CHAPTER 5

Wild Atlantic salmon in Europe: status and perspectives

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Abstract

Despite its status as a flagship species, wild Atlantic salmon (*Salmo salar*) has been in decline in most of Europe for the last three to four decades. Better catch records during this period, and increasing numbers of escaped farm salmon, suggest that the actual decline in wild salmon has been stronger than that estimated from catches. The decline has been particularly strong in some rivers producing high proportions of late-maturing salmon. The causes for the decline are manifold and include both natural environmental variation and man-made changes. Among the former, marine conditions are believed to have been unfavourable for both growth and survival of salmon since the early 1980s. Among the latter, negative effects associated with the build-up of salmon farming, such as the spread of diseases and escape of farm fish, are believed to be major contributors, together with the more "traditional" causes like pollution and watercourse regulation. Moreover, by-catches of salmon at sea may contribute to the decline of some populations. There are, however, some positive trends, in particular in rivers previously affected by local or long-transported pollution. The future of wild Atlantic salmon seems to depend on better inter-departmental co-operation in recognizing and controlling the man-made factors affecting wild populations, and on research which improves our understanding of the regulating factors in salmon populations. A major challenge lies in developing salmon farming into a sustainable industry.

Introduction

Atlantic salmon (*Salmo salar*) is a highly valued species, and has probably been so since humans colonised the Atlantic coasts of Europe and North America many thousands of years ago. The current use of the species is clearly not sustainable. Many populations have gone extinct, and a mixed-stock fishery depresses the size of many populations. Efforts to restore lost populations have been only partly successful. Aquaculture, which originally was seen as a relief to wild populations, has brought other problems related to competition, gene flow and disease transmission between farm and wild fish.

Population trends have been negative on a broad geographical scale since the 1970s, and total catches have declined to their lowest level for probably more than a century. Populations composed of a large proportion of late-maturing salmon seem to be most strongly affected by this decline. The negative trends, and little control over some of the factors affecting salmon populations, have led to concerns about future population viability. The picture is not completely bleak, however, as some populations seem to be recovering, concerted management efforts are emerging both nationally and internationally.

The objectives of this paper are (1) to provide information of the current status of Atlantic salmon populations in Europe, (2) to discuss causes for the changes in population abundance, and (3) outline some critical factors for successful management.

Status and trends of Atlantic salmon populations

Atlantic salmon are distributed in rivers and in the ocean from northern Portugal in the south to northern Norway and Russia in Europe, and from New England in the south to the Ungava Bay of northern Quebec in North America (MacCrimmon and Gots 1979). In the ocean, Atlantic salmon are found over large areas in the North Atlantic. The life cycle of Atlantic salmon consists of the following stages: adult atlantic salmon migrate upstream in rivers during spring and summer; eggs are laid in gravel in late autumn and incubated in the gravel during winter; alevins hatch in spring and 3-4 weeks later start feeding as fry; parr establish territories and remain in fresh water for 2-4 years, occasionally 1 year in the warmer rivers and 6-8 years in colder rivers; when attaining a size of 12-18 cm and 20-60 g, they migrate to the sea as smolts in the spring. Salmon travel long distances in the sea and feed there for 1-4 years before returning to fresh water to spawn at sizes ranging from 40 cm and 1 kg to 140 cm and 35 kg.

In contrast to Pacific salmon (*Oncorhynchus* spp.), Atlantic salmon can survive spawning and 70-80% migrate to sea a second time. Only about 10% return to spawn a second time. The population size of Atlantic salmon usually ranges from 20 to 2,000 anadromous spawners, and very few rivers have more than 10,000 spawners. This is in contrast to several species of Pacific salmon, which may have population sizes on the order of hundreds of thousands to millions.

The current status of Atlantic salmon has been assessed by WWF (2001) which collated information on 2,600 rivers from national representatives in all of the countries holding self-reproducing populations of wild salmon. Of these, information was considered sufficient for a rough classification of status in 2,005 rivers. This information is summarized as country-by-country averages in Figure 5.1.

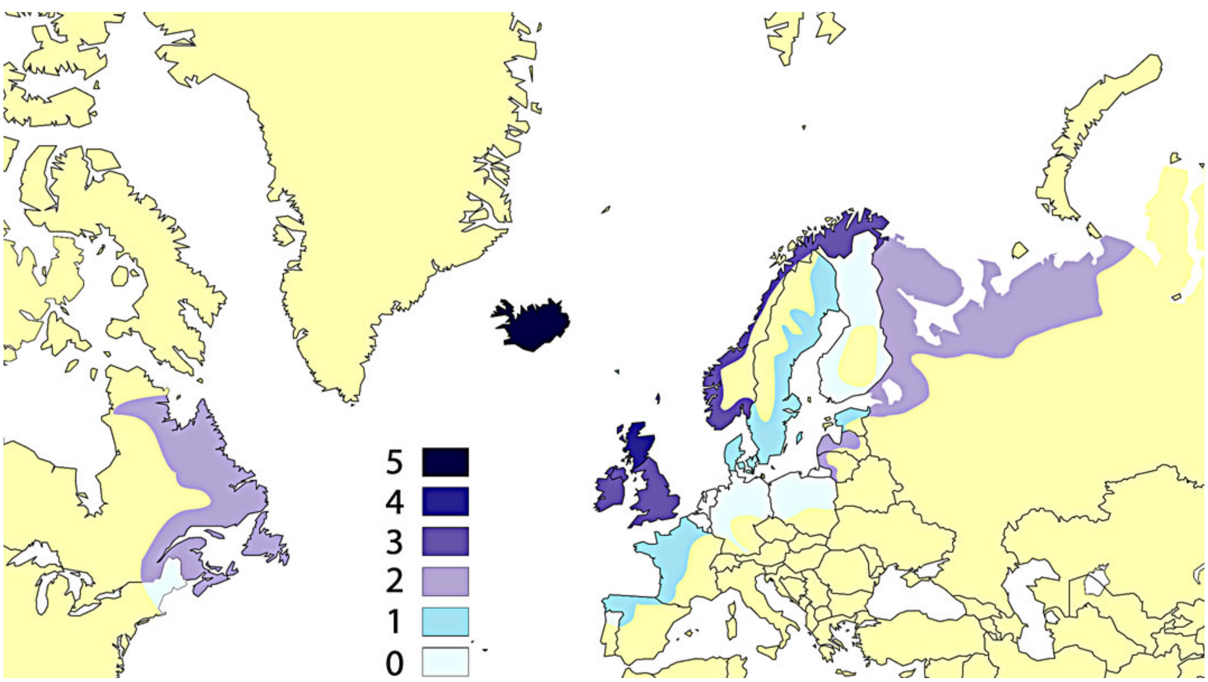

Figure 5.1. Status of wild Atlantic salmon populations worldwide. Country averages based on classification of 2005 rivers by WWF (2001) as being 5 – Healthy, 3 – Vulnerable, 2 – Endangered, 1 – Critical and 0 – Extinct.

Atlantic salmon populations are considered to be *extinct* from 309 rivers (15 %) and from the following countries: Germany, Switzerland, Netherlands, Belgium, Czech Republic, and Slovakia. They are considered to be *endangered* in Estonia, Portugal, Poland and the United States. At the other end of the scale, Atlantic salmon populations are considered to be *healthy* in 867 rivers (43 %), most of which are located in Iceland, Scotland, Norway, and Ireland (WWF 2001).

During the period from 1970-2000, worldwide catches of Atlantic salmon fell by 70% from approximately 10,000 tonnes to 3,000 tonnes. Better catch statistics, and an increasing proportion of farm escapes in the catches during this period (Hansen et al. 1999) mask a possibly stronger negative trend of wild fish in some areas. Large-sized fish, or multi-sea-winter (MSW) salmon, appear to be the stock component showing the most rapid decline in many rivers (Youngson et al. 2002). These negative trends have initiated international reports to protect wild Atlantic salmon (NASCO 1999) as well as government reports in Norway (NOU 1999) and the USA (USFWS/NMFS 1999), among other countries.

Causes of changing population sizes

Natural and man-made causes have probably interacted to produce a downward trend in abundance of Atlantic salmon during recent decades. Among the natural environmental changes affecting salmon, marine conditions are probably a primary cause. Long-term tagging studies of outmigrating salmon smolts have shown highly correlated return rates between two rivers in Scotland and Norway (Friedland et al. 2000). The authors suggest a link between ocean climate and both survival and growth of the salmon during the first months at sea. In particular, high sea surface temperatures (that occurred during the 1970s) during May in the North Sea and along the Norwegian coast seem to have led to increase in survival, whereas low sea surface temperatures (1980s and 1990s) have led to a decrease in survival. Moreover, conditions that favour survival also seem to favour individual growth rate. The mechanisms linking climatic conditions to both growth and survival are not clear but could, for example, be related to a higher growth rate resulting in an improved ability to avoid predators.

The man-made changes affecting the abundance of Atlantic salmon are numerous and only partly understood. Overharvesting may be a problem locally, but on the whole, the fisheries for Atlantic salmon have been greatly reduced since the 1970s. The high-seas fisheries have been bought out or controlled by quotas. Coastal fisheries are also being controlled (often by method), and in the rivers, recreational fisheries have been limited in fishing season or even closed down completely.

Recently, some authors have pointed to the possibility that Atlantic salmon are inadvertently harvested in the high seas during the post smolt stages, as they have been found to co-occur with herring and mackerel in some areas of the North Atlantic (Holm et al. 2003). Thus, bycatch may be a larger problem for Atlantic salmon than hitherto recognized.

Habitat changes in fresh water have for many years (centuries in urban Europe) been a major cause for declining salmon populations. Domestic and industrial pollution affecting water quality, and watercourse regulations obstructing migration and changing spawning grounds and temperature/flow, have reduced smolt production dramatically over large regions. In the rivers draining to the Baltic Sea, it has been estimated that the numbers have decreased from a historical 8-10 million wild smolts produced annually to the current numbers of approximately 0.5 million (Anon. 1999). Damming and pollution are probably the major causes for the decline. In Norway, freshwater acidification (> 25 rivers) during the 1900s has been the major cause for extinction and population reduction. Several acidified rivers are now being limed to a water quality that is acceptable to salmon, providing an example that some remedial actions have the capacity to re-establish self-reproducing populations (Hesthagen and Larsen 2003).

The high level of escapes of farm salmon, outnumbering wild salmon in many rivers in Norway and elsewhere, has led to concerns about the impact of salmon aquaculture on wild populations (Hindar et al.

1991; Hutchinson 1997). Production of Atlantic salmon in fish farms increased from 100 tonnes to 700,000 tonnes between 1970 and 2000. Escaped farm salmon are capable of spawning in the wild. Their offspring outgrow and partly displace those of wild origin, but also show maladaptive behaviour and may suffer higher mortality during some life stages. In a whole-scale river experiment in Norway, the lifetime reproductive success of farm salmon was 16 % compared to that of the native salmon (Fleming et al. 2000). The smolt productivity of the population was depressed by 30 % relative to expectation from stock-recruitment relationships in this river (Jonsson et al. 1998). Similar results concerning growth and survival have been found in a whole-scale experiment in Ireland, where second generation effects suggested a cumulative fitness depression of the population (McGinnity et al. 2003).

These genetic and ecological effects come on top of occasional epidemics following transmission of parasites and pathogens between farm and wild environments. As long as fish farming does not operate in fully enclosed systems there is always a possibility that disease organisms may be transferred from farm to wild fish (or from wild to farm and back to wild at considerably higher densities). The Norwegian experience regarding endemic and introduced diseases shows that it is difficult to operate large-scale aquaculture without disease-related problems for wild fish. Notably, veterinary certificates were given for both introductions which have had the largest effect on wild salmon in Norway, i.e. *Gyrodactylus salaris* from Sweden and *Aeromonas s. salmonicida* from Scotland (Johnsen and Jensen 1991, 1994).

Critical factors for success in sustaining Atlantic salmon populations

Research Needs

More research needs to be conducted in order to understand better both the environmental and biological basis for stock-recruitment (S/R) relationships in Atlantic salmon. Despite many decades of research on Atlantic salmon, representative stock-recruitment relationships and dynamic S/R models are still lacking for the large majority of rivers holding salmon populations. This is a serious hindrance to making informed predictions about how many spawners need to be present to avoid extinction of the population, and what the optimum number is for producing a harvestable surplus that can be sustained in the longer term. Some progress in this area has been made through statistical modelling with an aim to transfer information from a few well-studied European rivers to data-poor rivers (Prévost et al. 2003).

Understanding the effects of disease transfer between farm and wild populations is another important research area. We know a great deal about diseases in captive environments (hatcheries and fish farms), but still very little about diseases in the wild and how fish culture alters transmission routes and pathogen-host dynamics (Bakke and Harris 1998).

A third area of required research is at the level of metapopulations; that is, understanding the genetic and ecological dynamics of a group of populations exchanging a limited number of migrants. Models for genetic conservation and population viability are quite well developed for single populations, but are poorly developed at the metapopulation level. The latter seems more appropriate for salmon populations. Tufto and Hindar (2003) developed a model that maximizes the harvest of a group of populations, subject to constraints set by maintaining the total effective population size (a measure of genetic conservation). They showed that considerable gain may be made in total effective size through harvesting based on knowledge about genetic structure. For example, when populations differ in their degree of isolation it pays to harvest relatively less in isolated populations. In a source-sink system, where one population (the source) emits more migrants than it receives from its neighbours (the sink), it pays to harvest the source more strongly than the other populations.

Management Actions

Management needs to recognize and better control the man-made factors affecting wild populations of Atlantic salmon. This depends to a large extent on inter-departmental and international cooperation. A major challenge lies in developing salmon farming into a sustainable industry, which it is not at the moment (Naylor et al. 2000). The most important measure for salmon aquaculture in the longterm, is to base it on closed culture where the possibility for escape is eliminated and where in-flowing and out-flowing water is controlled. A shorter-term measure could be to base aquaculture on sterile (all-female) fish, which can be produced at a large scale through simple, inexpensive technology. Whereas this measure cannot alleviate problems related to competition in the sea and transmission of parasites and pathogens, it would be an efficient and rapid way of reducing genetic problems. Sterility should at any rate be used while developing a technology that targets full containment.

Several recent initiatives at the national or international level provide some hope for a brighter future for wild Atlantic salmon. In the Norwegian governmental report on the status and future of Atlantic salmon, a number of rivers and fjords were targeted as being 'national salmon rivers or protection zones' (NOU 1999). In these areas, management plans for other areas such as agriculture, aquaculture, hydropower development, and transportation, need to adjust to the protection of the local salmon population(s). In the Baltic area, an international "Salmon Action Plan" has been set forth to restore wild salmon populations (Anon. 1999). The goal is to increase salmon production to at least 50 % of the potential capacity of each river by year 2010. In the European Union, much hope is attached to the Water Framework Directive (Directive 2000/60/EC) which has the potential to achieve good ecological status for whole river basins, and sets a time frame for its implementation. Thus, even though Atlantic salmon have declined in many European countries, some concerted management actions on both the national and international level provide some hope for the future.

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