Conservation Status Report, Atlantic Salmon in Atlantic Canada and Quebec: Part I – Species Information

Canada Department of Fisheries and Oceans and
Québec Ministère des Ressources naturelles et de la Faune

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Table of Contents

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Abstract

This report is the synthesis by an editorial committee of information presented in working papers developed by Atlantic salmon scientists from the DFO Regions of Atlantic Canada and the Province of Quebec. It describes the 'Species Information', the first of five components of a DFO-outlined 'Conservation Status Report'. The 'Species Information' summarizes the population structure, biology, abundance, status, potential for recovery and scope for harm of Atlantic salmon.

Highlights include:

- the identification of 28 Atlantic salmon 'Conservation Units' CUs) in Eastern Canada i.e., groups of individuals likely exhibiting unique adaptations that are largely reproductively isolated from other groups, and that may represent an important component of a species' biodiversity;
- the presentation of salmon population information for each of the CUs in terms of their abundance, trends thereof, and status relative to current conservation requirements and other reference points;
- the presentation of a general decision-making framework to define thresholds between implementation of critical *recovery* actions, important new *management* actions/ interventions, and continuation of existing management/conservation approaches;
- the presentation of evidence suggesting that the status of Eastern Canadian Atlantic salmon CUs is declining, particularly in the more southern extremities of its range. While some river populations on the south coast of insular Newfoundland (CU 5) appear to require management action, required direct recovery actions appear to be limited to Mainland Nova Scotia (i.e., Southern Upland) and Bay of Fundy (i.e., both outer and inner) salmon populations (i.e., CUs 14 – 17). River populations in Quebec and the southern Gulf of St. Lawrence are not considered to require recovery action although direct management actions for certain CUs may be required.

Résumé

Le présent document est une synthèse, établie par un comité de rédaction, de l'information présentée dans les documents de travail rédigés par des spécialistes scientifiques du saumon atlantique des Régions du MPO du Canada atlantique et du Québec. Il contient une rubrique « Renseignements sur l'espèce », constituant la première des cinq parties dont se composent les « Rapports sur l'état de la conservation » du MPO. Cette rubrique résume la structure, la biologie, l'abondance et l'état des populations de saumon atlantique, leur potentiel de rétablissement et la marge de tolérance aux éventuels dommages qu'elles subiraient.

Faits saillants
- Le document définit 28 « unités de conservation » (UC) du saumon atlantique dans l'est du Canada. Il s'agit de groupes d'individus qui sont susceptibles de présenter des traits d'adaptation uniques, sont largement isolés d'autres groupes sur le plan de la reproduction et peuvent représenter une importante composante de la biodiversité de l'espèce.
- Le document présente des renseignements sur l'abondance et les tendances de la population de saumon de chaque UC ainsi que sur sa situation eu égard aux besoins de la conservation et aux autres points de référence.
- Un cadre décisionnel général est établi, qui définit les seuils justifiant la mise en œuvre soit de mesures de *rétablissement* essentielles soit d'importantes nouvelles mesures de *gestion,* ou le maintien des régimes de gestion et de conservation en place.
- Le document présente aussi des éléments d'information qui portent à croire que les populations de saumon atlantique des UC de l'est du Canada sont en baisse, en particulier dans l'extrême sud de leur aire de répartition. Bien que les populations de certaines rivières de la côte sud de l'île de Terre-Neuve (UC 5) semblent nécessiter des mesures de gestion, des mesures de rétablissement directes ne s'imposent apparemment que chez les populations de saumon de la péninsule néo-écossaise (p. ex. sud du bas-plateau de la Nouvelle-Écosse) et de la baie de Fundy (avant-baie et arrière-baie), soit dans les UC 14 à 17. On ne considère pas que les populations des rivières du Québec et du sud du golfe du Saint-Laurent ont besoin de mesures de rétablissement, quoique des mesures de gestion directes puissent être nécessaires dans certaines UC.

Introduction

With the full impact of the Species at Risk Act **(**SARA)[2] now being felt by the responsible federal agencies, the DFO Species at Risk Secretariat developed in 2004 a prioritized list of aquatic species for which there were indications of declining abundance and which had, to that point, not been addressed through the full purview of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). For a few of these species the Secretariat funded the development of a 'Conservation Status Report' (Terms of Reference: Appendix1).

DFO staff, potentially in partnership with other jurisdictions, was then tasked to develop a report that would form the basis for a COSEWIC Status Report, an Allowable Harm Assessment, listing consultations and analyses, and Recovery Strategy. This report could also facilitate strategic and operational work planning at the species and regional levels; and most importantly enable DFO to implement pre-emptive management measures prior to any assessment and potential designation by COSEWIC and subsequent listing under the SARA. It would as well increase transparency, stakeholder and independent scientific peer involvement throughout the process; provide better lead-time to consult with stakeholders and afford DFO the information to prepare for a COSEWIC assessment and any recommendation for a SARA listing.

DFO intended that Conservation Status Reports ('CSRs') would employ DFO (not COSEWIC or SARA) language and report formats. The planned process for development of the CSR was for DFO to initiate an assessment of the status of the species followed by a review through existing DFO Advisory Processes that include stakeholder and independent scientific peer participation. DFO could also use the outcome of such an assessment to consult with stakeholders regarding possible management and/or conservation measures.

In Canada, sea-run[3] **(**or 'anadromous') Atlantic salmon **(***Salmo salar* L.)[4] have been identified as a conservation concern because of nearly two decades of decline in abundance **(**supported by various regional DFO Status Reports, fishery management closures, and ICES Reports of the Working Group on North Atlantic Salmon[5]). More recently, concern has been elevated in the southern portion of its distribution by the 2002 listing under the SARA of the inner Bay of Fundy Atlantic salmon populations as 'endangered' and documentation within DFO of evidence supporting the potential for designation by COSEWIC of the outer Bay of Fundy and Southern Upland Atlantic salmon populations.[6]

This report is the synthesis by an editorial committee of information presented in working papers developed by Atlantic salmon scientists from the DFO Regions of Atlantic Canada and the

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[2] *Species at Risk Act* (SARA). (see http://laws.justice.gc.ca/en/S-15.3/)

[3] Landlocked salmon are not addressed in this report.

[4] Distributed in Canada from Ungava Bay in northern Québec southward to the Canada-US boundary waters of the St. Croix River in New Brunswick.

[5] See ICES Working Group on North Atlantic Salmon, 2006, available at http://www.ices.dk

[6] Conservation Concerns for Maritimes Region Atlantic salmon (*Salmo salar*). pp 52-58 *In* Diadromous Fish Division 2007. Technical Review of Utility and Costs of Maritimes Region Biodiversity Facilities. 2004 Unpubl. MS Rep. DFO Science Branch, Maritimes Region.

Province of Quebec. It describes the 'Species Information', the first of five components of a DFO-outlined Conservation Status Report (Appendix 1). The 'Species Information' summarizes the population structure, biology, abundance, status, potential for recovery and scope for harm of Atlantic salmon.

Components two through five (Appendix 1) i.e., threats, existing protection, potential conservation targets, and significance of Atlantic Salmon in Canada have been addressed in the companion documents 'Conservation Status report, Atlantic salmon in Atlantic Canada and Quebec – PART II – Anthropogenic Considerations' (DFO and MNRF 2008) and 'The Economic Significance of Atlantic Salmon in Eastern Canada" (Marshall *et al* 2008). The social/cultural, Aboriginal and economic aspects of the salmon's 'significance' map the background for an economic assessment of the impacts as a consequence of any prescribed reductions in harm.

The working papers for this component, i.e., PART I 'Species Information' were reviewed in the presence of the contributors, 'external' scientists and a consultant writer who helped to shape the document following workshops held in Moncton, NB, February 14-17, 2006, and Dartmouth NS, March 6-9, 2007. Most working papers presented at the workshops were designated for upgrade and with special permission[7] inclusion in the Canadian Scientific Advisory Secretariat (CSAS) Research Document Series. The proceedings of the workshops including the Terms of Reference, list of participants, and identification of working papers assigned Research Document status appear in the CSAS Proceeding Series, DFO (2006 and 2007).

Species Information

1. Description of Species[8]

1.1 Name and Classification

Atlantic salmon, *Salmo salar* L., is endemic to rivers bordering the North Atlantic ocean and within that range is referred to as Atlantic salmon. Landlocked forms in North America, which are not dealt with in this report, are sometimes referred to as 'Kennebec salmon', 'Sebago salmon', or 'ouananiche'. Carolus Linnaeus termed the species *Salmo salar*, in 1758, '*salmo*' being the Latin term for salmon of the north Atlantic and '*salar*' being a derivative of 'salio' to leap, in reference to the species' ability to jump water falls several meters in height (Scott and Crossman 1973; Reiser and Peacock 1985) while ascending rivers prior to spawning. Atlantic salmon are well-known members of the family Salmonidae in the order Salmoniformes, a grouping that also includes Pacific salmonids, trout, charr and whitefish. Members of the family possess either freshwater or anadromous life histories.

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[7] Because of the magnitude of this undertaking and the limitation of resources, this CSR document was based on information internal to the responsible jurisdictions for Atlantic salmon in Eastern Canada. While the science and most other elements were reviewed in workshop by non-partisan science experts, affected jurisdictions, stakeholders (industry and non-government organizations) and Aboriginal Peoples were not consulted and thereby precluded the derivation of an overall DFO 'Science Advisory Report'.

[8] Most of Sections 1.1 through 1.4 have been drawn directly from O'Reilly (2006); the narrative for Section 1.5 was developed by O'Reilly as an outcome of the March 2007 workshop (DFO 2007a).

Taxonomic classification of Atlantic salmon

Phylum: Chordata
      Class: Osteichthyes (bony fishes)
            Order: Salmoniformes
                  Family Salmonidae (Salmon and trout)
                      Subfamily Salmoninae
                          Species: *Salmo salar* Linnaeus

The genus *Salmo* is quite large, containing approximately 30 species world-wide. However, Atlantic salmon is the only naturally occurring representative in Canada; brown trout *(Salmo trutta),* though present, is an exotic species introduced into Newfoundland in 1884, Quebec in 1890, New Brunswick in 1921 and Nova Scotia in 1925 (MacCrimmon and Marshall 1968). Where the two species overlap, they can be distinguished by a number of physical characteristics (see below). Previously, freshwater populations were thought to be taxonomically distinct from anadromous populations, and, in some cases, were given subspecies status, e.g., Lac Saint John salmon of Quebec *(Salmo salar ouananiche)* and Sebago Lake salmon of Maine *(Salmo salar sebago)* (see Scott and Scott 1988). Systematic studies by Wilder (1947) (cited in Scott and Scott 1988) failed to support these sub-specific designations. In fact, most do not recognize any subspecies designations within Atlantic salmon, though molecular genetic studies have found European and North American salmon to be highly divergent, and Baltic Sea salmon being quite distinct from other European salmon [see O'Reilly (2006) for a more thorough discussion with relevant citations].

1.2 Morphological Description

Atlantic salmon adults are typically trout-like in shape, with elongated or fusiform bodies that are somewhat laterally compressed. The caudal peduncle is slender, and the dorsal fin fairly large and very slightly forked. A fleshy adipose fin is present anterior to the caudal peduncle. According to Scott and Crossman (1973), the main morphological features that distinguish Atlantic salmon from its closest relatives are:

> "small scales (lateral line 115 – 200), teeth well developed on jaws and vomer; caudal fin usually truncate, occasionally forked; young (<15 cm.) with dark, vertical blotches (parr marks) on sides; anal rays 7 – 12 (usually 9 – 11); body and caudal fin with/without black spots; black spots present on head and body; scales conspicuous, fewer than 165 in lateral line; pelvic and anal fins without white leading edges; vomer flat with teeth extended backward in 2 rows on shaft; caudal fin usually unspotted; body never with regular rows of black spots; reddish spots sometimes on body; scale rows 110 – 130; maxillary to below centre of eye in 15 cm fish seldom far behind eye (except in large males); gill cover with 2 or 3 large spots only; branchiostegals usually 12; dorsal fin rays usually 11; vomerine teeth usually not well developed; small fish have red spots between parr marks; no red on adipose fin."

While at sea, the adults are typically silver on the sides, white on the bottom, and green, blue or brown on the top, with numerous small, often X shaped dark spots on their heads, and upper half of their bodies. As they move into fresh water and prepare to spawn, adults take on a more bronze or brown colour, particularly the males, with red spots on the head and body. A small kype

(turning up of the lower jaw) forms in the female and a much larger kype and general expansion of both the upper and lower jaws occurs in the males. Juveniles are more slender than adults and exhibit 8-11 dorso-ventrally elongated marks (i.e., parr markings) on both sides of their body throughout much of their residence in fresh water. Prior to their ocean migration, however, these marks are lost and the fish takes on a more silvery appearance of the adults. The various life stages of Atlantic salmon are described in Section 4.1.

1.3 Biogeography

Obligate freshwater spawners, Atlantic salmon spend the first and last stages of their life cycle in rivers and streams along the Atlantic coast, from the Maine-New Brunswick border north around Cape Breton and Newfoundland, along the north and south shores of the Gulf of Saint Lawrence, north again along Labrador and into Ungava Bay (Parrish *et al* 1998). Salmon spend most of the remaining portion of their life cycle in the ocean environment, over-wintering and feeding in the Labrador Sea off Greenland (Saunders *et al* 1965) or in more local coastal waters (Scott and Scott 1988). Within the various ecozones, stream habitat occupied by juveniles may vary greatly in terms of spring and summer mean temperature, bedrock, gradient, prey abundance, predators, and other characteristics. For example, stream gradients and current velocities tend to be lower in rivers of the Bay of Fundy relative to those in Gaspé and Newfoundland-Labrador (Claytor *et al* 1991). Habitats and environments may vary considerably within rivers particularly relative to the distance from the river mouth.

Among-population variability in several meristic and morphometric characteristics has been studied in Atlantic salmon from representative rivers from several regions in North America, including rivers from the State of New York, north to Labrador (Claytor and MacCrimmon 1988; Claytor *et al* 1991). Considerable overlap in meristic characteristics was observed among rivers surveyed (Claytor and MacCrimmon 1988), though meristic characteristics were correlated with latitude, longitude and April-May temperatures, with the latter explaining much of the observed variation (Claytor *et al* 1991). No obvious latitudinal or longitudinal clines were reported for morphometric characters surveyed, though Newfoundland-Labrador and Gaspé-Maritime populations were found to be distinct from other North American salmon surveyed (Claytor and MacCrimmon 1988). At a finer spatial scale, several morphological characteristics, including head length, body width, and body depth were influenced by stream gradient and current velocity; head length increased while body width and depth decreased with gradient (Claytor *et al* 1991).

Evidence from broad-scale transplantation studies involving Atlantic salmon indicate the possibility of among river differences in marine migration routes on moderate to large geographic scales (Ritter 1975); similar findings were reported by Reisenbichler (1988) for coho salmon (*Oncorhynchus kisutch).* Common garden experiments involving northern and southern populations from Europe also suggest the likely presence of other important broad-scale adaptive differences in Atlantic salmon. When reared under similar conditions, Atlantic salmon obtained from northern rivers exhibited higher growth rates and conversion efficiencies than salmon obtained from southern locations (Nicieza *et al* 1994). Another example of evidence for the existence of adaptation on larger geographic scales include findings of a south to north cline in the frequency of certain Me-2 alleles (malic enzyme locus) in European and North American Atlantic salmon that is suspected of having adaptive significance (Verspoor and Jordan 1989).

Populations may also vary with respect to the presence of major underlying lineages of salmon, reflecting post Pleistocene colonization from genetically divergent salmon from different nearby refugia (for example, see Verspoor *et al* 2002). Given the (1) geographically extensive and variable nature of the species freshwater environment in Canada, (2) relative geographic isolation of rivers, and remarkable homing precision of salmon to spawning sites of origin, (3) the presence and distribution of different ancestral lineages of Atlantic salmon in Eastern Canada, and (4) evidence in the literature for the presence of local adaptation in salmonids in general (reviewed by Taylor 1991), it would seem likely that considerable variation exists at small and medium spatial scales among Atlantic salmon from Eastern Canada in life history and other fitness related traits that may have a genetic basis.

Finally, distinct salmon populations may also exist which occupy the same location or environment reproductively isolated largely or entirely by timing or behaviour (sympatry). One of the best known examples in the salmonid literature is the presence of highly genetically divergent even-odd year pink salmon runs in rivers from the Pacific Northwest, though examples of reproductively isolated populations inhabiting the same location also exist in Atlantic salmon (see Potvin and Bernatchez 2001). Identification of units of conservation must consider all levels of Atlantic salmon biodiversity if the species as a whole is to be adequately protected in Canada.

1.4 Population Structuring among Anadromous Atlantic Salmon

Phenotypic and parasite differences between North American and European salmon. The most obvious discontinuity in the freshwater geographic distribution of Atlantic salmon lies between Europe and North America, where thousands of kilometres of ocean or largely uninhabitable coastline separate salmon populations from the two continents. During the marine phase of their life cycle, however, many salmon from Europe and North America migrate to feeding areas off Greenland, where they mix and are often captured together in high-seas and coastal fisheries (Reddin *et al* 1988; ICES 2004). Conservation concerns and therefore restructured management objectives associated with this fishery precipitated further research into discriminating European and North American-origin salmon caught off Greenland.

Early research by Nyman and Pippy (1972) indicated that North American and European salmon differed in terms of mean river age and mean fork length; European salmon usually smoltify after two years in fresh water versus two or three years for North American salmon, and are, on average, several centimetres longer, though considerable variation exists within both continents. Nyman and Pippy (1972) also reported differences in the abundance and incidence of occurrence of two parasites, *Anisakis simplex* and *Eubothrium crassum*, respectively, in salmon from the two continents. Extensive research into the use of scale pattern variation and discriminant function analysis (reviewed in Reddin and Friedland 1999) has shown that European and North American salmon also differ in terms of scale growth patterns.

Molecular genetic differences between North American and European salmon. Nyman (1966) and Nyman and Pippy (1972) provided some of the first evidence of a biochemical distinction between European and North American salmon, demonstrating consistent differences in electropherograms of serum proteins and liver esterases. Stahl (1987) later reported deep divisions between North American and European salmon through enzyme electrophoresis.

Allozyme differences between salmon from the two continents were also reported by Bourke *et al* (1997) and Verspoor and McCarthy (1997). In fact, extensive genomic divergence between North American and European salmon can be inferred by the observation that substantial allele frequency differences have been found repeatedly at multiple classes of genetic markers surveyed, including allozymes, as stated above, but also nuclear rRNA genes (Cutler *et al* 1991), minisatellite DNA (Taggart *et al* 1995), microsatellite DNA (McConnell *et al* 1995; King *et al* 2001; Gilbey *et al* 2005), and mitochondrial DNA (Bermingham *et al* 1991; Birt *et al* 1991; Kauppi *et al* (1997); King *et al* 2000; Nilsson *et al* 2001; Asplund *et al* 2004; Gilbey *et al* 2005). The magnitude of difference observed between mitochondrial DNA (mtDNA) types commonly found in European and North American Atlantic salmon, and assumptions regarding the rate of nucleotide substitution over time (the molecular clock hypothesis), has allowed different researchers to estimate the time of divergence of salmon from these two continents. Nilsson *et al* (2001) identified 10 substitutions in the 1227 base pair segment of the ND1 gene analyzed, representing DNA sequence divergence of 0.8%, suggesting a time of divergence of greater than 1 million years. Kauppi *et al* (1997) reported a higher substitution rate (1.8%) in the 940 base pair D loop region analyzed, though D loop sequence is generally more mutable than other regions of the mitochondrial genome in most organisms studied to date.

The existing database of information on mitochondrial and microsatellite DNA variation in Atlantic salmon from within North America and Europe is becoming increasingly comprehensive, a result of advancements in technology that permit analyses of additional samples from a greater number of locations from a given study, but also because data from different studies continues to accrue over time; both types of molecular markers have been in use for over 15 years, and are still the primary molecular genetic markers employed today. Despite the large number of loci surveyed, and the thousands of samples analyzed, the above pattern of continent-specific microsatellite and mtDNA variation still largely holds today. However, over a very small portion of the species range in Europe and North America, a percentage of salmon can exhibit mitochondrial and nuclear alleles typical of populations from the alternate continent. For example, European 'type' mitochondrial and nuclear microsatellite alleles have been observed in salmon from rivers in Labrador and Newfoundland (King *et al* 2000; King *et al* 2001; Gilbey *et al* 2005). It should be noted, however, that the mitochondrial variant observed in Newfoundland salmon is actually intermediate between the common North American and European types (King *et al* 2000). Also, North American 'type' microsatellite and mtDNA variants have been observed in the River Pecha, northern Russia (Gilbey *et al* 2005), albeit at low frequencies. These disjunct distributions of mitochondrial and nuclear variants in the two continents likely represent limited low level gene flow between several North American and European populations during early colonization of the species' modern range following retreat of the Pleistocene ice sheet (Knox *et al* 2002; Gilbey *et al* 2005). Still, overall patterns of variation observed at the mitochondrial ND1 and D loop regions indicate that salmon from these two continents have been largely reproductively isolated for a very long time, probably throughout the last four ice ages.

A review of molecular genetic variation in North American Atlantic salmon. A well known characteristic of Atlantic salmon is that mature adults often return to their natal streams to spawn (recently reviewed in Hendry *et al* 2004). This, and the possibility of lower survival of offspring of salmon that do stray into habitat in which they are not well adapted, contributes to reduced gene flow among neighbouring groups of salmon. But some salmon do stray, spawn successfully, and produce offspring that are capable of surviving to spawn in later years. Analyses of

molecular genetic variation can help determine the extent of reproductive isolation among salmon from different locations and hence the potential for adaptive differences to accrue (Waples 1991). Analyses of molecular genetic variation can also help identify highly divergent lineages that may have accumulated substantial genetic differences over long periods of reproductive isolation (Utter *et al* 1993).

Several analyses of genetic variation, involving different types of molecular markers, have been carried out that include salmon from one or more rivers in eastern Canada (Table 1). Most consist of sample collections from several rivers from one or two regions, and a few include collections from one or two rivers from several or all regions. Assessment of heterogeneity among samples within rivers was not a focus of the published studies from Table 1, but was considered by Verspoor (2005). Within-river heterogeneity was not observed among multiple samples collected from four of five rivers; significant differences were only observed between distant tributaries of the very large Saint John River (Verspoor 2005). Surprisingly, few studies actually tested for significant differences between collections from neighbouring rivers either, although within population differentiation was reported from a south coast Newfoundland stock using microsatellite DNA analyses (Beacham and Dempson 1998). Verspoor (2005) reported that "variation among loci was highly heterogeneous at all polymorphic loci", but did not provide information on specific pair-wise comparisons. King *et al* (2001), in a hierarchical gene diversity analysis, partitioned variance among provinces or states, among rivers within provinces or states, and within rivers; only 2.99% of the variance was associated with among river comparisons (within province or state), as opposed to 5.28% among countries in Europe. Pair-wise tests for significant differences among populations (rivers) were not provided. McConnell *et al* (1997) used bootstrap analyses to test for pair-wise differences among sample collections from different rivers for three different genetic distance measures, Roger's modified genetic distance, allele sharing genetic distance, and Goldstein's $(\delta\mu)^2$ distance; significant differences were observed between all pair-wise estimates of Roger's distance, nearly all estimates of allele sharing genetic distances, but for very few estimates of Goldstein's $(\delta\mu)^2$ distance, most of which involved the Gander River, Newfoundland. Again, only a few rivers in each region were surveyed in this study.

Verspoor (2005) presents the most geographically comprehensive study published to date, and includes multiple river populations from multiple regions (Newfoundland and Labrador, Quebec, Gulf, and Maritimes). In this study, variation was surveyed at 23 allozyme loci, of which nine were informative (genetically variable). Multi-dimensional scaling analyses, and construction of nearest-neighbour joining trees, both based on Nei's D_A distance, indicated to the author the presence of six large-scale groupings of Atlantic salmon in Eastern Canada (Figures 1 and 2): Labrador and Ungava, Gulf of Saint Lawrence, Newfoundland (excluding Gulf rivers), Atlantic shore/Southern Upland of Nova Scotia, inner Bay of Fundy (iBoF), and outer Bay of Fundy (oBoF). Many of the groupings suggested by Verspoor (2005) are clearly evident; Labrador and Ungava rivers clearly group together and distinct from all other samples analyzed (Figures 1 and 2), as are salmon from Newfoundland rivers, excluding those that drain into the Gulf of Saint Lawrence. Generally speaking, salmon from the Atlantic coast of Nova Scotia/ Southern Upland cluster together and are distinct from all other samples analyzed (Figures 1 and 2), as are salmon from the inner Bay of Fundy. Samples from the Gulf of Saint Lawrence and the west coast of Nova Scotia group together, but are not obviously different from many outer Bay of Fundy populations (Figures 1 and 2).

Many of the regional groupings identified above have also been reported in other studies, involving different molecular markers. Verspoor *et al* (2002) identified a mtDNA haplotype in multiple inner Bay rivers at moderate to high frequency, that is completely absent in outer Bay of Fundy samples surveyed. In a recently expanded, though not yet published analysis of mtDNA in Atlantic salmon from Eastern Canada, Verspoor also noted the complete absence of the inner Bay mtDNA haplotype in 16 rivers of the Southern Upland (Figure 3). In this same study, Verspoor (op. cit.) identified a mtDNA haplotype in nearly all Southern Upland rivers surveyed that is also absent in the Bay of Fundy and all salmon elsewhere in Eastern Canada (Figure 3).

Salmon from the inner Bay of Fundy are also distinct from salmon from the Southern Upland at a suite of nine microsatellite loci (unpublished data, Figure 4). In this analysis, FST values were estimated for pairs of populations surveyed from the outer Bay of Fundy, the inner Bay of Fundy, and the Southern Upland, and populations clustered by similarity using the Unweighted Pair Group Method with Arithmetic mean (UPGMA) method. Generally speaking, salmon from the inner Bay of Fundy grouped together, as did populations from the Southern Upland. The three highly divergent inner Bay of Fundy populations (GAK, Gaspereau; GRV, Great Village; and ECO, Economy) were recently bottlenecked, exhibiting marked decreases in both the number of alleles and heterozygosity relative to other populations of the inner Bay (O'Reilly unpubl data); the positioning of these rivers likely reflects the effects of rapid recent drift as opposed to long-term reproductive isolation.

The grouping of outer Bay of Fundy (Saint John River) and inner Bay of Fundy (Big Salmon River) samples may reflect past stocking of the Big Salmon River with Saint John origin salmon (see Gibson *et al* 2003a). Alternatively, the observed similarity may also reflect limited historic or ongoing gene flow from population(s) from the large Saint John River to the nearby Big Salmon River. Given the relative size of the two populations, and the absence of inner Bay mtDNA haplotypes in the Saint John River, gene flow from the Big Salmon populations to Saint John population(s) is unlikely. Spidle *et al* (2003) and King *et al* (2001), in surveys of largely overlapping suites of microsatellite variation, focused on resolving differences among Maine salmon, also found the few inner Bay and Southern Upland populations to be highly distinct from all other populations analyzed. In the UPGMA tree of microsatellite-based pair wise estimates of Roger's genetic distance published in McConnell *et al* (1997), the 10 Southern Upland populations all cluster together, as do Stewiacke and St. Croix, NS populations (two inner Bay populations); the Gaspereau River sample again groups separately from all other clades, a likely result of population bottleneck and rapid recent genetic drift.

The minimal difference reported by King *et al* (2000) between inner and outer Bay of Fundy populations at the mitochondrial sites surveyed simply reflects the lack of phylogeograhically informative sites surveyed compared to mtDNA survey of Verspoor *et al* (2002). Substantial evidence also exists for the distinctiveness of Newfoundland populations relative to other North American salmon at microsatellite (Spidle *et al* 2003; King *et al* 2001) and mtDNA (King *et al* 2000), though differences found in the latter study may largely reflect the presence of haplotypes intermediate between North American and European salmon found in east coast Newfoundland samples. Very few surveys included samples from Labrador, and even fewer considered samples from Ungava (but see Fontaine *et al* 1997). King *et al* (2001) and Spidle *et al* (2003), in analyses

of largely overlapping microsatellite loci, identified the Labrador populations surveyed as highly distinct from other populations.

Overlap or similarity observed between samples from the Gulf and the outer Bay of Fundy by Verspoor (2005) for allozyme loci, was also noted by King *et al* (2001) and Spidle *et al* (2003) for microsatellite markers. It would be interesting to see whether Gulf and outer Bay of Fundy salmon also exhibit similar mtDNA haplotype frequencies. Although such information is presently unavailable, Verspoor does intend on publishing a North American-wide survey of mtDNA variation in the near future. In addition, a study of 14 microsatellite loci in 50 anadromous runs of Atlantic salmon along the coast of Quebec, Labrador and Ungava is presently underway by L. Bernatchez and colleagues at Laval University. Eight of the microsatellite loci surveyed by this group are also common to loci surveyed in Maritime Atlantic salmon, and microsatellite allele sizes have been standardized across laboratories at Laval and Bedford Institute of Oceanography. Finally, efforts are now underway to accrue information for the six additional loci analyzed in Quebec salmon from Maritime populations. This combined analysis will include information from over 80 salmon populations at 14 microsatellite loci, and will represent one of the most extensive microsatellite datasets ever assembled for Atlantic salmon.

1.5 Delineation of Conservation Units in Anadromous Atlantic Salmon from Eastern Canada

Considerable effort has been expended in recent years to develop objective methods of assessing and categorizing within-species variation for conservation purposes. The myriad of approaches available vary somewhat in terms of the types of information used, the priority or importance of different kinds of biological and other information used, and the way such information is used in categorizing biodiversity (see Fraser and Bernatchez 2001; Ford 2004; O'Reilly 2006). However, common to most approaches is the identification of units of conservation (termed Conservation Units or CUs here) based on whether or not the population (or group of populations) is sufficiently reproductively isolated, and adaptively diverged, from other representatives of the species. In the context of this report Conservation Units are defined as: ***groups of individuals likely exhibiting unique adaptations that are largely reproductively isolated from other groups, and that may represent an important component of a species' biodiversity*** *(DFO 2007)*. The following information, listed in order of importance, was used to assess reproductive isolation and adaptive significance of proposed CUs: 1) the presence of unique ancestral lineages, 2) evidence of phenotypic distinctiveness, 3) genetic structure, 4) ecological information, and 5) geographic information (see Tables 1 and 2; Figure 5).

Presence of unique ancestral lineages. This is of the utmost importance because it identifies major components of within-species genetic diversity. Evidence for unique ancestral lineages may come from several sources, including existing valid taxonomic designations (based on shared derived characters or embryological or developmental information), biogeographical data (e.g., evidence for the persistence of individuals over long periods in one or more isolated glacial refugia), and molecular genetic information from typically non-recombining haploid markers, such as mtDNA or sex linked markers. An example of the latter is 'reciprocal monophyly', a situation when all individuals in a particular group share an assemblage of mtDNA types that are more closely related to each other than any mtDNA type in another group, and vice versa (see

Moritz 1994). The more divergent these two assemblages of mtDNA are, the longer the groups of individuals may have been reproductively isolated and hence the greater the opportunity for evolutionary divergence; under the strict criteria identified by Moritz (1994), populations must also exhibit significant differences in nuclear allele frequencies to be considered distinct. The pattern of mtDNA variation observed in European and North American salmon is a good example of reciprocal monophyly. With very few exceptions, European salmon exhibit an assemblage of mtDNA haplotypes highly differentiated (approximately 1% sequence divergence) from mtDNA from nearly all native salmon from North America and vice versa (Nilsson *et al* 2001; see also Kauppi *et al* 1997). In the presence of broad scale population genetic information and other data, less stringent frequency-based information from mtDNA can also be cited as evidence for the existence of distinct ancestral lineages within a species (see Verspoor *et al* 2002), though such information is typically weaker than the former.

Evidence of phenotypic distinctiveness. This involves characteristics that are observable, including morphological (e.g., body depth or fin shape), meristic (e.g., number of vertebrae), and life history traits (e.g., egg size, age at smoltification, number of years at sea, behaviour, etc.). The strongest evidence of this type includes characters for which there is substantial evidence of adaptiveness or, in other words, observable differences that have a genetic basis and that increase the reproductive success of an individual in its native habitat. Often, such evidence is unavailable (but see Riddell and Leggett 1981). However, information on the presence of phenotypic differences, and circumstantial evidence of a likely genetic and/or adaptive basis is more common (see Claytor and MacCrimmon 1988; Claytor *et al* 1991). The weakest evidence within this category includes phenotypic differences for which there is little or no information on its genetic basis or adaptive significance.

Evidence of genetic structuring. Information on genetic structuring addresses the issue of reproductive isolation and hence potential for adaptive differences to accrue. Genetic structure is usually assessed using presumably neutral molecular genetic markers, such as microsatellites, allozymes, mtDNA, Amplified Fragment Length Polymorphims (AFLP), Single Nucleotide Polymorphims (SNP), Expressed Sequence Tags (ESTs). If the candidate CUs are adjacent pairs of populations, evidence may consist of simple tests for significant differentiation in allele frequency distributions, but may also include tests for differences in allelic diversity, or analyses of private alleles (alleles that occur in one population but not the other). Obviously, the greater the degree of differentiation at the neutral marker loci surveyed, the stronger the evidence for CU status. Other relevant traditional approaches include Analysis of Molecular Variance (AMOVA) to assess proportion of variation within versus among proposed CUs, phylogentic analyses of populations to see whether populations within CUs cluster together and apart from populations in neighbouring CUs, and Multi Dimensional Scaling (MDS) analyses to visually represent the juxtaposition of populations in multi-dimensional space. Recently developed, computationally intensive but more powerful approaches, include analyses that attempt to identify groups of interbreeding individuals reproductively isolated from other such groups in the absence of information on the location from which samples were obtained (Pritchard *et al* 2000), and methods that estimate gene flow under non-equilibrium conditions (reviewed by Pearse and Crandall 2004).

Ecological information. Ecological information includes differences in stream gradient and water velocity, distance of spawning areas from river mouths, variation in predator or prey

communities and abundance, water chemistry, temperature, etc. The rationale behind this line of evidence is that, where gene flow is limited, important ecological differences may be a reasonable predictor for the possible presence of adaptive differences. Certain ecological variables may be better predictors of underlying adaptive differences in specific traits than others. For example, whereas both temperature and stream gradient have been shown to influence the morphology of juvenile Atlantic salmon, an adaptive basis has been demonstrated for morphological differences (body shape and fin size) associated with variation in stream gradient (Riddell and Leggett 1981); morphology appears to be more labile with respects to temperature (Martin 1949). Claytor *et al* (1991), in a large scale analysis of morphological and meristic characters in juvenile salmon across much of the species' distribution in North America and Europe, found that stream gradient explained more of the morphological variation observed than did temperature, further suggesting an adaptive response to stream gradient, and highlighting the importance of this ecological variable in identifying CUs.

Geographic information. This also addresses the potential for gene flow among neighbouring CUs. Here, we include three types of geographic information: 1) coastal geographic distance between adjacent candidate CUs, 2) the presence of range disjunctions between adjacent CUs, and 3) the presence of geographic barriers (or partial barriers) between CUs. Increasing geographic distance between CUs is taken as evidence for likely reduced straying and possible reduced reproductive success of immigrants (and their offspring) in increasingly different environments. Range disjunction, or the absence of populations between adjacent candidate CUs, is also given as possible evidence for reduced gene flow (Dizon *et al* 1992). The existence of physical barriers to movement and gene flow seems less applicable to an anadromous species such as Atlantic salmon, which would appear to have access to any adjacent river, including those on islands and separate land masses. However, extreme coastal features, high currents and other barriers separating rivers may reduce somewhat the stray rate and hence gene flow among populations more than what one would predict based on coastal geographic distance alone. Furthermore, even geographically proximate rivers may drain into different basins (e.g., Gulf of St. Lawrence versus the Cabot Strait). If there are heritable differences in ocean migration routes (see Ritter 1975, Reisenbichler 1988), basin differences may represent barriers to straying, or may impact return rates of offspring of parents that do stray.

Table 1. Summary analyses of molecular genetic markers in Atlantic salmon from Eastern Canada.

Region [1]	Number of populations	Number of loci	Marker type	Sample distribution	Summary of findings	Reference (source)
M,G,Q,N,L	11	11	Mi	Course	NFLD highly distinct, Labrador highly distinct, SU highly distinct, Quebec highly distinct, iBoF highly distinct; minimal differentiation between oBoF and Gulf populations.	Spidle *et al* (2003).
M,G,Q,N,L	22	1	Al	Course	NFLD and Labrador similar and distinct from Gulf and NS; NS + Maine + Gulf similar.	Moller (2005)
M,G,Q,N,L	10	12	Mi	Course	NFLD highly distinct, Labrador highly distinct, SU highly distinct, iBoF highly distinct; minimal differentiation between oBoF and Quebec. Note: this is a similar dataset as that used by Spidle *et al* (2003).	King *et al* (2001)
M,N	13	8	Mi	Course	Ten SU populations grouped together and separate from all others; individual iBoF highly divergent, but group together before clustering with others; NFLD groups with Gulf.	McConnell *et al* (1997)
M	46	1	Mt	Fine	iBoF divergent from oBoF and from SU, and SU distinct from NFLD and Gulf (presentation of data not designed to reveal differences among remaining regions).	Verspoor *et al* (2005)
M,G,Q,N,L	53	23	Al	Fine	Six regional groupings suggested by author, including 1) Labrador/Ungava, 2) Gulf of Saint Lawrence, 3) Newfoundland (excluding Gulf), 4) Atlantic shore/SU, 5) iBoF, 6) oBoF. According to author NFLD and Labrador highly distinct from all others, East Coast NFLD cluster together (European influence?), Gulf similar to oBoF, iBoF distinct and SU distinct.	Verspoor (2005)
M	10	1	mtDNA	Fine	iBoF distinct from oBoF. Note: subset of data from Verspoor unpublished.	Verspoor *et al* (2002)

Region	Number of populations	Number of loci	Marker type	Sample distribution	Summary of findings	Reference (source)
M,N	7	1	mtDNA	Course	Minimal difference between oBoF and iBoF and SU; NFLD distinct because of the presence of haplotypes intermediate between North American and European in some east coast populations.	King *et al* (2000)
Q,L	7	5	Mi	Course	Some Quebec populations more differentiated from other adjacent populations than from the Ungava population.	Fontaine *et al* (1997)
M	20	9	Mi	Fine	oBoF and iBoF similar; iBoF highly distinct from SU.	O'Reilly *et al* unpubl data
M,G,Q,L	>50	8-14	Mi, MHC?	Fine	Incomplete	Bernatchez, O'Reilly

[1] M=Maritimes; G=Gulf; Q=Quebec; N=NFLD; L=Labrador + Ungava

Mi=Microsatellite; Al=Allozyme; mtDNA=Mitochondrial DNA; MHC=Major Histocompatibility Complex genes

iBoF=inner Bay of Fundy; oBoF=Outer Bay of Fundy; SU=Southern Upland

Table 2. Proposed Conservation Units (CUs) and supporting evidence.

Proposed CU	Nearby candidate CU		Evidence for CU designation			
		Presence of unique lineage(s)[1]	Evidence of distinctiveness (phenotypic information[2] and movement[3])	Genetic structure[4]	Ecologic information[5]	Geographic information[6]
1 North Labrador	2, 28	-unique salmon lineage within Labrador stocks identified, based on analyses of multiple allozyme loci Verspoor (2005)	-lower incidence of maturation after one winter at sea relative to other Labrador CUs -run timing is later than other Labrador stocks including those to the south -migration routes differ from those salmon originating in CUs 2 & 3	-boundary between CU 1 and CU 28 approximately corresponds with boundary between Ungava/ Labrador and Gulf groupings based on allozyme information in Verspoor (2005)	-charr are the dominant salmonid species in this CU	-CU 1 rivers typically of higher gradient than other Labrador rivers -start of the Torngat Mountains
2 Lake Melville, Labrador	1, 3	-unique salmon lineage within Labrador stocks identified by Verspoor (2005), based on analyses of multiple allozyme loci	-higher incidence of maturation after one sea-winter in Kenamu River relative to other Labrador CUs -run timing is earlier than other Labrador stocks including those to the south -migration routes differ from those salmon originating in CUs 1 & 3	-boundary between CU 1 and CU 3 based on allozyme information, Cape Caribou River varies from other Labrador samples. Verspoor (2005)	-CU 2 rivers typically of lower gradient than other Labrador rivers draining into the Churchill basin lowland - mainly salmon and sea trout (*S. fontinalis* populations	- Lake Melville area is geographically and ecologically distinct from CUs 1 & 3
3 South Labrador	2, 8, 26	-unique lineage within Labrador stocks based on analyses of multiple allozyme loci Verspoor (2005)	-higher incidence of maturation after one winter at sea relative to other Labrador CUs -run timing is earlier than in North Labrador stocks but later then CU 2 -migration routes are different for South Labrador versus CU 1 & 2 salmon	-boundary between CU 3 and CU 26 approximately corresponds with boundary between Ungava/Labrador and Gulf groupings based on allozyme information Verspoor (2005)	-CU 3 rivers typically of lower gradient than CU 1 rivers but higher than CU 2 -*S. alpinus*, *S. fontinalis* and salmon occur somewhat equally in this CU	-CU 3 rivers drain the Eagle Plateau of central Labrador

4 Northeast Coast NF	5, 8	N/A	-maturation after one winter at sea and smolt age predominantly age 3 as compared to CU 8 -smolt run timing earlier than CU 8.	-N/A	- mixture of very large to very small rivers that are of low gradient that drain directly into the Northwest Atlantic -high ratio of lake to river habitat, rivers of pH 6.1-6.5	-N/A
5 Southeast Coast NF	4, 6	N/A	-mixture of runs with some characterized by small grilse versus other stocks characterized by larger-sized grilse (55cm) -run timing varies among rivers with some having median values similar to rivers in southern Labrador -modal smolt age of 4^+ for some stocks versus other rivers with 3^+ -at least one stock with MSW salmon	-some information from four rivers based on allozyme information Verspoor (2005)	-historically, rivers in this area demonstrated moderately low mean alkalinities and are potentially sensitive to acidification damage -rivers generally characterized with mean pH values of 5.5 to around 6.0 -generally rivers with relatively small drainage areas (<300 km^2) with only a few >400 km^2 in size	-N/A
6 South Coast NF	5, 7, 13, 14	N/A	-some rivers characterized by smaller-sized grilse -run timing varies among rivers with at least one stock associated with very early runs -modal smolt age of 3^+ for most rivers	-some information from two rivers based on allozyme information in (Verspoor 2005) -differences among tributaries reported from one stock based on microsatellites (Beacham and Dempson 1998)	-some rivers located in areas proximate to salmonid aquaculture activities -historically, rivers in this area demonstrated low mean alkalinities with average pH values often < 5.5 and thus less than rivers in CU 5 -a mixture of rivers that vary in drainage area from moderate (1,000 to 2,500 km^2) to small (<300 km^2)	-N/A
7 Southwest Coast NF	6, 8	N/A	primarily age 3^+ smolts -higher incidence of 2 & 3 sea winter fish compared to CUs 6 & 8 -migration route is primarily through the Cabot Straight as op-posed to those of CU 8	-N/A	-rivers are small, gradient is low, lake habitat is minimal	-physical barriers confined to headwaters

8 Northwest Coast NF	6, 7, 26	N/A	-N/A[2] -Strait of Belle Isle migration corridor	-N/A	-high ratio of lake to river habitat .	-separated from CU3 by Strait of Belle Isle -- -separated from CU4 by Strait of Belle Isle and Northern Peninsula. -separated from CU26 by Gulf of St. Lawrence
9 Northern. NB	10, 18	N/A				
10 Central NB	9, 11, 12	N/A				
11 PEI	6, 10, 12	N/A				
12 North-eastern NS	6, 10, 11, 13	N/A				
13 Cape Breton East Highlands (CBEH) NS	6, 12, 14	N/A	-N/A[2] -N/A[3]	-absence of a mitochondrial haplotype observed in SU populations (Verspoor *et al,* 2005; Verspoor, pers comm)	-CBEH rivers typically of higher gradient than South coast NF or CBEL rivers	-separated by 10's of kms from CBEL rivers and by Cabot Strait from South Coast NL rivers -no disjunction
14 Cape Breton East Lowlands (CBEL) NS	6, 13, 15	N/A	-N/A[2] -N/A[3]	-N/A	-CBEL rivers typically of lower gradient than CBEH rivers	-separated by 10's of kms from CBEH rivers, and by Cabot Strait from South coast NL rivers -possible disjunction between CBEL and SU (SU populations geographically close but separated by large break from nearest CBEL salmon bearing river); no disjunction between CBEL and CBEH rivers -CBEL and SU separated by Strait of Canso and Chedabucto Bay; CBEL and CBEH separated by Bras D'Or lakes; CBEL and South Coast NL separated by Cabot Strait
15 Southern Upland (SU) NS	14, 16, 17	-mtDNA haplotype not observed in adjacent	-N/A[2] -N/A[3]	-mtDNA haplotypes observed in SU but not iBoF and vice versa	-high incidence of acidified rivers within SU relative to the iBoF,	-10's of kms from iBoF, oBoF and CBEL rivers

		populations but do not know if globally endemic (Verspoor *et al* 2005; Verspoor pers comm)		-mtDNA haplotypes seen in SU salmon not in CBEL, oBoF, or other southern or northern populations (Verspoor *et al* 2005, pers comm) -SU salmon cluster separately from iBoF, CBEL and oBoF salmon at allozyme loci and identified as a distinct grouping (Verspoor 2005) -SU populations largely group separately from iBoF and oBoF populations at microsatellite loci surveyed (O'Reilly, unpubl data); limited microsatellite information available for SU-CBEL comparisons	oBoF and CBEL	-possible disjunction between SU and iBoF (few salmon bearing streams on SE shore of Bay of Fundy between Cornwallis and Annapolis rivers) -possible disjunction between SU and CBEL (SU populations geographically close then large break to nearest CBEL salmon bearing river) -iBoF at the head of the Bay of Fundy and largely internal to Cape Split NS and very high tides; -SU and CBEL separated by Chedabucto Bay and Strait of Canso, -SU and oBoF separated by Bay of Fundy
16 Inner Bay of Fundy (iBoF) NS and NB	15, 17	-unique mtDNA haplotype one mutation from a common North America variant suggestive of possible refugium for iBoF salmon (Verspoor *et al* 2002)	-higher incidence of maturation after one winter at sea relative to oBoF and SU salmon (Amiro *et al* 2003) -distribution of tag returns from marine environment differs between iBoF and oBoF (Amiro *et al* 2003) -evidence of prolonged residency within the Bay of Fundy (Lacroix *et al* 2005)	-mtDNA lineage at high frequency in iBoF not observed elsewhere in global distribution of the species, including oBoF and SU (Verspoor *et al* 2002) -iBoF salmon group separately from oBoF and other populations at multiple allozyme loci and considered a distinct regional grouping by Verspoor (2005) -oBoF and nearby Chignecto Bay iBoF populations have very similar microsatellite allele frequencies (O'Reilly unpubl data) -iBoF populations largely group separately from SU	-at least part of the marine phase of their life cycle spent in high tide, high energy environment of the Bay of Fundy -tendency for lower stream gradients in Bay of Fundy compared to Gaspé and Newfoundland-Labrador rivers (Claytor *et al* 1991)	-<10 of kms from oBoF and SU rivers - no obvious disjunction between iBoF and oBoF rivers -possible disjunction between iBoF and SU salmon (few salmon bearing streams on SE shore of Bay of Fundy between Cornwallis and Annapolis Rivers). -iBoF located towards the head of the Bay of Fundy relative to the nearest oBoF and SU rivers and is internal to Cape Split NS and with very high tides

				populations at microsatellite loci surveyed (O'Reilly, unpubl data)		
17 Outer Bay of Fundy NB (oBoF)	16	N/A	-higher incidence of maturation as 2SW fish than in iBoF (Amiro *et al* 2003) - ocean migration to the North Atlantic compared to Gulf of Maine and proximity for iBoF pop's (Amiro *et al* 2003) -unique but small Serpentine stock of the Saint John River enters estuary in November, ascends the river in May-June and spawns that fall (Huntsman 1933a, b; Saunders 1978) -Tobique trib. of the Saint John R. has a significant fall migration of pre-smolts (Jones *et al* 2003)	-oBoF and iBoF salmon exhibit very different mtDNA haplotype frequencies (see iBoF-oBoF for more details) (Verspoor *et al* 2002) -oBoF salmon group separately from iBoF and most other populations at multiple allozyme loci and are considered a distinct regional grouping (Verspoor 2005) -oBoF and nearby Chignecto Bay NB/NS iBoF populations have very similar microsatellite allele frequencies (O'Reilly, unpubl data)	-early marine phase of the life cycle spent in high tide, high energy environment of the Bay of Fundy -tendency for lower stream gradients in Bay of Fundy compared to Gaspé and Newfound-land-Labrador rivers (Claytor *et al* 1991)	- <10 of kms from iBoF -no obvious disjunction between iBoF and oBoF rivers - oBoF at the entrance of the Bay of Fundy, iBoF towards the head of the Bay of Fundy
18 Salmon Zone Q1 QU	9, 19		- ocean migration in Chaleur Bay (Belding et Préfontaine 1937)	-based on 13 microsatellite markers. Dionne *et al* In prep[7]		
19 Salmon Zone Q2 QU	18, 20		- ocean migration in Gaspé area (Belding et Préfontaine 1937)	-based on 13 microsatellite markers. Dionne *et al* In prep[7]		
20 Salmon Zone Q3 QU	19, 21, 27		- ocean migration along the South Shore of St. Lawrence (Belding et Préfontaine 1937)	-based on 13 microsatellite markers. Dionne *et al* In prep[7]		
21 Salmon Zone Q4 QU	20, 22	No salmon present				
22 Salmon Zone Q5 QU	21, 23			-based on 13 microsatellite markers. Dionne *et al* In prep[7]		
23 Salmon Zone Q6 QU	22, 24			-based on 13 microsatellite markers. Dionne *et al* In prep[7]		
24 Salmon Zone Q7 QU	23, 25		- ocean migration along the North Shore of St. Lawrence (Belding et Préfontaine 1937)	-based on 13 microsatellite markers. Dionne *et al* In prep[7]		

25 Salmon Zone Q8 QU	24, 26, 27		- ocean migration along the North Shore of St. Lawrence (Belding et Préfontaine 1937)	-based on 13 microsatellite markers. Dionne et al In prep[7]		
26 Salmon Zone Q9 QU	3, 8, 25		- ocean migration by Strait of Belle-Isle (Belding et Préfontaine 1937)	-based on 13 microsatellite markers. Dionne et al In prep[7]		
27 Salmon Zone Q10 QU	20, 25		- ocean migration proximate (?) to Anticosti Island (Belding et Préfontaine 1937	-based on 13 microsatellite markers. Dionne et al In prep[7]		
28 Salmon Zone Q11 QU	1		Ocean migration mostly coastal within Ungava Bay (Power 1969)	-based on 13 microsatellite markers. Dionne et al In prep[7]		

Footnotes:

[1] Information indicating the presence of unique or distinct lineages within the proposed CU, including evidence of distinct refugial (glacial) origins, reciprocal monophyly at mtDNA, etc.)

[2] Presence of observable differences including morphological, meristic, life history (egg size, age at smoltification, sea age, etc.) for which there is evidence that the character(s) in question are adaptive (are genetically based and confer a fitness advantage). Note: include information on the strength of evidence for adaptiveness of the trait(s).

[3] Movement information includes tagging, telemetry or other data pertaining to movement that could indicate distinctiveness.

[4] Information from 1) presumably neutral molecular genetic markers such as microsatellites, mtDNA, AFLPs, allozymes, etc., that indicate the presence of largely reproductively isolated groups of organisms, and 2) frequency or fixed differences at MHC and other coding loci that may be adaptive.

[5] Ecological differences between environments occupied by proposed units that may have led to the development of adaptive differences, including stream gradient, river sizes, temperature regimes, general water quality differences (pH), bedrock types, prey types, predators, etc. for which local adaptation could occur that would lead to distinctiveness.

[6] Includes 1) geographic distance between proposed units, 2) geographic range disjunction (yes/no, see accompanying text for details) and 3) presence of physical barriers.

[7] Dionne, M. et al In prep. Genetic structure of Atlantic salmon populations and local adaptation. A description of the genetic structure of salmon populations in Q1 to Q11 and Labrador in relation to their geographic distribution. Laval University.

Abbreviations:

NF-insular Newfoundland NB-New Brunswick NS-Nova Scotia PEI-Prince Edward Island QU-Quebec N/A-Not Available (should not necessarily be considered as negative evidence)
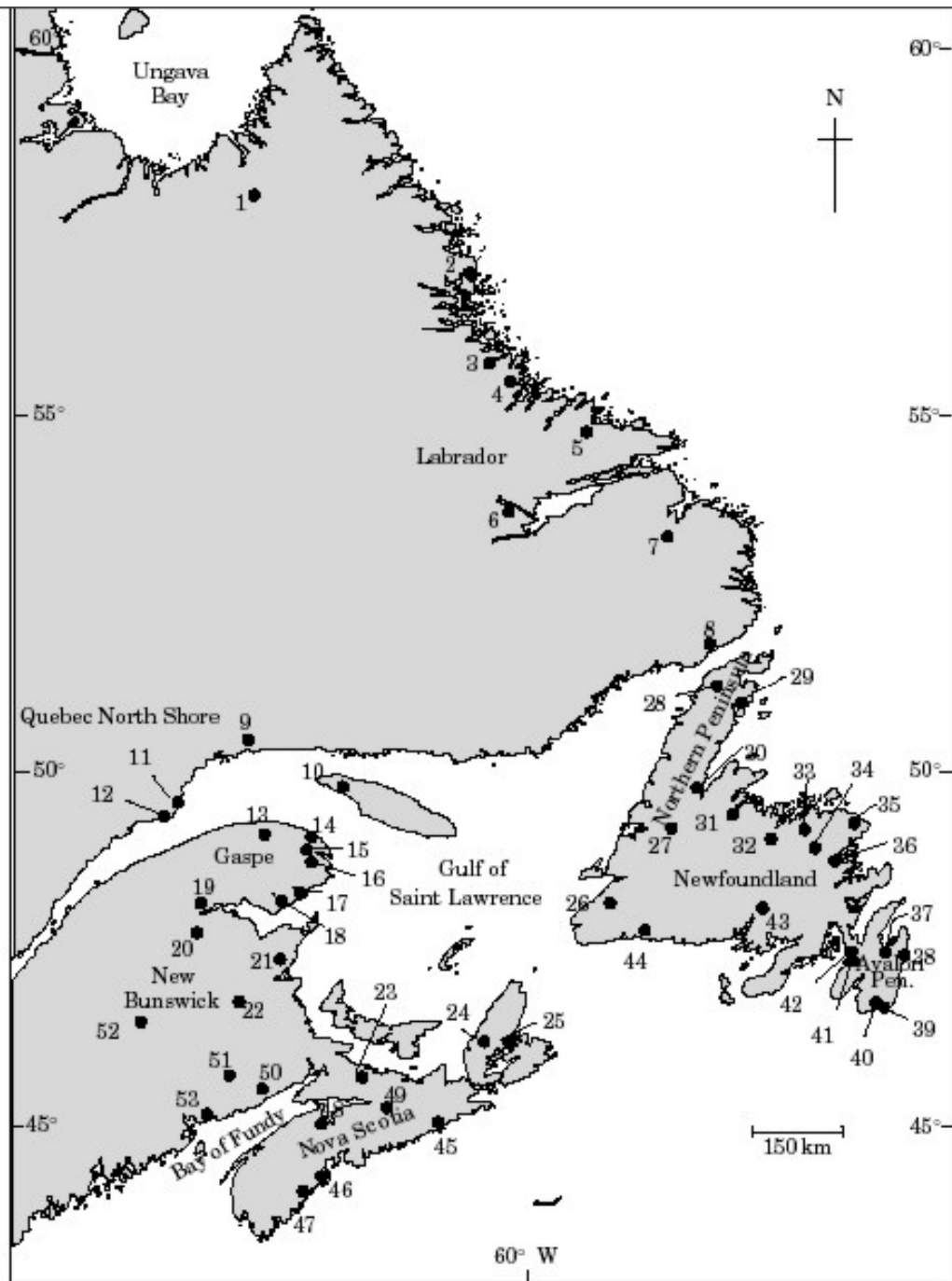
Figure 1. Map of the location of Canadian rivers sampled for allozyme analysis by Verspoor (2005).
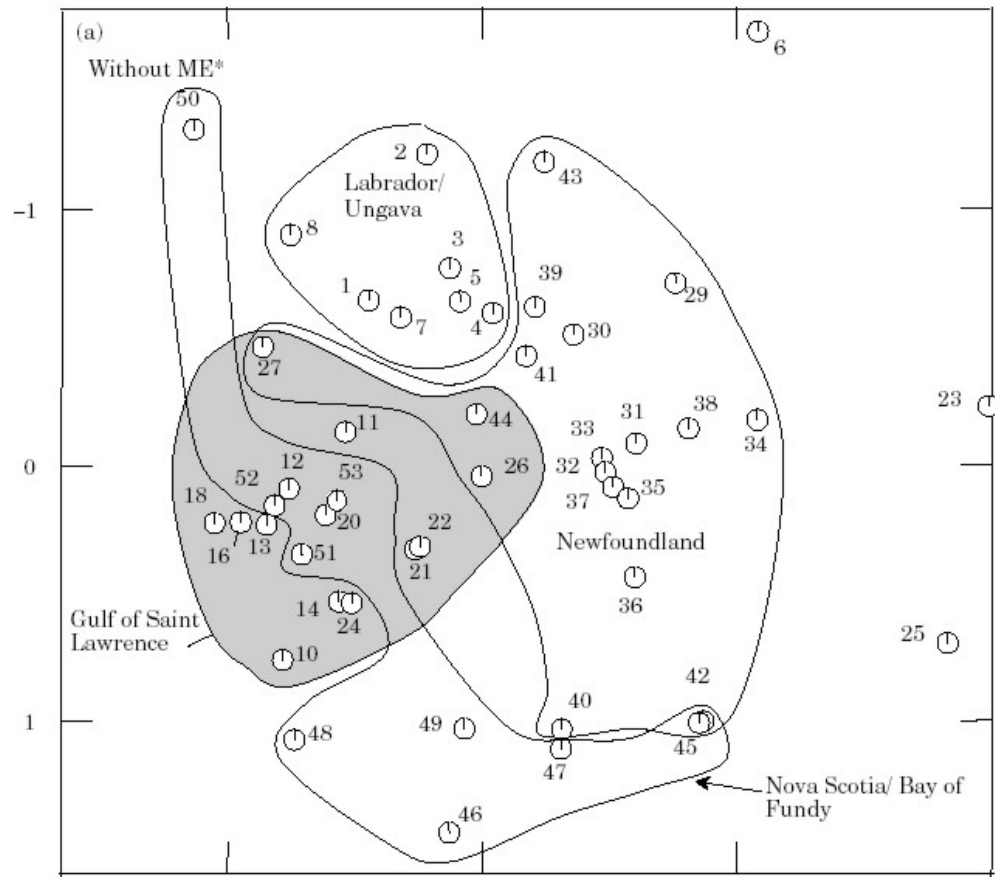
Figure 2. Two dimensional Multi-Dimensional Scaling (MDS) plot based on Nei's D_A genetic distance indicating the presence of six large-scale groupings of Atlantic salmon in Eastern Canada: Labrador and Ungava; Gulf of St. Lawrence; Newfoundland (excluding Gulf rivers); Atlantic Coast and Southern Upland of Nova Scotia; Inner bay of Fundy; and Outer Bay of Fundy (Verspoor 2005).

Figure 3. Distribution and frequency of mitochondrial DNA haplotypes unique to salmon of the inner Bay of Fundy (black) and Southern Upland (grey), from Verspoor *et al* (2005).

```
                                    +BSR98X
                                 +--1
                              +--4 +BSR99X
                              !  !
                           +--6 +BSR00X
                           !  !
                           !  +SJR
                        +--11
                        !  !      +STW00X
                        !  !   +--2
                        !  +--3 +STW98X
                     +-15   !
                     !  !   +STW99X
                     !  !
                     !  !  +PWF
                     !  +--12
                     !     +USR
                     !
                     !              +COU
                     !              !
                     !              !                +ECU
                     !              !             +--5
                  +-18          +-13         +--8 +SMA
                  !  !          !  !         !  !
                  !  !          !  !      +--9 +LIS
                  !  !          !  !   +--10 +GLD
                  !  !       +-14  !   !  !
                  !  !       !  !  !   !  +LAH
                  !  !       !  !  !   +--7
               +-19 !    +-16  !   !     +MED
               !  ! !    !  !  !   !
               !  ! !    !  !  +TSK
               !  ! !  +-17  !
            +-20 !  !    !  +--MSQ
            !  ! !  !    !
         +-21 !  !    +--SAD
         !  ! !  !
         !  ! !  +--MOS
      +-22 !  !
      !  ! !  +--GAK
     -23 !  !
      !  ! +--GRV
      !  !
      !  +---ECO
      !
      +---ROH
```

Figure 4. Unweighted Pair Group Method with Arithmetic mean (UPGMA) tree of pairwise estimates of Nei's 1978 genetic distance. BSR-Big Salmon River, SJR-Saint John River; STW-Stewiacke; PWF-Point Wolfe; USR-Upper Salmon River; COU-Country Harbour; ECU-Ecum Secum; SMA-Saint Mary's; LIS-Liscomb; GLD-Gold; LAH-LaHave; MED-Medway; TSK-Tusket; MSQ-Musquodoboit; MOS-Moser; GAK-Gaspereau; GRV-Great Village; ECO-Economy; ROH-Round Hill (Verspoor *et al* 2005).

Figure 5. Proposed Conservation Units (CUs) for Atlantic salmon of Eastern Canada. (There are no salmon in CU 21.)

2. Distribution[9]

2.1 Global Range

The world range of the Atlantic salmon has changed substantially over recent centuries, principally because of attempts to introduce the species on all continents (MacCrimmon and Gots 1979; Blais and Legendre 1978). These attempts have sometimes succeeded in establishing freshwater populations, termed *ouananiche* or landlocked salmon. However, the range of natural anadromous Atlantic salmon remains essentially the North Atlantic Ocean and adjacent rivers.

On the east side of the Atlantic, salmon reproduced in the south in several rivers in Portugal, and then, in order from south to north, in Spain, France, the United Kingdom, Iceland, Ireland, Sweden, Finland, Norway, and northern Russian rivers flowing into the Barents Sea, the White Sea, and the Kara Sea (MacCrimmon and Gots 1979). Atlantic salmon also breed in rivers flowing into the Baltic Sea; meanwhile, contact of Baltic salmon with the Atlantic populations is known to be rare.

On the west side of the Atlantic, the Atlantic salmon's natural range extends from the Hudson River north to include rivers of the Bay of Fundy, the Maritime Provinces, and Québec. As one proceeds north along the Labrador coast, Arctic charr tend to dominate although there are a few sporadic instances of small runs of salmon. Salmon parr have been obtained north of Nain. In the northwest, the salmon is found in rivers at the southern end of Ungava Bay, and in the northeast, there are local populations in rivers in southern Greenland. Atlantic salmon have never been resident in rivers of Hudson Bay or the Faeroe Islands.
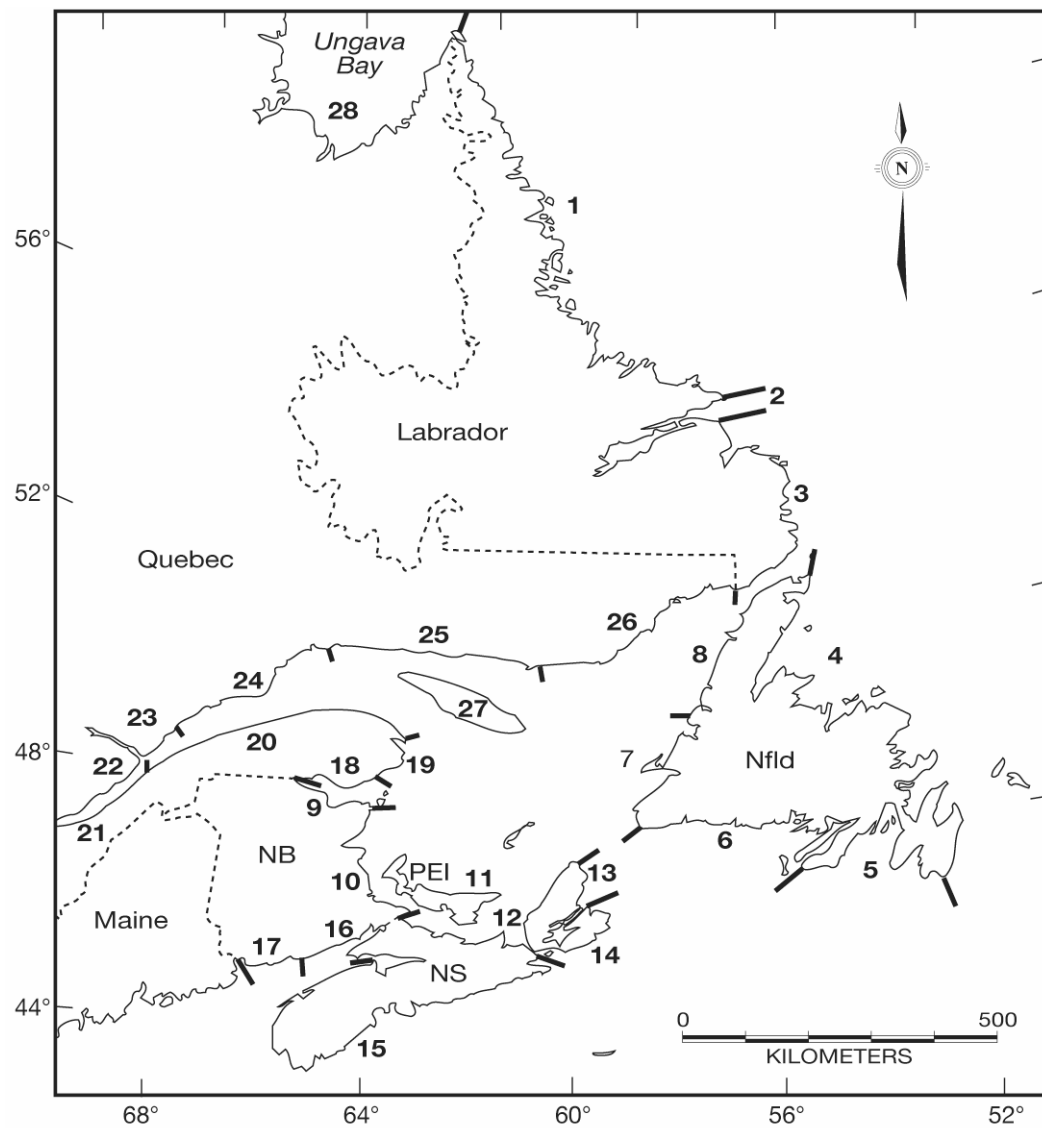
Landlocked Atlantic salmon populations are found in interior waters of a number of regions colonized by salmon after the retreat of the glaciers, notably in Norway, Finland, Sweden, in Canada, and in the New England States (MacCrimmon and Gots 1979; Blais and Legendre 1978).

More recently, there has been an enormous expansion of cage culture of *S. salar* both in areas of current distribution (e.g. east coast of Canada, Norway, Scotland) and also in non-native areas (e.g. Chile, Pacific coast of Canada). In 2006, production on the east coast of Canada attained a new high of 46,504 t (ICES 2007), is concentrated in the Bay of Fundy in coastal southern New Brunswick and was predominately derived from Saint John River broodstock in the early 1980s.

2.2 Canadian Range (Past and Present)

The first historic mention of Atlantic salmon in North America comes from Leif Erickson about the year 1000 (Rafn 1838). The Atlantic salmon had been a source of food for Aboriginal peoples long before the arrival of John Cabot in 1497 (Taylor 1986). Jacques Cartier mentioned the presence of salmon in rivers on his first voyage to North America (Campeau 1984).

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[9] Section 2 based on Caron *et al* (2006).

On the Atlantic coast of Canada, the Atlantic salmon's range runs from the US border at the mouth of the Bay of Fundy to the Fraser River in the region of Nain, Labrador (MacCrimmon and Gots 1979), and in Ungava Bay. The distribution of anadromous salmon in the St. Lawrence River has not changed since the beginning of European colonization. Contrary to frequent reports, *anadromous* salmon were never found upstream of their present distributional limits in the Jacques Cartier River on the north shore near Québec City, and in the Ouelle River on the south shore (Legendre *et al* 1980). Salmon completely disappeared from various rivers of the Gulf of St. Lawrence in Québec because of dams or because of poor water quality due to release of untreated wastewater; however, they have been successfully re-introduced into all of these rivers except the Trois-Pistoles. The species has also been introduced after establishing fish passage in a number of rivers that, because of impassable falls, could not naturally colonize.

With regard to freshwater salmon, Legendre *et al* (1980) has shown that upstream populations on the St. Lawrence system, including Lakes Ontario and Champlain are apparently landlocked, based on the complete absence of historic salmon landings in fisheries upstream from the Jacques Cartier River. The Atlantic salmon does not appear in the Great Lakes other than Lake Ontario (Legendre *et al* 1980). The last capture of native salmon occurred in 1841 in Lake Champlain and in 1898 in Lake Ontario (Huntsman 1944).

2.3 Salmon Rivers in Canada

As of July 2008[10], 728 rivers in 28 CUs of Atlantic Canada had been identified in which salmon are or were present within the last half century. This total revises upwards those reported for Canada in O'Connell *et al* (1997a); Anon (1978); WWF (2001); and ICES (2004) and is attributable to a number of factors including information available, especially in Labrador, where recent information for presence of salmon, and definition of a 'river'[11] has changed. The number of salmon rivers per CU is as follows:

CU	No. Rivers	CU	No. Rivers	CU	No. Rivers
1	28	10	25	19	10
2	20	11	5	20	9
3	41	12	33	22	3
4	127	13	8	23	4
5	49	14	21	24	12
6	55	15	63	25	17
7	40	16	37	26	21
8	34	17	17	27	25
9	15	18	5	28	4

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[10] Revisions ongoing

[11] Definitions: 'river' (versus 'tributary') is a fluvial system flowing directly into tidal water; a 'salmon river' is any river where *anadromous* salmon have occurred as parr or adults in the past century.

3. Habitat Considerations

3.1 Freshwater Habitat Requirements[12]

Introduction and Overview.   Canadian Atlantic salmon populations have reportedly declined by at least 75% from 1970 to 2000 (WWF 2001). Despite closures (1985, 1992 and 2000) of Canadian net fisheries for Atlantic salmon and restrictive recreational fishing regulations since 1983, populations in many rivers continue to decline. At least 550 Canadian rivers were considered to have contained Atlantic salmon historically (ICES 2004; WWF 2001). This number of rivers harbouring populations of salmon is likely a significant underestimate by some 25% (Caron *et al* 2006) when remote rivers and smaller rivers in remote areas are accounted for. Loss of habitat is known to be responsible for some of the more sudden and dramatic declines usually, but not always, associated with the construction of barriers to fish passage (Leggett 1975; Dunfield 1985). However, more indirect and subtle effects have also been documented that cause slow chronic declines in populations. This section surveys the literature for attributes of salmon habitat that may be useful to document freshwater habitat required to support viable Atlantic salmon populations and documented changes in the productive capacity of freshwater salmon habitat, i.e., the capacity of the total habitat of a river to produce Atlantic salmon smolts at the established conservation requirement level. This approach infers that populations are significantly impacted by habitat quality and quantity that affects local fitness of salmon.

Fish habitat is defined under Section 34 of the Fisheries Act as, "Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes" and applies to, "All waters in the fishing zones of Canada, all waters in the territorial sea of Canada and all internal waters of Canada". This definition is noted for its broad inclusion of habitat required to supply food and migration from one stage to another as well as direct and indirect effects and inclusion of all life stages but does not provide a means to specify, compare or evaluate habitat.

The Species at Risk Act (SARA)[13] has specific provisions for the protection of 'critical habitat': "… *no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species …*"[14] 'Critical habitat' is defined in the SARA as "*habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species*". In SARA, habitat for aquatic species is defined as "*spawning grounds, and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life*

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[12] This section has been abstracted and/or synthesized from a more comprehensive literature review and synthesis on this topic by Amiro (2006a).

[13] SARA Public Registry - The Act (http://www.sararegistry.gc.ca/the_act/default_e.cfm)

[14] http://www.sararegistry.gc.ca/the_act/HTML/Part9c_e.cfm

processes, or areas where species formerly occurred and have the potential to be reintroduced". By this definition, habitat can be identified based on the functions it provides, and therefore habitat is sufficiently protected if its capacity to fulfill its functions is protected (see <u>Section 3.4</u> in this document for more detail on 'critical habitat' for Atlantic salmon).

Freshwater habitat utilization by Atlantic salmon is diverse, widely documented and the subject of substantial reviews (Bjornn and Reiser 1991; Gibson 1993; Bardonnet and Bagliniere 2000; Armstrong *et al* 2003a; Rosenfeld 2003). Publications report a range of habitats used by juvenile and adult salmon in freshwater fluvial, lucustrine and estuarial environments (see Appendix 2 for summary). Individual fish may often use several habitat types during their freshwater residency (Erkinaro and Gibson 1997; Bremset 2000) for demographic (Saunders and Gee 1964), ecological (Morantz *et al* 1987), as well as dynamic reasons (Bult *et al* 1999).

Identification and quantification of freshwater habitats that support or limit salmon production in catchments are incorporated in stock assessments, environmental monitoring and protection activities and include *ad hoc* as well as regionally standardized methods at the micro, meso and macro scales depending on the requirements of the data or information. Perhaps because of this diversity there is no standard accepted method utilised for measurement or assessment of Atlantic salmon freshwater habitat across the North Atlantic range of the species. In fact, common terms such as 'run', 'riffle', 'pool', 'boulder', 'cobble', and 'gravel' (Elson 1942; Allen 1941) which may have standard definitions in geological, engineering or other physical sciences can vary between surveys and within regions. Objective methods have been postulated (e.g. Jowett 1993) but standardization remains unresolved and seldom are these attributes measured and calculated.

However, this lack of standardization has not presented a serious problem because the use of survey data is generally limited to responses for site-, river-, or region-specific questions. Also, wide-area surveys are usually at the macro or meso scale and seldom based on these precise micro-habitat definitions. There is a relative scarcity of wide-area freshwater habitat surveys for Atlantic salmon. Nonetheless, there are benefits to cooperative management of a highly migratory species that utilizes a common marine environment, and these benefits underlay a common pursuit to develop standardized wide-area survey methods that could be economically applicable across the North Atlantic range of Atlantic salmon (Crozier *et al* 2003 Chapter 5).

Habitat-related constraints to production*.* A review of some chemical and physical habitat factors known to constrain populations follows.

<u>Chemical</u>

1. Nutrient-limited production: No studies were found that directly link the concentration of carbon, nitrogen and phosphorus to the production or productivity of Atlantic salmon. However, one study noted increased salmon production in agricultural areas compared to forested areas (Hesthagen *et al* 1986). Studies have also shown that fertilization can increase productivity of streams draining oligotrophic catchments

(Wilson *et al* 2003) and enriched streams have been shown to recover from a catastrophic loss in production due to flooding faster than non-enriched sections (Weng *et al* 2001).

2.   pH and acidity and acid neutralizing capacity: North American emissions of SO_2 increased during the industrial revolution. They peaked in the early 1970s. Reductions in emissions were implemented as a result of concerns about effects on human health and the environment. Approximately 60% of the wet sulfate deposition is from human activities in North America; the remaining 40% is background concentration. Of the 60% anthropogenic component, roughly 75% is from United States sources; 25% is from Canadian sources.

The reduction in emissions is correspondingly reflected in both wet sulfate depositions and hydrogen ion concentrations at monitored sites. Anthropogenic sulfate deposition has decreased about one third since the mid-1980s (DFO 2000a). This has caused a large decrease in the deposition of acidifying substances. Unfortunately the reduction in atmospheric hydrogen (H^+) deposition has not resulted in a substantial decrease in lake acidity at measured sites in Nova Scotia, as only two of the lakes have shown reductions in acidity. Furthermore, reduction in acid deposition is not reflected in the acid neutralization capacity (ANC), as six sites show a worsening, and only three sites show improvement. Moreover, 15 lakes show a decrease in acid neutralizing base cation (C_b) concentrations. Calcium, a major component of (C_b), is an important element in salmon survival (DFO 2000a).

At least 65 rivers in the Southern Upland region of Nova Scotia are severely affected by acidification. The underlying geology of the Southern Upland is the principle reason for the vulnerability to acidification. Other areas in Atlantic Canada that are somewhat vulnerable to the effects of acid depositions are southwestern and northeastern Newfoundland (Environment Canada 2004). In these areas, the critical sulphate loads exceed the capacity of the soils to balance pH and release base cations. Although there has been a reduction in sulphate emissions and depositions, there has not been a corresponding increase in pH or ANC in these areas. Furthermore, at the projected sulphate deposition rates, the time for recovery of base cations in these catchments is 60 to 80 years (Clair *et al* 2004).

Physical

1.   Temperature: Temperature has been described as the most pervasive abiotic attribute controlling the production of teleost fishes in streams (Heggenes *et al* 1993). Because fish are poikilotherms almost all of their vital activities or rates are controlled by temperature. The growing season for salmon has been determined as the number of days when air temperature is greater than 5.6◦C (Power 1981) or water temperature greater than 7.0◦C (Symons 1979). Temperature and day length has been integrated into a growth index metric that is the product of the number of days where temperature exceeds the minimum times the number of daylight hours in a month (Metcalfe and Thorpe 1990). The maximum incipient lethal temperature for salmon (the temperature at which all salmon would exit a habitat if the opportunity were available) was estimated to be 27.8◦C (Garside 1973). In fact many of the reported fish kills that were not associated with

disease or some other physical event may be the result of prolonged exposure to temperature in excess of this limit, e.g. Moser River 1937 and 1939 (Huntsman 1942).

A description of a function for productivity of juvenile salmon within this temperature window could not be found and therefore the optimum temperature regime is undetermined.

A **cline** is a gradual change of a character or feature ([phenotype](#)) in a [species](#) over a geographical area, often as a result of environmental heterogeneity. In [population genetics](#), a cline could include a spectrum of [subspecies](#).

Based on the gradual increase in smolt age with the increased severity of winters/ latitude and the potential differences in the number of smolts produced per spawning salmon observed over its range, it is entirely possible that an optimum temperature regime and therefore maximum smolt productivity limit exists for Atlantic salmon. This maximum is more likely at the middle latitudes rather than at the extremes of the range and may be confounded by the diversity of prey, predators and their abundances.

Temperature can also affect the movement of salmon. Juvenile salmon begin to migrate downstream as well as seek shelter in the interstitial spaces of the stream bed at about 9°C (Gibson 1978). Smolt migrations seem to coincide with rising temperatures in the spring of the year that are over 5°C and maximum movement has been associated with 10°C in some studies in eastern Canada (Forsythe 1968) and can continue up to 20°C. A switch from nocturnal to diurnal migration occurs below 7 and above 16°C (Thorpe *et al* 1994). Whalen *et al* (1999a) found that when water temperatures were cold early in the year but discharge was high; few smolts were caught in their sampling trap and therefore were assumed to not be migrating. This, they suggest, indicates that that there is a hierarchy of cues for smolt migration with water temperature dominating discharge.

2.   Discharge: Regardless of one's preference for a limiting habitat factor that is associated with regulating or controlling salmon populations in rivers, mortality and/ or growth, both are affected by the amount of suitable habitat available, which is a direct function of discharge and born out in modeling, e.g., Instream Flow Incremental Methodology (IFIM), (Bovee 1978), and Physical HABitat SIMulation (PHABSIM) (Bovee 1982). While, exposure of juvenile populations to low flows may contribute to limiting production in streams, variation in flow is a normal expectation of salmonids occupying streams in a temperate climate. Atlantic salmon have been noted for their capacity to cope with this variation in flow and associated physical constraints better than sympatric salmonids. This adaptability and tolerance contributes to habitat separation and sometimes segregation. Juvenile salmon were noted to move from pool to riffle habitats at higher discharges (Bult *et al* 1999), which is complementary to the noted preference to pools at low discharge (Morantz *et al* 1987). Both papers note that movement is local rather than distant. Juvenile salmon have the ability to adapt to changes in flow and tolerate high temperature. This enables juvenile salmon to occupy extensive sections of streams that experience these variations in flow and temperature that are out of the habitat use range of some competitive sympatric species. However, the frequency, degree and

duration of these low flow events has become a subject of renewed interest due to recent climate change that has increased the frequency if not the extremity of these events. This change in frequency and intensity as well as timing of events could potentially affect survival of some or several stages and therefore the potential for persistence of an affected population. Further examination of the effects of these variations on population persistence is an emerging important area for research.

While it is widely held that adult run timing is keyed to discharge, there is a paucity of information in the literature that develops this relationship. In fact, Lilja and Romakkaniemi (2003) found that environmental indicators of the timing of river entry of Atlantic salmon in River Tornionjoki in Norway were rarely statistically significant and those that were significant in the original study did not hold over the years. Delayed entry associated with low discharge is, on the other hand, widely observed. Observations of salmon holding in an estuary during low discharge events and their behavior in those estuaries have been monitored and reported (Stasko 1975; Brawn 1982).

3.   Geo-morphological: In respect to the hypothesis that Atlantic salmon demonstrate both ideal free and ideal despotic distribution (Boisclair 2004) depending on ecological and dynamic states as well as adaptive selection for habitat based on familial affinity and homing, a range of habitat types may be required in a river for population stability. Furthermore, because the proportionate distribution of these habitats is a function of geomorphology and fluvial processes that vary considerably across the range of the species, it is unlikely that a single habitat type or definition will dominate the constraint of salmon populations across all regions. While there have been some reviews to classify habitat with respect to geomorphologic process on the macro scale (Netboy 1968; Elliot *et al* 1998), no meso- or micro-habitat classifications based on geomorphology and hydraulic process were found. Such research could provide a more scientific basis for the variety of freshwater habitat-based constraints observed and reported.

4.   Obstructions: Obstructions, both natural and manmade, severely reduce the production of salmon. In general, most obstructions in excess of 3.4 m will block the upstream passage of salmon (Powers and Orsborn 1985). The maximum height depends on the burst speed of the fish, which is a function of body length. Generally, the burst speed of a salmon is 8 to 12 body lengths per second (Reiser and Peacock 1985). Ideally, a passable falls will have a plunge pool with a vertical drop and a depth of 1.25 times the height. Depending on the shape of the falls and plunge pool, the maximum height can be considerably less.

Dams with, and without, specifically constructed fishway passages probably account for the most loss of salmon habitat in North America. Prior to the development of hydroelectric power there were extensive small mill dams. From 1815 to 1855 more than 30 mills a year were being built in the Atlantic provinces (Dunfield 1985) and by which time the decline in the numbers of salmon were being noticed. Although fish bypass legislation was passed in some colonies as early as 1786, the rules were seldom followed. In Nova Scotia alone, there were a total of 1,798 dams in 1851 when the first river wardens were appointed. In both Nova Scotia and New Brunswick, surveys by Moses

Perley, W.H. Venning and Captain William Chearnley documented severe habitat loss and destruction caused by dams and mill waste. Estimates made at the time indicated that 70 to 80% of the habitat for salmon was impacted. The first fishery regulations that included specifics for fish passage at dams were passed in 1865, but compliance was found to be lacking. A similar situation was occurring in 'Upper Canada' at this time and by 1866 salmon in the tributaries of Lake Ontario, both in Canada and in the United States, were severely depleted and extirpated from many rivers. This situation led Samuel Wilmot to begin artificial propagation of salmon in Wilmot Creek in 1866, the first salmon hatchery in North America (Dunfield 1985).

With the development of the *Fisheries Act* shortly after confederation in Canada, some habitat conditions improved, but much damage to the populations was already done. A new round of technology began in the late 1920s to develop hydroelectricity. This technology involved the construction of high-head concrete dams that flooded vast areas of rivers. Fish passage structures, when required, proved to be difficult to operate effectively and in many cases were eventually abandoned due to the lack of fish. Many of the major rivers were developed for hydroelectric power over the next forty years and more salmon populations were lost. Because hydro developments were naturally attracted to existing falls, not all hydroelectric power developments were the direct cause for the loss of a salmon population. No complete inventory of dams and habitat loss has been found in the literature. However, it is notable that five of the largest rivers in Nova Scotia, all of which had salmon prior to European colonization, were subsequently developed for hydropower and no longer have indigenous salmon populations. This observation is clearly not unique to Nova Scotia.

5.   Sedimentation and Siltation: Infiltration of sediment into stream bottoms has been suggested as a cause for significant decrease in the survival, emergence and over-wintering success of Atlantic salmon juveniles (Chapman 1988). Sediment size and movement in a stream (bedload) is a natural process and the natural activity of redd (egg nest) construction prepares a location such that the expected normal bedload will not significantly affect survival to emergence. However, a multitude of impacts can increase the input of sediments to streams that exceed the capacity of the hydraulic process to migrate and sort substrates (for a more detailed description of these processes and their impacts see Meehan (1991). The result of these increased inputs of sediments is that stream substrates become embedded to the point that any stage of juvenile rearing that requires interstitial space (between the rocks) is negatively impacted. Because all but the oldest of juvenile salmon require interstitial occupation at some stage or environmental condition, exceeding the equilibrium input of sediments into streams can have devastating effects on the viability of salmon populations. The first stage affected, and perhaps the most sensitive, is eggs in redds – as little as 0.02% silt has been shown to decrease the survival to the pre-eyed stage by 10% (Julien and Bergeron 2006). Survival to the eyed stage has been shown to be sensitive to as little as 0.03-0.041% silt. Emergence survival is also sensitive to the bedload transport of sand that prevents the escapement of alevins from the gravel pockets to free swimming fry. Local stream geology, substrate distribution and resulting hydraulics act to vary these impacts

throughout a stream and result in the wide range of impacts of these events and causes of juvenile mortality reported in the literature.

3.2 Freshwater Habitat Status and Trends

Amiro (2006) reviewed the literature and provides the following 'summary conclusions':

- "Due to the diversity of habitats in Canadian rivers and the plasticity of Atlantic salmon to occupy those habitats a range in optimum habitat configurations exists across the range of the species in Canada.
- Prior to 1870 as much as 50% of the habitat was lost or the populations that utilized those areas were lost. The majority of these populations and areas were in the Upper St. Lawrence and Great Lakes (Leggett 1975).
- The net loss of productive capacity by 1989 was estimated at 16% since 1870, 8% due to loss in productive capacity, 7% due to impoundment and 3% due to acidification and 2% increased from fish passage development (Watt 1989).
- While the construction of dams and resulting flooding and flow controls may be the most prolific cause for the loss of freshwater salmon habitat in Canada, an array of distant (e.g. pH) and local (industrial land use) impacts continue to affect salmon habitats in Canada. However, no substantial and significant acute loss in freshwater habitat was reported or noted in the past twenty-five years when salmon recruitment has drastically declined.
- Development of a wide area survey method to inventory freshwater salmon habitat remains a goal for Canadian as well as international salmon management.
- An up to date inventory of the status of salmon habitat in Canada is required.
- Because some populations have been declared endangered and others meet that criteria, and because habitat explicit population viability analysis requires further development and analysis, declaring all remaining producing freshwater habitat as crucial for population recovery in listed areas would be precautionary for their recovery.
- The potential impact of climate change on the ability of freshwater habitat to support Atlantic salmon remains a research gap."

3.3 Marine Habitat Requirements[15]

Introduction. Salmon move, as smolts or 'kelts', from fresh water to brackish estuaries to the full sea water of the open ocean. (See Figure 6 for a generalized outline of current understanding of Atlantic salmon migration routes for 1SW and 2SW salmon.) O'Connell *et al* (2006) report that it is in the ocean where "growth… is rapid relative to that in fresh water…, weights increase about 75-fold between the smolt stage and 1SW salmon stage, and over 200-fold from smolts to 2SW salmon". Reddin (2006) indicates that overall natural mortality in the sea is high and/or variable and there are many factors there that

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[15] This section is taken or synthesized from Reddin (2006)

can effect the survival of Atlantic salmon, some habitat-related. However, Reddin (2006) also reports that "population-specific information is lacking concerning the cause of these mortalities and this is due partly because detailed information on migration routes and distribution is generally unavailable for specific populations, although it is thought that their distributions generally overlap in the North Atlantic."
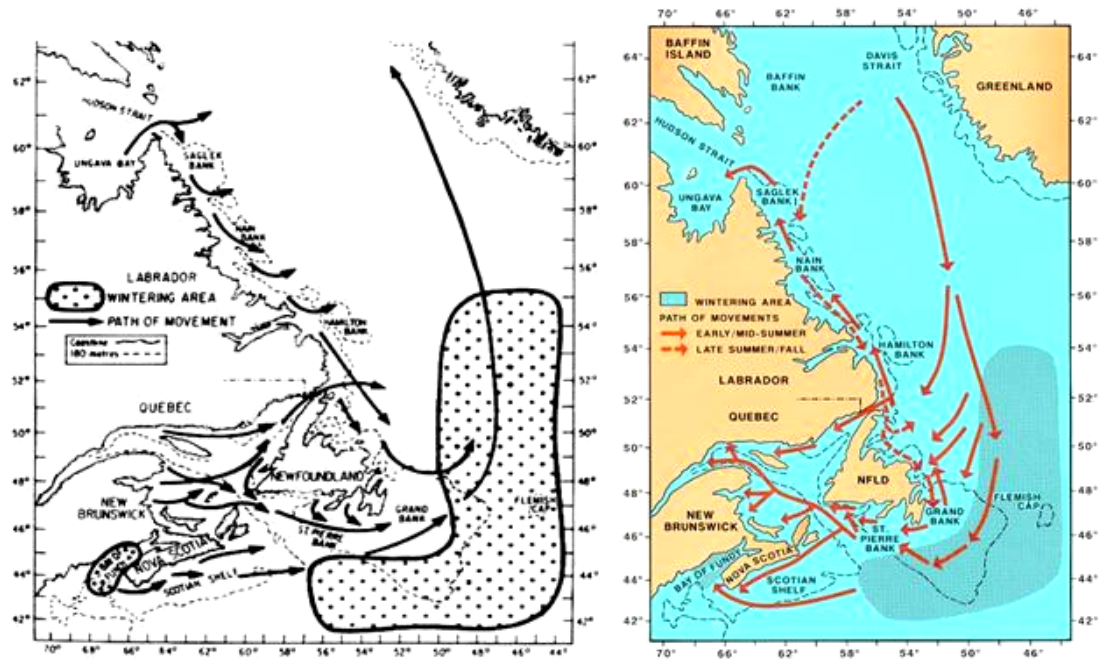
Figure 6. Migratory outgoing smolt and returning salmon routes for 1SW and 2SW North American salmon (from Figures 2 and 3 in Reddin 2006)

Entry into sea by smolts and kelts. Reddin (2006) summarizes[16] that the transition from fresh water to ocean life for Atlantic salmon, whether smolts or kelts, can be of serious consequence and therefore an important factor controlling year-class strength. It is generally thought that water temperature is the main controlling environmental variable for smoltification, although photoperiod is also important. The smolt transformation process is accompanied by changes in metabolic rate with increases in energy demands underpinning the need for the fish to immediately begin feeding. Of all the variables influencing survival of 'postsmolt'[17] salmon, temperature is particularly important because temperature controls metabolic rate. If they are to survive, individuals must quickly adapt to their new physical environment and be able to escape predators and capture prey. Temperatures recorded in one study ranged from below 0 to nearly 20°C;

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[16] See "Transition from freshwater to the marine environment" sub-section in Introduction section of Reddin (2006) for references.

[17] 'Postsmolts' are salmon during their first calendar year at sea.

although most were 8 to 15°C[18]. The length of time spent in the estuary or near the home estuary is thought to be brief although in some cases may still be critical to postsmolt survival. Estuarine residence time could be as brief as one or two tidal cycles and in some cases presumably limits opportunities for predation so that survival is high. In general, postsmolts' movement to oceanic areas has been found to be rapid[19]. This rapid movement away from estuaries towards the open sea has been confirmed by tracking studies, which additionally showed that migration was influenced by tidal currents and wind. One exception to this was in the Gulf of St. Lawrence where salmon postsmolts were caught in a nearshore zone late in the summer presumably long after they had left their home river and estuary (Friedland *et al* 1999). On both sides of the Atlantic, movement of postsmolts, once in the open sea, seems to be generally northwards. Montevecchi *et al* (1988) showed that the diet of northern gannets around the Funk Is., Newfoundland consisted of postsmolts. The river ages of the postsmolts and presence of tags suggested a southerly origin away from the island of Newfoundland as far as the state of Maine.

Salinity as a marine habitat requirement. In estuaries, there is a transition zone where the water changes abruptly or gradually, depending on the topography, from fresh water to sea water. Handeland *et al* (2003) showed that there was an approximate 48 hour period when salmon postsmolts exhibited signs of osmotic stress while adjusting to the transition from fresh to sea. This may result in increased predation as the osmotic stress impairs their ability to avoid predators. Otherwise, salinity does not appear to be of any significant consequence. In the Northwest Atlantic, in areas where salmon frequent, salinity ranges between 33.4 to 34.6 PPM and is generally around 34 PPM. Reddin (2006) does not consider salinity to be a problem for "healthy salmon that have successfully made the transition"; Reddin (2006) concludes that, "the effects of salinity may be more important at a population level when salmon are entering the ocean as smolts and/or when returning to fresh water prior to spawning as adults."

Distribution of salmon at sea. Research surveys for postsmolts in the Northwest Atlantic have yielded highest catches and catch rates between 56° and 58° N in the Labrador Sea; capture dates and behaviour suggest that some postsmolts probably over-winter there as well (Reddin 2006). Postsmolts in the Labrador Sea originate from rivers over much of the geographical range of salmon in North America, but the degree of their migration to the Labrador Sea varies by population. Postsmolts have also been caught as bycatch in herring gear in the northern Gulf of St. Lawrence in late summer. It is not known if all these postsmolts would have exited the Gulf later in the year or would have remained there over-winter. Postsmolts from rivers in the inner Bay of Fundy have been observed to remain in the Bay of Fundy until late summer. Although the over-winter location of iBoF salmon is unknown, the lack of tag recoveries from distant interceptory fisheries

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[18] Reddin *et al* (2006) recorded temperature profiles collected by data storage tags applied to salmon smolts at Campbellton River that provided detailed information on the thermal habitat of postsmolts for periods ranging from a few days to about two months at sea.

[19] Exception noted by Lacroix *et al* 2004, studying inner Bay of Fundy postsmolts' dispersal, observed that most of the mortality, even though low, took place in the immediate vicinity of fish farms where potential predators were abundant.

could indicate that iBoF salmon overwinter outside the Bay of Fundy but not as far north as other salmon stocks.

With respect to adult salmon, generally, they are found concentrated in abundance in the spring off the eastern slope of the Grand Bank and less abundantly in the southern Labrador Sea and over the Grand Bank; during summer to early fall, adult salmon are concentrated in the West Greenland area and less abundantly in the northern Labrador Sea and Irminger Sea. Again, as for postsmolts, few adult salmon from the inner Bay of Fundy are caught outside of the Bay itself. Another specialized area is the Ungava Bay where salmon from local rivers are known to over-winter.

Sea temperature and salmon.

May (1973) first hypothesized that sea ice, an indicator of low sea surface temperature (SST), could modify salmon movements and that these modifications could be measured by analysing catches. Reddin (2006) provides evidence that SST and ice distribution control run timing and distribution at sea. The relationship between catch rates and SSTs was determined during research vessel cruises in the Northwest Atlantic area (Figure 7). These results show variable catch rates depending on sea temperature. Salmon were found at sea in water with SSTs between 1 and 12.5°C. Peak abundance was recorded at SSTs of 6-8°C. Reddin (2006) indicates that previously published results in which it was stated that

Figure 7. Sea surface temperature and salmon abundance (Figure 5 from Reddin 2006)

salmon in the Labrador Sea were more abundantly found in SSTs between 4-8°C are revised to 4-10°C (this range includes 80% of the salmon). The significant relationship for SSTs and salmon catch rates suggests that salmon may modify their movements at sea depending on SST.

Sigholt and Finstad (1990) and Handeland *et al* (2003) reported that lethal sea water temperatures for both wild and farmed salmon smolts adapting to seawater occurred at very low and high temperatures. At the lower end of the range in temperatures, some mortalities for postsmolts newly introduced into sea cages occurred at sea temperatures of 6-7°C while at the higher end, mortalities occurred at temperatures over 14°C, suggesting that there may be environmental windows for successful smolt transition into the sea in locations other than at the extreme edges of the species distribution as observed by Power *et al* (1987). Lethal temperatures for adult salmon occur below 0°C (Fletcher *et al* 1988). At-sea mortality has been recorded for cod and other species where water temperatures

are cold (Templeman 1965) especially in the vicinity of ice. This may explain the tendency of salmon to avoid ice covered water as reported by May (1973).

Marine habitat influences on salmon production.   Friedland (1998) reviewed ocean climate influences on salmon life history events including those related to age at maturity, survival, and growth and therefore production of salmon at sea. He concluded that ocean climate and ocean-linked terrestrial climate events affect nearly all aspects of salmon life history. For example, higher sea surface temperature has been implicated in increasing the ratio of grilse to MSW salmon (Saunders *et al* 1983; Jonnson and Jonsson 2004), perhaps through growth rates (Scarnecchia 1983). Also, Scarnecchia (1984), Reddin (1987), Ritter (1989) Reddin and Friedland (1993), Friedland *et al* (1993), Friedland *et al* (1998, 2003a, 2003b), and Beaugrand and Reid (2003) showed significant correlations between salmon catches/production and environmental cues including those related to plankton productivity. Reddin and Shearer (1987) correlated temperatures by area in the Labrador Sea with the abundance of salmon at West Greenland and, together with spawning stock size, used the relationship to provide fisheries management advice to NASCO through 2004 (ICES 2005). Assessments of the inner Bay of Fundy and Miramichi River populations have also included environmental parameters thought to influence the survival of salmon during the early postsmolt stage and have been included in predictions of 1987 run sizes (Ritter 1989). However, Reddin (2006) states that, "the biological basis for these relationships is, to date, only speculative and deserves further study."

Colbourne (2003), Friedland *et al* (2003a), and Downton and Miller (1998) and many others have examined relationships between environmental variables and abundance of Pacific and Atlantic salmon and other fish species with a view to improved forecasts of abundance, but without specific knowledge of what thermal habitat regimes the fish prefer. Uncovering relationships between physical ocean environment and recruitment of salmon could contribute to improved forecasts of population abundance and better management of fisheries (Bisbal and McConnaha 1998; Friedland 1998; Colbourne 2003). Physical conditions in the ocean have been shown to be related to mortality and growth of some other species (Brander 1995; Dutil *et al* 1999; Watanabe and Yatsu 2004). Blackbourn (1993) and Downton and Miller (1998) have suggested that freshwater survival rates for some species of Pacific salmon are even related to SSTs experienced by potential spawners shortly before their return to fresh water. These studies indicate the value of information of the physical oceanography and ecology of salmon at sea.

Reddin and Friedland (1993) showed a profile of sea temperatures and research catch rates suggesting Atlantic salmon were commonly found in Northwest Atlantic waters with temperatures from 4 to 10°C. Reddin *et al* (2004) indicated that Atlantic salmon kelts tagged with DSTs were found where recorded temperatures ranged from a low near 0 to over 25°C, although most of the time kelts stayed in seawater of 5 to 15°C. This was similar to temperatures found for adults by Sturlaugsson (1995) and Karlsson *et al* (1996). Reddin *et al* (2006) indicated that salmon postsmolts are located in water temperatures ranging from 8 to about 15°C immediately after entering the sea.

Temperature and particularly thermal fronts and eddies appear to have influenced the survival of Norwegian and Scottish salmon in the early marine stage (Friedland *et al* 2000; and Reddin and Friedland 1996). In the Pacific Ocean, shifts in ocean climate have been detected on a basin scale level (Beamish *et al* 1997). These shifts have resulted in sharp thermal fronts that restrict steelhead trout and Pacific salmon distribution at sea and therefore may control production, further underscoring the need to collect data on salmon thermal habitat preference and use (Welch *et al* 1995; Welch *et al* 1998). In particular, it has been shown that Pacific salmon abundance trends were closely associated with changes in the climate-ocean environment and that these changes occurred throughout the distribution of Pacific salmon (Beamish and Bouillon 1993). At present, our knowledge of thermal regimes for Atlantic salmon suggest that, unlike Pacific salmon, no defined upper temperature limit has been detected, although relationships among temperature, survival and abundance remain (Reddin 2006; Reddin and Friedland 1993; Friedland 1998; Friedland *et al* 1998; Friedland *et al* 2000).

3.4 Marine Habitat Status and Trends

For most populations of Pacific salmonids, marine survival and consequently productivity and catches improved following a climate event in 1976-77 (Beamish and Bouillon 1993). These natural fluctuations are associated with the concepts of regimes and regime shifts and can result in either increased or decreased productivity (Hare and Francis 1995; Steele 2004; Beamish *et al* 1997). Beamish *et al* (1997) noted that change can occur quickly and it can be large. In the northwest Atlantic, there is evidence that a basin-scale shift has impacted the productivity of Atlantic salmon (Reddin *et al* 2000; Chaput *et al* 2005). Basin-scale events e.g. as a consequence of changes in the North Atlantic Oscillation Index, may also be linked to downturns in salmon abundance in the North Atlantic similar to the Pacific (Dickson and Turrell 2000). Coincidental with these regime shifts in the North Atlantic are shifts in recruitment of salmon (Beaugrand and Reid 2003; Jonsson and Jonsson 2004; Chaput *et al* 2005).

Peterman *et al* (1998), Pyper *et al* (2001) and Pyper *et al* (2002) examined spatial patterns of covariation in survival rate for long time series among stocks of wild pink salmon (*Oncorhynchus gorbuscha*), sockeye (*O. nerka*) and chum (*O. keta*) salmon in the Pacific and found strong evidence of positive covariation among stocks within region and between certain adjacent regions but little evidence of co-variation between stocks of distant regions (e.g., separated by 1000 km or more). This suggests that important environmental processes affecting temporal variation in survival rates of pink salmon from spawners to recruits operate at regional spatial scales rather than at the larger ocean basin scale. This may also be the case for Atlantic salmon in the North Atlantic Ocean.

Recent downturns in Atlantic salmon abundance in the late 1980s and 1990s are unprecedented in magnitude and once again have drawn attention to the lack of knowledge of salmon ecology during the marine phase (Reddin 2006). Because declines in salmon abundance have been widespread, and there have been few indications of reduced smolt production in fresh water, it has been concluded that the main cause lies within the ocean life of salmon (Reddin and Friedland 1993; Friedland *et al* 1993; also

see Section 5.4 of this report). For many of the rivers where marine survival is measured, the lowest recorded values have occurred in recent years. These low survivals have coincided with greatly reduced marine exploitation (i.e., fishing) achieved through massive reductions in effort or in some cases complete bans (ICES 2005) leaving the conclusion that something other than fishing is the main cause. Beaugrand and Reid (2003) have detected large scale changes in the biogeography of calanoid copepod crustaceans in the northeast Atlantic in relation to sea surface temperature. It seems that copepod assemblages associated with warm water have shifted about 10 degrees of latitude northwards. At the same time, a number of biological variables have shown to be directly related to these changes, including salmon, which is in a decreasing mode. This regional temperature increase therefore appears to be an important parameter presently governing the dynamics of northeast Atlantic pelagic ecosystems with possible consequences for biogeochemical processes, all fish and fisheries.

3.5 Habitat Protection/Ownership

Identifying, protecting habitat, and restoring and rehabilitating degraded aquatic habitats are critical to maintaining their integrity and sustaining ecosystems. The *Fisheries Act*[20] contains specific provisions that provide DFO's Habitat Management Program with the regulatory framework for the conservation and protection of fish and fish habitat. The habitat protection and pollution prevention provisions of the *Fisheries Act* provide the Minister of Fisheries and Oceans with considerable powers (see Secs 20 - 22, 30, 32, 25, and 36). Environment Canada is responsible for administration and enforcement of Section 36 (pollution control provisions) while DFO retains responsibilities for the administration and enforcement of the other provisions. The application of these latter provisions is guided by the *Policy for the Management of Fish Habitat* [21] (Habitat Policy) and related operational documents. The Habitat Policy includes: a policy objective of "net gain of habitat for Canada's fisheries resources"; three goals (conservation, restoration and development); a guiding principle of "no net loss of the productive capacity of fish habitat" to support the conservation goal; eight implementation strategies that includes the concept of integrated planning for habitat management.

3.6 Identification of Critical Habitat[22]

The Species at Risk Act (SARA)[23] has specific provisions for the protection of 'critical habitat': "… *no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species …*"[24] 'Critical habitat' is defined in the SARA as "*habitat that is necessary for the survival or recovery of a listed wildlife*

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[20] See "http://laws.justice.gc.ca/en/F-14/text.html" for text of the Fisheries Act.

[21] See "http://www.dfo-mpo.gc.ca/canwaters-eauxcan/infocentre/legislation-lois/policies/fhm-policy/index_e.asp"

[22] This section is copied, abstracted &/or synthesized from Amiro, P.G., A.J.F. Gibson, and S.F. O'Neil. (2006b)

[23] SARA Public Registry - The Act (http://www.sararegistry.gc.ca/the_act/default_e.cfm)

[24] http://www.sararegistry.gc.ca/the_act/HTML/Part9c_e.cfm

species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species". In SARA, habitat for aquatic species is defined as *"spawning grounds, and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where species formerly occurred and have the potential to be reintroduced"*. By this definition, habitat can be identified based on the functions it provides, and therefore habitat is sufficiently protected if its capacity to fulfill its functions is protected.

The SARA requires that critical habitat be defined in recovery strategies or action plans "to the extent possible", i.e., there is a degree of judgment in identifying habitat which must be protected. Therefore, there is an obvious requirement for an *operational* definition of critical habitat and then specific delimitations thereof for listed species, including existing (i.e., inner Bay of Fundy populations) or potentially listed populations of Atlantic salmon. In order to illustrate this 'operational definition', the conclusions from the Expert Opinion pertaining specifically to the critical habitat of the inner Bay of Fundy populations[25] follow:

- "Given that at least 32 of more than 40 rivers within the iBoF were known to contain harvestable populations of salmon prior to the collapse of the population after 1990 and given that the existing conservation requirements have been accepted as reasonable conservation goals and are less than historical population counts and estimates, the **recovery target** for iBoF salmon has been set as the conservation spawning requirement expressed as the number of salmon on a river by river basis.
- Based on the quantity and quality of life stage specific habitat information for Atlantic salmon, the extent of the documentation of use and occupancy of salmon within the freshwater habitat of 32 rivers of the inner bay of Fundy and the uncertainties with respect to the dependency of population persistence on specific delineated areas, the freshwater habitat which is naturally accessible in the 32 rivers identified in recovery objectives is considered critical to the recovery of iBoF salmon.
- Because of the diversity in migration strategies observed for iBoF salmon and the uncertainty in the temporal distribution of iBoF salmon in the **marine environment**, precise spatial and temporal statements of the probabilities of occupation by iBoF salmon for all marine habitat areas cannot be made. Nonetheless, there is a body of evidence that indicates that some areas have a long history of use and occupation by specific stages of salmon during their marine phase and that salmon do move throughout most of the Bay of Fundy. However, the contribution that individual areas make to the persistence or recovery of the populations cannot be determined at this time. Therefore, it is recommended that increased vigilance for habitat impacts in these areas of known frequent

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[25] Inner Bay of Fundy Atlantic salmon populations have been listed as "endangered" both by COSEWIC and under the SARA.

occupancy be provided as a minimum. Designation of either these areas or of the Bay of Fundy as critical habitat should be considered."

In general, the Expert Opinion indicates that, description of critical habitat as a spatially defined *minimum amount of habitat* necessary to support a *minimum viable population* is neither possible nor advisable given uncertainties in the spatial dynamics of the population and the spatial requirements for recovery. Based on the large amount of information linking habitat and salmon distribution, however, critical or crucial habitat could be identified. This would be important if recovery objectives were to move from the existing management objectives of escapements that maximize production as determined from local biological characteristics and total habitat area, to population recovery targets based on a minimum population size and distribution. This management decision would entail the assumption of additional population risk.

3.7 Studies Required to Identify Critical Habitat

Guidance for identifying freshwater critical habitat. Habitat types used by juvenile Atlantic salmon have been extensively researched and are summarized by life stage in Amiro *et al* (2003) and Amiro (2006), and Amiro *et al* (2006b) and these references provide a guide to habitat characteristics that can be used to identify function.

Stream gradient has been shown to be a general coarse predictor of juvenile salmon density and, by inference, habitat quality. As an example, a total of 22 of the 32 listed inner Bay of Fundy river populations have had their juvenile salmon habitat quantified (Amiro *et al* 2006b) by stream gradient using a standard air-photo measurement technique (Amiro 1993). The reaches of the various streams identified using the orthophoto maps have been digitized and attribute data (stream width, gradient and distance from the river mouth) are in a GIS (Trzcinski *et al* 2004). Habitat inventories for some of the remaining rivers (e.g., Petitcodiac River) have been collected by various methods, but all of the area is not presently available in a geo-referenced format. Although these maps are not maps of critical habitat per say, they do provide guidance about the location, likely quality and quantity of habitat within each river (Amiro *et al* 2003). Additionally, unless otherwise restricted, juvenile salmon would be expected to naturally occur below waterfalls of 3.4 m (Powers and Orsborn 1985). These falls are generally associated with changes in map-interpreted stream gradients of greater than 30% (length of stream/ rise in elevation), as identified in the GIS, and the maps therefore provide guidance to the upper extent of the proposed areas.

Guidance for identifying marine critical habitat. To date there has been little progress in the identification of marine critical habitat for Atlantic salmon. Amiro *et al* (2003) largely identified preferred habitat on the basis of temperature preferences, satellite derived monthly mean sea surface temperatures and tag return data for inner Bay of Fundy salmon in the Bay, Gulf of Maine and Scotian Shelf areas. However, before critical marine habitat could be specified it would be necessary to set criteria for the frequency and timing of use, risk to population persistence for a loss of that habitat function and the desired management risk tolerance. Furthermore, because the spatial and temporal distribution of Atlantic salmon is not complete, it is impossible to designate the

entire critical marine habitat for any Atlantic salmon. Spatial and temporal subsets of that distribution are known for most CUs and therefore specific locations could be identified if required e.g. estuaries, headland channels and straights.

3.8 Identification of Residence

The SARA also has specific provisions for the protection of 'residences': "*No person shall damage or destroy the residence of one or more individuals of a wildlife species that is listed as an endangered species or a threatened species ...*"[26] There is an apparent requirement for an operational definition of a residence and then specific delimitations thereof for listed species, including existing (i.e., inner Bay of Fundy populations) or other, potentially listed populations of Atlantic salmon.

Gibson (2006) considered there were at least four life stages of Atlantic salmon that use three kinds of dwelling places that potentially meet the criteria for being a residence. These residences are redds (used by eggs and yolk-sac fry), home stones (used by juvenile salmon in fresh water) and staging or holding pools (used by adults). Each of these locations is habitually occupied during part of the salmon's life cycle. These locations are essential to the successful performance of specific, crucial functions of the salmon's life cycle.

More recent deliberations on the residence of Atlantic salmon reverted to the concept that a residence is something that is not considered a natural part of the environment but rather something that the animal made for itself and would be protected (DFO 2008). Thus it may be argued that only a salmon redd could be considered a residence and that anything else is a part of the habitat.

4. Biology

4.1 Life Cycle, Population Dynamics, and Reproduction[27]

Life history of anadromous populations.   Anadromous Atlantic salmon display considerable phenotypic plasticity and variability in life history characters. It is an iteroparous species, one that can spawn repeatedly, as opposed to most species of Pacific salmon (*Oncorhynchus*), which are semelparous and die after a single spawning. A defining characteristic of anadromous Atlantic salmon is the ability to return with a high degree of fidelity to the natal river or tributary for spawning (homing). Such precision in homing has led to the formation and maintenance of river-specific or local adaptations, resulting in much of the variability in genetic, life history, behavioral, and other traits observed throughout the range of the species. Figure 8 is a generalized depiction of the salient features of the life cycle of Atlantic salmon and will be the focus of the broad-scale description of life history to be presented below.

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[26] Section 33 of the SARA (http://www.sararegistry.gc.ca/the_act/HTML/Part9a_e.cfm)

[27] This section is copied, abstracted &/or synthesized from O'Connell *et al* (2006). Detailed descriptions of the various life history elements can be found in O'Connell *et al* (2006) along with all relevant literature citations.
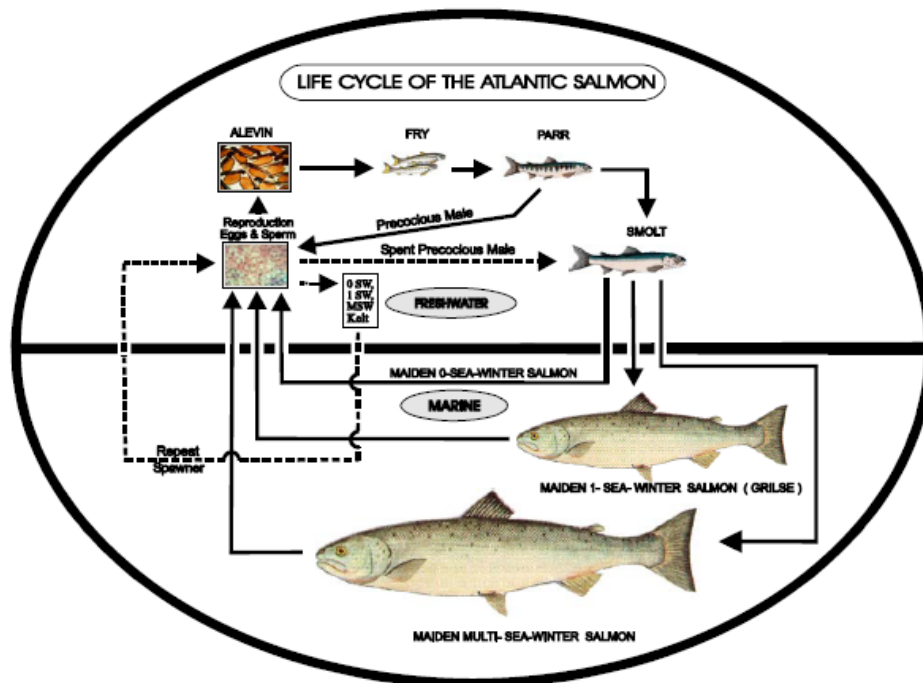
Figure 8. Generalized life cycle of the Atlantic salmon (from O'Connell *et al* 2006)

Depending on the population, spawners returning to rivers are comprised of varying proportions of 'maiden fish' (those spawning for the first time) and 'repeat spawners'. Most maiden salmon in turn consist of varying proportions of smaller fish that return to spawn after one winter at sea (1-sea-winter [1SW]) also known as 'grilse' and larger fish that return after two or more winters at sea ('2, 3-sea-winter', also designated as 'multi-sea-winter' [MSW]). Some rivers possess a component that returns to spawn after only a few months at sea (0-sea-winter [0SW]).

Collectively over its entire range in North America, adult Atlantic salmon return to rivers from feeding and staging areas in the sea mainly between May and November, but some runs can begin as early as March and April. In general, run timing varies by river, sea age, year, and hydrographic conditions. Run timing metrics pertain to where salmon are counted within a river system, whether it be an enumeration facility in the lower section of the river close to the estuary or ocean, or at a fishway located well upstream from the river mouth. As such, direct comparisons among rivers can be problematic although variability within a population over time (years) is consistent for each individual system. Occasionally there can be some element of predictability in run timing of individual populations; however, variation among years within rivers can still be substantive with median dates differing by five to six weeks or more in some populations. (Further detail on run timing can be found in O'Connell *et al* 2006).

Spawning usually occurs in October and November in gravel-bottomed riffle areas of streams. Fertilization of eggs can involve both adult males and sexually mature male parr. Spawned-out or spent adult salmon (kelts) either return to sea immediately after spawning or remain in fresh water until the following spring. Eggs incubate in the spawning nests or redds over the winter months and hatching usually begins in April. The hatchlings or alevins remain in the gravel for several weeks living off large yolk sacs. Upon emergence from the gravel in late May – early June, the yolk sac is absorbed and the free-swimming young fish, now referred to as 'fry' or
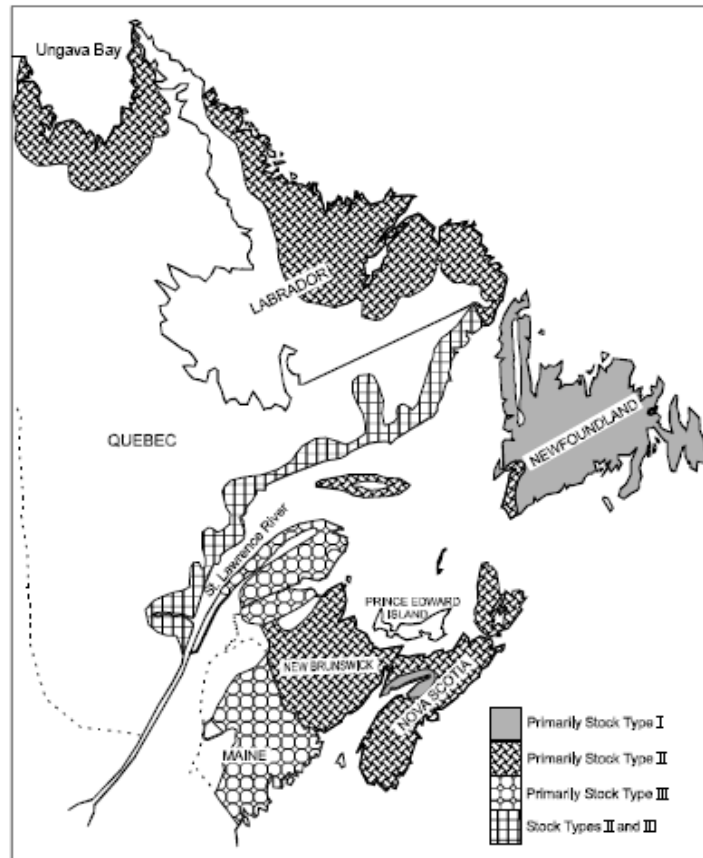
Figure 9. Distribution of generalized grouping of types of self-sustaining populations of Atlantic salmon in North America. Population Type I consists mainly of 1 SW spawners, Type II has 1 SW and 2SW spawners and Type III is comprised of 1SW, 2SW and 3SW spawners. Within each population type area there may be a few populations which belong to another population type. (Figure 2 in O'Connell *et al* 2006 and adapted from Porter *et al* 1986)

under-yearling parr begin active feeding. Parr rear in fluvial (riverine) and lacustrine (standing water) habitats for two to eight years after which time they enter the smolt stage and migrate to sea.

Relative proportions of the various maiden sea-age and repeat spawning age groups and associated biological characteristics vary widely among populations and with geographic location in North America. For example, population composition can vary from being comprised of three sea ages, such as those on the Gaspé Peninsula, to consisting of a single sea age, which is characteristic of most of Newfoundland (Figure 9).

Even within populations with a simple sea-age structure like many of those of Newfoundland, there can be a multiplicity of individuals with different spawning histories contributing to egg deposition in a given year. In addition to virgin fish

corresponding to the various smolt-age groups, which constitute the bulk of spawning escapements, there can be significant numbers of consecutive and alternate spawners present. All sea-age groups possess repeat spawners and this obviously greatly increases the potential for additional spawning types depending on the population. All these adult spawning types plus sexually maturing male parr may occur in the same population, constituting a 'bet hedging' strategy maximizing survival and population stability.

In Ungava Bay, at the northern extremity of the North American distribution, a form referred to as 'estuarine' salmon occurs in addition to 1SW and MSW salmon. Unlike 1SW and older salmon, which undergo extensive oceanic migrations, these fish can reach maturity and return to fresh water after only a few months in the estuary and are referred to as '0-sea-winter (0SW) salmon'. This form has also been encountered sporadically in low numbers over the years in some Newfoundland rivers (e.g., Campbellton River), but has become more abundant in recent years (Downton *et al* 2001). There also are populations in the inner Bay of Fundy that had a low frequency of distant migrations and were more often recaptured in more localized fisheries. Unlike the estuarine or 0SW type however, inner Bay of Fundy populations are characteristically 1SW with a significant repeat spawner component.

Life history of non-anadromous populations[28]**.**   Non-anadromous or land-locked salmon, complete their life cycle entirely in fresh water. Development of non-anadromous from anadromous salmon appears to have occurred during isostatic rebound of coastal regions following the last ice age, approximately 10,000 years ago. Non-anadromous salmon occur not only above impassable physical barriers, but are also found in sympatry with anadromous salmon in river systems that are fully accessible to the sea[29]. For some sympatric occurrences, there is evidence to suggest the forms are reproductively isolated (Verspoor and Cole 1989). Others, however, also viewed the occurrence of both forms in sympatry as phenotypic polymorphisms within a single population, as alternative evolutionarily stable strategies.

Size and growth in fresh water.   The factors with the strongest correlation to body size and growth of juvenile salmon in fresh water include temperature, food availability and density. Variations in growth rate are expected to result in variations in size and age at smoltification. Several studies have reported on the short growing season of wild Atlantic salmon such that the size at age is reached earlier in the year than would be expected based on temperature alone (O'Connell *et al* 2006).

Variations in juvenile salmon size-at-age.   Growth in length and weight in Atlantic salmon juveniles in fluvial fresh water habitats tends to be initially rapid in June and July, sometimes into August, but limited in September and October. The growth trajectories

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[28] This section is copied, abstracted or synthesized from O'Connell *et al* 2006. Detailed descriptions can also be found there along with all relevant literature citations.

[29] In eastern Hudson Bay (Nastapoka River), there is also a northern form that migrates to the estuary for a brief time, but this one differs from the estuarine salmon of Ungava Bay in that it does not undergo smoltification and growth rates are lower.

may also differ among age groups with growth of fry occurring over a longer period of time than that of parr. Within a river, there are important among-site differences in fork length of juveniles attained by the end of the growing season (see Figure 10 in this report for an illustration for fry and parr in the Margaree and Miramichi; similar findings for other rivers are reported by O'Connell *et al* 2006 in their Figure 4.). Juvenile anadromous salmon use lacustrine habitat for rearing purposes to a considerable degree in Newfoundland rivers, and over the years there have been various studies of this aspect of life history. Habitats other than fluvial, including lacustrine, had been considered as marginal or secondary for juvenile anadromous salmon, occupied by individuals displaced from preferred stream habitat. However, the widespread use of lacustrine habitat by parr is believed to be due to the relative lack of predators and competitors. Growth of parr occupying lakes and ponds has been shown to be higher than for those of fluvial habitat. It has been demonstrated that juvenile growth rate in rivers in Newfoundland dominated by lacustrine habitat was higher than in those comprised mainly of fluvial habitat; O'Connell *et al* 2006 (their Figure 6a) show results for several rivers combined in each category. Fry and parr mean size shows important annual variations within and among the monitored rivers of the Maritimes (see their Figure 6 in O'Connell *et al* 2006).

Sexual maturation of juveniles in fresh water. The sexual maturation of male parr is widespread and highly variable throughout the distribution of the species. Male parr successfully mate with adult females both in the presence and absence of adult males. Different mechanisms have been proposed to explain the co-existence of precocious and adult males within a single population of Atlantic salmon (see O'Connell *et al* 2006 for further details).
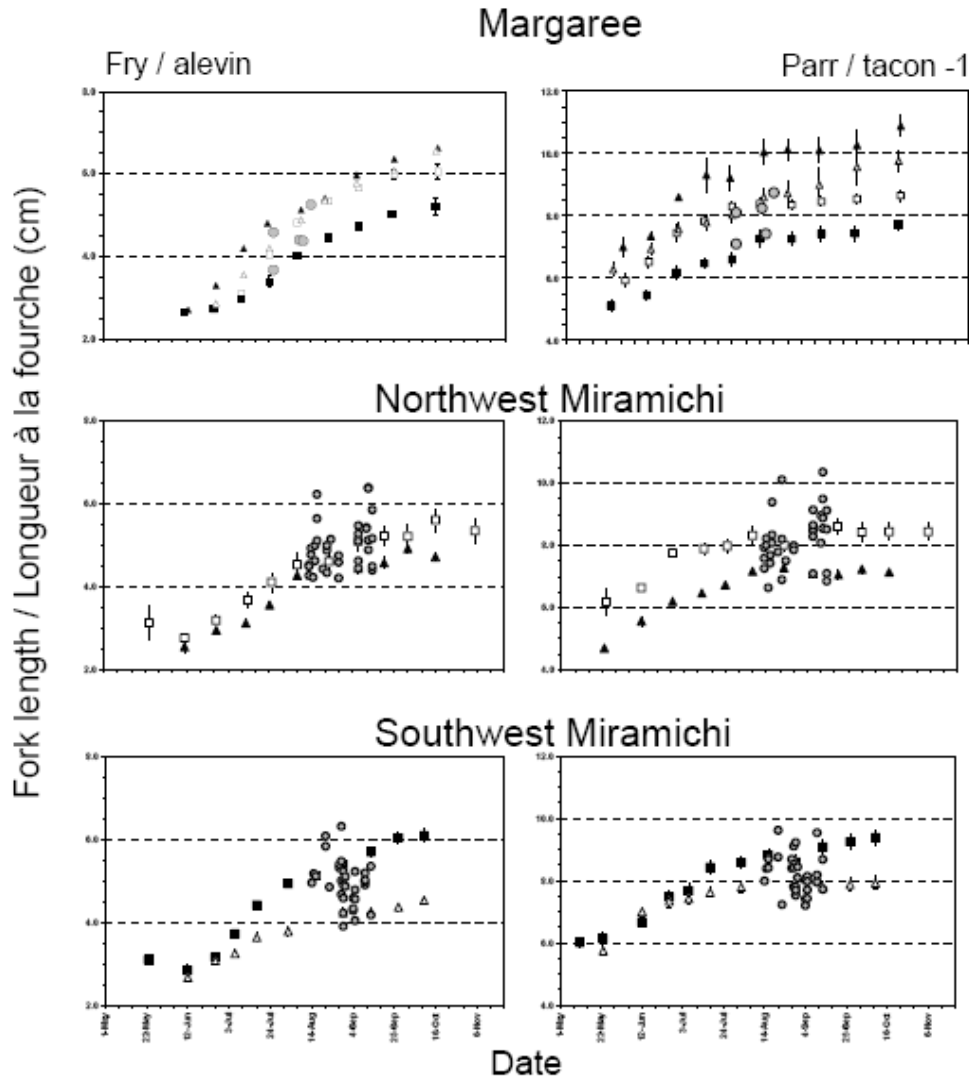
Figure 10. Seasonal fork length trajectories for 2001 by research sampling locations of fry and parr – 1 from the Margaree, Northwest Miramichi and Southwest Miramichi rivers. Shaded bullets are mean lengths at annual index sites sampled in 2001. (Figure 3 in O'Connell *et al* 2006.)

Smolt growth. Variations in growth rate of juveniles are expected to result in variations in size and age at smoltification. There is a negative association between an index of growth potential (combination of degree-days and day length) and mean age at smoltification for Atlantic salmon throughout its range.

The age at smoltification has been shown to be in part associated with the growth rate or size achieved at several points in the life cycle, and there is an increased probability of smoltification if a threshold size or growth rate is achieved by a critical time. As a consequence, small changes in initial growth rates of a cohort can affect the mean age at smoltification. In the Margaree River population, there is a positive association between the age at smoltification (2 or 3 years) and size achieved at the end of the first freshwater

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year. In salmon populations throughout Eastern Canada there are general and positive associations between marine survival, smolt size, and smolt condition.

Smolt size, age and sex ratios. During the last ten years, smolt monitoring programs in the Maritime Provinces and Québec have provided information on wild Atlantic salmon smolt characteristics (See O'Connell *et al* 2006 for details).

Size and growth in marine waters[30]. Atlantic salmon management in eastern Canada is based on two size groups defined by fork length; 'small salmon' are less than 63 cm fork length, 'large salmon' are of fork length greater than or equal to 63 cm. Salmon return to rivers of eastern Canada to spawn after one year, two years, and in some areas after three years at sea (further details are found in O'Connell *et al* 2006).

The observed differences in the proportions at age at maturity in the anadromous salmon of eastern Canada suggest that this trait reflects an adaptation of the populations to spatially variable conditions (Hutchings and Jones 1998). The factors which are considered to be important determinants of age at maturity of returning adult salmon include growth rates (in fresh water and at sea), survival in fresh water and at sea, fecundity, and heritability (Meerburg 1986; Chadwick 1987; Friedland and Hass 1996; Hutchings and Jones 1998). Age at maturity of parents remains an important factor determining age at maturity of progeny (see papers in Meerburg 1986).

Repeat spawning salmon are present in all rivers of eastern Canada and they contribute both biologically and economically to the value of the salmon resource (Atkinson and Moore 1999). Repeat spawners were particularly prominent in some of the inner Bay of Fundy rivers in SFA 22 and have become so in other areas since the reduction of exploitation in fisheries (Ducharme 1969; Moore *et al* 1995). Small salmon are greater than 90% maiden salmon with repeat spawners in that size group most abundant in the rivers of the south and northeast coasts of Newfoundland. Repeat spawners constitute between 70% and 98% of the large salmon category in the south and northeast coasts of Newfoundland compared to only 5% to 30% in most other rivers of eastern Canada (Figure 12 in O'Connell *et al* 2006). As a result of changes in fisheries, the repeat spawner abundances have increased in numerous rivers of eastern Canada, most notably in the MSW stock of the Miramichi River. The proportion of the large salmon comprised of repeat spawners over the past 35 years has increased from less than 5% to between 30% and 55% in the last decade (see Figure 13 in O'Connell *et al* 2006). In contrast, the repeat spawner proportions have not changed in the Saint John River and the Saint Jean River. Dempson *et al* (2004) noted an increase in the contribution of consecutive spawners during the moratorium years (post-1991) although in some stocks (e.g. Gander; Conne) the increase was only observed several years later. In the multi-sea-winter salmon stocks, repeat spawners are derived from all age groups of maiden salmon. In the Miramichi River, the repeat spawners were predominantly from the maiden 1SW salmon in the 1970s. However, since the reduction in harvest of 2SW salmon that resulted from the closure of the Maritime commercial fisheries and the mandatory release of all large

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[30] This section is copied, abstracted or synthesized from O'Connell *et al* (2006).

salmon in the recreational fisheries since 1984, the contribution of maiden 2SW salmon to MSW salmon are now proportionally similar to the contribution of maiden 1SW salmon (see Figure 14 in O'Connell *et al* 2006). The spawning age structure has become more complex in many rivers with salmon in the Miramichi River on their seventh spawning migrations observed almost annually since 1995 (Chaput and Jones 2006). Salmon repeat as either consecutive or alternate stages and in all combinations of these in subsequent spawning migrations. Switching between consecutive and alternate life histories also occurs frequently (see Table 1 in O'Connell *et al* 2006). Collectively over the years, as many as 20 spawning types have been encountered for Conne River (Dempson *et al* 2001) and 26 for Gander River (O'Connell *et al* 2001) whereas in the Miramichi River, 49 sea age types have been interpreted, excluding the freshwater age combinations (Table 1 in O'Connell *et al* 2006). The broad spawning age structure has resulted in 8 or 9 year classes present on the spawning grounds in the recent decade, an increase from the 4 to 5 year classes in the earlier years when there were fewer repeat spawners (Chaput and Jones 2006).

Growth in the marine environment is rapid relative to that in fresh water. Where, after two to four years of growth in fresh water, smolts attain fork lengths of 12 to 16 cm; after one year of growth at sea, fork length can range between 45 to as much as 65 cm. After two years at sea, salmon measure in the range of 70 to 80 cm fork length. Weights increase about 75-fold between the smolt stage and 1SW salmon stage, and over 200 fold from smolts to 2SW salmon.

There are important regional and population differences in the proportion of females in the maiden 1SW and large salmon components across eastern Canada. For example, maiden 1SW salmon returning to Bay of Fundy and Atlantic coast of Nova Scotia rivers are generally comprised of a high proportion female, between 20% and 70%, while the stocks from the Gulf of St. Lawrence and Québec are characterized by a low proportion of female among maiden 1SW salmon (1% to 20%), with very few females (<5%) in many rivers of Chaleur Bay. Large salmon are characterized by proportions of females which are generally greater than 50% and do exceed 90% in some populations.

Fecundity varies considerably both within and among salmon stocks. Egg number and size increase with body size (Thorpe *et al* 1984; Jonsson *et al* 1996). In a dwarf or stunted freshwater resident population from Newfoundland, mean fecundity was 33.0 eggs (Gibson *et al* 1996). In contrast, Randall (1989) reported mean fecundities of 12606 and 16585 eggs for 3SW and previous spawning salmon in Restigouche River. Although absolute fecundity varies greatly among individuals, as expected owing to high variability in adult body size, relative fecundity (eggs per kilogram) as a measure of reproductive effort varies much less but is inversely related to fish size. For Miramichi River, New Brunswick, relative fecundity ranged from 1,331 eggs kg⁻¹ in previous spawning salmon (mean length 82.1 cm) to 2,035 eggs kg⁻¹ in 1SW fish (Randall 1989). Rouleau and Tremblay (1990) reported values of 1,628 eggs kg⁻¹ for 2SW salmon, 1,256 eggs kg⁻¹ for 3SW salmon, and 1,244 eggs kg⁻¹ for repeat spawners. In a survey of 2,440 specimens from 10 Newfoundland rivers, mean relative fecundity varied from 1,278 to 2,500 eggs per kg (O'Connell *et al* 1997a). The variability in relative fecundity that can occur within

a stock is rarely, if ever, taken into consideration when estimates of egg deposition are determined. Consequences related to conservation spawning levels achieved and studies on population dynamics are obvious.

A copiously illustrated companion document summarizes geographically the available information for selected phenotype characteristics of wild Atlantic salmon and adults from 112 rivers in eastern Canada (Chaput *et al* 2006a)[31]. The variations in biological characteristics described support many of the previous analyses of geographic variation of phenotype in Atlantic salmon. Age-at-smoltification has a significant positive association with latitude with the additional feature that mean age also increases along a west to east gradient. There are important differences in the characteristics of stocks of Newfoundland from other areas in eastern Canada, differences primarily in smolt ages of Labrador origin salmon and differences in some characteristics of salmon from rivers at the southern edge of the distribution. The characteristics of many stocks show similarities that override the provincial and management boundaries. When small and large salmon characteristics are combined, four broad groups are defined: Gulf of St. Lawrence including some rivers of southwest Newfoundland, Maritime provinces including some rivers of the southern Gulf, insular Newfoundland, and Labrador. Some biological characteristics of the Atlantic coast of Nova Scotia rivers, such as the proportion female and fork length of small salmon, are more similar to the Newfoundland rivers' characteristics than to those from the other rivers of the Maritime provinces (Chaput *et al* 2006a).

4.2 Predation

Salmon as prey in fresh and marine waters. Cairns (2006) provides a detailed discussion and listing (Table 3) of predation of salmon in fresh water.

Eggs: It has been estimated that Atlantic salmon parr (particularly maturing males) consumed about 6% of Atlantic salmon eggs spawned in Catamaran Brook, New Brunswick (Cunjak and Therrien 1998). Chaput and Cairns (2001) suggest that predation by birds and fish on Atlantic salmon eggs is likely a common phenomenon. Munro and Clemens (1937) believed that most eggs taken by mergansers had drifted downstream and had never been incorporated into the redd. Such eggs would probably not have hatched even in the absence of predation. It is not known to what extent predation by fish and birds of Atlantic salmon eggs might target eggs in the redd which would otherwise have a good chance of hatching, or eggs outside the redd which would have little chance of hatching.

Juvenile salmon: A wide variety of predators feed on juvenile Atlantic salmon, but the best documented predation is by birds, particularly the common merganser, the belted kingfisher, and the double-crested cormorant (Cairns 1998 and Table 3 of this paper). Bioenergetic models estimate that common mergansers and belted kingfishers harvest from 21% to 45% of juvenile salmon in Maritime rivers in each juvenile year (age 0+ to 2+) (Cairns 2001a). However, analysis of historic culling experiments provides no

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[31] This paragraph is largely the abstract copied from Chaput *et al* 2006a.

evidence that a reduction in merganser and kingfisher numbers leads to increased juvenile salmon populations (Cairns 2001a). Mortality due to mergansers and kingfishers therefore appears to be compensatory rather than additive.

Smolts: Outgoing smolts may be eaten by returning adult salmon, other fish species, mergansers, loons, gulls, and seals (Table 3). Feltham (1995) estimated that common merganser predation removed 3-16% of smolt production in a Scottish river. Dieperink *et al* (2002) tracked downstream movement of smolts in a Danish river with radio tags and determined that predation was light in the river, but was intense in the first few hours after sea entry, with major losses to gulls and cormorants. Larsson (1985) estimated that predation removed at least 50% of smolts from Swedish study sites before they reached the Baltic Sea. Hvidsten and Mokkelgjerd (1987) obtained an adult return rate from smolt stocking at sea that was three times higher than the return rate from river stocking. They interpreted these findings as evidence for heavy predation in waters near the river mouth, which the at-sea stocking bypassed.

As Atlantic salmon smolts enter the sea they encounter changed salinity and new predator fields. Osmotic stress may therefore contribute to the substantial predation mortality reported in some areas for salmon that have newly arrived in marine waters. Handeland *et al* (1996) tested this effect with cod as a predator, and found that predation losses increased when smolts were subject to abrupt salinity shifts.

On the other hand, some studies indicate low predation impact in the days after river exit: Svenning *et al* (2005) found that only two of 2,308 otoliths recovered from common merganser stomachs at a Norwegian river mouth were from Atlantic salmon and Lacroix *et al* (2005) reported a survival of at least 71-88% for smolts leaving Passamaquoddy Bay to the open Bay of Fundy.

Cairns and Meerburg (2001) examined the hypothesis that sea-pens for cultured salmon attract predators, thereby increasing predation on out-going smolts that pass near the pens; seal surveys show no evidence of concentrations near sea-pens. Most of the small number of losses of out-going smolts leaving Passamaquoddy Bay for the open Bay of Fundy occurred in the vicinity of salmon farms, but causes of these losses were not documented (Lacroix *et al* 2004).

Fish (in particular gadoids, Hansen *et al* 2003) that feed heavily on salmon that have just left their natal rivers presumably also eat salmon in the open sea. Atlantic salmon have been found in stomachs of skate, halibut, ling, cod, porbeagle, Greenland shark, and pollock (Wheeler and Gardner 1974; Mills 1989; Hislop and Shelton 1993; Hansen *et al* 2003).

Postsmolts: Grey, harp, and harbour seals, common murres, and northern gannets are documented predators of postsmolt and Atlantic salmon in North America (Table 3), but records of predation events are very sparse (except for the northern gannet, see below). Cairns and Reddin (2000) calculated that, if the major seal and bird predators consumed 100% of a postsmolt cohort, salmon would only be 0.04% of the diet of these predators.

This means that the amount of predation on Atlantic salmon cannot be reliably estimated without impractically large sample sizes of predators. It follows that, because salmon are a minute fraction of total prey biomass in the North Atlantic, they are likely also to be a minute fraction of predator diets (Cairns 2006).

The northern gannet, a large plunge-diving seabird, occupies waters in the salmon's marine range on both sides of the Atlantic Ocean. Because of its specialization in near-surface prey, it appears to be particularly adept at taking postsmolt salmon. Gannet regurgitation samples obtained in August at Funk Island, off Newfoundland's east coast, were 0.29% salmon in 1977-1989 and 2.53% salmon in 1990-2000 (Montevecchi *et al* 2002). Salmon consumed during August at this colony were an estimated 0.22% and 2.7% of total North American biomass of the cohort. Given that these estimates apply to only one month and one (of six) gannet colonies, predation impact by gannets on post-smolt salmon is potentially high. However, gannet diet at times other than August, and at colonies other than Funk Island, is too poorly known to determine if this is so.

Adult salmon: Salmon at sea and those that have returned to the river to spawn may be preyed upon by bottlenose dolphins, belugas, harbour porpoises, and seals at sea and seals that have ventured into the lower reaches of rivers, and otters. Middlemas *et al (*2003) reports that cetaceans, including bottlenose dolphins, belugas, and possibly harbour porpoises, consume marine-phase Atlantic salmon. In Europe, Thompson and MacKay (1999) found that 19.5% of returning salmon in northeast Scotland were scarred, but they felt, on the basis of scar patterns, that most of the damage had been inflicted by toothed whales and/ or dolphins rather than by seals. Baum (1997) reported that 2% of adults returning to the Penobscot River in Maine had seal bites, and that the percent of scarred animals had risen in recent years.

Behavioural mechanisms which marine-phase Atlantic salmon employ to reduce predation risk are poorly known. Schooling is the main anti-predator strategy of pelagic fishes **(**Krause *et al* 1998). Low salmon numbers, particularly in the Bay of Fundy, could prevent marine-phase salmon from forming schools, and thereby increase their vulnerability to predation (Cairns 2001b, Lacroix and Knox 2005).

Table 3. Predators of Atlantic salmon in North America. (Cairns 2006)

Salmon life stage	Predator	Region	Comments	Source
Fry	Atlantic salmon	Massachusetts	Fry were of hatchery origin	Henderson and Letcher 2003
Fry	Brook trout	Massachusetts	Fry were of hatchery origin	Henderson and Letcher 2003
Fry	Brown trout	Massachusetts	Fry were of hatchery origin	Henderson and Letcher 2003
Fry	American eel	New Brunswick		Godfrey 1957
Fry	Greater yellowlegs	Cape Breton Island		White 1939
Fry	Spotted sandpiper	Cape Breton Island		White 1939
Fry, parr	Smallmouth bass	Maine	Smallmouth bass is an introduced species	Baum 1997
Fry, parr	Great blue heron	Cape Breton Island		White 1939
Fry, parr, smolt	Brook trout	Cape Breton Island		White 1939
Parr	White perch	Cape Breton Island		White 1939
Parr	American eel	Nova Scotia		Elson 1941
Parr	Harbour seal	Waterford R., Nfld	Sight record, possibly a trout	Cairns and Reddin 2000
Parr	Common goldeneye	Cape Breton Island		White 1939
Juvenile	Double-crested cormorant	New Hampshire, Maine, Maritime Provinces, eastern Quebec	During smolt run: salmon were 17.3% of diet	Cairns 1998
Juvenile	Double-crested cormorant	New Hampshire, Maine, Maritime Provinces, eastern Quebec	Not during smolt run: salmon were 0.1% of diet	Cairns 1998
Juvenile	Common merganser	Maritime Provinces	Salmon were 27.2% of diet	Cairns 1998
Juvenile	Red-breasted merganser	Maritime Provinces	Salmon were 0.5% of diet	Cairns 1998
Juvenile	Belted kingfisher	Maritime Provinces	Salmon were 14.9% of diet	Cairns 1998
Smolt	Chain pickerel	Maine	Chain pickerel is an introduced species	Baum 1997
Smolt	Striped bass	Maine		Blackwell and Juanes 1998
Post-smolt	Harbour seal	Near Grand Manan I., NB	Tag recovery	B. Beck, in Cairns and Reddin 2000
Post-smolt	Common murre	Witless Bay, Nfld	Tag recovery	Montevecchi et al. 1988
Post-smolt	Northern gannet	Funk I., Nfld	Mean contribution of post-smolts to gannet diet in August ranged from 0% to 6.4% in 1977-2000.	Montevecchi et al. 2002
Small adult	Harp seal	St.Lawrence estuary		Beck et al. 1993
Small adult	Harp seal	Notre Dame Bay, Nfld		O'Connell et al. 1998
Adult	Grey seal	Anticosti I., Magdalen Is., Miramichi estuary	In some cases salmon might have been stolen from nets	Fisher and Mackenzie 1955, Mansfield and Beck 1977, Benoit and Bowen 1990
Adult	Grey seal	St. Marys Bay, Nfld	Sight record	Cairns and Reddin 2000
Adult	Grey seal	White Bear estuary, Labrador	Sight record	Cairns and Reddin 2000
Adult	Grey seal	Paradise estuary, Nfld	Sight record	Cairns and Reddin 2000
Adult	Otter	Cape Breton Island		White 1939
Adult	Bald eagle	Cape Breton Island		White 1939
Kelt	Harp seal	Twillingate, Nfld	Sight record	Cairns and Reddin 2000

4.3 Inter-specific Interactions

Atlantic salmon juveniles are territorial and competitive, and year-class abundance declines over time as a result of competition for resources (Chaput 2001). Atlantic salmon in fresh water compete for resources with conspecifics and with other species, particularly other salmonids[32].

Because of their large pectoral fins, juvenile Atlantic salmon have a particular ability to hold position on the bottom in fast water (Gibson 1993). The basic pattern of juvenile salmon life in fresh water is to occupy areas in riffle habitat, and to defend these areas against other fish. This section refers to these areas as 'home ranges' although 'territory' is also used in the literature. Juvenile salmon may also use other types of stream habitat, including deep low-current waters (Gibson 1993).

Where Atlantic salmon are allopatric with brook trout, salmon displace the trout from riffle habitat (Gibson 1993). Atlantic salmon are less aggressive than trout in pools, and trout may limit salmon growth in that habitat (Gibson 1993). Pool-dwelling species such as percids and cyprinids may also limit Atlantic salmon numbers in slow waters. Working in Newfoundland, Gibson *et al* (1993) found salmon biomass was higher in riffles and trout biomass was higher in pools. Salmon biomass was higher in the absence of trout. Gibson and Dickson (1984) found that Atlantic salmon juveniles showed enhanced growth in an otherwise fishless area of boreal Québec, and also in a stream from which brook trout had been removed. Laboratory and field experiments indicate that Atlantic salmon fry used the same variety of habitats when alone and when in the presence of rainbow trout, but 1+ salmon parr were constrained to riffle habitat in the presence of rainbows, which were highly aggressive towards the salmon (Fausch 1998).

Raffenberg and Parrish (2003) found no significant relations between survivorship of Atlantic salmon fry and abundance of brook and rainbow trout in 24 stream reaches in Vermont. Instead, fry survival was positively related to abundance of brook trout parr and to benthic food abundance. This suggests that the view that competition forces an inverse relation between trout and salmon populations may not be tenable on a geographic scale that encompasses a number of stream reaches (Cairns 2006).

The brown trout, native to Europe, has been introduced to numerous North American systems used by Atlantic salmon. Brown trout tend to use the margins of runs and pools where water velocity is lower, in contrast to riffle specialization by Atlantic salmon (Fausch 1998, Bremset and Heggenes 2001, Heggenes *et al* 2002). Nevertheless there is overlap in types of habitat used by the two species (Heggenes and Dokk 2001). Gibson and Cunjak (1986) reported that introduced brown trout in the Avalon Peninsula, Newfoundland, were largely segregated from Atlantic salmon by habitat choice and to

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[32] Fausch (1998) reviewed 17 experiments on inter-specific competition between juveniles of Atlantic salmon and other species, and concluded that many studies lack proper replicates and controls. This casts some doubt on the extent to which findings from these studies can be generalized to other times and areas.

some degree also by food habits. No negative effects by brown trout on salmon were demonstrated. European studies suggest that stocked Atlantic salmon show poorer growth and survival in the presence of brown trout, but these studies suffer from a lack of replication (Mills 1989, Fausch 1998). Hojesjo *et al* (2005) found that large brown trout dominated smaller Atlantic salmon in a stream channel, but that salmon food intake was nevertheless not suppressed because the salmon fed sneakily by darting into the trout's space. Juveniles of both brown trout and Atlantic salmon are nocturnal in winter, and tend to occupy slower-flowing water during winter than in summer (Heggenes and Dokk 2001). Harwood *et al* (2001) found that in the presence of brown trout, wintering Atlantic salmon either shifted their habitat use into shallower water while remaining nocturnal, or became more diurnal. Wintering juvenile salmonids require daytime shelters for survival, and such shelters may be subject to intense intra- and inter-specific competition if demand exceeds supply (Cunjak *et al* 1998). Experiments with Atlantic salmon and brown trout revealed that prior residence was a major factor in determining shelter ownership, that the two species showed similar levels of aggression, and that neither species was able to consistently exclude the other from shelters when these were in short supply (Harwood *et al* 2002).

4.4 Adaptability[33]

Evidence from broad-scale transplantation studies from Atlantic salmon (Ritter 1975) (and parallel studies in Coho salmon, *Oncorhynchus kisutch,* conducted by Reisenbichler 1988) indicates the possibility of genetically-based differences in marine migration routes on moderate to large geographic scales. Experiments involving Northern and Southern European salmon also suggest the presence of other important broad-scale adaptive differences. When reared in common environments, Atlantic salmon obtained from northern rivers exhibited higher growth rates and conversion efficiencies than salmon obtained from southern locations (Nicieza *et al* 1994). Another example of evidence for the existence of adaptation on larger geographic scales include findings of a south to north cline in the frequency of certain Me-2 alleles (malic enzyme locus) in European and North American Atlantic salmon that are believed to have adaptive significance (Verspoor and Jordan 1989). Within the various ecozones, rivers and streams may vary greatly in terms of bedrock, gradient, prey abundance, predators, and other characteristics. Within rivers, environments may vary in terms of proximity to river mouth, temperature, gradient, and substrate type. Clearly, populations of Atlantic salmon in Canada occupy a wide range of habitats. Populations may also vary with respects to the presence of major underlying lineages of salmon, reflecting post Pleistocene colonization from genetically divergent salmon from different nearby refugia (for example, see Verspoor *et al* 2002). Given the (1) geographically extensive and variable nature of the species freshwater environment in Canada, (2) relative geographic isolation of rivers, and remarkable homing precision of salmon to spawning sites of origin, (3) the presence and distribution of different ancestral lineages of Atlantic salmon in Eastern Canada, and (4) evidence in the literature for the presence of local adaptation in salmonids in general (reviewed by Taylor 1991), it would seem likely that considerable phenotypic and genetic variation exists among salmon from different reaches within

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[33] Copied, abstracted or synthesized from O'Reilly (2006)

rivers, and among rivers. Finally, distinct salmon populations may exist that occupy the same location or environment but that are reproductively isolated largely or entirely by timing or behaviour (sympatry) (see Potvin and Bernatchez 2001).

5. Population Size, Trends, Trajectories, Status, and Recovery Feasibility

5.1 Information Sources Sought/Considered

Basic abundance and trends data are drawn from fisheries catch statistics, various index surveys (e.g. snorkelling/canoe) and counting fence data. Three DFO regions (Newfoundland, Gulf and Maritimes) and the Province of Québec produced documents[34] for review at either or both of the 2006 and 2007 workshops (DFO 2006; 2007). Key documents arising from or contributory to text in Section 5 include Dempson *et al* (2006) for Newfoundland and Labrador, Caron and Fontaine (2007) for Quebec, Chaput *et al* (2006b) for Gulf New Brunswick and Nova Scotia, Amiro *et al* (2006a) for the Atlantic coast and Bay of Fundy Nova Scotia, and Jones *et al* (2006) for Bay of Fundy New Brunswick. These reports addressed population size, status and trends as well as marine survival although not all authors provided information or commentary on each of abundance, status and marine survival for all CUs within their regional coverage. In addition, Gibson *et al* (2006) provided assessments both at the provincial and overall Eastern Canadian levels. Their assessment considered both (i) % adherence to conservation requirements [i.e., river specific egg deposition requirements (O'Connell *et al* 1997a, Chaput 2006)] over several different time frames, and (ii) % abundance/ population change between 1989 and 2004 (i.e., over three salmon generations). Overviews of Canadian abundance and trends originated from the deliberations of ICES Working Group on North Atlantic salmon (ICES 2007).

Guidance for commentary on 'Recovery Feasibility', included within Section .5, stems from the considerations offered by Environment Canada (2005). Feasibility is interpreted in terms of

> "… technical and biological feasibility. Other considerations such as aesthetic, economic or other social values <u>shall not </u>be considered when making a determination on recovery feasibility. These other considerations will be taken into account later in the recovery process if recovery is deemed to be feasible.

> Determinations of recovery feasibility shall be based on the following criteria and must be defensible. Species recovery should be determined *not feasible* if the answer to any one of the following questions is *no*. If the answer to all of these questions is *yes* or *unknown*, recovery should be determined feasible.

> 1. Are individuals capable of reproduction currently available to improve the population growth rate or population abundance?

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[34] Note that the data of Dempson *et al* (2006), Amiro *et al* (2006), and Jones *et al* (2006) extends only to 2005; the remainder of contributions include data from 2006. Data utilized by Gibson *et al* (2006) is of varied duration.

2. Is sufficient suitable habitat available to support the species or could it be made available through habitat management or restoration?

3. Can significant threats to the species or its habitat be avoided or mitigated through recovery actions?

4. Do the necessary recovery techniques exist and are they demonstrated to be effective?"

Commentary and analyses on recovery feasibility is largely restricted to the most southern of CUs where metrics suggest that populations are in decline and beyond correction by traditional management measures.

5.2 North American Overview

The ICES Working Group on North Atlantic salmon carries out annual assessments of the status of North American Atlantic salmon for six geographic regions of North America, five in Canada and one in the USA. One-sea-winter and 2SW returns and spawners were estimated by a variety of methods to data available for individual river systems and management areas. Methods included counts at monitoring facilities, population estimates and application of angling and commercial statistics, angling exploitation rates and measurements of freshwater habitat. Mid-point estimates of 2SW returns to North America in 2006 totalled 73,700 fish, similar to the previous 3 years (ICES 2007). Returns of 1SW salmon in 2006 totalled 532,000 fish, slightly more than in 2005 and 30% more than in 2004. Repeat spawners (multi-sea-winter fish) are not considered in the analyses; returns to Canada generally comprise more than 98% of 2SW and greater than 99% of North American returns.

The mid-point estimate of 2SW spawners in 2006 was 66,000 fish, about the same as in each of the previous 3 years (ICES 2007). This number is but 43% of the North American spawner requirement of 152,548 fish exclusive of the 500 or so fish (O'Connell *et al* 1997) required for the inner Bay of Fundy populations (the USA component is approximately 29,200 [19%] of the total North American). One-sea-winter conservation limits have not been established.

The Working Group (ICES 2007) annually submits total North American 1SW and 2SW returns to a 'run-reconstruction model' in order to estimate pre-fishery abundance of maturing and non-maturing salmon (Figure 11) and forecasts of 2SW returns in the following year. In 2007 (ICES 2007) estimates of pre-fishery abundance reveal continued low abundance of North American adult salmon. The Working Group (ICES 2007) noted that the total population of 1SW and 2SW Atlantic salmon in the northwest Atlantic has oscillated round a generally declining trend since the 1970s (Figure 11). During 1993 to 2005, the total population of 1SW and 2SW Atlantic salmon was about 600,000 fish, about half of the average abundance during 1972 to 1990. The maturing component has declined by 47%, the non-maturing has declined by 92% (ICES 2007).
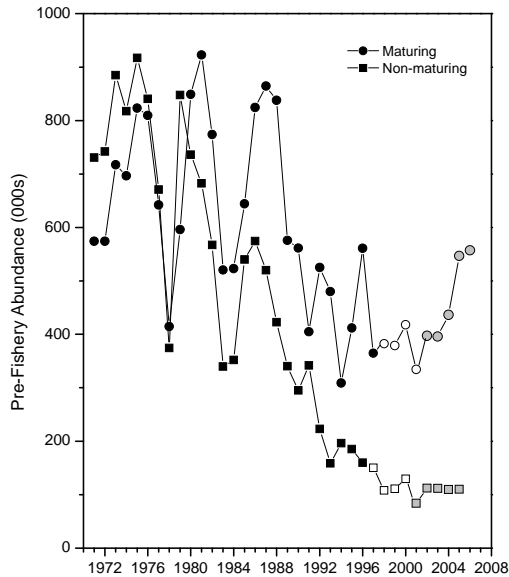
Figure 11. Pre-fishery abundance estimate of maturing and non-maturing salmon in North America. Open symbols are for the years that returns to Labrador were assumed as a proportion of returns to other areas in North America and grey symbols are returns estimated from returns per unit of drainage area (ICES 2007).

ICES (2007) as well noted: i) exploitation rates on 1SW and 2SW fish have fluctuated annually since 1984, but, due to phased closures of commercial fisheries and non-retention of large salmon in many recreational fisheries, have declined to the lowest values in 36 years; ii) return rates of 2SW fish, in particular, to many monitored rivers, have declined and remain low; and iii) a number of salmon stocks suffer reduced reproductive capacity, particularly in the Bay of Fundy, Atlantic coast Nova Scotia, and USA and are threatened with extirpation.

5.3 Eastern Canadian Regional Overview

The ICES assessment of North American stocks is premised on returns and spawners to five geographic regions of Canada (Newfoundland, Labrador, Quebec, Gulf of St. Lawrence, [New Brunswick, Nova Scotia and Prince Edward Island], and Scotia-Fundy [Atlantic coast of Nova Scotia and Bay of Fundy Nova Scotia and New Brunswick]). (Reference Figure 12 and Appendix 3.)

Two-sea-winter returns in 2006 were most numerous in Quebec and Gulf regions (~25,000 each) followed by Labrador (~15,000), Newfoundland (~4,000) and Scotia-Fundy (~2,500) (Figure 12; ICES 2007). In all cases, returns in 2006 ranked among the lower 50% (or 25%) of returns over the 36 year period of record. Quebec and Gulf stocks achieved about 60 and 80% of their respective spawning requirements while Labrador met less than 50% of the requirement. Newfoundland met the requirement while Scotia-Fundy met only about 10% of its requirement (Figure 12).
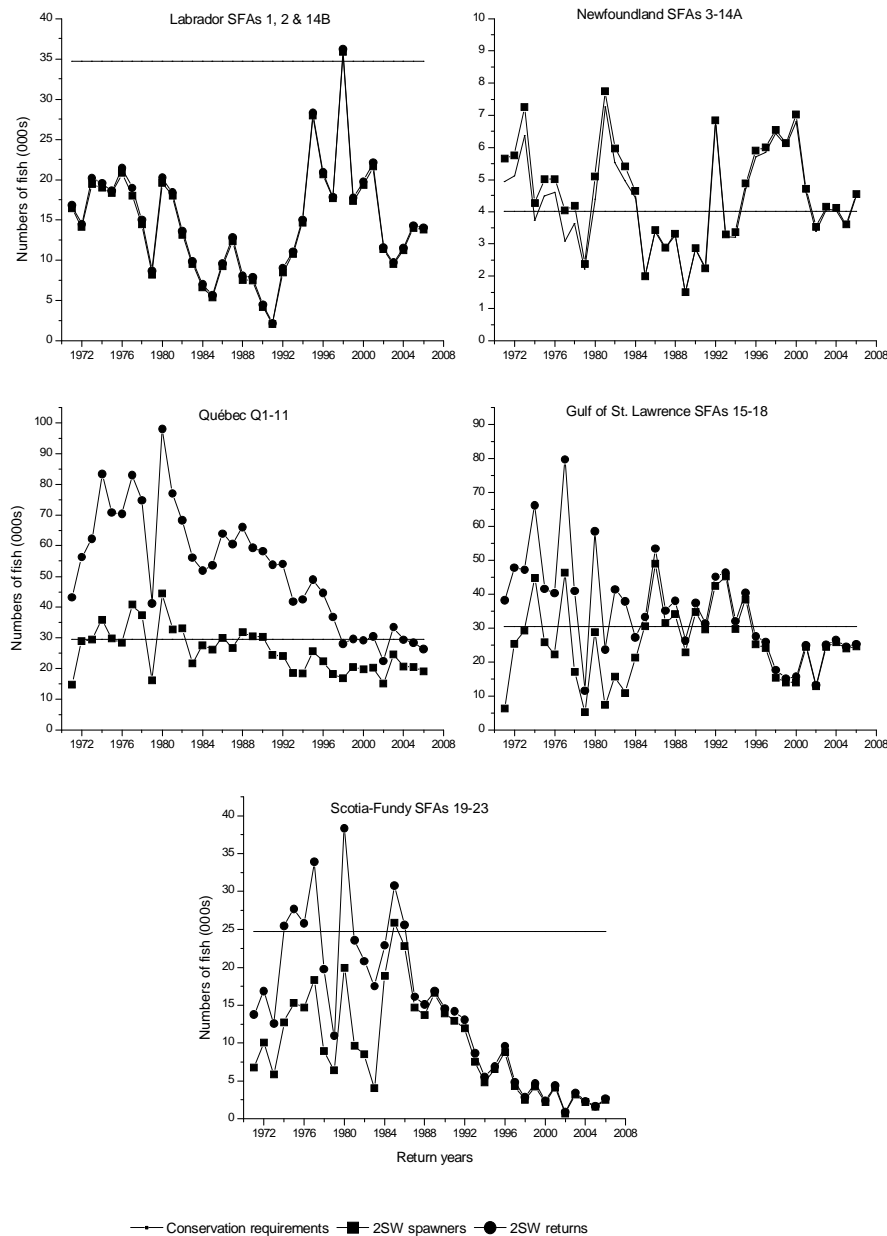
Figure 12. Comparison of estimated mid-points of 2SW returns, 2SW spawners, and 2SW conservation requirements for five geographic areas in Canada. Returns and spawners for Scotia-Fundy do not include those from Salmon Fishing Area (SFA) 22 and a portion of SFA 23. (See Appendix 3 for distribution of Salmon Management Areas/ Zones in Atlantic Canada and Quebec.)

One sea-winter returns in 2006 exceeded 200,000 in each of Newfoundland and Labrador. Gulf and Quebec regions followed with about 60,000 and 30,000 respectively; returns to Scotia-Fundy approximated 10,000 fish (Figure 13; ICES 2007).
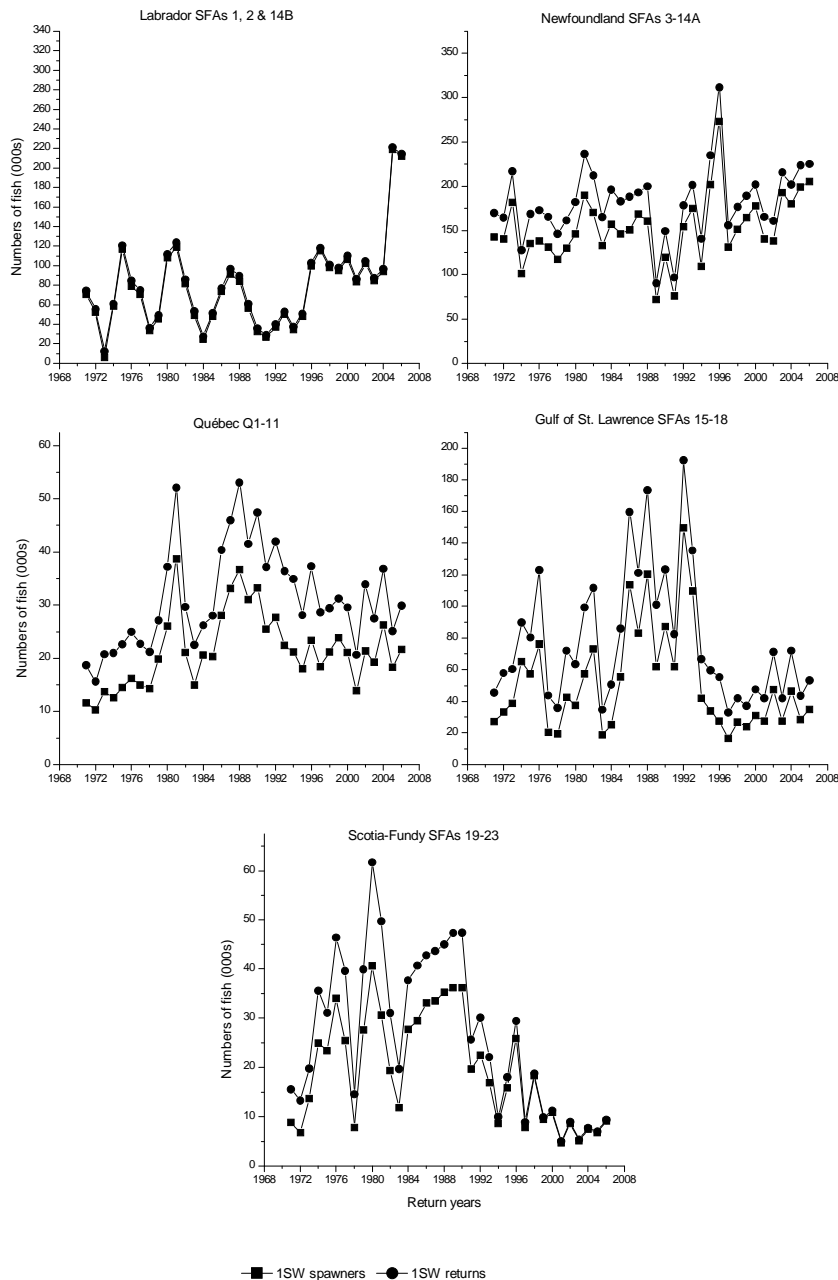
Figure 13. Comparison of estimated mid-points of 1SW returns to and 1SW spawners in rivers of five geographic areas in Canada. Returns and spawners for Scotia-Fundy do not include those from SFA 22 and a portion of SFA 23. (See Appendix 1.0 for distribution of salmon management areas/zones in Atlantic Canada and Quebec.)

Gibson *et al* (2006) considered the percent change in abundance over three salmon generations for individual monitored rivers within 17 of the 28 CUs (Figure 5). (Results are summarized in Figure 14). All assessed populations in CUs 15-17 (SFAs 20 to 23)

have declined by more than 80%. Nearly three quarters of the populations in CU 14 (SFA 19) have declined by 30% or more. Within CU 12 (SFA 18), some populations have declined by more than 50%, although uncertainty exists because the estimates are variable and sensitive to the time period used. Additionally, abundance series for these rivers are derived from the recreational catches, which are influenced by more than just abundance. Within CU 10 (SFA 16), the Restigouche River population shows a decline, but this population is near its conservation requirement and has shown increases during the last few years. The decline of the single population in CU 10 (SFA 16) is not significantly different from zero. Trends in populations in Québec are variable with the largest declines in Anticosti I. (CU 27/Q10). Although abundance in a few populations in Newfoundland and Labrador (SFA 4, 5, 9, 11, 13, 14) has declined, overall populations in this region do not show evidence of declines in abundance over the last three generations.

Figure 14. Summary of a three generation change in population size for salmon populations by CU with size categories combined. The point shows the median value for each CU, the box shows the inter-quartile spread and the whiskers are drawn to the minimum and maximum. The solid and hollow points represent values for large and small salmon respectively. Points that are outside the range of the graph are labelled with their value. Shading represents the COSEWIC categories of endangered (>70% if cause is known and stopped, >50% if cause is unknown) and threatened (>50% if cause is known and stopped, >30% if cause is unknown). (From Figure 14 in Gibson *et al* 2006)
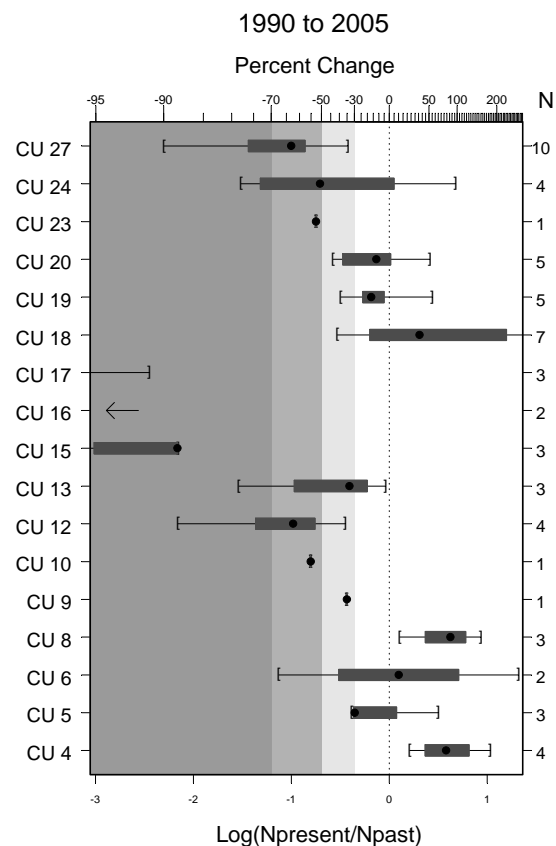
5.4 Abundance, Trends, Marine Survival, Trajectories, Status, and Recovery Feasibility by CU

Specific information regarding Atlantic salmon abundance and trends thereof, marine survival, trajectories, status and recovery potential (see Section 6 for definition) are presented in this section. In general, 'abundance' refers to absolute numbers of a population; 'status' is distinguished from 'abundance' as 'status' refers to abundance of a population relative to a conservation standard/reference point such as (i) the egg deposition rate in number of eggs/m^2 (Chaput 2006), or (ii) a COSEWIC population decline criteria.

Population information for selected river salmon populations within Eastern Canada is presented by five 'sub-regions' of rivers: (i) Labrador, (ii) Newfoundland, (iii) Québec, (iv) southern Gulf of St. Lawrence rivers and (v) rivers emptying directly into the Atlantic Ocean from Nova Scotia or into the Bay of Fundy. This information is organized below by CU (see Figure 5 for a map of all 28 putative CUs of Eastern Canada; a map of existing salmon management areas of Eastern Canada are provided in Appendix 1.0) or aggregations thereof, all within each of the five sub-regions identified above. Note that not all of the population indicators of abundance, marine survival, trajectories, status and recovery potential are presented for every CU.

CUs 1 - 3 (Labrador Rivers)[35]

Abundance and trends: Salmon abundance data for Labrador rivers are limited. Only the Sand Hill River population (within CU 1) has been monitored over any extensive period of time, 1970 - 1973 and 2002 to the present. Returns of large salmon vary by river with the Sand Hill River having, on average, about 15% of the run composed of large fish. In contrast with insular Newfoundland, most large fish in Labrador are MSW salmon which first returned after two or more years at sea. Aboriginal subsistence fisheries for salmon (as well as trout and Arctic charr) occur in Labrador. In recent years subsistence harvests have increased from about 16t y^{-1} to about 30 t in 2004. This contrasts with the last year of the Labrador commercial fishery when about 47t were harvested, versus an average of 111t y^{-1} from 1990 to 1997.

Returns to the Sand Hill River, 1970 - 1973 averaged 3,499 (2,038 to 4,761) small salmon and 271 (138 to 504) large salmon. Some 25 years later during the later stages of the Labrador commercial fishery, returns to Sand Hill River averaged 2,765 (2,180-3,319) small salmon and 568 (414-730) large salmon. From 2002-2004, the run of small salmon averaged 3,440 fish, thus similar to that of 1970-1973. Large salmon returns were much higher (561 to 627) than in the early 1970s. In 2005, returns of 7,007 small and 875 large salmon exceeded those of any of the previously monitored years.

Recovery Feasibility: Formal recovery objectives have not been defined for rivers in CUs 1 to 3 (SFAs 1 - 3) as the population size and hence the need for recovery is

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[35] For CUs 1-3, relevant paragraphs are copied, abstracted &/or synthesized from Dempson *et al* (2006).

undefined for most Labrador salmon populations. Similar to Newfoundland, a proxy objective is for stocks to attain returns that are generally at or above designated conservation spawning requirements. For the most part, monitored rivers in Labrador (CUs 1-3) have met or exceeded conservation thresholds, at least better than 50% of the time, during the 2002 - 2007 period. For these stocks, the potential to impose additional management measures, which could further increase escapements, suggests that neither 'designation' nor recovery feasibility are presently an issue. Should the need arise, the angling and native food fisheries collectively harvest considerable numbers of small and large salmon that could be used to augment current stock levels.

In Labrador, principle conservation concerns exist for MSW salmon. Adult populations of MSW salmon are 75% lower in recent years by comparison with historic returns. While the MSW component of these stocks is generally below current conservation thresholds, management measures and stewardship initiatives have contributed to many of these populations showing dramatic improvements in returns in recent years likely as a result of reductions in marine removals of salmon. There is no information to judge spawning escapement versus conservation objectives for rivers in CU 2. A cautious approach to the utilization of these resources is warranted.

The primary stressor affecting the ability of Labrador salmon populations either to increase their productivity or sustainability, or prevent further population decline is assumed to be continued low at-sea survival. While there is no data on survival for Labrador stocks, everywhere else that salmon populations exist in the North Atlantic at-sea survival is the key issue. The current low abundance of multi-sea winter salmon in Labrador similar to other jurisdictions further indicates that low sea survival is also an issue for Labrador salmon stocks. Commercial fishing in Labrador ceased in all areas beginning in 1998. Reasons why marine survival remains low are not clear.

CUs 4 - 8 (Insular Newfoundland Rivers) [36]

<u>Abundance and trends</u>: Major salmon rivers of insular Newfoundland and their physical data appear in Appendix 4. Changes to the ways salmon stocks were managed in Newfoundland and Labrador have been occurring for many years. In the 1880s, salmon fishers who had completely blocked the mouths of rivers with dykes and weirs were forced to move away from rivers and river mouths to allow some salmon in to spawn. After Confederation with Canada in 1949, commercial fishing was reduced from an all-year fishery to a seasonal fishery of 15 May to 30 December. In 1970, out of concern for mainland Canada salmon stocks, a driftnet fishery at Port aux Basques was closed (Pippy 1982). In 1978 a management plan was implemented to reduce harvests of Bay St. George salmon and increase spawning escapements. In spite of all these changes, salmon continued to decline (Chadwick *et al* 1978).

From 1974 to 1983, the average harvest in the Newfoundland commercial salmon fishery was 905t yr^{-1}. Owing to continued concern over depressed Atlantic salmon stocks in

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[36] For SFA's 3-14, relevant paragraphs are copied, abstracted and synthesized from Dempson *et al* (2006).

mainland Canada and southwest Newfoundland, another comprehensive management plan was introduced in 1984 to support rebuilding of stocks. Key elements of the 1984 plan involved catch restrictions in the recreational fishery, including the mandatory release of all large salmon (salmon $\geq$ 63 cm), with season changes and reductions in the number of fishers and amount of gear used in the commercial fishery (O'Connell *et al* 1992). During the period of the 1984 management plan (1984-1991) commercial landings of salmon in Newfoundland declined to about 600t yr^{-1} varying from a low of 355t to a high of 925t. This was equivalent to a harvest of 141,000 - 361,000 salmon yr^{-1}. However, an evaluation of the 1984 plan showed that restrictions in the commercial fishery did not result in any consistent increase in salmon escapement to rivers in Newfoundland (O'Connell *et al* 1992). In fact, significant declines (P < 0.05) ranging from 50 to 70% or more in total returns of small salmon were noted in some populations including Exploits River (CU 4), Middle Brook (CU 4), Biscay Bay River (CU 5), and Conne River (CU 6) (see Fig 7.2 in Dempson *et al* 2006), while returns of large salmon fell 58 to 80%. Salmon returns also declined at other locations including Gander and Terra Nova rivers (CU 4), or remained stationary with little or no consistent change (e.g. Lomond River, Torrent River, Western Arm Brook – all in CU 8). Consequently, conservation concerns in these and other rivers of Atlantic Canada resulted in the most important change in the management of Newfoundland salmon stocks, namely the closure of the commercial salmon fishery beginning in 1992. Expectations resulting from the closure were intuitive: terminate a directed fishery with moderate to high rates of exploitation and escapements of salmon to rivers should increase immediately. It was also expected that improved spawning escapements beginning in 1992 would result in increased recruitment manifested as greater returns starting in 1997 (Dempson *et al* 1998).

In 1992, there was a closure ('moratorium') placed on the Newfoundland commercial salmon fishery. An analysis of the impact of the 1992 closure (Dempson *et al* 2004) showed predictable results in terms of increased returns of small salmon for various rivers along the Northeast (CU 4) and Northwest (CU 8) coasts (Figure 15), as well as dramatic improvements in returns of large salmon during the first five years of the moratorium. In some cases, runs doubled or tripled during the first few years of the fishery closure by comparison with the period immediately preceding the moratorium. At Gander River (CU 4), for example, runs of small salmon varied from about 6,700 to 7,700 from 1989-1991 then rose to 18,000 to 26,000 fish during the next five years (1992-1996). A parallel situation occurred at Exploits River (CU 4); counts of small salmon varied from about 5,600 to 7,600 from 1989-1991, but rose to 13,500 to 30,000 for 1992 to 1996. A comprehensive analysis of the 1992 moratorium showed that an abundance index for small salmon increased by over 70% for Northeast and Northwest coast rivers during the 1992-1996 period in contrast with 1984-1991 (Dempson *et al* 2004) (Figure 15).
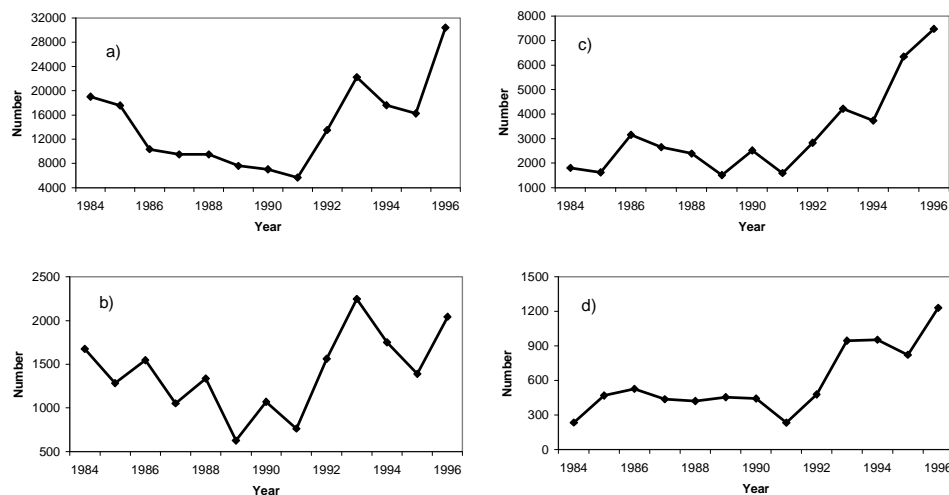
Figure 15. Trends in total returns of small Atlantic salmon to: a) Exploits River, b) Middle River, c) Torrent River, and d) Western Arm Brook Newfoundland, 1984-1996 (Figure 7.3 in Dempson *et al* 2006).

Returns of large salmon to these regions increased by a factor of four or more. In contrast, returns to South coast monitored rivers showed no improvement coincident with the moratorium (Figure 16) as individual rivers (e.g. Conne River (CU 6), Northeast Brook, Trepassey, and Biscay Bay River – all CU 5) had lower returns of small salmon during the 1992-1996 period than they did prior to the closure of the commercial fishery. The most substantive decline was recorded at Conne River where returns of small salmon fell from 8,000 to 10,000 in 1986-1988 to 1,500 salmon by 1994. Despite cautious optimism for increased recruitment beginning in 1997, albeit in those regions where significant increases in total returns occurred from 1992 to 1996, there was either no change (Northwest coast – CUs 7, 8) or a significant decline (south coast – CUs 5, 6) in the abundance of small salmon for the 1997-2002 period by comparison with 1992-1996 (Figure 16). With respect to large salmon, the only region that experienced a significant increase was the Northwest coast (CUs 7, 8).

The above discussion relates to information on salmon returning to monitored rivers. However, more appropriate comparisons of trends in total stock size can be evaluated by summarizing trends in composite abundance indices for all Newfoundland harvests and counts, an approach followed by O'Connell *et al* (2005). Thus, index values for the pre-moratorium period from 1984 to 1991 were adjusted to account for marine exploitation. In all cases, exploitation rates used were the average of the median values obtained from nine rivers as described in Dempson *et al* (2001a), and were 45.3% for small salmon and 74.2% for large salmon. In contrast to the perception obtained when examining data unadjusted for marine exploitation, the combined index of small salmon abundance show declining trends for the northeast and south coasts, as well as for all Newfoundland (Figure 17). South coast stocks have declined by 74% from the peak in 1986 to returns in 2005. There has been a small but insignificant increase in abundance in recent years for northeast coast rivers. Insufficient data existed for the southwest coast pre-moratorium period to make a similar comparison. However, the southwest coast is the only region that has shown a trend for increased returns since the early 1990s. With respect to large

salmon, which are predominately repeat spawning grilse, a dramatic decline (88%) in the abundance has occurred in south coast monitored stocks while total stock size for the northeast coast and Newfoundland as a whole has remained relatively flat (see Figure 7.6 in Dempson *et al* 2006). Abundance of large salmon has increased somewhat for northeast coast rivers by comparison with the pre-moratorium period. As noted for small salmon, increased returns of large salmon have also occurred in the southwest coast region. Collectively, in most regions with the exception of the southwest coast, total stock size or abundance of salmon is either similar to or lower now (e.g. south coast) than it was prior to the closure of the Newfoundland commercial salmon fishery.

Dempson *et al* (2006) summarize that, despite sporadic signs of improved salmon returns to some Newfoundland rivers in some years, total population size is no higher now than it was prior to the closure of the commercial fishery. During the first five years of the 1992 moratorium, immediate improvements in spawning escapements to various northeast and northwest coast rivers did not result in any longer term increases in abundance and/or trends thereof. One region of particular concern is the south coast (CUs 5, 6) where the greatest declines in returns of both small (-74%) and large salmon (-88%) have occurred relative to their peak abundances. The Conne River population has declined by ≥ 50%.
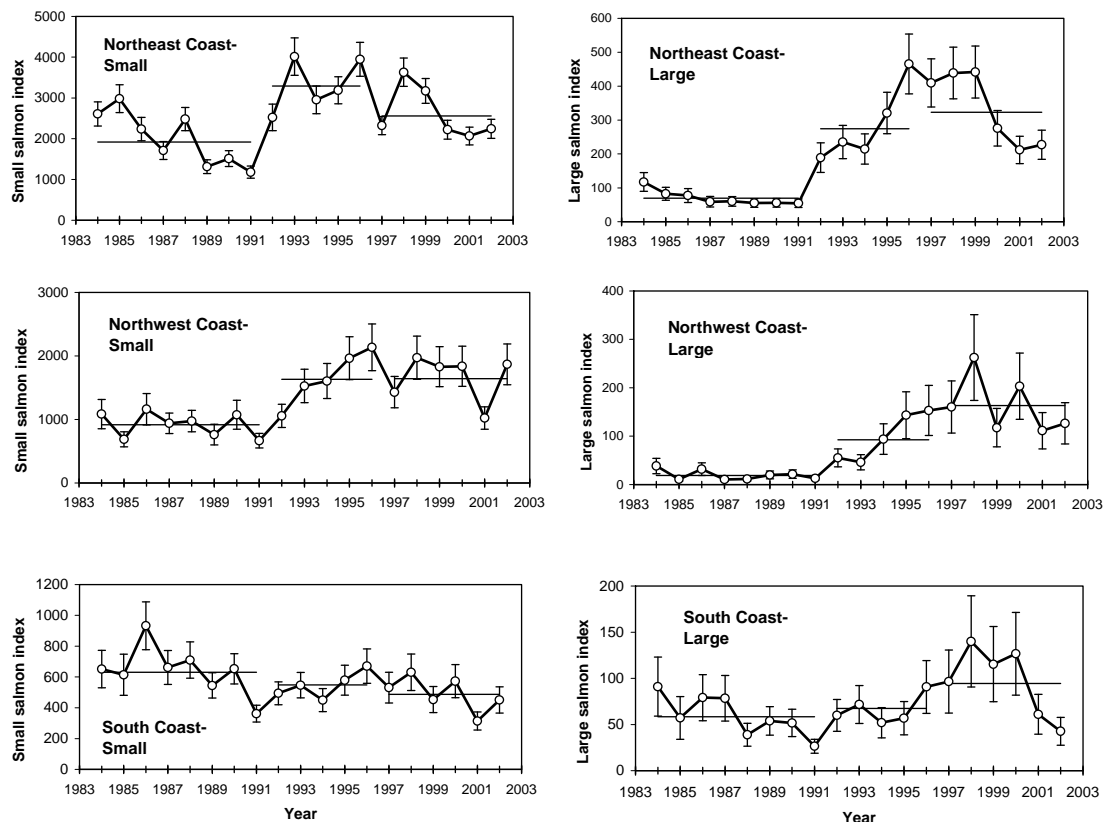
Figure 16. Trends in abundance of small and large salmon by CU in Nfld, 1984 - 2002. Vertical lines represent ± 1 standard error. Horizontal lines illustrate the mean abundance index for the periods 1984 - 1991, 1992 - 1996, and 1997 - 2002. (From Figure 7.4 in Dempson *et al* 2006. 'South coast' refers to CUs 5, 6; 'Northwest Coast' CUs 7, 8; "Northeast Coast : CU 4)
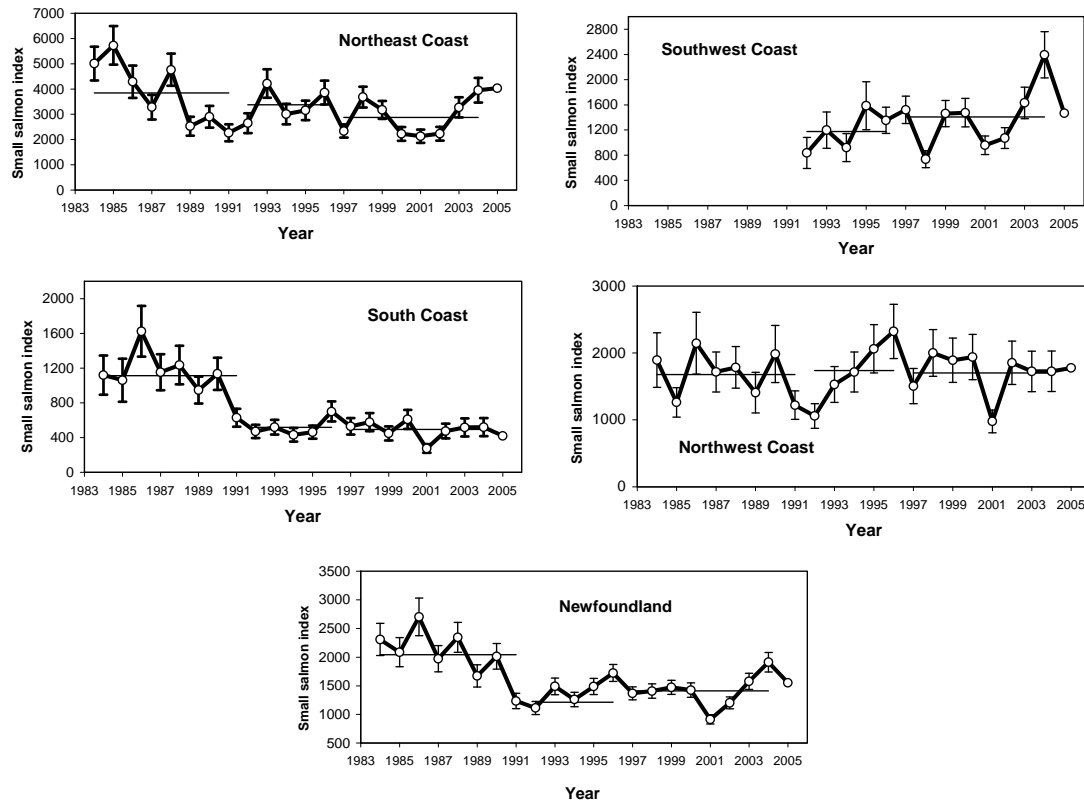
Figure 17. Trends in abundance of small Atlantic salmon by region and for all insular Newfoundland, 1984 - 2005. Vertical lines represent ± 1 standard error Horizontal lines illustrate the mean abundance index for the periods 1984 - 1991, 1992 - 1996, and 1997 - 2004. Returns for 1984-1991 have been adjusted to account for marine exploitation. (from Figure 7.5 in Dempson *et al* 2006)

Marine survival: Trends in smolt production are summarized in Figure 18. Numbers of smolts varies among rivers, and among years within rivers. Variation within rivers is moderately low with coefficients of variation ranging from 17% at Conne River to 36% at Rocky River. Peak smolt production occurred in 1997 at four of six monitored rivers (Figure 18). In general, there have been no appreciable changes in smolt production over time with the exception of Campbellton River. There, numbers of smolts have declined precipitously falling from 62,000 smolts in 1997 to 30,000 in 2005, the lowest recorded for this river (Figure 18). The decline occurred in spite of having exceeded conservation levels consistently on an annual basis. At Western Arm Brook, smolt production has gradually risen over time, but dropped sharply in 2005 to the lowest value in 26 years going back to 1979. Smolt monitoring ended at Highlands River in 2000.
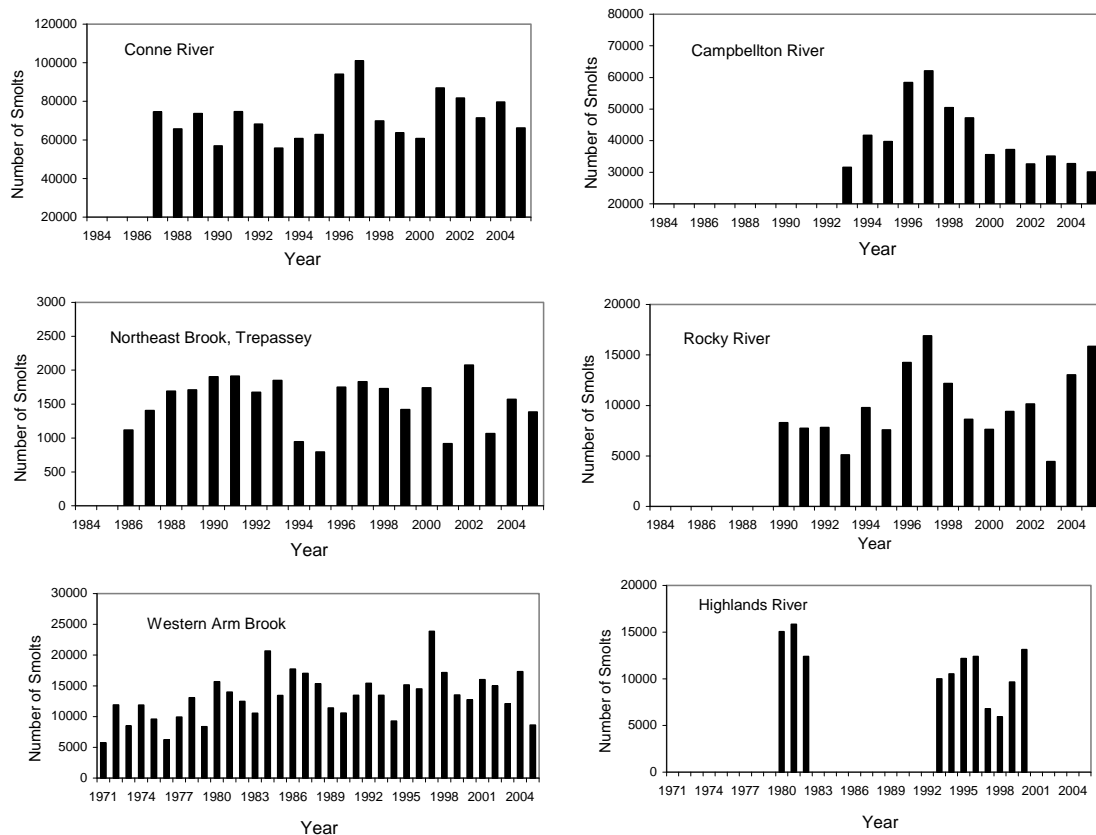
Figure 18. Trends in smolt production from various insular Newfoundland salmon rivers. (From Figure 7.7 in Dempson *et al* 2006)

Numbers of smolts produced appears to be constrained to certain carrying capacities of the respective systems. At Western Arm Brook, rarely have there been more than 18,000 smolts produced regardless of the number of spawners entering the system as numbers typically fall with the range of 10- to 16,000. Similarly, at Conne River, only twice have surveys shown more than 90,000 smolts, with 65- to 80,000 most common while at Northeast Brook, Trepassey, there appears to be an upper limit of about 2,100 smolts for this system. An overview of egg-to-smolt (freshwater) survival rate was provided in the Abundance section of this report.

Marine survival of smolt to adult small salmon also varies among rivers, and among years within rivers (Figure 19). Overall, survival is low with most values falling within the range of 2 – 7 %. Values illustrated are not adjusted for marine exploitation during the period prior to 1992. Several rivers have experienced marine survival rates that are lower, on average, than values prior to the closure of the commercial fishery (e.g. Northeast Brook, Trepassey and Conne River). Also, higher rates of survival have occurred at some rivers in the past when directed ocean fisheries were in existence. Survival is somewhat higher for Campbellton River and Western Arm Brook, rivers located on the northeast and northwest coasts. Lowest survivals, with the exception of

Highlands River that has a 2SW component, are for south coast rivers (Rocky, Conne, Northeast Brook (Trepassey)).
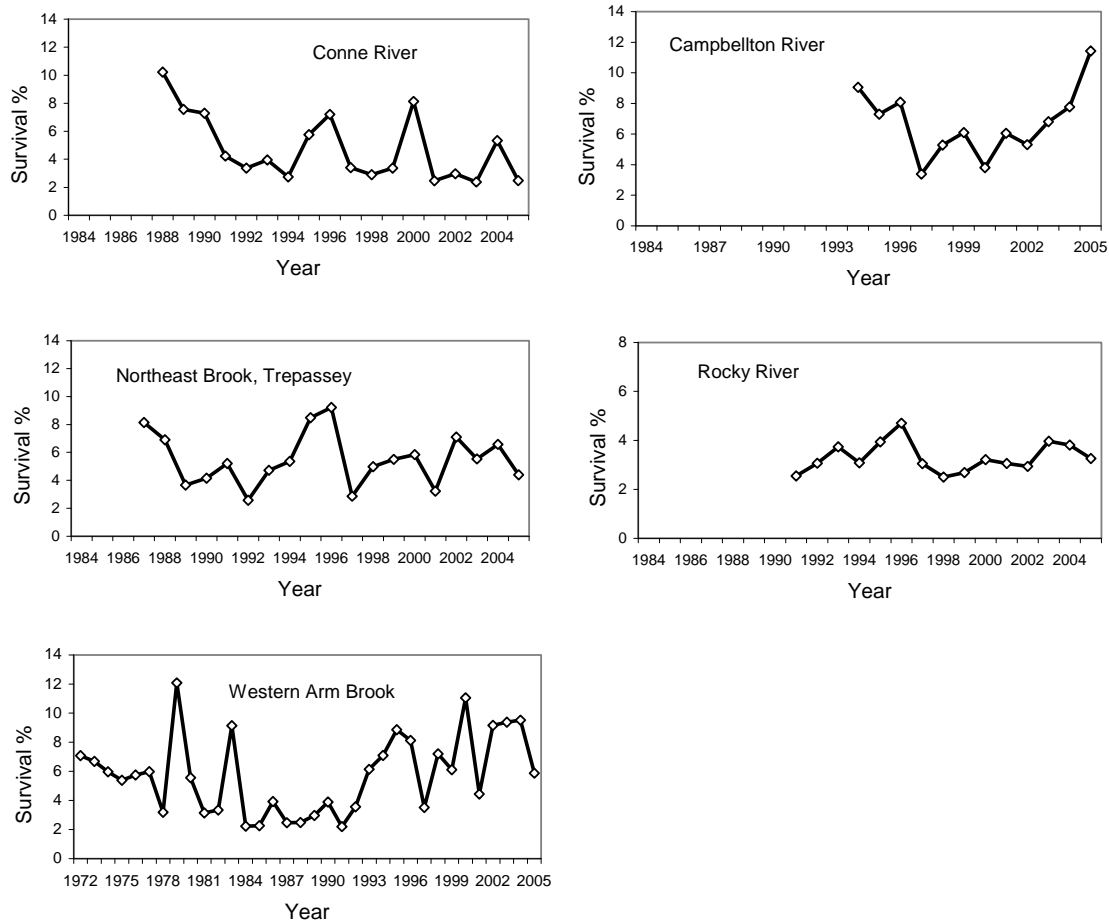
Figure 19. Marine survival rates for adult small salmon at various rivers in insular Newfoundland. Survival rates have not been adjusted for marine exploitation in years prior to 1992 when commercial fisheries for salmon occurred. Thus, values represent actual survival of salmon back to their river or local home waters. (From Figure 7.8 in Dempson *et al* 2006)

A composite index of survival across all rivers (except Highlands) is shown in Figure 20. Here, index values represent standardized Z-scores averaged across all rivers where at least three values (stocks) were available for each year. Values shown are relative to the overall average of the time series (zero) for all five rivers. In recent years, variability in survival has been reduced somewhat, but since 1988 survival has shown no particular increasing or decreasing trend despite major modifications to directed marine salmon fisheries. South coast rivers, by themselves, show a decline in survival over time (Figure 20).
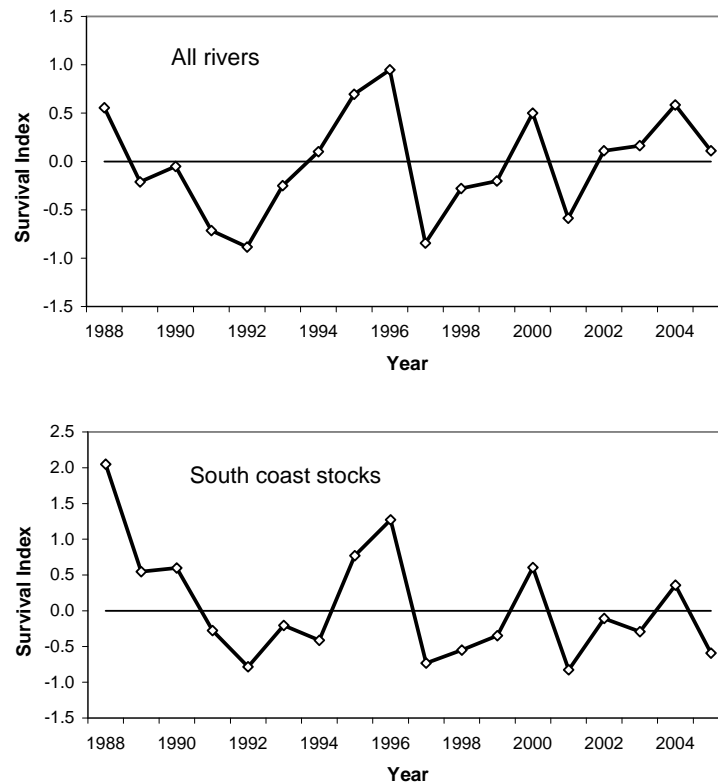
Figure 20. Overview of estimated marine survival in insular Nfld. of smolts to adult small salmon. Upper chart includes all five rivers, while the bottom chart is for three South Coast (CUs 5, 6) populations only. Index values represent averages of standardized (Z-score) survival values relative to the overall mean of the data series used. (From Figure 7.9 in Dempson *et al* 2006)

The variability in marine survival among and within rivers influences the subsequent pattern of adult salmon returns. For rivers in insular Newfoundland, the emigration of greater numbers of smolts does not consistently result in more adults returning (Figure 21). Scatter plots of numbers of smolts versus adult returns in the following year show a bewildering pattern for some rivers. There is somewhat of an increase in adult returns with smolt production at Rocky River and Western Arm Brook during the moratorium years, but at other rivers there does not seem to be any correspondence between smolts and subsequent adult returns.
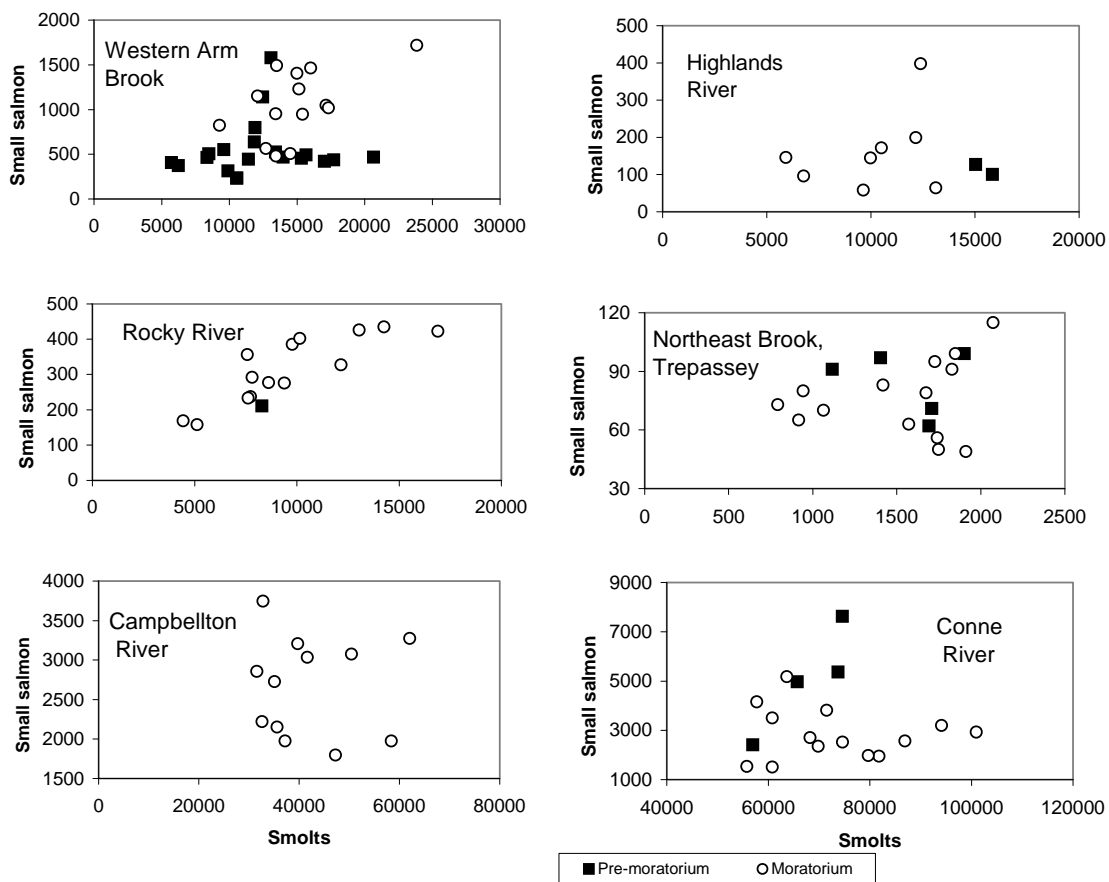
Figure 21. Relationship between smolt production and subsequent returns of adult small salmon from various insular Newfoundland rivers (CUs 4 - 8). Moratorium years (1992 to 2005) are shown separately. (From Figure 7.10 in Dempson *et al* 2006)

Reddin (2006) also provides an example of marine survival for the Western Arm Brook salmon population in CU 8 (Figure 22). The data series there extends from 1972 and therefore enables comparison of survival rates pre- and post-salmon fishing moratorium (1992). It is clear that sea survival has declined substantially since 1984.
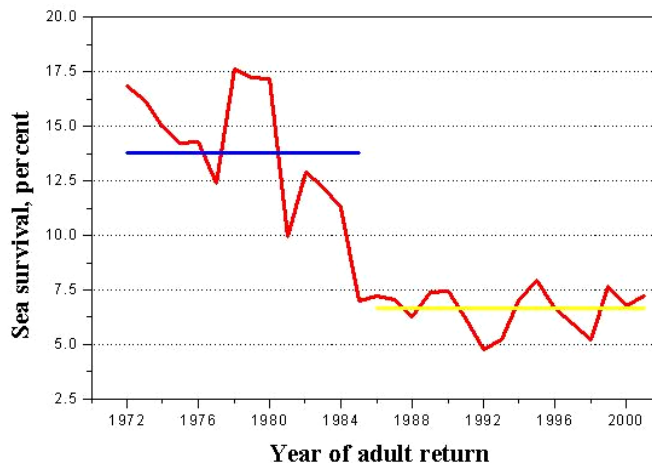
Figure 22. Sea Survival for Western Arm Brook (from Reddin 2006).

Status: Dempson *et al* (2006) looked at the, "Average percentage level of conservation that has been reached (Table 4). Exploits River (CU 4), Terra Nova River (CU 4), and Rocky River (CU 5) average less than 50% of conservation. Rivers with conservation levels averaging between 50 and 75% include: Northwest Brook, Port Blandford, Highlands River, Middle Barachois Brook, Crabbes River, Fischells River, and Harry's River. For all other stocks, the average percentage level of conservation attained has been greater than 100% (Table 4). Ironically, with the exception of Rocky River, all other monitored south coast stocks have average conservation levels that meet or exceed 100% of the conservation requirement, but these are also the stocks that have shown the greatest decline over time with little or no evidence of any consistent improvement following the commercial salmon moratorium. On the other hand, the most consistent improvement in total returns since the moratorium in 1992 have occurred in Bay St. George stocks (SFA 13) even though most populations have attained conservation less than 50% of the time, with five stocks averaging between 50 and 75% of their conservation spawning requirement."

Dempson *et al* (2006) also noted that conservation spawning levels provide reference points for managing the resource. Achieving conservation, however, may not necessarily provide for a harvestable surplus and therefore taken in isolation could give an overly optimistic picture of the 'status' of a stock. As noted above, the most dramatic declines in salmon abundance have occurred in south coast rivers, but for the most part these rivers are at or above required 'conservation' levels. Attaining conservation may help to ensure runs persist, but do not necessarily provide the assurance that returns will increase or provide for maximum yeild. Indeed, despite attaining conservation in most years, Biscay Bay River, Conne River, and Northeast Brook, Trepassey, all were trending downward.

Table 4. Characteristics of Newfoundland Atlantic salmon rivers conventionally assessed in the past and status with respect to conservation requirements. Data are derived from fish counting fences (F), fishways (Fw), snorkel counts (Sc), mark-recapture (MR) or estimated from tributary river counts (EFw). SFA = Salmon Fishing Area. Percent of run refers to the overall percentage of the entire run made up of small (< 63 cm) salmon, and of those, the % that are maiden 1 SW fish. Min and Max refer to the lowest and highest total returns recorded within the interval 1984 to 2005. N = number of years of abundance data from 1984 onwards. Average % conservation is for the last 10 years (1996 – 2005) or the last 10 years a stock was monitored. (This table is copied from Table 7.1 in Dempson *et al* 2006). SFA 3-7=CU4; SFA 9-10 = CU 5; SFA 11 – 12 = CU 6; SFA 13 = CU 7; SFA 14A = CU 8.

SFA	River	Map Location Code	Drainage Area km²	Data Source	Small salmon % of run	Small salmon % 1SW	Small salmon Min	Small salmon Max	Years N	Years First	Years Last	Average % Conservation
Northeast Coast												
4	Exploits River	1	11272	Fw	94.7	94.0	5659	30425	22	1984	2005	41
	Campbellton River	2	296	F	91.3	86.7	1798	4001	13	1993	2005	229
	Gander River	3	6398	F, EFw	89.1	91.9	6745	26205	22	1984	2005	100
5	Middle Brook	4	276	Fw	94.1	91.8	626	2625	22	1984	2005	188
	Terra Nova River	5	1883	Fw	81.8	84.0	1127	3050	22	1984	2005	36
	Northwest Brook, Port Blanford	6	689	F	78.1	89.8	102	1210	11	1995	2005	51
South Coast												
9	Biscay Bay River	7	239	F	94.9	85.6	394	2688	13	1984	1996	106
	Northeast Brook, Trepassey	8	21	F	83.9	92.4	49	158	22	1984	2005	202
	Rocky River	9	296	F	82.2	84.2	80	435	19	1987	2005	45
10	Northeast River, Placentia	10	94	Fw	88.3	89.3	313	1532	19	1984	2002	424
11	Conne River	11	602	F	94.4	95.6	1503	10155	20	1986	2005	132
	Little River	12	183	F	89.2	94.0	55	674	19	1987	2005	185
Southwest Coast												
13	Highlands River	13	183	F	62.5	97.1	58	507	13	1993	2005	74
	Crabbes River	14	551	Sc	82.0	98.8	494	2150	10	1996	2005	72
	Middle Barachois River	15	241	Sc	87.8	92.2	563	1142	10	1996	2005	69
	Robinsons River	16	439	Sc	87.1	99.0	882	1976	10	1996	2005	100
	Fischells Brook	17	360	Sc	86.3		205	1800	9	1997	2005	72
	Flat Bay Brook	18	635	Sc	91.9	85.8	1150	2397	10	1996	2005	109
	Harrys River	19	816	EFw, F	84.8		888	2828	14	1992	2005	59
	Humber River	20	7679	MR	90.5	99.3	5724	30445	10	1990	1999	109
Northwest Coast												
14A	Lomond River	21	470	Fw	88.5	97.4	393	1529	19	1984	2002	143
	Torrent River	22	619	Fw	91.1	95.5	1510	7475	19	1984	2002	719
	Western Arm Brook	23	149	F	95.7	99.9	233	1718	19	1984	2002	412

Trajectories: Despite sporadic signs of improved salmon returns to some Newfoundland Rivers in some years, total population size is no higher now than it was prior to the closure of the commercial fishery (Dempson *et al* 2006). No trajectory has been suggested at this time.

Recovery Feasibility: Formal recovery objectives have not been defined for rivers in CUs 4 to 8 (SFAs 3 -14A). However, a proxy objective is for stocks to attain returns that are generally at or above designated conservation spawning requirements. For the most part, monitored rivers in insular Newfoundland (CUs 4-8) have met or exceeded conservation thresholds, at least better than 50% of the time, during the 1996 - 2005 period. For these stocks the potential to impose additional management measures which could further increase escapements suggests that neither 'designation' nor recovery feasibility are presently an issue.

Monitored stocks for which conservation thresholds have never been achieved include Exploits River, Terra Nova River, Northwest Brook - Port Blandford, and Rocky River.

However, these rivers have been subject to enhancement activities or had additional habitat areas opened up such that full colonization of the watersheds has not occurred. It is noted that the lower section of the Exploits River has attained conservation in 9 of 14 years during the period 1992 to 2005. In contrast, it is the upper and middle sections of the river where conservation deficiencies remain. With the exception of Northwest Brook - Port Blandford and the lower section of the Exploits River, it is doubtful that the other stocks will achieve conservation in the foreseeable future even if additional management measures such as closure of the recreational retention fisheries were imposed. This is because returns would have to increase by a factor of almost three (3) in order for these stocks to reach conservation and this is highly unlikely given the historical trends in abundance of these stocks. At Terra Nova and Exploits rivers, recreational fishery removals average less than 15% of the total returns of small salmon and thus egg depositions would increase marginally in the absence of retention fisheries.

CUs where conservation concerns exist include CUs 5 - 7. Despite monitored populations often attaining conservation thresholds in CUs 5 and 6, some of these stocks have experienced the most dramatic declines in abundance since the closure of the Newfoundland commercial salmon fishery in 1992. Adult escapements are 50 to 75% lower in recent years by comparison with historic returns. Salmon stocks in CU 7 include those characterized by maiden MSW salmon. While these stocks are generally below current conservation thresholds, management measures and stewardship initiatives have contributed to many of these populations showing dramatic improvements in returns in recent years likely as a result of reductions in illegal removals of salmon. Nevertheless, a cautious approach to the utilization of these resources is warranted.

The primary stressor affecting the ability of Newfoundland salmon populations either to increase their productivity or sustainability, or prevent further population decline is continued low at-sea survival. Where data exist, it was found that marine survival rates were no different during the commercial fishery moratorium period than they were prior to the closure of the Newfoundland commercial salmon fishery (Dempson *et al* 2006), implying that factors other than exploitation are contributing to the lack of population rebuilding. Consequently, marine survival rates would have to increase and stay at levels well above those experienced in the past in order to affect substantive increases in salmon abundance. Reasons why marine survival remains low are not clear.

CUs 18 – 28 (Québec Rivers)

Quebec is divided into 11 Conservation Units (CUs), CU 18 to 28, corresponding to salmon zones Q1 to Q11 (Table 5; Appendix 5). CU 21 is currently devoid of salmon rivers. In other CUs, each river possesses at least one salmon population and, for management purposes, some rivers are subdivided into sections or tributaries for which statistics can be determined independent of the main stem. In total there are 118 salmon rivers.

In most of the southern zones (CUs 18-24 and 27) and in CU 25, salmon runs are predominantly composed of large MSW salmon, whereas in CU 26 and in CU 28 runs are comprised of a mix of large and small salmon with a preponderance of small salmon in

most rivers. On average, salmon runs are composed of two-thirds large salmon (MSW) and one-third grilse (1SW) except in CU 26 where the majority of populations are comprised of grilse. In CU 28, Ungava, there are marine and 'estuarine' stocks in some rivers (Robitaille *et al* 1986).

CU	Zone	Name	N River
18	Q1	Baie-des-Chaleurs	5
19	Q2	Péninsule de la Gaspésie	10
20	Q3	Bas-Saint-Laurent / Rive nord de la Gaspésie	9
21	Q4	Chaudiere-Appalaches	0
22	Q5	Capitale-Nationale	3
23	Q6	Saguenay / Lac Saint-Jean	4
24	Q7	Haute Côte-Nord	12
25	Q8	Moyenne Côte-Nord	17
26	Q9	Basse Côte-Nord	21
27	Q10	Île d'Anticosti	24
28	Q11	Ungava	4

Table 5. Correspondence between CUs and salmon zones in Quebec.

The returns in the majority of Québec rivers are exclusively wild salmon. Only few rivers received hatchery-originated juvenile fish at different stages and on a global scale, contribution to the returns is negligible. No farmed salmon have been reported so far in Québec salmon runs.

Conservation limits for Quebec salmon rivers: The 'Fish and Wildlife Conservation Act' stipulates that the spawner requirement is to be attained before any of (in order of priority) native peoples' subsistence, recreational, or commercial fishing is allowed to fish. Commercial fishing licences were bought back in 2000, consequently, only two user groups can qualify to fish for salmon.

Since 2000, the conservation limit has been established for each river. The conservation limit is "the minimum egg deposition required on each river to reach maximum sustainable yield (MSY)" (Caron *et al* 1999). Stock-recruitment analysis for six index rivers was used to define reference points for management, the most important point being 'the conservation limits'.

To assess stock status beyond these six index rivers, the transport of reference points across river systems was done using a 'habitat suitability index' (HSI). Preference curves derived from electrofishing and physical river characteristic data collected on 1,313 sample sites were used to determine relative carrying capacity of the habitat. The HSI used is the product of (substrate + width + type of flow)/3 for each homogenous section of river, and a growth index developed from Power (1981). Parameter values ranging from 0 to 1 are multiplied by the wetted area for each homogenous section of river. The result is termed a salmon Unit of Production (UP); the total number of UPs for a given river permits scaling among rivers.

The conservation limit was calculated from stock and recruit curves for each of the six rivers and converted to the number of eggs per UP (1.67 eggs per UP) as necessary to attain the conservation limit in Quebec salmon rivers.

Fishing regulations in respect of the attainment of conservation limits: In practice, regulations are set before the season so as to maintain each salmon population above the conservation limit. When a river fails to reach its conservation limit for three consecutive years, the following conservation measures are invoked:

- Annual quota on large salmon catch
- Release of large salmon for a part of the season
- Release of large salmon for all the season
- Release of large salmon + restocking of juvenile
- Closure of fisheries

Mid-summer salmon counts are conducted in the most important rivers in the southern zones to estimate the ongoing annual run. Salmon are categorized according to size: small salmon are those of 63 cm fork length or less and are generally 1SW. Large salmon (MSW) are mainly 2SW fish although some of them are three-sea-winter (3SW) or previous spawners. Whenever and wherever the salmon run seems to be weak and unable to reach the conservation limit, release of large salmon becomes obligatory.

Commercial fishing: Commercial fishing was totally banned for all regions in Quebec in 2000. Commercial fishing was restricted to the northern rivers after 1993. In CU 28 (Ungava), there is a moratorium on commercial fishing.

Native fishery: Native peoples' subsistence fishing takes place through agreements or permits issued to the bands. There are 10 bands with subsistence fishing, in addition to the fishing activities of the Inuit in Ungava (CU 28), who fish in estuaries or in rivers. The permits generally stipulate gear, season and catch limits. Catches for subsistence fishing have to be reported collectively by each Native user group. However, reports are seldom provided thereby requiring that catches be estimated.

Sport fishing: Salmon retained by fishermen have to be registered by law and in most cases fish weight and length are recorded by the local river organizations that are in charge of the river's recreational fishery. All data are transmitted to the MRNF for compilation. Salmon are categorized according to size.

Regulations to achieve 'conservation limits' on each river are set in advance of the opening of the fishing season. Three different fishing permits are available: a season permit with entitlement to seven salmon, a one-day permit that allows the catch of two salmon, and a season 'catch and release' only permit.

The northern CUs (25, 26 and 28) include 42 salmon rivers managed mainly on a zone basis. Sport fishing is permitted on 40 rivers and retention of landed small and large

salmon is permitted on 39 rivers. The maximum daily limit is two fish a day. Release of large salmon is done mainly on a voluntary basis. In these areas salmon rivers are less accessible and water coloration does not permit a visual count.

The southern CUs (18-24 and 27) contain 67 rivers, which are managed on a river-by-river basis. Fishing is not authorized on 29 rivers, possession of small salmon only is authorized on 24 rivers and possession of small and large salmon is authorized on 14 rivers. On these rivers, fishing for the day ends if the first fish caught is a large salmon. If the first fish caught is a small salmon, then fishing could continue on most rivers until the second fish-small or large-is caught.

Chaleur Bay (CU 18; Zone Q1)

CU 18 is located in the Chaleur Bay region and contains a total of eight independently managed salmon rivers and tributaries. The Bonaventure, Petite Cascapédia, Cascapédia and Nouvelle rivers flow directly into Chaleur Bay. The Matapédia, Patapédia, Causapscal and Kedgwick rivers are part of the Quebec portion of the Restigouche River watershed, which borders on the Province of New Brunswick. The Matapédia and Cascapédia rivers are the largest.

Sport fishing: All of the salmon rivers in the CU are open to sport fishing. The Matapédia River is the most popular river among sport fishermen in Quebec and sustains more than 8,000 fishing days per year.

Fishing for large salmon is authorized on all rivers except the Nouvelle and Petite Cascapédia. On the Matapédia, a mid-season action plan is used to control the large salmon harvest to ensure that the conservation threshold is reached. On this river, catch-and-release fishing for black salmon is also authorized during the second half of May. On the Patapédia there is a sector that is harvested jointly by Quebec and New Brunswick, where compulsory catch-and-release provisions for large salmon are in effect.

For the entire CU 18 the mean annual exploitation for the years 2002-2006 was 3,151 salmon (1,799 small and 1,352 large).

Native (subsistence) fishing: Two Mi'kmaq communities conduct subsistence fishing with gillnets under agreements with Quebec's MRNF. The Listiguj community fishes in the estuary of the Restigouche River and harvests an estimated 1,000 salmon per year. The Gesgapegiag community fishes in the estuary of the Cascapédia River and harvests an estimated 170 salmon per year.

Population status: End-of-season diver counts of spawners are used to determine egg depositions on all rivers but the Causapscal River, which is equipped with a counting fence. The conservation threshold is usually exceeded in all but the Petite Cascapédia and Nouvelle rivers (Table 6). Natural production in the Nouvelle River only is supplemented with the stocking of juveniles; stocking on the Petite Cascapédia River ended in 2000 after 25 years of operations.

Table 6. Conservation threshold, egg deposition as a percentage of conservation threshold, and permissible harvest for rivers of CU 18 (Zone Q1).

Zone Q 1	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
Kedgwick (trib)	0.97	216%	184%	207%	202%	182%	166%	G
Causapscal (trib)	1.65	219%	204%	186%	216%	155%	210%	G
Nouvelle	1.91	19%	13%	18%	27%	16%	9%	M
Patapédia (trib)	1.92	201%	203%	189%	210%	189%	175%	G
Petite rivière Cascapédia	2.05	80%	70%	95%	82%	129%	90%	M
Bonaventure	4.62	92%	115%	168%	119%	101%	85%	G-M
Cascapédia	5.65	148%	166%	296%	213%	270%	265%	G
Matapédia	5.99	232%	164%	227%	213%	176%	157%	G

G-retention of large salmon (and grilse); M- retention of grilse only.

Recovery Feasibility: In view of the current state of spawning runs, the management measures and on-going monitoring, neither 'designation' nor recovery feasibility are issues for salmon of CU 18.

Gaspé Peninsula (CU 19; Zone Q2)

The Gaspé Peninsula stretches from Gaspé to Port-Daniel and comprises 10 status salmon rivers. In this zone, the Saint-Jean River is one of two index rivers used for monitoring salmon stocks in Quebec.

Sport fishing: All salmon rivers except the Petite rivière Port-Daniel are open to fishing but with harvests governed by stock levels. On rivers where fishing for large salmon is authorized, a mid-season action plan (Dartmouth and York) or a quota (Grande-Rivière) is established in order to control harvesting. Fishing for grilse is permitted throughout the season. The mean annual harvest, 2002 to 2006, was 584 salmon (335 grilse and 249 large salmon).

Subsistence fishing: Since 2003, the Gespeg Mi'kmaq community has carried out subsistence fishing in the Grand Gaspé rivers (primarily the York River). These activities are governed by agreements with the MRNF. Average landings are about 16 salmon per year.

Population status: End-of-season diver counts of spawning salmon are used to determine the annual egg depositions on nine of the ten salmon rivers of CU 19 (the Petite rivière Port-Daniel being excepted). In recent years the conservation threshold has generally been reached and exceeded in six of the nine rivers (Table 7). Rivers that are below the conservation threshold are restricted to hook and release fishing. No stocking of juvenile salmon is carried out in CU 19.

Table 7. Conservation threshold, egg deposition as a percentage of conservation threshold, and fishing provisions for rivers of CU 19 (Zone Q2)

Zone Q 2	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
Petite rivière Port-Daniel	0.19							X
Malbaie	0.28	139%	179%	250%	207%	275%	114%	M
Port-Daniel Nord	0.33	39%	67%	218%	130%	148%	39%	M
Du grand Pabos Ouest	0.46		76%	113%	143%	91%	107%	M
Du petit Pabos	0.89		26%	16%	28%	48%	29%	M
Du grand Pabos	0.90		38%	102%	73%	83%	76%	M
Grande Rivière	1.43	79%	78%	178%	76%	117%	85%	G-M
Saint-Jean	1.88	239%	187%	276%	185%	247%	206%	M
Dartmouth	1.94	133%	120%	225%	164%	152%	143%	M-G
York	2.64	186%	196%	299%	206%	229%	233%	M-G

G-retention of large salmon (and grilse); M- retention of grilse only; X-Closed

Recovery Feasibility: In view of the current state of salmon runs, the management measures that are applied and with the monitoring that is conducted, neither 'designation' nor recovery feasibility are issues for salmon of CU 19.

Lower St. Lawrence and North Shore Gaspé (CU 20; Zone Q3)

CU 20 comprises the south shore of the St. Lawrence River and comprises nine salmon rivers. The Matane River is the largest in this zone. Because of the presence of natural waterfalls, fish passage facilities have been built on three rivers: the Madeleine, the Mitis and the Rimouski.

Sport fishing: The salmon fishery is closed on two small rivers (the Mont-Louis and the Sud-Ouest); and fishing for large salmon is authorized on a few rivers, if stock levels are sufficient. The harvest (retained fish) amounts to nearly 900 grilse and 550 large salmon, on average, each year, with nearly 70% of this total being caught in the Matane River.

Subsistence fishing: No Aboriginal groups carry out subsistence fishing in this CU.

Population status: The fishery for large salmon is governed by a mid-season action plan aimed at implementing release provisions for large salmon if stock levels are insufficient to meet conservation limits. The Ouelle River can as well be closed as a result of overly high water temperatures and severe low flow conditions. Stocking of juvenile salmon is confined to the Rimouski River, which is under development.

Table 8. Conservation threshold, egg deposition as a percentage of conservation threshold, and fishing provisions for rivers of CU 20 (Zone Q3).

Zone Q 3	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
Du Sud-Ouest	0.08							X
De Mont-Louis	0.16			34%	44%	6%	6%	X
Cap-Chat	0.82	99%	90%	123%	222%	141%	137%	M
Rimouski	0.99	152%	20%	71%	42%	78%	55%	M
Ouelle	1.12							G
Mitis	1.13	145%	101%	94%	251%	166%	140%	G-M
Sainte-Anne	1.26	114%	63%	202%	217%	152%	144%	G Note 1
Madeleine	2.60	123%	47%	97%	105%	112%	84%	G
Matane	3.18	145%	128%	150%	159%	168%	131%	G

Note 1: Upper reaches, grilse fished only since 1999

G-retention of large salmon (and grilse); M- retention of grilse only; X-Closed

Recovery Feasibility: In view of the management measures that are applied and the monitoring that is carried out, neither 'designation' nor recovery feasibility are issues for salmon of CU 20.

Quebec City (Capitale nationale) (CU 22; Zone Q5)

CU 22 stretches from the Jacques-Cartier River to the eastern tip of the Quebec City area. It is the westernmost salmon zone in Quebec and contains only three salmon rivers: the Jacques-Cartier, Gouffre and Malbaie rivers.

Sport fishing: Sport fishing has been prohibited on the Jacques-Cartier River since 2004. On the Malbaie and Gouffre rivers, large salmon must be returned to the water (compulsory release), but one grilse may be kept. The harvest, 2002- 2006, (retained fish) averaged 119 grilse.

Subsistence fishing: No Native groups carry out subsistence fishing in this zone.

Population status: Salmon runs are monitored annually at fishways on the Jacques-Cartier and Malbaie rivers. Returns to the Malbaie River are believed to be underestimated as a certain proportion of the fish spawn downstream of the fishway. Similarly on the Gouffre River, salmon runs are believed to be underestimated because the electronic fish counter incorporated in a counting fence does not operate effectively during high river discharges, usually occurring at the beginning of the run.

None of the three rivers in CU 20 have ever attained their conservation threshold (Table 9). Consequently, a number of measures have been implemented to enhance the status of their populations:
- closure of the salmon fishery on the Jacques-Cartier River;
- annual stocking of salmon fry on the Jacques-Cartier River;

- installation of smolt bypass facilities at all the hydro-electric power plants on the Jacques-Cartier River;
- stocking of parr on the Malbaie River;
- grilse fishing only on the Malbaie and Du Gouffre rivers, and
- an effort to assess complete returns to the Du Gouffre and Malbaie rivers.

Table 9. Conservation threshold, egg deposition as a percentage of conservation threshold, and fishing provisions for rivers of CU 22 (Zone Q5).

Zone Q 5	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
Du Gouffre	1.60				14%[1]	16%[1]		M
Malbaie	2.45	6%	9%	24%	33%	13%	18%	M
Jacques-Cartier	3.00	11%	6%	4%	6%	9%	8%	X

[1] Partial assessment of the spawning run

M- retention of grilse only; X-Closed

Recovery Feasibility: The three rivers in CU 22 are below the conservation thresholds but, in view of on going management and assessment measures, neither 'designation' nor recovery feasibility are issues for salmon of CU 22.

Saguenay, Lac Saint-Jean (CU 23; Zone Q6)

The salmon region of the Saguenay extends from the mouth of the Saguenay Fjord at Tadoussac to the Chute-à-Caron at Jonquière. There are five salmon rivers in this CU, all tributaries of the Saguenay: the Sainte-Marguerite, the Sainte-Marguerite Nord-Est, the Rivière à Mars (Mars River), the Saint-Jean and the Petit-Saguenay rivers.

Sport fishing: Sport fishing for grilse is permitted in all rivers; large salmon that are caught must be released in accordance with provisions introduced in 2003. For the five rivers, 2002-2006, the harvest (retention) averaged 0.3 large salmon and 33 grilse.

Subsistence fishing: No subsistence fishing is carried out in this zone.

Population status: Counts of spawners are conducted annually on the Sainte-Marguerite, the Sainte-Marguerite Nord-Est, the Rivière à Mars and the Saint-Jean rivers. Counting methods include counting fences, fishways and diver surveys. In the Petit-Saguenay River, a partial count of spawners was conducted in 2001 and 2005.

As a consequence of 3-year average egg depositions being less than the conservation threshold in three of the rivers (Table 10), the compulsory release of large salmon was imposed on all five rivers in 2003. This will remain in effect until the 3-year average for egg deposition again exceeds the conservation threshold and reaches the management targets.

Table 10. Conservation threshold, egg deposition as a percentage of conservation threshold, and fishing provisions for rivers of CU 23 (Zone Q6).

Zone Q 6	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
À Mars	0.37	127%	111%	159%	324%	108%	97%	M
Saint-Jean	0.40	168%	133%	115%	120%	158%	278%	M
Sainte-Marguerite Nord-Est (trib)	1.32	114%	55%	71%	118%	85%	41%	M
Petit Saguenay	1.40	41%				16%		M
Sainte-Marguerite	1.41	101%	61%	85%	91%	88%	101%	M

M- retention of grilse only

To promote the building of populations, all large salmon are being allowed to spawn, fry are being released from government hatcheries and stream side incubators, and in two rivers, habitat is being enhanced (Table 11).

Table 11. Actions taken to attain conservation thresholds in rivers of CU 23. (Zone Q 6).

Zone Q 6	Kelt reconditioning	Fry production from government hatcheries	Fry production from stream side incubators	Habitat restoration
À Mars	X	X		X
Saint-Jean	X		X	
Sainte-Marguerite Nord-Est	X		X	
Petit Saguenay	X		X	
Sainte-Marguerite	X	X	X	X

Recovery Feasibility: In view of the management measures that are applied and the monitoring that is carried out, neither 'designation' nor recovery feasibility are issues for salmon of CU 23.

Upper North Shore (CU 24; Zone Q7)

The Upper North Shore extends from Tadoussac to Port-Cartier and comprises 12 salmon rivers, one of which (Trinité River) is one of the two provincial index rivers for salmon.

Sport fishing: Sport fishing is prohibited on the Betsiamites, the Rivière aux Anglais, the Mistassini, the Franquelin, the Petite rivière de la Trinité, and the Calumet. The Betsiamites River is reserved exclusively for subsistence fishing by the Betsiamites Innu community. Harvests (retained salmon) from the remaining rivers, 2002-2006, averaged 54 large salmon and 300 grilse.

Subsistence fishing: In addition to Betsiamites Innu community that has since 2002 harvested an average of 178 salmon per year from the Betsiamites River, the Essipit Band Council carries out subsistence fishing near the mouth of the Escoumins River. Historical

data provided by the Band Council suggests that, on average, 50 large salmon are harvested annually.

Population status: Counts of migrating salmon, estimates of egg deposition and the attainment of the conservation threshold are performed on the Escoumins, the Rivière aux Anglais, the Godbout, the Trinité and the Rivière aux Rochers. Since 2002, only the Rivière aux Anglais has attained the conservation threshold every year (Table 12). In the other rivers, the conservation threshold has not been attained consistently.

Management measure that have been implemented include:
- the closure of very small rivers to sport fishing;
- stocking of fry and parr in the Escoumins, the Godbout and Rivière aux Rochers;
- grilse-only fishing in the Laval and Pentecôte rivers, and
- a quota of 40 large salmon on the Rivière aux Rochers (grilse –only thereafter).

Table 12. Conservation threshold, egg deposition as a percentage of conservation threshold, and fishing provisions for rivers of CU 24 (Zone Q7).

Zone Q 7	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
Aux Anglais	0.05			270%	160%	120%	180%	X
Du Calumet	0.06							X
Mistassini	0.11							X
Franquelin	0.14							X
Petite r.de la Trinité	0.14							X
Pentecôte	0.38							G
Laval	0.44	143%	72%					G
De la Trinité	1.63	64%	63%	91%	104%	67%	161%	M
Des Escoumins	1.70	70%	37%	46%	100%	48%	55%	M
Aux Rochers	2.28	106%	68%	98%	161%	113%	133%	G-Q
Betsiamites	3.29							note 1
Godbout	3.57	76%	37%	65%	90%	81%	83%	M

Note 1: reserved exclusively for Aboriginal fishery

G-retention of large salmon (and grilse); M- retention of grilse only; X-Closed, and Q- quota for large salmon.

Recovery Feasibility: In view of the management measures that are applied and the monitoring that is carried out, neither 'designation' nor recovery feasibility are issues-for salmon of CU 24.

Middle North Shore (CU 25; Zone Q8)

The Middle North Shore region stretches from Sept-Îles to Natashquan and contains 17 salmon rivers.

Sport fishing: Sport fishing for salmon is prohibited in the Matamec, which is located in an ecological reserve, and the Sheldrake. In the other 15 rivers, the harvest (retained fish), 2002 to 2006, averaged 872 large salmon and 353 grilse.

Subsistence fishing: Three Native groups carry out subsistence fishing in this zone. The Uashat mak Mani-Utenam community annually catches about 137 large salmon in the Moisie River. The Nutashkuan community harvests about 975 salmon in the Natashquan, and the Ekuanitshit community catches about 50 salmon annually in the Romaine and Puyjalon rivers.

Population status: There are no counts of salmon migrating upstream in rivers of the Middle North Shore region. Thus estimates of the attainment of conservation thresholds are based on a comparison of available 'catch per effort' data (Table 13) with the mean catch per effort data for rivers of CUs 18-20 (zones Q1 to Q3) (Figure 23).

Table 13. Conservation threshold (eggs required), adjusted fishing success (salmon caught per day), and fishing provisions for rivers of CU 25 (Zone Q8).

Zone Q 8	Eggs required	Adjusted fishing success						Harvest
	(million)	2001	2002	2003	2004	2005	2006	
Magpie		0.23*	0.20*	0.22*	0.23*	0.22*		G
Pigou	0.01							G
Sheldrake	0.07							X
Piashti	0.07	0.46	0.23	0.30	0.06	0.61	0.95	G
Au Bouleau	0.08							G
De la Corneille	0.09	0.34	0.47	0.37	0.46	0.26	0.57	G
Petite rivière Watshishou	0.20	0.61	0.26	0.08	0.10	0.58	0.48	G
Aguanus	0.29	0.11	0.10	0.18	0.22	0.31	0.22	G
Jupitagon	0.38	0.07*	0.08*	0.12*	0.14*	0.11*	0.07*	G
Matamec	0.45							X
Watshishou	1.45	1.05	0.74	0.96	1.04	1.17	1.09	G
Mingan	1.93	0.37*	0.25*	0.29*		0.11*	0.34*	M
Nabisipi	2.48	0.60	0.64	0.96	0.20	0.71	0.67	G
Romaine	4.06	0.31*	0.20*	0.22*	0.24*	0.22*	0.25*	G-note 1
Saint-Jean	6.72	0.27	0.21	0.25	0.40	0.17	0.33	G
Natashquan	17.86	0.85*	0.83*	0.83*	0.95*	0.85*	0.81*	G
Moisie	20.39	0.18	0.12	0.21	0.20	0.16	0.22	G

* Fishing success not adjusted

Note 1: fishing permitted between 100m downstream of the first waterfall and the big waterfall (50°23'14"N 63°15'13"O); elsewhere fishing prohibited

G-retention of large (and small) salmon; M- retention of grilse only, and X-Closed
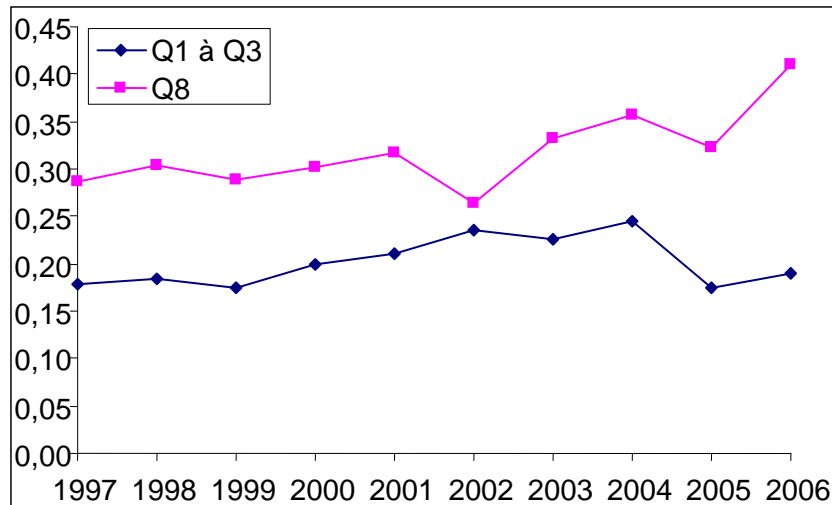
Figure 23. Mean fishing success (number of salmon caught/day) in CU 25 (Zone Q8) compared to mean fishing success in CUs 18-20 (zones Q1 to Q3).

The comparison indicates that the mean annual catch per day values (0.26 to 0.41) in CU 25 (Zone Q8) have always exceeded those of the reference zones and suggests that on average, conservation thresholds have been attained since 1997. The differences were largest in 2005 and 2006. Compulsory release of salmon is limited to the Mingan River.

Recovery Feasibility: The indication that conservation thresholds have in most cases been exceeded and the potential to impose management measures which could further increase escapements suggest that neither 'designation' nor recovery feasibility are issues for salmon of CU 25.

Lower North Shore (CU 26; Zone Q9)

The Lower North Shore region stretches from Kegaska to Blanc Sablon and contains 22 salmon rivers.

Sport fishing: Sport fishing for large and small salmon is permitted on all of the rivers. Harvests (retained fish), 2002-2006, averaged 123 large salmon and 820 grilse. There is as well a significant voluntary release of large salmon.

Subsistence fishing: The Montagnais communities of Unamen Shipu and Pakua Shipu conduct subsistence fishing for salmon. The Unamen Shipu Band Council authorizes sport fishing by some community members at the Pourvoirie (outfitter) Étamamiou, in the river of the same name, pursuant to an agreement entered into with the outfitter. The Pakua Shipu community fish only the Saint-Augustin River, and annually harvest an estimated 350 fish comprised mostly of salmon.

Population status: There are no counts of salmon migrating upstream in rivers of the Lower North Shore region. Thus estimates of the attainment of conservation thresholds

are based on a comparison of available 'catch per effort' data (Table 14) with the mean catch per effort data for rivers of CUs 18-20 (zones Q1 to Q3) (Figure 24).

Mean annual catch per effort values of 0.56 to 1.23 in CU 26 (Zone Q9) are triple or more the values for the reference zones (Figure 24) and appear to have increased since 2002. The Kécarpoui and Kégaska rivers have low catch per effort values but are small rivers in which very few large salmon are harvested. The comparison suggests that none of the stocks in this CU are declining and supports the retention of large salmon.

Table 14. Conservation threshold (eggs required), adjusted fishing success (salmon caught per day), and fishing provisions for rivers of CU 26 (Zone Q9).

Zone Q 9	Eggs required	Adjusted fishing success						Harvest
	(million)	2001	2002	2003	2004	2005	2006	
Chécatica	0.00							G
Musquaro	0.01	0.46	0.71	0.71	1.13	0.71	0.52	G
Ruisseau des Belles Amours	0.01	0.50*		0.50*	0.44*			G
Véco	0.01	0.36*			0.45*	0.42*	0.34*	G
Nétagamiou	0.03							G
Washicoutai	0.04	0.11	0.11	0.37	0.33	0.44	0.64	G
Kécarpoui	0.06	0.37	0.83	0.79	0.19	0.13	0.10	G
Musquanousse	0.06	0.63	0.76	0.38	0.39	0.17	0.28	G
Du Gros Mécatina	0.08	0.76	0.84	0.85	1.63	1.16	1.03	G
Coacoachou	0.08							G
Brador Est	0.09	0.44*	0.44*	0.46*	0.43*	0.43*	0.33*	G
Kégaska	0.12	0.44*	0.44*	0.20*	0.09	0.08*	0.10*	G
Du Petit Mécatina	0.14							G
Ruisseau au Saumon	0.16	0.33*	0.43*	0.46*	0.44*	0.42*	0.33*	G
Du Vieux Fort	0.32	1.13	1.38	1.17	1.12	0.98	0.85	G
Saint-Augustin Nord-Ouest (trib)	0.79							G
Napetipi	0.99	1.21	0.90	1.85	2.18	1.09	0.92	G
Coxipi	1.12							G
Olomane	1.20							G
Étamamiou	2.62	1.00	1.89	1.33	1.20	1.14	1.14	G
Saint-Augustin	4.36							G
Saint-Paul	4.51	0.86	1.01	1.79	1.71	1.58	1.59	G

* Fishing success not adjusted

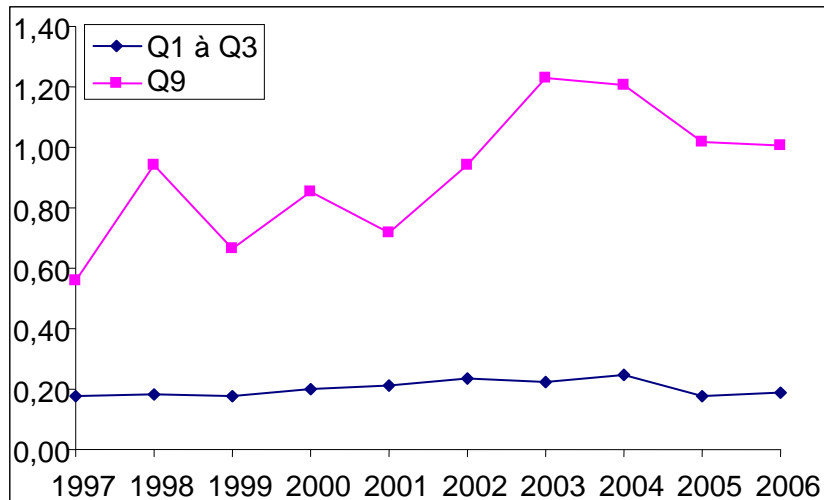G-retention of large (and small) salmon

Figure 24. Mean annual fishing success (number of salmon caught/day)
in CU 26 (Zone Q9) compared to mean fishing success in CUs 18-20
(zones Q1 to Q3).

Recovery Feasibility: Based on the evidence that conservation thresholds have in most cases been exceeded, and there remains further capacity to impose management measures which could further increase escapement, neither 'designation' nor recovery feasibility are issues for salmon of CU 26.

Anticosti Island (CU 27; Zone Q10)

Anticosti Island is located in the middle of the Gulf of St. Lawrence and has 24 salmon rivers.

Sport fishing: Only the Chaloupe, Ferrée, Rivière aux Saumons, Jupiter and Loutre rivers are currently open to salmon fishing (Table 15) but under the caveat that all large salmon must be released. The average annual grilse harvest for all rivers, 2002 to 2006, totaled 253 fish.

Subsistence fishing: There is no subsistence fishing on the Island.

Population status: Diver counts of spawners have been conducted annually since 2001 on the Chaloupe and Jupiter rivers. The information permits assessment of the attainment of each river's conservation threshold and the relative status of the other populations in the CU. From 2002 to 2006, the Chaloupe River twice reached its conservation threshold; the Jupiter River reached the threshold only once. As a result, compulsory release of large salmon has been a requirement since 2001 in all rivers open to fishing.

Table 15. Conservation threshold (eggs required), egg deposition as a percentage of conservation threshold, and fishing provisions for rivers of CU 27 (Zone Q10).

Zone Q 10	Eggs required (million)	Conservation threshold attained						Harvest
		2001	2002	2003	2004	2005	2006	
À la Patate	0.12	75%	48%	78%				X
Du Pavillon	0.12							X
Vauréal	0.14	71%						X
Bec-Scie	0.15	40%	24%					X
Ferrée	0.16	225%	84%	156%				M
Ruisseau Box	0.17							X
Aux Plats	0.17							X
Sainte-Marie	0.17							X
À l'Huile	0.19	16%	6%	48%				X
MacDonald	0.19	26%	22%	81%				X
Aux Cailloux	0.19							X
Galiote	0.19							X
Petite rivière de la Chaloupe	0.20							X
Maccan	0.20							X
Chicotte	0.20							X
Du Renard	0.21							X
Bell	0.21							X
Petite rivière de la Loutre	0.24							X
À la Loutre	0.24	33%	76%	114%	83%			M
Ruisseau Martin	0.26							X
Dauphiné	0.43							X
De la Chaloupe	0.58	118%	44%	112%	69%	58%	159%	M
Aux Saumons	0.80	78%	23%	48%				M
Jupiter	1.98	99%	37%	84%	76%	49%	117%	M

M- retention of grilse only, and X-Closed

Recovery Feasibility: The rivers of CU 27 have experienced a sharp decline in the number of spawners. Since the management plan was implemented, fishing has been prohibited in all the small rivers and compulsory release provisions for large salmon have been imposed on the remainder. In view of the current management measures and monitoring of two of the five open to fishing, neither 'designation' nor recovery feasibility are issues for salmon of CU 27.

Ungava (CU 28; Zone Q11)

Situated at the northern limit of Atlantic salmon in North America, CU 28 has four large rivers that drain into Ungava Bay and support Atlantic salmon. These rivers are the Rivière aux Feuilles, the Koksoak, the Rivière à la Baleine, and the George. Summers are short and salmon growth is restricted to fewer than 100 days per year. Distances from sea spawning areas are large, e.g., salmon of the Koksoak River must migrate about 480 km of river before reaching the spawning grounds in the tributary Rivière aux Mélèzes.

Salmon is neither the most abundant species nor the most popular among fishers of CU 28. These rivers also support populations of brook charr (*Salvelinus fontinalis*), Arctic charr (*Salvelinus alpinus*), lake whitefish (*Coregonus clupeaformis*) round whitefish (*Prosopium cylindraceum*), lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), suckers (*Catostomus catostomus* and *Catostomus commersoni*), burbot (*Lota lota*) and slimy and mottled sculpin (*Cottus cognatus* and *Cottus bairdii*).

Management of northern salmon populations poses special challenges for the following reasons: the salmon habitat of these rivers is not well documented; salmon co-exist with 13 other species; and the salmon life cycle differs from their more southern counterparts. For example, smolt ages range from 5 to 9 years, smolts may in some circumstances descend to and remain in the river's estuary before possibly returning to the river in the winter or migrating in a direction that takes them toward Greenland. As well, adult salmon may spend two consecutive years in the river in order to spawn.

Table 16. Conservation threshold (eggs required) for each river, adjusted fishing success (salmon caught per day), and fishing provisions for CU 28 (Zone Q11).

Zone Q 11	Eggs required (million)	Adjusted fishing success						Harvest
		2001	2002	2003	2004	2005	2006	
Aux Feuilles	0.40	1.31	1.52	1.98	1.68	1.13	2.38	G
Baleine	4.35	1.09*				1.02		G
George	4.35	0.69	0.25	0.65	0.41	0.76	0.80	G
Koksoak	5.80	2.32	1.44	3.21	3.53	3.34	2.57	G

 * Fishing success not adjusted
G-retention of large salmon (and grilse)

Fishing success in CU 28 has ranged from 0.25 to 3.53 salmon caught per day fished and generally been much greater than that of the reference CUs (see Figure 23). Also fishing success of the three rivers with a continuum of data since 2001 has generally increased relative to that of the reference CUs.

Recovery Feasibility: Historical salmon fishing reports suggest that rivers of CU 28 have always exhibited large fluctuations in salmon abundance. However, recent fishing success relative to that of CUs 18-20 suggests that conservation thresholds are being exceeded and that neither 'designation' nor recovery feasibility are issues for salmon of CU 28.

Overview for CUs 18-28

Survival of salmon in rivers and at sea are best documented for the Saint-Jean 9 (CU 2) and Trinité (CU 7) rivers which are on opposite shores of the St. Lawrence River and differ somewhat in their sea-age composition (Figure 25).
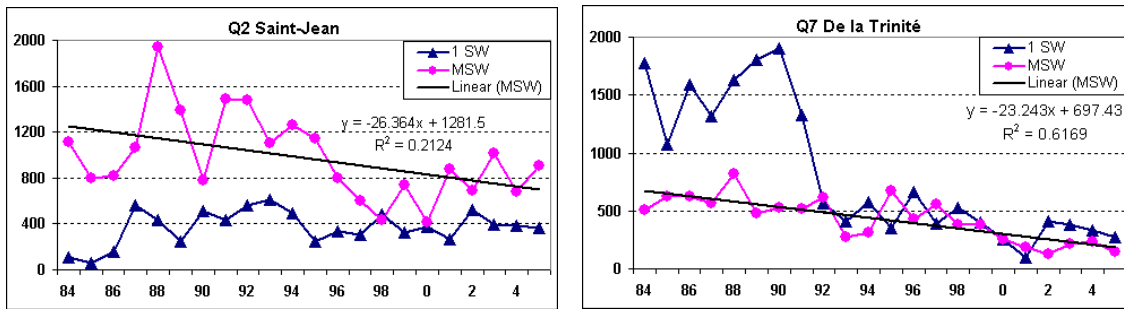
Figure 25. Sea-age composition of Atlantic salmon returning to the Saint Jean and Trinité rivers, 1984-2005.

In-river egg to smolt survival, 1980-2001 for the two rivers ranged from 1.5% to 5% (Figure 26). Mean values for the Saint-Jean and Trinité rivers were 2.86% and 2.31% respectively. Values for the most recent years have been somewhat less variable.

Figure 26. Egg to smolt survival rates for the Saint-Jean and Trinité rivers, where 'year' is that of egg deposition.

Return rates for Trinité smolts approximated 5% 1988-90, but thereafter and like those of the Saint-Jean, have largely encompassed a range of 0.5 to 2% (Figure 27). Values since 1999 suggest a return rate of 2% is again possible.
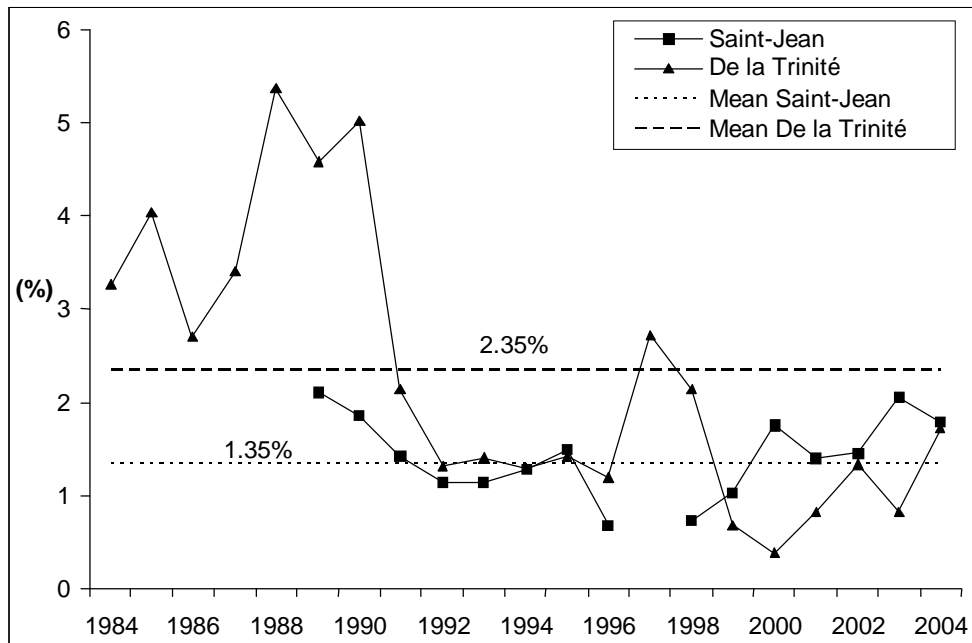
Figure 27. Survival rates for the Saint-Jean River and the Trinité rivers, where year is that of the smolt migration.
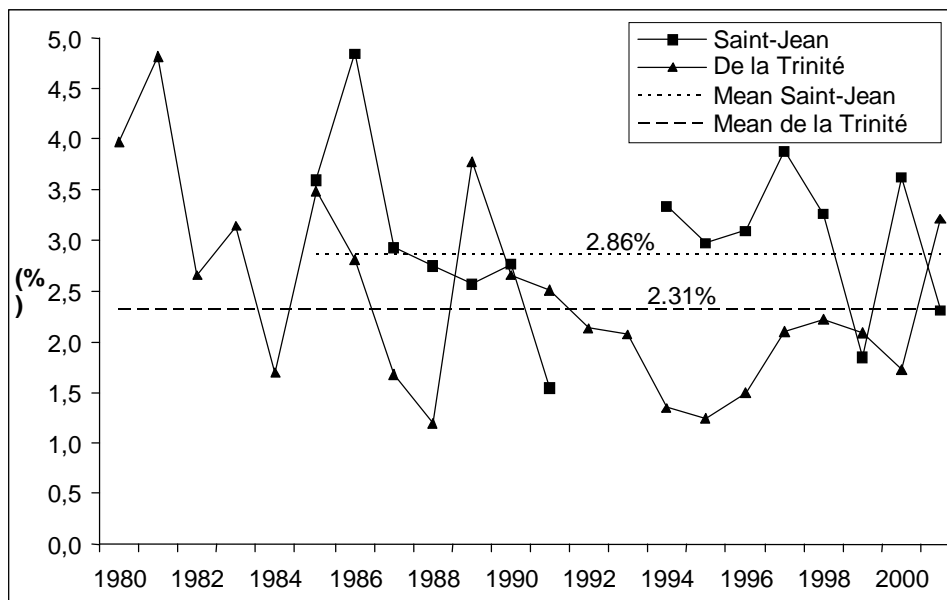
The total estimated number of large salmon returns to all salmon rivers in Quebec 1984 to 2006) (Caron and Fontaine 2007) has declined from about 75,000 per year during the period 1984 to 1992 to about 60,000 from 1993 to 1998 and to about 40,000 for the period 1999 to 2006 (Figure 28). Returns of grilse have declined less so, from about 40,000 per year for the period 1984–1996 to some 30,000 returns, 1997–2006 (Figure 28).

Declines in the number of spawners are less pronounced than the trend for returns, e.g., from roughly 37,000 large salmon during the first half of the period to 27,000 during the second half. A similar trend for grilse has occurred (Figure 28).
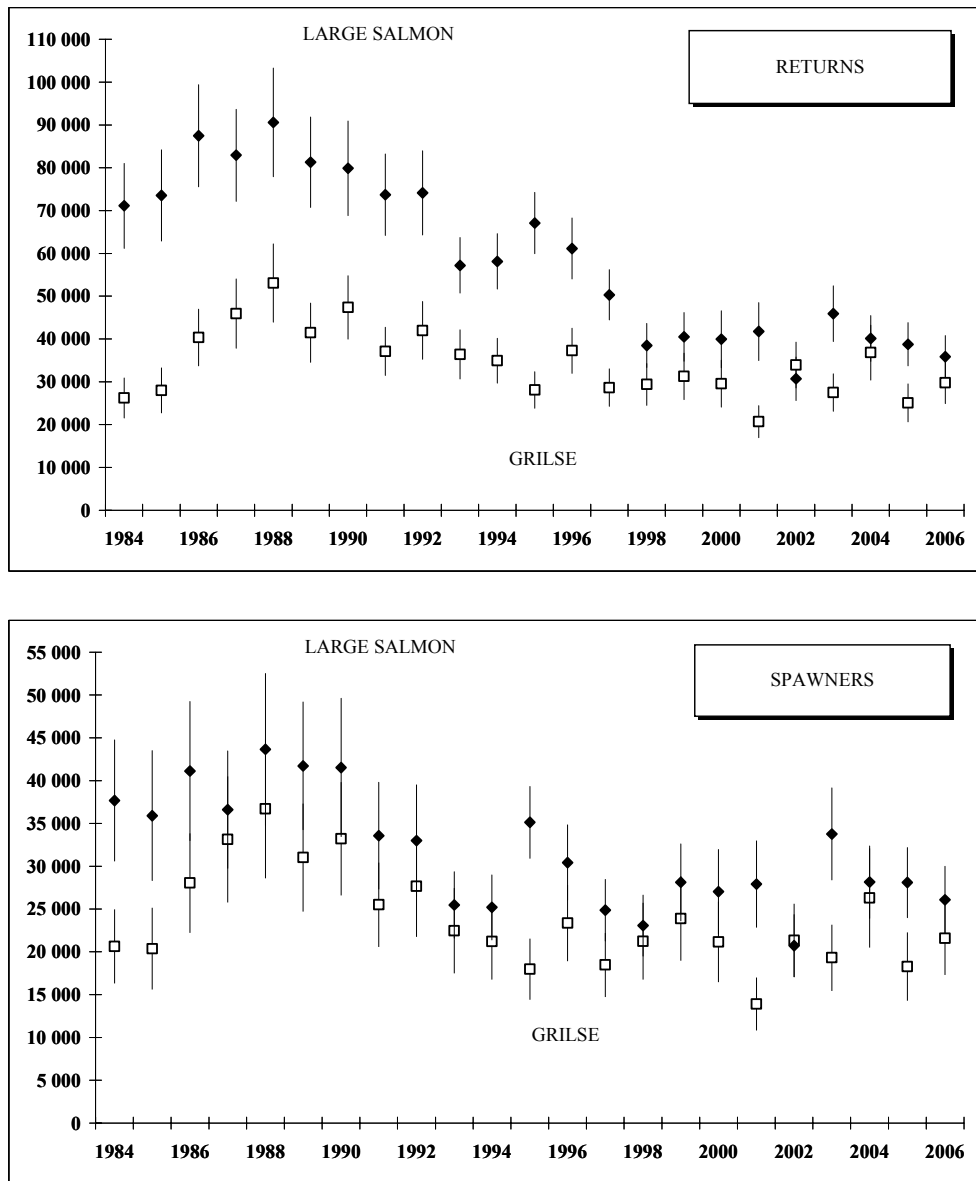
Figure 28. Numbers of returns and spawners (large salmon and grilse) to Quebec rivers, 1984 to 2006.

The narrowing of the gap between returns and spawners is attributable to the major management measures that have reduced catches, especially of large salmon. Measures included the gradual reduction since 1993 of commercial fishing and its total closure in 2000, and compulsory release provisions for large salmon, i.e., nearly 50% of the reported sport catch (Caron and Fontaine, 2007).

Because: i) the decline in sea survival of smolts appears to have been arrested; ii) conservation measures put in place appear to be sufficient to ensure maintenance of the spawning stocks above the conservation threshold in most rivers for which counts of spawners are carried out; iii) harvesting is prohibited in the case of small stocks; and iv)

special monitoring efforts are directed at stocks that are in trouble, neither designation nor recovery feasibility are considered necessary to ensure the maintenance and development of salmon stocks in Quebec.

CUs 9 – 12 (Southern Gulf of St. Lawrence Rivers)[37]

Northern New Brunswick (CU 9)

Abundance and trends: This unit area consists of the rivers defined within Salmon Fishing Area (SFA) 15 (see Appendix 6 for map of CUs in southern Gulf of St. Lawrence rivers). There are 15 rivers recognized with Atlantic salmon in this area of which the Restigouche River is the largest river. The Matapédia River, a major tributary in the lower portion of the Restigouche, is assessed separately by the province of Québec but considered part of this conservation unit. Most of the other rivers are comparatively small with freshwater habitat areas of less than one million m². Small salmon make up less than 50% of the returns to these rivers and are comprised mostly of males. Large salmon include 2SW and 3SW maiden spawners as well as repeat spawners. These older age groups are often greater than 70% female. Smolt age varies from predominantly two year old smolts in Nepisiguit to mostly three year old smolts in the Restigouche (Table 17). Large salmon (sexes combined) have a fecundity of about 6,000 eggs per fish. Most salmon return to the Restigouche prior to September 1, with bright salmon in the river by mid- to late-May. Salmon continue to ascend to the spawning areas into October. Salmon are counted through the Jacquet River and Nepisiguit River counting facilities into late October. Smolts migrate from mid-May to mid-June. Salmon from these rivers undertake long oceanic migrations as shown by recoveries of tagged salmon from these rivers at West Greenland. Salmon tagged as smolts from the Restigouche River have been intercepted at West Greenland in the last three years. Several rivers in this area have been stocked during the previous decades. Hatchery stocking was especially important in the Nepisiguit River with modest stocking programs in the Restigouche River. Stocking still occurs in the Nepisiguit and Restigouche rivers. Returns to the Restigouche River from stocking programs are considered to be less than 1% of total returns.

Abundance of adult salmon in the Restigouche River as inferred from the angling catches and from catch per unit effort indices indicates a slight decrease or an increase for the period 1992 to 2006 (Table 17; Figure 29). On average, about 7,000 salmon are angled annually in the Restigouche River. Counts at the two headwater barriers indicate a 50% decrease in abundance in the Northwest Upsalquith River tributary whereas the Causapscal River barrier (tributary of the Matapedia) indicates an increase (Table 17; Figure 29). Juvenile abundance in the Restigouche River has been monitored annually since 1972. Densities of fry, small parr and large parr all increased post-1984 and remain or are increasing to record high levels (Figure 29). Fry abundance since 1992 shows a slight decrease whereas small parr and large parr show strong increases in density (Table17; Figure 29). All sites sampled have become and remain occupied by juveniles with the exception of some small streams which are prone to periodic blockages to
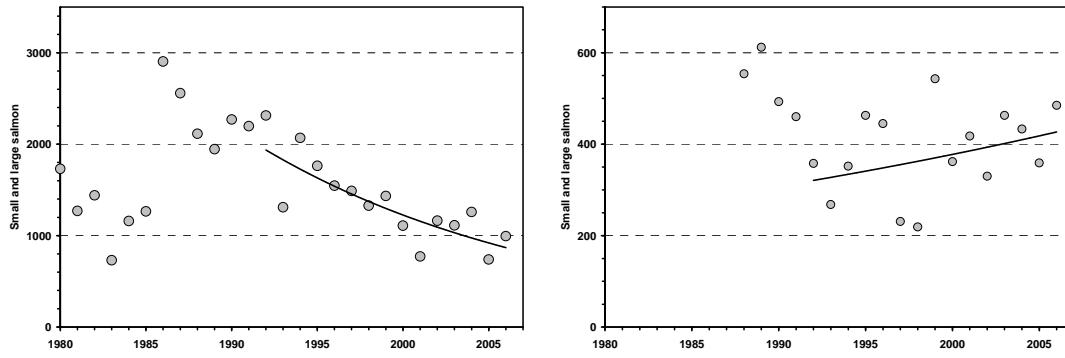
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[37] Copied, abstracted & synthesized from documents provided by Chaput, based on data available in Chaput *et al* 2006b.

spawners by beaver dams. The Matapédia River time series is shorter, starting in 2000, and densities of juveniles are at comparable levels to those of the Restigouche (NB) sites.

Table 17. Summary of status indicators and trends for rivers in CU 9, Northern New Brunswick.

		Restigouche		Matapedia		Nepisiguit		Jacquet	
	Life stage	Level in past 5 years	Trend (1992 to 2006)	Level in past 5 years	Trend (1992 to 2006)	Level in 2000 to 2004	Trend (1992 to 2006)	Level in 1999 to 2004	Trend (1992 to 2006
Angling catch	Adult	5,828	+ 2%	1,677	+ 24%				
CPUE (fish per rod day)	Adult	0.64	+ 38%	0.20	- 8%				
Barrier counts	Adult	1,009	- 57%	423	+ 36%			550 (incomplete counts)	-65% (based on incomplete counts
Juvenile abundance (fish/100 m²)	Fry	53	- 9%	58		33	+149%	71	
	Small parr	18	+ 39%	22		5	- 1%	29	
	Large parr	7	+ 73%	11				6	
	Distribution of juveniles	Found at all sites (N = 65 to 79 annually)	All sites remain occupied	Found at all sites (N = 13 to 27 annually)		N = 11 to 12 sites	N = 6 to 13 sites	N = 6 sites	
Returns relative to conservation requirements		Qualitative indicator, met in most years	Presumably met in most years	157% to 226%	Met in 13 of 15 years	At or above for most years assessed	At or above since 1994 (based on redd counts)	Incomplete counts owing to numerous washouts	
Large salmon in returns	Adult	55%		65%		50%		48%	
Maiden salmon in returns	Adult	94%				91%			
Maiden age structure 1SW-2SW-3SW	Adult	51%-39%-11%				62% - 27% - 11%			
Smolt ages 2-3-4-5	Smolt	27%-70%-4%-0				90% - 10% - 0 - 0			
Percent female in 1SW-2SW-3SW	Adult	7%-67%-80%				5% - 51% - 79%			
Fork length cm) of 1SW-2SW-3SW		54 - 76 - 92				55 – 78 - 93			

Counts of all adult salmon at the Northwest Upsalquitch Barrier (left) and Causapscal Barrier (right).
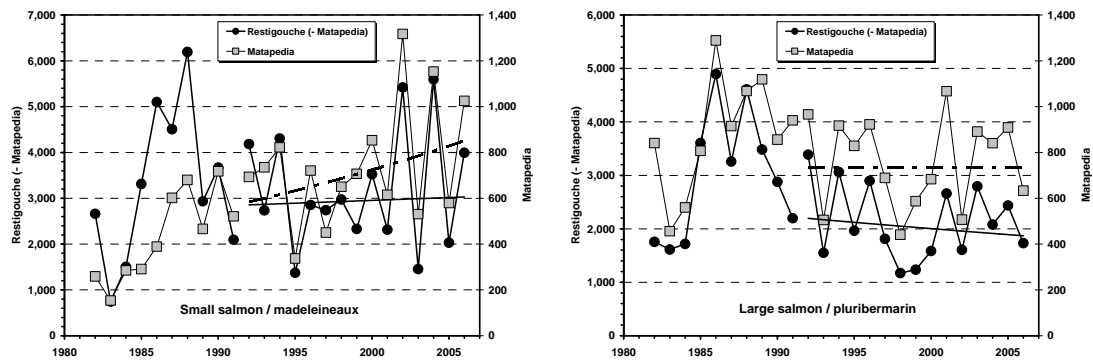
Angling catches of small salmon (left) and large salmon (right) from Restigouche River (excluding Matapedia) and Matapedia River.
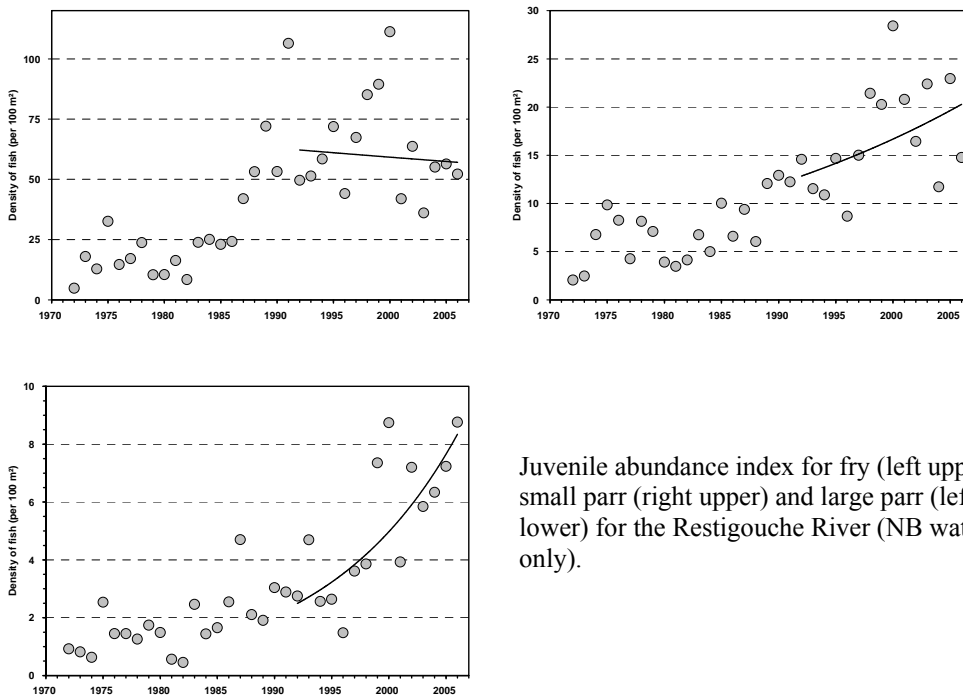
Juvenile abundance index for fry (left upper), small parr (right upper) and large parr (left lower) for the Restigouche River (NB waters only).

Figure 29. Restigouche indices of salmon abundance (CU 9).

Status: A number of qualitative indicators have been used to infer whether conservation requirements were met. Based on the requirement of 7,000 large salmon and an assumed catch rate of 30% in the angling fishery, conservation would have been met in 12 of 15 years since 1992. In the Matapédia River, conservation has been achieved every year since 1994. Spawning escapements above conservation are consistent with the sustained high densities of juveniles in the Restigouche River.

Over the last two decades, assessment data have also been collected from the Jacquet River and the Nepisiguit River (Table 17). Counts of salmon at a protection barrier near the head of tide on the Jacquet River have frequently been incomplete due to washouts or late installations. The status of the Nepisiguit River has been uncertain. Estimates of returns and escapements based on fence counts which are generally incomplete indicated that conservation requirements had been achieved in only 2 of 15 years when the stock was assessed (1982 to 1996) (Locke *et al* 1997), but estimates based on redd counts in late fall collected by the Nepisiguit Salmon Association indicated that spawning escapement had been around the conservation requirements since 1994 (DFO 2001).

Salmon fry densities in the Nepisiguit River have increased since the 1980s whereas parr abundance has remained unchanged (Figure 30). Juvenile abundances in the Jacquet River are at comparable levels to those of the Restigouche River. Adult abundance in the Jacquet River has exceeded the conservation requirement at the start of the time series, but, in recent years, its status relative to conservation is unknown due to frequent washouts, especially in the fall (Figure 30).
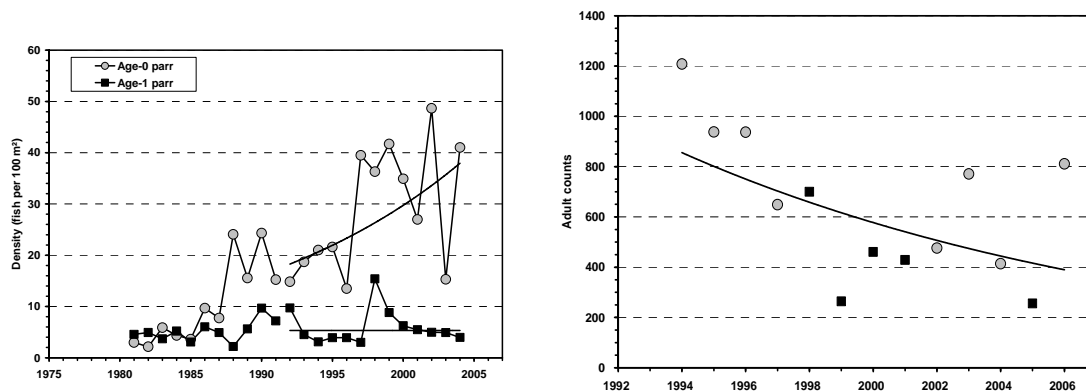
Figure 30. Juvenile indices of abundance from the Nepisiquit River (left panel) and counts of salmon at the Jacquet River barrier. Square black symbols show years with incomplete counts (right panel).

Recovery feasibility: Although recovery objectives have not been defined for the rivers in CU 9, a proxy objective could be to attain returns that are generally at or above the conservation limit (8 of 10 years for example). Returns to CU 9 meet that objective so recovery feasibility is not considered an issue.

Central New Brunswick (CU 10)

Abundance and trends: This CU consists of the rivers defined within Salmon Fishing Area (SFA) 16 (see Appendix 6 for map of CUs in southern of Gulf of St. Lawrence

rivers). There are 25 recognized Atlantic salmon rivers in this area of which the Southwest Miramichi River is the largest with a drainage area of over 5,800 km². Four rivers within this area have greater than 5 million m² of juvenile rearing area, whereas 13 rivers are very small with less than 0.5 million m² of habitat area.

Small salmon (fork length < 63 cm) make up less than 50% of the returns to the small rivers in this area but are, on average, two-thirds of the adult salmon returning to the Miramichi River (Table 18). The small salmon are about 80% male in the Miramichi and 90% or higher in the other small rivers. There are a few 3SW maiden age salmon in this area, but most of the large salmon (fork length >= 63 cm) are maiden 2SW and repeat spawners. These older age groups are most often greater than 80% female and predominantly of freshwater age-2 and age-3 – only a few are of age-4. Large salmon (sexes combined) have a fecundity of about 6,000 eggs per fish. Most salmon return to the small rivers in this area during September to October. The return of salmon to the Miramichi estuary has a bimodal distribution with a first peak around early to mid-July (early run) and a second peak in late September to mid-October (late-run) (Figure 31). Smolts migrate from mid-May to mid-June. Salmon from these rivers undertake long oceanic migrations as shown by recoveries of tagged salmon from these rivers at West Greenland. Salmon tagged as smolts and as bright salmon from the Miramichi River are annually intercepted at West Greenland. Several rivers in this area have been stocked during the previous decades. Hatchery stocking has occurred annually in the Miramichi River but returns from stocking represent about 1% of total returns. Stocking programs have been initiated in a few of the small rivers in the southeast portion of this area.

The abundance of adult salmon in the Miramichi River has decreased by 58% over the period 1972 to 2006 (Figure 32). The average abundance during 2002 to 2006 has been 53,000 fish representing about 35,000 small salmon and 18,000 large salmon (Table 18; Figure 32). The decline in small salmon has been more important than for large salmon. During 1992 to 2006, the small salmon abundance has ranged from the lowest to the highest levels estimated dating back to 1971 (Figure 32). Counts at headwater facilities in the branches of the Miramichi show a decline of 37% in adult salmon abundance in the Northwest Miramichi and a 22% decline in the Southwest Miramichi (Table 18; Figure 33). The catch per rod day of angling effort in the crown reserve waters of the Northwest Miramichi has declined by 58% since 1992, (Table 18; Figure 33). Juvenile abundances of all age groups have increased to record highs in both the Northwest and Southwest Miramichi (Figure 34). Fry and small parr abundances in the Southwest Miramichi have declined by 30% and 24% respectively, since 1992 consistent with the decline in returns and spawners to the Miramichi River (Table 18; Figure 31). Fry abundance has declined slightly in the Northwest Miramichi whereas both small parr and large parr abundances have continued to increase (Table 18; Figure 34). Standing biomass per site in both branches of the Miramichi has averaged 415 g for the past five years. Estimates of smolt production from the Miramichi River have ranged from 600 thousand to 1.5 million fish, a production rate range of just over 1 to over 3 smolts per 100 m².

The smaller southeast rivers of this area have been closed to all fishing since 1998. Assessments of adult returns to the Buctouche River, the index river for this group of southeast rivers, indicated that the conservation limit was met or exceeded once in eight

years between 1993 and 2000 (Table 18). Juvenile abundance in these rivers has generally been much lower than in the Miramichi River. Following on the returns of 1999, which were estimated to have exceeded the conservation requirement, fry abundances in 2000 increased to over 40 per 100 m² followed by small parr abundance in 2001 of over 25 per 100 m², the highest levels observed in the time series (Figure 35). Similar increases in fry were observed in 2000 (Figure 35) in other southeast rivers suggesting that returns in 1999 to all these rivers had been much better than previously and that the Buctouche River and the juvenile sampling were sufficient indicators of adult abundance in these rivers. Based on the juvenile abundance index, the other rivers have likely been consistently below conservation since at least 1993.

Table 18. Summary of status indicators and trends for rivers in CU 10, Central New Brunswick.

| | | Miramichi | | | | Tabusintac | | Buctouche | |
| | | Northwest Miramichi | Southwest Miramichi | Northwest Miramichi | Southwest Miramichi | | | | |
	Life stage	Level in past 5 years		Trend (1992 to 2006)		Level (1993 to 1999)	Trend	Level	Trend
Returns of adult salmon	Small	35,400		-60%		976		90	None
	Large	17,700		-47%		1,046		157	None
	Adult	53,000		-58%		2,023		247	None
Relative to conservation requirements	Returns	93% (85% for spawners)		-54% (conservation met in 7 of 15 years)		> 100% in four years assessed		33% to 100%	Met in 1 of 8 years
Barrier counts	Adult	788	2,441	-37%	-22%				
CPUE angling (crown reserve)	Adult	0.31		-58%					
Juvenile abundance (fish/100 m²)	Fry	59	75	-10%	-30%	61		20	
	Small parr	26	22	+ 28%	-24%	17		13	
	Large parr	8	5	+249%	+174%	9		3	
	Distribution of juveniles	Found at greater than 97% of sites (N = 30 to 34 sites)	Found at greater than 97% of sites (N = 34 to 38 sites)	All sites remain occupied	All sites remain occupied	Salmon juveniles at 18 of 25 sites in 1999		Salmon juveniles at all 8 to 9 sites	
Large salmon in returns	Adult	37%		+8%		53%		63%	
Maiden salmon in returns	Adult	93%		-7%		90%		84%	
Maiden age structure 1SW-2SW-3SW	Adult	73%-27%-1%		+3% for 1SW -7% for 2SW				46%-54%-0	
Smolt ages 2-3-4	Small	40%-58%-2%				18%-78%-4%		40%-56%-5%	
	Large	46%-53%-1%				35%-65%-0		66%-34%-0	
Percent female in 1SW-2SW-3SW	Adult	20%-89%-90%		No trend		6% - ? - ?		11%-86%-?	
Fork length (cm) of 1SW-2SW-3SW		54 - 74 – 88		+ 2% 1SW fork length + 3% 2SW fork length		57 - ? - ?		56 – 76- 101	
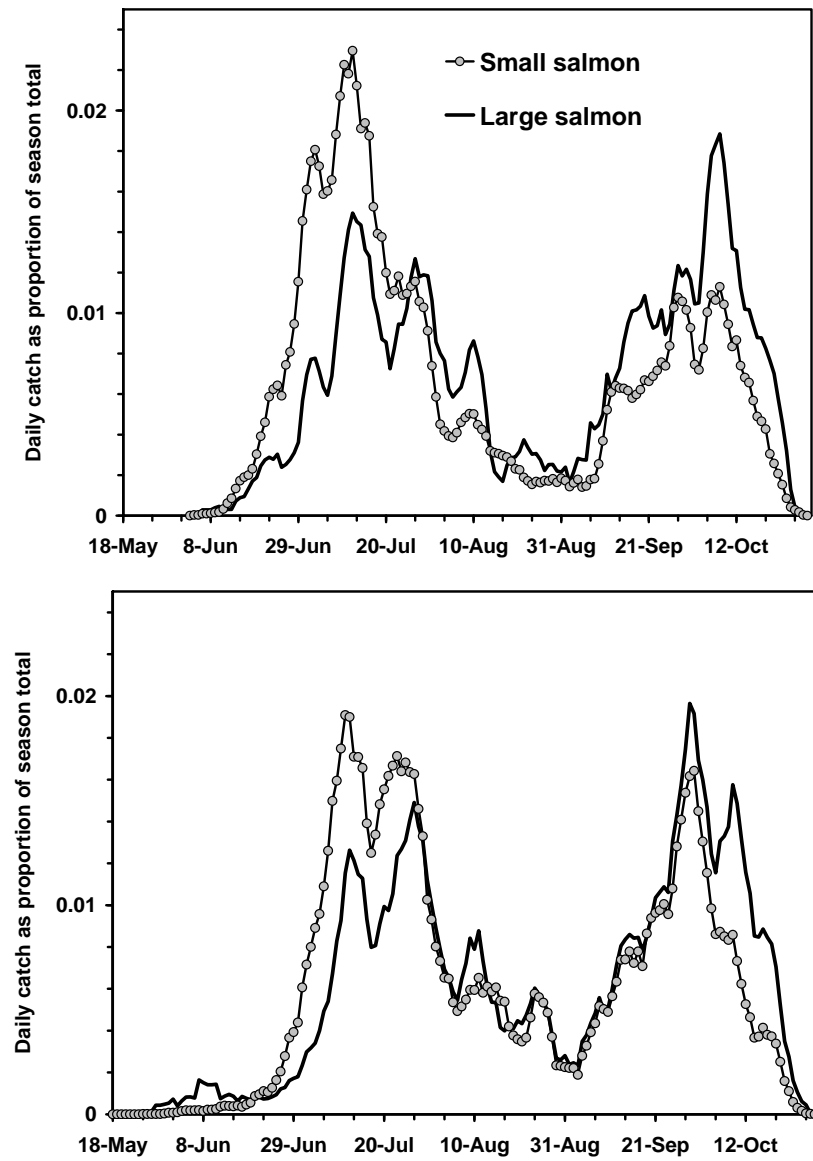
Figure 31. Timing of catches at estuarine trapnets in the Northwest Miramichi (upper) and the Southwest Miramichi (lower).
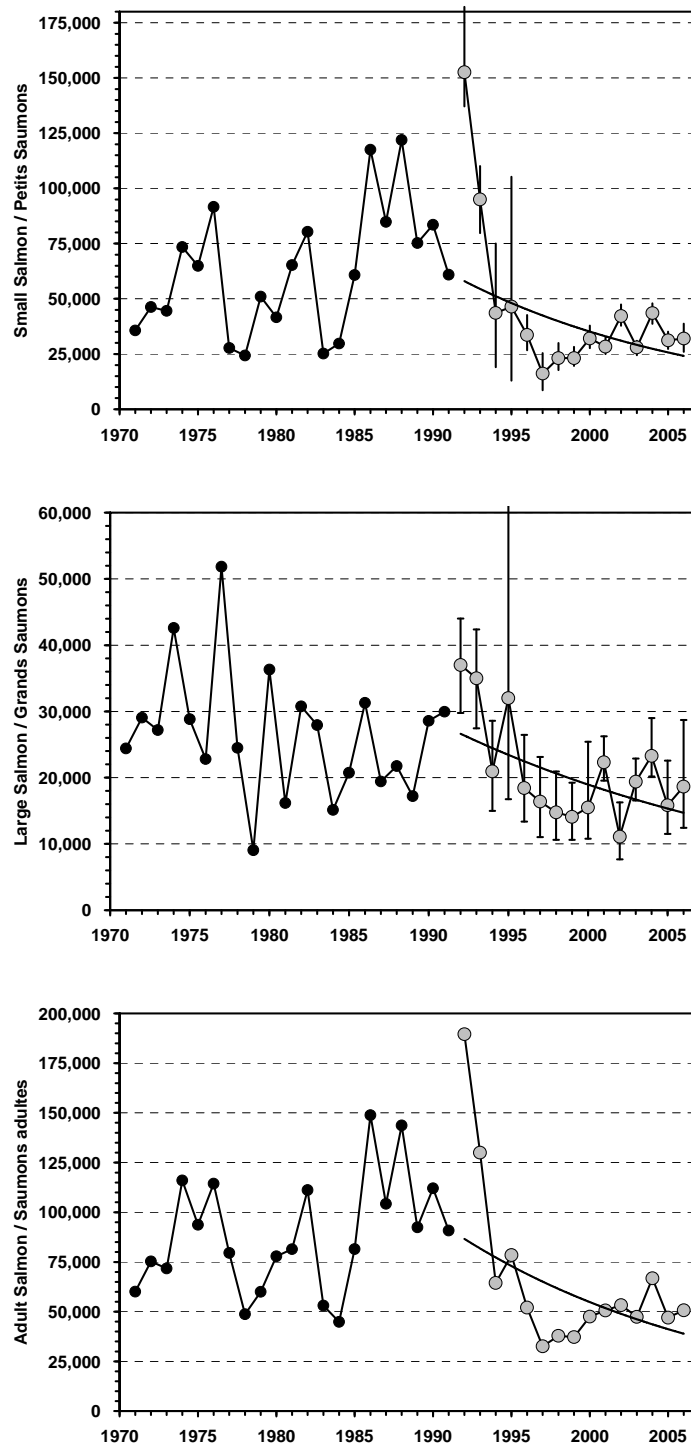
Figure 32. Estimates of returns of small salmon (upper), large salmon (middle) and size groups combined (lower) to the Miramichi River, 1971 to 2006. (Open points based on mark-recapture experiments on each of the Southwest and Northwest branches; closed points derived from counts at an estuarial trap and estimated trap efficiency.)
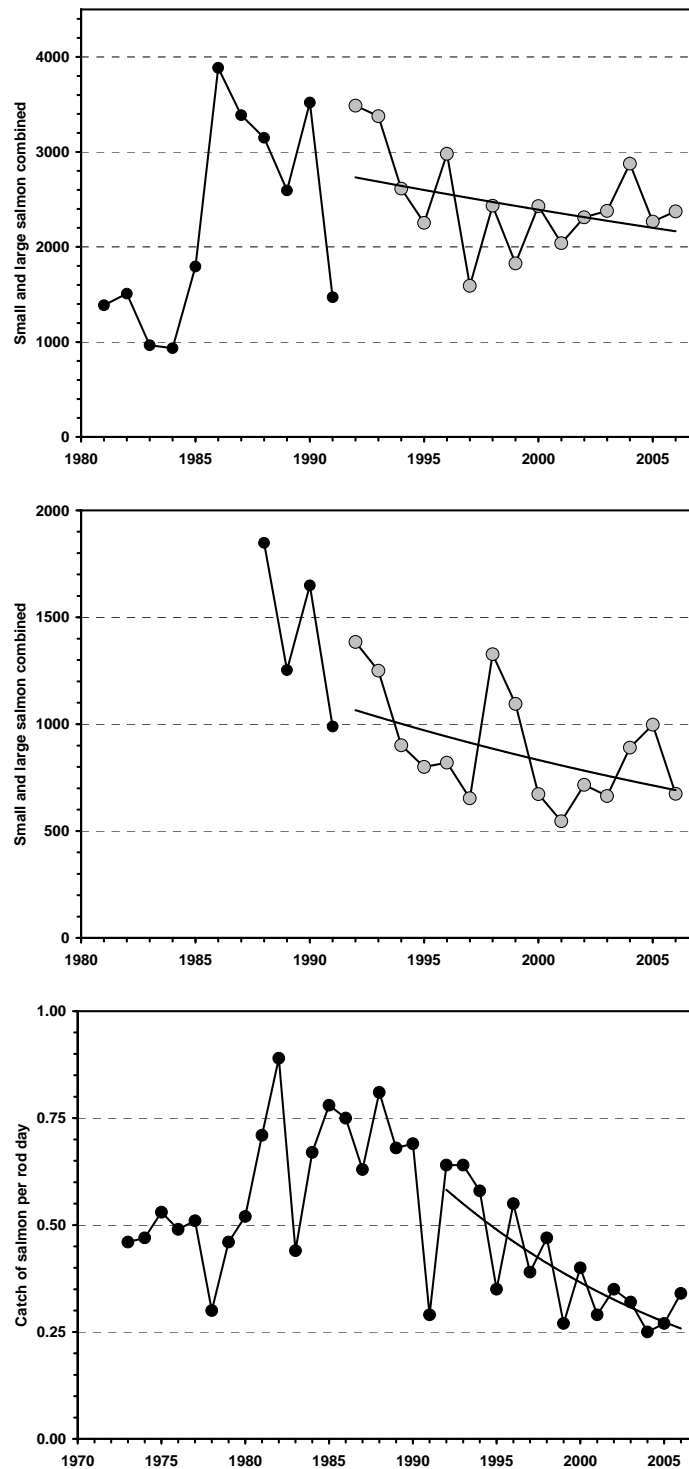
Figure 33. Counts of salmon (size groups combined) at the two headwater barriers in the Southwest Miramichi (upper), at the single headwater barrier in the Northwest Miramichi (middle), and angling catch per rod day in the crown reserve waters of the Northwest Miramichi (lower).
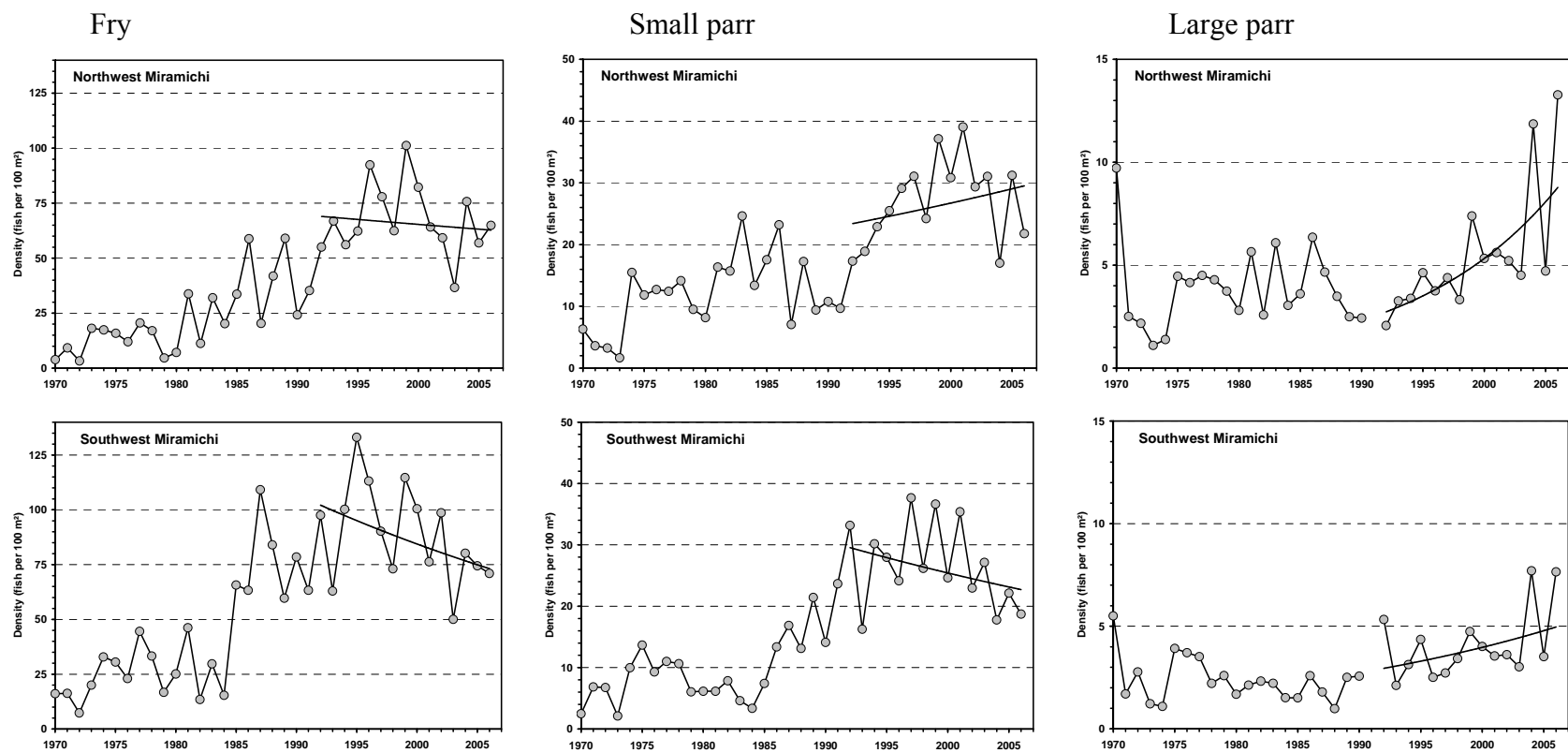
Figure 34. Indices of abundance (fish per 100 m²) of juvenile salmon by age/size groups in the Northwest Miramichi (upper panels) and the Southwest Miramichi (lower panels), 1970 to 2006.
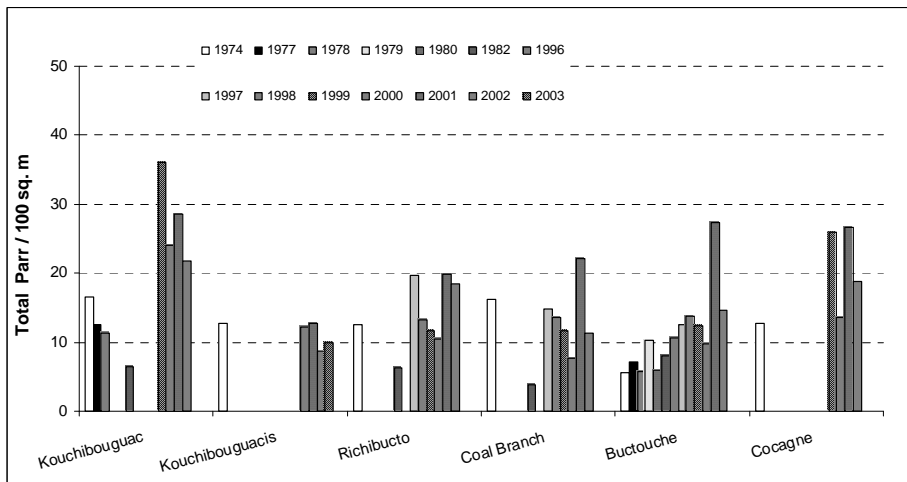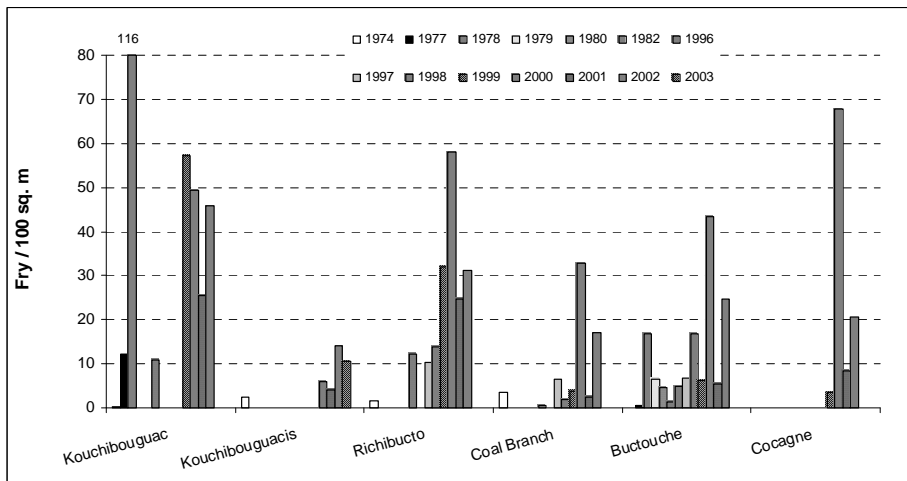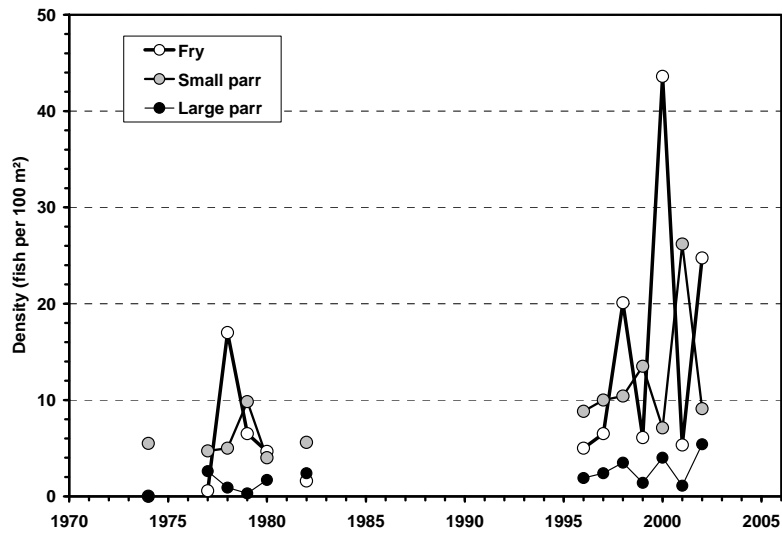
Figure 35. Juvenile abundance in the Buctouche River (upper) and comparisons of juvenile abundances in the small southeast rivers of SFA 16.

Marine survival trends: In CU 10, smolt enumeration programs began in 1999 in the Miramichi River. Return rates for 1SW salmon have varied between 2% and 6% whereas return rates for 2SW salmon have been between 0.5% and 2%. The adult salmon return rate to a second and subsequent spawning has been increasing since the 1970s. Return rates to a second spawning for 1SW maiden salmon have exceeded 5% in the past five years while return rates for 2SW maiden salmon were greater than 10% and have been as high as 25% (Figure 36a and b). These return rates are uncorrected for in-river fisheries removals in river. In CU 11 (PEI), there are no recent estimates of return rates of hatchery origin salmon. In the late 1980s and early 1990s, return rates of hatchery smolts to adult salmon ranged from less than 0.2% to as high as 9.0% (Cairns *et al* 1996). In CU 12, smolt enumeration programs began in 2001 in the Margaree River. Return rates to large salmon were roughly estimated to be between 2.9% and 5.4%.

	2001	2002	2003	2004	2005	2006
Smolt run size estimates		63,200	83,050	109,000	91,700	114,200
Large salmon returns		1,494	2,783	3,443	3,277	3,167
Coarse return rate (year+2)				**5.4%**	**3.9%**	**2.9%**
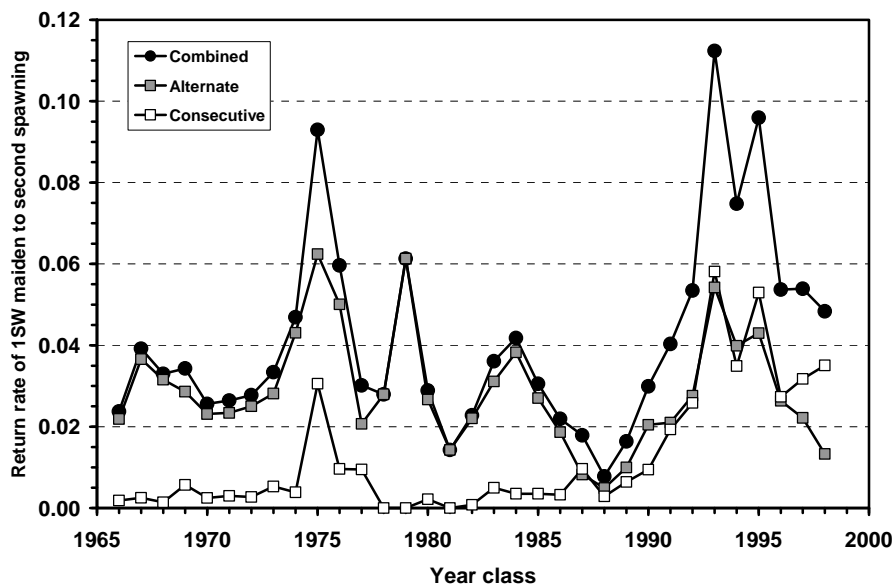
Figure 36a. Return rates to a second spawning of 1SW maiden maiden salmon in the Miramichi River.
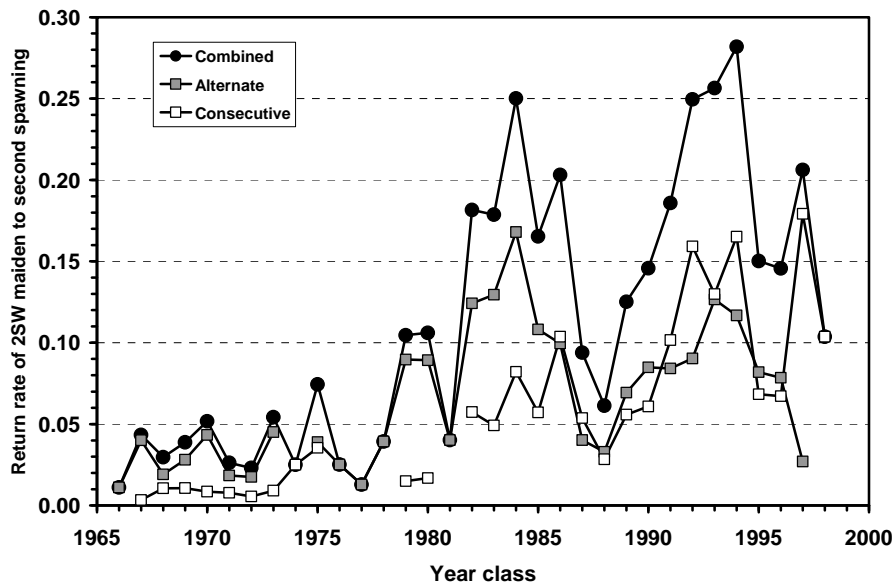
Figure 36b. Return rates to a second spawning of 2SW maiden salmon in the Miramichi River.

Status: Based on the data series from the Miramichi River, adult abundance was higher in the late 1980s and early 1990s than in the past decade. As a result of changes in fisheries management, particularly the closure of the Maritime Provinces and Québec commercial fisheries and the mandatory catch and release measures in the angling fishery since 1984, spawning escapement has increased which has resulted in increased abundance of juvenile salmon. Juvenile salmon abundance has started to decline as returns have declined but juveniles remain well dispersed in the Miramichi and densities are more than twice the abundances of the 1970s and early 1980s. Returns to the Miramichi have been sufficient to meet the conservation requirements in 2 of the last 10 years. Eggs in the returns of adult salmon during 1992 to 2006 have been sufficient to meet or exceed the conservation requirements for the Miramichi in 7 of the 15 years although conservation requirements have only been met or exceeded in 2 of the last 10 years (Figure 37). Losses of large salmon occur primarily in the First Nations fisheries with an additional assumed loss due to catch and release fishing. On average, 83% of the conservation requirement was estimated to have been met by spawners in the past 5 years (Figure 37). The abundance of repeat spawners in the Miramichi has increased since the closure of the retention fisheries on large salmon. Repeat spawners represent between 30% and 50% of the large salmon and salmon on their fifth to seventh spawning migrations have been regularly sampled since 1992 (Figure 38). Annual returns to the Miramichi River are now derived from 8 to 9 year classes compared to the 5 to 6 year classes during the 1970s and 1980s (Chaput and Jones 2006). Fork lengths of 1SW and 2SW salmon have also been increasing since the late 1980s (Figure 38). There has been a 2% increase in fork length of 1SW salmon and a 3% increase in fork length of 2SW salmon since 1992 (Table 18; Figure 38).

The Tabusintac River has exceeded its conservation requirement in the four years it was assessed (Table 18). The smaller southeast rivers have generally not met their conservation requirements. Juvenile abundance remains low in these rivers reflecting

lower adult abundance and possibly lower carrying capacity of the habitat. These smaller rivers have remained closed to all fisheries since 1998.
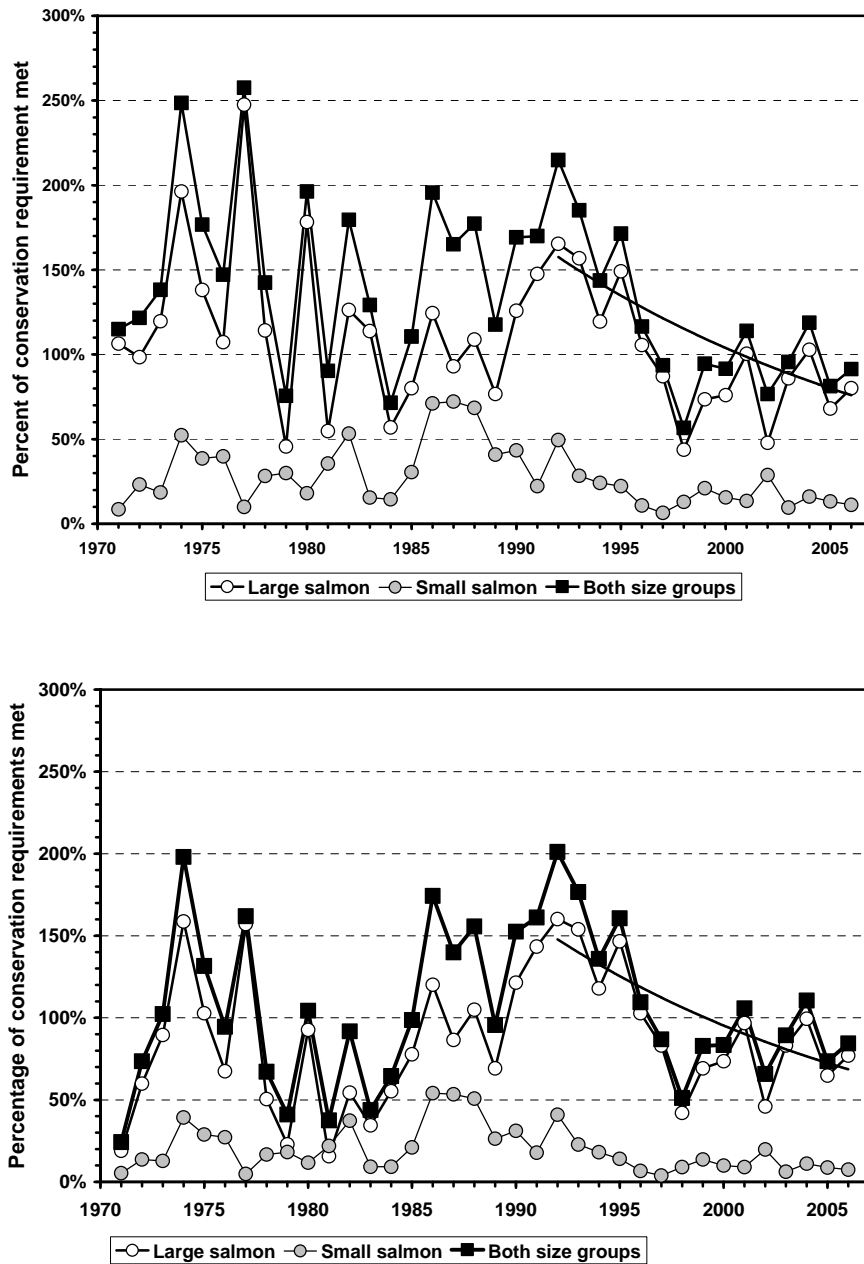
Figure 37. Estimated percent of conservation requirement (eggs) met by returns (upper) and spawner (lower) to the Miramichi River, 1971 to 2006.
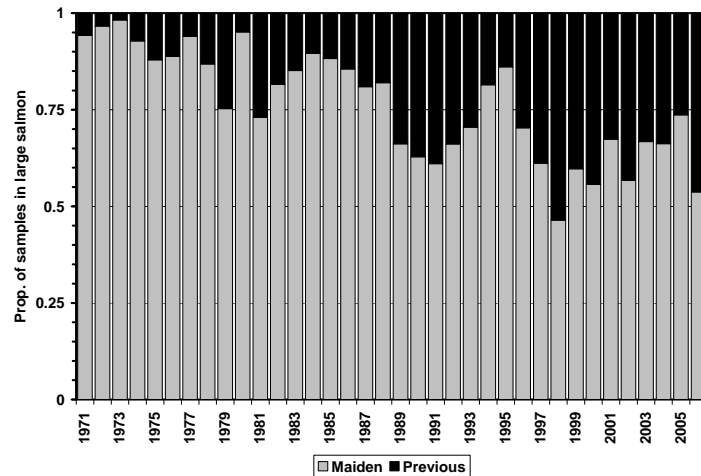
	Spawning migrations							Total
Year	1	2	3	4	5	6	7	Samples
1971	550	17	1	.	.	.	.	568
1972	1180	17	.	.	.	.	.	1197
1973	1451	15	.	.	.	.	.	1466
1974	1904	39	3	.	.	.	.	1946
1975	1317	40	2	.	.	.	.	1359
1976	1159	21	1	.	.	.	.	1181
1977	902	30	3	.	.	.	.	935
1978	638	38	.	.	.	.	.	676
1979	803	22	4	.	.	.	.	829
1980	851	14	5	.	.	.	.	870
1981	643	12	4	.	.	.	.	659
1982	594	17	2	.	.	.	.	613
1983	277	11	.	.	.	.	.	288
1984	323	9	.	1	.	.	.	333
1985	357	16	5	.	.	.	.	378
1986	667	38	3	.	.	.	.	708
1987	360	11	1	.	.	.	.	372
1988	530	37	6	2	.	.	.	575
1989	421	65	6	1	.	.	.	493
1990	494	109	33	7	.	.	.	643
1991	333	81	39	12	.	.	.	465
1992	1324	178	105	49	10	2	.	1668
1993	636	79	47	24	3	.	.	789
1994	1728	127	34	19	4	3	.	1915
1995	2068	172	40	19	3	2	1	2305
1996	1275	211	61	20	2	3	.	1572
1997	1292	308	123	51	6	2	1	1783
1998	1339	210	91	36	5	1	1	1683
1999	1261	168	76	36	9	2	.	1552
2000	1837	275	108	61	21	2	1	2305
2001	2807	499	125	66	31	6	2	3536
2002	2670	208	71	31	27	4	1	3012
2003	1345	220	59	28	8	7	1	1668
2004	2539	320	94	32	8	1	1	2995
2005	1143	179	48	17	5	.	.	1392
2006								
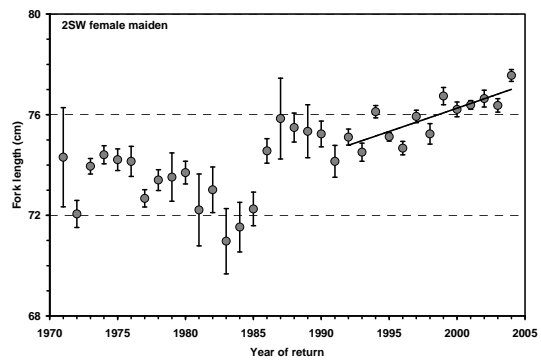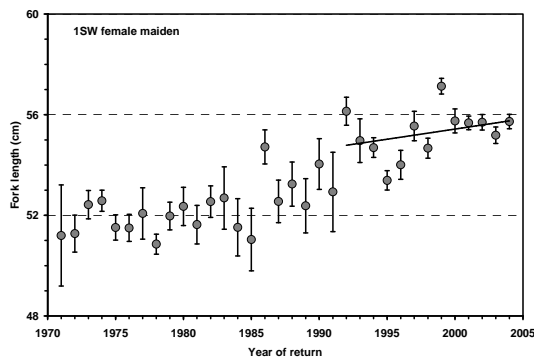
Figure 38. Variation in biological characteristics of Atlantic salmon from the Miramichi River.

Recovery feasibility: The small rivers in the southeast part CU 10 have been consistently below their conservation requirements and it is questionable whether the productivity of these rivers is sufficient to produce salmon consistently above those levels. These rivers have remained closed to directed salmon fisheries.

Based on the proposed recovery objective of generally meeting or exceeding the conservation requirement, the Miramichi River would not be considered recovered as it has only met the conservation requirement in 2 of the past 10 years. Juvenile abundance remains high and there is no evidence of contraction of spawning distribution. Increased abundance of repeat spawners and the increasing diversity of spawning age structure has tempered the overall decline in maiden salmon returns. The 1991 to 1995 year classes have not replaced themselves as maiden spawners nor in terms of their lifetime egg contributions (Figure 39). The 1996 to 1998 year classes will have replaced themselves over their lifetime but only as a result of the increase in repeat spawners for those year classes (Figure 39). The recruitment to parental stock dynamic for the Miramichi suggests that the recruitment is most frequently less than the parental stock abundance when egg depositions are above the conservation requirement (Figure 39). The recruitment trajectory has been flat and below the historical recruitment levels as egg depositions have declined from 1992 to 1998 (Figure 39).

Chaput and Jones (2006) have concluded that the prognosis for the Miramichi remains positive. Freshwater production and marine return rates of 1SW and 2SW maiden salmon appear to be sufficient in recent years to replace the eggs which produced them, at least when egg depositions were below 150 million eggs. Size at age has increased such that every female now has the potential to produce more eggs, there is a high survival to second and third spawning, and juvenile production remains high. The outstanding question is whether inter-cohort competition of the juveniles is resulting in density dependent mortality in fresh water resulting in reduced smolt production, whether observed declines in adult abundance are due to reduced marine survival in the past decade, or a combination of both.
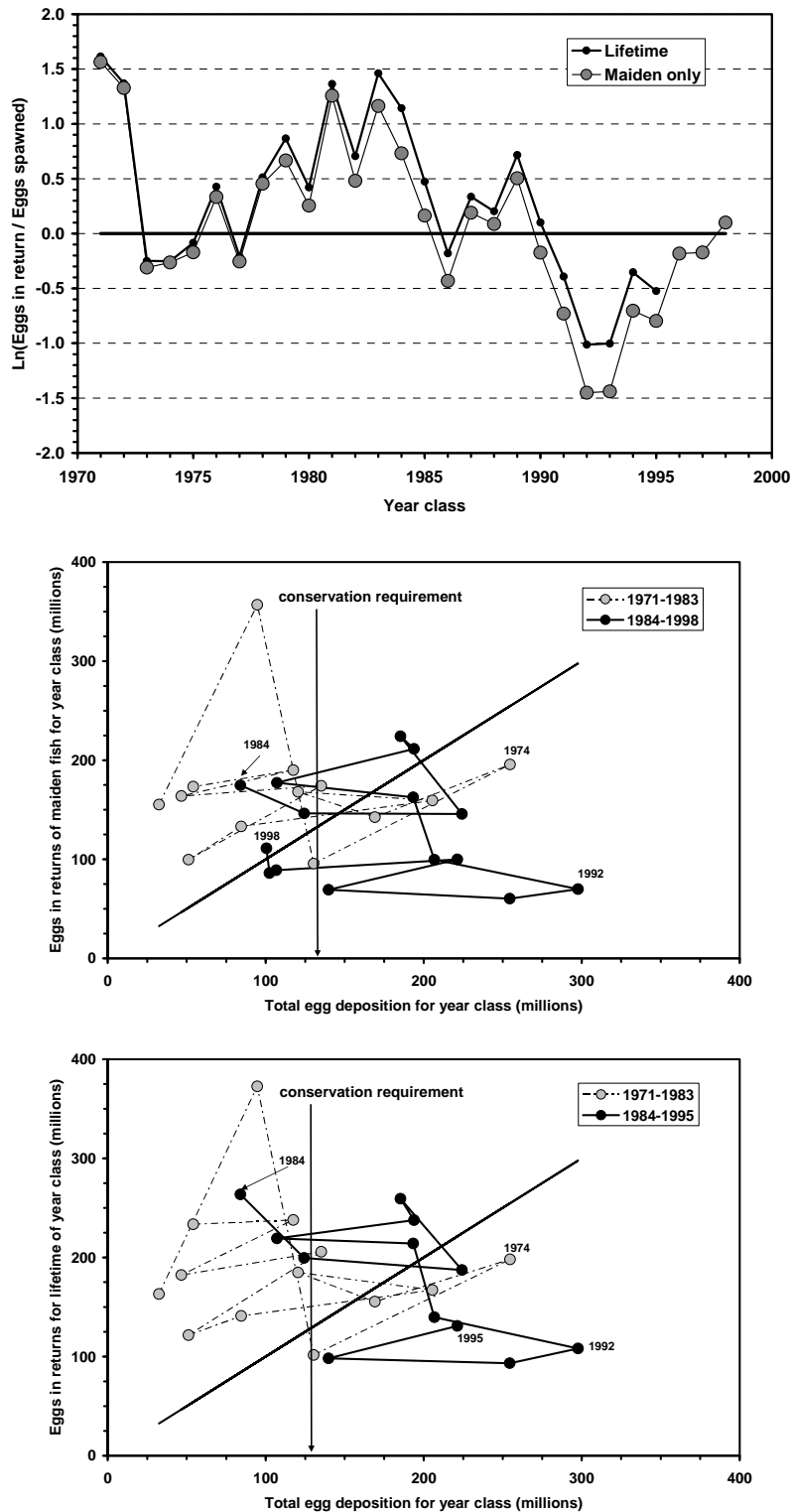
Figure 39. Replacement ratio (upper) and egg recruitment to maiden stage (middle) and lifetime egg recruitment (lower) versus egg depositions for Miramichi River Atlantic salmon.

111

Prince Edward Island (CU 11)

Abundance and trends: Between 1955 and 1980, annual catches of adult salmon in the Morell River were generally less than 25 fish, with a maximum annual catch of 51 fish recorded in 1963 (Cairns *et al* 1996). After 1985, and as a consequence of the increased hatchery program, annual catches in the Morell increased to hundreds per year with a maximum of 781 fish in 1992. Since then, annual catches have declined to a few hundred or less fish per year. The catches from the Morell River generally represent more than 90% of the total catch for this area. Returns to the Morell River in 1988 were just under 1,500 adult salmon but these levels could not be sustained without hatchery stocking.

Trends in marine survival: There are no recent estimates of return rates of hatchery origin salmon. In the late 1980s and early 1990s, return rates of hatchery smolts to adult salmon ranged from less than 0.2% to as high as 9.0% (Cairns *et al* 1996).

Status: In the late 1980s and early 1990s, returns of salmon to the Morell River were estimated to have been greater than the conservation requirement with hatchery origin salmon contributing more than 80% of the eggs (Cairns *et al* 1996). Returns of wild origin salmon have never been greater than 25% of the conservation requirement. Returns to the other rivers in this area have consistently been less than 25% of requirement. A small amount of natural production occurs in the Morell and other stocked rivers. Small runs of late-returning salmon persist in a number of unstocked rivers. Egg depositions have little influence on future returns in stocked rivers because most returns are of hatchery origin. Juvenile levels in the Morell River are low compared to the abundances in the neighbouring rivers in CU 10 and 12.

Recovery feasibility: If a recovery objective was to be defined for the rivers in this area, it would be that the returns are generally at or above the conservation limit (8 of 10 years, for example). All the rivers in this area are considered to be below the recovery objective.

The chief limitation to Atlantic salmon production in PEI is stream sedimentation caused by agriculture and other land use activities (DFO 2000b). Cultivation techniques, which reduce erosion and pesticide run-off, have become more widespread in recent years, but potato farming acreage has also increased. Substantial self-sustaining salmon runs cannot be expected to occur or be re-established until these impacts are significantly reduced.

Some PEI rivers produce small numbers of wild-reared fish. Egg deposition from wild-reared spawners is far below conservation requirements in all systems. It had been recommended that protection be provided for wild-reared salmon (as indicated by an intact adipose fin). Measures to protect wild fish would affect the Morell and other large streams. They would not affect unstocked systems with late-running salmon that enter rivers after the angling season has closed.

Northeastern Nova Scotia (CU 12)

Abundance and trends: This unit area consists of the rivers defined within Salmon Fishing Area (SFA) 16. There are 33 recognized Atlantic salmon rivers in CU 12 of

which the Margaree River is the largest with a drainage area of 1,100 km². Thirteen rivers in CU 12 have less than 100,000 m² of juvenile rearing area. The returns to these rivers are dominated by large salmon (fork length >= 63 cm), which return to rivers in the fall, from September onward (Table 19). A few exceptions to these are the Cheticamp River which has an important early run of fish which ascends from June onward, the Margaree River which has an early run of salmon but with a stronger late run, and the River Philip which historically had fish returning in June and July but in recent years has fish in July only when water conditions are suitable. Smolts migrate from mid-May to mid-June. The small salmon are greater than 90% male in these rivers with the Margaree River having a slightly lower percentage male at 84% (Table 19). There are a few 3SW maiden age salmon in this area, with most of the large salmon (fork length >= 63 cm) are maiden 2SW and repeat spawners. These older age groups are generally greater than 75% female. The age-2 and age-3 year old smolts comprise the bulk of the smolt run – there are a few 4 year olds. Large salmon (sexes combined) have a fecundity of about 6,000 eggs per fish. Salmon from these rivers undertake long oceanic migrations as shown by recoveries of tagged salmon from these rivers at West Greenland. Salmon tagged as smolts have been recaptured at West Greenland and tagged bright salmon from the Margaree River have been recaptured along the Strait of Belle Isle and northeast coast of Newfoundland. Several rivers in this area have been stocked during the previous decades. Hatchery stocking still occurs in only the Margaree River, using annual collections of early run wild salmon as broodstock. The overall contribution of clipped salmon to the large salmon returns never exceeded 10% and contributions of hatchery origin adults to egg depositions averaged 5% in the early 1990s.

Catches of salmon, large salmon and catch rates were higher in the late 1980s and early 1990s than those seen recently (Figure 40). During 1992 to 2006, catches uncorrected for effort have declined 64% to 73% in River Philip and East River (Pictou) and by 38% to 48% in West River (Antigonish) (Table 19). Declines in catch per unit effort have also occurred, by less than 50% for River Philip, by less than 25% for East River (Pictou) and less than 27% for West River (Antigonish) (Table 19). Catch rates in the Margaree River have, in contrast, increased by 30% for large salmon during the same time period (Table 19).

High juvenile densities have been recorded in River Philip, East River (Pictou) and West River (Antigonish) over the past five years (Table 19). Juvenile salmon are readily found at all the sites sampled in these three index rivers as well as in several other rivers monitored in recent years including Wallace River, River John, West River (Pictou), Barney's River, Pomquet River, and Afton River.

The abundance of adult salmon in the Margaree River has decreased by 31% over the period 1992 to 2006 (Figure 40). The average abundance during 2002 to 2006 has been just under 3,000 large salmon (Table 19; Figure 41).

Returns to the Cheticamp River in 2004 to 2006 ranged between 260 and 400 fish over these three years.

Table 19. Summary of status indicators and trends for rivers in CU 12, Northeastern Nova Scotia.

	Life stage	River Philip		East River (Pictou)		West River (Ant.)		Margaree	
		Level (recent 5 years)	Trend	Level	Trend	Level	Trend	Level	Trend
Angling catch	Adult	220	-64%	104	-68%	236	-38%	1,575	-33%
	Large	123	-71%	70	-73%	144	-48%	1,158	-30%
CPUE angling	Adult	0.24	-38%	0.28	-10%	0.36	-13%	0.19	+24%
	Large	0.13	-49%	0.18	-25%	0.24	-27%	0.14	+30%
Estimated return	Large							2,833	-31%
Relative to conservation requirements	Return							273%	Exceeded every year since 1985
Juvenile abundance (fish/100 m²)	Fry	133		93		146		124	-15%
	Parr	48		48		73		73	+29%
	Distribution of juveniles	Common		Common		Common		Present at all 13 sites sampled	No contraction
Large salmon in returns	Adult	92%		89%				69%	
Maiden salmon in returns	Adult	89%		87%		90%		92%	
Maiden age structure 1SW-2SW-3SW	Adult	9%-90%-1%		13%-85%-2%				34%-62%-4%	
Smolt ages 2-3-4	Small	76%-23%-1%		41%-59%-0		57%-37%-6%		59%-38%-3%	
	Large	84%-16%-0		74%-26%-0				64%-35%-1%	
Percent female in 1SW-2SW-3SW	Adult	4%-68%-100%		9%-69%-100%		2% - ? - ?		16%-73%-92%	
Fork length (cm) of 1SW-2SW-3SW	Adult	56 – 75 - 86		57 – 76 – 89		57 – 77 - 92		56 – 76- 89	

River Philip
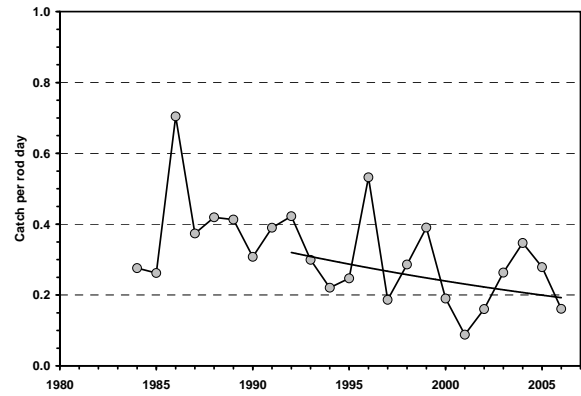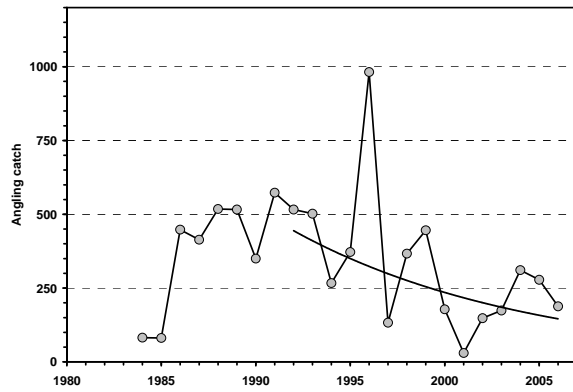
East River (Pictou)
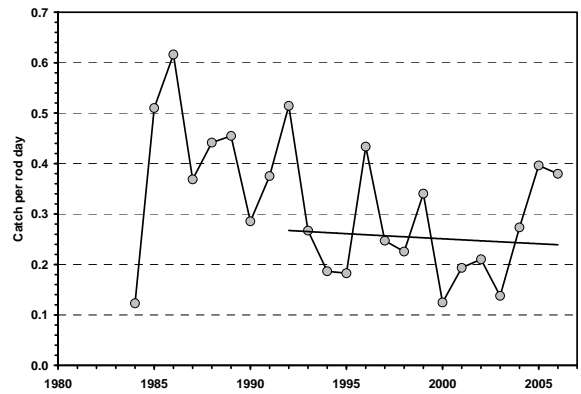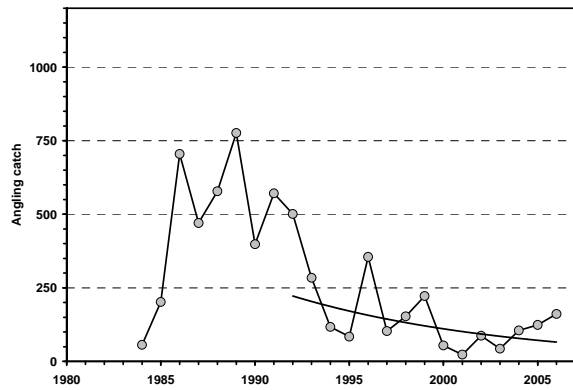
West River (Antigonish)
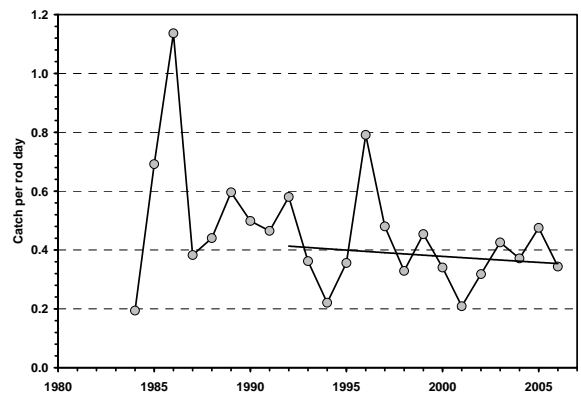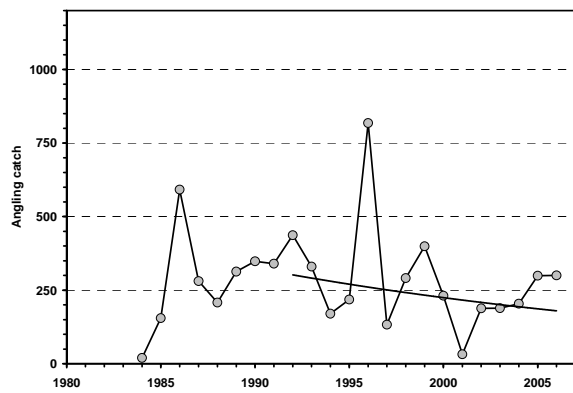
Figure 40. Angling catch (left panels) and catch per rod day (right panel) for rivers from the mainland portion of CU 12, 1984 to 2006.
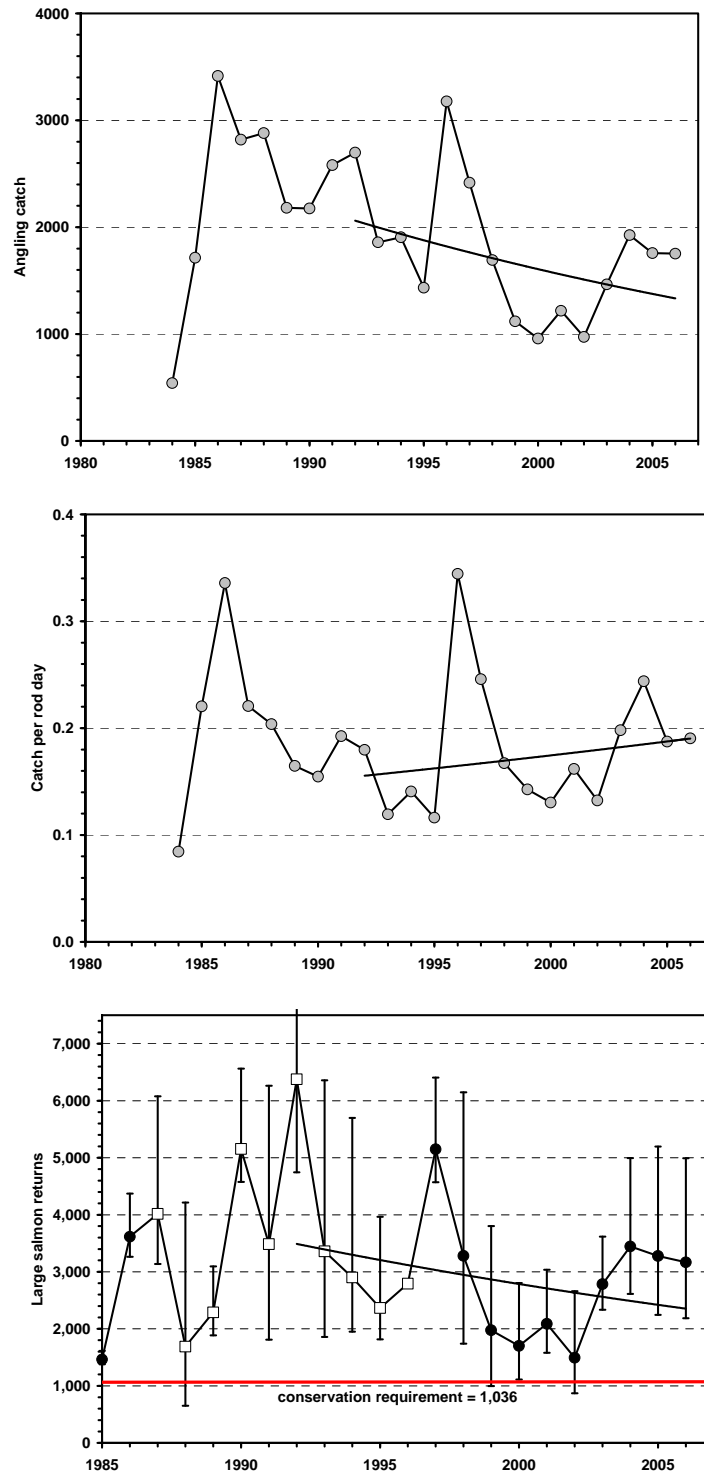
Figure 41. Catch of salmon (size groups combined, upper), catch per rod day (middle) and estimated returns to the Margaree River, 1984 to 2005.

Status: Assessments conducted in the late 1990s indicated that returns to River Philip, East River (Pictou) and West River (Antigonish) were greater than 150% of conservation requirements for these rivers. Although catches and catch rates have declined, the returns to these rivers are still considered to have been sufficient to meet the conservation objectives. Returns to the Cheticamp River in 2004 to 2006 ranged between 260 and 400 fish and exceeded the conservation requirement in all three years.

Similarly to the other areas in the southern Gulf, adult abundance was higher in the late 1980s and early 1990s than in the past decade. As a result of changes in fisheries management, particularly the closure of the Maritime Provinces and Québec commercial fisheries and the mandatory catch and release measures in the angling fishery since 1984, spawning escapement has increased which has resulted in increased abundance of juvenile salmon in the Margaree River. Fry abundance has declined over the past 15 years but remains at very high densities, 124 fry per 100 m2 (Table 19; Figure 42). Parr abundances are also at high densities and have been increasing over the past 15 years (Table 19; Figure 42). Returns and spawners to the Margaree River have exceeded the conservation requirements every year since 1985 and have averaged 273% of conservation requirements in the past five years (Table 19; Figure 41).
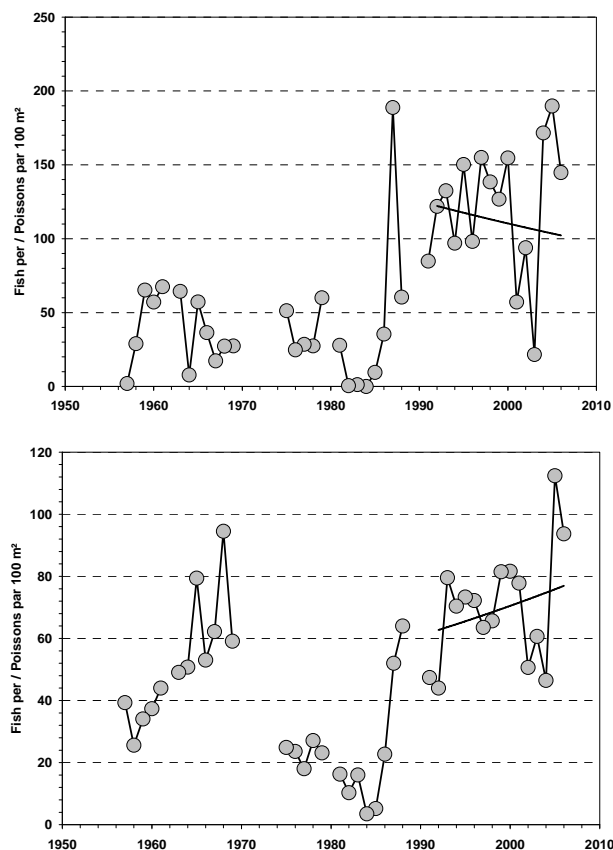
Figure 42. Fry (upper) and parr (lower) abundance indices from the Margaree River.

117

Wild smolt production from the Margaree River has increased from 2.3 to 4.1 smolts per 100 m² during 2002 to 2006. There have been 39 to 60 smolts produced per large salmon return.

Year class	Smolt age				Total Smolts	Salmon Returns	Smolts per salmon
	2	3	4	5			
1999	23,665	46,139	5,537	1,114	76,454	1,976	39
2000	33,528	59,517	8,539		101,584	1,702	60
2001	42,562	49,748	5,518		97,828	2,088	47
2002	32,299	37,187				1,494	
2003	71,495					2,783	

Trends in marine survival: Smolt enumeration programs began in 2001 in the Margaree River. Return rates to large salmon are coarsely estimated to be between 2.9% and 5.4%.

	2002	2003	2004	2005	2006
Smolt run size estimates	63,200	83,050	109,000	91,700	114,200
Large salmon returns	1,494	2,783	3,443	3,277	3,167
Coarse return rate (year+2)			**5.4%**	**3.9%**	**2.9%**

Recovery feasibility: Recovery objectives have not been defined for the rivers in CU 12. A proxy could be described as having returns that are generally at or above the conservation limit (8 of 10 years for example). All of the rivers in CU 12 meet this objective and therefore preclude issues regarding recovery feasibility.

CUs 13 - 17 (Atlantic Nova Scotia and Bay of Fundy Rivers)

General Findings for CUs 13 –17

Overall abundance and trends: Gibson *et al* (2006) considered change in abundance of Atlantic salmon stocks for selected river populations in this sub-region among the past three five-year periods (i.e., over the past three salmon generations). Gibson *et al* (op cit) determined (see Figure 43) that the 5-year mean population size ending in 2004 was greater than the 5-year mean population size ending in 1986 in only two of the assessed rivers (Baddeck and Middle Rivers in CU 13 of Cape Breton). All regional rivers outside of Cape Breton (CU 13 & 14) show declines of greater than 75%. Furthermore, Gibson *et al* (2006) provided trends in abundance from 1970 to 2005 for many salmon populations in this region (see Figure 44). The same consistent declines in abundance are shown across the region.

Overall trends in marine survival: Given the widespread and dramatic nature of the population declines that Gibson *et al* (2006) documented throughout Maritimes Region, conservation activities in 2005 were focused exclusively on maintaining the Live Gene Bank. Marine survival of inner Bay of Fundy salmon populations was found to be extremely low in 2003; rivers supported by the Live Gene Bank produced sufficient smolts to prevent extirpation but not to maintain viable populations. Based on monitoring

programs in surrounding SFAs in 2005, there is no indication that marine survival of Atlantic salmon has increased in recent years.

Overall comments on trajectories: While not saying much about trajectories, *per se*, Amiro (2007) indicated that all of the populations in SFA's 20 – 23 (CUs 14-17) were either in serious decline, at critically low levels or already extirpated.
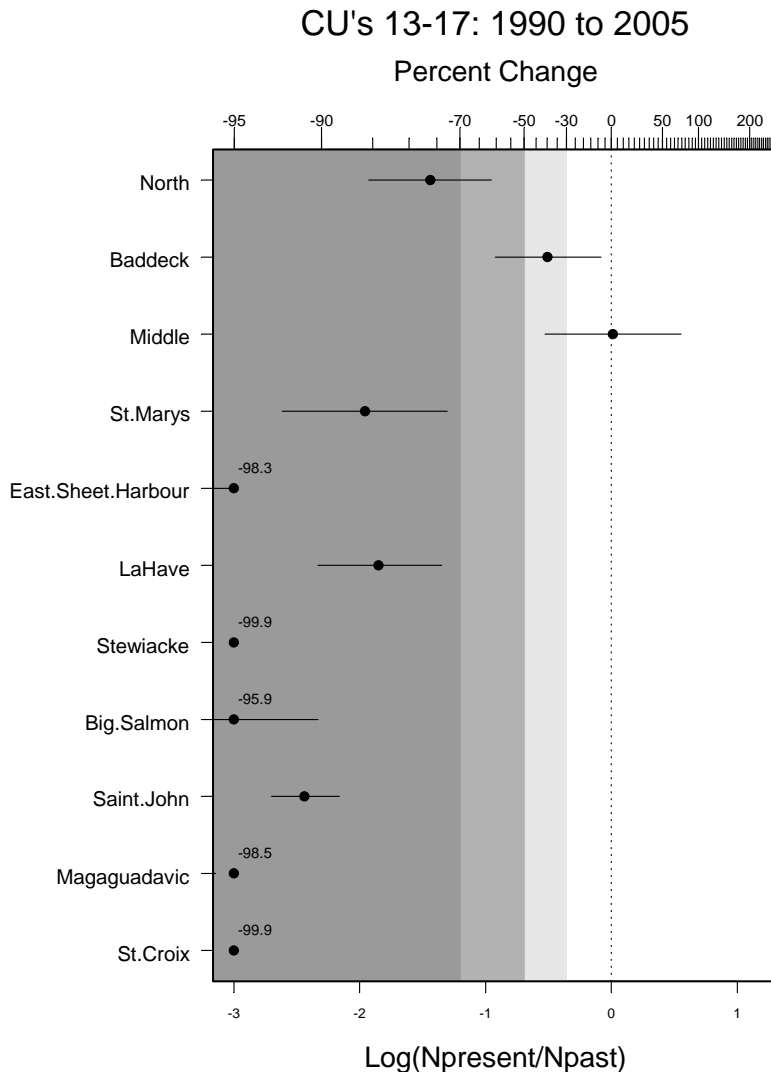
Figure 43.   Three generation changes in abundance (large and small salmon combined) for salmon populations in the DFO Maritimes Region estimated using maximum likelihood and the ratio model. Each point represents the change in 5-year mean population size for the time periods ending in 1990 and 2005. Error bars are likelihood ratio-based 95% confidence intervals based on a lognormal error distribution. The Baddeck, Middle, and North rivers are in CU 13, the St. Mary's, East Sheet Harbour, and the LaHave rivers are in CU 15, the Stewiacke and Big Salmon rivers are in CU 16 and the Saint John, Magaguadavic, and St. Croix rivers are in CU 17. (Figure 11 in Gibson *et al* 2006.)
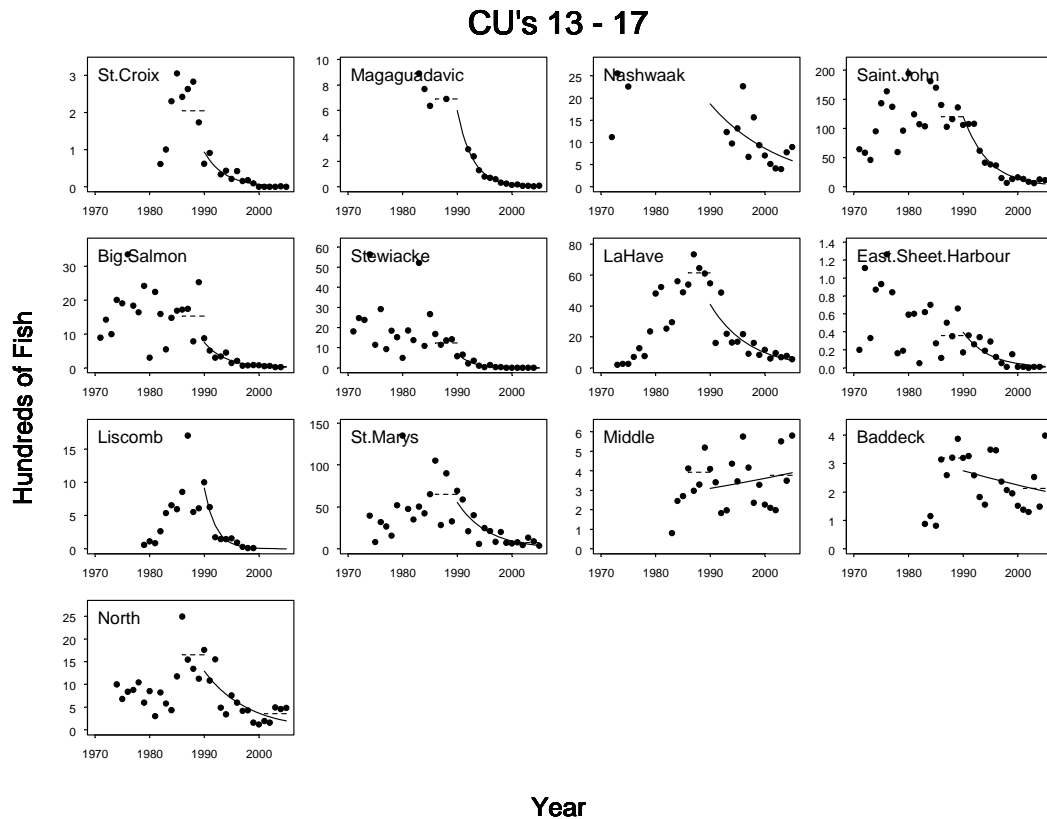
Figure 44. Trends in abundance of salmon populations in CUs 13 - 17 from 1970 to 2005. The St. Croix, Magaguadavic, Nashwaak, and Saint John rivers are in CU 17, the Big Salmon and Stewiacke rivers are in CU 16, the LaHave, East Sheet Harbour, and Liscomb rivers are in CU 15, and the Middle, Baddeck, and North rivers are in CU 13. The curved solid line shows the trend from 1990 to 2005 obtained from a log-linear model. The short horizontal dashed lines show the 5-year average population sizes for the time periods ending in 1990 and 2005. Y-axis is numbers of fish (100s); X-axis is year. (Excerpted from Figure 4 in Gibson *et al* 2006.)

Overall Status[38]: Average wild salmon population sizes in CUs 13 -17 relative to their conservation requirements were evaluated by Gibson *et al* (2006) (Figure 45) for a recent time period (2001-2005), a time period 1 decade or 2 generations previous to now (assuming a 5 year generation time: 1991 to 1995) and 4 generations ago (1981 to 1985). Returns generally exceeded the conservation requirements in the early time period. Exceptions include rivers impacted by acidification (East River Sheet Harbour, Liscomb in CU 15) and those impacted by dams (Saint John, St. Croix in CU 17). Although salmon abundance in some rivers has increased slightly, the figure shows an overall decline in abundance from time period to time period. By the 1991 to 1995 period, none of the populations within CUs 13 -17, outside of the North River, were consistently larger than their conservation requirements, and only North River populations were consistently larger than the requirement by the 2001 to 2005 time period. Presently, all populations

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[38] This entire paragraph is copied, abstracted or synthesized from Gibson *et al* 2006.

outside of the Cape Breton rivers (CU 13 and 14) and the St. Mary's and LaHave rivers (CU 15) are at less than 10% of the requirement for both small and large salmon.
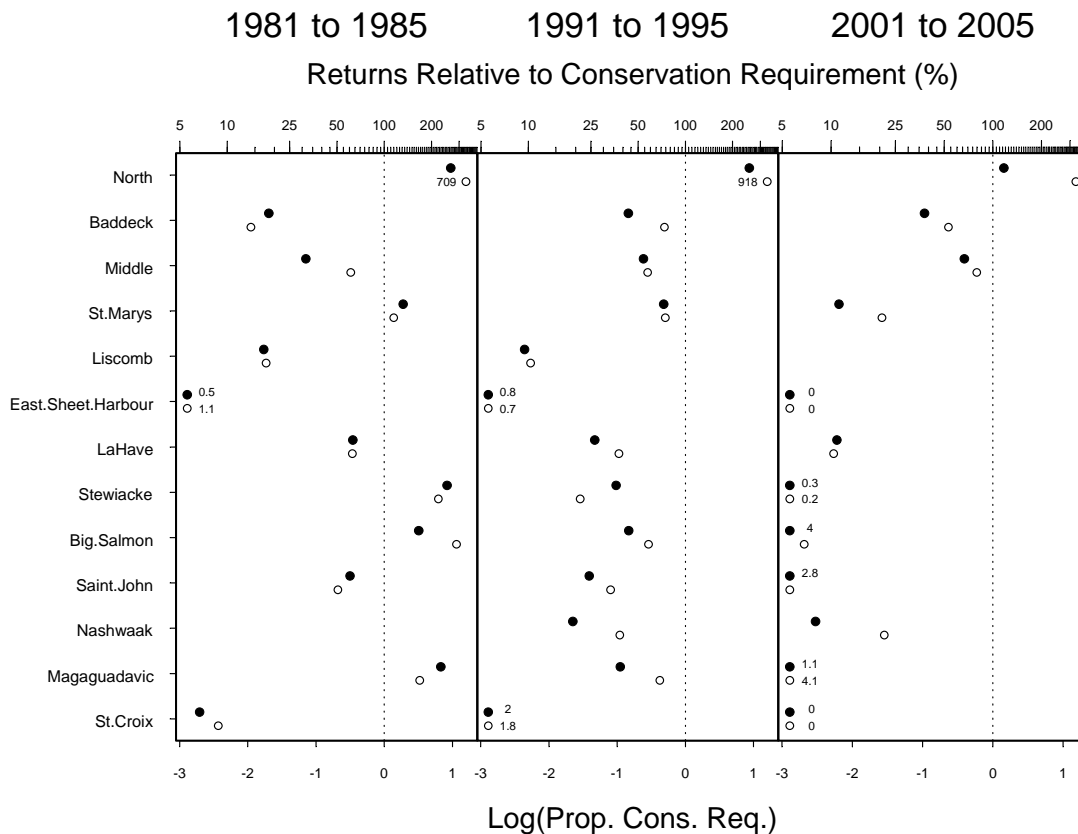
Figure 45. Five year mean numbers of large (closed circles) and small (open circles) salmon returning to Eastern Cape Breton (CU 13) Atlantic Nova Scotia (CU 15) and Bay of Fundy rivers (CUs 16 and 17) as a percentage of the conservation spawner requirement for the river. Three time periods are shown. Spawner requirements for both size categories are not used for all rivers. Points that are outside the range of the graph are labelled with their value. (Excerpted from Figure 1 in Gibson *et al* 2006.)

- For these same CUs (i.e., 13 -17), Amiro (2008) proposed an analytical approach based on multiple indicators to determine the status of the various salmon populations within the region. In defining these requisite thresholds or 'breakpoints' for this framework, Amiro (2008) proposed an approach similar to DFO (2005b) discussed later in Section 1.6, - Potential for Recovery. While Amiro (2008) does not assess risk, this integrated approach may be conceptually represented by the following risk management figure. Points 1 and 2 are known thresholds or trial benchmark breakpoints and point 3 is any management target in excess of the upper threshold.
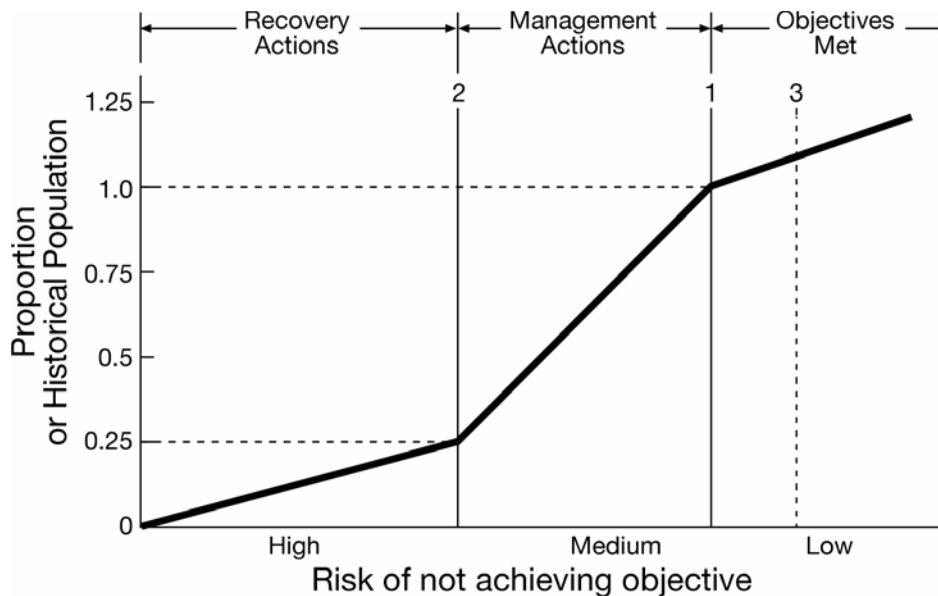
Application of this multiple indicator proposal involves:

- establishing 12 quantitative indicators of status (Table 20);
- defining a 'requisite management action framework' of three semi-quantitative categories (ranging from 'recovery actions required' to 'management objectives met') with associated 'breakpoints' or thresholds subdividing each of these three categories (Table 20);
- In this example population replacement benchmarks were set to 1.0 for the upper benchmark and 0.94 for the lower benchmark reflecting the COSEWIC three generation decline of 50%;
- In this example population trend benchmarks were based on historical DFO management which was risk averse to a 25% chance of meeting a fishery objective (lower benchmark) and an ad hoc proposed risk prone position equal to a 50% increase equal to a 0.625 chance of achieving a fishery objective.
- The conservation requirement benchmark was set to 100% of management objectives for the upper benchmark and 25% for the lower benchmark reflecting DFO management history;
- Evaluate available data for river populations within various CUs by scoring these populations against the 12 status indicators, and
- Determine where each selected river population occurs within the three category management action framework using computed scores or subsets to assess status (Table 21).

Using this approach, Amiro (2008) found that only salmon populations within CU 13 (Eastern Cape Breton Highlands) were meeting the management objectives associated with no recovery action requirements. All other CUs (i.e., 14-17) required direct and extra-ordinary recovery actions signaling that current management actions were insufficient to adequately protect these particular populations.

Indicators	Recovery Actions Recommended -1-	Adjust Human Induced Mortality, Assess Threats and Review Management -2--	Objectives Met -3-
1. Cohort R/S[1] over one generation (e.g. over 5 years)	<0.94	<1	>=1
2. Synthetic[2] R/S over one generation (e.g. over 5 years)	<0.94	<1	>=1
3. Average annual "λ"[3] (lamda, no cohort account) over 3 generations	<0.94	<1	>=1
4. Geomean of generation smoothed "λ"	<0.94	<1	>=1
5. Proportion of Conservation requirement over one generation	<0.25	<1	>=1
6. Smolt to Adult Survival/(Smolt/Adult) for one generation	<0.94	<1	>=1
7. Total migratory return in last year compared to 3 generation average	<0.25	<0.625	>=0.625
8. Last total parr density of 3 generation average	<0.25	<0.625	>=0.625
9. Projected population in three generations as proportion of current generation or population	<0.25	<0.625	>=0.625
10. Proportion of rivers in a DU that salmon occupy relative to a five generation history	<0.25	<0.625	>=0.625
11. Projected population of the DU in three generations as a proportion of the current population	<0.25	<0.625	>=0.625

Table 20. Breakpoint values of status indicators, classification level and associated actions for Atlantic salmon rivers or conservation unit populations with rationales and comments. Grey cells apply to groups of rivers. (Table 1 in Amiro 2008.) where [1] is Recruit/Spawner and [2] Is based on data derived from population indices, like catch, and biological rates like size, fecundity and sex and [3] is generational replacement ratios without adjustment for biological characteristics.

Indicator	Southern upland		CB East H Highlands		CB East L Lowlands		inner Bay of Fundy [1]		outer Bay of Fundy	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Cohort (R/S) over one generation	0.43	8								
2. Synthetic R/S over one generation	0.60	4	0.94	5					0.53	4
3. Average annual "λ" (lamda, no cohort account) over 3	0.52	6	1.38	1	0.97	2	0.04	5	1.03	1
4. Geomean of generation smoothed "λ"	0.87	2	0.98	4	0.83	3	0.70	1	0.87	3
5. Proportion of Conservation requirement over one	0.57	5	0.65	7	0.14	5	0.08	3	0.13	8
6. Smolt to Adult Survival / (Smolt/Adult) for one	0.36	9								
7. Total migratory return in last years compared to 3 generation	0.50	7	1.03	2	0.23	4	0.04	6	0.46	5
8. Last total parr density of 3 generation average	0.90	1					0.06	4		
9. Projected population in three generations as proportion of	0.20	10	0.78	6	0.06	6	0.02	7	0.15	7
10. Proportion of rivers in a CU	0.73	3	1.00	3	1.00	1	0.50	2	0.90	2
11. Projected population of the	0.15	11							0.21	6

[1] iBoF prior to 2001

	Southern upland	CB East H Highlands	CB East L Lowlands	inner Bay of Fundy	outer Bay of Fundy
Totals	5.82	6.75	3.24	1.45	4.28
Average all	0.53	0.96	0.54	0.21	0.53
Average high four	0.77	1.10	0.76	0.34	0.83
Average low four	0.29	0.84	0.32	0.04	0.24
Average same (4,5,7,9,10)	0.57	0.89	0.45	0.27	0.50
Score all	1	3	1	1	1
High four score	2	3	2	1	3
Low four score	1	3	1	1	1
Average same five score	2	3	2	1	2

Table 21. Combined indicator values and category scores evaluated using average break points for five Conservation Units for Atlantic salmon areas of the Maritimes Region. Results are colored red for estimates below the lower break point, yellow for estimates below the upper break point and green for values above the population replacement or stability breakpoint. (Table 5 in Amiro 2008.)

<u>Abundance and trends by individual CU</u>: In addition to these broader region-wide, 'overall' perspectives presented above, Amiro *et al* (2006a) provides CU by CU assessments of changes in abundance as well as status for CUs 13 -17[39] (see Appendix 7 for map).

Eastern Cape Breton (CU 13 and 14)

<u>Abundance and trends</u>: In general, water quality in the river systems of Eastern Cape Breton (see Appendix 8 for map) is better for Atlantic salmon than that of the river systems on the Atlantic coast mainland Nova Scotia and the habitat is the least impacted by human activities. While some populations have undergone declines, salmon abundance in some rivers of CUs 13 & 14 have remained relatively stable for the last decade. CUs 13 & 14 support the largest recreational fisheries in the Scotia-Fundy region. Salmon population monitoring in Eastern Cape Breton Island (CU 13 & 14) is focused on four major river systems: Middle, Baddeck, North and Grand (see Appendix 8 for map). Over 80% of the annual recreational fishing effort in Eastern Cape Breton takes place on these four rivers (Table 22). Adult assessments in CU 13 & 14 are based on recreational catches, which are reported through a license-stub return program, as well as fishery-independent counts of salmon by surface divers, where observation efficiency is estimated through mark-recapture calibration. The Department of Fisheries and Oceans (DFO) has not assessed juvenile salmon abundance in CU 13 & 14 since 2002. The results from past juvenile sampling surveys (1996 – 2002) are presented in Robichaud-LeBlanc and Amiro (2004).

Since 1998, the recreational salmon fishery on Middle River has been limited to catch and release fishing exclusively, within June 1– July 15 and September 1- October 31 (shortened season). Previous to 1998, the fishing season was continuous from June 1 – October 31 (full season). Anglers spent an estimated 458 rod-days on the Middle River in 2005. This was approximately 2.5 times higher than 185 rod-days in 2004 and was double the previous 5-year average of 231 rod-days (Table 22). The angling catch of both small and large salmon was high in 2005 relative to recent years, estimated at 38 and 133 fish, respectively (Table 22). For small salmon, this was nearly double the mean of the previous 5-year period (38 fish as compared to 21) while the catch of large salmon was slightly greater than double the 5-year mean (133 fish as compared to 60). Mean catch rates (1994 – 2005) were estimated at 0.28 (90% CI = 0.21, 0.34) and 0.42 (90% CI = 0.33, 0.52) for small and large salmon respectively, which would predict total returns of 103 (90% CI = 85, 131) small and 462 (90% CI = 374, 604) large salmon to the Middle River in 2005 (Figure 46). Removals of adults from the system (including those due to angling mortality) were relatively low, estimated at 1 small and 4 large salmon in 2005 (see Table 2 in Amiro *et al* 2006a). Total returns were estimated to be 456 salmon, and estimated escapement was 451 fish, of which 20% were small. Overall, escapement was

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[39] This entire section for the individual CUs 13 – 17 in the rivers of Eastern Cape Breton, Atlantic Nova Scotia and Bay of Fundy is copied, abstracted or synthesized from Amiro *et al* (2006a).

17% greater than in 2004, and was comprised of 94 (90% CI = 80, 113) small and 357 (90% CI = 305, 430) large salmon (Figure 46). In general, while some populations have undergone declines, salmon abundance in some rivers of CU 13 have remained relatively stable for the last decade.

Adult salmon returns and escapement (returns - removals) to North River in 2005 were estimated from recreational catches and the mean catch rate derived for this river. Mortality rates from angling were assumed to be 5% of the released catch. Although population estimation based on mark-recapture dive counts was completed from 1994 – 1998, marking has not been possible in recent years (1999 - 2005). Furthermore, adverse water conditions have prohibited diver counts during the same time period (1999 - 2005) except for July 2001, October 2002, and October 2004. In 2004, only pools in section 1 of the river (see Figure 7 in Amiro *et al* 2006a) were surveyed, although the usual reaches were swum in the lower sections (see Appendix 1 in Amiro *et al* 2006a). The angling catch of small salmon was very similar to the 5-year mean in 2005 (55 fish as compared to 50.8), while the catch of large salmon was nearly double the 5-year mean (171 fish as compared to 88.2). Mean angling catch rates (1994-2005) were estimated to be 0.84 (90% CI = 0.38, 1.30) and 0.47 (90% CI = 0.25, 0.69) for small and large salmon, respectively, which would predict total returns of 62 (90% CI = 40, 137) small and 361 (90% CI = 245, 683) large salmon to North River in 2005. Removals (due to angling mortality) of adults from the system were relatively low, estimated at 2 small and 5 large salmon (see Table 4 in Amiro *et al* 2006a).

The Grand River has not been monitored by fishery-independent methods since 2000, and as a result, adult returns and escapement (returns + removals) in recent years have been estimated from recreational catches (assuming a catch rate of 0.5) exclusively. Mortality due to recreational catch and release fishing was estimated to be 4% of the released catch from 1998 onwards (shortened season) and 7% prior to 1998 (full season). The angling catch in 2005 consisted of 20 small and 0 large salmon, from which total returns were estimated to be 30 small and 0 large individuals (see Table 5 in Amiro *et al* 2006a). Given the relative scarcity of large salmon, the two size categories were combined for monitoring purposes. Total returns in 2005 (30 fish) were nearly double those in 2004 (18 fish) and were 30% lower than the previous 3-year mean (data is not available from 2000 and 2001). Removals (due to angling mortality) of adults from the system were extremely low, estimated at 1 small salmon (see Table 5 in Amiro *et al* 2006a).

Table 22. Recreational catch and effort for small (1SW) and large (MSW) Atlantic salmon on rivers open to angling throughout SFAs 19, 20 and 21 (CUs 13, 14, and 15). Values are estimated from license-stub returns for 2005 and 2004, and the 5-year mean (2000 – 2004) is presented for comparison. (Table 1 in Amiro *et al* 2006a; index rivers bolded.)

| | 2005 | | | | 2004 | | | | 5-Year Mean (2000-2004) | | | | | | | |
| | Grilse (1SW) | | Salmon (MSW) | | Grilse (1SW) | | Salmon (MSW) | | Grilse (1SW) | | | | Salmon (MSW) | | Effort | |
River	Retained	Released	Released	Effort	Retained	Released	Released	Effort	Retained	95% C.I.	Released	95% C.I.	Released	95% C.I.	Rod-Days	95% C.I.
SFA 19: EASTERN CAPE BRETON ISLAND																
ACONI BROOK	0	0	0	0	0	0	0	0	0.0	0.0	0.8	2.1	0.3	0.7	2.8	7.7
BADDECK	0	40	109	397	2	14	53	185	0.6	1.0	15.8	6.7	49.1	27.4	185.4	58.6
BARACHOIS	0	1	0	16	0	0	0	11	0.0	0.0	0.5	0.9	0.5	0.9	12.9	6.8
CATALONE	0	0	0	0	0	0	0	0	0.0	0.0	1.9	3.0	1.3	2.3	5.5	7.7
CLYBURNE	0	0	0	0	0	0	0	4	0.0	0.0	0.0	0.0	0.0	0.0	5.6	10.5
FRAMBOISE (GIANT LAKE)	0	0	0	1	0	0	0	0	0.0	0.0	2.5	4.4	0.0	0.0	10.6	17.1
FRENCHVALE BROOK	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GASPEREAUX	0	0	0	1	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	2.8
GERRATT	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRAND	0	20	0	13	0	7	2	35	0.0	0.0	15.0	14.4	1.2	1.6	54.4	39.6
GRANTMIRE BROOK	0	4	7	9	0	14	3	16	0.0	0.0	2.7	7.6	1.8	2.4	6.3	8.0
INDIAN BROOK	0	5	0	9	0	0	2	11	0.0	0.0	0.0	0.0	1.0	1.9	8.1	3.5
INGONISH	0	1	1	4	0	2	7	4	0.0	0.0	0.3	0.9	1.4	3.8	3.1	1.7
INHABITANTS	0	5	4	7	0	2	2	7	0.0	0.0	4.3	6.9	5.6	12.9	16.6	17.6
LITTLE LORRAINE	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LORRAINE BROOK	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MACASKILL'S BROOK	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MARIE JOSEPH	0	0	0	1	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIDDLE	0	38	133	458	0	22	44	185	0.3	0.7	20.4	7.7	59.9	58.4	231.0	122.0
MIRA	0	1	0	43	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	4.1
NORTH ASPY	0	7	21	63	0	0	22	29	0.0	0.0	0.0	0.0	7.5	11.7	20.7	23.4
NORTH	1	54	171	441	0	70	152	505	0.0	0.0	50.8	28.5	88.2	76.2	364.9	170.5
NORTHWEST BROOK (RIVER	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RIVER BENNETT	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RIVER DENY'S	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RIVER TILLARD	0	0	0	0	0	0	0	2	0.0	0.0	0.0	0.0	0.3	0.8	3.4	5.0
SAINT ESPRIT	0	0	0	0	0	0	0	0	0.0	0.0	0.3	0.7	0.3	0.7	0.3	0.7
SALMON: CAPE BRETON CO.	0	0	0	38	0	0	2	5	0.0	0.0	3.1	4.3	3.1	5.0	11.0	8.3
SKYE	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYDNEY	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SFA TOTALS :	1	176	447	1501	2	130	289	1000	0.8	1.0	118.4	43.4	221.3	156.2	946.6	358.6

Table 22. continued.

| River	2005 Grilse (1SW) Retained	Released	2005 Salmon (MSW) Released	Effort	2004 Grilse (1SW) Retained	Released	2004 Salmon (MSW) Released	Effort	5-Year Mean (2000-2004) Grilse (1SW) Retained	95% C.I.	Released	95% C.I.	Salmon (MSW) Released	95% C.I.	Effort Rod-Days	95% C.I.
SFA 20: EASTERN SHORE																
CLAM HARBOUR	River Closed				River Closed				0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
EAST SHEET HARBOUR	0	0	0	0	0	0	0	5	0.0	0.0	0.0	0.0	0.3	0.8	3.3	2.8
ECUM SECUM	River Closed				River Closed				0.0	N/A	1.4	N/A	0.0	N/A	8.8	N/A
GUYSBOROUGH	0	1	0	1	River Closed											
LISCOMB	River Closed				River Closed				0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3
MOSER	River Closed				0	2	0	2	0.0	N/A	0.9	N/A	0.0	N/A	1.6	N/A
MUSQUODOBOIT	0	1	4	25	0	15	2	38	0.3	0.7	10.9	12.7	1.7	1.4	45.5	48.4
NEW HARBOUR	River Closed				River Closed				0.0	N/A	4.4	N/A	0.0	N/A	2.9	N/A
SAINT MARY'S	0	13	0	119	0	39	21	105	0.0	0.0	57.5	80.6	36.2	84.8	181.1	173.9
SALMON RIVER	0	43	14	87	0	19	12	25	0.0	0.0	13.1	12.8	6.7	8.4	31.3	35.3
SFA TOTALS :	0	59	18	232	0	75	34	176	0.3	0.7	57.4	52.9	29.1	44.4	186.2	186.2
SFA 21: SOUTHWEST NOVA SCOTIA																
CLYDE	0	0	0	3	0	0	0	0	6.1	16.9	0.9	2.4	1.4	2.9	79.8	134.4
GOLD	0	0	0	1	River Closed				0.0	N/A	13.2	N/A	1.5	N/A	23.5	N/A
JORDAN	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LAHAVE	0	165	61	599	0	121	34	325	0.0	0.0	112.8	93.8	50.1	51.3	315.0	257.5
MEDWAY	0	1	0	1	River Closed											
MERSEY	1	3	4	62	17	0	5	444	8.5	8.2	1.6	3.6	1.8	2.7	196.6	178.7
MUSHAMUSH	0	1	0	5	0	0	0	0	0.0	0.0	0.4	1.2	0.0	0.0	0.4	1.2
SACKVILLE	0	3	0	30	0	0	0	31	0.0	0.0	2.0	5.0	1.4	3.1	33.5	25.8
TUSKET	0	0	0	12	0	5	3	62	0.0	0.0	4.9	6.7	1.7	2.4	55.1	35.0
SFA TOTALS :	1	173	65	713	17	127	43	862	14.6	20.4	123.7	101.1	56.0	51.4	667.3	246.6

128
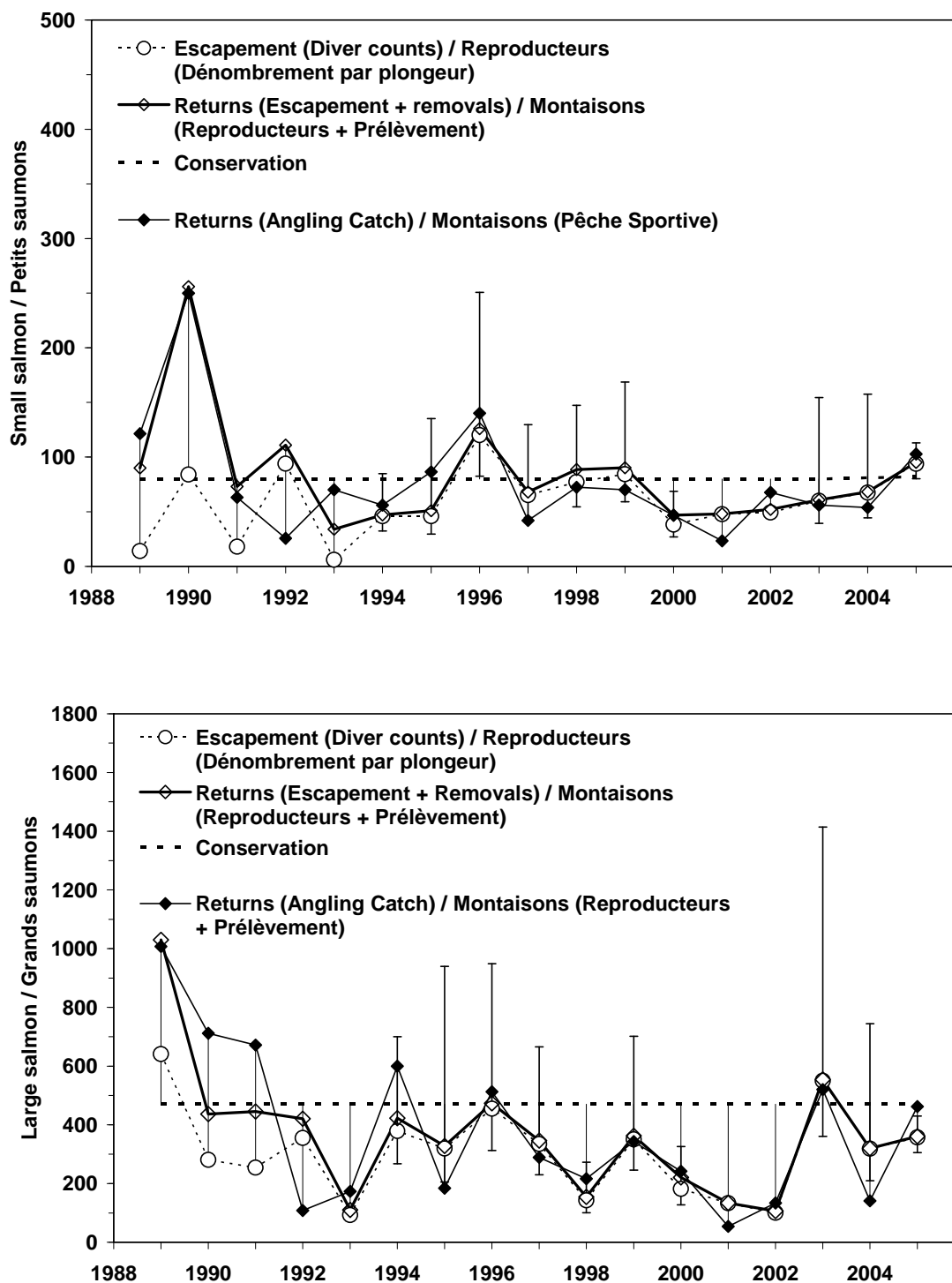
Figure 46. Adult returns (small salmon – top panel; large salmon – bottom panel) and escapement (+/- 90% CI) relative to the conservation requirement for Middle River (1989-2005). Returns and escapement were higher in 2005 than in 2004, but only small salmon exceeded the conservation requirement (dashed line). (Figure 4 in Amiro *et al* 2006a.)

Status: On the basis of estimated adult escapement, conservation requirements were generally not achieved in the monitored rivers of Eastern Cape Breton in 2005. However, there is some indication that escapements may be above the requirements for the North River. The adult returns in 2005 were generally higher than those in 2004 for all rivers surveyed. Only returns on the North River may remain above the conservation requirement. However, a comparison between fishery-independent and fishery-dependent estimation procedures suggest that returns to the North River may have been overestimated in 2005. Adult returns are below conservation requirements on Middle and Baddeck, and it is unlikely that these rivers will consistently meet or exceed conservation requirements in the near future. Meeting or exceeding conservation requirements on the Grand River in the near future is very unlikely.

Southern Upland (CU 15)

Abundance and trends*:* Rivers draining the coastal plain known as the Southern Upland (Roland 1982) generally pass through lowlands characterized by shallow soils or peat bogs underlain by granite and other metamorphic rocks (Watt 1987). As a result, water is generally organic-acid-stained and less productive than more mineral-rich rivers. When such waters are influenced by acid precipitation, conditions can become toxic for Atlantic salmon (LaCroix 1985). At a mean annual pH below 5.1, salmon production is considered unstable and only remnant populations may persist. Interspersed within the Southern Uplands are limestone-rich soils (drumlins), which provide local regions of less-acidified water.

As of 1986, twenty-two rivers in CU 15 (fourteen in SFA 20 and eight rivers in SFA 21) were classified as either low- or non-acidified (pH greater than 5.1) and were known to contain Atlantic salmon populations (the rivers have historically been fished for Atlantic salmon). As of 1986, there were twenty rivers that were partially acidified (pH ranges from 4.7 - 5.0) and at least fourteen rivers that were heavily acidified (pH < 4.7). Despite reductions in sulphate deposition (acid precipitation) in recent years, the pH in rivers of the Southern Upland has not recovered at rates observed in other geographic areas (Watt 1987). Hydroelectric power facilities or impoundment for domestic water use have resulted in significant barriers to upstream migration and a loss of spawning habitat on 10 of the rivers in the Southern Upland region.

Based on electrofishing surveys done in 2000, juvenile salmon could not be found in 28 of 57 rivers sampled within the Southern Upland region. In addition, 16 of the 29 rivers with juvenile salmon had fewer than 5.0 juvenile salmon per 100 m^2 or 7% of a 'normal' abundance (see Appendix 9 for map). These data suggest that population extirpations have occurred and that most populations are critically low.

For assessment purposes, two of these rivers were chosen as index rivers for long-term monitoring (Amiro *et al* 2000): the St. Mary's River in CU 15 (SFA 20) and the LaHave River (above Morgans Falls) in CU 15 (SFA 21). Amiro *et al* (2006a) indicated, "The status for most if not all low- or non-acidified rivers in CU 15 is expected to be similar or worse than that of the index rivers (O'Neil *et al* 1998, Amiro *et al* 2000)."

The St. Mary's River has two branches (west and east) as well as a main stem that empties to the Atlantic Ocean at the town of Sherbrooke, Guysborough County, in Nova

Scotia (see Figure 12 in Amiro *et al* 2006a). In the St. Mary's River, most Atlantic salmon juveniles spend two years in fresh water and migrate to sea as two-year-old smolts. Historically, adult returns in the system were characterized by a high proportion of 2SW (and some 3SW) salmon, of which approximately 60% were female (Marshall 1986). However, more recent assessments have shown significant increases in the proportion of adults maturing after one winter at sea (O'Neil and Harvie 1995). Length-fecundity relationships derived for the St. Mary's River (Amiro, unpublished data) show that 1SW fish have approximately one-half of the fecundity of MSW females.

Anglers spent an estimated 119 rod-days on the St. Mary's River in 2005. This was slightly higher than 105 rod-days in 2004, but was below the previous 5-year mean of 181.1 rod-days. Similarly, catches were down from 39 small and 21 large salmon in 2004, and were more than 4 times lower in 2005 than the previous 5-year mean for both size categories (Table 22).

In the St. Mary's River prior to 1996, adult escapement estimates were derived from recreational catches and annual exploitation rates imported from the LaHave River (O'Neil *et al* 1998). However, river-specific escapement estimates have been calculated since 1997. Mark-recapture experiments (to estimate abundance) were conducted in the St. Mary's River from 1997-2001, and were attempted without success in 2002-2005.

Estimated escapement to the West Branch of the St. Mary's River in 2005 was 198 fish of which 92% were small salmon (Table 23). When compared with historical data, this represents a substantial increase in the proportion of 1SW salmon in the spawning population (Amiro *et al* 2000 and Amiro 2006a). Given that 55% of the river's juvenile habitat is contained within the West Branch, total escapement to the St. Mary's River in 2005 was estimated to be approximately 359, 331 small and 28 large salmon. As compared with 2004, this estimate represents a reduction in escapement of more than one-half for small salmon and approximately one-third for large salmon (Table 23).

Table 23. Estimated escapement of adult Atlantic salmon relative to the conservation requirement in the entire St. Mary's River for the years 1995 – 2005. Sampling takes place in the West branch of the river and is multiplied by 1/0.55 to scale up to the entire river. (Table 7 in Amiro *et al* 2006a.)

Year	Grilse	Salmon	% Egg Conservation
1995	2038	437	78
1996	1535	590	67
1997	709	110	32
1998	1926	74	63
1999	559	150	22
2000	572	46	20
2001	580	193	24
2002	400	29	14
2003	1092	221	42
2004	843	41	28
2005	331	28	11

Smolt abundance estimates for the St. Mary's River: In total, 757 smolts were captured, the majority of them in the west-side wheel (see Figure 13 in Amiro *et al* 2006a). Of these, 78 fish were tagged, indicating that they had been captured a second time. From

these data, the number of smolt emigrating from the West Branch was estimated to be 7,350 smolts (90% C.I. = 6,000, 9,000), and capture efficiency at the west and east wheels was approximately 8.5% and 1.8% respectively. Based on an estimated 3,985,400 m^2 of juvenile habitat contained in the entire St. Mary's River (55% in the West Branch), smolt production was 0.33 smolts per 100 m^2. The biological characteristics of the sampled population were estimated from a subset of the total population (229 individuals). Of these, 81% (181 smolts) were age-2 and 19% (44 smolts) were age-3. Overall, mean fork length was 14.9 cm (range: 11 – 19). On average, age-2 smolts were approximately 2 cm smaller than age-3, with mean fork lengths of 14.5 cm and 16.3 cm respectively.

Juvenile abundance in the St. Mary's River: Mean age class densities were calculated based on data from 12 sites in 2004 (see Table 8 in Amiro *et al* 2006a), and 11 sites in 2005 (see Table 8 and 9 in Amiro *et al* 2006a). In 2005, the estimates of fry (age-0) and total parr (age-1 and age-2 combined) densities are slightly greater than in 2004. Fry density (age-0) is at its highest value since 2001, and parr densities (age-1 and age-2 respectively) are the highest values recorded within the last three years (Figure 47). Nonetheless, the densities are still low relative to values in the mid 1990s. Any recent juvenile population increase must be interpreted with caution. Given that adults return to spawn roughly four years after their parents, the adults in 2005 would have been fry in 2001. Mean fry densities in 2005 remain below mean densities in 2001. The mean fry density observed in 2005 is consistent with the predicted linear relationship between estimated salmon returns and subsequent fry density for the years 1993-2005 (Figure 48). The similarity between the predicted and observed relationship for 2005 suggests that escapement in 2004 (884 fish) was accurately estimated. In contrast, it is likely that actual escapement in 2003 was significantly less than the estimated value; given an observed fry density of 3.08 fish per 100 m^2 in 2004.

Historically, for other rivers in the SFA 20 portion of CU 15, annual stocking of smolts as well as electrofishing surveys to monitor juvenile density have taken place on the Musquodoboit River. Similarly, electrofishing surveys were carried out on the Ecum Secum River in 1999, and adult returns to the Liscomb River fishway were monitored from 1983-1999 (Amiro *et al* 2000). These monitoring programs have not continued to the present time.

In an effort to re-establish viable Atlantic salmon populations in the SFA 20 portion of CU 15, a supportive rearing program has been in place since 2003. As many fry and parr as possible were recently captured and collected from six low-acidified rivers in SFA 20 (see Table 10 in Amiro *et al* 2006a). These individuals are being raised to adulthood before being released in fresh water. Despite considerable effort the numbers of juvenile fry and parr located and collected from any river were below those expected to produce a viable population, so it was necessary to pool the entire production of adult salmon for release into a single river. In the SFA 20 portion of CU 15, the Quoddy River was considered to be the best non-origin release location for two reasons: (1) only a remnant wild population persists, and (2) the river contains suitable habitat (good pH, as well as an estimated 6,849 habitat units for juvenile production). In 2005, 69 adults, mostly from the 2003 juvenile collection, were released above 3rd lake on the Quoddy River.
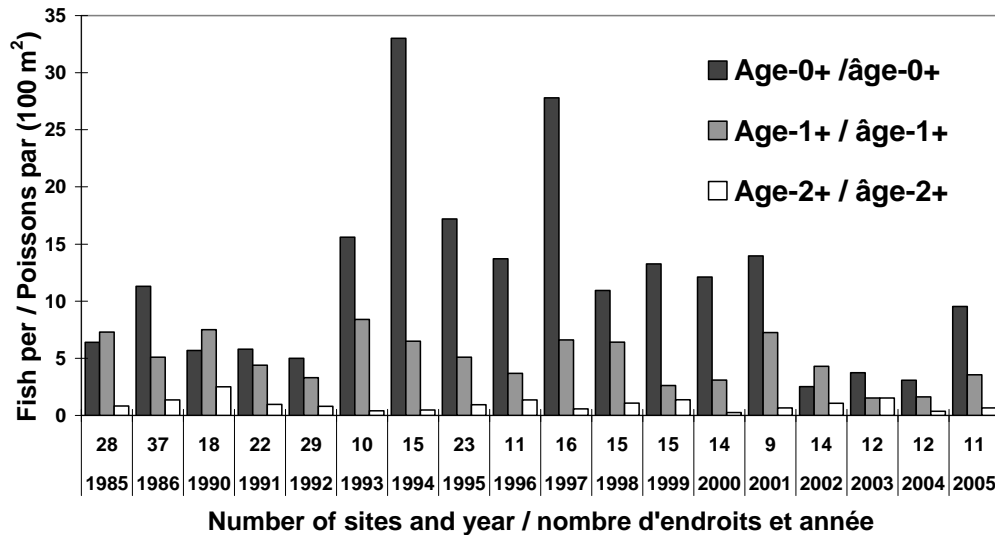
Figure 47. Mean density for the three age classes of juvenile salmon (age-0, age-1 and age-2) during 1985 – 1986, and 1990 – 2005. The number of sampling sites that the mean is based on is listed immediately below the x-axis. (Figure 14 in Amiro *et al* 2006a.)
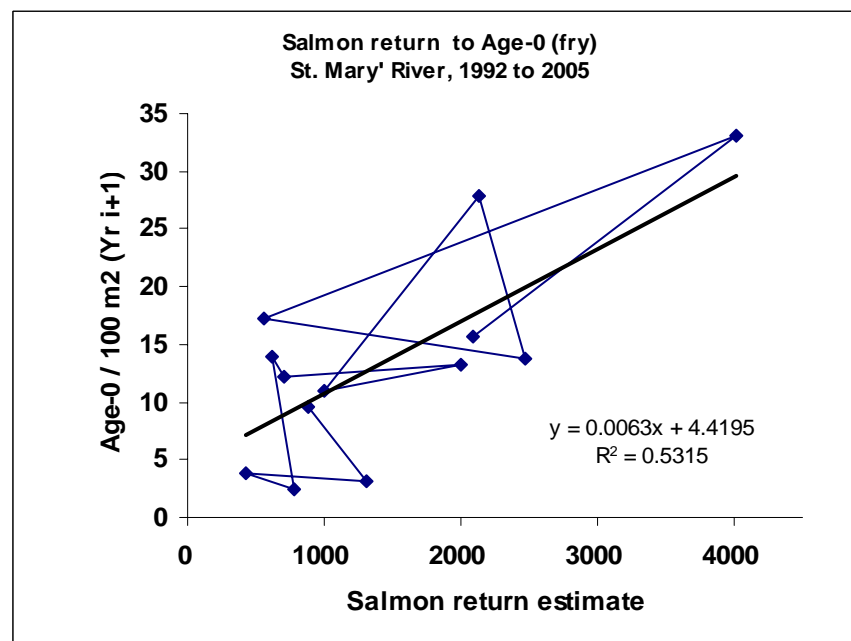
Figure 48. Observed fry density as a function of estimated adult returns to the St. Mary's River for the years 1993 – 2005. The linear equation for the predicted relationship (thick line) as well as the associated R^2 value for the regression is given. Points in the lower left corner are the most recent. (Figure 15 in Amiro *et al* 2006a.)

The LaHave River drains approximately 1,670 km^2 of the Southern Upland of Nova Scotia, and enters the ocean at Bridgewater, Lunenburg County. The drainage contains 113 lakes with a total surface area of 7,515 ha, and consists of five major sub-drainages: West Branch, North Branch, Ohio River, North River and the Main Stem (see Figure 16

133

in Amiro *et al* 2006a). Throughout its length, the LaHave River contains several natural and manmade barriers to salmon migration. One of the larger natural obstacles is Morgans Falls, presently the site of a hydroelectric facility built in 1995. Morgans Falls (see Figure 16 in Amiro *et al* 2006a) is on the main stem of the LaHave River and is downstream of the Ohio and North River sub-drainages.

Prior to 1969, Atlantic salmon had limited access to the watershed upstream of Morgans Falls. In 1969, a functional fishway was constructed to bypass the falls and DFO began a stocking program to enhance the development of a salmon run. Original broodstock were taken from the nearby Medway River, and the first hatchery-reared smolts were released above Morgans Falls in 1971 (Table 24). Since 1971 (excluding 1982), the LaHave River was stocked annually with hatchery-reared smolts until 2005, when the program was curtailed. After 1972, all broodstock were collected at the Morgans Falls fishway or in an eel weir below the falls above Wentzel's Lake.

The biological characteristics of the wild proportion of the population differ from those of the hatchery proportion. In general, the majority of wild juveniles undergo smoltification after two years in fresh water and approximately 80% mature after one winter at sea. About 40% of wild 1SW fish are female and about 90% of wild 2SW salmon are female (Amiro, unpublished data). In contrast, approximately 60% of juveniles of hatchery origin undergo smoltification after one year in fresh water. The proportion of adults of hatchery origin contributing to annual egg deposition has ranged from 94% to 11% and since 2003, the last year of adult broodstock collection for enhancement, has declined to zero. Overall, 1SW salmon (wild and hatchery) contribute approximately 1, 240 eggs per fish annually, while 2SW salmon contribute an average of 5,120 eggs per fish. Despite differences in escapement among large and small salmon, each size class contributes approximately 50% of the total annual egg deposition above Morgans Falls.

Nine rivers in the SFA 21 portion of CU 15 were open to angling from June 1 to July 15 in 2005. More than 80% of the total fishing effort occurred on the LaHave River, which accounted for more than 90% (226 fish) of the total recreational catch (Table 22) in CU15. Anglers spent an estimated 599 rod-days on the LaHave River in 2005, nearly double the 325 rod-days spent in 2004 and the previous 5-year mean (315 rod-days). Catches in 2005 were above those in 2004, at 165 small and 61 large salmon (as compared to 121 small and 34 large in 2004). Similarly, the catch in 2005 was 46% higher than the previous 5-year mean for small, and 22% higher for large salmon (Table 22).

Upstream-migrating adult salmon have been counted at the Morgans Falls fishway since 1972, and downstream migrating smolts have been counted each May since 1996. Since 1994 scale samples for aging have been taken from all large wild and hatchery salmon, all wild small salmon and every 5th hatchery small salmon trapped in the fishway. In 2005, 500 adult salmon (416 small and 84 large) were counted, of which, 233 small and 43 large were of wild origin. The total number of wild salmon (276 fish) was the lowest recorded value since 2001 (Figure 49; also see Table 12 in Amiro *et al* 2006a). Recent wild returns are similar to those recorded before the fishway enabled efficient passage upstream of Morgans Falls. Very few Atlantic salmon were removed for broodstock in

2005, and all were of hatchery origin (Table 25). The DFO smolt enhancement program on the LaHave River was discontinued in 2003, so no broodstock were removed for stocking purposes in 2004 or 2005.

The biological characteristics of the adults sampled at Morgans Falls in 2005 are summarized in Table 13 in Amiro *et al* (2006a). The majority of individuals (wild and hatchery) spent 2 years in fresh water and one winter at sea before returning to spawn. Combining the various ages, first-time spawners made up approximately 96% of the sampled population, second-time spawners less than 3%, and third-time spawners the remainder (< 2%). For both size categories, wild salmon were proportionally more abundant than hatchery salmon, with 60% 1SW and 12% MSW wild (72% total) as compared to 18% 1SW and 10% MSW of hatchery origin (28% total) (Figure 49, Table 24). The LaHave River above Morgans Falls was the most heavily stocked river within the Southern Uplands region, receiving 32,219 smolts in 2004 and 1,880 smolts in 2005 (Appendix 2 in Amiro *et al* 2006a). Only two other rivers in SFA 21 were stocked with smolts in 2005, the Tusket River (1,880 smolts) and the Medway River (300 smolts). All smolts of hatchery origin are tagged or adipose-clipped before being released into the rivers.

Since 1996, migrating smolts have been counted annually at the Morgans Falls Power fish by-pass and mark-recapture methods were used to obtain estimates of population size. In 2005 smolts were captured and held daily in the collection chamber and counts took place on weekdays from May 3 – June 8, although no smolts were found in the bypass after June 2. A total of 1,430 marked smolts (700 T-bar tagged and 530 adipose clipped) of hatchery origin were released upstream of Morgans Falls during May, 2005.

The maximum likelihood estimate of smolt population abundance for the LaHave River above Morgans Falls was 6,690 fish (90% C.I. = 6,120, 7,400). Of the 1,430 marked individuals, 238 were recaptured, giving an estimated mean catch rate of 0.67 for 2005. After accounting for smolts of hatchery origin, wild smolt production in 2005 was estimated to be 5,260 fish (90% C.I. = 4,690 and 5,970). This is significantly lower than any value recorded during the years 1996 – 2004 (Figure 49, Table 26). Smolt production in 2005 was nearly 4 times lower than in 2004, and was over 3 times lower than the previous 5-year mean. Irregular flow patterns were experienced in the LaHave River in 2005, so it is possible that this estimate is low relative to actual smolt production.

Based on a subset of 158 wild smolts, approximately 70% (110 fish) of the sampled population were age-2 and 30% (48 fish) were age-3. On average, mean fork length of age-2 smolts was approximately 2 cm smaller than for age-3, at 16.37 cm (range: 13.5 – 19.7) and 18.80 cm (range: 15.8 – 23.5) respectively.

Because 96% of the LaHave adult population returns to spawn after one winter at sea, the ratio between smolt production and subsequent 1SW returns provides a relatively complete estimate of at-sea survival. For the LaHave River above Morgans Falls, return rates have ranged from 1.1% to 4.8%, with half of the values being >2% (Table 26). Return rates have been declining steadily since 2001, with the lowest estimate being recorded in 2004. The 2006 adult count at Morgans Falls was 418 1SW fish representing a 7.95% return rate - the highest in the time series. Return rates for 1SW salmon

elsewhere in the region were also high (Jones pers com.) suggesting that the high return rate above Morgans Falls was not the result of an under estimate of smolts in 2005. The mean length of the 2005 smolt class was in fact larger than normal (consistent with low abundance), and the possibility that a severe flood in April 2003 could have severely impacted the smolt class as emerging fry. The 2006 1SW survival rate of 7.9% is more than twice the long-term mean and 65% higher than the previous high return rate of 4.8%. The return to a low survival rate in 2007 (1.5%) suggests that the value in 2006 is unlikely to be indicative of a new phase or a return to historical marine survival rates for wild salmon. (Figure 51).

The return rate of hatchery smolts as 1SW fish has been consistently lower than that of wild fish. In 2005, it decreased to 0.57% from 0.72% in the previous year, and is below the 5-year mean value of 0.64% (Figure 51). Prior to 1994 broodstock selection favoured 2SW salmon and lower return rates for 1SW could be expected if age at maturity has a high heritability. Since 1996, broodstock selection by age at maturity was proportional to the wild population; however, low numbers of wild salmon necessitated using some fish of hatchery origin. Proportions of hatchery salmon in the returns and broodstock approached 50% in later years, which initiated a review of the enhancement strategy. The collection of adult salmon for broodstock for enhancement purposes ceased at Morgans Falls in 2003, and therefore, the proportion of hatchery origin salmon has declined rapidly since 2006.

A total of 16 electrofishing sites, 9 located above Morgans Falls and 7 located below, were surveyed on the LaHave River in 2004 and 2005, respectively (see Table 15, Table 16 in Amiro *et al* 2006a). Mean parr density (age-1 and age-2 combined) for the LaHave River in 2005 was 11.5 fish/100 m^2 above Morgans Falls (7 sites), and 6.5 fish/100 m^2 below (9 sites) (Figure 52). The overall mean of 8.5 fish/100 m^2 in 2005 is similar to the 1972 to 2004 mean density of 7.3 fish/100 m^2. Despite relatively large changes in escapement at Morgans Falls over time (refer back to Figure 49) mean parr density at these sites has remained relatively unchanged (Figure 53, Table 24).

Table 24. Stock origins and the sea-age composition of adult Atlantic salmon counted at the Morgans Falls fishway on the LaHave River, 1970 – 2005. (Table 11 in Amiro *et al* 2006a)

Year	Hatchery		Wild		Totals		
	1SW	MSW	1SW	MSW	1SW	MSW	Combined
1970	--	--	2	4	2	4	6
1971	--	--	3	--	3	--	3
1972	9	--	8	2	17	2	19
1973	138	9	14	7	152	16	168
1974	442	19	29	2	471	21	492
1975	466	68	38	5	504	73	577
1976	468	108	178	23	646	131	777
1977	974	84	292	25	1266	109	1375
1978	567	209	275	67	842	276	1118
1979	1064	99	856	67	1920	166	2086
1980	336	489	1637	288	1973	777	2750
1981	1181	226	1866	366	3047	592	3639
1982	621	230	799	256	1420	486	1906
1983	27	100	1129	213	1156	313	1469
1984	250	36	2043	384	2293	420	2713
1985	102	77	1343	638	1445	715	2160
1986	135	78	1579	584	1724	662	2386
1987	573	79	2529	532	3102	611	3713
1988	1056	59	2464	390	3520	449	3969
1989	443	183	2087	511	2530	694	3224
1990	596	112	1880	396	2476	508	2984
1991	109	90	495	236	604	326	930
1992	574	58	1915	215	2489	273	2762
1993	381	84	777	121	1158	205	1363
1994	207	119	641	128	848	247	1095
1995	371	85	577	143	948	228	1176
1996	395	83	735	113	1130	196	1326
1997	146	65	303	66	449	131	580
1998	200	68	719	69	919	137	1056
1999	134	44	318	88	452	132	584
2000	293	53	501	67	794	120	914
2001	190	81	189	101	379	182	561
2002	711	33	422	38	1133	71	1204
2003	206	108	231	99	437	207	644
2004	326	56	312	66	638	122	760
2005	183	41	233	43	416	84	500

Table 25. Broodstock collected for smolt stocking programs in the LaHave River (1969 – 2005). Collections in 2005 were for educational purposes (Fish Friends). M.F. stands for Morgans Falls fishway. (Table 12 in Amiro *et al* 2006a)

| Year | River | Location | 1SW | | | | MSW | | | | Total |
| | | | Males | | Females | | Males | | Females | | |
			Hatch	Wild	Hatch	Wild	Hatch.	Wild	Hatch	Wild	
1969	Medway	Greenfield	0	47	0	25	0	14	0	30	116
1970	Medway	Greenfield	0	20	0	7	0	3	0	7	37
1971*	Medway	Greenfield	0	83	0	12	0	12	0	23	130
1972	Medway	Greenfield	0	27	0	19	0	10	0	22	78
1973	LaHave	M. F.	57	8	46	16	4	6	7	17	161
1974	LaHave	M. F.	21	0	24	4	9	1	12	0	71
1975	LaHave	M. F.	4	0	3	0	17	0	20	0	44
1976	LaHave	M. F.	2	0	0	0	13	4	32	8	59
1977	LaHave	M. F.	21	7	15	15	8	9	8	27	110
1978	LaHave	M. F.	18	6	6	3	19	6	25	11	94
1979	LaHave	M. F.	7	0	12	9	16	0	30	1	75
1980	LaHave	M. F.	0	5	0	0	12	3	12	2	34
1981	LaHave	M. F.	0	2	0	0	14	11	15	10	52
1982	LaHave	M. F.	0	2	0	0	4	7	10	6	29
1983	LaHave	M. F.	0	0	0	0	6	18	13	44	81
1984	LaHave	M. F.	0	0	0	0	0	43	5	59	107
1985	LaHave	M. F.	0	10	1	20	4	59	12	125	231
1986	LaHave	M. F.	0	0	0	0	6	27	10	112	155
1987	LaHave	M. F.	9	15	0	0	9	25	23	132	213
1988	LaHave	M. F.	14	39	0	3	8	8	24	109	205
1989	LaHave	M. F.	3	20	0	0	8	22	40	75	168
1990	LaHave	M. F.	5	27	2	5	13	9	28	74	163
1991	LaHave	M. F.	9	8	33	5	4	49	28	64	200
1992	LaHave	M. F.	21	31	4	46	5	12	17	59	195
1993	LaHave	M. F.	21	43	8	43	1	4	29	30	179
1994	LaHave	M. F.	8	14	0	24	9	3	33	23	114
1995	LaHave	M. F.	21	37	14	30	2	2	10	25	141
1996	LaHave	M. F.	19	22	2	12	6	1	16	17	95
1997	LaHave	M. F.	15	41	2	21	2	3	8	12	104
1998	LaHave	M. F.	15	69	5	43	0	2	16	7	157
1999	LaHave	M. F.	2	29	4	21	3	6	8	19	92
2000	LaHave	M. F.	3	38	6	6	3	0	12	12	80
2001	LaHave	M. F.	6	35	0	5	0	1	10	14	71
2002	LaHave	M. F.	6	16	4	14	0	0	6	6	52
2003	LaHave	M. F.	3	14	0	6	0	2	1	11	37
2004	LaHave	M. F.	0	0	0	0	0	0	0	0	0
2005**	LaHave	M. F.	5	0	6	0	0	0	0	0	11

* LaHave broodstock collection consisted of 5 females and 22 males.
** Hatchery broodstock collected for Fish Friends

Table 26. The estimated production (90% C.I.), density and return rate of wild smolts above Morgans Falls on the LaHave River during 1996 – 2005. The 'Return rate to 1SW' is a measure of the proportion of smolts that mature after one winter at sea and return to Morgans Falls in the following year. (Updated Table 14 in Amiro *et al* 2006a)

|	Wild smolts		Return rate to 1SW
Smolt year	Estimate (5th – 95th)	per 100 m²	
1996	20,510 (19,890 – 21,090)	0.40	1.47%
1997	16,550 (16,000 – 17,100)	0.32	4.33%
1998	15,600 (14,700 – 16,625)	0.31	2.04%
1999	10,420 (9,760 – 11,060)	0.20	4.82%
2000	16,300 (15,950 – 16,700)	0.32	1.16%
2001	15,700 (15,230 -16,070)	0.31	2.70%
2002	11,860 (11,510 – 12,210)	0.23	1.95%
2003	17,845 (8,821 – 26,870)	0.35	1.75%
2004	21,613 (19,613 – 21,513)	0.41	1.13%
2005	5,270 (4,670 – 5,920)	0.10	7.95%
2006	22,971 (20,166 –26,271)	0.40	1.48%
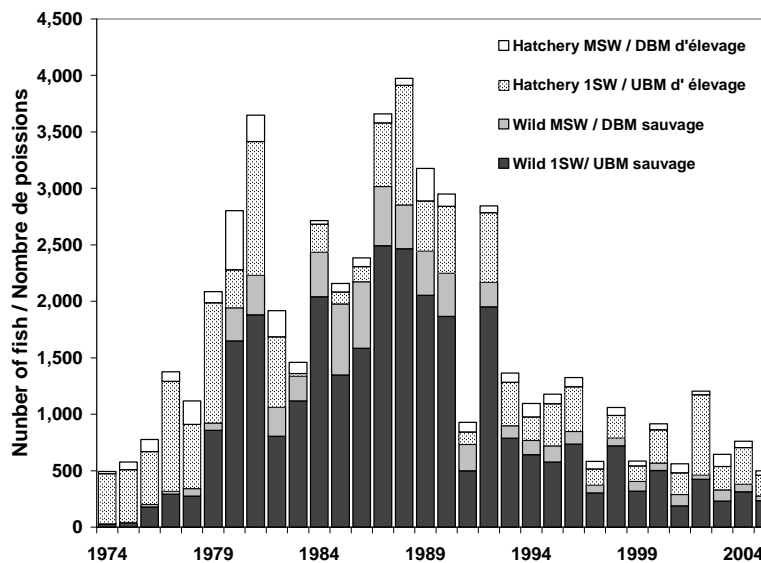
Figure 49. Annual returns of salmon to the LaHave River above Morgans Falls during 1974 – 2005 broken into the proportions of small (1SW) and large (MSW) as well as hatchery and wild in the sampled population. (Figure 17 in Amiro *et al* 2006a)
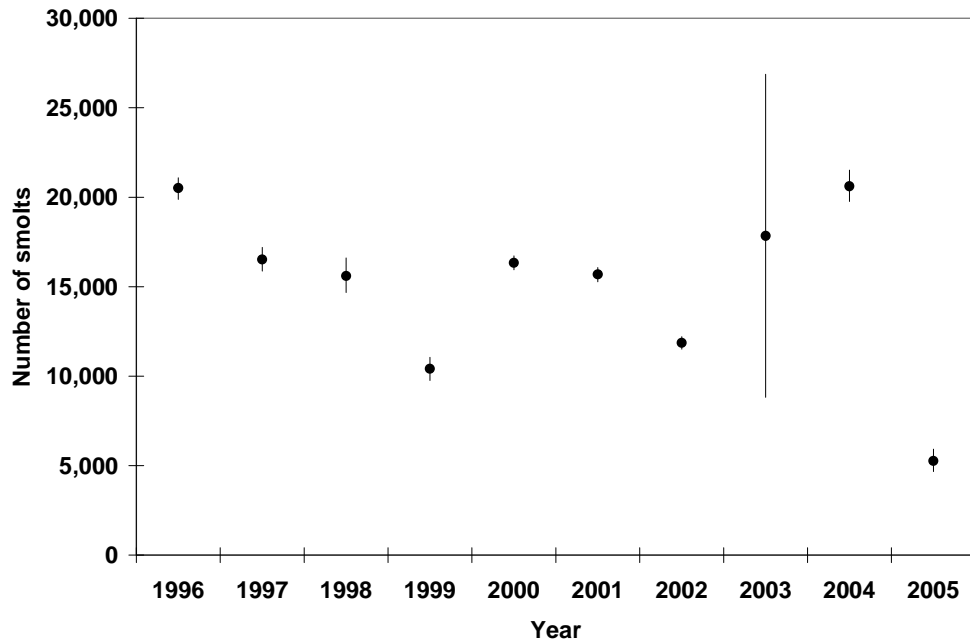
Figure 50. Estimated numbers of outward-migrating, wild smolts passing through the Morgans Falls fishway in the years 1996 – 2005. Vertical bars show the 90% confidence interval of the estimate. (Figure 18 in Amiro *et al* 2006a)
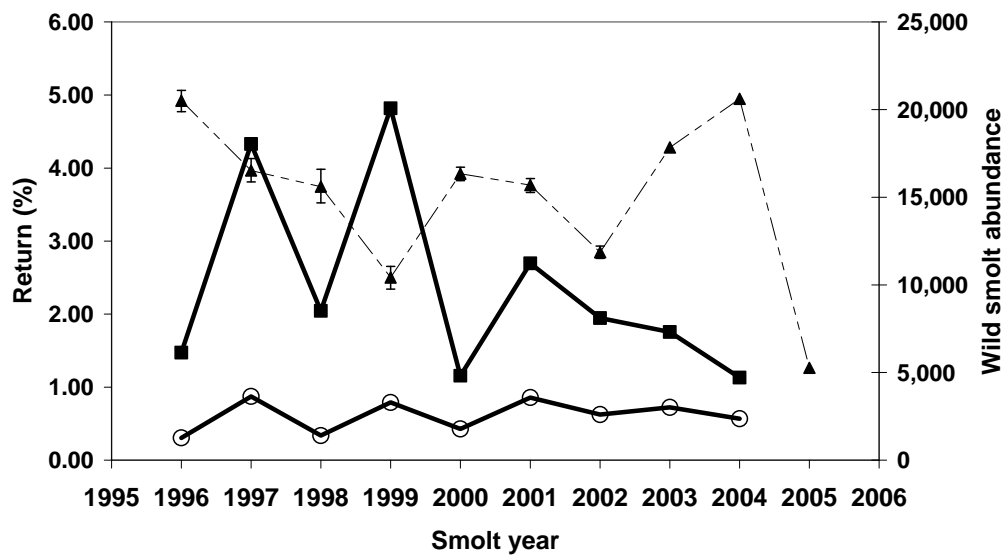

Figure 51. The estimated return rate of 1SW adult salmon of hatchery origin (open circles) and wild salmon (closed squares) as a result of estimated wild smolt abundance (closed triangles, dashed line) in the same year at Morgans Falls on the LaHave River (Figure 19 in Amiro *et al* 2006a)
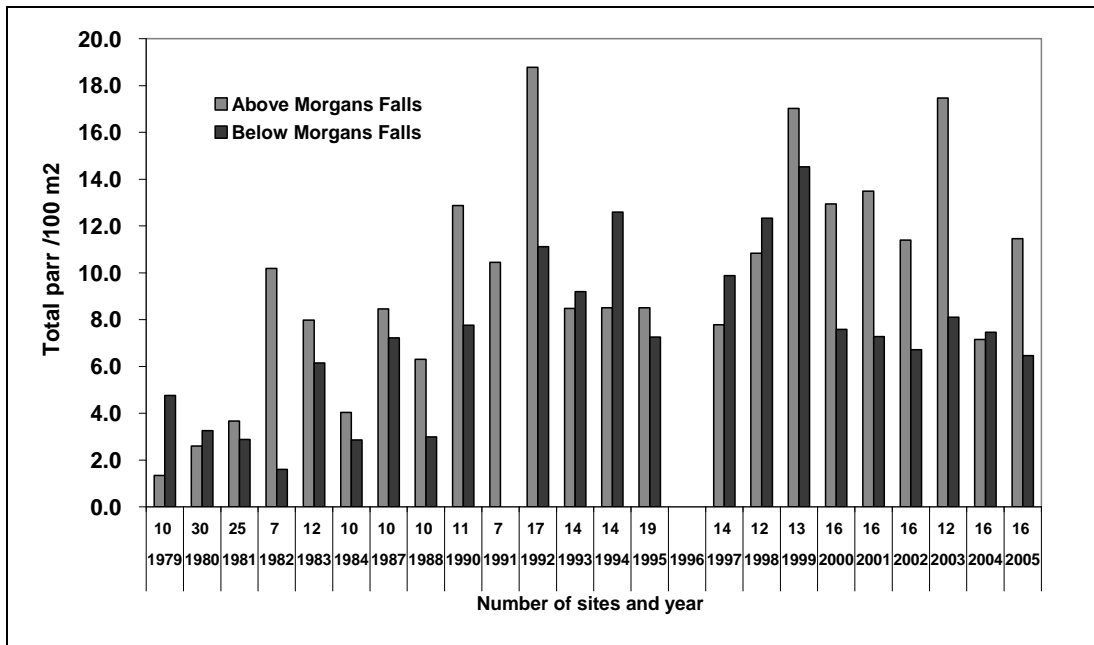
Figure 52. Mean juvenile salmon density above (light grey bars) and below (dark grey bars) Morgans Falls on the LaHave River in 1979 - 2005. Of the 16 sites monitored in 2005, 7 were above and 9 were below Morgans Falls. (Figure 20 in Amiro *et al* 2006a)
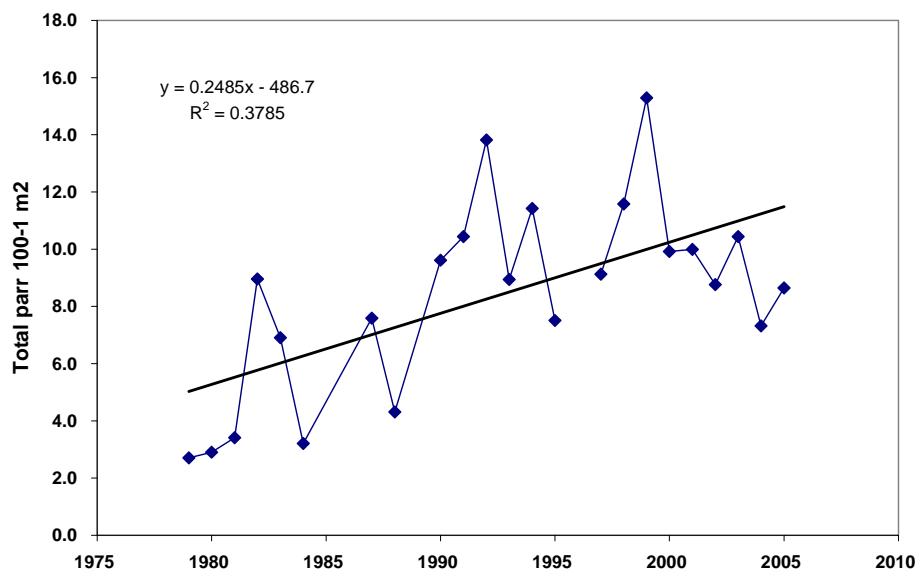

Figure 53. Estimated parr density (age-1 and age-2 combined) from the entire LaHave River (above and below Morgans Falls) from 1979 to 2005. The predicted relationship is based on a linear regression, where the equation as well as the R^2 value is given. Although parr density appears to be increasing slightly over time, the trend is not significant (p-value = 0.23). (Figure 21 in Amiro *et al* 2006a)

A fully cohort-adjusted recruit per spawning salmon analysis (Figure 54) indicates that the wild population of salmon above Morgans Falls on the LaHave River has not replaced itself since 1985. Consequently the population has contracted to a lower mean abundance and, therefore, is more vulnerable to the negative effects of demographic and

environmental variations. This status is being closely monitored through adult, smolt, and juvenile assessments for sudden shifts in population size.
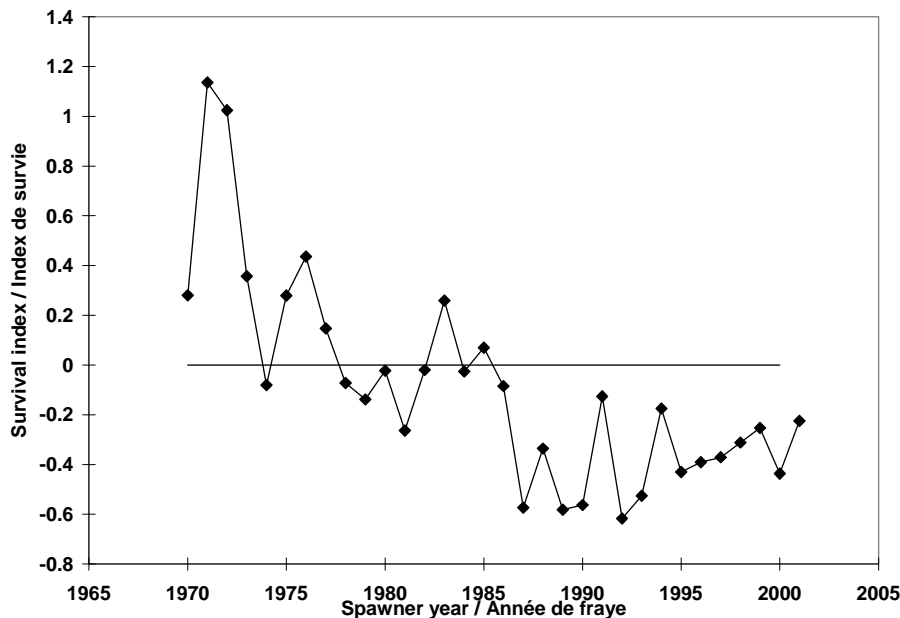

Figure 54. Population survival index (Ln cohort adjusted adult recruits per spawning salmon) determined from counts and age of salmon ascending Morgans Falls fishway and trap 1970 to 2006 (updated from Amiro *et al* 2000).

With respect to other rivers in the SFA area within CU 15, two fishways on the partially-acidified Tusket River (Yarmouth Co.) were not monitored for adult escapement in 2005 (escapement results were last reported by Amiro 2000). However, enhancement activities have been ongoing since 1979, and a total of 1,800 hatchery smolts were released into the Tusket River in 2005. The heavily-acidified rivers of SFA 21 (part of CU 15) are thought to be unable to support viable salmon populations, although remnant populations may still persist in some rivers. Based on the 2000 electrofishing survey on rivers throughout the SFA 21 area within CU 15 (Amiro 2000) and parr broodstock collections in 2003 and 2004, residual populations in partially-acidified and heavily-acidified rivers are critically low and their persistence is in jeopardy.

Status: For the St. Mary's River, the low escapement estimates, increased proportion of first-time spawners in the past eight years, low smolt production, and low juvenile densities in the previous three years indicate that the Atlantic salmon population in the St. Mary's River is unstable and in decline. Estimated returns in 2005 are at their lowest point in 11 years. Compounding these issues is the diminishing age-at-maturity of adults and an increase in the proportion of age-2 smolts. The mean number of years to recruitment is now closer to four years than five, which decreases the degree of overlap among age classes. If marine survival remains unchanged and adult returns do not substantially increase in 2006, actions to mitigate population decline and to protect genetic diversity may need to be considered.

For the La Have River, declining wild returns, low smolt-to-adult return rates, and low survival of hatchery smolts in 2005 demonstrated that the salmon population in the LaHave River above Morgans Falls was substantially below conservation requirements. Marine survival of wild smolts as indicated by the return rate of 1SW adults have decreased since 2001.

Based on the status of the wild salmon stock above Morgans Falls on the LaHave River and the estimates of returns to the St. Mary's River, *other* low-acidified rivers in CU 15 (SFA 20 and 21) are not expected to achieve conservation requirements in 2006. Supplementation of smolts does not appear to be sufficient to either off-set low marine survival or be a viable option for long-term conservation. Establishment of living gene banks for the remaining wild populations of the Southern Upland region has been initiated and needs to be assessed as a conservation measure.

Inner Bay of Fundy (CU 16)

<u>Abundance and trends for the Nova Scotia portions of CU 16</u>: Status of juvenile salmon in the Nova Scotia portion of CU16 was traditionally assessed by monitoring on the Stewiacke River and by electrofishing on other rivers. Traditional assessment activities have not been undertaken in the Nova Scotian portion of the inner Bay of Fundy since 2003, and conservation activities have been focused almost exclusively on maintaining the Live Gene Bank (LGB) at two biodiversity facilities. As of 2002, data for the Stewiacke River salmon population consisted of catch-effort data from the recreational fishery (27 years), estimates of juvenile densities obtained by electrofishing (23 years), an index of adult abundance obtained by electrofishing by boat (10 years) and counts of adults bypassing a fence (4 years). Using these data, the Stewiacke River population was estimated to be between 1,100 and 6,700 returning adults during the 1960s and early 1970s (Gibson and Amiro 2003), with high inter-annual variability. Estimates of the number of returning adults was less than 50 for the years 1997 to 2001 with a 90% probability that 4 or less salmon returned to the river in 2001. The analyses indicate a 90% probability that the population has declined by more than 99.6% between 1967 and 2000, and by more than 92% since the early 1990s. An electrofishing survey in 2003 did not find evidence of increased spawner abundance in recent years, although juvenile abundance has increased in the river as a result of the Live Gene Bank (LGB) program (Gibson *et al* 2004).

During 2002 (Gibson *et al* 2003b), the most extensive, recent electrofishing survey was undertaken to estimate the abundance of juvenile Atlantic salmon in all iBoF rivers in New Brunswick and Nova Scotia. During the survey, a total of 246 sites were electrofished in 48 rivers. Of the 34 rivers without LGB support, fry were not found in 30 and parr were absent in 22. Where salmon were present in rivers without LGB support, mean densities of fry and parr were very low. On the Nova Scotia side of the iBoF in rivers without LGB support, fry were totally absent and mean densities of parr were less than 7.1 fish/100 m^2 (and were much lower in most rivers). On the New Brunswick side of the iBoF, mean densities of fry were less than 5.2 fish/100 m^2 and parr were less than 3.8 fish/100 m^2. These results indicate a high likelihood that river-specific extirpations

have occurred in this region and juvenile abundances are extremely low in rivers without LGB support.

Based on smolt monitoring in 2006 in the Stewiacke River and the Gaspereau River, sufficient smolts to prevent extirpation were produced to support the Live Gene Banks. Marine survival of inner Bay of Fundy salmon populations from the Big Salmon and Gaspereau rivers were found to be extremely low from 2003 to 2005. Based on monitoring programs in adjacent rivers of CU 16, there is no indication that marine survival of Atlantic salmon has increased in recent years.

<u>Abundance and trends for the New Brunswick portions of CU 16</u>:   On the New Brunswick side, monitoring was continued on the Big Salmon River (45° 25'0"N, 65° 24'0"W) which flows 27 kms from the outlet of Walton Lake to the Bay of Fundy. It has a drainage area of 332 km^2 with an estimated 494,000 m^2 of accessible salmonid rearing habitat (Jessop 1975, 1986). Further characterisation of the river can be found in Jessop (1975, 1986). The Big Salmon River is home to a number of freshwater and diadromous fish species including one of the river populations of the inner Bay of Fundy (iBoF) Atlantic salmon population complex, and is presently one of the key index rivers used in the recovery strategy for this salmon population. Historical reviews of Atlantic salmon at all life stages in the Big Salmon River were completed by Jessop (1975, 1986). An index-based model for the Big Salmon River salmon population was fit to recreation catch data, juvenile densities obtained by electrofishing, adult fence counts, stream-side and dive counts for adults and redd count data (Gibson *et al* 2003c). The analyses indicate a spawning run size in the range of 1,000 to 4,000 salmon during the 1960s and early 1970s, and a spawning run size of less than 100 fish from 1996 to 2002. Estimates of the percent decline from the early 1990s ranged between 63% and 80%, and between 92% and 97% over the 30-year time period from 1967 to 2000. Although adult abundance has remained low, juvenile abundance has recently increased in both the Big Salmon and Stewiacke River as a result of the LGB program.

All adult salmon information for the Big Salmon River in 2004 and 2005 was collected through periodic dive counts between July and October, and annual fall redd surveys conducted by New Brunswick Department of Natural resources (Jones *et al* 2006). Usually, counts from the latest in-season observations were used to determine the population estimate of returning adults to the Big Salmon River. There was an estimated return of 60 adults to the Big Salmon River in 2005 - the largest estimated return since 2000 (Figure <u>55</u>). It should be noted, however, that this is potentially a minimum estimate since high water conditions did not permit further observations or counts later in the season (i.e., October). The annual redd survey conducted on Nov 8 observed 70 possible redds in the headwater region of the Big Salmon River. It was estimated that 16 and 60 salmon returned to the Big Salmon River in 2004 and 2005, respectively (Figure <u>55</u>). Juvenile salmon surveys were completed at 7 closed sites (barrier nets) and 11 open sites (spot-checks and mark-recapture) in the Big Salmon River in 2004 and 2005. In 2004 and 2005, the mean density (fish per 100 m^2) for wild salmon was greatest for age-0+ parr (14.0 in 2004 and 15.9 in 2005), and decreased as parr grew older (see Table 17 in Jones *et al* 2006). For hatchery salmon age-1+ densities were 3.4 (2004) and 1.9 (2005), and for age-2+ parr were 0.3 in 2004 and 0.1

in 2005 (see Table 17 in Jones *et al* 2006). The large fluctuations associated with the age-0+ wild densities in particular are likely attributed to the location of sites in respect to unfed fry releases from the Big Salmon river Live Gene Bank. Densities for all age classes were similar to those estimated since 2000 (Gibson *et al* 2003c, 2004).
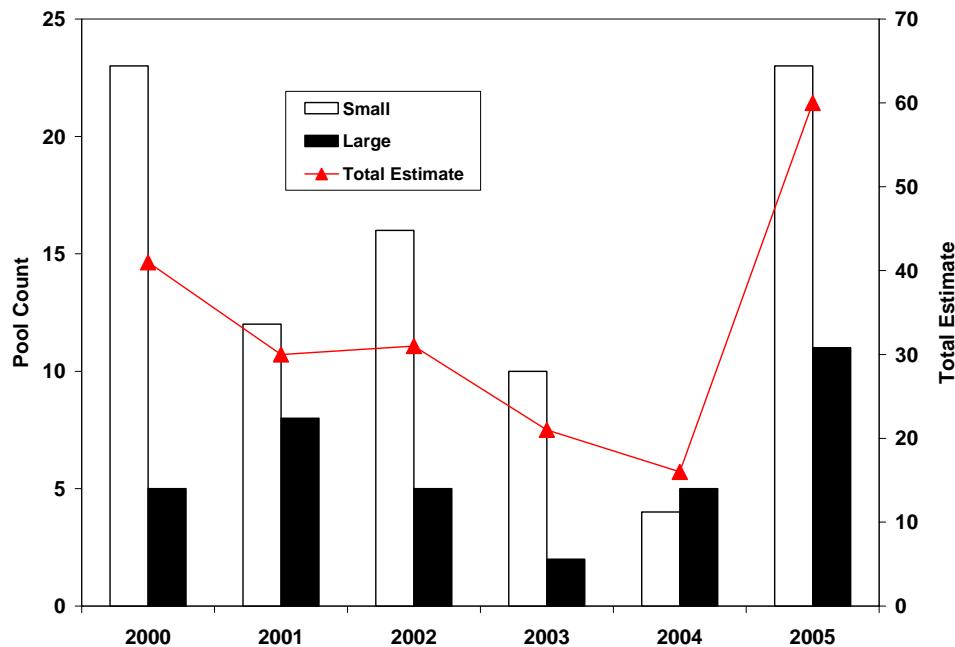

Figure 55. Small and large salmon numbers from dive counts, and the yearly population estimate from the Big Salmon River, 2001 – 2005. (Figure 30 in Jones *et al* 2006)

<u>Status</u>: Regarding the Nova Scotia portion of CU 16 (inner Bay of Fundy populations), Amiro *et al* (2006a) indicate that conservation activities in 2005 were focused exclusively on maintaining the Live Gene Bank because of the widespread and dramatic nature of the population declines throughout the region (Gibson *et al* 2006). Marine survival of inner Bay of Fundy salmon populations has been found to be extremely low since 2003; rivers supported by the Live Gene Bank produced sufficient smolts to prevent extirpation through the Live Gene Banks but, because of continuing low marine survival, do not maintain viable populations. Based on monitoring programs in surrounding CUs in 2005, there is no indication that marine survival of Atlantic salmon has increased in recent years.

With respect to the New Brunswick portion of CU 16 (inner Bay of Fundy populations)**,** Jones *et al* (2006) indicate that although the estimated number of adult returns to the Big Salmon River has increased slightly in 2005, it represents only 2.4% and 17.9% of the large and small salmon conservation requirement identified in Marshall *et al* (1992). In addition to current juvenile densities and smolt estimates, which are largely the result of supplementation of unfed fry, fall fingerlings and spring smolts from the Big Salmon River Live Gene Bank, the inner Bay of Fundy population of Atlantic salmon in the Big Salmon River is likely to remain critically low.

Outer Bay of Fundy (CU 17)[40]

Abundance and trends: This section addresses the abundance and trends thereof of Atlantic salmon CU 17 populations within SFA 23. This CU comprises the outer Bay populations of the western part of SFA 23, including the Saint John River upriver of Mactaquac Dam, the Nashwaak River (a tributary to the Saint John River downriver of Mactaquac Dam), the Magaguadavic River and the St. Croix River.

With respect to the Saint John River upriver of Mactaquac Dam**,** unadjusted counts of salmon at Mactaquac in 2005 totalled 1,126 1SW and 363 MSW salmon (Table 27). Estimated adjusted wild-origin and hatchery-origin returns in 2005 were 1,159 1SW and 350 MSW fish (Figure 56). Both one-sea-winter and MSW returns were the lowest in a 36-year time series (Figure 56). Adjusted returns of wild-origin 1SW salmon were similar to those of 2004, and the previous 5- and 10- year means but was the seventh lowest annual estimate since 1970 (Figure 56). Adjusted returns of wild-origin MSW salmon were the third lowest in 36 years and were well below the five and ten year mean estimates (Figure 56). The return rate to Mactaquac of 1SW fish released as one year smolts was 0.00381 – a slight improvement from the previous two years (Figure 57). The return rate of one year smolts to Mactaquac as virgin 2SW salmon (Figure 57) was 0.00051 - second lowest on record and about half that of the previous year. The mean density of wild fry (age-0+) at 16 sites on the Tobique River in 2004 and 2005 was 7.8 and 5.3 fry per 100 m^2. Both values were an improvement from the 0.5 value observed in 2003 (Figure 58). With the exception of 1995, mean densities at the index sites have been below the 'Elson norm' of 29 fry per 100m^2 (Elson 1967). No wild fry were captured at 10 (17%) and 21 (36%) of the 58 electrofishing sites completed in 2004 and 2005, respectively (see Table 8a, Table 8b in Jones *et al* 2006). Mean density of age-1+ and older wild parr at the same 16 sites was 5.4 parr per 100 m^2 in 2005. These values are well below Elson's (1967) 'normal index' of 38 small and large parr per 100 m^2 (Figure 58). This value is above the mean density (2.6) observed in 2004, and reflects the improved mean fry density recorded in 2004. Despite the low densities, the parr appear to be well distributed throughout the watershed as only 10 and 6 of the 58 sites were void of wild parr (see Table 8a, Table 8b in Jones *et al* 2006).

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[40] This entire section is copied, abstracted and/or synthesized from Jones *et al* (2006).

Table 27. Counts of wild, hatchery and aquaculture origin Atlantic salmon (as identified by fishway operators) trapped at fishways/ fences of four rivers in southwest and central New Brunswick. The Saint John counts are provided by Mactaquac Biodiversity Facility sorting facility staff. (Table 2 in Jones *et al* 2006.)

Year	Saint John Wild 1SW	Wild MSW	Hatchery 1SW	Hatchery MSW	Nashwaak Wild 1SW	Wild MSW	Hatchery 1SW	Hatchery MSW	Dates of Operation	Magaguadavic Wild 1SW	Wild MSW	Aquaculture 1SW	Aquaculture MSW	St. Croix[c] Wild 1SW	Wild MSW	Hatchery 1SW	Hatchery MSW	Aquaculture 1SW	Aquaculture MSW
1967	1,181	1,271	-	-															
1968	1,203	770	-	-															
1969	2,572	1,749	-	-															
1970	2,874	2,449	94	-															
1971	1,592	2,235	336	37															
1972	784	4,831	246	583	259	859	-	-	8/18-10/29 e										
1973	1,854	2,367	1,760	475	596	1,956	-	-	6/10-11/05 e										
1974	3,389	4,775	3,700	1,907															
1975	5,725	6,200	5,335	1,858	1,223	1,036	-	-	6/28-10/29 e										
1976	6,797	5,511	7,694	1,623															
1977	3,504	7,257	6,201	2,075															
1978	1,584	3,034	2,556	1,951															
1979	6,234	1,993	3,521	892															
1980	7,555	8,157	9,759	2,294															
1981	4,571	2,441	3,782	1,089															
1982	3,931	2,254	2,292	728										53	15	27	3		df
1983	3,613	1,711	1,230	299						282	607	21	30	33	62	2	28		df
1984	7,353	7,011	1,304	806						255	512			120	40	63	17		df
1985	5,331	6,390	1,746	571						169	466			36	250	12	46		df
1986	6,347	3,655	699	487										31	128	29	130		df
1987	5,106	3,091	2,894	344										43	147	181	21		df
1988	8,062	1,930	1,129	670						291	398			45	22	55	274		df
1989	8,417	3,854	1,170	437										46	19	95	73		df
1990	6,486	3,163	1,421	756 a										11	40	4	54		df
1991	5,415	3,639	2,160	587 a										30	83	42	52		df
1992	5,729	3,522	1,935	681 a						155	139	83	62 bd						
1993	2,873	2,601	1,034	379 a	72	113	11	42	8/19-10/12 de	112	125	96	52 bd	3	30	5	66		d
1994	2,133	1,713	1,180	493 a	376	251	27	23	7/15-10/25 de	69	61	1,059	81 bd	24	19	23	18	97	
1995	2,429	1,681	2,541	598 a	544	294	25	14	7/12-10/18 de	49	30	491	168 bd	7	14	7	19	7	6 d
1996	1,552	2,413	4,603	726 a	854	391	86	38	6/13-10/18 de	48	21	174	20 bde	10	32	13	77	15	5 d
1997	380	1,147	2,689	629 a	332	339	38	27	6/18-11/02 d	35	24	59	23 bd	7	8	26	2	11	16 d
1998	476	367	4,413	624 a	464	142	1	9	6/08-10/27 de	28	3	211	3 bd	12	6	20	3	14	11 df
1999	700	1,112	2,511	680 a	303	84	2	0	6/03-10/13 de	19	5	80	10 bd	7	2	1	3	23	0 df
2000	1,408	393	1,573	200 a	428	161	0	0	6/19-10/26 de	13	1	25	2 bd	0	0	15	5	30	0 df
2001	730	680	942	521 a	242	271	2	1	6/21-11/01 d	8	9	120	4 bd	0	0	13	7	33	23 df
2002	709	212	1,616	178 a	342	73	1	6	6/10-10/28 d	7	0	29	0 bd	0	0	14	6	2	4 d
2003	443	279	838	464 a	181	82	7	3	6/05-10/26 de	3	3	14	2 bd	0	0	13	2	3	3 df
2004	863	446	562	296 a	473	168	13	4	6/03-10/26 de	2	0	0	17 bd	1	0	5	4	0	4 d
2005	862	269	264	94 a	405	94	20	3	6/09-10/07 ade	9	0	62	1 bd	0	0	2	4	30	3 d

a- Small numbers of aquaculture fish, see Tables 3,4a & b. b- Aquaculture. c- Hatchery designation to be reviewed; sea-cage fish could be among hatchery fish prior to 1994.
d- Corrected by scale analysis. e- Partial count. f- breakdown changed from Jones et al. 2004

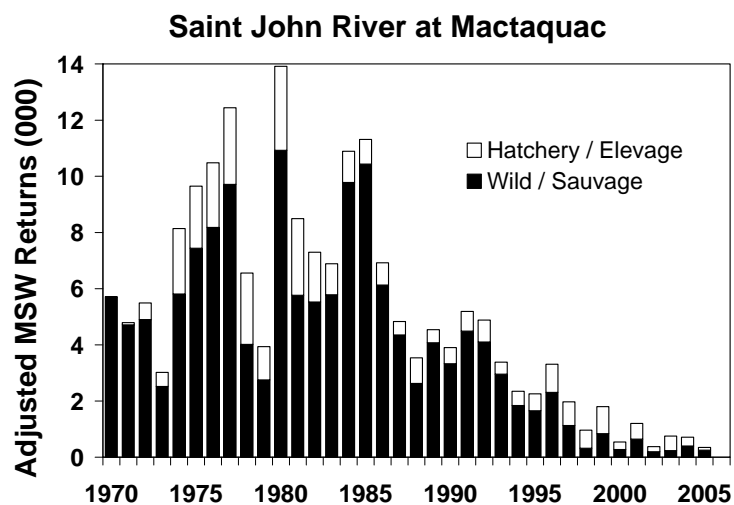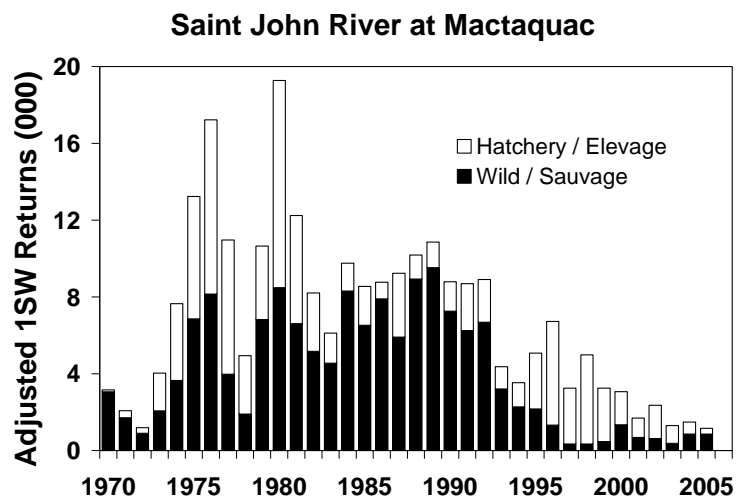**Saint John River at Mactaquac**

Figure 56. Estimated total adjusted returns of wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam, Saint John River, 1970 – 2005. (Figure 3 in Jones *et al* 2006)
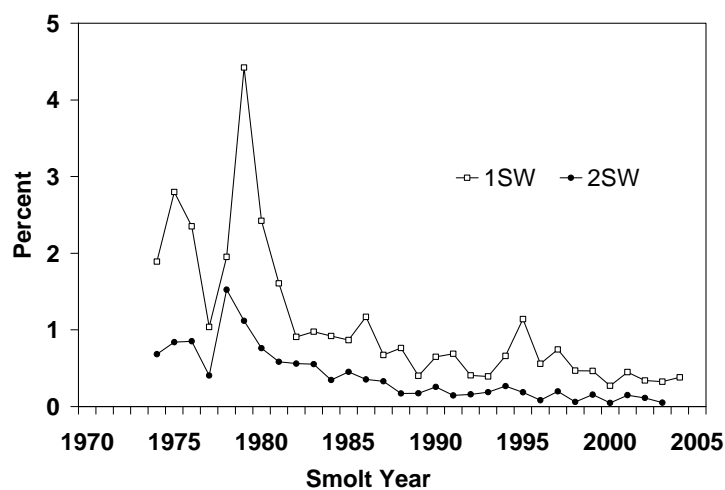

Figure 57. Return rates of hatchery reared smolts to virgin 1SW and virgin 2SW salmon destined for Mactaquac Dam, Saint John River, by smolt year, 1974 – 2004 (Figure 4 in Jones *et al* 2006)
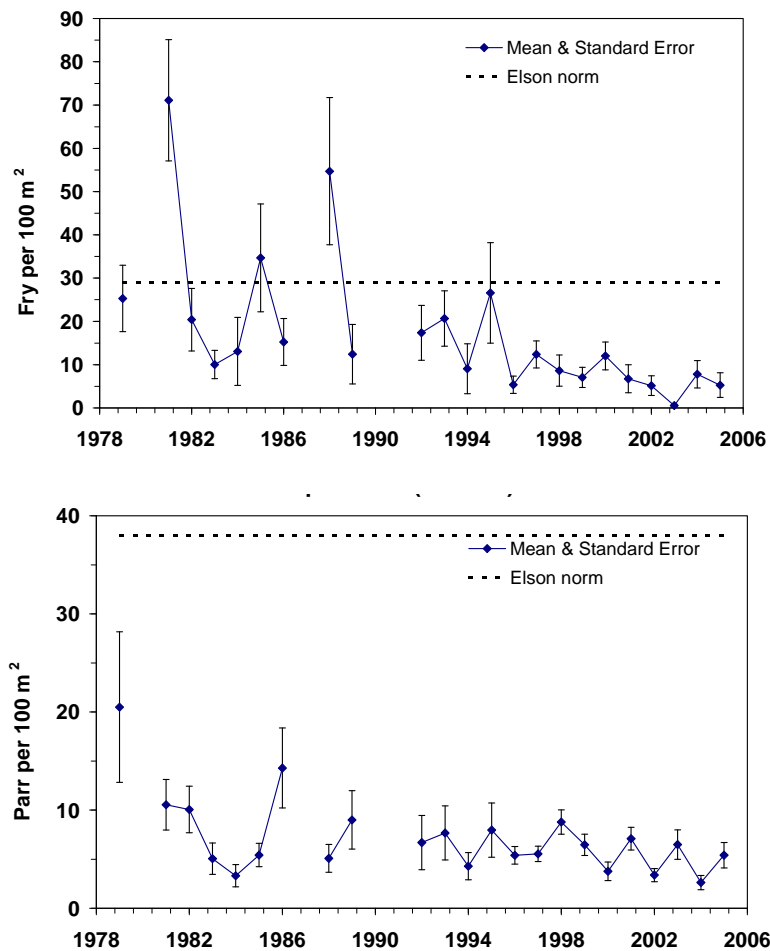
Figure 58. Mean densities of age 0+ fry (upper) and age 1+ and older parr (lower) from 20 electrofishing sites on the Tobique River relative to the 'Elson Norm' from 1978 to 2005. (Figure 8 in Jones *et al* 2006)

Returns of 1SW salmon to the Saint John River downstream of the Mactaquac Dam (CU 17/ SFA 23, western part) at the Nashwaak River declined from highs in the early 1990s but have recently increased; 2005 returns were 20% higher than those in 2004 and were the second highest since 1996 (Figure 59). There has been a steady increase in the number of wild 1SW returns since 2001. MSW returns for the Nashwaak River decreased 20% from 2004 and were the third lowest since 1993 (Figure 59). The wild MSW salmon returns in 2005 were similar to the five-year mean and around 44% below the 10-year mean. Previous spawning salmon represented about 10% of the wild MSW returns.

1SW Salmon Returns to the Nashwaak River
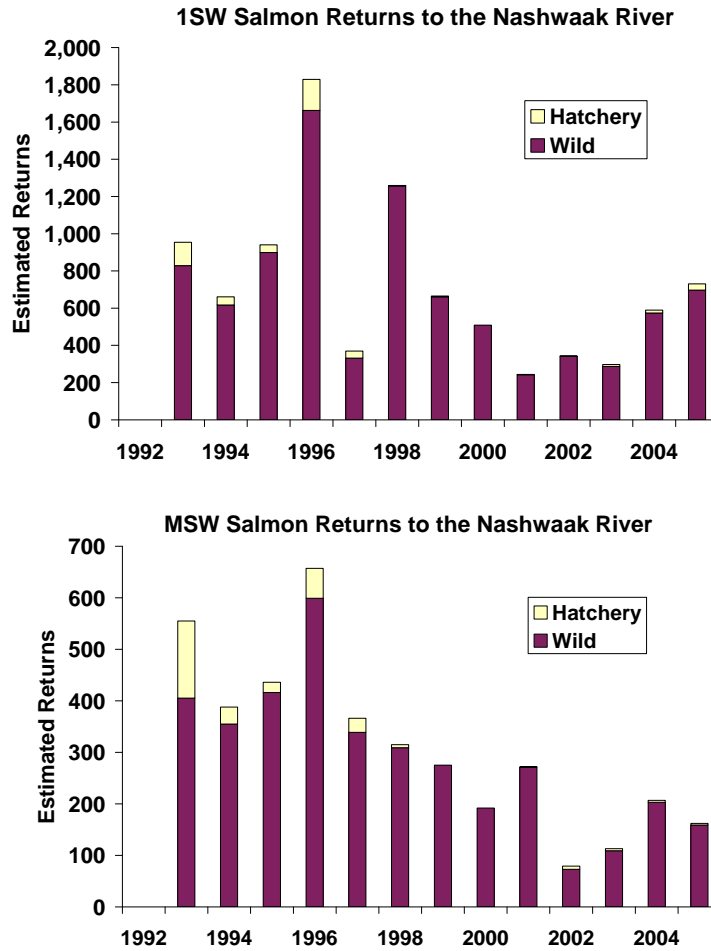

MSW Salmon Returns to the Nashwaak River

Figure 59. 1SW and MSW returns to the Nashwaak River. (Figure 19 in Jones *et al* 2006)

The Magaguadavic River flows southeasterly for 97 km to the Passamaquoddy Bay, Bay of Fundy at St. George, N.B. (Martin 1984). The 13.4m-high dam and 3.7 megawatt hydroelectric station (with 4 Francis turbines) located at the head-of-tide was replaced with a new 15 megawatt hydroelectric station (with 2 Kaplan turbines) in 2004. Upstream passage is provided by a fishway. A new downstream bypass and assessment facility was constructed in the new hydroelectric station. Assessment of the anadromous fish resources is done using a trap in the third pool from the top of the fishway. In 2005, the fishway trap was monitored for salmon from late April until early December. Salmon count data and analyses were provided by the Atlantic Salmon Federation[41]. In 2005, similar to the previous year, no fish of aquaculture origin that were captured at the trap were released to the river. All salmon of suspected aquaculture origin were sacrificed for sampling of pathogens. Wild returning salmon have been rapidly declining since 1992 and have averaged less than 15 fish per year since 1998. Aquaculture fish are escapes from aquaculture cages in the Fundy Isle area which, in 2005, produced approximately 35,000 tonnes of Atlantic salmon. Counts of

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[41] Jon Carr- Atlantic Salmon Federation, PO Box 429, St. Andrews, NB, E0G 2X0

1SW salmon in the trap numbered five wild and four hatchery fish. There were no wild or hatchery MSW salmon counted in 2005. Aquaculture escapes ascending the fishway in 2005 numbered six postsmolts, 62 1SW and one MSW salmon. It is possible that some of the 'wild' salmon counted may be the result of early life stage juvenile escapes from any of the three private hatcheries in the drainage. Counts made since 1992, when aquaculture escapes were identified, and those in 1983 - 1985 and 1988, when escapes were largely unnoticed, are in Table 27. Total counts of both wild 1SW and MSW salmon were the highest observed since 2001 and higher than the mean for the last five years (see Figure 25 in Jones *et al* 2006). Counts of suspected aquaculture escapes were the second highest in the past five years.

The St. Croix River, a USA-Canada international river bordering the State of Maine and Province of New Brunswick, drains southeasterly into Passamaquoddy Bay in the Bay of Fundy. Approximately 1,619 km^2 of the drainage basin is in New Brunswick and 2,616 km^2 is in Maine (Figure 27 in Jones *et al* 2006). Historically a significant producer of Atlantic salmon, this salmon population has succumbed to industrial development - initially cotton mills, then pulp mills, and now dams and headponds at three hydroelectric facilities. The main stem and East Branch (84 km), the Chiputneticook lakes (66 km) and Monument Brook (19 km) determine 169 km of the international boundary (Anon 1988), the fluvial portions of which comprise the bulk of the potential rearing area for Atlantic salmon. No natural returning adult salmon have been released upriver since 1997. Future returns are dependant on hatchery programs. Without a dramatic shift in sea survival, these conservation efforts are not expected to yield any significant number of naturalized salmon in the near future. Counts of salmon at the Milltown fishway by St. Croix International Waterway Commission near head-of-tide on the St. Croix River in 2005 numbered 4 MSW and 2 1SW hatchery-origin fish, 3 MSW and 33 1SW aquaculture escapes, and no wild fish (Figure 28 in Jones *et al* 2006). Aquaculture escapes were removed from the fishway trap, sacrificed for laboratory disease analysis and found to be negative for the infectious salmon anaemia (ISA) virus. All hatchery-origin fish were live-tested for the ISA virus and also found to be negative. There have been no wild returning adult salmon to Milltown fishway since 2000 (Table 27).

Status of CU 17 Saint John River upriver of Mactaquac Dam: The conservation requirement is based on an accessible salmon-producing rearing area upriver of Mactaquac (excluding the Aroostock River) of 13.47 million m^2 [>0.12% and <15.0% gradient (Amiro 1993); excludes headponds and 21.0 million m^2 of river with gradient <0.12%; (Marshall *et al* 1997)]. Based on an assumed requirement of 2.4 eggs/m^2 (Elson 1975), the conservation requirement is 32.3 million eggs. The numbers of spawners necessary to obtain the conservation requirement are estimated at 4,900 MSW and 4,900 1SW salmon (Marshall *et al* 1997). Similar to previous years, egg deposition and spawners in 2005 were estimated on the basis of length, external sexing and interpretation of age from scales collected from fish captured at the Mactaquac fishway (Jones *et al* 2004). Projected returns, based on the average returns of the previous five years, for populations originating upriver of Mactaquac Dam on the Saint John River in 2006 are 1,600 (90% C.I.; 820 - 2,360) 1SW and 680 (90% C.I.; 160 – 1,250) MSW salmon. The probabilities of attaining the conservation requirement of 4,900 for both 1SW and MSW

salmon are near zero for both forecasts. Based on escapement in 2001 (20%) and 2002 (6%), and Tobique smolt production (2005) wild 1SW salmon returns for 2006 will only increase if marine survival improves from recent years. Hatchery smolt releases in 2005 were 48% higher than 2004 so there could be a slight improvement in the number of hatchery 1SW salmon returns for 2006. A 67% decrease in the number of hatchery smolts released in 2004 from 2003 suggests fewer hatchery 2SW returns in 2006.

Nashwaak River: Salmon production area upriver of the fence is estimated to be 5.35 million m^2 and the conservation requirement is 12.8 million eggs (Marshall *et al* 1997). The numbers of spawners necessary to obtain the conservation requirement are estimated at 2,040 MSW and 2,040 1SW salmon (Marshall *et al* 1997). Egg deposition and spawners in 2005 were estimated on the basis of length, external sexing and interpretation of age from scales collected from fish passing through the fence. Predicted returns to the Nashwaak River in 2006 using the five year average are 440 1SW fish (90% C.I.; 120 - 780). There is a near zero probability that the 1SW requirement of 2,040 fish will be met. The forecast of MSW returns is 170 fish (90% C.I.; 50 - 290) and the probability that the conservation requirement of 2,040 MSW fish will be attained is also near zero. Applying the minimum and maximum range of smolt-to-1SW return rates observed since 1999 to the 2005 wild smolt estimate indicates the predicted 1SW returns to the Nashwaak in 2006 could be between 80 and 330 fish. This method has proven to be a more reliable forecast in comparison to the five year mean. The predicted 2SW salmon returns in 2006, from the 2004 smolt class, range from 40 to 210 fish using the observed smolt-to-2SW return rates. Despite slight improvements in the numbers of adult returns and subsequent spawners, particularly 1SW salmon, parr densities remain low and suggest that returns will not be adequate to achieve the egg conservation requirement for several years to come.

Magaguadavic River: The conservation requirement of 1.35 million eggs is based on an estimated 563,000 m^2 of juvenile rearing substrate (Anon 1978) and a deposition of 2.4 eggs per 100 m^2 (Elson 1975). The numbers of spawners necessary to obtain the conservation requirement are estimated at 230 MSW and 140 1SW salmon (Marshall and Cameron 1995). The estimated number of females suggests a potential egg deposition of 7,500 eggs or less than 2% of the requirement. Estimates of escapement and attainment of the conservation requirement have steadily declined since 1994 (see Fig. 26 in Jones *et al* 2006). Wild 1SW and MSW returns to the Magaguadavic River in 2006 are projected to be no greater than the returns in 2005. There is a near zero probability of attaining the conservation requirement in 2006. Progeny of the last 'disease free' wild adult returns in 1998 were distributed to the Magaguadavic watershed in 2003 as unmarked age-0+ parr (Appendix v in Jones *et al* 2006) and are expected to contribute to adult returns in 2006 - 2007. This undertaking is a result of the action plan by the Magaguadavic Recovery Committee. Preliminary results from electrofishing surveys in 2003 indicate that the release of the 56 mature (35% female) captive reared broodstock in 2002 is unlikely to make a significant increase in adult returns in 2006 - 2007.

St. Croix River: Returns to the St. Croix River in 2006 are unlikely to differ greatly from the mean value of 17 hatchery returns from 2001 to 2005. This is because all returning adults have been retained as broodstock since 1997 and the number of stocked juveniles

from these collections has remained constant and low. Under any scenario for returns in 2006, there is no probability of attaining the conservation requirement.

Recovery feasibility CUs 13-17:   Human activities have impacted upon salmon populations in the inner and outer Bay of Fundy, Southern Upland and Eastern Cape Breton regions for more than a century. Despite closures of both commercial and recreational fisheries, recent declines of populations in these regions have continued. At present, outside of eastern Cape Breton, none of the assessed wild populations in these CUs are at more than 30% of their conservation spawner requirement, and declines (Figure 43) of the wild component of assessed populations exceeded 50% in the last 15 years in all cases. Within Eastern Cape Breton, only North River has met its conservation requirement in recent years. Evaluation of both the recovery potential and recovery feasibility requires the identification of the threats to populations as well as knowledge of the effects of the threats on the population's dynamics. This information exists for some rivers in this region and can be used to evaluate how populations are expected to change in response to human activities, including recovery activities.

Gibson *et al* (2008) provide four case studies that illustrate the relationship between threats and recovery potential of salmon in the Atlantic Nova Scotia and Bay of Fundy sub-region: the Big Salmon River and the Tobique River in New Brunswick, and the LaHave River and West River (Sheet Harbour) in Nova Scotia. They use equilibrium models to show the present status of each population as well as the expected effect of recovery actions on the population. Equilibrium models split the life cycle of a species into two or more parts and determine the population size at which the rates in each part of the life cycle are balanced such that the population does not increase or decrease in size. By varying the life history parameters in a manner that represents the expected response to a human activity and examining the resulting change in equilibrium population size, the effects of the activity on the population can be evaluated in a way that places the expected response in the context of other threats to the population (Figure 60). The threats and stressors discussed in each case study are representative of some of those affecting salmon population viability in Bay of Fundy and Nova Scotia Atlantic Coast Rivers: acidification, hydroelectric development, low freshwater habitat productivity and low at-sea survival.
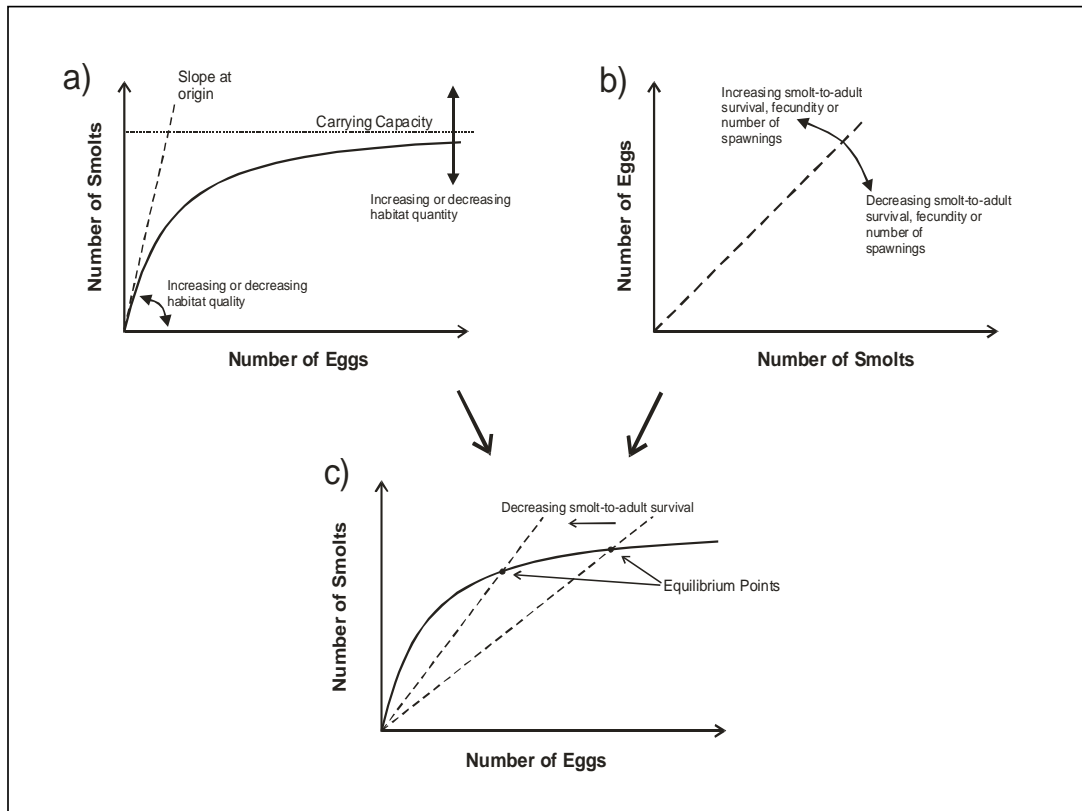
Figure 60. An equilibrium model linking habitat quality and quantity to fish population dynamics. A Beverton-Holt model (a) is used to model the density-dependent relationship for survival from eggs to smolt. The slope at the origin of this model, which is the maximum number of smolts produced per egg 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 (b) throughout its life, 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 in balance with the production of eggs by smolts throughout their lives, and is the size at which the population will stabilize if all rates and the carrying capacity remain unchanged. The population equilibrium changes as the vital rates change and can be used to assess how a population is expected to change in response to human activities. Figure from Gibson *et al* (2008).

The LaHave River (above Morgans Falls) case study, developed using data specific to this population, illustrates the effect of reduced at-sea survival (Gibson *et al* 2008). A freshwater production curve (Figure 61) was derived using estimates of annual egg deposition (available for the period from 1973 to 2005) and estimates of the number and age composition of smolts emigrating from this river are available for the years 1996 to 2005. The lifetime egg production by smolts throughout their lives was estimated using return rate data for the 1996 to 2004 smolt year classes, population specific fecundities and estimates of repeat spawning frequency. Return rates to LaHave River have averaged 2.37% (range: 1.09% to 4.33%) for salmon maturing after one winter at sea and 0.48% (range: 0.24% to 0.97%) for salmon maturing after two winters at sea. Presently, only low at-sea survival has been identified as a threat for this population. Opportunities to

154

increase either productivity (slope at the origin) or capacity (total population) are limited, but could be expected to improve population recovery. At the lowest return rates, the population has an equilibrium size of zero; while at the average return rates, the equilibrium population size is roughly 1.1 million eggs, a value similar to recent egg depositions. At the maximum return rates observed during this period (during 1999), the population would be well above its conservation limit. The case study illustrates that if these higher at-sea survival rates were maintained, populations would be expected to increase to levels where fisheries could also be maintained.
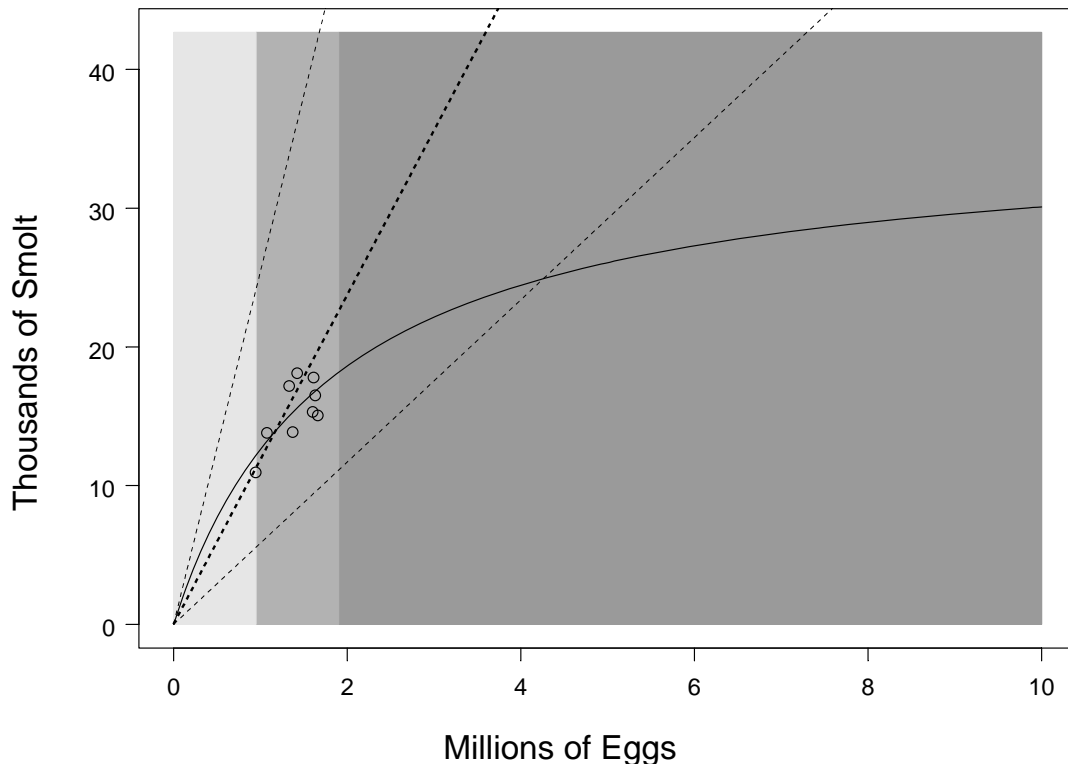

Figure 61. Effect of changing at-sea survival on the dynamics of the LaHave River (above Morgans Falls) salmon population. The points are the observed egg depositions and smolt production for the 1994 to 2001 cohort years. The solid line is a Beverton Holt model obtained by fitting these data to the population spawning above Morgans Falls and shows the expected number of smolts as a function of egg deposition. The dashed lines show the replacement lines calculated using the minimum (left), average (middle) and maximum (right) smolt to adult return rates observed for this population between 1996 and 2004. Shading indicates the status relative to the conservation egg requirement: dark shading is above the requirement, the medium shading is between 50% and 100% of the egg requirement and the light shading is below the requirement. The population equilibrium (the size at which the population will stabilize if none of the rates change) is the intersection of the dashed and solid lines. At the highest recent return rates, the equilibrium is above conservation requirement, whereas at the lowest recent return rates, the population equilibrium is zero. Figure from Gibson *et al* (2008).

The Big Salmon River case study, thought to be representative of salmon populations in CU 16, is again based on population-specific data Gibson *et al* (2008). Although other threats exist, the primary stressor to populations within this CU is also low at-sea

survival, which is much lower than CU 15. The effect of decreased at-sea survival for the Big Salmon River population is a shift in the equilibrium population size from about 4 times the conservation egg requirement to a population that is not viable (equilibrium of zero). In the absence of human intervention or a change in at-sea survival, these populations are expected to become extirpated. In the past, population size was very sensitive to the amount of habitat; however, at present, increasing habitat quantity or quality is expected to have little to no effect on population size given present at-sea survival rates. Increasing at-sea survival, such that return rates are 4% for 1SW and 0.5% for 2SW, results in a shift of the population equilibrium to about twice the conservation egg requirement. The case study illustrates how factors influencing one part of the life cycle (in this case at-sea survival), can limit the effectiveness of recovery actions focused on other parts of the life cycle (freshwater habitat restoration). These results do not indicate that freshwater habitat is unimportant. Clearly, if these populations are to recover, a sufficient amount of freshwater habitat will be required to support the populations. In fact, the recovery potential of this population is dependent on the continued capacity of the freshwater habitat to support a healthy population.

Interactions among multiple stressors are illustrated in the other two case studies presented in Gibson *et al* (2008). The salmon population in the Tobique River (CU 17) is also under stress from reduced at-sea survival, but is further impacted by reduced survival of smolts which must migrate downstream past hydroelectric generating stations and though impoundments. Freshwater habitat productivity also appears low based on analyses of egg-to-smolt survival and juvenile abundance data undertaken as part of the case study. The potential for recovery of Tobique River salmon is shown graphically for two fish passage scenarios (Figure 62). Given present freshwater production and at-sea survival, the population is not viable irrespective of the status of fish passage even at the maximum observed return rates used in this analysis. If marine survival increases to a hypothesized (but plausible) 8% for 1SW and 3% for 2SW salmon, the population is still not viable at present passage survival rates, but a small equilibrium population size exists if fish passage is improved. If freshwater production is increased and marine survival increases, the population equilibrium is greater than the conservation requirement if fish passage survival is increased to 100%, but is less than half the requirement at present passage survival rates. Fish passage mortality therefore can substantially limit the potential effectiveness of other recovery efforts, but addressing the fish passage survival issue only is not expected to be sufficient to produce viable populations.
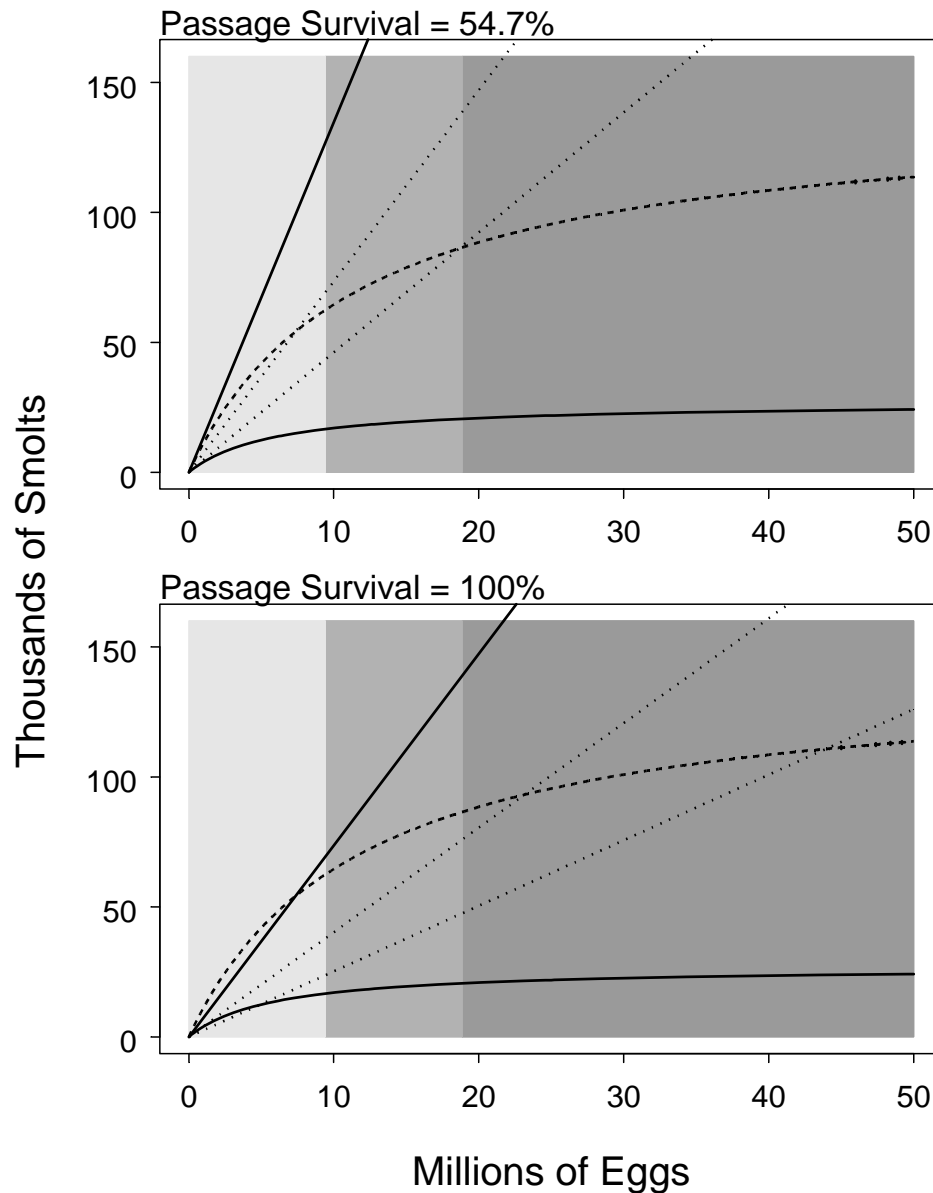
Figure 62. Analysis of the effects of alleviating threats to the Tobique River salmon population. The curved, solid line is the freshwater production curve obtained from the statistical model, and the curved dashed line is the freshwater production curve obtained if the asymptotic recruitment level is doubled to 18.6 age-1 parr per 100 m^2 and survival of age-1 and older parr is doubled to 49%. Three replacement lines are shown: the slope of the solid line is calculated using the average return rates from Nashwaak River, the middle line is calculated using the maximum observed rates and the left dashed line represents a hypothetical scenario of 8% and 3% return rates for 1SW and 2SW salmon, respectively. The dynamics are shown for two fish passage scenarios: fish passage mortality of 45% (status quo) and fish passage mortality reduced to zero. Dark shading indicates egg depositions above the conservation egg requirement: the medium shading is between 50% and 100% of the egg requirement and the light shading is below the requirement. Figure from Gibson *et al* (2008).

A similar outcome was found in the West River (Sheet Harbour) case study (Gibson *et al* 2008). This river is impacted by both acidification and reduced at-sea survival. Low equilibrium population sizes can be obtained by addressing either threat, although population viability in a randomly fluctuating environment is unknown. Based on the model results, both at-sea survival and acidification would have to be addressed to affect population recovery. These case studies illustrate that where multiple threats exist for a population, multiple responses are likely required to bring about recovery of the population.

For populations with information about status and threats, the effects of recovery actions, recovery feasibility and recovery costs can be evaluated. However, two impediments exist for determining the recovery potential of Bay of Fundy, Southern Upland and Eastern Cape Breton salmon on a regional basis (Gibson *et al* 2008). The first is the lack of a comprehensive list of threats to populations on a river-by-river basis that can be used to evaluate recovery potential on a regional scale. While the modelling approaches presented here can be used to evaluate the activities required for recovery on a population-specific basis, in the absence of an evaluation of the extent of the threats, the magnitude of the effort required to affect regional recovery is unknown. Second, the models used here assume that abundance within populations is sufficient that a response is possible. Juvenile salmon were not found in 28 of 57 rivers sampled during an electrofishing survey on the Southern Upland in 2000, and 16 of the 29 rivers with juvenile salmon had fewer than 5.0 juvenile salmon per 100 m^2, suggesting that many populations are extirpated or are critically low. Electrofishing surveys on monitored rivers (the LaHave River and St. Mary's River) indicate declining juvenile abundance since 2000. At present, the number of rivers with sufficient abundance of salmon for recovery to occur is not known.

The analyses summarised above, coupled with information about status in CUs 14-17 can be used to answer the questions posed by Environment Canada (2005).

> *1. Are individuals capable of reproduction currently available to improve the population growth rate or population abundance?*

As shown in Section 5, individuals are available in each of CUs 14-17, but are not in all formerly occupied rivers. Presence of juveniles demonstrates that these salmon are capable of reproduction. However, population growth rates are linked to threats which need to be alleviated before population abundance will increase.

> *2. Is sufficient suitable habitat available to support the species or could it be made available through habitat management or restoration?*

Habitat is available in the geographic areas in each of the 4 CUs, although access issues as a result of hydroelectric development, tidal barriers, culverts or other factors do exist on some rivers. Habitat is degraded in some watersheds (DFO and MNRF 2008), particularly for CU 15 for which acidification has occurred (34 of

56 rivers are either partially or heavily acidified - Section 5). Where it is required, suitable habitat can be made available through restoration and management.

3. Can significant threats to the species or its habitat be avoided or mitigated through recovery actions?

Although other threats exist, low at-sea survival is presently a major stressor responsible for the decline of salmon stocks in these CUs, the cause of which is unknown. This mortality is being mitigated by live gene banking in CU 16 which has the lowest at-sea survival. These methods could be used for the other CUs where appropriate, and are thought to be sufficient for at least short term maintenance of genetic diversity in anticipation of the identification of the cause of the reduced survival or a change in survival rates.

4. Do the necessary recovery techniques exist and are they demonstrated to be effective?

Technical expertise and infrastructure exists to operate a LGB program. Wild juvenile salmon have been successfully raised to maturity in captivity and their offspring have been observed to survive in the wild and to become smolts at viable rates. Stocked LGB juveniles have also been recaptured from the wild, raised to maturity, spawned and the resulting eggs incubated to rear another generation. The technical aspects of the program have been adequately resolved and a variety of life stages of iBoF salmon have been held in captivity or released. Monitoring of juvenile salmon in the wild has confirmed that the population can be maintained for perhaps three generations through this process of bypassing the marine phase of the life cycle. However, until the cause(s) of low at-sea survival is identified, whether the population-level effects of this mortality can be alleviated, is not known.

6. Potential for Recovery[42]

6.1 Expected Target(s) for Recovery

Of the various SARA provisions relevant to *setting of recovery targets* (also see Sections 37 - 40, 73 - 76, 83 - 86), Section 41 is most specific, requiring the Recovery Plan to specify: an identification of threats to species and habitats and a description of 'broad strategy'; a statement of population and distribution objectives and a general description of research and management activities needed to meet these objectives; and a description of critical habitat. DFO (2005b) indicates that, "(the subsequent) Section 42 requires the Minister of the accountable jurisdiction to place the Recovery Plan on the Public Registry because the Minister of Fisheries and Oceans is accountable for the provisions of the recovery plans of aquatic species; it is necessary to ensure that the recovery targets are

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[42] This entire section is copied, abstracted or synthesized from DFO (2005b).

scientifically well-based." The SARA does not define 'recovery', but does require that expert groups reach consensus on what biological characteristics (or *targets*) constitute 'recovery' of a population/species. Recovery targets are also important because, while a Recovery Plan is in place for a species, activities that might kill, harm, harass, or destroy the species or its residence can only occur under conditions specified explicitly in the Recovery Plan. Given these legal underpinnings for recovery plans and therefore recovery targets, consistent standards must be used in advising on recovery targets across species.

A national workshop was held by DFO (DFO 2005b) to consider what comprises 'recovery' for aquatic species possibly at risk. The meeting reviewed a wide range of case histories. In each case, information was presented on past and present population sizes, distribution, and biology, in part structured by a common template to organize the information consistently. Results from that workshop were summarized (DFO 2005b) as follows:

• "The 'precautionary framework' currently being finalized for fisheries management was considered suitable as the starting point for recovery of species at risk as well. The framework has three zones for a population: healthy, cautious, and critical (see Figure 63).

• There are both strengths and weaknesses to placing a biologically-based recovery target at either the critical-cautious boundary, or at the cautious-healthy boundary. There is at present no compelling *science* argument pointing definitively to one position or the other, or any specific position between them.

• Recovery plans which aim to increase biomass or abundance to the cautious-healthy boundary are expected to result in stocks not assessed as Threatened or Endangered by COSEWIC, whereas recovery plans which only aim to increase a population to the critical-cautious boundary may find that COSEWIC assessments still conclude that the population is at unacceptable risk of extinction in the medium term.

• Sixteen biological attributes were reviewed for each of fifteen case histories, with regard to their usefulness as components of recovery descriptions and recovery plans. Direct measures of Abundance and Total Range Occupied emerged as the preferred biological traits to use in specifying recovery targets and focusing recovery efforts.

• Several other traits were considered to be valuable supplementary features to consider in recovery targets and recovery plans. There are circumstances where supplementary traits may be as important as direct measures of abundance and range.

• A reasonable suite of attributes to include in a description of recovery, and address in recovery plans, would be an abundance goal in the context of the historical population size, a population growth rate or level of surplus production, an age composition, and an abundance-weighted description of range. This list comprises a useful starting point for case-specific discussions by recovery planning teams, and scientists supporting those teams."
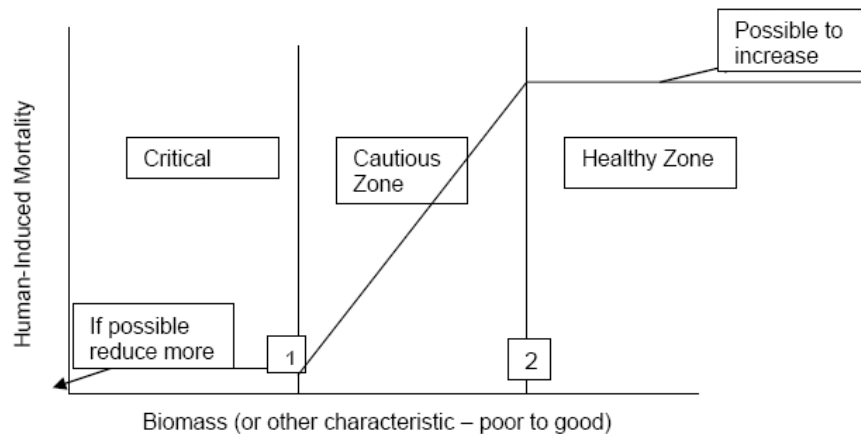
Figure 63. The fisheries management framework being considered for use in recovery descriptions and planning. Positions 1 and 2 correspond to the critical-cautious and cautious-healthy boundaries described in the text. (Figure 2 in DFO 2005b)

Guidelines were also developed to help provide consistent interpretations of 'recovery' to recovery teams developing recovery plans. In that regard, it was observed at the workshop that, "To bring consistency to this diversity of species and recovery issues, only general guidelines are possible. These guidelines need to be clear and specific enough so that they can be interpreted in a similar way for all of these cases, to ensure that a consistent and defensible standard of conservation is being applied in science advice on recovery targets. Nonetheless, they have to be applicable to very different kinds of information and indicators of status, and flexible enough to accommodate the differences in life histories found in aquatic species."

Using this overview as guidance, DFO has produced several 'recovery potential assessments' since DFO (2005c). These cover a wide range of aquatic species. The reader is referred to the CSAS website for further publications but DFO (2005c) has often been used as the template for this kind of analysis. This particular paper (DFO 2005c) provides the following format: current species status & trajectories, recovery targets, recovery potential (including assumptions about population growth potential, analytical methods, evaluation of possible recovery trajectories, and impacts of harvest on recovery). Feasibility is not directly addressed in this paper, nor in DFO 2005b.

With regard to recovery targets for Atlantic salmon, little discussion was generated at the workshops. Most jurisdictions favored the attainment of 'conservation requirements' as a recovery target. Because most populations and CUs were described as being at that level, input to any discussion of recovery targets in a SARA context, was limited. It was in fact unclear where such a target would be positioned in the proposed model (Figure 63). The attainment of conservation requirements infers that stocks should at least be in or approaching the 'healthy zone', while the severe restrictions in virtually all CUs (absence of commercial and a great deal of former recreational fisheries) required to attain that level would suggest the point is well down in the 'cautious zone'.

161

Further in this regard, it is to be noted that Atlantic salmon conservation requirements are based on egg deposition rates and these vary by sub-region: lacustrine habitat has different targets than for rivers in Newfoundland and Labrador CUs; southern Gulf of St. Lawrence Rivers have a target of 2.4 eggs/m^2, while Québec CUs have a target of 1.68 eggs/m^2 and Atlantic Nova Scotia and Bay of Fundy CUs have a target of 2.4 eggs/m^2.

6.2 Recovery Feasibility

The principles of recovery feasibility were addressed in Section 5.1; specifics for many CUs were addressed in Section 5.4.

6.3 Rescue Effect

Atlantic salmon in North America once ranged from the Hudson River, New York, north to Ungava (see Section 2.1). US Atlantic salmon populations have been separated into four discrete Distinct Population Segments (DPS: a subgroup of a vertebrate species that is treated as a species for purposes of listing under the U.S. *Endangered Species Act*) (Faye *et al* 2006), the two most southern having been extirpated. The remaining segments consist of the Gulf of Maine DPS and the Outer Bay of Fundy SFA. The outer Bay of Fundy SFA populations are supplemented by Saint John River Atlantic salmon stock and the core populations of this DPS have freshwater nursery areas in Canadian watersheds (Faye *et al* 2006).

Salmon of the Gulf of Maine (GOM) DPS are listed as 'endangered' under the US *Endangered Species Act*. The GOM DPS is comprised of all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River, (excluding the US-Canada St. Croix boundary river) but including all associated conservation hatchery populations at Green Lake and Craig Brook National Fish Hatcheries (Faye *et al* 2006). The Penobscot population, which is heavily hatchery supported, represents about 90% of all GOM adult returns (1,480 in 2006; ICES 2007) and only attains about 10% of its conservation spawning requirement (Kocik and Sheehan 2006). Kocik and Sheehan (op. cit.) note that most other populations are also dependent on hatchery production and that current marine survival regimes are compromising the long-term prospects of even these hatchery-supplemented populations.

Based on observed life history similarities (Baum 1997) and genetic structure among populations within the range of the GOM DPS (Spidle *et al* 2003), life history similarities and genetic structure among salmon stocks to the north (Verspoor *et al* 2002), and differences in life history strategies and genetic structure between the GOM DPS and salmon stocks to the north (Spidle *et al* 2003, Baum 1997), the GOM DPS is considered discrete from those in Canada. Evidence (Faye *et al* 2006) suggests that the genetic differences observed are not only substantial on their own but evidence of local adaptation to the GOM specifically. Hence, neither abundance nor genetics support the

prospects of a rescue effect on Canadian populations from south of the Canada-US boundary.

6.4 Expected General Time Frame for Recovery

No time frames for recovery are offered here or in each CU in Section 5. Few CUs have been identified as needing 'recovery' given that the 'majority' chosen recovery target was the 'attainment of conservation requirements in most years' and these CUs had attained this target in the majority of years. Therefore, despite dramatic declines in abundance of Canadian stocks in general and most assessed populations within the 28 CUs described here-in, conservation requirements are in fact being met albeit with minimal or no harvestable surpluses, i.e., recovery is not an issue. In the remaining CUs, which have not been attaining conservation requirements and in which self sustainability appears to be jeopardized, scientists have for the most part sought, with as yet little success, to describe the 'recovery target' more within a SARA/COSEWIC framework, i.e., reversal of declines in abundance and optimization of sustainable use and benefits (see Section 6.1). The core problem in identifying a time frame for recovery has been the inability to identify significant 'threats', e.g., cause of reduced marine survival, that could contribute to the analysis, possible management action, and subsequent reduction of those threats to a safe level, thereby enabling the estimation of a time frame to achieve any selected recovery target.

7. Scope for Harm

7.1 Is There Scope for Harm/Mortality to the Species That Will Not Impede Recovery?

Given the status of Atlantic salmon described in previous sections, assessments of the scope for harm/mortality that would not impede recovery is necessarily confined to those southern CUs which are not attaining their conservation requirements. Section 5.4 'recovery feasibility' provides case studies for the LaHave, Big Salmon, Tobique and West Sheet Harbour rivers, suggesting that reduced sea survival is the dominant impedance to recovery and that additional threats, e.g., acidification, reduced/low habitat productivity, and hydroelectric developments (it is assumed that there would be no exploitation) jeopardize persistence, i.e., there is no scope for additional harm in the southern most CUs.

For the inner Bay of Fundy populations (CU 16) which were subjected to an 'allowable harm assessment', DFO concluded that any level of human-induced harm could jeopardize its survival or recovery and that all efforts were encouraged to minimize the impact of human activities on the populations (DFO 2004).

7.2 What is the Maximum Harm/Mortality That Will Not Impede Recovery?

The absence of a consensus on 'recovery target', especially for those CUs in which self sustainability appears to be at risk, identification of the 'threats', e.g., within reduced survival, the inability to address (and reduce) many or any of the remaining 'threats', and inability to model the potential outcomes with threats addressed for various populations or CUs precludes the ability to ascertain a level of mortality that will not impede recovery.

Glossary

Aboriginal Traditional Knowledge (ATK). Includes but is not limited to the knowledge Aboriginal peoples have accumulated about wildlife species and their environment. Much of this knowledge has accumulated over many generations.

Atlantic salmon. Atlantic salmon (*Salmo salar*) are the only species of the genus *Salmo* that are native to northeastern North America. There are both landlocked/freshwater and sea-run forms; only the sea-run form of Atlantic Canada and Québec is considered in this policy. Landlocked Atlantic salmon, (*S. salar*) var. known as landlocks, ouananiche or Sebago salmon are restricted in size, numbers, and distribution to a relatively small number of lakes in the northeastern USA, Ontario, Atlantic Canada, and Québec and not considered in this policy. The other member of the genus *Salmo* is the brown trout (*Salmo trutta*), which was introduced from Europe in the 1880's, and is widely distributed in North America. Unlike European salmon rivers there are few salmon rivers in Atlantic Canada that support readily measurable populations of brown trout.

Biodiversity or biological diversity. The full range of variety and variability within and among living organisms and the ecological complexes in which they occur; the diversity they encompass at the ecosystem, community, species, and genetic levels; and the interaction of these components.

Conservation. The protection, maintenance, and rehabilitation of genetic diversity, species, and ecosystems to sustain biodiversity and the continuance of evolutionary and natural production processes.[43]

Conservation Limit. "A target egg deposition rate of 2.4 eggs/m^2 of fluvial rearing habitat, and in addition for insular Newfoundland, 368 eggs/hectare of lacustrine habitat. The 2.4 eggs/m^2 reference level is assumed to provide a modest margin of safety for some instream adult losses between the time salmon enter into a river and

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[43] For further details see Shuter *et al* (1997), Grumbine (1994), Mangel *et al* (1996)

subsequent spawning, as well as for disproportionate adult exploitation and unequal rate of recruitment of the multiple populations comprising a river population complex. CAFSAC (Canadian Atlantic Fisheries Scientific Advisory Committee) considers that the further the spawning escapement is below the biological reference level, and the longer this situation occurs even at rates only slightly below that level, the greater the possibility exists of incurring risks which may cause irreversible damage to the stock."[44]   The 2.4 eggs/m^2 reference level is here-in treated as the *lower benchmark*. Similar benchmarks but at different levels have been established for rivers in Québec and Newfoundland (accounting for production in lacustrine habitat). All have been regarded as proxies for the level of spawners which would result in the maximum sustained yield (MSY) or 'conservation limit'. The *higher benchmark* identifies a management target with the intention of providing optimum use of the resource and will be determined on a case-by-case basis. This level may change through time but there would be a near negligible probability of losing the population(s) and SMA.

Conservation Unit (CU). A group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to re-colonize naturally within an acceptable timeframe.

Deme. A group of salmon at a persistent spawning site or within a stream comprised of individuals that are likely to breed with each other (i.e., well mixed). A single population may include more than one deme.

Ecosystem. A community of organisms and their physical environment interacting as an ecological unit.

Enhancement. The application of biological and technical knowledge and capabilities to increase the productivity of Atlantic salmon that are already meeting or exceeding the lower benchmark. It may be achieved by altering habitat attributes (e.g., habitat restoration) or by using fish culture techniques.

Escapement. The number of returning mature salmon that spawn.

Extirpation. The local extinction of a *species*.

Fish habitat. Spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly to carry out their life processes.

Genetic diversity.   The variation at the level of individual genes, and provides a mechanism for populations to adapt to their ever-changing environment. It refers to the differences in genetic make-up between distinct species and to genetic variations within a single species.

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[44] CAFSAC (1991). *Definition of Conservation for Atlantic salmon.*

Geographic diversity. Spatial variability observed within a species. This variation may have a genetic basis and/or may reflect habitat and developmental differences expressed by the species.

Index River. An index river is comprised of fish from one or more persistent spawning locations or populations that are assumed to be representative of some aspect of an SMA. An index river may be an index site or stream selected to detect annual changes in abundance and/or survival, or a Level 3 (see Action Step 1.2) site or stream selected to monitor species distribution and general habitat status. The overall status of salmon in the aggregate SMA is inferred, in part, by comparing measures of abundance gathered by monitoring the index river to benchmarks.

Juvenile salmon. Salmon in fresh water, previous to the smolt stage.

Mitigation. Actions taken during the planning, design, construction, and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats.

Population. A group of interbreeding organisms that is relatively isolated from other such groups and is likely adapted to the local habitat.

Postsmolts. Salmon during their first calendar year at sea.

Precautionary approach. When used in an advisory context in support of decision making by the Government of Canada, this term conveys the sense that the advice is provided in situations of high scientific uncertainty. It is intended to promote actions that would result in a low probability of harm that is serious or difficult to reverse.

Precocious. Sexually mature juveniles (usually males) that have never gone to sea.

Restoration (of habitats). The treatment or clean-up of fish habitat that has been altered, disrupted or degraded for the purpose of increasing its capability to sustain a productive fisheries resource.

Resource management. Actions, policies or programs, implemented by the Department or other managing bodies, that has an intended direct or indirect effect on resource status.

Riparian zone and functions. The area of vegetation near streams is known as the riparian zone. Riparian function includes the interaction of hydrologic, geomorphic, and biotic processes within the riparian environment that determine the character of the riparian zone and the influences exerted on the adjacent aquatic and terrestrial environments (e.g., temperature controls, shading).

Smolt. A juvenile salmon that has completed rearing in fresh water and migrates into the marine environment. A smolt becomes physiologically capable of balancing salt and water in the estuary and ocean waters. Smolts vary in age and somewhat in size depending on the environment in which they were reared.

Species. The fundamental category of taxonomic classification consisting of organisms grouped by virtue of their common attributes and capable of interbreeding. A taxonomic species is equivalent to the term 'species' but the phrase may be used to indicate the collective species throughout its distribution.

Stakeholder. A person, group or agency that has a direct interest in an issue for which the department has a mandate or legal responsibility, and may or may not be directly affected by the department's programs and activities.

Stock assessment. The use of various statistical and mathematical models to determine the status of a population. Quantitative predictions about the reactions of populations to management choices are often part of an assessment.

Watershed. The area contributing water to a selected point along a stream channel. The term is interchangeable with 'drainage basin'.

Wild Atlantic salmon. Salmon that have spent their entire life cycle in the wild and originate from parents that were also produced by natural spawning and continuously lived in the wild.

References

Allen, K.R. 1941. Studies of the biology of the early life stages of the salmon (*Salmo salar*) III Growth in the Thurso River system Caithness. J. Animal Ecol. 10:273-295.

Amiro, P.G. 1993. Habitat measurement and population estimation of juvenile Atlantic salmon (*Salmo salar*). Pp.81-97. *In* R.J. Gibson and R.E. Cutting [*eds.*] Production of juvenile Atlantic salmon, *Salmo salar*, in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118.

Amiro, P.G. 2000. Assessment of the status, vulnerability and prognosis for Atlantic salmon stocks of the Southern Upland of Nova Scotia. DFO Can. Stock Assess. Sec. Res. Doc. 2000/062.

Amiro, P.G. 2003. Population status of inner Bay of Fundy Atlantic salmon *(Salmo salar)* to 1999. Can Tech. Rep. Fish. Aquat. Sci. No. 2488, 44p + vi.

Amiro, P.G. 2006. A synthesis of fresh water habitat requirements and status for Atlantic salmon (*Salmo salar*) in Canada. Can. Sci. Advis. Sec. Res. Doc. 2006/017.

Amiro, P.G. 2008 (In prep). A proposal for status indicators, breakpoint benchmarks, status classifications and management actions for Atlantic salmon populations in the Maritimes Region. Can. Sci. Advis. Sec. Res. Doc 2008/068, 24p.

Amiro, P.G., D.A. Longard, and E.M. Jefferson. 2000. Assessments of Atlantic salmon stocks of Salmon Fishing Areas 20 and 21, the southern Upland of Nova Scotia, for 1999. Can. Stock. Assess. Sec. Res. Doc. 2000/009.

Amiro, P.G., A.J.F. Gibson, and K. Drinkwater. 2003. Identification and exploration of some methods for designation of critical habitat for survival and recovery of inner Bay of Fundy Atlantic salmon (*Salmo salar*). Can Stock Advis. Sec. Res. Doc. 2003/120.

Amiro, P.G., A.J.F. Gibson, and H.D. Bowlby. 2006a. Atlantic salmon (*Salmo salar*) overview for eastern Cape Breton, Eastern Shore, Southwest Nova Scotia and inner Bay of Fundy rivers (SFA 19 to 22) in 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/024.

Amiro, P.G., A.J.F. Gibson, and S.F. O'Neil. 2006b. Science expert opinion on critical habitat designation for inner Bay of Fundy Atlantic salmon. DFO Maritimes Region Expert opinion 2006/04.

Anon. 1978. Biological Conservation Subcommittee Report. Appendix B, Atlantic Salmon Review Task Force Review. 203p.

Armstrong, J.D., P.S. Kemp, G.J.A. Kennedy, M. Ladle, and N.J. Milner. 2003a. Habitat requirements of Atlantic salmon and brown trout in rivers and streams. Fisheries Research 62:143-170.

Armstrong, J.D, C.F. Holm, P.S. Kemp, and D.J. Gilvear. 2003b. Linking models of animal behaviour and habitat management: Atlantic salmon parr and river discharge. J. Fish Biol. Vol. 63, suppl. 1, p. 226.

Asplund, T., A. Veselov, C.R. Primmer, I. Bakhmet, A. Potutkin, S. Titov, A. Zubchenko, I. Studenov, S. Kaluzchin, and J. Lumme. 2004. Origin of maternal lineages of anadromous Atlantic salmon (*Salmo salar* L.) in the Barents Sea and White Sea rivers. Annales Zoologici Fennici. 44:465-475.

Atkinson, G. and D. Moore. 1999. The case for releasing grilse. Atlantic Salmon Journal Autumn 1999 Vol. 48(3):68-72.

Bagliniere, J.-L. F. Marchand, and V. Vauclin. 2005. Interannual changes in recruitment of the Atlantic salmon (*Salmo salar*) population in the River Oir (Lower Normandy, France): relationships with spawners and in-stream habitat. ICES J. Mar. Sci. 2005 62(4):695-707.

Bardonnet, A. and J.-L. Bagliniere. 2000. Freshwater habitat of Atlantic salmon. Can. J. Fish. Aquat. Sci. 57:497-506.

Baum, E. 1997. Maine Atlantic salmon: a national treasure. Atlantic Salmon Unlimited, Hermon, Maine 04402 USA. 224p.

Beacham, T. D. and J. B. Dempson. 1998. Population structure of Atlantic salmon from the Conne River, Newfoundland as determined from microsatellite DNA. J. Fish Biol. 52: 665-676.

Beamish, R.J. and D.R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Can. J. Fish. Aquat. Sci. 50:1002-1016.

Beamish, R.J., C.-E.M. Neville, and A.J. Cass. 1997. Production of Fraser River sockeye salmon (*Oncorhynchus nerka*) in relation to decadal-scale changes in climate and the ocean. Can. J. Fish. Aquat. Sci. 54:543-554.

Beaugrand, G. and P.C. Reid. 2003. Long-term changes in phytoplankton, zooplankton and salmon related to climate. Global Change Biology 9(6):801-817.

Beck, G.G., M.O. Hammill, and T.G. Smith. 1993. Seasonal variation in the diet of harp seals (*Phoca groenlandica*) from the Gulf of St. Lawrence and western Hudson Strait. Can. J. Fish. Aquat. Sci. 50:1363-1371.

Beland, K.F., R.M. Jordan, and R.L. Meister. 1982. Water depth and velocity preferences of spawning Atlantic salmon in Maine rivers. N. Amer. J. Fish. Manage. 2:11-13.

Beland, K.F., J.G. Trial, and J.F. Kocik. 2004. Use of riffle and run habitats with aquatic vegetation by juvenile Atlantic salmon. N. Amer. J. Fish. Manage. 24:525-533.

Belding, D.L. and G. Préfontaine 1937. Études sur le saumon de l'Atlantique (*Salmo salar* L.)-I. Ph.D thesis, Univ. Montréal, Canada.

Benoit, D., and W.D. Bowen. 1990. Summer diet of grey seals *(Halichoerus grypus)* at Anticosti Island, Gulf of St. Lawrence, Canada. Can. Bull. Fish. Aquat. Sci. 222:227-242.

Bermingham, E., S.H. Forbes, and K. Friedland. 1991. Discrimination between Atlantic salmon *(Salmo salar)* of North American and European origin using restriction analysis of mitochondrial DNA. Can. J. Fish. Aquat. Sci. 48:884-893.

Birt, T.P., J.M. Green, and W.S. Davidson. 1991. Mitochondrial DNA variation reveals genetically distinct sympatric populations of anadromous and nonanadromous Atlantic salmon, *Salmo salar*. Can. J. Fish. Aquat. Sci. 48:577-582.

Bisbal, G.A. and W.E. McConnaha. 1998. Consideration of ocean conditions in the management of salmon. Can. J. Fish. Aquat. Sci. 55:2178-2186.

Bjornn T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Amer. Fish. Soc. Spec. Publ.19:83-138.

Blackbourn, D.J. 1993. Sea surface temperature and the subsequent freshwater survival rate of some salmon stocks: a surprising link between the climate of land and sea. p23-32 *In* K.T. Redmond and V.L. Tharp [Eds]. Proceedings of the 9th Annual Pacific Climate (PACLIM) Workshop, 21-24 Apr., 1992. Tech. Rep. No. 34. Calif. Dep. Water Resources, Interagency Ecological Studies Program, Pacific Grove.

Blackwell, B.F. and F. Juanes. 1998. Predation on Atlantic salmon smolts by striped bass after dam passage. N. Amer. J. Fish. Manage. 18:936-939.

Blais, J.-P. and V. Legendre. 1978. Tentatives de création d'eaux à ouananiches : les introductions de saumons atlantiques, *Salmo salar*, marins et dulcicoles dans les eaux douces du Québec, 1867-1977. Gouv. du Québec, Min. du tourisme, de la Chasse et de la Pêche, Serv. De l'aménagement et de l'exploitation de la faune. Rapport technique, 124p.

Boisclair, D. 2004. The status of Atlantic salmon (*Salmo salar*): populations and habitats. Can. J. Fish. Aquat. Sci. 61:2267-2270.

Bourke, E.A., J. Coughlan, H. Jansson, P. Galvin, and T.F. Cross. 1997. Allozyme variation in populations of Atlantic salmon located throughout Europe: diversity that could be compromised by introductions of reared fish. ICES J. Mar. Sci. 54:974-985.

Bovee, K.D. 1978. The incremental method of assessing habitat potential for coldwater species, with management implications. Am. Fish. Soc. Spec. Publ. 11: 340 – 346.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. US Fish and Wildlife Service, Fort Collins, Colo. Instream Flow Inf. Pap. 12.

Brander, K.M. 1995. The effect of temperature on growth of Atlantic cod (*Gadus morhua* L.). ICES J. Mar. Sci. 52:1-10.

Brawn, V.M. 1982. Behavior of Atlantic salmon (*Salmo salar*) during suspended migration in an estuary, Sheet Harbour, Nova Scotia, observed visually and by ultrasonic tracking. Can. J. Fish. Aquat, Sci. 39:248-256.

Bremset, G. and J. Heggenes. 2001. Competitive interactions in Young Atlantic salmon (Salmo salar L.) and brown trout (*Salmo trutta* L.) in lotic environments. Nord. J. Freshw. Res. 75:127-142.

Bremset, G. 2000. Seasonal and diel changes in behaviour, microhabitat use and preferences by young pool-dwelling Atlantic salmon, *Salmo salar*, and brown trout, *Salmo trutta*. Environmental Biol. Fishes. 59:163-179.

Bremset, G. and O.K. Berg. 1999. Three-dimensional microhabitat use by young pool-dwelling Atlantic salmon and brown trout. Animal Behaviour. 58:1047-1059.

Bult, T.P., S.C. Riley, R.L. Haedrich, R.J. Gibson, and J. Heggenes. 1999. Density-dependent habitat selection by juvenile Atlantic salmon (*Salmo salar*) in experimental riverine habitats. Can. J. Fish. Aquat. Sci. 56:1298-1306.

Cairns, D.K. 1998. Diet of cormorants, mergansers, and kingfishers in eastern North America. Can. Tech. Rep. Fish. Aquat. Sci. No. 2225.

Cairns, D.K. 2001a. Hypothesis: avian predators reduce juvenile survival. P.13 *In* D.K. Cairns [Ed]. An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. No. 2358.

Cairns, D.K. 2001b. Hypothesis: marine survival is declining in a self-fueling spiral because post-smolts are too scarce to form schools. Pp. 29-30 *In* D.K. Cairns [Ed.]. An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. No. 2358.

Cairns, D.K. 2006. A review of predator-prey and competitive inter-specific interactions in Atlantic salmon (*Salmo salar*). DFO Can. Sci Advis. Sec. Res. Doc. 2006/019.

Cairns, D.K. and D. Meerburg. 2001. Hypothesis: aquaculture sites attract predators, thereby increasing predation on out-going smolts. P.19 in D.K. Cairns (Ed.). An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. No. 2358.

Cairns, D.K. and D.G. Reddin. 2000. The potential impact of seal and seabird predation on North American Atlantic salmon. Can. Stock Assess. Sec. Res. Doc. 2000/12.

Cairns, D., R. Angus, M. Murray, and K. Davidson. 1996. Status of Atlantic salmon in the Morell, Mill, Dunk, West and Valleyfield rivers, Prince Edward Island, in 1995. DFO Atl. Fish. Res. Doc. 1996/120, 35p.

Campeau, S. 1984. Jacques Cartier, récits de mes voyages au Canada (1534-1535-1540). Textes et documents retrouvés. Editions Pacifique St-Laurent. 96p.

Caron, F., P-M Fontaine, and S.E. Picard. 1999. Seuil de conservation et cible de gestion pour les rivières à saumon (*Salmo salar*). Québec City, Faune et Parc Québec, Direction de la faune et des habitats

Caron, F., G. Chaput, M.F. O'Connell, and A.J.F. Gibson. 2006. Distribution of salmon. Working Paper and tabulation of rivers developed for and updated after the Workshop on the Conservation Status of Atlantic Salmon. Presented 13-16 February 2006, Gulf Fisheries Centre Moncton NB.

Caron, F. and P.-M. Fontaine. 2007. Status of Atlantic salmon stocks in Quebec, 2006.Working Paper presented to the ICES Working Group on North Atlantic Salmon, April, Copenhagen.

Chadwick, E.M.P. 1987. Causes of variable recruitment in a small Atlantic salmon stock. Amer. Fish. Soc. Symp. 1:390-401.

Chadwick, M., R. Porter, and D. Reddin. 1978. Atlantic Salmon Management Program Newfoundland and Labrador, 1978. Atlantic Salmon Journal 1:9-15.

Chapman, D. W., 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Trans Amer. Fish. Soc. 117:1–21.

Chaput, G. 2001. Hypothesis: Inter- and intra-specific competition reduces juvenile survival. Pp.13-14 *In* D.K. Cairns [Ed.]. An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. No. 2358.

Chaput, G. 2006. Definition and application of conservation requirements for the management of Atlantic salmon (*Salmo salar*) fisheries in Eastern Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/021.

Chaput, G. and D.K. Cairns. 2001. Hypothesis: Predation reduces egg survival. Pp. 9-10 *In* D.K. Cairns (Ed.). An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. No. 2358.

Chaput, G. and R. Jones. 2006. Reproductive rates and rebuilding potential for two multi-sea-winter Atlantic salmon (*Salmo salar* L.) stocks of the Maritime provinces. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/027.

Chaput, G., C. Legault, D. Reddin, F. Caron, and P. Amiro. 2005. Provision of catch advice taking account of non-stationarity in productivity of Atlantic salmon (*Salmo salar*) in the Northwest Atlantic. ICES J. Mar. Sci. 62:131-143.

Chaput, G., J.B. Dempson, F. Caron, R. Jones, and J. Gibson. 2006a. A synthesis of life history characteristics and stock groupings of Atlantic salmon (*Salmo salar* L.) in eastern Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/015.

Chaput, G., P. Cameron, D. Moore, D. Cairns, and P. LeBlanc. 2006b. Stock status of Atlantic salmon, *Salmo salar* L. from rivers of the Gulf Region (SFA 15-18). DFO Can. Sci. Advis. Sec. Res. Doc. 2006/023.

Clair, T.A., I.F. Dennis, P.G. Amiro, and B.J. Cosby. 2004. Past and future chemistry changes in acidified Nova Scotian Atlantic Salmon *(Salmo salar)* rivers: A dynamic modeling approach. Can. J. Fish. Aquat. Sci. 61:1965-1975.

Claytor, R.R. and H.R. MacCrimmon. 1988. Morphometric and meristic variability among North American Atlantic salmon *(Salmo salar)*. Can. J. Zool. 66 310-317.

Claytor, R.R., H.R. MacCrimmon, and B.L. Gots. 1991. Continental and ecological variance components of European and North American Atlantic salmon *(Salmo salar)* phenotypes. Biol. J. Linnean Soc. 44:203-229.

Colbourne, E. 2003. Physical oceanographic conditions on the Newfoundland and Labrador Shelf during 2002. DFO Can. Stock Assess. Sec. Res. Doc. 2003/020.

Coulombe-Pontbriand, M. and M. Lapointe, 2004. Landscape controls on boulder-rich, winter habitat availability and their effects on Atlantic salmon (*Salmo salar*) parr abundance in two fifth-order mountain streams. Can. J. Fish. Aquat. Sci. 61:648-658.

Crisp, D.T. and P.A. Carling. 1989. Observations on siting, dimensions and structure of salmonid redds. J. Fish Biol. 34:119-134.

Crozier, W.W., E.C.E. Potter, E. Prévost, P-J. Schön, and N. Ó Maoiléidigh. [Eds]. 2003. A coordinated approach towards the development of a scientific basis for management of wild Atlantic salmon in the North-East Atlantic (SALMODEL). Queen's University of Belfast, Belfast. 431p.

Cunjak, R.A. and J. Therrien. 1998. Inter-stage survival of wild juvenile Atlantic salmon *Salmo salar* L. Fish. Manage. Ecol. 5:209-223.

Cunjak, R.A. 1988. Behaviour and microhabitat of young Atlantic Salmon (*Salmo salar*) during winter. Can. J. Fish. Aquat. Sci. 45:2156-2160.

Cunjak, R.A., T.D. Prowse, and D.L. Parrish. 1998. Atlantic salmon (*Salmo salar*) in winter: "the season of parr discontent"? Can. J. Fish. Aquat. Sci. 55 (Suppl. 1):161-180.

Cutler, M.G., S.E. Barlett, S.E. Hartley, and W. Davidson. 1991. A polymorphism in the ribosomal RNA genes distinguishes Atlantic salmon *Salmo salar* from North America and Europe. Can. J. Fish. Aquat. Sci. 48:1655-1661.

deGraaf, D.A. and L.H. Bain. 1986. Habitat Use by and Preferences of Juvenile Atlantic Salmon in Two Newfoundland Rivers. Trans. Amer. Fish. Soc. 11:671-681.

Dempson, J.B., C.J. Schwarz, D.G. Reddin, M.F. O'Connell, C.C. Mullins, and C.E. Bourgeois. 2001a. Estimation of marine exploitation rates on Atlantic salmon (*Salmo salar* L.) stocks in Newfoundland, Canada. ICES J. Mar. Sci. 58:331-341.

Dempson, J.B., D.G. Reddin, M.F. O'Connell, J. Helbig, C.E. Bourgeois, C. Mullins, T.R. Porter, G. Lilly, J. Carscadden, G.B. Stenson, and D. Kulka. 1998. Spatial and temporal variation in Atlantic salmon abundance in the Newfoundland-Labrador region with emphasis on factors that may have contributed to low returns in1997. DFO Can. Stock Assess. Sec. Res. Doc. 98/114, 161p.

Dempson, J.B., G. Furey, and M. Bloom. 2001. Assessment of the status of the Atlantic salmon stock of Conne River, SFA 11, Newfoundland, 2000. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/030, 45p.

Dempson, J.B., M.F. O'Connell, and C.J. Schwarz. 2004c. Spatial and temporal trends in abundance of Atlantic salmon, *Salmo salar,* in Newfoundland with emphasis on impacts of the 1992 closure of the commercial fishery. Fish. Manage. Ecol. 11:387-402.

Dempson, J.B., M.F. O'Connell, D.G. Reddin, and N.M. Cochrane. 2006. Stock status summary for Atlantic salmon from Newfoundland and Labrador. DFO Can. Sci Advis. Sec. Res. Doc. 2006/028, 38p.

DFO 2000a. The Effects of Acid Rain on the Atlantic Salmon of the Southern Upland of Nova Scotia. DFO Maritimes Regional Habitat Status Report 2000/2E, 19p.

DFO 2000b. Atlantic Salmon Maritime Provinces Overview for 1999 DFO Stock Status Rep.D3-14 (2000), 38p.

DFO 2001. Atlantic Salmon Maritime Provinces Overview for 2000. DFO Stock Status Rep. D3-14 (2001) (revised), 41p.

DFO 2004. Allowable harm assessment for inner Bay of Fundy Atlantic salmon. DFO Stock Status Report 2004/30, 4p.

DFO 2005a. Canada's Policy for Conservation of Wild Pacific Salmon. Fish. and Oceans Canada, Vancouver. v + 49p.

DFO 2005b. A framework for developing science advice on recovery targets for aquatic species in the context of the Species at Risk Act. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/054.

DFO 2005c. Recovery Assessment Report for Interior Fraser Coho Salmon (Onchorhynchus kisutch). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/061.

DFO 2006. Proceedings of a Workshop on the Conservation Status of Atlantic salmon, 13-16 February, 2006. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2006/043, 44p.

DFO 2007. Proceedings of a Second Workshop on the Conservation Status of Atlantic salmon in Eastern Canada. 6-9 March, 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/043, 45p.

DFO 2008 [In prep]. Recovery Potential Assessment of Atlantic Salmon (Lake Ontario Population), 1-2 March 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/xxx, 45p.

DFO and MNRF. 2008 [In prep]. Conservation Status Report, Atlantic salmon in Atlantic Canada and Québec: PART II – Anthropogenic Considerations. Can. Manus. Rep. Fish. Aquat. Sci. xxx.

Dickson, R.R. and W.R. Turrell. 2000. The NAO: the dominant atmospheric process affecting oceanic variability in home, middle, and distant waters of European Atlantic Salmon. Pp. 92-115. *In*: Derek Mills (Ed.) The ocean life of Atlantic salmon: environmental and biological factors influencing survival. Proceedings of a Workshop Held at the Freshwater Fisheries Laboratory, Pitlochry, on 18th and 19th November, 1998. Blackwell Scientific, Fishing News Books. 228p.

Dieperink, C., B.D. Bak, L.-F. Pedersen, M.I. Pedersen, and S. Pedersen. 2002. Predation on Atlantic salmon and sea trout during their first days as postsmolts. J. Fish Biol. 61:848-852.

Dizon, A.E., C. Lockyer, W.F. Perrin, D.P. Demaster, and J. Sisson. 1992. Rethinking the stock concept: a phylogeographic approach. Conserv. Biol. 6(1):24-36.

Downton, M.W. and K.A. Miller. 1998. Relationships between Alaskan salmon catch and North Pacific climate on interannual and interdecadal time scales. Can. J. Fish. Aquat. Sci. 50:1002-1016.

Downton, P. R., D. G. Reddin, and R. W. Johnson. 2001. Status of Atlantic salmon (*Salmo salar* L.) in Campbellton River, Notre Dame Bay (SFA 4), Newfoundland in 2000. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/031, 73p.

Ducharme, L.J.A. 1969. Atlantic salmon returning for their fifth and sixth consecutive spawning trips. J. Fish. Res. Bd. Can. 26:1661-1664.

Dunfield, R.W. 1985. The Atlantic salmon in the history of North America. Can. Spec. Publ. Fish. Aquat. Sci. 80, 181p.

Dutil, J.-D, M. Castonguay, D. Gilbert, and D. Gascon. 1999. Growth, condition, and environmental relationships in Atlantic cod (*Gadus morhua*) in the northern Gulf of St. Lawrence and implications for management strategies in the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 56:1818–1831.

Elliot, S.R., T.A. Coe, J.M. Helfield, and R.J. Naiman. 1998. Spatial variation in environmental characteristics of Atlantic salmon (*Salmo salar*) rivers. Can. J. Fish. Aquat. Sci.. 55 (Suppl. 1):267-280.

Elson, P.F. 1941. Atlantic salmon and trout investigations. Eels as a limiting factor in salmon smolt production. Fish. Res. Bd. Can. MS Rep. Biol. Stations. 213(16), Rept 16.

Elson, P.F. 1942. Behavior and survival of planted Atlantic salmon fingerlings. Trans. North Amer. Wildl. Conf. 7:202–207.

Elson, P.F. 1967. Elson, P.F. 1967. Effects on wild young salmon of spraying DDT over New Brunswick forests. J. Fish. Res. Bd. Can. 24(4):731-766.

Elson, P.F. 1975. Atlantic salmon rivers smolt production and optimal spawning: an overview of natural production. Int. Atl. Salmon Found. Spec. Publ. Ser. 6:96-119.

Environment Canada. 2004 Canadian acid deposition science assessment. Cat. N7o. En4-46/2004E-MRC.

Environment Canada. 2005. Policy on the feasibility of recovery. Draft, 4p.

Erkinaro, J. and R.J. Gibson. 1997. Interhabitat migration of juvenile Atlantic salmon in a Newfoundland river system, Canada. J. Fish Biol. 51:373-388.

Fausch, K.D. 1998. Interspecific competition and juvenile Atlantic salmon (*Salmo salar*): on testing effects and evaluating the evidence across scales. Can. J. Fish. Aquat. Sci. 55:218-231

Fay, C., M. Burton, S. Craig, A. Hecht, J. Pruden, R. Saunders, T. Sheehan, and J. Trial. 2006. Status Review for Anadromous Atlantic Salmon (*Salmo salar*) in the United States. Report to the National Marine Fisheries Service and U.S. Fish and Wildlife Service. 294p.
http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsalmon.pdf

Feltham, M.J. 1995. Predation of Atlantic salmon, *Salmo salar* L., smolts and parr by red-breasted mergansers, *Mergus serrator* L. on two Scottish rivers. Fish. Manage. Ecol. 2:289-298.

Fisher, H.D. and B.A. Mackenzie. 1955. Food habits of seals in the Maritimes. Fish. Res. Bd Can., Prog. Rep. Atl. Coast Stations No. 61:5-9.

Fletcher G.L., M.H. Kao, and J.B. Dempson. 1988. Lethal freezing temperatures of Arctic char and other salmonids in the presence of ice. Aquaculture, 71:369-378.

Fontaine, P.-M., J.J. Dodson, L. Bernatchez, and A. Slettan. 1997. A genetic test of metapopulation structure in Atlantic salmon *(Salmo salar)* using microsatellites. Can. J. Fish. Aquat Sci. 54:2434-2442.

Ford, M.J. 2004. Conservation units and preserving diversity. Pp. 338-357 *In* Hendry, A.P. and S.C. Stearns [*Eds*]. Evolution illuminated: salmon and their relatives. Oxford Univ. Press, NY.

Forsythe, G.M. 1968. Analysis of the 1966 smolt run in the Northwest Miramichi River, New Brunswick. Fish. Res. Bd. Can. Tech. Rpt. No. 91, 33p.

Fraser, D.J. and L. Bernatchez. 2001. Adaptive evolutionary conservation: towards a unified concept for defining conservation units. Molecular Ecology. 10:2741-2752.

Friedland K.D., L.P. Hansen, and D.A. Dunkley. 1998. Marine temperature experienced by postsmolts and the survival of Atlantic salmon, *Salmo salar* L. in the North Sea area. Fisheries Oceanography 7:22-34.

Friedland, K.D. and R.E. Hass. 1996. Marine post-smolt growth and age at maturity of Atlantic salmon. J. Fish Biol. 48:1-15.

Friedland K.D, J.-D. Dutil, and T. Sadusky. 1999. Growth patterns in postsmolts and the nature of the marine juvenile nursery for Atlantic salmon, *Salmo salar*. Fishery Bulletin 97**:**472–481.

Friedland, K.D., D.G. Reddin, and M. Castonguay. 2003b. Ocean thermal conditions in the post-smolt nursery of North American Atlantic salmon. ICES J. Mar. Sci. 60:343-355.

Friedland, KD., D.G. Reddin, J.R. McMenemy, and K.F. Drinkwater. 2003a. Multidecadal trends in North American Atlantic salmon (*Salmo salar*) stocks and climate trends relevant to juvenile survival. Can. J. Fish. Aquat. Sci. 60:563-583.

Friedland, K.D., L.P. Hansen, and D.A. Dunkley. 1998. Marine temperatures experienced by postsmolts and the survival of Atlantic salmon, *Salmo salar* L., in the North Sea area. Fisheries Oceanography 7:22-34.

Friedland, K.D. 1998. Ocean climate influences on critical Atlantic salmon (*Salmo salar*) life history events. Can. J. Fish. Aquat. Sci. 55:119-130.

Friedland, K.D., D.G. Reddin, and J.F. Kocik. 1993. Marine survival of North American and European salmon: effects of growth and environment. ICES J. Mar. Sci. 50:481-492.

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

Garside, E.T. 1973. Ultimate upper lethal temperature of Atlantic salmon *Salmo salar* L. Can. J. Zool. 51:898-900.

Gibson, A.J.F. 2006. Application of the residence concept to inner Bay of Fundy Atlantic salmon (*Salmo salar*). Unpubl. Manus.

Gibson, A. J. F. and P. G. Amiro 2003. Abundance of Atlantic salmon (*Salmo salar*) in the Stewiacke River, NS, from 1965 to 2002. CSAS Res. Doc. 2003/108.

Gibson, A.J.F., J. Bryan, and P. Amiro. 2003a. Release of hatchery-reared Atlantic salmon into Inner Bay of Fundy Rivers from 1900 to 2002. Can. Data Rep. Fish. Aquat. Sci. 1123, vi + 28 p.

Gibson, A.J.F., P.G. Amiro, and K.A. Robichaud-LeBlanc. 2003b. Densities of juvenile Atlantic salmon (*Salmo salar*) in inner Bay of Fundy rivers during 2000 and 2002 with reference to past abundance inferred from catch statistics and electrofishing surveys. DFO Can. Stock Assess. Sec. Res. Doc. 2003/121.

Gibson, A.J.F., RA. Jones, P.G. Amiro, and J. J. Flanagan. 2003c. Abundance of Atlantic salmon (*Salmo salar*) in the Big Salmon River, New Brunswick, from 1951 to 2002. DFO Can. Stock Assess.Sec. Res. Doc. 2003/119, i + 55p.

Gibson, A.J.F., R.A. Jones, and P.G. Amiro. 2008. Equilibrium analyses of the recovery feasibility of four Atlantic salmon (*Salmo salar*) populations in Nova Scotia and Southwest New Brunswick. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/010.

Gibson, A.J.F., R.A. Jones, S.F. O'Neil, J.J. Flanagan, and P.G. Amiro. 2004. Summary of monitoring and live gene bank activities for inner Bay of Fundy Atlantic salmon in 2003. Can Sci. Advis. Sec. Res. Doc. 2004/016, ii + 45p.

Gibson, A.J.F., B. Hubley, G. Chaput, J.B. Dempson, F. Caron, and P. Amiro. 2006. Summary of status and abundance trends for eastern Canadian Atlantic salmon (*Salmo salar*) populations. DFO Can. Sci Advis. Sec. Res. Doc. 2006/026. 31 p.

Gibson, R.J. 1978. The behaviour of juvenile Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*) with regard to temperature and to water velocity. Trans. Amer. Fish. Soc. 107:703-712.

Gibson, R.J. 1993. The Atlantic salmon in freshwater: spawning, rearing and production. Rev. Fish Biol. Fish. 3:39-73.

Gibson, R.J. and T.A. Dickson. 1984. The effects of competition on the growth of juvenile Atlantic salmon. Naturaliste Can. 111:175-191.

Gibson, R.J. and R.A. Cunjak. 1986. An investigation of competitive interactions between brown trout (*Salmo trutta* L.) and juvenile Atlantic salmon (*Salmo salar* L.) in rivers of the Avalon Peninsula, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. No. 1472.

Gibson, R.J., D.E. Stansbury, R.R. Whalen, and K.G. Hillier. 1993. Relative habitat use, and inter-specific and intra-specific competition of brook trout (*Salvelinus fontinalis*) and juvenile Atlantic salmon (*Salmo salar*) in some Newfoundland rivers. Pp. 53-69 *In* R.J Gibson and R.E. Cutting (Eds.). Production of juvenile Atlantic salmon, *Salmo salar,* in natural waters. Can. Spec. Publ. Aquat. Sci. 118.

Gibson, R.J., D.D. Williams, C. McGowan, and W.S. Davidson. 1996. The ecology of dwarf fluvial Atlantic salmon, *Salmo salar* L., cohabiting with brook trout, *Salvelinus fontinalis* (Mitchill), in southeastern Newfoundland, Canada. Polskie Archiwum Hydrbiologii 43:145-166.

Gilbey, J., D. Knox, M. O'Sullivan, and E. Verspoor. 2005. Novel DNA markers for rapid, accurate, and cost-effective discrimination of the continental origin of Atlantic salmon (*Salmo salar* L.). ICES J. Mar. Sci. 62:1609-1616.

Girard, I.L., J.W.A. Grant, and S.O. Steingrimsson. 2004. Foraging, growth, and loss rate of young-of-the-year Atlantic salmon (*Salmo salar*) in relation to habitat use in Catamaran Brook, New Brunswick. Can. J. Fish. Aquat. Sci. 61:2339-2349.

Godfrey, H. 1957. Feeding of eels in four New Brunswick salmon streams. Fish. Res.Bd. Can. Progr. Rep. Atlantic Coast Stations No. 67:19-22.

Gries, G. and F. Juanes. 1998. Microhabitat use by juvenile Atlantic salmon (*Salmo salar*) sheltering during the day in summer. Can. J. Zool. 76:1441-1449.

Guay, J.C., D. Boisclair, D. Rioux, M. Leclerc, M. Lapointe, and P. Legendre. 2000. Development and validation of numerical habitat models for juveniles of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 57:2063-2075.

Handeland, S.O., T. Jarvi, A. Ferno, and S.O. Stefansson. 1996. Osmotic stress, antipredator behaviour, and mortality of Atlantic salmon *Salmo salar* smolts. Can. J. Fish. Aquat. Sci. 53:2673-2680.

Handeland, S.O., B.Th. Bjornsson, A.M. Arnesen, and S.O. Stefansson. 2003. Seawater adaptation and growth of post-smolt Atlantic salmon (*Salmo salar*) of wild and farmed strains. Aquaculture 220:367-384.

Hansen , L.P., M. Holm, J.C. Holst, and J.A. Jacobsen. 2003. The ecology of post smolts of Atlantic salmon. Pp25-39 *In* D. Mills [Ed.]. Salmon at the edge. Blackwell, Oxford.

Hare, S.R. and R.C. Francis. 1995. Climate change and salmon production in the Northeast Pacific Ocean. Pp.357-372 *In*: R.J. Beamish [Ed.]. Ocean climate and northern fish populations. Can. Spec. Pub. Fish. Aquat. Sci. 121.

Harwood, A.J., N.B. Metcalfe, J.D. Armstrong, and S.W. Griffiths. 2001. Spatial and temporal effects of interspecific competition between Atlantic salmon (Salmo salar) and brown trout (*Salmo trutta*) in winter. Can. J. Fish. Aquat. Sci. 58:1133-1140.

Harwood, A.J., N.B. Metcalfe, S.W. Griffiths, and J.D. Armstrong. 2002. Intra- and inter-specific competition for winter concealment habitat in juvenile salmonids. Can. J. Fish. Aquat. Sci. 59:1515-1523.

Heggberget, T.G. 1991. Some environmental requirements of Atlantic salmon. Amer. Fish. Soc. Symp. 10:132-135.

Heggenes, J., S.J. Saltveit, D Bird, and R. Grew. 2002. Static habitat partitioning and dynamic selection by sympatric young Atlantic salmon and brown trout in south-west England streams. J. Fish Biol. 60:72-86.

Heggenes, J. and J.G. Dokk. 2001. Contrasting temperatures, waterflows, and light: seasonal habitat selection by young Atlantic salmon and brown trout in a boreonemoral river. Regul. Rivers: Res. Manage. 17:623-635.

Heggenes, J., O.M.W. Krog, O.R. Lindas, J.G. Dokk, and T. Bremnes. 1993. Homeostatic behavioural responses in a changing environment: brown trout (*Salmo trutta*) become nocturnal during winter. J. Anim. Ecol. 62 295-308.

Henderson, J.N., and B.H. Letcher. 2003. Predation on stocked Atlantic salmon (*Salmo salar*) fry. Can. J. Fish. Aquat. Sci. 60:32-42.

Hendry, A.P., A. Castric, M.T. Kinnison, and T.P. Quinn. 2004. The evolution of philopatry and Dispersal: Homing Versus Straying in Salmonids. Pp. 52-91 *In* Hendry, A.P. and S.C. Stearns [Eds]. Evolution illuminated: salmon and their relatives. Oxford Univ. Press, NY.

Hesthagen, T., J-O Ousdal, and A. Bergheim. 1986. Smolt production of Atlantic salmon (*Salmo salar*) L. and brown trout (*Salmo trutta*) L. in a small Norwegian river influenced by agricultural activity. Polish Arch. Hydrobiol. 33 (3-4):423-432.

Hislop, J.R.G. and R.J.G. Shelton 1993. Marine predators and prey of Atlantic salmon (*Salmo salar*). Pp. 104-118 *In* D. Mills [Ed]. Salmon in the sea and new enhancement strategies. Fishing News Books, Oxford.

Hojesjo, J., J.D. Armstrong, and S.W. Griffiths. 2005. Sneaky feeding by salmon in sympatry with dominant brown trout. Animal Behavior.69:1037-1041.

Huntsman, A.G. 1933a. St. John November salmon – the earliest run known. Pp. 7-10 Biol. Bd. Canada. Progr. Rep. Atl. Biol. Sta., St. Andrews, NB. No. 6, Note No. 25, January 1933.

Huntsman, A.G. 1933b. Passamoquody sardine fishing makes Tobique salmon angling. Pp. 6-9. *In* Biol. Bd. Canada. Progr. Rep. Atl. Biol. Sta., St. Andrews, NB. No. 8, Note No. 32 July 1933.

Huntsman, A.G. 1944. Why did Ontario salmon disappear? Trans. Royal Soc. Canada, Ann. Rep. 1947, App. II:37-38.

Huntsman. A.G. 1942. Death of salmon and trout with high temperature. J. Fish. Res. Bd. Can. 5:485-501.

Hutchings, J.A., and M.E.B. Jones. 1998. Life history variation and growth rate thresholds for maturity in Atlantic salmon, *Salmo salar*. Can. J. Fish. Aquat. Sci. 55 (Suppl. 1):22-47.

Hvidsten, N.A., and P.I.Mokkelgjerd. 1987. Predation of salmon smolts, Salmon salar L. in the estuary of the River Suma, Norway. J. Fish Biol. 64:1731-1736.

ICES. 2004. Report of the Working Group on North Atlantic Salmon. ICES Doc. CM 2004/ACFM:20, 286p.

ICES 2005. Report of the Working Group on North Atlantic Salmon (WGNAS). 5-14 April 2005 Nuuk, Greenland. ICES C.M. 2005/ACFM:17. Ref. I.

ICES 2007. Report of the Working Group on Working Group of North Atlantic Salmon (WGNAS). ICES Doc. CM 2007/ACFM:13, 253p

Jessop, B.M. 1975. Investigation of the salmon (*Salmo salar*) smolt migration of the Big Salmon River, New Brunswick. Tech. Rep. Ser. No. MAR/T-75-1. Environment Canada, Fish. Mar. Serv. ix + 56p.

Jessop, B.M. 1986. Atlantic salmon (*Salmo salar*) of the Big Salmon River, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. No. 1415.xii + 50p.

Jones, R.A, L. Anderson, J.J. Flanagan and T. Goff 2006. Assessments of Atlantic salmon stocks in southern and western New Brunswick (SFA 23), an update to 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/025.

Jones, R.A., L. Anderson, and T. Goff. 2004. Assessments of Atlantic salmon stocks in southwest New Brunswick, an update to 2003. DFO Can. Stock Assess. Sec. Res. Doc. 2004/019.

Jonsson, N. and B. Jonsson. 2004. Size and age of maturity of Atlantic salmon correlate with the North Atlantic Oscillation Index (NAOI). J. Fish. Biol. 64:241-247.

Jonsson, N., B. Jonsson, and I.A. Fleming. 1996. Does early growth cause a phenotypically plastic response in egg production of Atlantic salmon? Functional Ecology 10:89-96.

Jowett, I.G. 1993. A method for objectively identifying pool, run, and riffle habitats from physical measurements. N.Z. J. Mar. Freshw. Res. 27:241–248.

Julien, H.P. and N.E. Bergeron. 2006. Effect of fine sediment infiltration during the incubation period on Atlantic salmon (*Salmo salar*) embryo survival. Hydrobiologia. 563:61–71.

Karlsson, L., E. Ikonen, H. Westerberg, and J. Sturlaugsson. 1996. Use of data storage tags to study the spawning migration of Baltic salmon (*Salmo salar* L.) in the Gulf of Bothnia. ICES C. M. 1996/M:9, 15p.

Kauppi, R., L. Kvist, M. Ruokonen, A. Soivio, and J. Lumme. 1997. Lack of variation in mitochondrial DNA of the Baltic salmon *(Salmo salar)* indicates a bottleneck during or long before postglacial recolonisation of the Baltic Sea? Oulanka Rep. 17:19-23.

Kennedy, G.J.A., and C.D.Strange. 1982. The distribution of salmonids in upland streams in relation to depth and gradient. J. Fish Biol. 20:579-591.

King, T.L., A.P. Spidle, M.S. Eackles, B.A. Lubinski, and W. B. Schill. 2000. Mitochondrial DNA diversity in North American and European Atlantic salmon with emphasis on the downeast rivers of Maine. J. Fish Biol. 57: 614-630.

King, T.L., S.T. Kalinowski, W.B. Schill, A.P. Spidle, and B.A. Lubinski. 2001. Population structure of Atlantic salmon *(Salmo salar L.)*: a range-wide perspective from microsatellite DNA variation. Molecular Ecology. 10:807-821.

Kocik, J.F. and T.F. Sheehan. 2006. Status of Fishery Resources off the Northeastern US NEFSC - Resource Evaluation and Assessment Division. Atlantic Salmon http://www.nefsc.noaa.gov/sos/spsyn/af/salmon/#cenneweng.

Knox, D., K. Lehmann, D.G. Reddin, and E. Verspoor. 2002. Genotyping of archival Atlantic salmon scales from northern Quebec and West Greenland using novel PCR primers for degraded mtDNA. J. Fish Biol. 60:266-270.

Krause, J., G.D. Ruxton, and D. Rubenstein. 1998. Is there always an influence of shoal size on predator hunting success? J. Fish. Biol. 52:494-501.

Lacroix, G.L. 1985. Survival of eggs and alevins of Atlantic salmon (*Salmo salar*) in relation to the chemistry of interstitial water in redds in some acidic streams of Atlantic Canada. Can. J. Fish. Aquat. Sci. 42:292-299.

Lacroix, G.L., D. Knox, and M.J.W. Stokesbury. 2005. Survival and behaviour of post-smolt Atlantic salmon in coastal habitat with extreme tides. J. Fish Biol. 66:485-498.

Lacroix, G.L. and D. Knox. 2005. Distribution of Atlantic salmon (*Salmo salar*) postsmolts of different origins in the Bay of Fundy and Gulf of Maine and evaluation of factors affecting migration, growth, and survival. Can. J. Fish. Aquat. Sci. 62:1363-1376.

Lacroix, G.L., P. McCurdy, and D. Knox. 2004. Migration of Atlantic salmon postsmolts in relation to habitat use in a coastal system. Trans. Amer. Fish. Soc. 133:1455-1471.

Larsson, P.O. 1985. Predation on migrating smolt as a regulating factor in Baltic salmon, *Salmo salar* L., populations. J. Fish Biol. 26:391-397.

Legendre V., J.-R. Mongeau, J. Leclerc, and J. Brisebois. 1980. Les salmonidés des eaux de la Plaine de Montréal. Gouv. du Québec, Min. du Loisir de la Chasse et de la Pêche. Rapp. techn. 06-27.

Legget, R. 1975. Ottawa waterway: gateway to a continent. Univ. Toronto Press, Toronto Ontario, xi, 291p.

Lilja, J. and A. Romakkaniemi. 2003. Early-season river entry of adult Atlantic salmon: its dependency on environmental factors. J. Fish. Biol. 62(1):41-50.

Locke, A. F. Mobray, G. Landry, A. Madden, and E. Leblanc. 1997. Status of Atlantic salmon in the Nepisiguit and Jacquet rivers, New Brunswick, in 1996. Can. Sci. Advis. Sec. Res. Doc. 1997/17.

MacCrimmon, H.R. and B.L. Gots. 1979. World distribution of Atlantic salmon, *Salmo salar*. J. Fish. Res. Board Can. 36:422-457.

MacCrimmon, H.R. and T.L. Marshall. 1968. World distribution of brown trout, *Salmo trutta*. J. Fish. Res. Bd. Canada. 25(12):2527-2548.

Maki-Petays, A., A. Huusko, J. Erkinaro, and T. Muotka. 2002. Transferability of habitat suitability criteria of juvenile Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 59:218-228.

Mansfield, A.W., and B. Beck. 1977. The grey seal in eastern Canada. Dept. Fisheries and Environment, Fish. Mar. Serv. Tech. Rep. No. 704.

Marshall, T.L. 1986. Estimated spawning requirements and indices of stock status of Atlantic salmon in the St. Mary's River, Nova Scotia. DFO Can. Atlantic Fish. Sci. Advis. Res. Doc. 1986/022, 19p.

Marshall, T.L., D. Liew, and K. Brickley. 2008 [In prep]. Economic significance of Atlantic salmon in Eastern Canada.

Marshall, T.L. and J.D. Cameron. 1995. Assessment of Atlantic salmon stocks of Saint John River and southwest New Brunswick, 1994. DFO Atl. Fish. Res. Doc. 95/129, iii + 49p.

Marshall, T.L., P.G. Amiro, J.A. Ritter, B.M. Jessop, R.E. Cutting and S.F. O'Neil. 1992. Perfunctory estimates of allowable harvests of Atlantic salmon in 18 rivers of Scotia-Fundy Region. Can. Atl. Fish. Sci Advis. Comm. Res. Doc. 92/16, 28p.

Marshall, T.L., R. Jones and T. Pettigrew. 1997. Status of Atlantic salmon stocks of southwest New Brunswick, 1996. DFO Can. Stock Assess. Sec. Res. Doc. 97/27, iii + 67p.

Martin, W.R. 1949. The mechanisms of environmental control of body form in fishes. Publ. Ont. Fish. Res. Lab. No. 70, 81p.

Martin, J.D. 1984. Atlantic salmon and alewife passage through a pool and weir fishway on the Magaguadavic River, New Brunswick, during 1983. Can. Man. Rep. Fish. Aquat. Sci. 1776, iii + 11p.

May, A.W. 1973. Distribution and migration of salmon in the northwest Atlantic. Int. Atl. Salmon Symp. 1972. Int. Atl. Salmon Found., Spec. Publ. 4:372-382.

McConnell, S.K., D.E. Ruzzante, P.T. O'Reilly, L. Hamilton, and J.M. Wright, 1997. Microsatellite loci reveal highly significant genetic differentiation among Atlantic salmon *(Salmo salar* L.)* stocks from the east coast of Canada. Molecular Ecology. 6:1785-1789.

McConnell, S.K., P.T. O'Reilly, L. Hamilton, J. Wright, and P. Bentzen. 1995. Polymorphic microsatellite loci from Atlantic salmon *(Salmo salar)*: genetic differentiation of North American and European populations. Can. J. Fish. Aquat. Sci. 52(9):1863-1872.

Meehan, W.R. [Ed.] 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. Amer. Fish. Soc. Spec. Publ.19, Bethesda, Maryland.

Meerburg, D.J. [Ed.]. 1986. Salmonid age at maturity. Can. Spec. Publ. Fish. Aquat. Sci. 89, 118p.

Metcalfe, N.B. and J.E. Thorpe. 1990. Determinants of geographic variation in the age of seaward-migrating salmon, *Salmo salar*. J. Anim. Ecol. 59:135-145.

Middlemas, S.J., J.D. Armstrong, and P.M. Thompson. 2003. The significance of marine mammal predation on salmon and sea trout. Pp. 43-60 *In*: D. Mills [Ed.] Salmon at the edge. Fishing News Books, Blackwell Scientific Publications, Oxford.

Mills, D. 1989. Ecology and management of Atlantic salmon. Chapman and Hall, London.

Mitchell, J., R.S. Mckinley, G. Power, and D.A. Scruton. 1998. Evaluation of Atlantic Salmon Parr Responses to Habitat Improvement Structures in an Experimental Channel in Newfoundland, Canada. Regul. Rivers: Res. Manage. 14:25-39.

Moir, H.J., C. Soulsby, and A. Youngson,. 1998. Hydraulic and sedimentary characteristics of habitat utilized by Atlantic salmon for spawning in the Girnock Burn, Scotland. Fish. Manage. Ecol. 5:241-254.

Moller, D. 2005. Genetic studies of serum transferrins in Atlantic salmon. J. Fish Biol. 67(A):55-68.

Montevecchi W.A., D.K. Cairns and V.L. Birt. 1988. Migration of postsmolt Atlantic salmon, *Salmo salar*, off northeastern Newfoundland, as inferred by tag recoveries in a seabird colony. Can. J. Fish. Aquat. Sci. 45:568-571.

Montevecchi, W.A., D.K. Cairns, and R.A. Myers. 2002. Predation on marine-phase Atlantic salmon (*Salmo salar*) by gannets (*Morus bassanus*) in the northwest Atlantic. Can. J. Fish. Aquat. Sci. 59:602-612.

Moore, D.S., G. Chaput, and R. Pickard. 1995. The effect of fisheries on the biological characteristics and survival of mature Atlantic salmon (*Salmo salar*) from the Miramichi River. *In* E.M.P. Chadwick [Ed.] Water, science, and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. No. 123.

Morantz, D.L, R.K. Sweeney, C.S. Shirvell, and D.A. Longard. 1987. Selection of Microhabitat in Summer by Juvenile Atlantic Salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 44:120-129.

Moritz, C. 1994. Defining 'evolutionary significant units' for conservation. Trends Ecol. Evol. 9:373-375.

Munro, J.A. and W.A. Clemens. 1937. The American merganser in British Columbia and its relation to the fish population. Biol. Board Can. Bull. No. 55.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583-590.

Netboy, A. 1968. Atlantic salmon: a Vanishing Species? London: Faber and Faber. 475p.

Nicieza, A.G., F.G. Reyes-Gavilan, and F. Brana. 1994. Differentiation in juvenile growth and bimodality patterns between northern and southern populations of Atlantic salmon *(Salmo salar* L.*)*. Can. J. Zool. 72:1603-1610.

Nilsson, J., R. Gross, T. Asplund, O. Dove, H. Jansson, J. Kellonieni, K. Kohlmann, A. Löytynoja, E.E. Nielsen, T. Paaver, C.R. Primmer, S. Titov, A. Vasemägi, A. Veselov, T. Öst, and J. Lumme. 2001. Matrilineal phylogeography of Atlantic salmon *(Salmo salar* L.*)* in Europe and postglacial colonisation of the Baltic Sea area. Molecular Ecol. 1:89-102.

Nislow, K.H., C.L. Folt, and D.L. Parrish. 1999. Favorable foraging locations for young Atlantic salmon: application to habitat and population restoration. Ecological Applications. 9(3):1085-1099.

Nyman, O.L. 1966. Geographic variation in Atlantic salmon. Rep. Swed. Salmon Res. Inst. 3, 6p.

Nyman, O.L., and J.H.C. Pippy. 1972. Differences in Atlantic salmon, *Salmo salar*, from North America and Europe. J. Fish. Res. Bd. Can. 29(2):179-185.

O'Connell, M.F., J.B. Dempson, T.R. Porter, D.G. Reddin, E.G.M. Ash, and N.M. Cochrane. 1992. Status of Atlantic salmon (*Salmo salar* L.) stocks of the Newfoundland Region, 1991. Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 92/22, 56p.

O'Connell, M., D.G. Reddin, P.G. Amiro, F. Caron, T.L. Marshall, G. Chaput, C.C. Mullins, A. Locke, S.F. O'Neil, and D.K. Cairns. 1997a. Estimates of the conservation spawner requirements for Atlantic salmon (*Salmo salar* L.) for Canada. Can Stock Assess. Sec. Res. Doc. 1997/100, 58p.

O'Connell, M.F., J.B. Dempson, C.C. Mullins, D.G. Reddin, N..M. Cochrane, and D. Caines. 1997. Status of Atlantic salmon (*Salmo salar* L.) stocks of the Newfoundland region, 1996. DFO Can. Stock Assess. Sec. Res. Doc. 97/42.

O'Connell, M.F., J.B. Dempson, C.C. Mullins, D.G. Reddin, N.M. Cochrane, and D. Caines. 1998. Status of Atlantic salmon (*Salmo salar* L.) stocks of insular Newfoundland (SFAs 3-14A), 1997. Can. Stock Assess. Res. Doc. 98/107.

O'Connell, M.F., J.B. Dempson, C.C. Mullins, D.G. Reddin, N.M. Cochrane and D. Caines. 2001. Status of Atlantic salmon (*Salmo salar* L.) stocks of insular Newfoundland (SFAs 3-14A), 2000. DFO Can Stock Assess. Sec. Res. Doc. 2001/078, 72p.

O'Connell, M., J.B. Dempson, D.G. Reddin, C.E. Bourgeois, T.R. Porter, N.M. Cochrane, D. Caines. 2005**.** Status of Atlantic salmon (*Salmo salar* L.) stocks of insular Newfoundland (SFAs 3-14A), 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/064, 73p.

O'Connell, M.F., J.B. Dempson, G. Chaput. 2006. Aspects of the life history, biology, and population dynamics of Atlantic salmon (*Salmo salar* L.) in Eastern Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/014, 47p.

O'Neil, S.F. and C.J. Harvie. 1995. Estimates of Atlantic salmon stock status on the Eastern Shore of Nova Scotia, Salmon Fishing Area 20 in 1994. DFO Atl. Fish. Res. Doc. 1995/ 132, 36p.

O'Neil, S.F., C.J. Harvie, D.A. Longard, and P.G. Amiro. 1998. Stock status of Atlantic salmon (*Salmo salar* L.) on the Eastern Shore of Nova Scotia, Salmon Fishing Area 20, in 1997. DFO Can. Stock Assess. Sec. Fish. Res. Doc. 1998/37, 56p.

O'Reilly, P.T. 2006. Towards the identification of Conservation Units in Atlantic salmon from Eastern Canada. DFO Can Sci. Advis. Sec. Res. Doc. 2006/012, 41p.

Okland, F., E.B. Thorstad, and T.F. Nesie. 2004. Is Atlantic salmon production limited by number of territories? J. Fish Biol. 65:1047-1055.

Parrish, D.L., R.J. Behnke, S.R. Gephard, S.D. McCormick, and G.H. Reeves. 1998. Why aren't there more Atlantic salmon *(Salmo salar)*? Can. J. Fish. Aquat. Sci. 55 (Suppl. 1):281-287.

Pearse, D.E. and K.A. Crandall. 2004. Beyond FST: analysis of population genetic data for conservation. Conservation Genetics 5:585-602.

Peterman, R.M., B.J., M.F. Lapointe and M.D. Adkinson. 1998. Patterns of covariation in survival rates of British Columbian and Alaskan sockeye salmon (*Oncorhynchus nerka*) stocks. Can. J. Fish. Aquat. Sci. 55:2503-2517.

Pippy, J. [Chairman] 1982. Report on the Working Group on the Interception of Mainland Salmon in Newfoundland. Can. MS Rep. Fish. Aquat. Sci., 1654: x + 196p.

Porter, T.R., M.C. Healey, M.F. O'Connell, E.T. Baum, A.T. Bielak, and Y. Côté. 1986. Implications of varying sea age at maturity of Atlantic salmon (*Salmo salar*) on yield to the fisheries. Pp. 110-117 *In* D. J. Meerburg [Ed.] Salmonid age at maturity. Can. Spec. Public. Fish. Aquat. Sci. 89, 118p.

Potvin, C. and L. Bernatchez. 2001. Lacustrine spatial distribution of landlocked Atlantic salmon populations assessed across generations by multilocus individual assignment and mixed-stock analyses. Molecular Ecology. 10:2375-2388.

Power, G. 1969. The salmon of Ungava Bay. Arctic Institute of North America. Tech. Paper 22:1-72.

Power, G. 1981. Stock characteristics and catches of Atlantic salmon (*Salmo salar*) in Québec, and Newfoundland and Labrador in relation to environmental variables. Can. J. Fish. Aquat. Sci. 38:1601-1611.

Power G., M.V. Power, R. Dumas, and A. Gordon. 1987. Marine migrations of Atlantic salmon from rivers in Ungava Bay, Québec. Pp. 364-376 *In* M.J. Dadswell *et al* [Eds] Symposium on Common Strategies in Anadromous/Catadromous Fishes, Amer. Fish. Soc. Bethesda Md.

Powers, G.M. and J.F. Orsborn. 1985. Analysis of barriers to upstream fish migration: an investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. U.S. Department of Energy, Bonneville Power Administration, Project 82-14. Portland Oregon.

Pritchard, J.K., M. Stephens, and P.T. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155:945-959.

Pyper, B.J., F.J. Mueter, and R.M. Peterman. 2001. Spatial covariation in survival rates of Northeast Pacific pink salmon (*Oncorhyncus gorbuscha*). Can. J. Fish. Aquat. Sci. 58:1501-1515.

Pyper, B.J., F.J. Mueter, R.M. Peterman, D.J. Blackbourn, and C.C. Wood. 2002. Spatial covariation in survival rates of Northeast Pacific chum salmon. Trans. Amer. Fish. Soc. 131:343-363.

Raffenberg, M.J., and D.L. Parrish. 2003. Interactions of Atlantic salmon (*Salmo salar*) and trout (*Salvelinus fontinalis* and *Oncorhynchus mykiss*) in Vermont tributaries of the Connecticut River. Can. J. Fish. Aquat. Sci. 60:279-285.

Rafn, C.C. 1838. American discovere in the tenth century. An abstract of the historical evidence contained in the "Antiquitates americanae". William Jackson, New York. 32p.

Randall, R.G. 1989. Effect of sea-age on the reproductive potential of Atlantic salmon **(***Salmo salar*) in eastern Canada. Can. J. Fish. Aquat. Sci. 46:2210-2218.

Reddin D.G. 1987. Contribution of North American salmon (*Salmo salar* L.) to the Faroese fishery. Naturaliste Canadien, 114(2):211-218.

Reddin, D.G. 2006. Perspectives on the marine ecology of Atlantic salmon (*Salmo salar*) in the Northwest Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/018.

Reddin D.G. and W.M. Shearer. 1987. Sea_surface temperature and distribution of Atlantic salmon in the Northwest Atlantic Ocean. Pp. 262-275 *In* M.J. Dadswell *et al* [Eds] Symposium on Common Strategies in Anadromous/Catadromous Fishes, Amer. Fish. Soc. Bethesda Md.

Reddin, D.G. and K. D. Friedland. 1993. Marine environmental factors influencing the movement and survival of Atlantic salmon. Pp. 79-103. *In* Derek Mills [Ed.] Salmon in the sea and new enhancement strategies. Fishing News Books. 424p.

Reddin, D.G. and K.D. Friedland. 1996. Declines of Scottish spring salmon and thermal habitat in the northwest Atlantic. How are they related? Pp. 45-66. *In*: Derek Mills [Ed.] Enhancement of Spring Salmon. Proceedings of a One-day Conference Held in the Rooms of the Linnean Society of London. 26 January 1996. The Atlantic Salmon Trust, Pitlochry, Scotland.

Reddin, D.G. and K.D Friedland,. 1999. A history of identification of continent of origin of Atlantic salmon *(Salmo salar* L)* at West Greenland, 1969-1997. Fisheries Research 43:221-235.

Reddin, D.G., K.D. Friedland, and P. Downton. 2006. Early marine use of thermal habitat by Atlantic salmon smolts (*Salmo salar* L.). Fish. Bull.104:415-428.

Reddin, D.G., J. Helbig, A. Thomas, B.G. Whitehouse, and K.D. Friedland. 2000. Survival of Atlantic salmon (*Salmo salar* L.) related to marine climate, pp. 89-91. *In*: Derek Mills [ed.] The ocean life of Atlantic salmon: environmental and biological factors influencing survival. Proceedings of a Workshop held at the Freshwater Fisheries Laboratory, Pitlochry, on 18th and 19th November, 1998. Blackwell Scientific, Fishing News Books. 228p.

Reddin, D.G., K.D. Friedland, P. Downton, J.B. Dempson, and C.C. Mullins. 2004. Thermal habitat experienced by Atlantic salmon kelts (*Salmo salar* L.) in coastal Newfoundland waters. Fish. Oceanogr. 13:24-35.

Reddin, D.G., W. King, S. Oliver, R. Nuna, and R.J. Poole. 2004. Harvests in various fisheries for salmonids and environmental conditions in Labrador, 2003. DFO Can. Sci Advis. Sec. Res. Doc. 2004/111, 20p.

Reddin, D.G., D.E. Stansbury, and P.B. Short. 1988. Continent-of-origin of Atlantic salmon *(Salmo salar* L.*)* at West Greenland. J. Cons. Intern. Explor. Mer 44:180-188.

Reisenbichler, R.R. 1988. Relation between distance transferred from natal stream and recovery rate for hatchery coho salmon. N. Amer. J. Fish. Manage. 8:172-174.

Reiser, D.W. and R.T. Peacock. 1985. A technique for assessing upstream fish passage problems at small-scale hydropower development. Pp. 423-432 *In* F. W. Olson, R.G. White and R.H. Hamre [Eds]. Symposium on small hydropower and fisheries. Amer. Fish. Soc., Western Div., Bethesda, MD.

Riddell, B.E. and W.C. Leggett. 1981. Evidence of an adaptive basis for geographical variation in body morphology and time of downstream migration of juvenile Atlantic salmon *(Salmo salar).* Can. J. Fish. Aquat. Sci. 38:308-320.

Rimmer, D.M., U. Paim, R.L. Saunders. 1984. Changes in the selection of microhabitat by juvenile Atlantic salmon (*Salmo salar*) at the summer-autumn transition in a small river. Can. J. Fish. Aquat. Sci. 41:469-475.

Ritter, J.A. 1989. Marine migration and natural mortality of North American Atlantic salmon (*Salmo salar* L.). Can. MS Rep. Fish. Aquat. Sci. No. 2041, 136p.

Ritter, J.A. 1975. Lower ocean survival rates for hatchery-reared Atlantic salmon *(Salmo salar)* stocks released in rivers other than their native streams. ICES CM 1975/M:26:10.

Robichaud- LeBlanc, K., and P.G. Amiro. 2004. Assessments of Atlantic salmon stocks in selected rivers of Eastern Cape Breton, SFA 19, to 2003. Can. Sci. Advis Sec. 2004/017, 66p.

Robitaille, J.A., Y. Cote, G. Schooner and G. Hayeur. 1986. Growth and maturation patterns of Atlantic salmon, *Salmo salar*, in the Koksoak River, Ungava, Quebec Pp.62-69 *In* D.J. Meerburg. [Ed.] 1986. Salmonid age at maturity. Can. Spec. Publ. Fish. Aquat. Sci.89 118p.

Roland, A. E. 1982. Geological Background and Physiography of Nova Scotia. N.S. Inst. of Sci. Ford Publishing Co., Halifax, N.S., xii + 311p.

Rosenfeld, J. 2003. Assessing the Habitat Requirements of Stream Fishes: An Overview and Evaluation of Different Approaches. Trans. Amer. Fish. Soc. 132:953-968.

Rouleau, A. et G. Tremblay. 1990. Détermination du nombre d'ovules par femelle chez le saumon Atlantique anadrome du Québec. Pp. 154-167. *In* N. Samson et J.-P. le Bel [Eds.]. Compte rendu de l'atelier sur le nombre de reproducteurs requis dans les rivières à saumon, île aux Coudres, février 1988. Ministère du Loisir, de la Chasse et de la Pêche du Québec, Direction de la gestion des espèces et des habitats. 329p.

Roussel, J.M., R.A. Cunjak, R. Newbury, D. Caissie, and A. Haro. 2004. Movements and habitat use by PIT-tagged Atlantic salmon parr in early winter: the influence of anchor ice. Freshwater Biology. 49:1026-1035.

Saunders, R.L. and J.H. Gee. 1964. Movements of young Atlantic salmon in a small stream. J. Fish. Res. Bd. Can. 21:27-36.

Saunders, R.L., C.J. Kerswill, and P.F. Elson. 1965. Canadian Atlantic salmon recaptured near Greenland. J. Fish. Res. Bd. Can. 22:625-629.

Saunders, R.L. 1978. The stock concept, a major consideration in salmon restoration. Atl. Salmon Journal., October,:. 21-23.

Saunders, R.L., E.B. Henderson, B.D. Glebe, and E.J. Loundenslager. 1983. Evidence of a major environmental component in determination of the grilse: larger salmon ratio in Atlantic salmon (*Salmo salar*). Aquaculture, 33:107-118.

Scarnecchia, D.L. 1983. Age at sexual maturity in Icelandic stocks of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci., 40:1456-1468.

Scarnecchia D.L. 1984. Climatic and oceanic variations affecting yield of Icelandic stocks of Atlantic salmon (*Salmo salar*). Can. Fish. Aquat. Sci., 41:917-935.

Scott, W. B. and E.J. Crossman,. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Bd. Can. 184, 966p.

Scott, W.B., and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219, 731p.

Sigholt, T. and B. Finstad. 1990. Effect of low temperature on seawater tolerance in Atlantic salmon (*Salmo salar*) smolts. Aquaculture, 84:167-172.

Soulsby, C., A.F. Youngson, H.J. Moir, I.A. Malcolm. 2001. Fine sediment influence on salmonid spawning habitat in a lowland agricultural stream: a preliminary assessment. Sci. Total Environ. 265:295-307.

Spidle, A. P., S.T. Kalinowski, B.A. Lubinski, D.L. Perkins, K.F. Beland, J.F. Kocik, and T.L. King. 2003. Population structure of Atlantic salmon in Maine with reference to populations from Atlantic Canada. Trans. Amer. Fish. Soc. 132: 196-209.

Stahl, G. 1987. Genetic population structure of Atlantic salmon. Pp. 121-140 *In* Ryman, N. and F. Utter [Eds]. Population Genetics and Fishery Management, Seattle: Univ. Washington Press.

Stasko, A.B. 1975. Progress of migrating Atlantic salmon (*Salmo salar*) along an estuary, observed by ultrasonic tracking. J. Fish. Biol. 7:329-338.

Steele, J.H. 2004. Regime shifts in the ocean: reconciling observations and theory. Progr. Oceanogr. 60:135-141.

Sturlaugsson, J. 1995. Migration study on homing of Atlantic salmon (*Salmo salar* L.) in coastal waters W-Iceland - depth movements and sea temperatures recorded at migration routes by data storage tags. ICES C.M. 1995/M:17, 13p.

Svenning, M.A., S.E. Fagermo, R.T. Barrett, R. Borgstroem, W. Vader, T. Pedersen, and S. Sandring. 2005. Goosander predation and its potential impact on Atlantic salmon smolts in the River Tana estuary, northern Norway. J. Fish Biol. 66:924-937.

Symons, P. 1979. Estimated escapement of Atlantic salmon (*Salmo salar*) for maximum smolt production in rivers of different productivity. J. Fish. Res. Board Can. 36:132-140.

Taggart, J.B., E. Verspoor, P. Galvin, P. Moran, and A. Ferguson. 1995. A minisatellite DNA marker for discriminating between European and North American Atlantic salmon *(Salmo salar)* . Can. J. Fish. Aquat. Sci. 52:2305-2311.

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

Taylor, V.R. 1986. Les débuts de la pêche du saumon de l'Atlantique à Terre-Neuve et au Labrador. Publ. spéc. can. sci. halieut. aquat. 76, 75p.

Templeman, W. 1965. Mass mortality of marine fishes in the Newfoundland area presumably due to low temperature. Int'l Comm. Northw. Atl. Fish. Spec. Publ., 6:137-147.

Thompson, P.M. and F. MacKay 1999. Pattern and prevalence of predator damage on adult Atlantic salmon, *Salmon salar* L., returning to a river system in north-east Scotland. Fish. Manage. Ecol. 6:335-343.

Thorpe, J. E., M. S. Miles, and D. S. Keay. 1984. Developmental rate, fecundity and egg size in Atlantic salmon, *Salmo salar* L. Aquaculture 43:289-305.

Thorpe, J.E., N.B. Metcalfe, and N.H.C. Fraser. 1994. Temperature dependence of switch between nocturnal and diurnal smolt migration in Atlantic salmon. *In* D.D. MacKinlay, [Ed], Fish Physiology Association, BC (Canada), ISBN 0969863101.

Trzcinski, M.K., Gibson, A.J. F., Amiro, P.G., and R.G. Randall. 2004. Inner Bay of Fundy Atlantic salmon (*Salmo salar*) critical habitat case study. Can. Sci. Adv. Sec. Res. Doc. 2004/114, 77p.

Utter, F., J.E. Seeb, and L.W. Seeb. 1993. Complementary uses of ecological and biochemical genetic data in identifying and conserving salmon populations. Fish. Res. 18:59-76.

Verspoor, E. 2005. Regional differentiation of North American Atlantic salmon at allozyme loci. J. Fish Biol.67:80-103.

Verspoor, E. and L.J. Cole. 1989. Genetically distinct sympatric populations of resident and anadromous Atlantic salmon, *Salmo salar*. Can. J. Zool. 67:1453-1461.

Verspoor, E. and E. McCarthy. 1997. Genetic divergence at the NAD+dependent malic enzyme locus in Atlantic salmon from Europe and North America. J. Fish Biol. 67(A):213-218.

Verspoor, E., .M. O'Sullivan, A.L. Arnold, D. Knox, A. Curry, G. Lacroix, and P. Amiro. 2005. The nature and distribution of genetic variation at the mitochondrial ND1 gene of the Atlantic salmon *(Salmo salar* L.*)* within and among rivers associated with the Bay of Fundy and Southern Upland of Nova Scotia. Fish. Res. Scotland, Res. Serv. Intern. Rep. No 18/05, 8p. + Figs.+Tables.

Verspoor, E. and W.C. Jordan. 1989. Genetic variation at the Me-2 locus in the Atlantic salmon within and between rivers: evidence for its selective maintenance. J. Fish Biol. 35(A): 205-213.

Verspoor, E., M. O'Sullivan, A.L. Arnold, D. Knox, and P.G. Amiro. 2002. Restricted matrilineal gene flow and regional differentiation among Atlantic salmon *(Salmo salar* L.*)* populations within the Bay of Fundy, Eastern Canada. Heredity 89:465-472.

Waples, R.S. 1991 Pacific salmon, *Oncorhynchus*., and the definition of 'species' under the endangered species act. Mar. Fish. Rev. 53:11-22.

Warner, K. 1963. Natural Spawning Success of Landlocked Salmon, *Salmo salar*. Trans. Amer. Fish. Soc. 92(2):161-164.

Watanabe, C. and A. Yatsu. 2004. Effects of density-dependence and sea surface temperature on interannual variation in length-at-age of chub mackerel (Scomber japonicus) in the Kuroshio-Oyashio area during 1970-1997. Fish. Bull. 102:196-206.

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

Watt, W.D. 1989. The impact of habitat damage on Atlantic salmon (*Salmo salar*) catches. *In* C.D. Levings, L.B. Holtby and M.A. Henderson [Eds]. Proc National Workshop on effects of habitat alteration on salmonid stocks. Can. Spec. Pub. Fish. Aquatic Sci. 105:154-163.

Welch, D.W., A.I. Chigirinsky, and Y. Ishida. 1995. Upper thermal limits on the oceanic distribution of Pacific salmon (*Oncorhynchus* spp.) in the spring. Can. J. Fish. Aquat. Sci. 52:489-503.

Welch, D.W., Y. Ishida, and K. Nagasawa. 1998. Thermal limits and ocean migrations of sockeye salmon (*Oncorhynchus nerka*): Long-term consequences of global warming. Can. J. Fish. Aquat. Sci. 55:937-948.

Weng, Z., N. Mookerji, and A. Mazumder. 2001. Nutrient-dependent recovery of Atlantic salmon streams from a catastrophic flood. Can. J. Fish. Aquat. Sci. 58:1672-1682.

Whalen, K.G., D.L. Parrish, and S.D. McCormick. 1999a. Migration timing of Atlantic salmon smolts relative to environmental and physiological factors. Trans. Amer. Fish. Soc. 128:289-301.

Whalen, K.G., D.L. Parrish, M.E. Mather. 1999b. Effect of ice formation on selection of habitats and winter distribution of post-young-of-the-year Atlantic salmon parr. Can. J. Fish. Aquat. Sci. 56:87-96.

Wheeler, A. and D. Gardner. 1974. Survey of the literature of marine fish predators on salmon in the North-east Atlantic. J. Inst. Fish Manage. 5:63-66.

White, H.C. 1939. Bird control to increase the Margaree River salmon. Fish. Res. Board Can. Bull. No. 58.

Wilder, D.G. 1947. A comparative study of the Atlantic salmon, *Salmo salar* Linnaeus, and the lake salmon, *Salmo salar sebago* (Girard). Can. J. Res., D, 25:175-189.

Wilson, G.A., K.I Ashley, R.W. Land, and P.A. Slaney. 2003. Experimental enrichment of two oligotrophic rivers in south coastal British Columbia. Pp. 149-162. *In* Nutrients in salmonid ecosystems: sustaining production and biodiversity. Amer. Fish. Soc. Symp. 34:149-162.

WWF 2001. The Status of Wild Atlantic Salmon: A River by River Assessment. World Wildlife Fund, 173p. *http://www.worldwildlife.org*

Appendices

Appendix 1. Conservation Status Report - Terms of Reference (2004)

<u>**Context**</u>

<u>DFO Species Priority List</u>

What:
- DFO priority list based on biological and socio-economic information

How:
- DFO and other jurisdictions (possibly through CCFAM) would identify priorities for assessment through general status, COSEWIC Priorities etc.

Why:
- Identification of species requiring conservation measures
- DFO staff (potentially in partnership with other jurisdictions) would develop Conservation Status Reports that would form the basis of a COSEWIC status report, allowable harm assessment and recovery strategy
- Allows for the development of annual/regional species work plans to maintain equitable division of labour

<u>Conservation Status Report</u>

What:
- Conservation Status Reports that would form the basis of a COSEWIC status report, allowable harm assessment and recovery strategy
- DFO and not SARA language used
- DFO would subsequently submit COSEWIC status report for consideration (potential for no submission)

How:
- DFO initiates an Assessment (see content below)
- Assessment is reviewed through Advisory Processes (which includes stakeholder participation)
- Enables DFO to implement pre-emptive management measures prior to listing
- Increases transparency & stakeholder involvement in process
- Integrates the SARA process into normal DFO operations
- DFO would use the outcome of this assessment to consult with stakeholders and implement management measures (if possible)

Why:
- Provides ample lead-time to consult with our stakeholders
- DFO would have the information required to prepare for listing
- Provides better info to COSEWIC
- Potentially prevent unnecessary listings
- Decreases duplication of effort

This species was identified as a conservation concern through a previous Science peer-review. The species status report was developed by (name) and was reviewed on (date) in (place) (cite CSAS documents).

Drafting of this document was begun on (date) by (DFO or consultant) using existing jurisdictional information. A peer-review meeting was held (date) with representatives from affected jurisdictions, stakeholders (industry, NGOs) and Aboriginal Peoples, to gather further information and discussion. Proceedings of the RAP were published on (date). Comments were incorporated into the present document.

Contents of Conservation Status Report (CSR) — Component 1

Note: The following contains required content of
- COSEWIC status report
- Allowable Harm Assessment Framework
- SARA Recovery Strategy or Action Plan

1. Species Information
Summary introduction of species and rationale for conducting CSR for that species (i.e., rationale and basis for reviewing the conservation status of the species at this time)

1.1 Description of Species
1.1.1 Name and Classification
1.1.2 Morphological Description
1.1.3 Genetic Description
1.1.4 Ecologically Significant Units (if applicable)

1.2 Distribution
1.2.1 Global Range
1.2.2 Canadian Range

1.3 Habitat Considerations
1.3.1 Habitat Requirements
1.3.2 Habitat Trends
1.3.3 Habitat Protection/Ownership
1.3.4 Identification of Crucial Habitat (if possible at this point)
1.3.5 Studies Required to Identify Crucial Habitat (if needed)
1.3.6 Identification of Residence (where applicable)

1.4 Biology
1.4.1 Life Cycle and Reproduction
1.4.2 Predation (identify main predators)
1.4.3 Physiology (e.g. depth, temperature requirements)
1.4.4 Dispersal/Migration
1.4.5 Inter-specific Interactions
1.4.6 Adaptability

1.5 Population Size, Trends, and Uncertainty
1.5.1 Search Effort (data sources sought/considered)

1.5.2 Abundance
1.5.3 Recent/historical Trends (including natural fluctuation)
1.5.4 Potential for Recovery (including recovery feasibility)
1.5.5 Rescue Effect

1.6 Scope for Harm
1.6.1 Present/recent species trajectory?
1.6.2 Present/recent species status?
1.6.3 Expected order of magnitude/target for recovery?
1.6.4 Expected general time frame for recovery to the target?
1.6.5 Is there scope for harm/mortality to the species that will not impede recovery?
1.6.6 What is the maximum harm/mortality that will not impede recovery?

2. Threats to the species
2.1 Limiting Factors and Threats (domestically and internationally)
2.1.1 List of threats (including real or potential mortality/harm)
2.1.2 Degree of harm from each threat
2.1.3 Aggregate total harm/mortality from threats and compare to allowable harm to determine what level of mitigation is needed

2.2 Assessment of Cross-Jurisdictional Authorities in relation to Threats

2.3 Early Identification of 'Principal Stakeholders' in relation to Threats

3. Existing Protection
3.1 Legislation
3.2 Existing Status Designations (domestically and internationally)
3.3 Recovery Measures Currently In Place

4. Potential Conservation Targets
4.1 Goal of Conservation Measures
4.2 Proposed Species Rebuilding/Habitat Restoration Strategy
4.3 Recommended Actions/Recovery Schedule
4.4 Other Studies Needed

5. Significance of the Species
5.1 Scientific (endemicity, worldwide status…)
5.2 Ecological (top predator, significant prey item…)
5.3 Social/Cultural
5.4 Aboriginal
5.5 Economic

Implementation/Management Considerations

- Once the Conservation Status Report has been drafted, a socio-economic analysis of the contents of the assessment (e.g. proposed conservation targets) is initiated (in consultation with other jurisdictions as needed).

- A regional or national peer-review meeting (RAP/NAP) is planned and convened to review the assessment. This meeting includes clients, Sectors, First Nations, and jurisdictions.

- Proceedings and Part 1 of the Conservation Status Report are produced.

- Science (National Headquarters) formally informs operational sectors on outcome of Allowable Harm Assessment (AHA) (Phases 1 & 2).

- DFO Sectors and other jurisdictions (as required) determine how AHA can be implemented (through integrated management plans, MPAs, mitigation measures and alternative activities to be considered). Includes how to partition harm amongst competing activities.

- Socio-economic analysis and consideration are developed on AHA implementation and impacts of listing.

- Sectoral perspectives are integrated into draft management approach including intent to send status report to COSEWIC.

- Communications strategy is produced (DFO species management strategy and communications plan).

Contents of Conservation Status Report (CSR)— Component 2 —Socio-Economic Report

Note This part will be peer-reviewed in a NAP type meeting with all stakeholders/ partners included. The results will be combined with Part 1 to produce the final Conservation Status Report.

Background:
Methodology, assumptions, limitations
- Identification and description of base case
- Allowable harm assessment/(Fisheries) Management scenarios
- Listing prohibitions; recovery actions

Accounts (As Relevant – All may not apply)

1. Fishing

a. Commercial fishing sector impacts (Dependence, economic viability and income support)
- Total number of fishers: number of licences, permits, enterprises, vessels, persons employed
- Identification of fisheries where there is by-catch
- % of income attributed to species (dependency): Crew members affected
- Geographical distribution of affected licence holders
- Income Support: number of EI recipients by area; average amount awarded by area
- Price trends: landed price and market price per pound by area
- Fishing enterprises: number, revenue, costs
- Other sources of income

b. Recreational fishing sector impacts
- Total landings, by area
- Profile of activities affected (employment, value)

c. Processing Sector
- Plants processing species: Quantity processed, location (geographical distribution, cod as a percentage of total processed [dependency, viability], value added, employment (EI)

2. First Nations impacts
- Fishing (Communal licences, FSC allocations)
- Employment, income
- Economic development impacts

3. Impacts to other industries (This may require partnering with provinces for information)
- Agriculture, mining, electricity, oil and gas, tourism, etc.: Activity, production and viability, revenue, wages, employment, costs and net returns

4. Habitat Enhancements

5. Social Impacts
- Community Profiles (employment, demographic trends etc.)
- Regional development

6. Government
- Sectors (federal, provincial, municipal)
- Revenues (e.g. taxes), costs (e.g. science)

Departmental Recommendation/Proposed Action Plan

- Decision is made on whether to send a species status report to COSEWIC
- If yes, DFO implements management measures prior to COSEWIC listing
- Relevant Sectors consult with jurisdictions, Wildlife Management Boards (WMBs), First Nations, and clients as required
- Implementation of management approach includes promoting stewardship and developing tools/process/system to monitor success or the impact of management measures

Appendix 2. Habitat characteristics for Atlantic salmon (Amiro 2006).

Life Stage: Egg

* = mean value +/- Standard Deviation where available	Habitat characteristic					
Reference:	**Water depth (cm)**	**Velocity (cm/sec)**	**Substrate composition**	**Home stone diameter (cm)**	**Cover stone diameter (cm)**	**Egg depth (cm)**
Bardonnet and Bagliniere (2000)	20-30	40-50				15-25
Moir *et al* (1998)	*24.8	*53.6				
Soulsby *et al* (2001)	*25.6	*51.8				
Heggberget (1991)	50	40				
Warner (1963)			83% gravel, 16-17% sand			*20.3

Life Stage: Alevin (Fry) (6 to 7 months post-egg deposit)

* = mean value +/- Standard Deviation where available	Habitat characteristic					
Reference:	**Water depth (cm)**	**Velocity (cm/sec)**	**Substrate composition**	**Home stone diameter (cm)**	**Cover stone diameter (cm)**	**Riffle, Run, Pool**
Morantz *et al* (1987)	20-40	5 to 10				
deGraf and Bain (1986)		10 to 30	gravel			
Girard *et al* (2004)	20 to 39	6 to 48	pebble			
Gries and Juanes (1998)	18 to 82	*20.6+/- 1.1		pebble (47%), cobble (39%), gravel (8%), boulder (9%)	cobble (62%), boulder (39%)	riffle-run (58%), pool (42%)
Kennedy and Strange (1982)	<20cm preferred					riffle

Appendix 2 (cont'd)

Life Stage: Fry (8-12 months post-egg deposit)

* = mean value +/- Standard
Deviation where available

Habitat characteristic

Reference:	Water depth (cm)	Velocity (cm/sec)	Substrate composition	Home stone diameter (cm)	Cover stone diameter (cm)	Riffle, Run, Pool
Armstrong *et al* (2003b)	<10					
Beland and Trial (2004)	*28.9+/- 1	*24.7+/- 1.5	cobble			
Bremset and Berg (1999)	*139+/- 9	*<60				
Maki-Petays *et al* (2002)	15 to 60	20 to 80	cobble to boulder			
Mitchell *et al* (1998)	*23.5 +/- 2.78	*12.5+/- 3.5	daytime - *9.22+/- 5.77cm, night - *5.77+/-4.33 cm			
Nislow *et al* (1999)		12.8				
Rimmer *et al* (1984)	24-36	summer =*16.8, autumn= <10		summer *6.6, autumn *17.8		
Morantz *et al* (1987)	20-40	5 to 10	gravel			
DeGraff and Bain (1986)		10 to 30	gravel			

Appendix 2 (cont'd)

Life Stage: Age 1-Parr

* = mean value +/- Standard
Deviation where available

<div align="center">Habitat characteristic</div>

Reference:	Water depth (cm)	Velocity (cm/sec)	Substrate composition	Home stone diameter (cm)	Cover stone diameter (cm)	Riffle, Run, Pool
Armstrong et al (2003b)			cobble to boulder			
Bagliniere *et al* (2005)						Riffle
Beland *et al* (2004)	*35.7+/- 1.2	*22.9+/- 1.9	gravel			Riffle
Bremset (2000)	>300	4 to 10	avoided fine substrates			Pool
Bremset and Berg (1999)	*156+/- 6.0	<60				
Bult *et al* (1999)						Run
Gries and Jaunes (1998)	*52.5 +/- 3.7	*23.7 +/- 4.5		2 to 19	15 to 44	Pool (53%) and riffle-run (47%)
Guay *et al* (2000)	30 to 70	60 to 75	gravel			
Maki-Petays *et al* (2002)	25 to 65	20 to 80	cobble to boulder			
Nislow *et al* (1999)		21 to 57				
Roussel *et al* (2004)	20 to 30 early winter, 60 cm late winter		boulders and rubble (20-30) early winter, large boulders >40 cm late winter			
Whalen et al. (1999a)	>30	<40				
Rimmer et al. (1984)	24-36	summer *29.3, autumn <10		*<20 summer, *20.9 autumn		
Cunjak (1988)	40 to 50	38 to 46		17 to 23		
Morantz et al. (1987)	30 to 60	7 to 15	gravel and cobble			
Coulombe-Pontbriand and Lapointe (2004)			boulder			

Appendix 2 (cont'd)

Life Stage: Age 2-Parr

* = mean value +/- Standard Deviation where available

<div align="center">Habitat characteristic</div>

Reference:	Water depth (cm)	Velocity (cm/sec)	Substrate composition	Home stone diameter (cm)	Cover stone diameter (cm)	Riffle, Run, Pool
Bremset (2000)	>300	4 to 10				
Bremset and Berg (1999)	*156+/- 6	*< 60				
Guay *et al* (2000)	30 to 70	60 to 75	gravel			
Mitchell *et al* (1998)	*20.47 +/- 3.02	*11.8 +/- 5.3				
Roussel *et al* (2004)	20 to 30 early winter, 60 cm late winter		boulders and rubble (20-30) early winter, large boulders >40 cm late winter			
Whalen *et al* (1999)	>30	<40				
Rimmer *et al* (1984)	24-36	summer 30-50, winter <10			summer 6.4, autumn 24.4	
Morantz *et al* (1987)	30 to 60	10 to 20	gravel and cobble			
Coulombe-Pontbriand and Lapointe (2004)			boulder			

Life Stage: Age 3-Parr &

<

* = mean value +/- Standard Deviation where available

<div align="center">Habitat characteristic</div>

Reference:	Water depth (cm)	Velocity (cm/sec)	Substrate composition	Home stone diameter (cm)	Cover stone diameter (cm)	Riffle, Run, Pool
Beland and Trial (2004)	*35.7 +/- 1.2	22.9 +/- 1.9	gravel		cobble or <	
Bremset (2000)	>300	4 to 10				
Bremset and Berg (1999)	156+/- 6	< 60				
Okland *et al* (2004)	60					riffle (88%), pools (11%)
Coulombe-Pontbriand and Lapointe (2004)			boulder			

Appendix 2 (cont'd)

**Life Stage: Adult (Spawning Habitat)**

* = mean value +/- Standard
Deviation where available

<center>Habitat characteristic</center>

| Reference:	Water depth (cm)	Velocity (cm/sec)	Substrate composition	Home stone diameter (cm)	Cover stone diameter (cm)	Riffle, Run, Pool
Armstrong *et al* (2003)	17 to 70		gravel (little silt and sand)		boulders important for migrating adults	
Moir *et al* (1998)	24.8	53.6	gravel			
Soulsby *et al.* (2001)	25.6	51.8				
Heggberget (1991)	50	40	gravel (10 cm diameter)			
Crisp and Carling (1989)		>15-20	gravel, sand, and silt (median 20-30mm)			
Beland *et al* (1982)	39	53				
Warner (1963)			83% gravel, 16-17% sand			
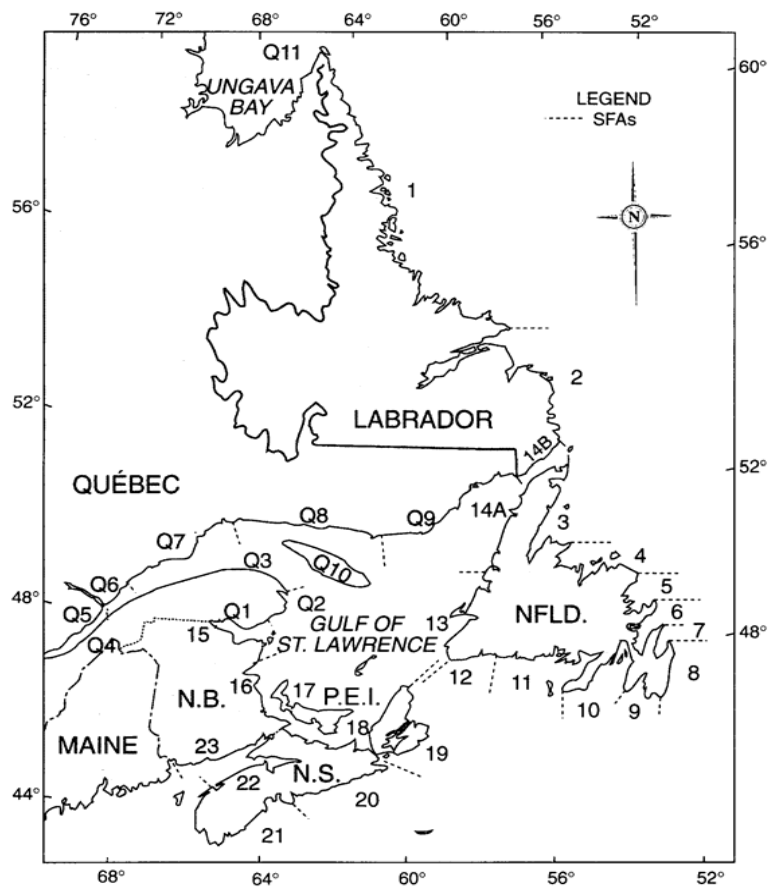
Appendix 3. SMAs (Salmon Fishing Areas 1-23 and Q1-Q11) in Eastern Canada.
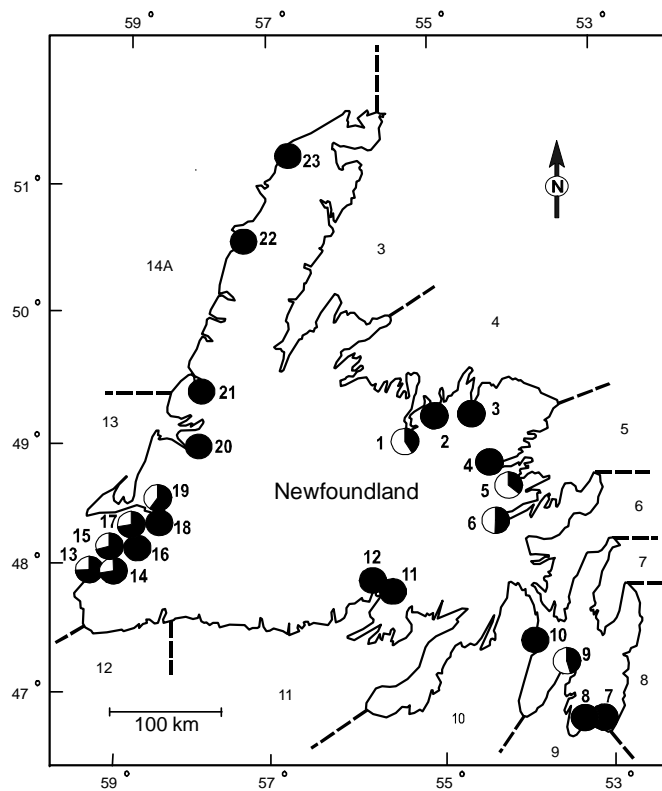
| SFA	River	Map Location Code	Drainage Area km²
Northeast Coast			
4	Exploits River	1	11272
	Campbellton River	2	296
	Gander River	3	6398
5	Middle Brook	4	276
	Terra Nova River	5	1883
	Northwest Brook, Port Blanford	6	689
South Coast			
9	Biscay Bay River	7	239
	Northeast Brook, Trepassey	8	21
	Rocky River	9	296
10	Northeast River, Placentia	10	94
11	Conne River	11	602
	Little River	12	183
Southwest Coast			
13	Highlands River	13	183
	Crabbes River	14	551
	Middle Barachois River	15	241
	Robinsons River	16	439
	Fischells Brook	17	360
	Flat Bay Brook	18	635
	Harrys River	19	816
	Humber River	20	7679
Northwest Coast			
14A	Lomond River	21	470
	Torrent River	22	619
	Western Arm Brook	23	149

Appendix 4. Insular Newfoundland Rivers.

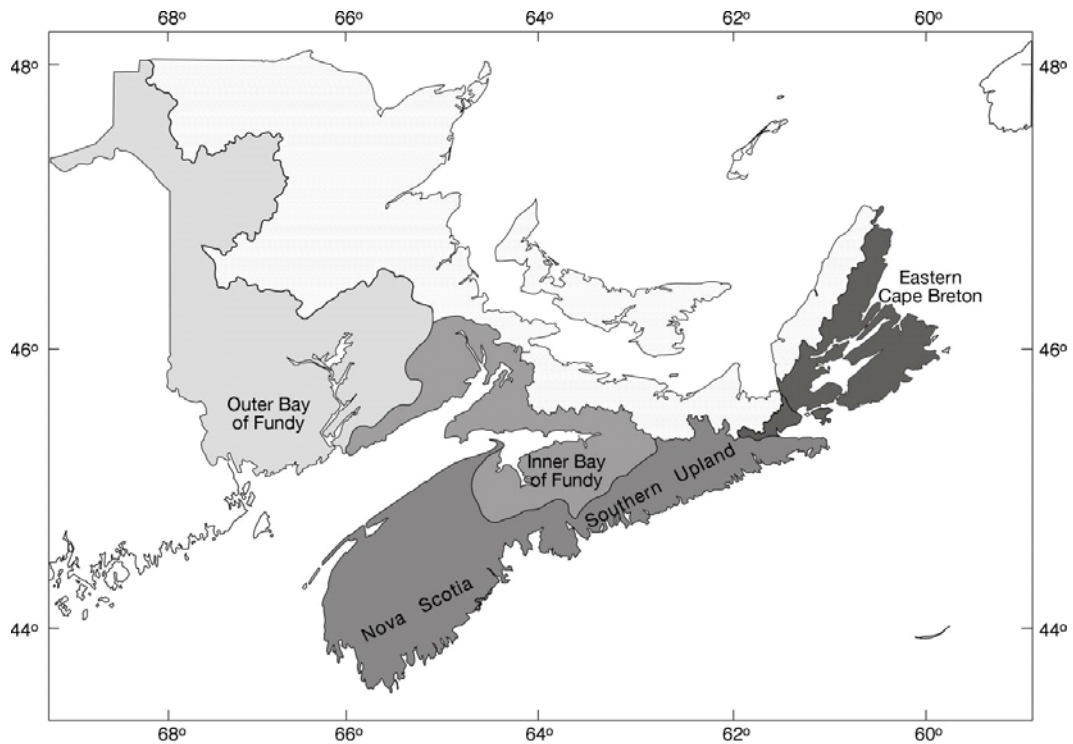Where SFA 3-8 = CU 4, SFA 9-10=CU 5, SFA 11 – 12 = CU 6, SFA 13 – 14A = CU 7 & 8 respectively).
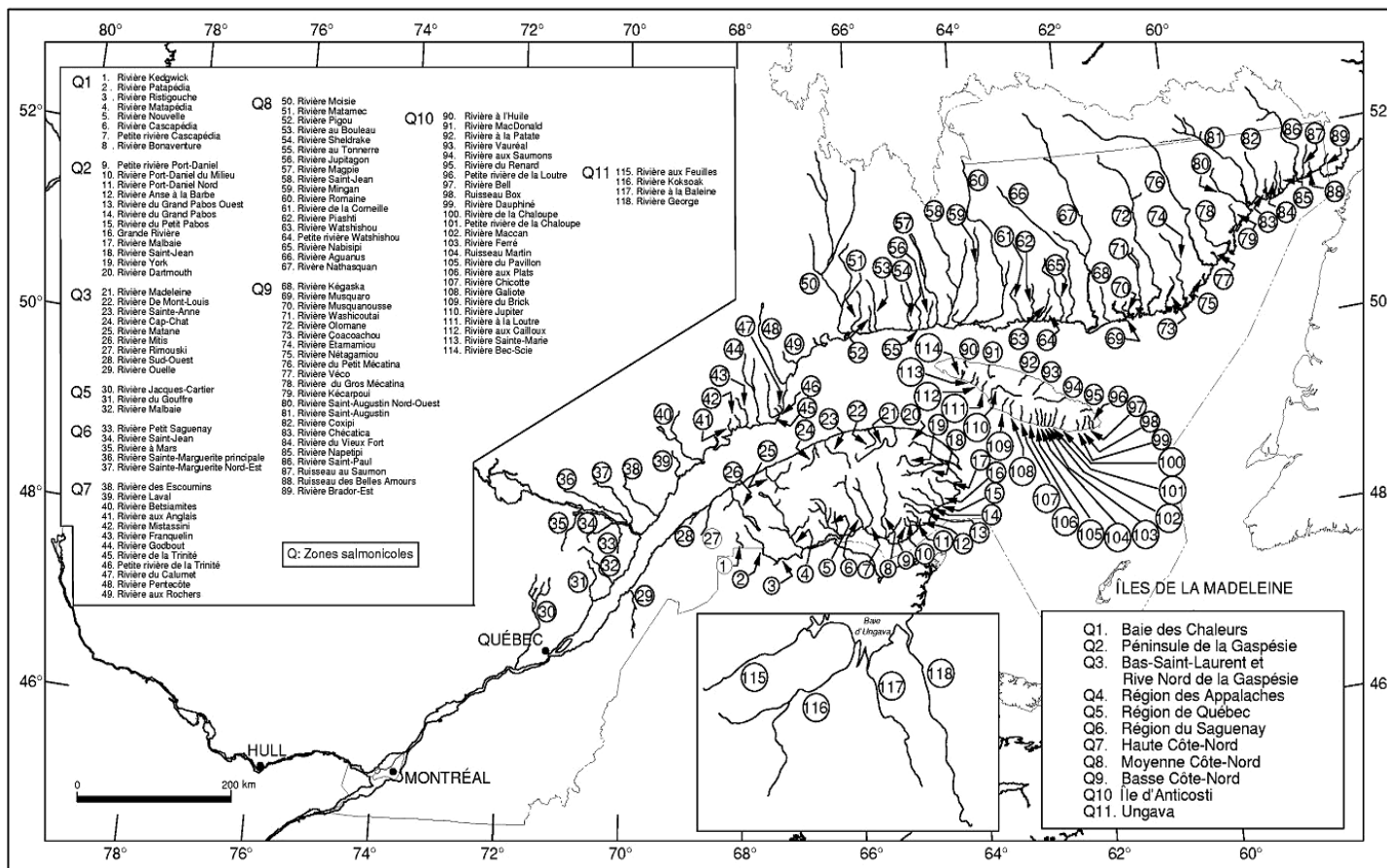
*River lists include assessed tributaries

Appendix 5. Map of Quebec CUs.

Where Quebec Sport Fishing Area Q 1=CU 18, Q2=CU 19, Q3= CU 20, Q4= CU 21, Q5 = CU 22, Q6 = CU 23, Q7 = CU 24, Q 8 = CU 25, Q 9 = CU 26, Q 10 = CU 27, Q 11 = CU 28) .
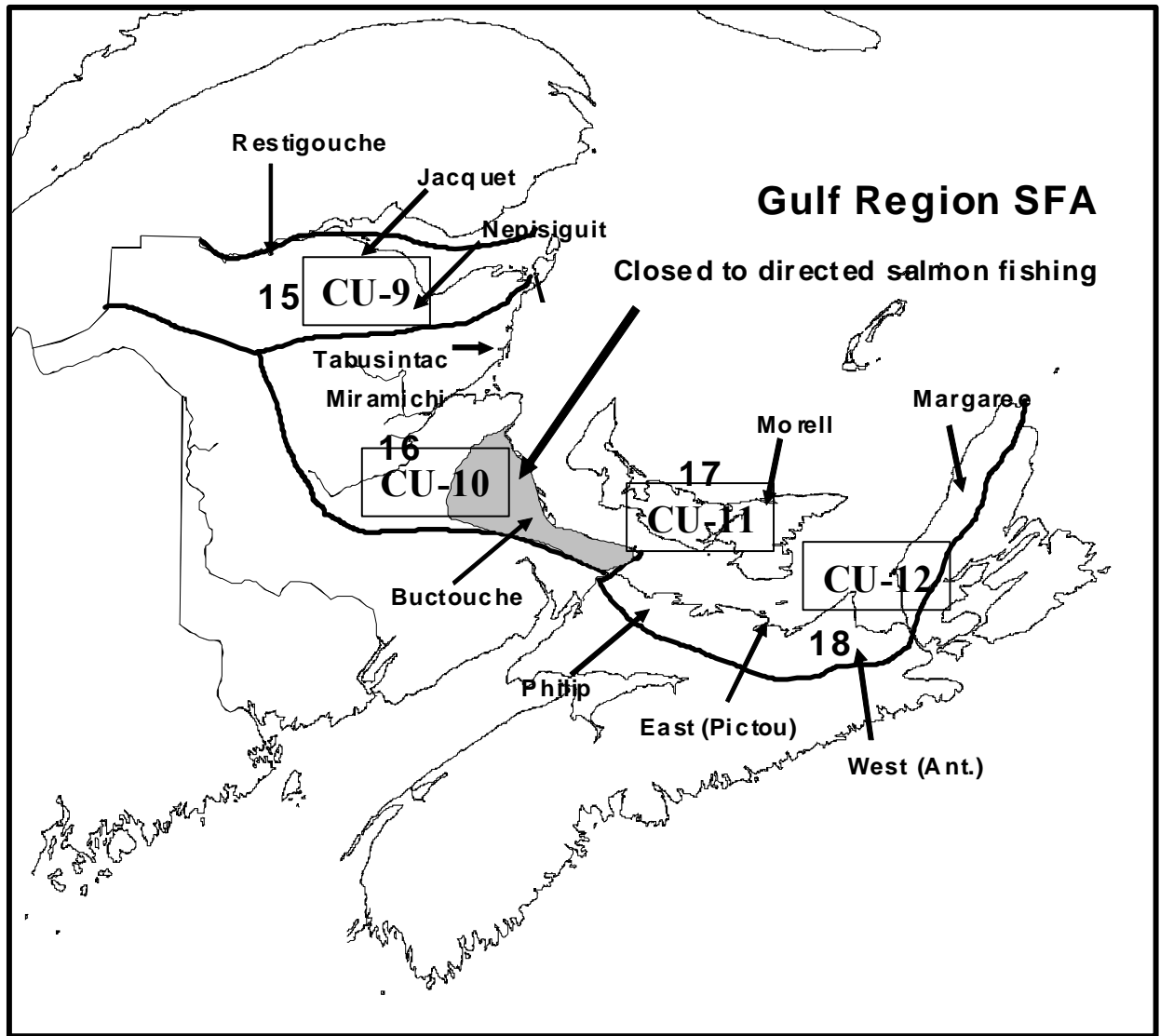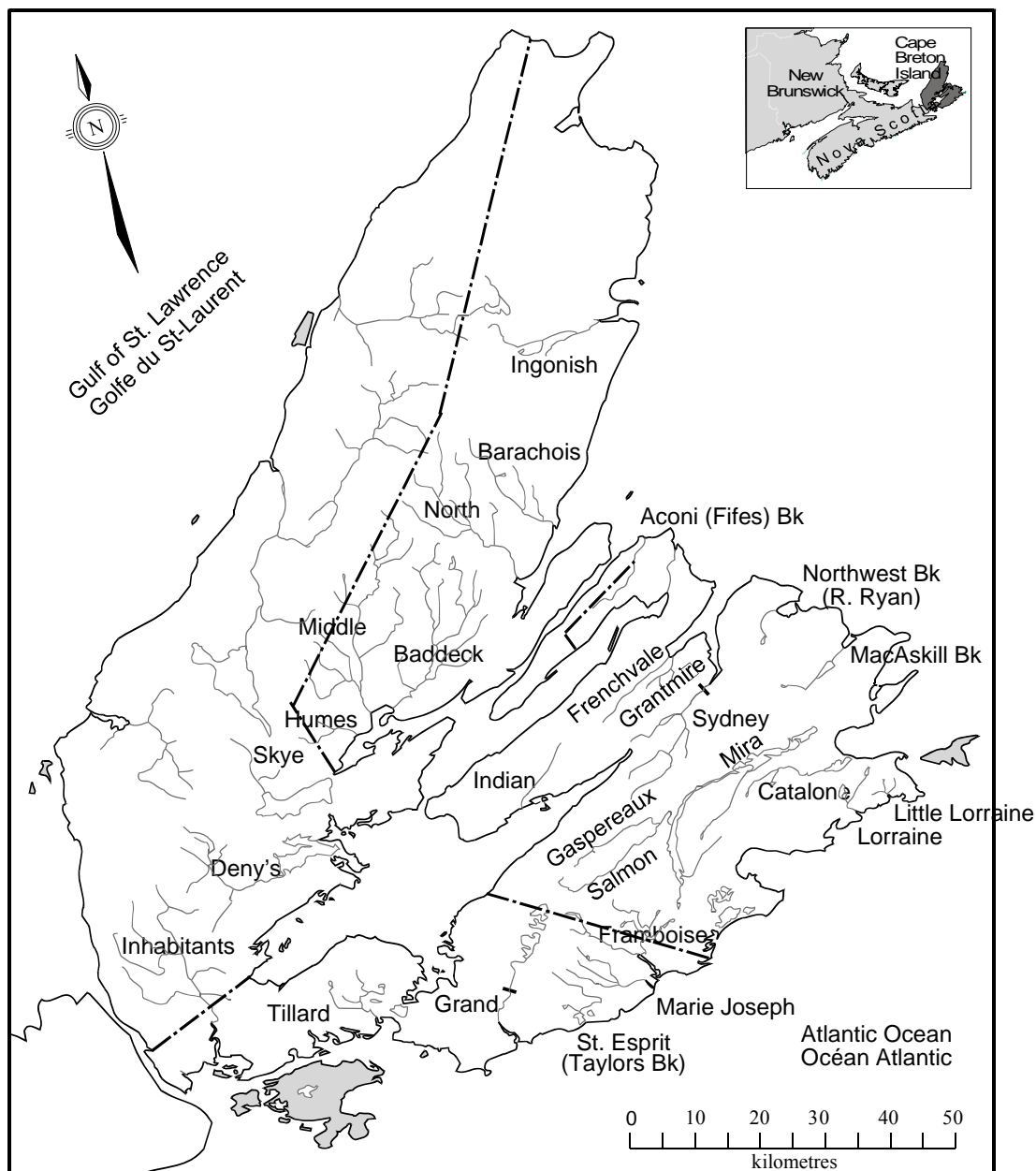
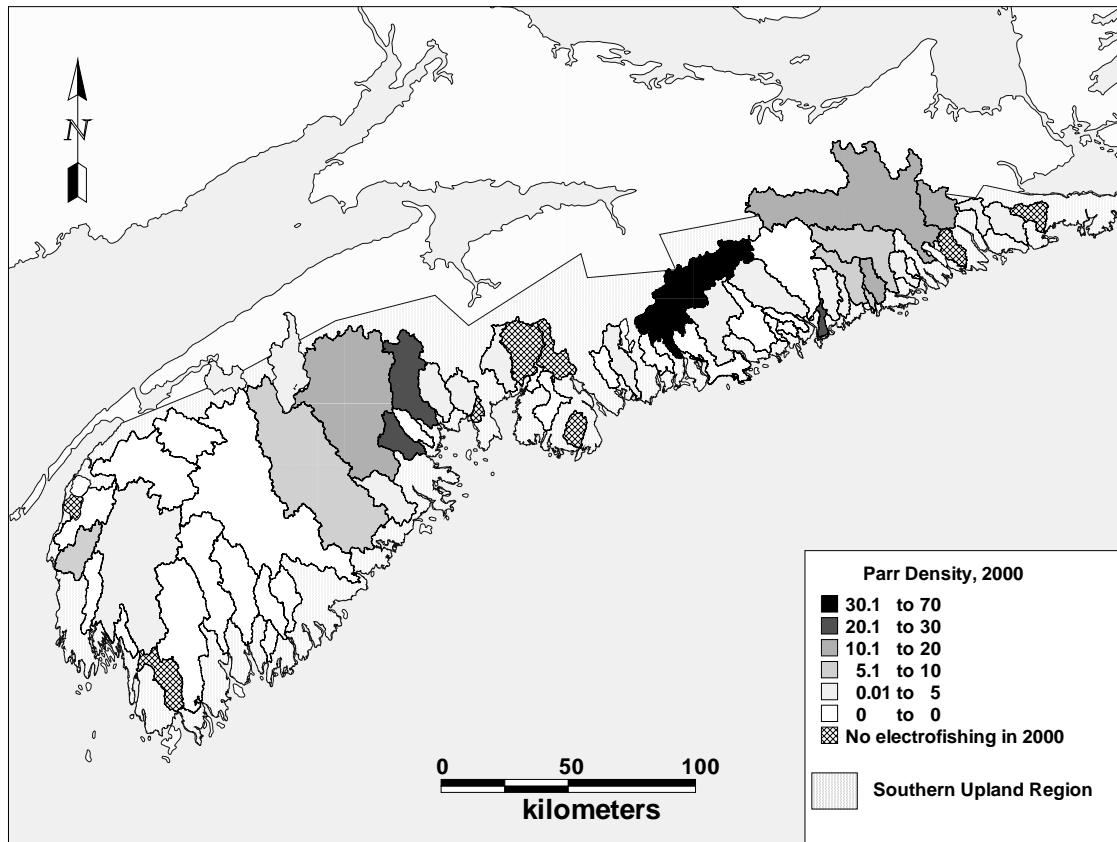**Appendix 6. SFAs and CUs for rivers of the Southern Gulf of St. Lawrence.**

Appendix 7. CUs in Atlantic Nova Scotia and Bay of Fundy

where Eastern Cape Breton =CU 13 and 14/SFA 19; the Southern Upland = CU 15/SFA 20 and 21; the inner Bay of Fundy = CU 16/parts of SFA 22 and 23 and, outer Bay of Fundy = CU 17.

Appendix 8. Geographical location of the rivers in Eastern Cape Breton (CU 13-14/ SFA 19).

Appendix 9. Map of the river drainage areas in the Southern Upland region (CU 15)
and their associated total juvenile Atlantic salmon density (number per100 m^2), as determined by electrofishing in 2000.