CHAPTER 6

Wild Atlantic salmon in North America: status and perspectives

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Abstract
Wild Atlantic salmon abundances in North America are presently at their lowest levels ever. Actions are urgently needed in the southern part of the species distribution where many populations are now officially listed as endangered in both Canada and the USA. In a number of instances, the most probable causes responsible for a major part of the declines of a salmon run are known. These causes include dams and acid precipitation, and remediation methods are available. However, the remediation costs are expensive, and it is a big challenge to raise the necessary money. New research is beginning to point to possible solutions to other difficult challenges. By focusing on key river systems and point source causes it should be possible to achieve large increases in North American wild Atlantic salmon returns.

Introduction
Wild salmon are one of North America's great treasures, a source of natural capital that has benefited generations of humans on the continent. For something so valuable, it is quite difficult to believe that we have permitted the abundance of wild salmon on both coasts to decline to their present levels (e.g., Montgomery 2003, Lichatowich 1999). This paper briefly reviews the status of wild Atlantic salmon populations in eastern North America, focusing in particular on the most troubled areas. It explores some aspects of what is being done, and what can be done, to attempt to restore populations in areas where they are troubled or lost.

A brief history of North American Atlantic salmon
Historically, sea run Atlantic salmon occurred from the Hudson River up into the Hudson Bay region, and there were landlocked populations of the species in freshwater lakes throughout this region, including Lake Ontario (Christie 1973, Dunfield 1985, Scott and Crossman 1973). We do not know what the pre-European abundance of Atlantic salmon runs was for sure, but it could have been in the range of five to 12 million returning spawners per year (Dunfield 1985). Native Americans in the region were heavily dependent on the resource.

The first instance that I have found of a European modifying a North American salmon river occurred in 1606, when Samuel de Champlain dammed part of the Annapolis River to create a trout pond, two years after he arrived in present day Canada with the first French colonists (Morison 1972). Subsequently, impact rates picked up. Watt (1988, 1989) estimated that by 1870, due to dams, habitat destruction, pollution, water diversions and other impacts the North American production capacity for Atlantic salmon had been reduced to 52% of its original value. By 1970, we were down to only 32%.

Since 1973, the declining abundance trend has continued for wild salmon returning to North America (ICES 2003, Figure 6.1). Returns of fish are well below the biological reference points that scientists believe should be maintained to insure the conservation of the species. The cause or causes for the trend remain speculative, but increased mortalities of the fish at sea appear to be a major contributor. A "regime shift" appears to have occurred in the ocean in the late 1980s, or early 1990s, and this is associated with a large deterioration in the stock-recruit relationship (ICES 2003).

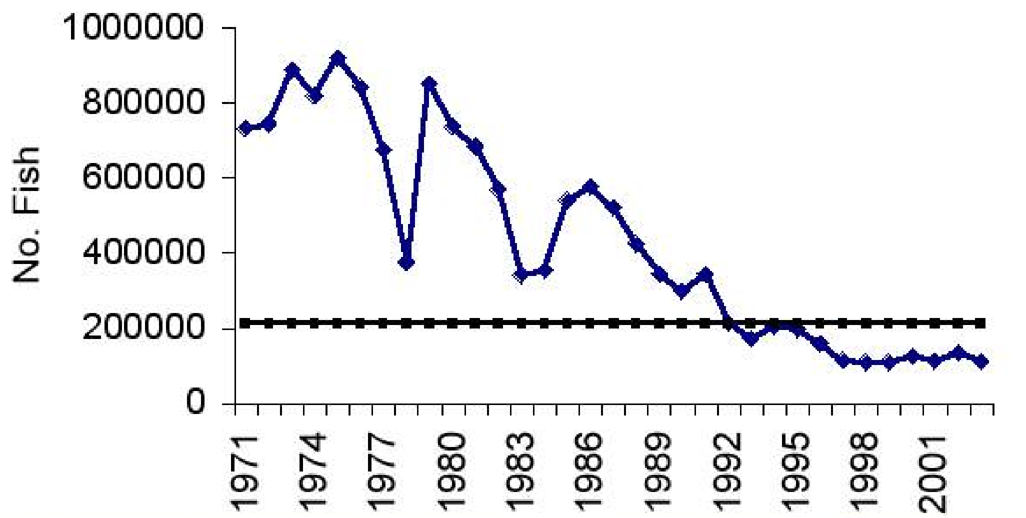

Figure 6.1. Trends in abundance for wild Atlantic salmon from all rivers in North America at their feeding grounds off the coast of Greenland, prior to returning home for spawning. The conservation threshold, the biological reference point below which managers do not wish to see fish abundance fall, is given by the constant value line. Data from ICES 2003.

While the abundance of Atlantic salmon is generally depressed in both Europe and North America, the depth of the depression is much greater in the south than in the north (ICES 2003). In North America, there is a real possibility of biological extinction of virtually all Atlantic salmon populations south of Cape Breton Island, Nova Scotia. About 65 rivers in southern Nova Scotia have been impacted by acid rain, which is apparently compounding the impacts of the other stressors that have caused the general decline (DFO 2002, Watt 1987). The drainage basins of these rivers fall in whole or part on the Southern Uplands. Previously, this area had a limited natural buffering capacity, but acid depositions from anthropogenic sources have stripped away much of it. The pH values in several of the region's rivers now fall below those where salmon reproduction can occur, and they are at levels that impede reproduction to varying degrees in most of the other rivers.

In Canadian rivers draining to the Bay of Fundy, salmon populations are severely depressed (DFO 2003). The populations of 32 rivers in the inner Bay region were officially listed as *endangered* in 2001 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (for background, see Kenchington 1999, Amiro 2003). The precipitous declines of these runs began as recently as 1990. Most of the other populations in the region are similarly depressed (DFO 2003) and may be candidates for listing by COSEWIC. Across the border in northern Maine, which harbors most of the United States remaining wild, self-sustaining salmon populations, eight population segments were listed as endangered in November 2000.

Salmon farming

The potential impacts of the intensive sea cage rearing of domestic strains of Atlantic salmon upon wild salmon populations remain an area of great concern. On the east coast of North America, the sea cage industry in the USA is concentrated in northern Maine, and in Canada in the Quoddy Region of New Brunswick. Wild salmon populations in both of these areas are severely depressed and many are listed as endangered.

The principal fears for wild Atlantic salmon revolve around the potential of escaped farmed salmon to breed with wild fish, reducing individual fitness for the offspring and depressing population sizes (Fleming et al. 2000, McGinnity et al. 2003 a,b), and the potential of the large biomasses present on the farms to foster out-of-control parasite and disease problems (e.g., Holst et al. 2003) that could in turn impact wild fish.

The debates about the potential environmental impacts of salmon farming have frequently been acrimonious (e.g., Goode and Whoriskey 2003), which has impeded making progress on the issues. However, measures are available to address many substantial issues, and tangible improvements are occurring in some places and areas (Goode and Whoriskey 2003, Lord Lindsey and Rae 2003).

Two examples of these improvements come from the east coast of North America, and involve minimizing the impacts of escaped farm salmon. The Atlantic Salmon Federation maintains a counting facility on the Magaguadavic River in New Brunswick. This river is situated in the heart of Canada's East Coast salmon farming industry, and is in close proximity to the core of the US industry in Maine. Since 1992, we have been counting the number of wild and farmed salmon running to this river to provide an indicator of the potential interactions between wild and escaped farmed salmon in the region (Carr et al. 1997). Historically 800 – 1,000 wild salmon returned to the river annually. Since 1992 however, there has been a desperate decline in the size of the wild run (Figure. 6.2). During this same period, as many as 1,200 escaped farm salmon were captured entering the river. However, improvements by the industry in cage technology and in their operating procedures have steadily reduced the number of escapees that were detected (Figure. 6.2).

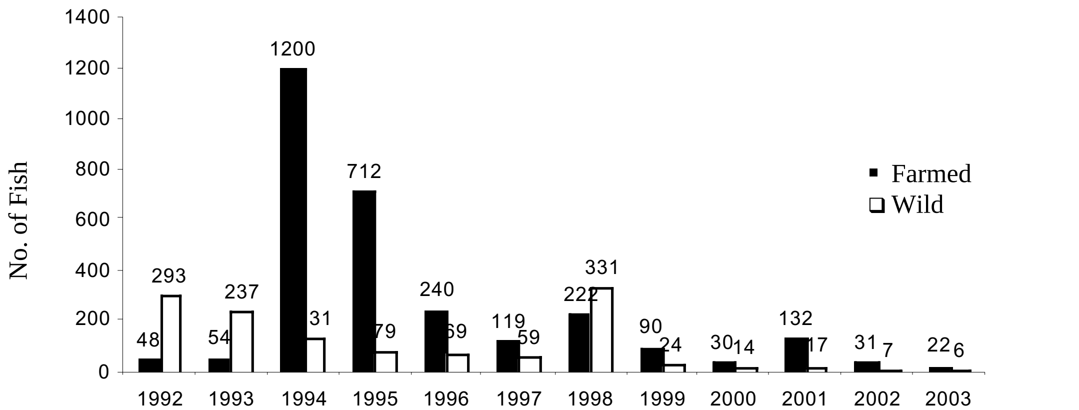

Figure 6.2. Numbers of wild and farmed fish caught annually entering the Magaguadavic River, New Brunswick, since 1992. Numbers of fish are plotted on the top of each histogram.

The second example involves the development of a cooperative agreement between the industry and environmental groups entitled "Framework for a Salmon Aquaculture Containment Policy in the State of Maine" (Goode and Whoriskey 2003). The framework outlined a Containment

Management System (CMS) designed to minimize interactions between wild and farmed salmon, and it has now been implemented. The agreement set standards, but let industry use its expertise and choose the feasible and cost effective ways to implement them. The process was successful because of the direct involvement in the negotiations of senior salmon farm company executives (as opposed to trade association representatives), because of the pivotal role the salmon growers played in the drafting and implementation of the CMS, because the agreement occurred in a non-regulatory arena, because a neutral, outside expert in Hazard Assessment Critical Control Processes (HAACP) was engaged to facilitate the development of the CMS, and because of a timely grant that paid for the expert.

These steps clearly do not resolve all the issues surrounding salmon farming. However, we acknowledge as well the efforts of the industry to coordinate their efforts on disease control and other environmental impacts (e.g., New Brunswick's Bay Area Management Strategies, Ireland's CLAMS (Coordinated Local Area Management Strategy), and Scotland's Scottish Quality Salmon mandatory commitment to its Environmental Management System (Goode and Whoriskey 2003, Lord Lindsay and Rae 2003). I believe the key to making continued progress is to focus on issues and the development of mutually acceptable ways to resolve them.

The way forward

The steps for recovery of wild Atlantic salmon are conceptually simple, but very difficult to put into practice. In my opinion, they basically boil down to:

- Keep what we have got
- Claw back what we have lost
- Do not let it happen again.

The first task involves adopting management measures that insure that we maintain the populations that are presently healthy, and stabilize those that have been declining. To meet the second, recovery plans are needed for areas in which production capacity has been lost. The third is dependent on developing better monitoring networks to provide good data on salmon population status, and timely interventions when the data show that problems are developing.

The availability of resources to meet these missions has been declining. This puts a premium on "strategic" intervention, especially in recovery attempts. For the Atlantic salmon, we will most probably obtain the biggest bang for our buck by intervening as early as possible. In North America there are a number of restoration efforts using "foreign" donor stocks presently underway at sites where wild salmon populations have gone extinct. These are all long-term and expensive efforts and so far have been not nearly as successful as desired (e.g., the Connecticut River, aux Rochers River). Interventions in rivers in areas such as the inner Bay of Fundy, where some native donor populations are available, are very new (Amiro 2003). Hope for all these efforts stems from the fact that a number of spectacular range extensions of Atlantic salmon within their home rivers have been obtained by opening up new habitat and colonizing it with fish from the same watersheds (Mullins et al. 2003).

I suggest that the biggest restoration benefits will occur in sites where a clear cause ("point source") is badly damaging a salmon population, over a significant portion of its range. The principle is not new. It is the same approach that has been adopted for dealing with industrial pollution. Three areas that meet some of these criteria, and which are becoming a major focus of the Atlantic Salmon Federation's attention, are 1) the inner Bay of Fundy salmon populations including a restoration of runs to the Petitcodiac River, 2) dealing with fish passage on the Saint John and Penobscot Rivers, and 3) mitigating for acid rain in Nova Scotia's Southern Uplands.

Inner Bay of Fundy salmon

In the upper Bay of Fundy region, about 32 rivers were home to a unique Atlantic salmon complex, now referred to as “inner Bay of Fundy salmon”. These fish differed from those in surrounding rivers in their marine migration routes (they mostly stayed in the Bay of Fundy and Gulf of Maine region as opposed to migrating to waters off Greenland), life history characteristics (early maturity, high rates of repeat spawners in the populations), and genetics (see Amiro 2003). As recently as 1990, up to 40,000 salmon may have returned annually to these 32 rivers. Subsequently, populations crashed, and fewer than 500 adult fish are now believed to be entering the rivers, and the COSEWIC listed these fish as *endangered* in 2001.

Following the listing, a recovery team chaired by the Department of Fisheries and Oceans was formed. It draws its membership from government agencies, First Nations, non-governmental organizations, and local stakeholder groups. Key activities of the group include the establishment of a live gene bank containing Inner Bay lineages for restoration purposes and to provide animals for necessary, ongoing monitoring of the success of restoration activities, research into the potential causes of the declines, and development of a communications strategy for the public.

The Petitcodiac River historically accounted for approximately 30% of the freshwater habitat for the inner Bay of Fundy salmon. Its runs probably averaged about 2,000 – 3,000 salmon annually (Amiro 2003). In 1968, a causeway was completed across the lower section of the river, effectively blocking access by salmon to most of the 3,000 km^2 watershed (www.petitcodiac.org). The causeway was fitted with a series of gates that could control upstream water levels upstream, and a fish ladder (Niles 2001). The impounding created a freshwater reservoir that became a focal point for recreational activities, and the gates have mostly stayed closed since the causeway went into operation.

It rapidly became evident that the fish passage that was provided was ineffective for the anadromous and catadromous fishes using the river, including Atlantic salmon. The presence of the causeway also affected the river’s tidal exchange, sediment transport, and other ecosystem functions (Niles 2001). Canada’s Department of Fisheries and Oceans repeatedly called for free flow, at least during the anadromous fish migration period, but this did not happen (Niles 2001). Sometime in the early 1990s the wild native salmon population of the river went extinct.

Clearly, the restoration of inner Bay of Fundy salmon lineages to the Petitcodiac River could have a significant positive effect on the population demographics for the group as a whole. Championed by the Petitcodiac Riverkeeper (Daniel LeBlanc, see www.petitcodiac.org), an effort is currently underway to restore the natural flow regimes to the river by replacing the causeway with a bridge. Over 140 studies have been conducted on the impacts of the causeway since it was built, all basically concluding that free passage is the only option that will help restore the migratory fish populations to the river (D. LeBlanc, personal communication). An environmental assessment is presently underway to evaluate options for the river (these range from *status quo* to providing free passage), with the draft and its recommended solutions due to be made public in December 2004. A final decision will be made in 2005. No solution will satisfy all stakeholders, and some are adamantly opposed to free passage.

Saint John and Penobscot River passage

Dams, by blocking or delaying fish passage, and by grinding fish up as they pass through hydroelectric turbines, can have terrible impacts upon salmon populations. In eastern North America, the Saint John and Penobscot Rivers are the two large wild Atlantic salmon rivers whose native strain of salmon remain, but which are in need of relief from the impacts of multiple large dams. If these problems can be corrected or significantly improved, big benefits for wild North American Atlantic salmon would result.

The Saint John River, named by Samuel de Champlain and the Sieur des Monts in 1604, is the largest river system in the Province of New Brunswick. It has a drainage area of 54,930 km^2, of which 53%, 38% and 9% fall in New Brunswick, Maine and Quebec, respectively (Carr 2001). Atlantic salmon production in the system has been severely impacted by the presence of hydroelectric dams, in particular (in order from the headwaters to the sea, with year of completion in parentheses) the Tobique Narrows (1953), Beechwood (1957) and Mactaquac (1968) dams. No firm estimates are available for historic salmon run sizes in the river. They were clearly abundant (Peabody 2003) and may have historically gone as high as 100,000, and within the last few decades were in the tens of thousand range. Now the returns are totaling a few thousand fish (2,734 fish returned to Mactaquac dam's passage facility in 2002, see DFO 2003).

While upstream passage is provided at each of theses facilities, smolts moving downstream must either spill over the dams or pass through turbines. Turbine passage mortalities as high as 18% have been recorded, although they are generally lower. However, the major problem for migrating smolts appears to be migration delays. As water currents slow or disappear in the headponds, the smolts appear to lose their orientation and downstream movements stop. The Mactaquac headpond, located closest to the ocean, is over 80 km long. Up to 100% of sonically tagged migrating smolts that entered this reservoir failed to find the downstream exit. Delays of lesser magnitude were detected at the other sites (Carr 2003).

The power produced by these facilities is critically important to New Brunswick; hence the dams are here to stay. What is needed is an innovative guidance system to encourage smolts to continue their downstream movements in the headponds. Scientists from Oak Ridge Laboratory are working on an acoustic guidance system that just might be able to guide the fish from point to point, leading steadily towards the reservoir exit (Whoriskey 2003). We hope to initiate a trial of it in the Mactaquac headpond in the near future.

A panel of the US National Research Council (Committee on Atlantic Salmon in Maine 2004) has just completed a review of the status of the Atlantic salmon in Maine. Their report singled out the Penobscot River as the place that should be the "primary focus for rehabilitating the species in Maine" (p. 160). The Penobscot River drains about 23,310 km^2, and is the second largest river in New England. It has about 805 km channel of spawning and rearing habitat for Atlantic salmon, and salmon occurred as far as 240 km upstream from the sea. Salmon runs historically may have numbered as many as 100,000 fish, but recent returns are hovering at 1,000 or less (ICES 2003).

An agreement involving the corporation owning the dams, conservation groups and government has just been signed to put in motion a $50 million (US) project to comprehensively restructure the hydropower capacity of the river. The key is to reconfigure and rebuild the network so that a smaller number of dams can generate about the same amount of power as the present scattered network. If the funding for the program can be raised, it will remove two large dams on the lower river, decommission a third and provide it with a natural fish bypass channel, and improve existing fish passage on several others where hydropower generation would be increased to make up for taking the others out of service. This has been termed the "last, best chance for saving wild Atlantic salmon in Maine" (A. Goode, quoted in Watts 2003). The hard part is coming up with the money.

Acid rain

One potential solution to the acid deposition problem in the Southern Uplands region of Nova Scotia is liming (e.g., Watt 1986). The Nova Scotia Salmon Association, a Council of the Atlantic Salmon Federation composed of individual watershed groups dedicated to the conservation of wild Atlantic salmon, is striving to get efforts underway to deal with the acid problem in their region (Acid Rain Committee 2002).

Their first attempts at liming involved distribution of lime into lakes within acid-impacted watersheds. The idea was that with a good lime load, the lake could act as a source of buffer for the waters downstream of it for a period of up to a year. There was little money to support the effort, so the operation ran on a shoestring budget. Council volunteers obtained the lime, and would move it onto the lake's surface with trucks or tracked vehicles over the ice during the winter. The spring ice melt would release the lime to the lake, immediately buffering the spring runoff acid pulse and hopefully providing longer term relief as well. The effort had to be abandoned when another environmental problem intervened. Because of warm winter temperatures (probably linked to global warming), the surface of lakes in the region was not freezing solidly enough to support the weight of the vehicles necessary to distribute the lime.

At present, the Council is developing partnerships and looking to get liming pilot programs underway on a few watersheds in the region. As a first step, a Norwegian expert was brought in to evaluate the situation (Hindar 2001). The liming strategies being considered include the direct dosing of either cement kiln dust or crushed, slurried limestone into rivers on a continuous basis, and the intriguing possibility of a whole watershed aerial distribution of lime from aircraft that could provide relief for 60 or more years. These are very expensive projects, and the focus at this time is to develop the business plans and raise funds to make execution of the plans possible.

New research is showing that the acid rain problem is more daunting than anticipated. Recent work has shown that even short exposures to acidified stream water can strip a smolt of its ability to osmoregulate once it enters sea water, resulting in death (Magee et al. 2003). In addition, model simulations suggest that even under the most optimistic projects of reductions of acid deposition, it will take over 100 yeasrs in the Southern Uplands regions to recover the acid buffering capacity that it has lost (T. Clair, in Arter 2003). These findings highlight the need for quick actions, which will have long-lasting benefits.

Conclusion

Technology is opening previously undreamed of opportunities to study salmon, especially during their migrations at sea. Remote sensing devices are going to revolutionize our capacity to document where fish go, and what the environmental conditions are like around them (Copley 2004). This may open a window that helps us understand why salmon survival at sea is currently depressed. However, the significant potential gains for wild Atlantic salmon that I have outlined above are not dependent on new research. The solutions are known; what is lacking is the will or the resources to implement them. Time, the most precious commodity of all, is slipping away for these menaced populations.

References

Acid Rain Committee 2002. Assessment of candidate rivers for liming in the southern upland of Nova Scotia. Nova Scotia Salmon Association manuscript report. 5 pp.

Amiro, P. 2003. Population status of Inner Bay of Fundy Atlantic salmon (*Salmo salar*), to 1999. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2488 44 pp.

Arter, B. 2003. Status and trends of water chemistry in Maine Atlantic salmon watershed. A report on the conference findings and round table discussion. Project SHARE Research and Management Committee. 14 pp.

Cairns, D. (Ed.) 2001. An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic salmon. Canadian Technical Report of Fisheries and Aquatic Sciences 2358 67pp.

Carr, J. W. 2001. A review of downstream movements of juvenile Atlantics salmon (*Salmo salar*) in the dam-impacted Saint John River drainage. Canadian Manuscript Report of Fisheries and Aquatic Sciences. No 2573. 76 pp.

Carr, J. W., J. M. Anderson, F. G. Whoriskey and T. Dilworth. 1997. The occurrence and spawning of cultured Atlantic salmon (*Salmo salar L*.) in a Canadian River. ICES Journal of Marine Science 54: 1064-1073.

Christie, W. J. 1973. A review of the changes in the fish species composition of Lake Ontario. Great Lakes Fishery Commission, Ann Arbor, Michigan. Technical Report 23. 72 pp.

Committee on Atlantic Salmon in Maine 2004. Atlantic Salmon in Maine. National Research Council, National Academy Press, Washington, DC. 260 pp. http://books.nap.edu/openbook/0309091357/html/index.html

Copley, J. 2004. All wired up. Nature 427: 10 – 12.

DFO 2002. The effects of acid rain on the Atlantic salmon of the southern upland of Nova Scotia. Department of Fisheries and Oceans, Maritimes Region Habitat Status Report 2000/2E. 18 pp.

DFO 2003. Atlantic Salmon Maritime Provinces Overview for 2002. Department of Fisheries and Oceans, Science. Stock Status Report 2003/027.

Dunfield, R. W. 1985. The Atlantic salmon in the history of North America. Canadian Special Publication of Fisheries and Aquatic Sciences 80. 181 pp.

Fleming, I., K. Hindar, I. Mjølnerod, B. Jonsson, T. Balstad and A. Lamberg. 2000. Lifetime success and interactions of farm salmon invading a native population. Proceedings of the Royal Society of London B. 267: 1517 – 1523.

Goode, A. and F. Whoriskey. 2003. Finding resolution to farmed salmon issues in eastern North America. Pp 144-158 in: Mills, D. (Ed.). Salmon at the edge. Blackwell Science, Ltd. Oxford. 307 pp.

Hindar, A. 2001. Recommended liming strategies for salmon rivers in Nova Scotia. Norwegian Institute for Water Research. Report No. 0-211124. 42 pp.

Holst, J. C., P. Jacobsen, F. Nielsen, M. Holm, L. Asplin, and J. Aure. 2003. Mortality of seaward migration post-smolts of Atlantic salmon due to salmon lice infection in Norwegian salmon smolts. pp. 136 – 137 in: Mills, D. (Ed.). Salmon at the edge. Blackwell Science, Ltd. Oxford. 307 pp.

ICES 2003. Report of the Working Group of North Atlantic salmon. ICES CM 2003/ACFM:19, Ref. D,F,C. 310 pp.

Kenchington, E. 1999. Proceedings of the Inner Bay of Fundy Salmon Working Group Regional Advisory Process. Department of Fisheries and Oceans. Regional Advisory Process. Maritimes Region. Canadian Stock Assessment Proceedings Series 99/29. 39p.

Lichatowich, J. 1999. Salmon without rivers. Island Press, Covelo, California. 317 pp.

Lord Lindsay and G. Rae. 2003. Delivering the solutions- the salmon farmer's point of view. Pp. 159 –171 in: Mills, D. (Ed.). Salmon at the edge. Blackwell Science, Ltd. Oxford. 307 pp.

Magee, J. A., M. Obedzinski, S. D. McCormick and J. F. Kocik. 2003. Effects of episodic acidification on Atlantic salmon (*Salmo salar*) smolts. Canadians Journal of Fisheries and Aquatic Sciences 60: 214–221.

McGinnity, P. E.. A. Ferguson, N. Baker, D. Cotter, T. Cross, D. Cooke, R. Hynes, B. O'Hea, N. O'Maoiléidigh, P. Prodöhl and G. Rogan. 2003 a. A two-generation experiment comparing the fitness and life history traits of native, ranched, non-native, farmed and "hybrid" Atlantic salmon under natural conditions. Pp. 138 – 143 in : Mills, D. (Ed.). Salmon at the edge. Blackwell Science, Ltd. Oxford. 307 pp.

McGinnity, P., P. Prodöhl, A. Ferguson, R. Hynes, N. O'Maoiléidigh, N. Baker, D. Cotter, B. O'Hea, D. Cooke, G. Rogan, J. Taggart and T. Cross. 2003 b. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon. Proceedings of the Royal Society London B 270: 2443 – 2450.

Montgomery, D. 2003. King of fish: The thousand-year run of salmon. Westview Press, Cambridge, Massachusetts. 290 pp.

Morison, S. E. 1972. Samuel de Champlain: Father of New France. Atlantic Monthly Press, New York.

Mullins, C. C., C. E. Bourgeois, and T. R. Porter. 2003. Opening up new habitat: Atlantic salmon (*Salmo salar L*.) enhancement in Newfoundland. Pp. 200 – 221 in: Mills, D. (Ed). Salmon at the edge. Blackwell Science, Ltd. Oxford. 307 pp.

Niles, E. 2001. Review of the Petitcodiac River causeway and fish passage issues. Prepared for the Minster of Fisheries and Oceans Canada. 32 pp. Available at www. petitcodiac.ca.

O'Neil, S., J. Ritter and K. Robichaud-LeBlanc (Eds.). 2000. Proceedings of a workshop on research strategies into the causes of declining Atlantic salmon returns to North American rivers. Canadian Stock Assessment Secretariat Proceedings Series 2000/18. 80p.

Peabody, G. 2003. Caught a noble salmon. Atlantic Salmon Journal 52 (4): 32 – 37.

Scott, B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184 of the Fisheries Research Board of Canada. Ottawa. 966 p.

Watt, W. D. 1987. The case for liming some Nova Scotia rivers. Water, Air and Soil Pollution 31:775–789.

Watt, W. D. 1987. A summary of the impact of acid rain on Atlantic salmon (*Salmo salar*) in Canada. Water, Air and Soil Pollution 35: 27 – 35.

Watt, W. D. 1988. Major causes and implications of Atlantic salmon habitat losses. Pp. 101 – 112 in: Stroud, R. H. (Ed.). Present and future Atlantic salmon Management. Atlantic Salmon Federation, Ipswich, Massachussetts. 210 pp.

Watt, W. D. 1989. The impact of habitat damage on Atlantic salmon (*Salmo salar*) catches. pp. 154–163 in: Levings, C. D., L. B. Holtby and M. A. Henderson (Eds.). Proceedings of the national workshop on effect of habitat alterations on salmonid stocks. Canadian Special Publication of Fisheries and Aquatic Sciences 105.

Watts, D. 2003. Penobscot reborn. Atlantic Salmon Journal 52(4): 26– 31.

Whoriskey, F. G. 2003. Dambusters and pied pipers. Atlantic Salmon Journal 52(4): 22 – 24.