Proceedings of the Symposium: What works? A Workshop on Wild Atlantic Salmon Recovery Programs

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Executive Summary

The Atlantic Salmon Federation (ASF) hosted a workshop titled 'What works? A Workshop on Wild Atlantic Salmon Recovery Programs' in St. Andrews, New Brunswick, Canada from September 18-19, 2013. More than 100 people attended representing federal and provincial/state governments, First Nations, academia, river stakeholder groups, and non-government organizations (NGOs) from Canada, United States, United Kingdom, Netherlands, and France. Numerous others linked to the workshop remotely via live stream.

On the first day, the keynote address was given by Dr. Ian Fleming (Memorial University of Newfoundland, St. John's, Newfoundland, Canada) who spoke on the ecology and genetics of salmon recovery. This was followed by summaries of regional wild Atlantic salmon recovery programs in eastern North America that included population status, threats, role of hatcheries, and recovery actions. The next series of presentations focused on gene banking and life history stocking strategies. Day one concluded with presentations of case studies of various hatchery-assisted salmon stocking programs and an assessment of their effectiveness.

Throughout the keynote and session presentations on the first day, the repeated message was: stocking alone cannot produce recovery; it should not be the first and definitely not the only response to declining salmon populations in a watershed; and, when used, the goal must ultimately be to maximize wild or "wild-like" exposure in order to prevent loss of fitness. Fleming (this workshop) highlighted that salmon need to be adapted (population genetics) to their watersheds (ecology). The thermal tolerances of New Brunswick (NB) and Quebec (QC) populations reported by Corey et al. (this workshop) demonstrated adaptive differences. On the Little Southwest Miramichi (NB), salmon parr aggregated in cold water refugia as water temperature reached 27 ^{o}C; however in the Ouelle River (QC), parr tolerated water at 27 ^{o}C. Fleming (this workshop) proposed that for hatchery intervention to be a success, hatchery products must be from river specific broodstock, survive, breed, and produce offspring that contribute to natural production. A stocking program that simply replaces or displaces wild production is not a success and will likely damage the wild population. However, success is difficult, because hatchery salmon are much less likely to have as great a lifetime contribution to the population as their wild counterparts (Table 1). Additionally when hatcheries are used, the intervention may impede future adaptive potential of the population if its genetic composition is changed. If hatcheries are necessary (e.g., live gene banking of endangered species) he proposed these tenants: stocking is a temporary tool; rearing environments should mimic natural streams; and extending wild exposure improves survival and fitness of hatchery products.

Table 1. Summary of studies comparing relative success of wild and hatchery salmon.

Type	Species	Relative Success (Hatchery : Wild)	Reference
Near-natural streams (breeding to egg deposition)			
Hatchery	coho salmon	0.61 – 0.82	Fleming & Gross 1993
Hatchery	Atlantic salmon	0.66 – 0.86	Fleming et al. 1997
River releases (genetic screening)			
Hatchery	steelhead	0.75-0.79 (0+ parr)	Leider et al. 1990
Hatchery	steelhead	0.04-0.07 (2+ smolts)	McLean et al. 2004
Hatchery	steelhead	0.18-0.37 (2+ smolts)	Kostow et al. 2003
Hatchery	steelhead	0.06-0.87 (lifetime)	Araki et al 2007a,b, 2009
Hatchery	brown trout	0.78-0.97 (0+ parr)	Dannewitz et al. 2004
Hatchery	brown trout	0.09 (lifetime)	Hansen 2002
Hatchery	coho salmon	~1.0 (lifetime)	Ford et al. 2006
Hatchery	coho salmon	0.62-0.95 (lifetime)	Thériault et al. 2011
Hatchery	Chinook salmon	~1.0 (lifetime)	Hess et al. 2012
Hatchery	Atlantic salmon	0.30-0.64 (0+ parr)	Milot et al. 2013

The principles Fleming discussed were highlighted in regional summaries and within Sessions 3 and 4. River specific broodstock have been developed and maintained for endangered, threatened, or declining populations in the Inner Bay of Fundy (O'Neil et al., this workshop), Maine (Trial, this workshop), Gulf Region (Chaput et al., this workshop), and Quebec (April, this workshop). The use of semi-natural instead of conventional hatchery ponds resulted in morphology and fin condition more similar to wild fish (Samways et al., this workshop).

As a temporary tool, management decisions to begin or end stocking hatchery products in a watershed need to be supported by data. April (this workshop) described how Quebec uses demographic and population genetics modeling to make the initial decision to stock a watershed and to calculate the number of juveniles to be stocked. Atkinson (this workshop) chronicled how annual data on spawning density and distribution were used to suspend fry stocking in a watershed. In the absence of agreed upon criteria, ending hatchery intervention can be difficult. For example, since some federally-funding hatcheries were closed in eastern Canada, other groups have initiated hatchery programs in order that stocking could be continued (Hambrook, this workshop). There were 11 presentations that discussed the relative effectiveness of stocking different life stages of Atlantic salmon. Few had assessed the lifetime contribution to the population of stocking cohorts. Captive reared adults stocked in the Tobique River, New Brunswick (O'Reilly et al., this workshop) and several rivers in Maine (Atkinson et al., this workshop) spawned successfully and produced juvenile populations. Egg planting (Christman and Overlock, this workshop) and streamside egg incubation (Chiasson, this workshop) produced salmon that incubated under ambient stream water conditions, emerged in synchrony with their wild counterparts, and entered the stream environment in essentially the same manner as wild fish. Clark (this workshop), Salonius (a,b, this workshop), and Jones et al. (this workshop) all noted that 0+ fry stocked in spring had long-term advantages over 0+fry held in the hatchery for 3 to 5 months. A comparison of smolt production and adults returns from 0+ fall parr (stocked at increasingly higher densities) and unfed fry is underway in the East Machias River, Maine (van de Sande, this workshop). The design of a new study evaluating the effectiveness of stocking as a recovery strategy for Atlantic salmon in the Miramichi River, NB was described (Wallace and Curry, this workshop).

None of the case histories told of successful hatchery based restoration of declining or extirpated populations. Each highlighted that recovery also requires addressing the threats to freshwater and marine survival to improve the chances that hatchery Atlantic salmon can contribute to future generations. A large scale stocking program (1970s to 2006) failed to restore Atlantic salmon (Sochasky, this workshop) to the St. Croix River, which was once the largest salmon producing river between the Penobscot and St. John Rivers. In addition to poor marine survival, freshwater habitat loss and predation from smallmouth bass contributed to the failure. Hawkes (this workshop) assessed hatchery smolt movement and survival data for the Dennys River and estuary. He concluded that the high post-smolt mortality in the bay meant that stocking smolt, and likely any life stage, in the watershed was unlikely to produce adult returns. On the Magaguadavic River, over one million fry have been stocked since 2002 and produced minimal adult returns (Carr, this workshop). The low return rates were influenced by high numbers of exotic species within the system; fish passage issues at a head of tide hydro-electric dam; and competition, disease, parasite and genetic introgression associated with both freshwater and marine salmonid aquaculture escapee salmon. Range expansions using hatchery products, as shown in the Exploits River (Newfoundland), can be successful (Parsons, this workshop), but these are fundamentally not considered to be restoration programs

Habitat recovery actions were the focus of day two. The keynote speaker was Dr. Jamie Gibson (Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada). He provided an overview of the role of population dynamics in recovery planning for Atlantic salmon. Population dynamics studies short-term and long-term changes in the size and age structure of populations, and the biological and environmental processes that influence those changes. His presentation was followed by sessions on habitat recovery initiatives, dams and fish passage, and water quality. The day concluded with a discussion panel based on three questions. Responses to these contributed to a workshop synthesis (conclusions).

On this day the repeated message was that habitat restoration projects need to re-establish natural stream processes and must focus on addressing the root cause of problems, not the symptoms. Gibson (this workshop) explained the interaction of habitat productive capacity and self-sustaining populations (e.g., ongoing reproduction, recruitment and replacement). In support of recovery planning for endangered Atlantic salmon, population dynamics models have been developed for several populations using an equilibrium modeling approach (Figure 2). This kind of analysis begins by splitting the life cycle into two parts, and determining the population size at which life history parameters (e.g. survivals, maturities, fecundities) in each part of the life cycle are balanced such that the population does not increase or decrease in size. When the population is in this state, it is said to be at its equilibrium for that specific set of parameter values. Once the life history parameters are known for a population, they can be varied in a manner that represents the expected response to a recovery activity. By examining the resulting change in equilibrium population size, the effects of the activity on the population can be evaluated.

He also provided examples of how population modeling allows managers to investigate: 1) the changes in population dynamics that resulted in population decline; and 2) the expected response of populations to specific recovery actions based on current or hypothesized dynamics. Understanding the effects of threats on populations and the responses to actions to mitigate threats are essential to effective restoration planning. Results of this type of modeling predict that recovery actions in the Southern Uplands of Nova Scotia focused on improving freshwater productivity are expected to reduce extinction risk for salmon, but on their own are not expected to recover populations to past abundance levels without a change in at-sea survival (Levy et al., this workshop).

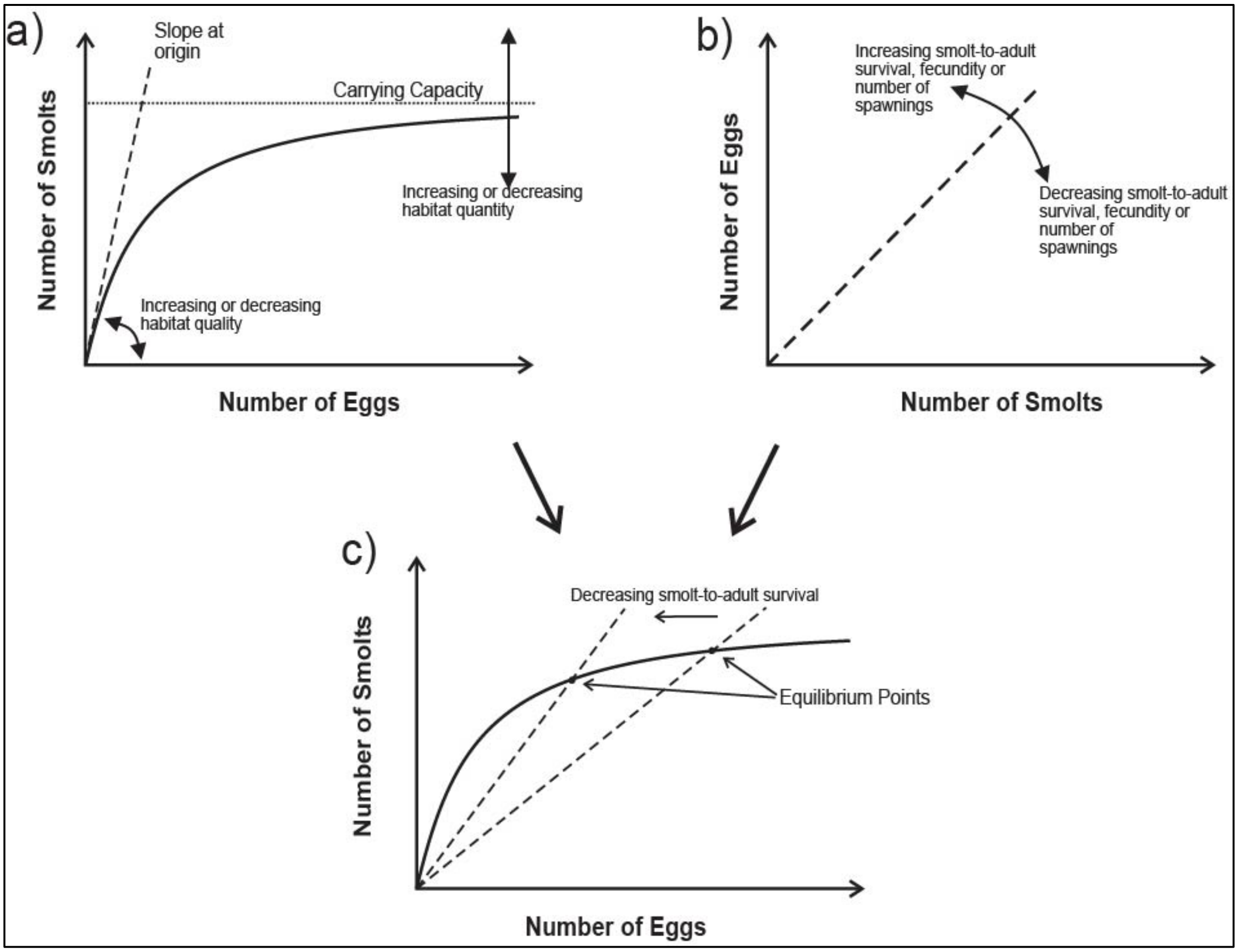

Figure 2. Conceptual diagram showing how an equilibrium model can be used to analyze the dynamics of a fish population and to determine how a population will respond to either changes in life history parameter values or recovery actions. A Beverton-Holt model (a) is used to model the density-dependent relationship for survival from eggs to smolt. The slope at the origin of this model, which is the maximum number of smolts produced per egg in the absence of density dependent effects, changes as habitat quality changes, whereas changes in the amount of habitat changes the carrying capacity. The number of eggs produced per smolt throughout its life (b) changes with smolt-to-adult survival, fecundity, age-at-maturity or the number of times a fish spawns throughout its life. The population equilibrium (c) occurs at the population size where the production of smolts by eggs is equal to the production of eggs by smolts throughout their lives, and is the size at which the population will stabilize if all life history rates and the habitat carrying capacity remain unchanged. The population equilibrium changes as the values of the life history parameters change.

Within the three sessions that followed, most of the restoration projects described were directed at addressing the root cause of an identified problem (e.g., low pH, poor fish passage, sedimentation, human activity) and reported success (e.g. restored stream function). Small scale projects (e.g., digger logs, rock sills, deflectors) were less likely to be successful when the root causes were not identified (Jenkins, this workshop). The Restigouche River Watershed Management Council (RRWMC) provided excellent examples of projects that effectively and collaboratively restored stream habitat function by addressing the root causes of sedimentation (LeBlanc, this workshop). The three RRWMC projects resulted in forest landowners and managers restoring dozens of sediment runoff sites, farmers reducing field soil loss and stream sedimentation, and both groups protecting cold water refugia (Figure 3). Some freshwater habitat can be very important. For example, when lethal temperatures are surpassed, both juvenile and adult salmon move long distances to areas of cooler water (Corey et al., this symposium). Refugia near larger seeps can hold tens of thousands of fish in what is essentially a 1m x 100m plume of cooler water. These refugia can define the carrying capacity of system where lethal temperatures occur. Therefore, there are great benefits to watersheds and salmon protection and recovery potential to ensure that the magnitude and integrity of cold water refugia is maintained and improved wherever possible.

Reduced carrying capacity of Atlantic salmon habitat from lowered stream productivity caused by low pH and reduced spawners in other anadromous fish species can be mitigated. Halfyard (this workshop) provided an overview of a lime doser project to mitigate low pH in a Nova Scotia river and reported preliminary data on increased juvenile densities in treated reaches. Adding marine derived nutrients or carcass analogs increased primary production, invertebrate abundance, and Atlantic salmon parr condition in streams (Guyette and Samways, this workshop). These recovery actions do not address the ultimate root cause of lower stream productivity, but they provide a way to improve conditions in the short-term.

Restoring access to habitat blocked by culverts or remnant log drive and hydroelectric dams improves stream function and increases the amount of usable salmon rearing habitat. The presentations by Saunders (this workshop) and Nieland et al. (this workshop) covered different aspects of an extensive project that has removed several Penobscot River hydro-electric dams to improve diadromous species access (Figure 4). In contrast, Project SHARE uses small crews and simple mechanical advantage to remove remnant log driving dams (Koenig, this workshop) with the same goal. Culverts with fish passage problems were replaced over the course of five years on almost all tributaries to Old Stream, Maine and this likely contributed to increasing natural spawning success and the suspension of fry stocking (Atkinson, this workshop). Simulation programs accurately predict the ability of fish to pass through different culvert designs (e.g., roughness, length and slope) at different streamflows (e.g., by month, watershed size) (Bergeron, this workshop) and are an invaluable tool to assist with improved designs for better fish passage.

Restoration programs on large land tracts under the control of a single owner can more comprehensively address root causes, as illustrated by restoration activities on a Canadian military base (Smith, this workshop).

Synthesizing the diverse information presented in the workshop to answer the question posed in the title ‘What works? A Workshop on Wild Atlantic Salmon Recovery Programs’ was not an easy task. One reason for this difficulty is that each person has a different idea of what the word “works” or “success” means in the context of population recovery. Recovering robust self-sustaining wild Atlantic salmon populations that could support fisheries was a primary goal among attendees. Some envisioned a catch and release fishery; others a retention fishery. Regardless of this intention, where populations are currently listed as threatened or endangered, an initial recovery goal should be to recover and rebuild populations robust enough to be removed from these protections for the long-term.

Based on the data and experiences workshop participants shared, five guiding principles emerged that will assist in developing salmon recovery programs. The following guiding principles are described in more detail in the Workshop conclusions:

1. **Team**
2. **Holistic Approach**
3. **Long-term commitment (funding and leadership)**
4. **Monitoring and evaluation**
5. **Outreach and communication**

Introduction

Wild Atlantic salmon populations in their natural range in Eastern North America have precipitously declined over the past three decades (ICES 2014). Although some of the more northern rivers have achieved conservation limits in recent years, many populations throughout the southern range are already extirpated or are on the verge of extirpation. Dozens of factors are hypothesized for the salmon’s decline, some of which include chemicals, pollution, climate change, aquaculture, passage obstructions, prey availability, and predation (Cairns 2001). These are all anthropogenic.

Many Atlantic salmon recovery initiatives have been attempted over the past several decades with the goal to conserve, protect, and restore declining salmon populations. In many cases, programs focused on stocking to increase salmon numbers and overlooked key threats that might limit population recovery. Fifty years ago the quick answer would likely have been to produce smolts for stocking (U.S. Fish and Wildlife Service 1989; Marshall et al., 1994). Economically this may have been a reasonable approach, but the adult production and subsequent progeny may have been genetically inappropriate for the long-term. Current thinking would suggest that the money should be spent on improving habitat (e.g., quality, connectivity, ecosystem health, etc.) with a smaller amount, if any, for supportive rearing programs.

In recent years, there has been a shift towards an ecosystem approach with new innovative ideas coming to the forefront (Saunders et al. 2006). Salmon numbers are just one part of the ecosystem, other factors, including habitat, invasive species, and other diadromous fish must be considered in recovery.

To highlight the latest information on salmon recovery initiatives, the Atlantic Salmon Federation (ASF) hosted a workshop titled ‘What works? A Workshop on Wild Atlantic Salmon Recovery Programs’ in St. Andrews, New Brunswick, Canada on September 18-19, 2013. More than 100 people attended representing federal and provincial/state governments, First Nations, academia, river stakeholder groups, and non-government organizations (NGOs) from Canada, United States, United Kingdom, Netherlands and France. Numerous others unable to travel to the meeting linked to the workshop remotely via live streaming.

The workshop was intended as a forum for networking among river stakeholder groups, biologists, ecologists, scientists, policy makers and managers to foster collaborations and to pool all available data for wild Atlantic salmon recovery and rebuilding programs in eastern North America. The aim of the meeting was to review progress in the field and to present the latest research findings and to identify knowledge gaps, with the goal of integrating biological, socio-economic, and managerial perspectives.

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1. Keynote Address 1:

Ecology and Genetics of Salmon Recovery: What is Success?

Ian A. Fleming

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Summary

The problem

Atlantic salmon are declining throughout much of their native range, particularly in southern regions. Numbers of returning adults in the Northwest Atlantic have declined by 68% between early 1980s and the mid-1990s, and have remained low since then. As a result, populations such as those in Maine and in the Inner Bay of Fundy were listed as endangered in the United States and Canada, respectively. More recently, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has recommended extending endangered status to populations in Eastern Cape Breton Island, Anticosti Island, the Nova Scotia Southern Uplands and the Outer Bay of Fundy, as well as threatened status for populations of Newfoundland's South Coast.

Resilience

Holling (1973) proposed that the behavior of ecological systems could be defined by two properties, stability and resilience. Stability refers to the ability of a biological system to return to equilibrium after a disturbance and resilience is a measure of the system's ability to absorb fluctuations and still maintain its basic system of relationships without flipping into a different configuration. In this age of rapid environmental change, the resilience of ecological systems and the role that biological diversity plays in this have become a predominant theme in ecology and conservation biology. The thinking is that more diverse systems provide greater buffering to environmental variation, an idea analogous to the benefits of asset diversity in a financial portfolio (e.g. the spreading of risk). Much of the initial focus in ecology was on the contribution of species diversity to ecosystem resilience, with little consideration given to the importance of biological diversity within individual species. This perspective, however, has expanded to recognize that population and life history diversity are similarly keys to species and population resilience. Research on fishes, particularly salmonid fishes, has been at the forefront of this change (Hilborn et al. 2003; Greene et al. 2010; Schindler et al. 2010; Moore et al. 2010; Carlson and Satterthwaite 2011).

Among the best examples of the importance of intraspecific diversity in buffering the effects of environmental variability derives from research on the sockeye salmon (*Oncorhynchus nerka*) complex of Bristol Bay, Alaska (Hilborn et al. 2003; Greene et al. 2010; Schindler et al. 2010). Hilborn et al. (2003) showed that several hundred discrete spawning populations, having diverse life history characteristics and local adaptations, enabled the complex to sustain its productivity despite major fluctuations in climatic conditions affecting the freshwater and marine environments. In essence, different geographic and life history components of sockeye populations that were minor producers during one climatic regime were dominant during others. Schindler et al. (2010) estimated that the complex of populations was shown to be 77% more stable than if the system consisted of a single homogenous population, with life history diversity being central to this buffering capacity (Greene et al. 2010). These results point to the fundamental importance of population and life history diversity in providing resilience to environmental variation, including that from anthropogenic sources (e.g., habitat destruction, homogenization of populations). Habitat diversity will provide the basis for the expression of life history complexity within populations, as well as population complexity (biodiversity), and in doing so, provide resilience. Therefore, any recovery program will likely need to be founded on habitat restoration and protection.

Salmon Recovery

In conjunction with habitat restoration and protection, harvest regulation and addressing other sources of mortality, captive breeding (hatcheries) has become one of the main approaches to restoration. For a long time, however, the contributions of hatcheries were not so auspicious in terms of salmon conservation. With the ability to artificially spawn and rear salmonid fishes came the belief that humans should control reproduction and increase the numbers of salmon. A hatchery model was born that reflected the industrial revolution in some ways, and became a "techno fix." That is, they were seen as a means of replacing lost habitat and production, and parts (populations) were considerable interchangeable. This was in contrast to what we now realize is the uniqueness of populations as expressed in local adaptations. At one point, the US Fish Commission proclaimed that "artificial propagation would make salmon so abundant there would be no need to regulate harvest or protect habitat." This vision of hatcheries persisted for nearly a century from the 1860s to 1960s, and salmon were moved within and outside of their native range.

Holes, however, began to appear in the hatchery model as expected returns were not there and in some cases, populations experienced remarkable declines in productivity. There was recognition that a production model of hatcheries was not compatible with a conservation model. Moreover, with the changing shape of restoration in the 1990s, questions were raised about the role of traditional hatcheries. It became clear that the very nature of hatcheries (i.e. divergent from nature) significantly reshape salmon through developmental and evolutionary forces that can impair a fish's performance in the wild. For hatchery supplementation of wild populations to be considered successful it must not only bypass high, natural mortality that fish experience during particular life stages, but also have those fish survive, breed and produce offspring that *contribute* to natural production in the wild (i.e. not simply replace or displace it). However, success is difficult as evident from the studies that have investigated it (Table 1.1).

Table 1.1. Summary of studies comparing relative success of wild and hatchery salmon.

Type	Species	Relative Success (Hatchery : Wild)	Reference
Near-natural streams (breeding to egg deposition)			
Hatchery	coho salmon	0.61 – 0.82	Fleming & Gross 1993
Hatchery	Atlantic salmon	0.66 – 0.86	Fleming et al. 1997
River releases (genetic screening)			
Hatchery	steelhead	0.75-0.79 (0+ parr)	Leider et al. 1990
Hatchery	steelhead	0.04-0.07 (2+ smolts)	McLean et al. 2004
Hatchery	steelhead	0.18-0.37 (2+ smolts)	Kostow et al. 2003
Hatchery	steelhead	0.06-0.87 (lifetime)	Araki et al 2007a,b, 2009
Hatchery	brown trout	0.78-0.97 (0+ parr)	Dannewitz et al. 2004
Hatchery	brown trout	0.09 (lifetime)	Hansen 2002
Hatchery	coho salmon	~1.0 (lifetime)	Ford et al. 2006
Hatchery	coho salmon	0.62-0.95 (lifetime)	Thériault et al. 2011
Hatchery	Chinook salmon	~1.0 (lifetime)	Hess et al. 2012
Hatchery	Atlantic salmon	0.30-0.64 (0+ parr)	Milot et al. 2013

Captive Breeding

Captive or conservation breeding programs are now charged with limiting further demographic decline and helping in the restoration of population viability. Such programs, however, face several obstacles, including inbreeding depression, loss of genetic variation, accumulation of deleterious alleles, adaptation to captivity that is deleterious in the wild, and outbreeding depression. Numerous tools, some species-specific, are used to mitigate these concerns associated with domestication, including mean-kinship minimizing breeding designs, equalizing reproductive success, minimizing the time or generations spent in captivity, and mimicking natural environments in captivity.

The environment experienced early in ontogeny can greatly influence phenotypic development and fitness of an organism. Salmon are reared in captive environments for many reasons, including restocking into nature. Phenotypic traits of salmon reared in captivity are markedly different than those of their wild counterparts and it has been observed that captive-reared fish typically perform poorly in wild environments. Recent efforts have attempted to mitigate this problem by manipulating conditions in fish-rearing facilities to promote the expression of phenotypic traits that may be more favorable in nature. In a study by John Winkowski, an MSc student in my laboratory, Atlantic salmon eggs were incubated in two environments (with and without gravel) until emergence (‘swim-up’). He found that gravel-incubated fish were heavier and in better condition, fed more readily on live prey, and outperformed (in terms of growth and survival) non gravel-incubated fish in semi-natural stream channels. In addition, fish from the complex incubation environment took on average longer to reappear from shelter after a simulated predator attack. He did not detect differences (absolute or size-corrected) in whole brain, telencephalon, or olfactory bulb volumes of fish incubated in the two environments. His results suggest that adding gravel to incubation environments in captivity can have a significant influence on phenotypic development of juvenile Atlantic salmon and that gravel-incubated salmon may have an advantage if releasing them into the wild for restocking.

Another series of experiments, led jointly by Melissa Evans and Nate Wilke, postdoctoral fellow and PhD student, respectively, in my laboratory, explored the transgenerational effects of parental rearing environment (exposure to the wild) on the survivorship of captive-born offspring in the wild. As natural populations decline, captive breeding and rearing programs have become essential components of conservation efforts. However, exposure to captivity, particularly during development, can cause unintended phenotypic and/or genetic changes that adversely impact on population restoration efforts. They tested whether the ontogenetic exposure of captive-reared Atlantic salmon to natural river environments (i.e. “wild-exposure”) can serve as a mitigation technique to improve the survivorship of descendants in the wild. Using genetic pedigree reconstruction, they observed a two-fold increase in the survivorship of offspring of wild-exposed parents compared to the offspring of captive parents. Their results suggest that harnessing the influence of transgenerational effects in captive-rearing programs may substantially improve the outcomes of endangered species restoration efforts.

Conclusions

(1) Captive rearing environments can be altered to promote phenotypic traits that may be more favorable in nature. (2) Wild exposure can improve short (within generation) and long term (transgenerational) fitness in captively bred populations. Captive rearing and supplementation , however, are not without potential ecological and genetic risks that include: (a) removal of wild fish for broodstock; (b) alter phenotypes and domestication (reducing biodiversity); (c) impede future adaptation; (d) disguise problems (e.g. habitat degradation) by appearance of high local abundance; (e) enhance predator populations; and (f) allow for "surplus" for exploitation, with concomitant mortality of wild fish. While there are clear risks, the potential value of captive breeding is large. Our understanding of how to effectively use and manage it is growing, but remains far from complete. It should be recognized as a temporary tool and should not inhibit other restoration /recovery measures. Finally, it will not be sufficient by itself to restore resiliency.

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2. Session 1: Regional Perspectives

2.1 New England

Joan Trial, Department of Marine Resources (retired)

Overview of the salmon resource in the region

There are three programs within New England; each is related to an historic meta-population area (Figure 2.1.1); Long Island Sound (LIS), Central New England (CNE), and Gulf of Maine (GOM). A subset of the Maritimes Region Atlantic Salmon Designatable Unit 16 (Outer Bay of Fundy) also contributes to the New England Atlantic salmon resource as some of its area lies within northern and eastern New England. The NASCO Rivers Database lists 45 historic Atlantic salmon rivers in New England, two of which are shared with Canada (Maritimes Region Atlantic Salmon Designatable Unit 16: Outer Bay of Fundy) and not included in any of the New England programs. The species is extirpated from most rivers (28), and populations are maintained annually by hatchery support in 13. The others either have intermittent stocking (3) or natural reproduction (1).

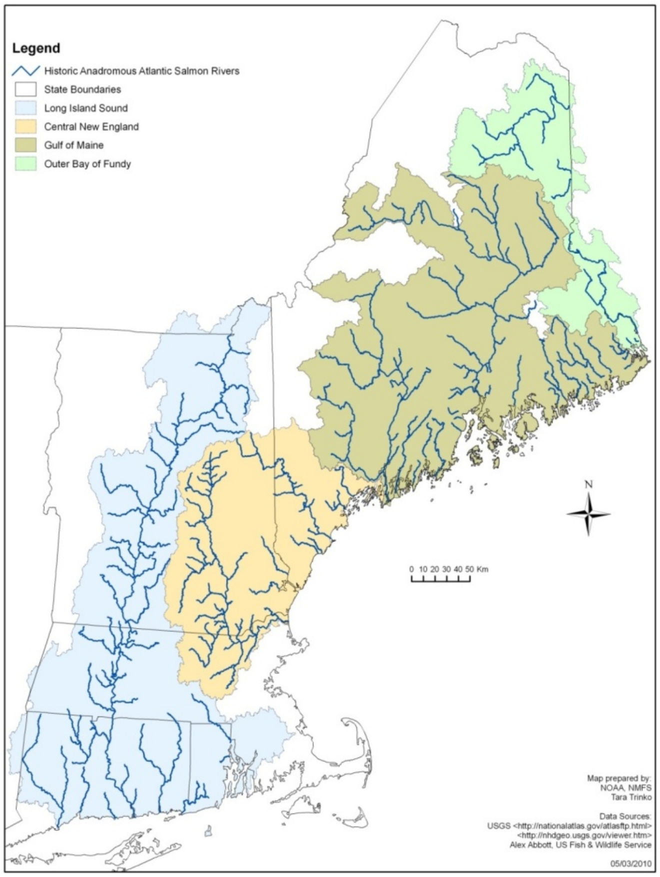

Figure 2.1.1 Map of geographic areas used in summaries of New England data for returns and stocking in 2012.

Returns are well below conservation spawner requirements and haven't exceeded 6,000 spawners in 30+ years (Figure 2.1.2). For 2012 returns of 2SW fish from traps, weirs, and estimated returns were only 3 % of the 2SW conservation spawner requirements, with returns to the three areas ranging from 1.2 to 4.5 % of spawner requirements (Table 2.1.1). Most returns in 2012 occurred in the Gulf of Maine area, with the Penobscot River accounting for 66% of the total return (Figure 2.1.3). Most (74%) returns were of hatchery smolt origin and the balance (26%) originated from natural reproduction, planted eggs, or hatchery fry. Annual assessment updates for the New England stock complex are provided by the U.S. Atlantic Salmon Assessment Committee (http://www.nefsc.noaa.gov/USASAC/Reports/).

Table 2.1.1. Documented 2012 Atlantic salmon returns to New England by Distinct Population Segments (Gulf of Maine (GOM), Central New England (CNE) and Long Island Sound (LIS)). "Natural" includes fish originating from natural spawning and hatchery fry.

Area	1SW		2SW		3SW		Repeat Spawners		
	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	TOTAL
LIS	0	0	1	55	0	0	0	0	56
CNE	0	1	93	27	15	3	0	0	139
[1] GOM	14	9	560	145	9	0	2	5	744

[1] Includes numbers based on redds, ages and origins are pro-rated based upon distributions for GOM coastal rivers with traps

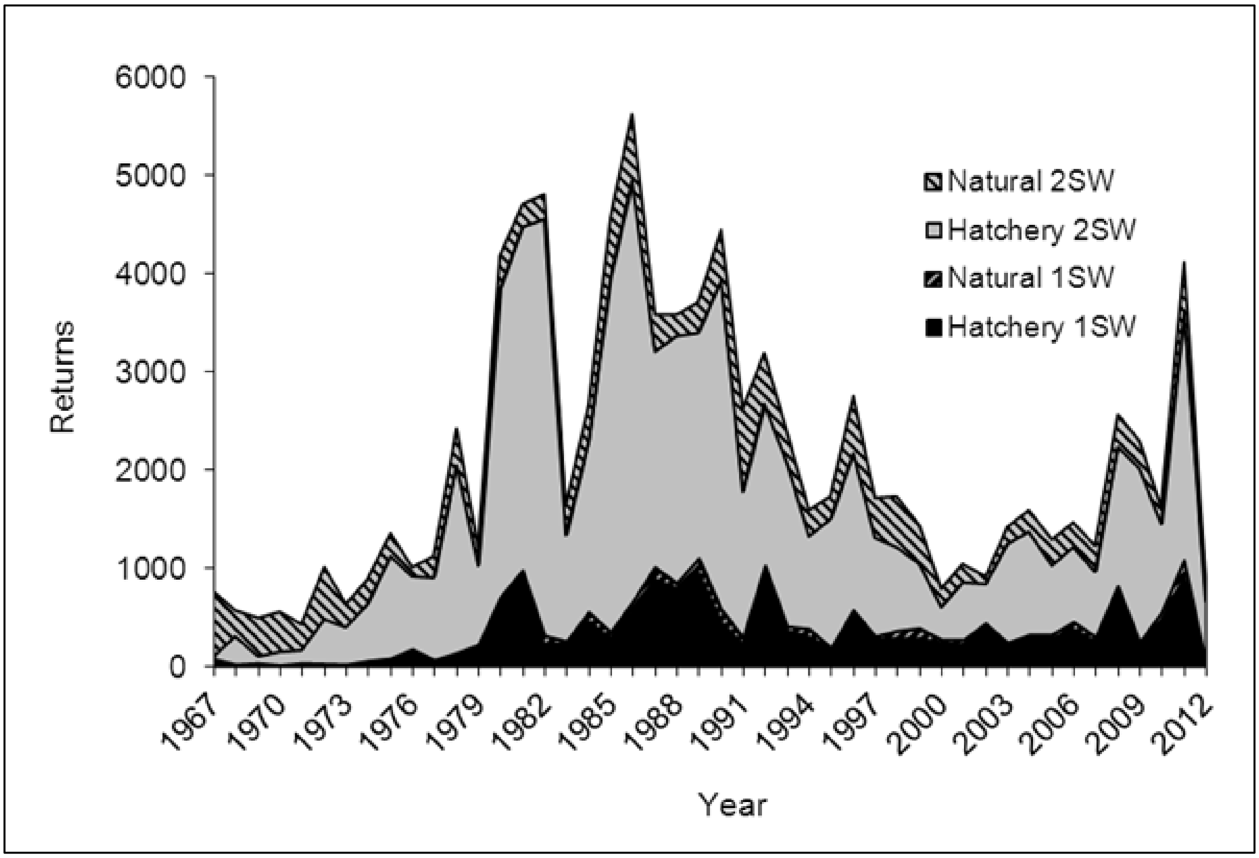

Figure 2.1.2. Origin and sea age of Atlantic salmon returning to New England rivers, 1967 to 2012.

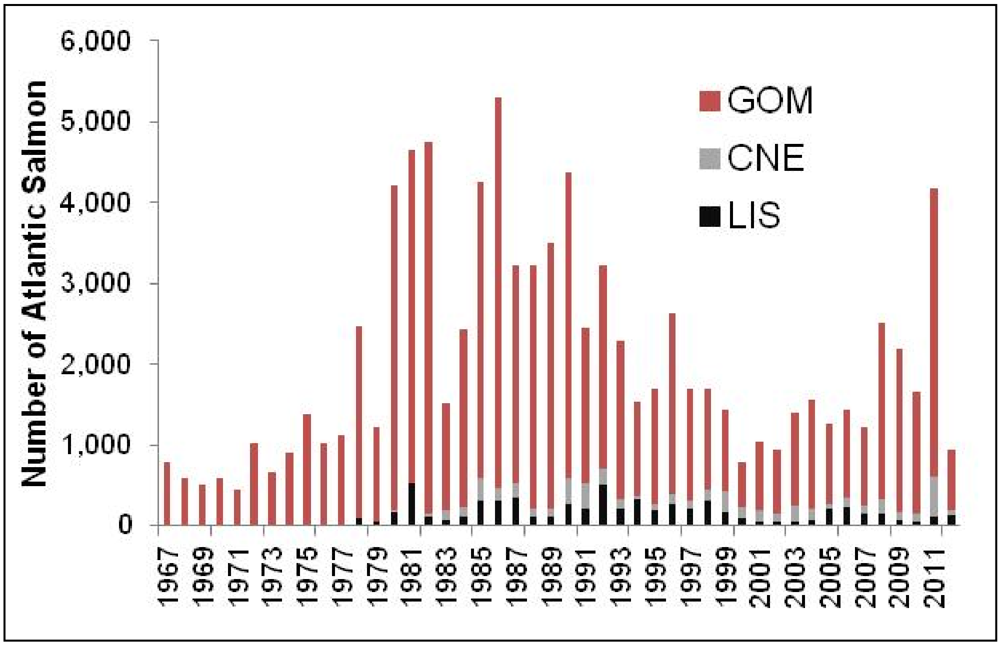

Figure 2.1.3. Number of Atlantic salmon returning to New England rivers, 1967 to 2012 by Distinct Population Segments (Gulf of Maine (GOM), Central New England (CNE) and Long Island Sound (LIS)).

Overview of the threats within the region

Current threats to Atlantic salmon persistence in New England are: low marine survival (estuarine and North Atlantic) related to 1) global climate change, 2) predation, 3) shift in ocean ecology; and freshwater survival compromised by reduced habitat access and productivity, and altered thermal and hydrologic regimes (climate change and land use). Commercial and recreational fisheries for sea-run Atlantic salmon are closed in USA waters although US origin fish are still subjected to mixed-stock fisheries operating at Saint-Pierre et Miquelon, Labrador Canada and off the west coast of Greenland.

Overview of program objectives

The primary role of hatcheries is to prevent extinction and maintain genetic diversity of remaining stocks of Atlantic salmon from New England. Long term goals are to recover self-sustaining naturally reproducing populations and eliminate hatchery population support. Current hatchery programs provide most of the recruitment to freshwater and marine habitats in New England.

Overview of recovery actions within the region

There is the belief that Atlantic salmon recovery is a function of the status of the co-evolved diadromous species complex (community) as well as the quality (conditions) and accessibility of physical habitat (connectivity). Freshwater recovery actions for Atlantic salmon in New England are focused on addressing threats associated with these three themes. Marine recovery actions are focused on understanding the causes driving decreased marine survival and using the information gained to improve the management of the species.

Connectivity

Programs throughout New England are focusing on improved access to habitat for all diadromous species by negotiating better fish passage at dams through Federal Energy Regulation Commission relicensing, large and small dam removals (e.g. Penobscot River Restoration Project (http://www.penobscotriver.org/) to legacy mill and logging dams), and replacing undersized culverts and bridges with ones appropriately sized for ecological connectivity along stream corridors.

Conditions

Actions are targeted at increasing the carrying capacity of freshwater habitat for Atlantic salmon, focusing on improving physical (channel), thermal, hydrologic, and chemical (water quality) conditions. Riparian land protection, through purchase, easement, education, and regulation in conjunction with riparian plantings are a direct way to influence stream temperatures and hydrology. Wood loading is low in New England streams because it was removed to facilitate log driving. In addition, dams were built and streams were cleared of wood and boulders to drive logs to mills. Removing the remnants dams and adding large wood to streams changes thermal and hydrologic conditions. Reduced deadwater areas reduce temperatures and large wood increases velocity variability, alters sediment sorting, creates pools, and provides cover for juvenile fish. Nutrient limitation can be an important control on salmon production and population abundance. In the short- and mid-term, stream productivity depends on upstream/upslope inefficiency in nutrient processing and retention. In the long-term, reductions in nutrients in forests and soils will be reflected in stream dynamics. Acidification and forest practices are potential sources of cultural oligotrophication in small coastal rivers and these two sources may interact because both result in depleted soil cations. Maine is adding marine mollusk shells in reaches with low pH to affect water quality. Additions of carcass analogs, while experimental to this point, promise to increase productivity of streams. The issue is how to do artificial additions on a watershed scale, which is why there is a focus on restoring the diadromous fish community in New England.

Community

Diadromous fish species populations are depleted in New England. Efforts to prevent further declines and restore these species are being pursued as a healthy co-evolved diadromous complex is believed to provide significant ecosystem functions necessary for Atlantic salmon restoration (Saunders et al. 2006). Anadromous species effectively transfer nutrients from the marine system to typically less productive freshwater environments through discharge of urea, gametes, and deposition of post-spawn adult carcasses. Further assimilation, transport, and, ultimately, supplemental/secondary deposition of these nutrients also likely resulted from the activities of predators and scavengers present along the migration routes. Conversely, juvenile emigrants of these sea-run species represented a massive annual outflux of forage resources for Gulf of Maine predators, while also serving to complete the cycling of imported base nutrients back to the ocean environment. The dynamics and ecological significance of this nutrient cycling function by anadromous fish species assemblages has been well established for North American Pacific coastal ecosystems but is less studied in New England.

Shad, alewife, and blueback herring are native to Atlantic salmon watersheds. In high numbers these species likely provided a robust alternative forage (or prey buffer) for opportunistic native predators of salmon. Immigrating alewife and blueback herring overlap emigrating salmon smolts in upper and middle estuaries when avian predators are active. Adult shad likely provided alternate prey for otters and seals consuming immigrating Atlantic salmon adults. Juvenile shad and blueback herring could have represented a substantial prey buffer toward potential predation on Atlantic salmon fry and parr by native opportunistic predators such as mergansers, herons, mink, and fallfish. The historical abundance of other diadromous species may have represented significant food resources for juvenile salmon in sympatric habitats. Anadromous rainbow smelt are known to be a favored spring prey item of Atlantic salmon kelts. Sea lamprey, in constructing their nests, likely alter substrate making it more attractive to spawning Atlantic salmon and their carcasses are a spring influx of nutrients to coastal streams just as salmon are emerging from redds.

In addition, non-native fish species have been spread throughout New England, legally and illegally, primarily as game fishes for recreational anglers. Species include brown trout, rainbow trout, smallmouth and largemouth bass, and northern pike. In Maine, agency consultations have reduced or eliminated stocking non-native salmonids in most GOM Atlantic salmon watersheds and non-native fish daily bag limits have been liberalized. Northern pike, recently introduced to a lake in Penobscot River sub-drainage are being captured and removed during their spawning period.

<u>Marine</u>

Marine recovery actions are primarily research focused investigating the causal mechanisms driving the decreased marine survival of North American stocks. Ultrasonic telemetry studies investigate the dynamics and cause of nearshore mortality. Ocean sampling programs investigate the marine ecology of the species and mixed-stock fishery sampling assesses the contributing stocks to the remaining fisheries harvesting New England fish. Results from these programs contribute to the management of the species in terms of adaptive management programs to increase adult returns, knowledge based permitting and for hatchery product betterment and use and to help inform international negotiations concerning mixed-stock fisheries.

Overview of the role of hatcheries in the region

The modern New England conservation model includes maintaining river specific stocks through the collection of wild-exposed juveniles at a late stage in freshwater for captive broodstock, DNA-based mating to maximize genetic variability; early stocking of progeny (eyed eggs, or fry) to maximize natural selection in freshwater, or the release of captive-reared adults for natural spawning to allow for mate choice and selection from the egg stage. In addition to captive reared broodstock (12% of eggs), New England programs also use gametes from sea run returns captured at dams (25.6%), domestic (62% hatchery adults reared from sea run eggs), and rejuvenated kelt (0.4%) spawners.

Stage at stocking has been heavily weighted to fry, however, all life stages from eggs to adult are stocked (Figure 2.1.4), with spatially and temporal segregation observed to allow the recapture of broodstock from each and tracking effectiveness in contributing to the next generation. During 2012 about 6,936,800 juvenile salmon (83% fry) were released into 13 river systems. The 419,000 parr released in 2012 were primarily the by-products of smolt production programs. The majority of smolts were stocked in one river in each of the areas: Long Island Sound DPS (71,200), Central New England DPS (11,900), and Gulf of Maine DPS (555,000). In total, 5,097 adult salmon were also released into New England rivers with more than half these adults being spent broodstock. The number of juveniles released was less than in 2011 because one Federal hatchery in the Long Island Sound DPS was closed and hatchery production within the Central New England DPS was reduced. An overview of current hatchery resources in New England is as follows:

<u>Long Island Sound DPS</u>

- Number of hatcheries (3) and affiliation: State (2) and Private (1)
- Broodstock source: Connecticut River specific stock
- Primary product: Fry stocking

<u>Central New England DPS</u>

- Number of hatcheries (3) and affiliation: Federal (2) and Private (1)
- Penobscot River base stock
- Primary Products: Fry, parr, smolt (production and stocking ended in 2014/2015)

<u>Gulf of Maine DPS</u>

- Number of hatcheries (5) and affiliation: Federal (3) and Private (2)

- Primary Products: All life stages (egg to adult) stocked

The estimated annual operating cost for all Federal hatcheries is approximately 3 million (USD) annually). Approximately, 300 thousand (USD) are spent annually on genetic monitoring and an additional 2.5 million (USD) on annual monitoring programs associated with the hatchery operations.

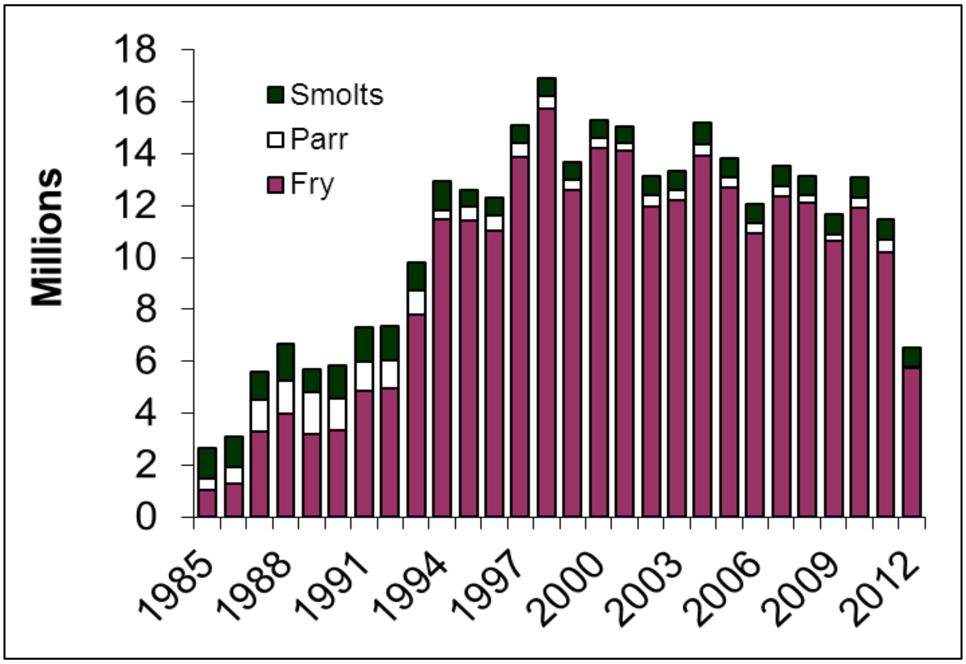

Figure 2.1.4. Number of Atlantic salmon stocked by life stage in New England rivers, 1985 to 2012. Adult stocking numbers are not presented but amount to less than a few thousand per year in year years.

2.2 Quebec

Julien April Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs

Overview of the salmon resource in the region

In the past few years, around 37,000 multi-sea-winter (MSW) and 25,000 one-sea-winter (1SW) Atlantic salmon have returned to the 114 salmon rivers of Quebec **(**Figure 2.2.1). Returns of Atlantic salmon are down from historic highs, but have remained relatively stable over the past 2 decades (Figure 2.2.2). A total of 40 rivers are monitored through direct adult counting. A long term monitoring program of both adults and smolts is conducted in 2 rivers. In the last five years, more than half (52 % to 79 %) of monitored rivers reached their conservation limits.

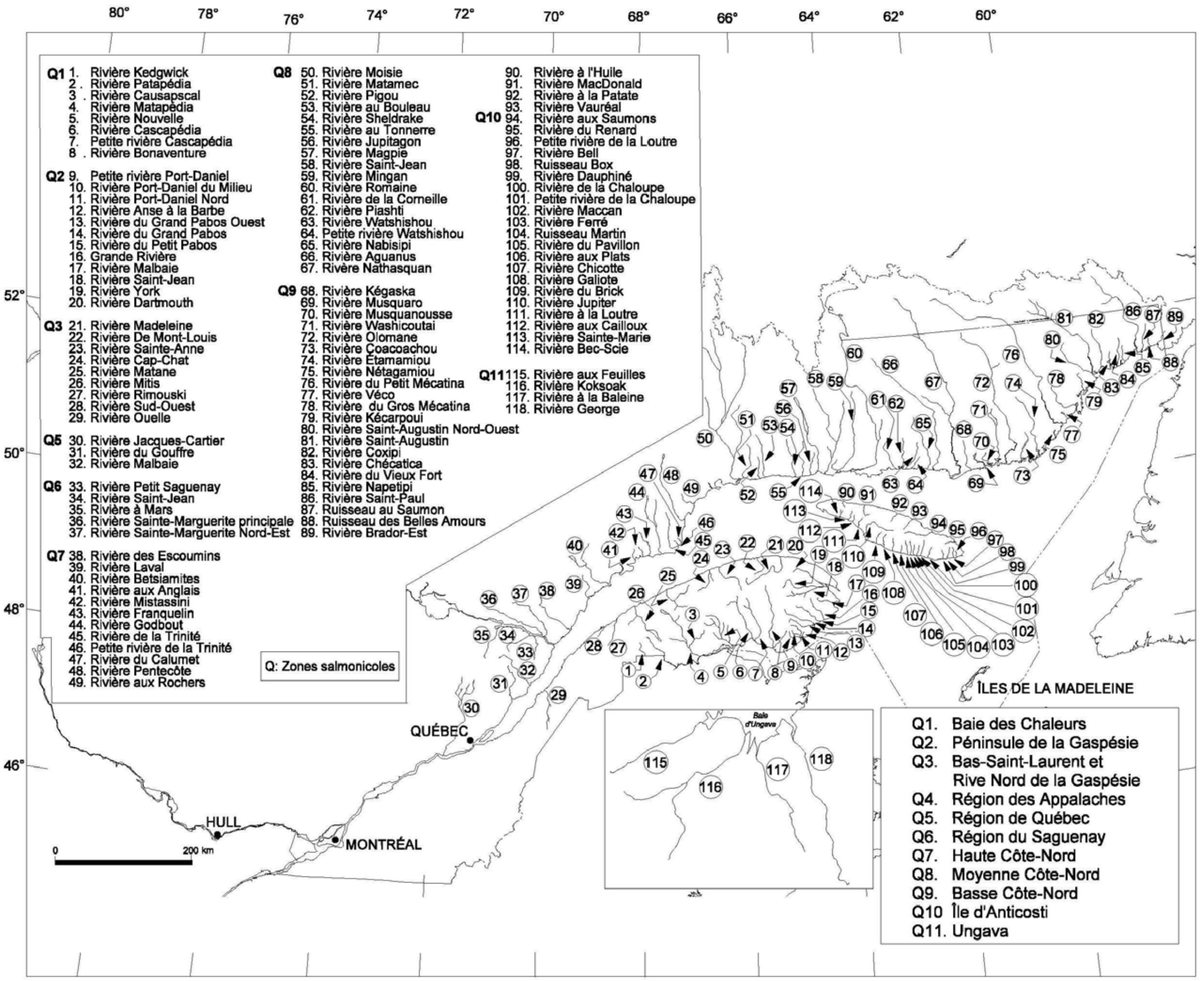

Figure 2.2.1. Map of the Atlantic salmon rivers of Quebec.

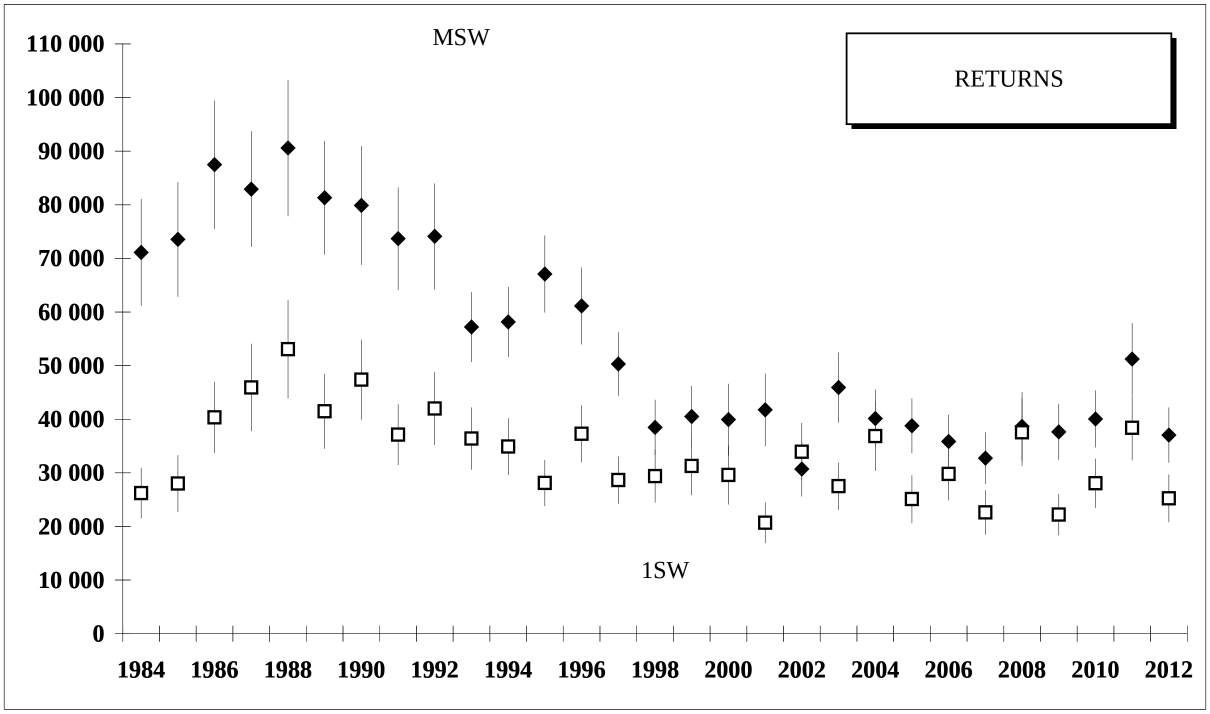

Figure 2.2.2. Number of multi-sea -winter (MSW) and one-sea-winter (1SW) Atlantic salmon returning to Quebec's rivers.

Total exploitation rate in 2013 was 15%. Native fisheries harvested a total of 3,449 salmon (15,706 kg) and recreational fisheries harvested 5,828 salmon (21,732 kg). There are no commercial fisheries for Atlantic salmon in Québec.

Overview of the threats within the region

The main general threats to Atlantic salmon in Quebec is reduced marine survival. The increased marine mortality rate observed in different populations may be caused by ecological changes and global warming. In freshwater, threats may include global climate change affecting temperature and water levels, exotic species (e.g. Rainbow trout), and habitat deterioration.

Overview of program objectives

The general objective of Atlantic salmon management in Quebec is to ensure the self-perpetuating of populations. This is mainly done through exploitation control and through the conservation/restoration of habitat. Management promoting the natural reproduction of wild individuals is always privileged over other approaches.

Hatcheries are used for conservation purposes. Atlantic salmon are stocked in populations that have reduced abundance, to increase the population to a secure size. Hatcheries are not used to enhance fishing potential.

Overview of recovery actions within the region

Different recovery actions have been undertaken to restore Atlantic salmon populations, including stocking, dam removal, the use of fish ladders, and habitat restoration.

Overview of the role of hatcheries in the region

Millions of juvenile Atlantic salmon have been stocked into Québec watersheds since 1857. In 2003, the stocking of smolts was stopped given the reduced rate of return (i.e. marine survival) of hatchery origin smolts compared to wild origin smolts. As an alternative, 0+ parr stocking programs were implemented. In 2013, four rivers were included in the governmental stocking program. Stocked 0+ parr are intensely monitored, all fish being marked and adult returns being monitored on all stocked rivers.

Governmental hatcheries have played an important role in restoration programs. However, concerns have been raised about the potential ecological (competition between stocked and wild juveniles) and genetic impacts (homogenization between rivers and reduced diversity within a river) of such practices. Indeed, when fish and their offspring are moved from one river to another, we expect a decrease in population differentiation and therefore homogenization between rivers and a loss of local adaptation. Even when fish are not moved from one river to another, there are still some concerns. On one hand, when captive individuals from a particular river produce relatively more progeny than their wild counterparts and their offspring are stocked in this same river, the expectation is for a demographic gain, but coupled with a decrease in genetic diversity. On the other hand, when captive individuals produce the same level of offspring as their wild counterparts, the expectation is for no genetic diversity effects, but no demographic gain.

In the actual governmental stocking program, the ecological concerns are addressed by reducing potential competition between wild and stocked juveniles. This is done by only stocking Atlantic salmon in rivers that have low population size (i.e. populations below conservation limits). Furthermore, fish are stocked in river segments with low wild juvenile densities.

Different measures have been adopted to address the genetic concerns. The genetic integrity of the salmon population is protected by using spawners that are from the population to be stocked. For each river, at least 30 broodstock (or 10% of the wild population) are used to obtain a representative genetic composition for the stocked fish. Demographic and population genetic modeling (Ryman and Laikre 1991) is used to evaluate the number of juveniles to be stocked in each of the rivers to ensure that the stocking program will allow a demographic increase of at least 15% without a loss of over 10% of the effective population size.

References

Ryman, N. and L. Laikre. 1991. Effects of supporting breeding on the genetically effective population size. Conservation Biology. 5: 325-329.

2.3 Newfoundland and Labrador

Martha Robertson, Fisheries and Oceans Canada

Overview of the salmon resource in the region

There are 394 Atlantic salmon Rivers in Newfoundland (305) and Labrador (89); 186 of which are scheduled for recreational salmon fishing (158 and 28 respectively). Atlantic salmon population monitoring facilities are located on 16 rivers throughout the region (Figure 2.3.1). In general, abundance of small and large salmon varies annually across Newfoundland and Labrador (Figure 2.3.2 and 2.3.3). The only notable trend in population is the increase in large salmon abundance since 2010 in Labrador (Figure 2.3.3). On a smaller scale, the south coast of Newfoundland (SFAs 9-11, Figure 2.3.1) salmon populations decreased from 1994-2007 by 37% and 25% for small and large salmon respectively. The Committee on the Status of Endangered Wildlife in Canada designated South Newfoundland (Designatable Unit, DU 4) salmon populations as Threatened in 2010 (COSEWIC, 2010). The other four DUs proposed for Atlantic salmon in Newfoundland and Labrador were assessed as Not at Risk.

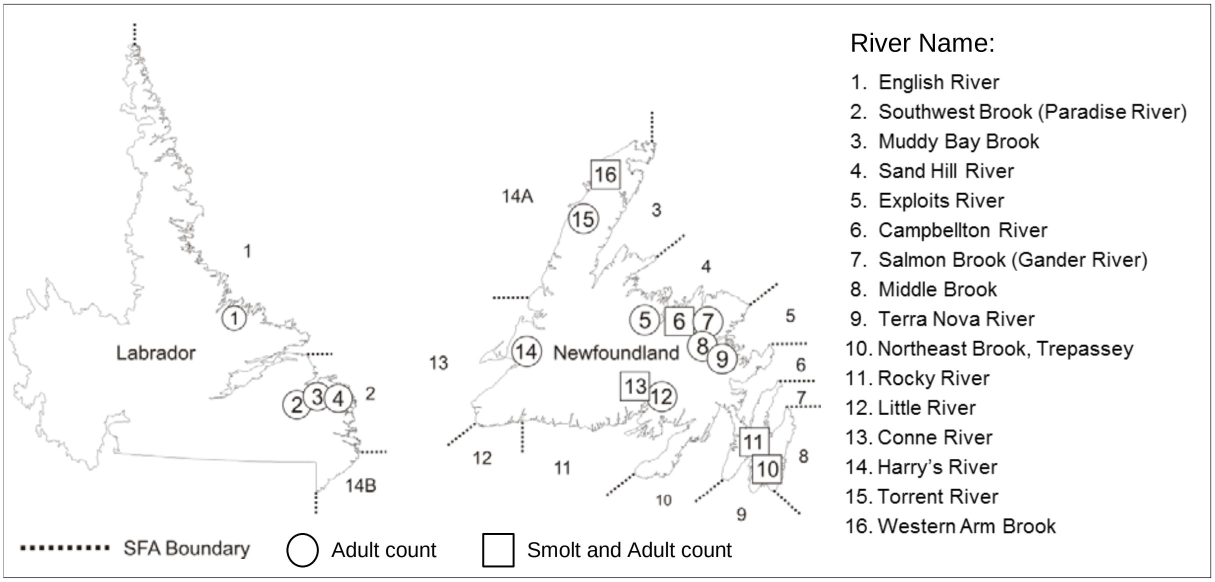

Figure 2.3.1. Salmon Fishing Areas (SFAs) and assessment locations in Newfoundland and Labrador.

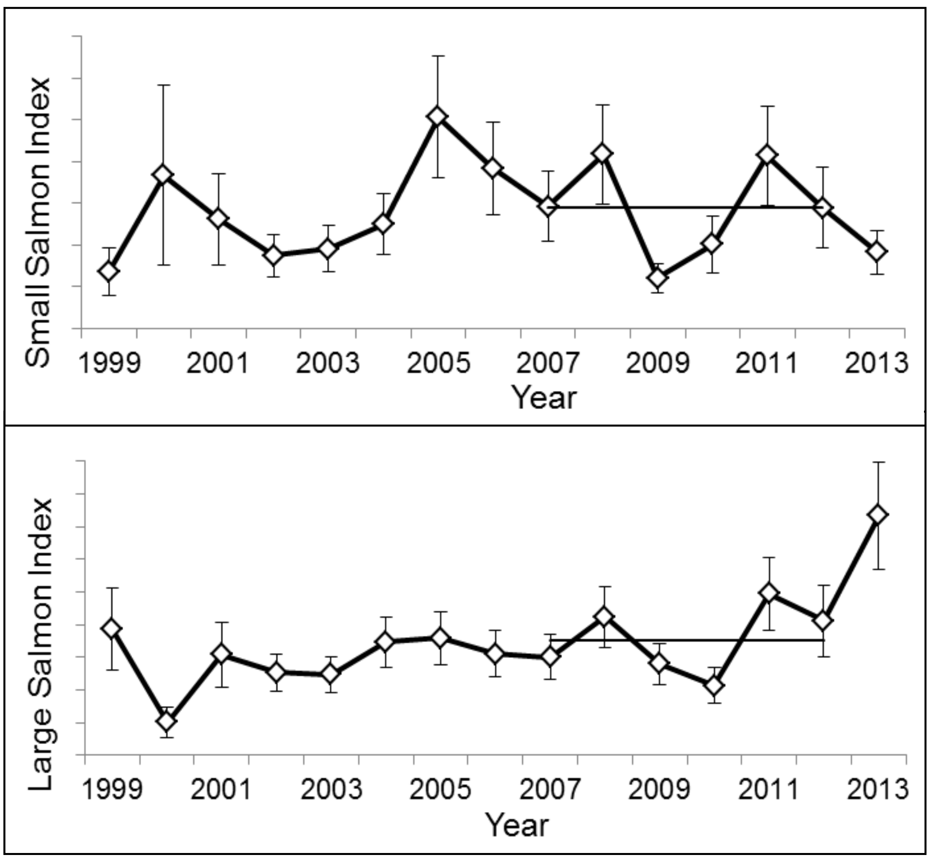

Figure 2.3.2. Trends in abundance of small and large Atlantic salmon in Labrador, 1999 to 2013. Horizontal lines illustrate the previous six-year mean 2007-2012. Vertical lines represent ± 1 standard error.

For the monitored Atlantic salmon river populations (Figure 2.3.1), six (40 %) of the 15 in Newfoundland and Labrador achieved their conservation egg requirement in 2012 (Table 2.3.1). Of the nine populations that did not achieve conservation, three have historically undergone enhancement activities including fish passage and stocking which opened up new habitat that may still not be colonized. The remaining six stocks that failed to achieve conservation are in SFA 2 (2 stocks), SFA 9 (1 stock), SFA 11 (2 stocks) and SFA 13 (1 stock) (Figure 2.3.1).

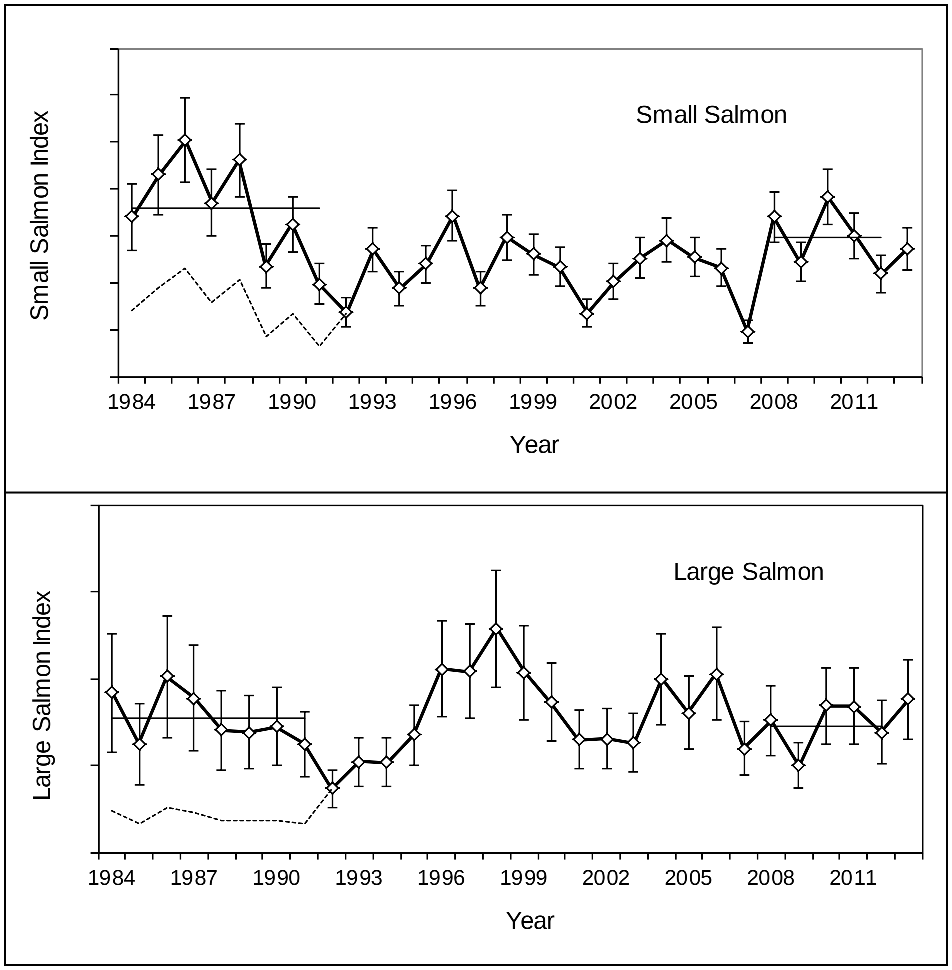

Figure 2.3.3. Trends in abundance of small and large Atlantic salmon in Newfoundland, 1984-2013. Returns from 1984 to 1991 have been corrected to account for marine exploitation. Horizontal lines illustrate the mean abundance index for the periods 1984-1991 and 2008-2012. Vertical lines represent ± 1 standard error. The fine dashed line represents returns unadjusted for exploitation for the period 1984-1991.

Table 2.3.1. Summary of Atlantic salmon population status in Newfoundland and Labrador, 2012.

Region			Total Returns				Conservation Egg Requirement Achieved (%)			Status in 2012		
			2012		2006-2011 mean					Smolts Relative to:	Marine Survival Relative to:	Conservation Achieved Relative to:
River	SFA	Method	Small	Large	Small	Large	2012	2006-2011 mean	2006-2012	2006-2011 mean	2006-2011 mean	2006-2011 mean
LABRADOR												
English River	1	Fe	**423**	**82**	403	75	**129**	120	6 of 7 yrs			⇔
Sand Hill River	2	Fe	**3527**	**734**	4238	678	**96**	108	3 of 7 yrs	⇧		↓
Southwest Bk. (Paradise River)	2	Fe	**211**	**29**	291	28	**75**	96	4 of 7 yrs			↓

Region			Total Returns				Conservation Egg Requirement Achieved (%)			Status in 2012		
			2012		2007-2011 mean					Smolts Relative to:	Marine Survival Relative to:	Conservation Achieved Relative to:
River	SFA	Method	Small	Large	Small	Large	2012	007-2011 me	2007-2012	2007-2011 mear	2007-2011 mean	2007-2011 mean
INSULAR NEWFOUNDLAND												
Northeast Coast (SFA's 3-8)												
Exploits River	4	Fw	**25349**	**5578**	31953	5778	**49**	63	0 of 6 yrs			↓
Campbellton River	4	Fe	**3755**	**548**	3691	486	**394**	364	6 of 6 yrs	⇧	⇔	⇔
Gander River [1]	4	EFw	**22652**	**1698**	20409	1407	**128**	111	5 of 6 yrs			⇧
Middle Brook	5	Fw	**2828**	**173**	2137	135	**299**	215	6 of 6 yrs			⇧
Terra Nova River	5	Fw	**3746**	**452**	3346	373	**64**	56	0 of 6 yrs			⇧
South Coast (SFA's 9-11)												
Northeast Brook (Trepassey)	9	Fe	**24**	**0**	64	3	**55**	148	5 of 6 yrs	⇔	↓	↓
Rocky River	9	Fe	**430**	**30**	616	39	**46**	66	0 of 6 yrs	↓	⇔	↓
Little River	11	Fe	**65**	**4**	139	4	**30**	61	1 of 6 yrs			↓
Conne River	11	Fe	**1965**	**71**	1826	85	**79**	75	1 of 6 yrs	↓	⇧	⇔
Southwest Coast (SFA's 12-13)												
Harry's River [2]	13	D	**2248**		3188		**64** [3]	96	3 of 6 yrs			↓
Northwest Coast (SFA 14A)												
Torrent River	14A	Fw	**3950**	**474**	3772	1250	**670**	865	6 of 6 yrs			↓
Western Arm Bk	14A	Fe	**1173**	**93**	1382	35	**405**	484	6 of 6 yrs	↓	↓	↓

Assessment Methods:
Fe = counting fence
Fw = fishway count
EFw = estimated from tributary fishway count
D = DIDSON (Dual-Frequency IDentification SONar)

Trend symbols:
↓ > 10% decrease
⇧ > 10% increase
⇔ no change = ± 10%

Footnotes:
Marine survival is from smolts in year i to small salmon in year i + 1.
190 eggs/100 m2 was used to determine the conservation levels for Labrador rivers.
[1] Gander River was assessed using a counting fence 1989-1999, and was estimated from a tributary count after
[2] Harry's River shows total returns of salmon (small + large).
[3] Based on proportion of large from 5 year average (2006-2010).

Overview of the threats within the region

Exploitation

Estimates of retained and total catch (retained + released) in the recreational fishery for Newfoundland and Labrador have been trending up in recent years and the estimates of retained catch and total catch for 2011 are above the previous five-year mean by 17 % and 12 % respectively (Figure 2.3.4). Estimates of removals in the Labrador subsistence fisheries (net fisheries) in 2011 have increased by 21 % and 27 % by number and weight respectively over the previous six-year mean (Figure 2.3.5.).

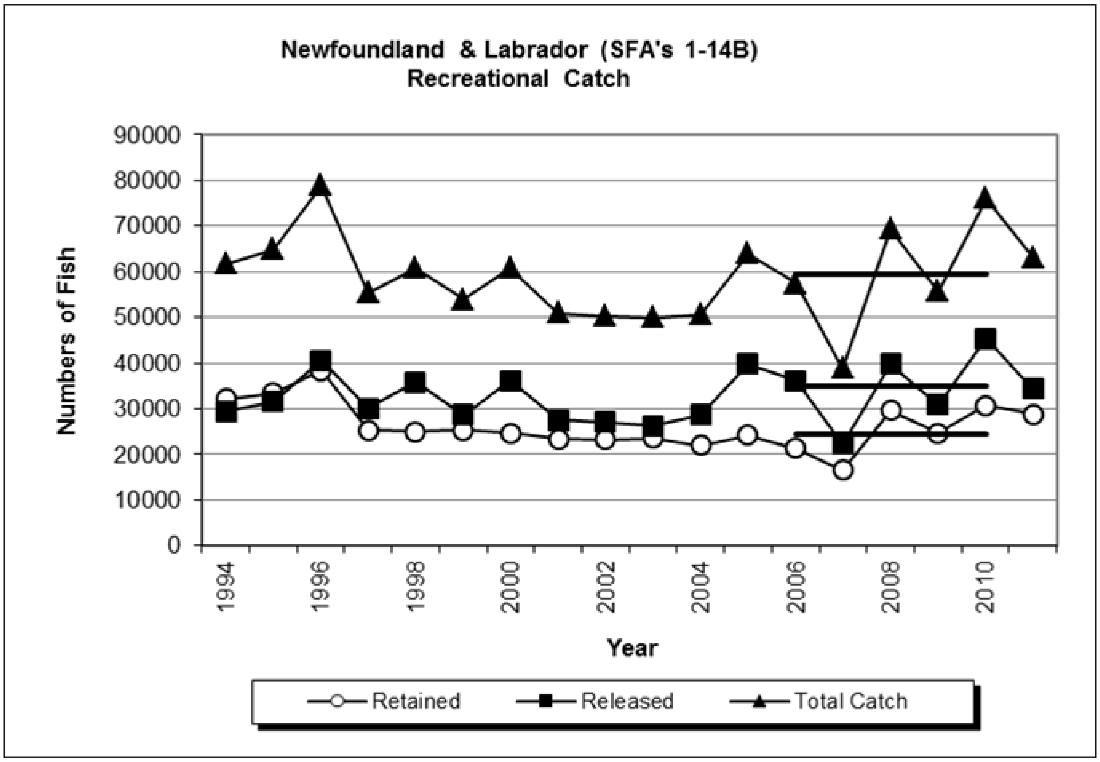

Figure 2.3.4. Angled catch of Atlantic salmon for the Newfoundland and Labrador Region (1994-2011). Horizontal solid line represents the mean for the previous five years (2006-10).

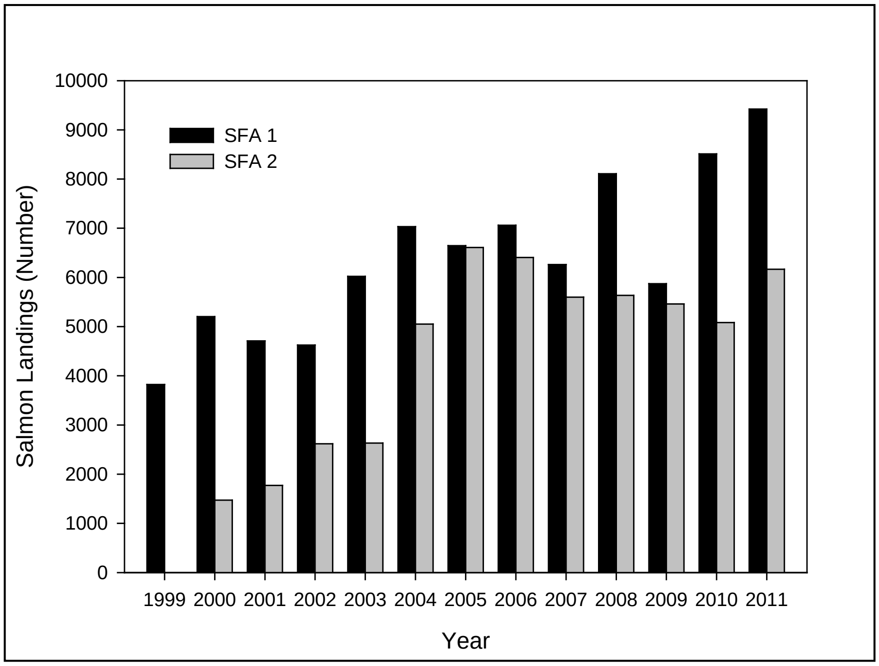

Figure 2.3.5. Landings (number of fish) reported in the Atlantic salmon food fisheries in Labrador for SFAs 1 and 2 (1999-2011).

<u>Marine survival</u>

Marine survival appears to be the major factor contributing to the abundance of Atlantic salmon within the region. Inter-annual variation in the index of marine survival continues to fluctuate widely (Figure 2.3.6.).

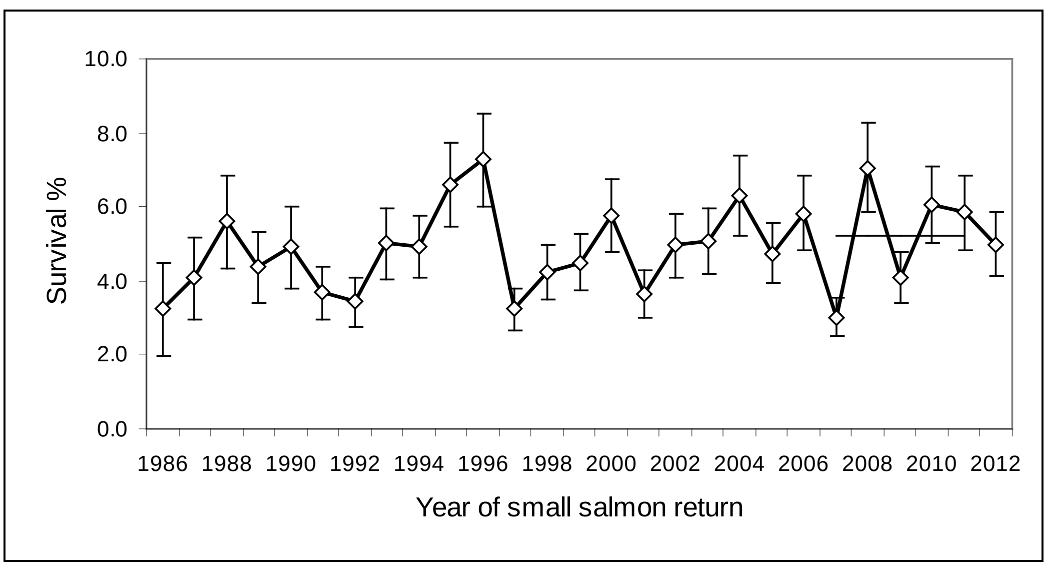

Figure 2.3.6. Standardized mean survival of smolts to adult small salmon derived from a general linear model analysis of monitored Newfoundland rivers. Year represents the year of adult small salmon return. Vertical lines represent one standard error about the mean. Horizontal solid line illustrates the mean for the previous five years (2007-11).

Dams/Hydroelectric power generation

There are a total of 402 dams in the province: 315 dams in Newfoundland (234 hydroelectric, 81 water supplies) and 87 in Labrador (85 associated with Upper Churchill, 2 water supplies). A total of 39 of the dams in Newfoundland are considered major dams (≥10 m, Canadian Dams Association Registry 2003) and they are all hydroelectric.

Eight of these are located on the south coast. The largest facility on the south coast has three hydroelectric stations located at Bay d'Espoir (1967, 604 MW), Upper Salmon (1983, 84 MW) and Granite Canal (2003, 41 MW). Four watersheds (Salmon River, Grey River, White Bear River, and Victoria River) were altered in 1967 with dams to divert water to the Bay d'Espoir station. These diversions did not remove accessible habitat, but did alter natural stream flow. Fisheries compensation water releases do occur for habitat protection and fish migration. The long term impact of the freshwater released into the head of Bay d'Espoir on Atlantic salmon is unknown.

Transportation and infrastructure (Connectivity)

Man-made barriers associated with road construction can fragment Atlantic salmon habitat and reduced connectivity affects the abundance and distribution of Atlantic salmon populations. Culverts are frequently installed at road crossings and improperly placed or designed culverts create barriers through hanging outfalls, increased water velocities, or insufficient water velocity and depth within the culvert (Gibson et al. 2005). Culverts can also degrade upstream and downstream habitat quality and food production as a result of damming, scouring, and deposition of sediments. In addition, bridges with openings less than the natural high flow stream width increase velocities and create hydraulic conditions that can delay or block fish passage, as well as alter or disrupt habitat above and below an improperly designed and installed bridge.

Aquaculture siting

Aquaculture sites have the potential to affect fish habitat predominantly though the accumulation of organic waste. There are 81 licensed salmonid aquaculture sites on the south coast of Newfoundland and approximately 52 of these are in the Bay D'Espoir area (SFA 11). However, not all sites are active in a given year and some sites have never been active. For example, from 2006 to 2010 between 10 and 23 sites were active in each year. The number of active sites is expected to rise and expand into other areas on the south coast.

Agriculture/Forestry/Mining

Pesticides used for agriculture, forestry, and other land use practices can have direct or indirect adverse effects on Atlantic salmon or their habitats. Direct effects occur when Atlantic salmon and the chemical come in direct contact. Indirect effects result from chemically induced modifications to habitat or non-target organisms (e.g. food sources). The effects of pesticides on salmonids may range from acute (leading to sudden mortality) to chronic (leading to increased cumulative mortality).

Many anthropogenic activities associated with or directly the result of forestry and agriculture can cause sedimentation. Clearing vegetation near watercourses or permitting livestock to enter streams and rivers can allow runoff to transport sediments into watercourses. Sedimentation may reduce the quality of spawning substrates and has been shown to reduce the survival of developing eggs and yolk-sac fry.

Mining impacts Atlantic salmon both directly and indirectly. Blasting can directly kill fish and destroy fish habitat. It can also disrupt groundwater patterns, which in turn influence groundwater fed water courses and their associated habitats. Effluents discharged from mines can impact salmon by altering water quality, for example, changing temperature, pH, increasing suspended particulate matter, and introducing heavy metals into the water. The flow of effluents can also indirectly alter downstream erosion patterns and alter hydrology. Another significant threat from mining is water extraction from either ground or surface water, the impacts of which are site specific.

Air Pollutants/Acid Rain

Sulphur-dioxide (SO2) emissions (from metal smelting, coal-fired electrical utilities) and nitrous oxide (NOx) emissions (combustion) are the principal acidifying pollutants transported over long distances and falling as acids in precipitation. Newfoundland watersheds do not appear to be as affected by acidification as those in other regions of eastern Canada. However, research has shown that two areas of Newfoundland have headwater lakes with relatively low pH values, and are likely more susceptible to potential acidification. One of these areas is the southwest portion of the south coast, in DU 4, and the other is the southeastern portion of the Northern Peninsula.

Overview of program objectives

DFO's Salmonids Program in Newfoundland and Labrador is responsible for providing scientific advice regarding the status of Atlantic salmon stocks within the Region. Status information is used by other DFO programs (e.g,. Fisheries Management, Fisheries Protection) to manage and conserve these stocks. Currently, information on the status of Atlantic salmon is collected through the use of 16 monitored rivers located throughout the region.

Overview of recovery actions within the region

Four of the five proposed populations of Atlantic salmon in Newfoundland and Labrador are considered to be Not at Risk (COSEWIC, 2010). The south coast of Newfoundland that was considered Threatened by COSEWIC is not listed under the Species at Risk Act and no recovery actions have been developed or implemented. The Recreational Fisheries Habitat Stewardship Program provides funding for watershed groups to conduct habitat restoration programs.

Overview of the role of hatcheries in the region

Stocking has primarily been used as a tool to increase production of Atlantic salmon through range expansion, primarily from the 1940s – mid-1990s although contemporary projects are currently underway (Rennies River and Rattling Brook projects). New habitat was opened up by fishway construction or colonization and production was supplemented with stocking (adults or unfed fry). All efforts to establish or enhance populations seem to be successful. Straying is cost effective but slower than stocking and naturally spawning adults (stocked or strayed) provided better recruit / spawner than fry stocking. Fry stocking was generally successful when fry were incubated with river water, stocked in non-utilized habitat at 75 fry/100m^2, and transport time was less than 1 hour (O’Connell et. al. 1983; O’Connell and Bourgeois 1987).

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To link to this article: http://dx.doi.org/10.1577/1548-8659(1987)7<207:ASEITE>2.0.CO;2

2.4 Maritimes Region

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Overview of the salmon resource in the region

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) identified four large groups of Atlantic Salmon, referred to as Designatable Units (DUs), in the Maritimes Region: the outer Bay of Fundy (OBoF; corresponding to the western part of Salmon Fishing Area or SFA, 23), the Nova Scotia Southern Upland (SU; SFAs 20, 21 and part of 22), the inner Bay of Fundy (IBoF; part of SFAs 22 and 23), and Eastern Cape Breton (ECB; SFA 19) (Figure 2.4.1).

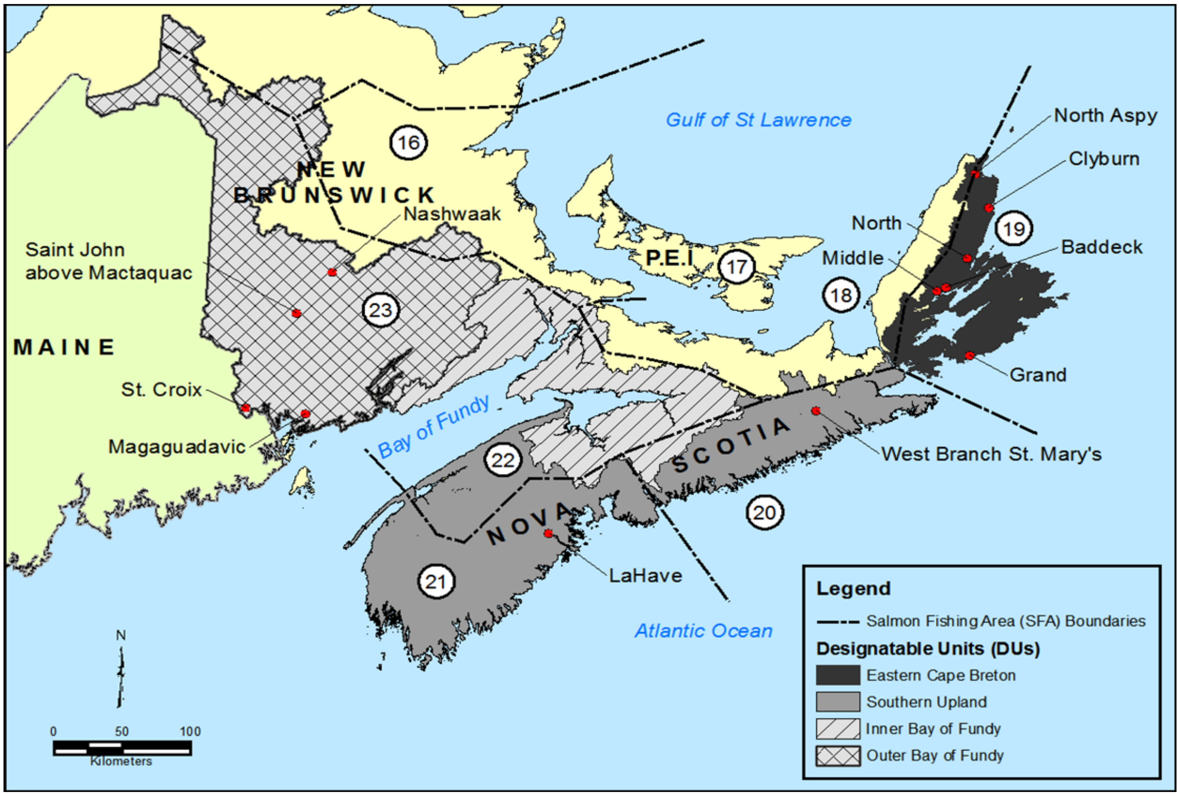


Figure 2.4.1. Map showing the location of the four Atlantic Salmon Designatable Units and associated salmon management areas in the Maritimes Region.

Abundance of Atlantic Salmon in the Maritimes Region has been in decline for more than two decades (Figure 2.4.2). The IBoF Atlantic salmon population is currently protected as endangered under the federal Species at Risk Act (SARA). Populations from the SU, ECB and OBoF DUs were assessed by COSEWIC as endangered in 2010 and these DUs are currently undergoing the federal government listing process to determine if they will be listed under the SARA or not. Atlantic Salmon commercial fisheries were closed in the Maritimes Region by 1985. In addition, increasingly restrictive management measures for recreational salmon fisheries have been implemented, including the complete closure of IBoF rivers in 1991, OBoF rivers in 1998, and eastern and southern shore Nova Scotia rivers in 2010 (DFO 2013a). Widespread recreational fishery closures for Atlantic Salmon in ECB occurred in 2010, and in 2013 all but three rivers were closed to recreational salmon fishing (DFO 2014a).

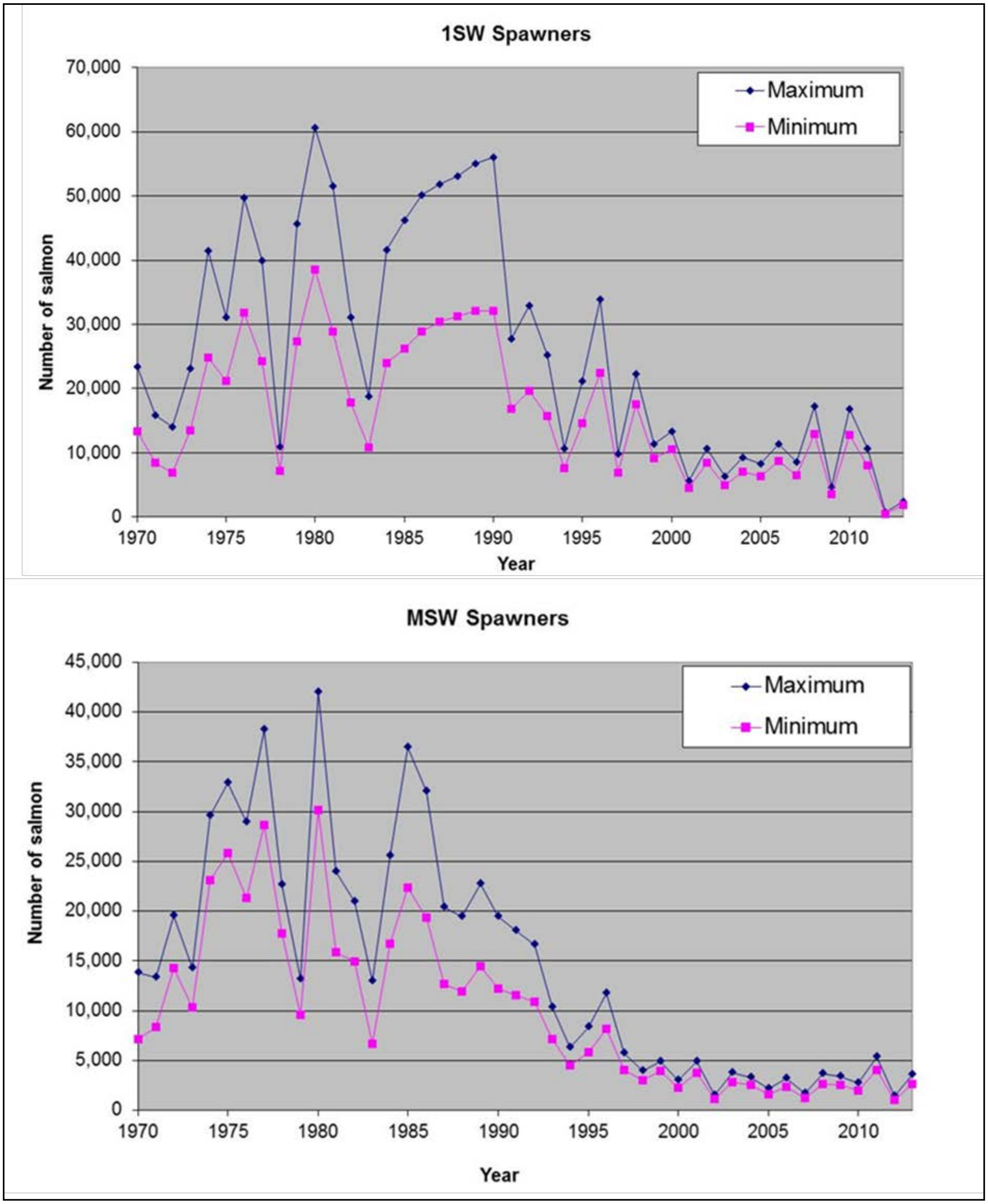
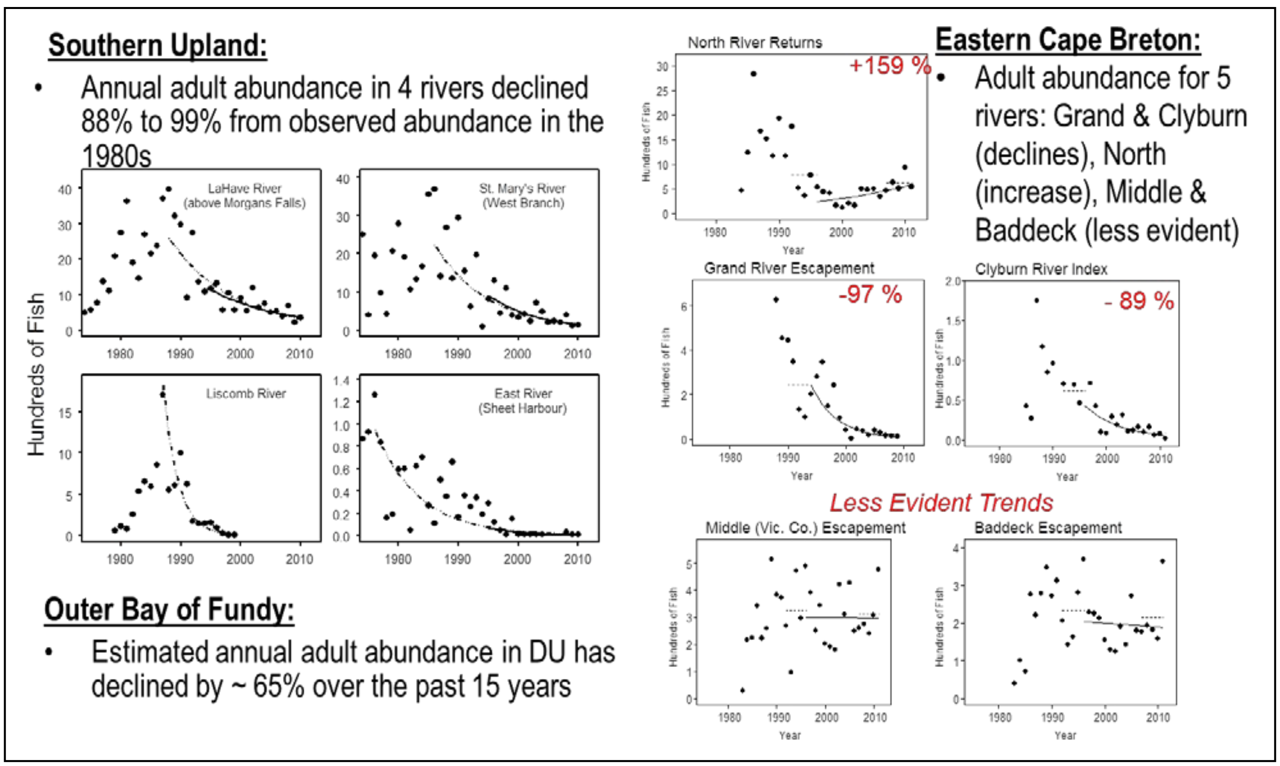


Figure 2.4.1. Estimated number of total Atlantic salmon spawners for the Maritimes Region as 1 sea-winter (1SW) and multi-sea winter (MSW) fish, 1970 to 2013, indicating the decline, especially evident over the past two decades.

Status and trends of Atlantic salmon populations within Maritimes Region is assessed on a number of index populations via adult salmon assessments, electrofishing surveys, and through analysis of recreational catch data. Status of salmon populations within the SU and OBoF remain at critically low abundance with adult salmon returns to the LaHave River (SU index river), the St. John River upriver of Mactaquac Dam and the Nashwaak River (OBoF index rivers) remaining among the lowest on record in 2013 (estimated egg depositions ranging between 2 - 12% of conservation requirements, DFO 2014a; Figure 2.4.3). Some populations in ECB are closer to conservation requirements than those in the OBoF and SU regions; however, substantial declines are evident in other ECB populations (e.g., Grand and Clyburn rivers). Regional electrofishing surveys provide evidence for river specific extirpations in the IBoF (Gibson et al. 2008) and significant ongoing declines and river specific extirpations in the SU (Gibson et al. 2011). Regional electrofishing surveys in the OBoF indicated that salmon (juveniles) are still present in 15 of the 20 salmon rivers, but at low abundance in most rivers (Jones et al. 2014). Regional electrofishing data in ECB generally indicates that juvenile abundance is low throughout much of the region; however, in contrast with both the SU and IBoF, there is no evidence in the surveys that river-specific extirpations have occurred (DFO



2013b).

Figure 2.4.2. Atlantic salmon population trends from the Maritimes Region DUs (based on material prepared for the Recovery Potential Assessments).

Population dynamics and viability modeling was conducted during Scientific Recovery Potential Assessments (RPAs) for each DU. Wild IBoF salmon have declined to critically low levels and population modeling indicates that IBoF salmon would rapidly become extinct in the absence of the Live Gene Bank (LGB) program, whereas populations with LGB support are expected to persist at low population size (DFO 2008). Modeling indicates that the larger populations in the SU have a high probability of extirpation in the absence of human intervention or a change in survival rates for some other reason (Gibson and Bowlby 2013), and the abundance of populations in the OBoF will continue to decline at current population dynamics (e.g., Nashwaak River population, index for populations on the St. John River below Mactaquac Dam) or extirpate (e.g., Tobique River population, index for populations on St. John River upriver of Mactaquac Dam) unless the number of spawners replaced from one generation to the next improves (DFO 2014b). Population modeling data was only available for two of the healthier populations in ECB (Middle River and Baddeck River populations), which are not considered to be representative of other populations in the DU (DFO 2013b). The modeling results for these two populations indicate a low probability of extinction if conditions in the future are similar to those in the recent past (DFO 2013b).

Overview of the threats within the region

The RPAs for each of the four DUs within the Maritimes Region (DFO 2008, DFO 2013b, DFO 2013c, and DFO 2014b) provide a review of threats to Atlantic salmon populations within each respective DU. Some threats were common to all DUs (e.g., marine ecosystem changes, salmonid aquaculture), whereas others were particularly relevant to a given DU (e.g., acidification in the SU, hydropower dams in the OBoF). Threats with a high level of overall concern to persistence and recovery in freshwater and estuarine and marine environments for each of the DUs are identified in Table 2.4.1. A further description of these threats, and those with lower levels of overall concern, can be found in the RPAs for each DU and supporting research documents (Amiro et al. 2008; Bowlby et al. 2013; Gibson et al. 2014; and Clarke et al. 2014).

Table 2.4.1. High level threats to the persistence and recovery of Atlantic salmon within the Maritimes Region.

THREATS (Those with a high level of concern)	**Inner Bay of Fundy**	**Southern Upland**	**Eastern Cape Breton**	**Outer Bay of Fundy**
Freshwater:				
Acidification		X		
Altered hydrology		X		
Barriers to passage / Habitat fragmentation due to dams and culverts	X	X		
Changes in environmental conditions	X			
Contaminants	X			
Depressed population phenomenon	X			
Freshwater fisheries	X			
Hydroelectric dams				X
Illegal fishing activities (e.g. poaching)		X	X	X
Invasive fish species		X		
Estuarine and Marine:				
Depressed population phenomenon	X			X
Diseases and parasites			X	X
Fisheries: incidental catches of salmon	X			
Marine ecosystem changes	X	X	X	X
Salmonid aquaculture	X	X	X	X

Overview of program objectives

Program objectives include population monitoring and assessment and live gene banking in support of population maintenance. Atlantic salmon programs in the Maritimes Region are required to provide: input on advice required for fishery management and precision on harvest control rules for salmon in Nova Scotia and New Brunswick; input on advice required for habitat and aquaculture decisions; input on species at risk advice; and input on strategic research required to support recovery and action plans. Fisheries and Oceans Canada (DFO) currently monitors Atlantic salmon populations on rivers in each DU:

IBoF: Salmon collections for LGB on Big Salmon, Stewiacke, and Gaspereau rivers; and smolt and adult assessments on Big Salmon and Gaspereau rivers.

ECB: Adult assessment monitoring on Middle, Baddeck, and North rivers.

SU: Juvenile assessments on the St. Mary's River; and adult, smolt and juvenile assessments on the LaHave River.

OBoF: Adult assessments on St. John River at Mactaquac Dam; adult, juvenile and smolt assessment monitoring on the Tobique River; and adult, juvenile and smolt assessment monitoring on the Nashwaak River.

Overview of recovery actions within the region

Due to the declining status of stocks, the DFO Fisheries and Aquaculture Management group implemented commercial fishery closures by 1985, and has progressively implemented restrictions on recreational fisheries leading to the complete closure of recreational Atlantic salmon fisheries for the majority of rivers within the Region by 2010. In 2013, only the Middle, Baddeck and North rivers (all in ECB) had recreational fisheries (i.e. hook and release only) for Atlantic salmon and fishing seasons on these rivers were limited to cooler water temperature periods in an effort to reduce incidental hook and release mortality. Seasonal river and pool closures for fishing all species has also been implemented on select salmon rivers (e.g., St. John (including Tobique), Medway, LaHave, and St. Mary's) to further prevent angling for Atlantic salmon under the guise of fishing for trout.

The primary recovery activity that has been used to prevent the extinction of IBoF salmon to date has been the LGB program. The LGB is a form of captive breeding and rearing designed to minimize the loss of the genetic diversity and support the recovery of salmon populations into IBoF rivers once conditions are suitable for their survival (O'Reilly and Doyle 2007). Extirpations in rivers without the support of live gene banking are ongoing; however, juvenile abundance has increased in rivers receiving LGB support (DFO 2008).

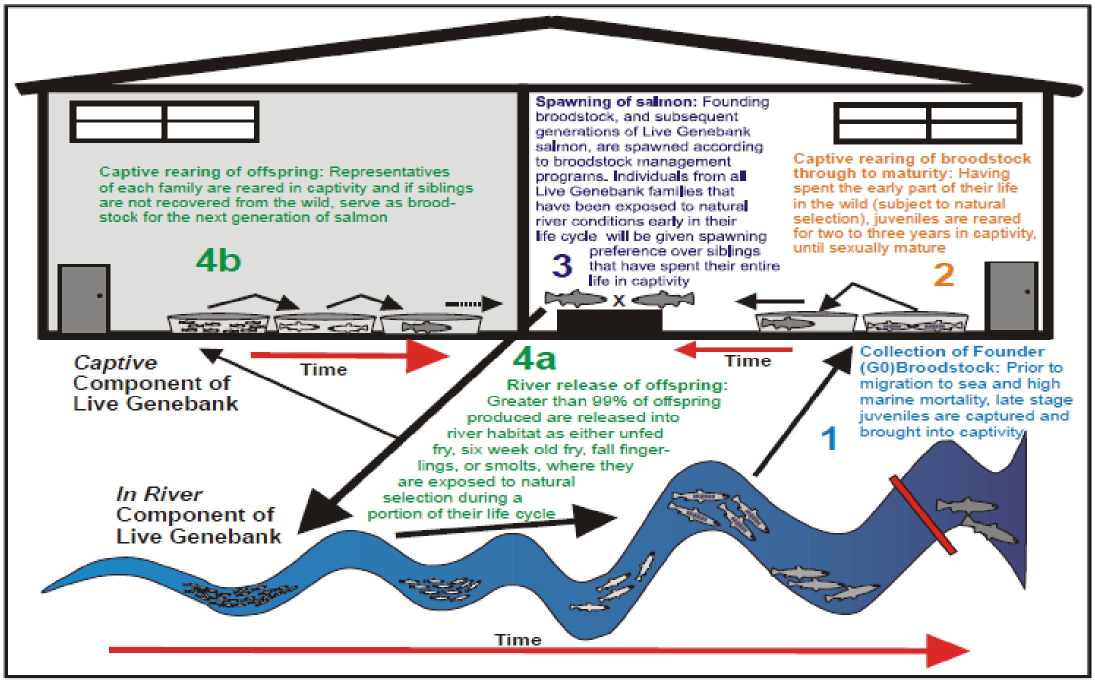


Figure 3. Schematic depicting the inner Bay of Fundy live gene banking program, including 'captive' and 'in river' components. (Source: O'Reilly and Harvie 2009)

In addition to closure of commercial and recreational fisheries, DFO conservation actions in recent years have primarily involved the use of supportive rearing programs. Supportive rearing involves collecting wild juveniles, rearing them to adults in captivity, and releasing the adults back into the wild to spawn (e.g., Gold, Medway, Quoddy, and St. Mary's rivers in SU) or keeping them as broodstock (e.g., St. John River populations above Mactaquac Dam in OBoF). Preliminary analyses of and review of the literature on supportive rearing programs indicate that the overall efficacy of these programs can be quite variable and unless the number of spawners, and year-to-year spawning consistency, can be increased, such programs, on their own may not be very efficient at maintaining genetic variation, even in the short term (5-10 generations, P. O'Reilly, Personal Communication). Supportive rearing is currently only used in the OBoF, where it is used to conserve St. John River populations above Mactaquac Dam.

Science-based RPAs have recently been completed for the SU, ECB and OBoF DUs to provide scientific information and advice to meet the various requirements of the SARA listing process. The scientific advice in these RPAs can also serve to help guide recovery actions for each DU. Each RPA contains information on population viability and recovery potential for populations with enough information to model population dynamics, as well as information on threats to persistence and recovery, recovery targets, and a discussion of mitigation and alternatives. Recovery initiatives as a result of the SARA listing process for the SU, ECB and OBoF have not been developed or implemented to date, as listing decisions are pending.

NGO groups are also undertaking various Atlantic salmon recovery actions, includes the Nova Scotia Salmon Association's acid rain mitigation project on the West River, Sheet Harbour, in the SU. This project uses a single lime doser that is operated year round to mitigate the impacts of acidification on the mainstem.

Overview of the role of hatcheries in the region

There are two federally owned and operated Atlantic salmon biodiversity facilities (hatcheries) within the Maritimes Region: 1) Mactaquac Biodiversity Facility located outside Fredericton, NB, and 2) Coldbrook Biodiversity Facility located in the Annapolis Valley, NS. The role of hatcheries within the Region has evolved over the years from enhancement of Atlantic salmon populations to conservation of declining populations. The Mactaquac Biodiversity Facility was constructed in the 1960s to numerically offset the effects of hydroelectric development on salmon in the St. John River, primarily by producing smolts from sea-run broodstock captured at fish collection facilities at Mactaquac Dam. The Mactaquac Biodiversity Facility now maintains the LGB program for IBoF populations in New Brunswick, and since 2004 the smolt offsetting program has been refocused toward conserving and restoring a declining resource on the St. John River using captive-reared adults, originally collected from the wild as juveniles, for both broodstock and adult releases for natural spawning upriver of Mactaquac Dam (Jones et al. 2004). In addition to core activities, the facility also serves collaborative research projects, and client program agreements (MacDonald and Ratelle 2011). The Coldbrook Biodiversity Facility maintains the LGB for IBoF populations in Nova Scotia, and has also cultured fish for conservation efforts in Nova Scotia (e.g., supportive rearing and kelt reconditioning initiatives) and in support of research projects.

Atlantic salmon population status for the Maritimes Region and the way forward

The recovery process, as required under the Act, will take time and involve process. To limit the risk of losing an entire DU, efforts will have to proceed with a sharp focus to conserve, maintain, and facilitate recovery, of limited larger populations.

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2.5 Gulf Region

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Overview of the salmon resource in the region

Atlantic salmon (*Salmo salar*) management areas in DFO Gulf Region, which encompasses all rivers flowing into the southern Gulf of St. Lawrence, are defined by four salmon fishing areas (SFA 15 to 18) in the three Maritime provinces (New Brunswick, Nova Scotia, and Prince Edward Island) (Figure 2.5.1). Sixty percent of the 126 rivers in Gulf Region, for which conservation requirements have been defined, are small rivers with conservation egg requirements of less than 0.5 million eggs (Figure 2.5.2). Only a few large rivers, Restigouche in SFA 15A, Southwest Miramichi, Northwest Miramichi and Little Southwest Miramichi in SFA 16A have conservation egg requirements that exceed 15 million eggs each. At approximately 6,000 to 7,000 eggs per large female salmon and a sex ratio of about 80% female in the large salmon category, the conservation egg requirements would be met by about 100 large salmon in most of the small rivers.

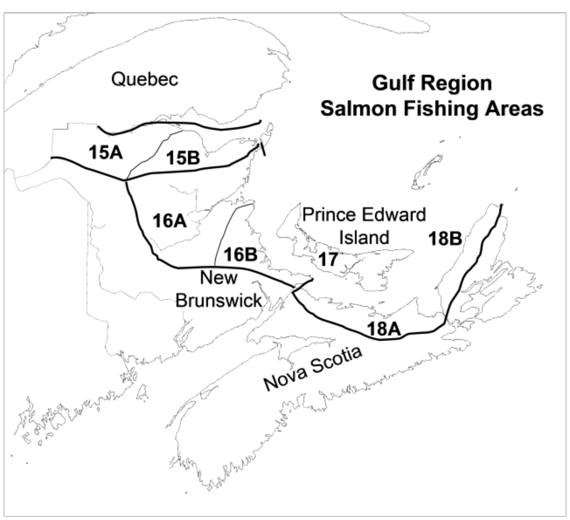

Figure 2.5.1. Salmon fishing areas (SFA) in DFO Gulf Region.

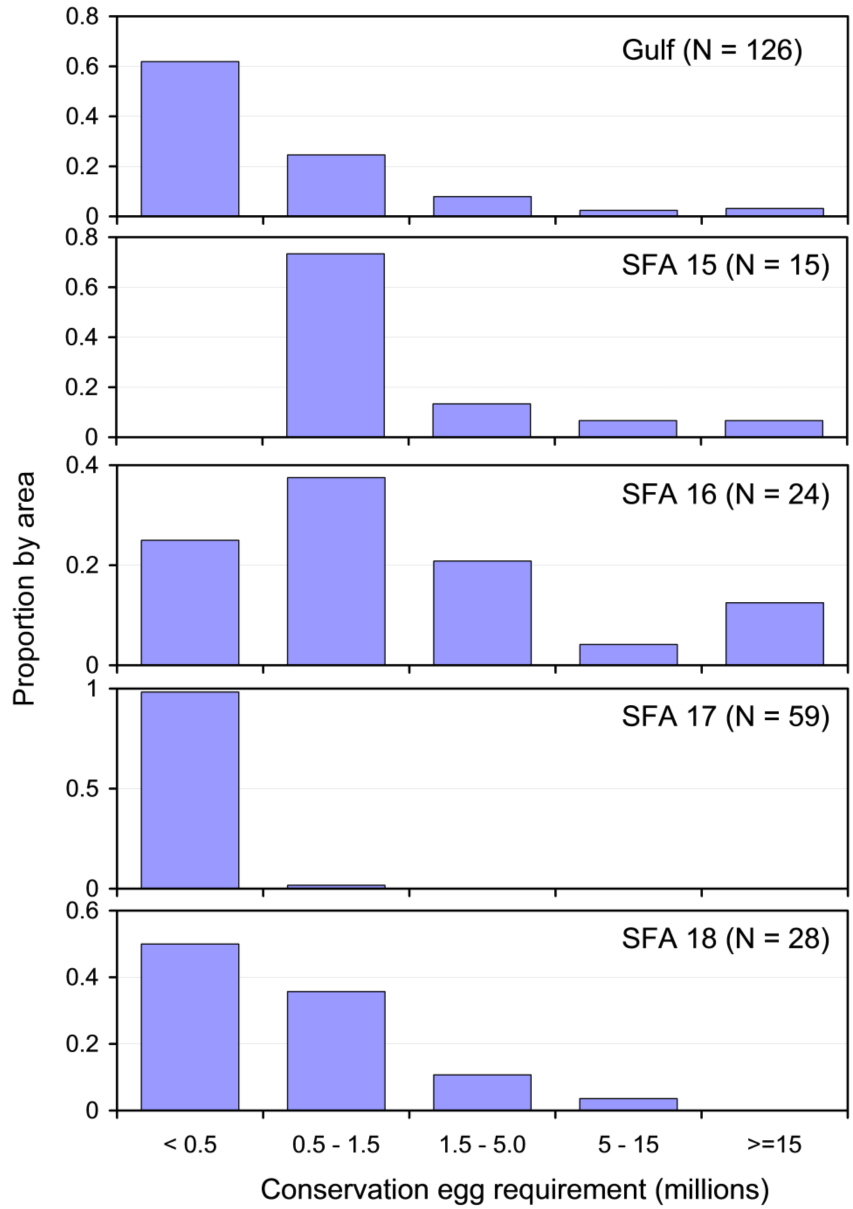

Figure 2.5.2. Proportion of rivers within each SFA and for Gulf Region overall with defined conservation requirements by category of conservation egg requirements. (from DFO 2012b).

Anadromous Atlantic salmon populations in Gulf Region are comprised of important proportions of one-sea-winter (1SW), two-sea-winter (2SW), three-sea-winter (3SW) and repeat spawners. Small salmon, mostly 1SW fish, in SFAs 15 to 18 are mainly males (> 90%), with the exception of early run of small salmon in parts of the Miramichi which can be comprised of larger percentages (up to 40%) of females. Large salmon, consisting mostly of 2SW, 3SW and repeat spawners, are predominantly females.

Juvenile salmon spend from two to five years in rivers before migrating to sea as smolts, a migration which takes place in May and June. Salmon from Gulf Region can undertake long seaward migrations, as far as Greenland and occasionally in the northeast Atlantic (east of Iceland) to feed.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) grouped the rivers of DFO Gulf Region with those of the Gaspe Peninsula of Quebec into one designable unit and assessed its status as special concern (COSEWIC 2010).

Estimates of total returns and spawners of small salmon (fork length < 63 cm, predominantly 1SW) and large salmon are derived from monitored rivers for each SFA and overall for Gulf Region. Returns of large salmon to Gulf Region in 2011 were estimated to be about 75,000 fish, at near maximum levels over the 1970 to 2011 time series (Figure 2.5.3). Returns of large salmon in 2012 were much lower than in 2011 at 28,000 fish, and on a comparable scale with returns during 1996 to 2010. The high returns in 2011 and lower returns in 2012 were estimated in all SFAs. Small salmon returns for Gulf Region in 2011 were estimated at about 73,000 fish and near the highest levels estimated since 1994 but were still low relative to the returns estimated during 1985 to 1993 (85,000 to 190,000 fish) and in several years during the 1970s (Figure 2.5.3). Small salmon abundance in 2012 was estimated at about 25,000 fish, the lowest of record for the region.

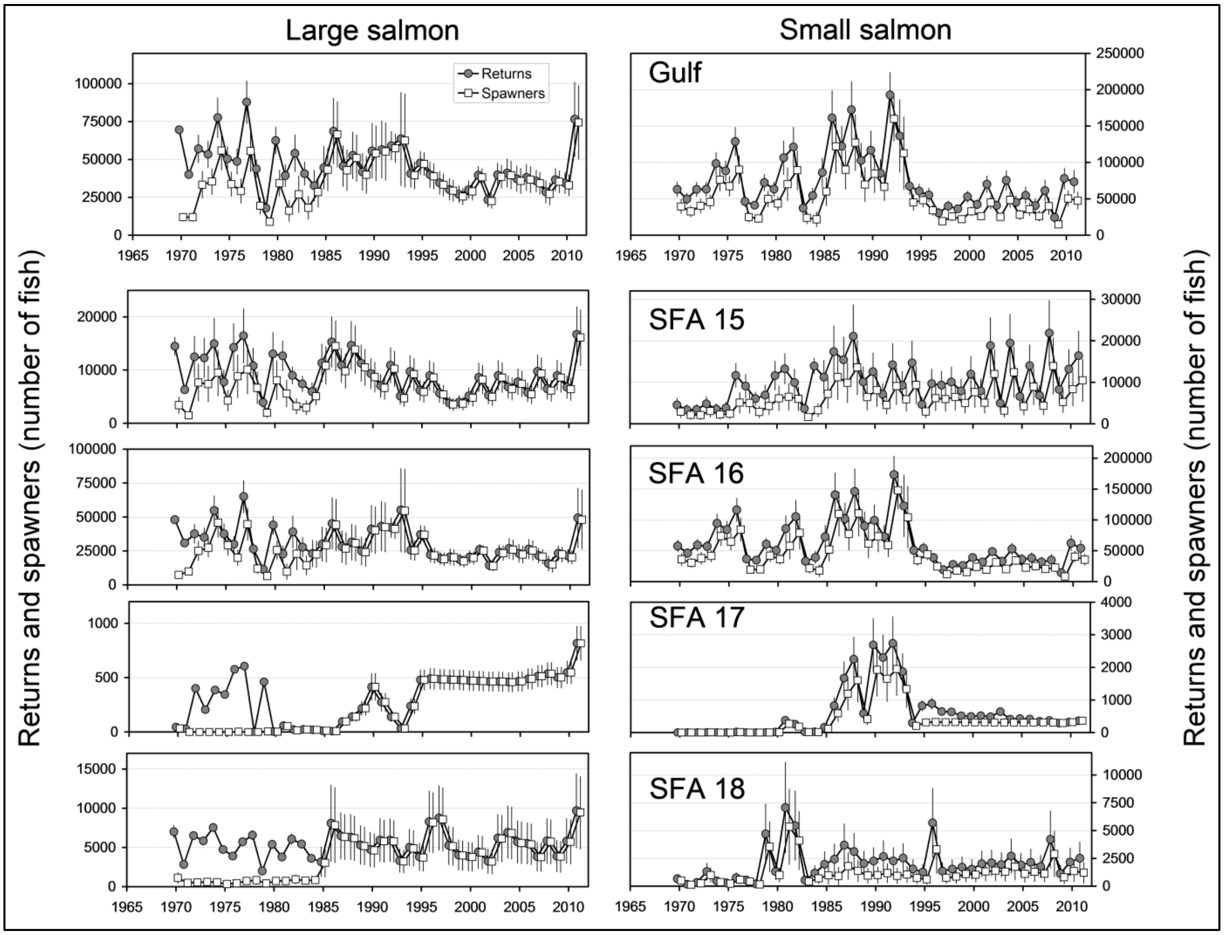

Figure 2.5.3. Estimates (median, 95% Confidence Interval range) of total returns and spawners of large salmon (left panels) and small salmon (right panels) to each of SFA 15, 16, 17, and 18, and to Gulf Region 1970 to 2011. (from DFO 2012b).

Indices of freshwater production are derived from electrofishing surveys of juvenile salmon and estimates of smolt production for index rivers. Atlantic salmon occupy 115 rivers (that empty into estuaries) in Gulf Region and with exception of Prince Edward Island (SFA 17), juvenile abundances are sustained at moderate to high levels. Smolt assessments in the three main rivers in Gulf Region indicate that the total production from freshwater has generally improved over the past decade and smolt production rates are within the range (3 to 5 smolts per 100 m²) expected for salmon producing rivers in the Maritime provinces (Figure 2.5.4).

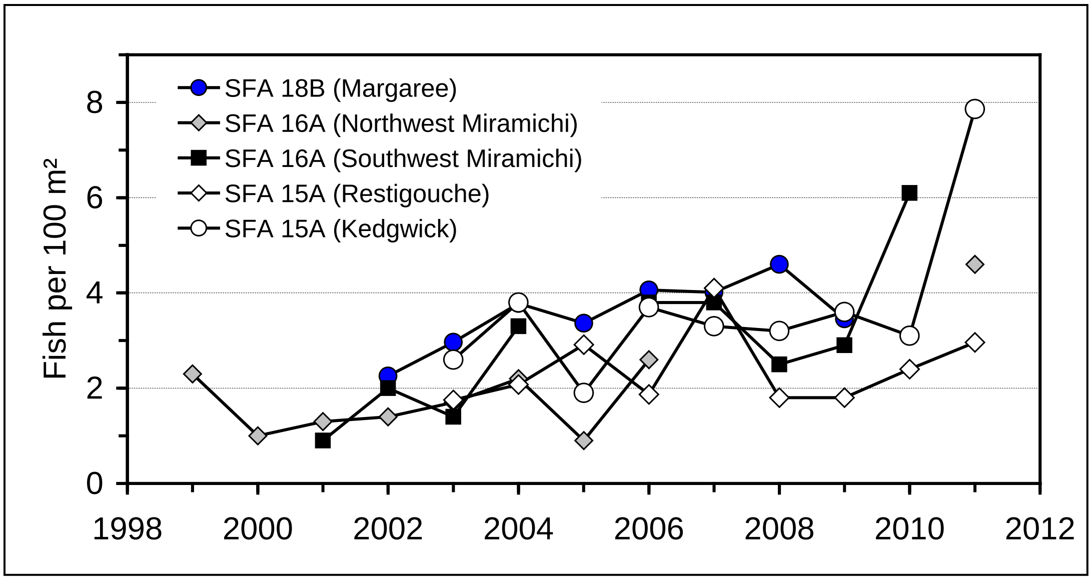

Figure 2.5.4. Smolt production, expressed as fish per 100 m² of wetted habitat area, from monitored rivers in Gulf Region, 1999 to 2011. Smolt production from the Kedgwick River (SFA 15A) is included in the total smolt production from the Restigouche River. (from DFO 2012b).

Overview of the threats within the region

Fisheries exploitation

Atlantic salmon are presently harvested in aboriginal Food Social and Ceremonial (FSC) fisheries and in recreational fisheries. Exploitation rates, expressed as losses (returns minus spawners) divided by returns, were calculated for the overall Gulf Region. These values declined sharply for large salmon in 1984 after closure of the homewater commercial fisheries and the mandatory catch–and-release of large salmon in the recreational fisheries (Figure 2.5.5). Exploitation rates on large salmon since 1985 have varied between 3% and 6% of total returns. Small salmon exploitation also declined after 1984 but has remained at levels between 17% and 40% of estimated total returns.

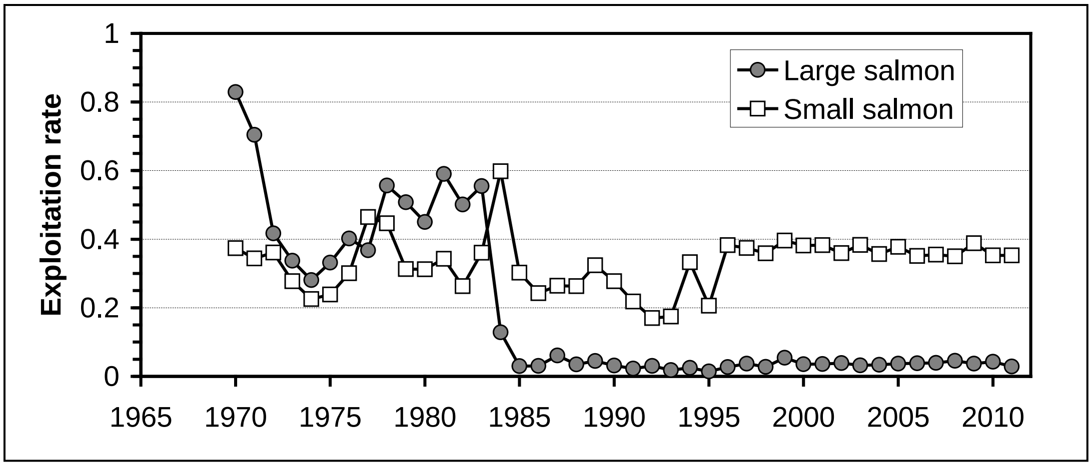

Figure 2.5.5. Estimated exploitation rate (expressed as losses (returns – spawners) divided by returns) of large salmon and small salmon from all homewater salmon fisheries in Gulf Region, 1970 to 2011. (from DFO 2012b).

The fishery at West Greenland exploits salmon from Gulf Region rivers, as evidenced from recaptures of salmon originally tagged as smolts (from Restigouche, Miramichi, and Margaree rivers) and as reconditioning kelts (from Miramichi tag recoveries). The estimated exploitation rate on Gulf Region salmon in the Greenland fishery in the past five years is higher (3% to 10%) than the estimated exploitation rate on large salmon in the homewater FSC and recreational fisheries (3% to 6%).

Of the commercial fisheries for other species which occur in the Gulf of St. Lawrence, the drift surface gillnet fishery for mackerel which occurs in June likely has the greatest potential for salmon bycatch, particularly in years when abundance of salmon in the Gulf Region is high, as in 2011. There are no estimates of the number of salmon intercepted in this fishery which would be expected to intercept salmon from rivers in SFA 15 and 16.

<u>Marine survival</u>

As with other salmon stocks of eastern North America, reduced marine survival over the past two decades is considered to be constraining the abundance of adult anadromous Atlantic salmon. Large scale climatic factors are hypothesized to be determinant of sea survival of salmon by changing the distribution and migration at sea and their consequent interactions with prey and predators. Causal factors of variations in marine survival remain speculative.

<u>Freshwater environmental conditions</u>

Adult Atlantic salmon return to rivers in eastern Canada over a broad range of river water temperatures with river migration seemingly favored at water temperatures in the range of 14 to 20°C. When in freshwater, juvenile and adult salmon are subjected to large variations in water temperature and water levels, within and among seasons. High summer water temperatures together with low water and reduced flow conditions frequently occur in salmon rivers in the Maritimes: together they pose an environmental stress that can be particularly severe for early-run adult salmon. During July and August, water temperatures in rivers of the southern Gulf of St. Lawrence can exceed 25°C. Temperature-related stress in juvenile and adult Atlantic salmon has been associated with behavioral changes such as abandonment of feeding territories and aggregations at cool-water seeps (Breau et al. 2011).

Warm water temperature events in the Miramichi River, defined as days when the maximum temperature exceeded 23ºC, occur repeatedly but with the intensity varying annually (Figure 2.5.6). Adult salmon mortalities associated with stressful environmental conditions have been recorded in some of these years, in particular 1995, 1999, 2001 and 2010. Mortality from catch-and-release angling increases at water temperatures above 20ºC and protocols for managing angling activities during these warm water periods have recently been developed (DFO 2012a).

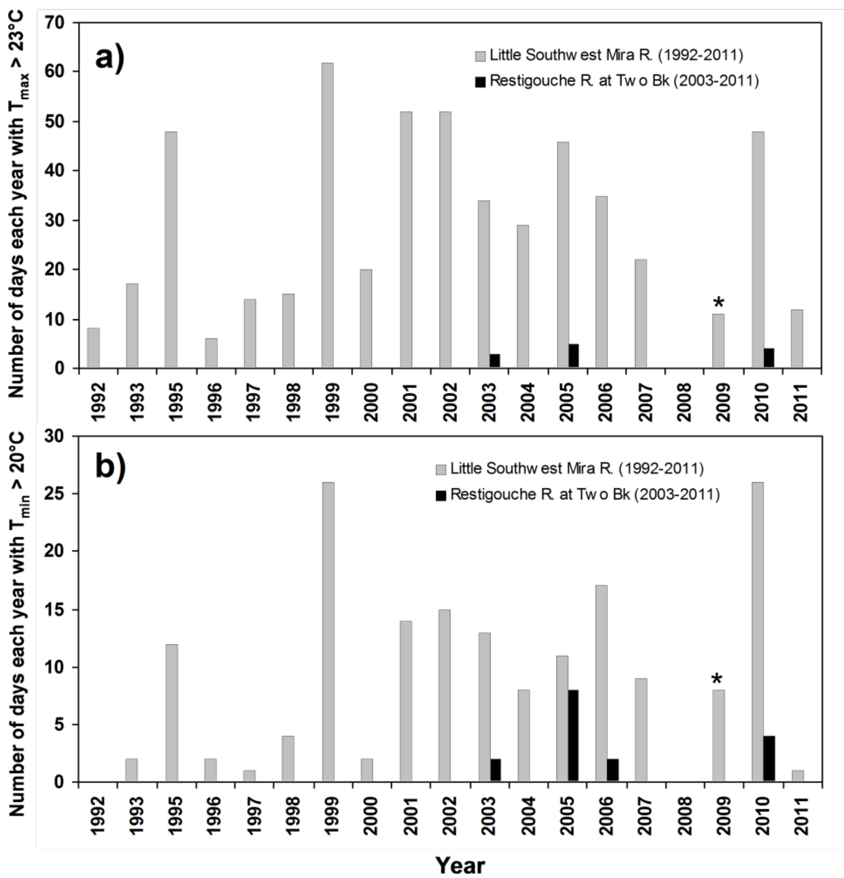

Figure 2.5.6. Number of days per year in which (a) the daily maximum water temperature (Tmax) exceeded 23°C and (b) the daily minimum water temperature (Tmin) exceeded 20°C for the Little Southwest Miramichi River (years 1992 to 2011, excluding 1994) and the Restigouche River at Two Brooks (years 2003 to 2011). The * indicates a year (2009) with incomplete data. (from DFO 2012a).

Occasionally, excessive precipitation and/or snow melt can result in severe discharge conditions that modify streambed structure and which can lead to egg and juvenile salmon mortalities. Such an event occurred in December 2010 in the Margaree River. A 100-year flood event occurred which resulted in important changes in the river morphology and movement of the streambed. The absence of fry in the majority of the sites sampled in 2011 was interpreted as the consequence of destruction of eggs in redds due to the exceptional discharge event.

Land use

In Prince Edward Island (SFA 17), salmon production is constrained by sediment input from agricultural and other sources (Cairns et al. 2010, 2012; DFO 2012). Fish kills due to pesticide inputs, water quality problems (low dissolved oxygen, high temperatures), and competition with introduced rainbow trout also threaten salmon. Artificial dams that lack fishways, beaver dams, and improperly installed culverts prevent access to numerous small tributaries. Land-use impacts in other areas of Gulf Region are less severe than in SFA 17 but inadequate fish passage and sedimentation are general issues in the region.

Overview of the role of hatcheries in the region

Prior to 1997, all salmonid enhancement activities were conducted by DFO. In 1997, the hatcheries were divested to the private sector and four of these continue to stock juvenile salmon at various stages in a limited number of rivers. All current enhancement activities have involved placing juvenile progeny back to rivers/tributaries from which the parents were collected. With the exception of a few rivers in Prince Edward Island, the scale of enhancement activities relative to wild production is small and generally Atlantic salmon adult runs to rivers are reliant on natural production.

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3. Session 2: Gene Banking and Life Stage Stocking Strategies

David Meerburg, Atlantic Salmon Federation

The life stages at which Atlantic salmon have been historically and currently stocked varies greatly from the transfers of mature adults, to the planting of eggs and unfed 0+ parr, to juveniles that have been fed and released at older ages such as 0+ parr released in the fall months and to smolt releases at either 1 year or 2 years of age. In many cases, while the intent of such programs has been to increase adult production in future years, there has only been limited assessment to determine if the programs were beneficial or not.

The gene banking and life-stage stocking strategies section of this workshop aimed to provide information, assessment and insights into some novel as well as more commonly used stocking techniques. Seven workshop presentations were covered in this session, two of which dealt with captive adult outplants, that is, adult releases that were reared to maturity from juveniles taken from the river. In the case of the Tobique River (O'Reilly et al., this workshop), a tributary of the St. John River, it was demonstrated using genetic techniques that captive adults (from smolt) were spawning successfully. However, the success of their progeny to go to sea and return was only half that of wild parents (O'Reilly et al., this workshop).

Preliminary analysis of smolt production by female parent type

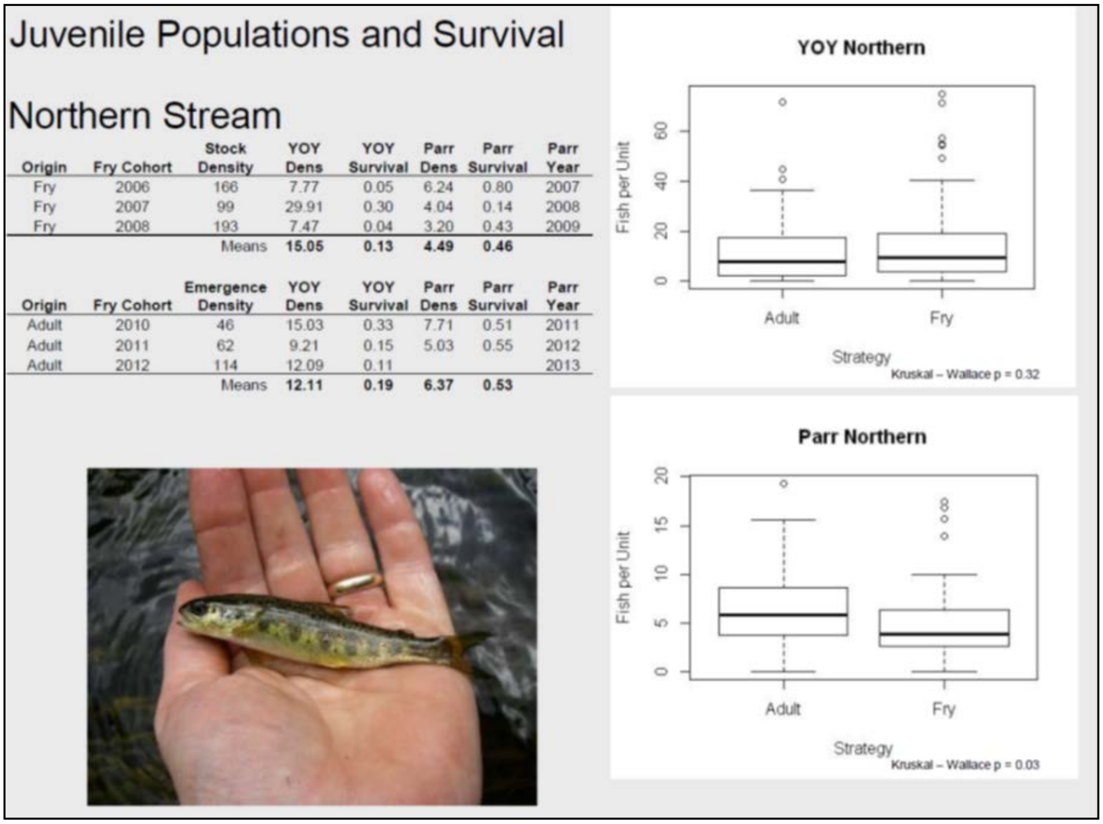
% contribution | % spawning success

	Offspring as presmolt	Total	Percent of total	Number female parents	Presmolt/ female parent	Number estimated eggs from group (RJ)	Offspring as presmolt	Estimated number smolt (total)	Eggs/ smolt	Smolt/egg (fert succ and surv)
Wild maternal parent	**46**	135	34.07	120	0.38					
Hatchery maternal parent	**1**	135		11	0.090909					
Searun maternal parent	**47**	135	34.81	131	0.358779	463590	**47**	**2064**	9863.617	0.004452
Captive Tobique adult release maternal parent	**87**	135	64.44	376	0.231383	1878141	**87**	**3824**	982.2462	0.002036
Captive Beechwood adult release materal	**1**	135	0.74	44	0.022727					

Estimated number smolt (total) (5% SW eff & 65% 2+ & 70% presmolt)
Smolt/egg (total) (5% SW eff & 65% 2+ & 70% presmolt)

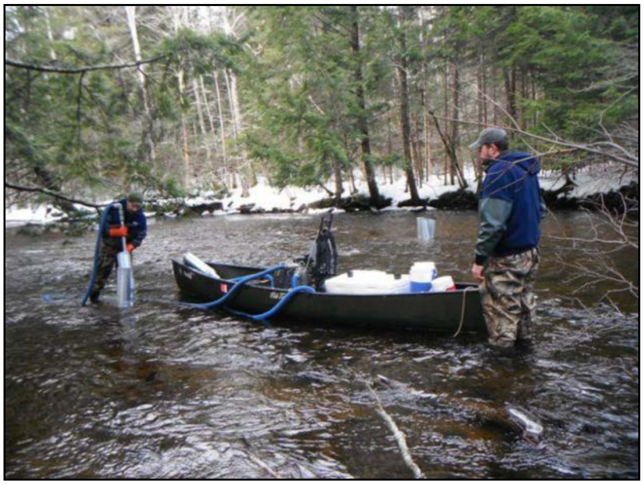
O'Reilly et al., this workshop. Slide 19. Tobique River, NB, spawning success was twice as high (.004 vs .002) for sea run maternal parents compared to captive adult releases.

In Maine (Atkinson et al., this workshop), captive adults (reared from parr) were demonstrated to have normal migratory and spawning behavior and produced 0+ and 1+ parr densities similar to those in fry stocked areas. It has not yet been possible to make adult-to-adult fitness comparisons (Atkinson et al., this workshop).



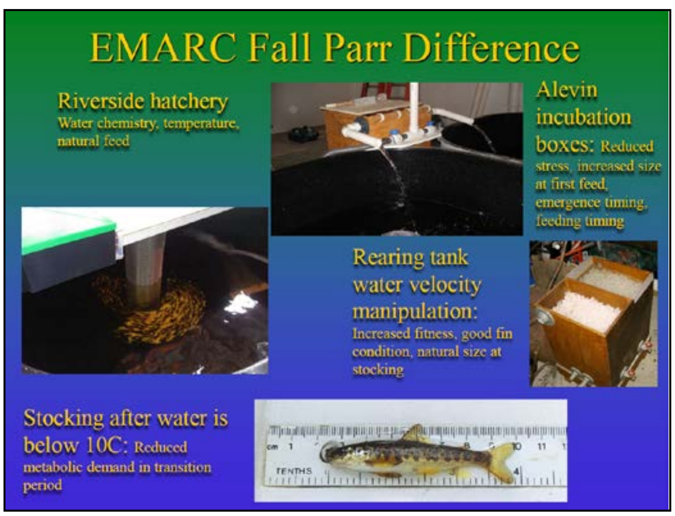
Atkinson et al., this workshop. Slide 15. In Northern Stream, Maine, YOY and parr densities were similar in both fry stocked areas and areas where juvenile production resulted from released captive adults (reared from parr) that had been allowed to spawn naturally.

The other five presentations in this section evaluated the age of the salmon at stocking and considered their effectiveness. In Maine on the Sandy River, Christman and Overlock (this workshop) compared streamside incubators with eyed egg plantings and showed better efficiency and increased capacity for juvenile production using the hydraulic planter.



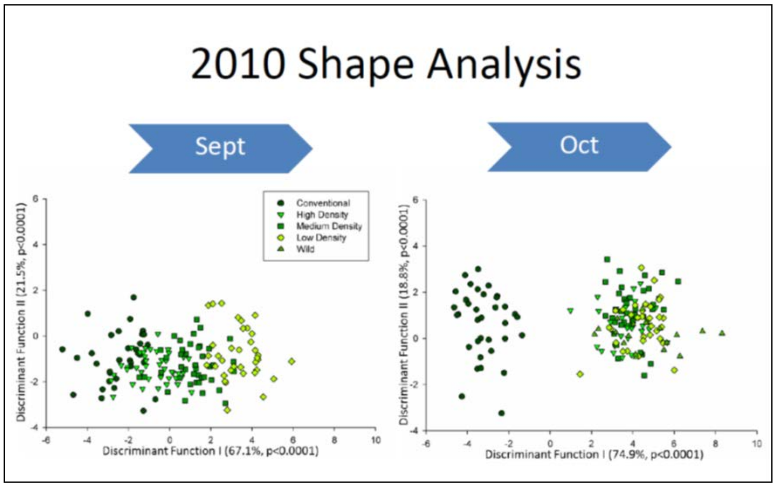
Christman and Overlock, this workshop. Slide 8. Hydraulic planting of eyed eggs in winter on the Sandy River, a tributary of the Kennebec River in Maine, USA.

Also in Maine on the East Machias River (van de Sande et al., this workshop), studies are ongoing to evaluate the effectiveness of releasing 0+ fall parr compared to historical releases of unfed fry. Results are not yet available for this study, however, it is hoped that the hatchery techniques being used will create more natural, physically fit, and cryptically colored 0+ parr.



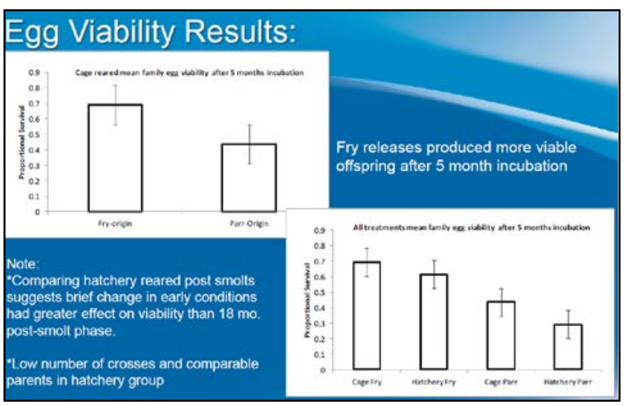
van de Sande et al., this workshop. Slide 10. The East Machias River, Maine strategy for improving salmon survival by releasing fall Atlantic salmon parr.

Along the same line, improvements in fish morphology and fin condition (to be more similar to wild fish) was demonstrated to occur in semi-natural rearing ponds in New Brunswick compared to conventional rearing ponds (Samways et al., this workshop).



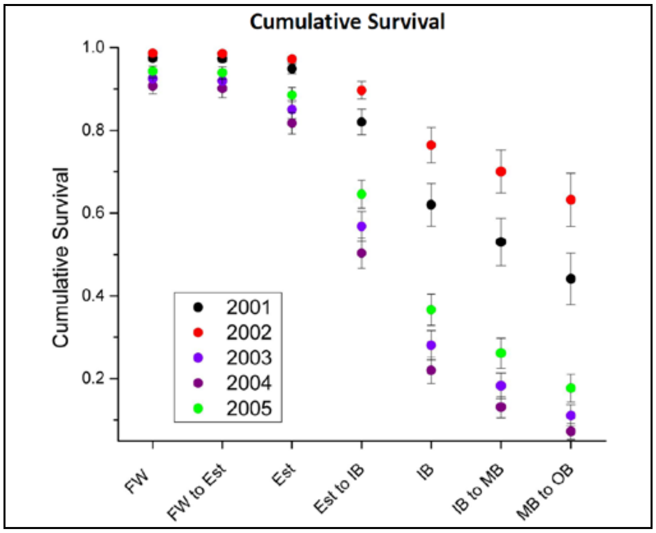
Samways et al., this workshop. Slide 24. By October there are clear distinctions in shape of salmon fingerlings that have been raised in conventional rearing facilities compared to fingerlings raised in semi-natural conditions (low, medium, high densities) or those found in the wild.

In the Inner Bay of Fundy (Clarke et al., this workshop), salmon released as fry exhibited higher levels of fitness later in life and into the next generation compared to fish that were held in the hatchery for 5 months of feeding.



Clarke et al., this workshop. Slide 15. Comparison of egg viability after 5 months incubation with eggs originating from parents that were either released as fry or parr on the Upper Salmon River NB.

There has also been evaluation of the 1+ smolt stocking program on the Dennys River in Maine, a program that was expected to increase adult returns (Hawkes, this workshop). From acoustic tracking it was determined these stocked smolts had difficulty migrating through the estuary resulting in high mortality, raising suspicions of smolt quality issues.



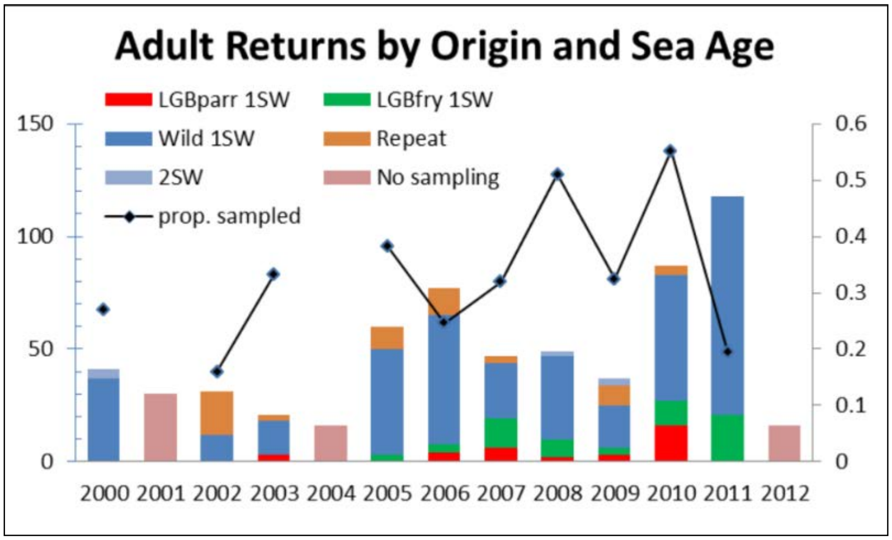
Hawkes, this workshop. Slide 13. Cumulative survival plotted by year against location (Freshwater, Estuary, Inner Bay, Middle Bay, Outer Bay) for smolt releases into the Denny's River Maine in 2001-2005.

On the Nashwaak River, two studies documented the negative effects of hatchery rearing on Atlantic salmon survival. Salmon parr (0+) were held and fed for an additional 3 months (stocked in September) and compared to their siblings that were also stocked in June above an inaccessible falls on the Dunbar Stream of the Nashwaak River NB (Salonius a, this workshop); their increased size did not confer any survival advantage when evaluated over a period of 12 months.


IMPASSABLE FALLS ON THE DUNBAR STREAM

Salonius a, this workshop. Poster 1. Evaluation of various stocking strategies occurred above this falls on the Dunbar Stream, Nashwaak River NB

A separate study (Salonius b, this workshop) showed that summer rearing of fry produced survivals at sea that were lower than wild fry and/or fry that had only been reared for a short period (released in June). However, in a detailed study on the Big Salmon River (Jones et al., this workshop), fall parr releases had average in-river survival to the smolt stage four times greater than progeny released as unfed fry; these unfed fry however had return rates to 1SW adults that were double that of the fall parr releases.



Jones et al., this workshop Poster. Adult returns by origin and sea age on the Big Salmon River NB). Returning adults from LGB fry (n=63) have been almost two times the number from LGB parr (n=34).

While it is difficult to generalize, and some exceptions can always be found, prudent managers should be minimizing the time that they maintain Atlantic salmon in hatcheries, and where possible, utilize hatchery management practices such as semi-natural rearing that produce a product that is as close to natural/wild as is possible.

4. Session 3: History/Case Studies

Tim Sheehan, NOAA Fisheries Service

The History/Case Studies section of the workshop provided examples of restoration programs on specific rivers while highlighting the pitfalls and successes of the hatchery activities employed. The oral and poster presentations provided an overview of many of the restoration activities underway within North America. An overview of the St. Croix River and Magaguadavic River restoration programs, an overview of 30 plus years of enhancement efforts on the Nepisiguit River, a presentation on the contribution of the Live Gene Bank Program to the smolt population on the Big Salmon River, an evaluation the effectiveness of stocking as enhancement technique and an overview of the Exploits River stocking program were all presented.

In addition to the presentations detail below, presentations from other sessions provided information pertinent to this section. As an example, Atkinson (this workshop) provided overviews of restoration efforts on Old Stream (a tributary to the Machias River in Maine) and Levy (this workshop) the Southern Upland assemblage of Atlantic salmon populations in Nova Scotia. Summaries of these efforts can be found in Session 4 (Habitat Recovery Initiatives).

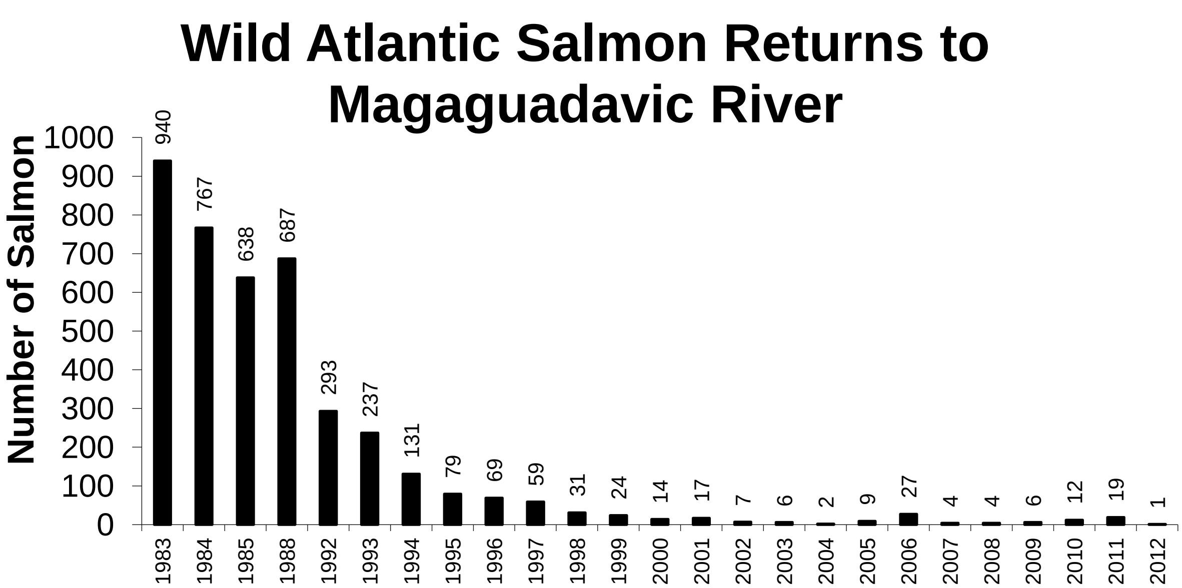
Historically, the St. Croix River was the largest salmon producing river located between the Penobscot and St. John Rivers (Sochasky, this workshop). In the mid-1800’s large-scale hydro-electric development extirpated the native Atlantic salmon population. During the latter part of the 1900’s, fish passage efforts once again opened access to spawning habitat and led to a government funded Atlantic salmon restoration effort. Large scale stocking and accompanying monitoring were conducted with modest results. Decreasing budgets forced restorations efforts to pursue collaborative approaches with local groups. In 2006 the last Atlantic salmon stocking was conducted within the river and the Atlantic salmon restoration program ended. In addition to poor marine survival, freshwater habitat issues, including habitat loss and predation from abundant smallmouth bass, are believed to be the primary causes for the failure of the St. Croix program to restoring Atlantic salmon to the watershed.

Setting the stage:

- **<u>Into 1800s</u>**. Largest runs on the Atlantic coast between the Saint John and Penobscot River systems.
- **<u>Mid 1800s-1964</u>**. Industry: 1, Fish: 0
- **<u>1965-1980</u>**. Wrongs righted; ready to restore

Sochasky, this workshop. Slide 3. Setting the stage for Atlantic salmon restoration on the St. Croix River.

Wild Atlantic salmon returns on the Magaguadavic River number upwards of 1000 spawners as late as 1983 (Carr, this workshop). By 1995, the number had decreased to less than 100. The Magaguadavic River Salmon Recovery Group, which consisted of individuals from angling and conservation groups, government agencies, and the aquaculture industry, was formed with the stated goal of protecting and restoring the wild salmon population in the Magaguadavic River. In 2001, a captive rearing program was initiated, which has resulted in the release of over one million fry since 2002. Minimal adult returns were generated from this program with the primary limiting factors identified as the high number of exotic species within the system, fish passage issues related to a lower river hydro-electric dam and competition, disease, parasite and genetic introgression issues associated with both freshwater and marine salmonid aquaculture.



Carr, this workshop. Slide 3. Wild Atlantic salmon returns to Magaguadavic River, 1982-2012.

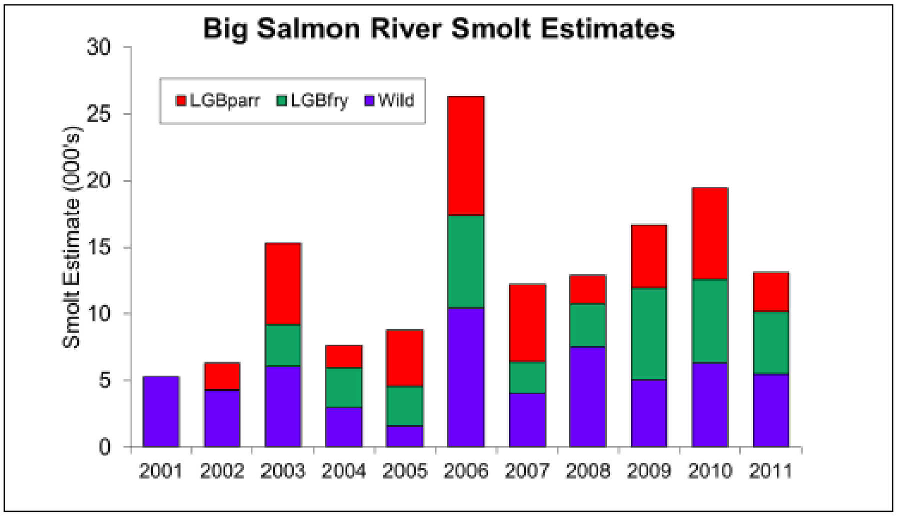
In both of these case studies, stocking was not able to achieve recovery. Neither protective legislation nor fish culture programs can save Atlantic salmon from extinction in habitat that man has degraded (MacCrimmon 1965). Recovery requires addressing the threats to freshwater and marine survival, improving the chances that hatchery Atlantic salmon can contribute to future generations, and recognizing the value and limitations of captive rearing.

Two other presentations highlighted results from different alternative rearing efforts. Streamside incubation boxes on the Nepisiguit River have been used since the mid-1980's (Chiasson, this workshop). Fertilization, incubation and hatching under generally controlled conditions greatly increased survival rates compared to the wild, which increased per female contribution to subsequent cohorts. Although the demographic benefits seem clear, there was no evaluation of the evolutionary, ecological, and disease risks associated with the practice (Anderson et al., 2014). The contribution of different live gene bank (LGB) release strategies to smolt and adult returns was determined on the Big Salmon River (Jones et al., this workshop). Progeny of the LGB Program were released as unfed fry, age-0 parr or age-1 smolts. Unfed fry and fall parr released fish increased the smolt population by three-fold since 2001. Fall parr released fish had a higher survival to the smolt stage than unfed fry although 1SW return rates from unfed fry were double that of fall parr. Overall, LGB adults have comprised about 20% of the total returning adults to the Big Salmon River.

Incubation Box Summary 1985 to 2011

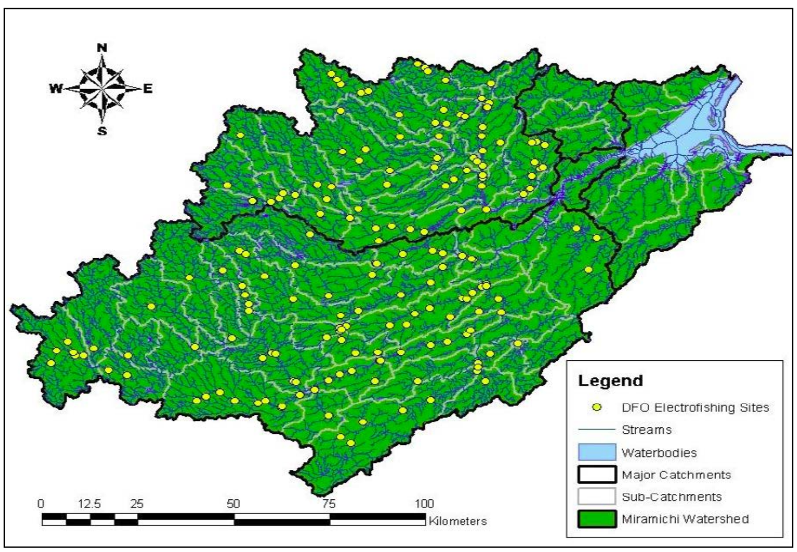
Year	Site	# Eggs	# Fry	% Survival
1985	Pabineau Brk.	26176	25669	98,1
1986	Pabineau Brk.	50000	48312	96,6
1987	Grand Falls	150000	144450	96,3
1988	Grand Falls	300000	293465	97,8
1989	Grand Falls	350000	335533	95,9
1990	Grand Falls	350000	342981	98,0
1991	Grand Falls	300000	243016	81,0
1992	Grand Falls	350000	335801	95,9
1993	Grand Falls	350000	336277	96,1
1994	Grand Falls	350000	304079	86,9
1995	Grand Falls	350000	105000	30,0
1996	Grand Falls	350000	285939	81,7
1997	Grand Falls	350000	323537	92,4
1998	Grand Falls	350000	337354	96,4
1999	Grand Falls	153408	151228	98,6
2000	Grand Falls	350000	340236	97,2
2001	Grand Falls	350000	345272	98,7
2002	Grand Falls	219000	216532	98,9
2003	Grand Falls	197275	192412	97,5
2004	Grand Falls			
2005	Grand Falls	168270	160960	95,6
2006	Grand Falls			
2007	Grand Falls	50000	49000	99,4
2008	Grand Falls	88400	86270	97,5
2009	Grand Falls	42500	42104	98,9
2010	Grand Falls	300900	290452	96,5
2011	Grand Falls	208000	196376	90,7
Grand Total		6,103,929	5,532,255	92,5

Chiasson, this workshop. Poster. Summary of incubation box efforts on the Nepisiguit River, 1985-2011, including site of incubation, number of eggs and fry with corresponding percent survival.



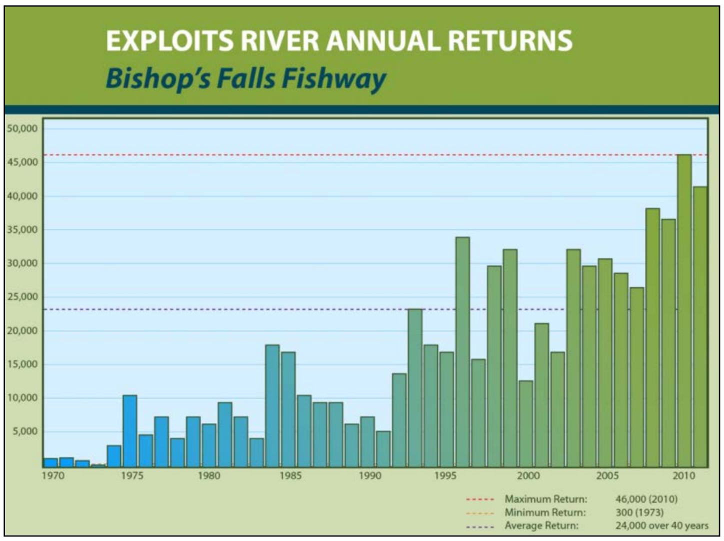
Jones et al., this workshop. Poster. Adult return estimates to the Big Salmon River by origin and sea age, 2000-2012. Overall, LGB adults have comprised about 20% of the total returning adults since 2003.

There was also an overview provided for a new project whose goal is to determine the effectiveness of stocking as a recovery strategy for Atlantic salmon in the Miramichi River (Wallace and Curry, this workshop). This effort will rely on modeling of catchment and landscape level variables along with electrofishing data to predict the distribution of juvenile salmon densities within the watershed. Once the model is finalized, modeled juvenile salmon densities at specific stocking locations will be compared to estimated densities from field data to determine if stocking has been an effective enhancement technique in the Miramichi River.



Wallace and Curry, this workshop. Poster. Fisheries and Oceans Canada electrofishing sites in the Miramichi watershed.

The final presentation wasn't an example of a restoration effort, but rather a range expansion (Parsons, this workshop). In the early 1960's DFO began to explore if the Exploits River could produce salmon. The Exploits River is the largest river in insular Newfoundland and was devoid of Atlantic salmon in all but its lower reaches as 90% of it was inaccessible due to natural falls and hydroelectric facilities. A large range expansion effort was undertaken that aimed to create upstream passage into inaccessible habitat, colonize the newly accessible habitat with Atlantic salmon fry, and continue with additional habitat restoration efforts while improving passage for downstream migrating smolts and kelts. It was an ambitious, expensive, and successful effort. By addressing a number of the threats in freshwater and with the benefit of decent marine survival (DFO 2009; ICES 2013), the effort resulted in a self-sustaining salmon population that has approached 50,000 individuals in recent years.



Parsons, this workshop. Slide 27. Adult returns to the Bishop's Falls fishway on the Exploits River, 1970-2011.

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5. Keynote Address 2:

The Role of Population Dynamics in Recovery Planning for Atlantic Salmon

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Summary

The problem

Two fundamental issues in the recovery planning of endangered species are: 1) determining what has changed such that populations that were viable in the past are now at risk of extirpation; and 2) determining how populations are expected to respond to recovery activities and whether these activities will lead to a population's recovery. With the abundance declines observed in many Atlantic salmon populations, which in some cases have been extreme enough to lead to their extirpation, addressing these issues is quite important to ensure that recovery plans are sufficient to achieve their goals. The solutions fall within the field of population dynamics, which is a sub-discipline of ecology dealing specifically with how populations respond to changes in survival, fecundity, age-at-maturity or other life history parameters that affect the nature of population growth.

A population dynamics model for Atlantic salmon

In support of recovery planning for endangered Atlantic salmon in DFO's Maritimes Region in Canada, population dynamics models have been developed for several populations using an equilibrium modeling approach. This kind of analysis begins by splitting the life cycle into two parts, and determining the population size at which life history parameters (e.g. survivals, maturities, fecundities) in each part of the life cycle are balanced such that the population does not increase or decrease in size. When the population is in this state, it is said to be at its equilibrium for that specific set of parameter values. Once the life history parameters are known for a population, they can be varied in a manner that represents the expected response to a recovery activity. By examining the resulting change in equilibrium population size, the effects of the activity on the population can be evaluated.

The approach is illustrated in Figure 5.1. In the case of Atlantic salmon, a natural split in the life cycle occurs at the smolt stage when fish are migrating to the marine environment. The first part of the model gives freshwater production (the number of smolt produced as a function of egg deposition). In this example, a Beverton-Holt function is used to model smolt production in fresh

water (Figure 1a). This model has two parameters. The first parameter is the slope of the function at the origin which is defined as the maximum rate at which eggs survive to become smolts, based on the idea that survival is greatest when population sizes are very low because competition between fish, which can result in reduced growth and increased mortality, is low. The other parameter in the freshwater production model is the carrying capacity of the river for smolt. This is the number of smolts that would be produced if egg depositions were extremely high. This model is based on the assumption that resource availability in fresh water, which determines carrying capacity, limits the production of smolt within a river. Changes in habitat quantity, possibly as a result of providing fish passage to areas that were previously inaccessible, have the effect of changing carrying capacity (Figure 5.1a). Changes in habitat quality, possibly as a result of improving or reducing water quality, has the effect of changing the slope at the origin, but may also change carrying capacity as well. Although only two parameters are used in the model, they result from the combined effects of egg-to-fry survival, fry-to-parr survival, parr-to-smolt survival and age-at-smoltification.

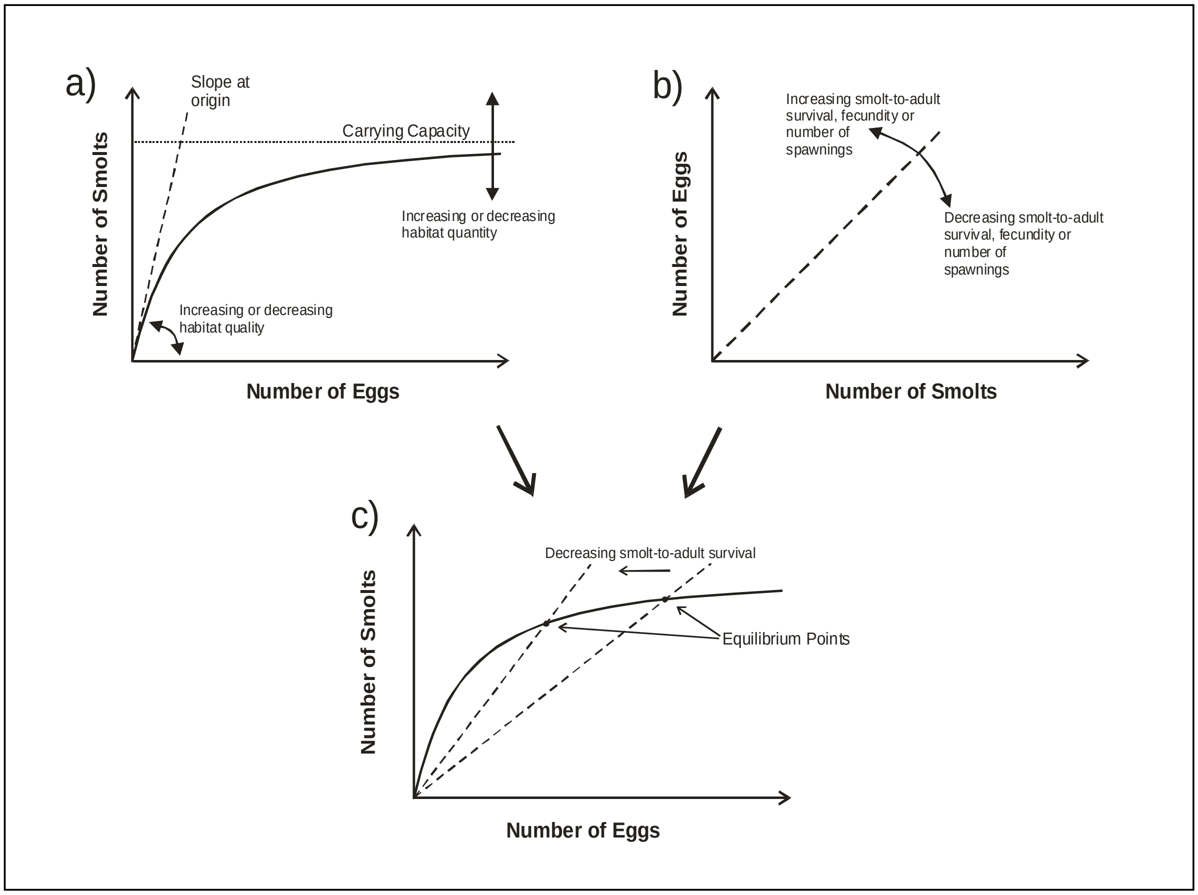

Figure 5.1. Conceptual diagram showing how an equilibrium model can be used to analyze the dynamics of a fish population and to determine how a population will respond to either changes in life history parameter values or recovery actions. A Beverton-Holt model (a) is used to model the density-dependent relationship for survival from eggs to smolt. The slope at the origin of this model, which is the maximum number of smolts produced per egg in the absence of density dependent effects, changes as habitat quality changes, whereas changes in the amount of habitat changes the carrying capacity. The number of eggs produced per smolt throughout its life (b) changes with smolt-to-adult survival, fecundity, age-at-maturity or the number of times a fish spawns throughout its life. The population equilibrium (c) occurs at the population size where the production of smolts by eggs is equal to the production of eggs by smolts throughout their lives, and is the size at which the population will stabilize if all life history rates and the habitat carrying capacity remain unchanged. The population equilibrium changes as the values of the life history parameters change.

The second part is the lifetime egg production per smolt (EPS) relationship (Figure 5.1b), which is the number of eggs a smolt is expected to produce throughout its entire life. In contrast with the freshwater production model above, the lifetime EPS relationship is assumed to be density independent, which means that the rate at which smolts produce eggs throughout their lives does not depend on the number of smolts that are produced. This is the equivalent of assuming resource availability in the marine environment is not limiting population growth, and therefore mortality at sea is not density dependent. This paradigm is consistent with most population models for diadromous fish, and is further supported by a recent analysis of the timing of density dependence in Atlantic salmon, which found strong evidence for density dependence in salmon populations within fresh water and little evidence for density dependence in salmon within the marine environment (Gibson 2006). The rate at which smolts produce eggs is calculated based on the survival of juvenile salmon in the marine environment, age-at-maturity, fishing mortality, fecundity, and the number of times a fish spawns throughout its life.

The population equilibrium is derived by finding the abundance at which the production of smolts by eggs equals the reciprocal of the production of eggs by smolts, as can be shown graphically by flipping the axes in Figure 5.1b, so that the plot can be overlain on Figure 5.1a. The equilibrium, which occurs where the freshwater production and EPS curves intersect (Figure 5.1c), is the population size at which the population will stabilize if all model parameters remain unchanged. The effects of changes to life history parameters such as survival are evaluated by examining how the equilibrium changes. In the example shown in Figure 5.1c, a decrease in smolt-to-adult survival shifts the equilibrium point to a smaller population size. If smolt-to-adult survival decreases far enough, the equilibrium population size goes to zero and the population will become extirpated unless one or more of the vital rates change as a result of either human intervention or for some other reason. Although an equilibrium population size of zero does mean the population is expected to become extirpated, the inverse is not necessarily true. An equilibrium population size that is greater than zero does not mean that the population is viable, because other factors, such as random variability in life history parameters or catastrophic events, may also lead to extirpation.

From the perspective of recovery planning, the model can be quite useful because, once the life history parameter values are determined, the fate of a population can be determined. Additionally, the effectiveness of proposed recovery actions can be evaluated by changing survival or other vital rates in a way that mimics the expected effect of the recovery action, and then examining the resulting change in the equilibrium population size. As an example, working with colleagues Ross Jones and Heather Bowlby at DFO, I developed a model of salmon in the Tobique River, NB. We showed that the population is presently not viable in the absence of supportive rearing due to the combined effects of reduced at-sea survival, low habitat productivity and low survival of smolts emigrating downstream through reservoirs and past hydroelectric generating stations (Gibson et al. 2009). Using the model, we also showed that addressing any one of these three issues in isolation from the others would not be sufficient to recover populations; rather two or more of these issues would need to be addressed if populations were to be expected to recover.

An important life history parameter that can be derived from this model is the maximum lifetime reproductive rate, defined as the maximum number of spawners that a spawner can produce throughout its life. This maximum occurs at very low population size in the absence of density dependent effects. If the maximum lifetime reproductive rate is less than one, a population would be expected to become extirpated because each individual spawner is not able to produce, on average, one individual to replace itself. For this reason, abundance in the population will eventually go to zero. The maximum lifetime reproductive rate is a measure of how rapidly a population can grow, which in turn determines its resiliency to increased mortality or episodic mortality events.

The mathematics underlying this modeling approach, including methods for estimating life history parameter values, are described in Gibson et al. (2009) and Gibson and Bowlby (2013).

Population dynamics of Maritimes Region Atlantic Salmon

Equilibrium population models have been developed for two populations that are part of the Southern Upland designatable unit (DU) of Atlantic Salmon (Gibson and Bowlby 2013), for two populations in the outer Bay of Fundy DU (Gibson et al. 2009; Gibson et al. 2014), and two populations that are part of the eastern Cape Breton DU (Gibson and Levy 2014). A summary of these analyses (Table 5.1) shows that the maximum lifetime reproductive rate varies among these populations and that the way these rates are achieved also differs among populations. For example, the maximum lifetime reproductive rates for the two Southern Upland and two Outer Bay of Fundy populations are all very near or below one, indicating the populations have little to no capacity to increase in size. The equilibrium population sizes for the Tobique, LaHave and St. Mary’s populations are zero or near zero. Although the Nashwaak population in the Outer Bay of Fundy has a higher equilibrium size than these populations, it is still thought to be at risk of becoming extirpated due to random variability in environmental conditions. The Middle and Baddeck populations in eastern Cape Breton have the highest maximum lifetime reproductive rates of these six populations and, primarily for this reason, the lowest extinction risk.

Table 5.1. Comparison of life history parameters used to characterize the dynamics of five Atlantic Salmon populations within DFO's Maritimes Region.

	Population					
	LaHave River (above Morgans Falls)	**St.Mary's River (West Branch)**	**Nashwaak River**	**Tobique River**	**Middle River**	**Baddeck River**
Designatable unit	Southern Upland	Southern Upland	Outer Bay of Fundy	Outer Bay of Fundy	Eastern Cape Breton	Eastern Cape Breton
Max. egg-to-smolt survival	0.017	0.034	0.007	0.005	n/a	n/a
Smolt carrying capacity (number per 100 m^2 of habitat)	4.6	4.8	1.8	0.3	n/a	n/a
1SW return rate (%)	2.2	1.2	4.95	n/a	n/a	n/a
2SW return rate (%)	0.3	0.1	1.29	n/a	n/a	n/a
Lifetime egg production per smolt	63	30	151	83*	n/a	n/a
Maximum lifetime reproductive rate (spawners/spawner)	0.84	1.01	1.13	0.41	3.22	1.61
Equilibrium population size (millions of eggs)	0.00	27,932	1,761,400	0.00	1,180,900	1,116,600
Equilibrium population size (number of large and small adults)	0 small & 0 large	11 small & 1 large	577 small & 162 large	0 small & 0 large	78 small & 329 large	54 small & 211 large

The maximum lifetime reproductive rates for the St. Mary's and Nashwaak populations only differ by about 10%, but the way these rates are obtained differs between the populations. Due mostly to differences in their return rates, the lifetime egg production per smolt for the St. Mary's population is only about 20% that of the Nashwaak population (Table 5.1), but the maximum survival from egg to smolt is estimated to be about 5 times higher for the St. Mary's population than for the LaHave. This suggests higher freshwater productivity and lower marine survival for the St. Mary's population than the Nashwaak population.

Other Applications

In addition to the comparison of population dynamics provided above, the output from these models can be used in several ways. For example, Jason Bryan, an MSc student in my lab, analyzed the dynamics of salmon in the Big Salmon River, NB, and derived an at-sea survival rate time series that extended from 1963 to 2004. Jason then compiled a set of 84 indices representative of changes in environmental conditions, in the fish community and changing human activities in the Bay of Fundy. Few indices showed long-term changes of similar magnitude to the decreases in at-sea survival, thereby reducing the number of hypotheses for the causes of the reduced at-sea survival (Bryan 2008).

Another MSc student in my lab, Brad Hubley, developed a model for examining the repeat spawning dynamics of Atlantic salmon in the LaHave River. This work, which separated survival in the first year after spawning (for both alternate and consecutive year repeat spawners) from survival in the second year (alternate year repeat spawners only), showed that mortality in the first year showed an increasing trend. However, mortality in the second year did not show this pattern, but was correlated with the North Atlantic Oscillation Index (Hubley and Gibson 2011), a measure of large-scale climatic conditions.

The output from the models described above can also be used as inputs for population viability analyses, which are models used to project abundance forward through time to evaluate the probabilities of extinction or recovery in a given time frame. Working with my colleague Heather Bowlby, we used this type of analysis to evaluate the effects of increased freshwater productivity and increased at-sea survival on the viability of Southern Upland Atlantic salmon. The analyses revealed that relatively small increases in freshwater productivity could markedly reduce extinction risk in Southern Upland salmon, although increased at-sea survival was likely necessary for populations to increase to sizes above their respective conservation requirements (Gibson and Bowlby 2013). Heather also developed a method to include fitness reductions resulting from captive-rearing in a similar model based on the dynamics of Big Salmon River. This example suggested that captive rearing can substantially increase population sizes over the short term, but that fitness effects have the potential to counteract abundance increases in the population when stocking takes place over the long term (Bowlby and Gibson 2011).

Conclusions

(1) Population dynamics models are very useful for recovery planning because a) they provide information about the expected fate of populations under current conditions; b) can be used to determine the life stages where losses to populations are occurring; and c) can be used to evaluate the effectiveness of proposed recovery actions. (2) Based on the comparison of their population dynamics: a) the two Eastern Cape Breton populations are presently more productive than the Southern Upland or outer Bay of Fundy populations and as such have lower extinction risk; b) the two Southern Upland populations have higher freshwater productivity, but lower at-sea survival than the two Outer Bay of Fundy populations; c) the Southern Upland and Tobique populations are expected to become extirpated in the absence of human intervention or a change in their vital rates; and d) the Nashwaak population could also be at risk of extirpation due to random environmental variability due to its low maximum lifetime reproductive rate. (3) Although population models are a valuable tool for recovery planning for salmon, it is also important to keep in mind that these models are highly-simplified representations of life (which is quite complicated) and for this reason populations may behave very differently than predicted by the model. This does not mean that the models are not useful, only that we need to be mindful of potential issues when they are being used.

Acknowledgements

The research on the dynamics of Atlantic salmon populations in the Maritimes Region was undertaken with many collaborators, including Heather Bowlby, Peter Amiro, Ross Jones, Alex Levy, Jason Bryan, Gregor MacAskill, and Brad Hubley. This research was only possible due to the hard work of many people over several decades to collect the data upon which the analyses are based. In particular, Larry Marshall, Peter Amiro and Ross Jones directed many of the programs leading to the creation of these datasets.

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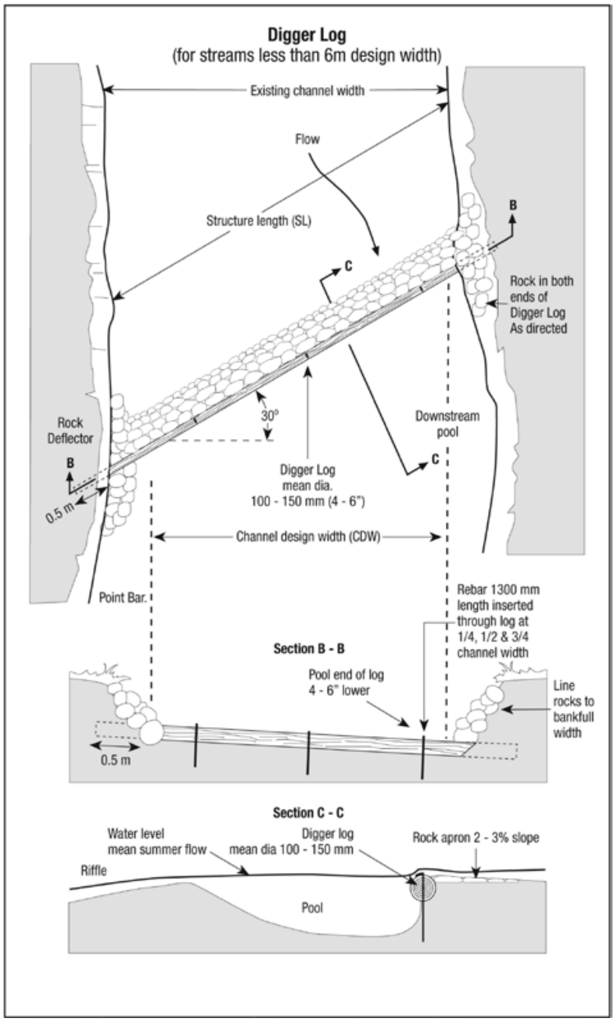
6. Session 4: Habitat Recovery Initiatives

Jamie Gibson, Fisheries and Oceans Canada

As an anadromous species, Atlantic salmon are dependent upon several diverse habitats to complete their life cycle and there are several good reviews of their habitat requirements (Gibson 1993; Bardonnet and Bagliniere 2000; Armstrong et al. 2003; Finstad 2011). Different freshwater habitats support feeding, over-wintering, spawning, early life-stage nursery, rearing, and upstream and downstream migration. In addition to habitat quality, quantity, and interspersion, connectivity among these habitats is also important in habitat recovery planning. Habitat restoration is a salmon recovery/enhancement strategy used by many organizations, with success determined by stream processes occurring on different spatial scales (Roni et al. 2002).

There were four oral presentations and one poster presentation in the session on habitat recovery initiatives. One of the presentations was focused on the use of in-stream structures to modify the flow of water and sediment, and another on some new technologies that can used to improve knowledge of habitat issues that could be targeted for remediation. Two other presentations discussed the interactions among habitat recovery projects and other recovery initiatives. The fifth presentation described fish habitat protection and restoration strategies at the 5th Canadian Division Support Base (5 CDSB) Gagetown.

Constructed in-stream rock and/or wood structures are a relatively inexpensive way to modify flow, to remove or redistribute silt and sediment, to create pools, or to re-shape the channel for some other reason. Digger logs, rock sills, deflectors, and crib walls have been used to restore salmon habitat (Jenkins, this workshop) with varying degrees of success. The key determinants of success are: site geomorphology; an understanding of channel controls, responses, and evolution; and regional, watershed, watercourse segment, stream reach, and micro scales processes.

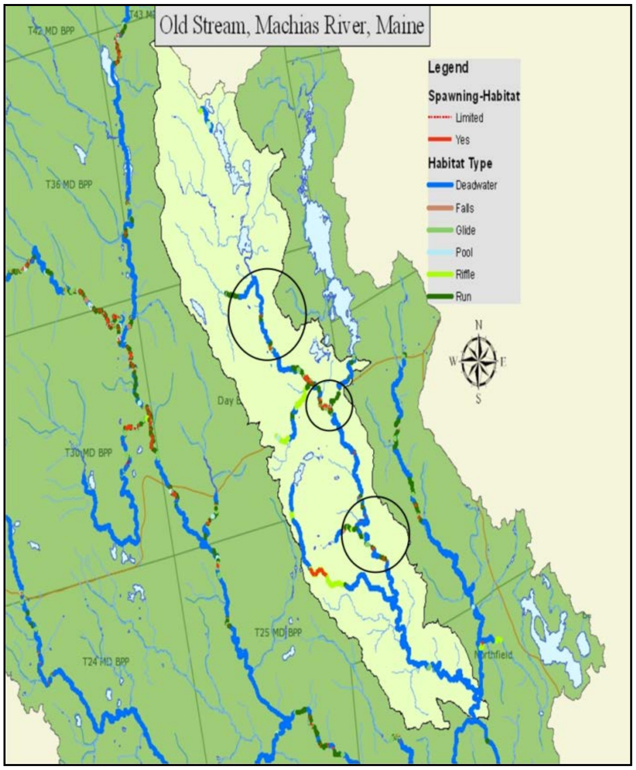


Jenkins, this workshop. Slide 12. Diagram showing how digger logs should be installed in a small stream.

The Restigouche River Watershed Management Council reported on three innovative projects; characterizing salmon habitat with simultaneously acquired thermal and optical images: 1) finding sediment runoff with aerial surveys; 2) using LIDAR imagery to identify soil erosion from potato fields; and 3) calculating equivalent cut area with GIS (LeBlanc, this workshop). As a result of the projects, forest landowners and managers have restored dozens of sediment runoff sites; farmers are reducing field soil loss and stream sedimentation; and cold water refugia are being protected.

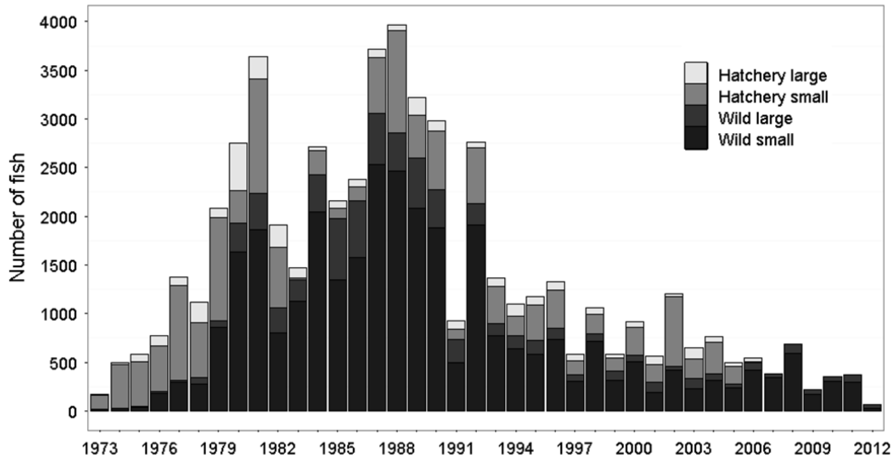
LeBlanc, this workshop. Slide 32. Example of a LIDAR model of surface flow and runoff on an agricultural field in the Restigouche River watershed.

Habitat restoration within salmon habitat is intended to improve habitat carrying capacity and juvenile salmon populations. Thus the projects may also include salmon population assessments, stocking, and harvest regulation. In Old Stream, a highly productive cold water tributary to the Machias River, habitat restoration projects to improve access among tributaries to help maintain stream functions were conducted over a 5 year period (Atkinson, this workshop). While tributary stream access was being improved juvenile salmon density was strongly related to increased adult escapement not numbers of fry stocked. With Old Stream at or close to its conservation spawning escapement, stocking hatchery products was suspended after 2008. Since then juvenile densities have remained high. Although it is too early to evaluate whether wild production will be sufficient to maintain this population in the long term (the first cohort of adults has not yet returned), improved stream function is likely contributing to natural spawning success.



Atkinson, this workshop. Slide 3. Map of Old Stream, circles indicate juvenile sampling locations.

Enhancement and recovery measures for Southern Upland (SU) Atlantic salmon populations have included: stocking to enhance fisheries, construction of fish passage to establish populations above natural barriers, closure of commercial fisheries, increasingly restrictive recreational fisheries management measures for ultimately leading, and supportive rearing programs to augment declining populations (Levy et al., this workshop). Stocking and providing fish passage in the LaHave and Liscomb were successful in increasing abundance during the 1970's and 1980's, but were not sufficient to prevent abundances declines through the 1990's and 2000's. Recovery actions focused on improving freshwater productivity are expected to reduce extinction risk for SU salmon, but are not expected to recover populations to past abundance levels without a change in at-sea survival. Large-scale habitat restoration initiatives addressing landscape-scale threats are expected to lead to greater reductions in extinction risk than small scale habitat restoration.



Levy et al., this workshop. Slide 4. Counts of wild and hatchery Atlantic salmon at the Morgan's Falls fishway from the shortly after its construction in the early 1970's to 2012.

The Army's Strategic Environmental Direction for 5 CDSB Gagetown is based on environmental stewardship, compliance, and identifying sustainable ranges and training areas, and stream restoration (Smith, this workshop). Habitat restoration on the 3,200 km of streams within 5 CDSB Gagetown include improving fords, decommissioning road, improving road crossings, constructing wetlands, riparian tree planting, and installing in-stream structures. Fish and aquatic insect populations and water quality and quantity are monitored to evaluate the success of stream restoration projects.

Smith, this workshop. Poster. An example of stream restoration at 5 CDSB Gagetown: a deflector and log cover creates a pool and improves habitat diversity.

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7. Session 5: Dams and Fish Passage

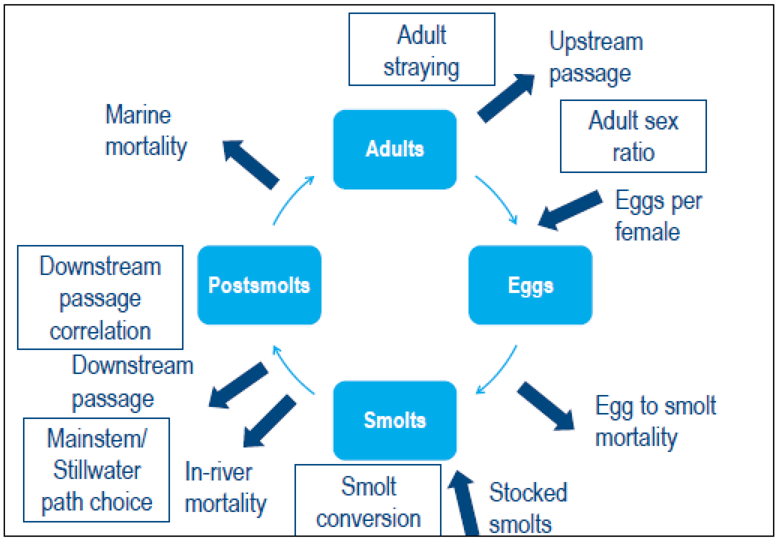
Joan Trial, Department of Marine Resources (retired)

Although rivers and streams with naturally reproducing anadromous Atlantic salmon populations vary widely in physical characteristics, all have access to the ocean. Atlantic salmon require a diverse array of well-connected habitats to complete their life cycle. Historically, the upstream extent of anadromous Atlantic salmon included the mountainous headwaters of even the largest watersheds in the northeastern United States and Canada, as well as all but the smallest of tributaries on smaller coastal rivers. Today, upstream migrations are substantially restricted, with many productive spawning and rearing areas not well connected; either completely or partially inaccessible because of mainstem hydroelectric dams, smaller dams, and rail and road stream crossings.

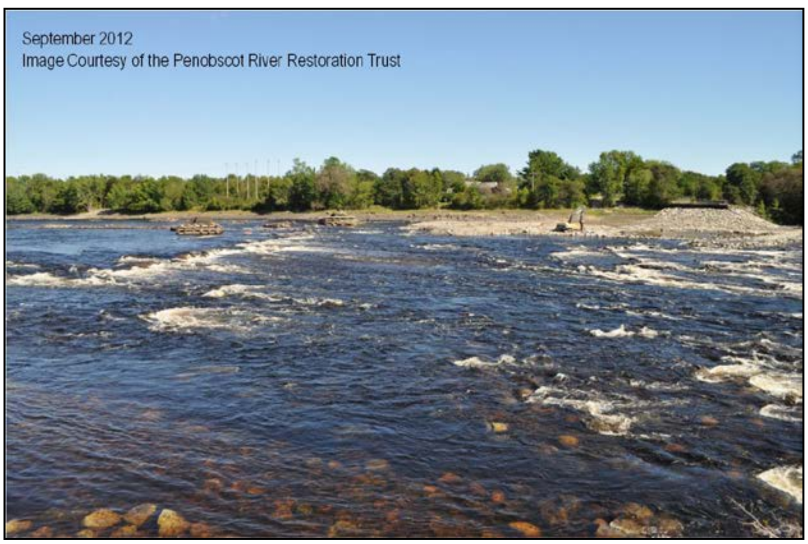
Whether in a small coastal river or a tributary to a larger river, adult salmon need unobstructed migratory corridors to and from quality spawning and incubation habitat. Spawning habitat in turn needs to be interspersed with sufficient quantity, quality, and diversity (e.g., including overwintering, summer thermal refugia, etc.) of accessible rearing habitat that support the resultant fry and parr. Smolts produced need to migrate successfully to the ocean. Survival of resident and migrating juveniles is, in part, controlled by abiotic conditions, cycles, and variability (e.g., annual hydrological regime; annual, seasonal and daily temperature cycles; water chemistry; physical structure of the stream channel and floodplain).

Dams and road crossings fragment Atlantic salmon habitat in rivers and streams, alter abiotic conditions, cycles, and variability, and increase mortality of migratory adults and juveniles within rivers throughout eastern North America. Fragmented stream networks expose populations in the accessible reaches and sub-drainages to demographic, environmental, and genetic stochasticity increasing vulnerability to extinction (Hanski 1991; Drechler and Wissel 1998; Fahrig 2002; Morita et al. 2002; Letcher et al. 2007).

Dams impede migration pathways and increase mortality of Atlantic salmon and other co-evolutionary diadromous fish by: directly and indirectly killing spawners and emigrants going through or around the structure; creating impoundments that degrade the productive capacity by inundating formerly free-flowing rivers, reducing water quality (i.e. water temperature) and changing fish communities; delaying outmigration; delaying upstream migration of adults; and altering natural flow regimes. A population viability model developed using data for direct mortality and passage inefficiencies at hydro-electric dams in the Penobscot River watershed (Nieland et al., this workshop; Nieland et al. accepted) demonstrated that all dams did not affect populations equally and the cumulative effect of all the dams was not as straight forward as the summation of losses, in part due to path choice by migrants. The model will also be used to evaluate the potential gains in habitat and population viability from the Penobscot River Restoration Project (Saunders, this workshop). This multi-million dollar restoration project is the result of government agencies and non-government groups working collaboratively with energy companies to remove two dams and substantially improve access at three more without loss of power generation (http://www.penobscotriver.org/). The process can serve as a model and inspiration for improving Atlantic salmon habitat access on large industrialized rivers. Remnant log driving dams can be removed with small crews and simple mechanical advantage, removing barriers to fish passage and restoring habitat (Koenig, this workshop).



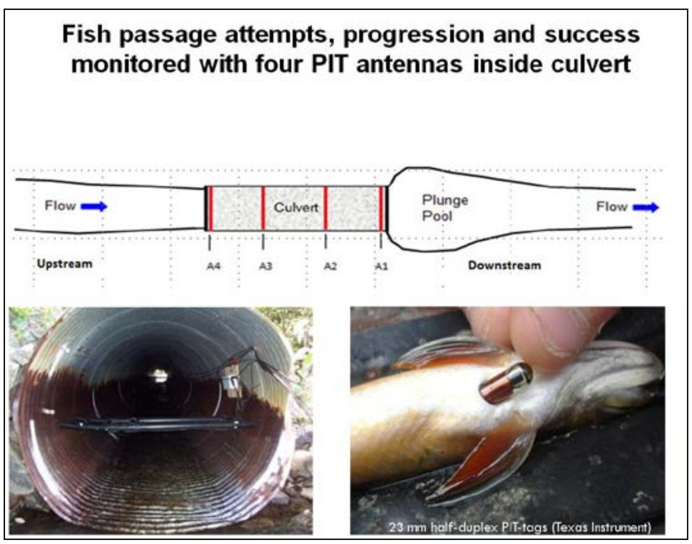
Nieland et al., this workshop. Slide 6. Diagram of the population viability model developed for the Penobscot River based on river specific hydrologic and fish passage data.



Saunders, this workshop. Slide 12. Penobscot River flowing through the area where the Great Works Dam stood just a few months earlier.

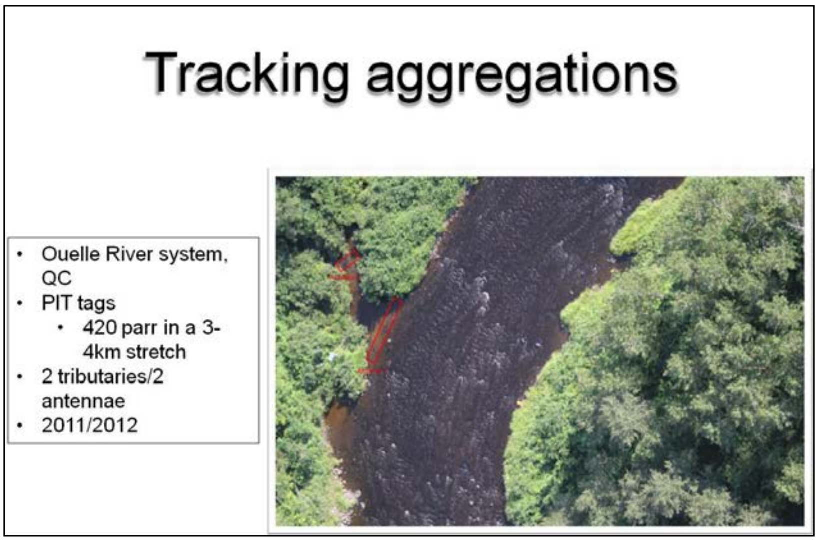
Koenig, this workshop. Field trip. Picture of grip hoist set up to remove logs from a remnant log drive dam.

Corrugated metal, concrete, or plastic culverts are generally placed at rail and road crossings of smaller streams, where they are more likely to create passage barriers to Atlantic salmon than bridges or other bottomless structures (Gibson et al. 2005). Improperly placed and undersized culverts create fish passage barriers (MacPherson et al. 2012) through hanging outfalls, increased water velocities, or insufficient water and depth within the culvert, affecting species dispersal (Perkin et al. 2013) and access to spawning and rearing habitat. Simulation programs accurately predict the ability of larger fish to pass culverts based on roughness, length, slope, and discharge; however they may under estimate upstream passage success of smaller fishes (Bergeron, this workshop).



Bergeron, this workshop. Slide 13. Experimental design and data collected to evaluate culvert passage by brook trout in Quebec.

Impassable culverts on smaller streams often limit access to cooler headwater streams that are important rearing and thermal refuge (Breau et al. 2007; Corey et al., this workshop; Sweka and Mackey 2007) habitat for Atlantic salmon. In addition to direct loss of habitat, culverts also degrade upstream and downstream channels through scour and deposition altering food production (Bates 2003). Culverts also alter small streams export of sediment, course particulate organic matter, and invertebrates that influence fish productivity in the receiving stream (Binkley et al. 2010; Wipfli and Gregovich 2002; Wipfli 2005; Wipfli et al. 2007). In unaltered stream networks, inputs at confluences are spatial discontinuities that result in "hot spots" of biological productivity and diversity (Kiffney et al. 2006), contributing to the water quality in receiving streams (Alexander et al. 2007).



Corey et al., this workshop. Slide 17. Thermal refugia identified by Corey et al. (red boxes) in a small tributary and at its confluence with the Miramichi River.

Removing dams and culverts, and improving passage at remaining structures decreases fragmentation by increasing access to habitat essential for Atlantic salmon spawning and juvenile rearing. Increasing access helps restore ecological complexity allowing salmon to select among diverse habitats, which in turn helps protect populations from environmental stochasticity and maintain genetic diversity.

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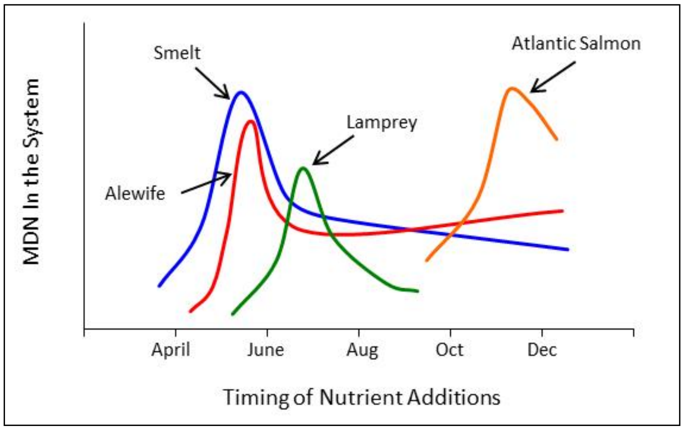
8. Session 6: Water Quality Considerations

Jon Carr, Atlantic Salmon Federation

Water quality is a critical component to the overall health and survival of Atlantic salmon. There were three presentations at the workshop that provided an overview on different aspects related to water quality: marine derived nutrients, thermal tolerances, and acidification. These presentations provided insight into different methods for improving water quality for Atlantic salmon in freshwater streams. One theme that came to the forefront during the presentations was that any application to address water quality issues should be designed in concert with other restoration practices and long term performance measures to monitor the success of the various approaches.

<u>Marine Derived Nutrients</u>

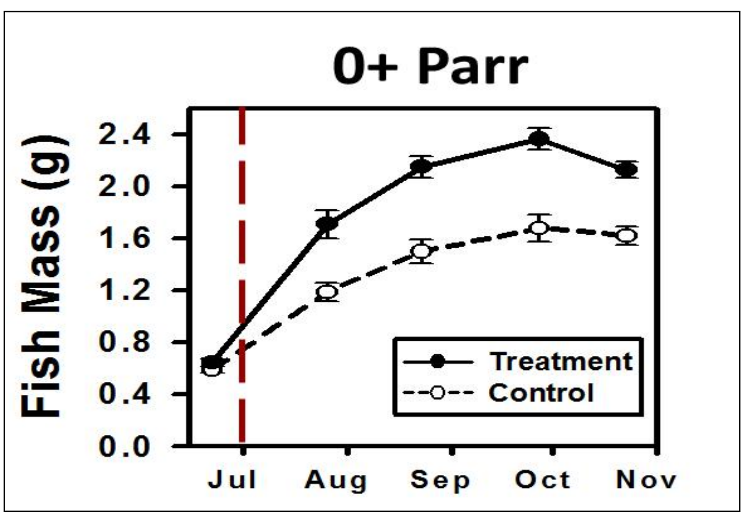
Anadromous fish deposit marine derived nutrients (MDN) in northeastern North American freshwater streams in the form of excretory products, eggs, and carcasses. Many of these streams are considered to be nutrient limited, therefore MDNs are an important driver of stream productivity. There are several anadromous species in the Northeast which include Atlantic salmon, shortnose sturgeon, Atlantic sturgeon, rainbow smelt, brook trout, tomcod, alewife, blueback herring, American shad, striped bass, and sea lamprey. Each of these species has diverse life histories such as different spawning times and habitat locations, and the amount of MDN contributions (Guyette and Samways, this workshop). For example, alewives are spring lake spawners while Atlantic salmon are autumn stream spawners.



Guyette and Samways, this workshop.Slide 38. Spawn timing and MDN contributions of various anadromous fish species found in northeastern North America.

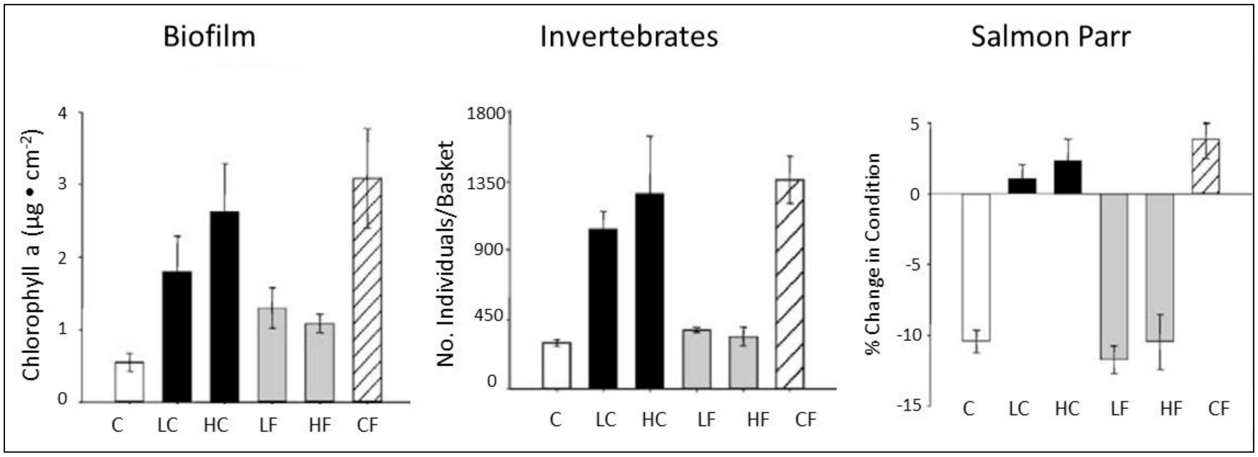
Historically these fish collectively provided huge amounts of MDN to their natal rivers upon return from the ocean but now many watersheds along the east coast of North America are suffering from a nutrient deficit because of the crash in many anadromous fish populations. This could have profound effects on nutrient dynamics and aquatic production (primary, secondary, tertiary).

Nutrient addition via carcass analogs has been considered as a way to help restore rivers to their natural productivity state at various trophic levels. Increases in primary production, invertebrate abundance, and Atlantic salmon parr condition have been observed in streams with MDN or carcass analogs present (Guyette and Samways, this workshop).



Guyette and Samways, this workshop. Slide 23. Changes in body mass of Atlantic salmon aged 0+ parr in the presence of MDN (treatment) versus no MDN (control).The dashed red line indicates when MDN (carcasses) were added to the stream.

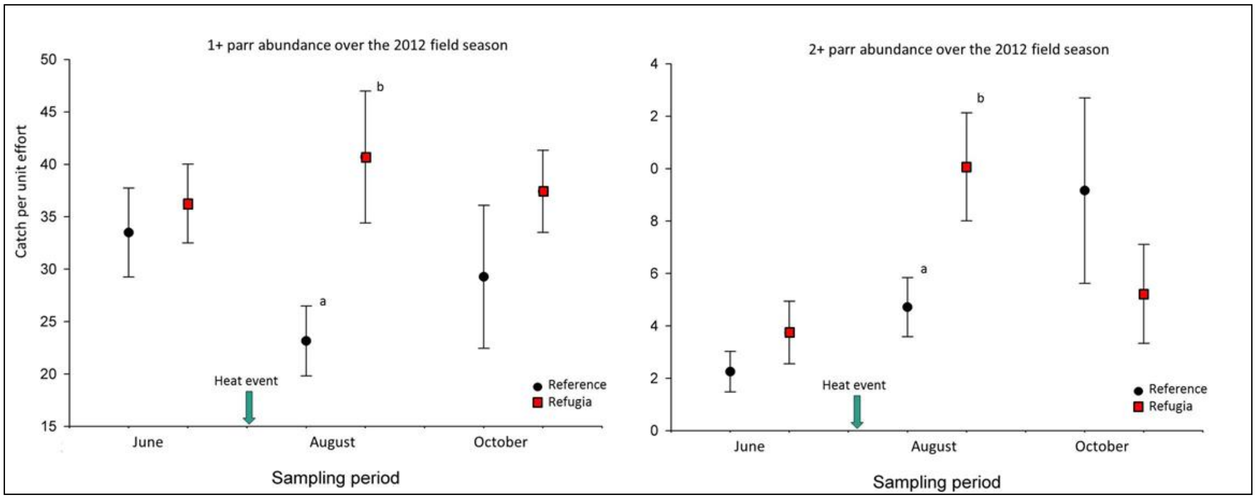
Wipfli et al. (2010) suggested that carcass analogs are more effective than artificial fertilizers to deliver an increase in production at all trophic levels (Guyette and Samways, this workshop). Nutrient subsidies have a small effect range (500 m) and should be used strategically based on specific restoration goals (i.e. consideration of life strategy of the species of interest) and in concert with other restoration techniques.



Guyette and Samways, this workshop. Slide 29. Comparing the productivity responses of biofilm, invertebrates and salmon parr to the release of MDN carcass analogs and fertilizer concentrations into streams. C = Control, LC = Low Carcass, HC = High Carcass, LF = Low Fertilizer, HC = High Fertilizer, CF = Low, Carcass & Low Fertilizer (Wipfli et. al 2010).

Thermal Tolerances

Global warming is causing surface temperatures to rise, and consequently water temperatures of freshwater ecosystems are experiencing high temperature events. Little Southwest Miramichi River (LSWM), a wide and shallow system exposed to solar radiation, has experienced high water temperatures that exceed the optimal thermal range for Atlantic salmon (Corey et al., this workshop). When the lethal temperature limit is surpassed there is a wide scale movement of both juvenile and adult salmon to areas of cooler water (Breau et al. 2007). These areas of cooler water, termed thermal refugia, are a result of cool water inputs by small tributaries, springs, and ground water seeps. Water temperatures at many refugia sites in the LSWM are near 20˚C compared to about 30˚C throughout most remaining stretches of the river. Refugia near larger seeps can hold tens of thousands of fish in what is essentially a 1m x 100m plume of cooler water that hugs the bank. Corey et al. (this workshop) reported a near even distribution of parr at reference and refugia sites prior to increased water temperature events, a decrease in the numbers captured in the reference sites immediately after a heat stressor event with a mass movement to refugia sites. Fish remained is cool water in close to refugia for the duration of the summer, and had redistributed to reference and refugia sites by October.



Corey et al., this workshop. Slides 13 & 14. The abundance (CPUE) of aged 1+ and 2+ Atlantic salmon parr in the Little Southwest Miramichi River before (June), during/shortly after (August), and post (October) heat stress events, 2012. Significantly more parr were found at the refugia sites than at the reference sites during and shortly after the heat events (1+ parr: P=0.03, 2+ parr: P=0.04).

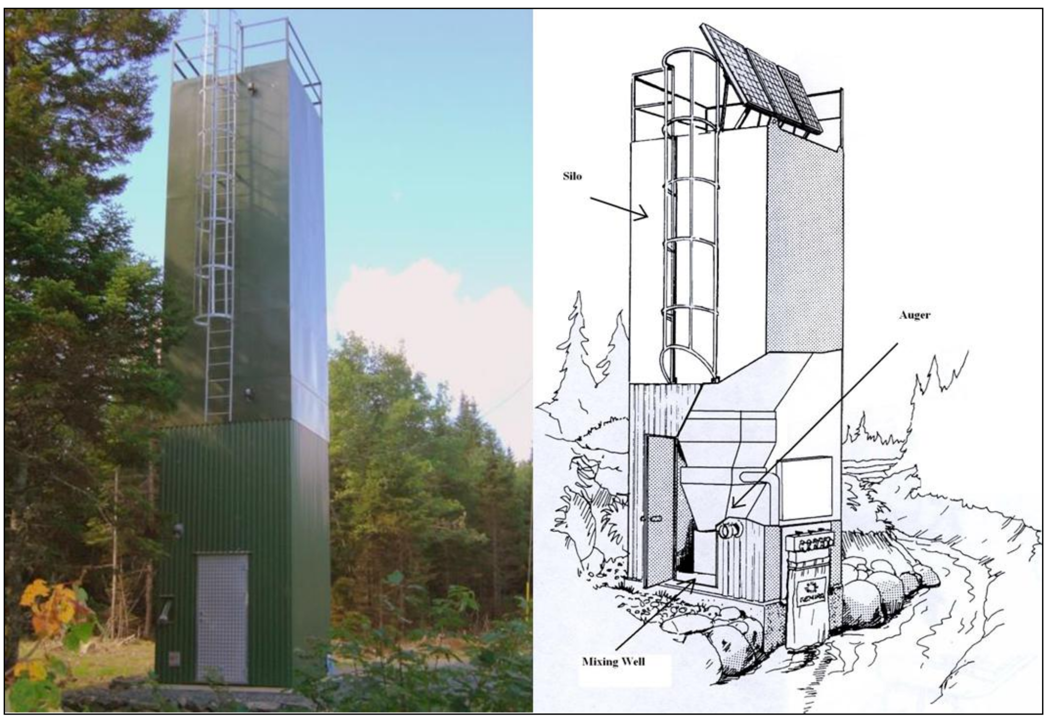
In the LSWM salmon parr moved more than 11 km to reach thermal refugia. The expenditure of energy associated with these movements, along with the limited number of accessible refugia, may partially explain high mortalities of adult salmon and parr observed during water temperature spikes in the LSWM (Corey et al., this workshop).

The LSWM Atlantic salmon parr aggregations in thermal refugia were observed when water temperature reached the near lethal temperature of 27˚C. However in the Ouelle River (Quebec), parr were observed to tolerate water temperatures at 27˚C, with aggregations observed only when water temperatures approach 30˚C. (Corey et al., this workshop). Local adaptation could be the reason for this, with certain populations evolved to acclimate and withstand warmer water temperatures better than others, possibly a result of long term exposure. Preliminary results from laboratory studies conducted by Corey et al. (this workshop) demonstrated that salmon parr acclimated to warmer temperatures, but exposure to $\geq$3 days of high heat events resulted in greater mortality rates.

When water temperatures approach lethal limits, salmon must abandon their territories in order to survive. Refugia are essential to their survival during these times. The availability of thermal refugia to both juvenile and adult salmon will play an important role in the persistence of Atlantic salmon in northeastern North America.

Acidification

Acid rain is a limiting factor to the well-being of Atlantic salmon. It was thought that the signing of the Canada/USA Clean Air Agreement in 1990 would lead to a reduction in acid rain causing emissions and a recovery of pH in affected areas. This has not been the case and the recovery of salmon rivers affected by acid rain may take at least 50 years (DFO 2000). Rivers with a mean annual pH less than 4.7 cannot support Atlantic salmon (Amiro 2000). In rivers with an average pH between 4.7 and 5.1, salmon production is considered unstable (Watt 1987). In Nova Scotia more fish habitat has been lost due to acid rain than any other region in North America. Acid rain has resulted in the extirpation of Atlantic salmon in at least 50 of the 65 salmon rivers in the Southern Uplands of Nova Scotia. In 2005, the Nova Scotia Salmon Association (NSSA), Atlantic Salmon Federation (ASF) and other organizations introduced the first lime dosing project in North America on the West River with the goal of mitigating the effects of acid rain on about ¼ of the West River system's habitat that was once utilized by salmon (Halfyard, this workshop). The liming involved the use of a single doser (Norwegian-manufactured Kemira Kemwater lime system), operated year-around (Halfyard, this workshop).



Halfyard, this workshop. Slide 7. Norwegian manufactured Kemira Kemwater lime doser used in West River, Nova Scotia.

The Project is supported by a long term monitoring program (≥10 years) to assess changes in water chemistry, invertebrate community structure, and fish species composition and abundance in limed and unlimed regions of the West River. The pH of the main stem (limed) of the West

River has increased to mean levels within the range for successful reproduction and survival of Atlantic salmon (5.5 to 7.0). An increase in invertebrate abundance and a shift in community structure were also observed after the first year of liming, although limited subsequent monitoring suggests that this trend has not persisted. Annual smolt production post-liming increased 3-fold in treated sections of the watershed yet remained low or declined in the unlimed sections. Comparing inter-annual and inter-cohort trends with nearby index rivers (e.g., Lahave River, St. Mary's River, Nashwaak River), the positive trend observed in limed sections is atypical and likely represents the effects of liming.

Liming in concert with other restoration programs seems to have decreased the risk of extirpation of the Atlantic salmon in the West River. Lime dosing is a feasible solution to reversing the adverse effects of acid rain to freshwater systems when part of a larger conservation program. However, it is an expensive program and a long-term commitment along with careful planning and diligent operation of the equipment is critical to its success.

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9. Panel Discussion Questions

A series of three questions were posed to the attendees to stimulate discussion of the take home messages from the Workshop. At the end of the meeting there was moderator-led discussion on each question. Workshop participants also had the opportunity to email responses to the questions for summation in the final report.

Question 1: How has the role of hatchery/supportive rearing programs in Atlantic salmon recovery changed? Generally speaking, stocking was thought to be a tool to increase returning adult abundance, but this concept has been challenged over the past few years given the realized effectiveness of stocking, major issues with poor marine survival and our continual education of the genetic risks associated with captive rearing. What recommendations could be made regarding improved practices?

Question 1 was intended to challenge the workshop participants to evaluate if their assessment of the roles of hatcheries in Atlantic salmon restoration has changed due to the presentations provided during the workshop and what recommendation would they now propose for hatchery related restoration activities. A summation of the discussion and written comments on this question follows:

There was a strong sentiment that consideration should be given to convert our contemporary production hatchery facilities to conservation facilities, at a minimum on an experimental scale. To do this traditional fish culturists will need to switch from a goal of maximizing productivity to a goal of maximizing biodiversity, resulting in the production of ecological viable fish better prepared for survival in the wild (Samways and MacDonald, this workshop). Fish culturists should be continually striving towards integrating demographic, genetic, ecological and evolutionary considerations into their hatchery programs to the greatest extent possible. The use of semi-natural rearing ponds may result in fish better suited for life in the wild as compared to the conventionally reared counterparts. The question of when to initiate a supportive rearing program which involves weighing the risks associated with supportive rearing with the risk of extirpation in the absence of the program. There is evidence of river-specific extirpations having occurred in the last 15 years in the inner Bay of Fundy and Southern Upland regions. Time is of the essence for many of our populations.

There has been an evolution in our understanding of what may constitute effective Atlantic salmon restoration. We need to create and/or maintain ecological and genetic diversity within these populations. This diversity affords population resiliency and allows varying ecological responses to the specific environments that fish are exposed to. This concept has been referred to as the portfolio effect and it is analogous to the effects of asset diversity on the stability of financial portfolios (Schindler et al. 2010). To further this analogy, many of our populations are heavily invested in a single sector and they are not divested enough to withstand the current and expected volatility of our contemporary environmental marketplace.

There was a realization that a number of hatcheries involved in Atlantic salmon restoration activities have been evolving their approaches over the past few years. In some respects, we are travelling back in time and incorporating practices that were common back in the early part of the 20^{th} century. As an example, egg planting is again being used to supplement freshwater production. The difference now is that we have a greater understanding of some of the variables that are important to its success (e.g., timing, temperature requirements, etc.). We are also doing a better job of modifying approaches to improve success (Christman and Overlock, this workshop).

There was a strong acceptance that many freshwater systems are broken. Fish of different life stages are being stocked into habitats that we know are not functioning properly and therefore cannot support salmon. We need to continually work to correct our sins of the past while striking a proper and coordinated balance between habitat restoration and stocking.

There was strong agreement that hatchery programs alone are not a recovery program. Stocking large numbers of fish can mask issues within the population or habitat and in almost all cases just increasing the numbers of juveniles in a river system will not lead to recovery for the population. Supplementation programs can lead to a number of other problems such as reduction of escapement into the natural system, genetic effects and reduced biodiversity through altered phenotypes and domestication thereby impeding future adaptation and fitness. The addition of large numbers of hatchery origin individuals can also disguise the problems of broken habitat or excessive harvest given the appearance of high local abundance. However, hatchery programs do have a large role to play in preventing extirpations and can reduce the time to recovery if used properly and if the threats to populations are also addressed.

While a captive breeding approach to hatcheries still have ecological and genetic risks, these are reduced compared to a production facilities, and the potential value is large. We are continually learning how to more effectively use and manage this approach. It should only be thought of as a temporary tool and should not inhibit other restoration and recovery measures; rather they should work in tandem. It is important to note that hatcheries, whether they be production facilities or captive breeding facilities, will not be sufficient by themselves to restore the resiliency that our populations need for recovery. Hatcheries should be thought of as a single tool in our restoration tool box. If we do not address the other threats to the population, stocking large numbers of compromised hatchery origin fish will not lead to recovery (Carr, this workshop; Hawkes, this workshop; Levy et al., this workshop; Sochasky, this workshop).

Generally, the less human intervention (e.g., feeding, and artificial culture) the better. We have a number of rivers throughout North America whose salmon populations are doing OK. These rivers should be left alone to allow the systems to operate naturally. Without interference, these systems and populations will maintain and build up their resiliency. Effort should be focused on the systems that are in dire straits.

Incubating alevins in substrate is a much preferred approach than incubating them in pans or heath trays. Salmon should be stocked out at early stages. If they must be maintained within the hatchery, then efforts should be pursued to utilized semi-natural rearing conditions. Where possible, stocking of smolts should be minimized. If the freshwater habitat cannot support juvenile salmon, then possibly they shouldn't be stocked there in the first place and habitat restoration efforts should be pursued. It was noted that for many of these populations, marine survival appears to be a major threat (Gibson, this workshop; Nieland et al., this workshop). In these cases, consideration should be given to raising wild smolts in captivity until they achieve maturity and can be used in supportive rearing programs.

There was strong sentiment that workshops such as this one are a valuable tool for researchers and managers, government and non-government organizations, local groups, stakeholders, industry, and Aboriginal Peoples to exchange information and experiences. It was recognized that government cannot do it alone and that there is not enough program money or internal capacity to address all the needs for all our regional species. Workshops such as these can facilitate efficacy and can provide a venue for investigating where pooling of resources may have large benefits.

There are a large number of recovery documents that have been drafted by diverse groups that can provide strategic direction and scientific advice for recovery efforts. Often these efforts have built upon the local knowledge and interest groups that already exist and incorporated the current restoration underway. These documents can be a significant resource to guide restoration efforts.

References

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Question 2: What constraints/limiting factors need to be addressed to affect salmon recovery in North America?

Question 2 was intended to allow workshop participants the opportunity to provide input on the issues that are limiting progress on recovering Atlantic salmon populations. Discussion fell into two broad themes: 1) the specific issues that need to be addressed, either through recovery actions or research to address knowledge gaps, and 2) broader, contextual issues that make it difficult to address specific problems.

Specific issues that need to be addressed include habitat restoration, marine survival, and the impacts of aquaculture on wild Atlantic salmon. The use and effect of in-stream and riparian habitat restoration methods are reasonably well understood. However, methods to mitigate the effects of human activities and development within the watershed on salmon habitat and populations are not well developed, in part because direct links are not as easily demonstrated. Climate change and human activities on a wider spatial scale have the potential to override the positive benefits of in-stream habitat restoration. This uncertainty should not hinder action to address known habitat issues now. There seemed to be consensus that more research was needed to understand marine survival, but that it was also important to maintain and restore freshwater habitat so populations could thrive if marine survival increases. Discussion about the impacts of aquaculture related primarily to its effects on marine survival, with aquaculture-origin parasites suggested as one of the agents compromising the survival and migration of salmon smolts produced in all eastern North American rivers. Suggested future research on this question included deploying smolts in sentinel cages along the migration routes and near aquaculture sites to assess survival, as well as plankton trawls to assess parasite egg and unattached juvenile densities in cold sea water circulation just before and during wild smolt migration.

A portion of the discussion centered on the broader context of socio-economics and the perceptions of salmon recovery. Salmon recovery (as well as many other conservation issues) can be in direct competition with socio-economic agendas. There might be more information about the effects of salmonid aquaculture on wild Atlantic salmon populations in the region (southwest New Brunswick and Maine) if it were not of very high socio-economic importance. Similarly, the political will to address habitat issues caused by other industries, human population growth, and urbanization is also lacking. Outreach and education were considered the primary tools to increase public awareness of these conflicts, the direct economic benefits of healthy Atlantic salmon populations, and the indirect economic benefits of high quality salmon habitat for other species. Recovery of Atlantic salmon will take government in conjunction with all interested citizens (Canadian and US) working together towards the common goal. Interested citizens are enlisted and maintained through education and outreach. Finally, to make the best use of limited resources, improved information sharing among the many groups interested in salmon recovery would allow groups to learn from the successes and failures of others.

Question 3: What are your "take-home messages" and recommendations to your organization? Do you envision any future changes to your program based on what you heard/learned during this meeting?

Comments and written responses articulated a wide range of take home messages, which would be expected from such a diverse community of attendees representing local watershed groups and NGOs, government agencies, First Nations, and academic institutions. Some responses related to specific practices (e.g., hatchery and stocking) or principles (maximizing freshwater smolt production in the face of continued high marine mortality); while others contained more general recommendations (e.g., communication, collaboration, and public engagement, and political will).

Respondents noted that the risks and limitations of hatchery involvement are being recognized and this is driving an evolution and improvement of hatchery and stocking practices. As such, there have been great strides made in changing these practices to maximize wild exposure, including the more "wild-like" exposure that is provided by semi-natural rearing ponds.

A representative of the Nashwaak Watershed Association indicated that the proceedings reinforced their own experience rearing and releasing fall fed fry. In a river that continues to support a natural spawning population (albeit highly reduced) like the Nashwaak, the message would be to not release fall fed fry because of the reduced fitness compared to the wild fry. However, the Association might consider other stocking options covered at this workshop (e.g., planting of eggs, the release of unfed fry, or the captive rearing of wild smolts to adulthood for subsequent natural spawning, all of which provide greater wild exposure than releasing fall fed fry).

Another respondent indicated that the proceedings will not result in any changes to their specific stocking practices but will focus their efforts to identify the causes of smolt mortality in the estuary and bay. Their take-away message from the workshop was: time is running short due to critically low populations in certain areas; therefore, do something now that leads to increasing the number of wild or early wild-exposed smolts exiting the rivers under recovery.

Although not all experiments and research programs will be considered successful in terms of increasing wild populations, it was noted that there is always great value in the results whether or not they support the initial hypothesis. It is precisely this outlook that has led to the evolution of hatchery and stocking practices that may lead to greater successes in the future.

One attendee suggested that people "take more politicians and their families fishing". The value of recovery programs for wild Atlantic salmon and the ecosystems on which they depend require the buy-in of decision and policy-makers. Recovery programs for wild Atlantic salmon will only have limited success if the general public and our politicians are disconnected from the resource and do not recognize the great value of our natural heritage, and the need to restore and protect it. Children who are turned on to angling will carry memories that last a lifetime and this may influence future support for recovery programs. This is an initiative well within the reach of most grassroots organizations and is an investment in the future.

Although it is not possible to predict the future, it is possible to acknowledge that the changing climate is already affecting wild Atlantic salmon populations. These effects may increase or accelerate in the coming decades. Will climate change drive a shift in the timing of smoltification and will this result in increased mortality at this sensitive life stage? These and other questions will have to be incorporated into research programs and recovery efforts must start to observe and assess what these changes might be.

Regardless of what the effects of climate change may turn out to be, there are actions that can be taken now within each watershed that will address threats to habitat. NGO's and local stewardship groups must work with partners and local governments to identify the list of problems specific to a given watershed. They must then prioritize and address the ones that can be dealt with, one at a time, using the resources that are available. Replacing and upgrading poorly functioning culverts is an example that was discussed. These proceedings reinforce the value of restoring full passage to headwater spawning and rearing reaches for wild Atlantic salmon.

One of the respondents noted that there are many issues affecting Atlantic salmon. With the vast amount of effort in identifying, understanding, and resolving these issues throughout the range of Atlantic salmon, there are likely redundancies. For example, higher water temperatures are not necessarily restricted to the southern range of Atlantic salmon in the Northeast U.S. and eastern Canada. It was suggested that there needs to be a multi-jurisdictional committee that is aware of the work happening on all these areas and can share that information on an ongoing basis. If not already in place, there may be an opportunity to develop a means of sharing this information using an existing multinational structure such as NASCO to accomplish this.

A central thread connecting a number of responses dealt with the need for information sharing and collaboration between government, NGOs, First Nations communities, and industry. Government agencies that carry responsibility for the conservation, protection and restoration of wild Atlantic salmon are compromised by ongoing cut-backs to program funding. As such, grassroots organizations need to assume even greater responsibility in carrying out these efforts. Meaningful partnerships can be established at various levels. While stocking may not be "the answer" to all problems, it can have a role when carried out in conjunction with a holistic habitat restoration program.

To facilitate continued information sharing, ASF was asked to include the contact list of presenters and attendees along with the presentations and convener's report on the ASF website (http://asf.ca/2013recoveryworkshop.html). A workshop focusing on addressing marine migration and mortality issues was suggested as a logical follow-on to this workshop, which focused primarily on the freshwater environment. Finally, a shared database was proposed as a way to foster dialogue, provide updates on efforts and research findings (including successes and failures), enable networking, and share new knowledge.

Conclusions

Developing a salmon restoration plan is a complicated undertaking. There are numerous factors that need to be considered from the state of the salmon resource in question, to the state of the riverine, estuarine, and marine environments as well as the societal and political factors. The complexities of these issues were clearly exemplified by the content of the presentations, posters and panel discussion associated with this workshop. There is not one clear universally agreed upon approach or menu that practitioners can apply to create a successful salmon restoration program. There are however, general guiding principles that we can recommend based on our experiences from this workshop.

Suggested Approach

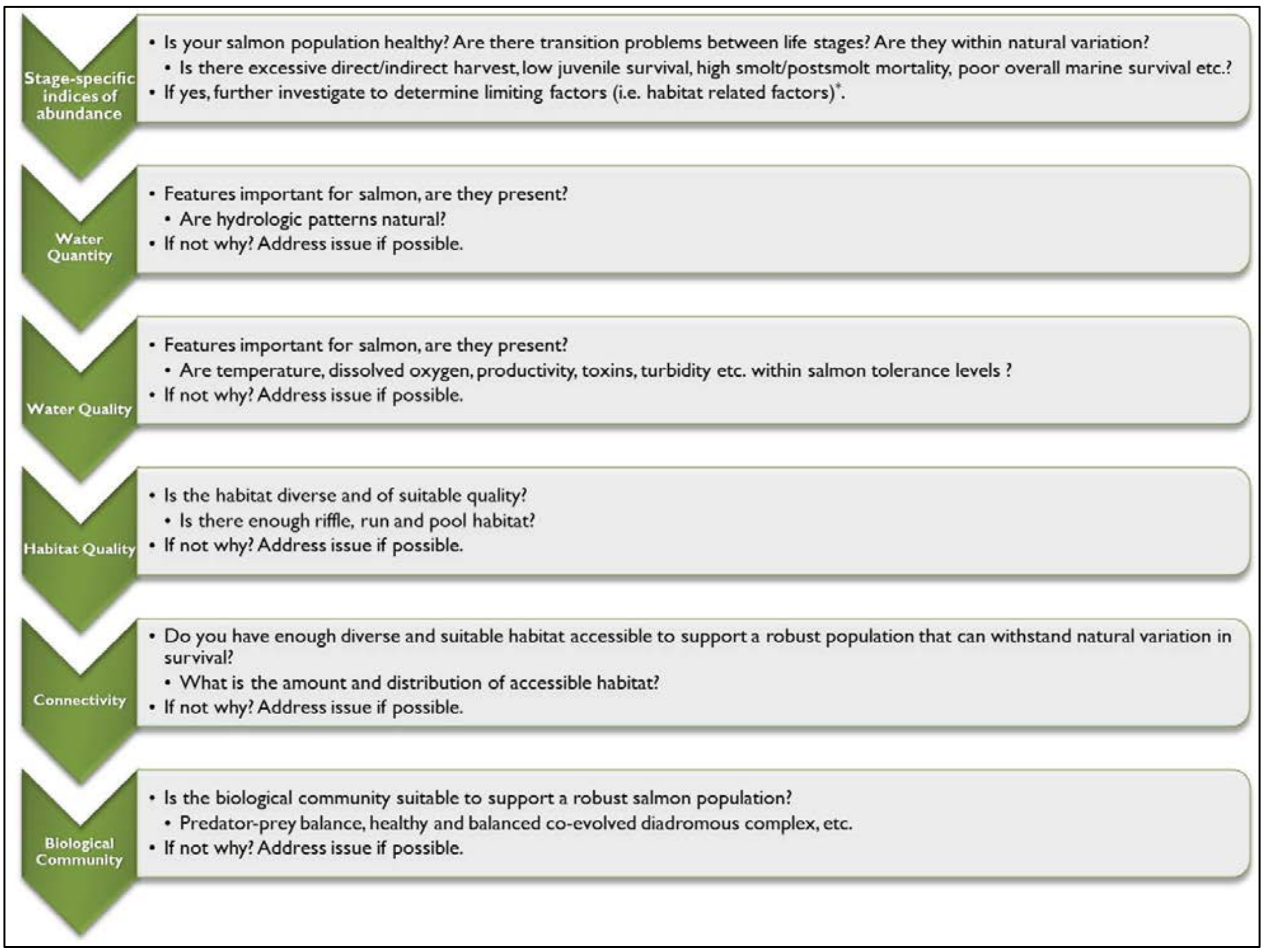
In a completely natural state, Atlantic salmon survival and productivity will vary over time. Significant decreases in adult abundance due to natural variation can be interpreted as a call for concern and action. However, it is important to consider population abundance trends over some specified time-frame. Short-term population fluctuations are expected and therefore, should not carry the same weight or level of concern as long-term population declines. Maintaining long-term monitoring programs allows for the detection of these types of population trends and allows the increases and decreases to be put into historical context. It is difficult for local, provincial/state and federal agencies to maintain the funding needed for these types of programs as they often do not compete well against other short-term projects and investigations. However, maintaining these programs is essential to the responsible management of any salmon population. In the absence of long-term monitoring, contemporary field data can provide information on population status. In the absence of any contemporary data, expert opinion may be the best information available, including that provided by local and traditional knowledge. This hierarchy highlights the importance of long-term monitoring data and underscores that it is never too late to start a monitoring program.

Healthy and diverse freshwater, estuarine, and marine habitats are fundamental to having healthy wild salmon populations. These provide the key elements needed for salmon survival and productivity and the basis for life history complexity within a population. Life history complexity (e.g., multiple river ages, multiple sea ages, ‘early’ and ‘late’ returns, repeat spawners, etc.) enables the development of increased population complexity. Diverse populations and ecosystems are more resilient, thereby providing greater buffering against environmental variation. When stock diversity decreases it can lead to increased annual fluctuations in returning salmon and a higher probability of major population declines (Schindler et al. 2010). Long-term population declines and loss of life history and ecosystem diversity can often be caused by anthropogenic (i.e., human induced) impacts on aquatic communities (e.g., out of balance predator-prey relationships, declining co-evolved diadromous complex, excessive indirect or direct harvest etc.), habitat conditions (e.g., decrease water quality and quantity, decrease habitat quality and quantity etc.) and/or connectivity (limited access to the full suite of habitats types needed). Therefore, the first principles of any recovery program will need to be founded on habitat restoration and protection combined with sound management based on population monitoring.

As referenced earlier, the process of developing a salmon restoration plan is complicated and there is no one template available that will fit all possible situations. The development of an effective restoration program for Atlantic salmon requires:

- An understanding of the problem
- A clear statement of desired outcomes
- An evaluation of available options
- A long-term commitment to the program

The following flow chart is intended to provide guidance on the steps that should be taken when assessing the status of the salmon population and habitat in the watershed, both of which are essential components for the development of an effective restoration plan.



**Gibson (this workshop, see Section 5) provided clear examples of how population modeling can allow scientists and managers to investigate 1) how the dynamics of the populations have changed, resulting in the population decline and 2) how populations would be expected to respond to specific recovery actions based on those dynamics. Understanding the impacts of threats to the population through these types of modeling effort are absolutely essential to effective and efficient restoration planning.*

Following the above process will aid managers in determining what root-cause problems are affecting the productivity of the salmon population(s) they are focused on so that suitable plans can be developed to address them.

Stocking

For many years, stocking has been used as the default method of countering low fish numbers. However, stocking has often resulted in unforeseen consequences (e.g., deleterious genetic changes resulting in loss of wild traits) and as such, must be very carefully considered before incorporating into a recovery plan. Otherwise, the "stock first" approach is knee-jerk and could eventually inflict more harm than it does good for the population under recovery. Hatcheries were originally thought of as a "techno" fix to the problem of declining salmon populations. Instead of analyzing and fixing the habitat problems and/or reducing the excess harvest of adult spawners, hatcheries were designed to simply increase the number of salmon available. This practice often simply disguised the problems limiting production. The flow chart above will focus the manager's attention on the task of identifying the limiting factors for the population. Unless the factors limiting the population are identified and mitigated, stocking will not achieve population recovery.

Through continued research and innovation of hatchery and rearing practices, our understanding of how to effectively use and manage hatcheries is continually growing, but remains far from complete. There are significant ecological and genetic risks associated with the use of hatcheries. Salmon stocks were once viewed as interchangeable (i.e. transferrable from one region or watershed to another), which is in contrast to the contemporary knowledge of unique populations within and among rivers.

Despite these concerns, the use of hatcheries to rear Atlantic salmon for stocking may be justified in some cases. A clear example for hatchery intervention is when populations are in danger of extirpation. In other situations stocking should only be considered after all available fishery management measures have been exhausted and a full understanding of the threats has been developed (see figure above) and actions have been undertaken to improve habitat quality and quantity, and fish passage. Simply put, stocking fish into poor habitat and/or areas with poor fish passage will likely yield few, if any, benefits toward recovery.

If stocking is to be considered as part of the overall recovery plan, it is important to have an understanding of the goals and timelines for hatchery intervention. There are a number of guiding principles that should be considered for hatchery intervention:

- First, consult with population dynamics and genetic experts to fully understand the pros and cons of the proposed effort.
- If the objective of the program is recovery of wild populations then human intervention should be minimized so as not to interfere with natural smolt recruitment processes.
- The start and finish of a stocking program should be predetermined.

Spawning and Rearing

- Use local wild broodstock if available.
- Use a large number of randomly selected breeders (e.g., mix sizes of fish).
- Obtain a representative genetic composition to balance the demographic gains with genetic diversity (April, this workshop). Minimize time spent in the hatchery.
- Maximize wild or "wild-like" exposure.
- Alter artificial rearing environments to promote fish traits that may be more favorable in nature.
- Wild exposure of hatchery products can improve short (within generation) and long term (transgenerational) success of artificially reared fish.

Releases

- Need to identify and fix limiting factors that may impede survival at each life stage and plan releases accordingly.
- Carefully consider the most appropriate choice of life stage to be stocked, based on the tenet of minimizing hatchery involvement and maximizing wild exposure.
- Long term monitoring is essential to understanding long-term contribution of the stocked fish and therefore to measuring success (egg to at least F1 generation).

And remember that:

- Stocking should be considered a temporary tool.
- Stocking should not inhibit other restoration/recovery measures.
- Stocking, by itself, will not be sufficient to recover/restore populations.

Wrap-Up

The information presented at this workshop and above demonstrates the significant progress that has been made in our knowledge of wild Atlantic salmon recovery and restoration programs. In this workshop there were a series of presentations that described advantages and disadvantages of various hatchery techniques, stocking strategies, habitat restoration and fish passage improvement methods. The workshop presentations did not span the full range of human intervention but highlighted various approaches along the spectrum. Some techniques showed promise, but in all cases hatchery intervention alone did not result in recovery.

For many years fisheries professionals have focused on monitoring for the primary purpose of assessing stock abundance. Stock restoration and enhancement techniques were often undertaken without a firm understanding of the full suite of threats in the watershed; the effect of these on the population; and the risks, limitations, and benefits associated with particular recovery actions. The lessons highlighted and demonstrated within this workshop show the benefit of, and our progress towards, moving away from this paradigm.

The existing approach to resource management typically has not achieved long term conservation goals. Science based decisions have been compromised by short term government priorities and the needs of dominant stakeholders. This often leads to short term band aid approaches (e.g. stocking) rather than addressing long term management of habitat and harvest. These approaches need to change. More stakeholders (NGOS, recreational anglers, scientists, First Nations) need to become involved to create an active and committed decision making body to develop locally tailored solutions.

The lessons highlighted within this workshop are not unique to salmon recovery initiatives. They are reflective of the general evolution towards an ecosystem approach to natural resource management and restoration. There are many other recent examples of ecosystem and holistic based natural resource management, which can be helpful guides when developing an Atlantic salmon management plan. For example, Palmer et al. (2005) proposed five criteria that could be used to measure the success of river restoration projects. These criteria help bring an ecological perspective to processes of river restoration. Given that salmon restoration and river restoration activities often overlap (Fleming, this workshop), the criteria proposed by Palmer et al. (2005) may provide a solid foundation for both evaluating the potential effects of proposed salmon restoration actions, as well as the outcomes of salmon restoration efforts post-implementation.

The five criteria proposed by Palmer et al. (2005) are summarized below:

1. There should be a specific guiding image of the restoration effort under consideration that envisions a more dynamic and healthy state than currently exists.
2. The ecological condition of the system/population must be measurably improved.
3. The population should be more self-sustaining and resilient to external perturbations so minimal follow-up is needed.
4. No lasting harm should be inflicted.
5. Both pre- and post-assessment activities must be completed and data must be made publicly available.

This workshop focused on the science and management of Atlantic salmon, with particular emphasis on the biology and ecology of the species and new techniques in restoration. However, the successful restoration and management of the species will involve a full suite of additional considerations such as regional economics, the available resources (e.g. fiscal, standing stock, infrastructure, etc.), and political and societal views of the effort. The development of an effective management and or restoration plan for the species will require that all of these additional factors be taken into account.

It is impossible for us to suggest a recovery plan that would meet the needs of your watershed and salmon population. The particulars of what you are dealing with within your watershed (e.g., population status, habitat status, politics and local engagement) will determine the best course of actions. We can, however, suggest a number of building blocks or principles that should form the foundation of any recovery plan. Below we present five guiding principles:

1. **Team**
   a. The foundation of a recovery plan requires a solid and committed team to create a local decision making body.

   b. A ‘champion’ (individual or organization) needs to be identified as project leader.

      i. Teams need a good leader, someone who has passion for the watershed, restoration tasks, and can leverage the strengths of each member to ensure the work identified as needed by the team is accomplished. Finding effective leaders is no simple task, but is essential to success.

   c. The team should consist of a diverse group of stakeholders (e.g. NGOs, First Nations, recreational anglers, scientists, and watershed users), government officials (i.e. science and management) and policy makers (i.e. elected officials).

   d. Partnering allows for the pooling of resources, increases funding options and allows for the addressing of critical questions at a broader level.

   e. Team members must share knowledge, discuss options for best recovery strategies, and work together to plan and prioritize projects using science based decision processes that include and take into consideration local and traditional knowledge wherever possible.

   f. The team must meet regularly to review progress (e.g., stock status reports, research projects, etc.) and determine best management options.

2. **Holistic Approach**
   It is now generally recognized in conservation circles that any given population cannot be recovered in isolation of other co-existent native fish populations and ecosystem circumstances, nor is there much chance at recovery if the strategy is to address symptoms as opposed to root cause issues. As such, we suggest that any recovery strategy must take a holistic approach, taking into consideration the following:

   a. Need to take a multi-species and ecosystem-wide approach if you want to achieve the best chance of salmon recovery (e.g., status of population in nearby rivers/watersheds, status of other native fish communities).

b. Must identify and understand the root cause(s) of limiting factors and how they relate to the entire ecosystem.

c. Coupling salmon restoration interests with those of the diadromous species complex will ensure that:

    i. The salmon's long-term interests are represented.
    ii. Actions taken will provide greater benefit to the entire ecosystem that supports wild Atlantic salmon.
    iii. There is a broader ecosystem recovery potential.
    iv. An expanded potential resource pool is available to support restoration efforts.

d. Practical, management plans should be developed for each watershed. A practical management plan accurately characterizes the status of the salmon resource as best as can be accomplished with combined scientific, local and traditional knowledge. It will also characterize the effects of individual threats allowing managers to identify and prioritize restoration actions on a watershed by watershed basis.

    i. Specific issues/threats are often not limited to a single tributary, but rather are occurring within the larger watershed. For example, conducting targeted stream bank restoration programs to address localized erosion issues often only serve as applying "band-aids" on issues that are symptomatic of larger scale issues that should be addressed.
    ii. This should not be considered an indictment of in-stream work. It can often provide important short-term benefits. However, the larger watershed level issues (i.e. the root causes) must be properly identified and addressed to support a long term solution so as to avoid or prevent similar problematic symptoms in the future.

e. Prioritizing actions should occur independently of fiscal concerns, and perhaps more importantly political concerns.

f. A multilevel approach is needed: (local, regional, national, international).
    i. Local groups should focus efforts in freshwater and estuarine areas, i.e. areas within their sphere of influence.
    ii. Larger efforts (e.g., marine mortality) must be taken on by larger entities, with the support of local groups.

g. The causes of marine mortality and an understanding of post-smolt to adult migration behavior and mortality (where, when, and how), including indirect bycatch and directed harvest, must be identified. Increase support to study marine mortality using the state of the art technologies.

h. Productivity limitations caused by low marine survival should not be considered a reason to prevent freshwater actions. One of the fundamental goals of any recovery effort should be to improve or maximize freshwater production of highly fit juvenile salmon to help offset the effects of high marine mortality.

3. Long-term commitment (funding and leadership)

a. Any recovery effort requires a long term commitment by the team involved.

b. Clear goals and timelines (e.g., start and end dates) must be defined for each phase of the project.

c. Performance measures must be established for each phase of the project.

d. Funding sources must be confirmed and reviewed periodically.

4. Monitoring and evaluation

a. Monitoring and evaluation must be fundamental components of any recovery program.

b. There must be a clear understanding of the project purpose, experimental design, and performance measures when designing a monitoring program so that the outcomes of the recovery effort can be understood and adjustments can be made as necessary.

c. Spatially and temporally representative monitoring of all restoration efforts is needed to assess effectiveness.

d. Thorough monitoring and evaluation of a recovery program can take multiple generations, extending well beyond the time frame of the recovery actions (it takes 4 to 8 years to complete a single salmon generation from egg to returning adult).

5. Outreach and communication

a. Recovery and management plans that are based on science and local/traditional knowledge must be communicated to policy makers and politicians.

b. The science and management information needs to be transferred to policy makers and politicians.

c. A collective vision (from the team) would help inform and influence decision makers (i.e. elected officials) and others (e.g., industry, philanthropist foundations who can influence policy and funding actions).

d. Documenting and sharing lessons learned from failed restoration programs is just as important as for successful programs to prevent future failures.

e. Ultimately, political will is needed to accomplish on the ground recovery actions, and this of course depends entirely on the presence of a strong team with strong leadership.

One final thought

There are no guarantees that a holistic recovery program that addresses multiple threats within a watershed in support of either a wild population, or a live gene banking program will be successful in recovering salmon. However, by ensuring that freshwater habitat is as productive as possible, it puts the watershed and its salmon population in a better position so that the chances of recovery are improved.

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10. Appendices

A. Program Agenda

WHAT WORKS? A Workshop on Wild Atlantic Salmon Recovery Programs
The Wilfred M. Carter Atlantic Salmon Interpretive Centre
Chamcook, New Brunswick, Canada

September 18-19, 2013

<u>WORKSHOP PROGRAM</u>

<u>Pre-Workshop Field Trip, Tuesday, September 17</u>

10:00 – 2:00 Field workshop for remnant log dam removal
Steve Koenig, Project SHARE

<u>Day 1: Wednesday, September 18</u>

8:00 – 8:45 CONTINENTAL BREAKFAST (ASF Interpretive Center)
Pick up registration package

8:45– 9:00 Welcome & Opening Remarks
Jonathan Carr, Atlantic Salmon Federation

KEYNOTE SPEAKER

9:00-9:40 The ecology and genetics of salmon recovery: what is success?
Ian Fleming, Memorial University

REGIONAL PERSPECTIVES Moderator: Tim Sheehan

Regional speakers will provide an overview of the Atlantic salmon resource, population status, threats, role of hatcheries, and recovery actions in each region.

9:40 – 10:05 New Brunswick & Nova Scotia
Shane O'Neil, Fisheries and Oceans Canada
Presented by Alex Levy, Fisheries and Oceans Canada

10:05 – 10:30 BREAK

10:30 – 10:55	Newfoundland & Labrador Martha Robertson, Fisheries and Oceans Canada
10:55 – 11:20	Quebec Julien April, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs
11:20 – 11:45	Non-Government Organization Mark Hambrook, Miramichi Salmon Association
11:45 – 12:10	New England Joan Trial, Maine Department of Marine Resources/Retired
12:10-1:15	LUNCH (ASF Interpretive Centre)

Gene Banking and Life-Stage Stocking Strategies Moderator: Joan Trial

1:15 – 1:35	Insight from DNA-based parentage assignment analyses on some early indicators of the efficacy of an adult-release stocking program on the Tobique River, New Brunswick Sherisse McWillian-Hughes, Fisheries and Oceans Canada
1:35-1:55	Maine’s experience with captive adult Atlantic salmon outplants Ernie Atkinson, Maine Department of Marine Resources
1:55-2:15	Atlantic salmon eyed ova planting and streamside incubation in the Sandy River Paul Christman, Maine Department of Marine Resources
2:15-2:35	Assessing the effectiveness of “on river” hatchery reared 0+ “fall parr” to increase juvenile abundance and adult returns on the East Machias River Jacob van de Sande, Downeast Salmon Federation
2:35-2:55	Evaluation of migration performance of hatchery restoration products (age 1 smolts) using acoustic telemetry Jim Hawkes, NOAA’s National Marine Fisheries Service
2:55-3:20	BREAK (Posters available for viewing)
3:20-3:40	Impacts on fitness due to captive exposure depends on life-stage in captivity for inner Bay of Fundy Atlantic salmon

Corey Clarke, Parks Canada

3:40-4:00	Where you are raised does matter: the use of semi-natural rearing ponds as an Atlantic salmon conservation tool Kurt Samways, University of New Brunswick Danielle MacDonald, Fisheries and Oceans Canada

History/Case Studies Moderator: Geoff Giffin

4:00-4:20	Exploits river stocking program- River of Dreams Fred Parsons, Salmonid Council of Newfoundland
4:20-4:40	The rise and fall of Atlantic salmon restoration on the St Croix (ME/NB) Lee Sochasky, International Resource Planner
4:40-5:00	One step forward, two steps back: obstacles to salmon recovery in the Magaguadavic Jon Carr, Atlantic Salmon Federation
5:00-6:30	RECEPTION (Official Poster Session) Smoked salmon from closed containment project, cash bar

Day 2: Thursday, September 19

8:00 – 8:50	CONTINENTAL BREAKFAST (ASF Interpretive Centre)

KEYNOTE SPEAKER

8:50-9:30	The role of population dynamics in the recovery planning for Atlantic salmon Jamie Gibson, Fisheries and Oceans Canada

Habitat Recovery Initiatives Moderator: Jamie Gibson

9:30 – 9:50	An overview of historical enhancement and recovery initiatives for Southern Upland Atlantic salmon Alex Levy, Fisheries and Oceans Canada
9:50 – 10:00	A brief history of Old Stream: how nothing can be the best strategy Ernie Atkinson, Maine Department of Natural Resources

10:00-10:20	BREAK (Posters available for viewing)
10:20 – 10:40	Success partnership in the use of high technology in the management of salmon habitat: case of the Restigouche River David LeBlanc, Restigouche River Watershed Management Council
10:40 – 11:00	Geomorphic approaches to Atlantic salmon habitat restoration Ron Jenkins, Parish Geomorphic Ltd

Dams and Fish Passage Moderator: John Bagnall

11:00 –11:20	A river runs through it: how culverts disrupt salmonid habitat connectivity in rivers Normand Bergeron, Institut national de la recherche scientifique Centre Eau Terre Environnement
11:20 – 11:40	Evaluating the ecological effects of the Penobscot River Restoration Project Rory Saunders, NOAA's National Marine Fisheries Service
11:40-12:00	Using the dam impact analysis model to assess the recovery potential of Atlantic salmon Tim Sheehan, NOAA's National Marine Fisheries Service
12:00-1:10	LUNCH (ASF Interpretive Centre)

Water Quality Considerations Moderator: Mark Hambrook

1:10-1:30	Marine-derived nutrients in the natural and model systems in eastern North America: how nutrients subsidies benefit resident and anadromous fishes Kurt Samways, University of New Brunswick
1:30-1:50	Movement and distribution of juvenile Atlantic salmon during periods of thermal stress in two eastern Canadian rivers Emily Corey, University of New Brunswick
1:50-2:10	Buffering acid and providing hope: early results of the West River (Sheet Harbour, NS) acid mitigation project Edmund Halfyard, Nova Scotia Salmon Association

SPECIAL PRESENTATION: North American Salmon Restoration Plan

2:10-2:40 Todd Dupuis, Atlantic Salmon Federation

2:40-3:00 BREAK (Posters available for viewing)

3:00-4:00 DISCUSSION AND WRAP-UP

POSTER PRESENTATIONS

Enhancement methods and results obtained over a thirty-plus year program on the Nepisiguit River
Bob Chiasson, Charlo Salmonid Enhancement Center

Contribution of different live gene banking strategies to the production of smolt and returning adult Atlantic Salmon on the Big Salmon River
Ross Jones, Fisheries and Oceans Canada

Extended tank rearing of salmon fry decreases success in fresh water
Peter Salonius, Nashwaak Watershed Association

Poor marine survival of summer fed (ADC) hatchery fry compared to wild fish
Peter Salonius, Nashwaak Watershed Association

Rationale for treating the entire southern Maritimes as a single Bay Management Area
Peter Salonius, Nashwaak Watershed Association

Fisheries and Aquatic Habitat Management at 5th Canadian Division Support Base Gagetown
Andy Smith, National Defense

Evaluation of recovery strategy for Atlantic salmon: the effects of stocking hatchery raised juveniles on top of wild populations
Ben Wallace, University of New Brunswick

B. Abstracts

Alphabetical Order

Maine's experience with captive reared adult Atlantic salmon outplants

Ernie Atkinson[1], Colby Bruchs[1], and Paul Christman[2]

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Stocking strategies to restore endangered populations of Atlantic salmon (*Salmo salar*) within the Gulf of Maine DPS have used all hatchery life stages available; fry, parr, smolt, egg, and gravid adults. Management focusing on fry stocking has not resulted in significant adult returns and natural reproduction. Stocked smolts produce large returns but the long term benefits are unknown. Adult stocking circumvents much of the hatchery influence on mate selection and potentially results in progeny that are more likely to survive and reproduce in the wild. However, stocking adults sacrifices numerical production advantages achieved by traditional hatchery methods. In 2005 an adaptive management project began in selected streams in which river-specific Atlantic salmon adults, reared to maturity from large parr captured in the rivers, were stocked in the autumn. This work has expanded to other streams and includes investigations into movements, redd construction rates, site fidelity, and vital rates. Stocked adults successfully spawned producing juvenile Atlantic salmon. From acoustic telemetry gear we learned there was high fidelity to the release location at spawning. Juvenile assessments documented that 0+ and 1+ parr densities were similar to densities in fry stocked areas. Managers need to consider lifetime fitness in evaluating large scale gravid adult outplanting projects.

A brief history of Old Stream: how doing nothing can be the best strategy

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Old Stream is a highly productive cold water tributary to the Machias River located in Washington County, Maine. The Machias River is within the Gulf of Maine Distinct Population Segment for endangered populations of Atlantic salmon (*Salmo salar*) listed under the US Endangered Species Act. Among these drainages, Old Stream is a bright point. Annual escapement to Old Stream has been high; around 30 adults annually. Juvenile densities are among the highest in the Downeast SHRU and there is strong evidence suggesting that juvenile production is positively related to natural escapement rather than through hatchery related strategies such as fry stocking. Since 2008 there has been no enhancement from any hatchery product. The implications of this are many but two key points are; first, it reinforces that natural rearing is more likely to produce returning adults than artificial enhancements especially in years that marine survival is low among other strategies. Second, that habitat in Old Stream is functioning well thanks to projects improving access to stream reaches and helping to maintain stream functions.

A River Runs Through It: How Culverts Disrupt Salmonid Habitat Connectivity in Rivers

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Because culverts are the most economical type of stream crossings, they are found in large numbers in several Atlantic salmon (*Salmo salar*) river systems. Such culverts often form barriers that reduce or interrupt connectivity between habitats critical for the completion of the life-cycle of a fish, thereby significantly impacting productive capacity. This presentation reports the results of various field research projects conducted in Québec on the impact of culverts on brook trout (*Salvelinus fontinalis*) and describe similar work currently being initiated on Atlantic salmon. The salient results of the brook trout studies indicate that 1) a large proportion of culverts are impassable to brook trout, 2) predictive models often underestimate fish passage success, especially for small fish in corrugated culverts 3) fish behavior inside culverts maybe the key to improving fish passage predictions 4) habitat fragmentation affects the genetic structure of trout populations. Similar studies of salmon passage success within culverts will be conducted in order to develop models that help identify problematic crossings and prioritize those to be rehabilitated in order to maximize positive returns.

One step forward, two steps back: obstacles to Atlantic salmon recovery in the Magaguadavic River

Jonathan Carr
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The wild Atlantic salmon population in the Magaguadavic River decreased from about 1000 returning adults in the 1980s to fewer than 100 by the mid 1990s. A live gene bank program was established in 1998 and several stocking strategies have since been employed: unfed fry, first feeding fry, parr, smolt, and adults. These techniques have failed to provide a positive recovery response. Several limiting factors have hindered the recovery effort in this river such as exotic fish species, salmon aquaculture practices, fish passage obstructions, low marine survival, and even the stocking program. The main purpose of hatchery programs should be on preserving the genetic diversity of the wild population until the primary limiting factors are identified and addressed.

Atlantic salmon *(Salmo salar)* eyed ova planting and streamside incubation in the Sandy River

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The Maine Department of Marine Resource (formerly the Atlantic Salmon Commission) in 2003 began experimenting with streamside incubators and egg planting to reintroduce Atlantic salmon into vacant habitat in the Sandy River. The Sandy River watershed is approximately 1,536 km^2 and has more than 25,000 units of Atlantic salmon rearing habitat. The streamside incubators, constructed from discarded refrigerators, were operated from 2003 to 2007 and resulted in 146,000 fry being stocked. While streamside incubators were successful in introducing fry into the drainage, they were difficult to maintain and the number of eggs that could be incubated was not sufficient to achieve recovery of a large watershed. In contrast, a hydraulic planter allowed for large number of eyed eggs to be planted annually, 590,000, 860,000 and 920,000 in 2010, 2011, and 2012. Juvenile assessments conducted using emergent fry traps and Catch Per Unit Effort (CPUE) electrofishing surveys of planting sites documented successful emergence and dispersal from planting sites in the first year of growth. In addition, 30 randomly chosen (Generalized Random-Tessellation Stratified Design) sites sampled by CPUE methodology resulted in 73% and 67% of the sites containing salmon in 2011 and 2012. Based on juvenile size at age 0+, we determined that less than 50,000 eyed eggs should be distributed among sites that were with greater than 1 kilometer apart. The egg planting project has allowed for a large scale re-introduction of salmon to the Sandy River watershed.

Impacts on fitness due to captive exposure depend on life-stage in captivity for Inner Bay of Fundy Atlantic salmon

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The number of species assessed at some level of risk of extinction continues to increase. As a result, programs to captive rear and release wild-origin individuals are increasing in number and scope in attempts to lower risk of extinction. Atlantic salmon populations across much of their North American range characterize this situation well. Despite considerable efforts in the development and implementation of various combinations of captive rearing and re-introduction programs, undesirable effects of domestication are cited among the factors most limiting the realization of program objectives. We quantified the effects of two common juvenile release strategies (unfed fry, and 5 month feeding parr) on smolt phenotype, homing ability and offspring viability, all important measures of natural fitness for this animal. We followed cohorts of native salmon from release to the wild as age 0+ juveniles through to eyed-egg stage of the next generation. Results show those released as fry exhibited higher levels of natural fitness later in life and into the next generation. This finding is useful for managers of conservation programs considering which life stage to release when natural fitness is a program objective.

Movement and distribution of juvenile Atlantic salmon (*Salmo salar*) during periods of thermal stress in two Eastern Canadian rivers

Emily Corey[1], Stephen Dugdale[2], Cindy Breau[3], Tommi Linnansaari[1], Richard Cunjak[1], Normand Bergeron[2]

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Juvenile Atlantic salmon (*Salmo salar*) demonstrate a physiological stress response when water temperatures exceed 23ºC. Once temperatures approach the upper lethal limit (~28ºC), juvenile salmon manage their metabolism via behavioural thermoregulation. Territorial behaviour is abandoned in favour of an aggregated response in areas of cooler water (thermal refugia). The objectives of this study were to examine how the incidence of temperature stress affects the movement and distribution of juvenile salmon in two eastern Canadian rivers, the Little Southwest Miramichi (LSWM; NB), and the Ouelle (OU; QC). Passive Integrated Transponder (PIT) tags were utilized over two summers (2009/2010 LSWM; 2011/2012 OU) to monitor the temperature-related movements of 635 and 332- 1+ and 2+ parr, respectively. In 2009 (LSWM) and 2011 (OU), no juvenile salmon aggregations were observed despite maximum temperatures exceeding 24ºC for 7-consecutive days (max 26.1ºC; LSWM) and 8-consecutive days (max 28.2ºC; OU), respectively. In 2010, 33.6% of tagged parr were observed aggregating, when hourly temperatures remained >23ºC for 4-consecutive days (max 31.0ºC). Some parr traveled >10km to locate refugia during this period. Concurrent wide scale mortality was observed in all age-classes. In 2012, juvenile abundance in areas proximal to thermal refugia was 43.5% greater than in areas lacking refugia. Preliminary analysis suggests that cumulative high-temperature exposure may stimulate aggregations. With future climate change scenarios predicting these temperature thresholds will be surpassed more frequently, it is important that the behavioural and physiological responses of parr be considered to ensure species conservation and sound management.

The ecology and genetics of salmon recovery: what is success?

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Atlantic salmon populations are becoming increasingly threatened, particularly across the species' southern range. Recovery programs to rebuild these populations have met with varying "success." Success, itself, can come to mean different things in different contexts. Here, I explore recovery in the context of salmon ecology and genetics. Characteristics that make salmon populations resilient to environmental change, whether such change is natural or anthropogenic, can provide a fundamental understanding of what recovery might look like. I look closely at one of the most commonly applied salmon recovery approaches for rebuilding salmon populations that involves artificial culture, i.e. hatcheries and living gene banks. The relationship, both ecological and genetic, between hatchery and wild fish is largely dependent on what occurs during breeding and its subsequent effects on offspring performance. I examine the roles of phenotypic plasticity, non-genetic inheritance and domestication in shaping and dictating the "success" of released hatchery fish and their ecological relationship with wild fish.

Buffering acid and providing hope: Early results of the West River (Sheet Harbour, NS) acid mitigation project.

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The issue of acid rain has led to the extirpation of many salmon populations within Nova Scotia's Southern Upland region. To address the issue of river acidification, the Nova Scotia Salmon Association, the Atlantic Salmon Federation, and partners initiated an acid mitigation program in 2005 on the West River, Sheet Harbour. A fully-automated lime doser now buffers the river's water by releasing precise dosages of powdered dolomite lime.

An ongoing monitoring program has documented the efficacy of lime dosing and its impacts on the river's water quality and aquatic ecosystem. Following installation of the lime doser, the river's pH increased above the target of 5.5 along the entire 30 km treated reach, and in some locations, liming raised the average pH by 2.5 units. In response to this increased pH, aquatic invertebrate biomass has increased, there has been a shift in dominant invertebrate taxa, and acid-sensitive invertebrate species are now more common. Similarly, there is some evidence that the salmon population has responded to liming. For example, electrofishing-based estimates of juvenile densities generally increased in treated sections. Further, annual estimates of smolt production suggest that juvenile abundance has increased in treated areas which contrasts control (unlimed) sections of the watershed. Further, given the declining smolt production trends in nearby salmon index rivers, liming in the West River appears to have increased the quality of freshwater rearing habitat and subsequently increased egg-to-smolt survival.

Although these results are preliminary, should our observations reflect the actual ecosystem response, liming in Eastern Canada appears to be a viable and effective restoration strategy for acidified salmon rivers.

Evaluation of migration performance of hatchery restoration products (Age 1 smolts) using acoustic telemetry

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The Dennys River Atlantic salmon stock is at the northern extent of the endangered Gulf of Maine Distinct Population Segment's range. Although the stock once supported a prominent US salmon rod fishery, the population has since collapsed as a result of dams, pollution from an EPA superfund site, overfishing, and poor marine survival. Since 1875 hatchery supplementation has been the primary restoration tool used for the Dennys River salmon. From 1990 to 2000 fry were the primary hatchery product stocked. In 2001, managers decided to begin stocking Dennys origin river-specific 1+ smolts. Based on regional hatchery smolt marine survival it was estimated that stocking 32,000 to 50,000 smolts had a 75% probability of producing 67-117 2SW returns. Approximately 50,000 smolts were stocked annually from 2001 to 2005. To evaluate and describe estuarine and coastal migration performance of these hatchery smolts, we acoustically tagged a subset of smolts (n=70-150) each of the five years. We observed a significant number of reversals in the estuary and bay environments and losses (>50%) that were higher than those documented in many other systems. Reversal behavior, while potentially normal for smolts when transitioning into the marine environment, may suggest underlying issues of smolt quality. With few post-smolts making it to the Gulf of Maine or Bay of Fundy, recovery of this stock will be challenging.

Geomorphic Approach to Salmon Habitat Restoration

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Restoration and enhancement of salmon habitat is a common goal for many not-for profit and governmental organizations. This work often takes the form of modifying the flow of water and sediment by installing in-stream structures constructed of either rock or wood or a combination of both.

In-stream structures are popular because they are relatively inexpensive when compared to other means of modifying flow such as re-shaping the channel geometry or changing the planform, i.e. the way the channel meanders across the floodplain. As the popularity of these structures grew between the 1970s and 1990s so did the need for regulatory review and approval, resulting in the publication of various standards for their design and installation. These standards provided design methodologies that were necessarily simplified, if they presented any design criteria at all. The template approach was necessary because water and sediment dynamics in natural systems are inherently complex and take a combination of many fields of study and experience to understand and predict. The template approach lead to the inappropriate installation of many structures or their use in a riverine setting that would not support the desired outcome. As a result, the success rate of in-stream structures has been poor and well documented in the last decade, causing many funding and regulatory agencies across North America to be skeptical, and in a few regions a near blanket ban on their use has been implemented. This talk will summarize the history and development of a few of the most common structures and highlight their benefits, their weaknesses, and focus on the physical setting that lends itself best to the intended goal of each structure, ultimately being salmon habitat restoration and enhancement.

Contribution of different live gene banking strategies to the production of smolt and returning adult Atlantic Salmon on the Big Salmon River

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Evaluation of two different Live Gene Bank (LGB) release strategies has been possible because of ongoing collaborative monitoring projects in conjunction with genetic analysis or parentage assignment. The in-river LGB, i.e. progeny released as unfed fry and fall parr, has essentially increased the number of smolts emigrating from the Big Salmon River from 2004 to 2011 by three-fold. Progeny released as fall parr have an average in-river survival to the smolt stage that is four times greater (7.1 vs 1.7%) than progeny released as unfed fry although the return rate to 1SW salmon for smolts produced from the unfed fry is double that of the fall parr releases. In the past decade, progeny from the LGB have contributed to about 20% of the returning adults on the Big Salmon River.

Field workshop for remnant log drive dam removal

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Project SHARE (http://www.salmonhabitat.org/) has a holistic process-based habitat restoration program in Downeast Maine that includes culvert replacements, large wood additions, and removal of remnant log drive dams. Project SHARE has successfully used a grip hoist to remove remote remnant dams and for LWD additions. A workshop was held on September 17, 2013 at a remnant log drive dam on the East Machias River (Maine) to demonstrate how the grip hoist is used to remove a dam. Remnant dams and their impacts on streams are an overlooked legacy of human activity on the Maine and Maritimes landscape. Aerial photography helps identify their locations based on over-widened channel associated with historic reservoirs. While remnant dams generally do not present a major barrier to fish passage, habitat alterations remain long after the dam was breached. Stream reaches immediately upstream of historic dams typically do not possess habitat suitable for Atlantic salmon spawning and rearing. In addition to loss of Atlantic salmon habitat these dams affect stream flow, temperature, and sediment transport. Surveys of the site topography (longitudinal profiles and transects) reveal where the remnant dam was not completely removed to the natural stream bottom and pebble counts help identify material from the structure. The short-term effects of complete removal include: decreases in wetted width, increased current velocity, mobilization of fine sediments, and renewed juvenile salmon use of recovering salmon habitat.

The successful partnerships in the use of high technology to protect and restore salmon habitat in the Restigouche Watershed

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This presentation will demonstrate how partnerships between stakeholder groups were the basis for the successful completion of various projects. It will cover the different technologies used by the RRWMC to improve knowledge and the management of salmon habitat in harmonization with other activities while providing aquatic habitat protection. The four project to be presented will cover:

- Aerial surveys to search for sources of siltation run-off;
- Habitat characterization and location of thermal refuges through the use of high precision imaging;
- The use of LIDAR (Light detection and ranging) imagery to reduce the impact of agriculture and other activities on salmon habitat;
- The equivalent cut area calculation used to integrate protection of watersheds in forestry planning.

An overview of historical enhancement and recovery initiatives for southern upland Atlantic salmon

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Abundance of Atlantic salmon in Canada's Maritimes Region has been in decline for more than two decades. Substantial and ongoing declines in Nova Scotia's Southern Upland region have been observed, recent electrofishing surveys have provided evidence for river specific extirpations, and remaining salmon populations are considered to be at critically low abundance. The Southern Upland population of Atlantic salmon was evaluated as Endangered by the Committee on the Status of Endangered Wildlife in Canada in 2010 and Fisheries and Oceans Canada has begun the formal process to determine if it will be protected under the Federal Species at Risk Act. Population supplementation through artificial breeding and rearing has been used to enhance salmon fisheries for over a century. Increased reliance on supplementation programs for Southern Upland salmon arose due to the impacts of acidification. These programs appeared to be viable throughout the 1980's; however, they were discontinued in the 1990's and mid-2000's, as they could not offset the downturn in marine survival, which included economic considerations, and wild populations were not large enough to ensure genetic risks were low. Other enhancement and recovery measures for Southern Upland salmon have included fish passage and population enhancement to establish populations above natural barriers, efforts to restore populations that had been virtually extirpated, closure of commercial fisheries, increasingly restrictive management measures for recreational fisheries, and supportive rearing programs to augment declining populations. This presentation will provide an overview of enhancement and recovery initiatives undertaken within the Southern Upland and considerations for recovery.

Insight from DNA-based parentage assignment analyses on some early indicators of the efficacy of an adult-release stocking program on the Tobique River, New Brunswick

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In 2008, approximately 586 Atlantic salmon captured earlier as out-migrating smolt and reared in captivity at the Mactaquac Biodiversity Facility to adulthood, were tissue sampled and released back into natal waters of the Tobique River (above the Tobique Narrows dam) to hopefully spawn and contribute to the next generation of Atlantic salmon. In this same year, approximately 438 sea-run Atlantic salmon, including 348 wild-produced, and 90 hatchery-origin adult males and females, returned to the Tobique Narrows fishway where they were intercepted and tissue sampled before being allowed to continue on their way to waters above the dam. In 2010 and 2011, a large number of out-migrating pre-smolt and smolt collected near the confluence of the Tobique River and St. John main stem were tissue sampled, as were sea-run adult salmon returning back through the Tobique Narrows fishway in 2012. Interpretation of growth ring patterns from scale samples was then then used to estimate age and identify which of the above pre-smolt and smolt collected in 2011 and 2012, and adults collected in 2012, could be considered as candidate offspring of the captive and sea-run adults that spawned in the Tobique River in 2008. A portion (157) of the large number of available sampled candidate offspring, and nearly all of the above adult candidate parents (approximately 1024) have now been genotyped at 12 highly variable microsatellite genetic markers. The 157 candidate offspring were then tested against all of the genotyped candidate adult parents using single parent exclusion analyses. Despite the large number of pairwise comparisons involved (>160,000) and the existence of many non-genotyped candidate parents (unsampled mature male parr), nearly all candidate offspring were assigned unambiguously, and with a high degree of certainty, to single female candidate parents, and many to single male candidate parents. Although only a small portion of the available tissue sampled candidate offspring have been analyzed to date, these results are already providing preliminary information on a) absolute pre-smolt production by the group of released captive adult females, b) pre-smolt production by released captive adult females relative to wild-origin adult females, c) degree of spawning success of released captive and wild returning adult females, d) the mating structure of released captive and wild-origin adult salmon, e) variance in family size, effective number of breeders, and expected rates of loss of genetic variation associated with the captive adult release program, f) the extent of spawning between captive and wild-origin salmon, and much more. Further insight and increased certainty of many preliminary estimates is expected once the remaining larger group of candidate offspring are analyzed, including many more pre-smolt and smolt collected in 2010 and 2011, adults that returned in 2012, and adults expected to return to the Tobique River in 2013 and 2014.

Exploits river stocking program-River of Dreams

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In the early 1980's a group of local Businessmen and the Department of Fisheries and Oceans were asking themselves similar questions. Could the largest River in insular Newfoundland that was 90% unaccessible to Atlantic salmon become a Major producer ? Would adult fish return to new established habitat? Could this development be completed in conjunction with a major Plup and Paper Industry that were sole users of the Resource for almost a century for log driving and Power production? And the big one... could the Department of Fisheries and Oceans work as equal partners with a local Conservation group to even attempt this feat.

With determination and hard work by all involved the answers to these questions would result in the Exploits River joining the Ranks of Top Producers of Atlantic Salmon in North America. From construction of large and sometimes innovative fish passages to a major stocking program of over 50 Million Salmon fry in the middle and upper areas of the watershed, what some called a “Pipe Dream” is now a reality with annual returns approaching 50,000 Adults.

Poor Marine Survival of Summer Fed (ADC) Hatchery Fry Compared to Wild Fish

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Monitoring of seaward migrating salmon smolt is conducted by DFO using rotary fish wheels annually near Durham Bridge on the lower Nashwaak River near Fredericton, NB. Approximately 10% of the fish captured during the springs of 2008 and 2009 had been Adipose Fin Clipped (ADC) indicating that they had been tank reared during their first freshwater summer. DFO operates a fish counting fence in the same location each summer to estimate the population of returning adult salmon. Grilse (1 Sea Winter fish) that originated from ADC smolt, migrating seaward in 2008, made up 5.53% of the total grilse returns in the 2009 season, while grilse originating from seaward migrating ADC smolt in 2009 made up 2.34% of total grilse returns in 2010.Although we had already ascertained that summer rearing hatchery fry in tanks decreased their survival and growth in fresh water compared to fish stocked in June --- it is now evident that summer feeding hatchery fry to increase their size and supposedly enhance their success in the wild also compromises their survival in the sea.

Extended tank rearing of salmon fry decreases success in fresh water

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Half of 12,000 six week feeding hatchery fry were distributed, unmarked in June, 2006 above an impassable falls near Fredericton, New Brunswick. The other 6,000 were reared (summer fed) in cold spring water fed tanks until September, 2006 when they were similarly distributed (adipose fin clipped / ADC) into the same sites. The ADC summer fed, cold water reared fry were somewhat larger than their counterparts than their more wild counterparts when they were distributed in September, 2006,, however electrofishing of pre smolt in late summer 2007showed that the unmarked fish were much more numerous and considerably larger than their summer fed ADC counterparts. The trial comparison (this time rearing ADC fish in tanks fed by much warmer stream water) was repeated in 2008. When the ADC summer fed, warmer water reared fry were stocked into the stream in September, 2008, they were much longer and more than twice as heavy as their counterparts that had spent the summer in the wild, however electrofishing of pre smolt in late summer 2009 showed unmarked June distributed fish to be much more numerous and somewhat heavier than their summer fed ADC counterparts.

Rationale for Treating the Entire Southern Maritimes as a Single Bay Management Area

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Single bay management areas for sea cage aquaculture were established to decrease the cross transmission of salmon diseases and parasites between sites whose stocking, grow out, harvest and fallow periods were staggered in time. Research in Norway has shows that the eggs and the planktonic stages of salmon lice (*Lepeophtheirus salmonis*) remain infective for long periods in cold sea water and can be transported long distances on ocean currents, see: http://dpc.uba.uva.nl/ctz/vol69/nr01/art05. Damage to seaward migrating smolt by cold-water-transported aquaculture origin sea lice probably played a major role in the drastic decline of Outer Bay of Fundy and collapse of Inner Bay of Fundy salmon stocks in the 1990s, before the parasiticide Emamectin benzoate (SLICE) offered effective control of sea lice on farms. The correspondence between increasing loss of sea lice control from 2010 onward and the drastic reduction of adult salmon returns in the southern Maritimes and Maine suggests that sea lice are again major agents in wild salmon population dynamics. Establishing the entirety of the southern Maritimes as a single bay management area would allow wild smolt to migrate through farm-origin-sea-lice-free sea water during some years.

Marine-derived nutrients in natural and model systems in eastern North America:

How nutrient subsidies benefit resident and anadromous fishes

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Returns of anadromous fish have declined dramatically in the past century throughout eastern North America, reducing the delivery of marine-derived nutrients (MDN) to rivers. The role of MDN transport in coastal rivers in the region is a function of net nutrients transferred by all anadromous fish and collectively may result in MDN subsidies equivalent to those delivered by salmon on the Pacific coast. Temporal variation in MDN occurs because of variation in species composition, abundance, spawning strategy, and life history of anadromous fishes. The current scarcity of these fishes may have profound effects on aquatic production, particularly in nutrient-poor systems. Artificial nutrient addition to river systems is an environmental management strategy to subsidize for nutrient shortages in streams resulting from population declines. With multiple species spawning in the same rivers in a given year, it is important to understand how different timing and spawning strategies of anadromous fish affect nutrient and productivity dynamics for proper implementation of nutrient additions. Drawing from results from parallel MDN studies carried out in the maritime provinces of Canada and Maine, we will compare and contrast effects of natural and simulated anadromous fish runs on stream productivity. We will address how effective nutrient additions are in simulating natural conditions and the ways that nutrient additions may be most effective in anadromous fisheries management.

Where you are raised does matter: The use of semi-natural rearing ponds as an Atlantic salmon conservation tool

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The study of phenotypic plasticity is important in determining how species react to differential environmental pressures, and ultimately understand the processes leading to local adaptation and specialization. Under these optics, a shift into a new habitat may induce plastic responses in a variety of traits, creating opportunities for habitat-dependent pressures to select individuals that are better adapted to the new environment. Conventional and semi-natural rearing conditions for Atlantic salmon (*Salmo salar*) parr provide an exceptional system to study plastic responses because they offer contrasting habitats (uniform versus complex). These contrasting habitats are expected to promote differential pressures on key phenotypic traits, thus promoting plasticity and local adaptation. In this study, we investigated how fish morphology and fin condition responded to conventional or semi-natural rearing conditions under different stocking densities. We found that variations in morphology can be linked to habitat differences, with fish reared in semi-natural ponds converging to a wild-like shape and fish reared in conventional ponds diverging from this “optimal” form. In addition, we found profound differences in fin condition between semi-natural and conventionally reared fish. These results indicate that rearing fish under semi-natural conditions produces a more morphologically wild-like fish, which is important because it allows individuals to survive under changing environmental conditions.

Evaluating the ecological effects of the Penobscot River Restoration Project

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The Penobscot River Restoration Project (PRRP) is a unique and innovative aquatic restoration project that aims to increase connectivity by removing two mainstem dams and bypassing a third dam on an upstream tributary without a subsequent loss in hydro-electric generating capacity. Given the large investments being made nationally in the field of aquatic restoration, as exemplified by the PRRP, the lack of rigorous monitoring and research to support the assertions of the beneficial effects of dam removal is surprising. Investments from a number of partners including the Nature Conservancy, the Penobscot River Restoration Trust, NOAA's Northeast Salmon Team, and over $1.3M in NOAA Restoration Center support through the American Recovery and Reinvestment Act of 2009 are now supporting rigorous ecosystem monitoring of physical, chemical, and biological parameters. Thus, the PRRP provides an important opportunity for fisheries agencies, academia, and the general public to begin to learn and understand the true ecological effects of large scale dam removals. These investments in monitoring and research will allow the public to make informed decisions regarding the costs and benefits of large scale restoration projects well into the future.

Using the Dam Impact Analysis Model to Assess the Recovery Potential of Atlantic Salmon

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Dams are a major contributor to the historic decline and current low abundance of diadromous species, including endangered Gulf of Maine Atlantic salmon. We developed a population viability analysis to quantitatively evaluate the impact of fifteen federally licensed hydroelectric dams on Atlantic salmon population dynamics in the Penobscot River, Maine. We used a life stage-specific model to compare a salmon population under the current state of downstream dam passage success to scenarios with increased dam passage success and increased marine and freshwater survival rates. Performance metrics for the scenarios included adult abundance, distribution of adults throughout the watershed, and number and proportion of smolts killed by dam-induced mortality. Dams located on the mainstem of the Penobscot River had a greater impact on the Atlantic salmon population than dams located on tributaries, but all mainstem dams and all tributary dams did not affect the population equally. The combination of spatial location and passage success is important to the impact of each dam. This model will provide support for regulatory processes, will help prioritize future passage improvement efforts to maximize the benefits to the Penobscot River Atlantic salmon population, and is adaptable for use with other diadromous species and river systems.

Fisheries and Aquatic Habitat Management at 5th Canadian Division Support Base Gagetown

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5 CDSB Gagetown (formally known as CFB Gagetown) is home to several military units as well as the Army's Combat Training Centre and the Canadian Forces School for Military Engineering. Training activities include mounted and dismounted manoeuvres, small arms, artillery, demolition, bombing, urban operations and helicopter support.

Approximately 110 000 ha in size, the base contains over 3200 km of watercourses, 156 ponds or lakes and 6487 ha of wetlands. These water-bodies support Atlantic salmon, a locally important brook trout fishery among other fish species. Environmental stewardship, compliance, and sustainable ranges and training areas are key goals of the Army's Strategic Environmental Direction. Strategies to meet these goals with respect to the conservation of fisheries and aquatic habitats include: Environmental planning, protection and compliance; resource mapping; environmental monitoring; information and education; stream an d wetland enhancement; and water crossing improvements.

The rise and fall of Atlantic salmon restoration on the St. Croix River (ME/NB)

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For reasons common to many rivers, Atlantic salmon runs on the St. Croix River declined in the 1800s and 1900s. Improvements to fish passage and pollution treatment led to significant and innovative international restoration efforts in 1981-2006 but these ultimately failed. This rise and fall will be reviewed, with possible lessons for others.

Assessing the effectiveness of "on river" hatchery reared 0+ "fall parr" to increase juvenile abundance and adult returns on the East Machias River

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For the past 20 years the Atlantic salmon (*Salmo salar*) stocking program in the Downeast Maine has been focused on "unfed" fry and limited smolt stocking, but success has been limited. Research suggests that unnatural rearing conditions in hatcheries inhibit the ability of stocked fish to transition to the wild, resulting in high mortality. To address the limited success of the stocking program, Downeast Salmon Federation, in collaboration with federal, state, and NGO partners, is implementing a project to assess the effectiveness of rearing 0+ "fall parr" in an on-river hatchery to increase juvenile abundance and adult returns in the East Machias River. The 0+ parr are being reared in an "enhanced" rearing setting. Utilizing unfiltered river water, substrate incubators, dark colored tanks, natural feed, and water velocity manipulation, the DSF is producing a more natural, physically fit, and more cryptic 0+ parr. All parr were stocked in the fall after river temperatures were below 7^{o}C. Stocking densities have been increased to well above historic stocking levels. The project includes rigorous assessment of all life stages. Along with changes in rearing techniques, age at stocking, and stocking densities, there is a collaborative focus on addressing connectivity, adding large woody debris, and low pH mitigation in the East Machias watershed. This project is a new model for salmon recovery in the Downeast region.

Evaluation of a recovery strategy for Atlantic salmon: The effects of stocking hatchery raised juveniles on top of wild populations

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Faced with diminishing adult Atlantic salmon (Salmo salar) returns and mysteries surrounding at-sea survival of out-migrating smolts, it is important to maximize in-stream production of the species. Stocking of juvenile Atlantic salmon (*Salmo salar*) is a commonly used recovery and enhancement strategy; however, its effectiveness in increasing juvenile salmon densities and production has never been fully investigated. The purpose of this project is to determine if stocking has increased the overall production of juvenile salmon in the Miramichi River watershed. In order to accomplish this goal, historical electrofishing data has been obtained, allowing for the creation of a geographical model of salmon parr densities through time. This model will allow us to determine which landscape level variables (e.g., slope, upstream catchment area, distance to ocean etc.) best predict salmon parr densities across the watershed. The data will be examined in relation to stocking records (locations and rates) to determine how effective stocking has been in improving salmon production on the Miramichi River over the past 30+ years. The results of this ongoing investigation will lead to an improved understanding of stocking dynamics in the Miramichi watershed and may lead to the development of best management practices in relation to Atlantic salmon stocking programs.

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Smitka	Jerry	Trout Unlimited	smitka@rogers.com
Sochasky	Lee	Private Sector	lee.sochasky@rogers.com
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D. Presentations in PDF

The ecology and genetics of salmon recovery: what is success?

Ian Fleming, Memorial University

Ecology & Genetics of Salmon Recovery: What is Success?

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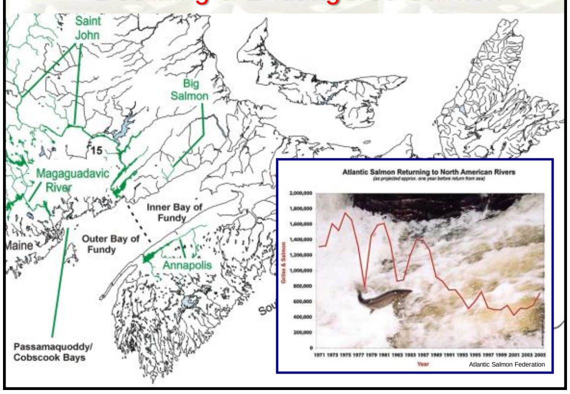
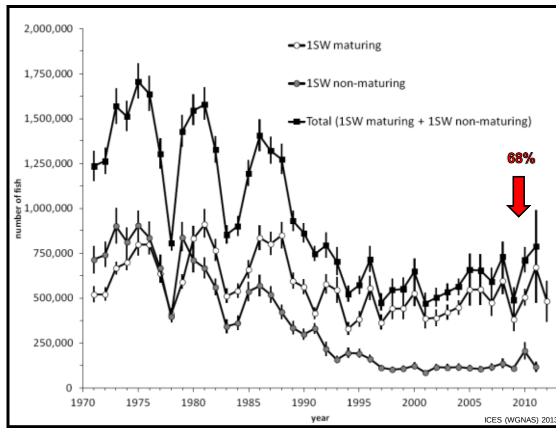
Ecology & Genetics of Recovery: What is Success?

- The problem
- Resilience
- Salmon Recovery
- Captive Breeding (living gene banks)
- Conclusions

Declining & Endangered Salmon





Ecology & Genetics of Recovery: What is Success?

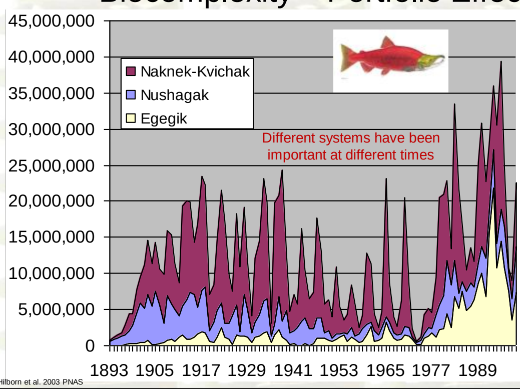
- The problem
- **Resilience**
- Salmon Recovery
- Captive Breeding (living gene banks)
- Conclusions

What is Resilience?

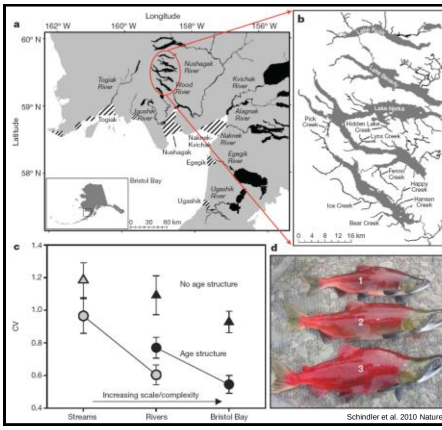
Concept developed by Holling in 1973

- "is a measure of the system's ability to absorb changes and still maintain its basic system of relationships without flipping into a different configuration."
- diverse systems provide greater buffering to environmental variation
- analogous to asset diversity in a financial portfolio

Biocomplexity – Portfolio Effect



Hilborn et al. 2003 PNAS



- 77% more stable than if the system consisted of a single homogenous population
- life history diversity central to buffering capacity

Schindler et al. 2010 Nature

Resilience

Population Complexity (biodiversity)

Life History Complexity

Habitat Diversity

Thus, any recovery programme will likely need to be founded on *habitat restoration & protection*

Ecology & Genetics of Recovery: What is Success?

- The problem
- Resilience
- Salmon Recovery
- Captive Breeding (living gene banks)
- Conclusions

What is a Salmon Recovery Program?

Beyond:
- Habitat restoration & protection
- Harvest regulation & addressing other sources of mortality

Hatcheries & Captive Breeding

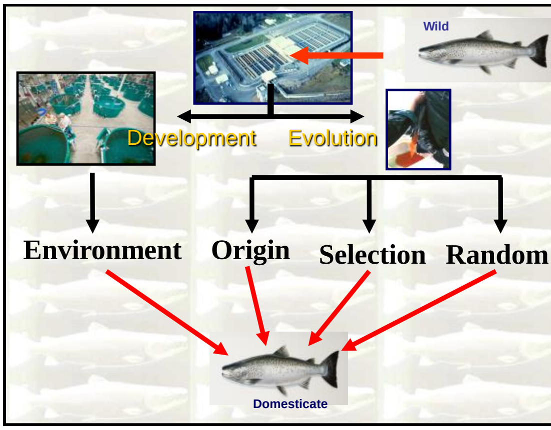
Hatcheries & Supplementation

- 1773 – start in Germany
- belief humans should control reproduction & increase the numbers of salmon
- Hatchery model born of the industrial revolution – "techno" fix
- Interchangeable parts (in contrast with what we now know as the uniqueness of populations)
- Nearly a century of this vision (1860s -1960s)
- Salmon were moved within and outside their native range

US Fish Commission proclaimed: ***artificial propagation would make salmon so abundant there would be no need to regulate harvest or protect habitat***

Holes in Hatchery Model appear

- Returns not there
- Becomes controversial – can it help?
- Recognition that a production model is not compatible with a conservation model
- Changing shape of restoration and questions about the role of traditional hatcheries
- Captive breeding – but where are we in our understanding?



Reshaping of Fish
Who's from the hatchery?

Morphology, physiology, behaviour, life history …

Hatcheries & Supplementation to be considered successful …

- Bypass high, natural mortality

&

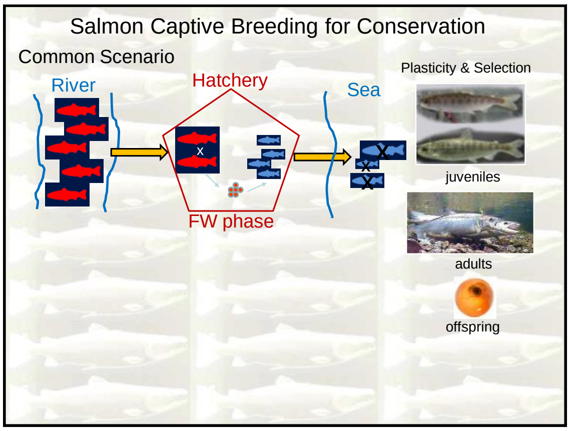
- Survive, breed & produce offspring that ***contribute*** to natural production in the wild

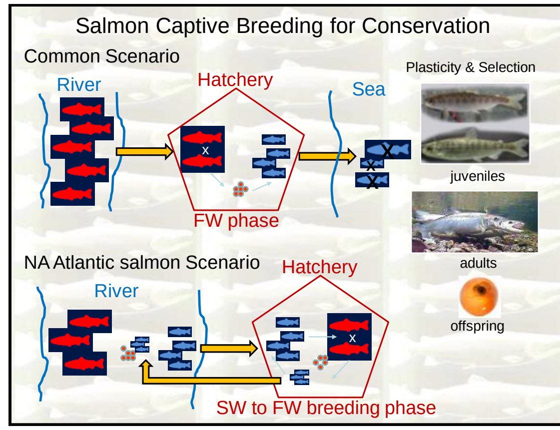
Success is Difficult

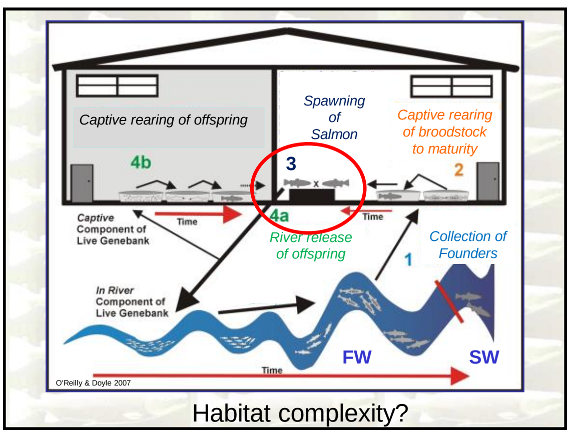
Type	Species	Relative Success (Hatchery : Wild)	
Near-natural Streams (breeding to egg deposition)			
Hatchery	Coho Salmon	**0.61-0.82**	Fleming & Gross '93
Hatchery	Atlantic Salmon	**0.66-0.86**	Fleming et al. '97
River Releases (genetic screening)			
Hatchery	Steelhead	**0.75-0.79** (0+ parr)	Leider et al. '90
Hatchery	Steelhead	**0.04-0.07** (2+ smolt)	McLean et al. '04
Hatchery	Steehead	**0.18-0.37** (2+ smolts)	Kostow et al. '04
Hatchery	Steelhead	**0.06-0.87** (lifetime)	Araki et al. '07a,b, '09
Hatchery	Brown Trout	**0.78-0.97** (0+ parr)	Dannewitz et al. '04
Hatchery	Brown Trout	**0.09** (lifetime)	Hansen '02
Hatchery	Coho Salmon	**~1.0** (lifetime)	Ford et al. '06
Hatchery	Coho Salmon	**0.62-0.95** (lifetime)	Thériault et al. '11
Hatchery	Chinook Salmon	**~1.0** (lifetime)	Hess et al. '12
Hatchery (1st gen. of captive breeding)	Atlantic Salmon	**0.30-0.64** (0+ parr)	Milot et al. '13

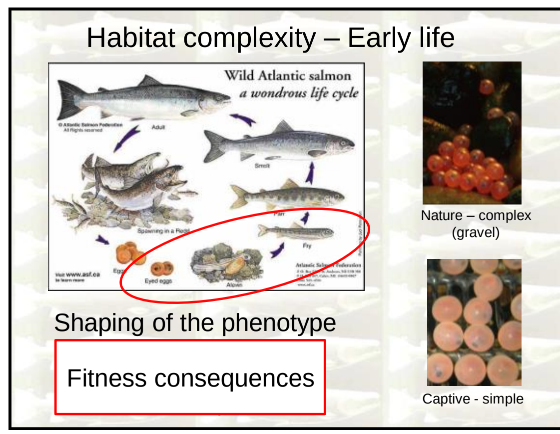
Ecology & Genetics of Recovery: What is Success?

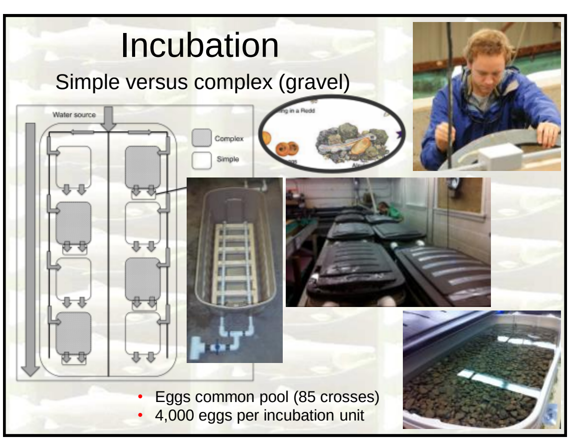
- The problem
- Resilience
- Salmon Recovery
- Captive Breeding (living gene banks)
- Conclusions

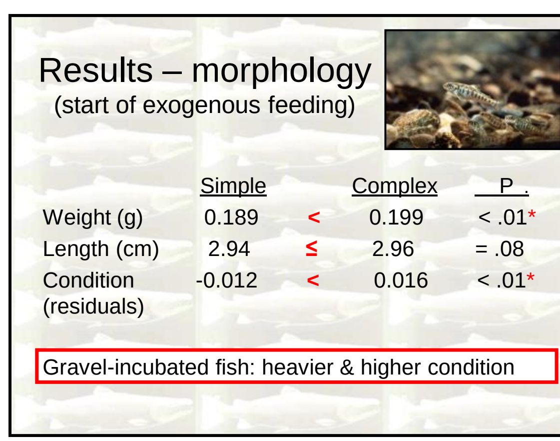

Salmon Captive Breeding for Conservation
Common Scenario
River
Hatchery
Sea
Plasticity & Selection
x
juveniles
FW phase
adults
offspring


Salmon Captive Breeding for Conservation
Common Scenario
River
Hatchery
Sea
Plasticity & Selection
x
juveniles
FW phase
adults
NA Atlantic salmon Scenario
Hatchery
River
offspring
x
SW to FW breeding phase

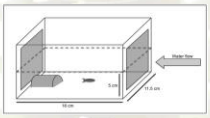

Captive rearing of offspring
Spawning of Salmon
Captive rearing of broodstock to maturity
4b
3
2
4a
Time
Time
Captive Component of Live Genebank
River release of offspring
Collection of Founders
1
In River Component of Live Genebank
FW
SW
Time
O'Reilly & Doyle 2007
Habitat complexity?


Habitat complexity – Early life
Wild Atlantic salmon
a wondrous life cycle
Nature – complex (gravel)
Shaping of the phenotype
Fitness consequences
Captive - simple


Incubation
Simple versus complex (gravel)
Water source
Complex
Simple
Eggs common pool (85 crosses)
4,000 eggs per incubation unit


Results – morphology
(start of exogenous feeding)
Simple Complex P .
Weight (g) 0.189 < 0.199 < .01*
Length (cm) 2.94 ≤ 2.96 = .08
Condition (residuals) -0.012 < 0.016 < .01*
Gravel-incubated fish: heavier & higher condition

Results – behaviour



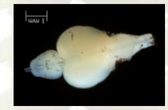
(start of exogenous feeding)

	Simple		Complex	P
Feeding (novel live prey)	74%	<	47%	= .02*
Simulated Predator				
Reacted	84%	=	90%	= .48
Sought shelter	59%	=	63%	= .80
Reemergence (s)	204	<	252	< .01*

Gravel-incubated fish: enhanced feeding & more risk adverse

Results – brain volume

(start of exogenous feeding)



(absolute and size-corrected measures)

	P
Whole brain	0.11 - 0.68
Telenchepalon	0.68 - 0.73
Olfactory bulb	0.76 – 0.83

No difference in brain volume

Summary

Incubation environment shapes:

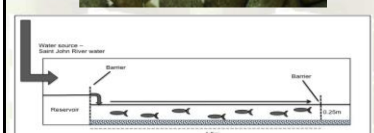
- Body morphology (movement, shelter, stress)
- Behaviour (stimulation & complexity)
- BUT not brain volume (cell proliferation, neuron number, dendrite length)

Do these phenotypic responses translate into performance (growth and survival) in semi-natural conditions?

Fitness - Semi-natural streams

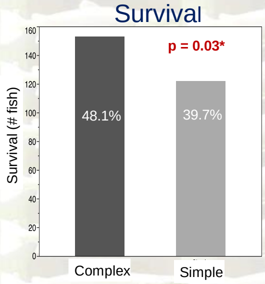
(start of exogenous feeding)

- 8 replicate streams
- 40 simple & 40 complex fish per stream
- 42 days

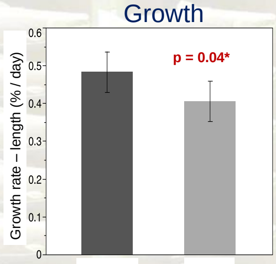


Results

Survival



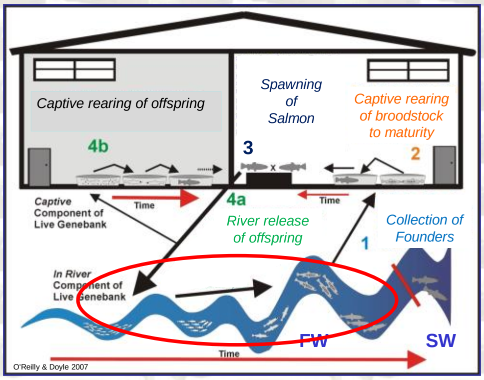
Growth



Gravel incubated fish: higher survival & faster growth in semi-natural streams

Conclusions & Implications

- Incubation environment profound effects on phenotype
- Affects subsequent survival and growth (fitness)
- Captive rearing environments can be altered to promote phenotypic traits that may be more favourable in nature



Wild Exposure?

Fitness returns from wild exposure?

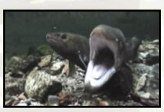
Series of Experiments

(1) Reproductive success of wild-exposed (FW juvenile phase) versus fully captive-reared adults.

(2) Transgenerational effects - offspring fitness of wild-exposed versus fully captive reared adults

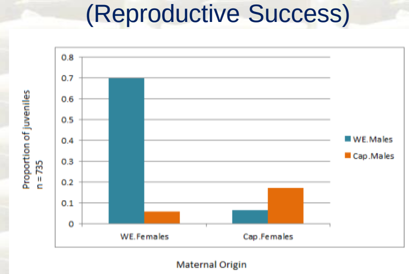
Reproductive Success Experimental Design

Spawning Arenas
(Mactaquac Biodiversity Facility)



4 Arenas
- 2 Mixed – Wild-Exposed (WE) and Captive-Reared (CR)
  (20 fish each, 5♀ & 5♂ of each type)
- 1 Pure – Wild-Exposed (WE)
  (20 fish, 10 of each sex)
- 1 Pure – Captive-Reared (CR)
  (20 fish, 10 of each sex)

Parentage in Mixed Arenas
(Reproductive Success)



- Reproductive success ($p < 0.001$)
  Wild Exposed (76.1% ♀ & 76.9% ♂) > Captive Reared (23.9 % ♀ & 23.1% ♂)
- Offspring -- pure > mixed origin ($p < 0.001$).

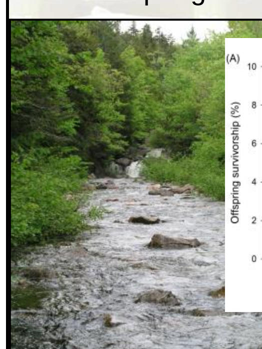
Transgenerational Fitness Experimental Design

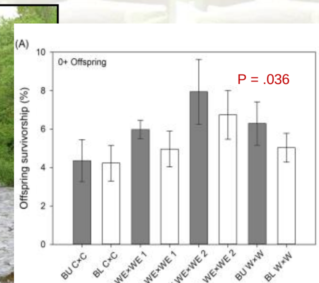
Release of unfed fry in Bonnell Brook, Big Salmon River

2 sites (~5 km apart)

Offspring from 4 parent types:
(1) Fully Captive-Reared (CR)
(8 families)
(2) Wild-Exposed 1 yr (WE1)
(10 families)
(3) of Wild-Exposed 2 yrs (WE2)
(9 families)
(4) Wild (W; captured as 1+)
(11 families)

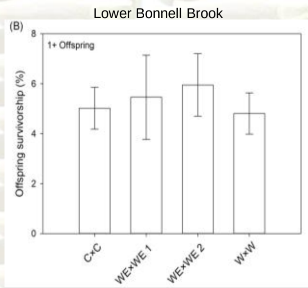
Offspring Survival (1st summer)





Wild Exposed 2 yrs > Captive

Offspring Survival (to 2nd summer)



Similar pattern, but NS

Conclusions

- Captive rearing environments can be altered to promote phenotypic traits that may be more favourable in nature
- Wild exposure can improve short (within generation) and long term (transgenerational) fitness in captively bred populations

Potential Ecological & Genetic Risks

- Removal of wild fish for broodstock
- Alter phenotypes & domestication (reduce biodiversity)
- Impede future adaptation
- Disguise problems (e.g., habitat degradation) by appearance of high local abundance
- Enhance predator populations
- Allow for “surplus” for exploitation, with concomitant mortality of wild fish

Captive Breeding

- While there is ecological & genetic risk, its potential value is large
- Our understanding of how to effectively use and manage it is growing, but remains far from complete
- Temporary tool
- Should not inhibit other restoration / recovery measures
- It will not be sufficient by itself to restore resiliency

Acknowledgements

The graduate students: John Winkowski, Nate Wilke, Becky Graham
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The Swedish Research Council Formas
Mountain Equipment Co-op

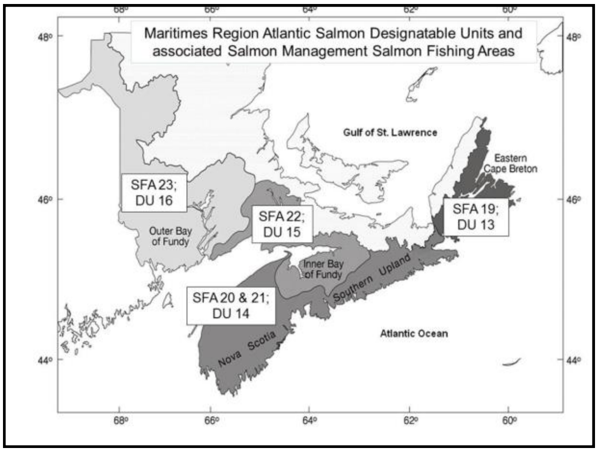
Maritimes Region Atlantic Salmon population status, trends, threats and points of discussion
Shane O'Neil, Fisheries and Oceans Canada

Maritimes Region Atlantic Salmon Population Status, Trends, Threats and Points for Discussion

Outline
- Population groupings and sizes
- Status by grouping- focus on Outer Bay of Fundy, Southern Upland and Eastern Cape Breton
- Trends by Designatable Unit
- Threats by Designatable Unit and summary
- Some mitigation that has occurred
- Where to from here

Prepared by S. O'Neil and presented by Alex Levy, Population Ecology Division, Science Branch, DFO

Fisheries and Oceans Canada Science



Salmon Populations – where did the number of rivers come from?

- Response to ICES request in 1997: Canadian numbers were summarized in O'Connell et al. 1997. Estimates of Conservation Spawner Requirements for Atlantic Salmon *(Salmo salar L .)* for Canada. CSAS Res Doc. 97/100
- NASCO database developed and updated
- In some cases: Adjustments based on data review and provided in Recovery Potential Assessments in 2012 and 2013.

Fisheries and Oceans Canada Science

Population status

- Inner Bay of Fundy Atlantic salmon populations, DU 15, were listed as endangered in 2001 (on Schedule 1 under SARA)
- Outer Bay of Fundy Atlantic salmon, DU 16, were designated as endangered by COSEWIC in 2010; listing decision is pending
- Southern Upland Atlantic Salmon, DU 14, were designated as endangered by COSEWIC in 2010; listing decision is pending
- Eastern Cape Breton Atlantic Salmon populations, DU 13, were designated as endangered by COSEWIC in 2010; listing decision is pending.

Fisheries and Oceans Canada Science

Inner Bay of Fundy DU

32 Rivers (original listing with COSEWIC); 50 rivers based on IBOF salmon Recovery Strategy and RPA

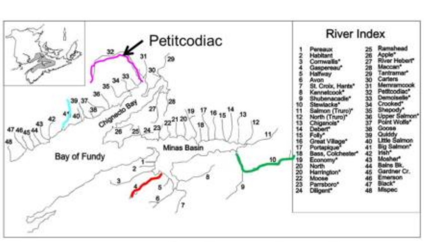
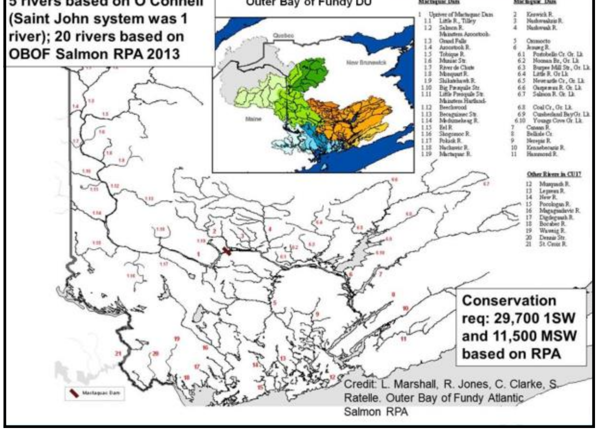


Figure 1. Map showing the approximate locations of inner Bay of Fundy rivers. Asterisk denotes those 32 rivers in which salmon are known to have inhabited.

Conservation spawner requirement: 7600 small; 2600 large based on original list of 32 rivers

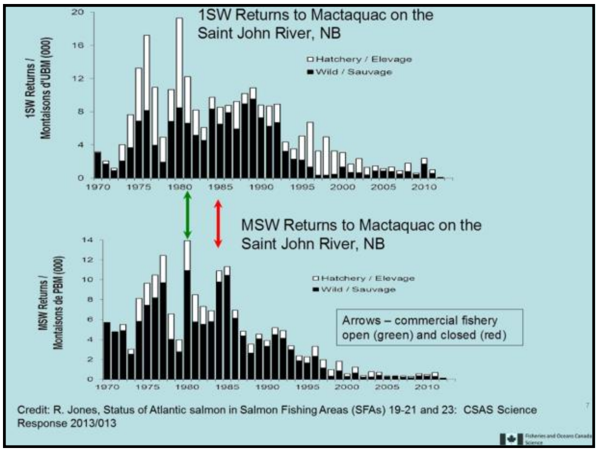
Credit: J.Gibson, P. Amiro, K. Robichaud-Leblanc. Densities of juvenile salmon……CSAS Res Doc 2003/121

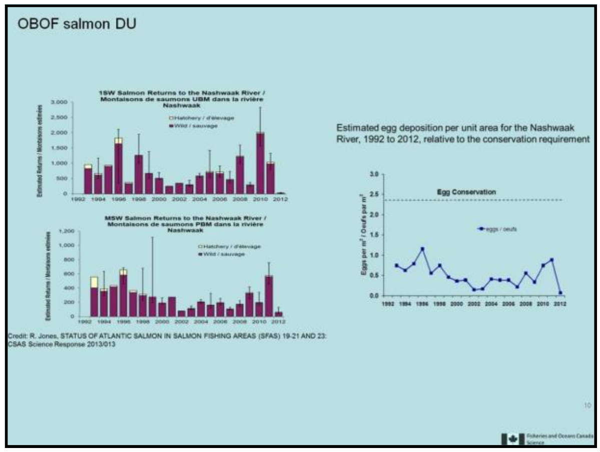
5 rivers based on O'Connell (Saint John system was 1 river); 20 rivers based on OBOF Salmon RPA 2013

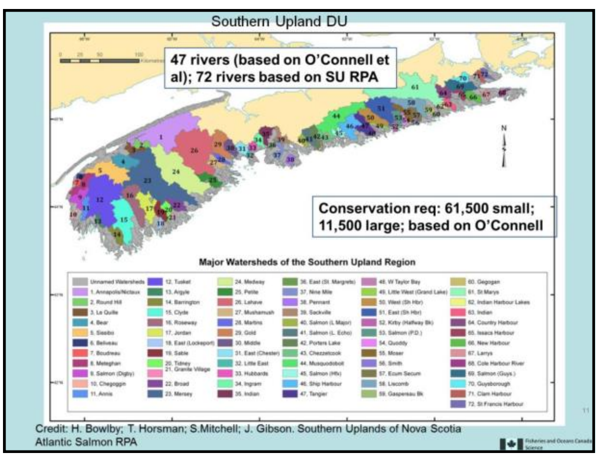


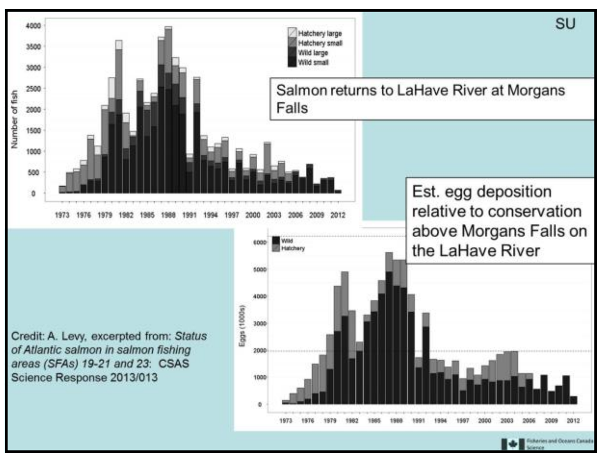
Conservation req: 29,700 1SW and 11,500 MSW based on RPA

Credit: L. Marshall, R. Jones, C. Clarke, S. Ratelle. Outer Bay of Fundy Atlantic Salmon RPA


1SW Returns to Mactaquac on the Saint John River, NB
Hatchery / Elevage
Wild / Sauvage
1SW Returns / Montaisons d'UBM (000)
MSW Returns to Mactaquac on the Saint John River, NB
MSW Returns / Montaisons de PBM (000)
Arrows – commercial fishery open (green) and closed (red)
Credit: R. Jones, Status of Atlantic salmon in Salmon Fishing Areas (SFAs) 19-21 and 23: CSAS Science Response 2013/013

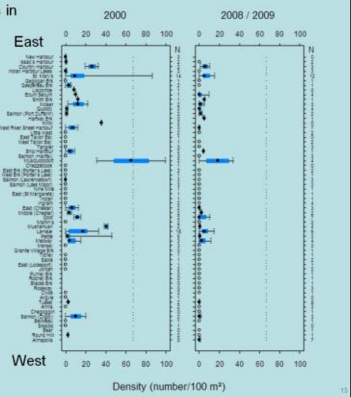

OBOF salmon DU
1SW Salmon Returns to the Nashwaak River / Montaisons de saumons UBM dans la rivière Nashwaak
MSW Salmon Returns to the Nashwaak River / Montaisons de saumons PBM dans la rivière Nashwaak
Estimated egg deposition per unit area for the Nashwaak River, 1992 to 2012, relative to the conservation requirement
Egg Conservation
Credit: R. Jones, STATUS OF ATLANTIC SALMON IN SALMON FISHING AREAS (SFAS) 19-21 AND 23: CSAS Science Response 2013/013


Southern Upland DU
47 rivers (based on O'Connell et al); 72 rivers based on SU RPA
Conservation req: 61,500 small; 11,500 large; based on O'Connell
Major Watersheds of the Southern Upland Region
Credit: H. Bowlby; T. Horsman; S.Mitchell; J. Gibson. Southern Uplands of Nova Scotia Atlantic Salmon RPA

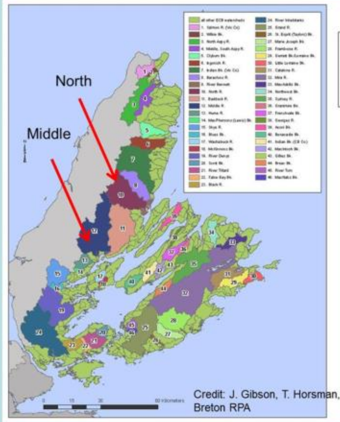

SU
Hatchery large
Hatchery small
Wild large
Wild small
Number of fish
Salmon returns to LaHave River at Morgans Falls
Est. egg deposition relative to conservation above Morgans Falls on the LaHave River
Eggs (1000s)
Credit: A. Levy, excerpted from: Status of Atlantic salmon in salmon fishing areas (SFAs) 19-21 and 23: CSAS Science Response 2013/013

Juvenile salmon densities in rivers in the Southern Upland

Key points:
- Juvenile densities throughout the SU DU are relatively low
- The number of "zero" fish sites increased between surveys



Gibson et al. 2011

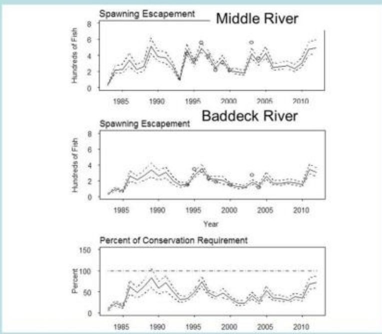


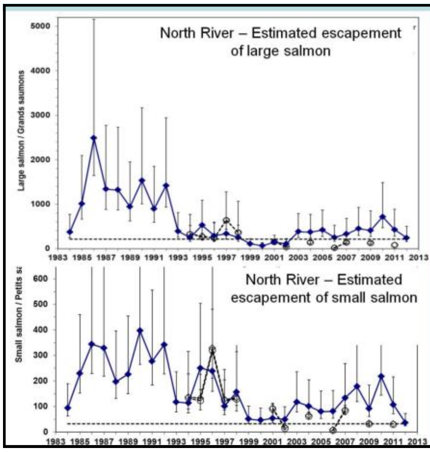
26 rivers based on O'Connell; : 46 rivers based on NASCO rivers database

Conservation reg.: 6,386 fish (80% large) based on O'Connell.

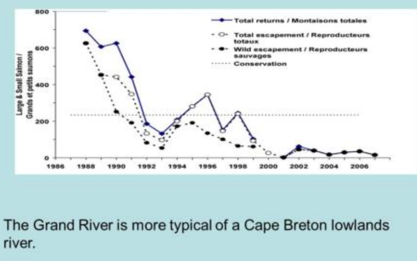
Credit: J. Gibson, T. Horsman, J.Ford, E. Halfyard; Eastern Cape Breton RPA

Eastern Cape Breton Atlantic Salmon Designatable Unit





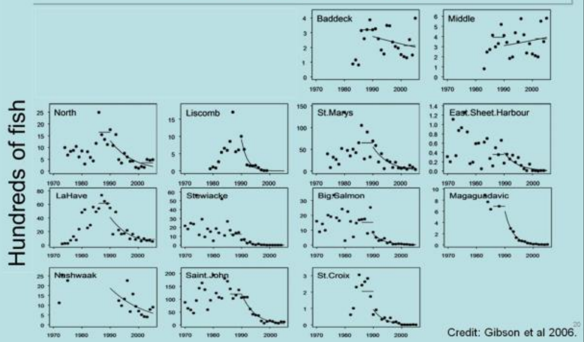
Estimated number of Large and small salmon returning to the Grand River



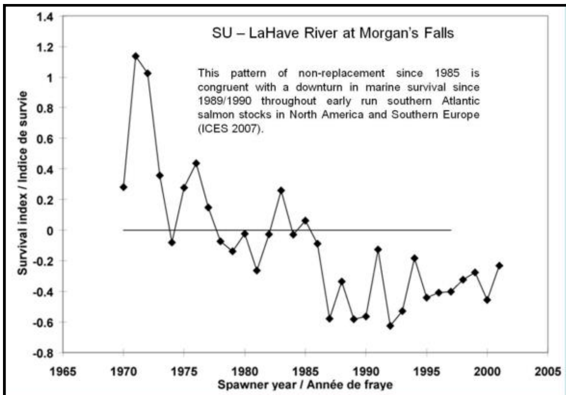
The Grand River is more typical of a Cape Breton lowlands river.

• Trends =======➔

Maritime Region salmon abundance trends 1970 to 2005



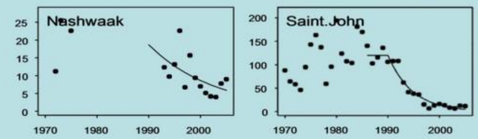
Credit: Gibson et al 2006.



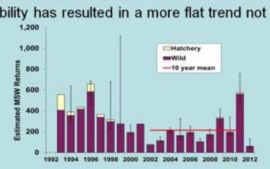
Credit: J. Gibson, excerpted from Status of Atlantic salmon in Salmon Fishing Areas (SFAs) 19-21 and 23 : CSAS Science Response 2008/001

OBOF Salmon DU

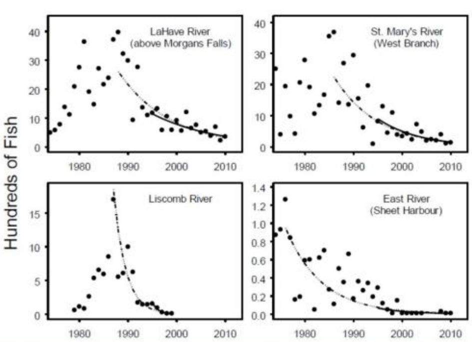
Adult salmon abundance trend for the Nashwaak and Saint John rivers (above Mactaquac)



- Recent returns to the Nashwaak River have **altered the trajectory**, but high variability has resulted in a more flat trend not an increasing one.



Southern Upland DU adult salmon abundance time series

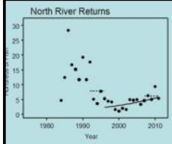


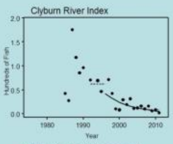
Credit: Bowlby et al. 2013

Population viability

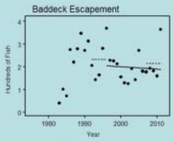
- Southern Upland: The extinction risk for the LaHave River population is 87% within 50 years.
- The population equilibrium rate is zero …the population will extirpate without a change in marine survival or human intervention

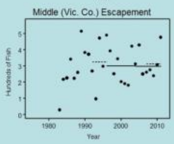
DFO. 2013. Recovery Potential Assessment for Southern Upland Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/009.

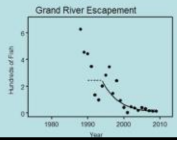




Eastern Cape Breton DU







Returns or escapement of salmon on several rivers in the Eastern Cape Breton DU

Credit: A. Levy and J. Gibson CSAS Res Doc in prep

- Threats =======➔

Threats

- Recovery Potential Assessments for 3 salmon DUs in the Maritimes Region identified threats for those populations with a scale of negligible to extreme
- The threats classified as high to extreme for the 3 DUs were reviewed for commonality
- Medium-rated threats were also reviewed in the same context but in the interests of time were not included here

High to extreme threats- Outer Bay of Fundy Salmon DU

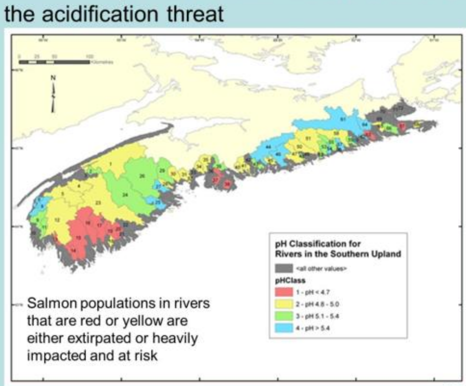
- Those that were classified as having a high level of concern included:
  - Physical barriers > Hydro dams
  - Directed salmon fishing – illegal fishing (poaching)

  - Biotic and abiotic shifts:
    - » salmonid aquaculture
    - » Diseases and parasites
  - with unknown severity:
    - » low population effects (Allee, etc.)
    - » Shifts in marine conditions (climate and predator-prey)

High to extreme threats- Southern Upland Salmon DU

- More threats fall into this category for this DU and include:
- Water quality and quantity:
  - » Acidification
  - » altered hydrology
- Changes to biological communities: invasive species
- Physical obstructions: habitat fragmentation
- Directed salmon fisheries: Illegal fishing and poaching
- Changes to biological communities: aquaculture
- Changes to oceanographic conditions: Marine ecosystem change

Southern Uplands DU Threats – The extent of the acidification threat



Salmon populations in rivers that are red or yellow are either extirpated or heavily impacted and at risk

Limestone doser on the West River, Sheet Harbour

❑ High to extreme threats- Eastern Cape Breton Salmon DU

- Directed Salmon Fishing: illegal fishing activities
- Changes to biological communities:
  - » Salmonid aquaculture – when operational
  - » Diseases and parasites
- Changes in oceanographic conditions: Marine ecosystem change

Threats summary

- Some threats are particularly relevant to a DU:
  - – In the case of OBOF salmon populations: hydro dams
  - – In the case of SU salmon populations: acidification
- Common to all DUs are:
  - » Shifts in marine conditions – not a threat that can be tackled to effect change in the time frames that modeling would suggest action is needed.
  - » Habitat fragmentation
  - » illegal fishing

Both of which can be tackled in the freshwater environment with the potential to improve productivity

Threats summary cont'd

- Also common to all DUs as a high or medium risk threat:
  - Changes to biological communities
    - » Invasive species – mostly in OBOF and SU DUs – potentially a threat that can be addressed

    - » Diseases and parasites – extent of impact not well understood – a threat that has the potential to be addressed in some capacity
    - » Aquaculture – potential effect would differ by DU

Where to go from here?

- The recovery process as required under the Act will take time and involve process
- To limit the risk of losing an entire DU, we will have to act now to conserve/maintain/facilitate recovery of limited larger populations

Recovery approach

- Atlantic salmon populations from each DU should have abundance and distribution components to any population maintenance and recovery process…..as much as feasible
- This was emphasized in the outcomes from the salmon recovery potential assessments for all DUs.

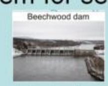
Where to act?

- Models indicate extirpations are imminent
- We in Science prefer to act on scientific data and the current paradigm is unprecedented
- We can't use history to guide our actions for population maintenance and recovery
- Or the luxury of long-term research
- To act now will require acceptance of some risk

- Risk that actions might hasten population decline
- Risk that actions might lose some populations because the chosen location to act excludes other locations/populations
- ➔Apply the most effective means to increase the populations chance of survival.

Tackle most obvious and "tractable" threats – for example:

- OBOF – hydropower on the Saint John River: how long would this take? It has been a recognized problem for several decades.



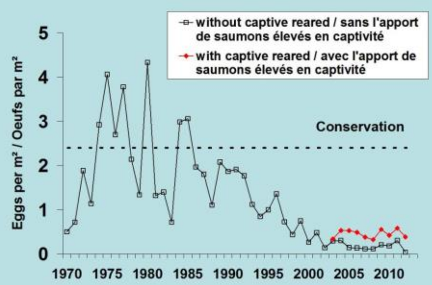
  - What to do while this threat is being addressed (e.g., DFO and NBP steering committee)? Supportive rearing is ongoing; continue while tackling the threat
  - That is just one option

OBOF salmon – Tobique River – modeling of population persistence:

- A key conclusion:
  - Given the current low marine survival of Atlantic salmon, increasing the survival of migrating smolt alone will not be sufficient to ensure a viable salmon population. A supportive rearing program will still be required at least in the near term.

DFO. 2006. Science Expert Opinion on conceptual facility to bypass Atlantic salmon smolts at the Tobique Narrows Dam. Maritimes Region, Expert Opinion 2006/02: 29p.

Can populations be maintained with supportive rearing or live gene banking



Credit: R. Jones

Tobique River – OBOF Salmon DU

More details on this example will be provided by Pat O'Reilly

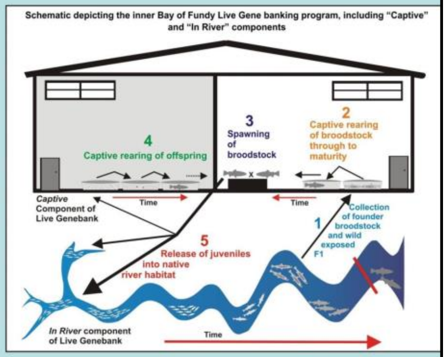
Live Gene Bank for IBOF salmon

- Population viability analysis conducted in support of the Recovery Potential assessment for this endangered population:
  - Noted that without the live gene bank the population would be extirpated in a very short time scale
  - Also noted that the threats would have to be addressed / change if there was to be a realistic prospect for recovery

DFO. 2008. Recovery Potential Assessment for Inner Bay of Fundy Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/050.

Live Gene Banking of Inner Bay of Fundy Atlantic salmon

1. Collection of founder fish from "at risk" population;
2. Spawning those fish when mature according to a pedigree-based mating plan;
3. Releasing fish into the wild for natural selection effects to occur;
4. Retaining a duplicate in captivity to limit the risk of loss of genetic diversity



Tackle most obvious and "tractable" threats

- For example: SU – altered hydrology and acidification
- The challenge is to take steps to reduce the impact of threats given the prognosis that recovery will be in the longer term
- In the case of the SU, liming acidic waters is a plausible mitigation of a threat but costly
- A factor that cannot be ignored in choosing where to take action

Salmon being released on the Salmon River (IBOF)

Wish I could be with you in St. Andrew's - Thanks

Newfoundland & Labrador
Martha Robertson,
Fisheries and Oceans
Canada

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Atlantic Salmon Newfoundland and Labrador

Martha Robertson
Research Scientist, Salmonids Section
Fisheries and Oceans Canada
Newfoundland and Labrador Region

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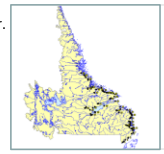
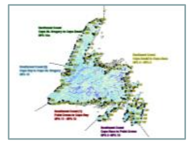
Number of Salmon Rivers

- 394 salmon rivers in Newfoundland and Labrador.
- 186 of these are Scheduled
  - Newfoundland 158 and Labrador 28

Region	Number	Drainage Km^2
1	28	24,956
2	20	30,931
3	41	30,947
4	127	40,077
5	49	6,191
6	55	16,278
7	40	15,743
8	34	6,424
Newfoundland	**305**	**84,714**
Labrador	**89**	**86,834**
Total	**394**	**171,549**





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Stock Status Atlantic Salmon Newfoundland and Labrador 2012

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Insular Newfoundland SFAs (3–14A) 2012

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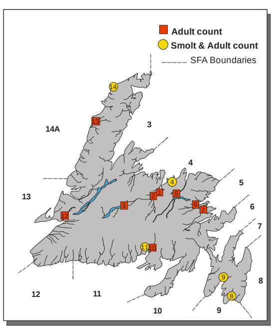
Fisheries and Oceans Canada Pêches et Océans Canada

Monitoring Facilities 2012



1. Exploits River (Bishops Falls fishway)
2. Exploits River (Grand Falls fishway)
3. Exploits River (Red Indian Lake fishway)
4. Campbellton River (fence)
5. Gander River (Salmon Brook fishway)
6. Middle Brook (fishway)
7. Terra Nova River (fishway)
8. Northeast Brook Trepassey (fence)
9. Rocky River (fishway/fence)
10. Little River (fence) - managed by Miawpukek First Nation.
11. Conne River (fence)
12. Harry's River (DIDSON)
13. Torrent River (fishway)
14. Western Arm Brook (fence)

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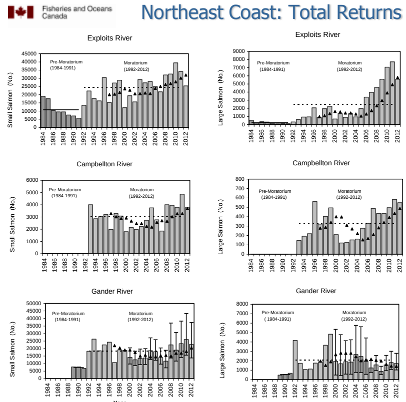
Northeast Coast: Total Returns



Previous 5-year Mean
Moratorium Mean
Pre-Moratorium Mean

Small salmon: Increasing trend of 5-year mean from 2005-2011

Large salmon (repeat spawners): Significant increasing trend of 5-yr mean from 2004-2011

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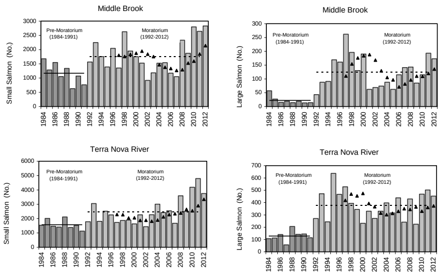
Northeast Coast: Total Returns con't



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Northeast Coast (SFAs 3-8): Conservation Requirement

		Total Returns 2012 Small	Total Returns 2012 Large	Total Returns 2007-2011 mean Small	Total Returns 2007-2011 mean Large	Conservation met (%) 2012	Conservation met (%) 2007-2011 mean	Conservation met (%) 2007-2012	2012 Egg Deposition Relative to: 2007-2011 mean
Northeast Coast (SFA's 3-8)									
Exploits River	Fw	25349	5578	31953	5778	49	63	0 of 6 yrs	↓
Campbellton River	Fe	3755	548	3691	486	394	364	6 of 6 yrs	⇔
Gander River*	EFw	22652	1698	20409	1407	128	111	5 of 6 yrs	⇧
Middle Brook	Fw	2828	173	2137	135	299	215	6 of 6 yrs	⇧
Terra Nova River	Fw	3746	452	3346	373	64	56	0 of 6 yrs	⇧

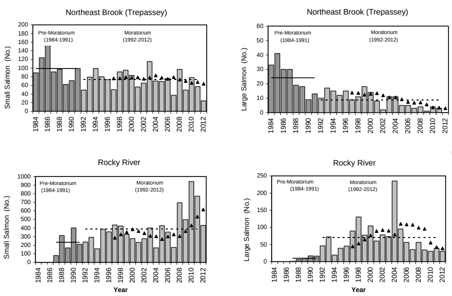
Assessment Methods: Fe = counting fence; Fw = fishway count; EFw = estimated from tributary fishway count

Trend symbols: ↓ > 10% decrease; ⇧ > 10% increase; ⇔ no change = ± 10%

Footnotes:

*Gander River was assessed using a counting fence 1989-1999, and was estimated from a tributary count after 1999.

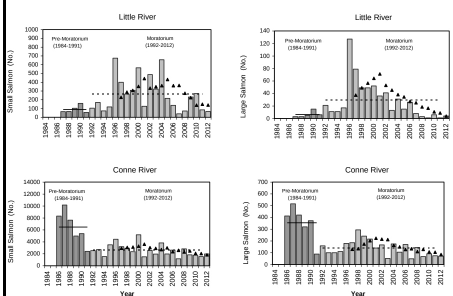
South Coast: Total Returns



- Declining 5-yr Means
- Increasing 5-yr Means for Small Salmon

Canada

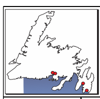
South Coast: Total Returns con't



- Declining 5-yr Means

Canada

South Coast (SFAs 9-11): Conservation Requirement

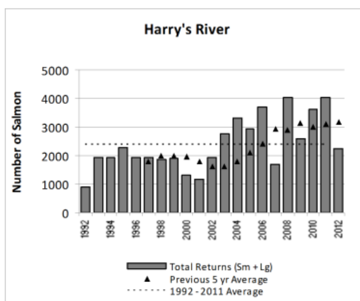


		Total Returns 2012 Small	Total Returns 2012 Large	Total Returns 2007-2011 mean Small	Total Returns 2007-2011 mean Large	Conservation met (%) 2012	Conservation met (%) 2007-2011 mean	Conservation met (%) 2007-2012	2012 Egg Deposition Relative to: 2007-2011 mean
South Coast (SFA's 9-11)									
Northeast Brook (Trepassey)	Fe	24	0	64	3	55	148	5 of 6 yrs	↓
Rocky River	Fe	430	30	616	39	46	66	0 of 6 yrs	↓
Little River	Fe	65	4	139	4	30	61	1 of 6 yrs	↓
Conne River	Fe	1965	71	1826	85	79	75	1 of 6 yrs	⇔

Assessment Method: Fe = counting fence

Trend symbols: ↓ > 10% decrease; ⇧ > 10% increase; ⇔ no change = ± 10%

Southwest Coast: Total Returns



- Stable 5-yr Means but Returns highly variable.

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Southwest Coast (SFAs 12-13): Conservation Requirement

		Total Returns		Conservation met (%)			2012 Egg Deposition
		2012	2007-2011 mean				Relative to:
		Small + Large	Small + Large	2012	2007-2011 mean	2007-2012	2007-2011 mean
Southwest Coast (SFA's 12-13)							
Harry's River	DIDSON	2248	3188	54*	96	3 of 6 yrs	↓

Assessment Method: DIDSON = Dual-Frequency IDentification SONar

Trend symbols: ↓ > 10% decrease; ⇧ > 10% increase; ⇔ no change = ± 10%

* Based on proportion of large from 5 year average (2006-2010).

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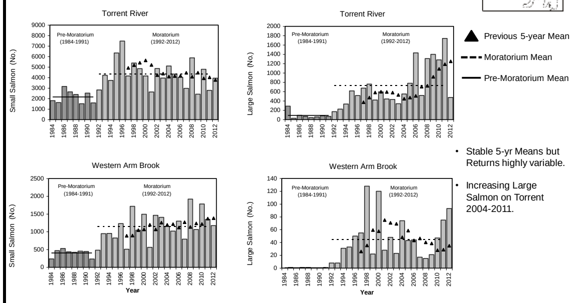
Northwest Coast: Total Returns



- Stable 5-yr Means but Returns highly variable.
- Increasing Large Salmon on Torrent 2004-2011.

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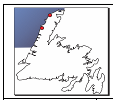
Northwest Coast (SFA 14A): Conservation Requirement



		Total Returns				Conservation met (%)			2012 Egg Deposition
		2012		2007-2011 mean					Relative to:
		Small	Large	Small	Large	2012	2007-2011 mean	2007-2012	2007-2011 mean
Northern Peninsula West (SFA 14A)									
Torrent River	Fw	3950	474	3772	1250	670	865	6 of 6 yrs	↓
Western Arm Bk.	Fe	1173	93	1382	35	405	484	6 of 6 yrs	↓

Assessment Methods: Fe = counting fence; Fw = fishway count

Trend symbols: ↓ > 10% decrease; ⇧ > 10% increase; ⇔ no change = ± 10%

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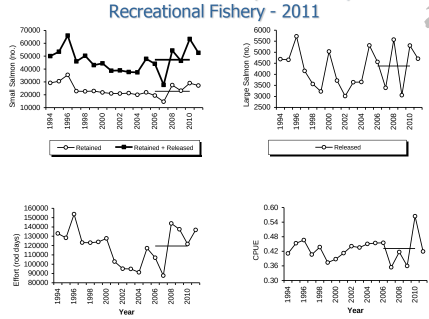
Insular Newfoundland (SFAs 3-14A) Recreational Fishery - 2011



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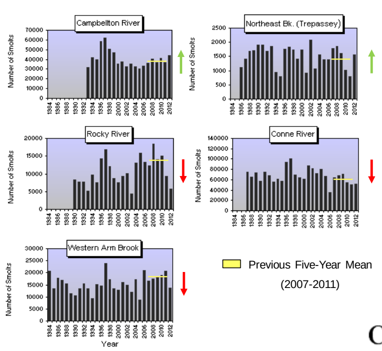
Trends in Atlantic Salmon Smolt Production



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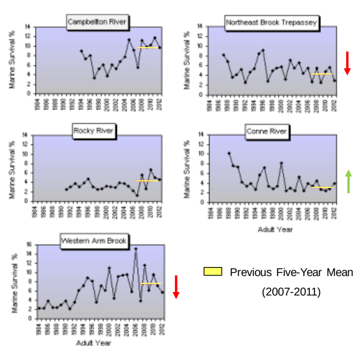
Trends in Atlantic Salmon Marine Survival



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Labrador SFAs (1, 2, & 14B) 2012

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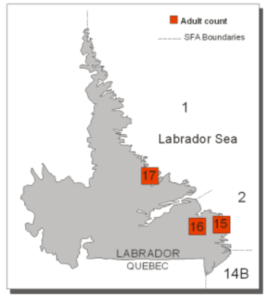
Monitoring Facilities 2012



15. Sand Hill River (fence)
16. Paradise River (fence)
17. English River (fence) – managed by Nunatsiavut Government

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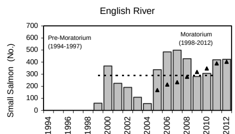
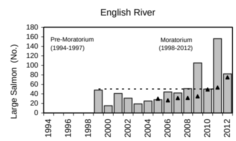
Labrador: Total Returns SFA 1



Previous 5-year Mean

Moratorium Mean



- Increasing trend of 5-yr Means.

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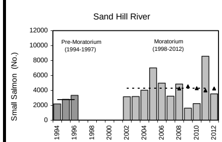
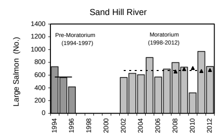
Labrador: Total Returns SFA 2



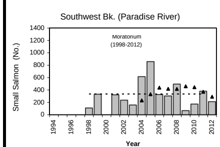


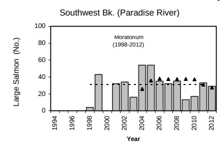
Previous 5-year Mean

Moratorium Mean

Pre-Moratorium Mean

- Stable 5-yr Means but Returns highly variable.





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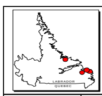
Labrador (SFA 1, 2, & 14A): Conservation Requirement



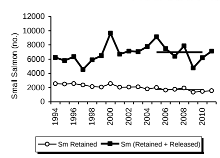
		Total Returns				Conservation met (%)			2012 Egg Deposition Relative to:
		2012		2006-2011 mean					
		Small	Large	Small	Large	2012	2006-2011 mean	2006-2012	2006-2011 mean
LABRADOR									
SFA 1									
English River	Fe	423	82	403	75	129	120	6 of 7 yrs	⇔
SFA 2									
Sand Hill River	Fe	3527	734	4238	678	96	108	3 of 7 yrs	↓
Southwest Brook (Paradise River)	Fe	211	29	291	28	75	96	4 of 7 yrs	↓

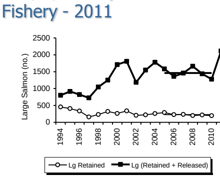
Assessment Method: Fe = counting fence

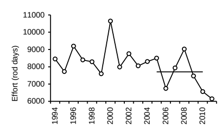
Trend symbols: ↓ > 10% decrease; ⇧ > 10% increase; ⇔ no change = ± 10%

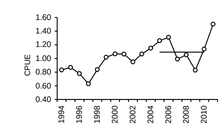
Fisheries and Oceans Canada | Pêches et Océans Canada

Labrador (SFAs 1, 2, & 14B) Recreational Fishery - 2011





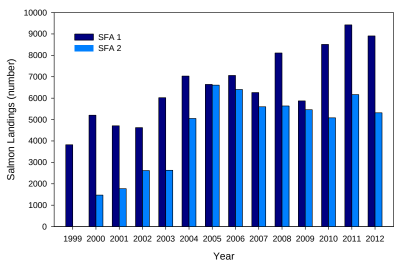




Canada

Fisheries and Oceans Canada / Pêches et Océans Canada

Reported Landings
Labrador Atlantic Salmon Food Fisheries - 2012



Canada

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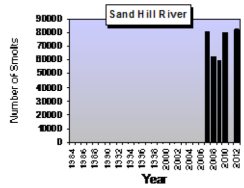
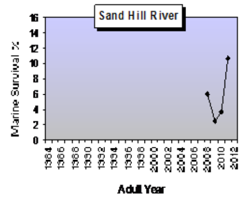
Trends in Atlantic Salmon
Smolt Production and Marine Survival





Canada

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Newfoundland and Labrador Atlantic Salmon Populations at Risk

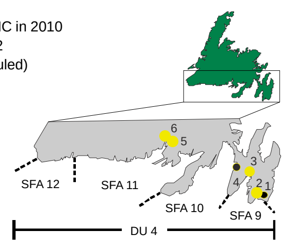
COSEWIC
Committee on the Status of Endangered Wildlife in Canada
COSEPAC
Comité sur la situation des espèces en péril au Canada

Canada

Fisheries and Oceans Canada / Pêches et Océans Canada

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): South Newfoundland Designatable (DU) 4

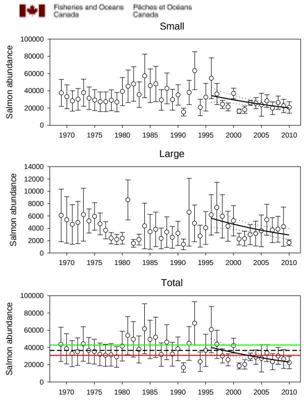
- Designated Threatened by COSWEIC in 2010
- Salmon Fishing Areas (SFAs) 9 – 12
- 104 known salmon rivers (58 scheduled)
- Atlantic salmon monitoring facilities:
  - Northeast Brook (Trepassey) 1984 - 2011
  - Rocky River 1987 - 2011
  - Little River 1987 - 2011
  - Conne River 1986 - 2011
  - Biscay Bay 1983 - 1996
  - Northeast River (Placentia) 1978 - 2002



Canada

Fisheries and Oceans Canada / Pêches et Océans Canada

DU 4 (SFAs 9-12)



Small: - 41.5% (P = 0.009*)
[CSR: - 37.3% P = 0.063]

Large: - 48.3% (P = 0.012*)
[CSR: - 26.2% P = 0.293]

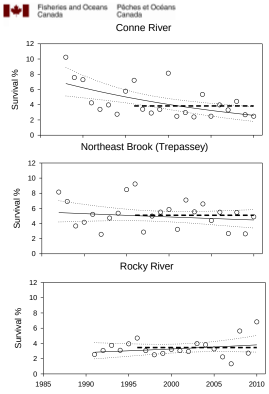
Total: - 42.4% (P = 0.006*)
[CSR: - 36.0% P = 0.071]

Pre-Decline Mean 1981-1995
Conservation Requirement

Canada

Fisheries and Oceans Canada / Pêches et Océans Canada

Marine Survival: DU 4 Monitored Rivers



- 62%

- 18%

+ 33%

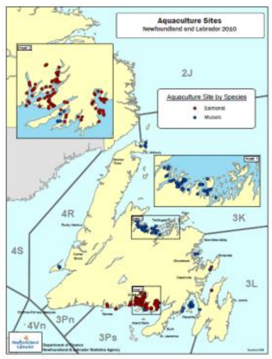
Canada

Abundance Trend Summary: DU 4 (SFAs 9-12)

- Declines in abundance have occurred over the last three generations (1996-2010) in all SFAs and rivers, except Rocky River. However, declines were most dramatic and statistically significant in SFA 11, Conne River and Little River.
- Large salmon declined in all analyses.

Anthropogenic Threats to Fish and Fish Habitat

Exploitation



Aquaculture

- 81 licensed salmonid aquaculture sites on south coast (DU 4)
  - Not all active in a given year (2006-2010, 10-23 active).

Dams/Hydroelectic Power Generation

- 402 dams in the province
  - 87 in Labrador (85 associated with Upper Churchill, 2 water supplies).
  - 315 in Newfoundland (234 hydroelectric, 81 water supplies).
- 39 major dams in Newfoundland
  (≥10 m, Canadian Dams Association Registry 2003), all hydroelectric
  - 8 on south coast (DU 4).
  - Bay d'Espoir did not remove accessible habitat but severely altered natural water flow to salmon rivers.

- Transportation and Infrastructure
- Agriculture/Forestry/Mining
- Climate Change

Historical Enhancement in Newfoundland: Opening Up New Habitat

- DFO program to increase production of Atlantic Salmon through range expansion (1940s – mid-1990s)
- Method:
  - Fishway construction
  - Colonization

Colonization Methods

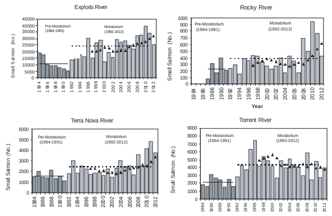
- Natural straying
- Stocking adults
- Stocking unfed fry
  - Artificial spawning channel
  - Upwelling incubation boxes

Stocking History - Highlights

From Table 17.1 of Mullins et al. 2003 Salmon on the Edge, Blackwell

River	Type of obstruction	Enhancement method	Year of fishway construction	Stocking method	Stocking period	Years of stocking
Enhanced stocks						
Great Rattling Brook	Natural, complete	Fishway	1960	Adult transfer and natural straying	1957–1964	8
				Fry stocking[1]	1987–1992	
Middle Exploits River	Natural, complete	Fishway	1974	Fry stocking and natural straying	1970–1992	22
Upper Terra Nova River	Natural, complete	Fishway	1955	Natural straying	1955–2001	
Rocky River	Natural, complete	Fishway	1987	Fry stocking	1984–1987	4
				Adult transfer	1987	1
				Fry stocking	1995–1996	2
Torrent River	Natural, complete	Fishway	1965	Adult transfer and natural straying	1972–1976	5

Stocking Effectiveness



- All stocks established or enhanced.
- Straying cost effective but slower than stocking.
- Naturally spawning adults (stocked or strayed) provided better Recruit / Spawner than fry stocking.
- Fry stocking successful if:
  - Stocked in non-utilized habitat.
  - Incubated with river water.
  - Stocked at 75 fry/100m².
  - Transport time < 1 hr.

VALE

Rennies River Salmon Reintroduction Project

SAEN

- Five year egg stocking program 2012-2016
- Eggs from Exploits River (Grand Falls Fishway)
- 100,000 eggs/yr at 130 sites
- Whitlock-Vibert and Scotty-Jordon stream incubators.
- Results:
  - Whitlock filled with silt, poor hatch rates
  - Scotties washed away, high hatch rates

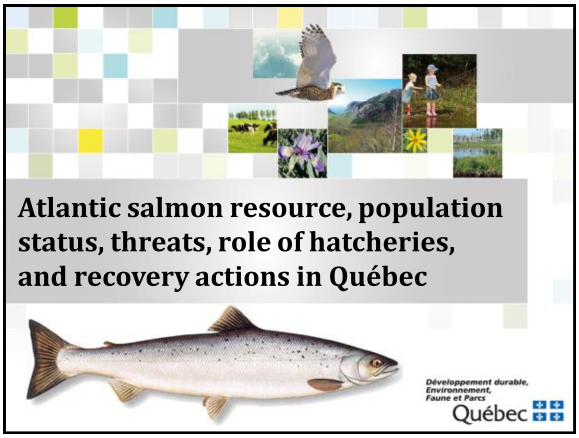
- 2013 Update
  - Scotty boxes secured in buried milk crates.
  - Young-of-year found at most sites electrofished.

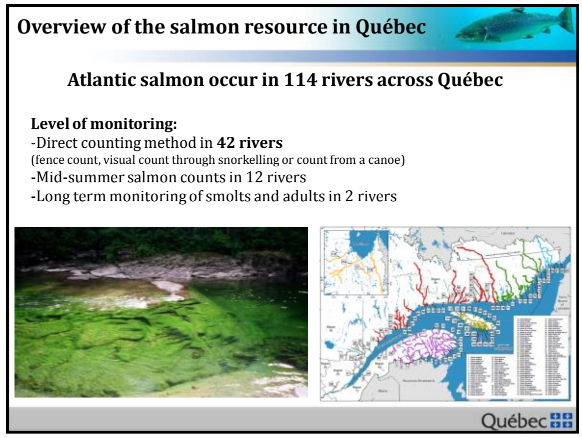
Rattling Brook

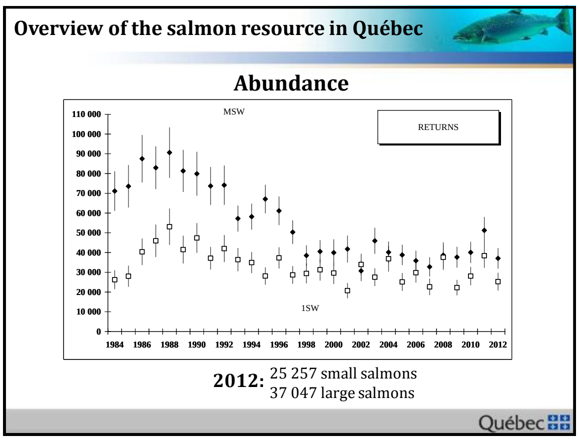
- DFO issued directive to Newfoundland Power to establish fish passage.
- Norris Arm and Area Economic Development Committee
  - Opportunity to develop stocking program instead of relying on straying alone for colonization.
  - Transfer adults from Great Rattling Brook (tributary of Exploits River).
    - Great Rattling Brook received fish from Rattling Brook in late 1950s.
    - Close geographically.
    - Removal of approximately 400 fish per year (2011-2013…2015?) would not impact Exploits River population.

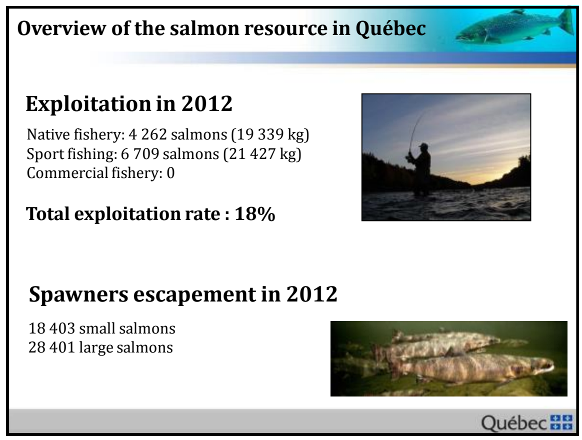
Quebec

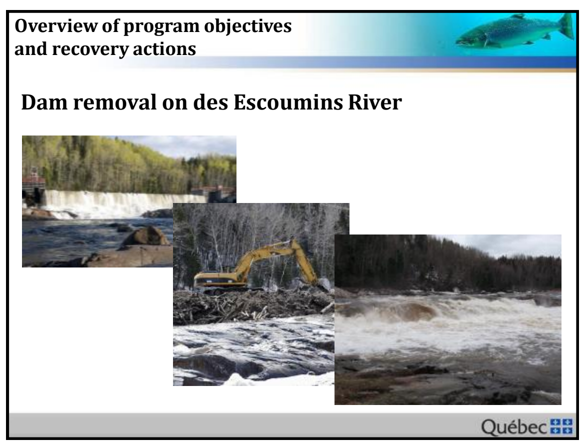
Julien April, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs











Overview of program objectives and recovery actions

Many projects involving fish ladders

Québec

Overview of program objectives and recovery actions

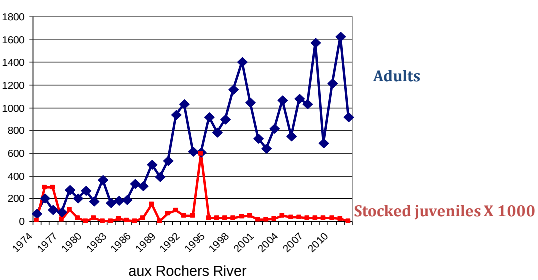
Atlantic salmon stocking: History

Many millions juveniles since the beginning in 1857
-Fry
-Parrs
-Smolts

Québec

Overview of program objectives and recovery actions

Atlantic salmon stocking: History



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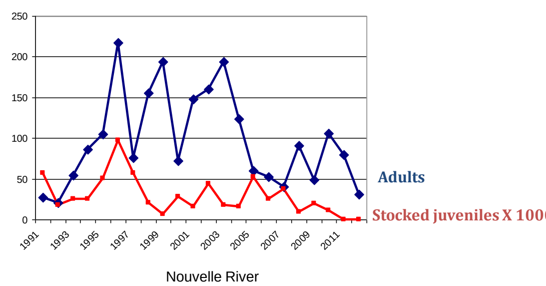
Overview of program objectives and recovery actions

Atlantic salmon stocking: History



Québec

Overview of program objectives and recovery actions

Atlantic salmon stocking: History

End of smolts stocking in 2003

- Reduced return rates for stocked smolts in Québec:

River	Mean return rate	
aux Rochers	0,4	**Stocked** Mean = 0,8
Madeleine	1,1	
Malbaie	0,4	
Matane	1,5	
Petit Saguenay	1,0	
Petite Cascapedia	0,5	
Sainte-Anne	0,5	
Malbaie	2,4	**Wild** Mean = 1,7
Saint-Jean	1,3	
Trinité	1,4	

- Pattern confirmed in different countries

(Saloniemi et al. 2004; Connell 2005, Jonsson & Jonsson 2006, Jokikokko et al. 2009)

Québec

Overview of program objectives and recovery actions

Atlantic salmon stocking: History

0+ parr stocking since 2004
(thermo regulated and natural thermal regime)

- Preliminary results based on a single river :

Mean survival from 0+ parr to adults = 0,2%
Mean survival from smolts to adults = 1,1%
Mean survival from smolts to adults from wild neighbour pop. = 2,1 %

- Survival monitoring in 4 additional rivers

Québec

Atlantic salmon stocking: Concerns

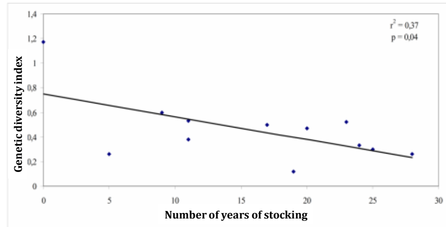
Ecological impact:
Competition between stocked and wild juveniles

Genetic impact:
-Homogenisation between rivers: Mixed between rivers
-Reduced diversity within river:

Captive individuals produce relatively more offspring than wild individuals : ↑ Demography ↓ Genetic diversity

Captive individuals produce as many offspring as wild individuals : ***No effect*** Demography ***No effect*** Genetic diversity

Genetic monitoring of populations



Data: 100 ind. X 10 rivers = 1000 ind. ; 15 microsalellites markers

Inbreeding increase with stocking intensity

Atlantic salmon stocking: Concerns

Reduced fitness

Isma River
Norway

Behavioral Ecology Vol. 8 No. 5: 470-480

Effects of early experience on the reproductive performance of Atlantic salmon 1997

Ian A. Fleming, Anders Lamberg, and Bror Jonsson
Norwegian Institute for Nature Research, Tungasletta 2, 7005 Trondheim, Norway

Relative reproductive success (Stocked/Wild)
Males: 0,51
Females: 1

Rivière Malbaie
Canada

Evolutionary Applications ISSN 1752-4571

ORIGINAL ARTICLE 2012

Reduced fitness of Atlantic salmon released in the wild after one generation of captive breeding

Emmanuel Milot,[1*] Charles Perrier,[1*] Lucie Papillon,[1] Julian J. Dodson[2] and Louis Bernatchez[1]

Relative reproductive success (Stocked/Wild)
Fry: 0,72
Parr: 0,42

Hatcheries are not the ultimate solution to all salmons problems

We must:

•Improve our methods

•Address the ecological and genetic concerns

Quebec's Atlantic salmon stocking guidelines:
(adhering to NASCO guidelines)

-Need to identify the cause of the decline and to give priority to natural reproduction

-Only for conservation
(population below conservation limits)

-Stocking in river segments that have low wilds juveniles densities

To preserve the genetic diversity of population:

-Stocking in the population of origin of the spawners

-Stocking only in population of at least 200 adults

-At least 30 spawners (or 10% of the population) need to participate to the stocking program

-Factorial cross implying at least 3 males and 3 females

-Annual spawners replacement rate must be at least 33%

-Spawners cannot de used more than three years

Overview of program objectives and recovery actions

Demographic gain VS loss of genetic diversity

Number of stocked juveniles and number of spawners must be predefined in order to:

-Allow a demographic increase of over 15%

-Without a decrease in effective population size (Ne) of over 10%

Québec

Overview of program objectives and recovery actions

Demographic gain without loss of genetic integrity

-**Demographic effect:** Basic model based on survival rates

-**Genetic effect:** Model of Ryman and Laikre (1991)

$$\frac{1}{N_e} = \frac{x^2}{N_c} + \frac{(1-x)^2}{N_w}$$

Ne = effective pop. size following stocking;
Nc = number of captive breeders;
Nw = effective pop. size in the wild;
x = number of offspring produced in captivity

Québec

Overview of program objectives and recovery actions

Stocking plan

Four rivers qualify to all selection criteria:

Rivière Jacques-Cartier:	30 spawners for 60 000 parrs
Rivière Rimouski:	30 spawners for 60 000 parrs
Rivière des Escoumins:	30 spawners for 65 000 parrs
Rivière Malbaie:	54 spawners for 105 000 parrs

Monitoring on all those four rivers

Québec

Conclusion

Wild Atlantic Salmon Recovery Programs

- **Integrating demographic, ecological, genetic and evolutionary considerations**
- **Monitoring**

Québec

Québec

Le modèle de Ryman et Laikre

Ryman et Laikre (1991) ont formalisé mathématiquement cette problématique en portant une attention particulière à l'effet des repeuplements de soutien sur la taille effective de la population (équation 9). Ces auteurs ont ainsi démontré que la taille effective (N_e) résultant d'un ensemencement de soutien est fonction de la taille effective des reproducteurs sauvages en nature (N_w) et ceux utilisés pour réaliser les croisements (N_c), de même que du carré de la proportion de la progéniture totale à la prochaine génération produite par les reproducteurs captifs (x) et ceux laissés en nature ($1-x$).

$$\frac{1}{N_e} = \frac{x^2}{N_c} + \frac{(1-x)^2}{N_w} \qquad (9)$$

Cette équation prédit notamment que, passé un certain optimum, une augmentation de la contribution x des reproducteurs captifs se traduira par une réduction de N_e, comparativement à ce qu'il aurait été sans repeuplement (figure 3). Aussi, pour une même proportion x de rejetons produits en captivité (par exemple, 0,5 sur l'un ou l'autre des graphiques de la figure 3), la taille effective sera d'autant plus réduite que le nombre de reproducteurs captifs sera faible (par exemple, les courbes 4 et 20).

Québec

Non-Government Organizations

Mark Hambrook, Miramichi Salmon Association

Non Government Organizations

by Mark Hambrook

President, Miramichi Salmon Association

Non-Government Organizations

- These are groups that have taken over former DFO hatchery facilities and the responsibility for stocking salmon in the late 1990's.
- Divested hatcheries to the non-profit sector include:
  - Mersey, Margaree, Cardigan, Charlo and Miramichi

Current Status of The Facilities

- Mersey – divested for a few years and taken back by DFO for the gene-banking program. The facility now has an uncertain future.
- Margaree – divested and operated by the Margaree Salmon Association for about 10 years and now operated by the Province of NS.

Current Status of the Facilities

- Cardigan – divested and operated by the AVC for a few years then sold to a private aquaculture firm. Stocking service for a fee is still available from the operator, but no salmon stocking is taking place.

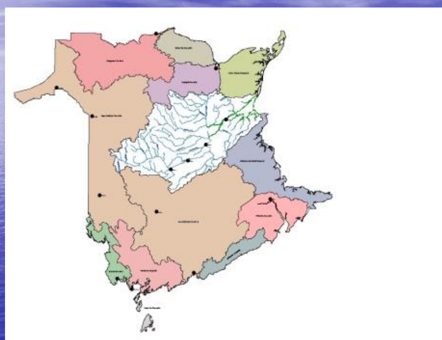
Current Status of the Facilities

- Charlo – divested and operated by a local non-profit group until recently where a private aquaculture firm is leasing the facility and providing the salmon stocking service for a reasonable fee. Projects are ongoing at this facility for the Nepisiguit R, Eel R, Little R and Restigouche R.

Current Status of the Facilities

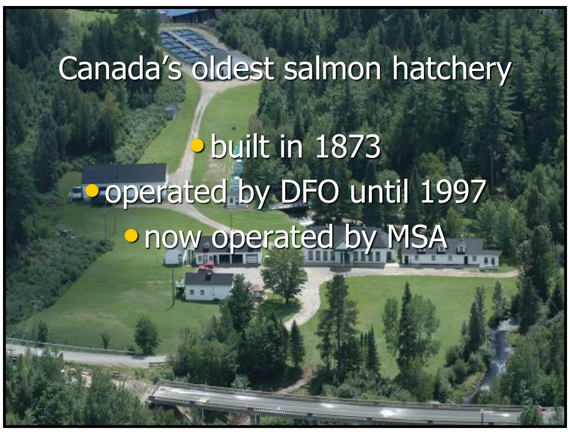
- Miramichi – divested and operated by a subsidiary of the Miramichi Salmon Association called Miramichi Fisheries Management and provides salmon stocking services for a fee to clients, including the MSA.

New Brunswick Watersheds



Former DFO Charlo Hatchery

Canada's oldest salmon hatchery



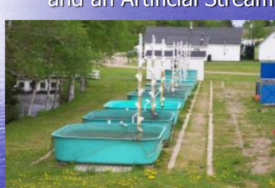
- built in 1873
- operated by DFO until 1997
- now operated by MSA

Improvements

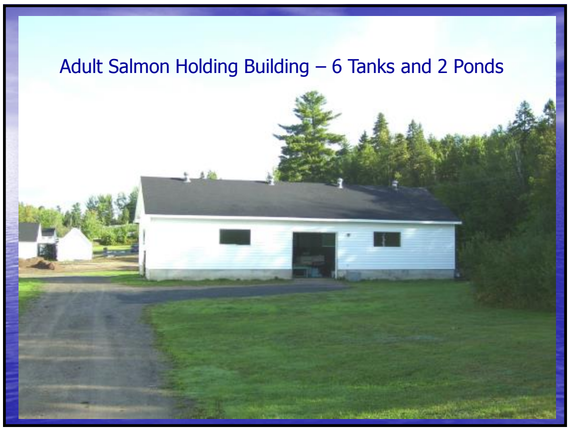
New Tarp Building Over the 16 Ponds

Improvements

New Tarp Building Over Tanks Providing a Year Round Facility With More Tanks, Storage Space and an Artificial Stream Channel for Research



Tanks and Artificial Stream Channel


Adult Salmon Holding Building – 6 Tanks and 2 Ponds


Egg Incubation Building


Multi-Use Building – 9 Tanks and Office


Brian Bowes 2006


Miramichi Salmon Association Inc.
60 years of conservation

The MSA Miramichi Program

- Southwest Miramichi usually meets spawning targets, but Northwest Miramichi has failed to meet targets for past decade.
- Very few permanent blockages to salmon migration.
- Major issue is estuary and marine survival of smolts.

The MSA Miramichi Program

- Objective is to maximize smolt production by stocking headwater areas and small streams where densities may be low.
- Only a minor amount is stocked in the lower main stems.

The MSA Miramichi Program

- Stocking has evolved from stocking older life stages to stocking 3 week feeding fry – less cost and good survival.
- Sites are determined by electrofishing surveys and post-stocking electrofishing is done to determine success.
- Target areas are areas that have densities below 50fry/100m^2, usually blocked by beaver dams

What are the Numbers?

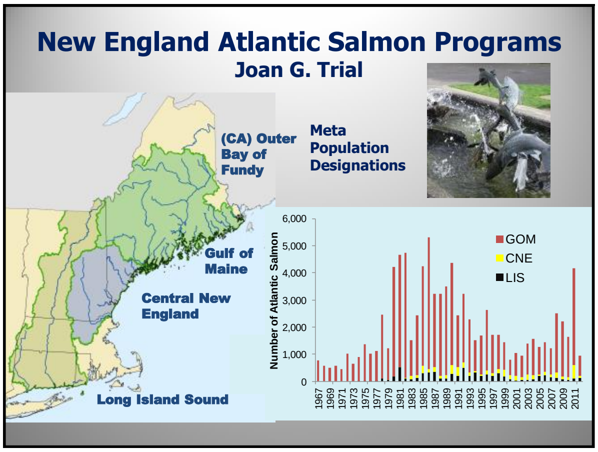
- Salmon sales $45,000 to $75,000 yearly.
- Approximately 300,000 to 500,000 salmon fry are stocked to the Miramichi and other areas within the traditional service area.
- Clients are charged $0.15 per fry.
- The MSA purchases up to $60,000 each year with some assistance from the NB Wildlife Trust Fund.

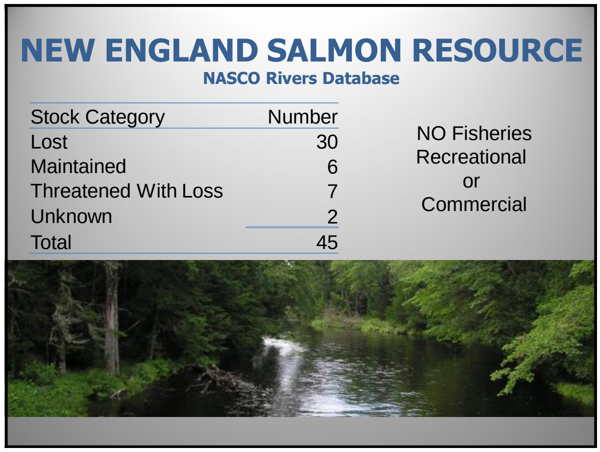
Economics

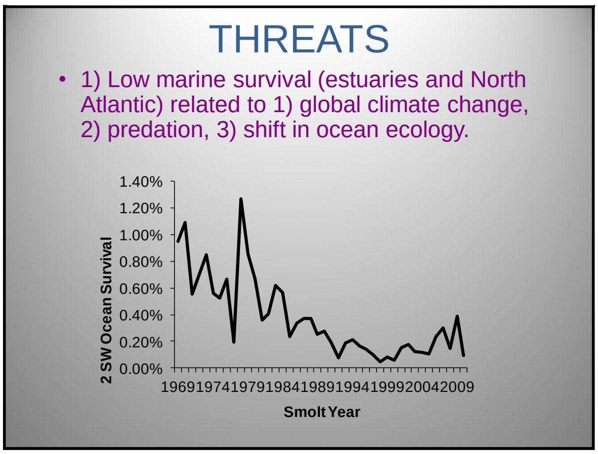
- Salmon sales don’t pay the bills but it’s the reason we have a hatchery!
- MFM rents office space, grows brook trout for DNR and for general sale, rents tank space and performs the Miramichi Crown Reserve maintenance contract to balance the books.
- Major renovations are planned over the next year.

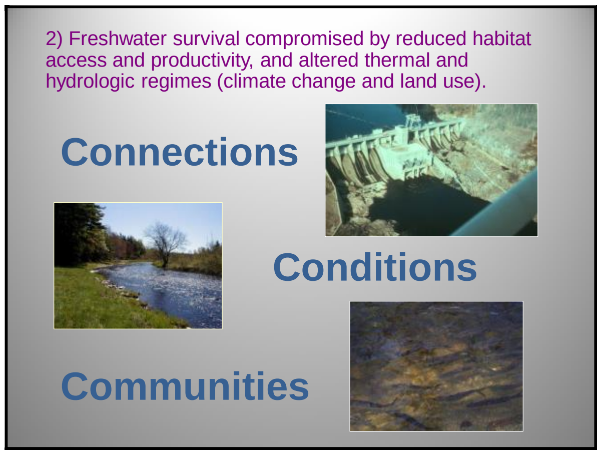
New England

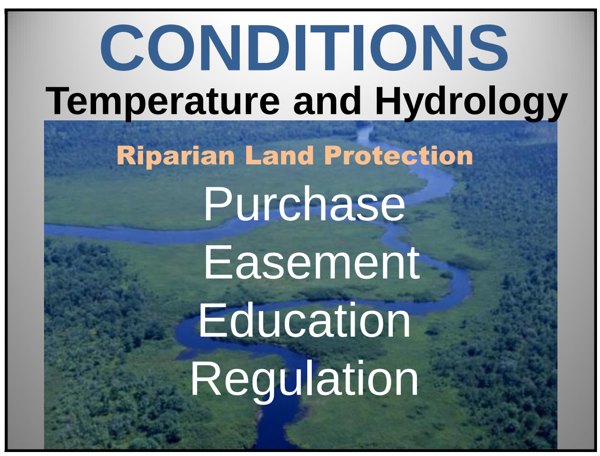
Joan Trial, Maine Department of Marine Resources/Retired



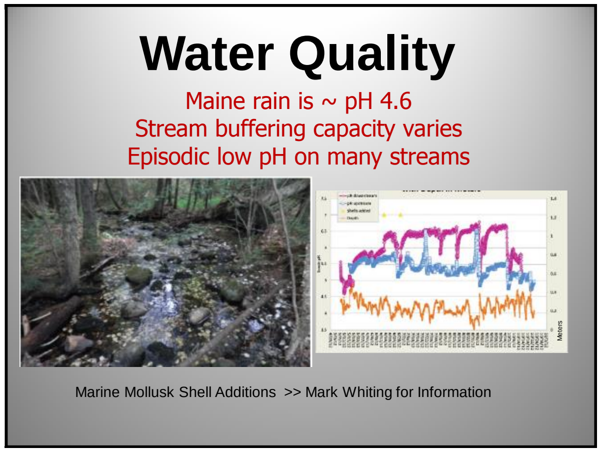






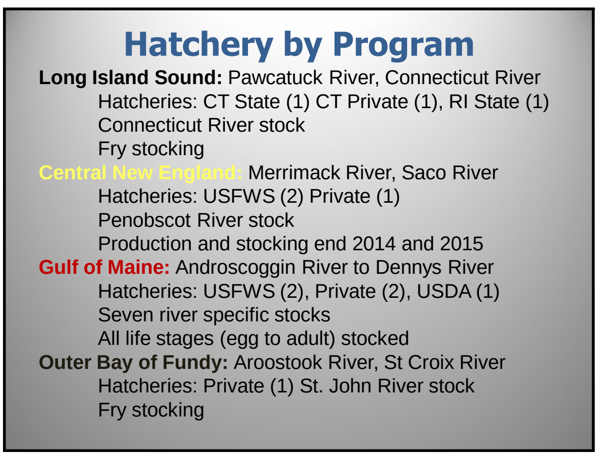



Temperature, Hydrology, Complexity
Remediate Channel Alterations


Water Quality
Maine rain is ~ pH 4.6
Stream buffering capacity varies
Episodic low pH on many streams
Marine Mollusk Shell Additions >> Mark Whiting for Information


COMMUNITIES
Restore Diadromous Fish
Alewife, Herring
Shad
Eel
Smelt
Limit Non-native Fish
Remove Spawners
Educate to limit illegal Stocking
Eliminate Stocking


HATCHERIES
LIFE SUPPORT
PREVENT EXTINCTION
Maintaining genetic legacy
Freshwater recruitment


Hatchery by Program
Long Island Sound: Pawcatuck River, Connecticut River
Hatcheries: CT State (1) CT Private (1), RI State (1)
Connecticut River stock
Fry stocking
Central New England: Merrimack River, Saco River
Hatcheries: USFWS (2) Private (1)
Penobscot River stock
Production and stocking end 2014 and 2015
Gulf of Maine: Androscoggin River to Dennys River
Hatcheries: USFWS (2), Private (2), USDA (1)
Seven river specific stocks
All life stages (egg to adult) stocked
Outer Bay of Fundy: Aroostook River, St Croix River
Hatcheries: Private (1) St. John River stock
Fry stocking


Hatchery Reared Broodstock
Wild Juveniles (Captive)
• Young-of-year, parr and smolts collected from six Maine watersheds.
Hatchery Juveniles (Domestic)
• Juveniles selected from production to broodstock (Domestic / Captive)

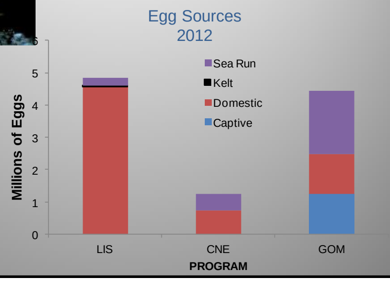
Sea-run Broodstock

Sea-run returns

collected at 1st Dam

Kelt

Families created are (can be) genetically characterized

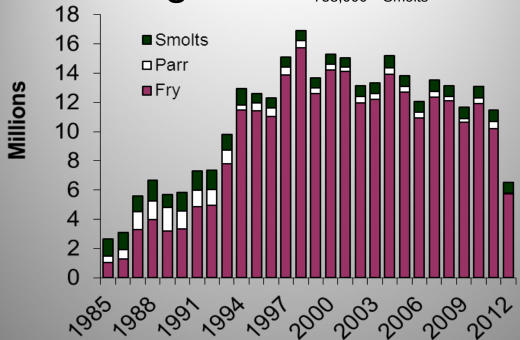


Eyed Egg Planting

1,344,000 eggs were planted in 2012

Stocking

5,758,000 Fry
22,000 Parr
758,000 Smolts
2012



Stocking

5,097 Adults in 2012

<u>Pre-spawn captive reared</u>

257 in Dennys River
Primary strategy change Fry to Adult stocking

640 in CNE
Captive reared and sea run

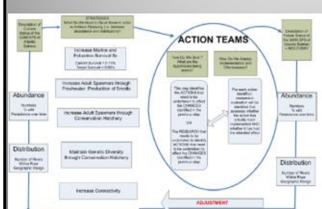
Remainder
Post-spawn broodstock

Integrating Habitat & Hatchery

- Stock newly accessible streams (culvert replacements, log dam removals, fishways)
- Stock reaches with large wood additions
- Stock reaches with clam shell additions
- Adjust smolt stocking location following dam removals
- Don't stock reaches with natural reproduction

Program Goals

PREVENT EXTINCTION
MAINTAIN GENETIC LEGACY
MAINTAIN SALMON IN FW COMMUNITY
IMPROVE PRODUCTIVITY OF FW HABITAT
RESTORE SELF SUSTAINING POPULATIONS



Objectives

Program specific:
Juvenile abundance & distribution
Smolt production
Adult abundance & distribution

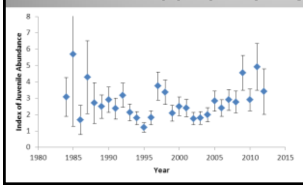
Monitoring

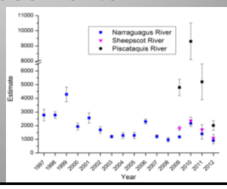
Adult Assessments

Returns to Traps

Spawning Surveys

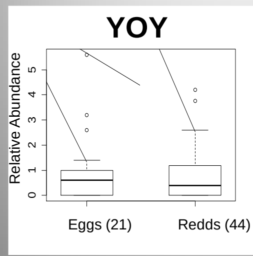
Juvenile Assessments

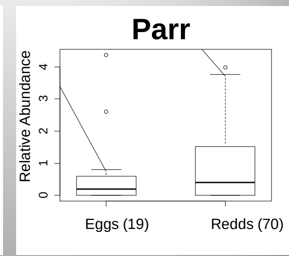




Results of Management

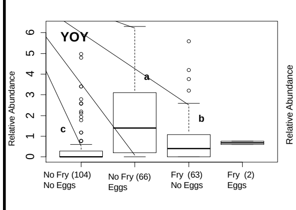
Egg planting vs spawning (returns or captive)

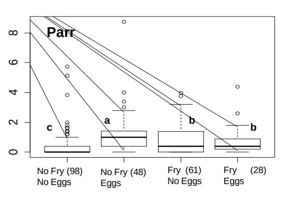




Results of Management

Fry vs egg planting & spawning (returns or captive)





Program Goals

- √ PREVENT EXTINCTION
- √? MAINTAIN GENETIC LEGACY
- √ MAINTAIN SALMON IN FW COMMUNITY
- ? IMPROVE PRODUCTIVITY OF FW HABITAT
- ∅ RESTORE SELF SUSTAINING POPULATIONS

Program Specific Objectives:

- ?? Juvenile abundance & distribution
- ∅ Adult abundance & distribution
- ?? Genetic diversity
- ∅ Accessible Habitat

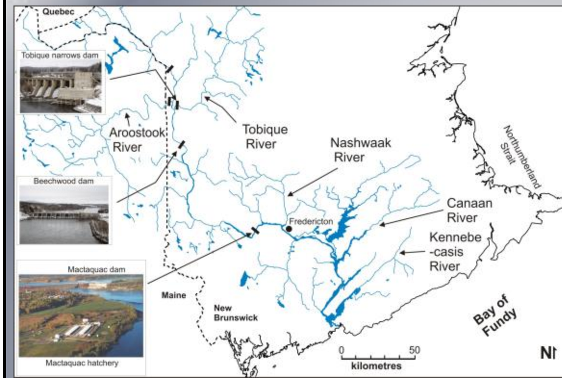
Insight from DNA-based parentage assignment analyses on some early indicators of the efficacy of an adult-release stocking program on the Tobique River, New Brunswick

Sherisse McWilliam-Hughes, Fisheries and Oceans Canada

Preliminary results of parentage analyses of 2010 Tobique River pre-smolt

Patrick O'Reilly, Ross Jones, Trevor Goff, Stephanie Ratelle, and Lorraine Hamilton

Presented by:
Sherisse McWilliam-Hughes



The Tobique River *conservation program*

Conservation Program Objectives

1) Immediate increase in the # of wild-born smolts produced in the Tobique R system

2) Increases in the # wild-born returning adults of Tobique origin

3) Increases in the # of wild-born successfully reproducing salmon in the Tobique R system

4) Increased likelihood of population persistence due to
   - a) sustained increase in production
   - b) minimized homogenization above Mactaquac and loss of local adaptation
   - c) possibly minimized domestication selection by i) reducing time spent in captivity overall??, ii) minimizing time spent in captivity early in the salmonid life cycle, and iii) potential gain from benefits of sexual selection via mate choice plus inter-male competition at spawning time

Information from the literature and relevant concerns

- Spawning success of captive-reared adult releases may be low*
- Spawning success of male adult releases in particular may be low*
- Survival of offspring of captive-reared parents may be depressed (genetic, maternal, epigenetic, redd site selection, etc.)*
- Introgression of domesticated genes into the wild component of the population and depression of fitness*
- Ecological effects

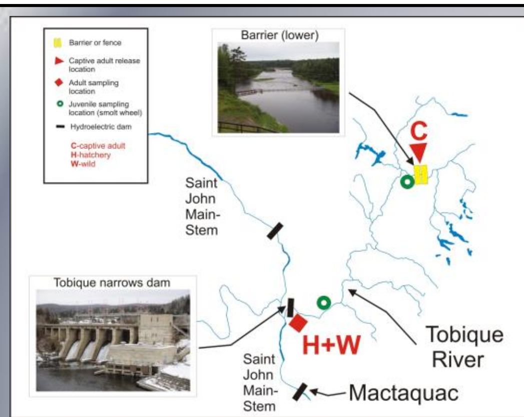
The Tobique River *conservation program*

vs.

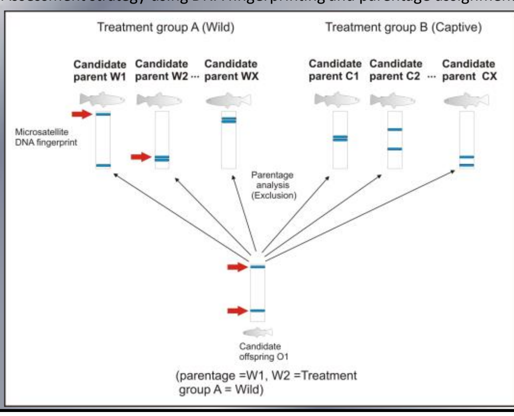
the Tobique River *conservation research program*

Research program objectives (questions)

- Are released adults spawning successfully… and are they spawning successfully in relation to wild returning salmon?
- What is the effect of the captive adult release program on the effective number of breeders and expected maintenance of genetic variation in the combined captive-wild population over time?
- To what extent are captive released adults contributing to the production of smolts?
- To what extent are captive released adults contributing to the production of returning adults?
- To what extent are returning adults produced by a) wild parents versus b) captive parents, spawning successfully?
- To what extent is the adult release program impacting the fitness of the combined wild/captive population?
- Are adult releases replacing or adding to **river production**?

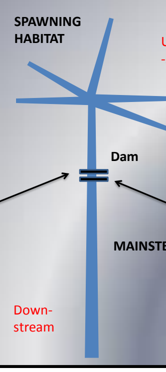


Assessment strategy using DNA fingerprinting and parentage assignment.



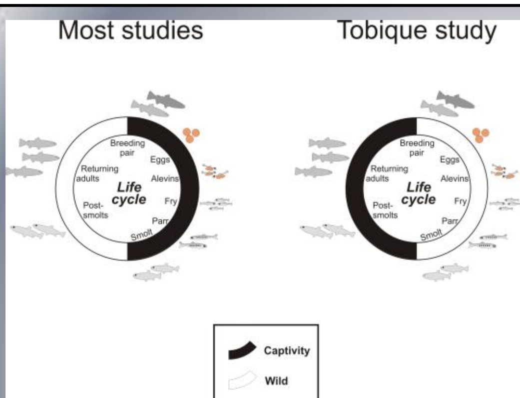
Schematic of experimental design common to studies of fitness/life time reproductive success in salmonids

Examples:
Araki et al. 2007, 2009
Theriault et al. 2011
Hess et al. 2012
Christie et al. 2012



All male and female adult parents intercepted at dam, tissue sampled, then released to spawn upstream

Offspring sampled as returning adults 1 generation later at dam (also serve as parents in study of the next generation)



Parent and offspring groups (2008 brood year)

Candidate parent groups

1) Wild returning males 228
2) Wild returning females 120

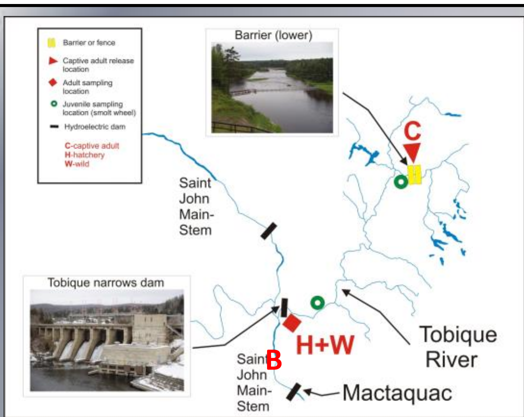
3) Hatchery returning males 79
4) Hatchery returning females 11

5) Tobique Captive males 171
6) Tobique Captive females 374

7) Beechwood captive males 28
8) Beechwood captive females 44

Candidate offspring groups

Captured, genotyped and analyzed
Captured, not genotyped and not analyzed
Not captured, not genotyped and not analyzed



Parent and offspring groups (2008 brood year)

Candidate parent groups

1) Wild returning males	228
2) Wild returning females	120
3) Hatchery returning males	79
4) Hatchery returning females	11
5) Tobique Captive males	171
6) Tobique Captive females	374
7) Beechwood captive males	28
8) Beechwood captive females	44
Males	506
Females	549
	1055

Candidate offspring groups

1) 2010 fall pre-smolts (1+)
2) *2011 spring smolts (2+)*
3) *2011 fall pre-smolts (2+)*
4) *2012 spring smolts (3+)*
5) *2012 grilse (3,1)*
6) *2013 grilse (4,1)*
7) *2013 MSW (3,2)*
8) *2014 MSW (4,2)*

Captured, genotyped and analyzed
Captured, not genotyped and not analyzed
Not captured, not genotyped and not analyzed

2010 fall pre-smolts (1+)

- 157 samples successfully genotyped
- 138 high & medium confidence assignments
  - 61 assigning to 2 parents
  - 77 assigning to 1 parent
- Only 17 Orphaned (did not assign)

Sources of missing female parents

1) *Genotyping errors resulting in failed assignments?*
2) *Assignment errors due to program/human errors? Note, ran two different programs written by two different people, and results > 98% concordant*
3) *Missing sea-run and Beechwood (and Beechwood like) females, jumpers)?*
4) *Non-tissue sampled captive females?*
5) *Failed parent samples (could not be genotyped)?*
6) *Resident mature females?*
7) *Females from 2007 holding in system?*
8) ***Incorrectly aged 2010 pre-smolt** (produced in 2007)*
9) *Others?*

Robustness of parent assignments

-Simulation analyses and analysis of patterns of Mendelian Inheritance indicate that assignments at 12 of 12 loci highly unlikely to occur due to chance alone under present conditions, and likely represent true parent-offspring relatedness

-These same analyses also indicate that the vast majority (>90%) of quite uncommon N-1 matches also probably represent true parent-offspring relatedness

-Assignments at N-2 loci may or may not be real, are very very rare, and await further analyses to confirm/refute

-overall, this is a remarkable dataset in that the vast majority of offspring submitted (~90%) can be assigned to a female with high confidence
Note, assignment success probably even higher, as I suspect 5 parents identified as males were actually females

Analysis assumptions:

- For now, have ignored missing male and female parents in all downstream calculations, assuming not biased towards any group
- For now, have ignored 22 offspring that do not assign to any known or "assumed" females (Note: some or all parents that offspring assigned to singly, and were identified as female, may indeed be male, indicating that as few as 17 offspring may be orphaned in this analysis)
- pre-smolt produced by different parental groups were equally likely to be sampled in 2010, and are representative of the other offspring groups soon to be analyzed (2011 pre-smolt, 2011 smolt, etc.)

Preliminary analysis of smolt production by female parent type

% contribution — % spanning success

	Offspring as presmolt	Total	Percent of total	Number female parents	Presmolt/ female parent	Number estimated eggs from group (RJ)	Offspring as presmolt	Estimated number smolt (total)	Eggs/ smolt	Smolt/egg (fert succ and surv)
Wild maternal parent	46	135	34.07	120	0.38					
Hatchery maternal parent	1	135		11	0.090909					
Searun maternal parent	47	135	34.81	131	0.358779	463590	47	2064	9863.617	0.004452
Captive Tobique adult release maternal parent	87	135	64.44	376	0.231383	1878141	87	3824	982.2462	0.002036
Captive Beechwood adult release materal	1	135	0.74	44	0.022727					

Estimated number smolt (total) (5% SW eff & 65% 2+ & 70% presmolt)
Smolt/egg (total) (5% SW eff & 65% 2+ & 70% presmolt)

Preliminary summary of detection of successful female spawners of different parent types via parentage analysis

	Wild sea-run females	Tobique captive females	Hatchery sea-run females	Beechwood females	Total females
Number released	120	376	11	44	551
Number detected	30	63	1	1	95
Percent detected	25%	17%	9%	2%	17%
Number full sib fams	30	63	1	1	95
Mean fam size	1.533	1.365	na	na	1.391
Variance family size	0.9471	0.5581			0.6574
Std var fam size (var/mean)	0.6178	0.4089			0.4726
Fam size range	1 to 5	1 to 5			1 to 5

Observed and expected numbers of crosses of different types

		Observed	Expected	Diff
Captive	Captive adult female x Captive adult male	15	12.244	2.756
	Captive adult female x wild adult male	22	22.556	-0.556
	Captive adult female x mature male parr	47	47.044	-0.044
	Captive adult female x hatchery male	3	4.811	-1.811
	Captive adult female x Beechwood adult male	0	0.644	-0.644
Wild	Wild adult female x captive adult male	3	6.474	-3.474
	Wild adult female x wild adult male	13	11.926	1.074
	Wild adult female x mature male parr	25	24.874	0.126
	Wild adult female x Hatchery male	4	2.385	1.615
	Wild adult female x Beechwood adult male	1	0.341	0.659
Hatchery	Hatchery adult female x wild adult male	0	0.141	-0.141
	Hatchery adult female x captive adult male	0	0.259	-0.259
	Hatchery adult female x mature male parr	1	0.541	0.459
	Hatchery adult female x Hatchery adult male	0	0.052	-0.052
	Hatchery adult female x Beechwood adult male	0	0.007	-0.007
Beechwood	Beechwood adult female x wild adult male	0	0.141	-0.141
	Beechwood adult female x captive adult male	1	0.259	0.741
	Beechwood adult female x mature male parr	0	0.541	-0.541
	Beechwood adult female x hatchery adult male	0	0.052	-0.052
	Beechwood adult female x Beechwood adult male	0	0.007	-0.007
		135		
	X2=9.821	d of f=19	P=>0.95	

Note: numbers exclude 3 "male" parents identified in single parent parentage analysis as sole parent

Genetic Conclusions

- High proportion of assignment to TWO parents at 12 of 12 loci AND one parent at 12 of 12 loci
- Very few N-1 assignments, and most appear to be real parent-offspring pairs
- High assignment success due to one or more of the following: a) increased variability of Tobique over other sample collections, b) increased signal to noise ratio of new set of 12 loci, c) increased sampling of parental groups, d) increased spawning success of sampled parental group, e) reduced genotyping error (single platform, etc.).

Conclusions

- Captive female adult releases produced an estimated 3824 2010 pre-smolt, almost 2X that produced by wild returning Tobique R salmon
- On a "per female parent" basis, wild returning salmon produced nearly 2X the number of 2010 pre-smolt than did captive adult releases
- On a "per egg basis", sea-run salmon produced slightly more than 2X the number of 2010 pre-smolt than did captive adult releases
- Candidate parents did not appear to exhibit any spawning preference for any parent type

Conclusions

- A larger portion of wild sea-run females were detected than captive adult females, but the difference observed was not very large
- A much larger portion of captive adult releases were detected than sea-run hatchery returns, with implications on the effects of CBR during these different life history stages, on spawning success and/or early offspring survival, but sample sizes were very small
- Very few Beechwood captive adults were detected, and seemed to have exhibited very poor spawning success

Conclusions

- Analyses of a small portion of submitted juveniles, which represent a small portion of produced smolt, which represent a small portion of produced juveniles, detected successful spawning by a large number of released, captive adults: ***Many captive adult releases, particularly the females, are spawning successfully***
- A larger number of released adult females likely spawned successfully, and more precise estimates will be obtained by a) analyzing several hundred additional smolt and pre-smolt, and b) plotting number of parents detected against number of offspring sampled

Where next?

- Confirm number of parents submitted and analyzed and resolve missing females
- Genotype 2 missing Serpentine females and 37 missing Serpentine males
- Investigate further N-1 mis-matches, possibly re-genotyping some offspring-parent pairs
- Analyze remaining juvenile offspring groups
- Finalize report on smolt production by captive Tobique River adult releases

Where next?

- Analyze 2008-origin 2012 Tobique adult return offspring
- Analyze 2008-origin 2013 and 2014 adult return offspring
- Estimate smolt to adult survival by parent type
- Estimate life time reproductive success of the different parent types involved in this study
- Consider additional brood years (2011, 2012)

Where next?

- Estimate Nb for different parent types in 2008, and for the Tobique R population with and without captive adult releases
- Estimate rate of loss of genetic variation given estimates of Nb
- Report levels of neutral molecular genetic variation in different offspring groups
- Consider modifying "experimental design" to potentially control for possible effects of past domestication on spawning success of wild Tobique salmon (could minimize difference between captive and wild spawners, impacting several results)

Acknowledgements

Sample collection:

Claude Fitzhebert, Leroy Anderson, Bob O'Donnell, & Mactaquac BF staff

Laboratory analyses:

Sara Rafferty, Darlene Mossman

Details of sample accounting, including samples submitted, samples analyzed and remaining discrepancies

SEX	TYPE	LOCATION (ORIGIN OR INITIAL CAPTURE)	LOCATION (FINAL CAPTURE, AS ADULT)	MACTAQUAC + NARROWS NAME	ANALYZED OR TISSUE SAMPLED F TOTAL	ANALYZED OR TISSUE SAMPLED M TOTAL	REPORTED F TOTAL	REPORTED M TOTAL	DIFFERENCE F TOTAL	DIFFERENCE M TOTAL	COMMENTS
FEMALE	WILD	TOBIQUE	NARROWS		120		125				Note: RJ reports 125 w f
MALE	WILD	TOBIQUE	NARROWS			228					-5 wild females
FEMALE	HATCH	TOBIQUE	NARROWS		11						Note: RJ reports 11 hatch f
MALE	HATCH	TOBIQUE	NARROWS			79					
FEMALE	**SEA-RUN**	**TOBIQUE**	**NARROWS**	**SEA-RUN**	131		135		-4		Note: TG reports 135 Searun
MALE	**SEA-RUN**	**TOBIQUE**	**NARROWS**	**SEA-RUN**		307		307		-5	-4 wild females
FEMALE	CAPTIVE	BEECHWOOD	NARROWS		44		42		"+2"		
MALE	CAPTIVE	BEECHWOOD	NARROWS			28		30		"-2"	
FEMALE	CAPTIVE	TOBIQUE	TOBIQUE		374						1) TG+CR=400 F ORIG 2) TG+CR= 233 M ORIG 3) TG+CR=TOB+SER
MALE	CAPTIVE	TOBIQUE	TOBIQUE			171					4) PO=SER SUB NOT ANALYZED 5) TG changed 233 to 203 6) 203+30 Beechwood=233
FEMALE	CAPTIVE	SERP	SERP		2		2				
MALE	CAPTIVE	SERP	SERP			39		37			
FEMALE	**CAPTIVE**	**TOB+SERP**	**TOB+SERP**	**CAPTIVE**	376		400		"-24"		-24 captive females
MALE	**CAPTIVE**	**TOB+SERP**	**TOB+SERP**	**CAPTIVE**		210		203		"+7"	
FEMALE	CAPTIVE	TOB+SERP+BEECH	TOB+SERP+BEECH		420		442				7) males close, +5 and 6 duplicates, 3 captive male
MALE	CAPTIVE	TOB+SERP+BEECH	TOB+SERP+BEECH			238		233			8) big and important discrepancy - females, -26
TOTAL BY GENDER					551	545	577	540	-26 females	+5 males	9) suggest 5 missing wild female
GRAND TOTAL						1096		1117			10) suggest 21 missing CAP TOB females

Sources: Goff, May 5, 2011, Jones May 26, 2011

DUPLICATED SAMPLES
1 CAP F PAIR
1 HATCH F PAIR
3 CAP M PAIR
3 C W M PAIR

NOTE: SERP CAPTIVE TABULATED/REPORTED WITH TOB, NOT SENT WITH TOB
NOTE: BEECHWOOD NOT INCLUDED WITH TREVORS CAPTIVE BUT ACCOUNTED FOR BY TOB NARROWS STAFF AS BEECHWOOD

Offspring numbers (2008 brood year)

- 2010 presmolt submitted: 200
- 2010 presmolt successfully analyzed: 157

- 2011 smolt submitted: 61
- 2011 presmolt submitted: 159
- 2012 smolt submitted: 25
- 2012 grilse adults submitted: ~22
- 2013 MSW adults submitted: N/A
- 2013 grilse adults submitted: N/A
- 2014 MSW adults submitted: N/A

Samples numbers actually analyzed and used in tabulation of all results

Total number of Candidate parents used in Tobique R analyses

SEX	TYPE	LOCATION (ORIGIN OR OR INITIAL CAPTURE)	LOCATION (FINAL CAPTURE, AS ADULT)	MACTAQUAC + NARROWS NAME	F TOTAL	M TOTAL
FEMALE	WILD	TOBIQUE	NARROWS		120	
MALE	WILD	TOBIQUE	NARROWS			228
FEMALE	HATCH	TOBIQUE	NARROWS		11	
MALE	HATCH	TOBIQUE	NARROWS			79
FEMALE	**SEA-RUN**	**TOBIQUE**	**NARROWS**	**SEA-RUN**	131	
MALE	**SEA-RUN**	**TOBIQUE**	**NARROWS**	**SEA-RUN**		307
FEMALE	CAPTIVE	BEECHWOOD	NARROWS		44	
MALE	CAPTIVE	BEECHWOOD	NARROWS			28
FEMALE	CAPTIVE	TOBIQUE	TOBIQUE		374	
MALE	CAPTIVE	TOBIQUE	TOBIQUE			171
FEMALE	CAPTIVE	SERP	SERP		2	
MALE	CAPTIVE	SERP	SERP			39
FEMALE	**CAPTIVE**	**TOB+SERP**	**TOB+SERP**	**CAPTIVE**	376	
MALE	**CAPTIVE**	**TOB+SERP**	**TOB+SERP**	**CAPTIVE**		210
FEMALE	CAPTIVE	TOB+SERP+BEECH	TOB+SERP+BEECH		420	
MALE	CAPTIVE	TOB+SERP+BEECH	TOB+SERP+BEECH			238
TOTAL BY SEX					551	545
GRAND TOTAL						1096

Note: Approximately 25 additional females (~5 wild, 20 captive) were reported to have been tissue sampled but their tissue samples appear to be missing
Note: This observation is consistent with 17 candidate offspring not assigning to ANY tissue sampled adult

Sample accounting (parents)

Problem #1 : Final number of samples submitted still does not equal the number reported to have been submitted

Problem #2: 17 of 157 pre-smolts do not come close to matching ANY known parent, and 22 of 157 pre-smolts do not come close to matching ANY known female

Note: average family size = 1.5, suggesting approximately 10-15 female parents contributing to the pre-smolts analyzed are missing

Note: if this group of offspring represents approximately 1 in 5 true parents, then ~50-75 true female parents may me missing overall (not sampled, genotyped)

Note: this is very early in the analyses, we still might identify additional parents, but we might not

Other "experimental design" problems

- Low number of some juvenile groups
- Low number of 2008 BY returning adults
- Duplicate genotypes (8 sets)
- Non-released adults?
- Different treatment of candidate parents
- Different probability of capture?
- Others

Simulation analysis results, testing 157 simulated offspring against 1051 actual Tobique candidate parents via single parent parentage analysis

Number of *chance* single parent-offspring matches	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Simulation run 1	0	0	11	97	757	3,280	10,543	23,504	37,694	42,226	30,991	13,394	2,510	165,007
Simulation run 2	0	0	17	111	787	3,401	10,722	23,821	37,736	41,904	30,886	13,100	2,522	165,007
Simulation run 3	0	0	14	104	843	3,445	10,857	23,898	37,265	41,823	30,769	13,334	2,655	165,007
Simulation run 4	0	0	7	109	744	3,370	10,579	23,879	38,270	41,855	30,621	13,114	2,459	165,007
Simulation run 5	0	0	12	121	794	3,472	10,353	23,813	37,909	41,792	30,619	13,473	2,649	165,007
Simulation run 6	0	0	10	123	789	3,481	11,086	24,185	38,692	41,746	29,868	12,651	2,376	165,007
Simulation run 7	0	0	17	137	784	3,639	11,035	24,055	38,083	41,536	30,432	12,922	2,367	165,007
Simulation run 8	0	0	12	125	853	3,692	11,174	24,599	38,324	41,519	29,780	12,541	2,388	165,007
Simulation run 9	0	3	12	135	817	3,491	10,830	24,026	37,914	42,276	30,054	12,915	2,534	165,007
Simulation run 10	0	1	15	123	799	3,441	10,773	24,076	38,264	41,605	30,200	13,218	2,492	165,007
Average	0	0.4	13	119	797	3,471	10,795	23,986	38,015	41,828	30,422	13,066	2,495	165,007
Variance	0	0.9333	9.7889	169.17	1156.2	14525	66925	82056	161142	67126	182418	95890	10566	0

Number of pairwise comparisons per run: 165,007 (157*1501) (offspring x parents)
Number of simulations: 10

Analysis assumptions:

- When 2 parents same sex, and sex of one is deduced, both parent sex and type (wild vs captive) correct
- When 2 parents same sex, and sex assumed, both parents of the same ***type*** (true in all cases but 1)
- When 2 parents same sex, and sex assumed, and types different, female assumed to be wild (1 case)
- Note: only 8 instances of same sex parents, and only 1 of any consequence (assumed, and diff)
- Assume all assignments (H, M and L) correct (very few M and L)

SUMMARY OF ASSIGNMENT RESULTS (GENERAL, Part I)	
PRESMOLT SUBMITTED	159
PRESMOLT SUCC GENOTYPED	157
-2 parents, 0 mismatch, MI	52
-2 parents, 1 or 2 mismatches, MI	9
Number assigning to 2 parents with high confidence (MI)	61
Note: 1 individual assigned to 1 male at 12 of 12 loci, and to 1 female at 10 of 12, and 3 loci out of MI, probably both prents but included as H conf assign to 1 male	
-1 parent, 0 mismatch (high confidence criteria)	68
-1 parent, 1 mismatch, 1 Repeat unit out, or P or O homozygous (medium confidence)	9
Number assigning to 1 parent with high or medium confidence	77
Note, most of the medium conf assignments prob true, re-genotyping required to confirm (20 dyads/triads, 1-2 loci)	
Total high confidence assignments	129
Total high + medium confidence assignments	138
Total additional possible single parent offspring assigments that may or may not be real (additional analyses required)	2
Total number of assignments used in the following tabulations	140
Number of ORPHANED 2010 presmolt	17

SUMMARY OF ASSIGNMENT RESULTS IN RELATION TO SEX (GENERAL, Part II)	
NUMBER ASSIGNING TO STATED FEMALE	132
(SINGLE FEMALE, MALE/FEMALE PAIR, FEMALE/FEMALE PAIR)	
NUMBER ASSIGNING TO SINGLE STATED MALE	5
NUMBER ASSIGNING TO STATED MALE PAIR	3
NUMBER ASSIGNING TO DEDUCED FEMALE (ONE OF MALE PAIR FOUND TO BE FEMALE)	1
NUMBER ASSIGNING TO ASSUMED FEMALE (ONE OF TWO MALES MUST BE FEMALE)	2
NUMBER ASSIGNIGN TO STATED, DEDUCED OR ASSUMED FEMALE	135
NUMBER ASSIGNING TO SINGLE STATED MALE	5
NUMBER ASSIGNING TO PARENTAL PAIR (2 MATCHING AND MI)	61
NUMBER OF SUSPECT ASSIGNMENTS TO 2 PARENTS	1
NUMBER OFFSPRING STATED PARENTS SAME	8
NUMBER OFFSPRING STATED PARENTS SAME SEX AND FEMALE	5
NUMBER OF 2 FEMALE PARENT SETS, WHERE 1 FEMALE DEDUCED TO BE MALE (RESOLVED)	3
NUMBER OF 2 FEMALE PARENT SETS, WHERE 1 FEMALE ASSUMED TO BE MALE	2
NUMBER OFFSPRING ASSIGNING SAME SEX AND FEMALE, NON RESOLVED AND DIFFERENT TYPES (WILD AND CAPTIVE)	1
NOTE: THIS IS AN ISSUE BECAUSE CANNOT ASSIGN SMOLT TO WILD OR CAPTIVE	
NOTE: OTHER FEMALE PAIR, WHERE MALE ASSUMED, BOTH CAP (CAP/CAP), NO EFFECT ON #'S	
NUMBER OFFSPRING ASSIGNING SAME SEX AND MALE, NON RESOLVED AND DIFFERENT TYPES (WILD AND CAPTIVE)	0
NOTE: THIS ALSO COUNTS, AS ONE OF TWO MALES ASSUMED TO BE FEMALE	
NOTE: FOR BOTH MALE PAIRS WHERE 1 MALE ASSUMED TO BE FEMALE, THE TWO PARENTS WERE OF THE SAME TYPE (1 WILD/WILD, 1 CAP/CAP)	

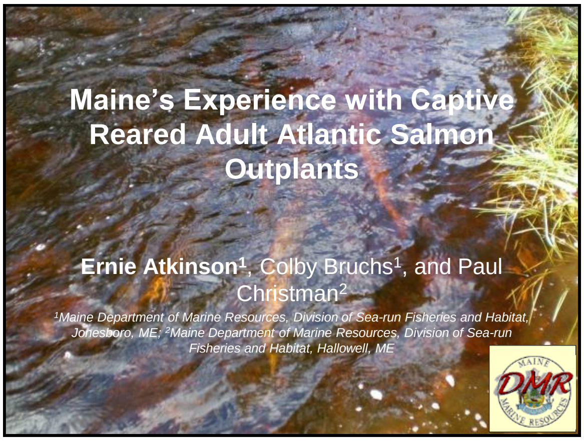
Details of frequency of occurrence of spawning by different parent types with other parent types

	Observed	Expected	O-E	dev 2	dev sqr / e	Number parent 1	Number parent 2	Freq of parent 1	Freq of parent 2	Expected freq of cross
Captive adult female x Captive adult male	15	12.244	2.756	7.593	0.620	87.000	19.000	0.644	0.141	0.091
Captive adult female x wild adult male	22	22.556	-0.556	0.309	0.014	87.000	35.000	0.644	0.259	0.167
Captive adult female x mature male parr	47	47.044	-0.044	0.002	0.000	87.000	73.000	0.644	0.541	0.348
Captive adult female x hatchery male	3	4.511	-1.511	2.283	0.506	87.000	7.000	0.644	0.052	0.033
Captive adult female x Beechwood adult male	0	0.644	-0.644	0.415	0.644	87.000	1.000	0.644	0.007	0.005
Wild adult female x captive adult male	3	6.474	-3.474	12.069	1.864	46.000	19.000	0.341	0.141	0.048
Wild adult female x wild adult male	13	11.926	1.074	1.154	0.097	46.000	35.000	0.341	0.259	0.088
Wild adult female x mature male parr	25	24.874	0.126	0.016	0.001	46.000	73.000	0.341	0.541	0.184
Wild adult female x Hatchery male	4	2.385	1.615	2.608	1.093	46.000	7.000	0.341	0.052	0.018
Wild adult female x Beechwood adult male	1	0.341	0.659	0.435	1.276	46.000	1.000	0.341	0.007	0.003
Hatchery adult female x wild adult male	0	0.141	-0.141	0.020	0.141	1.000	19.000	0.007	0.141	0.001
Hatchery adult female x captive adult male	0	0.259	-0.259	0.067	0.259	1.000	35.000	0.007	0.259	0.002
Hatchery adult female x mature male parr	1	0.541	0.459	0.211	0.390	1.000	73.000	0.007	0.541	0.004
Hatchery adult female x Hatchery adult male	0	0.052	-0.052	0.003	0.052	1.000	7.000	0.007	0.052	0.000
Hatchery adult female x Beechwood adult male	0	0.007	-0.007	0.000	0.007	1.000	1.000	0.007	0.007	0.000
Beechwood adult female x wild adult male	0	0.141	-0.141	0.020	0.141	1.000	19.000	0.007	0.141	0.001
Beechwood adult female x captive adult male	1	0.259	0.741	0.549	2.116	1.000	35.000	0.007	0.259	0.002
Beechwood adult female x mature male parr	0	0.541	-0.541	0.292	0.541	1.000	73.000	0.007	0.541	0.004
Beechwood adult female x hatchery adult male	0	0.052	-0.052	0.003	0.052	1.000	7.000	0.007	0.052	0.000
Beechwood adult female x Beechwood adult male	0	0.007	-0.007	0.000	0.007	1.000	1.000	0.007	0.007	0.000
	135			X2=	9.82132623	135	135	1	1	1

Note: numbers exclude 5 "male" parents identified in single parent parentage analysis as sole parent

Maine’s experience with captive adult Atlantic salmon outplants

Ernie Atkinson, Maine Department of Marine Resources



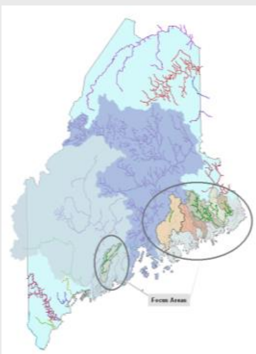
CHRONOLOGY

- Initial stocking (2005) Mopang Stream
- Followed in 2006 with Hobart Stream and Sheepscot
- Northern in 2009
- Dennys River 2011

STRATEGY

- Potentially improves lifetime fitness
- Sacrifices hatchery numerical advantage

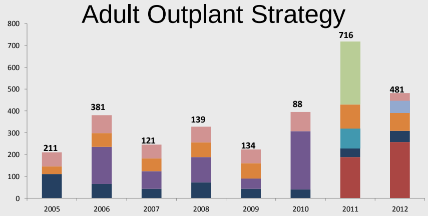
Downeast Maine

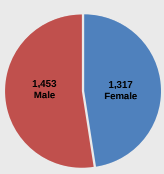


FOCUS Today…

- Reproductive Success
  - Outplanting activities
  - Spawning behavior and movement
- Juvenile production and survival estimates

Adult Outplant Strategy

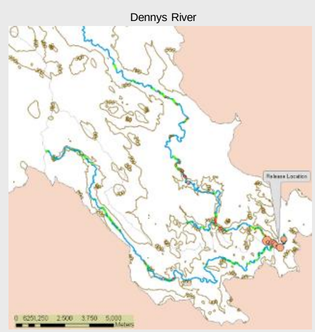




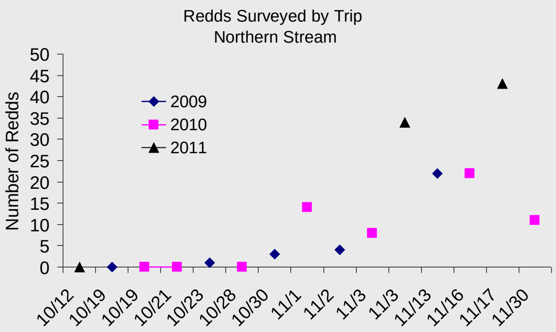
Redd Distributions

Northern Stream

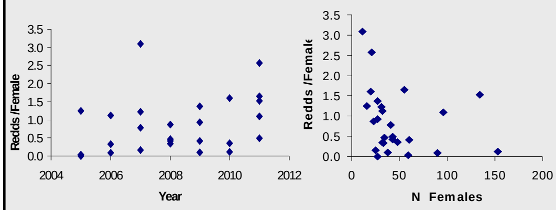
Dennys River



Timing of spawning activities

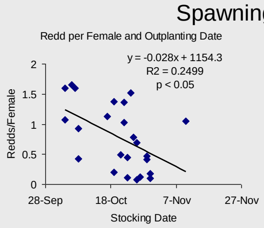


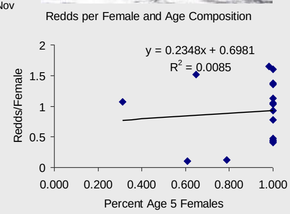
Spawning Success



- Between 0 and 3.1 redds/female
- Independent of number of females

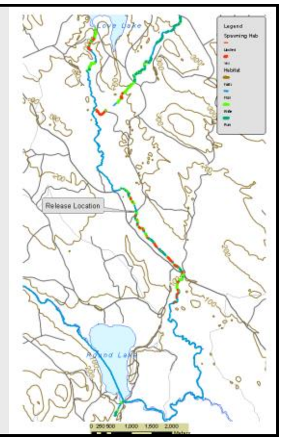
Spawning Success

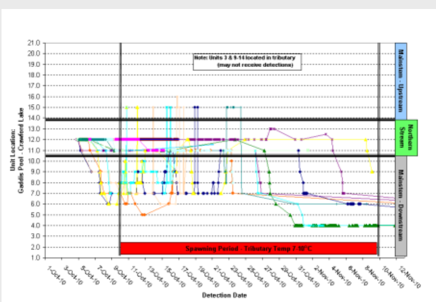




Acoustic Tracking Northern Stream

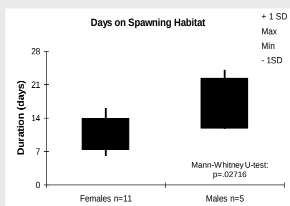
- All adults (40) Carlin tagged
- Adults released at a 1:1 ratio
- All females and ½ the males tagged with Vemco model V-16 acoustic tags
- 21 Vemco VR2 receivers deployed in Northern Stream and the greater East Machias Drainage





Year	Stream	Females Outplanted	Females Present	H♀f	Redds	Redds/H♀
2010	Northern Stream	20	16*	0.80	32	2.0
2010	East Machias River	0	1*	N/A	2	2.0

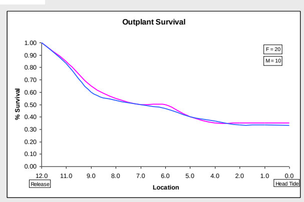
* Based on telemetry detection analysis



Males spent more time in spawning habitat

55% females and 50% males survived during spawning

Overall survival was 33% females and 30% males

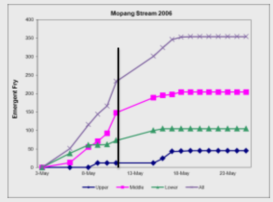


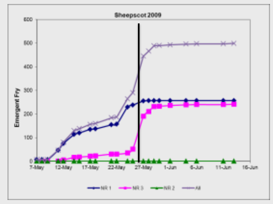
Fry Trapping

- Redds marked using white landscape rocks during fall surveys
- Nets placed late April

Emergence

- Mopang Stream 2006
  - Emergence from 3 May to 19 May
  - Median 11 May
  - 326 fry trapped
- Sheepscot River 2009
  - Emergence from 7 May to 13 June
  - Median May 27
  - 499 fry trapped



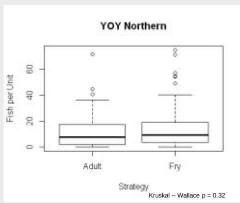


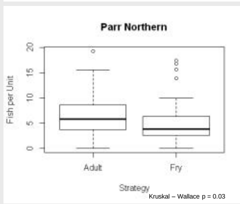
Juvenile Populations and Survival

Northern Stream

Origin	Fry Cohort	Stock Density	YOY Dens	YOY Survival	Parr Dens	Parr Survival	Parr Year
Fry	2006	166	7.77	0.05	6.24	0.80	2007
Fry	2007	99	29.91	0.30	4.04	0.14	2008
Fry	2008	193	7.47	0.04	3.20	0.43	2009
		Means	**15.05**	**0.13**	**4.49**	**0.46**	

Origin	Fry Cohort	Emergence Density	YOY Dens	YOY Survival	Parr Dens	Parr Survival	Parr Year
Adult	2010	46	15.03	0.33	7.71	0.51	2011
Adult	2011	62	9.21	0.15	5.03	0.55	2012
Adult	2012	114	12.09	0.11			2013
		Means	**12.11**	**0.19**	**6.37**	**0.53**	



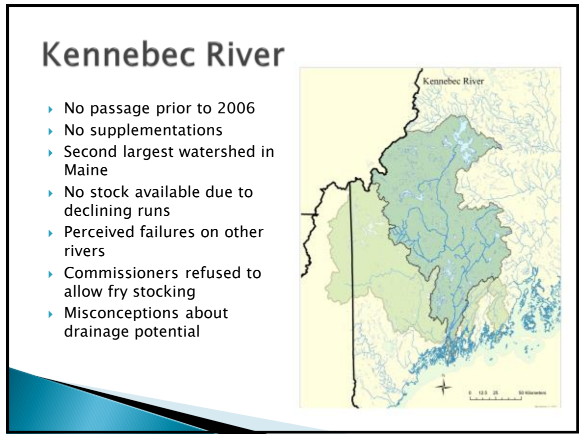


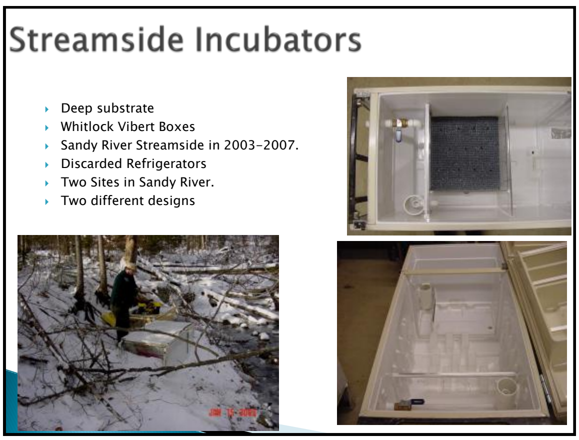
What have we learned?

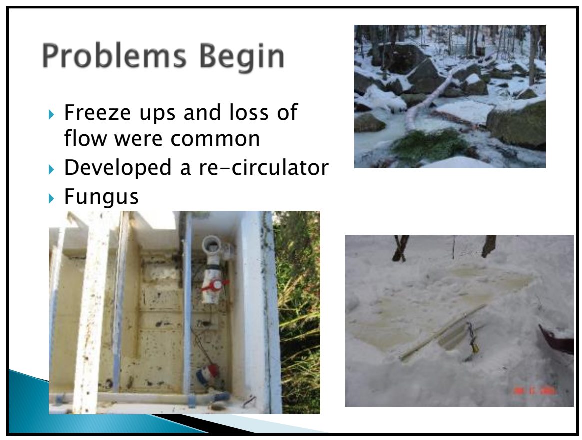
- **Reproductive Success**
  - Spawning behavior similar to sea-run
    - Timing of spawning
    - Observed courtship behavior
  - Redd distributions
  - Juvenile production and survival
    - Density and survivals similar for both strategies
- **Lifetime Fitness**
  - Adult to Adult –
    - comparisons coming soon

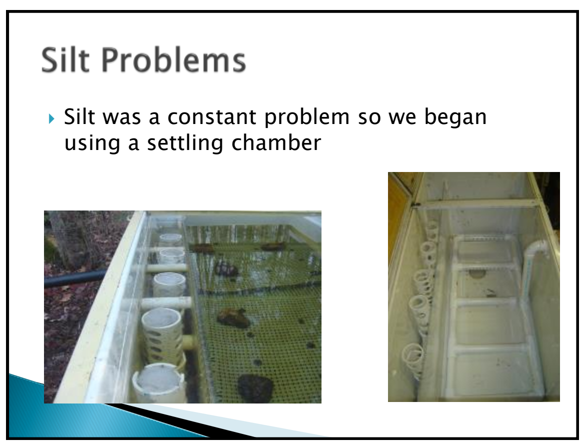
Questions?

Atlantic salmon eyed ova planting and streamside incubation in the Sandy River
Paul Christman, Maine Department of Marine Resources



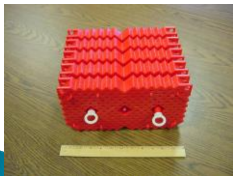






Egg Planting

- Initially started using incubation boxes
  - WV's, home made baskets
- While we had some production, overall limiting by effort and loss of eggs.




Developed the Hydraulic Planter

- We found some groups on the west coast were using a water pump to conduct direct plants.
- After several trails we were able to develop a fast productive means of planting eggs in the gravel
- Began using eyed eggs due to success and availability


The Sandy River Program

- In 2009 we developed a plan to use the new planter to start a large watershed reintroduction
  - Sandy River 593 sq miles (1,536 sq Kilometers)
  - >30,000 units of rearing
  - Average number of eyed eggs annual 757,000

Access Issues

- Getting to the river is not easy in the winter.
  - ATV's
  - 4X4
  - Snowshoe



Cold Temperatures

- Temperatures during the day are generally mild however they can be very cold
- Eggs are moved "dry" and placed in water at the river


Ice

- Frozen Rivers
  - Not as bad as we thought


Kennebec River Streamside Results

- Did not produce more than 57,000 fry in any year
- Given the small number of fry released very little data was collected on survival.
- Between 2006 and 2011 the Kennebec adult returns were larger than expected.

Table. Fry stocking and number of adult returns per 10,000 fry

Stocking Year	Streamside Fry	Eyed Eggs	Adult Returns	Kennebec	Penobscot
2003	41000	0	11	**2.68**	**1.43**
2004	57000	0	8	**1.40**	**0.64**
2005	32000	0	11	**3.44**	**0.48**
2006	8500	14000	5	**5.88**	**0.52**
2007	17400	9000	43	**24.71**	**1.31**
			Average	**7.62**	**0.79**

24.71 Second highest historically for all U.S. rivers

Sheepscot River Streamside

- A single year class was released in the Sheepscot River paired with hatchery fry
- Hatchery fry released 32,940
- Streamside fry released 29,389

Table 4. Numbers of parr and smolts assigned to either of the two treatments.

River Reach	Life stage	Hatchery	SSI	Ratio
Lower WB	0+	15	73	0.21
	1+	7	29	0.24
	smolt	8	36	0.22
Upper WB	0+	22	41	0.54
	1+	17	37	0.46
	smolt	27	54	0.5

Instream Results

- Our goal was to estimate survival and achieve widespread emergence of near 10%.

Site (KM)	Eggs planted	Total Fry	% Emerg.
Barker	5825	2764	47.45
Valley B 3.52	5731	258	4.5
Sandy 87.14	4471	94	2.1
Orbeton 11.59	4977	2163	43.46
Orbeton 12.77	7659	269	3.51
Cottle B. 5.00	3484	1603	46.01
Avon Valley 4.67	4773	41	0.86
Sandy 67.35	6180	1088	17.61
Temple S. 14.00	5667	2398	42.32
Sandy 82.60	3149	97	3.08
Sandy 87.14	2802	34	1.21
Sandy 73.73	3000	608	20.27
Sandy 65.06	2578	604	23.43
Cottle 0.07	3249	25	0.77
Perham 2.08	3013	542	17.99
Perham 3.22	2875	134	4.66
Orbeton 13.73	3294	756	22.95
Orbeton 7.95	4243	371	8.74
South Branch 0.51	2532	992	39.18
Avon Valley	2610	395	15.13
Mt. Blue	2537	1798	70.87
Temple	2778	815	29.34
		avg.	**21.16**

Egg planting Sandy River Survival

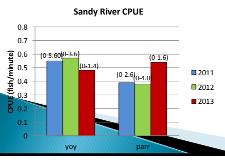
- Survival estimates for various locations around the drainage

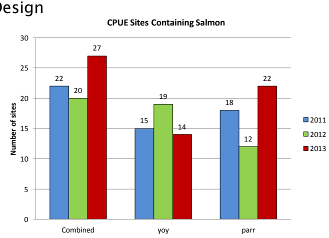
Table. Reach survival estimates for both 0+ and 1+parr.

Site	Eggs	0+parr Estimate	SD	0+ Survival	1+parr Estimate	SD	1+ Survival
Perham	46160	5377	1456	**0.12**			
Cottle	42500	6365	1724	**0.15**			
Mt. Blue	55930	23604	6392	**0.42**			
Orbeton	192920	16935	4586	**0.09**			
Temple	47940	14049	3805	**0.29**			
Sandy 73.64km	104130	16935	4586	**0.16**			
Barker	5825	1683	456	**0.29**			
Sandy 67.35km	47940	10371	2809	**0.22**			
Mt. Blue	28736	9339	2529	**0.33**	3825	1036	**0.41**
Perham	23736	3332	902	**0.14**			
Sandy 73.64km	58232	6522	1766	**0.11**			
Cottle	3000	452	n/a	**0.15**	396		**0.88**
Temple	58232	7431	2012	**0.13**			
			avg.	**0.20**			

Sandy River Random Sample

- >20,000 rearing units above Farmington
- Generalized Random-Tessellation Stratified Design
- 30 sites
- 2011–859,893 eggs
- 2012–920,888 eggs
- 2013–700,509 eggs





Summary

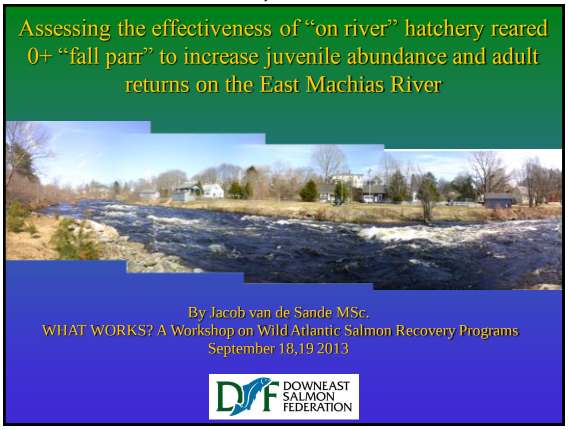
- Streamside
  - Difficult to operate
  - Limited to small drainages
  - Likely produced high quality juveniles
  - Likely resulted in increased adult return rate
- Egg Planting
  - Can be used on large watersheds
  - Likely also producing high quality juveniles
  - Maybe advantageous over fry stocking

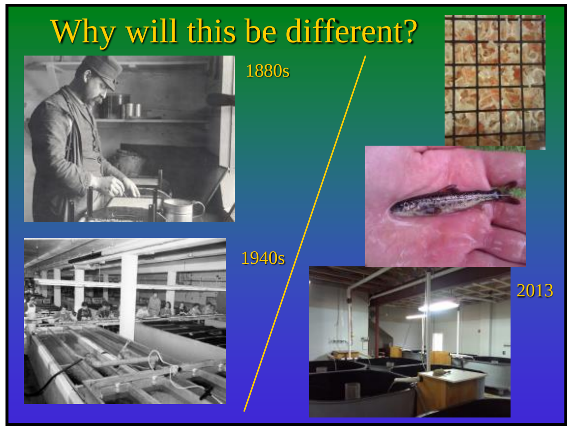
Thanks

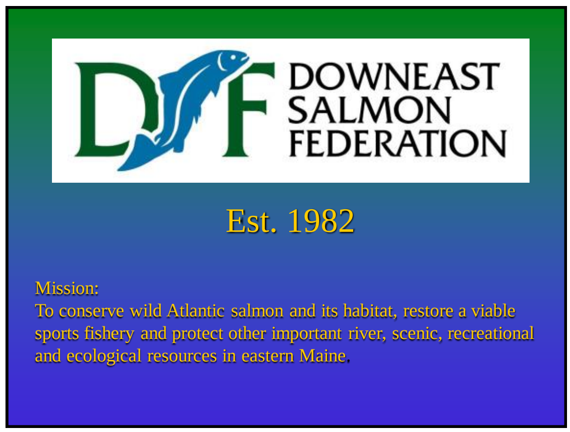
Jake Overlock
Jen Noll
Dan McCaw
Derik Lee
Kevin Dunham
Joan Trial
USFWS
NOAA
TU
Many volunteers

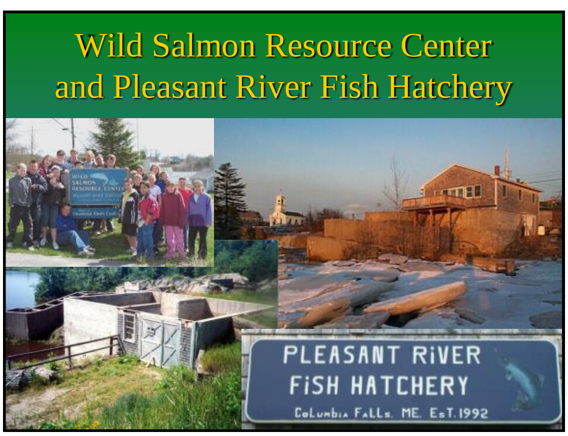
Questions?

Assessing the effectiveness of “on river” hatchery reared 0+ “fall parr” to increase juvenile abundance and adult returns on the East Machias River
Jacob van de Sande, Downeast Salmon Federation





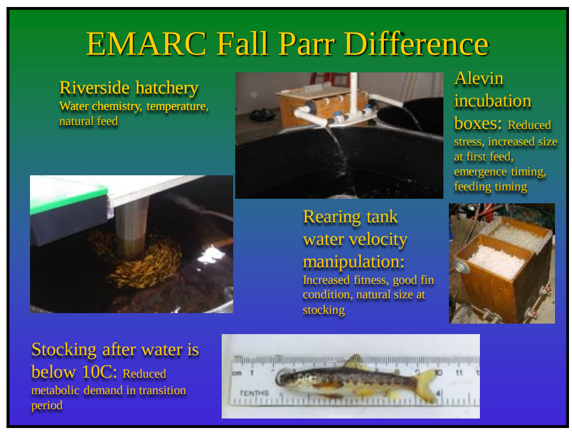


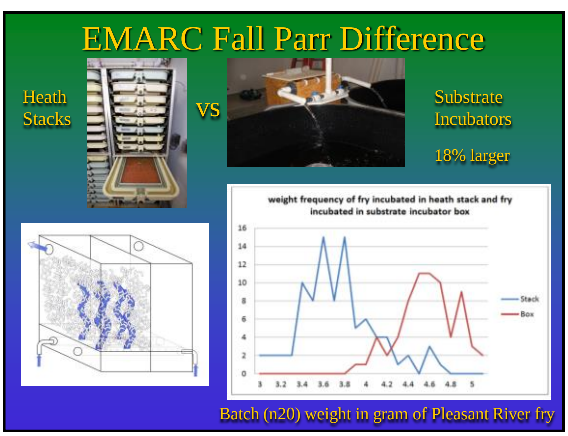


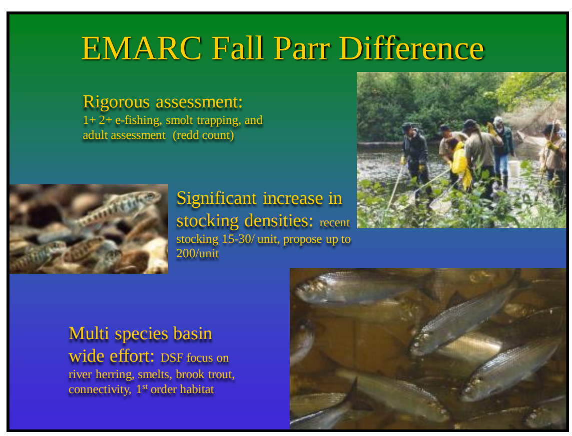

emarc
east machias
aquatic research center


New hatchery, new techniques
• 20 years of unfed fry have not resulted in measurable recovery
• Smolt stocking is expensive and has negative genetic impacts
Fall parr?


Collaboration is the key!
NASF
North Atlantic Salmon Fund
emarc
east machias
aquatic research center
DOWNEAST SALMON FEDERATION
NOAA FISHERIES
Department of Environmental Protection
WASHINGTON ACADEMY


EMARC Fall Parr Difference
Riverside hatchery
Water chemistry, temperature, natural feed
Alevin incubation boxes: Reduced stress, increased size at first feed, emergence timing, feeding timing
Rearing tank water velocity manipulation:
Increased fitness, good fin condition, natural size at stocking
Stocking after water is below 10C: Reduced metabolic demand in transition period


EMARC Fall Parr Difference
Heath Stacks
VS
Substrate Incubators
18% larger
weight frequency of fry incubated in heath stack and fry incubated in substrate incubator box
Stack
Box
Batch (n20) weight in gram of Pleasant River fry


EMARC Fall Parr Difference
Rigorous assessment:
1+ 2+ e-fishing, smolt trapping, and adult assessment (redd count)
Significant increase in stocking densities: recent stocking 15-30/ unit, propose up to 200/unit
Multi species basin wide effort: DSF focus on river herring, smelts, brook trout, connectivity, 1st order habitat

Assessment

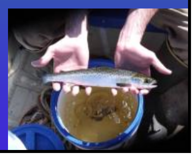
Smolt trapping

– 2013 recapture efficiency averaged 26.9%

SHRU	Drainage	Dates Deployed		Origin	Total Captures	First Capture	Last Capture	Median Capture Date
Downeast Coastal	East Machias	23-Apr	18-Jun	Wild	96	26-Apr	16-Jun	15-May
				Hatchery	45	11-May	16-Jun	2-Jun

SHRU	Drainage	Origin	Population Estimate	Std. Error
Downeast Coastal	East Machias	Wild	341	58
		Hatchery	238	81

Est. total 2013 579



Assessment

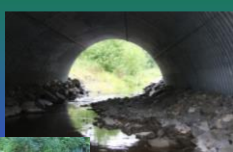
- E-fishing Sept 2013
  - Basin wide estimates (GRTS, plus index sites)

Redd counting

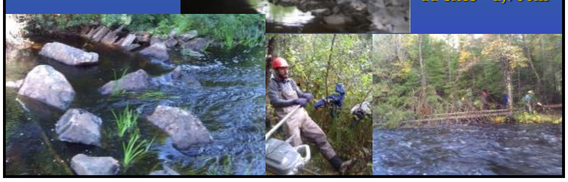
Physical Habitat Restoration

Culverts, remnant dam removal, Large wood additions

182 culverts surveyed
6 Arched culverts
2 Decommissioned
2 Remnant dams removed +1



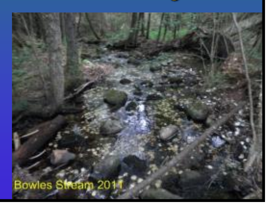
Large wood additions
11 sites= 1,700m



Habitat Restoration: Chemistry and nutrients

Alewife restoration/ management

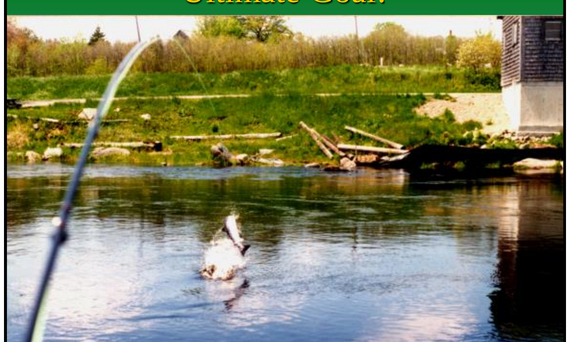
Clam shell additions
Salmon analogs?



Project status

- Stocked 52,000 0+ parr November 2012 (40/unit density)
- Rearing 90,000 parr for November 2013 (90/unit)
- E-fishing September 2013?
- > 200,000 eggs in 2014?
- Smolt trapping 2014 (first glimpse)
- …

Ultimate Goal!



Gaddis Pool East Machias River 199?

Acknowledgements

- Orri Vigfusson and John Ashton , North Atlantic Salmon fund
- Andy Goode, Atlantic Salmon Federation U.S. Program
- Kyle Winslow and Maria McMorrow, Downeast Salmon Federation
- Ernie Atkinson, Colby Bruchs, and Joan Trial, Maine DMR Division of Sea-Run Fisheries
- Peter Lamothe and Chris Domina, USFWS Craig Brook National Fish Hatchery
- John Kocik and James Hawkes, NOAA Fisheries
- Mark Whiting, Maine DEP
- Steve Koenig and Jacques Tardie, Project SHARE

Evaluation of migration performance of hatchery restoration products (age 1 smolts) using acoustic telemetry

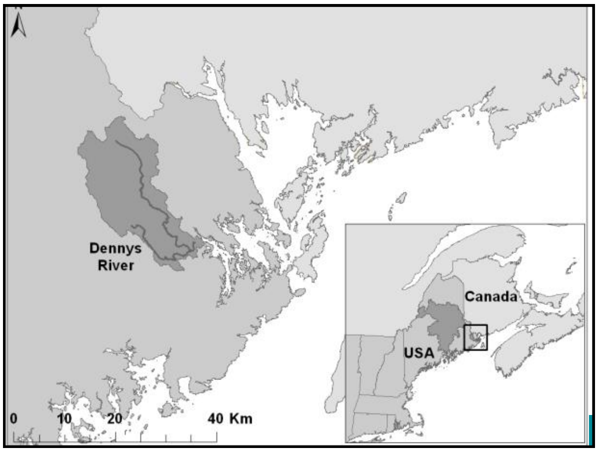
Jim Hawkes, NOAA's National Marine Fisheries Service

Evaluation of migration performance of hatchery restoration products (Age 1 smolts) using acoustic telemetry

James P. Hawkes[1], Timothy F. Sheehan[2], Daniel Stich[3], Joan Trial[4], & Ernest Atkinson[4]

[1] NOAA Fisheries Maine Field Station, Orono, ME
[2] NOAA Fisheries Woods Hole, MA
[3] USGS/University of Maine, Orono, ME
[4] Maine Department of Marine Resources

NOAA FISHERIES



Dennys River –

- 32 km headwater lake => estuary
  - Short estuary ~2 km
- Discharge - 3.8 m^3/ sec
- CSE = 138

Bay Complex (Dennys/Cobscook Bay) –

- Complex shallow env. with series of bays, channels, ledge, etc with much < 15 m depth
- Tidal fluctuations nearly 6 meters
- ~0.5 km^3 seawater enters and exits with each tide
- Influenced by cold, nutrient rich waters of GoM/BOF

Dennys River: Fisheries Past

- 1786 – settlers in the area
- 1832 – first rod catch in United States
- 1937 – 1980s
- Anecdotal Reports 100s – 1,000 fish
- Rod Catch averaged 58 fish (registered)
- Exploitation - commercial fisheries, poaching
- 2000 – Dennys R. protection under ESA

NOAA FISHERIES

Dams, Forestry & Agriculture

Dams
- 1786 – Dams after colonization
- 1930 – Last mainstem dam
- 1969 – Headwater lake regulated

Forestry
- 1980s clear cutting (budworm)

Agriculture
- Spraying practices for blueberry and potato cultivation

Superfund Site
- Toxic waste since the 1940s

mainerivers.org

Alexandersblueberries.com

NOAA FISHERIES

Restoration Activities (Hatchery)

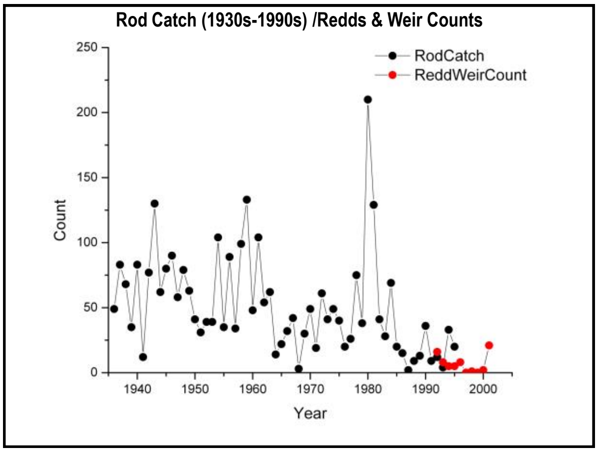
- 1875 – first stocked salmon (15 K) shipped by stage coach
- 1875 – 1890 - 250K fry stocked
- 1900s – brood stock contributions from several rivers
- 1960s – 2001– fry, parr & minimal smolt
- 1980s - Aquaculture escapees

Stagecoachfreighwagon.org

NOAA FISHERIES

Restoration Activities (Other)

- ESA Listing (No fishing)
- Culvert replacement on tributaries (Venture Brook)
- State Land Purchase



Hatchery Restoration 2001- 2005

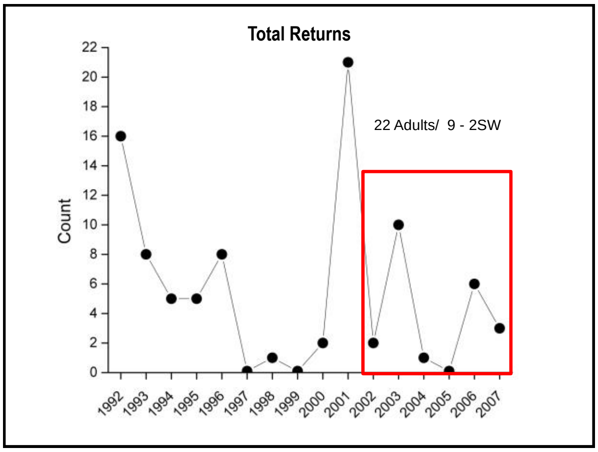
•2000 stocking plan developed

•River Specific Age-1 hatchery smolts

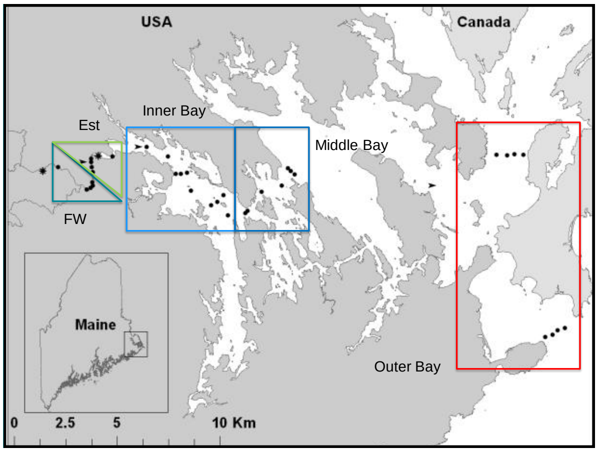
•Penobscot River 1973 – 1995

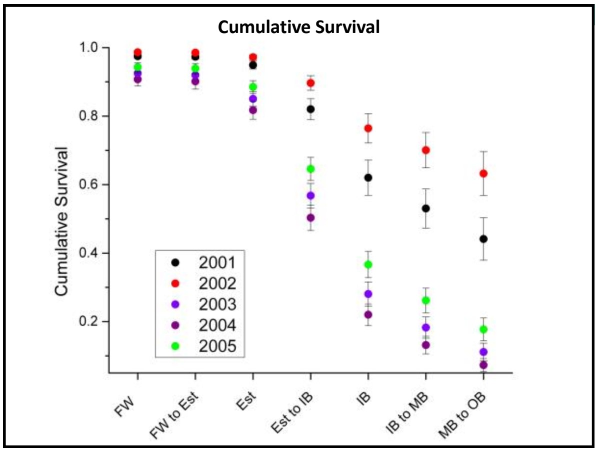
•30,000 to 50,000 =
75% Prob. of n = 70 – 120 2SWs

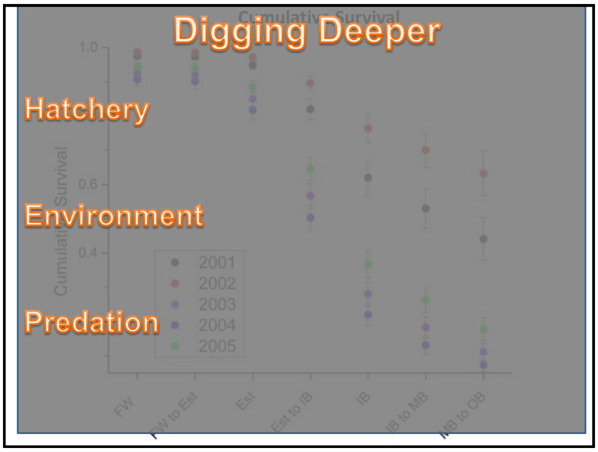
•2001 = ~ 50,000 smolts stocked annually



What Went Wrong?







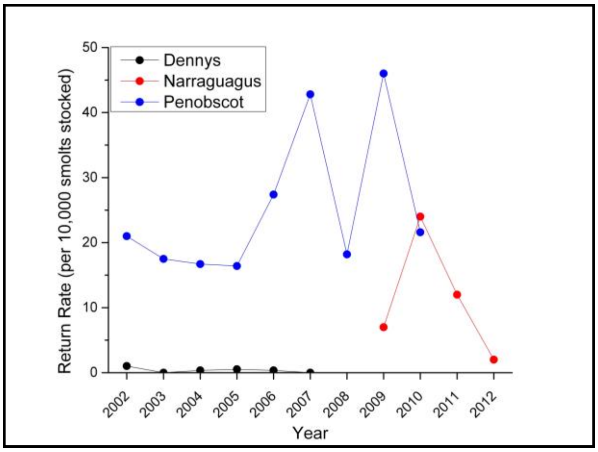
Hatchery

•Not the same fish since 1800s
  •Adaptive advantage lost?
  •Spencer et al. 2010

•Run timing/release – too early?
  •= Maine salmon rivers
  •2 weeks earlier than BoF

•Collection of Brood stock
  •Penobscot = marine survival
  •Dennys = freshwater survival

NOAA FISHERIES



Environment

Small river
- Immediate mixing/no buffer

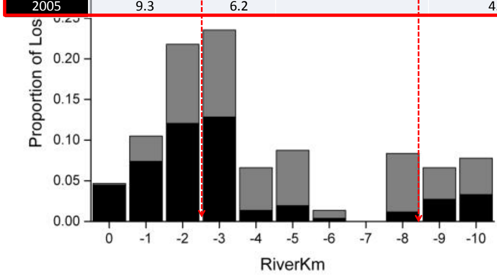
Massive tidal currents
- Energetic challenges

Mismatch in environments
- Earlier Snowmelts/runoff
  - Dudley & Hodgkins, 2002
- BoF coldwater

NOAA FISHERIES

Mean Daily Low Temperatures (°C) – First two weeks in May

Year	Estuary	Inner Bay	Middle Bay
2002	9.4		5.0
2003	8.4		3.5
2004	8.7	5.9	3.2
2005	9.3	6.2	4.3



Predation

- Large predator suite
  - •Harbor and Grey Seals
  - •Cormorants
  - •Gulls, etc.

•Shallow environment (esp. low tide)

•Compromised smolts (Temp and Phys)
- Immediate losses
- Reversals

NOAA FISHERIES

Thoughts going forward…..

- Hatchery restoration program (2001-2005) - FAILED

•Something about the hatchery supplementation is flawed?

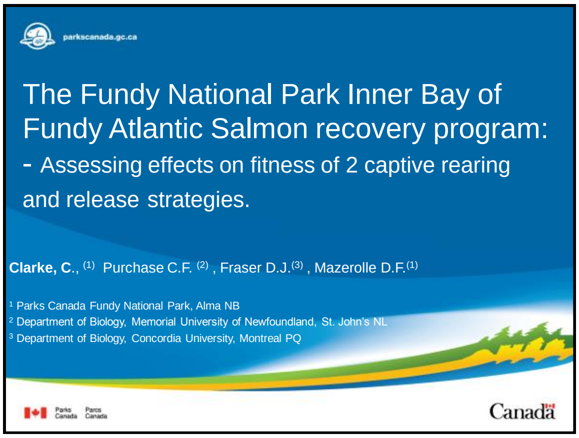
•Environmental conditions are exceptionally challenging

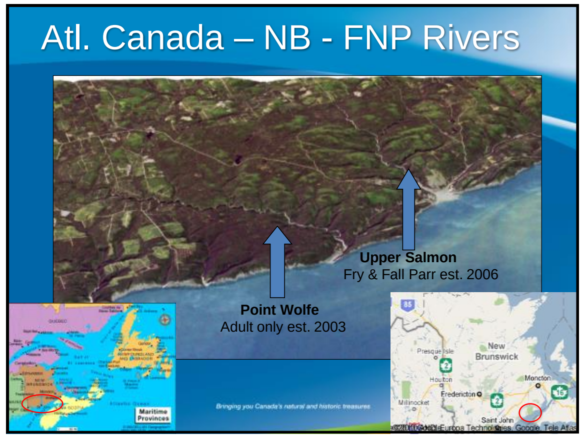
•Is there anything that can be done?
- •Lower expectations = restoration
- •Although not the same fish (historically) – gene banking?

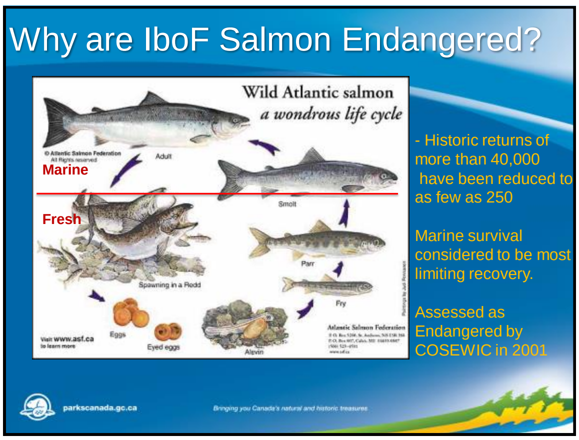
NOAA FISHERIES

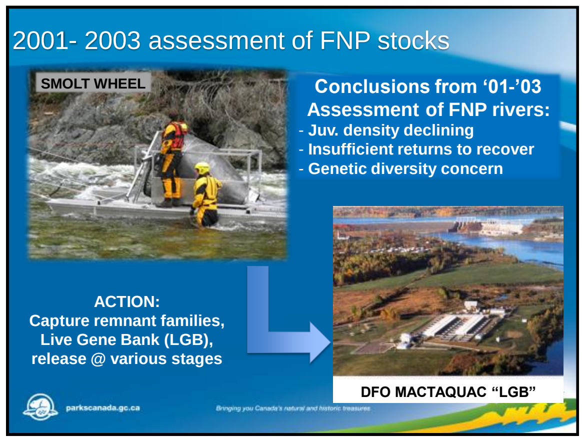
Impacts on fitness due to captive exposure depends on life-stage in captivity for inner Bay of Fundy Atlantic salmon

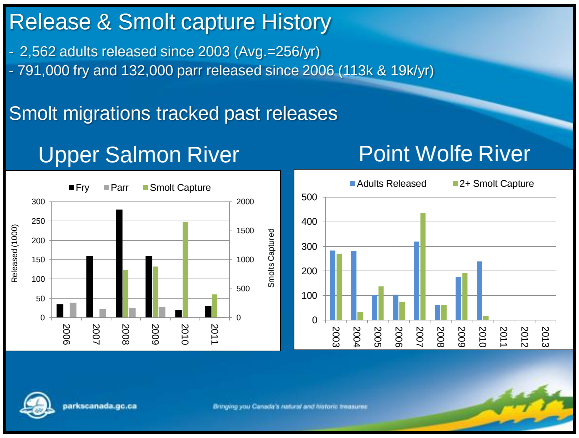
Corey Clarke, Parks Canada

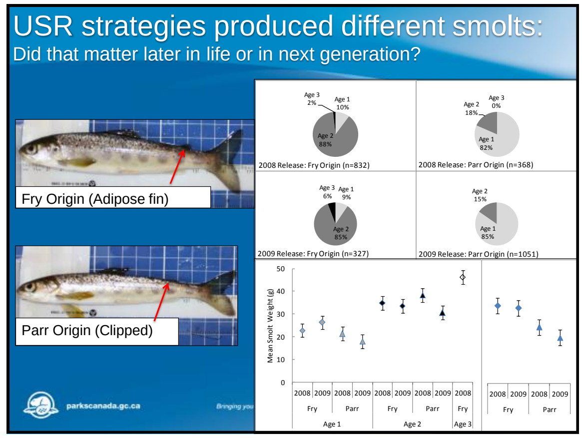


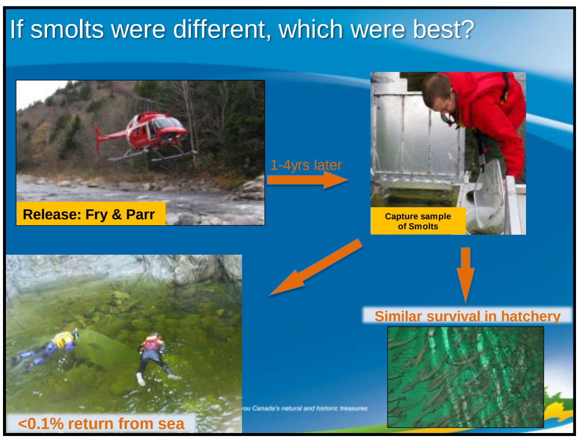


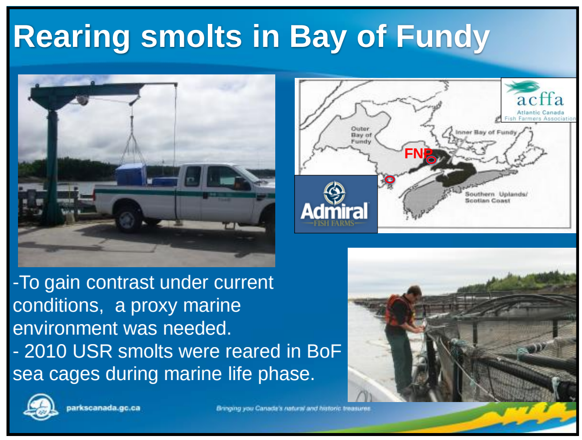





Release & Smolt capture History
- 2,562 adults released since 2003 (Avg.=256/yr)
- 791,000 fry and 132,000 parr released since 2006 (113k & 19k/yr)
Smolt migrations tracked past releases
Upper Salmon River
Point Wolfe River
Fry
Parr
Smolt Capture
Released (1000)
Smolts Captured
Adults Released
2+ Smolt Capture
parkscanada.gc.ca
Bringing you Canada's natural and historic treasures


USR strategies produced different smolts:
Did that matter later in life or in next generation?
Fry Origin (Adipose fin)
Parr Origin (Clipped)
2008 Release: Fry Origin (n=832)
2008 Release: Parr Origin (n=368)
2009 Release: Fry Origin (n=327)
2009 Release: Parr Origin (n=1051)
Mean Smolt Weight (g)
parkscanada.gc.ca


If smolts were different, which were best?
Release: Fry & Parr
1-4yrs later
Capture sample of Smolts
Similar survival in hatchery
<0.1% return from sea


Rearing smolts in Bay of Fundy
acffa
Admiral
FNP
-To gain contrast under current conditions, a proxy marine environment was needed.
- 2010 USR smolts were reared in BoF sea cages during marine life phase.
parkscanada.gc.ca
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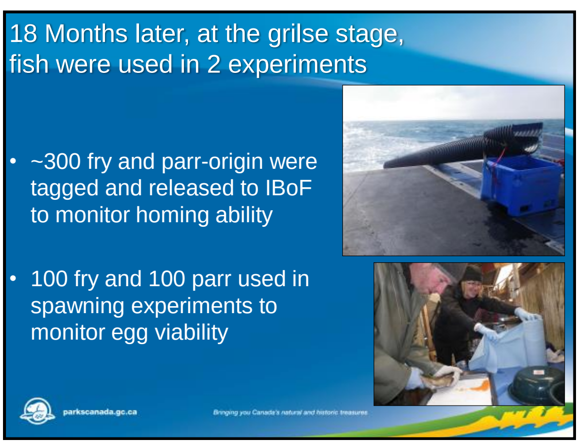
18 Months later, at the grilse stage, fish were used in 2 experiments
• ~300 fry and parr-origin were tagged and released to IBoF to monitor homing ability
• 100 fry and 100 parr used in spawning experiments to monitor egg viability
parkscanada.gc.ca
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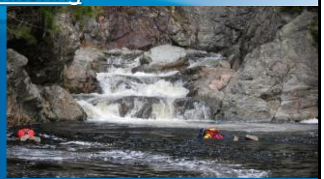
Released cage fish to IBoF, 2011
(15km from USR)
319 Released
- All Tagged externally
- 44 Acoustic Tagged
parkscanada.gc.ca

2011 Adult Return Monitoring

Upper Salmon (River of Smolt Origin):
Diver Observations
- **5** fish observed
- 4 (5%) Fry & 1 (0.3%) Parr

Acoustic Detections (1st pool & up)
- **6** fish detected
- 3 (14%) Fry & 3 (14%) Parr



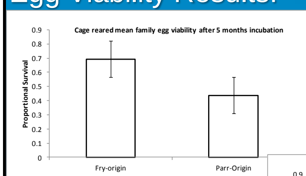
Overall Tracking Observations
- Divers observed:
  - 13 (16%) of the fry
  - 24 (9%) of the parr in 3 rivers
- 10 acoustic stations around BoF detected:
  - 17 acoustic tags from Fry (38%)
  - 16 acoustic tags from Parr (36%)
- Notable 2011 detections included:
  - New Minas Basin
  - Petticodiac River
  - Mactaquac Hatchery

Spawning Fry & Parr – origin parents

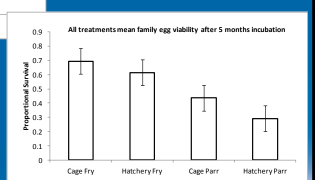
14 crosses of Fry parents
9 crosses of Parr parents

Viability recorded weekly for 5 months

Egg Viability Results:



Fry releases produced more viable offspring after 5 month incubation



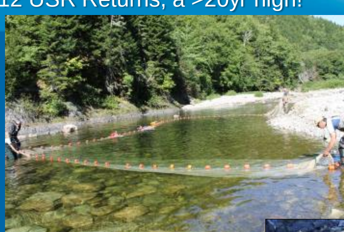
Note:
*Comparing hatchery reared post smolts suggests brief change in early conditions had greater effect on viability than 18 mo. post-smolt phase.

*Low number of crosses and comparable parents in hatchery group

Spawning experiment fish released to USR in fall 2011

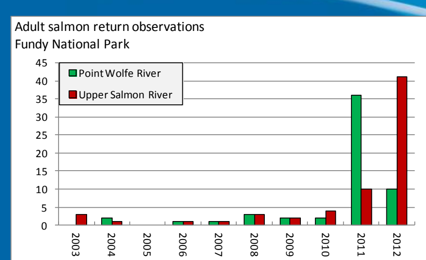
Slide pool on USR in 2012

2012 USR Returns, a >20yr high!



42 observed returns.
Of 188 Cage and 70 Hatchery rel:
-11% of Cage (13% Fry, 9% Parr)
-4% of Hatchery (7% Fry, 2% Parr)

Adult Returns to FNP



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~~What works?~~ , not sure
What may work better…

- Careful consideration of <u>what stage</u> and <u>how</u> to captive rear
  - Avoid earliest stages (although demographic and/or $ advantages)
  - Consider adaptive and selective plasticity of life stages for effects on wild fitness
  - Naturalizing captive environments continues to show promise
- Release volume is also likely important
  - Notable returns from adult releases approaching historic USR #'s
  - '14-'15 Smolts will index spawning success and be ideal broodstock

Thank you

Questions/Comments?

Parks Canada Parcs Canada

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Partners/Collaborators have been key to program achievements

acffa Atlantic Canada Fish Farmers Association

Admiral Fish Farms

Fisheries and Oceans Canada / Pêches et Océans Canada

Memorial University

Fundy Salmon Recovery

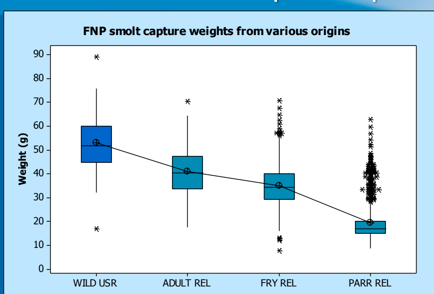
Atlantic Salmon Federation / Fédération du saumon Atlantique

Université Concordia University

Ocean Tracking Network

Parks Canada Parcs Canada Canada

Smolt size declines with captive exposure?



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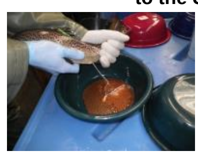
Current FRY Program Output Examined

- Average output 100k fry (2k smolt /yr)
- Production equivalent to ~30 spawnings
- 30 Spawning = <10% of natural levels (600+ rtns)
- 30 spawnings require ~30-females + X males.

In 2012, We had 30 females and 8 males return to the USR by August from adult releases.



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"Naturalized" Exposure??

QUESTIONS or COMMENTS?

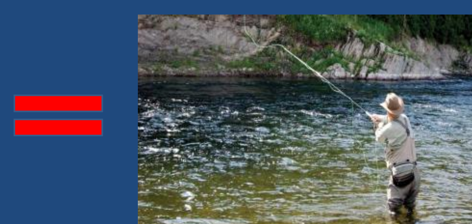
Parks Canada Parcs Canada Canada

Where you are raised does matter: the use of semi-natural rearing ponds as an Atlantic salmon conservation tool

Kurt Samways, University of New Brunswick
Danielle MacDonald, Fisheries and Oceans Canada

Historical and Present use of Salmon Hatcheries

Enhancement



Mitigation

Nature vs. Nurture

STAGE	Nature	Hatchery
EGGS/ALEVIN	Gravel, redds, upwelling current, predation, natural temperature regimes, constant dark…	Troughs, incubators (with or without substrate), varied lighting, artificial temperature regimes, handling, therapeutants
FINGERLINGS/PARR	Natural feed, foraging, natural substrate (cobble), complex flow regimes, predation, competition, natural temperature variation, dynamic stream environments with a variety of micro and macro habitats, natural light variation	Tanks generally without substrate, pelleted feed provided at intervals, constant flow, little temperature variation, homogeneous rearing environment lacking complexity, no predation, no competition with other species, high densities

Wild Fish

- "On Your Own"
- Increased Selective Pressures
- High Mortality in Early Life Stages
- Increased Natural Adaptations

Hatchery Fish

- "Constant Care"
- Decreased Selective Pressures
- Low Mortality in Early Life Stages
- Decreased Natural Adaptations

With the Best of Intentions

Salmon News

www.dailyscience.com THE WORLD'S FAVOURITE NEWSPAPER - Since 2012

5B Stocked Atlantic Salmon Missing!

Every year, over 5 billion hatchery reared Atlantic salmon are stocked into natural rivers and streams around the world. Yet, in many areas there have been sharp declines in salmon numbers in the wild over the last couple of decades. So where did all these stocked salmon go?

Global climate change is being considered as one of the potential variables resulting in the declining returns of mature adult salmon to their natal habitats. Other studies are looking at the effects of diseases, parasites, habitat degradation as well as other anthropogenic impacts.

Conservation and restoration are now key priorities for these populations. Folks who used to cast their lines into salmon pools are now sitting shoulder to shoulder with scientists, governments and the interested public at large to find solutions to restore this "king of fish" to its former glory.

To that end, the Atlantic Salmon Federation is hosting a restoration workshop "What Works, What Doesn't" in September.

Goal of Conservation

To restore self sustaining populations in the wild

Paradigm Shift

To Convert Production Facilities to Conservation Facilities the traditional fish culturists should switch from a goal of maximizing productivity to a goal of maximizing biodiversity.

Paradigm Shift

The end result would therefore become the production of ecological viable fish better prepared for natural releases and survival in a wild habitat.

But How?

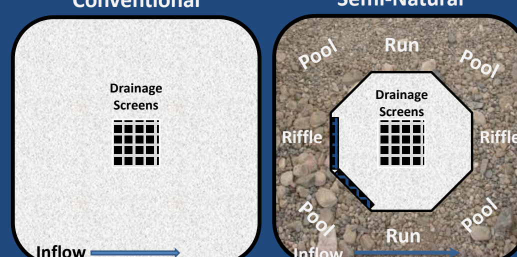
Research Question

Can semi-natural rearing ponds be used as a Conservation Tool in Atlantic Salmon restoration?

Study Metric

To measure the morphological responses of Atlantic salmon fingerlings to conventional, semi-natural and wild rearing conditions

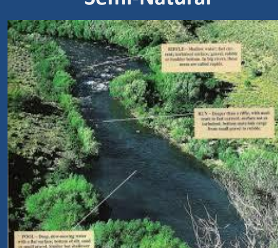
Study Ponds



Flow Patterns

Conventional

Semi-Natural



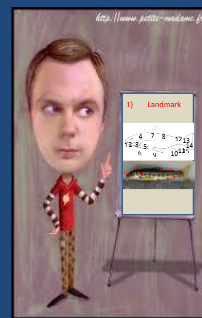
	2009		2010	
CONV	289 fish/m^3	289 fish/m^3	241 fish/m^3	241 fish/m^3
SN HD	319 fish/m^3	319 fish/m^3	284 fish/m^3	284 fish/m^3
SN LD	127 fish/m^3	127 fish/m^3	124 fish/m^3	124 fish/m^3
2009: Emergent 2010: SN MD	192 fish/m^3	192 fish/m^3	200 fish/m^3	200 fish/m^3

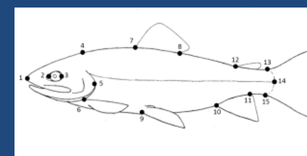
Timelines

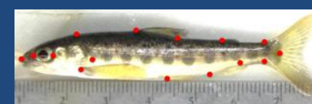
2009: Length, **Weight, Photographs**

2010: Length, Weight, Photographs & Fin Condition

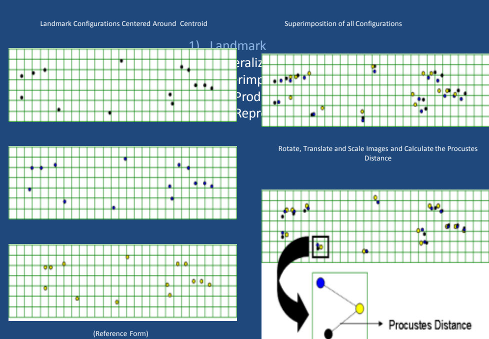
Steps for Shape Analysis for the Science Geeks







Steps for Shape Analysis for the Science Geeks



Steps for Shape Analysis for the Science Geeks

1) Landmark
2) Generalized Orthonganol Least-squares Procustes Superimposition
3) PCA on Partial Warps
   - Produces a Relative Warp Score matrix
   - A multivariate description of shape variation

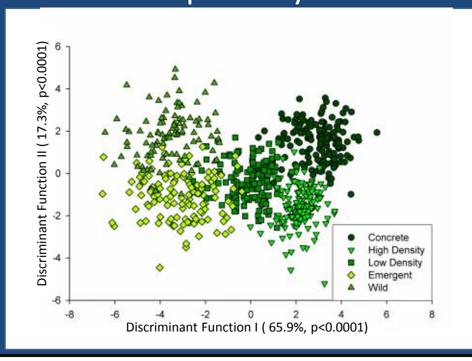
Steps for Shape Analysis for the Science Geeks

1) Landmark
2) Generalized Orthonganol Least-squares Procustes Superimposition
3) PCA on Partial Warps
4) ANCOVA to Test for Allometry
   - Does shape vary with size?
   - Remove linear dependencies of shape on size
   - Standardize relative warp scores

Steps for Shape Analysis for the Science Geeks

1) Landmark
2) Generalized Orthonganol Least-squares Procustes Superimposition
3) PCA on Partial Warps
4) ANCOVA to Test for Allometry
5) DFA on Standardized Relative Warps
   - Test for group membership & characterize variability between rearing treatments
     - MANOVA for Differences between Groups
       - Differences between rearing treatments
       - Post-hoc univariate F-tests for differences between groups

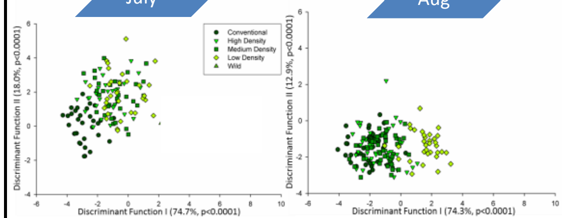
2009 Shape Analysis Results



2010 Shape Analysis

July

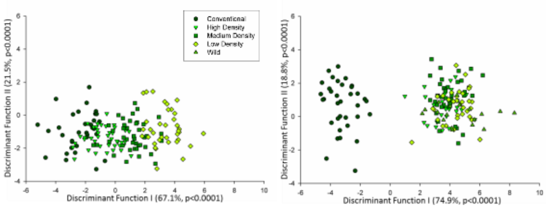
Aug

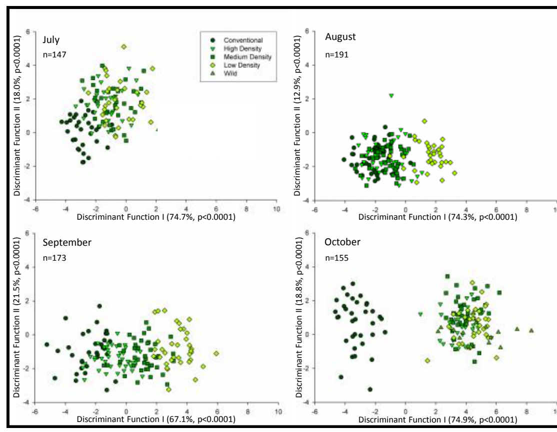


2010 Shape Analysis

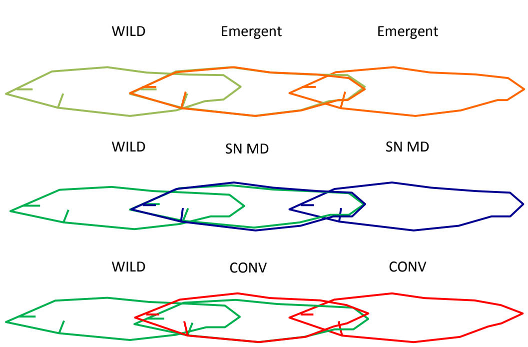
Sept

Oct



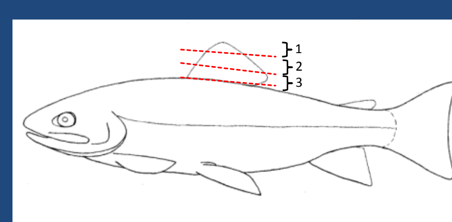


Why Shape Matters



2010 Fin Condition

The Frantsi Index

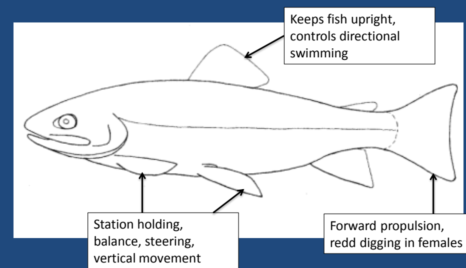


$$\text{Fin Index} = \frac{\text{Total sum of fin erosion observed in treatment}}{\text{Max. total of fin erosion for single fish} \times \text{\# of fish sampled}}$$

Fin Condition Results

% of Fin Contributing To Total Erosion	Dorsal Erosion	Right Pectoral Erosion	Left Pectoral Erosion	Upper Caudal Erosion	Lower Caudal Erosion	Fin Index Score
	74.78	8.88	10.7	2.06	3.58	100

Why Fins Matter



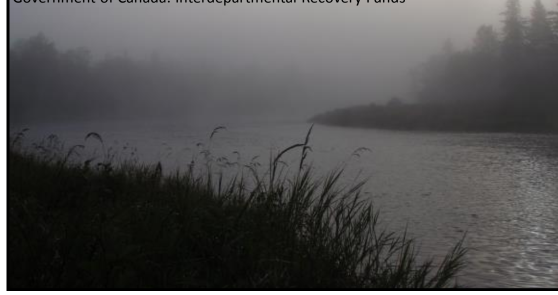
Summary

- *Semi-natural ponds produce fish more similar in shape and fin quality to their natural counterparts.*
- *Shape plasticity is not an immediate response in novel environments and can take months to fully occur.*
- *Substrate produces better fin qualities even at high densities.*
- *Increased habitat and flow complexity is beneficial in producing fish with a more wild-like shape*
- *Fish reared in semi-natural ponds may be better suited for life in the wild than their conventionally reared counterparts for a number of reasons including their overall shape and fin-condition (better at foraging, recognition of complex habitat structures, predator avoidance, etc…)*

Fisheries and Oceans Canada / Pêches et Océans Canada

Thank You

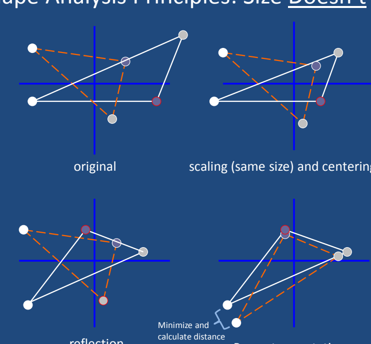
Mactaquac Biodiversity Facility: Trevor Goff, Stephanie Ratelle, and staff
Memorial University of Newfoundland: Ian Fleming
University of New Brunswick: Rick Cunjak
Government of Canada: Interdepartmental Recovery Funds

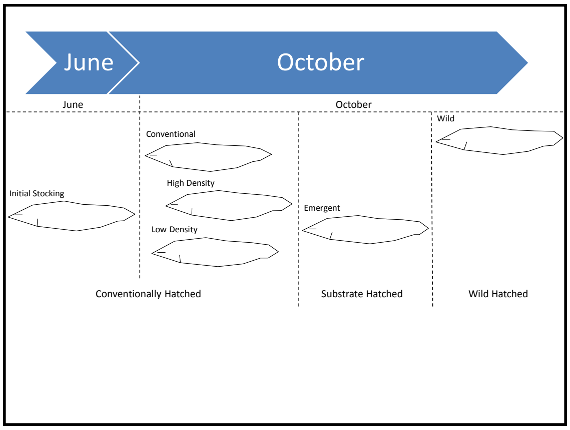


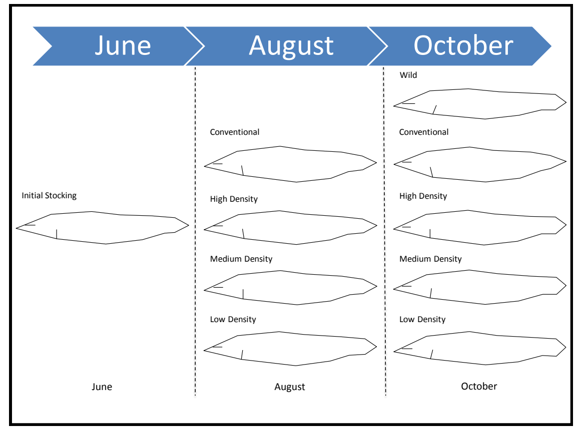
Other Research in these Ponds

- The use of semi-natural ponds for wild-like spawnings- DFO, UNB, MUN
- Over-wintering of hatchery smolts- DFO
- Over-wintering of fall to spring parr- PCA, MUN
- Over-wintering of eggs to emergent fry/parr- DFO, UNB, MUN
- Effects of hydro-peaking on smoltification-UNB
- Continued use of ponds for SJR program fingerling rearing

Shape Analysis Principles: Size Doesn't Matter



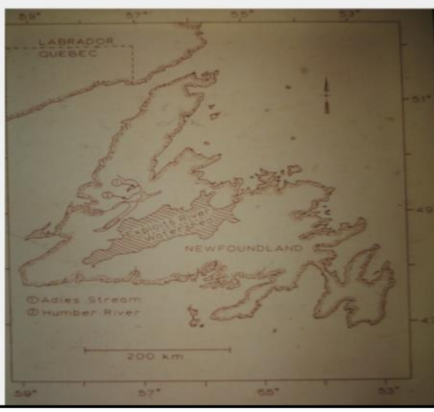

June
October
June
October
Wild
Conventional
High Density
Initial Stocking
Emergent
Low Density
Conventionally Hatched
Substrate Hatched
Wild Hatched


June
August
October
Wild
Conventional
Conventional
Initial Stocking
High Density
High Density
Medium Density
Medium Density
Low Density
Low Density
June
August
October

Exploits river stocking program- River of Dreams
Fred Parsons, Salmonid Council of Newfoundland

The Exploits River

River of Dreams

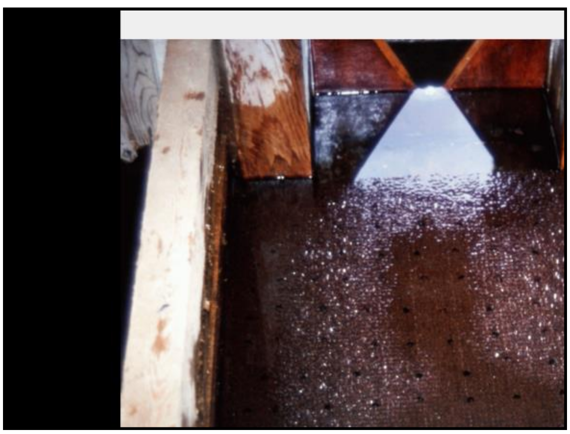


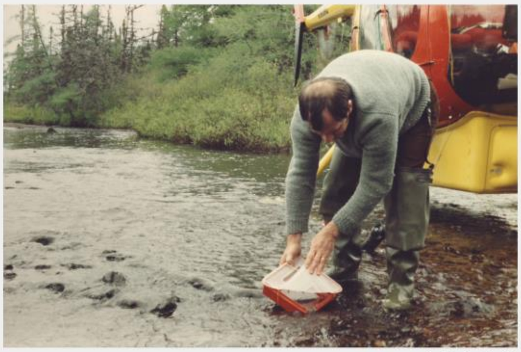
- Creating upstream Passage to New Habitat
- Colonization of New Habitat with Atlantic Salmon Fry
- Habitat Restoration of "Past Sins"
- Providing Safe Passage Downstream For Smolt and Kelt

Construction of Fish Passage

Colonization of New Habitat

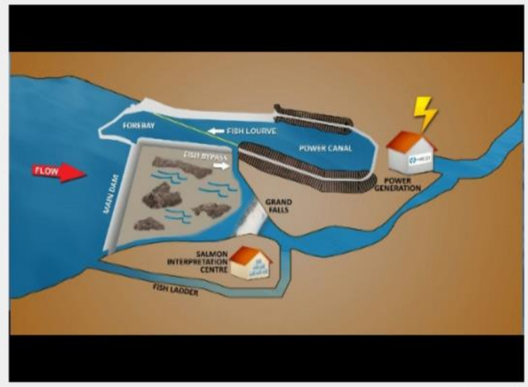


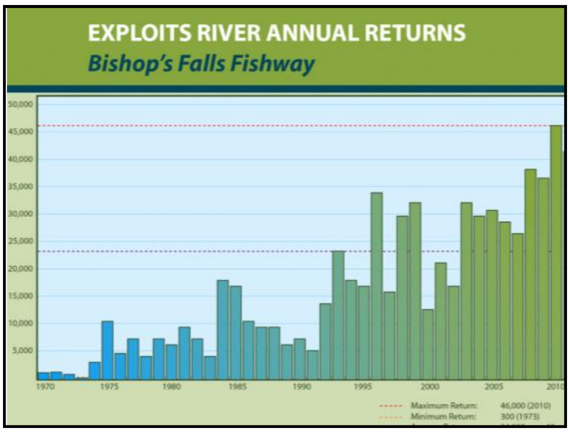


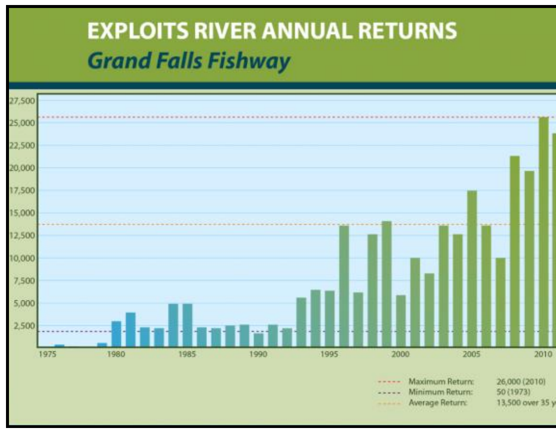



Habitat Restoration

Smolt and Kelt Safe Passage







Questions ??

The rise and fall of Atlantic salmon restoration on the St Croix (ME/NB)
Lee Sochasky, International Resource Planner

Rise and Fall of Salmon Restoration on the St. Croix

Setting the stage:

- **Into 1800s**. Largest runs on the Atlantic coast between the Saint John and Penobscot River systems.
- **Mid 1800s-1964**. Industry: 1, Fish: 0
- **1965-1980**. Wrongs righted; ready to restore

Into 1800s:

For millenia, Passamaquoddy fished annually at their *Siquoniw Utenehsis* (Spring Village) at Salmon Falls

"…salmon, shad, and gaspereau, were exceedingly abundant in the St. Croix; the average catch at the Salmon Falls was 200 salmon per day, for three months in each season."

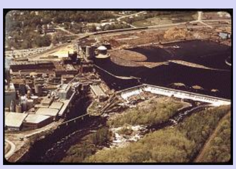
mid 1800s – 1964:

1800s: dams built on lower section of river, with limited or no fish passage

St. Stephen & Calais discharge extensive untreated wastes

mid 1800s – 1964:

1905. Woodland pulp mill, dam: intermittent fish passage, no waste treatment



1912. Grand Falls dam: no fishway, 99% of sea-run fish habitat eliminated

1965 – 1980:

- ✓ Fishways built or rebuilt at the first 3 dams; re-opening access to spawning habitat
- ✓ Pollution treatment facilities installed at Woodland mill and river communities, ending fish kills that occurred into the early 1970s.
- ✓ River ready for fish restoration!

Large-scale restoration:1981-1991

Government led and funded

- **Stocking:**
  1 million fry
  ¼ million parr
  ½ million smolt
  444 adults

Large-scale restoration:1981-1991

- **Returns:**

Research trap installed at Milltown

938 1SW
1502 MSW
2440 Total

Large-scale restoration:1981-1991

- **Counts at two upstream dams**
- **Radio-telemetry studies**
- **Fish health**

Large-scale restoration:1981-1991

What worked?

√ Large investment in smolt stocking

√ Large investment in research

Large-scale restoration:1981-1991

…and then came the cuts

Local-scale restoration:1992-2006

- ✓ Local collaboration with government, funded by grants and in-kinds
- ✓ Focus on re-developing a native strain
- ✓ Low cost, innovative solutions

Local-scale restoration:1992-2006

- **Stocking:**
  200,000 fry
  ½ million parr
  ¼ million smolt
  1274 adults

Returns:
281 1SW
342 MSW
559 Total

(+ 349 aquaculture escapees)

Local-scale restoration:1992-2006

What worked: habitat assessment

- ✓ 30 miles (95% of mainstem salmon habitat) assessed. Identifies prime salmon spawning and nursery habitat
- ✓ Identifies relationships with other fish habitat, especially smallmouth bass

Local-scale restoration:1992-2006

What worked: local broodstock

- ✓ Returning adults collected at Milltown, spawned and returned to river
- ✓ 400,000 parr, 33,000 smolt from these matings drive the restoration effort

Local-scale restoration:1992-2006

What worked: on-site parr rearing

- ✓ Rearing facility at Milltown raises 0+ parr, at low cost, after government options end

Local-scale restoration:1992-2006

What worked: site-specific stocking

- ✓ Fish stocked directly to prime nursery habitat

Local-scale restoration:1992-2006

What worked: adult stocking

- ✓ Cooperative effort – NMFS, Maine Atlantic Salmon Commission, Maine DMR, St. Croix International Waterway Commission, Domtar, NB Power, Atlantic Salmon of Maine

Local-scale restoration:1992-2006

What worked: adult stocking

- ✓ Cage-reared spawners of Downeast stock released in 2000 (750) and 2001 (524), to spawn naturally

Local-scale restoration:1992-2006

What worked: adult stocking

- ✓ Tracking, redd, emergence, e-fish and smolt studies to 2003

Local-scale restoration:1992-2006

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Local-scale restoration:1992-2006

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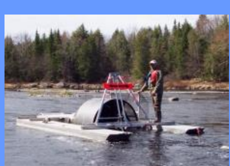
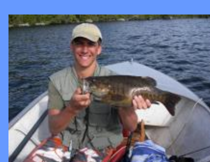


Local-scale restoration:1992-2006

Some other lessons:

Marine phytoplankton blooms impact wild salmon runs: Adult broodstock loss, 2003

Alexandrium bloom at aquaculture site 2003



Smallmouth bass have entirely adapted to salmonid habitat, displacing other species, to become the river's primary fish

Local-scale restoration:1992-2006

What failed: restoration

- **Potential for self-sustaining population severely compromised by smallmouth bass predation. Efforts ended.**

Local-scale restoration:1992-2006

Postscript…

- **Last fish stocked (St. Croix 0+ parr) in 2006**
- **Salmon trap counts end the same year**
- **Rearing tanks and equipment given to others**
- **Last St. Croix salmon recorded in 2008, a MSW female recovered from dam racks, presumed to be from the 2004 parr stocking.**

Future opportunities

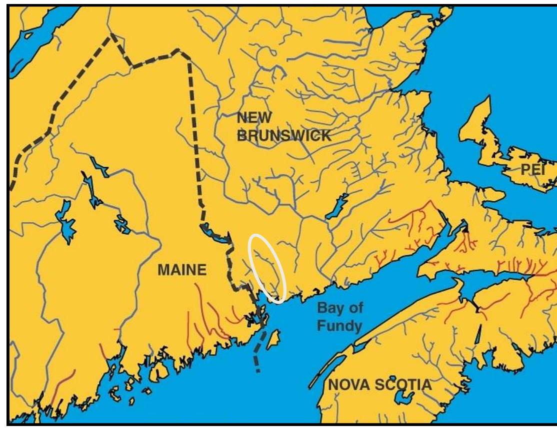
Other native diadromous species

One step forward, two steps back: obstacles to salmon recovery in the Magaguadavic
Jon Carr, Atlantic Salmon Federation

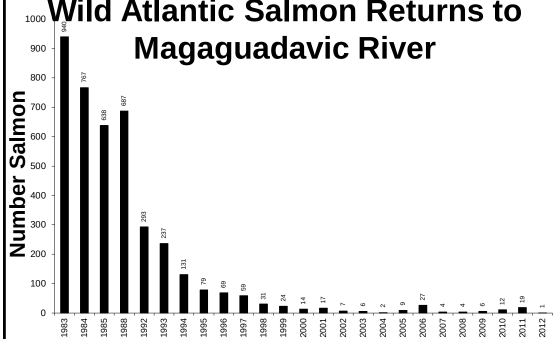
One step forward two steps back: Obstacles to salmon recovery in the Magaguadavic River

Jonathan Carr

Wild Salmon Recovery Workshop
September 18, 2013
Chamcook, NB



Wild Atlantic Salmon Returns to Magaguadavic River



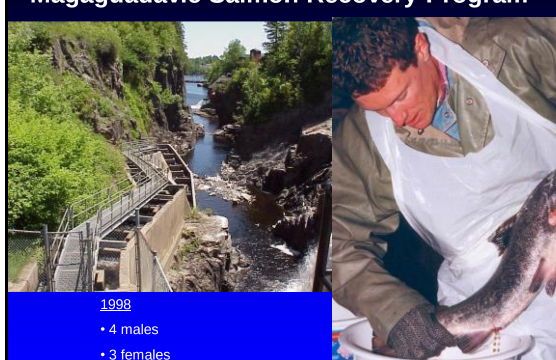
Magaguadavic River Salmon Recovery Group

- Angling Groups
- Conservation Groups
- Government Agencies
- Aquaculture Industry
- Private Industry

Goal:

Protect and Restore Wild Salmon Population in the Magaguadavic River

Magaguadavic Salmon Recovery Program



1998
- 4 males
- 3 females

Captive Rearing Program

- Pit Tag and Tissue sampling
- Donor Stocks
  - Black River 2003, 2004
  - Nashwaak River: 2004, 2006, 2007
- Annual Mating Plans

Release Strategies

Stocking Summary

Year	Fry	Parr	Smolt	Adult
2002	30,000			99
2003	25,856	7,336		
2004	24,861	8,434	1,706	
2005	6,665	2,000	904	
2006			924	
2007	89,000		700	38
2008	75,000	6,700	1600	15
2009	147,000		812	30
2010	204,000			
2011	310,000			732
2012	140000	9778		263

Captive-Reared Adult Releases

Objectives

- Movement rates and destinations
  - Seawater vs. freshwater — No differences
  - Early vs. late release groups
- Contributions to salmon production — Minimal

Carr, J.W., Whoriskey, F.G. & O'Reilly, P 2004. Efficacy of releasing captive reared broodstock into an imperilled wild Atlantic salmon population as a recovery strategy. Journal of Fish Biology 65(Supplement A): 38-54.

Stocking Summary

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2010	204,000			
2011	310,000			732
2012	140000	9778		263

Genetic Analysis of Adult Returns

Year	Adult Return	Live Gene Bank		Wild	Unknown
		Fry	Parr		
2005	9	1	3	1	4
2006	27	9	5	7	6
2007	4	2	0	2	0
2008	4	0	0	0	4
2009	6	0	1	0	5
Total	**50**	**13 26%**	**9 18%**	**10 20%**	**18 36%**

Limiting Factors

- Exotic Species
- Hydroelectric Dam
- Salmon Aquaculture

Exotic Species

Please visit http://nbaquaticinvasives.ca

Smallmouth Bass Summary

- Bass found at 55% of sites over 15 years
- Co-occurred with salmon at 36% of sites
- Bass found throughout main stem reaches
- In tributaries: bass found near lakes, reservoir, river's main stem
- YOY bass dominated sample sites
- Larger bass in main stem and near hatcheries

Carr, J.W. & Whoriskey, F.G. 2009. Atlantic Salmon (Salmo salar) and Smallmouth Bass (Micropterus dolomieu) Interactions in the Magaguadavic River, New Brunswick. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/074. Iv + 10pp.

Smallmouth Bass

- Bass found at head of tide dam
  - Displaced at times of high water
- Bass co-occurred with salmon smolts
  - Predation threat???

How do address potential impacts?

A. **Stock larger parr in riffle areas to displace bass**
B. **Avoid stocking juvenile salmon in bass occupied zones**

Please visit http://nbaquaticinvasives.ca

Fish Passage Issues

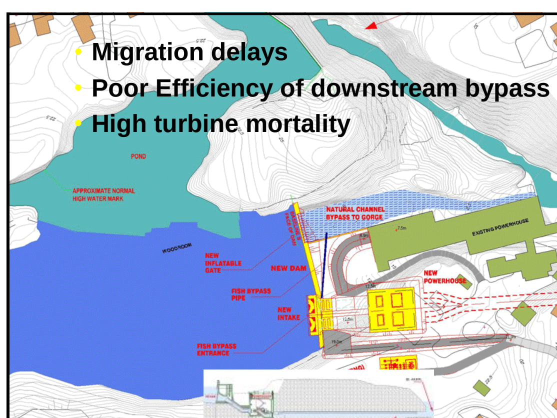
Prior to Upgrade

- **4 Francis Turbines**
- **3.7 MW capacity**

- **Upstream fish passage unchanged**

After upgrade

- **2 Kaplan Turbines**
- **15 MW capacity**
- **New downstream fish passage**

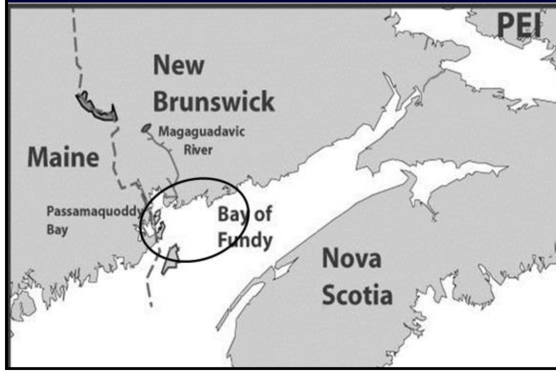


Dam Passage Summary

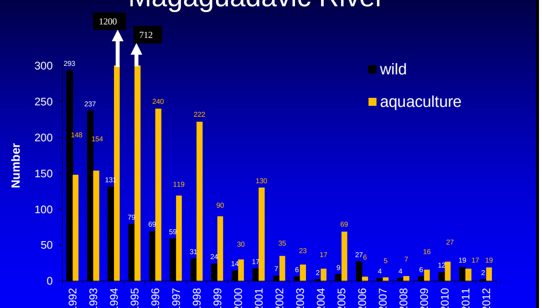
Species	No. at dam	Lost	Via Bypass	Via Turbine	Turbine Mortality
Smolt 05s	55	31%	0%	69%	29%
Kelt 07 08s	27	0	15%	75%	70%
Eel 06s	25	0	16%	76%	100%
Alewife 07s	13	38%	0%	62%	58%

Carr, J.W. & Whoriskey, F.G. 2008. Migration of silver American eels past a hydroelectric dam and through a coastal zone. Fish. Manag. Ecol. 15: 393-400.

Salmon Aquaculture

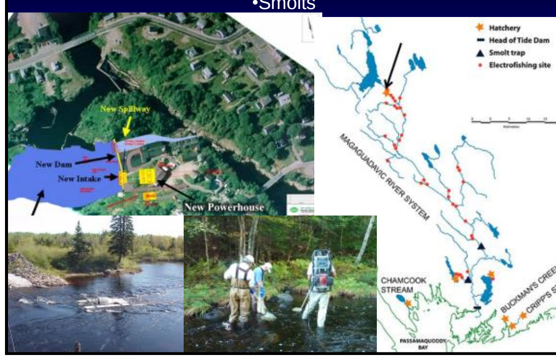


Wild vs Escaped Aquaculture Salmon Magaguadavic River



Leakage from Hatcheries

- Fry and parr
- Smolts



Salmon Aquaculture Impacts

- Competition
- Diseases
- Parasites
- Genetic Introgression

Bourett, V, O'Reilly, P.T, Carr, J.W, Berg, P.R & Bertatchez, L. 2011. Temporal change in genetic integrity suggest loss of local adaptation in a wild Atlantic salmon (*Salmo salar*) population following genetic introgression by farmed escapees. Heredity 106:500-510.

Multi River Approach

- Three Donor Rivers
  - Nashwaak
  - Canaan
  - Hammond

Acknowledgements

- New Brunswick Department of Agriculture, Aquaculture, and Fisheries
  - New Brunswick Total Development Fund
- Olin Foundation
- Canaan River Fish & Game Association
- Field and Office Staff

Land base Aquaculture

- Research suggests that land-based closed-containment systems for **Atlantic salmon** are:
  - **technically** viable
  - **biologically** feasible, and
  - **economically** sustainable at 3000 ton/yr scale
    - pilot and commercial-scale projects must demonstrate economic viability

Dam Delays

Species	Passage on 1st approach	Multiple approaches		
	No.	% (No.)	Median No. approaches	Median Hours at dam (range)
Kelt 07	9	25% (3)	4 (4 - 12)	5.1 (0.1 - 91)
Kelt 08	6	60% (9)	10 (2 - 23)	5.4 (0.5 - 61)
Eel 06	16	36% (9)	2 (2 - 4)	0.5 (0.02 – 100)
Alewife 07	9	31% (4)	2 (2 - 6)	4 (1 - 202)
Alewife 08	7	59% (10)	4.5 (2 - 9)	2 (1 - 199)

Conclusions

- Stocking has not made a difference in salmon recovery efforts
- Need to minimize key limiting factors
- Need to look at the big picture
  - Restore diadromous species

Turbine Passage

Species	No.	Alive	Median Size (Range) cm	Dead	Median Size (Range) cm
Smolt 05	38	27	17 (15-20)	29%	17 (15-17)
Kelt 07 08	19	3	49 (40-63)	84%	60 (45-87)
Eel 06	19	0		100%	92 (76-101)
Alewife 07 08	12	5	27 (26-30)	58%	25 (25-27)

Carr, J.W. & Whoriskey, F.G. 2008. Migration of silver American eels past a hydroelectric dam and through a coastal zone. Fish. Manag. Ecol. 15: 393-400.

Dam Passage Summary

Species	No. at dam	Lost	Spill	Fway	Bypass	Turbine
Smolt 05s	55	31%		0	0%	69%
Kelt 07s	15	20%	6.7%	0	6.7%	66.7%
Kelt 08s	12	0	0	0	25%	75%
Eel 06s	25	0	4%	4%	16%	76%
Alewife 07s	13	38%	0	0	0%	62%

Smallmouth Bass
Objectives

1. Reviewed 15 years of electrofishing data
   A. Occurrence of bass
   B. Potential for bass and salmon interactions

2. Reviewed bycatch information from smolt and adult salmon monitoring

Carr, J.W. & Whoriskey, F.G. 2009. Atlantic Salmon (Salmo salar) and Smallmouth Bass (Micropterus dolomieu) Interactions in the Magaguadavic River, New Brunswick. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/074. Iv + 10pp.

DNA Analysis of Adult Returns

Year	Adult Return	Live Gene Bank		Wild	Unknown
		Fry	Parr		
2005	9	1	3	1	4
2006	27	9	5	7	6
2007	4	2		2	0
2008	4	0	0	0	4
2009	6		1	0	5
Total	**50**	**13 26%**	**9 18%**	**10 20%**	**18 36%**

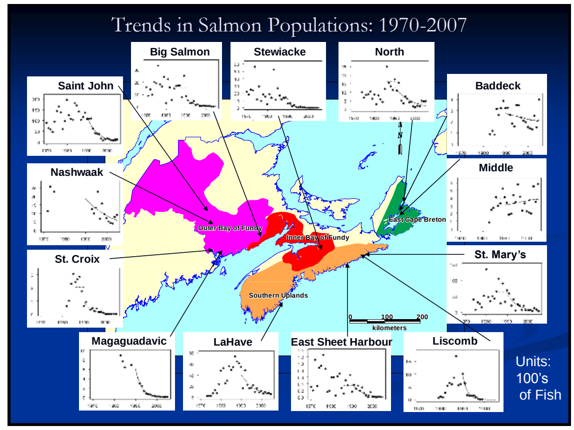
Smolt to Adult Survival

Fry = 1.5% & Parr = 0.2%

The role of population dynamics in the recovery planning for Atlantic salmon
Jamie Gibson, Fisheries and Oceans Canada

The Role of Population Dynamics in Recovery Planning for Atlantic Salmon Populations

Jamie Gibson
Fisheries and Oceans Canada
Bedford Institute of Oceanography
Dartmouth, Nova Scotia



What is Population Dynamics?

- Population dynamics is the sub-discipline of ecology dealing with factors that influence population growth
- Ideal for evaluating questions like:
  - Is a population expected to extirpate or recover?
  - How much of a change in a life history parameter is required to recover a population?
  - How long will it take a population to recover?
  - Will a proposed recovery action be sufficient to recover a population or will other interventions be required?

Overview

- Population dynamics and models for Atlantic Salmon
- Applications:
  - Past and present dynamics and population viability
  - Implications for stocking programs
  - Differences in dynamics among DU's and populations
  - Evaluating linkages between survival and environmental conditions
- Summary

Why Use Models?

- Models are mathematical or conceptual representations of a system that allow us to explore how the system will respond to changes in the inputs
- Humans use models all the time
- A population model can be used to explore how a population will increase or decrease in size with changes in survival rates, carrying capacity of watersheds, proportions maturing as 1SW or 2SW salmon, etc.
- Population models are always simplified representations of life, which is very complicated
- Models are not right or wrong, just more useful or less useful

Conceptual Framework: Equilibrium Analysis

- Begin by dividing the life cycle into two parts
  - eggs to smolt (assumed density dependent)
  - smolt to eggs (lifetime egg production: assumed density independent)
- Equilibrium population size occurs where the number of smolt/egg equals the inverse of number of eggs/smolt
- The equilibrium is an attractor towards which the population will move if the life history parameters do not change
- Recovery planning is about choosing actions that will move this attractor to a level above the recovery target

Egg to Smolt Survival

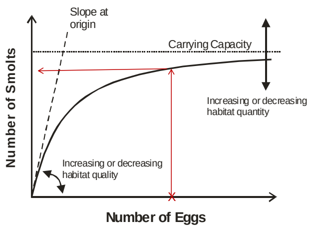
•Beverton-Holt Stock-Recruitment Model

•2 Parameters:

-slope at the origin

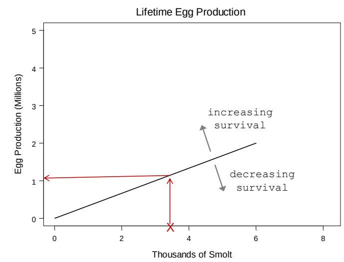
-asymptotic recruitment level (carrying capacity)

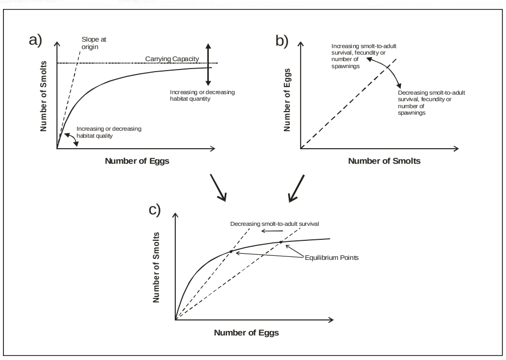
•Further detail possible



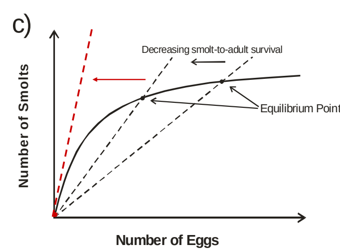
Lifetime Egg per Smolt Production

- Parameters:
  - survival at sea
  - post-spawning survival
  - sex ratio
  - fecundity
  - maturity probabilities

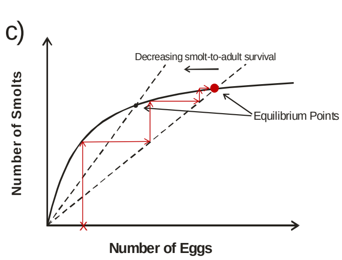




Equilibrium Points



Equilibrium Points as Attractors

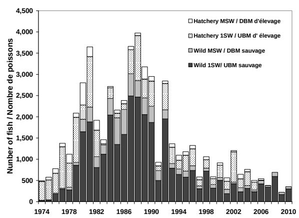


Changes in Dynamics of Populations from Past to Present

- For recovery planning, it is of interest to know how the dynamics of a population has changed
- In the Maritimes Region, changes in at-sea survival has been a focus
- Little information to quantify these changes
  - Wild smolt monitoring programs only extend back to the mid-1990's (Big Salmon River is an exception)
  - Most longer term inferences are from hatchery return rate time series
- Solution: Model the available data to evaluate past and present dynamics and quantify these changes

Example: LaHave River Atlantic Salmon

- Population above Morgan's Falls (at least a partial barrier to upstream migration)
- Abundance increased rapidly in the 70's and 80's due to:
  - Installation of a fish ladder
  - Stocking
  - Commercial fishery closures
- Declining trend in abundance since the mid-80's
- Acidification is not as significant as in some other rivers



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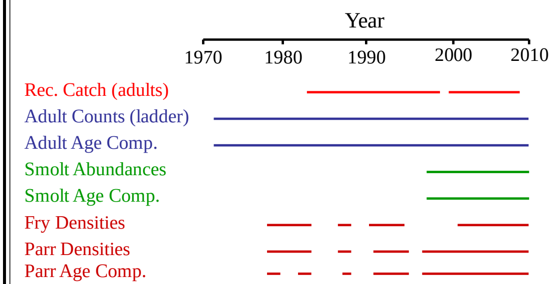
LaHave River Salmon Data



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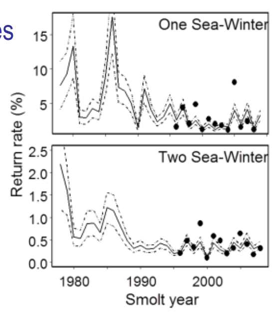
LaHave River: Smolt-to-Adult Return Rates

- 1SW return rates declined from an average of 7.3% in the 1980's to 2.2% in the 2000's
- 2SW return rates declined from an average of 0.7% in the 1980's to 0.3% in the 2000's
- Post-spawning survival has decreased from an average of 0.31 in the 1980's to 0.20 in the 2000's



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LaHave River Atlantic Salmon Population Dynamics: Past and Present

	1980's			2000's		
	Min.	Mean	Max.	Min.	Mean	Max.
Max. Egg-Smolt Survival:		0.017			0.013	
Carrying Capacity (smolts):		147,700			119,690	
Lifetime EPS:	87	**218**	489	29	**63**	111
Max. Lifetime Reprod. Rate:	1.44	**3.59**	8.08	0.39	**0.84**	1.49

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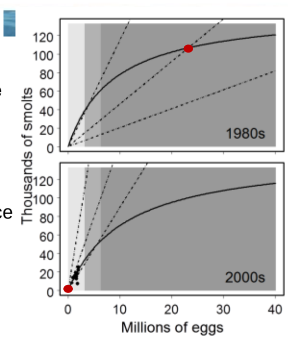
LaHave River Equilibrium Analyses

- Equilibrium occurs where the rate at which eggs produce smolts equals the rate at which smolts produce eggs throughout their lives

Equilibrium Spawner Abundance

	1980s	2000s
mean	**23.1**	**0**
min	3.9	0
max	63.3	4.4



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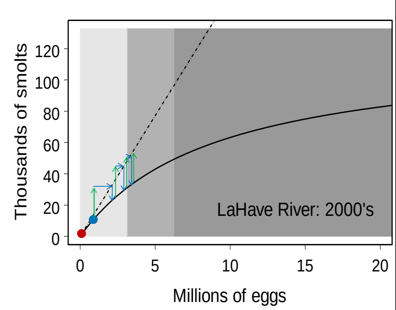
Evaluating Stocking Effectiveness with a Model

- Equilibrium shown in red; starting population in blue
- Stock 20,000 smolts/year (green lines)
- Assume no genetic effects of stocking
- Assume survival of wild and stocked smolts is the same
- Population grows to a new equilibrium of about 60% the CR



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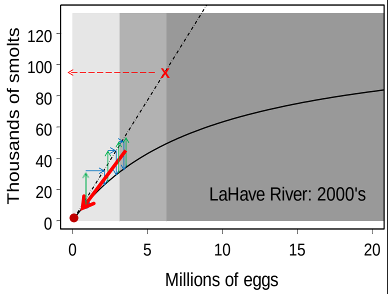
Evaluating Stocking Effectiveness

- If stocking ceases, the population rapidly returns to its original equilibrium
- The underlying dynamics of the population are unchanged
- Abundance increases are less if survival of stocked smolts is lower



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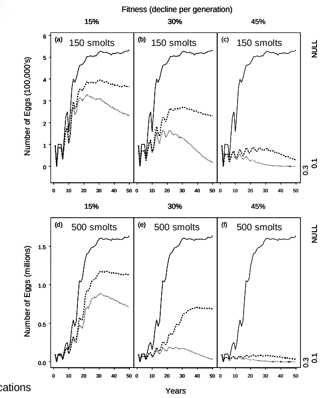
Fitness Effects

- Big Salmon River population dynamics assumed
- Smolts are collected as they leave river, raised to adults and bred in captivity
- Fitness effects modelled using the breeders equation
- Effects depend on the fitness decline per generation and heritability
- Effects only evident after a few generations



Bowlby and Gibson. 2011. Ecological Applications

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Stocking Evaluation Summary

- A hatchery program alone is not a recovery program per se
  - Can mask issues with the population
  - The numbers alone don't work out for many populations
  - Genetic effects may lead to fitness reductions
- Hatchery programs:
  - Do have a role in preventing extirpations
  - May have a role in reducing time to recovery if threats to populations are addressed

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Comparison of Dynamics of Southern Upland and Outer Bay of Fundy Salmon Populations

- Population dynamics models developed for two populations in the Southern Upland and two in the Outer Bay of Fundy
- Southern Upland:
  - Lahave River (above Morgans Falls)
  - St. Mary's River (West Branch)
- Outer Bay of Fundy
  - Nashwaak River
  - Tobique River
- Abundance is in decline in all 4 rivers

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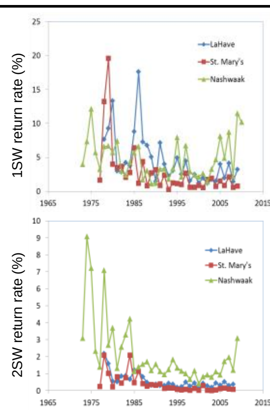
Comparison of Smolt-to-Adult Return Rates for 3 Populations

- Return rates are currently lowest for the St. Mary's (West Br.) population and highest for the Nashwaak population
- Little long term change for the Nashwaak population in 1SW return rates



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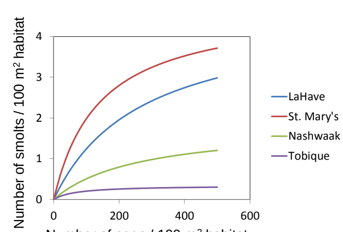
Comparison of Freshwater Production Curves for 4 Populations

- Both carrying capacity and max. egg-smolt survival is highest in the St. Mary's followed by the LaHave
- Freshwater production appears quite low in Nashwaak and Tobique
- Whether FW production in the St. Mary's and LaHave is also low is unclear



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Comparison of the Dynamics of Six Salmon Populations

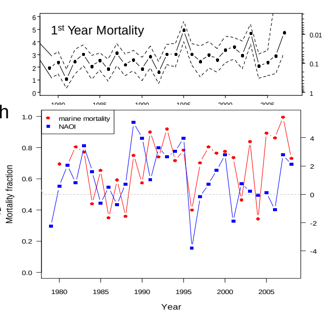
	Population					
	LaHave (above Morgans Falls)	St.Mary's (West. Br.)	Nashwaak	Tobique	Middle	Baddeck
Max. egg-to-smolt survival	0.017	0.034	0.007	0.005		
Smolt carrying capacity (number per 100 m² of habitat)	4.6	4.8	1.8	0.3		
1SW return rate (%)	2.2	1.2	4.95			
2SW return rate (%)	0.3	0.1	1.29			
Lifetime egg production per smolt	63	30	151	83*		
Max. lifetime reprod. rate (spawners/spawner)	0.84	1.01	1.13	0.41	3.22	1.61
Past max. lifetime reprod. rate	2.78	3.62	2.49			

Comparison of Dynamics Summary

- Abundance declines similar for all four populations but the dynamics are very different
- Southern Upland:
  - Both populations have very low at-sea survival with the compounding effects of potentially low freshwater productivity
- Outer Bay of Fundy:
  - Both populations have quite low freshwater productivity with the compounding effects of low at-sea survival
  - Tobique River has the added issue of reduced survival of smolts due to hydro-electric development
- All are predicted to extirpate in the absence of human intervention or an increase in survival for some other reason (the Nashwaak more slowly)

LaHave River: Repeat Spawning Dynamics

- Frequency of repeat spawning has decreased
- 1st year mortality trended upward through time
- 2nd year mortality did not show a trend but was correlated with the NAOI
- 1st year mortality may be occurring in freshwater or near shore

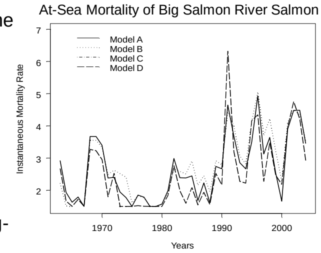


Hubley and Gibson, 2011, Can. J. Fish. Aquat. Sci.

Investigating Hypotheses about Declines in At-Sea Survival for IBoF Salmon

- Developed a model to derive a mortality rate time series
- Compiled a set of 84 indices representative of
  - Environmental conditions
  - Community changes
  - Human activities
- Few indices showed long-term increases similar to the mortality time series

At-Sea Mortality of Big Salmon River Salmon



Bryan, J. 2008. M.Sc. Thesis, Acadia University

Perspectives

- Useful for evaluating the effects of addressing well-studied threats (river acidification, fishing, fish passage, habitat loss)
- Not as useful for less well-studied threats (urbanization, agriculture, invasive species) because we can't link recovery actions directly to changes in life history parameters
- Population models nearly always include an assumption that the near future will be similar to the recent past
  - Can't be known *a priori*
- Do provide a logical test of our belief systems
  - In recovery planning, they can be used to help us determine the consequences of various courses of action, and in that way are use as a guide

Canada

An overview of historical enhancement and recovery initiatives for Southern Upland Atlantic salmon
Alex Levy, Fisheries and Oceans Canada

Fisheries and Oceans Canada / Pêches et Océans Canada

An Overview of Historical Enhancement and Recovery Initiatives for Southern Upland Atlantic Salmon

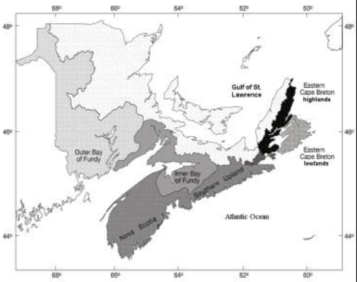
Alex Levy, Jamie Gibson, and Shane O'Neil
Fisheries and Oceans Canada
Bedford Institute of Oceanography
Dartmouth, NS

September 19, 2013

Fisheries and Oceans Canada / Pêches et Océans Canada

Overview

- COSEWIC identified 4 large groupings (Designatable Units, DUs) of A. salmon within the Maritimes Region
- COSEWIC assessed all four DUs as endangered in 2010
- Inner Bay of Fundy A. salmon listed under SARA since 2003
- Recovery Potential Assessment for Southern Upland A. Salmon completed in 2012



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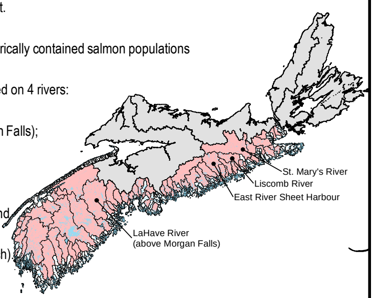
Southern Upland

- Population assemblage of A. salmon that occupies NS rivers from northeastern mainland near Canso into the Bay of Fundy at Cape Split.
- 72 rivers considered to have historically contained salmon populations
- Adult population monitoring focused on 4 rivers:
  1. LaHave River (above Morgan Falls);
  2. Liscomb River;
  3. East River Sheet Harbour; and
  4. St. Mary's River (West Branch).



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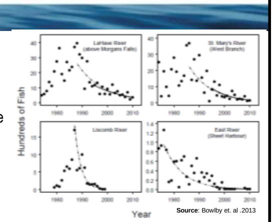
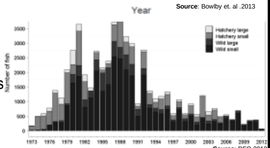
Status

- SU A. salmon populations have been in decline for more than two decades
- Annual adult abundance in four rivers declined by 88% to 99% from observed abundance in the 1980's
- Similar declines observed in recreational catch data series
- Region-wide comparisons of juvenile densities from more than 50 rivers indicate significant ongoing declines between 2000 and 2008/2009 & provide evidence for river-specific extirpations
- Remaining populations are at Critically Low Abundance





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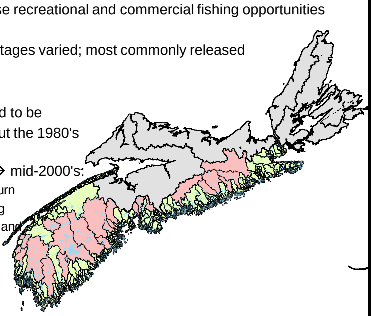
Stocking for Fisheries Enhancement

- Primarily intended to increase recreational and commercial fishing opportunities
- Broodstock locations & life stages varied; most commonly released young parr & smolts
- Widely applied and appeared to be numerically viable throughout the 1980's
- Discontinued in the 1990's → mid-2000's:
  - Could not offset the downturn in marine survival (including economic considerations); and
  - Wild populations were not large enough to ensure genetic risks were low.



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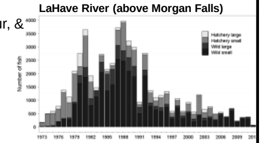
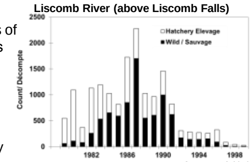
Contributions from Stocking

- Contributions from stocking in 3 of the major programs (LaHave, East River - Sheet Harbour, & Liscomb) were evaluated in the SU Recovery Potential Assessment (Bowlby et al. 2013) to assess whether they were successful for population increase or maintenance.
- Two general conclusions:
  1. Proportion of returning hatchery adults progressively declined despite relatively constant or generally increasing numbers of stocked smolts during the 1980's &1990's
     - Stocking was not able to maintain populations alone
     - Other recovery actions warranted to address threats
  2. Return rates of stocked fish were typically lower than return rates of wild fish.

LaHave River (above Morgan Falls)



Liscomb River (above Liscomb Falls)

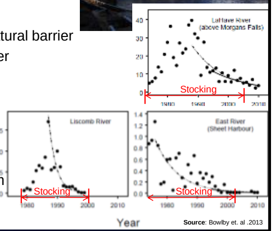


Fish Passage & Population Enhancement

LaHave River – Morgan Falls
- Increase / develop population above natural barrier
  - ~ 51 % of rearing area above barrier
- Fish-way constructed in 1969
- Juvenile stocking from 1971 - 2005

Liscomb River
- Increase / develop population above natural barrier
  - ~ 90 % of rearing area above barrier
- Fish-way constructed 1978
- Juvenile stocking from 1977* - 2000

East River (Sheet Harbour)
- Recolonize population lost to hydroelectric power development
- ~ 95 % of habitat above impassible dam
- Juvenile stocking from 1960's-2003
- Trap & Truck Program

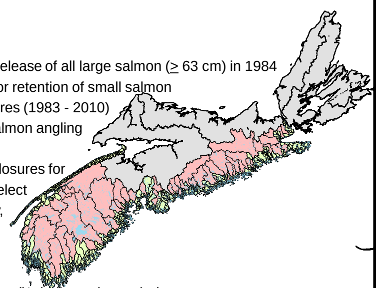


Commercial, Recreational and Aboriginal Fisheries

Commercial Fisheries
- Closure by 1985

Recreational Fisheries
- Mandatory catch-and-release of all large salmon (≥ 63 cm) in 1984
- Progressive closures for retention of small salmon
- Progressive river closures (1983 - 2010)
- Complete closure to salmon angling (2010)
- Seasonal river & pool closures for fishing all species on select salmon rivers (Medway, LaHave, & St. Mary's)

Aboriginal Fisheries
- Restrictions → Complete (including voluntary) closures



SU Supportive Rearing Programs

- **Program**: Collect wild juveniles → Rear to adults in captivity → Release adults

- **Gold River**
  - Juvenile collections in 2001 & 2002 → Adults released in 2003 & 2004
  - Monitoring via electrofishing surveys in 2004-2006
  - Genetic analyses of adults and juveniles

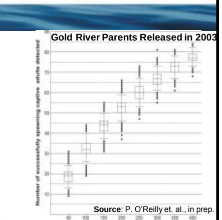
- **Quoddy**
  - Juvenile collections from 6 rivers (New Harbour, Indian Harbour, Ecum Secum, Gaspeareaux, Salmon - Guysborough County and Quoddy*) in 2003 & 2004

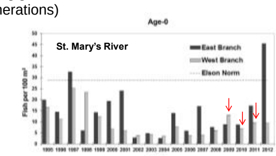
  → Adults released into the Quoddy River (remnant wild pop. & good habitat)

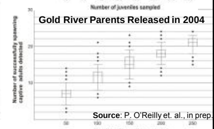
- **St. Mary's**
  - Collections initiated as an "insurance program" for LGB & Supportive Rearing
  - Juvenile collections (West Branch) in 2006 & 2007 → Adults released in 2008-2010
  - Annual e-fishing surveys as part of existing monitoring program

Supportive Rearing

- Genetic analyses of programs in the Maritimes Region indicates that although a moderate number of adults may spawn successfully in a given year, overall efficacy is highly variable
- Unless the number of spawners (and year-to-year spawning consistency) can be increased, such programs (on their own) may not be very efficient at maintaining genetic variation, even in the short term (5-10 generations)







SU RPA Considerations for Recovery

- In contrast with iBOF populations, recovery actions focused on improving freshwater productivity are expected to reduce extinction risk for SU salmon

- Large scale land use changes are the most likely to bring about substantial population increase in Southern Upland salmon
  - Greater impact on total abundance in the watershed rather than on localized density.
  - Coordination of activities at small scales may produce more immediate effects, but of shorter duration than addressing landscape-scale threats.

- SU populations are at critically low abundance - Sensitivity analysis examining the effect of starting population size on population viability highlights the risks associated with delaying recovery actions; recovery is expected to become more difficult if abundance continues to decline, as is predicted for these populations.

Source: DFO 2013b

Perspective on Moving Forward

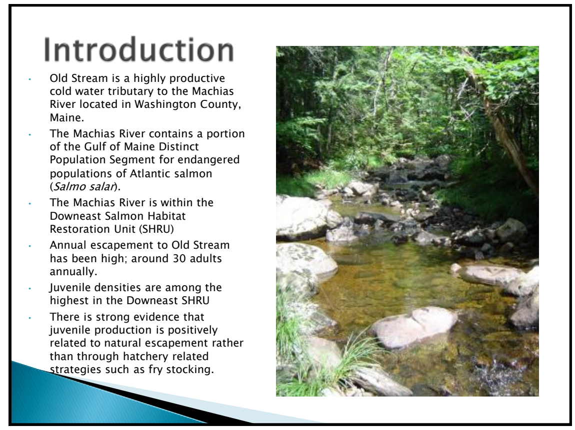
- **Traditional Stocking / Supplementation / Supportive Rearing**
- **Fisheries Closures (Commercial, Recreational, Aboriginal)**
  - **Did not recover populations**
  - **Highlights need to address other threats**

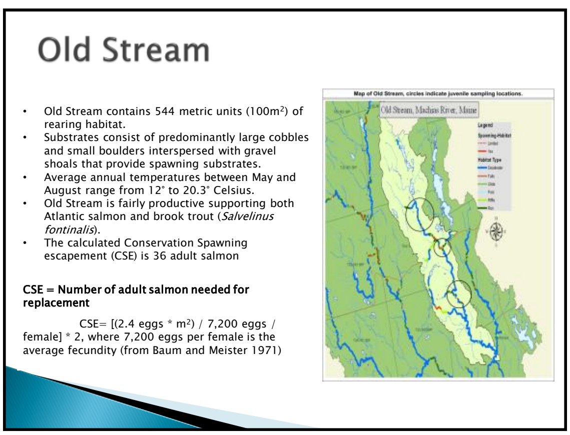
- **Addressing Threats**
  - Focus on improving freshwater habitat quality in Southern Upland to reduce risk of extirpation
  - Watershed planning to identify watershed specific threats for priority action
  - Need to evaluate efficacy of recovery actions (Experimental design & monitoring necessary)
    - To enable transfer of knowledge to other watersheds & Designatable Units with increased certainty and assess magnitude of change
  - Need to accept some level of risk with other recovery actions (w/o efficacy monitoring) in order to act now
  - Need to focus on multiple threats simultaneously

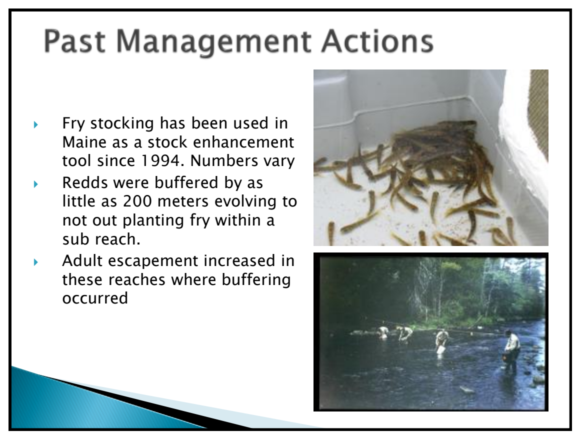
References Cited

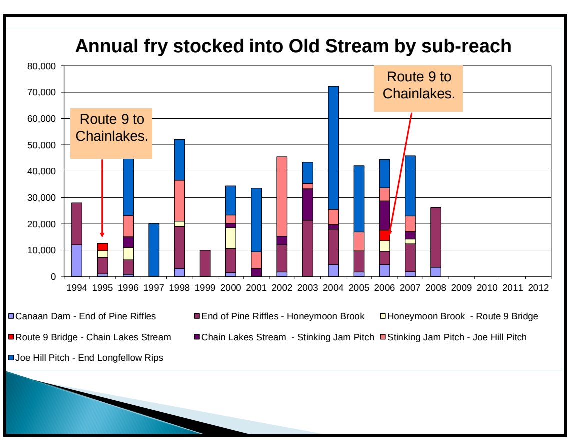
- Bowlby, H.D., Gibson, A.J.F., and Levy, A. 2013. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Status, Past and Present Abundance, Life History and Trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/005. v + 72 p.
- DFO. 2013. Status of Atlantic salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2013/013.
- DFO. 2013b. Recovery Potential Assessment for Southern Upland Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/009.
- DFO 2001. Atlantic salmon Maritime Provinces Overview for 2000. DFO Science Stock Status Report D3-14 (2001) (revised).

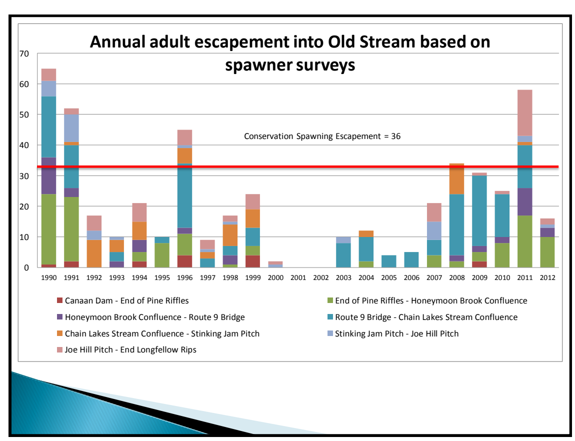
A brief history of Old Stream: how nothing can be the best strategy
Ernie Atkinson, Maine Department of Natural Resources

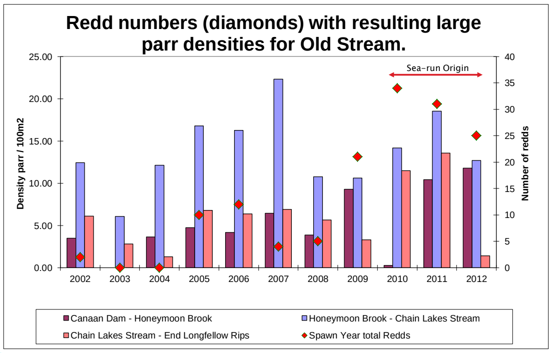










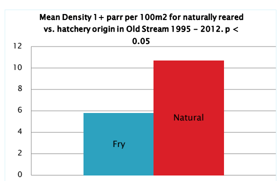


Adaptive Management Actions Taken

- Because juvenile data indicates a relationship between natural production and increased escapement,
- Because there are confounding factors such as fry drift from up stream stocking activities and general movement by salmon parr over two seasons,
- Because Old Stream has been at or close to CSE
- **All stocking of hatchery products was suspended after 2008.**

Results

- Juvenile densities continue to be high especially in historically productive reaches
- After two years without hatchery products, mean densities 10.80 parr /100m^2
  - Mean density for fry origin 1995 to 2009, 5.79 parr / 100m^2
  - Mean density for natural origin over all 10.01 parr / 100m^2
- First cohort of sea-run adults expected in 2013. **Stay tuned!**



Student, Newman, Keuls grouping of mean large parr densities within sample reaches

Group	Mean	n	Sample reach
A	13.006	24	Honeymoon Brook to Chain Lakes Stream
B	7.17	16	Chain Lakes Stream to Longfellow Rips
B	5.657	19	Canaan Dam to Honeymoon Brook

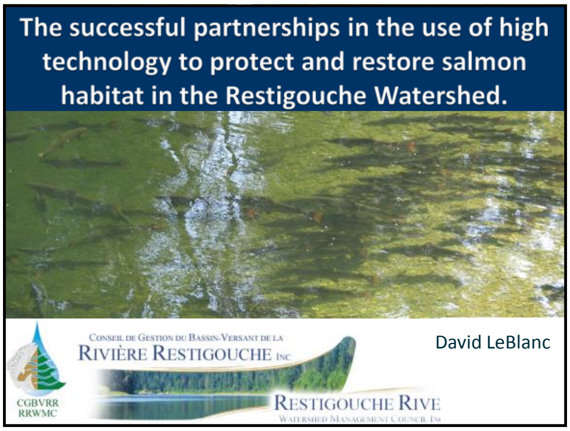
Summary

- Adult returns to the DPS have been low. However, returns to Old Stream have been at CSE.
- Natural production appears to be the difference in survival and return rates for Old Stream
- Large parr densities consistent from year to year with natural reproduction reaches such as the Route 9 Sub-reach more productive than fry origin reaches.
- Early data (2010 - 2012) continues to support that natural reproduction is and has been driving Old Stream salmon densities

Questions?

Success partnership in the use of high technology in the management of salmon habitat: case of the Restigouche River

David LeBlanc, Restigouche River Watershed Management Council

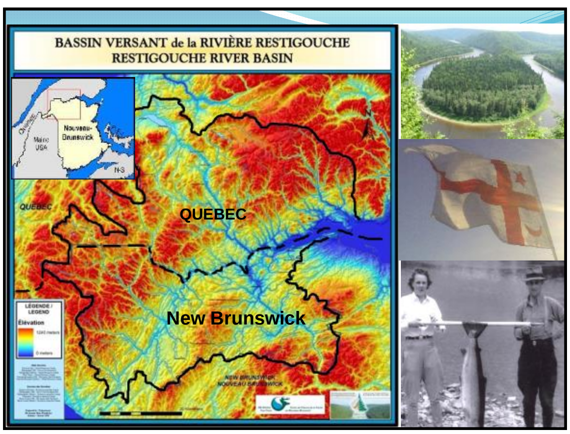


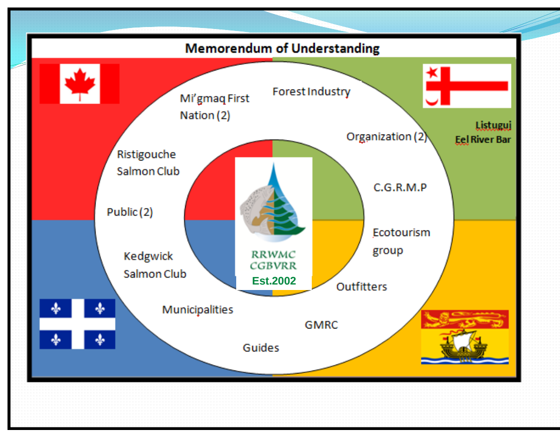
Presentation

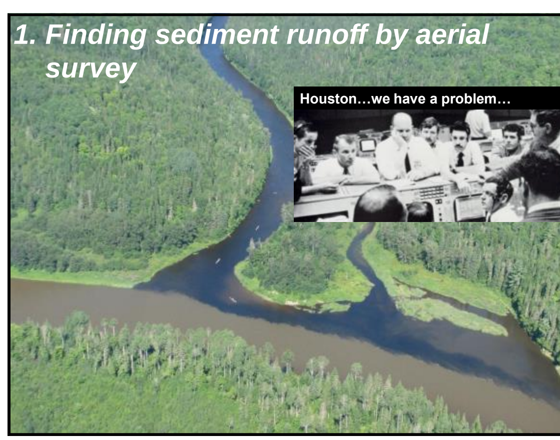
Brief overview of the Restigouche River Watershed Management Council (RRWMC)

What worked in getting partners :

1. Finding sediment runoff by aerial surveys;
2. Calculating Equivalent cut area with GIS in forestry management plan;
3. Using LIDAR imagery to reduce soil erosion from potato fields;
4. Characterizing Salmon habitat with simultaneous image acquisition (thermal and optical);



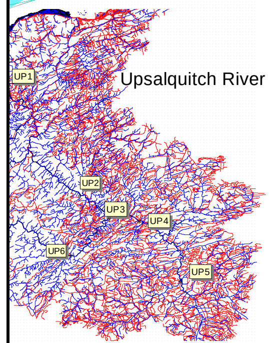




1. Finding sediment runoff by aerial survey

	Fisheries and Oceans Canada Discussion for developing a Protocol to assess erosion and sedimentation in a watershed (2008). Terry Melanson explaining airborne siltation survey.
	Madawaska/Restigouche forest integrated management Council RRWMC CGBVRR Fisheries and Oceans Canada IRVING J.D. IRVING, LIMITED
	ecoACTION IRVING J.D. IRVING, LIMITED
	RRWMC CGBVRR

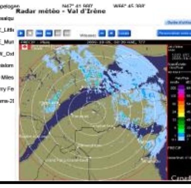
Flight planning



Upsalquitch River

Code	Description	Latitude (deg. min)	Longitude (deg. min.)
KK01	KK_Restigouche	N47° 39.875'	W67° 29.501'
KK02	Rapid_Depot	N47° 49.016'	W67° 44.216'
KK03	Kedgwick Forks	N47° 54.464'	W67° 54.418'
KK04	SBK_Union_Brook	N47° 49.633'	W67° 56.516'
KK05	NBK_Gin_Creek	N47° 58.730 '	W67° 56.084'
LM01	Jardine_Brook	N47° 35.644'	W67° 34.465'
LM02	Gounamitz_LM	N47° 31.441 '	W67° 38.479'
LM03	Gounamitz_forks	N47° 37.374'	W67° 54.513'
LM04	Waganis Brook	N47° 24.111'	W67° 47.618'
Pat01	Patapedia_Restigouche	N47° 50.664'	W67° 22.523'
Pat02	Pollard_Brook	N47° 57.373'	W67° 36.445'
RR01	Tracy_Brook	N47° 46.337'	W67° 25.170'
UP1	Upsalquitch_Restigouche	N47° 53.472'	W66° 57.381'
UP2	Popelogan	N47° 41.988'	W66° 45.398'
UP3	Upsalqu		
UP4	SE_Little		
UP5	SE_Mur		
UP6	NW_Od		
UP7	Ghislain		
10Mile	10 Miles		
Jerry	Jerry Fe		
Jerry2	Dams-2		

Radar météo - Val d'Irène



The flight

- Within 24 hrs after a 20mm+ min rain event
- GPS point. Departure from river forks
- Photos

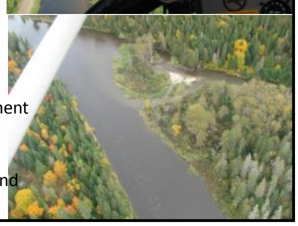
Difficulties

- Extreme events
- Flight conditions ref cloud ceiling

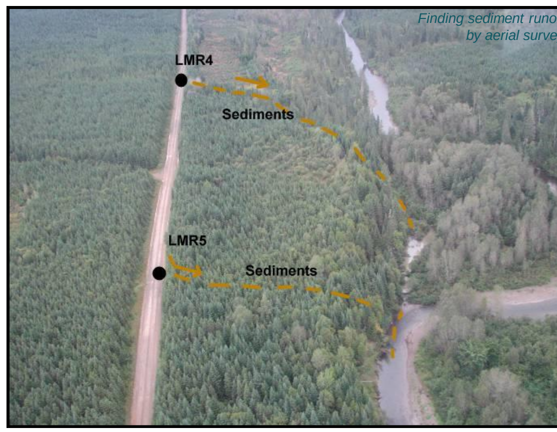
Benefits

- Allow a quick finding of sediment charged streams and stream crossing problems;
- Help to orientate the on ground monitoring

Finding sediment runoff by aerial survey



Finding sediment runoff by aerial survey



Finding sediment runoff by aerial survey

On ground monitoring:

- Precise GPS point
- Pictures and measurement, monitoring of the problem and restoration proposal;
- Fact sheet preparation.

Follow-up to the Forest Licensee

FICHE D'OBSERVATION TERRAIN. SITES D'APPORT EN SÉDIMENTS

Date de l'observation : 21 septembre 2009

Bassin versant : Kedgwick (South Branch)

Ruisseau : Hornes Brook

Localisation : N47° 58.223' W67° 53.908'

Niveau de la source : Important

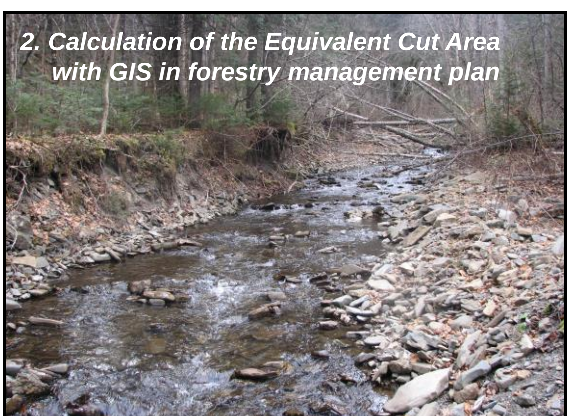
Problématique : Le fossé de la route forestière du côté Sud-Est du ponceau se déverse directement dans le ruisseau au niveau du ponceau.

Solution : Création de bassins de sédimentation et de fossés de déviation de l'écoulement en amont de la pente.

Photos :

Vue vers l'ouest	Vue vers l'est

Pour plus d'informations : David LeBlanc
Conseil de Gestion du Bassin Versant Restigouche
Tel : (506) 759-7380
Email : restigouche@globetrotter.net



2. Calculation of the Equivalent Cut Area with GIS in forestry management plan

	Workshop on water and watershed in forestry management, Campbellton, 2008. Plamondon as a guest speaker. Member of the «Madawaska/Restigouche forest integrated management Council»
	New Brunswick, ACADIAN TIMBER, AV Group
	RBC Blue Water Project™
	UNB

Two ways to address environmental issues !

Madawaska-Restigouche public forest integrated management Council

Studies on flow calculation and disturbance impacts

Robert Langevin, biologiste M. Sc.
Ministère des Ressources naturelles, de la Faune et des Parcs du Québec
Direction de l'environnement forestier

André P. Plamondon, ingénieur forestier Ph. D.
Université Laval
Faculté de foresterie et de géomatique

«Méthode de calcul de l'aire équivalente de coupe d'un bassin versant en relation avec le débit de pointe des cours d'eau dans la forêt à dominance résineuse»

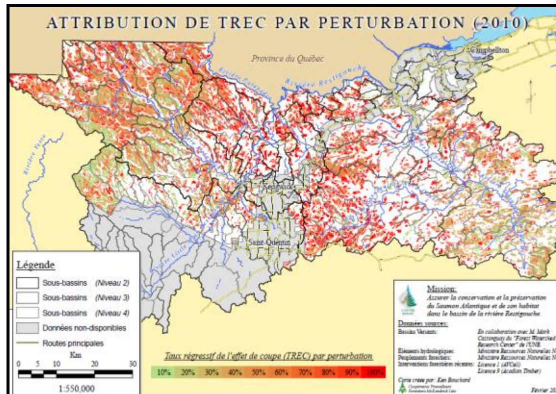
Equivalent Cut Area(ECA)

Regressive rate of cut effects (RRCE) for each of the forest disturbance

RRCE Standard per type of intervention or disturbance (%)

Âge of disturbance	Clear Cuts: Traditionnal	Clear Cuts: Regen Protection	Progressives cuts: Strip cut	Progressives cuts: Prescription	Sylvicultures: Comm. Thinning	Sylvicultures: Plantations	Sylvicultures: N.-Comm. Thinning	Sylvicultures: Herbicides	Natural: BlowD	Natural: Fire
	C, CC	*CCR*	*PA*	*DSH, HM, GS, LR*	*CT*	*BF, BP, BS,*	*BT, CL*	*HB*	*W*	*B*
	FW, RR	*OR*	*ST*	*OSH, PC, SA, SC*	*CTR*	*DF, DP, FP*	*DT, FC*			*BB*
	SE	*ORTH*		*SCTH, SH, SHELTH*		*PL, RF, RI*	*IT, TI*			*BU*
(year)		*RC*		*SR, SWR, TP*		*RP, RU*	*XT*			*PB*
0	100	85	50	35	35	100	85	100	80	100
1	100	80	50	30	30	100	80	95	80	100
2	100	75	50	25	25	100	75	90	80	100
3	100	70	50	20	20	100	70	85	80	100
4	100	65	50	15	15	100	65	80	80	100
5	100	60	50	10	10	100	60	75	80	100
6	95	55	47,5	5	5	95	55	70	75	95
7	90	55	45	0	0	90	55	65	70	90
8	85	50	42,5	0	0	85	50	60	70	85
9	80	45	40	0	0	80	45	55	65	80
10	75	45	37,5	0	0	75	45	55	60	75
11	70	40	35	0	0	70	40	50	55	70
12	65	35	32,5	0	0	65	35	45	50	65
13	60	35	30	0	0	60	35	45	50	60
14	55	30	27,5	0	0	55	30	40	45	55
15	55	30	27,5	0	0	55	30	35	40	55

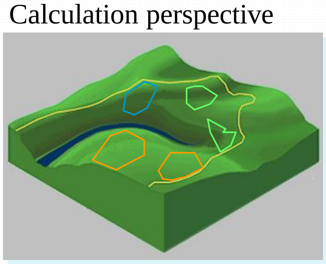
Equivalent Cut Area(ECA)



Equivalent Cut Area(ECA)

Equivalent Cut area (ECA) calculation

Calculation perspective



% of the watershed

ECA Value in 2010

RREC value

1995 – 25 % * 45 % = 11 %

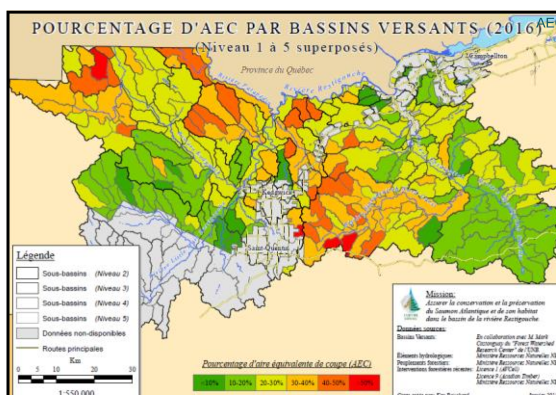
2000 – 10 % * 60 % = 6 %

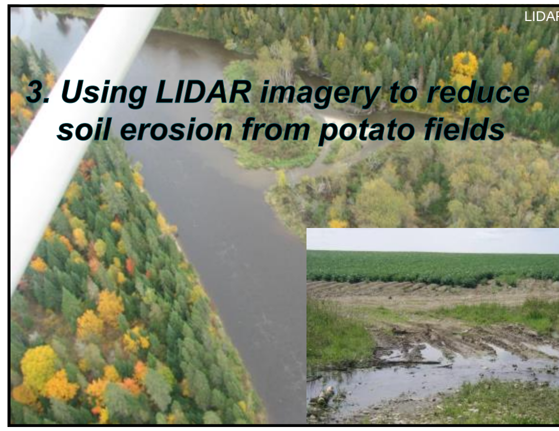
2003 – 35 % * 90 % = 32 %

TOTAL 70% 49% ECA

Represents the sum of areas of each of the disturbances, which are multiplied by their respective value in RRCE

Equivalent Cut Area(ECA)



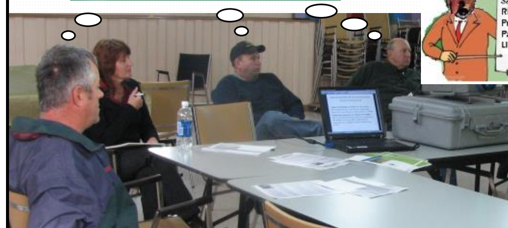


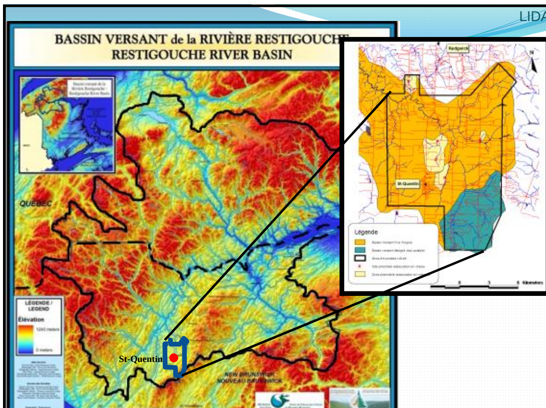
3. Using LIDAR imagery to reduce soil erosion from potato fields

	Sediment runoff survey!!
	RRWMC CGBVRR, Saint-Quentin, Savoie, New Brunswick Dept. Environment, New Brunswick Agriculture, Fisheries and Oceans Canada POTATO FARMERS
	Atlantic Salmon Conservation Foundation, New Brunswick Environmental Trust fund, Saint-Quentin, Savoie
	Eastern Canada Soil and Water Conservation Centre Centre de conservation des sols et de l'eau de l'est du Canada

Eastern Canada Soil and Water Conservation Centre

Centre de conservation des sols et de l'eau de l'est du Canada





LIDAR

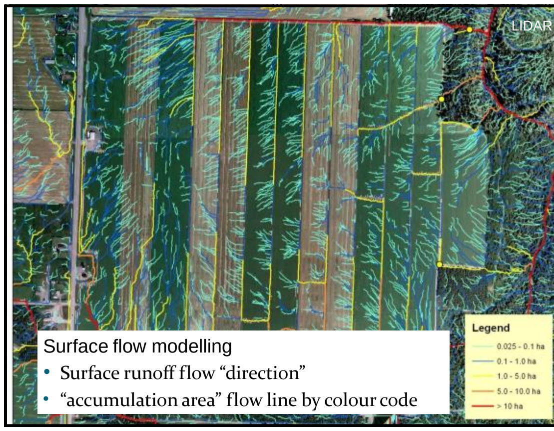
- LIDAR (Light Detection and Ranging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target.
- Laser airborne survey
- 1 point per sq. m
- Ground elevation precision 10-15 cm

Aerial survey – Data acquisition

Leading Edge Geomatics

- Leading Edge Geomatics (Oromocto)– June 14^{th} to 22^{nd}
- Joint projects in Northern NB to reduce costs
- Cessna equipped with RIEGL LiDAR Q-680
- LiDAR data that had been ortho-rectified, corrected, and partly classified and that had been then aggregated
  - « points XYZ, Bare Earth DEM ASCI
  - « Points All hits LAS »,
- Downloaded from FTP site

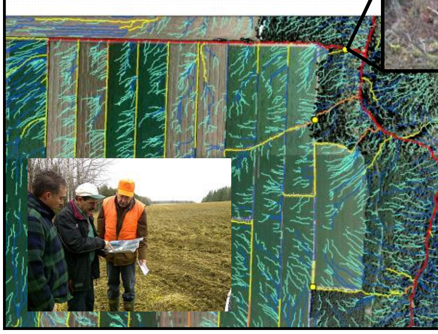
LIDAR

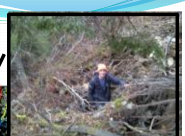


Surface flow modelling

- Surface runoff flow “direction”
- “accumulation area” flow line by colour code

Runoff location and field survey

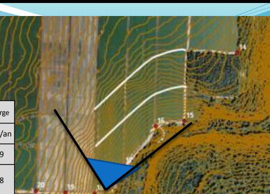


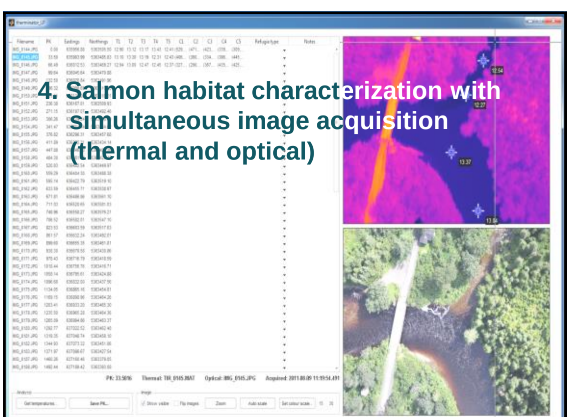


LIDAR

RUSLE2 software was then used to Determine soil loss and silt charge to be included in various scenarios

Points	Situation	Scenarios	Hill		Soil lost	Charge
			%	Length (m)	t/ha/y	t/ha/an
15	Actuel le+bande	Bande enherbée (3m)	4.9	420	11	1.9
15	Terrasse en contour	Avec 2 terrasses en contour.	4.9	420	3.1	2.8
16	Actuelle	Cultivé haut en bas	5.2	460	11	11
16	Actuel le+bande	Bande enherbée (3m)	5.2	460	11	2.1
16	Terrasse en contour	Avec 2 terrasses en contour.	5.2	460	3.3	3.0
17	Actuelle	Cultivé haut en bas	5.3	375	11	11
17	Actuel le+bande	Bande enherbée (3m)	5.3	375	11	1.9
17	Terrasse en contour	Avec 2 terrasses en contour.	5.3	375	3.2	2.9
18	Actuelle	Culture en contre-pente	2.2	600	4	4
18	Actuel le+bande	Bande enherbée (3m)	2.2	600	4	.73
19	Actuelle	Culture en contre-pente	1.8	275	2.8	2.8
19	Actuel le+bande	Bande enherbée (3m)	1.8	275	2.8	.42





4. Salmon habitat characterization with simultaneous image acquisition (thermal and optical)

4. Salmon habitat characterization with simultaneous image acquisition (thermal and optical)

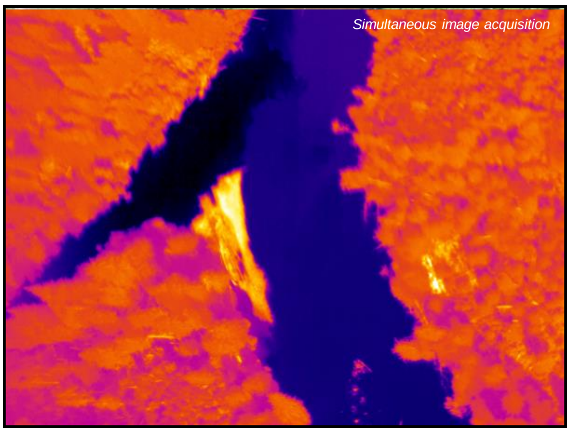
	High water temperature episode in 2009 (Miramichi) and planning to monitor and evaluate the situation on the Restigouche. *Ressources naturelles et Faune* Québec
	INRS Université d'avant-garde
	CRE Brunswick
	INRS Université d'avant-garde

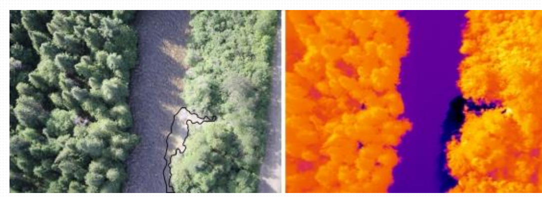
Objectives and applications:

- Locate cold water sources in the watershed to protect them;
- Update DFO's calculation of the amount of juvenile habitat;
- Locate habitat problems;
- Advance the research and knowledge on thermal refuges and survey technology to apply to other watersheds.

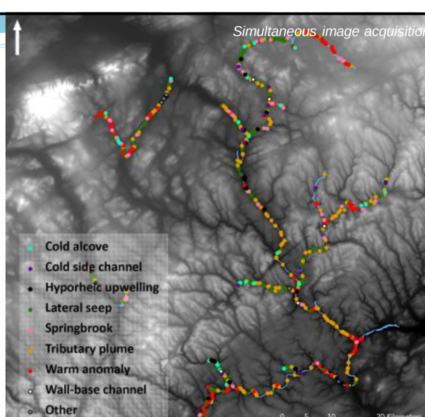
Major component of images acquisition

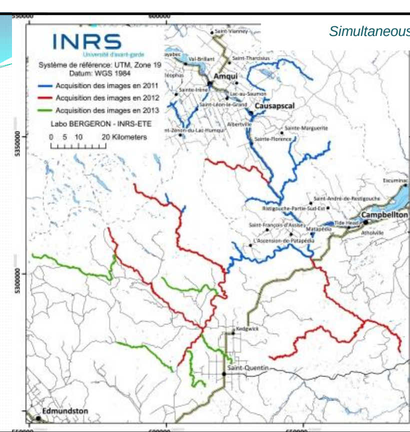
Component	Details	Notes
Thermograph	1-3 per tributary	T° every 15 min
TIR camera	FLIR SC660	640x480 pixels @ ±1°C
Optical camera	Canon EOS 550D	5184 x 3456 pixels (17.9 MP)
Pan-tilt system	Directed Perception PTU-D48	Permits 10° freedom of movement for cameras
GPS system	Garmin GPS76 CSx	Accuracy ~2m





- **Synchronized picture every 2 sec**
- **Speed of 30-40 km/hr**
- **Variable altitude, depending on watercourse width**





Conclusion

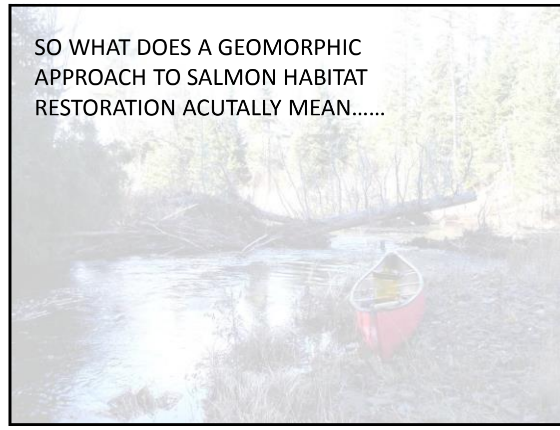
What worked in our collaboration projects:

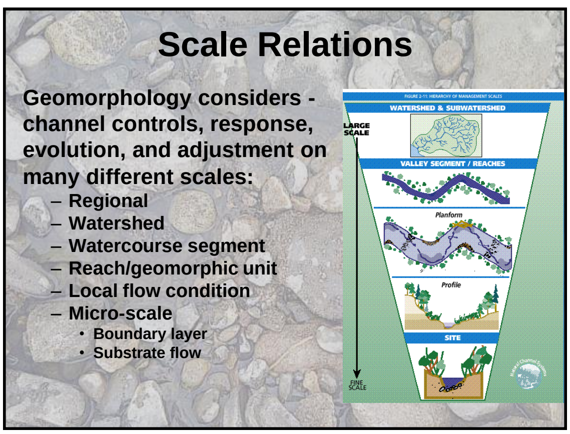
- JDI invested $250 000 in 2010 on road enhancement; Acadian Timber restored dozens of sediment runoff sites; long term collaboration;
- AVCell is now committed in reviewing and calculating ECA for the next management plan;
- Potato farmers started to adopt soil erosion prevention measures and a major project is approved for next year;
- Hundreds of thermal refuges have been located and thousands of high resolution image of 770 km salmon habitat have been acquired;
- ...

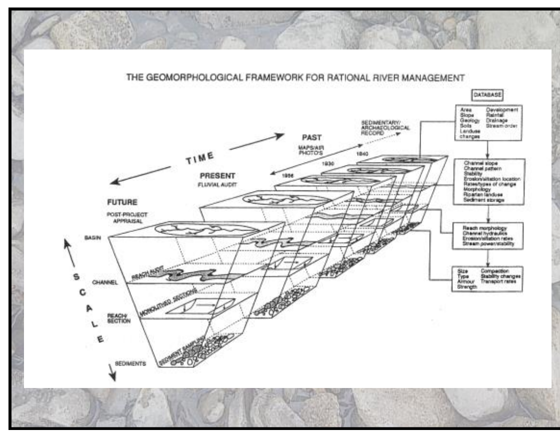
FULL PRESENTATION ON ASCF & CRI WEBINAR
SEPTEMBER 25, 2013 AT 2 PM AST - HABITAT ASSESSMENT TECHNOLOGY
(WWW.SALMONCONSERVATION.CA » RESOURCES)

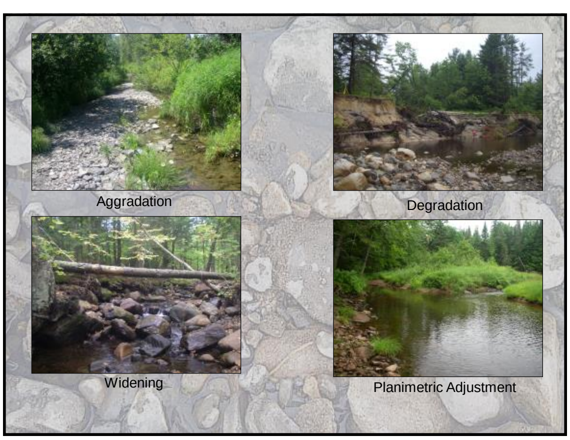
Geomorphic approaches to Atlantic salmon habitat restoration

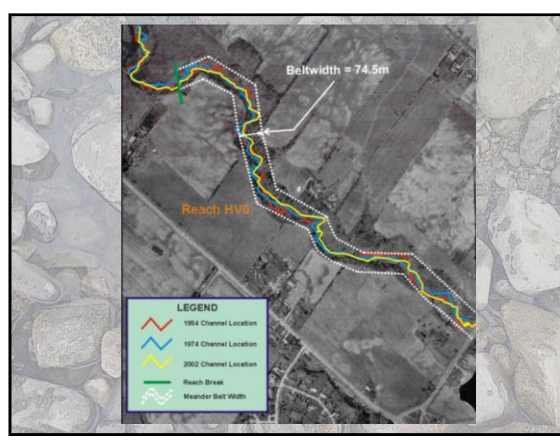
Ron Jenkins, Parish Geomorphic Ltd

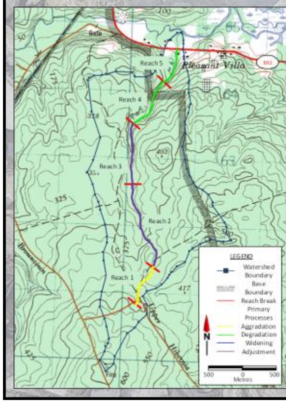












Geomorphic Processes

1) Aggradation
2) Degradation
3) Widening
4) Planimetric Adjustment

Restoration and stabilization works <u>must</u> take into consideration:

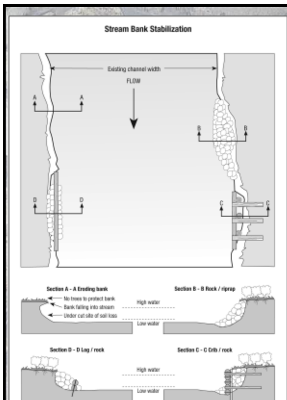
-The impacts of the work on the site, the reach and the stream as a whole?

-What may impact your works (i.e. channel adjustment)?

-What is the anticipated lifespan of the work?

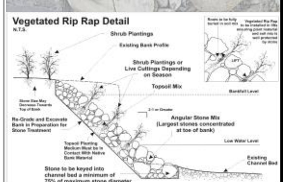
-Does the design consider the underlying causes that created the need for the work?

- Are the proposed works suitable for the site?

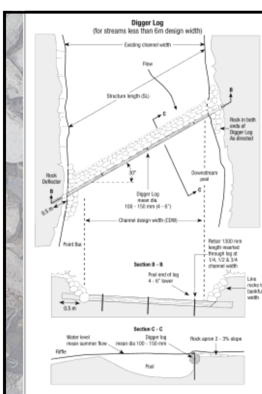


DFO: Ecological Restoration of Degraded Aquatic Habitats: A Watershed Approach, 2006

Riprap

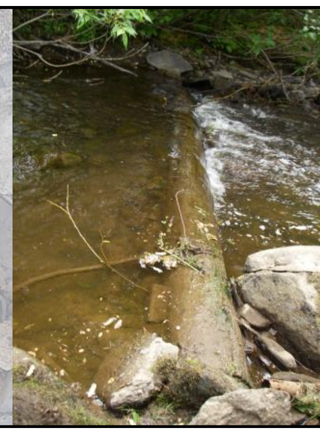


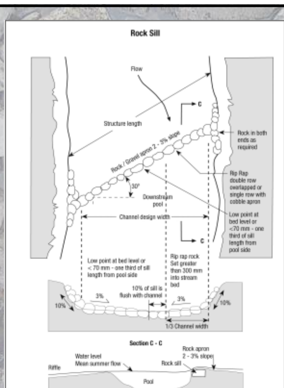
PARISH geomorphic



DFO: Ecological Restoration of Degraded Aquatic Habitats: A Watershed Approach, 2006

Digger Log

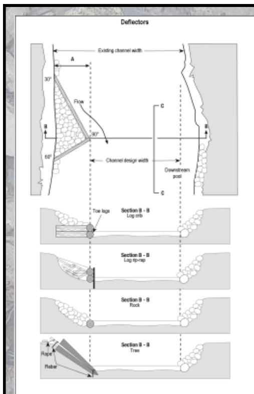


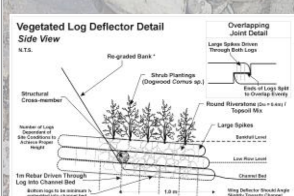


DFO: Ecological Restoration of Degraded Aquatic Habitats: A Watershed Approach, 2006

Rock Sill

Deflector





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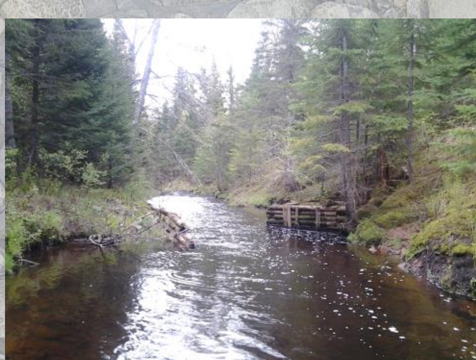
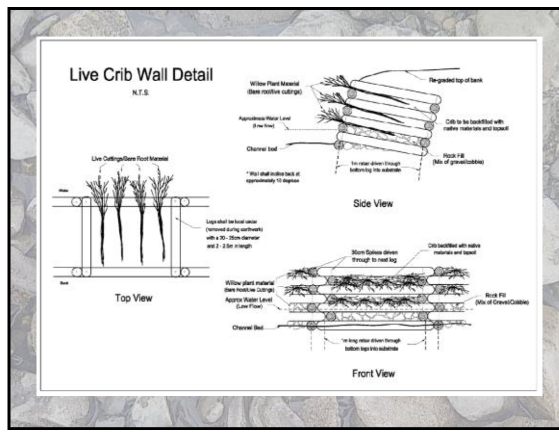
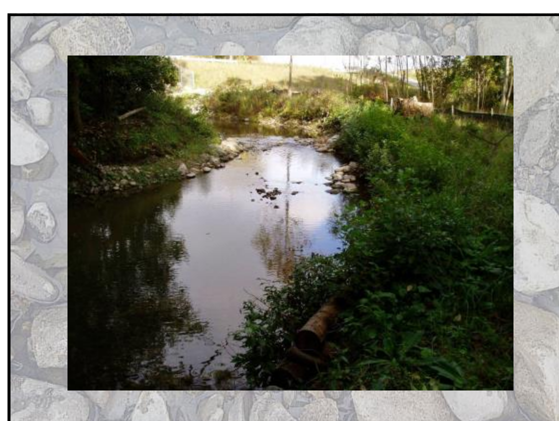
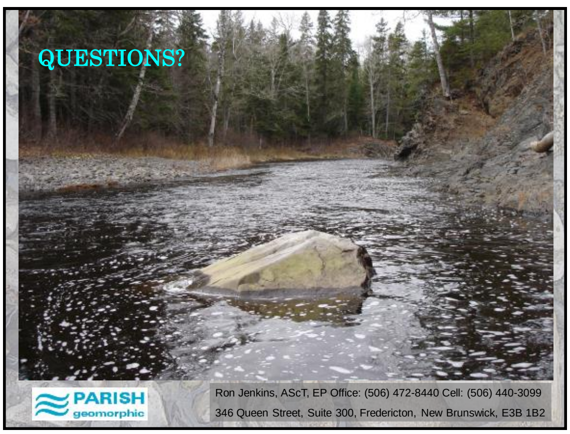


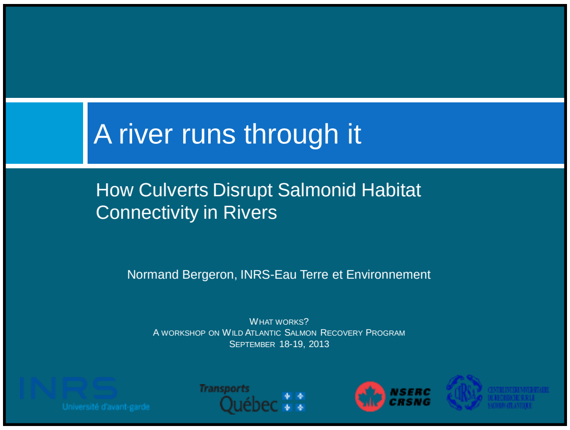


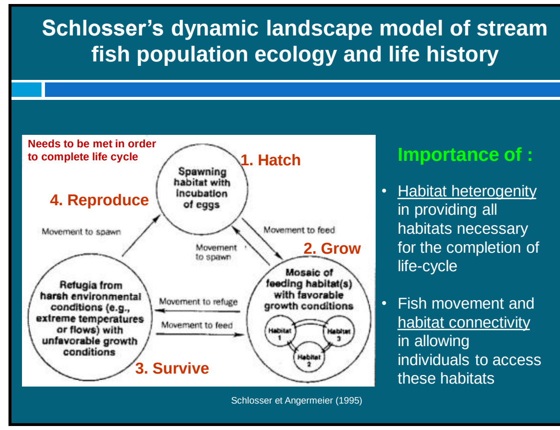
Live Crib Wall Detail
N.T.S.
Willow Plant Material
(Bare root/live cuttings)
Re-graded top of bank
Crib to be backfilled with
native materials and topsoil
Channel bed
Rock Fill
(Mix of gravel/cobble)
1m rebar driven through
bottom log into substrate
Live Cuttings/Bare Root Material
Logs shall be local cedar
(removed during earthwork)
with a 20 - 25cm diameter
and 2 - 2.5m in length
Top View
Side View
30cm Spikes driven
through to next log
Crib backfilled with native
materials and topsoil
Willow plant material
Approx Water Level
(Low Flow)
Rock Fill
(Mix of Gravel/Cobble)
Channel Bed
bottom logs into substrate
Front View

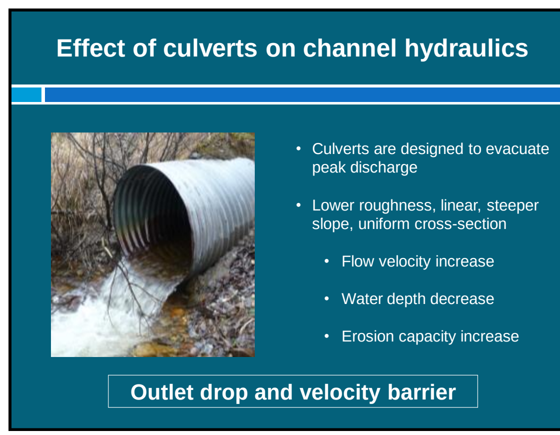


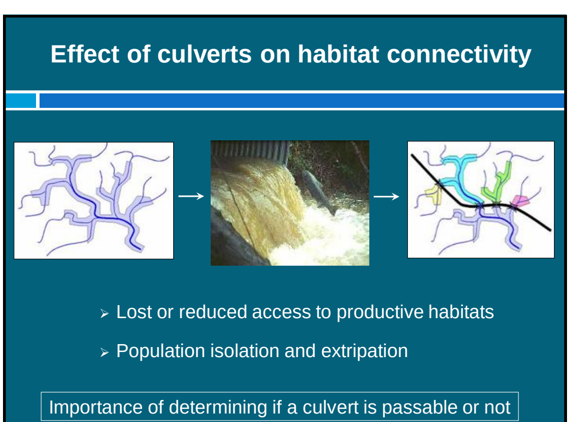

QUESTIONS?
PARISH
geomorphic
Ron Jenkins, AScT, EP Office: (506) 472-8440 Cell: (506) 440-3099
346 Queen Street, Suite 300, Fredericton, New Brunswick, E3B 1B2

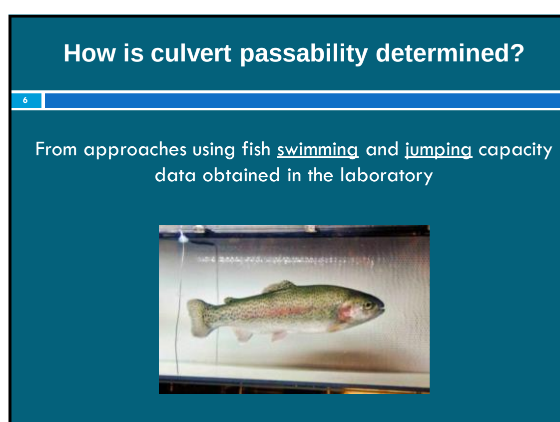
A river runs through it: how culverts disrupt salmonid habitat connectivity in rivers
Normand Bergeron, Institut national de la recherche scientifique
Centre Eau Terre Environnement





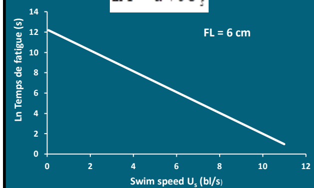






Velocity barrier: how far can a fish swim at a certain speed?

$\ln T = a + bU_s$

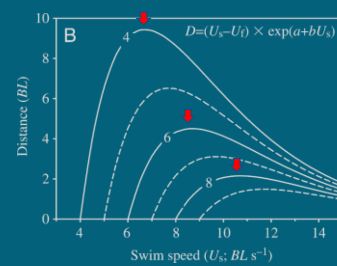


- Relation between swim speed and fatigue time in prolonged swim mode (Peake et al., 1997).
- Related to fish length and water temperature.

Distance achieved = Groundspeed x Fatigue time

Optimum swim speed maximizes distance achieved

8



Castro-Santos T (2005) J Exp. Biol. 208: 421-432.

Inventory of culvert passability by brook trout in the Saint-Louis River Basin using litterature criteria

9

- Use model brook trout of 6, 16 and 26 cm fork length
- Jumping capacity of 10-15 cm brook trout (Kondratieff and Myrick 2006)
- Swimming capacity data for brook trout (Peake, 1997)
- For each culvert:
  - Compute distance achieved if swimming at optimum speed against mean flow velocity in culvert at time of survey
  - Compare predicted distance achieved to culvert length

Large proportion of impassable culverts

	Passable	Impassable	
Hanging culvert	40 (58%)	29 (42%)	69
Velocity barrier			
Lf 6 cm	17 (30%)	40 (70%)	57
Lf 16 cm	35 (61%)	22 (39%)	57
Lf 26 cm	48 (84%)	9 (16%)	57

- Gibson et al. (2005) : 53% of studied culverts on Trans Labrador Highway were limiting juvenile salmon passage success
- Langill et Zamora (2002): 58% of culverts studied in Nova-Scotia were barrier to salmonids

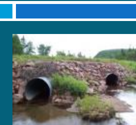
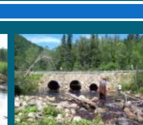
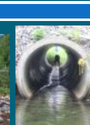
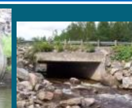
Very few field validations of predictions

Observed *vs* predicted brook trout passage success in natural culverts
Goerig E. (Ph.D student), Bergeron N. and Castro-Santos T.

Measure of fish passage attempts, swim speed, maximum distance of ascent and passage success using PIT antennas inside culverts

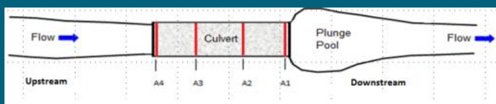

Photos Elsa Goerig

Study sites: 13 culverts of southern Québec

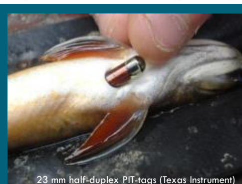





- Range of culvert characteristics:
  - Rough corrugated and smooth concrete and plastic
  - Slopes from 0,3 to 4,5%
  - Length from 9 to 45 m.
- Range of hydraulic conditions:
  - mean flow velocities from 0.4 to 2 m/s
  - flow depth from 0.03 to 0.46 m
  - Stream water temperatures from 1.4 to 18°C

Fish passage attempts, progression and success monitored with four PIT antennas inside culvert



(2004)



23 mm half-duplex PIT-tags (Texas Instrument)

Semi-experimental approach

- Fish passage trials conducted at various discharges and water temperatures
- For each trial, a group of 24 PIT-tagged brook trout was released for 48h in a cage fixed at culvert outlet
- 3 size groups (F_l)
  - Small: 90 à 119 mm
  - Medium: 120-149 mm
  - Large: 150-230 mm

(E. Goerig, 2009)

Two complementary approaches

1. Semi-experimental
   - 48h trials with a cage fixed downstream of the culvert
2. «Free conditions»
   - 72h trials with no cage
   - Fish released downstream

(E. Goerig, 2009)

N = 1090 fish of 90-230 mm in 50 trials

Observed *vs* predicted : passage success

	Passage Success (%)		
	All	Rough culvert	Smooth culvert
Observed	45	50	41
Predicted	28	28	28

N= 958 fish. 493 (51%) did at least one attempt

Predictive model **underestimates** passage success

- How good is the model at predicting the possible outcomes of an attempt ?
- In what situations does it perform better or worst ?

Observed *vs* predicted : effect of culvert type

Corrugated metal culverts

Observations (columns) / Prédictions (rows)

	Success	Failure	Total
Success	33	35	68
Failure	88	89	177
Total	121	124	245

Correct classification rate (CCR): 50 %
Misclassifications
Underpredict : 72%
Overpredict : 28%

Smooth concrete culverts

Observations (columns) / Prédictions (rows)

	Success	Failure	Total
Success	52	18	70
Failure	51	133	184
Total	103	151	254

Correct classification rate (CCR) : 73 %
Misclassifications
Underpredict : 73%
Overpredict : 27%

Effect of fish size

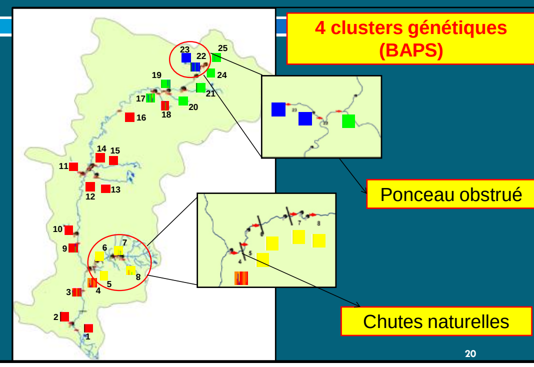
Fish length (FL =mm)	n	CCR (%)	TP (%)	TN (%)	FP (%) overpredict	FN (%) underpredict
Small (90-119)	176	63	87	13	5	95
Medium (120-149)	197	59	73	27	30	70
Large (150 +)	126	63	49	51	57	43

Laboratory fish swimming capacity data do not transfer well in natural field situations

- Different swimming behaviour in nature: sequence of burst swim / glide
- Small fish use corrugations for resting : not possible for larger fish
- Small fish better at using near-wall lower velocity zones

Riverscape genetics of rivière St-Louis

Torterotot (MSc student), Perrier, Bernatchez, Bergeron



20

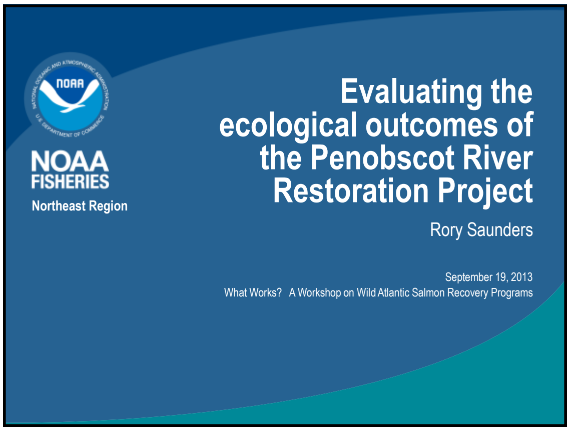
Effect of culverts on genetic richness and structure

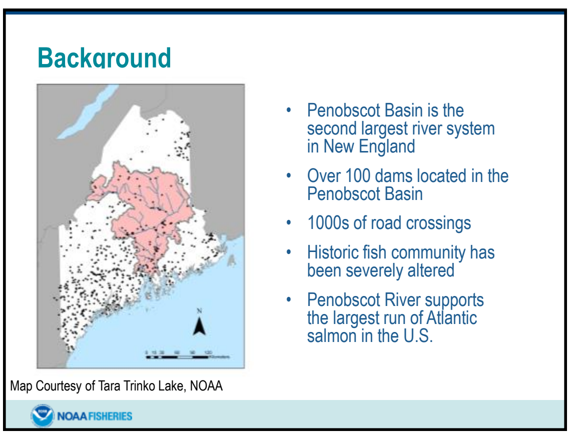
	Richness (A) AR		Structure (B) Pairwise F_{ST}	
	β	P-value	β	P-value
Intercept	12.0121	< 0.0001	0.0174	0.0998
Elevation	-0.0096	< 0.0001	-0.0001	0.1300
Culverts	-0.2298	0.0765	0.0090	0.0150
River distance	-	-	0.0010	0.0010
Waterfalls	-	-	0.0091	0.0900

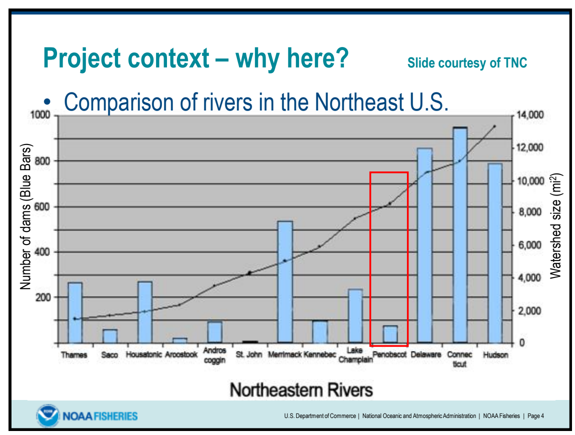
Culvert replacement: rough to smooth

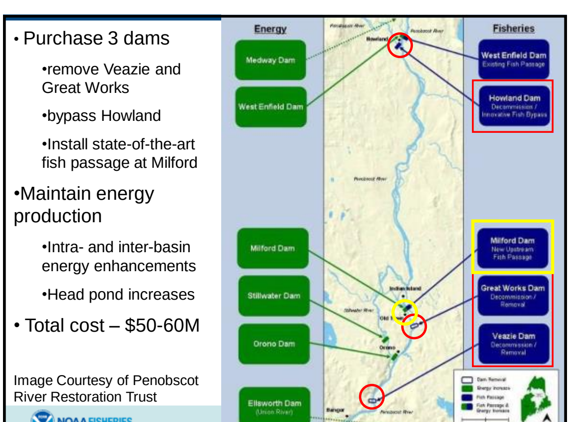
Cheers

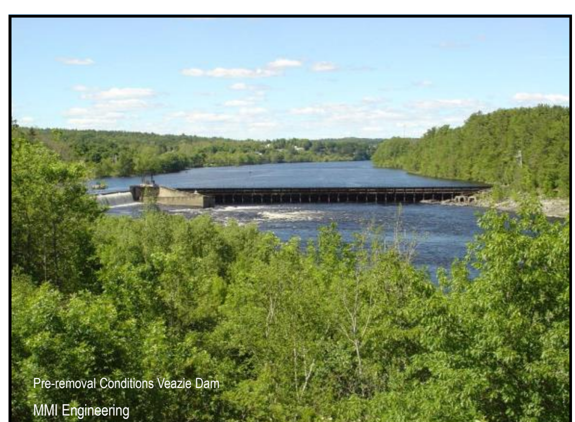
Evaluating the ecological effects of the Penobscot River Restoration Project
Rory Saunders, NOAA’s National Marine Fisheries Service









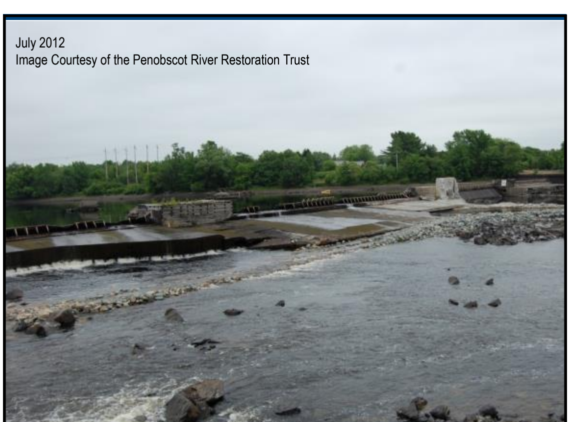


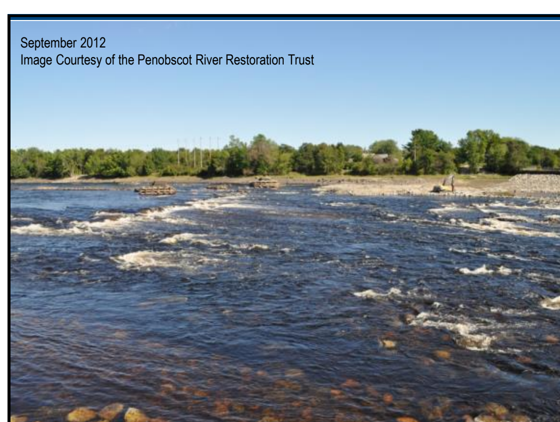

Projected Conditions Veazie Dam
MMI Engineering

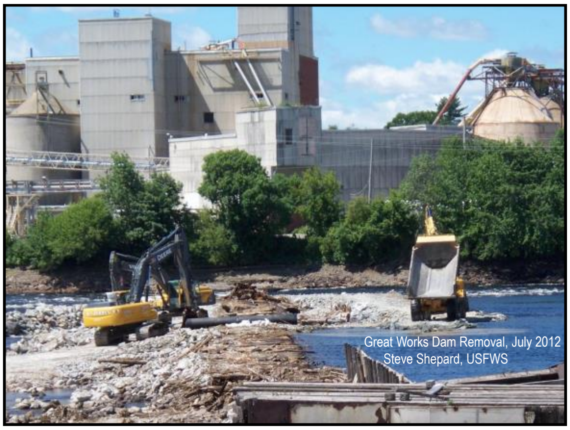

May 16, 2013 - Before
September 12, 2013 - During
Veazie Dam Removal, Steve Shepard, USFWS


Pre-removal Conditions Great Works Dam
MMI Engineering


Projected Conditions Great Works Dam
MMI Engineering


July 2012
Image Courtesy of the Penobscot River Restoration Trust


September 2012
Image Courtesy of the Penobscot River Restoration Trust

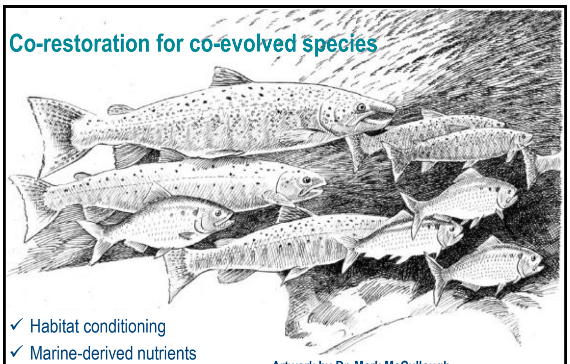


What works?

Palmer et al. 2005. Standards for ecologically successful river restoration. J. Applied Ecology 42:208–217

- **Guiding image**
- **Ecosystem improvement**
- **Increased resilience**
- No lasting harm
- Pre and post project assessment

Co-restoration for co-evolved species



Artwork by Dr. Mark McCullough

- ✓ Habitat conditioning
- ✓ Marine-derived nutrients
- ✓ Prey buffer
- ✓ Diversified prey base

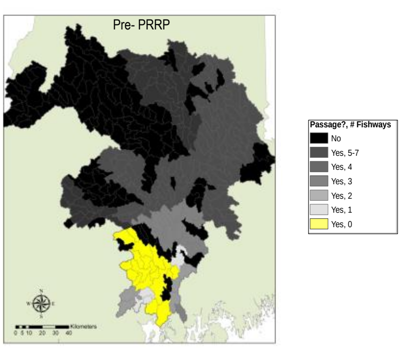
Saunders et al. 2006. Fisheries 31:537-547

- *Let's take an objective look….*

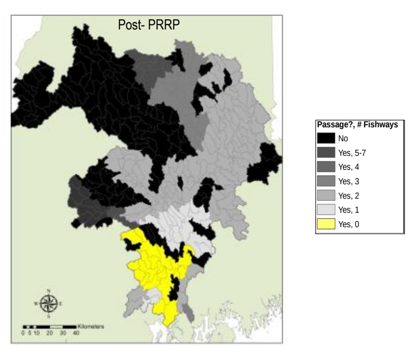

SPECIAL SECTION: AMERICAN SHAD AND RIVER HERRING

Evaluating Changes in Diadromous Species Distributions and Habitat Accessibility following the Penobscot River Restoration Project

Tara R. Trinko Lake, Kyle R. Ravana, and Rory Saunders



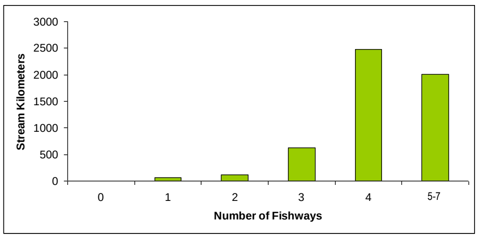
Trinko Lake et al. 2012. Marine and Coastal Fisheries 4:284–293



Trinko Lake et al. 2012. Marine and Coastal Fisheries 4:284–293

Trinko Lake et al. 2012. Marine and Coastal Fisheries 4:284–293

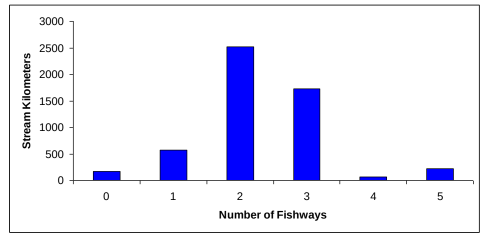
Pre-PRRP



NOAA FISHERIES

Trinko Lake et al. 2012. Marine and Coastal Fisheries 4:284–293

Post-PRRP



NOAA FISHERIES

- Lower river species (sturgeon, smelt, and striped bass) will regain 100% unimpeded access to historic habitat
- American shad and blueback herring will gain access to over 93% of historic habitat **IF** they pass up to five fishways (including Milford)
- The majority (66%) of alewife habitat is still inaccessible after implementation of PRRP
- Most habitat for highly migratory species (e.g., salmon) will be above 2-5 dams instead of 4-7 dams

NOAA FISHERIES

- The science helps us understand:
  - The PRRP is a great first step,
    - The PRRP will open an additional 11 miles of habitat AND improve access to 1000s of miles of habitat
    - We need to do more in order to see the PRRP live up to its potential.
  - We need to do more work on developing the “guiding image”
    - *If you don’t know what you want, that is about what you get.*

NOAA FISHERIES

What works?

Palmer et al. 2005. Standards for ecologically successful river restoration. J. Applied Ecology 42:208–217

- Guiding image
- Ecosystem improvement
- Increased resilience
- **No lasting harm**
- **Pre and post project assessment**

NOAA FISHERIES

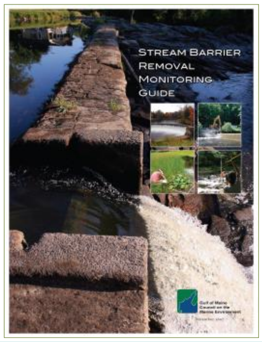
Progression of science interests

- 2002 – USGS and Maine DMR install and operate PIT array – fish migration studies begin
- 2003 – Penobscot Agreement announced
- 2004 – Penobscot Science Forum
- **2005 - 2008 – Penobscot Science Steering Committee (SSC)**
- 2005 – Ultrasonic telemetry array installed (NOAA, USGS, and UMaine)
- 2007 – Key publications
  - **Barrier Removal Monitoring Guide published – Gulf of Maine Council**
  - Penobscot SSC Monitoring Framework
- 2008
  - NOAA Priorities for PRRP Monitoring published
  - **NOAA and TNC begin substantial investments in monitoring (roughly $100k)**
- 2009 - American Recovery and Re-investment Act (ARRA)
  - Penobscot River Restoration Trust proposal for Great Works Dam removal ($6.1M)
  - **$1.3M – Infrastructure, student salary and tuition, PI salary, contracts, etc.**
- 2010-Present – ARRA-funded projects underway (TNC and NOAA funding)
- 2012 – Great Works removed
- 2013 – Veazie removed
- 2014 - Milford fish lift to be constructed

NOAA FISHERIES

Effectiveness monitoring studies

- Fish migration and habitat use
  - adult ATS upstream passage at dams
  - ATS smolt downstream passage at dams
  - sturgeon habitat use
  - diadromous fish biomass flux via hydroacoustics
- Fish community structure
- Riverine and marine ecosystem response
  - Riparian wetland response
  - Marine-freshwater food web linkages
- Water quality and benthic macroinvertebrates
- Channel and floodplain physical response



Challenges Ahead

•Lack of info on decline of most diadromous species

•Small barrier restoration

•Milford fish lift

•Does it work?

•How will we know?

•Funding

•Before and **AFTER** Control Impact (BACI)

•Guiding Image

•Refinement and agreement urgently needed

Acknowledgements

George Aponte Clarke
Barbara Arter
Charlie Baeder
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Blaine Kopp
Brandon Kulik
Dan Kusnierz
Dan McCaw
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Julie Nieland
Jeff Reardon
Catherine Schmitt
Joan Trial
Tara Trinko Lake
Karen Wilson
Gayle Zydlewski
Joe Zydlewski

Special Thanks To

George Aponte Clarke – Penobscot River Restoration Trust

Matt Collins – NOAA Restoration Center

Josh Royte – The Nature Conservancy

Tim Sheehan – Northeast Fisheries Science Center

Slide Title

- List item 1
  - List item 2

Channel geometry, sediments, and photo monitoring

•Principal Investigator: Alice Kelley, UMaine

•Objectives:

•Sediment grain size distribution survey

•Cross section elevation survey

•Bathymetric survey

•Photographic monitoring stations

Water quality and benthic macroinvertebrates

•Principal Investigator: Dan Kusnierz, Penobscot Nation
•Objectives:
  •Benthic macroinvertebrate community composition
    •Maine DEP aquatic life model
    •Indices of community structure
  •Water quality changes
    •Temp, DO, conductivity, BOD, E. coli bacteria, total coliform, total suspended solids, turbidity, secchi disc visibility, total P, chlorophyll a, pH

NOAA FISHERIES

Upstream passage of diadromous fish

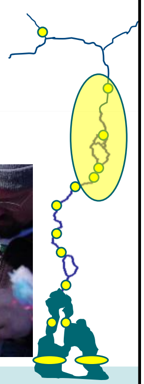
•Principal Investigator: Joseph Zydlewski, USGS
•Objectives:
  •Homing efficiency
  •Migratory delay at fishways
  •Passage rates
  •Environmental and operational variables effecting connectivity

New funding from USGS for radio telemetry!

NOAA FISHERIES

Downstream passage of salmon

•Principal Investigators: Joseph Zydlewski, USGS
•Objectives:
  •Characterize downstream survival
    •Focus on areas of higher loss
  •Evaluate path choice
    •Wild vs hatchery



NOAA FISHERIES

Fish community – Upper River

•Principal Investigator: Stephen Coghlan, UMaine
•Objectives:
  •Quantify “pre-removal” fish community structure
    •Continue and expand 2008 and 2009 data sets (Kleinschmidt Assoc.)
    •Spring/Fall sampling on 19 “transects”

NOAA FISHERIES

Riparian, riverine, and marine ecosystem response

- Assessing Marine-Freshwater Food Web Linkages Using Stable Isotopes – Wilson and Sherwood, GMRI
  - More trophic levels =
    - more diverse predator-prey interactions
    - greater prey availability
    - greater ecosystem complexity (i.e., more pathways for food web interactions)
- Wetland and Riparian Habitat Mapping – Boyle and associates
- Bird Community Monitoring – Hunter and Call, UMaine
- Estuarine Fish Community Monitoring – Lipsky, O’Malley, Stevens, Kocik, and Saunders; NOAA

NOAA FISHERIES

Using the dam impact analysis model to assess the recovery potential of Atlantic salmon
Tim Sheehan, NOAA's National Marine Fisheries Service

Using the Dam Impact Analysis Model to Assess the Recovery Potential of Atlantic Salmon

NOAA FISHERIES
NEFSC

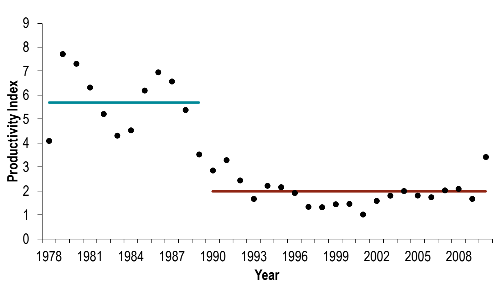
Julie L. Nieland, Timothy F. Sheehan, and Rory Saunders

September 19, 2013

U.S. Atlantic Salmon

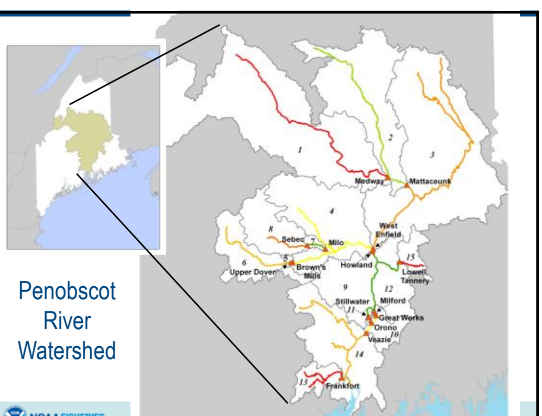
- Many populations are extirpated or endangered.
- Gulf of Maine Distinct Population Segment listed as endangered under the ESA in 2000 and 2009.
- Two primary threats: marine survival and dams.
- Need for quantitative analyses of the impacts of dams to support management actions.

Marine Productivity

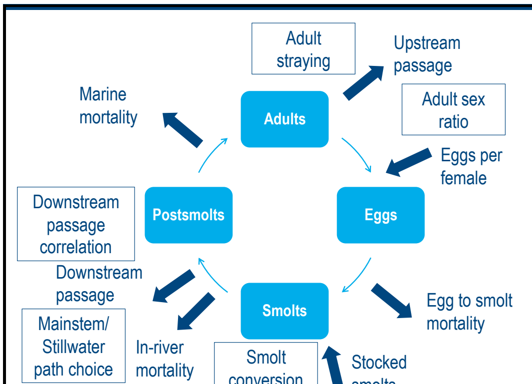


Dams

- Many negative effects of dams on Atlantic salmon.
- We can change how dams impact Atlantic salmon through:
  - Improving passage efficiency.
  - Removal.

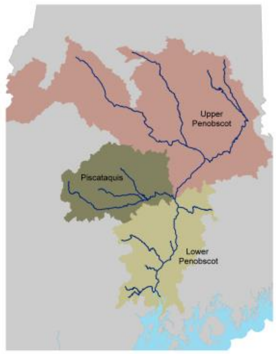


Penobscot River Watershed

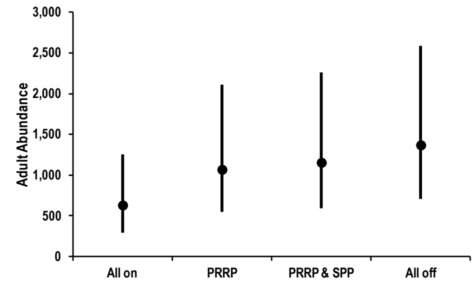


Performance Metrics

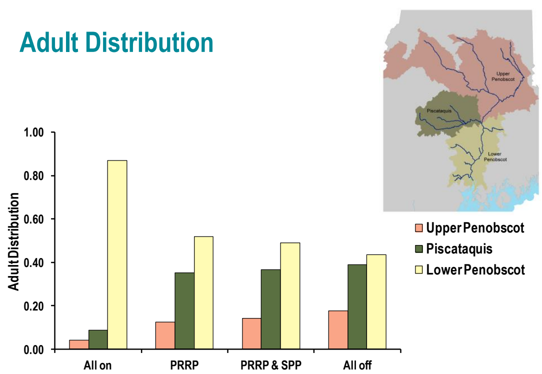
- Adult abundance.
- Adult distribution.
- Smolts killed.



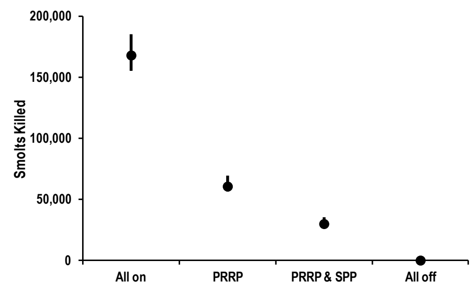
Adult Abundance



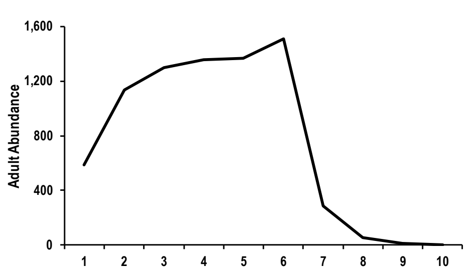
Adult Distribution



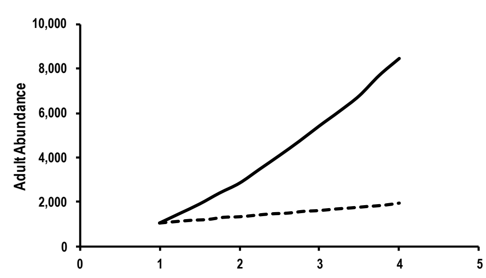
Smolts Killed



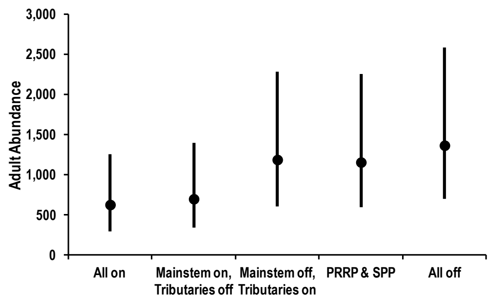
Stocking



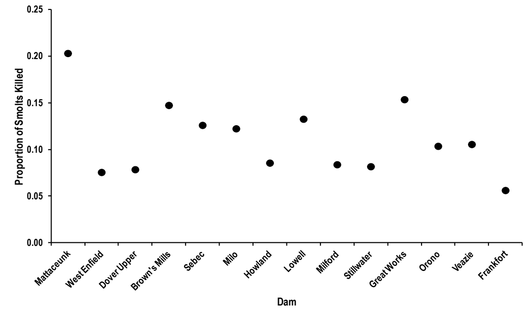
Marine *(solid)* and Freshwater *(dashed)* Survival



Dams



Individual Dams



Conclusions

- Current use:
  - Permitting support.
  - Informing the establishment of performance standards.
  - Expanding the model other systems in Maine.

Conclusions

- Future use:
  - Predict relative change given an action to support reasonable goal and objective setting.
  - Inform and help prioritize future recovery actions.
  - Help better understand the influences of freshwater and marine survival and dam-related mortality on salmon population dynamics.
  - Expand to model other species.

Acknowledgments

Department of Marine Resources, State of Maine

ALDEN Solving flow problems since 1894

Upstream Passage Expert Panel

USGS science for a changing world

U.S. Fish & Wildlife Service

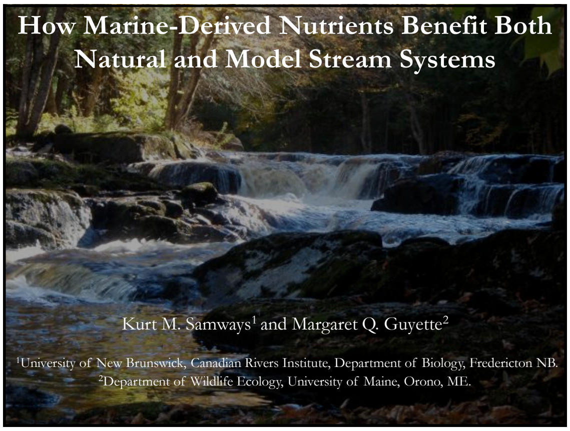
NOAA FISHERIES SERVICE

The University of Maine 1865

Northeast Fisheries Science Center
Northeast Regional Office
Restoration Center

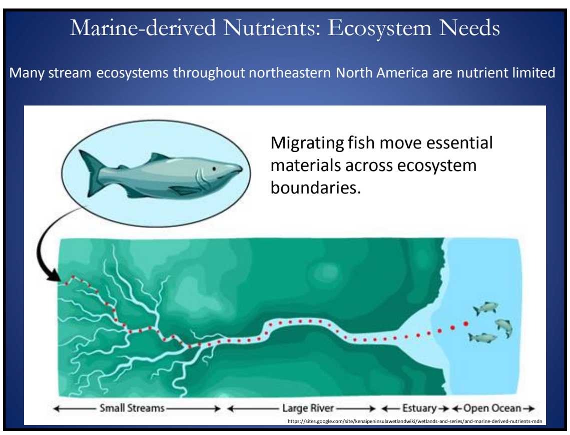
Marine-derived nutrients in the natural and model systems in eastern North America: how nutrients subsidies benefit resident and anadromous fishes

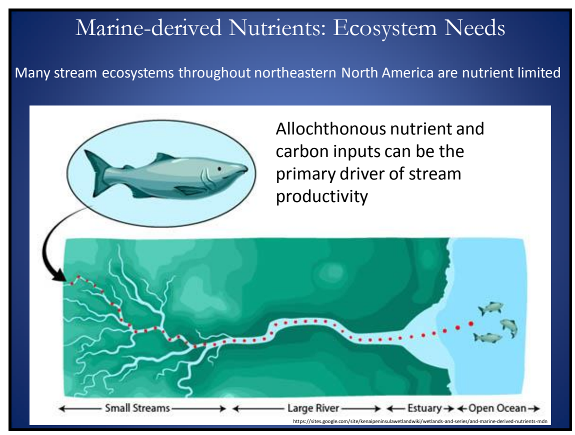
Kurt Samways, University of New Brunswick

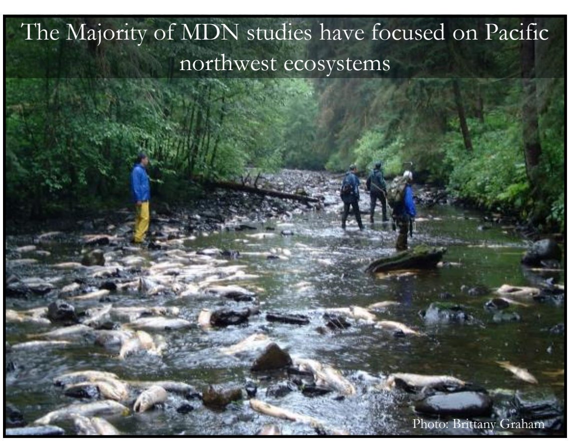


Marine-derived Nutrients: Ecosystem Needs

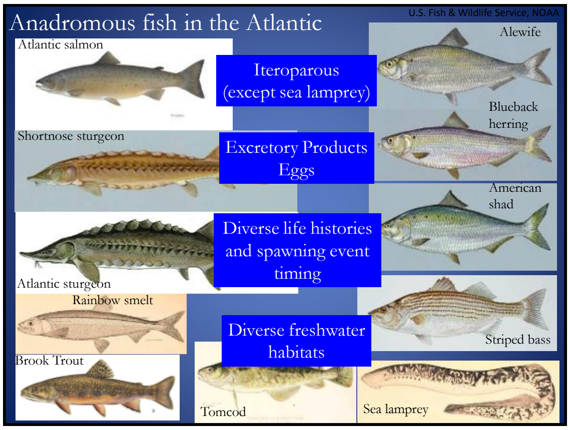
Many stream ecosystems throughout northeastern North America are nutrient limited







Anadromous fish in the Atlantic



Marine-derived Nutrients Impact Freshwater Productivity

Change in Marine Nutrient Loading

Adult salmon returns in the St. John River at the Mactaquac Dam

	1967	2012
1SW		
MSW		
Total		

Change in Marine Nutrient Loading

Adult salmon returns in the St. John River at the Mactaquac Dam

	1967	2012
1SW	1181	
MSW	1271	
Total	2452	

Change in Marine Nutrient Loading

Adult salmon returns in the St. John River at the Mactaquac Dam

	1967	2012
1SW	1181	81
MSW	1271	128
Total	2452	201

Change in Marine Nutrient Loading

Adult salmon returns in the St. John River at the Mactaquac Dam

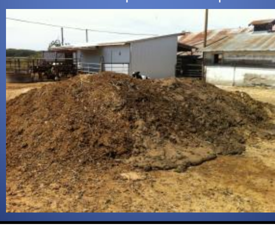
	1967	2012
1SW	1181	81
MSW	1271	128
Total	2452	201
* Total N	610 Kg	57 Kg
* Total P	8 Kg	0.5 Kg

* Calculations are based on excretory products and gametes only, <u>no mortality</u>

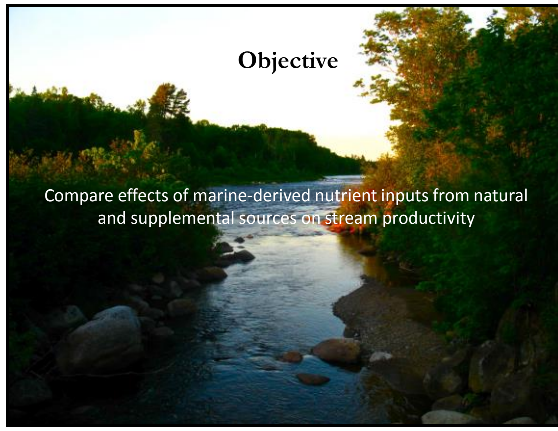
Change in Marine Nutrient Loading

	1967	2012
Cows	915	85
Manure	62.25 tonnes	5.75 tonnes

Number of cows/amount of manure to produce the equivalent amount of nutrients

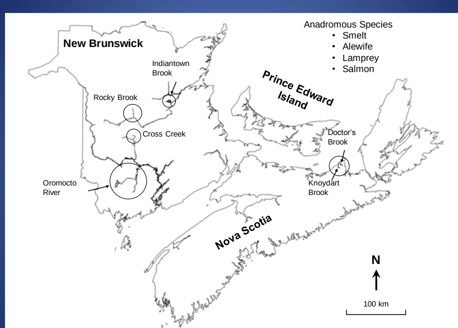


Objective



Compare effects of marine-derived nutrient inputs from natural and supplemental sources on stream productivity

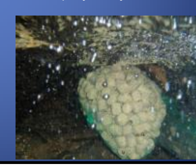
Study Areas – Natural Anadromous Populations



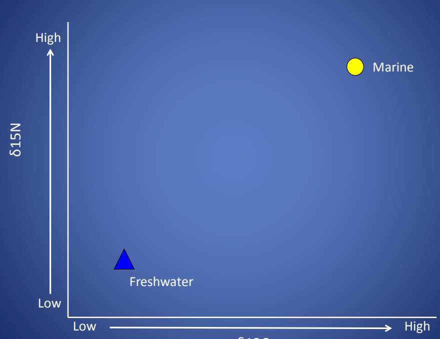
Study Area – Nutrient Addition Study

Kingsbury Plantation Piscataquis County Maine

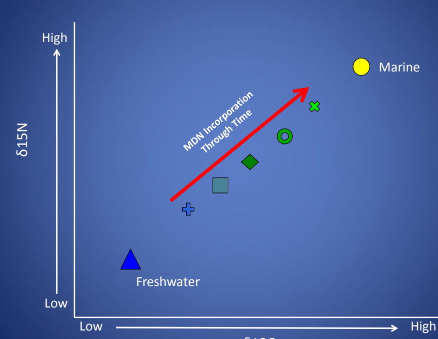
- 4 Streams
- Carcass Analog
  - BioOregon Product
  - Fall Chinook salmon (hatchery)
  - ~10%N, 2.2%P
  - Free of pathogens
- Density
  - 0.10 kg/m²
- Timing
  - "Lamprey": July

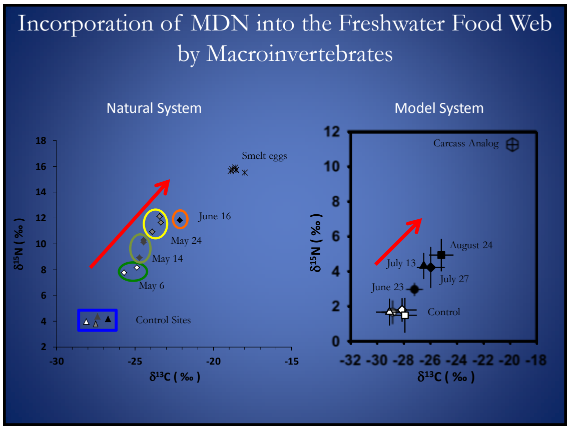


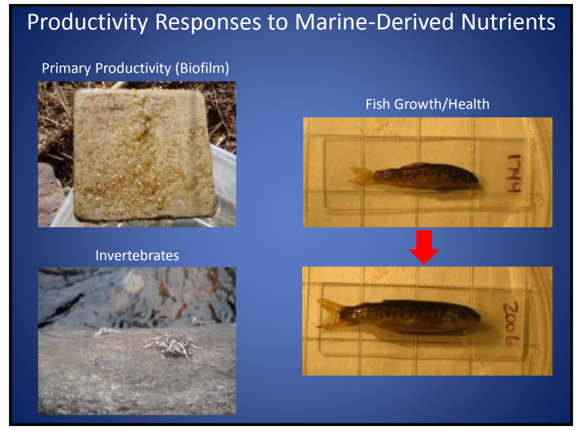
Stable Isotopes as Ecological Tracers

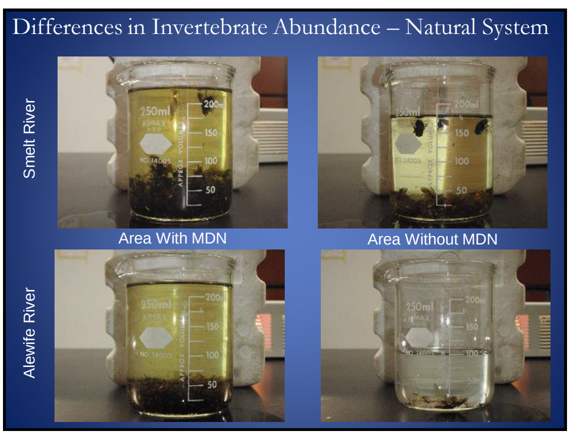


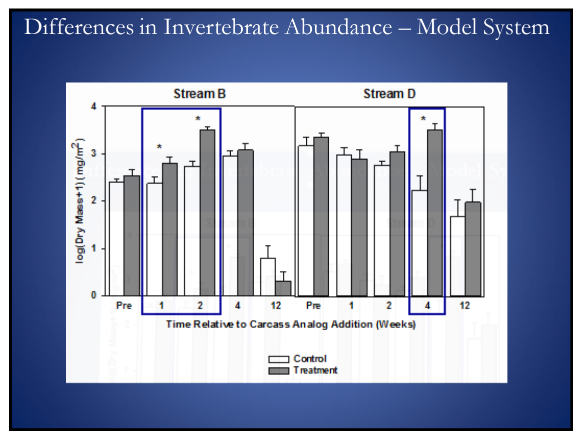
Stable Isotopes as Ecological Tracers

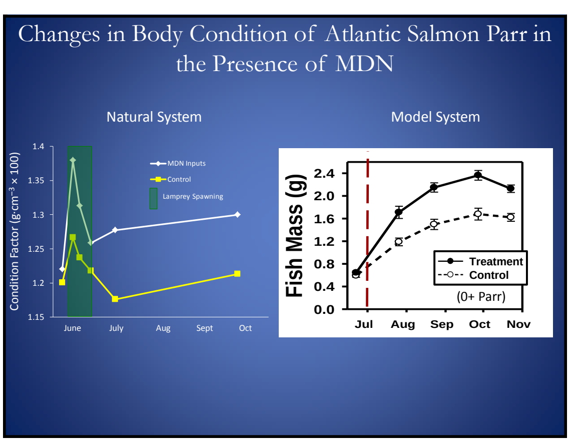


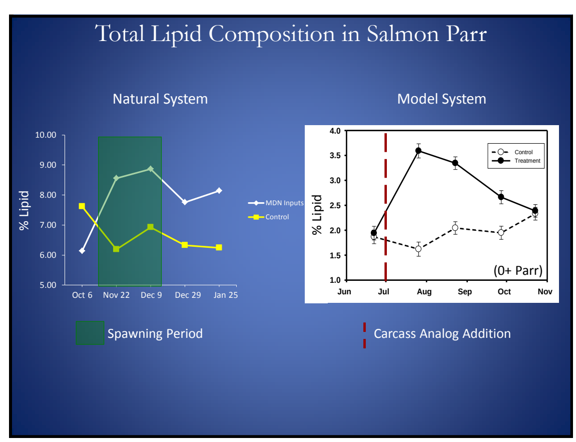

Incorporation of MDN into the Freshwater Food Web by Macroinvertebrates
Natural System
Model System
Smelt eggs
June 16
May 24
May 14
May 6
Control Sites
Carcass Analog
August 24
July 13
July 27
June 23
Control
δ15N (‰)
δ13C (‰)

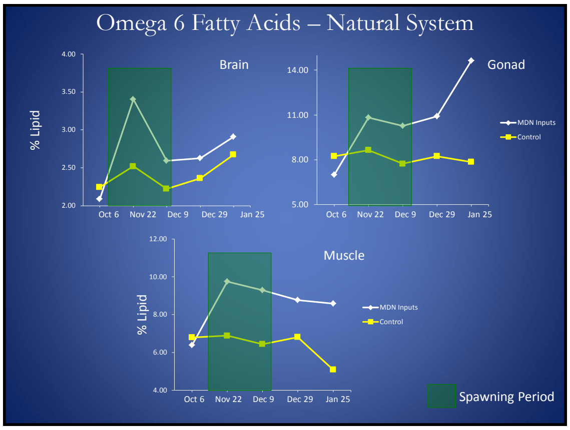

Productivity Responses to Marine-Derived Nutrients
Primary Productivity (Biofilm)
Fish Growth/Health
Invertebrates

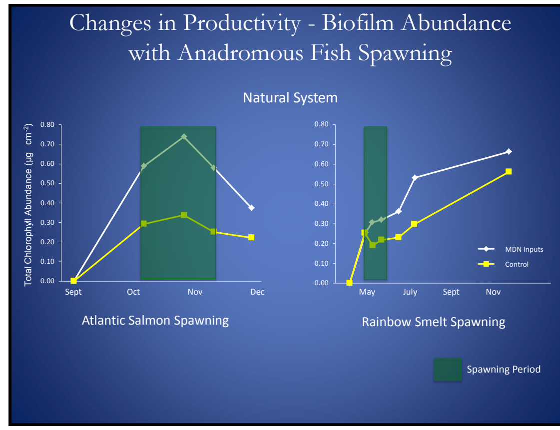

Differences in Invertebrate Abundance – Natural System
Smelt River
Alewife River
Area With MDN
Area Without MDN

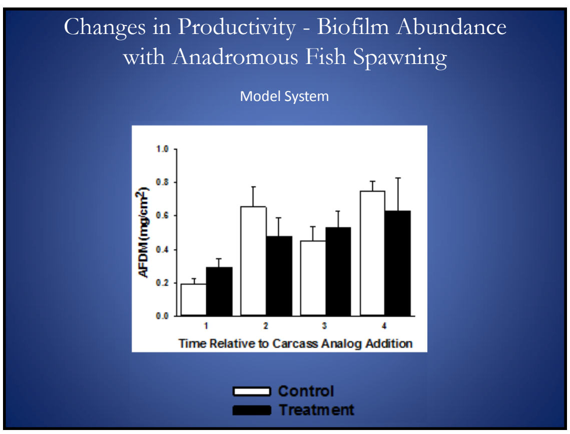

Differences in Invertebrate Abundance – Model System
Stream B
Stream D
log(Dry Mass+1) (mg/m2)
Time Relative to Carcass Analog Addition (Weeks)
Control
Treatment

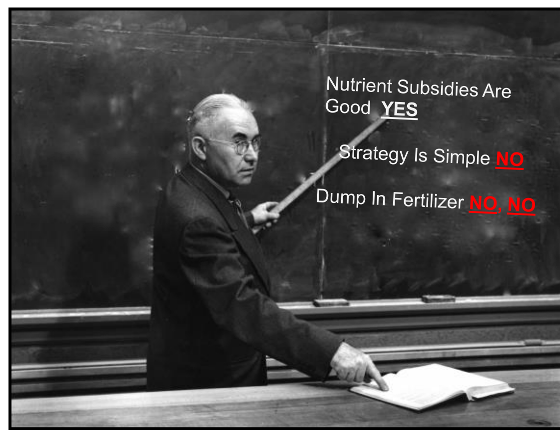

Changes in Body Condition of Atlantic Salmon Parr in the Presence of MDN
Natural System
Model System
Condition Factor (g·cm−3 × 100)
MDN Inputs
Control
Lamprey Spawning
June
July
Aug
Sept
Oct
Fish Mass (g)
Treatment
Control
(0+ Parr)
Jul
Aug
Sep
Oct
Nov

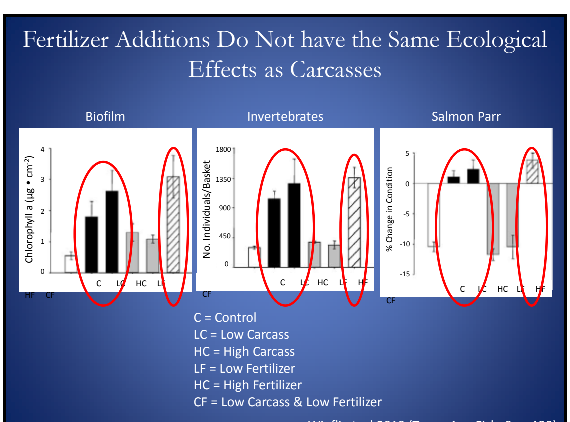

Total Lipid Composition in Salmon Parr
Natural System
Model System
% Lipid
MDN Inputs
Control
Oct 6
Nov 22
Dec 9
Dec 29
Jan 25
Treatment
(0+ Parr)
Jun
Jul
Aug
Sep
Oct
Nov
Spawning Period
Carcass Analog Addition

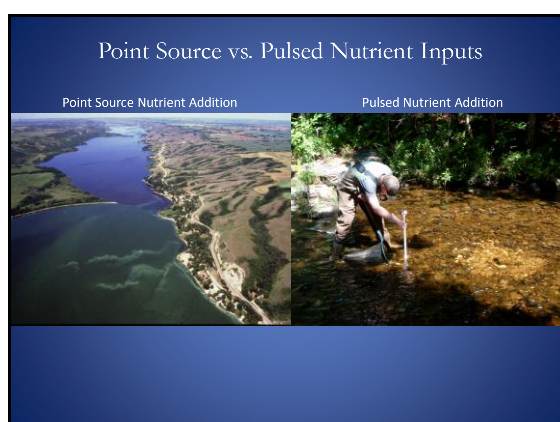

Omega 6 Fatty Acids – Natural System
Brain
Gonad
Muscle
% Lipid
Oct 6 Nov 22 Dec 9 Dec 29 Jan 25
MDN Inputs
Control
Spawning Period

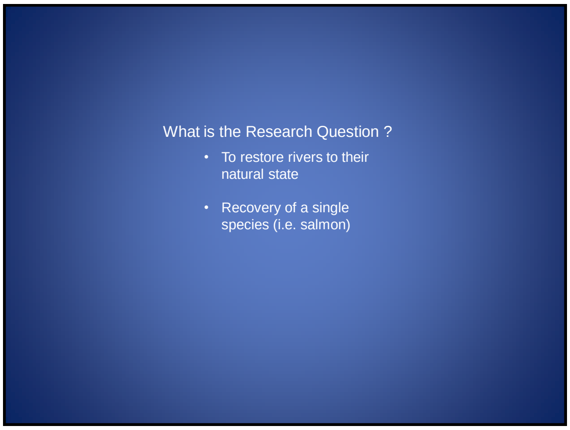

Changes in Productivity - Biofilm Abundance with Anadromous Fish Spawning
Natural System
Sept Oct Nov Dec
May July Sept Nov
MDN Inputs
Control
Atlantic Salmon Spawning
Rainbow Smelt Spawning
Spawning Period

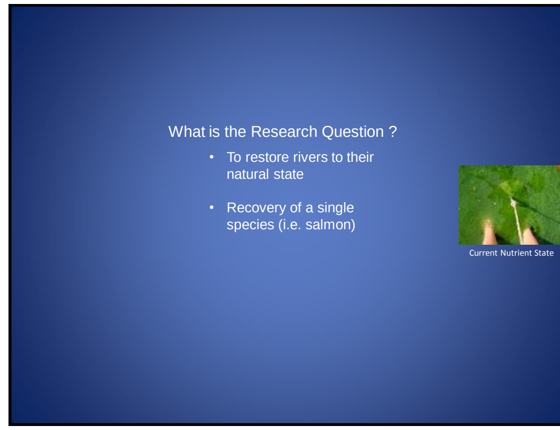

Changes in Productivity - Biofilm Abundance with Anadromous Fish Spawning
Model System
AFDM (mg/cm²)
Time Relative to Carcass Analog Addition
Control
Treatment

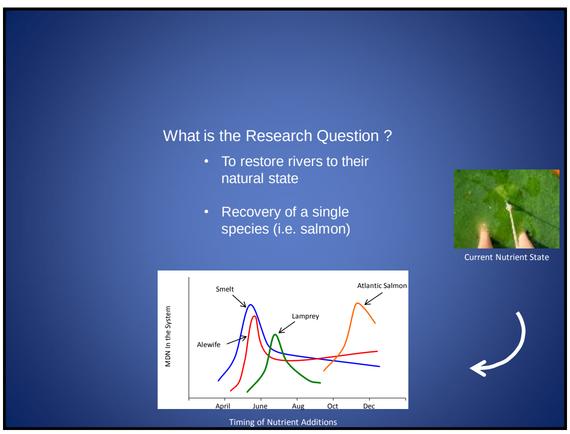

Nutrient Subsidies Are Good YES
Strategy Is Simple NO
Dump In Fertilizer NO, NO

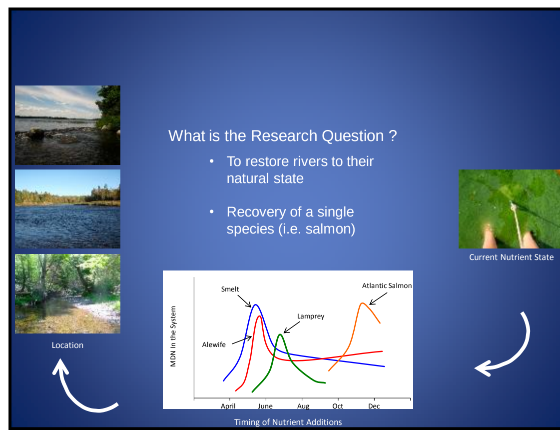

Fertilizer Additions Do Not have the Same Ecological Effects as Carcasses
Biofilm
Invertebrates
Salmon Parr
Chlorophyll a (µg • cm⁻²)
No. Individuals/Basket
% Change in Condition
C = Control
LC = Low Carcass
HC = High Carcass
LF = Low Fertilizer
HC = High Fertilizer
CF = Low Carcass & Low Fertilizer
Wipfli et. al 2010 (Trans. Am. Fish. Soc. 139)

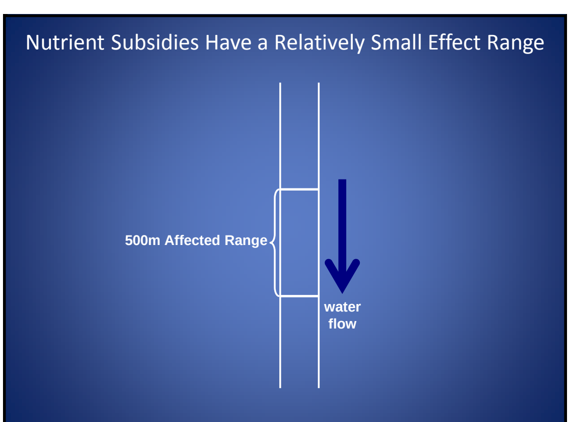

Point Source vs. Pulsed Nutrient Inputs
Point Source Nutrient Addition
Pulsed Nutrient Addition

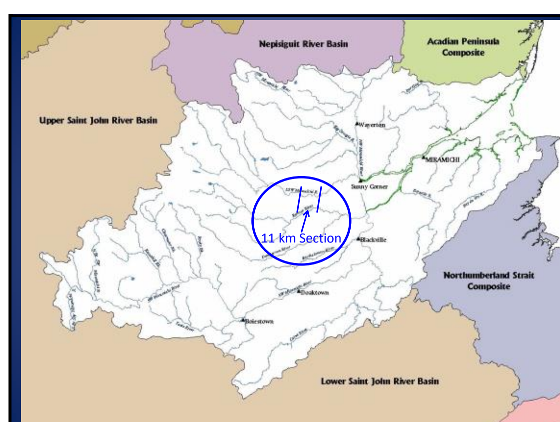

What is the Research Question ?
• To restore rivers to their natural state
• Recovery of a single species (i.e. salmon)


What is the Research Question ?
• To restore rivers to their natural state
• Recovery of a single species (i.e. salmon)
Current Nutrient State

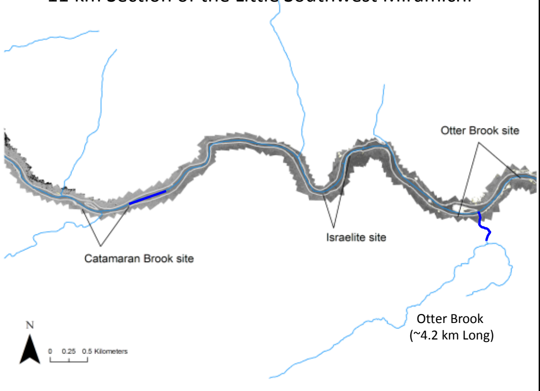

What is the Research Question ?
• To restore rivers to their natural state
• Recovery of a single species (i.e. salmon)
Current Nutrient State
Smelt
Atlantic Salmon
Lamprey
Alewife
MDN in the System
April
June
Aug
Oct
Dec
Timing of Nutrient Additions

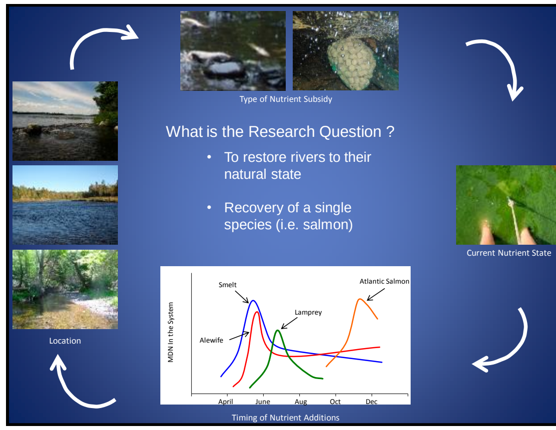

What is the Research Question ?
• To restore rivers to their natural state
• Recovery of a single species (i.e. salmon)
Location
Current Nutrient State
Smelt
Atlantic Salmon
Lamprey
Alewife
MDN in the System
April
June
Aug
Oct
Dec
Timing of Nutrient Additions


Nutrient Subsidies Have a Relatively Small Effect Range
500m Affected Range
water flow


Nepisiguit River Basin
Acadian Peninsula Composite
Upper Saint John River Basin
MIRAMICHI
Sunny Corner
11 km Section
Blackville
Doaktown
Boiestown
Northumberland Strait Composite
Lower Saint John River Basin

11 km Section of the Little Southwest Miramichi





Summary

- Anadromous fish bring nutrients and other constituents to freshwater ecosystems
- MDN/nutrient subsidies inputs result in increased productivity at various trophic levels
- Increased productivity is better “quality” with the incorporation of essential fatty acids
- Nutrient additions need to be strategic based on specific restoration goals
- Nutrient additions are designed to be used in concert with other restoration techniques

Canadian Rivers Institute
UNB
THE UNIVERSITY OF MAINE
SINLAB Stable Isotopes in Nature Laboratory
Fisheries and Oceans Canada Pêches et Océans Canada
USGS science for a changing world
Canada Research Chairs Chaires de recherche du Canada
NSERC CRSNG

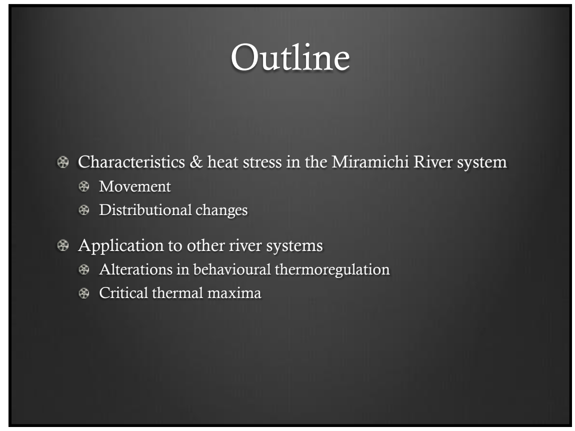
Acknowledgements

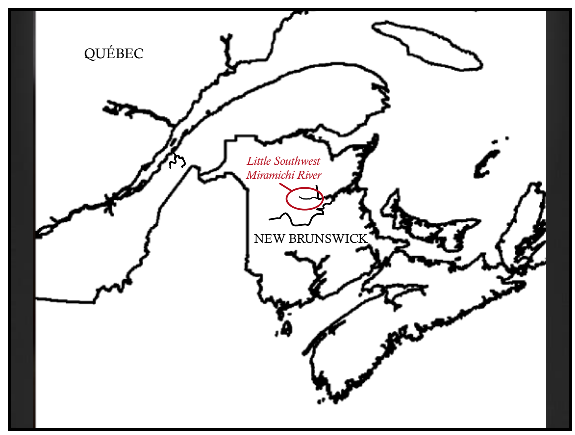
Cynthia Loftin and Joseph Zydlewski, USGS Maine Cooperative Fish and Wildlife Research Unit
USFWS Craig Brook National Fish Hatchery
Maine Department of Natural Resources Bureau of Searun Fisheries and Habitat

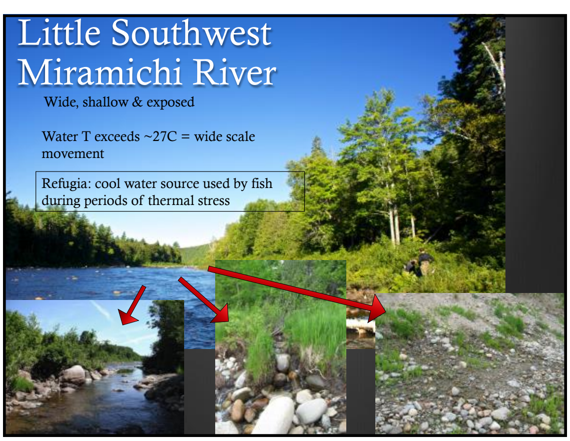
Rick Cunjak
SINLAB, Mactaquac Biodiversity Facility, St. Andrews Biological Station
Cunjak Lab

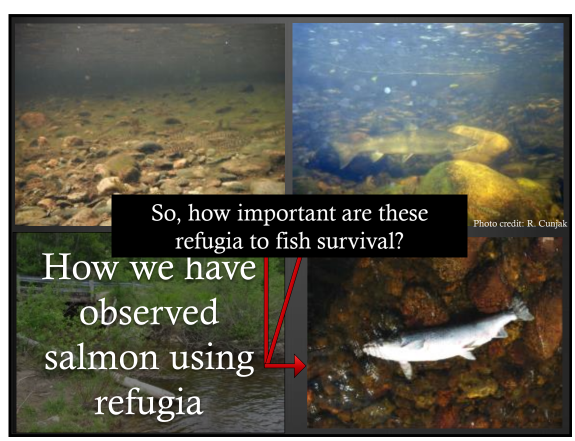
Photo credit R. Cunjak

Movement and distribution of juvenile Atlantic salmon during periods of thermal stress in two eastern Canadian rivers
Emily Corey, University of New Brunswick





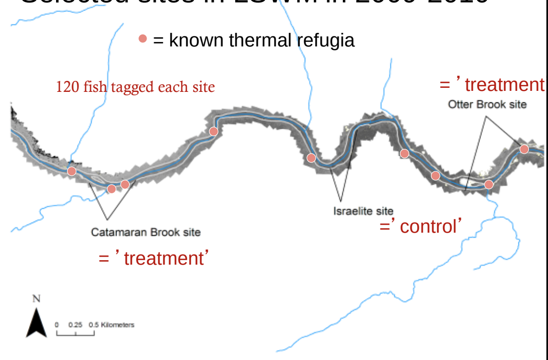




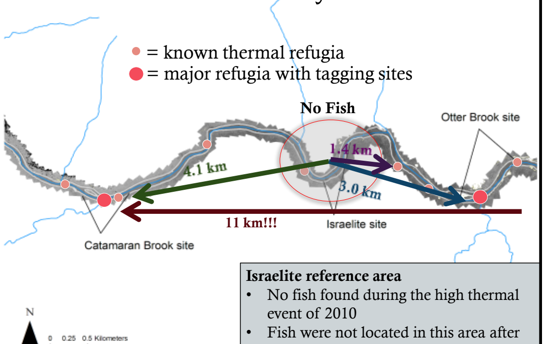
Objectives

1. Determine how the incidence of temperature stress events and proximity to thermal refugia affects the distribution of juvenile Atlantic salmon
2. Quantify thermal tolerance: Can differences in thermal exposure lead to an adaptive response in juvenile Atlantic salmon?

Selected sites in LSWM in 2009-2010

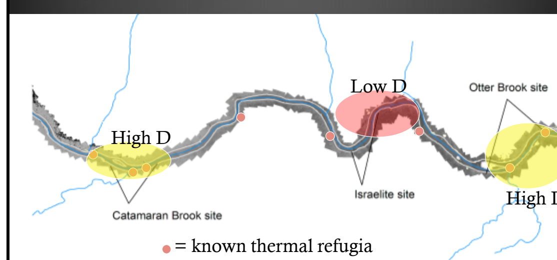


Heat-related movement July 2010



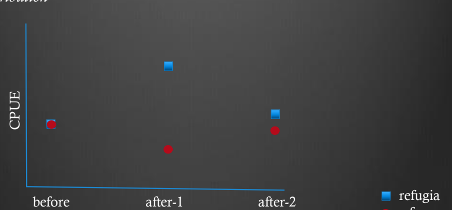
Israelite reference area

- No fish found during the high thermal event of 2010
- Fish were not located in this area after the event
- **Where did they go?**



Expected Results 2011

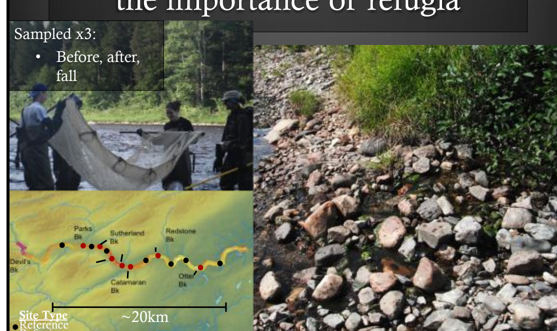
Prior to thermal event:
- *even distribution*

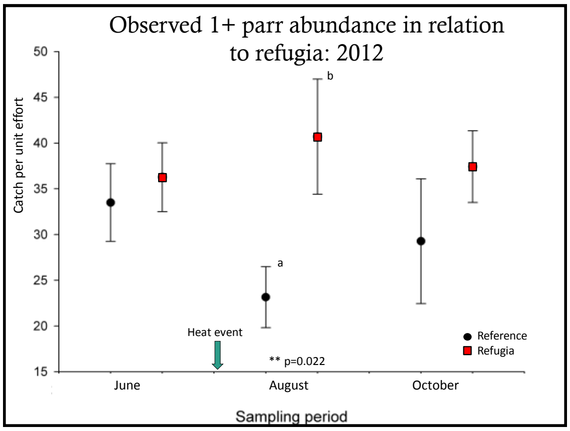


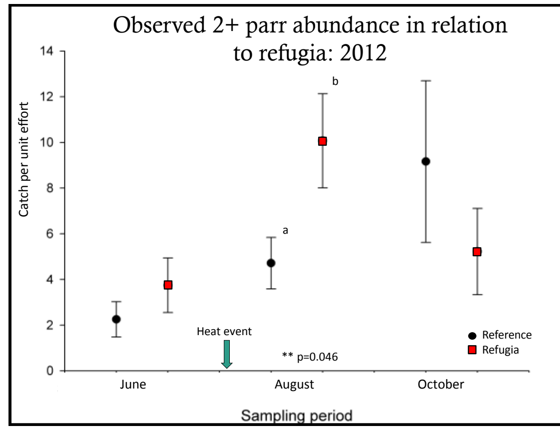
Post high-thermal event…
- *patchy distribution based on cool-water availability*

From a distribution standpoint… the importance of refugia

Sampled x3:
- Before, after, fall







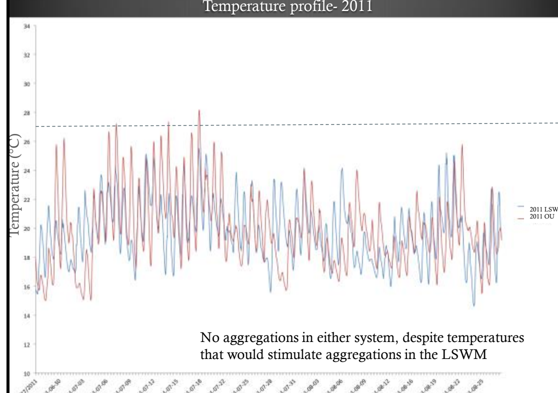
Objectives

1. Determine how the incidence of temperature stress events and proximity to thermal refugia affects the distribution of juvenile Atlantic salmon
2. Quantify thermal tolerance: Can differences in thermal exposure lead to an adaptive response in juvenile Atlantic salmon?

Tracking aggregations

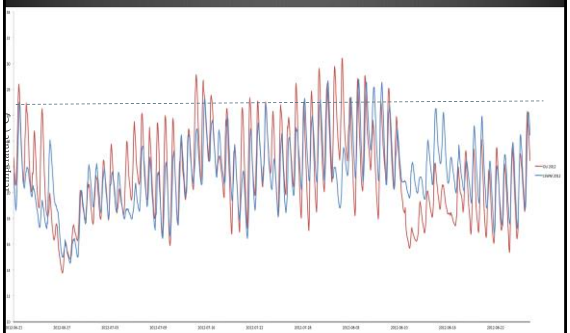
- Ouelle River system, QC
- PIT tags
  - 420 parr in a 3-4km stretch
- 2 tributaries/2 antennae
- 2011/2012

Temperature profile- 2011

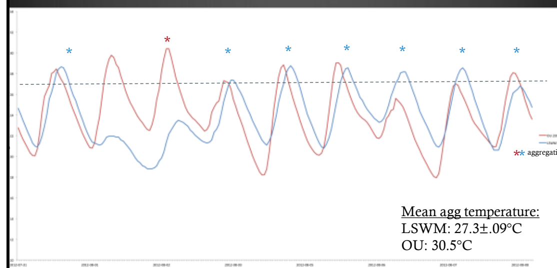


No aggregations in either system, despite temperatures that would stimulate aggregations in the LSWM

Temperature profile- 2012



July 31-August 8, 2012

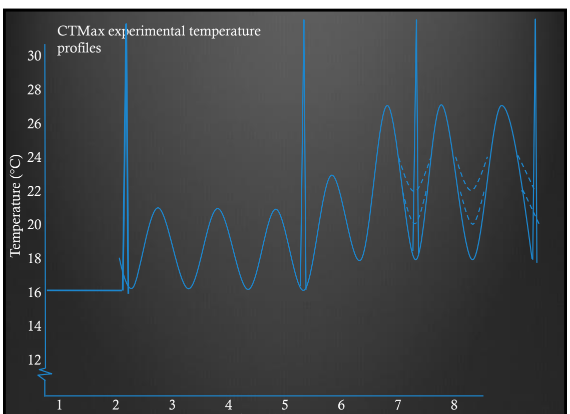


Critical thermal maxima (CTMax)

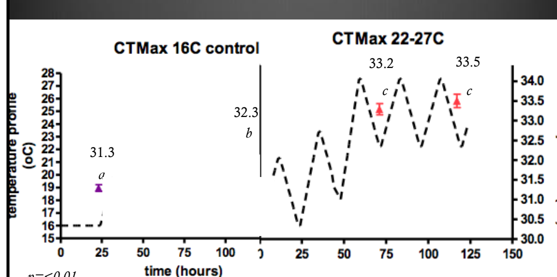
- **What is it?**
  Thermal tolerance test
- **How does it work?**
  ⇧T at a constant rate where internal body T matches environmental T
- **What is the endpoint?**
  Uncoordinated movements and loss of ability to escape conditions that will lead to death
  - In fish: T where loss of equilibrium (LOE) is observed

Critical thermal maxima (CTMax)

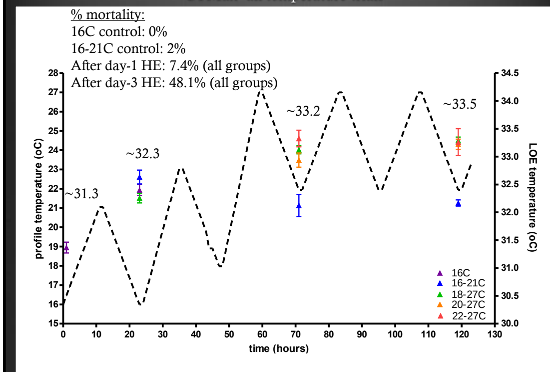
- Wild 1+ juvenile salmon used (mean+SEM)
  - FL=8.2±0.003g
  - wt=6.7±0.01cm
- Rate of temperature increase = 0.33°C/min (19.80°C/hr)
- All tests begun at min daily temperature & time
- n=9 for all timepoints



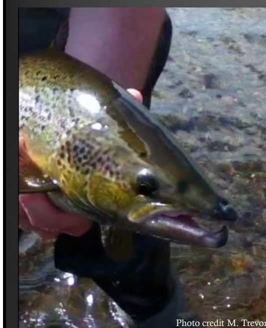
CTMax- preliminary results



CTMax- all temperature trials



In summary…



Increased water temps=

Wide scale movement & behavioural thermoregulation

Availability of refugia can have large implications on survival

Problem in many systems

- Exposure to increased temperatures=increased ability to withstand increased temperatures (?)
  - More work needed

Acknowledgments

NSERC CRSNG
UNB

NSERC Collaborative Research and Development (CRD)
Michel Lapointe (PI)

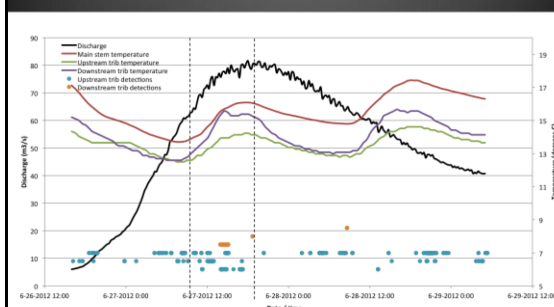
MSA Conservation 60th Anniversary 1953-2013

Cunjak Field & Currie Lab Crew

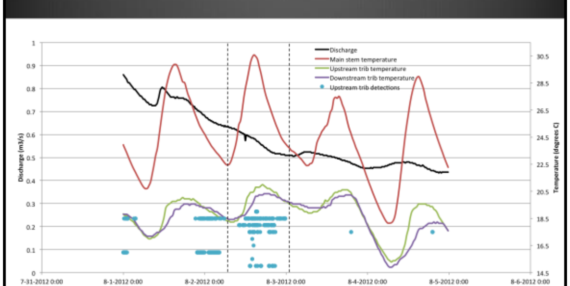
Aaron Fraser; Kurt Samways; Michelle Charest; Adrian Hards; Sherr Vue; Paula Thoms; ; Brittany Graham; Wayne Anderson; Sacha LeBlanc; Maria Thistle; Theoren Ellis; Korey Mabee; Thomas Hebrard; Brian Four; Chloe Bernard-Florat; Nicolas Clavel; Mat Fitzgerald

Canadian Rivers Institute

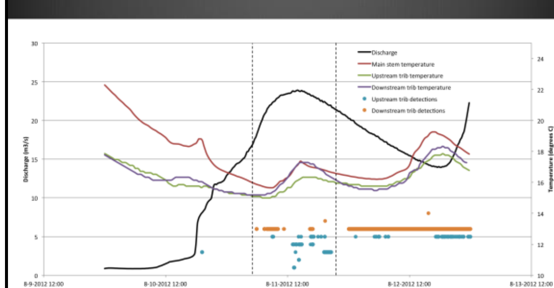
Ouelle Aggregation 1, July 27, 2012



Ouelle Aggregation 2, August 2, 2012



Ouelle Aggregation 3, August 11, 2012



Buffering acid and providing hope: early results of the West River (Sheet Harbour, NS) acid mitigation project

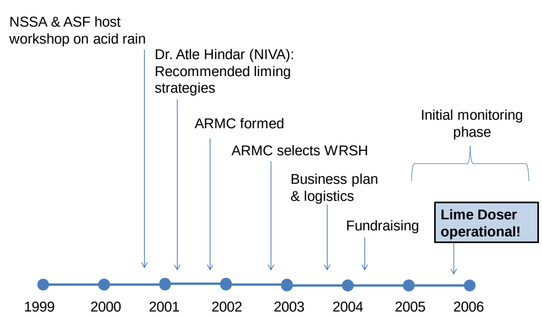
Edmund Halfyard, Nova Scotia Salmon Association

Overview

1. Project overview
2. Monitoring program
3. Initial and recent results
4. Conclusions
5. Lessons learned for SU recovery planning (recommendations)

Overview | Monitoring | Initial & Recent Results | Conclusions | Recommendations

Project Overview – Impetus & Formation



Overview | Monitoring | Initial & Recent Results | Conclusions | Recommendations

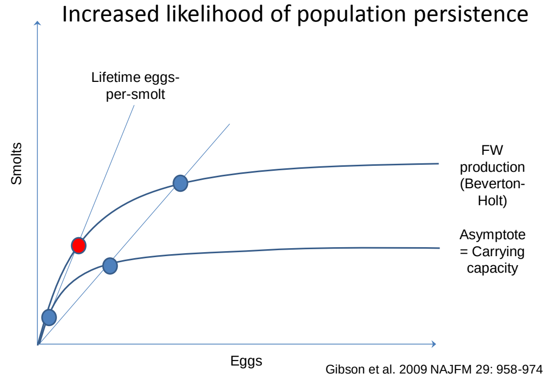
Project Overview – Impetus & Formation

NSSA & ASF recognized that acidification was limiting FW production of Southern Upland Atlantic salmon!

Goals

1) Increase likelihood of population persistence in WRSH
2) Increase FW productivity in WRSH
3) Monitor efficacy of lime dosing & associated biological response
4) Demonstrate efficacy of using lime dosing as part of a larger conservation effort

More on goal#1: Increased likelihood of population persistence



Gibson et al. 2009 NAJFM 29: 958-974

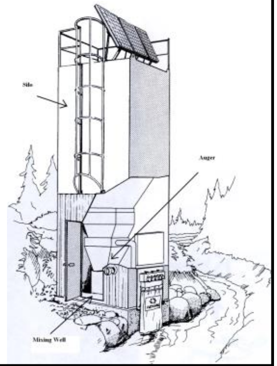
Overview | Monitoring | Initial & Recent Results | Conclusions | Recommendations

WRSH Set-up

- Kemira Kemwater lime doser
- First lime doser in North America on a salmon river
- ~30 km from HoT (all of accessible main branch)
- High organic water, dark colour (70-150 rcu)
- Primarily 2 y.o. smolt & 1SW (~80% each)
- Once 31+ lowhead dams on system (<1974)

What is a Lime Doser?

- Silo
- Auger
- Crock or Well
- Automated Dose Control

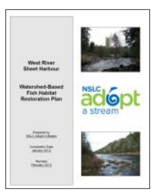


Project Finances

- ~ $700 000 invested
- ~ $30 000 annual operating budget
- ~$20 000 annual monitoring budget
- > 18 000 volunteer hours (~$180 000)

Other Initiatives

- Watershed habitat planning / mapping … enhancement
- Supportive rearing
- Kelt reconditioning
- River-specific research (smolt, sea trout)… predation related issues

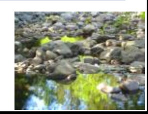


Project Monitoring

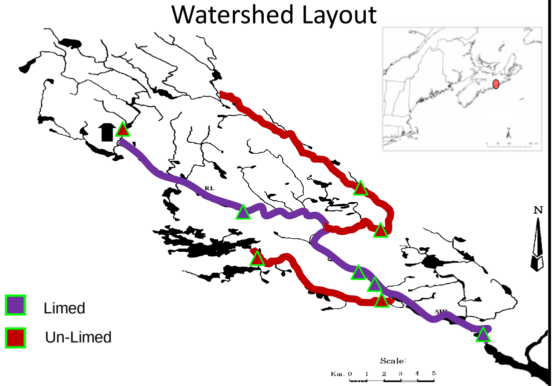
- BACI design
- Focused on ecosystem response

	Initial Phase (05-06)	On-going monitoring
Water chemistry (inc. pH)	Yes	pH -only
Aquatic invertebrates	Yes	Yes
Periphyton	Yes	No
E-fishing salmon	Yes	Yes
Smolt estimates	No	Yes

Primary focus during initial phase due to *S. salar* generational time & competing threats

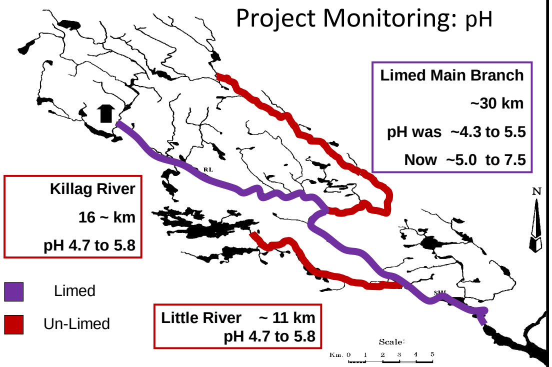


Watershed Layout



Results:
Initial monitoring phase & recent results

Project Monitoring: pH



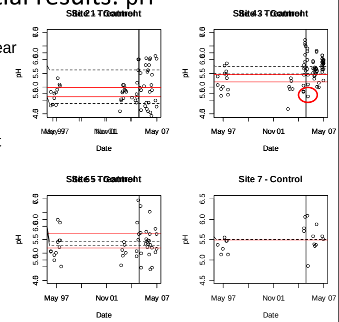
Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Initial results: pH

- pH of treated river at or near target level of pH 5.5.
- No sig. change at control sites
- Increased pH at treatment sites*

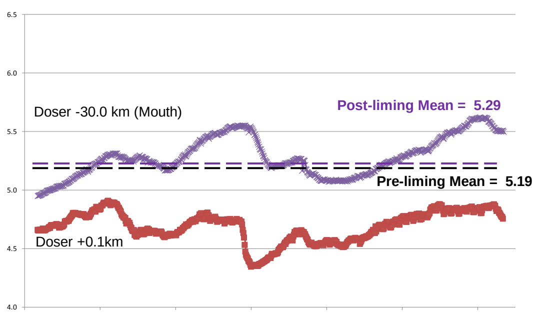
*n/s @ mouth, but still near target.

** Reduction in severity of episodic minima!



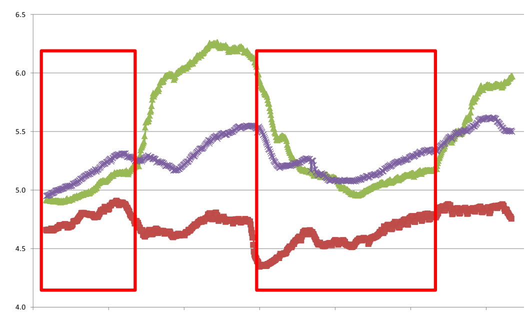
Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Recent results: pH Oct-Nov. 2012



Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

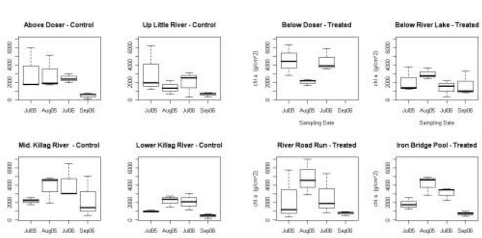
Recent results: pH Oct-Nov. 2012



Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Initial results: Periphyton

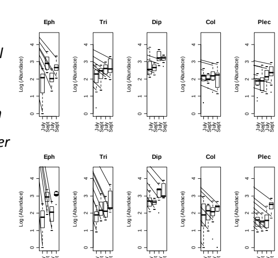
- No significant changes related to liming or among sites in year following liming
- Not continued in subsequent monitoring



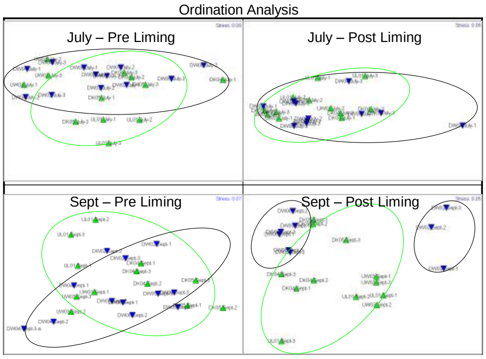
Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Initial results: Invertebrates

- Indicators of acidification and general stream health
- In treated sections;
  - *Community shifts occurred by fall of 1st treatment year*
  - *General increase in abundance in both control & treatment however disproportionate abundance increase at treatment sites*
  - *Shift in dominant taxa*



Ordination Analysis



Green = Control Blue = Treatment

Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

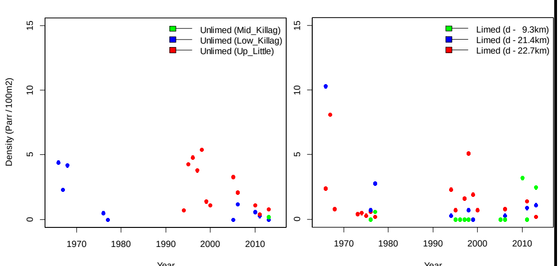
Recent results: Invertebrates

- Collected samples again in 2009
- Sorted, ID'd and QA/QC'd
- Analysis incomplete

Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Initial & recent results: Electrofishing

- Recent density estimates in treated areas relatively high



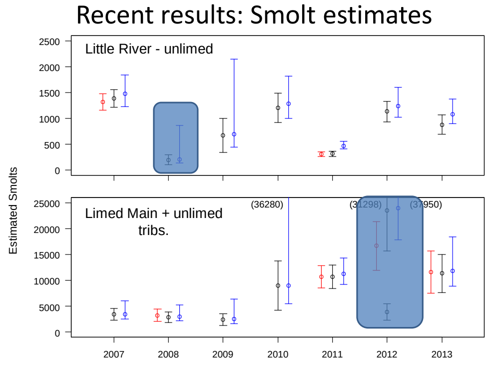
Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Initial & recent results: Electrofishing

- Data considerations:
  - Effect of supportive-rearing program / kelt-reconditioning
  - Without adult returns, difficult to interpret
  - Effect of patchy egg deposition
  - Inadequate spatial coverage to infer sub-watershed-level population chances
- However, smolt production extends e-fishing results

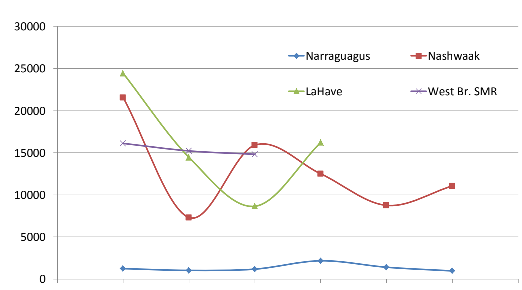
Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Recent results: Smolt estimates



Overview Monitoring **Initial & Recent Results** Conclusions Recommendations

Recent results: Smolt estimates



Recent results: Smolt estimates

- Data considerations:
  - Estimation limitations, like all M-R experiments
  - Effect of supportive-rearing program / kelt reconditioning
  - Without adult returns, difficult to interpret
- Cohort based assessment

Cohort	Little River (unlimed)	Limed Main + unlimed tribs.
2007 : 2011	0.23 (decline)	3.10 (increase)
2008 : 2012	*Too uncertain*	*Too uncertain*
2009 : 2013	1.31 (increase)	4.68 (increase)

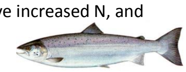
Recent results: Smolt estimates

- When compared to other regional estimates of smolt production

Cohort	Limed Main + unlimed tribs.	Little River (unlimed)	Narraguagus	Nashwaak	Restigouche
2007 : 2011	3.10 (increase)	0.23 (decline)	1.13 (increase)	0.41 (decrease)	0.73 (decrease)
2008 : 2012	*Too uncertain*	*Too uncertain*	0.94 (decrease)	1.51 (increase)	1.73 (increase)
2009 : 2013	**4.68 (increase)**	**1.31 (increase)**			

Summary

- Have increased pH in river, above target for much of the habitat
- Logistical / equipment issues have led to sub-optimal pH conditions
- Early signs of biological response (invertebrates)
- Electrofishing data inconclusive, but some signs of potential response
- Smolt production data suggestive of salmon response
- Liming + auxillary programs appear to have increased N, and likely decreased risk of extirpation

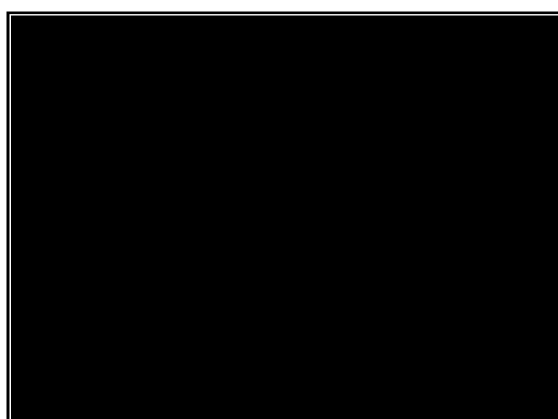


Lessons learned - Recommendations

1. Lime dosing feasible … careful planning required
2. Pro's and Con's for each liming method
3. Monitoring important, but;
   1. Expensive (20-30% of budget)
   2. Requires sufficient pre-treatment data
4. Liming should be considered only as part of a larger program
5. Even small-scale projects may provide benefit if planned properly. (i.e. limestone gravel spawning beds, ditch revetments)
6. Project goals should be achievable and tractable

Thank you

- Atlantic Salmon Federation
- Fisheries and Oceans Canada
- Nova Scotia Department of Fisheries and Aquaculture
- Donner Foundation Canada
- Nova Scotia Power
- Acadia University
- Atlantic salmon conservation foundation
- Northern Pulp
- Countless volunteers



North American Salmon Restoration Plan
Todd Dupuis

The Plan

Lists projects/programs that if completed would aid in wild Atlantic salmon recovery

Used to focus energy and limited recourses on specific projects/programs

Document Organization
(by Province/State)

Spawning requirements presented to provide magnitude of resource potential

Nova Scotia

SMA	Location	# Rivers	Major Rivers	Spawning Requirements
18	From NS/NB border to Cape North	22	Margaree, Philip, Wallace	19 tonnes 3,887 Large Salmon (Avg. wt. 4.5 kg) 1,147 Small Salmon (Avg. wt. 1.6 kg)
19	Cape Breton East	29	North, Middle, Mira, Framboise, Grand, Tillard, Inhabitants and Baddeck	18 tonnes 3,922 Large Salmon (Avg. wt. 4.4 kg) 620 Small Salmon (Avg. wt. 1.7 kg)
20	Eastern Shore	32	St. Mary's, Moser, Liscomb, West (Sheet Harbour), Musquodobit, Salmon (Guys Co), Salmon (Port Dufferin), Country Harbour, Isaac's Harbour, New Harbour	60 tonnes 3,129 Large Salmon (Avg. wt. 4.4 kg) 26,948 Small Salmon (Avg. wt. 1.7kg)
21	SW Nova Scotia, Halifax to Digby	20	LaHave, Medway, Gold, Petite, Mersey, Clyde and Tusket	95 tonnes 8,310 Large Salmon (Avg. wt. 4.4 kg) 34,550 Small Salmon (Avg. wt. 1.7kg)
22	Bay of Fundy, Digby to New Brunswick border	28	Stewiake, Shubenacadie, Gaspareau (King's Co), Folly, Debert, Portapique	18 tonnes 1,969 Large Salmon (Avg. wt. 4.4 kg) 5,471 Small Salmon (Avg. wt. 1.7 kg)
Spawning Requirements			**Total Tonnage**	210
Spawning Requirements			**Total Large Salmon**	21,217
Spawning Requirements			**Total Small Salmon**	68,736

Document Organization

Organized by five topics:

a) Fisheries Management/Stock Assessment
b) Scientific Research
c) Population Enhancement (stocking)
d) Habitat Restoration
e) Enforcement

Project/Program Examples

Restoration
Liming Southern Uplands NS

10 yr. costs ~ 8.0 million
(Lime doser experience)

Restoration: Saint-Jean River log jam

Estimated costs 1.1 million

Restoration: Downstream passage St. John River

Estimated Cost: $3.5M capital cost to build + $250K per year to operate.

Restoration: Dam Removal

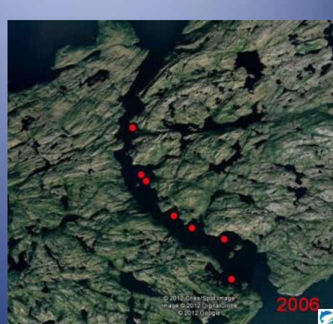
(Penobscot River Project)

Research Examples

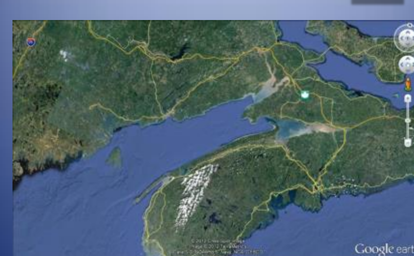
Research: *Impacts of Aquaculture*

Investigate impact of aquaculture on wild salmon in Conne River.

Partners: DFO, Conne River 1st Nations, ASF



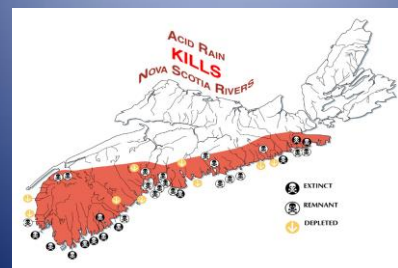
Research: *Tracking*



Research:
Ecosystem benefits of other diadromous fish species

Benefit to watershed?
Benefit to salmon?

Research
Determine smolt ability to osmoregulate post low pH exposure. (pH threshold?)



Research:

(PhD UPEI F

Population Enhancement (Stocking)

Population Enhancement: Stocking

Rattling Brook Salmon Restoration Project

- Recolonization above 50 year old hydro dam (transfer & stocking of adults from Exploits River)
- in 2nd year of 5 yr project

Population Enhancement: Stocking

Enforcement/Protection

Enforcement/Protection
Protection of cold water refugia

Protection of cold water pools (for adult salmon) and cold water seeps (for juveniles).

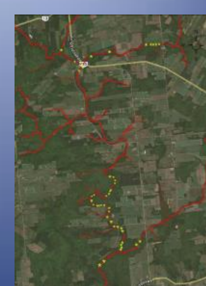
(Addition of jagged boulders on bottom to prevent pool sweeps with nets)

Needs Throughout Range

Needs Throughout Range
Mapping of Critical Habitat

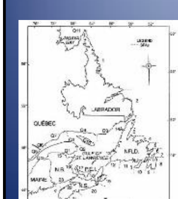
Need permanent protection of high value spawning and rearing habitats

(Redd Surveys PEI)



Needs Throughout Range: Stock Assessment

(At least one index site in each SMA (SFA))



Needs Throughout Range
Assessment of Habitat Fragmentation

- Culverts
- Fishway efficiency (DU/UPEI PhD)
- Upstream and downstream fish passage at hydroelectric dams

>60% not providing effective fish passage

Big and strong only. Species specific

Unanswered Questions

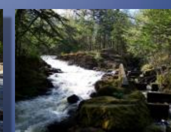
Question: Fish Passage?

Should the "Plan" support Atlantic salmon access over:

- Natural barriers (complete)
- Partial barriers
- Should the "Plan" support the maintenance/replacement of existing fishways at natural barriers

Nepisiguit River and distant view of Grand Falls, near Bathurst, NB, 1915

White Bear River, Labrador



Grande River at Grande River Falls NS

Question: Should the "Plan" support stocking?

If so in what form?

1) Put and take
2) Depressed stocks
3) Other?

Project/Program Prioritization

Question: Criteria for prioritization?

- - likelihood of success
- - potential to restore numbers
- - measurable results
- - costs
- - partnerships
- - location

Question: Document Name?

- Restoration Plan
- Strategic Recovery Plan
- Strategic Recovery Framework
- Strategic Framework

Likelihood of success

Will depend on:

1) Resources: ASCF, SARA, NBWT, PEIWMF, DFO Partnership Fund, NS Adopt-a-stream, other

2) Partnerships (Penobscot experience)

Next Steps

- External review
- Further refinement
- Project/Program prioritization
- Cost out top priority Projects/Programs
- Completion Date: Spring 2014

Atlantic Salmon Federation   Fédération du Saumon Atlantique

Enhancement methods and results obtained over a thirty-plus year program on the Nepisiguit River

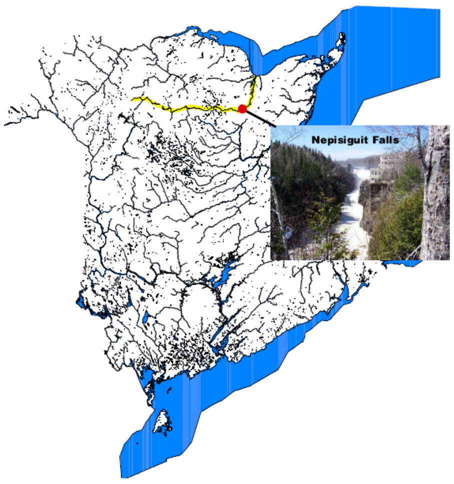
Bob Chiasson, Charlo Salmonid Enhancement Center

Enhancement methods and results obtained over a thirty-plus year program on the Nepisiguit River

Bob Chiasson, Charlo Salmonid Enhancement Center

Above Head of Tide, Nepisiguit River

Nepisiguit River



Results of stocking marked fall fry, Nepisiguit River 1981-1985

Year Stocked	Amount	Year/Grilse Returns	Marked Grilse	Total Grilse	Year/Salmon Returns	Marked Salmon	Total Salmon
1981	550,000	1984	228	1900	1985	312	1300
1982	294,000	1985	360	1200	1986	523	1341
1983	309,000	1986	855	2442	1987	783	2175
1984	280,000	1987	1136	2841	1988	619	2477
1985	327,000	1988	910	3794	1989	499	1664
Totals	1,760,000		3489	12,177		2736	8927
		% Total	28.7			30.6	

Based on normal returns, this indicates a +10% survival from marked fry to smolts.
Number of broodstock females = 220; ie., return of 6225 fish = 28 returns per female.
Natural spawning escapement for same time frame = 34 million eggs; minimum 3400 females.
For the 14,879 unmarked return, this = 4.4 fish per female, which indicates the advantage of the hatchery process, over six times the return per female.
To put this in perspective, in a river receiving only 50 % of required spawning escapement, removing 10% of these for a hatchery/incubation box process (5% of total) could yield the equivalent of an additional 30% to returns -, the same as a natural 75% of required spawning escapement- and over time, if performed each year, is cumulative to some extent, as shown by Nepisiguit returns.

Nepisiguit River (stocking from 1974 to 2012)

Year	fry (0)	fry (0+)	Parr (1)	Parr (1+)	Smolt	Total
1974	0	0	0	0	15000	15,000
1975	0	63054	0	6250	7600	76,904
1976		7821		5000	33109	45,930
1977	0	0	0	0	0	0
1978		173000	0	0	0	173,000
1979	0	87000	0	142711	3995	233,706
1980	0	156000	0	0	27000	183,000
1981	770000	0	16310	0	5819	792,129
1982	0	293740	0	2980	0	296,720
1983	0	514625	10645	0	10454	535,724
1984	0	326717	18667	0	10752	356,136
1985	25000	346618	11153	0	10650	393,421
1986	50000	36701	0	0	75477	162,178
1987	150000	289120	0	1872	10706	451,698
1988	300000	349000	0	0	10000	659,000
1989	342981	0	0	490000	10000	842,981
1990	342981	0	0	373020	10868	726,869
1991	0	243016	0	176713	9663	429,392
1992	335801	601293	6676	5765	11641	961,176
1993	0	485482	0	30944	0	516,426
1994	255000	104000	0	0	0	359,000
1995	105000	92400	0	0	0	197,400
1996	240939	272000	11100	12921	0	536,960
1997	273523	150000	0	0	12000	435,523
1998	306623	136700	0	0	0	443,323
1999	101228	79000	0	0	0	180,228
2000	291936	340000	0	0	0	631,936
2001	296188	226791	0	0	0	522,979
2002	173266	100000	0	0	0	273,266
2003	173173	0	0	0	0	173,173
2004	0	6000	0	0	0	6,000
2005	160960	0	0	0	0	160,960
2006	0	0	0	0	0	0
2007	49000	0	0	0	0	49,000
2008	86270	0	0	0	0	86,270
2009	42104	0	0	0	0	42,104
2010	290452	0	0	0	0	290,452
2011	196376	0	0	0	0	196,376
2012	0	84000	0	0	0	84,000
Grand Total	5,358,801	5,564,078	74,551	1,248,176	2,74,734	12,520,340

Incubation Box Summary 1985 to 2011

Year	Site	# Eggs	# Fry	% Survival
1985	Pabineau Brk.	26176	25669	98,1
1986	Pabineau Brk.	50000	48312	96,6
1987	Grand Falls	150000	144450	96,3
1988	Grand Falls	300000	293465	97,8
1989	Grand Falls	350000	335533	95,9
1990	Grand Falls	350000	342981	98,0
1991	Grand Falls	300000	243016	81,0
1992	Grand Falls	350000	335801	95,9
1993	Grand Falls	350000	336277	96,1
1994	Grand Falls	350000	304079	86,9
1995	Grand Falls	350000	105000	30,0
1996	Grand Falls	350000	285939	81,7
1997	Grand Falls	350000	323537	92,4
1998	Grand Falls	350000	337354	96,4
1999	Grand Falls	153408	151228	98,6
2000	Grand Falls	350000	340236	97,2
2001	Grand Falls	350000	345272	98,7
2002	Grand Falls	219000	216532	98,9
2003	Grand Falls	197275	192412	97,5
2004	Grand Falls			
2005	Grand Falls	168270	160960	95,6
2006	Grand Falls			
2007	Grand Falls	50000	49000	99,4
2008	Grand Falls	88400	86270	97,5
2009	Grand Falls	42500	42104	98,9
2010	Grand Falls	300900	290452	96,5
2011	Grand Falls	208000	196376	90,7
Grand Total		6,103,929	5,532,255	92,5

Pabineau First Nation, Salmon Counting Fence

Angling Summary 1981 to 2012

YEAR	GRILSE	SALMON	TOTAL	RELEASED	GR.TOTAL	*salmon Released
1981	285	40	325	75	400	
1982	629	95	724	104	828	
1983	240	60	300	60	360	
1984	600	0	600	300	900	150
1985	500	0	500	400	900	300
1986	800	0	800	900	1700	500
1987	800	0	800	1050	1850	500
1988	1000	0	1000	1100	2100	700
1989	600	0	600	600	1200	500
1990	500	0	500	400	900	300
1991	700	0	700	450	1150	300
1992	800	0	800	600	1400	270
1993	470	0	470	343	813	258
1994	370	0	370	430	800	250
1995	350	0	350	400	750	300
1996	450	0	450	550	1000	420
1997	200	0	200	350	550	300
1998	150	0	150	255	405	170
1999	300	0	300	300	600	100
2000	450	0	450	780	1230	330
2001	300	0	300	500	800	300
2002	200	0	200	365	565	190
2003	220	0	220	460	680	240
2004	230	0	230	490	720	250
2005	160	0	160	220	380	120
2006	255	0	255	390	645	165
2007	310	0	310	500	810	150
2008	625	0	625	761	1386	300
2009	410	0	410	524	934	269
2010	488	0	488	788	1246	300
2011	660	0	660	1170	1830	620
2012	489	0	489	726	1215	423
TOTAL	14541	195	14736	16341	31047	8975
AVERAGE	454		461	511	970	309

AVERAGE CATCH 1950-1960 = 700
1960-1968 = 500
1969-1978 = 118

1981 - START OF ENHANCEMENT PROGRAM

AVERAGE CATCH 1984-2012= 1016

AVERAGE RELEASE 1984...2012=.... 246 g 309 s

Last Ten Years

AVERAGE CATCH	2003-2012	985	
AVERAGE RELEASE	2003-2012	603	320 g 283 s

Return Data Nepisiguit River 1982 to 2012

Year	Eggs	Density	Fry	Parr	Grilse	Salmon	Total	Factor
1982	6.00	170	5.89	5.21	2442	2175	4617	4.03
1983	5.25	150	4.36	3.08	2847	2477	5324	5.27
1984	8.50	240	3.63	6.03	3794	1664	5458	3.76
1985	6.00	170	9.67	4.90	1300	1500	2800	2.55
1986	8.00	230	7.75	2.18	2000	1500	3500	2.61
1987	12.60	360	24.08	5.64	2000	1000	3000	1.38
1988	15.00	430	15.56	9.68	2000	964	2964	1.20
1989	9.80	280	24.32	7.18	1262	1558	2820	1.69
1990	9.00	250	15.23	9.70	1324	2189	3513	2.34
1991	9.00	250	14.84	4.50	1218	1598	2816	1.88
1992	4.50	130	18.70	3.10	1320	1535	2855	2.86
1993	5.25	150	21.00	3.90	681	1647	2328	2.41
1994	9.00	250	21.60	3.90	771	1378	2149	1.38
1995	9.58	274	13.50	3.00	1000	1896	2896	1.32
1996	7.68	219	39.50	15.40	1400	2000	3400	2.13
1997	7.52	215	36.30	8.80	1400	1300	2700	1.75
1998	8.60	245	41.70	6.30	1000	1600	2600	1.58
1999	7.43	210	34.90	5.46	1100	1675	2775	2.01
2000	9.50	270	26.98	4.81	1125	1250	2375	1.25
2001	11.20	320	48.7	4.92	900	1200	2100	1.05
2002	7to 8.0	~200	15.3	3.95	1200	1300	2500	1.92
2003	9.0	250	41	2.74	1700	1500	3200	2.00
2004	9.0	250	17.6	1.4	2500	1500	4000	2.39
2005	5to 9.0	~200	18.8	6.95	1500	1800	3300	2.64
2006	5 to 9.0	~200	18.3	>3.7 **	2200	2500	4700	3.92
2007	7 to 8.0	~200	>4 **	>3.7 **	2300	2100	4400	3.39
2008	8.5	240	10.3	5.75	1800			
2009	8.5	240	21.4	5.23				
2010	10.0	270	13	5				
2011	11.5	330	37.4					
2012	10.4	285						

1. Adults refers to only 2 sea winter and older fish, includes those taken to Charlo
2. Estimated spawning escapement in millions.
3. Density in number of eggs per 100 M2.
4. Fry - Resultant fry one year hence.
5. Parr - Resultant parr two years hence.
6. Grilse - returns of one sea winter fish four years hence.
7. Salmon - all multi year salmon five years hence - repeat spawners not factored.
8. Factor - Number of returning fish per original adult fish.

Nepisiguit River
Total Returns of Salmon 1982 -2012

Year	# Grilse	# Salmon	Total
1982	1600	700	2300
1983	800	600	1400
1984	1900	850	2750
1985	1200	1300	2500
1986	2442	1341	3783
1987	2847	2175	5022
1988	3794	2477	6271
1989	1296	1664	2960
1990	1500	2000	3500
1991	1700	1800	3500
1992	2000	1000	3000
1993	1250	1000	2250
1994	1324	1558	2882
1995	1218	2189	3407
1996	1320	1595	2915
1997	681	1535	2216
1998	771	1647	2418
1999	1000	1378	2378
2000	1412	1896	3308
2001	1400	2000	3400
2002	1000	1300	2300
2003	1100	1600	2700
2004	1125	1675	2800
2005	800-1000	1000-1500	1800-2500
2006	1200-1400	1200-1500	2400-2900
2007	1600-1800	1200-1400	2800-3200
2008	2500	1500	4000
2009	1500	1500	3000
2010	2200	1800	4000
2011	2300	2500	4800
2012	1800	2100	3900

Conclusion:

Considering the potential lost eggs during natural spawning, those not fertilized, mortality during winter and spring from freezing, erosion, ice damage to redds, natural predators, natural mortality during hatching,use of streamside incubation boxes, with fertilization, incubation and hatching under generally controlled conditions has resulted in a survival rate from five to ten times what would occur in natural spawning. In this way, a total of approximately 50-150 early run broodstock have contributed as much as 400-1200 fish spawning naturally.

In addition, it has been possible in most years to concentrate on the early run component, which will contribute to this segment of the gene pool in years to come.

Contribution of different live gene banking strategies to the production of smolt and returning adult Atlantic Salmon on the Big Salmon River

Ross Jones[1], Carolyn Harvie[2], Tim Robinson[3], Leroy Anderson[4], Patrick O'Reilly[2], Stephanie Ratelle[4]

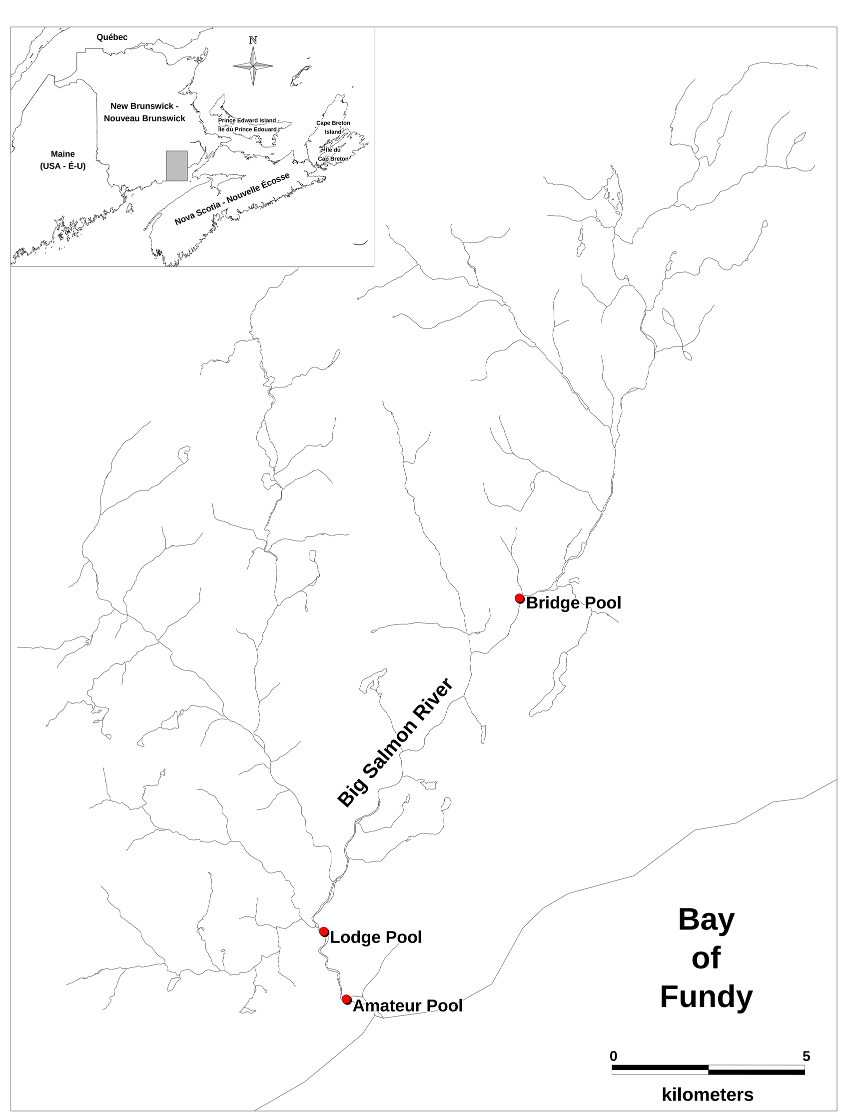
[1] Dept. of Fisheries & Oceans (DFO), Moncton, NB; [2] DFO, Dartmouth, NS; [3] Fort Folly First Nation, Dorchester, NB; [4] DFO, Mactaquac, NB

Abstract

Evaluation of two different Live Gene Bank (LGB) release strategies has been possible because of ongoing collaborative monitoring projects in conjunction with genetic analysis or parentage assignment. The in-river LGB, i.e. progeny released as unfed fry and fall parr, has essentially increased the number of smolts emigrating from the Big Salmon River from 2004 to 2011 by three-fold. Progeny released as fall parr have an average in-river survival to the smolt stage that is four times greater (7.1 vs 1.7%) than progeny released as unfed fry although the return rate to 1SW salmon for smolts produced from the unfed fry is double that of the fall parr releases. In the past decade, progeny from the LGB have contributed to about 20% of the returning adults on the Big Salmon River.

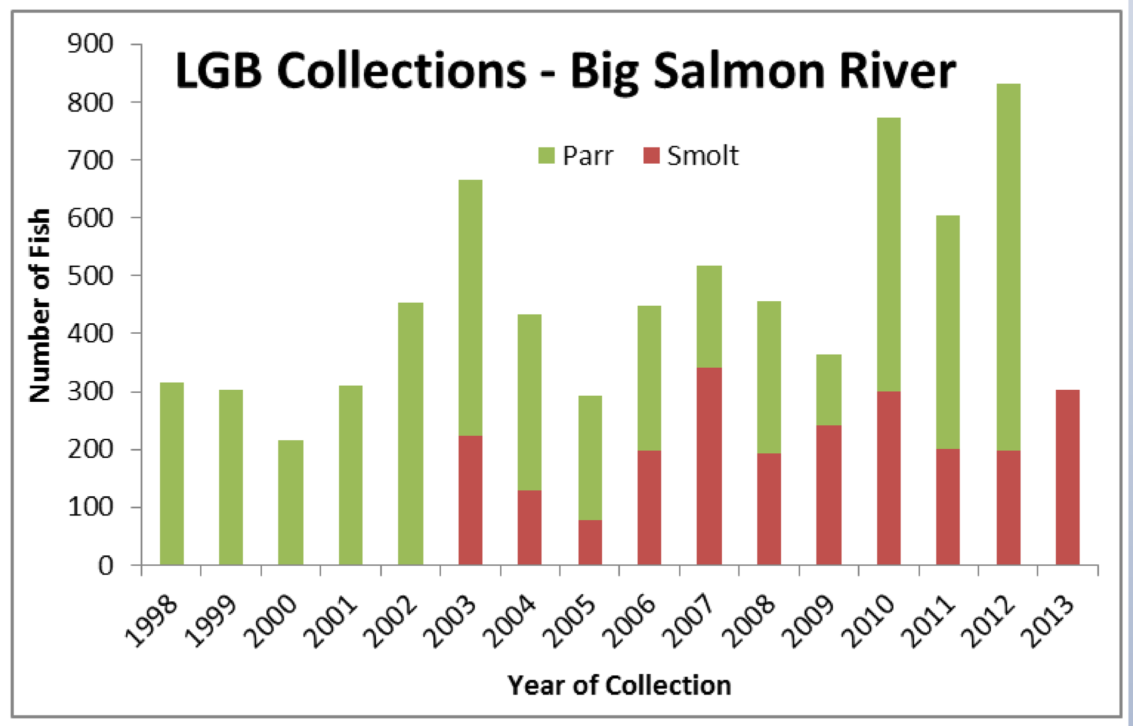
Study area

Located in southern New Brunswick, the Big Salmon River (45°25'0"N, 65°24'0"W) flows 27 kms from the outlet of Walton Lake to the Bay of Fundy. It has a drainage area of 332 km² with an estimated 494,000 m² of accessible salmonid rearing habitat. The Big Salmon River is home to a number of freshwater and diadromous fish species including the endangered Inner Bay of Fundy (IBoF) Atlantic salmon, and is a key index river identified in the recovery strategy for monitoring the state of this species in the wild. Approximately 280 small salmon and 420 large salmon are required to achieve the conservation requirement of 2.2 million eggs established for the Big Salmon River.

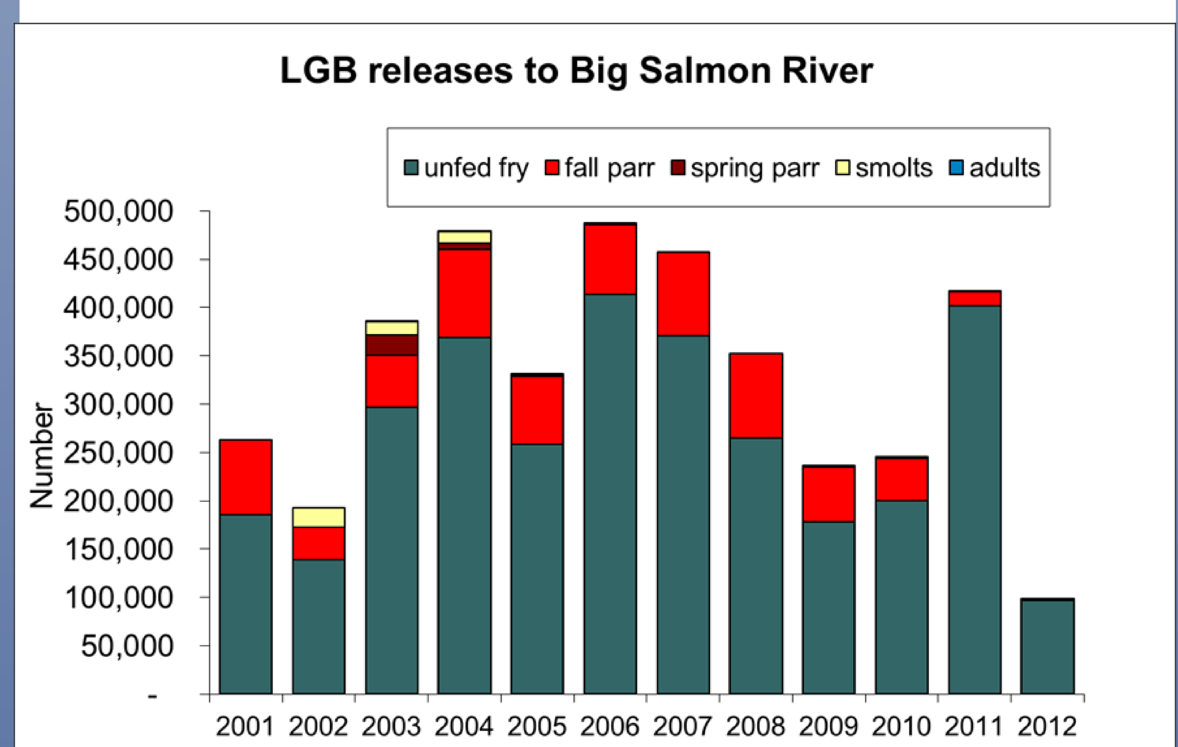


Live Gene Bank Program

As a result of declining adult abundance in IBoF rivers, a Live Gene Bank Program using juvenile salmon from the Big Salmon River was initiated in 1998 with the collection of about 300 wild-origin parr. Until 2002, about 300 parr were collected by electrofishing each fall. Starting in 2003, in addition to the parr collections, wild smolts were collected using a Rotary Screw Trap (RST) that was operated near the mouth of the river (Amateur Pool).

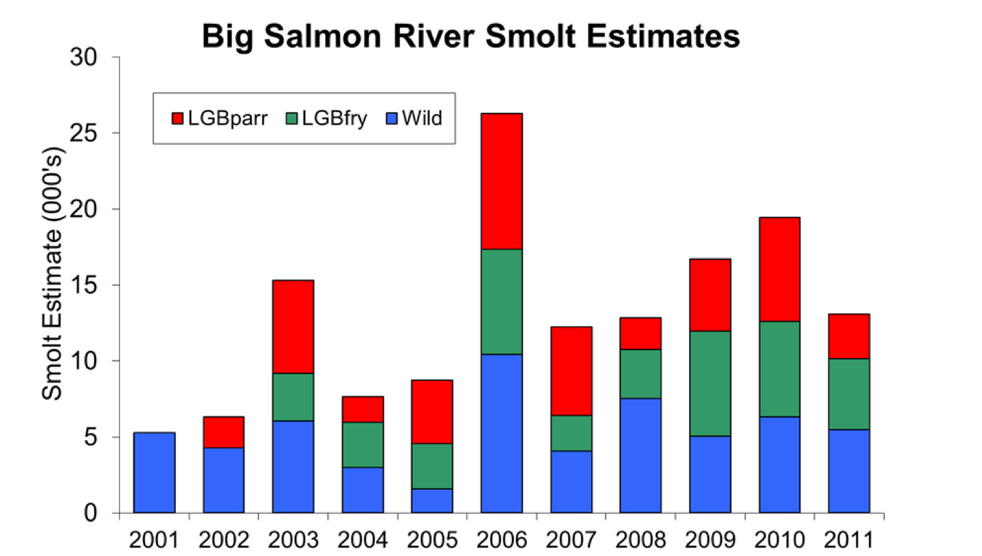


The parr and smolt were transported to Mactaquac Biodiversity Facility where they remained until sexually mature. Prior to spawning, all wild-caught juveniles, and sibling groups maintained exclusively in captivity, are DNA fingerprinted, and placed into the Big Salmon River pedigree using exclusion and likelihood-based parent assignment methods. Pedigree, and other associated information, is then used to identify salmon that are to be retained as broodstock, and to pair specific males with specific females for spawning. The purpose of this procedure is to minimize loss of genetic variation and to reduce inbreeding in future generations. As part of the in-river LGB, some progeny are released as unfed fry (LGB_{fry}) in early May, age-0 parr (LGB_{parr}) in September or age-1 smolts in May or June. An equal representation of each mating is retained at Mactaquac as part of the captive LGB.



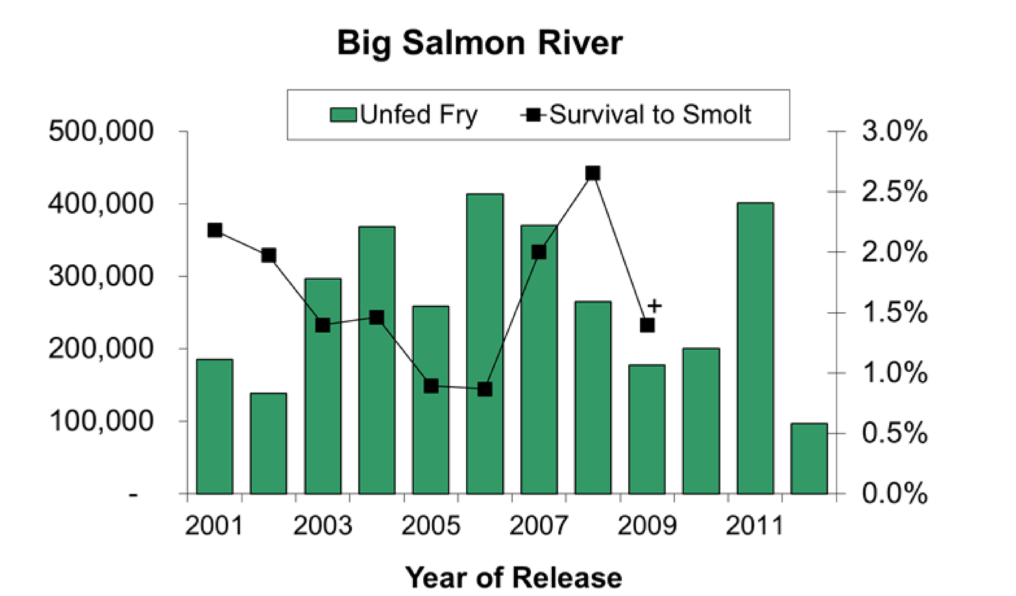
Smolt Assessment

A RST or smolt wheel has been operated on the Big Salmon River just above the high tide marker since 2001. Using mark and recapture methods, smolt assessments have been conducted from 2001 until 2011 along with the smolt collections for the LGB program. Genetic analysis (or parentage assignment) of tissue samples randomly collected from outgoing smolts in combination with assessment data provide smolt abundance estimates by origin (LGB_{fry} and wild). Smolt production from the remnant wild population has been around 5,400 fish while smolts from the in-river LGB_{fry} and LGB_{parr} releases have averaged about 4,400 and 4,800 fish, respectively, on an annual basis.

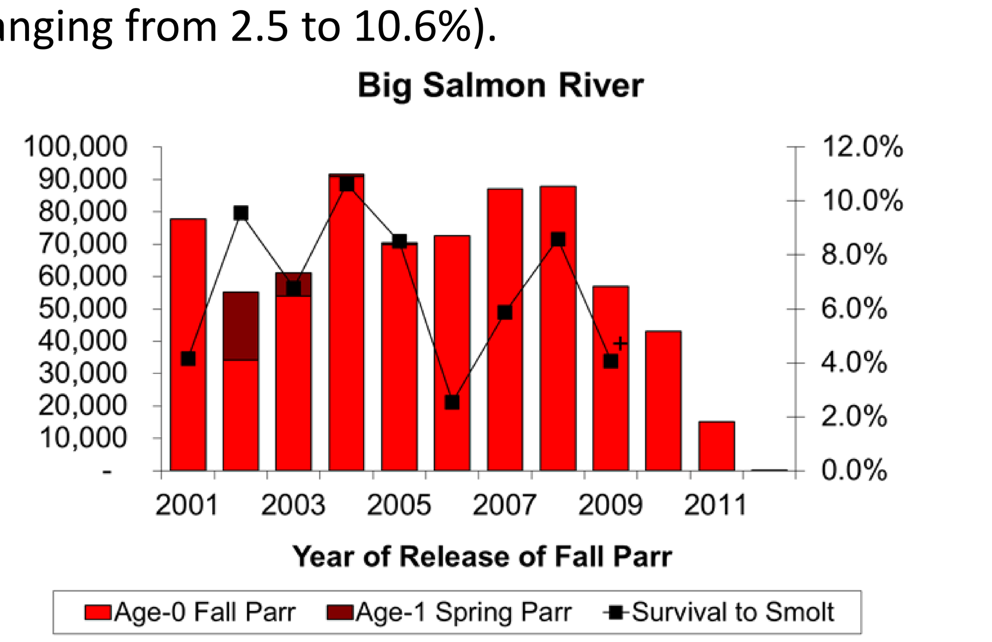


Survival to Smolt Stage

The percentage of released unfed fry surviving to the smolt stage has ranged from 0.9% to 2.7%. The mean survival rate over the time series has been 1.7%.



Mean survival to the smolt stage for the LGB progeny released as parr from 2001 to 2008 has been 7.1% (ranging from 2.5 to 10.6%).

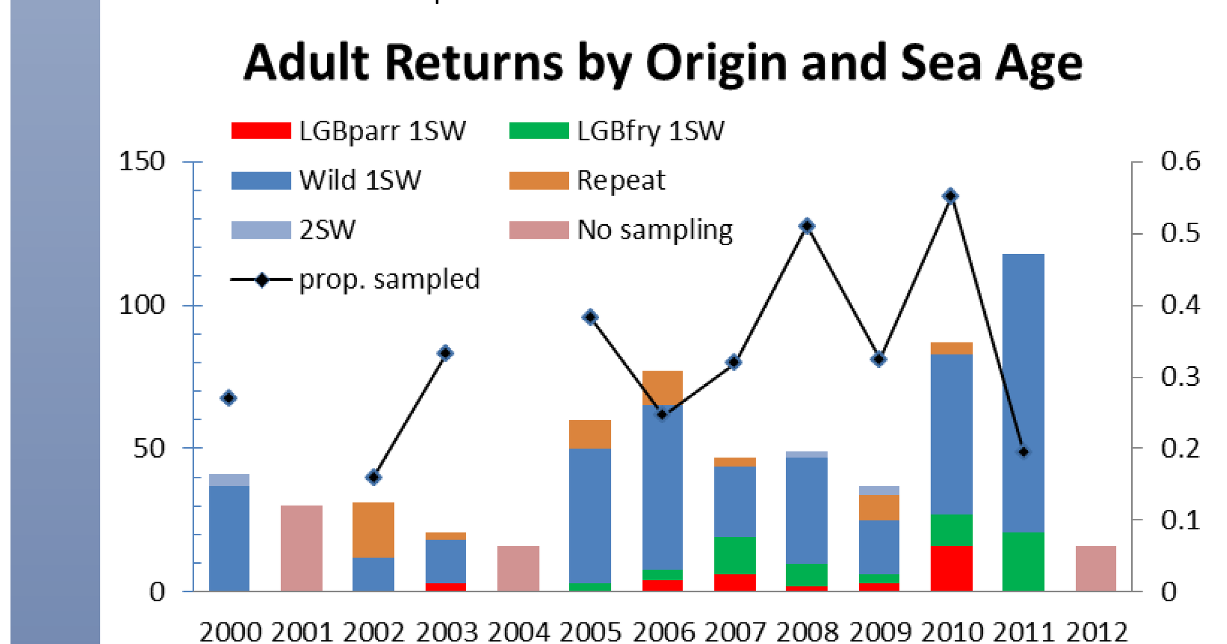


Adult Assessment

Counts of adults from snorkel or dive surveys are used to estimate the total number of returning adult salmon to the Big Salmon River each year. When numbers allow, mark and recapture techniques are used to estimate the diver observation rates (mean= .58). Estimates of total adult returns from 2001 to 2012 have averaged 49 fish but have been as low as 19 (2004, 2012) and as high as 118 (2011) fish.

LGB returns since 2003

From 2003 until 2011 (no adults sampled in 2004 and 2012), 172 returning adult salmon have been captured on the Big Salmon River, biological characteristics (length, sex, presence of fin clips/fin erosion) recorded, and scale plus caudal fin tissue samples taken. Returning adults missing an adipose fin were identified as LGB parr/smolt, which was later confirmed using DNA fingerprint information and parentage analysis, testing offspring against LGB crosses performed two to five years earlier. Returning adults exhibiting an adipose fin, but assigning to LGB crosses using DNA fingerprint information, were identified as LGB_{fry}. Returning adults exhibiting an adipose fin but that either a) assigned to previous sampled and genotyped returning adults via single-parent parentage analysis or b) failed to assign to any known LGB cross, were identified as WILD, or wild-produced. Note, adults that fail to assign to any genotyped candidate parent are potential offspring of non-genotyped mature male parr and non-captured, non-genotyped returning adults but may also be strays from nearby rivers. Returning adults from LGB_{fry} (n=63, rr=0.19%) have been almost two times the number of LGB_{parr} (n=34, rr=0.10%).



Overall, LGB adults have comprised about 20% of the total returning adults to the Big Salmon River since 2003.

Contact

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Extended Tank Rearing of Salmon Fry Decreases Success in Fresh Water

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QUESTION

- Does feeding salmon fry during the summer before stocking into the wild increase survival and growth?

EXPERIMENTAL DESIGN -- 2006

- 12,000 salmon fry were fed for 6 weeks at the Mactaquac Biodiversity Centre

- 6000 were stocked directly at 4 locations on the Dunbar Stream (a tributary of the Nashwaak River) -- above an impassable falls in early June 2006.

IMPASSABLE FALLS ON THE DUNBAR STREAM

- the remaining 6000 were fed until mid September in tanks at the Tay River rearing site which was fed by **cold spring water whose temperature seldom exceeded 11*C** , then these 6000 were stocked at the same 4 locations on the Dunbar Stream used in June.

RESULTS

EARLY STOCKED

TANK REARED (Adipose clip)

Weight, June, 2006 ***2.1 g***

2.1 g

Length, September, 2006 ***---***

7.4 g

Weight, September, 2006 ***---***

6.7 g

E-fished numbers, September, 2007 ***94***

17

E-fished length, September, 2007 ***12.3 cm***

10.7 cm

E-fished weight, September, 2007 ***20.4 g***

14.4 g

---- tank rearing hatchery salmon fry for the entire summer appeared to decrease survival and growth to the pre-smolt stage.

EXPERIMENTAL DESIGN -- 2008

- 12,000 salmon fry were fed for 6 weeks at the Mactaquac Biodiversity Centre

- 6000 were stocked directly at 4 locations on the Dunbar Stream (a tributary of the Nashwaak River) -- above an impassable falls in early June 2008.

- the remaining 6000 were fed until mid September in tanks at the Bourque rearing site on HWY 8 which was fed by **relatively warmer brook water whose temperature often exceeded 15*C**, then these 6000 were stocked at the same 4 locations on the Dunbar Stream used in June.

RESULTS

EARLY STOCKED

TANK REARED (Adipose clip)

Weight, June, 2008 ***1.8 g***

1.8 g

Length, September, 2008 (e-fished) ***6.9 cm***

8.8 cm

Weight, September, 2008 (e-fished) ***4.0 g***

8.4 g

E-fished numbers, September, 2009 ***60***

26

E-fished length,September,2009 ***12.2cm***

11.5 cm

E-fished weight, September, 2009 ***20.2g***

18.9 g

CONCLUSIONS

Electrofishing in September 2007 and September 2009 assessed salmon pre-smolts, most of which would migrate to the ocean in the following spring.

- These two stocking experiments (2006 and 2008) demonstrated // whether tank reared/fall-fed salmon fry have a small size advantage (reared in cold spring water) or a somewhat larger size advantage (reared in warm brook water) // they have poorer survival and growth outcomes than fish that were stocked with much less artificial feeding. Various journal papers suggest that rearing fish in a non diverse tank environment stunts brain development -- while fish in diverse and stimulating wild environments learn about food acquisition, predator avoidance and individual territory establishment.

Poor Marine Survival of Summer Fed (Adipose clipped) Hatchery Fry Compared to Wild Fish

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OPPORTUNITY

- we had a fairly good handle on numbers of seaward migrating hatchery smolt (Adipose clipped / ADC, from fall fed / tank reared fry) compared to numbers of wild smolt as a result of the annual Department of Fisheries and Oceans operation of Rotary Fish Traps at Durham Bridge on the Nashwaak (index river for streams below the Mactaquac dam) every spring.

ROTARY FISH TRAP CAPTURES SEAWARD MIGRATING SMOLT

QUESTION

- do smolt that spent their first summer being reared in tanks (supposedly to increase their size and decrease losses to predators) fare better than wild smolt in the ocean?

EVIDENCE

2006 ~40,000 ADC /summer tank fed fry stocked to the river in September.

2008 -- 96 of 777 seaward migrating smolt caught in the RST were ADC = ***12.3%***

2009 -- 11 of 199 grilse returning from the ocean were ADC = 5.53%

2007 ~ 22,000 ADC / summer fed fry stocked to the river in September.

2009 -- 74 of 814 seaward migrating smolt caught in the RST were ADC ***= 9.09 %***

2010 -- 20 of 855 grilse returning from the ocean were ADC = 2.34%

- Having already shown that feeding salmon fry during the summer, before stocking into the wild in the fall,
decreases survival and growth in fresh water (Dunbar Stream experiments) ---- we now have evidence that summer feeding

of hatchery fry in tanks (supposedly to increase their size and enhance their success in the wild) also compromises their survival at sea /// suggesting that the lack of early mental development that results from time spent in the non diverse, food rich environment of the tanks during the first few months of the life of these fish has deleterious effects in the marine environment as well.

Rationale for Treating the Entire Southern Maritimes as a Single Bay Management Area

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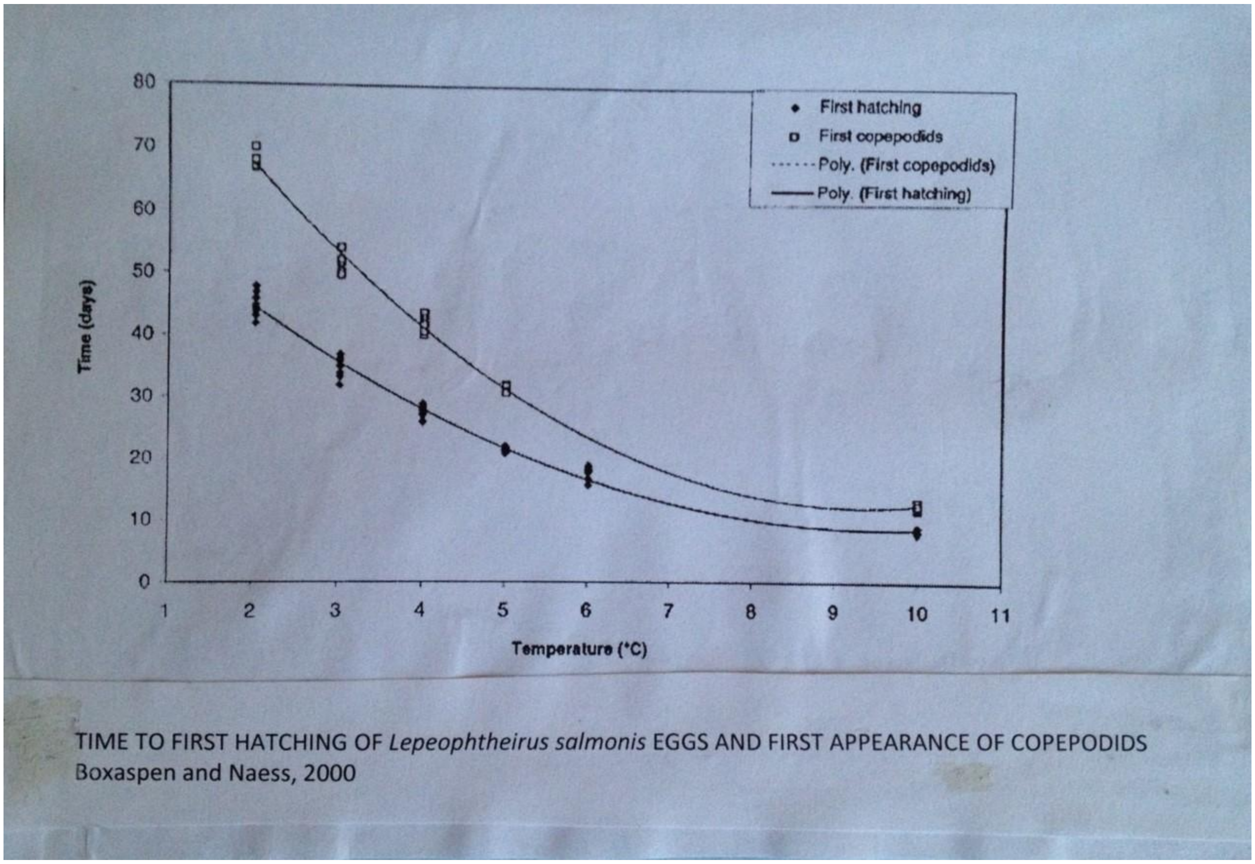
PROBLEM

- Bay Management Area (BMA) program in New Brunswick with synchronous stocking, grow out, harvest and fallowing - to avoid spread of infectious diseases and parasites between neighbouring farms ---------------- is not working.

-Sea lice infestations occur shortly after new smolts have been placed on farms(1).

- Transport of planktonic propagules (eggs and unattached juvenile lice) from distant farms is more common than previously thought.

- Sea lice eggs hatch very slowly and unattached infectious juvenile lice survive for long periods in cold sea water (2), facilitating long distance transport on ocean currents in late winter /early spring.



TIME TO FIRST HATCHING OF *Lepeophtheirus salmonis* EGGS AND FIRST APPEARANCE OF COPEPODIDS
Boxaspen and Naess, 2000

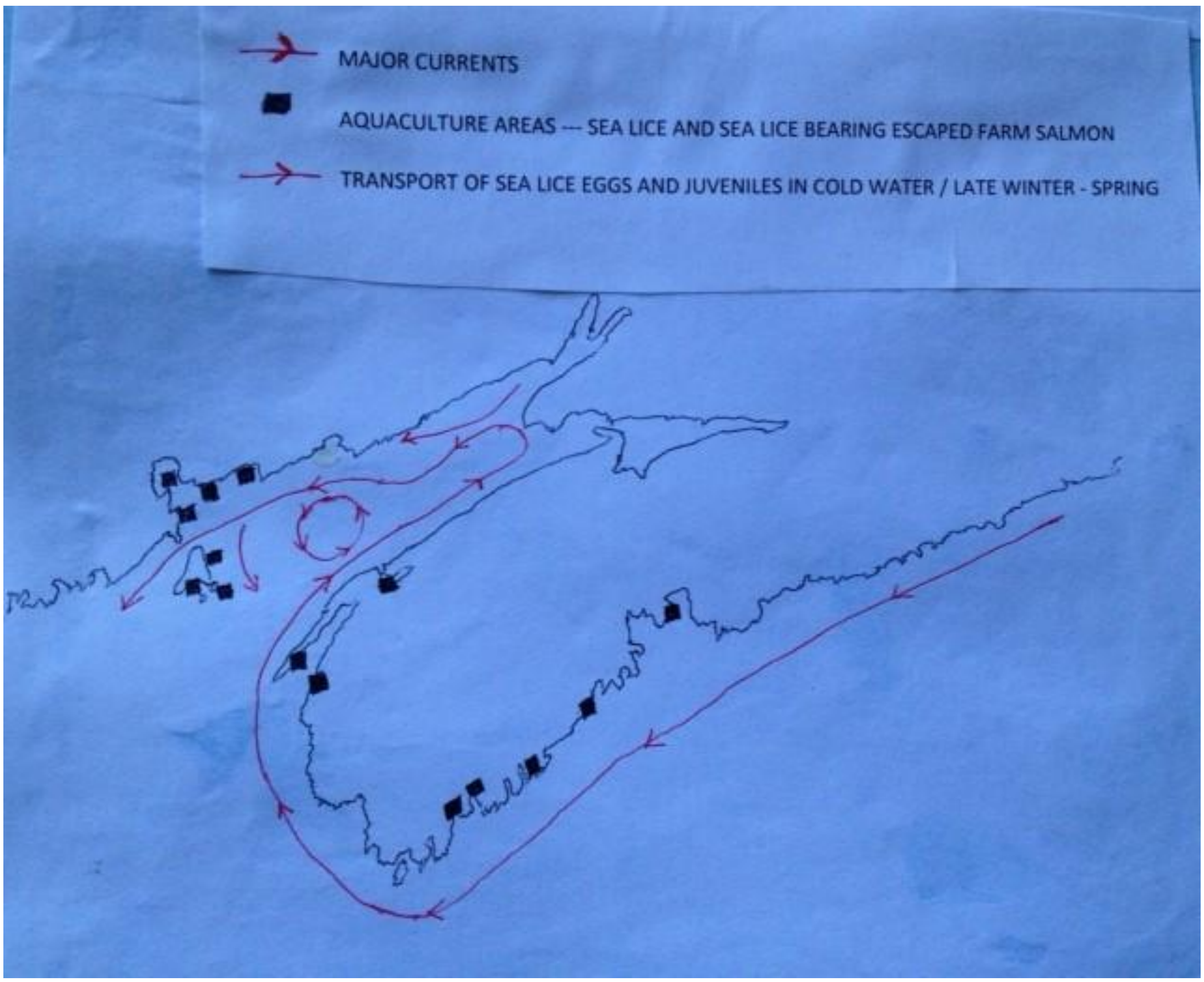
Planktonic salmon lice (*Lepeophtheirus salmonis*) development development from Boxaspen, K and Naess,T.2000 , see: http://dpc.uba.uva.nl/ctz/vol69/nr01/art05

- 2009 tolerance to parasiticide SLICE (emamectin benzoate) begins(3).

- Goal in Norway is reduction to **0.5 per fish adult female lice** on farms(4) during fallowing for three months before restocking in defined production zones (5) in the spring when wild salmon smolts are entering salt water and restocking is normally carried out.

- Goal in Ireland during the spring (March-May) is **0.3-0.5 adult female lice** (6).

- **11 adult female lice** - BMA 1, March, 2011 / **over 20 adult female lice** - BMA 2A, January and March 2012 (7) releasing eggs into circulating cold water currents in time to meet wild smolts when they enter salt water.



SOUTHERN NOVA SCOTIA / BAY OF FUNDY/ SOUTHERN NEW BRUNSWICK -- showing salmon aquaculture areas, major ocean currents sweeping sea lice along the NS coast, into the Bay of Fundy then back southwest along the NB coast toward Grand Manan Island then into the circular gyre in the middle of the BoF

- Disproportionately low sea run grilse returns in the southern Maritimes and Maine in 2012 / from smolts in 2011) and 2013 /from smolts in 2012 (as low as 7% of 2004-2008 average in the Saint John River System) ------------- sea lice infection weakening and killing wild smolts is likely the primary cause if these dismal returns.

PROPOSED REMEDY

- mandatory synchronous sea cage stocking in May (year 1), grow out , harvest by end of November (Year 2) and fallow December - May (year 3) for the entire southern Canadian Maritimes from St. Margaret's Bay, Nova Scotia to the Maine border---- repeat production cycle with synchronous sea cage stocking in May (year 3).

CONSEQUENCES

- obligatory fallowing for five months every second winter results in decreased employment and sales confined to frozen product during year 1 and much of year 2 of the production cycle.

BENEFITS

- decreased sea lice pressure for the sea cage aquaculture industry in Nova Scotia and New Brunswick.

- escaped farm salmon bearing sea lice living near sea cages die of starvation or are consumed by predators during five month fallow period every second winter.

- wild salmon smolts from southern Maritime rivers and Maine migrate toward the Labrador Sea feeding grounds through aquaculture-origin-sea lice free sea water every second year.

REFERENCES

1. Jones, S. and Beamish (Eds), 2011. Salmon lice : an integrated approach to understanding parasite abundance and distribution. John Wiley & Sons Inc. ---- p. 109.

2. *Ibid* ---- p. 4.

// Graph of planktonic salmon lice (*Lepeophtheirussalmonis*)

development from Boxaspen, K and Naess,T.2000 ,
see: http://dpc.uba.uva.nl/ctz/vol69/nr01/art05

3. *Ibid* ---- p. 105.

4. *Ibid* ---- p. 162.

5. *Ibid* ---- p. 174.

6. Ibid ---- p.182.

7. Atlantic Canada Fish Farmers Association, October 2012, Sea Lice Management in New Brunswick, see: http://0101.nccdn.net/1_5/2fd/239/206/Sea-Lice-Mgt-Report-October-2012.pdf

Fisheries and Aquatic Habitat Management at 5th Canadian Division Support Base Gagetown

Andy Smith - Aquatic Biologist, 5 CDSB Gagetown, Oromocto, New Brunswick, Canada

Background

5 CDSB Gagetown was established in the mid 1950's and is located in south central New Brunswick. Approximately 110 000 ha in size it includes impact (live fire) areas, urban operations areas, small arms ranges, engineer skills training area and other associated infrastructure. It is home to several military units as well as the Army's Combat Training Centre and the Canadian Forces School for Military Engineering. Training activities include mounted and dismounted manoeuvres, small arms, artillery, demolition, bombing and helicopter support.

There are over 3200 km of watercourses, 156 ponds or lakes and 6487 ha of wetlands within the boundaries of 5 CDSB Gagetown. These water-bodies support a locally important brook trout fishery and other recreational and commercial fish species.

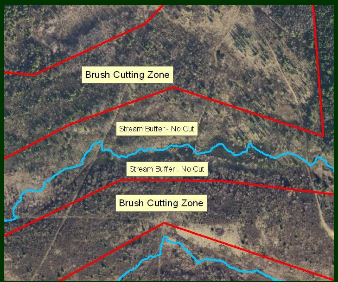
Fish at 5 CDSB Gagetown

Atlantic Salmon (COSEWIC – endangered)
American Eel (COSEWIC –special concern)
Striped Bass (COSEWIC – threatened)
Redbreast Sunfish (SARA – Special Concern)
Brook Trout
Smallmouth Bass
Chain Pickerel
Pumpkinseed Sunfish
Various baitfish

Environmental stewardship, compliance, and sustainable ranges and training areas are key goals of the Army's Strategic Environmental Direction. The following are examples of how 5 CDSB Gagetown is meeting these goals with respect to the conservation of fisheries and aquatic habitats.

Environmental Planning, Protection and Compliance

Training and base development are assessed by environmental specialists to ensure impacts to aquatic resources are minimized and activities are compliant with environmental legislation. Range standing orders include rules to ensure sensitive habitat is protected.



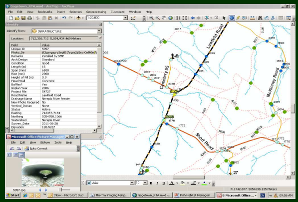
Watercourse Mapping

Pink – NB Hydrographic Network watercourse mapping
Blue – CFB Gagetown watercourse mapping

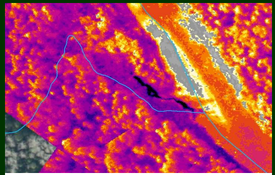
Depth to Water Table Mapping

DTWT can be an Indicator of watercourses, ephemeral channels, wetlands and shallow ground water.

Infrastructure Mapping



Thermal Infrared Imaging



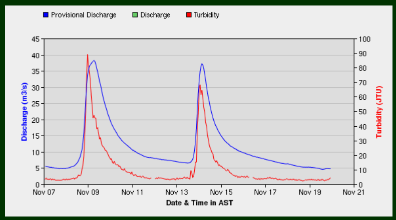
Cool water tributary (black) entering warmer main channel (orange).

Fisheries Monitoring

Electro-fishing to assess the effectiveness of a stream restoration project.

Atlantic Salmon

Water Quality and Quantity Monitoring



Aquatic Invertebrates Monitoring

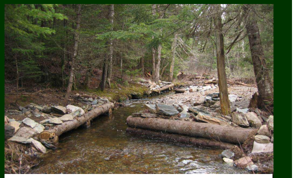
Aquatic invertebrates are an indicator of aquatic ecosystem health. Preliminary results suggest watercourses at 5CDSB Gagetown have similar invertebrate communities to watercourses where anthropogenic impacts are minimal.

Information and Education

Military and civilian personnel are provided environmental awareness training including fisheries and aquatic habitat issues. 5CDSB Gagetown is also a sponsor of the Fish Friends program in which school children raise and release atlantic salmon fry and learn about protecting aquatic ecosystems.

Stream Restoration

Lunker structure simulating an undercut bank and providing cover for a brook trout.



A deflector and log cover creates a pool and improves habitat diversity .

Ford Improvement

Crushed rock is installed on fords to reduce erosion and sedimentation of watercourses.

Road Decommissioning

Culverts are removed, the stream bed restored and banks replanted to improve fish habitat.

Road and Water Crossing Improvement

Undersized and perched culverts are replaced with larger culverts or bridges, in-stream habitat is restored, streamside vegetation is maintained or planted and the roads are capped with gravel. This work improves fish passage and habitat, reduces erosion and road flooding.

Wetland Construction

Constructed wetlands provide wildlife habitat, reduce sedimentation of streams and attenuate flashy flows.

Tree Planting

Trees planted in stream buffers help reduce bank erosion, reduce water temperature and provide wildlife habitat.

Evaluation of a recovery strategy for Atlantic salmon: effects of stocking hatchery raised juveniles on top of wild populations.

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Introduction

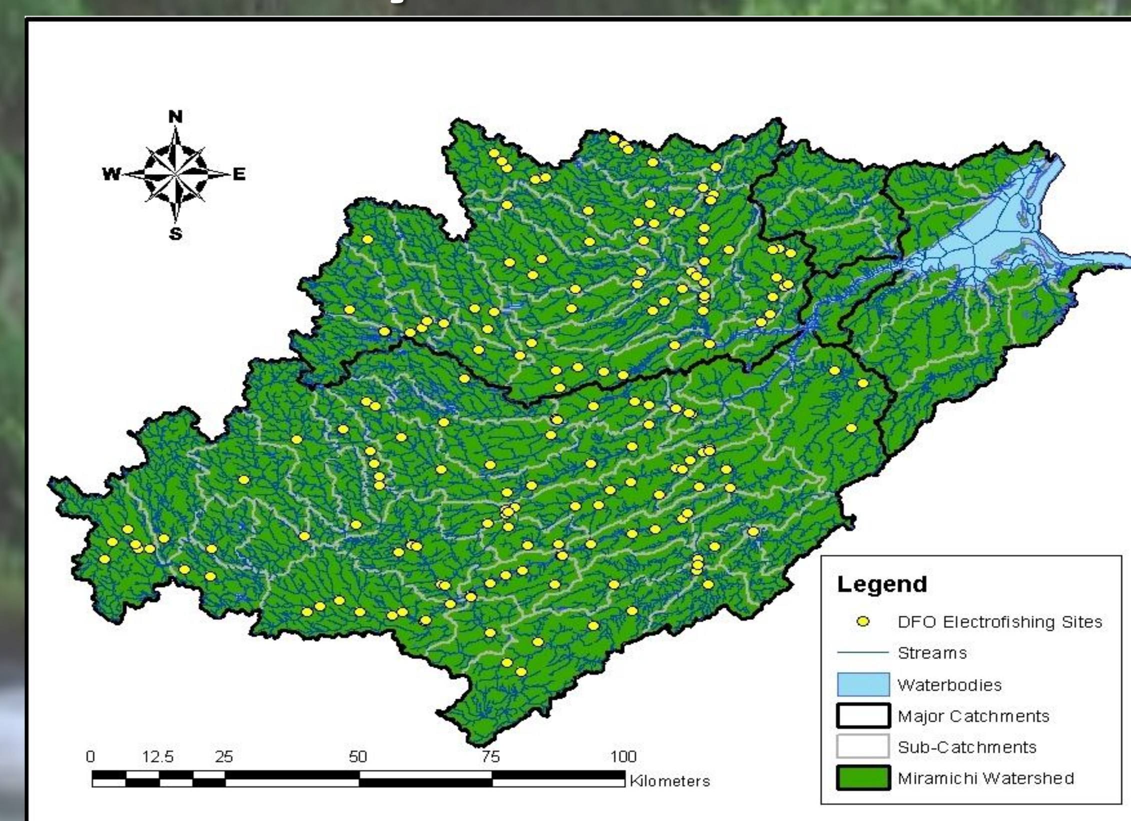
- Stocking hatchery-reared juveniles is a frequently used restoration technique used to enhance Atlantic salmon (*Salmo salar*) production; however, few studies have investigated the effectiveness of stocking and its impact on wild populations, particularly in Atlantic Canada.
- On the Miramichi River, New Brunswick, juvenile stocking has been practiced since the late 1800s, when the Miramichi Salmon Conservation Center was opened in South Esk.
- Faced with diminishing adult salmon returns and limited funds available for Atlantic salmon conservation, effective solutions are needed to maintain, enhance, and restore wild populations.
- The goal of this investigation is to determine the effectiveness of stocking as a recovery strategy for Atlantic salmon by analyzing the contribution of stocking to increasing the production of the Miramichi River.

Juvenile Atlantic salmon stocking

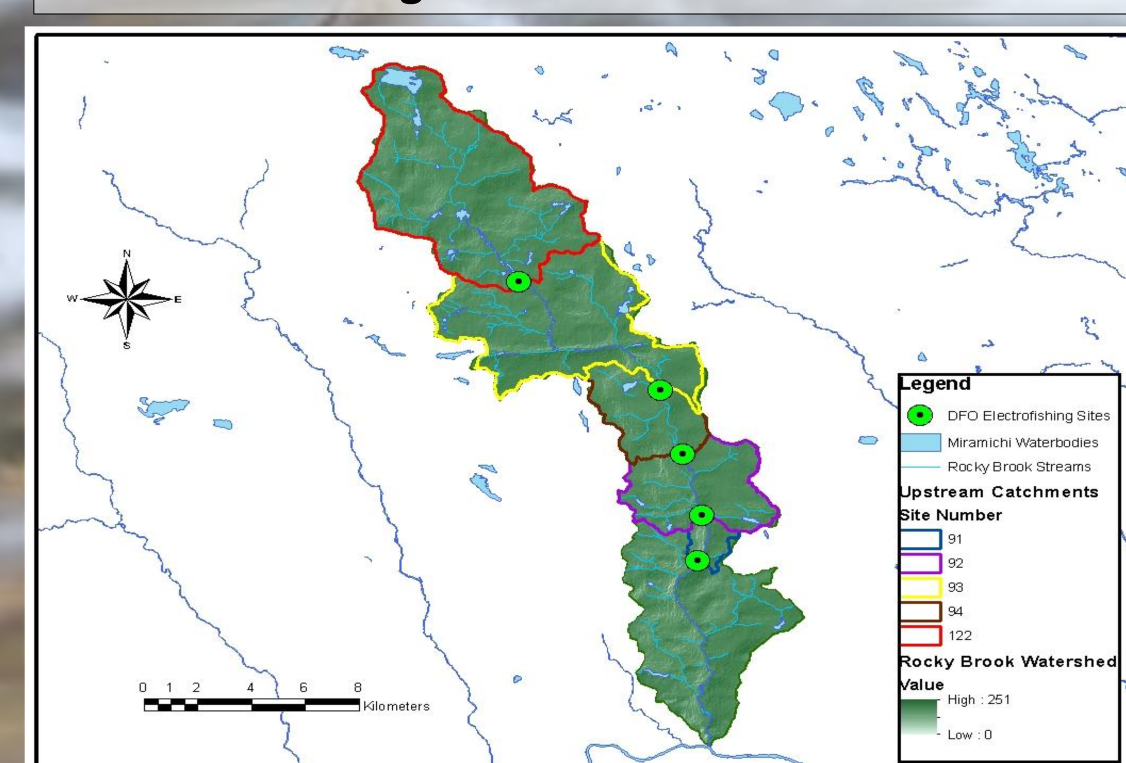
Objective 1:

Can site, catchment and landscape level variables be used to develop a model capable of predicting the distribution of juvenile Atlantic salmon (*Salmo salar*) densities on the Miramichi River, New Brunswick?

- Electrofishing data has been obtained and/or requested from the Department of Fisheries and Oceans, the Miramichi Salmon Association, NB Department of Natural Resources, International Paper and JD Irving Ltd.
- Geographical Information Systems (GIS) will be used to digitize the database and to establish landscape level variables (Table 1) for each site to be used in the creation of a predictive model of juvenile salmon densities.
- Partial Least Squares (PLS) Regression will be used to model juvenile salmon densities against the candidate variables across the Miramichi River watershed. Only un-stocked sites which are accessible to free-swimming adults will be considered in the analysis.
- Candidate models will be assessed and the best models for predicting fry (0+ age) and parr (1+ and 2+ age) densities will be selected for use in further analysis.



DFO electrofishing sites in the Miramichi watershed



DFO electrofishing sites in the Rocky Brook watershed, as well as the upstream catchment area for each

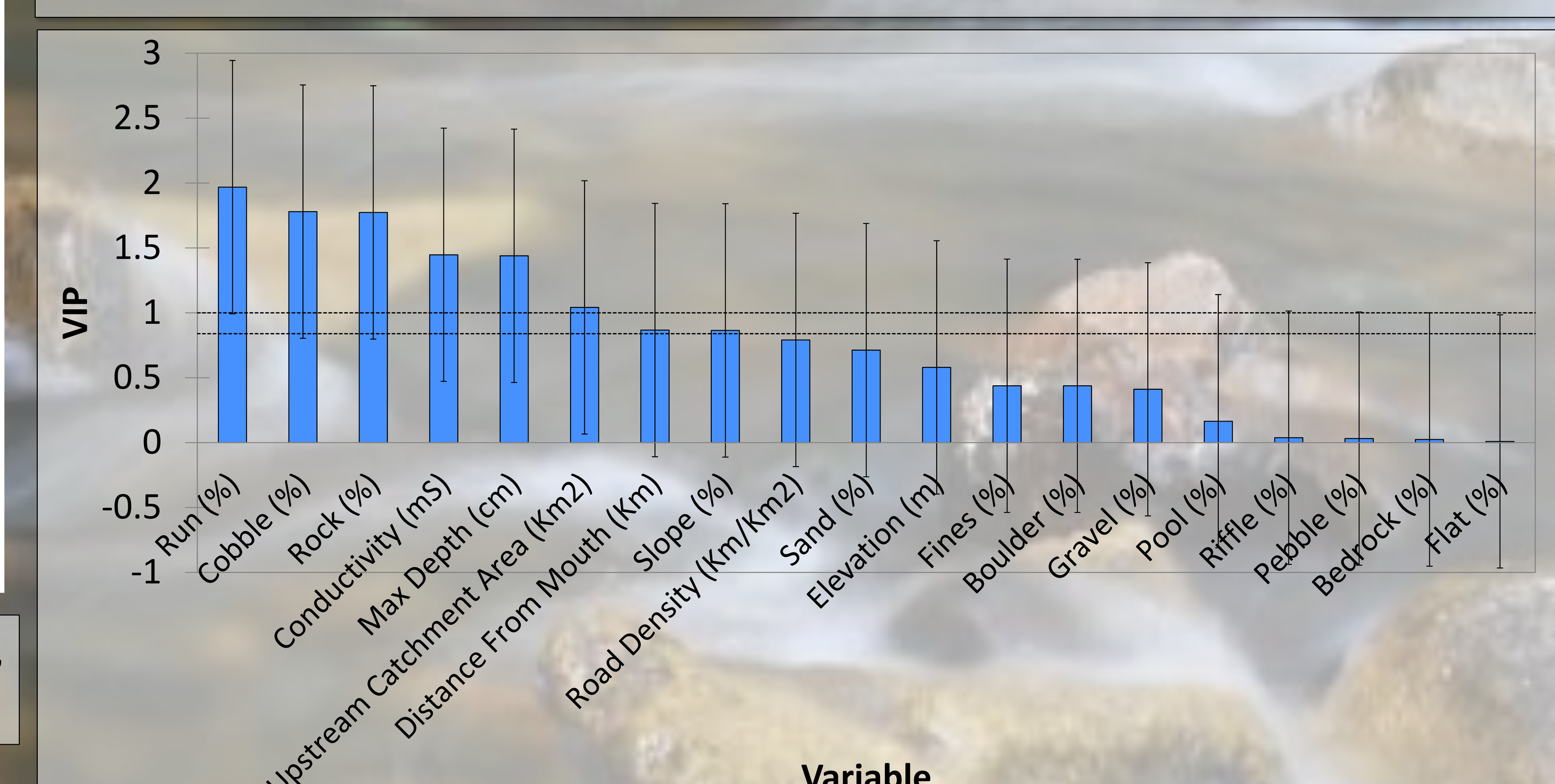
Table 1. List of candidate variables for use in Atlantic salmon modeling

Variable	Description	Predictor Level	Source
UCA	Upstream Catchment Area (Km²)	Catchment	DEM
RD	Road Density in UCA (Km/Km²)	Catchment	N.B. DNR
GEOL	Primary Underlying Geology in UCA	Catchment	N.B. DNR
SD	Stream Density in UCA (Km/Km²)	Catchment	DEM
SLPC	Average Slope of Upstream Catchment (%)	Catchment	DEM
DTO	Distance to the Ocean (Km)	Catchment	DEM
CUT	Proportion of UCA Harvested (%)	Catchment	N.B. DNR
LUSE	Primary Land Uses	Catchment	N.B. DNR
SLPS	Stream Slope at Site (%)	Site	DEM
STORD	Stream Order at Site	Site	DFO
COND	Conductivity (mS)	Site	DFO
RIF	Proportion of Site in Riffle (%)	Site	DFO
RUN	Proportion of Site in Run (%)	Site	DFO
FLAT	Proportion of Site in Flat (%)	Site	DFO
POOL	Proportion of Site in Pool (%)	Site	DFO
FINE	Proportion of Site Substrate in Fines (%)	Site	DFO
SAND	Proportion of Site Substrate in Sand (%)	Site	DFO
GRVL	Proportion of Site Substrate in Gravel (%)	Site	DFO
PEBB	Proportion of Site Substrate in Pebble (%)	Site	DFO
COBB	Proportion of Site Substrate in Cobble (%)	Site	DFO
ROCK	Proportion of Site Substrate in Rock (%)	Site	DFO
BOLD	Proportion of Site Substrate in Boulder (%)	Site	DFO
BEDR	Proportion of Site Substrate in Bedrock (%)	Site	DFO
MAXD	Maximum Site Depth (cm)	Site	DFO

Objective 2:

Does stocking increase juvenile Atlantic salmon (*Salmo salar*) densities at stocked sites on the Miramichi River, New Brunswick?

- Selected models will be used to determine upper and lower density estimates for stocked sites. These estimates will be compared to actual densities observed at stocked sites to determine the impact of stocking on juvenile production.
- If the actual densities fall within, or below the predicted range of densities at stocked sites, there will be evidence that stocking is ineffective at increasing juvenile densities.
- If densities at stocked sites are higher than the predicted densities, evidence will support stocking as an effective enhancement technique for Atlantic salmon on the Miramichi River.



Example Variable Impact on Prediction (VIP) scores from PLS Regression for parr density at un-stocked sites

Results to Date

- Electrofishing data has been obtained from the Department of Fisheries and Oceans and digitized into GIS.
- A predicted hydrometric network has been established for the Miramichi River drainage using ArcHydro tools.
- Variables have been calculated for all of the DFO electrofishing sites, additional sites are being added as new sources are added to the analysis.
- Preliminary modeling has shown both site level and catchment level variables to be important in predicting juvenile Atlantic salmon densities.
- Future plans focus on continued modeling to minimize variability and error, as well as incorporating additional data.

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