2000/2E. The effects of Acid rain on the Atlantic salmon of the Southern Upland of Nova Scotia. DFO Maritimes Regional Status Report 2000/2E.

DFO 2000 (D2-01). Newfoundland and Labrador Atlantic Salmon Stock Status for 1999. DFO Science Stock Status Report D2-01.

DFO 2000 (D3-14). Atlantic Salmon Maritimes Provinces Overview for 1999. DFO Science Stock Status Report D3-14 (2000).

Douglas, S. G. and D. Swasson. 2000. Status of Atlantic salmon (*Salmo salar*) in the Tabusintac River in 1999. Canadian Stock Assessment Secretariat Research Document 00/92.

ICES 2000. Report of the Working Group for North Atlantic Salmon. ICES CM 2000/ACFM: 13. 301pp.

Kenchington, E. 1999. Proceedings of the Inner Bay of Fundy Salmon Working Group Regional Advisory Process Maritimes Region. Can. Stock Assessment Proceedings Series 99/29.

Marshall, T. L., K. A. Rutherford, P. H. LeBlanc and R. A. Jones 1998. Follow-up to the assessment of Atlantic salmon in selected rivers of Cape Breton Island, 1998. Canadian Stock Assessment Secretariat Research Document.

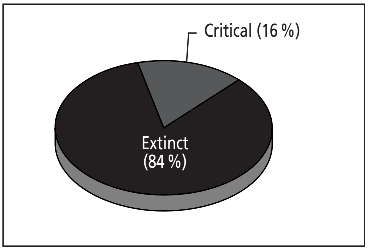
Marshall, T. L., P. H. LeBlanc, K. A. Rutherford and R. A. Jones 1999. Assessments of Atlantic salmon stocks in selected rivers of Cape Breton Island, 1999. Canadian Stock Assessment Secretariat Working Paper 99/96.

O'Neill, S. F., K. A. Rutherford and D. Aitken. 1999. Atlantic salmon (*Salmo salar* L>) stock status on rivers in the Northumberland Strait, Nova Scotia area, in 1999. Canadian Stock Assessment Secretariat Working Paper 99/87.

Tremblay, S. F. Caron, C. Groleau and D. Deschamps 2000. Bilan d'exploitation du saumon au Quebec en 1999. Société de la faune et des parcs du Québec, Direction du développement de la faune. 177 pp.

United States

Wild Atlantic salmon populations in the contiguous marine ecosystem of the Gulf of Maine have exhibited signs of extreme ecological stress and have consequently been afforded emergency protection under the powerful U.S. Endangered Species Act (EPA).



Categorization (%) of salmon-bearing rivers in the United States.

The U.S. Fish and Wildlife Service (2000) estimated, on the basis of redd counts, that the entire adult salmon population in the Gulf of Maine now numbers in the low hundreds. In New England, salmon populations in such rivers as the Connecticut, Pawcatuck and Merrimack were already extinct in the 1800s.

By 1948, the New England states had all banned commercial salmon harvests. Wild populations in eight rivers in Maine, while affected by interbreeding with other strains of farmed salmon, are considered to still have enough ancestral genetic characteristics to be considered a “Distinct Population Segment” (DPS) of North American Atlantic salmon. In 1995, the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service jointly reviewed the status of salmon in its remaining range and found that the DPS in eight rivers in the Gulf of Maine were in danger of extinction (Anderson et al., 2000). In November 2000 the FSW officially listed the Gulf of Maine DPS as endangered (FSW, 2000). Captive salmon broodstock developed from wild fish from the Dennys, East Machias, Machias, Narraguagus and Sheepscot Rivers are held at Craig Brook National Fish Hatchery in Orland, Maine. Their use has increased the effective size of salmon populations for these rivers, thus providing what the FSW calls a “buffer” against extinction (FSW, 2000).

Causes of salmon decline

At least 11 coastal watersheds outside Maine are known to have had wild salmon populations, but those populations have all been extirpated. In Maine, an estimated 28 to 34 rivers once supported wild salmon (FWS, 1999). For the purpose of this categorization, the figure of 31 historic salmon rivers has been used. The current range of Atlantic salmon is limited to the rivers of the Gulf of Maine, which includes several small to moderate-sized coastal river complexes. Eight significant salmon rivers in this complex (Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap, Sheepscot and Cove Brook, a subsidiary of the Penobscot River) and a handful of smaller drainage basins, still contain distinct populations of wild Atlantic salmon that retain original genetic material important to their survival. The Penobscot River’s wild Atlantic salmon may have been extirpated in the 1960’s. A restoration program has met with varied success with returns ranging from 5000 in the 1980s to 580 in 2000. The river has been stocked since the 19th century.

The United States also assessed the percentage of the conservation requirement (c.r.) for each of these rivers. The U.S. Fish and Wildlife Service (1999) has published the results of these assessments for seven Gulf of Maine rivers over periods ranging from eight to 28 years. These data indicate that all seven rivers have achieved less than 20 percent of the c.r. calculated for them over these periods, and that in the most recent year for which the data are available, they achieved only 2.4 percent of their c.r. on average. It is clear that wild salmon stocks in all eight rivers are in critical condition.

Thus salmon populations in 50 historic U.S. salmon rivers can be categorized as follows: in 42 rivers (84 percent), the populations are Extinct; and in eight rivers (16 percent), they are in Critical condition.

In the United States, Atlantic salmon stocks were already extirpated south of Maine's Kennebec river by the mid-1800s. The use of rivers to transport logs downstream to sawmills caused siltation and damage to the river bottom resulted, smothering eggs and displacing alevin from the spawning sites. Industrial dams completely blocked salmon migration in one river (Machias), and the salmon disappeared completely. Small numbers of salmon began to reappear in some Maine rivers in the 1950s and 1960s only after obstructions were removed from streams and fishways installed (Fenderson and Snyder, 1999).

Official alterations of the ecosystem in support of recreational fishing have also negatively affected the Atlantic salmon. Fisheries managers in Maine introduced Brown trout and Splake, both potential competitors of Atlantic salmon, as well as Smallmouth bass, a predator of parr and smolts, into historic salmon rivers (North Atlantic Salmon Task Force, 1997).

U.S. Salmon rivers continue to be threatened by river barriers, pollution, disease, agricultural water extraction and interactions with farmed salmon of different (European) strains. The federal Status Review of salmon populations in the seven rivers in 1995 identified forestry, recreational fishing, agriculture, and aquaculture as threats requiring in-depth conservation planning (North Atlantic Salmon Task Force, 1997). More recently, the Fish and Wildlife Service has cited salmon farming as the single largest threat to the remaining wild salmon in Maine. It is concerned about both disease and genetic competition from escaped farm salmon overwhelming the relatively few wild salmon remaining (Kaufman, 2000).

References

Atlantic Salmon Federation: Tinker, Whoriskey and Anderson *et al*, 2000.

Fenderson, J. and Snyder, G. Examination and Assessment of Success for Maine's Atlantic Salmon Conservation Plan. http://web.utk.edu/~buehler/endspp/salmon.html

Friedland, K. and Kocik, J. (2000). Atlantic Salmon. In *Status of Fishing Resources off the Northeast United States.* NOAA Technical Memorandum NMFS-NE-115. Washington, D.C.: National Oceans and Atmospheric Administration.

Kaufman, M. (2000). Maine Salmon Face Upstream Battle as Species. *The Washington Post.* September 3.

Maine Atlantic Salmon Commission. (2000). Atlantic Salmon Conservation Plan for Seven Maine Rivers: 1999 Annual Progress Report. http://www.state.me.us/asa/99 AnnRpt.html

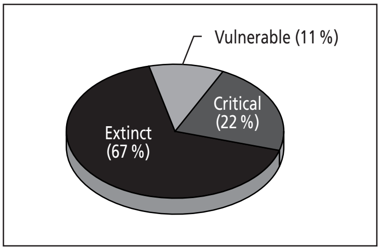
North Atlantic Salmon Task Force. (1997). Atlantic Salmon Conservation Plan for Seven Maine Rivers. http://www.state.me/asa/asapall.htm

U.S. Fish and Wildlife Service (FWS) (2000). Endangered and Threatened Species: Final Endangered Status for Distinct Population Segment of Anadromous Atlantic Salmon (*Salmo salar*) in the Gulf of Maine. *Federal Register* 65: 69451-69483.

U.S. Fish and Wildlife Service (FWS) (1999). Status Review for Anadromous Atlantic Salmon in the United States. http://news.fws.gov/salmon/asalmon1.html

7.4 Denmark

Salmon occurred historically in nine Danish rivers. Today, however, the natural salmon populations have been wiped out in six of those nine systems. In the remaining three rivers, the Skjern a, the Varde a and Ribe a, only a fraction of the original populations survive. Although anglers in Denmark have carried out small and sporadic releases of wild salmon into the rivers, these efforts have failed to re-establish self-sustaining stocks in any of the rivers.



Categorization (%) of salmon-bearing rivers in Denmark.

Status of salmon by river

The average annual catch in the estuary of the Skjern river from 1901 to 1977 was 1.3 tonnes, with the highest catch being 5.2 tonnes in 1903 (Johansen and Lofting, 1919). As of 1977, the River Skjern still had a small population of spawners estimated at about 250 from the original progeny, 160 from wild fish and 90 from stocked fish. However, since 1977, there has been no evidence that salmon have been caught in the river and spawning occurs only in a very restricted area (Geertz-Hansen and Jorgensen, 1996). Because of the great decline in spawning population, the salmon population in the Skjern river is considered to be Vulnerable.

The original populations of wild salmon in the Ribe and Varde rivers are dependent upon a very small base of spawners. The fact that very few of the salmon remaining are from the original stocks in those rivers was confirmed by recent DNA 1997). Therefore, it is believed that the stocks in these rivers are likely to be in Critical condition. (Analysis of old scale samples compared with fry caught by electro-fishing (Nielson *et al.*)

Of Denmark's nine historic salmon rivers, therefore, wild salmon populations are Extinct in six, in Critical condition in two and Vulnerable in one.

Causes of salmon decline

The River Guden, which is believed to have had the largest salmon population in Denmark historically, had an average annual catch of 14.8 tonnes from 1794 to 1831, but that average fell to 1.9 tonnes during the 1853 to 1914 period. In 1919, the river was still yielding 3 tonnes of salmon. The wild salmon population was decimated entirely sometime in the 1930s following the construction of a hydro power dam in 1920 (Johansen and Lofting, 1919).

The major cause of extinction of salmon in Danish rivers has been watercourse obstruction. Fewer than two percent of Denmark's rivers and streams have not been physically altered. River water withdrawal to supply about 450 trout farms has not only obstructed the migration of migrating wild fish, but also the downstream migration of smolts of salmon and trout. Canalization and culverting of natural streams, and the silting of spawning sites, have constituted the most serious insults to salmon in Danish rivers (Rasmussen, 2000).

In Eastern Denmark, organic pollution and groundwater exploitation are also major factors in salmon habitat degradation and destruction. Discharge of acid ferruginous water caused by lignite mining and draining, seriously limit, or preclude, salmonid life in several West Jutland streams.

During the last 20 years, however, public sentiment in favour of rehabilitation of salmon and sea trout in Danish rivers has become strong. Water authorities have restored many streams. Weed cutting and bottom dredging have been reduced to a minimum, salmonid spawning grounds have been restored, and fish ladders have been constructed. Most of the streams have improved considerably during this period (Koed *et al.*).

The Guden river has been restocked during each of the past several years with 100,000 smolts totally from foreign sources (Sweden, Scotland and Ireland). Today, the catch from the Guden river, totalling about 5 tonnes annually, consists of a commercial catch of about 1,000 fish in the estuary, and a sport fishing catch of about 1,000 fish in the river. In the future, the Danish government hopes to use only domestic salmon from the River Skjern river to restock the Guden river (Koed *et al.*, 1999).

References

Geertz-Hansen, P. and Jorgensen, J. (1996). Rehabilitation of salmon (*Salmo salar* L. in Denmark: status and methods. In Kirchhofer, A. and Heft, D. (eds*). Conservation of Endangered Freshwater Fish in Europe* Basel: Kirkauser. Pp. 172-79.

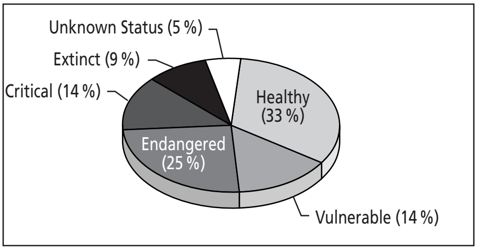
Johansen, A.C. and Lofting, J.C. (1919). *Om fiskebestanden og fiskeriet i Gudenaaens nedre lob og Randers fjord* [On the Fishes and Fisheries in the Gudenaa and Randers Fiord]. Skrifter udgirvet af Kommissionen for Havundersolgelser, Nr. 9, 144. 144 pp. with English resume.

Koed, A., Aaerestrup, K., Nielsen, E. E. and Glusing, H. (1999). *Status for Laksehandlingsplanen* (Status of the Salmon Rehabilitation Plan). DFU-rapport no. 66. 45 pp.

Nielsen, E. E., Hansen, M. M., and Loescheke, V. (1997). Analysis of microsatellite DNA from old scale samples of Atlantic Salmon Salmo solar: a comparison of genetic composition over 60 years. *Molecular Ecology* 6: 487-92.

Rasmussen G. (2000). Pers. comm. Gorm Rasmussen, Danish institute for Fisheries Research.

7.5 England and Wales



Categorization (%) of salmon-bearing rivers in England and Wales.

Although wild Atlantic salmon stocks in England and Wales may not be in serious decline overall, stocks in many rivers, and quite possibly most, are under considerable pressure. One of the most dramatic changes in England and Wales over the past 20 years has been the decline in 2 and 3 sea-winter fish, and in spring runs of these fish in particular. While this is a cyclical phenomenon that has been observed over at least 150 years, there is concern that exploitation and other anthropogenic actions may be deepening the decline and possibly compromising subsequent recovery.

A number of initiatives have been taken to protect early running fish; these include a ban on netting before June 1 each year, and catch and release only for anglers before June 16. There is also a growing ethos of voluntary catch and release by anglers later in the year too, particularly for larger fish.

The use of catch statistics as an index of stock size and wellbeing is a widespread practice, but it is fraught with danger, for several reasons. First, even complete catch statistics are an imperfect indicator of stock size. Gear and effort may vary between years, and conditions such as the weather and river flow may markedly influence the level of catch in any year. Moreover, rod catch varies less than stock, indicating that fishing is relatively more efficient at low stock levels than at high stock levels (Solomon and Potter, 1992). Effort may have changed considerably over the years. Kempster (1948) gives figures for the numbers of licences issued for salmon fishing in England and Wales in 1937. These are compared with equivalent figures for 1997 in Table 5. Although licence numbers are far from perfect as a measure of actual fishing effort, they are the only historic data set available. Thus generally rod fishing effort has increased and net fish effort has decreased over the past 60 years. However, both rod and net fisheries are likely to have become considerably more efficient over this period, with the introduction of lightweight rods and nylon line for anglers, and improved netting material (man-made fibre) and boats for netsmen.

Secondly, the quality of the statistics has varied considerably. Diligence in gathering rod catch statistics varies, both temporally and geographically. Sudden declines in catches have sometimes coincided with a change in methodology for gathering statistics. In 1992 and 1993, throughout England and Wales, the salmon angling licence was discontinued and a single licence was issued for all freshwater fish. Concurrent studies of catches on individual rivers using other methods of gathering data indicated a significant reduction in the overall level of reporting in these years.

Generally, the level of reporting of catches by netsmen has been higher, with often 10 percent of licensees making returns. However, changes in gear and close times, and general reduction in effort especially at times of lower catches, due to a fall in the real value of salmon, confound analysis of long-term trends. Finally, the majority of salmon caught by nets in England and Wales are in the North East Coast Fishery, where it is estimated that 80 percent of the fish caught are from Scottish rivers. Even this is changing, however, as the local English rivers recover from former industrial pollution. It is estimated that 20 years ago 95 percent of the catch was of Scottish origin.

In addition, a number of private net fisheries have existed that do not appear in the licensing figures. There has been a history of steady erosion of these fisheries as rights have been purchased and extinguished or at least not exercised. As these were typically situated upstream of the public net fisheries and close to the head of tide where fish may gather in large numbers, their catches were often prodigious.

Table 5

Salmon fishing licenses issued by fishing method: 1937 and 1997

	Rods (annual)	Nets	Fixed engine	Putchers*
1937	11,874	762	7	11,402
1997	21,146	528	5	3,550

*basket traps normally fish in ranks of several hundred to form a "weir" or fence.

In spite of these limitations, much can be learned from an analysis of catch data, both in terms of gross trends and relative changes between rivers. Available total reported catches from 1952 onwards in terms of numbers caught by rod, numbers caught by nets, and tonnage for both methods are shown in Figure 4. No trend in rod catches is apparent over the past 20 years, although there is a downward trend from the high catches in the 1960s. There is a steep downward trend in reported net catches over the past 20 years. However, if a longer period (45 years) is examined the graph is dome-shaped, with generally high catches in the 1970s and 1980s. As net catches dominate, the trend in total tonnage over the past two decades is sharply downward.

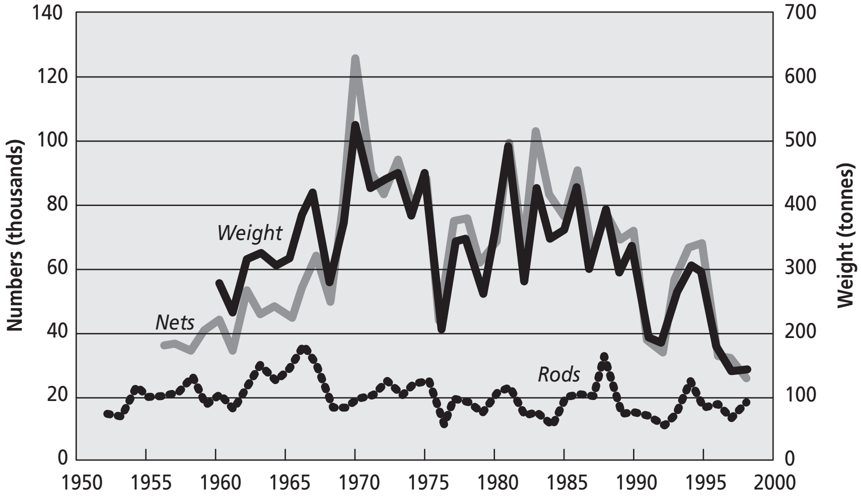


Figure 4. Reported rod and net catches (numbers) and total catch (tonnes) 1952-1998
Sources of data: numerical catches 1952 -1960, Russell *et al.*, (1995); numerical catches 1991-1998, NRA/EA statistics; total weight figures 1960 – 1979 ICES (1981); 1980-1990 Russell *et al.*, (1995); 1991-1998 NRA/EA statistics.

Although catches are currently below peak levels of 30 years ago, there appears to be little evidence of a major, long term and systematic decline in rod catches of salmon in England and Wales. A decline in reported net catches is mainly due to reduced effort. Given this reduction, an increase in rod catches might be expected, but none has been apparent. Further, reduction in industrial pollution, enlightened fisheries management and increasingly effective control of illegal exploitation should also be increasing rod catches. Overall, it appears that improvements in a number of environmental factors and an increase in the level of exploitation by rods may have tended to maintain rod catch levels, masking a more general decline in stocks due to other factors.

Status of salmon stocks by river

Analysis of the status of stocks in individual rivers may be based on either comparative catch data or performance in meeting minimum spawning targets. In recent years, CEFAS (Centre for Environment, Fisheries and Environmental Sciences), and the Environment Agency, have been developing the concept of spawning targets as a fishery management tool. A target number of eggs is calculated for maintenance of the maximum sustainable yield. This is based upon a stock and recruitment model, the available area of spawning and nursery ground in the river, and an assessment of the quality of the habitat. Catch statistics are then analyzed to estimate the extent to which spawning in any year meets the target.

Development of the spawning target methodology is still in its infancy, and further refinements are possible, for example in the Stock/Recruitment models, habitat assessments and measurement of actual egg deposition. However, it represents an additional tool for assessing the state of stocks beside trends in catch.

The average percent age of spawning targets achieved in each river for 1997 and 1998 has been calculated for 67 of the 73 rivers in England and Wales. Three other rivers are included in the categorization, because they are known to have lost their populations completely, for a total of 76 rivers, of which the status of 70 is known According to these data, 25 rivers (36 percent) achieved a mean of 90 percent or more of their spawning targets during the two years. Stocks in these rivers are categorized as *Healthy*. Eleven rivers (16 percent) achieved averages of 51-90 percent of their spawning targets, and these are categorized as *Vulnerable*, 19 (27 percent) achieved averages of 20-50 percent of their targets and are categorized as *Endangered*, and 10 (14 percent) achieved fewer than 20 percent of their targets and are categorized as *Critical*. Stocks in four rivers are categorized as *Extinct*, because they were lost completely and the rivers have had populations that disappeared completely: the Trent, the Yorkshire Ouse and the Mersey. So a total of seven rivers (10 percent) are categorized as *Extinct*.

Of the seven rivers that are known to have completely lost their salmon stocks in the past, most have been restocked or re-colonised in recent years. The only major rivers that have not been restocked are the Mersey, which is still too polluted and obstructed to support migratory fish, and the Trent, which has many obstacles to migration. These rivers both lost their runs more than 100 years ago. The Yorkshire Ouse has a minor stock, possibly as a result of restocking in the 1960s and 1970s, and a minor run in the Thames appears to be maintained entirely by hatchery-reared juveniles stocked into the river.

Few rivers in England and Wales have stocks that are truly in imminent danger of extinction. The Axe river stock appears to be on the verge of extinction, and some of the chalkstream stocks are seriously threatened. Their recovery may be dependent upon a series of years with normal or higher than normal patterns of rainfall. However, some rivers have suffered both considerably decreased catches and apparent reductions in spawning stocks. These stocks are vulnerable to genetic damage, as some stock components are bound to suffer more than others. In the River Torridge in South West England, for example, the traditional spawning tributaries, draining agricultural land, have virtually lost their salmon. The run on the river is nowadays being maintained almost entirely by spawning in a major tributary that drains "unimproved" moor land, and which had been unavailable for spawning for many years up to the 1970s due to a mill weir that was then removed. There is little doubt that the Torridge stock will have undergone genetic upheaval in recent years.

The most recent annual catch statistics for individual rivers, published by the Environment Agency, are for 1998. Figures are available from 1951 to 1990 from Russell *et al.* (1995), though the data for some rivers are missing or are grouped in some of the earlier years, extending to up to half the period. However, the figures from 1974 onwards allow an analysis of trends for 73 rivers over a period of around 20 years. In order to undertake a comparison, the five-year mean rod catches for 1994-98 are compared to those 1974-78. Fortuitously, direct comparison is simplified by the fact the mean total of rod catches for all rivers were broadly similar for the two periods at 19,220 and 17,699 fish. The rivers can be categorized according the 1994-98 catch as a percent age of that of the earlier period. Thus the most improved rivers are at the top of the list, and the most downgraded at the bottom.

The following categories are then identified based on catch statistics:

0 baseline	Re-colonised or re-instated rivers
500 or more percent	Greatly increased catches
150 – 500 percent	Increased catches
70 – 150 percent	Unchanged catches
50- 70 percent	Decreased catches
20- 50 percent	Greatly decreased
20 percent or less	Collapsed stocks

Almost half of the 73 rivers analyzed indicate a reduction in rod catch to less than 70 percent of the mean catch of 20 years ago. More than a fourth of the rivers have shown increased catch returns over the past 20 years or so, but this may be partly an artefact of catch reporting procedure. The 14 rivers with increased catch include some recovering from pollution in NE England (Coquet) and Wales (Neath, Ystwyth). Others (e.g., Exe, Teign) suffered badly from the disease UDN in the early 1970s, and in those cases, the increase in catches almost certainly reflects the stock recovery from that. However, several of the rivers (Ehen, Eden, Kent, Calder, Esk and Lune), plus the Border Esk from the “greatly increased” category, are in the NW of England and were generally not polluted or downgraded in any obvious way. Historically this area enjoyed low reporting rates of catches (often only of the order of 20 percent of anglers made returns) so at least part of the apparent increase in catches may be an artefact of reporting. There is little doubt that in some cases (e.g., Border Esk, Eden, Lune) the increases are at least partly a reflection of the recovery from UDN.

Over the 20-year period (1974-78 to 1994-98) four rivers fall into the re-colonised category, and five showed a great increase in catches. Of these nine, seven are rivers recovering from industrial pollution or other human influences that had eradicated salmon or virtually so. One of the other two (Yealm) is a small stream in SW England where the increased reported catch is less likely to reflect a true increase in stock, and may reflect increased fishing pressure or improved catch reporting. The last river in this category, the Border Esk, is discussed below.

Surprisingly few of the rivers (15 out of 73) had a 1994-98 mean catch of between 70 and 150 percent of that for 1974-98 and are thus considered to be of relatively unchanged stocks status. These rivers are spread throughout England and Wales without any obvious pattern. Of the 73 rivers, 34 (47 percent), of which 18 are in Wales, are in the decreased, greatly decreased, or collapsed categories. The total number of rivers with significant reductions in catch is surprising, because most of the rivers have good environmental conditions and no obvious over-fishing problems. Several of the rivers in these categories are the chalkstreams of Southern England (Frome, Piddle, Test, Hampshire Avon and Stour). There is no doubt that stocks have decreased severely in the chalkstreams. The situation was severely impacted by the drought of 1989-92, but the stocks appear to be recovering only very slowly. Only one chalk stream supporting salmon, the Itchen, appears in the "unchanged" category.

The relationship between the catch index discussed above and the spawning target assessment is complex. There is little pattern in the target figures for the "re-colonised" and "greatly increased" rivers, because some in the "greatly increased category have recovered from extremely low levels of catch two years earlier, whereas others still have some way to go to full recovery. In the cases of rivers in the "increased" category, of 13 rivers for which spawning data are available, seven achieved 100 percent or more of the targets, three achieved 50 to 90 percent of their targets, and three achieved less than 50 percent of their targets. Of the 14 rivers in the "unchanged" category, eight achieved about 100 percent or more of their targets, three achieved 50 to 90 percent of their targets, and three achieved less than 50 percent of their targets.

Most of the rivers in the "decreased" and "greatly decreased" categories, however, failed to achieve their spawning targets. Of the 27 rivers in the "decreased" and "greatly decreased" categories, only eight were near to 100 percent of their spawning targets or above it. And only five rivers in this category achieved 50-90 percent of their spawning targets, while 16 achieved less than 50 percent of their spawning targets. Both the rivers in the "collapsed" category for which spawning target data are available were well below their spawning targets. There are, however, a number of notable exceptions (e.g., Frome, Dwyryd, Conwy, Seiont and Yorkshire Esk) in which rivers with decreased reported catches are supposedly demonstrating a level of spawning in excess of that required for maximum sustainable yield.

Given the fact that statistics on catch trends may reflect either recovery from a collapsed stock or changes in effort or reporting rather than increases or decreases in stocks, the correspondence between categorization based on catch trends and on spawning targets, therefore, is only moderate. We rely, therefore, on the data on spawning targets as the basis for categorizing salmon rivers in England and Wales.

By using spawning targets we categorize the situation for salmon in 25 rivers as Healthy, in 11 as Vulnerable, in 19 as Endangered and in 10 rivers they are Critical. Salmon is Extinct in seven rivers and in four rivers we do not have enough information to categorize the salmon stocks.

Causes of salmon decline

Reasons for declines in salmon stocks include reduced marine survival, heavy exploitation depressing recruitment, and freshwater habitat degradation.

Marine survival is considered to be naturally low at present, probably due to natural marine conditions. It is possible, however, that the deterioration in marine conditions for salmon could be at least in part due to human activity, e.g., climate change or exploitation of forage species, although there is no direct evidence for this. There is evidence of low marine survival in the past, but the persistent cycle appears to be both deep and persistent. In particular the smolt year-classes of 1989 and 1998 appear to have had very low survival. There is relatively little that can be done to manage the marine environment for salmon. One exception is ensuring that industrial fisheries are not having an adverse effect upon salmon stocks at critical times and places. Fisheries for salmon on the high seas may exploit a wide range of stocks, often from several countries. This precludes management of individual stock components and such fisheries should be phased out as soon as possible.

Exploitation rates in rivers appear to be declining with the reduction in netting effort and adoption of increasing levels of catch and release by anglers. Anglers must release all salmon caught before June 15, and many are also practising voluntary catch and release later in the season as well. Many net fisheries in estuaries exploit a single stock, or overwhelmingly so, and allow management of the stock involved as a single unit. However, some coastal net fisheries, and some in estuaries shared by two or more rivers, exploit a mixture of stocks which precludes management of individual stock components. Such fisheries should be phased out as soon as possible.

Freshwater habitat degradation represents the greatest threat to salmon stocks, but this problem also offers the greatest scope for amelioration and constructive management. The problems faced by different rivers are wide ranging, including industrial pollution, agricultural pollution (often diffuse in nature), siltation of spawning and nursery areas, riparian damage by livestock, hydro-electric power schemes, obstruction to migration and eutrophication. Management of these problems, where they occur, is for the most part a catchment-specific issue and appropriate action must be assessed on a local level. A major development in this direction has been the introduction of catchment management plans, Local Environment Agency plans, and catchment-specific Salmon Action Plans by the EA. These involve extensive public consultation, and the result is a detailed assessment of environmental issues and a phased plan for addressing them. Practical initiatives include use of agricultural grant schemes to develop buffer zones, and gravel cleaning.

Virtually no salmon farming takes place in England and Wales, and the farming areas of the West Coasts of Scotland and Ireland are sufficiently distant that farm escapees are not an issue for local stocks.

Anglers in particular are enthusiastic supporters of any activity that increases the numbers of fish. The usual demand for stock enhancement is for production of smolts or other juvenile fish in a hatchery. While hatcheries do have an important role to play in salmon management, there is increasing concern regarding the genetic implications of large-scale hatchery production. A move to large-scale hatchery production as a “cure” for the present shortage of fish should be resisted. In the meantime there is an urgent need for hatchery practices to be evaluated so that they can take their proper place in the range of practices available to the fishery manager.

A considerable level of restocking of rivers has taken place over the years, often using genetic material from elsewhere, in particular Scotland. Whether this practice has caused any damage is unknown. However, a growing awareness of the poor cost/benefit ratio of restocking and of the genetic risks has led to a decrease in the practice, and adoption of sound genetic principles when it does take place.

Overall management of salmon stocks in the rivers and coastal waters of England and Wales lies with the Environment Agency. They have in place a developing infrastructure of monitoring and assessment of stocks, including the catch statistics used in this report, juvenile surveys, fish counters and the spawning target methodology.

References

Anon. (1999). Salmon stocks and fisheries in England and Wales, 1998. Preliminary assessment prepared for ICES, April 1999. London: CEFAS/Environment Agency.

Bledisloe, V. (1961). *Report of the Committee on Salmon and Freshwater Fisheries*. London: HMSO. Cmnd 1350.

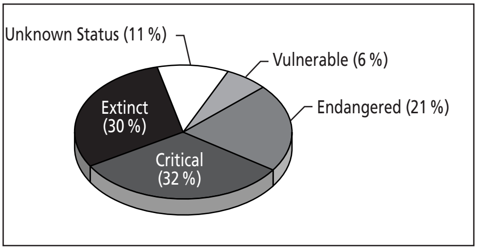
ICES (1981). *Reports of the ICES Working Group on North Atlantic salmon, 1979 and 1980 Cooperative Research Report 104*. Copenhagen: ICES.

Kempster, J. W. (1948). *Our rivers*. London: OUP.

Russell, I. C., Ives, M. J., Potter, E. C. E., Buckley, A. A. and Duckett, L. (1995). *Salmon and migratory trout statistics for England and Wales, 1951-1990.* MAFF, Fisheries Research Data Report No. 38.

Solomon, D. J. and Potter, E. C. E. (1992). *The measurement and evaluation of the exploitation of Atlantic Salmon*. Pitlochry, Perthshire: Atlantic Salmon Trust.

7.6 France



Categorization (%) of salmon-bearing rivers in France.

Atlantic salmon populations have disappeared entirely from most historic French salmon rivers. Most of the remainder are classified as either critical or endangered. Habitat has been destroyed, spawning grounds are no longer accessible, and so natural spawning capacity is insufficient to sustain wild populations.

For example, on the Loire basin, of 2,200 hectares of original spawning grounds, fewer than 300 ha are now accessible. Artificial stocking is widely practised to augment natural spawning and so maintain the runs. In the major systems (Dordogne, Garonne, Rhine), where the salmon have completely disappeared, new populations are gradually being reconstituted. In smaller systems, (Brittany, Normandy), the remaining small native populations are mixed with non-native progeny from hatcheries.

Precise data on the current status of salmon populations in specific French rivers are difficult to obtain from published sources. However, Table 6 gives an assessment of the status of populations in larger French rivers, based on MacCrimmon and Gots (1979) and recent data from the French Oceanographic Institute (Mazeaud, pers. comm.)

In addition to these larger rivers, other smaller rivers in Brittany and Normandy once held wild salmon stocks, but all these populations are now extinct. Thus, we find that of at least 47 historic French salmon rivers, the populations in 42 can be categorized, while those in 5 rivers remain of unknown status. Of the 42 systems that can be categorized, 14 (33 percent) are labelled Extinct, while 15 rivers (36 percent) are categorized as Critical. Populations in 10 rivers (24 percent) are considered Endangered, and those in 3 rivers (7 percent) are categorized as Vulnerable. The status of five rivers is categorized as Unknown.

Table 6

Status of salmon populations in French rivers[1]

Extinct (14): Dordogne, Garonne[2], Aulne, Vilaine, Sarthe, Seine, Aube, Yonne, Rhine[3], Moselle, Meuse, Tarn, Viaur, Ariège.

Critical (15): Loire, Allier, Vienne, Creuse, Gartempe, Orne, Yères, Somme, Adour, Aulne, Douffines, Couesnon, Trieux, Sèvres Niortaise.

Endangered (10): Nivelle, Nive, Scorff, Blavet, Risle, Bresle, Ellée, Gave de Pau, Sélune, Sée.

Vulnerable (3): Elorn, Gave d'Oloron, Adour.

Unknown (5): Authie, Basse Rissle, Blavet, Touques, Léguer.

Causes of extinction of salmon stocks

Salmon were abundant in all French rivers flowing into the Atlantic Ocean at least until the late 19th century. It is estimated that France enjoyed an Atlantic salmon population of as many as 800,000 returning fish in the 18th century. By 1900, however, 75 percent of potential spawning grounds had become inaccessible because of dams[4] and salmon had disappeared from most major French

---

1. This list is not complete, all rivers are not cited.
2. Important restoration programs are taking place in these large rivers, under technical authority of the CSP (Conseil Supérieur de la Pêche) and with a strong participation of fishermen's associations, for example MIGAGO: MIgrateurs GAronne DOrdogne on the Garonne and Dordogne rivers. The genetic material comes from the Loire and Allier salmon, the last remaining long-migrating (1,000 km) salmon population left in Europe.
3. A salmon restoration program was begun in 1986, following the Sandoz accident, with eggs originataing from the Loire and Allier basin.
4. Mac Crimmon and Gots, 1979.

rivers. The needs of the salmon were ignored in the harnessing of rivers for both hydroelectric energy and river development programs (navigation). Returning salmon were cut off from pristine spawning grounds on the upper Loire, the Garonne River, the Dordogne River, the Rhine, the Seine, etc[5].

In addition to barriers to migration, industrial, urban and agricultural pollution became factor in habitat degradation. One of the more serious manifestations of interference with the natural flowages was the exponential development of mud barriers in estuaries[6].

While industrial and urban pollution became an effective barrier to migration, a general apathy towards fishery regulations served to make matters worse. (MacCrimmon and Gots, 1979).[7]

Restoration programs

Despite constant efforts to restore runs by artificial propagation (mainly with eggs of Scottish origin), conducted by the Conseil Superieur de la Pêche, (CSP), by the mid-60s only 2,400 ha of suitable spawning habitat remained in all of France.

In northwestern France, priorities were given to the Bresle, Yères, Basse Rissle, and Authie rivers. In Brittany, management and restocking programs were initiated in the Aulne and Elorn rivers, and small tributaries, in 1974[8]. An estimated 66,000-100,000 salmon fry of Scottish origin have been released in the Scorff River annually since 1973. In the south west, restoration programs in the Nivelle River and the Gaves began in 1976/77.

To reinforce the national restoration efforts, three important plans were launched by the CSP: The “Plan Saumons” (1975), the “Plan Migrateurs” (1980), and the plan “Retour aux sources” (1992), with promising but inadequate results. The results are encouraging on the Dordogne, with more than 1,000 fish back in 2000. The Sélune, Sée (Normandy) and the Blavet, Ellée (Brittany) also now enjoy appreciable runs.

---

[5] Even the upper Allier river, where the last remaining long-migrating salmon of Western Europe reproduced, access was blocked with the building of the lethal Poutès-Monistrol dam (1941)

[6] On the Loire estuary, the mud barrier is now three times its historic size, and constitutes a lethal barrier for the migrating fish.

[7] Mac Crimmon and Gots, 1979. Commercial as well as recreational fishing has been banned on the Loire river since 1994, but by then the fish were on the brink of extinction.

[8] MacCrimmon and Gots, 1979.

On the other hand, despite the plan, the Loire and Allier salmon, the last long migrating stock in Western Europe, were on the brink of extinction at the beginning of the 90s. Consequently, in 1994, a particularly impressive plan to save these stocks was launched, after the Loire Vivante / WWF battle against a massive dam program planned on the river. This “Plan Loire Grandeur Nature”, was a governmental initiative intended to sustainably develop the Loire basin. Since then, two dams have been destroyed; an efficient fish ladder was built on the Vichy dam and a major hatchery (the largest in Europe) located on the Upper Allier, in Chanteuges, has begun to produce juvenile fish. Commercial and recreational fishing are banned.

Nevertheless, Atlantic salmon populations in France today are a mere fraction of historic levels. After a visit to France in 1990, the NASCO secretariat concluded that considerable restoration work had been undertaken in previous years to build up greatly depleted stocks of wild salmon, and there was great emphasis on the need to establish a more co-ordinated approach to conserving, regulating and managing wild Atlantic salmon (NASCO, 1990).

Despite the fact that in 1999, 515 salmon ascended the Allier river; and in 2000, under the “Saumon 2000” program, 80 salmon made it through the fish ladder on the Iffeszheim dam on the Rhine, the species remains in serious decline. Restoration efforts must be redoubled.[9] Atlantic salmon restoration is particularly challenging in a country where, for example, the hydro power industry is concentrated in a single, powerful organism, Electricité de France (EDF), which operates more than 400 large dams.

References

MacCrimmon H. and Gots. B. L. (1979). World distribution of Atlantic salon (salmo salar). *J. of Fish. Res. Board Canada* 36: 422-457.

NASCO (1990). Report by the secretary of NASCO on a visit to France in September 1990. CNL 9150, NASCO.

Mazeaud, pers. comm. Dr. Frederic Mazeaud, AIDSA, Institute Oceanographique, Paris. 8 of June, 2000.

Le saumon de l’Allier François Cohendet Thèse vétérinaire. 1993.

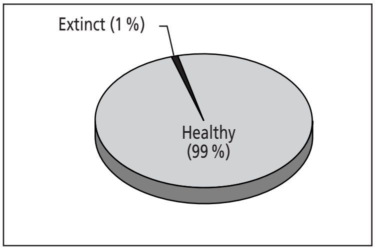
Les poissons migrateurs Le contrat retour aux sources Ministère de l’Environnement CSP 1992.

Migr’en Seine Stratégie pour le retour du saumon en Seine CSP – SIAPP 1992.

---

[9] We are, in fact, a long way from the 19th century situation, where, for example, 5 tonnes of salmon were caught in the lower parts of the Seine river.

7.7 Iceland



Categorization (%) of salmon-bearing rivers in Iceland.

Atlantic salmon is the most economically valuable of the five freshwater fishes native to Iceland (Gudjonsson, 1978). Salmon are found in 102 Icelandic rivers, of which 16 have annual angling catches of 1,000 or more (Gudbergsson, 2000; Gudjonsson, 1978. Iceland's salmon fishery is predominantly a sports fishery, with rod and line the main method, and gillnets forming a much smaller proportion of the effort. (Gudjonsson, 1978).

Harvest patterns suggest Icelandic salmon populations are stable. Since the number of sportfishery rod-days has been held to approximately the same level for the past quarter century, catch data have proved to be a reliable indicator of population dynamics. The catch has fluctuated considerably over this period, but these have been natural events. Total rod and net catch landed by year from 1974 to 1998, based on figures from the Institute for Freshwater Fisheries in Iceland (Gudbergsson, 2000) is shown in Figure 5. It shows annual variances as high as 33 percent have been common. Figures for total rod catch for the past six years do not indicate any significant departure from this historical pattern: the average catch is 32,416 salmon per year, only about 3,000 fewer than the average for the entire period.

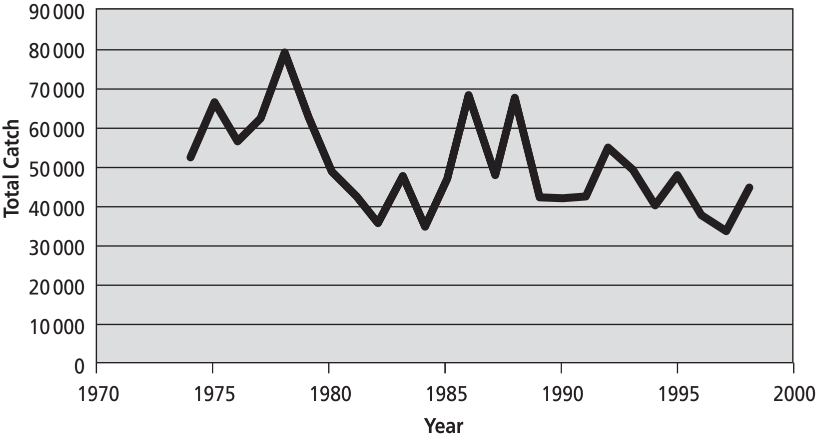


Figure 5. Annual Rod and Net Salmon Catch, 1974 – 1998
Source: Gudbergssonn, (2000).

So, there is no evidence of long-term decline in Icelandic salmon stocks over the past century. Fluctuations in population size appear to reflect cyclical environmental changes. Significant correlation has been found between the catch of grilse and ocean temperature at the time smolts migrate. (Scarnecchia, 1984; Antonsson *et al.*, 1996).

Status of salmon populations by river

The precise number of Icelandic rivers hosting Atlantic salmon is unknown, but 102 rivers are known to have an annual catch of 50 salmon or more, and several rivers have smaller populations that have maintained long-term stability. Only one river is known to have lost its population during the 20th century. (Antonsson, pers. comm.). Therefore, the populations in 102 salmon rivers are categorized as Healthy, and the population of one river is categorized as Extinct. This categorization is incomplete, since it does not include an indeterminate number of rivers with smaller populations.

Major threats to salmon stocks

Power plants in Iceland are mainly for hydro and geothermal electricity generation. During the past 20 years, most of the rivers harnessed for hydroelectric power generation have been glacier rivers that could not sustain Atlantic salmon. Although power plants were placed in some salmon-bearing streams prior to the 1970s, research has suggested that the harm to salmon stocks from these power plants has been minor. However, it is now estimated that production of salmon was reduced in three or four rivers (Antonsson, pers. comm.).

At the beginning of the 1980s, the number of fish farms in Iceland increased rapidly. As a result, escaped farmed salmon grew to constitute as much as 30 percent of the catch in some rivers in the southwestern part of Iceland (although the increase was less in other areas). During the 1990s, however, most fish farms suffered bankruptcy and the ratio of escaped salmon in rivers fell sharply. The extent of damage inflicted upon wild salmon stocks by escaped farmed fish is not yet clear. Research into the matter continues. (Antonsson, pers. comm.).

Commercial salmon fishing has been illegal in Icelandic coastal waters since 1930. Tagging experiments have shown that marine catches in Faeroe Island and Greenland fisheries have not impacted Iceland's wild salmon stocks, and no clear indicators of overfished salmon stocks have appeared in Iceland.

(Antonsson, pers. comm.) However, data gathered in the 1990s indicate that many rivers are experiencing high rates of exploitation. (Gudjonsson *et al.*, 1995). Studies are now being conducted, especially on small rivers with small populations. (Antonsson, pers. comm.).

Pollution of watercourses is a growing problem in Iceland, as it is for most countries, despite the fact that the population is only 270,000. Pollution is considered to be a future threat to nursing habitat, and may have already caused damage. All steps in the salmon's life cycle are being studied in three index rivers in different parts of the countries to monitor whether changes in stock size can be correlated to human activities (Antonsson, pers. comm.).

Very few instances of salmon diseases have occurred in Iceland. In the period of growth of the salmon aquaculture industry, problems of diseases spread by escaped farmed fish began to threaten wild salmon stocks, but the threat receded with the decrease in aquaculture. The first instance of furunculosis in an Icelandic river appeared in 1995, but has not been repeated (Antonsson, pers. comm.).

References

Antonsson, T., Gudbergsson, G. and Gudjonsson, S. (1996). Environmental Continuity in Fluctuation of Fish Stocks in the North Atlantic Ocean, with Particular Reference to Atlantic Salmon. *North American Journal of Fisheries Management* 16: 540-547.

Antonsson, T. (pers. comm.) Thorolfur Antonsson, Institute of Freshwater Fisheries, Reykjavik, Iceland.

Gudbergsson, G. (2000). Icelandic Salmon, Trout and Charr Catch Statistics 1999. Reykjavik: Institute of Freshwater Fisheries. (http://www.veidimal.is).

Gudjonsson, T. (1978). The Atlantic salmon in Iceland. *J. Agric. Res. Icel.* 10: 11-39.

Gudjonsson, S., Einarsson, S. M., Antonsson, T. and Gudbergsson, G. (1995). Relation of grilse/salmon ratio to environmental change in several wild stocks of Atlantic salmon (*Salmo salar*) from Icelandic Rivers. *Can. J. Fish Aquat. Sci.* 52: 917-935.

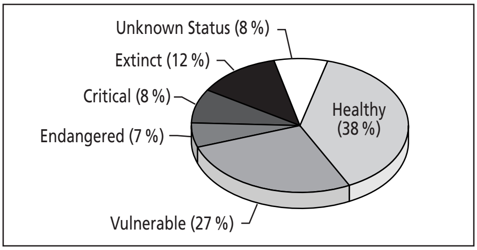
Scarnecchia, D. L. (1984). Climatic and oceanic variations affecting yield of Icelandic stocks of Atlantic salmon. *Can. J. Fish Aquat. Sci.* 9: 1234-1240.

7.8 Ireland and Northern Ireland

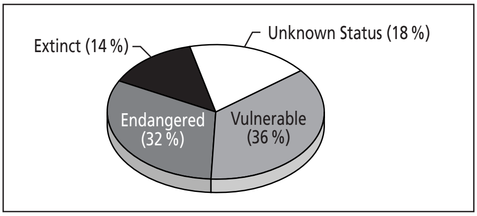
Status of stocks in Ireland

Although the quality of the data is poor, it is evident that in general salmon stocks in both Ireland and Northern Ireland are lower than in the past. This decline appears to be the result mainly of poor marine survival, particularly among multi-sea-winter stocks, which has become apparent throughout the range of North Atlantic Salmon.

Data on status and long-term trends of salmon stocks are available only for a handful of rivers in Ireland and for 1 sea-winter stocks, and for even fewer with regard spring salmon stocks. Data are available from ICES on the 2 sea-winter component from 1972 to 1989, when catches ranged from a low of 63 tonnes to a high of 274 tonnes and averaged 150 tonnes. These data are shown in Figure 6. Overall catches were as high as 2,216 tonnes in 1975 and as low as 515 tonnes in 1999.



Categorization (%) of salmon-bearing rivers in Ireland.



Categorization (%) of salmon-bearing rivers in Northern Ireland.

The trend in catch data for Northern Ireland, as shown in Figure 7 is similar to those in Ireland. Catches in the 1960s and 1970s were high, and as high as 449 tonnes in 1967, but they declined in the 1980s, and dropped to an even lower level in the 1990s, during which they have averaged slightly more than 80 tonnes.

River by river categorization

In both Ireland and Northern Ireland, the quality of the data on salmon stocks on a river by river basis is so poor that stocks could disappear before it is realized that they are endangered. A system of data collection needs to be put in place to provide timely information on the status of both 1 sea-winter and 2 sea-winter stocks on a river by river basis.

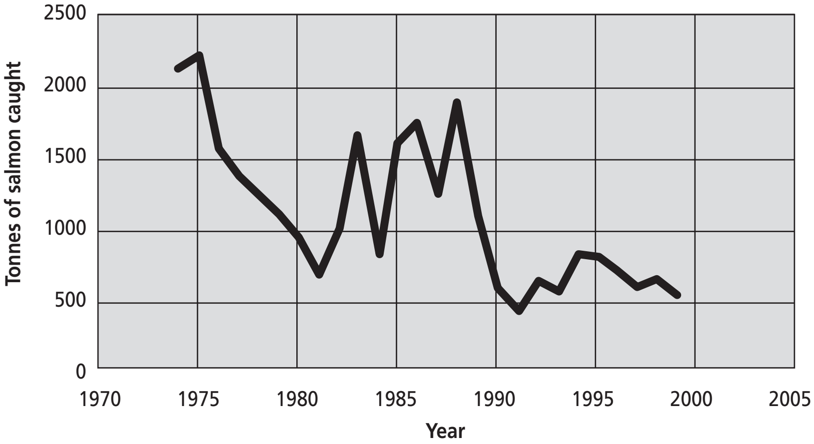


Figure 6. Nominal catch of salmon from Ireland (in tonnes round fresh weight), 1974 – 1999 (1999 figures include provisional data)

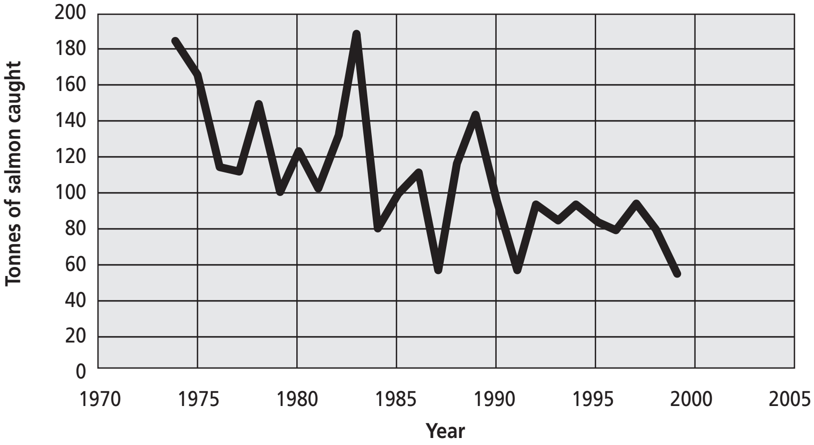


Figure 7. Nominal catch of salmon from Northern Ireland (in tonnes round fresh weight), 1974 – 1999 (1999 figures incude provisional data)

For this study, a database was assembled for 339 rivers in Ireland and 44 rivers in Northern Ireland in which salmon stocks are known to have existed historically. The data were collected from seven Regional Fishery Boards in Ireland, the Loughs Agency for the River Foyle, and the Department of Agriculture for Northern Ireland. Each of these official agencies was sent a database form, in electronic format or as a hard copy, asking for their assessment of the status of each of the rivers under their authority, based on the categorization scheme adopted by WWF. The forms were to be completed by the Fishery Inspectors in each of the regions.

For Ireland's 339 rivers, 27 (8 percent) could not be categorized, because of the absence of data. Of the 312 rivers on which sufficient information existed on which to base a categorization, 42 rivers (14 percent) have completely lost their salmon populations, 28 (9 percent) are in Critical condition, another 20 (7 percent) are Endangered, and 92 (32 percent) are Vulnerable. 130 rivers (45 percent) have salmon populations that are regarded as Healthy.

Of Northern Irelands' 44 historic salmon rivers, 8 (22 percent) could not be categorized because of lack of information. Of the remaining 36, six (16 percent) are categorized as Extinct populations, 14 (38 percent) are categorized as Endangered, whereas 16 (44 percent) are categorized as Vulnerable. None of the rivers is categorized as Healthy.

The River Foyle flows in both Ireland and Northern Ireland and is managed by a Commission composed of people from both Ireland and Northern Ireland. There are 3,000 km of riverine habitat and a declared commercial catch of 30-45,000 salmon with an angling catch between 10-15,000. The 2 sea-winter component as judged by the stocks on the River Finn where angling catches of 2 sea-winter salmon remain high, is in the order of 500 salmon.

These data must be treated with some caution, since are based largely on the impressions of fisheries officers rather than on hard data, which is scarce, as noted above. Nevertheless they offer the first river by river categorization of the salmon rivers in Ireland and Northern Ireland.

In Ireland, trends for the River Slaney spring salmon indicate that the level of spawning escapement is much lower than in the past and it appears that numbers have stabilised at this low level with no indication of an increase (O'Maoileidigh *et al.*, 1998). Trend data for the Careysville rod fishery on the Cork Blackwater indicate that the proportion of spring salmon has decreased dramatically (O'Halloran *et al.*, 1998).

In Ireland's Northeast and East, the majority of salmon rivers are small to medium coastal streams which support 1 sea-winter salmon. The River Bush is the most significant of these. It is a river with full counting facilities for smolts and adults. The spawning target for this river was reached or exceeded in eight of the 13 years prior to 1998 (Anon., 1998), indicating an adequate broodstock for the river. Crozier *et al.* (1998) state that the numbers of fish returning to spawn are being maintained against a background of poor marine survival. The explanation is that marine exploitation has been lower in recent years. There is a declining trend in freshwater survival as recorded in the River Bush. The decline is believed to be associated with deteriorating freshwater habitat (Anon., 1998]

The river Bann and Lough Neagh catchment rivers have significant runs of salmon, but little is known of the age structure or run timing of these stocks.

The management regime in Ireland has been based on effort limitation (i.e., limited the time available, the gears permitted for fishing and the manner in which the gears could be used). This method of management worked while stocks were relatively high (the 1960s and 1970s) or when the effort was relatively low (prior to 1960s). However, it is a dangerous method of managing stocks when marine survival is at a low level, because it does not relate the management measures to the size of the stock. A new method of salmon management has been proposed for Ireland (see the discussion under exploitation) and it is urgent that the new system is implemented to allow a quicker and more localised response to low stock levels and thus protect the stocks.

Factors affecting the status of stocks

The Salmon Management Task Force Report to the Minister (1996) identified up to 40 factors which mitigate against the salmon's survival and well-being in Irish waters, both marine and freshwater. O'Grady and Gargan (1993) identified 18 major factors affecting salmon populations and provided data on the magnitude of these problems in 27 catchments surveyed by the Central Fisheries Board. These catchments are fairly representative of the Irish situation. Table 7 shows the magnitude of individual problems in the 27 catchments surveyed by the Central Fisheries Board.

Table 7

Magnitude of individual problems in 27 catchments

Surveyed by the Central Fisheries Board
(Source: O'Grady and Gargan, 1993)

Problem Specification	*	**	***
Organic pollution/Eutrophication	–	5	8
Impassable Barriers	–	3	9
Excessive Shade	–	6	7
Bank Erosion	1	3	5
Lack of Bank Cover	–	1	11
Hydro-Schemes	–	2	5

Afforestation	–	2	4
Over-grazing (livestock)	1	–	4
Compaction/Siltation	1	–	7
Competition	–	–	6
Ponding	–	1	4
Pike Predation	–	1	4
Water Abstraction	–	–	5
Gravel Removal	1	1	–
Arterial Drainage	–	–	9
Calcification	–	–	5
Reservoir Creation	–	2	1
Lack of Gravel	–	–	3

*A problem of limited extent
**A serious problem in limited catchment areas
***A serious problem over extensive channel lengths

Overfishing

The greatest single threat to Irish salmon stocks is the overexploitation of the stocks by fishers. Exploitation of Irish adults begins in the high seas, at West Greenland and Faroes and is continued around the Irish coast with dritnets. Draft and other specialised estuarine nets such as snap and loop nets follow, and in some rivers traps operate. They are followed by angling, and finally poaching.

The rationale for the exploitation of salmon in fishery science is that there is an ideal spawning requirement for a river, and that numbers in excess of this will at best add nothing to the juvenile stock and in worst cases may reduce the juvenile stock. However, marine survival of salmon now appears to be very low across all Atlantic salmon stocks. While this extremely low survival of salmon in the sea persists, the salmon are more vulnerable to exploitation.

All three major reports on salmon in Ireland, the *Report of the Inland Fisheries Commission* (Anon., 1975), *Report of the Salmon Review Group* (Anon., 1987) and the *Report of Salmon Management Task Force* (Anon., 1996) highlighted the poor quality of the statistics on salmon catches. Both the 1975 and 1966 reports recommended a comprehensive programme of data collection on salmon stocks. But this recommendation still remains to be carried out.

The quality of returns from the various sectors is variable particularly the most important figure for the angling catch in each river, and this makes comparison of the relative take by each sector. Nevertheless, it is clear that the dritnet fishery takes a high proportion of the returning adults: current estimates puts the take at between 50-70 percent of the returning fish. The dritnet fishery in the main exploits 1 sea-winter salmon, whereas the main components of the stocks under pressure are the 2 sea-winter components. More than 90 percent of the catch of salmon in Ireland is 1 sea-winter salmon, and there are few data on 2 sea-winter stocks

Catch data are largely based on returns from dealers' registers for each district. This has meant in the past that the only angling returns were those where salmon had been sold. It has also meant that catches were not recorded on a river by river basis. The data available can be regarded as indicative of long term trends. Comparison of catches from year to year is not of great value, because many changes have occurred which affect effort in the fisheries, such as changes in the length of the close season, changes in weekly closure, the introduction of taxes, and the advent of better fishing gears and boats. Quality of the catch data also varies among sectors.

The quality of the data for dritnet catch also has changed from one time period to another. For instance the driftnet catches were collected with relatively good accuracy in the 60s and 70s, whereas the driftnet catches were often illegal and were poorly reported. In the 80s and 90s the data became more difficult to collect as the returns from draft nets diminished, and the sales outlets became more diffuse. The data for the dritnet fisheries improved in the 80s and 90s. Those for angling, however, have remained poor over the entire time series.

From 1929 to 1943 the average annual salmon catch was 950 tonnes. For the next 15 years catches averaged over 800 tonnes with the exception of 1951 when a catch of 1,274 tonnes was recorded. In the 60s and 70s the catch increased, reaching a peak of 2,188 tonnes in 1975.

Estuarine nets have accounted for most of the catch during the past half of the 20th century, but the proportion being taken by the dritnet fishery has increased at the expense of estuarine nets and angling. Angling accounted for only about 13 percent of the catch in the 1950s, and remained at the level until the 1990s, when it gradually increased to a high of 20 percent in 1999. But this may reflect the fact that, according to regional fisheries inspectors, the Regional Fishery Boards began collecting statistics on the angling catch on a river by river basis in 1995.

The 1996 Salmon Management Task Force Report to the Minister recommended a new more flexible management system for salmon management that would establish spawning targets for each river and allow only surplus stocks to be exploited. The system envisaged the introduction of a system of quotas to control exploitation and carcass tags to monitor it. It proposed prompt closing of fisheries if and when exploitation exceeded set limits. The report was referred to a Select Committee on Enterprise and Economic Strategy by Dail Ireland (the Parliament of Ireland) and approved.

In April 2000, the Minister finally put in place a Salmon Commission to over see the introduction of a new management system as recommended in the Task Force Report. The introduction of Carcass tags is one of the first tasks of the Commission.

There have been many delays in introducing this scheme, which had been approved by all political parties through a select committee of Government. Such delays may have serious consequences for Irish salmon.

Pollution

A review of water quality in Ireland is presented annually by the Environmental Protection Agency (EPA). A review of data arising from surveys carried out over 13,000 km of river channel, 120 lakes and 23 estuaries during the period 1995-1997 showed that while the overall condition of waters in Ireland remains satisfactory compared to other European countries, water quality is deteriorating (Lucey *et al.*, 1999).

The main problem is eutrophication, which is of concern mainly in freshwaters but may also now be affecting estuarine waters. The long-term trends (since 1971) show pollution continuing to increase from slight to moderate, attributable mainly to eutrophication from organic (animal manure) and artificial fertilizers and to a lesser extent from point sources (domestic sewage) discharges. More recent increases in seriously polluted channels are attributed mainly to suspected sewage discharges and to a lesser extent suspected agricultural activities (Lucey *et al.*, 1999).

A related problem is the growth of macrophytes in river channels resulting from the enrichment, which can trap large quantities of silt degrading the habitat. This problem can be exacerbated when associated with other factors such as soil erosion (Lucey *et al.*, 1999).

Agriculture is identified as the greatest single cause of the fish kills reported over the period 1995-1997, which showed a substantial increase over the previous period. During the period it was estimated that agriculture might have been responsible for 97 fish kills, industry for 37 and sewage for 24 (Lucey *et al.*, 1999).

Lakes pose a particularly difficult problem. Nineteen percent of the lakes surveyed were less than satisfactory, with the likelihood of significant impairment of beneficial use. Of these lakes, 18 exhibited algea growth indicative of a moderate to high eutrophic status, and five were classified in the hypertrophic category indicating a high level of pollution. The unsatisfactory water quality in 23 lakes classified as being eutrophic is due to excessive inputs of phosphorus. In the majority of these cases the principal sources of the nutrient are thought to be non-point discharges of agricultural origin. Discharges from municipal and industrial waste treatment plants are partly or wholly responsible for the enrichment of the other lakes (Lucey *et al.*, 1999).

Estuaries and coastal waters were not sampled as intensively as inland waters, but apart from local intermittent pollution, water quality is generally high. The main pollution source where it occurs is from effluent discharges.

The European (Quality of Salmonid Waters) Regulations of 1988 requires the designation of rivers as being capable of supporting salmon *(Salmo salar*), and other fish species. Designation imposes requirements that certain quality standards are met in these waters and compliance is determined by a specified sampling regime. The List of rivers and their tributaries designated by Minister for the Environment under this regulation includes only 22 rivers and 11 tributaries (European Community, 1988). These rivers and tributaries are shown in Table 8. Thus, less than seven percent of Irish rivers are considered to have water quality sufficient to support salmon and other fish species.

The EPA reported that there were 342 examples in excess of the limits set in the directive over the period 1995-1997, the most common being dissolved oxygen, copper, nitrite and BOD. The increase in incidence of low levels of dissolved oxygen was believed to reflect increasing eutrophication of rivers.

There are extensive areas with acid-sensitive water bodies in Ireland, which lie along the western seaboard an in Wicklow on the East Coast. The surface waters in these areas are low in alkalinity and consequently have poor buffering capacity. A survey carried out between 1987-1989 (Bowman, 1991) suggested that there is little evidence that artificially acidified precipitation is directly responsible for surface water acidification in Ireland. However in the areas investigated the run-off from extensive evergreen forests on soils of poor buffering capacity were found to have increased acidity and caused deterioration of water quality. This is a result of absorption by the trees of airborne pollutants and is most pronounced in the case of mature trees with closed canopies. It was suggested that rivers in County Wicklow were at particular risk.

Table 8

List of rivers and tributaries designated under EC regulations on quality of salmonid waters

Moy
Owengarve
Mullaghanoe
Spaddagh
Trimoge
Glore
Yellow
Gwesstion
Manulla
Castlebar
Deel
Corry
Munster Blackwater main channel
River Bride (tributary of Munster Blackwater)Lough Corrib and River Corrib
River Fergus
River Feale
River Swilly
River Finn (Donegal)
River Slaney
River Lee (above Cork Waterworks)
River Boyne
River Dargle
River Vartry
River Aherlow (trib Suir)
River Argideen
River Brown Flesk
River Maine

River Lurgy
River Glashagh
River Leannan
River Maggisburn
River Nore

Afforestation

Afforestation is a problem mainly on the western seaboard, although streams in Wicklow are also affected. Afforestation (non-deciduous trees) tends to make streams more acidic. Six catchments were affected, two of which had a serious problem in limited catchment areas.

The Department of Marine and Natural Resources (1995) outlined the requirements for good forestry practice in relation to fisheries in order to minimize the threat to fisheries from forestry development. Particular requirements are set for Designated Sensitive Areas, i.e. those which are particularly sensitive because of their important fisheries and low buffering capacity (low calcium levels). The guidelines include particular standards for these areas and also outline the designation procedures. However, no areas have been designated as sensitive to date.

Loss of quality of the riparian zone

There is a fine line between overgrown banks that exclude light, and banks with no growth to provide shading and protection for fish. There is also a link between bank cover erosion and overgrazing. All of these elements provide a quality of riparian zone and the amount of silt reaching the river. The REPS scheme.

Given this definition of the riparian zone few rivers are not affected by some aspect of poor riparian quality. There were links between overgrazing and erosion and between bank cover and the practice of arterial drainage. The most common problem was either overgrown or unshaped banks.

Under Measure 3 of the Rural Environment Protection Scheme (REPS) farmers can grant aided to make provision to fence off streams and a wider zone can be set aside under the scheme. The objectives of the Measure are

- to avoid, as far as possible, the nutrient enrichment of water bodies from agriculture and thus maintain or improve water quality and provide a healthy environment for fish and other wildlife;

- strengthen channel banks and allow natural streamside vegetation to develop and thus attract a wide range of both flora and fauna.

Hydroelectricity developments

Four major catchments in Ireland have been harnessed for the production of hydro-electricity, namely, the rivers Shannon, Liffey, Erne and Lee. These hydroelectric schemes were constructed between 1924 and 1957. In most cases provision for the upstream passage of salmon was made, but apparently no consideration was given to the downstream passage of smolts.

On the River Shannon a hydroelectric scheme was constructed between 1925 and 1929, in which no provision was made for the downstream passage of Atlantic salmon smolt at either the regulating weir or the generating station. Provision for the upstream passage of adult salmon was made at the regulating weir in the form of a conventional pool and traverse fish pass. In 1959 an unique 34 m vertical Borland-MacDonald fish-lock was constructed at Ardnacrusha to facilitate upstream passage of adult salmon.

On the River Liffey three hydroelectric generating stations were constructed during the 1940s. The two upstream stations, Pollaphouca and Golden Falls are situated above and at the upper limit of salmon distribution in the catchment, respectively. Only Leixlip lies in the path of salmon and it is the only Liffey generating station that will be considered in this paper. The construction of Leixlip resulted in the creation of a 2 km^2 reservoir immediately upstream.

On the River Erne two generating stations were constructed during the late 1940s involving major drainage works in the mid-catchment area. Assaroe Lake (2.3 km^2) was created between the hydroelectric generating stations. Fish passes of the White submerged orifice type were constructed at Cathaleen’s Fall and Cliff to facilitate the upstream migration of adult salmon. A tidal tailrace about 1.5 km long discharges to the Erne estuary.

The construction of the River Lee hydroelectric scheme commenced in 1953, and both Carrigadrohid and Inniscarra generating stations were commissioned in 1957. The scheme involved the creation of two reservoirs (5.3 and 9.3 km^2) upstream of both generating station, which increased the difficulty of salmon migration mainly downstream and increased predation on the salmon.

Peat siltation

Peat is an organic fossil fuel found mainly in the midlands and the West Coast that is harvested for power generation. The ground is prepared by cutting drainage channels to allow the peat to dry. The harvesting process involves milling a layer of peat a few centimeters deep over large areas of bogland. The peat is then gathered and stored before transport to large turf burning stations. The silt always blows into drainage ditches and then makes its way into streams and rivers. Although the peat is inert and is not an organic pollutant, it does cause major problems locally from smothering.

Arterial drainage

Arterial draining schemes are used in many places to increase water discharge from rivers and improve land for farming. All the tributaries and the main stem of the river are deepened by mechanical dredging that deposits the spoil on the banks. This results in a straighter channel faster water discharge. The banks are also higher and initially devoid of vegetation. This process is often devastating for the river and for the resident fish populations, as for example in the cases of the river Moy and some catchments of the river Boyne. Removing the gravel and the associated fauna is destabilising for the fish populations in the short term, although the long-term impacts of these schemes, may be positive or negative in relation to salmon stocks (O'Grady, 1991). These schemes are followed by a maintenance programme that also can disrupt fish populations just recovering from the initial scheme (O'Grady, 1991).

The catchments that have been subject to arterial drainage are shown in Table 9. In all 14 major schemes (greater than 100,000 acres) five medium schemes (25,000-100,00 acres) and 15 minor works (less than 25,000 acres) have been undertaken. In the past drainage engineers had little biological awareness. Now all drainage schemes are required to have an environmental impact statement (EIS). This will require the drainage authority to detail the activity to be undertaken and show the mitigation measures which will be put in place. In recent years a better relationship has developed between drainage engineers and the Fishery Boards, and fishery biologists are having input into the drainage plan through the EIS. As a result, drainage is carried out in a more ecologically responsible fashion.

Table 9

List of Irish catchments subjected to arterial drainage

Catchment	Period of works	Area /Acres
Brosna	1948-1955	86,200
Glyde and Dee	1950-1957	26,300
Feale	1951-1959	26,500
Corrib-Clare	1954-1964	74,900
Maine	1959-1963	11,600
Inny	1960-1968	50,000
Deel	1962-1968	11,900
Moy	1960-1971	61,000
Corrib-Headford	1967-1973	19,400
Boyne	1969-1986	119,000
Maigue	1973-1986	30,500
Corrib-Mask-Robe	1979-1986	24,000
Boyle	1982-1992	26,800
Blackwater (Monaghan)	1984-1992	5,850

Predators

Salmon are subject to many predators from birds to mammals. The effect of these predators on salmonid stocks varies from catchment to catchment and even within the catchment. The effects have to be studied locally and a balance struck between the predator and the salmonid stocks. All wildlife is protected by the Wildlife Act, and normally permission to cull or otherwise manage populations is difficult to obtain.

Gravel removal

Gravel removal often has serious local consequences for salmon, because of the importance of gravel to spawning sites, but it is a long-standing practice in many areas of the country. The only constraint is that the owner is not allowed to interfere with fish during the removal. This is difficult to establish and the owner has no obligation to inform the Fishery Board of his intention.

References

Anon. (1995). *Forestry and Fisheries Guidelines.* (Dublin: Forestry Service, Department of Marine and Natural Resources.

Anon. (1975). *Inland Fisheries:. Strategies for Management and Development*. Dublin: Central Fisheries Board.

Anon. (1975). *Report of the Inland Fisheries Commission* Dublin: Government Publications.

Anon. (1987). *Report of the Salmon Review Group*. Dublin: Government Publications.

Anon. (1996). *The Report on the Implementation of the Recommendations of the Salmon Task Force.* Dublin: Government Publications.

Anon. (1998). *Report of the Working Group on North Atlantic Salmon*. ICEC CM 1998/ACFM:15.

Bowman, J. (1991). *Acid Sensitive Surface Waters in Ireland*. Dublin: Environmental Research Unit, Environmental Protection Agency.

Commission of the European Communities. (1988). *Quality of Salmonid Waters* Regulations. Brussels: CEC.

Crozier, W.W. and Kennedy, G.J.A. (1998). Status of Northern Irish Spring Salmon Stocks. In K.F Whelan and F.S. O'Muircheartaigh (Eds), *Managing Ireland's Spring Salmon Stocks*. Newport: Salmon Research Agency.

Lucey, J., Bowman, J.J., Clabby, K.J., Cunningham, P., Lehane, M., MacCarthaigh, M., McGarrigle, M.L., and Toner, P.F. (1999.) *Water Quality in Ireland 1995-1997*. Dublin: Environmental Protection Agency.

O'Grady, M.F. (1991a). Rehabilitation of salmonid habitats in a drained Irish river system. In M. Steer (Ed), *Irish Rivers: Biology and Management*. Dublin: Royal Irish Academy. Pp. 187-204.

O'Grady, M.F. (1991b). Ecological changes over 21 years caused by drainage of a salmonid stream, the Trimblestown River. *Ir. Fish. Invest., Ser. A (Freshwater)* 33.

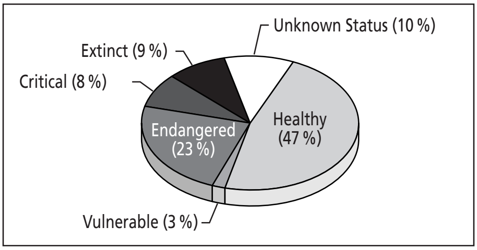
O'Grady, M.F. and King, J.J. (1992). Ecological changes over 30 years caused by drainage of a salmonid stream, the Bunree river. *Ir. Fish. Invest*., *Ser. A (Freshwater)* 34.

O'Halloran J., Morgan, G., O'Sullivan, W. M., O'Farrell, M.M., Mulcahy, M.F., Giller P.S., Smith, C.D., Cassidy, A. and Coughlan, J. (1988). The Munster Blackwater and the Lee. Chapter 8. In Moriarty, C. (Ed.), *Studies of Irish Rivers and Lakes*. Dublin: Marine Institute.

O'Maoileidigh, N., Browne, J., Cullen, A., McDermott, T., Bond, N., McLaughlin, D., Long, A., Draper, J. and Rogan, G. Estimating the status of Irish Salmon Stocks. In Whelan, K. F. and O'Muircheartaigh, F. S., (Eds.), *Managing Ireland's Spring Salmon Stocks.* Newport: Salmon Research Agency.

Whelan, B.J., O'Connor, R., and McCashin, A. (1974). *An Economic Evaluation of Irish Salmon Fishing, Part III.* Dublin: The Economic and Social Research Institute.

7.9 Norway



Categorization (%) of salmon-bearing rivers in Norway.

With approximately 667 Atlantic salmon rivers, several of the world's largest individual populations, and some of the world's largest specimens of wild Atlantic salmon (Norwegian Ministry of Environment, 1999), Norway remains the world's leading producer of the species. The salmon is also central to the cultures of the Sami and Kven northern indigenous peoples.

In recent years, Norway's relative share of world wild salmon production has increased because the species has been eradicated or reduced in the southern reaches of its range. Nevertheless, Norway's Atlantic salmon populations have also experienced a downturn.

The decline of the salmon stocks in Norway is clearly evident in catch statistics, which peaked in the 1960s and '70s. Since then, catches have diminished and the size composition has also changed. The percentage of small salmon has increased while large salmon have declined. Wild salmon catches in Norway have fallen from around 2,000 tonnes in 1980 to about 600 tonnes in 1999. (Actually, 811 tonnes of salmon was caught, but the additional balance was escaped farmed salmon.) Smaller catches are primarily due to a sharp decline in stocks, while more limited fishing is also a factor. Catches in the remaining fisheries have continued to decline despite the fact that fishing with drift nets, an interceptory mixed-stock fishery off the Faeroes and most of the coastal net fishing were either discontinued or reduced during in the 1990s. This gives justifiable grounds for concern about the development of spawning stocks. (Norwegian Ministry of Environment, 1999).

The 1992 Salmon Act protects the species, limits exploitation and provides a framework for improving stocks and raising yields for holders of fishing rights and anglers. Extensive measures and restrictions in salmon fisheries, however, have not arrested the sharp decline in wild Atlantic salmon populations in Norway.

The Norwegian Wild Salmon Committee was appointed by Royal Decree in July 1997 (Norwegian Ministry of Environment, 1999) and was given the following terms of reference:

> *The Committee shall review the overall situation with respect to wild salmon stocks and present proposals for management strategies and action programs. Issues associated with the regulation of fishing, watercourse management and salmon farming shall be given particular attention.*

The committee's report, published in March 1999, found that the plight of wild Atlantic salmon in Norway was very serious overall, and in many cases, in an acute state of crisis. (Norwegian Ministry of Environment, 1999).

River status

According to the Norwegian Directorate for Nature Management (1999) 667 rivers in Norway historically hosted populations of wild Atlantic salmon. Of the total, the status of 69 rivers is unknown. Thus, of the 598 rivers that can be assessed and categorized, 60 rivers (10 percent) are categorized as Extinct. The situation is Critical in 55 rivers (9 percent); salmon populations are Endangered in 155 rivers (26 percent) and Vulnerable in 13 systems (2 percent). Salmon populations in 315 rivers (53 percent) are categorized as Healthy.

This new categorization represents a much more pessimistic assessment than the one presented by Directorate for Nature Management as recently as 1996. (Directorate for Nature Management, 1996).

Causes of salmon decline

The decline in salmon stocks in Norway in the 1970s and 1980s was attributed to overfishing, acid rain, watercourse alterations, salmon farming and the parasite *Gyrodactylus salaris* (Norwegian Ministry of Environment, 1999). Natural variations are always a factor as well, so the complicated interplay of natural and unnatural factors makes it difficult to identify the individual loss factors and their precise respective contribution to the decline.

Overfishing

Salmon fishing in Norway has undergone great changes. Originally, salmon harvest was restricted to rivers, fiords and other coastal areas. Angling became popular in the mid-1800s, providing significant rental revenues and jobs. At the same time, commercial fishing moved out into the fjords and the bag-net became the main fishing gear. In the 1960s, ocean-going vessels, new types of seine and new expertise about salmon fisheries began to be employed in pursuit of wild migrating salmon.

The decline of salmon stocks since the 1970s is attributable in large part to that exploitation. Some restrictions were introduced in an effort to reduce overfishing, and from 1978 all fishing other than angling was, with few exceptions, banned in the rivers. Drift net fishing was curtailed in 1989 (Norwegian Ministry of the Environment, 1999).

Pollution

Salmon in Southern Norway began to be adversely affected by acid rain as early as the 1800s, and salmon stocks in 18 watercourses in Southern Norway have since been extirpated (Norwegian Ministry of the Environment, 1999). Wet deposition of airborne pollutants (acid rain) falling over Norway has been reduced in recent years, but naturally occurring geological buffering capacity has been eroded. Artificial liming of affecting watercourses is therefore expected to remain necessary well into the future. The problem of domestic pollution has been significantly reduced in recent years, although some localized problems of agricultural and industrial discharges remain.

Watercourse alteration

Watercourse alteration is cited as a major reason for the extinction and threatened or vulnerable status of salmon populations in 43 Norwegian rivers (Norwegian Ministry of the Environment, 1999). This figure probably underestimates the true impact of river alterations, however, because of the interaction with other damaging factors such as pollution.

A third of Norway's salmon rivers are affected by hydropower development, including most of the major rivers with the largest stocks. Mitigating measures include minimum flowage regulations and fish ladders etc. particularly in projects undertaken since the mid-1970s. Few major new hydropower development projects are planned. Other human activities, such as channelling, dredging, siltation and gravel excavation, remain a threat.

Diseases

Disease naturally occurs in fish whether they live in a free state or in captivity. The danger of infection from bacterial and viral disease from salmon aquaculture is *currently* not regarded as a major threat to wild salmon in Norway. However, the salmon louse represents a major problem. Although it naturally occurs in salt water, the sea louse now has unnaturally high numbers of hosts in coastal farm cages year-round. Consequently, the incidence of sea lice infestations in wild salmon has increased dramatically in proximity to significant salmon farm development. Sea lice are probably also a significant cause of mortality in migrating smolt. So, in addition to the damage caused to cultivated fish, there is a justifiable fear that massive occurrences of lice constitute one of the factors that may be debilitating wild populations of Atlantic salmon.

Investigations into the effects of salmon lice as a factor suppressing the populations of wild fish have been initiated. (Norwegian Ministry of the Environment, 1999). Massive increases in sea lice incidence have resulted in premature migration and inhibited growth in sea trout. Salmon that are unable to migrate prematurely die because of heavy infection. While salmon remain in fjord systems and coastal waters for a relatively short time before migrating into the ocean, sea trout and Arctic char remain in the fjord systems throughout their period in the sea. The latter are therefore both assumed, and seen, to be more at risk of attack by salmon lice during their adolescence.

The Marine Research Institute (1999) has reported on sea lice infecting ocean-bound smolts in Norwegian Fjords. In one of the largest fjords, Sognefjorden, researchers found that up to 86 percent of the juvenile salmon (smolts) were so heavily infected with sea lice after a short time in the ocean that they would succumb to the damage done by these parasites. In another fjord, Nordfjorden, it was determined that up to 81 percent of the salmon would die.

Salmon aquaculture

In 1997, Norwegian farmed salmon production totalled more than 330,000 tonnes (Norwegian Ministry of the Environment, 1999) – more than 500 times greater than the wild salmon catch. In 1998 the production of farmed salmon was 360,000 tonnes, whereas the production of Rainbow trout was 46,000 tonnes (Norwegian Directorate of Fisheries, 2000). According to the Federation of European Aquaculture Producers (FEAP, 2001) Norwegian production of salmon in 1999 amounted to 411,000 tonnes, and in 2000 – 450,000 tonnes. The industry is expected to continue to grow by 8-10 percent a year. (Norwegian Ministry of the Environment, 1999).

At least half a million farmed salmon escape annually and mix with the wild salmon in the sea, along the coast and in the rivers. These escaped fish, together with the unnaturally high production of sea lice, are regarded by the authorities as the most significant environmental problems connected with salmon aquaculture today. Thirty to fifty percent of the coastal catch may be farmed fish.

The percentage of farmed fish on spawning grounds varied between 15 and 34 percent in the period 1989-1999 (Norwegian Directorate for Nature Management, 2000), but the percentage has been as high as 70-90 percent in some rivers (Norwegian Ministry of the Environment, 1999). Escaped famed salmon which successfully spawn give rise to a worrisome genetic interaction between farmed and wild salmon. Such genetic interaction will weaken the natural stock structure of the species, causing a loss of genetic diversity, which in the longer term could lead to lower survival rates. (Norwegian Ministry of the Environment, 1999).

Norway is the only nation that has maintained and made public official statistics for escapes of farmed salmon. In the period 1993 – 1999 the official numbers of escaped salmon in Norway was 2,626,000 (Norwegian Directorate of Nature Management, 2000). In the same period, the number of smolts in the farms doubled from 67 million. In the period from 1988-1992 (Norwegian Ministry of the Environment, 1999) it is estimated that 1.6 million fish escaped annually, usually as a consequence of storms. This would mean that the total official number of escaped farmed salmon from Norwegian fish farms in the period from 1988 to 1999 was approximately 10.6 million.

Figures published by the Norwegian Directorate of Fisheries, (2000), based on information received from salmon farmers, suggest the number of escaped Norwegian farmed salmon since 1988 could be much higher than that official figure. In 1999, salmon farmers reported losing more than 20 million fish to diseases, escapes, predators and other causes, but could not account for a further 5.7 million fish. In 1998 the industry could not account for 3.7 million missing farmed salmon.

It appears likely that competition between farmed and wild fish results in lower production of wild progeny (and perhaps even lower total production). The release of genetically marked farmed and wild salmon in a Norwegian river resulted in a 30 percent reduction in overall smolt production – representing the second largest decline in 16 years of measurement. (Fleming *et al.*, 2000).

Interbreeding between farmed and wild fish has been demonstrated experimentally (Fleming *et al.*, 2000). The unabated high levels of gene flow from farmed to wild salmon will lead to gene pool dilution in the recipient wild populations being swamped by farmed salmon genes and, within a few generations, lead to a loss of genetic diversity.

Gyrodactylus salaris

The occurrence of the salmon parasite *Gyrodactylus salaris* was documented in Norway in 1975 following imports of smolt from Sweden. The parasite has been registered in 40 watercourses and 37 smolt farms (farms that grow smolts for stocking or for salmon aquaculture) in Norway and has affected several of the country's most important salmon stocks. Stocks are seriously threatened or even destroyed wherever the parasite has taken hold. (Norwegian Ministry of the Environment, 1999).

The removal of the parasite from fish farms and rotenone treatment of 25 infected watercourses has reduced its incidence. By 1999, the parasite had been eradicated in 13 rotenone-treated watercourses. Nine watercourses have been treated and are under supervision and evaluation for a clean bill of health. In 1999 the parasite was discovered in 19 watercourses. The effective use of rotenone is not feasible in every situation and the chemical has been controversial because of possible long term damage to non-target aquatic life forms. Few options exist, however. (Norwegian Ministry of the Environment, 1999).

Return rates for salmon smolts has declined during the last 15 to 20 years. (Norwegian Ministry of the Environment, 1999). The major causes of this higher at-sea mortality appear to be related to changes in marine environmental conditions and to increased lice infection, particularly in the early part of the sea phase. There are also concerns about the effect of salmon by-catches in the Norwegian Sea.

Hope for norwegian wild salmon

The Norwegian Wild Salmon Committee's March 1999 report (Norwegian Ministry of the Environment, 1999) concluded that the downward trend in wild Atlantic Salmon in Norway was generally quite serious, and in many cases, acute.

However, the report also allowed that it is not too late for mitigative measures to reduce the damage from old causes, and remove or reduce the significance of new threats. The Committee identified the fragmented system of resource management as being no longer viable, noting that legislative remedies have not been effective in affording protection to salmon to this point in time.

The Committee believed it was realistic for the Norwegian stock to recover much of its former vigour. While the decline occurred over a relatively brief space of time, the report suggested recovery presents a long-term scenario.

It called for the establishment of special protected areas for wild salmon, and for a much stronger hand in affording effective protective measures for Norway's most important salmon streams and coastal migration routes. The Committee proposed the establishment of a group of "International Salmon Heritage Rivers and Fjords" consisting of 50 specific watercourses and nine fjords or coastal stretches.

It proposed special protective measures for remaining healthy stocks, and for increased intervention against known threats such as watercourse alteration, road construction, pollution and salmonid aquaculture.

References

FEAP (2001). Federation of European Aquaculture Producers: http://www.feap.org/Countries/norprod.html

Finstad, B. and Grimnes A. (1997). Records of salmon lice on salmon, sea trout and arctic char in 1996. *NINA Contract Research Report no. 485*.

Fleming, I. A., Hindar, K., IMjølnerød, I. B., Jonsson, B., Balstad, T. and Lamberg, A. (2000). Lifetime success and interactions of farmed salmon invading a native population. *Proc. R. Soc. Lond. B* 267: 1517-1524

Hindar, K., Ryman, N. and Utter, F. (1991). Genetic effects of cultured fish on natural fish populations. *Can. J. Fish. Aquat. Sci.* 48: 945-957.

Marine Research Institute, 1999. Lice infection: Press release (in Norwegian): http://www.imr.no/info/pm/1999/pm19990813.htm Accessed 15 July 2000.

McGinnity, P., Stone, C., Taggart, J.B., Cooke, D., Cotter, D., Hynes, R., McCamley, C., Cross, T. and Ferguson, A. 1997. Genetic impact of escaped farmed Atlantic salmon (*Salmo salar* L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment. *ICES J. Mar. Sci.* 54, 998-1008.

Norwegian Directorate of Fisheries. 2000. *Nøkkeltall fra norsk havbruksnæring 1999*. (Key figures from Norwegian aquaculture). Bergen. Directorate of Fisheries.

Norwegian Directorate for Nature Management. (1996). "Species Management" http://balder.dep.no/md/publ/environment.96/chap2.html

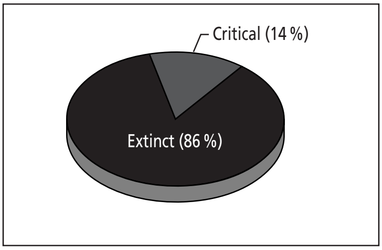
Norwegian Directorate for Nature Management. (1999). *Bestandssituasjonen for laks*. (The status for salmon populations). Trondheim. Directorate for Nature Management.

Norwegian Directorate for Nature Management. (2000). *Miljømål for norsk oppdrettsnæring.* (Environmental goals for the Norwegian fish farming industry) Trondheim. Directorate for Nature Management.

Norwegian Fish Farmers Association. (2000). *Nasjonal tiltaksplan mot rømming.* (An action plan against escapes) Trondheim. Norwegian Fish Farmers Association.

Norwegian Ministry of Environment. (1999).]. *Til laks åt alle kan ingen gjera* ("Not enough salmon for all?") Norwegian Governmental report NOU: 9 1999 http://balder.dep.no/nou/1999-9/innhold.htm

7.10 Portugal



Categorization (%) of salmon-bearing rivers in Portugal.

Portugal represents the southern limit of distribution of Atlantic salmon in Europe. Wild salmon formerly spawned in the major rivers of the north of the country in watersheds shared with Spain – the rivers Minato, Dour and To (the To being the Southern limit of distribution). The Minato, which constitutes the northern border between Portugal and Spain, flows from Spain, where the main part of the watershed is located. Salmon also occurred in the smaller rivers Nevi, Lima, Caved and Ave located between the Minato and To rivers.

The Portuguese Nature Conservation Services had classified salmon as "endangered" according to IUCN criteria by the early 1990s (Anon., 1991), but the situation has deteriorated since then.

River by river categorization

By 1990, Atlantic salmon populations could be found only in the Minato and the Lima, having become extinct elsewhere. Since the early 1990s, salmon specimens have been identified only occasionally in the Dour (Anon., 1991) and Caved (Pereira, 1994; Correia and Fidalgo, 1995).

Since 1991, a hydro dam has blocked fish passage on the Lima River near the estuary, and consequently salmon runs have declined to the point where (although a few stragglers still enter the river each year) the population is considered to be Extinct.

By the early 1990s, salmon catches in the Minato had been reduced by more than 97 percent from 1,400 in 1914 to fewer than 50 in 1989 (Correia and Fidalgo, 1995). This population has continued to decrease (Correia and Fidalgo, 1995), and is therefore categorized as being in Critical condition.

Thus, of seven historic Portuguese salmon rivers, six are now categorized as Extinct, and the seventh is categorized as having a population in Critical condition.

Causes of decline and current threats

By the end of the 19th century, several agreements had been reached to manage shared watersheds, including agreements in the 1940s and 1960s to manage flows for hydroelectric power generation. These agreements resulted in the construction of dams that obstructed the migration of diadromous species such as *Salmo salar*. The transition from Spanish territory to international territory is marked by the Spanish Freira dam, which prevents Atlantic salmon and other species from reaching spawning habitat in the upstream areas of the River Minato. Unnatural fluctuation of river levels due to discharges from the dam has damaged spawning areas.

In the Minato, parameters of water quality do not meet EU standards for salmonid species. In 2000, Portuguese authorities lowered minimum water quality standards for the Minato to the level required by Ciprinids in order to meet those criteria. Lowering water quality objectives from salmonids to ciprinids to meet EU Directive standards has posed a threat to the remaining salmon population in Portugal (Torres, pers. comm.)

Other major threats to the remaining wild salmon population in the Minho include habitat destruction, sand and gravel extraction from spawning beds, illegal fishing and water pollution, particularly in the estuary.

Conservation and restoration measures

Releases of salmon began around 1925 and have continued intermittently to the present time. Because of the difficulty in securing a supply of eggs, however, restocking has been on a small scale and therefore of questionable value. In 1991, the Portuguese government proposed a series of measures to conserve and restore salmon populations. (Anon., 1991). These include the following:

- Water classification and river basin management.
- Protection of the habitat and reproduction areas.

- Implementation of appropriate devices to increase access to reproduction areas.
- Management of fisheries, including the establishment of sanctuary areas and temporary prohibition of fisheries.
- Re-introduction of salmon into rivers with extinct populations.

However, these measures have not been implemented (Torres, pers. comm.). In order to save the remaining salmon population in the Minato River, authorities will need to implement not only the 1991 plan but also reclassify the Minato as Salmonid waters for water quality standards purposes, restore already degraded habitats, and better regulate water discharges by hydro dams.

References

Anon. (1991). *Livro vermelho dos vertebrados de Portugal* (Green Book of Vertebrates of Portugal, Vol. II: Freshwater Fish). Lisbon: Service of National Parks, Reserves and Nature Conservation, Ministry of Environment and Natural Resources. 55 p.

Anon. (1997). Estudos Complementares, 2nd Parte *In* Estudo de Impacte Ambiental do Aproveitamento Hidroeléctrico de Sela. (Complementary Studies, Part II in Study of the Environmental Impact of the Sela Hydroelectric Dam). Lisbon: Union Electrica Fenosa, S.A.; EDP, Electricidade de Portugal; Hidrorumo; Projecto e Gestão S.A.; Union Fenosa, Ingeneria, S.A.

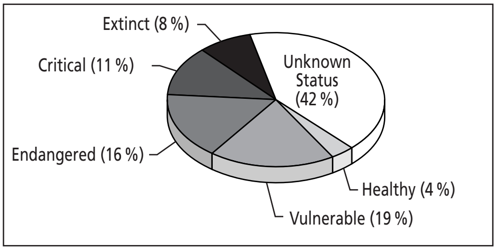
Correia, M.L.M. and Fidalgo, M. L. (1995). Study to evaluate the vulnerability and receiving capacity of the waters and the coastal zones of Portugal. Living resources in these coastal zones and their habitats. Fauna and flora of the terrestrial and aquatic environments. North region. (*Estudo de Avaliação da vulnerabilidade da capacidade de recepção das águas e zonas costeiras em Portugal. Recursos vivos na zona costeira e seus habitats. Fauna e Flora dos meios terrestre e aquático – região Norte*).. Lisbon: Directorate-General of Environment.

Pereira, C.A., (1994). *Espécies aquícolas de Portugal Continental* [Aquatic Species of Continental Portugal] Lisbon: Directorate General of Forests, Ministry of Agricuture and Fisheries 229 p.

Torres, I. (pers. comm.) Isabel Torres de Noronha. R. Sarmento Beires, nº 15 -8º Esq. 1900-410 Lisboa. PORTUGAL.

Correia, M.L.M. and Fidalgo, M. L. (1995). Study to evaluate (Avaliaçao) the vulnerability and receiving capacity of the waters and the coastal zones of Portugal; riverine ecosystems (Recursos) in these coastal zones and their habitats; fauna and flora of the terrestrial and aquatic environments. North region. Lisbon General direction of the Environment.

7.11 Russia



Categorization (%) of salmon-bearing rivers in Russia.

The Atlantic salmon is historically of great significance in Russia, both for the local fishery and for the marine fishery in international waters. Tradition called for maximum exploitation to the extent that fishing was conducted all year, during migration, in coastal zone and rivers, in wintering areas, and even on the spawning grounds. Juvenile salmon were fished, without thought of conservation or sustained harvest.

Even under such an onslaught, the richness of the wild Atlantic salmon resource and the isolation of much of the habitat allowed salmon populations to remain stable until the middle of the 20th century. Although a variety of regulatory mechanisms have been applied since then, the effort has not been sufficient to arrest the decline.

According to direct and indirect data at the end of the 19th century, annual catches in the rivers and coastal zones of the Barents, White, and Baltic Seas; and Ladoga and Onega lakes approximated 1,000-1,500 metric tonnes. The total catch, including the marine fishery and illegal catches, probably reached 4,000-5,000 metric tonnes per year – a level sustained until the middle of the 20th century. (Kazakov, 1998). Catches fell dramatically in the early 1980s, briefly, then collapsed in 1992 and have failed to recover.

The total catch of Atlantic salmon in Russia/Soviet Union from 1900 to 1997 is shown in Figure 8.

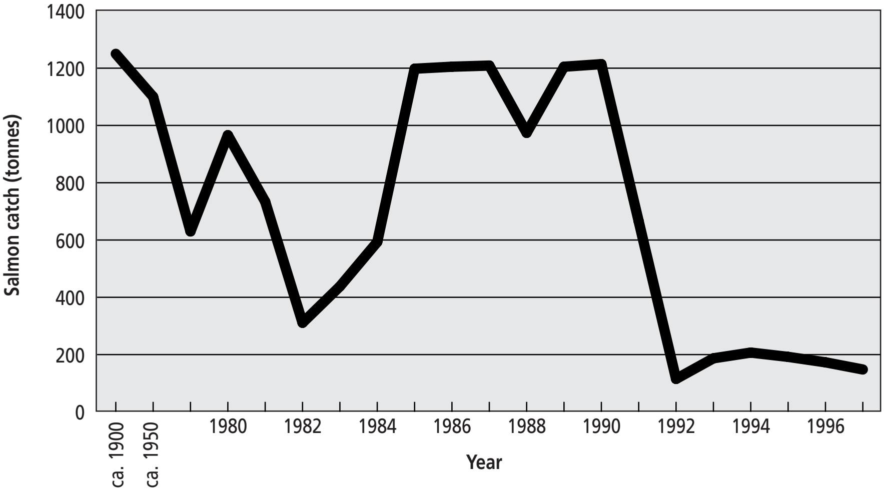


Figure 8. Atlantic salmon catch in Russia/Soviet Union 1900 – 1997

Sources: 1900 and 1950 from Kazakov (1998); all other years from FAO statistical bulletins.

The decline in catches has been accompanied by a drastic decrease in Atlantic salmon fishing effort. Historically, the salmon fishery took place in following five areas.

1. Baltic (Baltic Sea basin);
2. Lake (Ladoga and Onega lakes and lakes in the Karelia and Leningrad area);
3. Karelian (Karelian part of the White Sea basin);
4. Arkhangelsk (eastern part of the White Sea and the eastern-south coast of the Barents Sea);
5. Murman (Kola Peninsula).

Today, the Baltic, Lake and Karelia areas experience very low salmon returns. In the majority of small rivers of the Arhangelsk area, commercial salmon fishing has ceased. Commercial fishing in the Pechora river ended in 1989. In major rivers such as Mezen', Severnaya Dvina, Onega, the scope of the fishery has diminished with the resource. Runs have remained relatively stable on the Kola Peninsula for the past several decades (Kazakov, Veselov, 1998).

Historically, populations of wild Atlantic salmon are known to have existed in 224 rivers. Reliable published information is scarce to the extent that no meaningful information exists for about 42 percent of river systems. Available literature does provide clues to the status of salmon in 131 of the 224 rivers.

Although in some cases, we have had to infer the status of the river from indirect evidence in the literature, previous research has provided enough data on most rivers upon which to base a judgement on whether the salmon population in the river is extinct, critical, endangered, vulnerable or healthy.

A categorization by individual river, excluding rivers with an unknown status, shows that 14 percent (18) of Russia's salmon rivers have lost their salmon populations completely. 21 percent (27) of rivers have populations that are in Critical condition, and an additional 27 percent (36) are Endangered – for a total of 49 percent with threatened populations. Another 32 percent (42) of the rivers are considered Vulnerable. Only 6 percent (8) can be considered Healthy.

Causes of salmon decline

Factors negatively impacting Russian salmon populations include overfishing, timber rafting, chemical pollution, and hydroelectric dams.

Overfishing is known to have been a serious problem since the middle of 19th century. With progressive colonization of the Russian north, the pressure on wild salmon increased. Local inhabitants regarded the resource as an important food source and this sociological reality made regulation difficult. The kill from poaching was often as much as half of the official legal catch (Martynov, Zakharov, 1990; Alekseev *et al.*, 1998; Valetov, 1999). It is estimated that poaching remains at least that serious today.

According to interviews with local fishermen from the western and northern coasts of the White Sea in summer 1999 by one of the authors of this paper, there is local concern that poaching has dramatically impacted salmon populations. The relatively low living standards of the majority of local inhabitants, and the high commercial value of salmon, however, make for a strong temptation. With increasing ownership of cars, motorcycles and motorboats, local inhabitants have become more mobile, and the enforcement effort in the region is woefully inadequate, particularly in the less accessible higher reaches of the river systems.

Those interview data and other sources (Martynov, Zakharov, 1990; Valetov, 1999) suggest the areas of greatest poaching coincide with areas of the highest fishing intensity. It would be desirable, therefore, to conduct a more detailed evaluation of the real scale of poaching.

Other contributing factors, such as timber rafting, chemical pollution, and dam construction, have become increasingly significant since the 1950s. In some cases parasites may also be of real concern. An outbreak of the parasite *Gyrodactilus salaris* was probably one of the main factors in the decline the salmon population in Keret' river (the White sea basin) (Johnsen *et al.*, 1999).

The general economic crisis of the past decade has also been a factor. Timber rafting has ceased in nearly the all rivers of the Russian north (although timber cut earlier is still producing erosion and siltation at concentrations 10-20 times normal (Privezentzev, 1973; Gusev, 1975).

Chemical pollution has decreased during the past decade, but remains an important negative factor. Anthropogenic influences decreased in the juvenile stages of the salmon's life cycle.

Given a scenario of continued economic growth over the next few years, poaching should decline as alternative sources of economic stimulation increase, and the enforcement effort is improved. Russia will still face problems that already exist in western countries, such as the parasite *Gyrodactilus salaris* and the potentially harmful genetic effects of population mixing.

Without economic recovery in Russia, its seems likely illegal exploitation will continue to damage wild salmon populations, perhaps with irreversible consequences.

References

Alekseev, M. Y., Pavlov, V. N. and Ilmast, N.V. (1998). Population dynamics of the Atlantic salmon (Salmo salar L.) in some rivers in the Kola Peninsula where commercial fishing is undertaken. In: Kitaev, S.P. (Ed.) *Problemy Lososevykh na Evropeiskom Severe*. Karel'skii nauchnyi tzentr. Petrozavodsk, pp. 12-17.

Antonova, V.P. (1994). Stock of salmon in Pechora river and problems of control under its sttus. In: *Systematika, biologia i biotekhnika razvedenia lososevykh ryb.* SPb, Nauka press. pp. 12-13.

Bukov, O.V. (1990). Evaluation of completing of spawning grounds by Atlantic salmon spawners in basin of Verkhniaya Pechora. In: Symposium po atlanticheskomu lososiu. Syktyvkar, p. 24.

Chistobayeva, R.E. (1977). Natural reproduction of the Pechora salmon Salmo salar L. and the rate of sustainable removal by fisheries. *Voprosi Ikhtiologii* 17: 170-175.

Chuksina, N.A. 1977. State of stocks and ways of increasing of the number of valuable commercial fish in Pechora river basin. In: *Ispolzovanie i okhrana prirodnykh resursov severa Komi ASSR*. Syktyvkar. P. 51-57.

Danilevskii, N. I. (1875). Description of fishery in the north-western lakes. *Issledovania sostoiania rybolovstava v Rossii*. 9: 40-88.

Domrachev. P..F. (1929). Lakes of Zaonezhie. Fishery essay. *Trudy Olonetskoi nauchnoi ekspeditzii.* Leningrad. 8: 37-84.

Gosheva, T .D. and Shcherbina, L.I. (1976). Peculiarities of biology of salmon in the Soyana and Kulay Rivers. In: Ecology and Taxonomy of the salmonid fishes (the papers of the first conference on salmonid fish research). Leningrad. P. 27-31.

Gusev, A. G. (1975). *Okhrana rybokhozianstvennykh vodoemov ot zagriaznenii*. [Protection of fishery reservoirs from pollution] Moscow, Pitshevaia promyshlennost', 367 p.

Jensen, A. J., Zubchenko, A., Hvidsten, N. A., Johnsen, B. J., Kashin, E. and Nasje, T. F. (1998). *A five year study of Atlantic salmon in two Russian and two Norwegian rivers*. NINA-NIKU Project Report 008: 1-38.

Johnsen, B. O., Ieshko, E. P., Karasev, A., Jensen, A .J., and Schurov, I. (1999). *Report on the joint research on Gyrodactilus salaris in the northern region of Norway and Russia*. NINA-NIKU Project Report 009: 1-20.

Kazakov, R. V. 1998. Historical background of Atlantic salmon fishery in Russia and its up-to-date status. In: Kazakov, R. V. (Ed.), *Atlantic salmon*. St. Petersburg: Nauka Press. Pp. 335-382.

Kazakov, R. V. and Veselov, A.E. (1998). Population's fund of Atlantic salmon in Russia. In: Kazakov, R. V. (Ed.) *Atlantic salmon*. St. Petersburg: Nauka Press. Pp. 383-395.

Kozhin, N. I. (1927). Materials for knowledge of Onega lake fishery. Fishery of low stream of Suma river. *Trudy Borodinskoi biologichaskoi stantzii* 5: 225-440.

Logashev, M.V. (1931). Fishery area of eastern coast of Onega lake. *Izvestia Leningradskogo nauchno-issledovatel'skogo instituta* 12: 115-165.

Martynov, V. G. (1979). Atlantic salmon (Salmo salar) of Tshogur river. In: Pecherskii losos'. Syktyvkar. P. 5-32.

Martynov V. G. and Zakharov, A. B. 1990. Evaluating of illegal catch of Atlantic salmon in Pechora river by interweaving. Abstracts of symposium on Atlantic salmon. Syktyvkar, p. 28.

Mel'antzev, V. G. (1959). Piaozero lake. Fishes. In: Aleksandrov, B.M. *et al.* (Eds.). Petrozavodsk. Gosizdat Karel'skoi ASSR, pp. 558-573.

Mel'antzev, V.G. (1939). Fishery in Piaozero. *Rybnoye khoziaistvo Karelii*. 5:149-162.

Novikov, P. I. (1933). Fishes and fishery in lakes Alaiarvi and Iuliiarvi. Rybnoye khoziaistvo Karelii. 2. Petrozavodsk, pp. 48-63.

Novikov, P. I. (1959). Lakes Alozero (Aloiarvi) and Iuliiarvi. In: Aleksandrov, B.M. *et al.* (Eds.). Petrozavodsk. Gosizdat Karel'skoi ASSR, pp. 533-534.

Ozera Karelii. Handbook, 1959. Aleksandrov, B.M. *et al.* (Eds.). Petrozavodsk. Gosizdat Karel'skoi ASSR 619 p.

Ozeretzkovskii, N. I. (1812). Puteshestvia po ozeram Ladozhskomu, Onezhskomu i vokrug Ilmenia. [A journey to Ladoga and Onega Lakes and around Ilmnen' Lake]. Academia Nauk Press, Saint-Petersburg), 559 p.

Pallon, L .O. (1929). Fishes and fishery of lake Segozero. *Trudy Olonetzkoi nauchnoi ekspeditzii*. 8: 3-34.

Pravdin, I. F. (1954). Salmon (genera Salmo) of reservoirs of Karelian-Finnish SSR. *Trudy Karelo-Finskogo universiteta*. 5: 78-119.

Privezentzev, Ja. A. (1973). *Gidrokhimia presnykh vod: Prakticheskoe posobie dlia rybovodov*. Pitsheprom. Moscow, 120 p.

Slobodchikov, B. I.. and Shaposhnikova, G. K. (1933). Fishery investigation of lakes Nizhnee and Srednee Kuito of Kem' river basin. *Rybnoe khoziaistvo Karelii*. 2: 18-47.

Smirnov A.F. 1958. Conditions of forming of ichtyofauna of Segozero Reservoir: *Rybnoye khoziaistvo Karelii*. 7:118-134.

Smirnov A.F. 1959. Segozero lake. Fishes. In: Ozera Karelii, Aleksandrov, B. M. *et al.* (Ed.). Gosizdat Karel'skoi ASSR Petrozavodsk. Pp. 469-477.

Smirnov, Yu.A. (1979). *Presnovodnyi losos' (ekologia, vosproizvodstvo, ispolzovanie* (Freshwater salmon (ecology, reproduction, fishery)). Leningrad: Nauka Press. 156 p.

Studyonov, I. (1997). *Conditions and state of natural reproduction reproduction of Atlantic salmon in Severnaya Dvina river basin*. PhD thesis. Saint-Petersburg, State Research Institute for Lake and River Fishery, 24 p.

Studyonov I., Klimov, A., Antonov, L. and Studyonova, M. (2000) Biological parameters of salmon's parrs in Pizma river (inflow of Mezen river). Abstract volume of International conference "Atlantic salmon Salmo salar. Biology, conservation, reproduction." Petrozavodsk, 4-8 September 2000, p. 53.

Tshurov, I. L. (1998). Atlantic salmon of Keret river (artificial and natural propagation). In Kitaev, S.P. (Ed.) *Problemy Lososevykh na Evropeiskom Severe*. Karel'skii nauchnyi tzentr. Petrozavodsk, 50-63.

Tshurov, I. L., Shystov, J. A. and Bugaev, V .F. (1994). State of artificial and natural reproduction of Atlantic salmon in Karelian coast of the White Sea. In: Reshetnikov Yu. S. (Ed.) *Sistematika, biologia i biotekhnika razvedenia lososevykh ryb*. GosNIORKH, Saint-Petersburg. P. 230-323.

Valetov V.A. (1999). *Losos' Ladozhskogo ozera (biologia, vosproizvodstv* (Salmon of the Ladoga Lake) Petrozavodsk: Karel'skoe Basseinovoe Upravlenie po okhrane, vosproizvodstvu rybnykh zapasov i regulirovaniu rybolovstva.

Veselov, A.E. and Kazakov, R.V. (1998) Yield retrospective and Modern Revision of the Atlantic salmon (Salmo salar L.) populations in Russia. In: Kitaev S.P (Ed.) *Problemy Lososevykh na Evropeiskom Severe.* Petrozavodsk, P. 3-12.

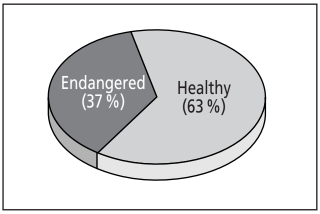
Vetshezerov, V. V. (1931). Fishery in south and south-eastern part of lake Onega. In: *Izvestia Leningradskogo nauchnogo ikhtiologicheskogo instituta.* 12: 77-114.

Zborovskaia, M. B. (1935). Materials on fishery and biology of lake Onega salmon. In: Trudy Karelskio nauchno-isledovatelskoi rybokhoziaistevennoi stantzii. V. 1. Pp 257-280.

Zubchenko, A., Kuzmin, O., Novikov O. and Sorokin, A. (1991). *Recreational salmon fishery on the Kola peninsula*. Murmansk: PINRO. 150 pp.

Zverintzhev, L. N. (1899). On the fishery in lake Segozero. In: *Vestnik rybopromyshlennosti* 14: 491-492.

7.12 Scotland



Categorization (%) of salmon-bearing rivers in Scotland.

There is evidence from a number of sources, including available catch data and the results of local research, to indicate a general decline in populations of North Atlantic Salmon throughout Scotland, and their virtual disappearance from certain rivers. In particular, the evidence suggests that discrete salmon populations that are based on small numbers of spawners are at risk of extinction (Routledge and Irvine, 1999).

Data on salmon catch in 1952 and in 1995 show an 82 percent decline from 1,512 tonnes to 278 tonnes, suggesting a dramatic reduction in salmon populations (Anon, 1983; Anon, 1999). Progressively stricter limits on salmon fishing by net and coble as well as by fixed engines during the period complicate the interpretation of these data. However, the available rod catch data indicates that, on a Statistical Region basis, all regions demonstrate a general decline in the rod catches of salmon and grilse, with the North West, West, Clyde Coast and Solway Regions showing the greatest changes in the last 10 years (Anon, 1999). The overall decline of rod catches from rivers around Scotland suggests that all salmon populations are affected regardless of river type or location.

At present in Scotland, management of salmon and sea trout stocks is undertaken by District Fishery Boards composed largely of proprietors, who contribute to the fishery in proportion to the value of their fishing rights. The right to fish for salmon is not a public right but is a separate heritable title, and the owners or lessees of those titles fund the management activities within each Fishery District. Scotland is divided into 100 Fishery Districts but only 62 Districts have constituted Fishery Boards. In addition, there are nine Statistical Regions encompassing the District Fishery areas. There is a trend for amalgamation of Fishery Boards into larger units which has reduced the number of District Fishery Boards to 51. In the Fishery Districts that do not have constituted Boards, the individual proprietors implement their own management policies within the constraints of the 1986 Salmon Act. The value of fishing rights resides in the income generated from letting the fishing or in selling the rights.

If the present observed decline in salmon stocks continues, the value of the fishing rights to certain stretches of river, which is a function of the number of salmon caught, is likely to decline. A continuing decline in early running spring salmon (the only salmon available for capture in the early part of the year, officially recorded as being those salmon captured before May 1) is likely to lead to a reduction in the length of the angling season. Those salmon fisheries on rivers that currently have spring salmon populations would suffer income losses. Under the current fishery structure in Scotland, such a loss of revenue could lead to a reduction in financial support for sound management measures.

Status of salmon rivers

Any attempt to quantify Scotland's salmon populations in numerical terms raises problems related both to geographical variation in conditions and to data availability. Not all watercourses contain salmon. Some systems may only contain small annual spawning populations of salmon due to the nature of the watercourse, with the most numerous migratory salmonid being the sea trout. Some systems may historically have had a dominant Atlantic salmon population, but salmon are now only present as a result of a small number of annual spawners. The larger, east coast river systems consisting of a main stem and several significant tributaries, may contain large numbers of spawners, and each tributary may contain discrete spawning groups. In the shorter, west coast rivers, such stock distinctions may not occur.

Data on salmon populations and salmon catch in individual rivers are currently unavailable for the whole of Scotland. Although individual proprietors (of nets or rods) are obliged to provide details of annual catches to the Scottish Executive Rural Affairs Department (SERAD), these data are not in the public domain and access has to be authorized by the proprietors concerned. Publication of the data is on a Fishery District by Fishery District basis, and while it is possible to determine the catches of some of the larger East Coast rivers where the river is the District, it is not possible to determine the catches from individual smaller rivers within a District.

At present, a program of fry and parr surveys developed by the Scottish Fisheries Co-ordination Centre, which covers about 2,000 salmon fry and parr survey sites throughout Scotland, is producing data relating to fry and parr densities. When these data become available, they will provide the basis for a significant improvement in the understanding of the biological status of Scotland's salmon populations. Under the current system, however, there are inherent difficulties both in the accurate monitoring of the numbers of salmon caught and in relating catch figures to data on fry and parr health within defined river systems.

In 1986 Gardener and Egglishaw attempted to assess salmon rivers on a national scale and produced a salmon distribution map of Scotland. At that time it was suggested approximately 350 rivers contained, or probably contained, salmon. Of these rivers, 40 were located on the east coast, 39 on the north coast and 271 on the west coast and west coast islands. Variation in the physical characteristics of Scotland's rivers can be readily identified and related roughly to geographical location. The 350 rivers identified by Gardiner and Egglishaw (1986) can be further allocated to statistical regions and classified on the basis of length and/or possessing tributaries of greater than five kilometres in length. The NASCO classification of a river is the main stem of the system of rivers and tributaries at the point where it reaches the sea and of a tributary is any river or stream which does not flow directly into the sea but into a river as defined. Table 10 summarises these details. The distribution map of Gardiner and Egglishaw (1986) serves as the baseline for the following summary of salmon distribution in Scotland

It can be seen from Table 10 that many of Scotland's salmon rivers are less than 5 km in length. Based on current evidence, this suggests that a significant proportion of its salmon populations must be considered to be in categories other than healthy. Table 10 also shows that the morphology of Scotland's rivers varies roughly according to region. Around half of the rivers in the Clyde coast, West, Northwest and Outer Hebrides Regions are 5 km or less in length, and few rivers have tributaries 5 km or greater in length. In contrast, with the exception of the north region, the remaining regions contain few rivers of 5 km or less in length and proportionately more rivers with tributaries 5 km or more in length. The North Region is broadly intermediate in terms of river type.

The available rod catch data indicates that, on a Statistical Region basis, all regions demonstrate a general decline in the rod catches of salmon and grilse, with the Northwest, West, Clyde coast and Solway Regions showing the greatest changes in the last 10 years (Anon., 1999, Figs. 2-11). The overall decline of catches from rivers around Scotland suggests that all salmon populations are affected regardless of river type or location.

The marked contrast between the encouraging grilse runs of 1998 with the poor grilse runs of 1999, and the overall decline in salmon numbers in rivers of all type and at all locations, points to an important common factor for salmon decline during the period salmon spend at sea. However, available data indicating local variations between regions suggest that local factors have an additional, compounding impact.

Most at risk are discrete salmon populations based on small numbers of spawners, and rivers of less than 5 km, which are generally in the north and west. These rivers are more subject to redd wash-out and water acidification in combination with afforestation. Based on this and the information in Table 10, we estimate that salmon stocks in 129 Scottish salmon rivers may be categorized as Endangered. Available information suggests that this is due to a combination of afforestation, redd washout and habitat degradation.

Although data are not available for the whole of Scotland, the work of Fisheries Trusts in the Solway, Loch Awe, Lochaber, Wester Ross and northwest areas does provide details of the juvenile salmon populations. In the Solway region, significant parts of individual rivers suffer from environmental degradation that could affect stocks (Sinclair, pers. comm.).

Little is known of the status of salmon populations within the Clyde Coast Region, although there may be significant change from the distribution indicated in Gardiner and Egglishaw (Morgan, unpublished data). Within the rivers running into Lochs Awe and Etive, Bull (1999) notes that salmon fry and parr densities were low, some year classes were missing and, in some areas, fry and parr were absent. Acid episodes, although occurring, were not at a level likely to cause egg mortality. Habitat degradation and decreased numbers of returning adults were suggested as the cause of the reduced juvenile populations.

In regard to the rivers draining into Loch Linnhe, Watt *et al.* (1999) have produced evidence for very low numbers of salmon fry and parr, with frequent examples of parr numbers exceeding fry numbers suggesting reduced egg deposition. It was also noted that in 1977 in the Rivers Strontian and Carnoch entering the head of Loch Sunart salmon fry were only found at one site. Watt *et al.*, (1999) conclude that in the mainly short rivers and in some of the larger rivers in the same areas, the salmon populations are in danger of extinction, and that sea lice from salmon rearing cages are probably a major cause for the changes noted.

To the north of this area, Butler (1999) concludes that juvenile salmon abundance is generally lower in rivers flowing into sea lochs containing salmon farming activity than in those rivers flowing into lochs unaffected by salmon farming. He also notes that, as with the area to the south, in rivers of 5 km or less in length, the trend is toward the extinction of wild Atlantic salmon populations. Redd wash-out and acid episodes are also recorded as factors reducing fry and parr populations.

In contrast, rivers on the Western Isles (Lewis, Harris, North and South Uist) do not appear to be displaying such severe downward changes in juvenile salmon population (Bilsby, pers. comm.). However, Western Isles rivers, unlike those of the mainland West coast, tend to be of shallow gradient and contain lochs, and therefore populations may not be as vulnerable to redd wash-out. Here, mink predation and habitat degradation caused by sheep, were noted as possible factors affecting fry and parr numbers. In the northwest, environmental factors, in particular, dry summers reducing riffle habitat, have been identified as having a possible impact on salmon (Marshall, pers, comm.).

Table 10

Scottish rivers containing or probably containing salmon by Statistical Region, length and tributary characteristics

Statistical region	Total no of rivers	No. of salmon rivers with 1 or more tributaries >5km	No. of salmon rivers<5km	Boundary rivers or areas of the region
Solway	11	7	1	Annan – Luce
Clyde Coast	51	6	25	Stinchar – Conie Water (Campbeltown)
West	81	6	49	Breackerie Water (Campbeltown) – Islay, Jura, Mull – Ardnamurchan
North West	83	3	43	Ardnamurchan – Skye and the small isles – Inver
Outer Hebrides	45	1	23	The Uists – Isle of Lewis Harris
North	39	11	11	Cape Wrath – Carron
Moray Firth	15	3	8	Alness – Deveron
North East	11	6	2	Ugie – South Esk
East	14	4	1	Tay – Tweed

Where the recovery or reappearance of salmon stocks has been recorded, this is invariably seen in watercourses running through major urban centres (Glasgow, Edinburgh, Falkirk) and is associated with improvements in water quality.

In the absence of either rod catch data for individual rivers or of the tributaries of larger river systems, or of comprehensive fry and parr density data, the following provisional conclusions seem warranted:

- Salmon populations in rivers of less than 5 km in length are at particular risk and these rivers may be approaching critically low levels of egg deposition
- Discrete salmon populations based on small numbers of spawners are likely to be at risk of extinction

- Egg deposition in rivers of less than 5 km in length may be compromised by increased winter rainfall (redd wash-out) or poor water quality (acid episodes).
- Reappearance of salmon in certain rivers is associated with improved water quality.
- The headwaters of larger rivers are likely to exhibit problems similar to those of smaller rivers.
- A correlation appears to exist between fish aquaculture and observed increases in sea lice loading and decline of salmon in areas with a number of fish farms.
- The reduced survival of smolts at sea during the marine migration and feeding phase appears to be an important factor in declining salmon populations in Scottish rivers.

Causes of salmon decline

A number of human activities are contributing to the decline in salmon populations. Some of these relate to freshwater and hence will ultimately affect the numbers of outmigrating smolts. Others relate to first entry into the marine environment, and some relate to salmon at sea. Certain factors can be at least partially addressed nationally through changes in policy and practice, while others are not easily addressed at a national level. Of the major localized factors to which salmon decline is attributed, the problems caused by hydro-generation, conifer afforestation, agricultural practices, habitat loss, salmon farming and human exploitation can to some extent be addressed at a national level.

Large scale hydro generation

Impacts on salmon of large-scale hydro schemes include inappropriate compensation flows and freshet releases, wholesale diversion of water from one catchment to another, difficulty of adult salmon upstream passage at dams and the blocking of access to headwaters. Where impassable dams are present, the cost and functional practicality of installing fish passes may be prohibitive. With regard to compensation flows, freshet arrangements and monitoring and improving the function of fishways, present experience suggests that the hydro-generation companies are generally willing to work with fishery managers in developing approaches that are beneficial to the salmon populations (e.g., Conon, Beauly, Cassley, Shin, Ness). Difficulties arise in resolving issues where water is diverted from one catchment to another, and drainage or partial drainage of watercourses results.

Afforestation

The role of coniferous afforestation, particularly in base poor environments, in respect of water acidification is noted below (Stephen, 1996). Afforestation also has an impact in terms of silt input, water loss through evapo-transpiration and changes in the nature of the river discharge (Anon., 1993). Silt input and bedload siltation can be significantly increased following pre-planting ground preparation, during the life of a forest and particularly at harvest (Neal *et al.*, 1992). Planted areas tend to be around river headwaters where other activities are not commercially viable, and the input of silt and drainage of small watercourses effectively remove salmon spawning and juvenile nursery opportunities. Current planting practices take account of these adverse watercourse effects to some extent, and forestry design is now more rigorous, with the inclusion of a greater proportion of native broadleaves.

Acidification

Acidification of watercourses is of particular concern in areas of base poor geology and soil types. It should be noted that periodic low pH episodes do not necessarily cause salmonids problems, but where the effects of acid deposition are exacerbated due to coniferous afforestation on base poor soil and rock types, there are significant implications for salmonid populations (Stephen, 1996). Forestry planning is obliged to take account of these interactions (see above), but the problem of emissions needs to be tackled at the source (SEPA, 1999).

Agricultural practices

The impacts of agricultural practices on watercourses are most prevalent in the east of Scotland, although not limited to that region. Those impacts can be classified into silt, agri-chemical inputs and eutrophication (Langan *et al.*, 1997). Intensive crop production is often associated with ploughing and sowing up to the edge of a watercourse with a minimal riparian buffer zone. The tendency towards winter sowing means that fields are ploughed in the autumn and the disturbed soils are exposed to rainfall that washes topsoil and associated nutrients and chemicals into watercourses (Anon., 1997). Damage to banks by cattle and sheep accessing unfenced watercourses results in silt inputs, broadening of the stream channel and reducing the water depth. In addition to pesticide and fertilizer runoff, sheep dip chemicals entering watercourses through leakage or poor disposal have been recorded as causing losses of invertebrate populations. Diffuse pollution from agricultural sources is a major problem that is difficult to regulate.

Aquaculture

Salmon from marine fish farms have escaped to both freshwater and marine environments, although the number of escapes has never been accurately quantified. The recent increase in marine fish farms has coincided with a dramatic downturn in sea trout and salmon stocks in certain rivers, particularly on the mainland and islands of the west coast where marine aquaculture is concentrated. The genetic impact and the physical presence and behaviour of adult escapees following entry to freshwater are major concerns. Mackay (1999) suggests that the relationship between sea lice associated with salmon farming and damage to stocks of salmon and sea trout should now be accepted as being beyond reasonable doubt. Watt *et al.* (1999) conclude that in the short rivers and in some of the larger rivers in the same area, the salmon populations are in danger of extinction. Sea lice from salmon rearing have been identified as the probable major cause of the threat of extinction of salmon populations in the Rivers Strontian and Carnoch. Butler (1999) concludes that juvenile salmon abundance is generally lower in rivers flowing into sea lochs containing salmon farming activity than in those rivers flowing into lochs unaffected by salmon farming.

Fish aquaculture also discharge nutrients and chemicals into the wider marine environment. The Scottish Environmental Protection Agency has an obligation to set discharge levels and monitor compliance with discharge consents, and has set out its role in the monitoring and regulation of marine cage fish farming in a recent procedures manual (SEPA, 1998).

Exploitation

Adults returning to spawn can be caught either by net or by rod. As well as rod catches of the potential spawning stock within a river, there are also net catches of mixed stocks outside the spawning rivers. Within rivers there is an increase in the numbers of grilse and salmon released after capture (18 percent in 1998) by rods. This move towards catch and release, particularly of the multi-sea winter component, is likely to increase. Nets do not have the option of releasing captured fish as retention of the catch is the aim. Given the existence of both methods, a management framework needs to be developed to ensure that both are carried out sustainably. More accurate models of returning adult stock abundance linked to spawning targets are needed to determine exploitation limits.

Extreme rainfall

Increasing evidence shows that rainfall patterns are changing in Britain. There is a trend towards higher annual rainfall, and in north-western Britain and Northern Ireland the two year rainfall record of 1998/1999 was particularly high (Anon. 2000). In addition, there may be increases in the extremities of precipitation and of the seasonality of floods (Black, pers comm.). For salmon, this pattern may impact either on eggs through wash-out in redds or on juveniles through loss of riffle habitat from drought. The evidence indicates that both events are occurring (Butler, 1999; Marshall pers. comm.). While such extreme seasonal effects cannot be regulated, their impacts can be reduced. The creation of good quality, stable habitats may mitigate against redd wash-out, and there may be a role for hatcheries in supplementing natural stocks.

Marine environment

The decline in salmon stocks throughout Scotland, a decrease in the survival of smolts at sea and the fluctuations in grilse numbers in 1998 and 1999, suggest a major impact in the marine environment which is affecting the numbers of adult salmon returning to freshwater. The nature of the marine influence is unclear, although it may be related to climate change. The surface water temperature of the Norwegian coast and the North Sea has been correlated with salmon survival (Friedland *et al.* 1998). There is also concern that herring and mackerel fisheries in the Norwegian Sea may be taking salmon smolts as a by-catch (NASCO, 1998). But the impact of this has not been quantified.

Predators

Salmon managers and anglers sometimes observe that predation by seals and birds (Red-breasted mergansers, Goosanders, and Great cormorants) is impacting on the numbers of returning adults and developing juveniles. Little evidence has been published, however, to indicate that adult salmon are a significant component of the seal diet (Thompson *et al.,* 1996; Tollit *et al.,* 1997). Furthermore, the impact of bird predation on juveniles is difficult to extrapolate to subsequent adult numbers (Marquis *et al.* 1999). However, given the decline in salmon populations, this may be an aspect that requires further research to determine its significance.

References

Anon (1903). *The 21st Annual Report of the Fishery Board for Scotland (being for the year 1902).* Part 2. Report on Salmon Investigations. Edinburgh: Fishery Board for Scotland.

Anon (1983). *Scottish Salmon Catch Statistics 1952-1981***.** Edinburgh: Department of Agriculture and Fisheries for Scotland..

Anon. (1993). *Forests and Water Guidelines***.** 3rd Edition. Edinburgh: Forest Authority.

Anon. (1997a). *Report of The Scottish Salmon Strategy Task Force***.** Edinburgh: The Scottish Office Agriculture, Environment and Fisheries Department.

Anon. (1997b). *Prevention of Environmental Pollution from Agricultural Activity***.** Edinburgh: The Scottish Office Agriculture, Environment and Fisheries Department.

Anon (1999). *Statistical Bulletin Scottish Salmon and Sea Trout Catches 1998.*. Edinburgh: Scottish Executive, Rural Affairs Department, Fisheries Research Services.

Anon. (2000). *Hydrological Summary for the United Kingdom. December*, 1999. Wallingford: Institute of Hydrology/British Geological Survey.

Bilsby, M. pers. comm. Mark Bilsby, Western Isles Fisheries Trust, February 2000.

Black, A pers. comm. Andrew Black, Dundee University, February 2000.

Bull, C.D. (1999) *Progress Report – 1997-1998***.** Oban: Awe Fisheries Trust.

Butler, J (1999). *Annual Review 1998-1999.* Inverness:Wester Ross Fisheries Trust

Friedland, K.D., Hansen, L.P. and Dunkley, D.A. (1998). Marine temperatures experienced by post-smolts and the survival of Atlantic salmon, *Salmo salar* L, in the North Sea area. *Fisheries Oceanography***,** 7:1, 22-34.

Gardiner, R and Egglishaw, H. (1986). *A Map of the Distribution in Scottish Rivers of the Atlantic Salmon,* Salmo salar**.** Edinburgh: Department of Agriculture and Fisheries for Scotland, Freshwater Fisheries Laboratory, Pitlochry. Scottish Fisheries

Langan, S. J., Wade, A .J., Smart, R., Edwards, A.C., Soulsby, C., Billett, M.F., Jarvie, H.P., Cresser, M.S., Owen, R. and Ferrier, R.C. (1997). The prediction and management of water quality in a relatively unpolluted major Scottish catchment: current issues and experimental approaches. *The Science of the Total Environment* 194/195: 419-435.

Mackay, D.W. (1999). *Perspectives on the Environmental Aspects of Aquaculture*. Transcript of a presentation made at Aquaculture Conference, Trondheim. October 1999 Dingwall, Scotland: Scottish Environment Protection Agency.

Marquiss, M., Carss, D.N., Armstrong, J.D. and Gardiner, R. (1998)**.** *Fish-eating Birds and Salmonids in Scotland*. Report on fish-eating birds research (1990-1997) to Edinburgh: The Scottish Office Agriculture, Environment and Fisheries Department.

Marshall, S. pers. comm. Shona Marshall, North West Fisheries Trust., February 2000.

North Atlantic Salmon Conservation Organization (NASCO). (1998). *By-catch of Atlantic Salmon*. CNL(98)23. Edinburgh: NASCO.

NASCO. (1999). Report on the ICES Committee on Fisheries Management. CNL(99)12. Edinburgh: NASCO.

Neal, C., Smith and C. J. Hill, S. (1992). *Forestry Impact on Upland Water Quality*. Report No. 119. Wallingford: Institute of Hydrology.

Routledge, R.D. and Irvine, J. R. (1999). Chance fluctuations and the chance of survival of small salmon stocks. *Canadian Journal of Fisheries and Aquatic Sciences* 56: 1512-1519.

Scottish Environment Protection Agency (SEPA). (1998). *Regulation and Monitoring of Marine Cage Fish Farming in Scotland*. Stirling, Scotland: Scottish Environment Protection Agency.

SEPA. (1999). *Improving Scotland's Water Environment*. Stirling, Scotland: Scottish Environment Protection Agency.

Sinclair, C. pers. comm. Callum Sinclair, West Galloway Fisheries Trust, February 2000.

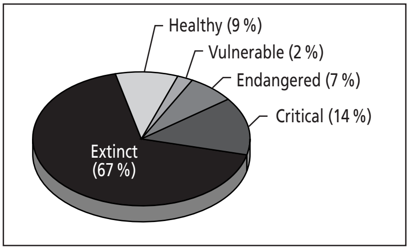
Stephen, A D. (1996). Interactions between catchment afforestation and Salmonid populations. *West Galloway Fisheries Trust, Annual Report*. 5-9

Thompson, P.M., McConnell, B.J., Tollet, D.J., Mackay, A., Hunter, C. and Racey, P. (1996). Comparative distribution and diet of harbour and grey seals from the Moray Firth, N.E. Scotland. *Journal of Applied Ecology* 33: 1572-1584.

Tollit, D.J., Greenstreet, S. P. R. and Thompson, P. M. (1997). Prey selection by harbour seals *Phoca vitulina*, in relation to variations in prey abundance. *Canadian Journal of Zoology* 75:1508-1518.

Watt, J., Bartels, B. and Barnes, R. (1999). Declines of West Highland sea trout and salmon with special reference to Loch Linnhe**.** Unpublished presentation given to the Scottish Office Agriculture, Environment and Fisheries Department.

7.13 Spain



Categorization (%) of salmon-bearing rivers in Spain.

Wild stocks of Atlantic salmon have declined precipitously in many Spanish rivers in recent decades, particularly in the north, due to a combination of over-exploitation and habitat degradation. Declines have been associated with a reduction in sea age and the numerical size of returns (Brana *et al.*, 1995a).

Stocking programs, based mainly on native fish, began early in the 20th century, but have relied on eggs imported from Scotland since the early 1970s. However, this practice failed to contribute significantly to production in the angling fisheries in Cantrabria and risked potentially negative genetic impacts on native salmon (Verspoor and Garcia de Leaniz, 1997)

A number of Spanish rivers now have populations that are close to extinction, and very few have populations that are not endangered.

River by river categorization

It is not clear how many Spanish rivers once held wild salmon, but MacCrimmon and Gots (1979) cite a figure of at least 50. A more recent source (Ferguson *et al.*, 1996), suggests that 41 Spanish rivers have had Atlantic salmon populations in the past. Based on these data, and additional information from the Centro Ictiologico de Arredondo, (2000) 43 historic salmon rivers in Spain are shown in Table 11. More recent (ca 1990) distribution is shown in Italics.

Table 11

Historic salmon rivers in Spain by region

Galicia: *Miño, Ulla, Mandeo, Landro, Masma, Eo, Verdugo, Lérez, Umia, Tambre, Castro, Grande, Allones, Mero, Eume, Xubia, Mera, Sor, Oro,*

Asturias: *Porcia, Navia, Esva, Nalón-Narcea, Sella, Deva-Cares, Bedón, Purón,*

Cantrabria: *Nansa, Pas, Ason, Deva, Saja, Besaya, Miera, Agüeira*

Euskadi: *Nervión, Oca, Lea, Deva, Urlola, Oria, Urumea*

Navarra, Euskadi and Francia: *Bidasoa*

Data on the status of salmon stocks are not collected and published at the national level, but remain at the regional level (Sancho, pers. Comm) and even then are only available for the Galicia region. Catch data for 12 rivers in Galicia for the period from 1975 to 1998 confirms that salmon stocks are very close to disappearing in those six rivers that still held stocks in the early to mid-1990s (Anon., 2000).

The River Eo, the Galician river with the largest population in the 1970s and 1980s, suffered a reduction of 99.5 percent in salmon catch over the 1975-1998 period. Only 12 salmon were caught in 1998.

In the River Mino, in which 301 salmon were caught in 1975, not a single salmon was caught in 1998; the first time that has ever occurred. In 1998 the total number of salmon caught in all six of these rivers was 20, indicating that these populations are in critical condition.

In Cantrabria, the presence of salmon is reported to be very limited in the three remaining salmon rivers, with access possible to only one quarter of the entirely length of the Ason, 16 percent of the Pas and only 3 percent of the Nansa.

Garcia de Leaniz *et al.* (1998) observed a shift to smaller, younger fish returning later in the season in Cantabrian rivers. The salmon populations in Ason, Pas and Deva are considered by the Centro Ictiologico de Arredondo (2000) to be endangered. Based on the same source, the Nansa population is categorized as Vulnerable.

According to a study of salmon populations in Spain's Cantrabria region (Brana *et al.*, 1995), a salmon population would need on average of 300 spawners with a minimum of 100 females to have sufficient reproduction to be safe from extinction. It is believed that only four Spanish rivers (Sella, Nalon-Narcea, Deva Cares and Bidasoa) have the requisite numbers not to be considered Endangered or Vulnerable (Ruiz, pers. comm.).

Thus, the 43 historic salmon rivers of Spain can be categorized as follows:

29 rivers (67 percent of the total) have had salmon populations that are now Extinct; six (14 percent) have populations that are in Critical condition; three (7 percent) have populations that are Endangered, one river is categorized as having a Vulnerable population, and four rivers (9 percent) have populations that may be considered Healthy.

Causes of salmon decline

In the Cantrabrian rivers, Atlantic salmon populations have been reduced by water abstraction, obstacles to fish passage, erosion and siltation from timber harvesting, loss of riparian vegetation and channelization of rivers (Garcia de Leaniz *et al.*, 1998). In some systems in Cantabria salmon are severely restricted by impassable dams or a combination of smaller obstacles and low water flow (Brana *et al.*, 1995b). Overfishing has also been a factor. Exploitation rates have been much higher for early running fish than for late running fish, resulting in a higher grilse ratio and an excess of males on the spawning grounds (Garcia de Leaniz *et al.*, 1998).

The population of the Mino River in Cantabria is particularly affected by the Freira dam, which denies migrating salmon access to 165 km of river and 2,166 sq. km of fluvial river basin. An EU project will attempt to eliminate the differences in water levels caused by the dam and enabling fish to return upstream.

The River Eo is unusual among Cantabrian rivers for the higher proportion of older and larger fish. The four old artificial dams that hinder the passage of salmon may have filtered out younger fish, but the hydroelectric station on the river causes high mortality of smolts passing through its turbines and is probably a more significant factor. (Brana *et al.*, 1995a).

Actions to restore salmon

An early restoration program for the River Bidasoa succeeded in reversing the decline in the Atlantic salmon population on the river back from the brink of extinction. Beginning in 1988, the restoration program involved improved monitoring of stocks, stocking and control of population levels, improvement of accessibility and quality of water and tighter regulation of angling. The result was a significant increase in the salmon run by 1992 (Alvarez *et al.*, 1995).

The Spanish government has not adopted a national plan for salmon conservation, however, and stocks are not being managed on a river-specific basis. Furthermore, commercial salmon fishing is still permitted. (Ruiz, Pers. comm.).

References

Alvarez, J., Lamuela, M., and Castien, E. (1995*). Restoration Planning for the Atlantic salmon in the River Bidasoa (Navarra): First Results*. Madrid: Instituto Nacional Para La Conservacion de la Naturaleza.

Anon. (2000). Seguimiento de Capturas del Salmon en Galicia. http://www.geocities.com/Yosemite/Falls/2740/salmon.htm#SEGUIMIENTO DE CAPTURAS DEL SALMÓN EN GALICIA

Brana, F., Garrido, R. and Nicieza, A. G. (1995a). Historical changes in age structure of Atlantic salmon, Salmo salar L., in the River Eo, northern Spain. *Fisheries Management and Ecology* 2: 279-287.

Brana, F., Garrido, R., Reyes-Gavilan, L. F., Toledo, M. M. and Nicieza, A. G. (1995b). Distribution of Atlantic salmon in the Iberian Peninsular: Location in the basin and within the context of fish assemblages. In Brana, F. (Ed), *Biologia Y Conservacion del Salmon Atlantico (Salmo salar) en Los Rios de la Region Cantabrica* [Biology and Conservation of Atlantic Salmon (Salmo Salar) From the Rivers of the Cantabica Region]. Madrid: Instituto Nacional Para la Conservation de la Naturaleza.

Centro Ictiologico de Arredondo. (2000). Untitled web page http://www.arrakis.es/~soniacdo/back.htm

Ferguson, A.; Verspoor, E., Cross, T.; García Vázquez, E.; McGuinnity, P. and Garçia de Leániz, C. (1996). *An assessment of the genetic consequences of the deliberate or Inadvertent Introduction of Non-Native Atlantic Salmon into natural Populations. Final Report. 1993-1996.*

Garcia de Leaniz, C., Serdio, A., Consuegra, S., and Verspoor, E. (1998). Decline of Atlantic Salmon in Cantrabrica (Spain): I. Habitat Loss and Changes in Population Structure. Paper presented to American Fisheries Society Annual Meeting, August 26.

MacCrimmon, H. and Gots, B. L. (1979). World distribution of Atlantic salon (*Salmo salar*). *J. of Fish. res. Board Canada* 36: p. 422-457.

García de Leániz, C; Martinez, J. J. (1988). The Atlantic salmon in the rivers of Spain, with particular reference to Cantrabrica. Chap. 10. In Mills, D and Piggins, D., (eds), *Atlantic Salmon: Planning for the Future.* London: Croom Helm & Timber Press. 179-209.

Ruiz, C. R. (pers. com.) César Rodriguez Ruiz, Coordinator, Environment Department of AEMS – Rivers for Life.

Sancho, G. (pers. comm.) Gorka Sancho, Department of Fisheries Resources, Technological Institute of Fisheries and Food, Sukarrieta, Spain.

Verspoor, E. and García de Leániz, C. (1997). Stocking success of Scottish Atlantic salmon in two Spanish rivers. *J. Fish Biology* 51: 1265-1269.

Glossary

1-sea-winter salmon	*early-maturing salmon which has spent one winter at sea*
2-sea-winter salmon	salmon which has spent two winters at sea
3-sea-winter salmon	salmon which has spent three winters at sea
Alevin	young salmon or sea trout, from hatching to end of dependence on yolk sac as primary source of nutrition, during which stage they remain within the gravel
anadromous	fish, born in freshwater, that migrates to sea and then returns to freshwater to spawn
by-catch	capture of non-targeted fish in a net
conurbation	an aggregation of towns, a built-up area
coble	traditional Scottish fishing craft
culverting	channeling of streams into artificial drainage pipes
drift net	type of gill net released from or attached to a boat and free to drift with the wind or tide
feral	a wild animal that has once been in a domesticated state and then escaped into the wild
feruginous	water containing so much iron that it influences on the survival of fish and other species
fishing weir	a structure across a river channel, either natural or man-made, which obstructs the free passage of salmon and sea trout and is used for the purpose of taking or facilitating the taking of fish
fixed engine	any fixed net or fixed device for catching fish

freshet	a periodic increase in the volume of water down a river due to rainfall, but also from a dam in order to maintain a flow for fish stocks
fry	young fish at stage from independence of yolk sac as primary source of nutrition to dispersal
gene flow	passage of genes through interbreeding
grilse	a small adult member of the species *Salmo sala*r, normally one that has first matured, or is about to mature, after one winter at sea
kelt a salmon that has spawned up until the time it re-enters salt watermixed stock fisheries	in this context fisheries that may catch salmon from several different rivers at the same time
multi-sea-winter salmon	salmon which has spent two or more winters at sea
netsmen	fishermen using nets, usually in a river
NOK	Norwegian Kroner (currency). 9.0 NOK = 1.0 US $ (27.03.01)
opportunity cost	the amount of other goods and services that must be given up to get something
parr young salmon, in stage	from dispersal from redd to migration as a smolt
ranching	release of reared fish (salmon smolts or elvers) int the wild with the intention of harvesting all the returning adults or to use them as broodstock
Redd	the depression made by a female salmon or trout in the gravel on the river bed in which her eggs are laid
reintroduction	the deliberate release of fish by man into a geographic area in which it was indigenous in historic times but where it subsequently became extinct
salmonid fish	a fish belonging to the *Salmonidae,* which includes the salmon *Salmo salar* and the Brown trout *Salmo trutta*

sea trout	form of trout of several species that after the smolt stage spends parts of its life in salt water
seine net	the most widely used netting method for taking salmon or sea trout in England and Wales. It consists of a wall of netting with weighted foot rope and floated head rope which is shot from a boat to enclose an area of water between two points on the shore. The net is then retrieved and any fish drawn up on to the shore.
smolt	fully silvered juvenile salmon migrating or about to migrate to the sea
spawners	salmon that are on the way to a river or up a river or in a river for the purpose of spawning (breeding)
splake	a cross (hybrid) between two strains of charr, the Lake trout and the Brook trout
spring salmon	multi-sea-winter salmon which return early in the year, generally before end of May
stocking	the repeated injection of fish into an ecosystem from one external to it. A stocked species may be either already native to a recipient water body or an exotic.
transgenic fish	genetically modified fish into which additional genes have been inserted

Appendix 1
Methodology used for river categorization

The categories of salmon rivers are defined as follows:

1. Extinct: Rivers with known salmon population in the past, in which extinction is evident from lack of successful reproduction by wild salmon for at least one salmon generation. This category includes a subcategory of rivers in which populations of Atlantic salmon have become extinct but have been reintroduced by stocking or natural re-colonization
2. Critical: Rivers in which populations are in imminent danger of extinction, meaning that they will disappear completely from that river if the threats to their extinction are not reduced or removed. Evidence of a river in which populations are in critical condition would includes one or more of the following:
    - Always less than 50 spawners (Cf. Frankel and Soulé, 1981; Allendorf *et al.*, 1997)
    - Decline in population size by an order of magnitude within the last generation (or 5 years)
    - Average percentage of less than 20 percent of spawning targets (usually expressed as number of eggs laid per square meter of river rearing habitat) achieved in the most recent years.

    This category also includes a subcategory of rivers in which the threat is to the genetic integrity of the salmon population. A population's genetic integrity is threatened if it is about to be replaced by non-native spawners, even if the combination of the two populations maintains a high number of total spawners. Thus the "Critical" category includes rivers that:

- Have high proportions of escaped salmon (an average over 5 years of 30 percent of spawners), which suggests that gene flow from escaped salmon may be higher than gene flow among wild populations (Cf. More *et al.*, 1999; Fleming *et al.*, 2000).
- Are continually stocked by non-native salmon making up more than 30 percent of smolts.

3. Endangered: Rivers in which salmon populations are at risk of eventual extinction if existing threat factors are not removed or reduced. These rivers have populations exhibiting one or more of the following indicators:
    - Fewer than 50 spawners at least once in each generation (i.e., over five years).
    - Population reduced by half within the past five years or by 75 percent over a longer period of time.
    - Average of 20-50 percent of spawning target achieved in two most recent years
    - This category also includes rivers in which populations are at risk for population failure because of genetic loss, as indicated by one or more of the following:
    - Escaped farm salmon representing more than 10 percent of spawners on average over five years or more.
    - Continuous stocking by non-native salmon that constitute more than 10 percent of smolts.
4. Vulnerable: Rivers that are at risk of continuing decline, as indicated by one or more of the following conditions:
    - 50 to 500 spawners and no serious decline in population size because of human activities
    - Average of 50-90 percent of spawning targets achieved in two most recent years.
5. Healthy: Rivers that have one or more of the more the following conditions:

- More than 500 spawners (cf. Frankel and Soulé, 1981) and no significant decline in population size because of human activities
- Average of 100 percent spawning targets achieved in two most recent years.

6. Unknown: Rivers for which too little information is available to make categorization possible.

Because the type of data available on the status of stocks river by river varies from one country to the next, it was necessary to define some of these categories of stock status in terms of more than one criterion. Thus the categorization scheme allows for the use of data on absolute numbers of spawners, changes in population size and achievement or spawning targets as an indication of the state of population in a given river. Moreover, wild salmon populations in some rivers may be endangered even though the number of salmon in the river is relatively large, since those stocks are made up in large part of escaped farm salmon or other non-native salmon. Therefore, the categorization methodology also takes into account the relationship between the original wild population and non-native salmon stocks in the river. In the Baltic the numbers of smolts leaving the river was used to categorize the rivers.

The Unknown status category was used when there was not enough data on the status of the salmon stock in the river, or because there was not information about the river. This can for instance be because the river is a small river or because the stock have become so small that there is no longer any fishing for salmon so one cannot use the catch as a indication for the status of the stock.

References

Allendorf, F.W., Bayles, D, Bottom, D. L., Currens, K. P., Frissell, C. A., Hankin, D, Lichatowich, J. A., Nehlsen, W., Trotter, P.C. and Williams, T. H. (1997). Prioritizing Pacific salmon stocks for conservation. *Conservation Biology* 11: 140-152.

Fleming, I. A., Hindar, K., Mjølnerød, I. B., Jonsson, B., Balstad, T. and Lamberg, A. (2000). Lifetime success and interactions of farm salmon invading a native population. *Proc. R. Soc. Lond.* B 267: 1517-1524.

Frankel, O. H. and Soulé, M.E. (1981). *Conservation and Evolution*. Cambridge, UK: Cambridge University Press.

Hindar, K. & B. Jonsson (1995). Impacts of aquaculture and hatcheries on wild fish, pp. 70-87. In D. P. Philipp, J. M. Epifanio, J. E. Marsden & J. E.

Claussen (Eds) Protection of Aquatic Biodiversity. Proceedings of the World Fisheries Congress, Theme 3. Oxford and IBH Publishing, New Delhi.

IUCN (2000). http://www.redlist.org/categories_criteria.html

Mork, J., Bentsen, H.B., Hindar, K, and Skaala, Ø. (1999). Genetiske interaksjoner mellom oppdrettslaks og vill laks (Genetic interactions between farmed Atlantic salmon and wild salmon). Appendix 4. *In. Til laks åt alle kan ingen gjera?(“Not enough salmon for all?”). Norges offentlige utredninger.* Oslo: Statens forvaltningstjeneste. pp. 181-200.

NASCO (North Atlantic Salmon Conservation Organization). (2000). *Report of the annual meeting of the council. Seventeenth annual meeting*. Miramichi, Canada, CNL (00)57, Edinburgh, NASCO.

Appendix 2
Data-sets

Country	Total number of historically salmon- bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Canada	550	398	42	20	12	63	15
Denmark	9	0	0	1	0	2	6
England and Wales	76	4	25	11	19	10	7
Estonia	9	0	0	0	0	7	2
Finland	25	0	2	0	0	0	23
France	47	5	0	3	10	15	14
Iceland	103	0	102	0	0	0	1
Ireland	339	27	130	92	20	28	42
Latvia	11	6	1	1	2	0	1
Lithuania	2	0	1	0	0	0	1
N. Ireland	44	8	0	16	14	0	6
Norway	667	69	315	13	155	55	60
Poland	8	0	0	0	0	1	7
Portugal	7	0	0	0	0	1	6
Russia	224	93	8	42	36	27	18
Scotland	350	0	221	0	129	0	0
Spain	43	0	4	1	3	6	29
Sweden	28	0	4	3	2	5	14
Sweden -West	23	0	12	2	1	8	0
United States	50	0	0	0	0	8	42

Table 1. Total number of historically salmon-bearing rivers (2,605) in the 19 countries investigated in this study and categorization of the rivers according to methodology given in Appendix 1.

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
Spain	43	0 %	9 %	2 %	7 %	14 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %

Table 2a. Categorization of salmon-bearing rivers in 19 countries. The countries are classified by alphabetical order and the status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %

Table 2b. Categorization of salmon-bearing rivers in 19 countries in 2000. The countries are sorted using the Unknown category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
Sweden - West	23	0 %	52 %	9 %	4 %	35 %	0 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %

Table 2c. Categorization of salmon-bearing rivers in 19 countries in 2000. The countries are sorted using the Healthy category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %

Table 2d. Categorization of salmon-bearing rivers in 19 countries in 2000. The countries are sorted using the Vulnerable category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %

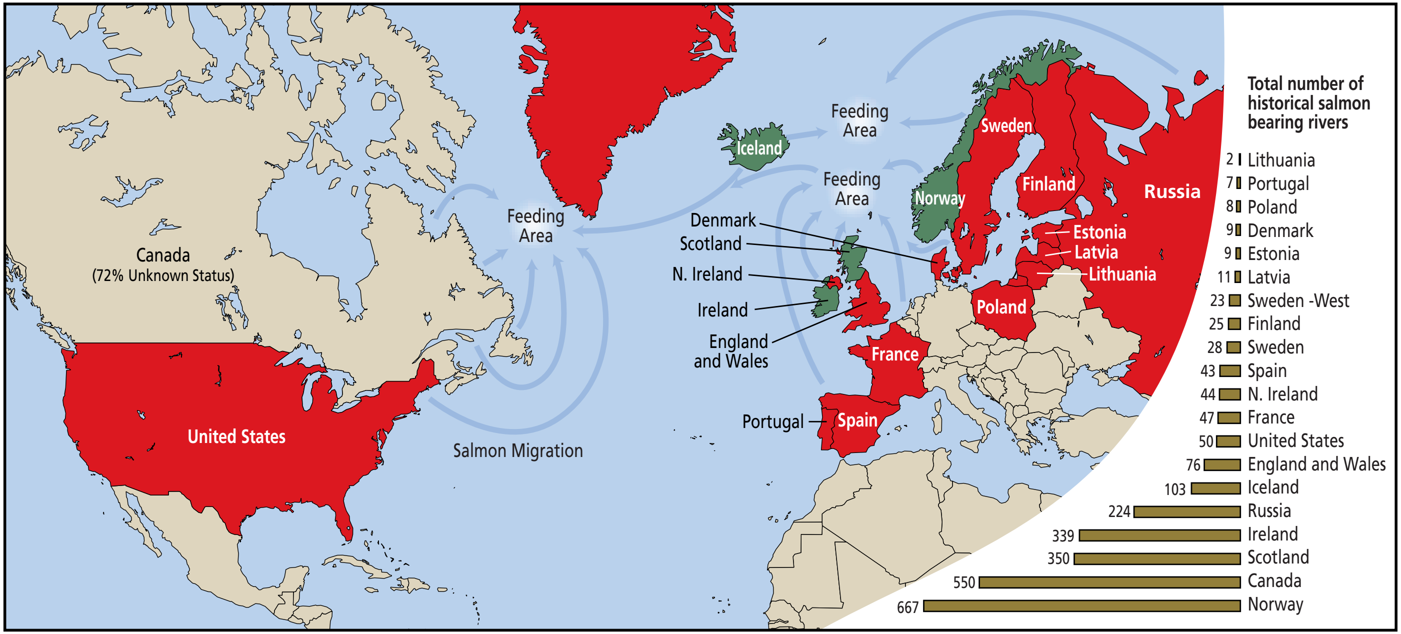
Table 2e. Categorization of salmon-bearing rivers in 19 countries in 2000. The countries are sorted using the Endangered category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %

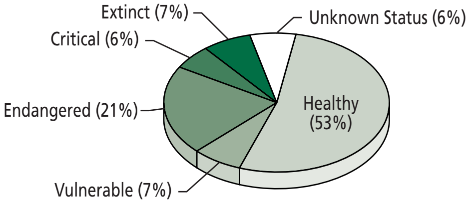
Table 2f. Categorization of salmon-bearing rivers in 19 countries in 2000. The countries are sorted using the Critical category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

Country	Total number of historically salmon bearing rivers	Unknown Status	Healthy	Vulnerable	Endangered	Critical	Extinct
Finland	25	0 %	8 %	0 %	0 %	0 %	92 %
Poland	8	0 %	0 %	0 %	0 %	12 %	88 %
Portugal	7	0 %	0 %	0 %	0 %	14 %	86 %
United States	50	0 %	0 %	0 %	0 %	16 %	84 %
Spain	43	0 %	9 %	2 %	7%	14 %	67 %
Denmark	9	0 %	0 %	11 %	0 %	22 %	67 %
Sweden	28	0 %	14 %	11 %	7 %	18 %	50 %
Lithuania	2	0 %	50 %	0 %	0 %	0 %	50 %
France	47	11 %	0 %	6 %	21 %	32 %	30 %
Estonia	9	0 %	0 %	0 %	0 %	78 %	22 %
N. Ireland	44	18%	0 %	36 %	32 %	0 %	14 %
Ireland	339	8 %	38 %	27 %	7 %	8 %	12 %
England and Wales	76	5 %	33 %	14 %	25 %	14 %	9 %
Latvia	11	55 %	9 %	9 %	18 %	0 %	9 %
Norway	667	10 %	47 %	3 %	23 %	8 %	9 %
Russia	224	42 %	4 %	19 %	16 %	11 %	8 %
Canada	550	72 %	8 %	4 %	2 %	11 %	3 %
Iceland	103	0 %	99 %	0 %	0 %	0 %	1 %
Sweden - West	23	0 %	52 %	9%	4 %	35 %	0 %
Scotland	350	0 %	63 %	0 %	37 %	0 %	0 %

Table 2g. Categorization of salmon-bearing rivers in 19 countries in 2000. The countries are sorted using the Extinct category. The status of the rivers is expressed as a percentage (salmon-bearing rivers in each category relative to the total number of rivers for each country).

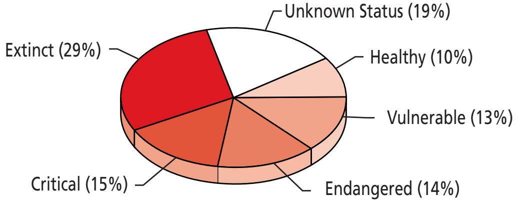


🟩 Aggregated categorization of salmon-bearing rivers in the four countries[1] that host the majority (more than 90%) of the remaining healthy rivers



[1] Iceland, Ireland, Norway and Scotland

🟥 Aggregated categorization of salmon-bearing rivers in 14 countries[2] where the majority of rivers are threatened (vulnerable, endangered and/or extinct)



[2] *Denmark, England and Wales, Estonia, Finland, France, Latvia, Lithuania, N. Ireland, Poland, Portugal, Russia, Spain, Sweden, Sweden - West, United States (Canada was not included since 72% of the rivers are Unknown Status)*

WWF-US
Marine Conservation Program
1250 24th Street, N.W.
Washington DC 20037 U.S.A.
Tel.: ++1 202 778 9604
http://www.worldwildlife.org

WWF-Norway
Postboks 6784
St Olavs plass
0130 Oslo, Norway
Tel.: ++ 47 22 03 65 00
http://www.panda.org

WWF European Freshwater Programme
Ryesgade 3F-DK-2200
Copenhagen
Denmark
Tel.: ++ 45 35 24 78 41
http://www.panda.org/europe/freshwater