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Updated Information on Atlantic Salmon (*Salmo salar*) Populations in Nova Scotia's Southern Upland (SU; Salmon Fishing Areas 20, 21, and Part of 22) of Relevance to the Development of a 2nd COSEWIC Status Report

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The purpose of this research document is to summarize and update the present status and recent trends of Atlantic Salmon populations in the Southern Upland (SU) Designatable Unit (DU 14) of relevance to the development of the status report by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Based on genetic evidence, regional geography and differences in life history characteristics SU Atlantic Salmon is considered to be biologically unique (Gibson et al. 2011) and its extirpation would constitute an irreplaceable loss of Atlantic Salmon biodiversity.

Within the SU DU, there are at least 72 rivers thought to contain, or to historically have contained Atlantic Salmon. The assessment of stock status is based on abundance of adults, juveniles and smolts in selected rivers, and the available data indicate that the abundances of SU Atlantic Salmon populations are low and declining. Region-wide comparisons of juvenile density data from more than 50 rivers indicate significant ongoing declines and provide evidence for river-specific extirpations. As of the most recent regional electrofishing survey, presence can be documented in 41% (22 of 54) of rivers that were assessed. Annual adult abundance data from four rivers show declines of 95% to 100% from maximum abundance, and Salmon returns to the SU index rivers (LaHave and St. Mary's) have been below the conservation requirement every year for the past 3 generations of available data. The regional estimate for Atlantic Salmon predicts that in 2019 the SU DU would be have produced less than 4% (2.42–6.35 million eggs) of the estimated regional conservation requirement of 187.95 million eggs. A number of threats to Atlantic Salmon are identified in the freshwater and estuarine/marine environment of the SU DU, including habitat fragmentation, invasive fish species, acidification of freshwater habitat, illegal fishing/poaching, salmonid aquaculture, and marine ecosystem change.

INTRODUCTION

The intent of this document is to provide an update of the Department of Fisheries and Oceans (DFO) Science information for the SU Atlantic Salmon (*Salmo salar*) population in support of the development of a status report of Atlantic Salmon in eastern Canada by COSEWIC. Abundance of Atlantic Salmon in the Maritimes Region has been in decline for more than two decades. Populations in many rivers are extirpated, and in November 2010, Nova Scotia Southern Upland (SU; Designatable Unit [DU] 14) Atlantic Salmon (Salmo salar) was assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as endangered (COSEWIC 2010).

There are at least 72 rivers thought to contain, or to historically have contained Atlantic Salmon in the SU DU, although it is likely salmon would also have used the smaller coastal or un-assessed rivers in the region (Bowlby et al. 2013). Rivers in the SU tend to be less productive than more mineral-rich rivers in adjacent DUs (Watt 1987), and river acidification caused by acid precipitation has significantly contributed to reduced abundance or extirpation of SU salmon populations from many rivers in the region over the last 50 years (DFO 2014). Although most systems are not acidifying further, few are recovering and most are expected to remain affected by acidification for more than 50 years (Bowlby et al. 2014).

Evaluation of the status of Atlantic Salmon in the SU is based on abundance monitoring for a number of index populations, which have been shown to be roughly indicative of trends throughout the region (Amiro 2000, DFO 2011, O'Neil et al. 1998).

Juvenile Atlantic Salmon were found in 22 of 54 river systems surveyed in 2008/2009, which was a slight decrease from the previous regional survey in 2000 (Bowlby et al. 2014). Adult returns to the LaHave and St. Mary's river index populations have declined by > 83% and > 79%, respectively, over the previous three generations for which there are data, and population modeling has indicated a high probability of extirpation within 50 years for these two populations in the absence of a change in survival rates (Gibson and Bowlby 2013).

Atlantic Salmon commercial fisheries within the Maritimes Region were closed in 1985, and in 2010, all recreational fisheries for Southern Upland salmon were closed; prior to the recreational closure, angling data indicate declines of > 95% in catch as well as effort for most rivers in the SU (Gibson et al. 2009). Threats facing Atlantic Salmon populations within the SU DU assessed with a high level of concern within the freshwater environment are acidification, altered hydrology, invasive fish species, habitat fragmentation (dams, culverts and other permanent structures) and illegal fishing/poaching. Threats assessed as high level of concern within the estuary/marine environment are salmonid aquaculture and marine ecosystem change.

Additional information about these populations, as well as previous assessment documents, can be found in Canadian Science Advisory Secretariat documents published by the Department of Fisheries and Oceans (DFO) in Ottawa, the most recent being: DFO (2020b) and four research documents prepared in support of the Recovery Potential Assessment (RPA) for the SU DU providing information on abundance, life history, and trends (Bowlby et al. 2013), genetic variation (O'Reilly et al. 2012), population dynamics and viability (Gibson and Bowlby 2013), and habitat use and threats to populations (Bowlby et al. 2014).

1. LIFE HISTORY CHARACTERISTICS

Southern Upland anadromous Atlantic Salmon populations exhibit a range of life history characteristics, with differences in growth, maturation, run timing, and sex ratio among populations (Hutchings and Jones 1998, O'Connell et al. 2006), although, several characteristics are similar among populations (Chaput et al. 2006). Generally, SU Atlantic

Salmon mature after either one or two years in the marine environment (called "one sea-winter salmon" or 1SW, "two sea-winter salmon" or 2SW, respectively); however, a small proportion of may mature after three years at sea ("three sea-winter salmon" or 3SW). Collectively, salmon that return following two or more winters at sea are referred to as multi-sea-winter (MSW). The rate of repeat spawning in monitored SU populations is low (< 5%; Bowlby et al. 2013), and the majority of returns are first-time (maiden) spawners. Most adult Atlantic Salmon enter the rivers throughout the spring (May/June) and summer (July/August) months; exact timing is partially determined by river flow. Spawning occurs in late October or November, and post-spawn adults (kelts) either return to the marine environment immediately or remain in fresh water before out-migrating during the following spring (O'Connell et al. 2006). Juveniles emerge from the gravel in early spring and typically spend 3–4 years in freshwater before migrating to sea as smolts. Detailed life history information for SU Atlantic Salmon is presented in Gibson and Bowlby (2013) and Bowlby et al. (2014).

The aquatic habitat that SU Atlantic Salmon need for successful completion of all life-history stages has been extensively described in Bowlby et al. (2014).

The most recent estimates of life history parameters for SU Atlantic Salmon (natural mortality and recruitment rates) are presented in Gibson and Bowlby (2013). These estimates are based on the two Atlantic Salmon populations in the SU that have sufficient data for estimating values for life history parameters: LaHave River (above Morgan Falls) and St. Mary's River (West Branch).

The following sections provide updated biological information relating to specific life history characteristics of the index rivers LaHave (above Morgan Falls) and St. Mary's (West Branch) where new data have been collected; more detailed information on methods used to collect data and assess status and trends can be found in Bowlby et al. (2013).

1.1. LAHAVE RIVER

Biological data have been collected for LaHave River Atlantic Salmon at the Morgan Falls fishway since 1970 (Table 1). Analyses of adult scale samples collected from wild LaHave River Atlantic Salmon indicate individuals in the population generally spend on average 2.1 years in fresh water prior to migrating to sea primarily as age-2 smolts. LaHave River Atlantic Salmon then spend on average 1.3 winters at sea prior to returning to LaHave River to spawn for the first time. Mean generation time is 4.4 years, which is calculated as the mean smolt age in addition to mean sea age for maiden spawners, with an additional year added to account for the year of egg deposition (COSEWIC 2010).

The length-fecundity relationship (Cutting et al. 1987) calculated from 65 adult salmon collected prior to 1986 is:

$$\text{Fecundity} = 446.54e^{0.0362*\text{Fork Length}}$$

The fecundity calculation is then used to estimate number of eggs per fish for 1SW and MSW returns based on fork length of returning adults, and the proportion female in each population (Table 2).

1.2. ST. MARY'S RIVER

Adult biological data were collected on St. Mary's River (West Branch) between 1999 and 2011. (Table 3). Scale samples indicate that St. Mary's River Atlantic Salmon spend on average 2.2 years in fresh water prior to migrating to sea, the majority as age-2 smolts. LaHave River Atlantic Salmon then spend on average 1.1 winters at sea prior to returning to LaHave River to spawn for the first time, which corresponds to a mean generation time of 4.3 years, calculated as above.

The length-fecundity relationship (Marshall 1986) calculated from adult broodstock collections during the period 1972 to 1985 is:

$$\text{Fecundity} = 340.832e^{0.0389*\text{Fork Length}}$$

The fecundity calculation is then used to estimate of eggs per fish for 1SW and MSW based on fork length of returning adults returns, and the proportion female in each population (Table 2).

1.3. SOURCES OF UNCERTAINTY

Limited data are available to characterize life history on other SU populations. Historical data exist for counts of adult salmon ascending fishways on the East River (Sheet Harbour) and the Liscomb River, each of which were similarly comprised of primarily 1SW returns before substantial declines halted monitoring (Gibson et al. 2010).

2. OVERVIEW OF DESIGNATABLE UNIT

The Southern Upland DU of Atlantic Salmon [DU 14; Salmon Fishing Area 20–22; CU 15] occupies rivers in a region of Nova Scotia extending from the northeastern mainland, approximately 45° 39” N, 61° 25” W, southward and into the Bay of Fundy to Cape Split, approximately 45° 20” N, 64° 30” W, (COSEWIC 2010, Gibson and Bowlby 2013). This region encompasses all rivers south of the Canso Causeway on both the Eastern Shore and South Shore of Nova Scotia draining into the Atlantic Ocean, as well as Nova Scotia rivers draining into the Bay of Fundy south of Cape Split (Figure 1). For management and assessment purposes the DU has been divided into three Salmon Fishing Areas (SFAs): SFA 20 (Eastern Shore), SFA 21 (Southwest Nova Scotia), and part of SFA 22 (Bay of Fundy rivers inland of the Annapolis River; Figure 2).

Genetic data suggest minimal gene flow between DU 14 and the neighbouring DUs (13 and 15; Verspoor 2005, Verspoor et al. 2005). Many rivers in DU 14 have lower proportions of MSW fish than rivers to the north in DU 13. Southerly populations in DU 14 also have some of the youngest smolt ages reported in Canada (Chaput et al. 2006). There is some genetic evidence for the increased similarity within the Eastern Shore and Southwest Nova Scotia populations; in general, populations clustered into two relatively distinct groups corresponding to populations in SFA 20 and SFA 21 (see Figure 3 in O’Reilly et al. 2012).

Beginning in 2016 Atlantic Salmon were collected from LaHave and St. Mary’s River for captive rearing in an effort to conserve genetic diversity representative of the SU DU (DFO 2020a; see Manipulated Populations).

3. TRENDS IN POPULATION INDICATORS

To facilitate long-term monitoring of Southern Upland Atlantic Salmon, certain populations have been chosen as index populations, and these have been shown to be roughly indicative of trends throughout the region (Amiro 2000, DFO 2011, O’Neil et al. 1998). Monitoring data on all life stages of Atlantic Salmon have been collected for two populations: LaHave River (above Morgan Falls) in SFA 21 and the St. Mary’s River in SFA 20 (Figure 2), which account for 6.5% and 5.1%, respectively, of the estimated total productive Atlantic Salmon habitat in the DU (Amiro 1993, O’Connell et al. 1997; see Section 2.1 and Table 2.1.2 in Bowlby et al. 2014). These data, in years they were collected since the most recent review of DFO Science information for Atlantic Salmon populations in the SU DU (Gibson et al. 2010), are presented in annual DFO Canadian Science Advisory Secretariat Science Response documents (DFO 2010–2018, 2020a, 2020b).

Additional data collected on other SU rivers consists of adult counts on the East River, Sheet Harbour (1970–2010), and Liscomb River (1979–1999), as well as widespread electrofishing surveys for juveniles in 2000 and 2008–09 (Gibson et al. 2011). Adult Atlantic Salmon assessments in SU also historically relied on recreational catches, which were reported through a license-stub return program, until the complete closure of Atlantic Salmon angling on SU rivers by 2010. Data from these non-index populations have not been updated since their presentation in Bowlby et al. (2013).

Evaluation of the status of Salmon in the Maritimes Region is based on abundance monitoring for a number of index populations. For most index populations where adult returns are available, status is evaluated using a comparison of the estimated egg deposition (calculated from the estimated abundance and biological characteristics of salmon stocks)relative to a reference point known as the conservation egg requirement. The river-specific conservation egg requirement is based on an egg deposition of 2.4 eggs/m^2 multiplied by the amount of accessible fluvial rearing habitat that is of suitable gradient. An egg deposition of 2.4 eggs/m^2 is considered to be a Limit Reference Point (LRP) in the context of DFO's Precautionary Approach Framework (DFO 2009, DFO 2012b, Gibson and Claytor 2012) for DFO's Maritimes Region. Conservation requirements for many of the rivers in the Maritimes Region are reported in O'Connell et al. (1997).

The equilibrium values for egg deposition, smolt abundance, and maximum lifetime reproductive rate, from years 1980–1989 and 2000–2009 for LaHave River (above Morgan Falls) and St. Mary's River (West Branch) are presented in Gibson and Bowlby (see Table 2.5.2 in Gibson and Bowlby 2013).

The following sections provide updated information on status and trends of the two Atlantic Salmon populations in the SU for which new data have been collected; up to 2019 (where available). More detailed information on methods used to collect data and assess status and trends can be found in Bowlby et al. (2013).

3.1. LAHAVE RIVER

3.1.1. Background

The LaHave River drains approximately 1670 km^2 of the SU region of Nova Scotia, and is one of the largest watersheds in SFA 21. The conservation requirement (CR) for LaHave River is 12.20 million eggs, which is met by 5,434 1SW and 1,307 2SW Atlantic Salmon (O'Connell et al. 1997). This was calculated based on an estimated 5,084,800 m^2 of available rearing habitat and a target egg deposition of 2.4 eggs/m^2 (O'Connell et al. 1997, Bowlby et al. 2013). An estimated 51% of the productive area in the watershed is above Morgan Falls (Amiro et al. 1996), yielding a CR of 6.22 million eggs for the LaHave River above Morgan Falls.

3.1.2. Status

3.1.2.1. Juveniles

Electrofishing surveys to estimate the densities of age-0, age-1, and age-2 and older juveniles have taken place on LaHave River both above and below Morgan Falls since 1990. Abundances are compared to Elson's norm values of 29 fry/100 m^2 and 38 parr/100 m^2 (Elson 1967) to evaluate productivity. Only single-pass open-site surveys have been done in recent years, so the mean catchability based on surveys in 2007 and 2008 is used to estimate juvenile densities (Gibson et al. 2010).

Age-0 salmon (fry) and total parr (age-1 and older) densities on LaHave River have been low in recent years and remain well below Elson's norm values (Table 4). Total parr densities (age-1 and age-2 combined) have ben < 25% of Elson's norm value in the past 9 years. Juvenile densities have shown significant declines of between 73–87% for all life stages over the past 3 generations (Figure 3).

3.1.2.2. Smolts

Smolts captured at the Morgan Falls Power hydroelectric facility bypass are marked and released upstream of Morgan Falls for a mark-recapture experiment. A corrected Petersen estimate of the total number of marked and recaptured smolts is used to estimate population size. The catchability of the downstream fishway is estimated as the proportion of recaptured to marked fish. The most recent smolt assessment occurred in 2016 (Table 5), and smolt production per unit juvenile rearing area (2,605,200 m^2) was estimated to be 0.99 smolts per 100 m^2. The estimated production is very low in comparison to the reference value of 3.8 smolts per 100 m^2 of habitat (Symons 1979), although this was the second-highest recorded estimate for smolt production since 1996.

3.1.2.3. Adults

Counts of adult salmon on LaHave River have occurred at Morgan Falls since 1970, where a fishway was constructed on the late-1960s to bypass a large natural obstacle that limited access to the upper watershed. DFO began a stocking program to enhance the developing salmon run.

In 2019, the LaHave River salmon population above Morgan Falls remained low with an estimated egg deposition of 4% of the conservation egg requirement (Table 6, Figure 4). Since the fishway was opened in the 1970s, estimated egg deposition above Morgan Falls has not reached the CR, although the population did come close in the late 1980s (Figure 4). Hatchery-origin smolts were no longer introduced after 2005, thus are not reflected in returns in the most recent 13 years of monitoring (roughly 3 generations).

The ratio between smolt production and subsequent adult returns provides an estimate of the return rate of smolts (indicative of at-sea survival). Smolt-to-adult return rates (a proxy for marine survival) for 1SW and 2SW Atlantic Salmon on the LaHave River have declined to values less than 1% from 2013 to 2016 (Table 5).

Return rates of hatchery-origin Atlantic Salmon between 1970–2005, based on estimated hatchery smolt output, were consistently < 1% for both 1SW and 2SW adults over the last decade of the time series (see Table 2.3.1 in Bowlby et al. 2013).

3.2. ST. MARY'S RIVER

3.2.1. Background

The CR for St. Mary's River is 9.56 million eggs, which is met by 3,155 1SW and 889 2SW Atlantic Salmon (O'Connell et al. 1997). This was calculated based on an estimated 3,985,400 m^2 of available rearing habitat and a target egg deposition of 2.4 eggs/m^2 (O'Connell et al. 1997, Bowlby et al. 2013). Approximately 55% of the suitable rearing habitat is in the West Branch (Amiro 2006), which yields a CR for the West Branch of 5.30 million eggs.

3.2.2. Status

3.2.2.1. Juveniles

Single-pass open-site electrofishing to estimate densities of age-0, age-1, and age-2 and older juveniles on the St. Mary's River have been conducted annually for over 30 years, using mark-recapture methods and a running ten year mean catchability rate.

Age-0 salmon (fry) and total parr (age-1 and older) densities on St. Mary's River have been lower on average at West Branch sites than East Branch, and both branches have remained below Elson's norm values for parr densities for the duration of the time series (Table 7). Fry (age-0) densities have been above Elson's norm value in the past decade for East Branch, however West Branch has been below 50% of Elson's norm since the late 1990's. Juvenile densities have remained relatively stable over past 3 generations on both the East and West branches of the St. Mary's River (Figure 3).

3.2.2.2. Smolts

Based on an estimated 2,191,970 m^2 of juvenile habitat contained in the West Branch of the St. Mary's River, smolt production in 2019 was 0.10 smolts per 100 m^2 (Table 8) which is very low compared to rates of smolt production that have been observed in rivers in the past (vs. 3.8 smolts per 100 m^2 of habitat; Symons 1979), and the lowest estimate on record since 2005. East Branch densities were similarly low at 0.38 smolts per 100 m^2 of habitat in 2019, although this is the only year with sufficient data for a smolt estimate.

3.2.2.3. Adults

Using estimated abundance from the seining mark-recapture survey in 2011, egg deposition was approximately 11% of the CR for the West Branch, St. Mary's River (Figure 5, Table 9). This is roughly double the percent CR estimate from the prior two years of returns although it is the third-lowest value in the mark-recapture time series (1997–2011). Surveys have not been conducted in recent years although juvenile and smolt assessments indicate wild population persistence.

3.3. DECLINE RATES OF ADULT POPULATIONS

Four SU populations have sufficient fisheries-independent time series data to assess trends in abundance; LaHave River (above Morgan Falls), St. Mary's River (West Branch), Liscomb River, and East River (Sheet Harbour; Table 10). Adult count data over the previous three generations and from the maximum observed abundance were analyzed using a log-linear model (Gibson et al. 2010) to characterize the trends. For LaHave River and St. Mary's River the analyses here have been updated to include data up to 2019 and 2011, respectively. No recent monitoring has taken place on Liscomb River or East River (Sheet Harbour); the results presented here are identical to those presented in Bowlby et al. (2013).

Populations on the LaHave and St. Mary's rivers are predicted to have declined by > 83% (Figure 6) and > 79% (Figure 7), respectively, over the previous three generations (Table 11). Declines from the maximum abundances observed in the full time series are > 90% for both populations. Decline rates over the past 3 generations on LaHave River (slope = -0.127) and St. Mary's River (slope = -0.120) are slightly lower than those previously predicted for East River (Sheet Harbour; slope = -0.152) or Liscomb River (slope = -0.805; Table 11).

Population modeling for two of the larger populations remaining in the SU DU (LaHave and St. Mary's; projected forward from data collected until 2010) indicate a high probability of extirpation within 50 years for these two populations in the absence of a change in survival rates (Gibson and Bowlby 2013).

3.4. SOURCES OF UNCERTAINTY

LaHave River electrofishing fry and parr densities were low at the majority of survey sites in 2019; while the average densities reported were similar to recent years data, the average values were influenced by sites on the West Branch LaHave River. There is uncertainty as to the effect of drought conditions on LaHave River in 2016 (and most recently in 2020) on juvenile Atlantic Salmon, particularly in the absence of smolt estimates since 2017. Low returns of 1SW Atlantic Salmon in 2018 and MSW Atlantic Salmon in 2019 may be reflective of low smolt output in 2017 caused by freshwater mortality from this event.

In certain years mark-recapture estimates of population were not possible for St. Mary's River (West Branch). As a result, proxies were used to estimate adult returns: for 2002–2005 and 2011 the mean mark-recapture seining efficiency estimate from past years was used to scale up seining results. For 2009 an escapement ratio based on the relationship between St. Mary's River (West Branch) and LaHave River (above Morgan Falls) counts was used. The use of these proxies adds an additional measure of uncertainty.

4. TRENDS IN DISTRIBUTION

Within the Southern Upland DU, there are at least 72 rivers thought to contain, or to historically have contained Atlantic Salmon, although it is likely salmon would also have used the smaller coastal or un-assessed rivers in the region (Bowlby et al. 2013); assessment data demonstrates that there is no apparent minimum watershed size for occupancy and 513 additional watersheds in the SU have been identified by the Nova Scotia Department of the Environment (DFO 2013b)

Combining information from all 72 watersheds known to contain or have contained SU Atlantic Salmon, there is an estimated 20,981 km^2 of drainage area (Bowlby et al. 2014). For the purposes of calculating productive Atlantic Salmon rearing area, all reaches within the 72 rivers with gradients greater than 0.12% and less than 25% are considered to be productive salmon habitat (Amiro 1993, O'Connell et al. 1997).This method yields 78,314,200m^2 of productive freshwater rearing area for Atlantic Salmon in the SU DU (see Section 2.1 and Table 2.1.2 in Bowlby et al. 2014).

The full extent of the marine range of SU Atlantic Salmon is not known, but tagging studies indicate that SU Atlantic Salmon can be found along the entire coast of Nova Scotia, from the inner Bay of Fundy to the tip of Cape Breton, throughout most, if not all, of the year. Further details on marine range and analysis of the tagging data are provided in Bowlby et al. (2014). Little data exist to evaluate long-term trends in marine distribution.

The evaluation of range and present distribution of SU Atlantic Salmon in fresh water is based on juvenile salmon surveys and angler-reported catch during the period that the recreational fishery was open in the SU.

4.1. REGIONAL ELECTROFISHING SURVEY

The most recent (2008–09) broad-scale electrofishing in the SU DU found juvenile Atlantic Salmon in 22 of 54 river systems surveyed (see Table 2.1.2 in Bowlby et al. 2014). Where detected, Atlantic Salmon densities were very low: 98% of rivers had densities less than ten salmon/100 m^2 in 2008–09 (see Appendix 2 in Bowlby et al. 2013 and Table 2.1.2 in Bowlby et al. 2014). The 2008–2009 electrofishing survey of 54 SU rivers was designed as a repeat sampling of sites visited in a broad scale electrofishing survey in 2000 (see Appendix 1 in Bowlby et al. 2013). The proportion of rivers with Atlantic Salmon presence declined to 41% in the recent 2008 survey (22 of 54 rivers) from the 54% observed in the 2000 survey (28 of 52 rivers); for a comparison of Atlantic Salmon detections among the 2000 and 2008 survey see section 2.2 in Bowlby et al. (2013).

4.2. RECREATIONAL CATCH AND EFFORT

Catch and effort data from the annual recreational Atlantic Salmon fishery have been monitored in Nova Scotia using a license-stub return program since 1983. Reported catch data are corrected for non-reporting using a regression developed from the change observed in the reported catch resulting from sending multiple reminder letters to license holders to increase the number of returned stubs .

Between 1984 and 2008, the recreational angling data indicate declines of > 95% in catch as well as effort for most rivers in the SU (Gibson et al. 2009). All recreational salmon fishing in the SU was closed in 2010 (DFO 2011), and in the final year of angling, 2009, there were 13 rivers open for salmon fishing on at least part of the river, but over 75% of the effort (and 85% of the catch) took place on the LaHave and the St. Mary's rivers (see Table 1.3.5 in Bowlby et al. 2013). Recreational angling data for years 1983–2007 are available in Appendix 5 in Gibson et al. 2010, and for years 2008–2009 in Table 1.3.5 in Bowlby et al. (2013)

4.3. SOURCES OF UNCERTAINTY

Data on juvenile abundance and distribution indicate extremely low juvenile density in the majority of rivers in the Southern Upland, and with as few as one site electrofished per river in the 2008–2009 survey it is possible that salmon are present in low abundances at greater than the 22 rivers with detections.

Recreational catch data, considered roughly indicative of abundance, can be influenced by under- or over-reporting which may affect population estimates. As populations decline there is typically an associated reduction in fishing effort as angler behavior changes; however, in general, any decline in reported recreational effort lagged behind the decline in reported recreational catch (Gibson et al. 2010).

5. ESTIMATES OF TOTAL POPULATION SIZE

5.1. RUN RECONSTRUCTION MODEL

The regional abundance of Atlantic Salmon is calculated annually for the International Council for the Exploration of the Sea (ICES) Working Group on North Atlantic Salmon, which provides annual catch advice to the North Atlantic Salmon Conservation Organization (NASCO) for high-seas fisheries.

The method used to calculate regional estimates of Atlantic Salmon production is described in Amiro et al. (2008). In brief, the escapement is based on the count of 1SW and MSW Atlantic Salmon at the Morgan Falls fishway on the LaHave River from 1970 to the present year, scaled up to the region using the relationship between this count and the recreational catch data for rivers in SFA 19 to 21 (SU and Eastern Cape Breton DUs) from 1970 to 1997 and a catch rate for the LaHave River from 1970 to 1997. Estimates of the returns also include estimates of landings in the commercial salmon fisheries in SFA 19–21 from 1970 to 1983. The model is fit using maximum likelihood, and the 90% confidence limits are carried forward as the minimum and maximum values. Although all major river systems in SFAs 19 to 21 are included in the calculation when this information is provided annually to ICES, only rivers in SFA 20 and 21 (i.e., those in the SU DU) were included in the estimates provided here.

Spawning escapement in 2019 was estimated to be in the range of 1,503 to 2,040 1SW adults and 128 to 180 MSW adults in the SU DU (Table 12). This represents an increase from 2018 for the 1SW component, and a decrease from 2018 in the MSW component; notably the 2019 MSW estimate range is the lowest on record for the 50 year time series.

The decline rate over the past 3 generations follows the trend of the LaHave River (Table 8) because the regional estimate has been indexed to LaHave River counts since 1998.

5.2. REGIONAL EGG DEPOSITION

Using the current estimate of total adult production in the SU region (1,631 to 2,220 adults; age classes combined), and a range of egg production values defined for SU Atlantic Salmon (1,482–2,862 eggs/fish; Bowlby et al. 2013), it is expected that the SU DU would be producing less than 4% (2.42–6.35 million eggs) of the estimated regional CR of 187.95 million eggs (see Bowlby et al. 2014).

5.3. STATUS OF ADJACENT POPULATIONS

Of the neighbouring DUs (13, 15, and 16) two populations were similarly assessed by COSEWIC as endangered in November 2010 (Eastern Cape Breton [DU13] and Outer Bay of Fundy [DU16]; COSEWIC 2010), and one population has been listed as endangered under the Federal Species at Risk Act since June 2003 (Inner Bay of Fundy [DU15]). All three DUs have suffered from declines from historic population levels in recent decades to low, and, in some cases critically low, abundances.

Genetic similarities among SU populations suggest overall low regional rates of straying, estimated at < 1% (Bowlby et al. 2014, O'Reilly et al. 2012). This, coupled with the currently low abundance in neighbouring regions, indicates a low likelihood for recolonization of SU systems from adjacent populations.

5.4. SOURCES OF UNCERTAINTY

There are two potential biases in the method used to calculate regional returns. During the 1970s, the LaHave River (above Morgan Falls) population was building following the opening of the fishway, which would mean it would likely under-represent the total abundance in the region during that time period (Gibson and Bowlby 2013). In more recent decades, many populations in the SU have extirpated, which could cause regional abundance to be over-estimated due to the method's reliance on the LaHave River count at Morgan Falls.

6. HABITAT CHARACTERISTICS

Rivers in the Southern Upland are characterized by organic acid-stained water and are typically low in dissolved minerals, which make them less productive than more mineral-rich rivers (Watt 1987). In addition, the region has been extensively impacted by sulfate deposition (acid precipitation); coupled with the hardrock geology and low buffering capacity of soils this has further acidified many SU rivers (Watt et al. 1983, Watt 1987, 1997, Korman et al. 1994). Interspersed within the SU are limestone-rich soils (drumlins) that result in some rivers and tributaries with less-acidified water. Bowlby et al. (2014) extensively described the functional properties of Atlantic Salmon habitat, the spatial extent of areas in the SU having these properties, the identified threats to habitat, the extent to which threats have reduced habitat quality or quantity in the SU.

7. THREATS

In 2013, a recovery potential assessment was carried out by Bowlby et al. (2014) and DFO (2013b) that provided a review on the current threats facing Atlantic Salmon populations within the SU DU. The following section provides a review on the assessment of threats by Bowlby et al. (2014) and DFO (2013b) and updates these threats when applicable. However, the level of concern, severity, extent, occurrence and causal certainty of threats (Table A1 and A2) are based off the original assessments by Bowlby et al. (2014) and DFO (2013b).

Threats have been organized into International Union for Conservation of Nature (IUCN) Threat Calculator Categories and discussed based on freshwater and estuary/marine impacts when appropriate. Threats assessed with a high level of concern within the freshwater environment are acidification, altered hydrology, invasive fish species, habitat fragmentation (dams, culverts and other permanent structures) and illegal fishing/poaching (Table A1). Threats assessed as high level of concern within the estuary/marine environment are salmonid aquaculture and marine ecosystem change (Table A2).

7.1. RESIDENTIAL AND COMMERCIAL DEVELOPMENT

7.1.1. Housing and Urban Areas

Urbanization has the ability to affect Atlantic Salmon populations in a variety of ways. Habitat loss/alteration/fragmentation, pollution and contaminants can arise from development of infrastructure associated with urbanization. The specific sources and effects of urbanization are discussed in greater detail throughout this document. Eight watersheds within the SU DU contain > 5% of area classified as urban: six of these watersheds are located within the Halifax Regional Municipality (Bowlby et al. 2014).

7.1.2. Commercial and Industrial Areas

There is one tidal hydroelectric generation station within the Annapolis River estuary mounted to a causeway that is equipped with two fishways, but it is thought that the majority of fish pass through the turbines (Gibson and Myers 2002). Mortality during turbine passage can occur via mechanical strikes, pressure changes, cavitation effects and shear forces with the impact of each varying with fish size and physiology (Bowlby et al. 2014). Mortality associated with Annapolis turbine passage ranged between 7% and 23% in fish species of similar size to Atlantic Salmon are; American Shad (*Alosa sapidissima*), Blueback Herring (*A. aestivalis*), Atlantic Herring (*Clupea harengus*) and Alewife (*A. pseudoharengus*) (Gibson and Myers 2002), however, these estimates may not be representative of Atlantic Salmon mortality (Bowlby et al. 2014). The Annapolis Tidal Hydroelectric Generation Station has not been operating since 2019.

7.1.3. Tourism and Recreation

No DFO data.

7.2. AGRICULTURE AND AQUACULTURE

7.2.1. Annual & Perennial Non-Timber Crops

As this section only includes discussion of threats pertaining to the clearing of land for agriculture and forestry practices and the effects on river hydrology and temperature, the effects of both forestry and agriculture are expected to be similar. The effects of chemical run-off is discussed in the pollution and contaminants section.

Land clearing from forestry and agriculture practices have the ability to alter river temperatures and hydrology. However, the magnitude of these effects is likely dependent on the extent of the land cleared and the systems susceptibility to changes. Research in Catamaran Brook in New Brunswick showed that when forestry practices cleared 2% of a sub-basin no changes in hydrology were experienced, however, when 23% was cut there was an increase in peak flows (Caissie et al. 2002). In the Nashwaak River in New Brunswick, when 90% of the basin was cleared there was a 59% increase in summer peak flows (Dickison et al. 1981). In Pockwock and Five Mile Lake in central Nova Scotia when a 20m buffer, compared to a 30m buffer, was used during forestry clearing there were detectable stream chemistry changes demonstrating the importance of riparian vegetation (Vaidya et al. 2008). Land clearing practices have been shown to reduce Atlantic Salmon density in the Cascapedia River (Deschenes et al. 2007) and the years after clear cutting, over-winter egg survival in Catamaran Brook was lower, however, juvenile survival was highly variable (Cunjak et al. 2004). In the SU DU, there are only 12 watersheds with total area classified as agricultural above 1% (Bowlby et al. 2014). Therefore, the effects of agriculture is expected to be low.

7.2.2. Livestock Farming and Ranching

No DFO data.

7.2.3. Marine & Freshwater Aquaculture

Freshwater aquaculture has the ability to impact SU populations via chemical contamination and siltation from wastewater, and from escapee salmon. In most freshwater facilities, a flow-through system is used where water is pumped through the facility and discharged downstream back into the environment (Michael 2003). Wastewater is commonly characterized as sources of elevated nitrogen and phosphorus concentrations, chemical residues (antibiotics) and solid organics and can lead to lower dissolved oxygen and increased siltation (Camargo et al. 2011, Michael 2003). These effects would vary with the production capacity of the facility, the morphology of the downstream environment and the wastewater regulations (Bonaventura et al. 1997). Escapee salmon from facilities can also potentially lead to increased competition and predator attraction downstream of the facility and facilitate the transfer of disease (Krueger and May 1991). Although the information is anecdotal, escapes from freshwater facilities within the SU DU have been reported (Bowlby et al. 2014).

Similar to other maritime DUs, salmonid aquaculture predominantly occurs in net pens within coastal estuaries and the marine environment (DFO 2013b). Atlantic Salmon populations in close proximity to aquaculture sites are likely impacted the most via increased interactions with the aquaculture sites/fish (disease transfer, predator attraction, habitat degradation, competition, genetic introgression). However, distant populations also have the potential to interact with the aquaculture industry via escapee aquaculture salmon straying into distant rivers/estuaries. Furthermore, migrants from distant populations may also be negatively affected if migration routes intersect with aquaculture sites (DFO 2013b). Many of the larger SU populations are in close proximity to aquaculture sites and populations such as the Annapolis/Nictaux have the potential to interact with all aquaculture within the DU during coastal migration (DFO 2013b). More northern populations would be less likely influenced by aquaculture sites (DFO 2013b). As populations within the SU DU are already low, genetic introgression from escapee Atlantic Salmon could pose a significant risk.

In the SU, there were 39 of 46 aquaculture sites that were licensed to grow out Atlantic Salmon, or both Atlantic Salmon and trout during the assessment by Bowlby et al. (2014). However, in the SU DU, there has been relatively little monitoring for aquaculture escapees (Bowlby et al. 2014). Morris et al. (2008) reported that of 8,800 salmon examined from 11 maritime rivers, with

71.5% of these being from LaHave River, aquaculture escapees constituted a mean proportion of 0.9% of a population with a range from 0–17% for all rivers. Currently there are 27 marine net pens sites within the SU DU licensed to grow finfish, with 22 of these licensed to grow only Atlantic Salmon or Atlantic Salmon and other finfish, four licensed to grow only Rainbow Trout (*Oncorhynchus mykiss*)and one with deficient data to determine finfish species (Nova Scotia Department of Fisheries & Aquaculture; Figure 8). There is also an additional four sites proposed to grow out Atlantic Salmon with two being an apparent expansion of the currently active leases (Nova Scotia Department of Fisheries & Aquaculture). From 2015 to 2019, the average yearly production of Atlantic Salmon from marine cages was 7,589 t for all of Nova Scotia (Figure 9). Given the majority of Atlantic Salmon aquaculture occurs within the SU DU, it is reasonable to assume that the vast majority of production also occurred within the SU DU. Between 2010 and 2019, there was only 44 aquaculture salmon escapees confirmed from aquaculture sites within the DU. However, in the neighbouring Outer Bay of Fundy DU, there has been substantially more aquaculture salmon escape events and between 2010 and 2019, there have been over 225,000 aquaculture salmon escaped from marine sites reported. The difference in the amount of escapees between the SU and Outer Bay of Fundy DUs is not entirely surprising as New Brunswick has substantially more aquaculture production occurring; average yearly production of 24,988 t (2015–2019).In comparison to salmonid aquaculture, Bivalve aquaculture is much more prevalent and distributed throughout the SU DU. Bivalve aquaculture can cause habitat alterations and occur in three ways; 1) Material processes (filtering food and producing waste), 2) Physical structures (anchoring physical structures for bivalve culture), and 3) Pulse disturbances (harvesting and maintenance which can disturb the ecosystem community and environment) (Dumbauld et al. 2009). A study by Grant et al. (1995) showed increased sedimentation, decreased oxygen concentrations and an increase in ammonium near mussel aquaculture sites compared to the surrounding environment. However, large scale changes to the environment from bivalve aquaculture has not been demonstrated within the SU DU (Bowlby et al. 2014).

7.3. ENERGY PRODUCTION AND MINING

7.3.1. Oil and Gas Drilling

No DFO data.

7.3.2. Mining and Quarrying

Mining activities can have a variety of environmental effects arising from land clearing/modification and chemical run-off. In this sections only altered hydrology is discussed and chemical contamination is discussed in the pollution and contaminants section.

Within SU watersheds, there are 2,283 abandoned mine openings with 93% of these being historic gold mines (Bowlby et al. 2014). The Mersey River is the most heavily impacted with a total of 432 mine openings while the Gegogan, Tangier, Ship Harbor, Salmon (Lake Major) and Gold watersheds have over 100 openings each (Bowlby et al. 2014). The majority of abandoned mine openings are concentrated on the eastern shore and middle southwest of Nova Scotia (Bowlby et al. 2014). The effects of land clearing for mine use would be expected to be similar to forestry and agriculture if the amount of land being cleared was sufficiently high to cause negative effects.

7.4. TRANSPORTATION AND SERVICE CORRIDORS

7.4.1. Roads and Railroads

Roads and railroads can have significant negative effects impeding Atlantic Salmon recovery (National Research Council 2003). Road crossings can limit access to habitat and introduce contaminants and increase sedimentation (discussed in Natural systems and modifications and pollution and contaminants sections).

In the SU DU, the amount of road infrastructure within a watershed is not directly proportional to the size of the watershed but dependent on the amount of anthropogenic use; Annapolis/Nictaux, Medway, LaHave and St. Mary's watersheds have over 1,000 km of road however, Tusket, Musquodoboit and Mersey rivers have less than 800 km (Bowlby et al. 2014). The Mersey, Medway and Tusket rivers, among other examples, also have a substantial amount more of unpaved roads which increase sedimentation (Bowlby et al. 2014).

7.4.2. Utility and Service Lines

Industrial corridors (power lines, pipe lines, railways) and other land clearing activities (gravel pits, landfills) account for over 3% of drainage area within the Sackville, Nine Mile, East (St. Margaret's) and Boudreau rivers (Bowlby et al. 2014). Similar to agriculture, the total area cleared is relatively small and expected to have minimal impact.

7.4.3. Shipping Lanes

Shipping traffic and noise is thought to cause an avoidance behaviour in Atlantic Salmon and other species (DFO and MRNF 2009) and therefore may alter the coastal habitat in areas with shipping lanes (Bowlby et al. 2014). There is a high degree of ship traffic along the Atlantic coast of Nova Scotia and New Brunswick up to the southern coast of Newfoundland (NFLD) (Bowlby et al. 2014). Ship traffic is highest exiting the Gulf of St Lawrence through the Cabot Strait and relatively high amounts also experienced near the Canso causeway, Halifax harbor, Yarmouth ferry and into the Bay of Fundy (Bowlby et al. 2014). As this traffic is concentrated in coastal environments and within marine migration routes, there is a high degree of interaction with immature and adult Atlantic Salmon (Bowlby et al. 2014).

7.5. BIOLOGICAL RESOURCE USE

7.5.1. Logging & Wood Harvest

Within the SU DU, 17 rivers have up to 30% and 14 rivers have > 15% of area used as forestry with two being very large systems (> 700 km^2 of drainage); Musquodoboit (15.3%) and St. Mary's (30.2%) (Bowlby et al. 2014). Twelve watersheds have < 15% of area used for forestry, however, other the larger watersheds (Tusket, Mersey and Medway rivers) have < 10% (Bowlby et al. 2014). Forestry practices are widespread throughout the DU but tend to be highest on the eastern shore (Bowlby et al. 2014).

7.5.2. Fishing & Harvesting Aquatic Resources

7.5.2.1. Indigenous and Labrador Resident's Food Fishery

Within Labrador, three Indigenous groups take part in the subsistence food fishery that occurs in estuaries and coastal bays using gillnets (ICES 2011) and account for the majority of catches from all Indigenous fisheries (Bowlby et al. 2014). Reporting rates for this fishery is thought to be over 85% (DFO and MRNF 2009). In 2010, total harvest estimate was 59.3 metric tons which is similar to harvest estimates within the previous five years (Bowlby et al. 2014). Since 2010, total harvest has ranged between 52.5 t and 70.4 t with 54.0 t in 2019. As it is estimated that 95% of this harvest is from Labrador fisheries, due to the fishery predominantly occurring in local river estuaries (ICES 2011), this fishery is expected to have little effect on SU populations (Bowlby et al. 2014).

Labrador residents also participate in the food fishery with an estimated catch of 2.3 t in 2010 (ICES 2011). Regulations minimize the capture of large MSW salmon, which could originate from SU populations, in this fishery and only 25% of total catch in 2010 were large salmon (ICES 2011). Since 2010, the harvest has decreased to 1.6 t with 47% of harvest being large salmon in 2019 (ICES 2020). The odds of SU salmon being captured in this fishery are also low.

7.5.2.2. Food, Social and Ceremonial Fisheries (within SU DU)

In the SU DU the Indigenous groups that take part in the Atlantic Salmon food, social and ceremonial fishery include the communities of Indian Brook, Acadia, Millbrook, Annapolis Valley, Glooscap and Bear River (Bowlby et al. 2014). As populations have declined substantially, regulations have been put into place to limit the effect of this fishery including retention of only individuals < 63 cm, relocated to alternative rivers/populations, forgone entirely (DFO and MRNF 2009) or limited to rivers stocked with hatchery salmon (Amiro et al. 2000). Historical estimates of salmon harvest for the fishery have been low, less than 10% of the estimated retention from the historical recreational fishery (Anon 1980).

7.5.2.3. International Fisheries

France has a limited gillnet fishery off the island of St. Pierre-Miquelon off the southwestern coast of Newfoundland and in 2010, there were nine and 57 professional and recreational licenses, respectively, issued (Bowlby et al. 2014). Recreational licenses are permitted to use one gillnet measuring 180 m while professional licenses are permitted three nets of 360 m each (ICES 2011). All sizes of salmon are allowed to be retained and in 2010 a total of 2.8 t was reported (ICES 2011). Genetic analyses show that 98% of this fishery consists of Canadian origin fish and, given its location and the distribution patterns of SU salmon, has potential to effect SU populations (Bowlby et al. 2014). More recently, the amount of professional licenses issued is similar to 2010 with seven being issued in 2019, however, the amount of recreational licenses has steadily increased to 80 in 2019 (ICES 2020). Since 2011, the highest harvest amount occurred in 2013 at 5.3 t but has since decreased to 1.29 t in 2019 (ICES 2020). In 2017, 2018 and 2019, it was estimated that 0% of fish harvested were from western Nova Scotia populations (ICES 2019; ICES 2020). Based on the proximity of the fishery and SU population distribution patterns, it is possible this fishery could impact SU populations, however, as western Nova Scotia populations accounted for 0% of this fishery from 2017 to 2019 (ICES 2019, ICES 2020), negative effects are likely minimal.

The Greenland fishery predominantly harvests MSW salmon (Bowlby et al. 2014). Using gillnets, driftnets and angling, catches in West Greenland was 38 t and 2 t East Greenland in 2010, marking a 53% increase from 2009 (ICES 2011, Bowlby et al. 2014). It is estimated that 80% of fish removed from this fishery are of North American origin (ICES 2011). From 2012 to 2014, there was a decision to allow factory landings with a 30 t to 35 t quota which did not include commercial or private catches (ICES 2019). In 2015, a 45 t quota was set that included catches from all three sources (ICES 2019). Comparing seven years where factory landings have been allowed (2012–2018) to seven years where factory landings were set to 0 t (2005–2011), total harvest has increased to 290 t (2012–2018) from 182 t (2005–2011) marking a 59% increase. In 2019, it was estimated that approximately 29.8 t were landed with 0% of total harvest in west Greenland being from Western Nova Scotia populations (ICES 2020) and thus it appears that SU populations currently make up an extremely small, if any at all, proportion of this fishery. This is not surprising as other rivers with higher abundances and greater proportions of individuals returning as MSW fish would be expected to make up a greater proportions of this fishery (Bowlby et al. 2014).

7.5.2.4. Commercial Fisheries

There are no local commercial fisheries allowed for Atlantic Salmon and therefore, the level of concern is Low.

7.5.2.5. Recreational Fishery

Recreational fishing management strategies have continually evolved within the SU region as population levels have continued to decline. This has ranged from size retention limits, to zero retention regulations, warm water protocols, complete closures of all rivers for Atlantic Salmon angling, and closure of angling for any species within sections of rivers where Atlantic Salmon are known to hold. Currently all rivers within the SU DU are closed to angling Atlantic Salmon and therefore, this threat is expected to have a limited effect. In 2013, recreational fishing was assigned a low level of concern (DFO 2013b). As rivers within the DU were closed to Atlantic Salmon angling in 2010, the severity of this threat currently is likely similar to when assessed in 2014.

7.5.2.6. Illegal Fisheries

There have been many reports of illegal targeting of salmon while fishing under a general license or poaching using angling, gillnets or other methods within the SU DU, however, these reports are anecdotal (DFO 2013b). These anecdotal reports make it difficult to quantify the effects on SU populations. It is expected that this threat would most impact smaller populations as each removal would be removing a larger proportion of the population (DFO 2013b). Given SU populations are already at low abundances, they have a limited ability to recover from illegal removals (DFO 2013b).

7.5.2.7. Bycatch in Other Fisheries

By-catch of salmon in other freshwater fisheries is expected to be low. In both Indigenous and commercial fisheries within freshwater, gear and fishing seasons have been restricted to limit the incidence of Atlantic Salmon by-catch (DFO and MRNF 2009). It is possible that parr are captured in recreational fisheries while targeting Brook Trout (*Salvelinus fontinalis*), however, given compensatory survival effects, it is estimated the effects of this by-catch would be very low (Bowlby et al. 2014).

Atlantic Salmon are caught as by catch in fisheries in Ungava Bay for Brook Trout, Arctic Char (*Salvelinus alpinus*), Lake Whitefish (*Coregonus clupeaformis*), Round Whitefish (*Prosopium cylindraceum*), Lake Trout (*Salvelinus namycush*) and Northern Pike (*Esox lucius*) (DFO and MRNF 2009). However, the expectation is that the effect of commercial fisheries on SU populations is low (Bowlby et al. 2014). However, there is concern of distant off-shore fisheries, as these fisheries operate outside regulation and monitoring systems (Bowlby et al. 2014). Immature Atlantic Salmon, herring and mackerel distributions overlap during certain times of the year, and these fisheries have the potential to remove immature salmon (ICES 2000) but no data supports this hypothesis (DFO an MRNF 2009).

7.5.2.8. Commercial Fisheries on Prey Species

Atlantic Salmon depend on a variety of prey species and a reduction of one of these species due to fishing could impact marine survival of populations within the SU DU, especially for immature Atlantic Salmon (Bowlby et al. 2014). However, this hypothesis is not supported by small demersal fish having increased in abundance along the Scotian Shelf in recent years (Bowlby et al. 2014). Gadoid abundance off Grand Banks in Newfoundland has decreased in recent decades (Bowlby et al. 2014), which may suggest that prey biomass in other areas along migration routes could be limiting marine survival. Regardless, there is little evidence that correlates commercial fisheries on prey species to SU population declines.

7.6. HUMAN INTRUSIONS AND DISTURBANCE

7.6.1. Recreational Activities

Scientific activities commonly involve the capture, handling, sampling (weight, length, scale and genetic sample) and tagging of Atlantic Salmon at multiple life stages using electrofishing, seine nets, smolt wheels and fish traps. These activities can cause stress on the individuals but efforts are made to minimize these impacts (DFO and MRNF 2009). Within the SU DU, population assessments are only carried out on the St. Mary's and LaHave rivers through electrofishing for juveniles and adult counts via fishway traps or seining and mortality associated with these activities is thought to be low (Bowlby et al. 2014).

7.7. NATURAL SYSTEMS MODIFICATIONS

7.7.1. Fire & Fire Suppression

No DFO data.

7.7.2. Dam & Water Management/Use

Permanent structures within river systems can result in the loss of important habitat and alter the habitat available. Permanent structures are commonly placed within and along rivers for water impoundment, bank stabilization and water diversion (Bowlby et al. 2014). Bank stabilization is likely the least severe threat of the three as long as it is carried out in a small proportion of the river with relatively little impact on the natural hydrology (Bowlby et al. 2014). Water diversions can reduce the flow downstream thus reducing the habitat available and lead to juvenile Atlantic Salmon mortality during extreme temperature events (Caissie 2006, DFO and MRNF 2009). Habitat fragmentation can also occur during low flow conditions or if the diversion is a dam that impedes upstream/downstream migration (Thorstad et al. 2011). Increased flows can also results in changes to channel morphology which can impact the quality and quantity of habitat (Bowlby et al. 2014).

Within SU watersheds, total barriers are likely having a high impact on populations. Of 233 dams or barriers, only 44 (18.9%) are considered passable to fish, and many of these occur in watersheds that already have impassable barriers to fish (Bowlby et al. 2014).

7.7.2.1. Culverts

Culverts are a significant contributor to impeding fish passage through a given watershed (Gibson et al. 2005). In the Annapolis watershed, 37% of barriers were assessed as full barriers to fish passage and 18% were assessed as partial barriers (DFO 2013b). In Colchester, Cumberland, Halifax and Hants counties, 61%, from a random sample of 50 barriers, were assessed as full barriers (DFO 2013b). In the St. Mary's River, 62 culverts were assessed and 40 did not meet the criteria for water depth, 35 exceeded water velocity criteria and 24 had outfall drops with potential to prevent fish passage (DFO 2013b). Not surprisingly, additional road crossings leads to increased amounts of culverts resulting in urban areas and areas where substantial forestry and agriculture are occurring being most affected (DFO 2013b). Within eight counties of Nova Scotia there was 215 new culverts installed between 1996 and 2000 (Langill and Zamora 2002). Gibson et al. (2005) also suggests that new installations do not always meet fish passage requirements as 53% of newly installed culverts in Newfoundland were barriers to

Atlantic Salmon. As culverts are highly associated with infrastructure development and given the rate of newly installed culverts observed by Langill and Zamora (2002), culverts represent a significant cause of habitat fragmentation within the SU DU (Bowlby et al. 2014).

7.7.2.2. Altered Hydrology

Altered hydrological regimes have the ability to affect habitat quality and quantity in a variety of ways that can affect multiple life stages dependent on the magnitude and timing of the alterations (Bowlby et al. 2014). Altered hydrological regimes can arise from a variety of sources including dams, water extractions and intensive land use (Bowlby et al. 2014). Yearly river discharge within the SU DU is already highly variable and can be exacerbated by land use resulting in increased runoff causing a river to become more prone to flooding in frequency, extent and duration (Bowlby et al. 2014). High flows can cause erosion and change channel morphologies while low flows can cause temperature extremes and limit food supply (DFO 2013b). High flows can directly cause mortality in juveniles from physical displacement (DFO 2013b), or indirectly by reducing habitat quality within a reach or displacing juveniles downstream into less suitable habitat. Low flows can result in temperature extremes and decrease habitat quantity that can cause mortality or stress in juveniles and adult salmon (DFO 2013b). During winter, low flows can also result in freezing of redds (DFO 2013b). Altered hydrological regimes can also influence behavioural aspects as river discharge can initiate smolt migration (McCormick et al. 1998) or adult spawning activity (Thorstad et al. 2011).

Reservoirs from dams and hydroelectric generation stations are one of the main sources to altered hydrology within river systems. Larger watersheds tend to be the highest impacted within the SU DU (Bowlby et al. 2014). The highest impact is within the Annapolis/Nictaux watershed where 102 reservoirs occur, however, the Mersey watershed has the highest amount of reservoir area with 19.3 km^2 within six reservoirs (Bowlby et al. 2014).

Environment Canada has hydrometric stations for long-term monitoring within the SU region to monitor water levels within, but not limited to, the St. Mary’s, Sackville, LaHave, Mersey and Roseway rivers (Bowlby et al. 2014). From long term trends in flow data within the St. Mary’s River (chosen as an example as it is unimpeded by dams), mean flows within June have become more variable in recent years and 1-day minimum flows were characterized as relatively high water between the 1960s and 1980s but have more recently (1990s to 2000s) switched to exclusively low water which coincides with substantial declines in Atlantic Salmon populations (Bowlby et al. 2014). In rivers with more anthropogenic hydrological alterations, the natural regime could be further stressed and having even larger effects on populations. Furthermore, as climate change continues to impact river systems, the effects of natural and anthropogenic stressors on populations could continue to worsen.

7.7.2.3. Hydropower Dams

Alongside the impacts on Atlantic Salmon habitat, hydropower dams also directly cause mortality to individuals during migration when passing through turbines. The combined influence of three dams within the St John River was estimated to cause a mortality of 45% in smolts during migration (Carr 2001). Within the SU DU salmon rivers assessed in 2014 by Bowlby et al. (2014), there were six NS power operated stations located at the head of tide in the Annapolis/Nictaux, Tusket, Bear, Sissibo and Mersey rivers), thus affecting the majority of the river system. At Morgan Falls within the LaHave River, there is a privately owned generation station where 51% of the habitat available within the river is above the dam, however fish passage is available (Bowlby et al. 2014). Southwestern Nova Scotia is predominantly the most impacted area with the Mersey River containing the highest number of facilities (four) (Bowlby et al. 2014).

7.7.3. Other Ecosystem Modifications

No DFO data.

7.8. NEGATIVE INTERACTIONS WITH OTHER SPECIES AND GENETIC INTERACTIONS

7.8.1. Invasive Non-Native/Alien Species

Chain Pickerel (*Esox niger*) and Smallmouth Bass (*Micropterus dolomieu*) have become abundant and widely distributed throughout the SU region with Chain Pickerel and Smallmouth Bass occurring in 69 and 174 documented locations, respectively (DFO 2013b). Chain Pickerel are top predators within SU ecosystems and have the ability to alter species abundances and richness (DFO 2013b). Smallmouth Bass have a similar influence on fish communities. Chain Pickerel affect Atlantic Salmon populations directly through predation, however, Smallmouth Bass effect populations through predation and competition and can cause shifts in habitat use by Atlantic Salmon juveniles (DFO 2013b).

In the last two decades, Didymo (*Didymosphenia geminata*) has started to expand its range within Canada and has characteristics of an invasive species (Bowlby et al. 2014). In New Zealand, Didymo has had negative impacts on natural systems by modifying stream flows, reducing other algal abundance and diversity and altering the composition of the invertebrate community (Bothwell and Spaulding 2008). There has been limited research on Didymo effects on Atlantic Salmon populations within Canada and preliminary research in Scandinavia suggest its effects are negligible (Bothwell and Spaulding 2008, Jonsson et al. 2008). Didymo has recently been introduced into Quebec and NB rivers but has yet to be found within the SU region, however, it would be prudent to limit any further spread given the negative effects on ecosystems within New Zealand (Bowlby et al. 2014).

Within the estuary and marine environment, the Green Crab (*Carcinus maenus*), invasive tunicates (*Ciona intestinalis*, *Botrylloides violaceus*, and *Botryllus schlosseri*), codium (*Codium fragile* spp.) and membranipora (*Membranipora membranacea*) have been introduced into SU DU (Bowlby et al. 2014). The Green Crab, codium and membranipora have the potential to alter the marine habitat and environment within coastal areas likely reducing productivity which could negatively affect the abundance of prey species and kelp forests used for predator avoidance and feeding (DFO and MRNF 2009, Bowlby et al. 2014). Invasive tunicates are viewed more of a fouling agent, attaching themselves to marine structures and have not been shown to affect benthic communities or marine ecosystems (Bowlby et al. 2014).

7.8.2. Negative Interactions with other Species and Genetic Interactions

7.8.2.1. Other Salmonid Stocking

Juvenile Atlantic Salmon, Brown Trout (*Salmo trutta*) and Brook Trout all share a similar environment during juvenile life stages leading to competitive interactions (Hearn 1987, Gibson 1988). Brown Trout are a more dominant species (Harwood et al. 2002) and tend to out-compete Atlantic Salmon for resources and habitat. Atlantic Salmon juveniles also tend to alter their behaviour in the presence of Brown Trout (Harwood et al. 2002) and Rainbow Trout (Blanchet et al. 2006) which can lead to higher risk of predation (Bowlby et al. 2014). The behavioural changes and inability to compete with Brown Trout would likely result in lower growth and survival rates. However, the effects of these interactions on populations are not well understood (Bowlby et al. 2014). There is a degree of habitat portioning between Atlantic Salmon and Brook Trout, however, in pool environments Brook Trout can out compete Atlantic Salmon through exploitative/interference competition (Gibson 1993, Rodriguez 1995). Adults of all three species would be expected to predate on juvenile Atlantic Salmon and there is a degree of concern with disease transfer from hatchery to wild fish (Bowlby et al. 2014).

The Nova Scotia Department of Fisheries and Aquaculture stocks waterbodies within the SU DU with Brown Trout, Rainbow Trout and Brook Trout. All three species are stocked in the spring and/or fall. During the previous assessment (Bowlby et al. 2014; DFO 2013b), there were five and eight lakes stocked with Brown Trout and Rainbow Trout, respectively, in 2011. There was 151 lakes stocked with Brook Trout in 2011 (Bowlby et al. 2014). Brown Trout were only stocked into systems where they were established and Rainbow Trout were stocked into lakes that were predominantly land-locked (Bowlby et al. 2014). Both Rainbow Trout and Brown Trout are stocked as sterile adults (Bowlby et al. 2014). Numbers stocked were not available for 2011. In comparison to 2020, stocking remains relatively similar with over 125 lakes stocked with Brook Trout, four rivers and one lake stocked with Brown Trout and ten lakes stocked with Rainbow Trout. Overall, there is little known about the interactions between stocked and wild fish in the SU DU (Bowlby et al. 2014).

7.8.2.2. Avian Predation

Although avian predation is a natural source of mortality, in conjunction other threats, predation rates may be higher (Bowlby et al. 2014). Since the 1920s, Double Crested Cormorants (*Phalacrocorax auritus*) have significantly increased in abundance and stomach content analyses have shown that smolts constitute an increasing proportion of their diet (Milton et al. 2002). Within the SU DU, acoustic telemetry programs have shown the sudden disappearance of smolts implanted with acoustic tags from the system near the head of tide which is indicative of an avian predation event (Halfyard et al. 2012); tags are removed from the river where acoustic receivers and active tracking can no longer detect them. The physiological changes during smoltification during the transition to saltwater have been hypothesized to increase susceptibility to predation (Jarvi 1989, 1990) and the effects of other threats that interfere with the smoltification process (acidification) may exacerbate predation risk (Bowlby et al. 2014). Similar to piscine predation, the effects of avian predation on the population would be dependent on life stage and whether density dependent mortality was concurrently occurring (Bowlby et al. 2014).

7.8.2.3. Diseases and Parasites

Due to an increased vulnerability, diseases and parasites are thought to have a higher effect on immature salmon survival as opposed to altering Adult spawning success (Harris et al. 2011). However, little information on disease and parasites in marine phases of Atlantic Salmon exists (Bowlby et al. 2014). Red vent syndrome has been linked to a nematode worm (*anisakis simplex*) (Beck et al. 2008), however there is no clear relationship between the syndrome and spawning success (ICES 2011), however, if the syndrome was causing mortality, those individuals would likely be removed at sea without the opportunity of being sampled (Bowlby et al. 2014). In the SU DU, there have been severe anisakis infestations found within adults returning to the LaHave River and to a lesser extent the St. Mary's River (Bowlby et al. 2014). As these are the only two rivers monitored for returning adults within the DU, it is impossible to determine the extent that anisakis is affecting populations, however, given the infestation levels found within these two rivers and the surrounding areas (see ICES 2011), it is likely to be affecting multiple populations (Bowlby et al. 2014).

Infectious salmon anaemia and infectious pancreatic necrosis are both federally reportable diseases. Between 2015 and 2019, there was a total of 79 cases of Infectious salmon anaemia reported in NB (all strains= 55; disease strains= 18), NS (all strains= 5; disease strains= 2) and NFLD (all strains= 19; disease strains= 10). Infectious pancreatic necrosis was also reported in other finfish species (Brook Trout, Rainbow Trout and Arctic Char [*Salvelinus alpinus*]) and from 2015 to 2019, there were 12 reported occurrences in NB (n= 3), NS (n= 7) and QC (n= 2).

Sea lice infestations can negatively affect salmonids via reduced swimming performance, growth, immunity, reproductive rates and can cause acute mortality (Finstad et al. 2011). It is generally accepted that Atlantic Salmon aquaculture net pens increases the likelihood of wild salmon being negatively affected by sea lice. The potential degree of the threat from sea lice is likely associated with a population’s proximity to aquaculture sites, or the amount of interaction with sites during migration. There have not been any links of sea lice from aquaculture to Atlantic Salmon declines within the SU DU (Bowlby et al. 2014).

7.8.3. Introduced Genetic Material

7.8.3.1. Historical Stocking

Stocking of Atlantic Salmon has been a widely used management strategy aimed to supplement declining populations or (re)introduce Atlantic Salmon into former or new areas. Individuals are normally captured as adults or smolts which are used as broodstock (Fraser 2008) to produce individuals that will be released, predominantly as fry, into the environment for supplementation. However, captive breeding of animals can lead to the accumulation of deleterious genes/traits in the wild population (Lynch and O’Hely 2001) and reduce fitness (Fraser 2008).

In the SU, traditional stocking methods were practiced in many of the larger systems in an attempt to mitigate the impacts of acidification (Bowlby et al. 2014). However, population levels became too low to ensure that the genetic risks of supplementation were not having negative effects and stocking programs ceased in 2005 (DFO 2012a) except for a few governmental programs (see current stocking section below) and small educational programs (Bowlby et al. 2014) that likely pose little risk.

From the late 1970s to mid-2000s, over 14 million Atlantic Salmon were stocked into SU rivers with 57.7% being stocked into the Tusket (1.8 million), Medway (2.1 million), LaHave (3.2 million) and Liscomb (1.4 million) rivers (Bowlby et al. 2014). Within each decade, the 1990s had the highest degree of stocking with 7.3 million fish stocked in comparison to the 1980s (4.8 million stocked), 2000s (1.9 million stocked) and the 1970s (725,000 stocked), however, the 1970s and 2000s only encompassed four years (1976–1979) and eight years (2000–2007), respectively, of stocking data (Bowlby et al. 2014).

The historical stocking practices used within the SU DU was highly variable between years and decades in term of life stages stocked and broodstock origin (Bowlby et al. 2014). However, in comparison to the 1980s and 1970s, there was a shift to using exclusively using native stock for broodstock fish and a change to releasing larger/later stage parr (Bowlby et al. 2014). Some of the large populations (Musquodoboit, Gold, LaHave, Medway, St. Mary’s and Tusket) used native stock as broodstock over longer periods of time and thus genetic impacts are expected to be less severe in these rivers. A formal analysis has not occurred to measure the degree of interbreeding between wild and stocked Atlantic Salmon within the SU DU, however, it is expected that genetic introgression into the wild population from stocked fish likely contributed to population declines in the 1990s to present (Bowlby et al. 2014). However the degree and rate of decline from the historical stocking program, and if these effects still persist, is unknown (Bowlby and Gibson 2011).

7.8.3.2. Current Stocking

More recent stocking practices have mostly centered on ensuring genetic diversity is not lost with further population declines through a Live Gene Bank Program or, for re-establishing extirpated populations. In 2005, the stocking of smolts began in the St Francis Harbor River in an attempt to restore an extirpated population, however, this program was ceased before 2010 (Bowlby et al. 2014). Another more recent program involved collecting approximately 200 wild smolts in six rivers in 2003 and 2004 to maintain genetic diversity in case of further population decline (Amiro et al. 2006). All salmon from this project were released once mature in the Quoddy River in an attempt to supplement this single population. A similar approach was also undertaken within the St. Mary's River except adults were released back into the river of origin (DFO 2010). Success of these programs is highly variable between systems (O'Reilly et al. 2009) and the potential negative effects are likely minimal as SU specific releases were limited (Bowlby et al. 2014).

7.9. POLLUTION AND CONTAMINANTS

7.9.1. Household Sewage & Urban Wastewater

Urbanization, road infrastructure and agriculture and forestry practices all lead to increased silt and sedimentation within a system. Silt and sedimentation can directly affect Atlantic Salmon through abrasions to the skin, eyes and gills and indirectly be decreasing the quantity and quality of habitat (O'Connor and Andrew 1998). When the fine sediments settle into the interstitial space of larger substrates in sufficient quantities, eggs can be smothered, alevins that have not emerged yet can be entombed and overwinter habitat is inaccessible (Soulsby et al. 2001, Julien and Bergeron 2006). Excess sedimentation within rivers can increase habitat homogeneity (Bowlby et al. 2014) and commonly occurs during large storm events where high quantities of sediment are transported downstream (Lisle 1989).

7.9.2. Industrial & Military Effluents

Introduction of contaminants are most likely to occur in areas where significant urbanization, forestry or agriculture are occurring. Depending on the type of contamination, magnitude, extent and duration of the contamination, effects on populations can vary.

Eutrophication from fertilizers can lead to reduced oxygen concentrations and algal blooms (Paul and Meyer 2001) resulting the quality and quantity of habitat decreasing. Nutrient run-off is expected to be highest in areas of high agriculture and residential use where significant riparian vegetation has been removed, which would have a cumulative effect with warmer temperatures (Paul and Meyer 2001).

Chemical contaminants that enter rivers can be of an acute and chronic nature. Acute toxicity would result from spills or containment failures (Bowlby et al. 2014) that result in sudden, and normally large, influxes of chemical into an environment and if concentrations are high enough, can lead to large amounts of fish kills. Chronic exposure is characterized by long term exposure to sub-lethal concentrations that affect the behaviour and physiology of fish resulting in reduced survival and lifetime output (Fairchild et al. 2002). Chemicals of the greatest concern are from man-made organic compounds as the ways in which the natural environment degrades them is limited (Bowlby et al. 2014). Determining the effects of a single chemical is difficult as multiple chemical contaminants are usually present and act synergistically (Currie and Malley 1998). Areas of highest concern for chemical contamination is in urban areas and areas used heavily for forestry and agriculture (Bowlby et al. 2014).

Within the SU Kejimkujik National park, acidification has been linked to high mercury levels found in fish and the Common Loon (*Gavia immer*) (Beauchamp et al. 1997, Nocera and Taylor 1998). Given the acidification within the freshwater of the SU DU, it is possible that mercury concentrations in animals is more widespread than thought (Bowlby et al. 2014). Insecticides used for forestry contain the solvent 4-nonylphenol and have reduced smolt survival and adults returns in the Restigouche River, NB (Fairchild et al. 1999) and similar chemicals have been used throughout the SU DU and 4 nonylphenol is associated with industrial effluents and municipal sewage (Bowlby et al. 2014).

Pulp and paper mills are another source of contamination. Effluents are high in organic compounds and chemicals linked to endocrine disruption in fish resulting in decreased gonad size, decreased egg production and alter secondary sexual characteristics (Hewitt et al. 2008), however, these effects have not been demonstrated in Atlantic Salmon (DFO and MRNF 2009) but have been shown to impact abundance (Fairchild et al. 1999). As there are only two pulp mills in the SU DU (largest located in the Mersey River), the extent of this threat is low (Bowlby et al. 2014).

Mining operations are another common way that contaminants enter a river via mine drainage. In the SU DU, abandoned mine opening are predominantly gold mines which can lead to elevated concentrations of arsenic (Cavanagh et al. 2010). Mine drainage can lead to acute immediate mortality or long term reproductive effects. In the SU DU, as discussed in the mining an quarrying section, the Mersey River contains the most abandoned mine openings followed by the Gegogan, Tangier, Ship Harbor, Salmon (L. Major) and Gold watersheds and are likely those most affected by contamination due to mining.

Estuaries and the marine environment can also be affected by contaminated rivers running into the estuary and marine environment, or by direct spills/contamination. Contaminants can precipitate out and influence bottom sediments, remain within the water column, or be absorbed within the food web (Bowlby et al. 2014). Given the connectivity of the marine environment, the extent of contamination can be wide ranging with similar effects as seen in the freshwater environment (Bowlby et al. 2014). A study examining eutrophication along the near shore environments of the Scotia Shelf (Cape Sable Island to Cape North) found nutrient concentrations to be relatively stable in surface waters year round, however, bottom waters had higher potential for eutrophication in estuaries of SFA 20 in the fall (Bowlby et al. 2014). However, there is no linkage of eutrophication to Atlantic Salmon declines within the SU DU (Bowlby et al. 2014).

7.9.3. Agricultural & Forestry Effluents

No DFO data.

7.9.4. Garbage & Solid Waste

No DFO data.

7.9.5. Air-Borne Pollution

The SU region has been heavily impacted by acidification. Originating from North American industrial sources, acid rain has mildly to substantially decreased river pH levels, with rivers in the southwestern portion of the DU being most affected (DFO 2013b). Although most rivers are not still declining in pH levels, they are not showing signs of recovering and are expected to remain affected for over 60 years (DFO 2013b). Acidification has the ability to affect populations through direct juvenile mortality or reducing ability to forage/compete and avoid predators, increasing susceptibility to disease and can interfere with the smoltification process (DFO 2013b). At a pH of 5.3, mortality for fry is expected to be at 50%, and values < 4.7 are insufficient to maintain populations (DFO 2013b). Korman et al. (1994), developed toxicity functions to estimate egg to smolt survival and found fry mortality to be 100%, 57%, 42% and 18% at pH levels of 4.75, 5.00, 5.25 and 5.50, respectively.

In the Medway and LaHave rivers, when seasonal pH levels ranged from 4.7–5.4, in comparison to 5.6–6.3, age-0 parr densities were 70% lower (Lacroix 1989a). Overwinter mortality was also more than double in a Medway tributary when pH fell below 5.0 (December-May) in comparison to the LaHave River that experienced higher pH levels (Lacroix 1989b).

In the previous threat assessment by DFO (2013b) there were 60 rivers classified on average yearly pH levels. Of the 60 rivers, Atlantic Salmon populations were thought to be extirpated in 13 rivers (pH < 4.7), reduced by 90% in 20 rivers (pH= 4.7–5.0), reduced by approximately 10% in 14 rivers (pH= 5.1–5.4) and unaffected in 13 rivers (pH > 5.4), and estimates suggest that 49.8% of total adult production in the SU DU was lost to acidification by the 1980s (Watt 1986). However, this research was based on data from the 1980s and more recent electrofishing data (2008/2009) suggests that reductions in productivity could be 95% and 58% for moderately and slightly impacted systems, respectively (Bowlby et al. 2014). Bowlby et al. (2014) concluded that between 316 726 and 334 322 out of a total of 351 918 habitat units from moderately impacted systems, and 19 431 to 112 701 out of a total of 194 312 habitat units in mildly impacted systems would be unsuitable for juvenile production. In other words, 90% to 95% and 10% to 58% of habitat is unsuitable for juveniles in moderately or mildly impacted systems, respectively.

7.9.6. Excess Energy

No DFO data.

7.10. GEOLOGICAL EVENTS

7.10.1. Volcanoes

No DFO data.

7.10.2. Earthquakes & Tsunamis

No DFO data.

7.10.3. Avalanches & Landslides

No DFO data.

7.11. CLIMATE CHANGE

7.11.1. Habitat Shifting & Alteration

In recent years there have been large shifts in oceanographic conditions and atmospheric climate throughout the range of Atlantic Salmon in North America (Bowlby et al. 2014). The Western Scotia Shelf has fluctuated from cold periods in the 1960s, to warmer temperatures until 1998 and then cooled again thereafter (Zwanenburg et al. 2002). The Eastern Scotia Shelf cooled from 1983 to the 1990s, and minimum temperatures have remained cool since (Zwanenburg et al. 2002). The North Atlantic Oscillation (NAO) has also been shifting from negative to more positive values since the 1970s to the early 2000s (Visbeck et al. 2001) causing low pressure, strong westerlies, higher air temperature in continental Europe and higher intrusion of the North Atlantic Current into the Nordic Seas (Bowlby et al. 2014). In recent years NAO values have lowered again, but models still predict a shift towards more positive average values (Osborne 2011). Winter NAO values are negatively correlated with sea-surface temperatures and have the potential to affect Atlantic Salmon behaviour and mortality at sea (Bowlby et al. 2014). The effects of NAO values on Atlantic Salmon catches in the marine environment have been weakly correlated, however, a study by Hubley and Gibson (2011) found that partitioning marine mortality into first year (near shore/freshwater environments) and second year (distant marine environments) demonstrated a strong correlation with NAO values and second year survival at sea for LaHave River salmon (Bowlby et al. 2014).

There is evidence of a whole ecosystem regime shift in the Eastern Scotian Shelf demonstrating significant change to the ecological community (Bowlby et al. 2014). A similar shift is also thought to be occurring along the Western Scotian Shelf with small pelagic and demersal fish and macroinvertebrates becoming dominant species as opposed to large bodied demersal fish (Bowlby et al. 2014). One way that this could be affecting Atlantic Salmon is through decreased prey availability and increased predation by grey seals (*Halichoerus grypus*), however, there is no evidence for this for SU populations (Bowlby et al. 2014). Mortality rates are likely highest in immature fish during their first few month at sea. One hypothesis is that mortality rate is related to larval fish abundances and thus the mechanisms that influence availability of these resources are likely having a significant impact on early marine mortality (Bowlby et al. 2014).

7.11.2. Droughts

No DFO data.

7.11.3. Temperature Extremes

Extreme temperatures can affect the survival, behaviour and growth in all life-stages of Atlantic Salmon and alter the amount of usable habitat (Bowlby et al. 2013). High temperature extremes can indirectly affect juvenile salmon survival via altering growth, increasing disease susceptibility or decreasing predator avoidance (Bowlby et al. 2014). High temperatures can also more directly cause mortality in juveniles via stranding. Mortality from lower temperatures can arise from redds freezing or being disturbed from ice scours (Cunjak and Therrein 1998) and reduce developmental rates (Crisp 1981).

Removal of riparian vegetation and altered hydrological regimes are two sources of direct thermal change to watersheds (Bowlby et al. 2013). Removal of riparian vegetation is associated with urbanization, agriculture and forestry. Altered hydrological regimes can arise from water extraction, reservoirs and dams. All of these activities can effect water temperatures within a system and when compounded with climate change, can have large effects on populations with smaller rivers/streams being most susceptible (Bowlby et al. 2014).

7.11.4. Storms & Flooding

No DFO data.

7.12. OTHER

7.12.1. Small Population Genetic Effects

Low population abundance can lead to inbreeding depression and the accumulation of deleterious alleles within the population while other, perhaps beneficial, alleles are lost. Research suggests that Atlantic Salmon populations within the SU DU are experiencing inbreeding depression (Bowlby et al. 2014). SU populations are currently at historically low abundances, genetic variation is lower in comparison to reference populations and within population genetic variation has declined over the last three to four generations (O’Reilly et al. 2012, Bowlby et al. 2014).

8. MANIPULATED POPULATIONS

The Southern Upland DU has an extensive history of stocking, including recent efforts to slow the decline of certain critically low populations in the DU. Bowlby et al. (2014) provide a detailed overview of historical stocking practices in the SU up to 2007.

Concerns over the possible extirpation of SU Atlantic Salmon led to collection of wild-origin salmon from the St. Mary's and LaHave rivers beginning with smolt collections in 2016. In 2018, smolts from the St. Mary's River, and smolts and adult salmon from LaHave River, were collected for an interim captive rearing pilot at the Coldbrook Biodiversity Facility, with the primary objective to conserve genetic diversity representative of the SU DU (DFO 2020a). As part of this effort, captive reared Atlantic Salmon (primarily at the unfed fry stage) have been released annually to their rivers of origin for the purpose of wild exposure of captive reared stock. Captive-held adults have been released in low numbers when surplus to program needs. Annual releases to SU rivers since 2010 are listed in Table 13.

REFERENCES CITED

Amiro, P.G. 1993. Habitat measurement and population estimation of juvenile Atlantic salmon (*Salmo salar*). Canadian Special Publications of Fisheries and Aquatic Sciences 118:81-97.

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

Amiro, P.G., A.J.F. Gibson, and H.D. Bowlby. 2006. 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., B. Hubley, J. Gibson and R. Jones. 2008. Estimates of returns and escapements of Atlantic salmon to Salmon Fishing Areas 19, 20 and 21, Nova Scotia, and update of returns and escapements to SFA 23, southern New Brunswick, 1970 to 2007. International Council for the Exploration of the Sea North Atlantic Salmon Working Group Working Paper 2008/014.

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. DFO Can. Sci. Advis. Sec. Res. Doc. 2000/009.

Amiro, P.G., E.M. Jefferson, and C.J. Harvie. 1996. Status of Atlantic salmon in Salmon Fishing Area 21, in 1995, with emphasis on the upper LaHave River, Lunenburg. Co., Nova Scotia. DFO Atl. Fish. Res. Doc. 96/126.

Anonymous. 1980. Blueprint for the future of Atlantic salmon. A discussion paper prepared by Department of Fisheries and Oceans. Government of Canada.

Beauchamp, S., N. Burgess, A. D'Entremont, R. Tordon, G. Brun, D. Leger, W. Schroeder, and J. Abraham. 1997. Mercury in air, water and biota in Kejimkujik National Park, Nova Scotia, Canada. Proceedings of the Third International Conference of Science and the Management of Protected Areas, 12-16 May 1997. Calgary, Alberta, Canada.

Beck M., R. Evans, S.W. Feist, P. Stebbing, M. Longshaw, and E. Harris. 2008. Anisakis simplex sensu lato associated with red vent syndrome in wild Atlantic salmon Salmo salar in England and Wales. Diseases of Aquatic Organisms 82:61-65.

Blanchet, S. J.J. Dodson, and S. Brosse. 2006. Influence of habitat structure and fish density on Atlantic salmon Salmo salar L. territorial behaviour. Journal of Fish Biology 68:951-957.

Bonaventura, R., A.M. Pedro, J. Coimbra, and E. Lencastre. 1997. Trout farm effluents: Characterization and impact on the receiving streams. Environmental Pollution 95:379-387.

Bowlby, H.D., and A.J.F. Gibson. 2011. Reduction in fitness limits the useful duration of supplementary rearing in an endangered salmon population. Ecological Applications 21:3032-3048.

Bowlby, H.D., A.J.F. Gibson, and A. Levy. 2013. Recovery Potential Assessment for Southern Upland Atlantic salmon: Status, past and present abundance, life history and trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/005.

Bowlby, H.D., Horsman, T., Mitchell, S.C., and Gibson, A.J.F. 2014. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Habitat Requirements and Availability, Threats to Populations, and Feasibility of Habitat Restoration. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/006. vi + 155 p.

Bothwell, M.L., and S.A. Spaulding. 2008. Synopsis. Proceedings of the 2007 international workshop on Didymosphenia geminata. Canadian Technical Report of Fisheries and Aquatic Sciences 2795.

Caissie, D. 2006. The thermal regime of rivers: A review. Freshwater Biology 51:1389-1406.

Caissie, D., S. Jolicoeur, M. Bouchard, and E. Poncet. 2002. Comparison of streamflow between pre and post timber harvesting in Catamaran Brook (Canada). Journal of Hydrology 258:232-248.

Camargo J.A., C. Gonzalo, and A. Alonso. 2011. Assessing trout farm pollution by biological metrics and indices based on aquatic macrophytes and benthic macroinvertebrates: A case study. Ecological Indicators 11:911-917.

Carr, J. 2001. Downstream movements of juvenile Atlantic salmon (Salmo salar) in the dam-impacted Saint John River drainage. Canadian Management Report in Fisheries and Aquatic Sciences 2573.

Cavanagh, J.E., J. Pope, J.S. Harding, D. Trumm, D. Craw, R. Rait, H. Greig, D. Niyogi, R. Buxton, O. Champeau, and A. Clemens. 2010. A framework for predicting and managing water quality impacts of mining on streams: appendices. Landcare Research. New Zealand. 156 p.

Chaput, G., J.B. Dempson, F. Caron, R. Jones, and J. Gibson. 2006. 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.

COSEWIC. 2010. COSEWIC assessment and status report on the Atlantic Salmon *Salmo salar* (Nunavik population, Labrador population, Northeast Newfoundland population, South Newfoundland population, Southwest Newfoundland population, Northwest Newfoundland population, Quebec Eastern North Shore population, Quebec Western North Shore population, Anticosti Island population, Inner St. Lawrence population, Lake Ontario population, Gaspé-Southern Gulf of St. Lawrence population, Eastern Cape Breton population, Nova Scotia Southern Upland population, Inner Bay of Fundy population, Outer Bay of Fundy population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xlvii + 136 pp.

Crisp, D.T. 1981. A desk study of the relationship between temperature and hatching time for the eggs of five species of salmonid fishes. Freshwater Biology 11:361-368.

Cunjak, R.A., and J. Therrein. 1998. Inter-stage survival of wild juvenile Atlantic salmon, Salmo salar L. Fisheries Management and Ecology 5:209-223.

Cunjak, R.A., R.A. Curry, D.A. Scruton, and K.D. Clarke. 2004. Fish-forestry interactions in freshwaters of Atlantic Canada. In: T.G. Northcote and G.F. Hartman [eds.]. Fishes and Forestry: Worldwide Watershed Interactions and Management. Blackwell Publishing Ltd. Oxford, UK. pp. 439-462.

Currie, R. and D.F.Malley. 1998. Inland freshwater ecosystems. In: R.C. Pierce, D.M. Whittle and J.B. Bramwell [eds.]. Chemical contaminants in Canadian aquatic ecosystems. Canadian Government Publishing – PWGSC. Ottawa, ON, Canada. pp. 137-188.

Cutting, R.E., E.M. Jefferson, and S.F. O'Neil. 1987. Status of the Atlantic salmon of the LaHave River, Nova Scotia, in 1986 and forecast of returns in 1987. Canadian Atlantic Fisheries Scientific Advisory Committee. Research Document 87/106.

Deschenes, J., M.A. Rodriguez, and R. Berube. 2007. Context-dependent responses of juvenile Atlantic salmon (Salmo salar) to forestry activities at multiple scales within a river basin. Canadian Journal of Fisheries and Aquatic Sciences 64:1069-1079.

DFO. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach. (Accessed July 2014)

DFO. 2010. Status of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2010/002. 25 p.

DFO. 2011. Status of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2011/005. 26 p.

DFO. 2012a. Status of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2012/014. 33 p.

DFO. 2012b. Reference points consistent with the Precautionary Approach for a variety of stocks in the Maritimes Region. DFO Can. Sci. Advis. Sec. Sci. Rep. 2012/035. 35 p.

DFO. 2013a. Status of Atlantic salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2013/013. 29 p.

DFO. 2013b. Recovery Potential Assessment for Southern Upland Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Rep. 2013/009. 60p.

DFO. 2014. Status of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2014/037. 14 p.

DFO. 2015. Status of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/021. 14 p.

DFO. 2016. Stock Status Update of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2016/029. 17 p.

DFO. 2017. Stock Status Update of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2017/020. 20 p.

DFO. 2018. Stock Status Update of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/038. 20 p.

DFO. 2020a. Stock Status Update of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19-21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/002. 20 p.

DFO. 2020b. Stock Status Update of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19–21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/031. 20 p.

DFO and MRNF. 2009. Conservation status report, Atlantic salmon in Atlantic Canada and Quebec: PART II – Anthropogenic considerations. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2870.

Dickison, R.B.B., D.A. Daugharty, and D.R. Randall. 1981. Some preliminary results of the hydrological effects of clearcutting a small watershed in central New Brunswick. In: Proceedings of the 5th Canadian Hydrotechnical Conference. Canadian Society of Civil Engineering, Fredericton, NB, Canada. pp. 59-75.

Dumbauld, B.R., J.L. Ruesink, and S.S. Rumrill. 2009. The ecological role of bivalve shellfish aquaculture in the estuarine environment: A review with application to oyster and clam culture in West Coast (USA) estuaries. Aquaculture 290:196-223.

Elson, P.F. 1967. Effects on Wild Young Salmon of Spraying DDT over New Brunswick Forests. J. Fish. Res. Board. Can. 24: 731-767.

Fairchild, W.L., S.B. Brown, and A. Moore. 2002. Effects of freshwater contaminants on marine survival in Atlantic salmon. North Pacific Anadromous Fish Commission (NPAFC) Technical Report Number 4:30-32.

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

Finstad, B. P.A. Bjorn, C.D. Todd, F. Whoriskey, P.G. Gargan, G. Forde, and C.W. Revie. 2011. The effect of sea lice on Atlantic salmon and other salmonid species. In: O. Aas, S. Einum, A, Klemetsen, and J. Skurdal [eds.] Atlantic Salmon Ecology. Blackwell Publishing Limited, Oxford, UK. pp. 253-276.

Fraser, D.J. 2008. How well can captive breeding programs conserve biodiversity? A review of salmonids. Evolutionary Applications 1:535-586.

Gibson, A.J.F., and Bowlby, H.D. 2013. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Population Dynamics and Viability. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/142. iv + 129 p.

Gibson, A.J.F., and R.R. Claytor. 2012. What is 2.4? Placing Atlantic Salmon conservation requirements in the context of the Precautionary Approach to fisheries management in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/043. iv + 21 p.

Gibson, A.J.F., and R.A. Myers. 2002. A logistic regression model for estimating turbine mortality at hydroelectric generating stations. Transactions of the American Fisheries Society 131:623-633.

Gibson, A.J.F., H.D. Bowlby, D.C. Hardie, and P.T. O'Reilly. 2011. Populations on the brink: low abundance of Southern Upland Atlantic salmon in Nova Scotia, Canada. North American Journal of Fisheries Management 31:733-741.

Gibson, A.J.F., H.D. Bowlby, D.L. Sam, and P.G. Amiro. 2010. Review of DFO Science information for Atlantic salmon (Salmo salar) populations in the Southern Upland region of Nova Scotia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/081. vi + 83 p.

Gibson, R.J. 1988. Mechanisms regulating species composition, population structure, and production of stream salmonids; a review. Polskie Archiwum Hydrobiologii 35(3-4):469-495.

Gibson, R.J. 1993. The Atlantic salmon in fresh water: spawning, rearing and production. Reviews in Fish Biology and Fisheries 3:39-73.

Gibson, R.J., R.L. Haedrich, and C.M. Wernerheim. 2005. Loss of fish habitat as a consequence of inappropriately constructed stream crossings. Fisheries 30:10-17.

Grant, J., A. Hatcher, D.B. Scott, P. Pocklington, C.T. Schafer, and G.V. Winters. 1995. A multidisciplinary approach to evaluating impacts of shellfish aquaculture on benthic communities. Estuaries and Coasts 18:124-144.

Halfyard, E.A., A.J.F. Gibson, D.E. Ruzzante, M.J.W. Stokesbury, and F.G. Whoriskey. 2012. Estuarine migratory behaviour and survival of Atlantic salmon smolts from the Southern Upland, Nova Scotia, Canada. Journal of Fish Biology 81:1626-1645.

Harris, P.D., L. Bachmann, and T.A. Bakke. 2011. The parasites and pathogens of the Atlantic salmon: lessons from Gyrodactylus salaris. In: O. Aas, S. Einum, A, Klemetsen, and J. Skurdal [eds.] Atlantic Salmon Ecology. Blackwell Publishing Limited, Oxford, UK. pp. 221-252.

Harwood, A.J., J.D. Armstrong, S.W. Griffiths, and N.B. Mecalfe. 2002. Sympatric association influences within-species dominance relations among juvenile Atlantic salmon and brown trout. Animal Behaviour 64:85-95.

Hearn, W.E. 1987. Interspecific competition and habitat segregation among stream-dwelling trout and salmon: A review. Fisheries 12(5):24-31.

Hewitt, L.M., T.G. Kovacs, M.G. Dube, D.L. MacLatchy, P.H. Martel, M.E. McMaster, M.G. Paice, J.L. Parrott, M.R. van den Heuvel, and G.J. van der Kraak. 2008. Altered reproduction in fish exposed to pulp and paper mill effluents: roles of individual compounds and mill operating conditions. Environmental Toxicology and Chemistry 27:682-697.

Hubley, P.B., and A.J.F. Gibson. 2011. A model for estimating mortality of Atlantic salmon, Salmo salar, between spawning events. Canadian Journal of Fisheries and Aquatic Sciences 68:1635-1650.

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.

ICES. 2000. Report of the working group on North Atlantic salmon (WGNAS). ICES Advisory Committee. ICES CM 2000/ACFM:13. 301 p.

ICES. 2011. Report of the working group on North Atlantic salmon (WGNAS). ICES Advisory Committee. ICES 2011/ACOM:09. 286 p.

ICES. 2019. Working Group on North Atlantic Salmon (WGNAS). ICES Scientific Reports. 1:16. 368 pp.

ICES. 2020. Working Group on North Atlantic Salmon (WGNAS). ICES Scientific Reports. 2:21. 358 pp.

Jarvi, T. 1989. Synergistic effect on mortality in Atlantic salmon, Salmo salar, smolt caused by osmotic stress and presence of predators. Environmental Biology of Fishes 26:149-152.

Jarvi, T. 1990. Cumulative acute physiological stress in Atlantic salmon smolts: the effect of osmotic imbalance and the presence of predators. Aquaculture 89:337-350.

Jonsson, I.R., G.S. Jonsson, J.S. Olafsson, S.M. Einarsson, and T.H. Antonsson. 2008. Occurrence and colonization pattern of Didymosphenia geminata in Icelandic streams. Proceedings of the 2007 international workshop on Didymosphenia geminata. Canadian Technical Report of Fisheries and Aquatic Sciences 2795.

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.

Korman, J., D.R. Marmorek, G.L Lacroix, P.G. Amiro, J.A. Ritter, W.D. Watt R.E. Cutting, and D.C.E. Robinson. 1994. Development and evaluation of a biological model to assess regional-scale effects of acidification on Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 51:662-680.

Krueger, C.C., and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48 (Supplement 1):66-77.

Lacroix, G.L. 1989a. Ecological and physiological responses of Atlantic salmon in acidic organic rivers of Nova Scotia, Canada. Water, Air, and Soil Pollution 46:375-386.

Lacroix, G.L. 1989b. Production of juvenile Atlantic salmon (Salmo salar) in two acidic rivers of Nova Scotia. Canadian Journal of Fisheries and Aquatic Sciences 46:2003-2018.

Langill, D.A., and P.J. Zamora. 2002. An audit of small culvert installations in Nova Scotia: habitat loss and habitat fragmentation. Canadian Technical Report of Fisheries and Aquatic Sciences 2422.

Lisle, T. E. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal California. Water Resources Research 25:1303-1319.

Lynch, M., and M. O'Hely. 2001. Captive breeding and the genetic fitness of natural populations. Conservation Genetics 2:363-378.

Marshall, T.L. 1986. Estimated spawning requirements and indices of stock status of Atlantic salmon in the St. Mary's River, Nova Scotia. CAFSAC Res. Doc. 1986/22.

McCormick, S.D., L.P. Hansen, T.P. Quinn, and R.L. Saunders. 1998. Movement, migration and smolting of Atlantic salmon (Salmo salar). Canadian Journal of Fisheries and Aquatic Sciences 55 (Supplement 1):77-92.

Michael, J.H. 2003. Nutrients in salmon hatchery wastewater and its removal through the use of a wetland constructed to treat off-line settling pond effluent. Aquaculture 226:213-225.

Milton, G.R., P.J. Austin-Smith, and G.L. Farmer. 2002. Shouting at shags: A case study of cormorant management in Nova Scotia. Colonial Waterbirds 18:91-98.

Morris, M.R.J., D. J. Fraser, A. J. Heggelin, F.G. Whoriskey, J.W. Carr, S.F. O'Neil, and J.A. Hutchings. 2008. Prevalence and recurrence of escaped farmed Atlantic salmon (Salmo salar) in eastern North American rivers. Canadian Journal of Fisheries and Aquatic Sciences 65:2807-2826.

National Research Council. 2003. Atlantic Salmon in Maine. The Committee on Atlantic Salmon in Maine, Board on Environmental Studies and Toxicology, Ocean Studies Board, Division on Earth and Life Sciences. National Research Council of the National Academies. National Academy Press. Washington, DC, USA. 260 p.

Nocera, J.J., and P.D. Taylor. 1998. In situ behavioral response of common loons associated with elevated mercury (Hg) exposure. Conservation Ecology 2(2):10. (Last accessed August 30, 2013).

O'Connell, M.F., J.B. Dempson, and 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.

O'Connell, M.F., 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. 1997. Estimates of conservation spawner requirements for Atlantic salmon (*Salmo salar* L.) for Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 1997/100.

O'Connor, W.C.K., and T.E. Andrew. 1998. The effects of siltation on Atlantic salmon, Salmo salar L., embryos in the River Bush. Fisheries Management and Ecology 5:393-401.

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. Res. Doc. 1998/37.

O'Reilly, P., S. Rafferty, and J. Gibson. 2012. Within- and among-population genetic variation in the Southern Upland designatable unit of Maritime Atlantic salmon (*Salmo salar* L.). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/077.

O'Reilly, P. T., R. Wissink, M. Cassista-Da Ros, C. Clarke, and A. Caissie. 2009. Use of molecular genetic marker data and pedigree inference to evaluate the efficacy of an adult-release stocking program on the Point Wolfe River, New Brunswick. Canadian Technical Report of Fisheries and Aquatic Sciences 2896.

Osborn, T.J. 2011. Variability and changes in the North Atlantic Oscillation Index. Advances in Global Change Research 46:9-22.

Paul, M.J., and J.L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333-65.

Rodriguez, M.A. 1995. Habitat-specific estimates of competition among stream salmonids: A field test of the isodar model of habitat selection. Evolutionary Ecology 9:169-184.

Soulsby, C., A.F. Youngson, H.J. Moir, and I.A. Malcolm. 2001. Fine sediment influence on salmonid spawning habitat in a lowland agricultural stream: a preliminary assessment. Swcience of the Total Environment 265:295-307.

Symons, P.E.K. 1979. Estimated Escapement of Atlantic Salmon (Salmo salar L.) for Maximum Smolt Production in Rivers of Different Productivity. J. Fish. Res. Board Can. 36: 132-140.

Thorstad, E.B., R. Whorisky, A.H. Rikardsen, and K. Aarestrup. 2011. Aquatic nomads: the life and migrations of the Atlantic salmon. In: O. Aas, S. Einum, A, Klemetsen, and J. Skurdal [eds.] Atlantic Salmon Ecology. Blackwell Publishing Limited, Oxford, UK. pp. 1-32.

Vaidya, O.C., T.P. Smith, H. Fernand, and N.R. McInnis Leek. 2008. Forestry best management practices: evaluation of alternate streamside management zones on stream water quality in Pockwock Lake and File Mile Lake watersheds in central Nova Scotia, Canada. Environmental Monitoring and Assessment 137:1-14.

Verspoor, E. 2005. Regional differentiation of North American Atlantic salmon at allozyme loci. Journal of Fish Biology 67:80-103.

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. Fisheries Research Scotland, Research Service Internal Report. No 18/05, 8p.+Figs.+Tables.

Visbeck, M.H., J.W. Hurrell, L. Polvani, and H.M. Cullen. 2001. The North Atlantic Oscillation: past, present and future. Proceedings of the National Academy of Sciences of the United States of America 98:12876-12877.

Watt, W.D. 1986. The case for liming some Nova Scotia salmon rivers. Water, Air and Soil Pollution 31:775-789.

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

Watt, W.D. 1997. The Atlantic Region Acid Rain Monitoring program in acidified Atlantic salmon rivers: trends and present status. DFO Canadian Stock Assessment Secretariat Research Document 97/28.

Watt, W.D., C.D. Scott, and W.J. White. 1983. Evidence of acidification of some Nova Scotia rivers and its impact on Atlantic salmon, *Salmo salar*. Canadian Journal of Fisheries and Aquatic Sciences 40:462-473.

Zwanenburg, K.C.T., D. Bowen, A. Bundy, K. Frank, K. Drinkwater, R. O'Boyle, D. Sameoto, and M. Sinclair. 2002. Decadal changes in the Scotian Shelf large marine ecosystem. Large Marine Ecosystems 10:105-150.

TABLES

Table 1. Proportions of freshwater (FW) age composition and sea age composition of first time spawners as determined from scale samples of adult Atlantic Salmon collected from LaHave River (Morgan Falls) during the 1970–2019 time period. N=total numbers

Year	FW Age 2	FW Age 3	FW Age 4	N	Sea Age 1	Sea Age 2	Sea Age 3	Sea Age 4	Sea Age 5	Sea Age 6	N
1970	1.00	0.00	0.00	2	1.00	0.00	0.00	0.00	0.00	0.00	2
1973	0.96	0.04	0.00	92	0.85	0.14	0.01	0.00	0.00	0.00	92
1974	0.99	0.01	0.00	149	0.97	0.03	0.00	0.00	0.00	0.00	149
1975	0.97	0.03	0.00	115	0.54	0.44	0.01	0.01	0.00	0.00	115
1976	1.00	0.00	0.00	81	0.63	0.35	0.02	0.00	0.00	0.00	81
1977	1.00	0.00	0.00	57	1.00	0.00	0.00	0.00	0.00	0.00	57
1978	0.94	0.06	0.00	47	0.60	0.23	0.15	0.02	0.00	0.00	47
1979	0.94	0.06	0.00	163	0.96	0.03	0.01	0.01	0.00	0.00	163
1980	0.98	0.02	0.00	234	0.59	0.36	0.01	0.02	0.01	0.00	234
1981	0.92	0.08	0.00	386	0.67	0.28	0.05	0.00	0.00	0.00	386
1982	0.91	0.09	0.00	55	0.87	0.07	0.05	0.00	0.00	0.00	55
1983	0.98	0.02	0.00	225	0.46	0.33	0.16	0.04	0.00	0.00	225
1984	0.99	0.01	0.00	152	0.19	0.66	0.08	0.05	0.01	0.01	152
1985	0.95	0.05	0.00	589	0.33	0.57	0.08	0.02	0.00	0.00	589
1986	0.88	0.12	0.00	663	0.37	0.38	0.11	0.13	0.00	0.01	663
1987	0.95	0.05	0.00	841	0.57	0.27	0.11	0.05	0.00	0.00	841
1988	0.94	0.06	0.00	913	0.66	0.22	0.08	0.03	0.01	0.00	913
1989	0.87	0.13	0.00	1052	0.73	0.16	0.08	0.01	0.01	0.00	1,052
1990	0.87	0.13	0.00	999	0.69	0.18	0.12	0.01	0.00	0.00	999
1991	0.86	0.14	0.00	407	0.50	0.34	0.10	0.04	0.01	0.00	407
1992	0.82	0.18	0.00	1161	0.82	0.13	0.04	0.00	0.00	0.00	1,161
1993	0.81	0.19	0.00	439	0.73	0.22	0.03	0.02	0.00	0.00	439
1994	0.87	0.13	0.00	273	0.55	0.32	0.10	0.03	0.00	0.00	273
1995	0.78	0.21	0.01	329	0.56	0.38	0.05	0.01	0.00	0.00	329
1996	0.81	0.19	0.00	297	0.63	0.29	0.06	0.02	0.00	0.00	297
1997	0.82	0.18	0.00	222	0.71	0.19	0.07	0.03	0.00	0.00	222
1998	0.81	0.19	0.01	370	0.81	0.11	0.08	0.00	0.00	0.00	370
1999	0.91	0.09	0.00	241	0.60	0.37	0.02	0.00	0.00	0.00	241
2000	0.83	0.17	0.00	242	0.72	0.21	0.06	0.00	0.00	0.00	242
2001	0.86	0.14	0.00	199	0.49	0.46	0.04	0.01	0.00	0.00	199
2002	0.90	0.10	0.00	182	0.80	0.08	0.10	0.02	0.01	0.00	182
2003	0.89	0.11	0.00	175	0.45	0.50	0.02	0.02	0.01	0.00	175
2004	0.84	0.16	0.00	144	0.54	0.38	0.08	0.00	0.01	0.00	144
2005	0.76	0.24	0.00	246	0.83	0.13	0.02	0.01	0.00	0.00	246
2006	0.75	0.25	0.00	424	0.83	0.14	0.03	0.00	0.00	0.00	424
2007	0.81	0.19	0.00	362	0.90	0.09	0.00	0.01	0.00	0.00	362
2008	0.79	0.21	0.00	677	0.86	0.13	0.01	0.00	0.00	0.00	677
2009	0.81	0.19	0.00	220	0.75	0.21	0.04	0.00	0.00	0.00	220
2010	0.84	0.16	0.01	346	0.84	0.14	0.01	0.01	0.00	0.00	346
2011	0.84	0.16	0.00	366	0.79	0.21	0.00	0.00	0.00	0.00	366
2012	0.87	0.13	0.00	67	0.43	0.48	0.07	0.01	0.00	0.00	67
2013	0.77	0.23	0.00	182	0.41	0.58	0.01	0.01	0.00	0.00	182
2014	0.77	0.21	0.02	61	0.67	0.33	0.00	0.00	0.00	0.00	61
2015	0.90	0.10	0.00	173	0.90	0.09	0.01	0.00	0.00	0.00	173
2016	0.54	0.46	0.00	67	0.33	0.67	0.00	0.00	0.00	0.00	67
2017	0.69	0.31	0.00	209	0.88	0.11	0.01	0.00	0.00	0.00	209

Year	FW Age 2	FW Age 3	FW Age 4	N	Sea Age 1	Sea Age 2	Sea Age 3	Sea Age 4	Sea Age 5	Sea Age 6	N
2018	0.91	0.09	0.00	11	0.09	0.91	0.00	0.00	0.00	0.00	11
2019	0.92	0.08	0.00	148	0.93	0.07	0.01	0.00	0.00	0.00	148

Table 2. Fork length (cm) at age of first time spawners determined from scale samples of adult Atlantic Salmon collected from LaHave River (Morgan Falls) 1970–2019, and over last 3 generations (2005–2019), and St. Mary's River (West Branch) 1999–2011. N=total numbers

River	Age	Mean Length	Max Length	Proportion Female	N
LaHave (1970–2019)	1	54.4	77.9	0.38	10,170
LaHave (1970–2019)	2	72.1	87.8	0.87	3,490
LaHave (1970–2019)	3	82.9	90.4	0.89	9
LaHave (2005–2019)	1	54.1	63.5	0.41	2,853
LaHave (2005–2019)	2	72.7	87.8	0.95	623
	3	74	76.3	0.67	3
St. Mary's	1	54.1	74.1	0.55	906
St. Mary's	2	73.2	81	0.98	84

Table 3. Proportions of freshwater (FW) age composition and sea age composition of first time spawners as determined from scale samples of adult Atlantic Salmon collected from the St. Mary's River (West Branch) during the 1999–2011 time period. N=total numbers

Year	FW Age 2	FW Age 3	FW Age 4	N	Sea Age 1	Sea Age 2	Sea Age 3	Sea Age 4	N
1999	0.92	0.08	0.00	95	0.74	0.24	0.02	0.00	95
2000	0.52	0.47	0.01	173	0.92	0.04	0.03	0.01	173
2001	0.84	0.16	0.00	83	0.73	0.20	0.05	0.01	83
2002	0.80	0.20	0.00	25	0.84	0.16	0.00	0.00	25
2003	0.80	0.20	0.00	79	0.84	0.16	0.00	0.00	79
2004	0.68	0.32	0.00	57	0.95	0.05	0.00	0.00	57
2005	0.55	0.45	0.00	31	0.96	0.04	0.00	0.00	25
2006	0.76	0.24	0.00	148	0.94	0.06	0.00	0.00	148
2007	0.86	0.14	0.00	144	0.85	0.14	0.01	0.00	144
2008	0.86	0.14	0.00	95	0.91	0.08	0.01	0.00	95
2010	0.82	0.18	0.00	44	0.82	0.16	0.02	0.00	44
2011	0.83	0.17	0.00	70	0.96	0.04	0.00	0.00	70

Table 4. Mean juvenile density by age class on LaHave River as estimated from mark-recapture electrofishing surveys for the years 1990–2019. In recent years (2009– present) mean catchability from 2007 and 2008 (0.214) is used to estimate juvenile densities instead of mark-recapture surveys. "-" = no data*. N=total numbers*

Year	N	Age-0 fry	Age-1 parr	Age-2+ parr
1990	11	3.40	7.76	0.89
1991	9	3.41	5.39	0.56
1992	14	6.72	2.87	0.70
1993	3	34.65	7.71	0.56
1994	11	2.12	6.12	0.33
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	13	10.77	12.23	1.78
2000	20	4.40	8.20	0.40
2001	21	5.30	7.50	0.40
2002	22	5.50	6.00	0.70
2003	15	5.10	11.10	0.20
2004	16	17.91	6.75	0.57
2005	11	14.17	15.12	1.08
2006	11	20.76	15.06	1.71
2007	6	14.41	10.73	0.88
2008	8	24.20	9.20	0.70
2009	9	29.50	4.00	0.60
2010	9	17.00	11.90	0.50
2011	11	3.00	3.30	0.90
2012	9	15.10	5.00	0.50
2013	8	6.00	8.10	0.10
2014	10	19.64	1.88	1.34
2015	9	0.82	6.84	0.97
2016	5	10.72	0.69	0.98
2017	11	4.91	3.25	0.25
2018	7	4.95	2.55	0.64
2019	6	9.30	2.53	0.10

Table 5. The estimated production (90% CI), density and return rate of wild smolts (as calculated directly from the monitoring data) for the LaHave River (above Morgan Falls) Atlantic Salmon population from 1996 to 2016. "-" = no data.

Smolt Year (t)	Wild Smolt Estimate	95% Confidence Interval	Production Per Unit Area (smolts/100 m²)	Return Rate (%) 1SW (t+1)	Return Rate (%) 2SW (t+2)
1996	20,511	19,886 – 21,086	0.79	1.47	0.23
1997	16,550	16,000 – 17,100	0.63	4.33	0.43
1998	15,600	14,675 – 16,600	0.60	2.04	0.34
1999	10,420	9,760 – 11,060	0.40	4.82	0.86
2000	16,300	15,950 – 16,700	0.63	1.16	0.11
2001	15,700	15,230 – 16,070	0.60	2.70	0.59
2002	11,860	11,510 – 12,210	0.46	1.95	0.45
2003	17,845	8,821 – 26,870	0.68	1.75	0.17
2004	20,613	19,613 – 21,513	0.79	1.13	0.33
2005	5,270	4,670 – 5,920	0.20	7.95	0.54
2006	22,971	20,166 – 26,271	0.88	1.48	0.40
2007	24,430	23,000 – 28,460	0.98	2.33	0.16
2008	14,450	13,500 – 15,500	0.55	1.16	0.30
2009	8,644	7,763 – 9,659	0.33	3.47	0.88
2010	16,215	15,160 – 17,270	0.62	1.81	0.19
2011	-	-	-	-	-
2012	-	-	-	-	-
2013	7,159	5,237 – 10,259	0.27	0.60	0.24
2014	29,175	23,387 – 37,419	1.12	0.55	0.15
2015	6,664	6,011 – 7,413	0.26	0.35	0.35
2016	25,849	23,311 – 28,750	0.99	0.74	0.20

Table 6. Estimated egg depositions ('000's) of Atlantic Salmon for LaHave River (above Morgan Falls) and percent conservation egg requirement (CER), 1973 – 2019. CER for LaHave River (above Morgan Falls) is 6,223,795 eggs.

Year	No. of eggs ('000's) Wild	No. of eggs ('000's) Hatchery	No. of eggs ('000's) Total	% CER
1973	50	87	137	2.2%
1974	25	372	397	6.4%
1975	91	501	592	9.5%
1976	190	727	917	14.7%
1977	396	1,086	1,482	23.8%
1978	452	1,367	1,819	29.2%
1979	1,292	1,284	2,576	41.4%
1980	2,698	1,680	4,378	70.3%
1981	3,263	1,641	4,904	78.8%
1982	1,683	1,779	3,462	55.6%
1983	1,968	335	2,303	37.0%
1984	3,059	248	3,307	53.1%
1985	3,421	413	3,834	61.6%
1986	4,079	499	4,578	73.6%
1987	4,899	720	5,619	90.3%
1988	4,381	958	5,339	85.8%
1989	4,315	1,024	5,339	85.8%
1990	3,414	652	4,066	65.3%
1991	1,354	376	1,730	27.8%
1992	2,867	508	3,375	54.2%
1993	1,140	522	1,662	26.7%
1994	1,177	455	1,632	26.2%
1995	926	446	1,372	22.0%
1996	1,085	519	1,604	25.8%
1997	507	440	946	15.2%
1998	903	431	1,334	21.4%
1999	717	359	1,076	17.3%
2000	926	499	1,425	22.9%
2001	829	785	1,614	25.9%
2002	870	972	1,842	29.6%
2003	878	1,071	1,950	31.3%
2004	1,027	926	1,953	31.4%
2005	628	515	1,143	18.4%
2006	915	216	1,131	18.2%
2007	540	20	561	9.0%
2008	1078	0	1,078	17.3%
2009	474	0	474	7.6%

Year	No. of eggs ('000's) Wild	No. of eggs ('000's) Hatchery	No. of eggs ('000's) Total	% CER
2010	687	0	687	11.0%
2011	1049	0	1,049	16.9%
2012	287	0	287	4.6%
2013	785	0	785	12.6%
2014	191	0	191	3.1%
2015	461	0	461	7.4%
2016	268	0	268	4.3%
2017	460	0	460	7.4%
2018	228	0	228	3.7%
2019	254	0	254	4.1%

Table 7. Mean juvenile density by age class on the West (WB) and East (EB) branches of the St. Mary's River as estimated from mark-recapture electrofishing surveys for the years 1990–2019. N=total numbers

Year	N	EB Age-0 fry	EB Age-1 parr	EB Age-2+ parr	N	WB Age-0 fry	WB Age-1 parr	WB Age-2+ parr
1990*	11	3.40	7.76	0.89	3	4.70	7.80	0.90
1991*	9	3.41	5.39	0.56	5	25.80	4.20	0.40
1992*	14	6.72	2.87	0.70	8	22.00	5.40	0.90
1993*	3	34.65	7.71	0.56	3	143.70	10.20	0.60
1994*	9	2.54	7.33	0.41	5	1.40	2.80	0.20
1995	11	19.99	4.13	1.00	4	16.60	2.61	0.36
1996	8	14.50	3.71	1.40	3	11.15	3.23	0.46
1997	7	32.67	3.01	0.36	8	25.22	10.44	0.80
1998	7	6.06	5.89	0.32	8	23.41	6.88	1.75
1999	7	14.29	1.68	1.18	8	12.37	3.44	1.53
2000	6	19.37	1.81	0.14	8	6.66	4.06	0.32
2001	4	24.02	9.51	0.60	5	5.91	5.43	0.71
2002	8	2.85	5.28	1.33	6	3.92	2.14	0.72
2003	6	4.85	2.23	2.58	6	4.23	5.27	0.48
2004	6	2.53	2.63	0.39	6	3.63	0.63	0.36
2005	5	13.98	5.23	1.18	4	7.72	5.58	0.87
2006	5	5.95	2.87	0.23	6	3.78	0.78	0.43
2007	6	17.06	6.25	0.24	7	4.02	2.51	0.06
2008	6	7.58	2.29	0.24	6	6.15	2.51	0.33
2009	7	8.86	4.30	0.37	9	13.13	2.01	0.03
2010	6	8.66	2.82	0.46	7	6.93	8.27	0.17
2011	5	17.30	6.97	0.45	7	9.76	3.70	0.24

Year	N	EB Age-0 fry	EB Age-1 parr	EB Age-2+ parr	N	WB Age-0 fry	WB Age-1 parr	WB Age-2+ parr
2012	5	45.44	6.68	0.62	5	9.33	4.98	1.33
2013	5	12.45	19.13	0.50	9	2.16	2.93	0.22
2014	5	10.50	3.34	0.71	5	8.38	1.85	0.85
2015	4	11.60	4.88	0.43	8	2.36	4.00	0.07
2016	4	13.26	3.01	0	5	7.32	1.56	0.37
2017	5	10.07	4.46	0.55	7	4.62	6.24	0.45
2018	3	33.02	5.58	0.25	3	15.55	3.21	0.78
2019	4	14.08	2.65	0.18	6	4.32	1.99	0.04

Note:

* Surveys completed by the St. Mary’s River Association and the ages of the juveniles captured were approximated from length-frequency information.

Table 8. The estimated production, 90% confidence intervals (CI), production per unit area (density), and return rate of wild smolts (as calculated directly from the monitoring data – Table 10) for the St. Mary’s River Atlantic Salmon population for years sampled from 2005 to 2019. “-“ = no data.

St. Mary's River Branch	Year	Wheel Efficiency	Abundance Estimate	90% CI	90% CI	Production per unit area (smolts/100 m^2)	Return Rate (%)1SW	Return Rate 2SW
West Branch	2005	0.103*	7350	6,000	9,100	0.43	3.02	0.32
	2006	0.028	25,100	18,700	40,300	1.48	0.73	0.14
	2007	0.054	16,110	12,735	20,835	0.95	2.24	0.10
	2008	0.031	15,217	9,451	24,154	0.90	0.63	0.09
	2009	0.026	14,820	8,600***	28,001***	0.88	0.51	0.05
	2011	0.0315**	8,066	4,402	14,216	0.48	-	-
	2016	0.0315**	4,394	2,073	8,451	0.26	-	-
	2017	0.013	15,190	6,175	30,380	0.90	-	-
	2018	0.0315**	4,171	1,943	8,067	0.25	-	-
	2019	0.037	1,742	708	3,485	0.10	-	-
East Branch	2019	0.045	6823	4176	10971	0.38	-	-

Notes:
* Two wheels were deployed side-by-side.
** Used mean wheel efficiency (excluding 2005)
*** 95% confidence interval

Table 9. St. Mary's River (West Branch) adult abundance, 1997–2011, calculated using mark-recapture seining experiments (1997–2001, 2006–2008, 2010), seining and seining efficiency estimates (2002–2005, 2011), or the mean ratio of escapement estimates for the West Branch of the St. Mary's relative to LaHave River (above Morgan Falls; 2009), and percent conservation requirement (CR). CR for St. Mary's River (West Branch) is 5.3 million eggs (1735 adult salmon based on historical life history information).

Year	1SW returns	MSW returns	% CER
1997	390	61	26.0%
1998	1,059	41	63.4%
1999	307	83	22.5%
2000	315	25	19.6%
2001	319	106	24.5%
2002	220	16	13.6%
2003	600	122	41.6%
2004	464	23	28.1%
2005	192	8	11.5%
2006	222	18	13.8%
2007	182	23	11.8%
2008	361	36	22.9%
2009	96	15	6.4%
2010	75	14	5.1%
2011	182	8	11.0%

Table 10. Escapement estimates for 1SW and MSW salmon in the four Southern Upland rivers on which adult monitoring has taken place. The values for wild- and hatchery-origin returns (combined) for LaHave River (above Morgan Falls), East River (Sheet Harbour), and Liscomb River are based on total counts at a fishway. The values for the St. Mary's River (West Branch) population are derived from adult mark-recapture experiments and recreational catch data, as described in Gibson and Bowlby (2013). "-" = no data.

Year	SFA 21 LaHave above Morgan Falls 1SW	SFA 21 LaHave above Morgan Falls MSW	SFA 20 East Sheet Harbour 1SW	SFA 20 East Sheet Harbour MSW	SFA 20 Liscomb 1SW	SFA 20 Liscomb MSW	SFA 20 St. Mary's West Branch 1SW	SFA 20 St. Mary's West Branch MSW
1970	2	4	31	0	-	-	-	-
1971	3	0	19	1	-	-	-	-
1972	17	2	111	0	-	-	-	-
1973	152	16	29	4	-	-	-	-
1974	471	21	87	0	-	-	2,226	278
1975	504	73	89	4	-	-	305	93
1976	646	131	120	6	-	-	1,779	164
1977	1266	109	83	1	-	-	776	203
1978	842	276	13	3	-	-	256	164
1979	1920	166	19	0	60	0	1,951	112
1980	1973	777	53	6	111	0	2,527	257
1981	3047	592	59	1	76	6	1,454	461
1982	1420	486	5	0	252	10	959	103
1983	1156	313	59	3	520	15	994	339
1984	2293	420	66	4	606	48	1,284	384
1985	1445	715	26	1	507	87	1,999	1,551
1986	1724	662	9	2	736	117	1,969	1,712
1987	3102	611	46	4	1614	88	832	581
1988	3520	449	32	3	477	76	1,637	1,047
1989	2530	694	57	9	532	75	697	661
1990	2476	508	16	1	955	44	2,509	431
1991	604	326	31	5	586	38	1,149	400
1992	2489	273	22	4	145	27	377	243
1993	1158	205	33	1	134	11	1,251	715
1994	848	247	17	2	134	10	52	42
1995	948	228	27	2	150	6	627	192
1996	1130	196	11	1	85	9	1,002	297
1997	449	131	4	1	27	1	390	61
1998	919	137	1	0	9	0	1,059	41
1999	452	132	15	0	9	0	307	83
2000	794	120	1	0	-	-	315	25
2001	379	182	1	0	-	-	319	106
2002	1133	71	0	0	-	-	220**	16**
2003	437	207	1	0	-	-	600**	122**
2004	638	122	1	0	-	-	464**	23**
2005	416	84	-	-	-	-	192**	8**
2006	425	115	-	-	-	-	222	18
2007	341	41	-	-	-	-	182	23
2008	593	98	3*	0	-	-	361	36
2009	168	53	0	0	-	-	96***	15***
2010	300	53	1*	0	-	-	75	14
2011	294	76	-	-	-	-	182**	8**
2012	28	39	-	-	-	-	-	-

Year	SFA 21 LaHave above Morgan Falls 1SW	SFA 21 LaHave above Morgan Falls MSW	SFA 20 East Sheet Harbour 1SW	SFA 20 East Sheet Harbour MSW	SFA 20 Liscomb 1SW	SFA 20 Liscomb MSW	SFA 20 St. Mary's West Branch 1SW	SFA 20 St. Mary's West Branch MSW
2013	75	111	-	-	-	-	-	-
2014	43	21	-	-	-	-	-	-
2015	160	19	-	-	-	-	-	-
2016	23	45	-	-	-	-	-	-
2017	192	26	-	-	-	-	-	-
2018	37	58	-	-	-	-	-	-
2019	142	11	-	-	-	-	-	-

Notes:

* Count was not separated by size class.

** Due to the low number of adults captured on the recapture pass, mean catchability was used to calculate the escapement estimate.

*** The mean ratio of escapement estimates for the West Branch of the St. Mary’s relative to the LaHave River (above Morgan Falls) for the past 5 years (0.52) was used to estimate escapement as seining was unsuccessful.

Table 11. Summary of declines in adult Atlantic Salmon abundance (large and small size categories combined) for four populations in the Southern Upland DU estimated using log-linear regression fit via least squares. Standard errors (for the slope) and 95% CI (for the declines) are provided in the brackets. Models were fit for two time periods: the last 3 generations and from the maximum abundance during the time period. The slope estimate corresponds to the 3 generation decline rate estimate. Data are provided in Table 2.1.1.

Fishing Area	Population	Number of Years	Time Period	Slope	3 generations	From Maximum
20	Liscomb	10	1989–1999	-0.805 (0.120)	98.2* (94.3, 99.8)	99.5 (98.5, 93.4)
20	East (Sheet Harbour)	15	1995–2010	-0.152 (0.061)	91.3* (40.3, 98.7)	99.1 (96.8, 99.7)
20	St. Mary's (West Branch)	13	1998–2011	-0.120 (0.032)	79.0 (52.6, 90.7)	94.6 (87.1, 97.8)
21	LaHave (above Morgan Falls)	14	2005–2019	-0.127 (0.034)	83.1 (56.7, 93.4)	97.0 (94.7, 98.3)

Note:

* Time for 3 generations defined as 15 years for Liscomb River and East River (Sheet Harbour)

Table 12. Total spawning escapement for the Southern Upland region (SFA 20 and 21), as estimated from recreational catch data using the maximum likelihood model described in Amiro et al. (2008). The minimum and maximum values represent the 90% confidence limits from the model.

Year	1SW abundance minimum	1SW abundance maximum	MSW abundance minimum	MSW abundance maximum
1970	8,660	15,943	1,833	3,250
1971	6,778	12,477	1,193	2,116
1972	6,860	12,629	1,307	2,318
1973	8,690	15,998	1,780	3,156
1974	15,711	28,923	1,768	3,135
1975	5,546	10,209	1,585	2,811
1976	13,548	24,940	1,155	2,048
1977	13,332	24,544	2,275	4,035
1978	2,258	4,157	1,605	2,847
1979	13,565	24,973	1,370	2,429
1980	16,555	30,476	3,349	5,938
1981	18,152	33,417	3,972	7,043
1982	9,249	17,026	1,477	2,620
1983	4,805	8,845	1,735	3,077
1984	11,282	20,769	1,214	2,152
1985	15,163	27,913	6,657	11,805
1986	15,809	29,102	6,505	11,535
1987	17,606	32,412	3,014	5,345
1988	15,716	28,932	4,130	7,324
1989	17,023	31,338	4,301	7,626
1990	19,286	35,504	3,306	5,863

Year	1SW abundance minimum	1SW abundance maximum	MSW abundance minimum	MSW abundance maximum
1991	5,924	10,905	1,861	3,300
1992	8,680	15,980	1,520	2,696
1993	8,978	16,529	2,145	3,804
1994	2,071	3,812	759	1,346
1995	5,721	10,532	1,634	2,897
1996	9,730	17,911	2,068	3,667
1997	2,544	4,683	828	1,468
1998	7,623	10,346	802	1,127
1999	3,367	4,569	1,011	1,421
2000	5,315	7,213	779	1,094
2001	2,001	2,716	1,174	1,650
2002	4,479	6,078	442	621
2003	2,446	3,319	1,,150	1,617
2004	3,314	4,498	767	1,078
2005	2,467	3,348	500	702
2006	4,426	6,006	918	1,290
2007	3,610	4,900	407	572
2008	6,279	8,521	1,139	1,601
2009	1,779	2,414	604	849
2010	3,176	4,311	616	866
2011	3,113	4,225	883	1,241
2012	296	402	453	637
2013	794	1,078	1,290	1,813
2014	455	618	244	343
2015	1,694	2,299	221	310
2016	244	330	523	735
2017	2,033	2,759	302	425
2018	392	532	674	947
2019	1,503	2,040	128	180

Table 13 Annual summary of Atlantic Salmon releases in Southern Upland rivers between 2010 – 2020, including the total number of each life stage stocked and the broodstock origin. Native is defined as broodstock from the river of origin. Data are from the hatchery distributions database maintained by DFO Science.

River Name	Year	Total releases per life stage Fry	Total releases per life stage Parr	Total releases per life stage Smolt	Total releases per life stage Adult	Stock Origin
LaHave River	2017	0	0	0	37	Native
LaHave River	2018	126,717	0	0	171	Native
LaHave River	2019	271,140	0	0	84	Native
LaHave River	2020	270,219	0	274	93	Native
Saint Mary's River	2010	0	0	0	114	Native
Saint Mary's River	2017	57,538	0	0	23	Native
Saint Mary's River	2018	168,270	327	0	76	Native
Saint Mary's River	2019	198,686	0	0	25	Native
Saint Mary's River	2020	146,004	0	82	18	Native
West River (Sheet Harbour)	2010	0	0	0	19	Native
West River (Sheet Harbour)	2011	0	0	0	162	Native
West River (Sheet Harbour)	2012	0	0	0	19	Native

FIGURES

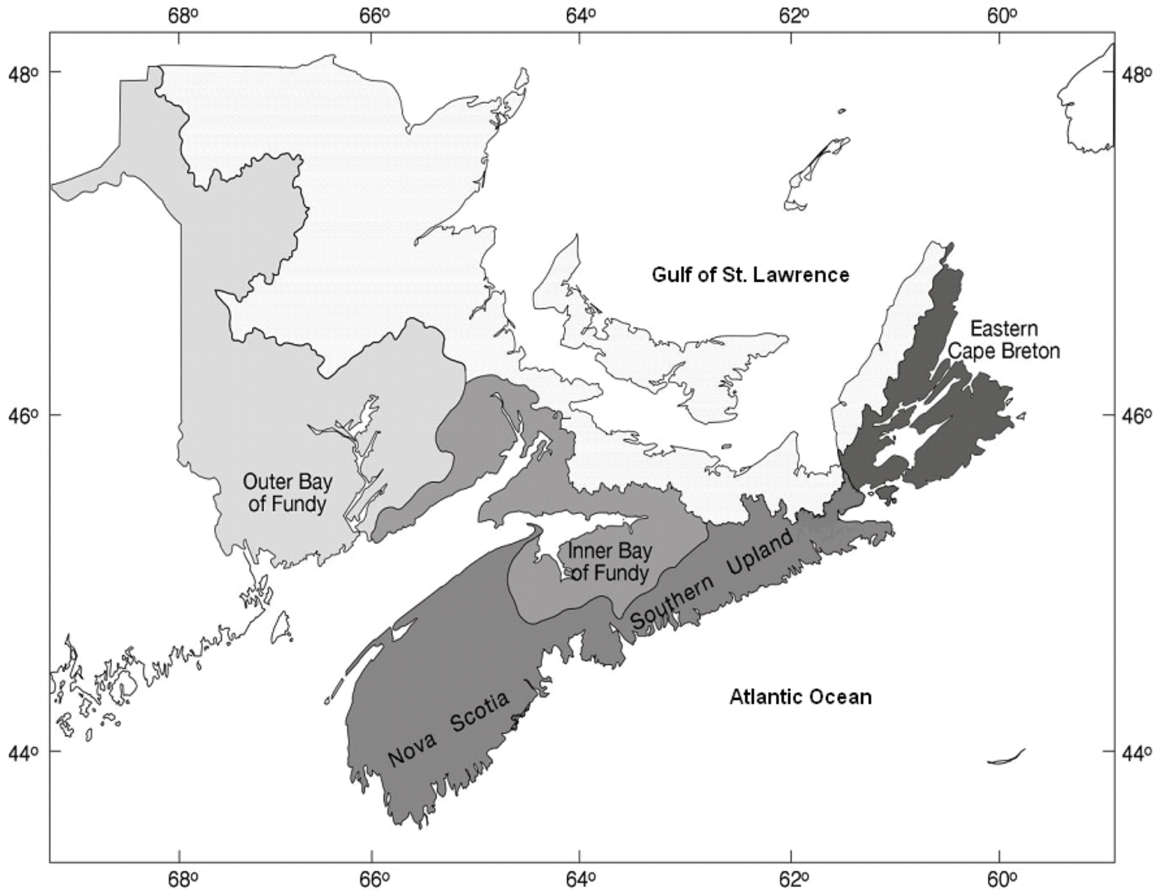

Figure 1. Map showing the location of the Southern Upland relative to the three other) Designatable Units (DUs) for Atlantic Salmon in the Maritimes.

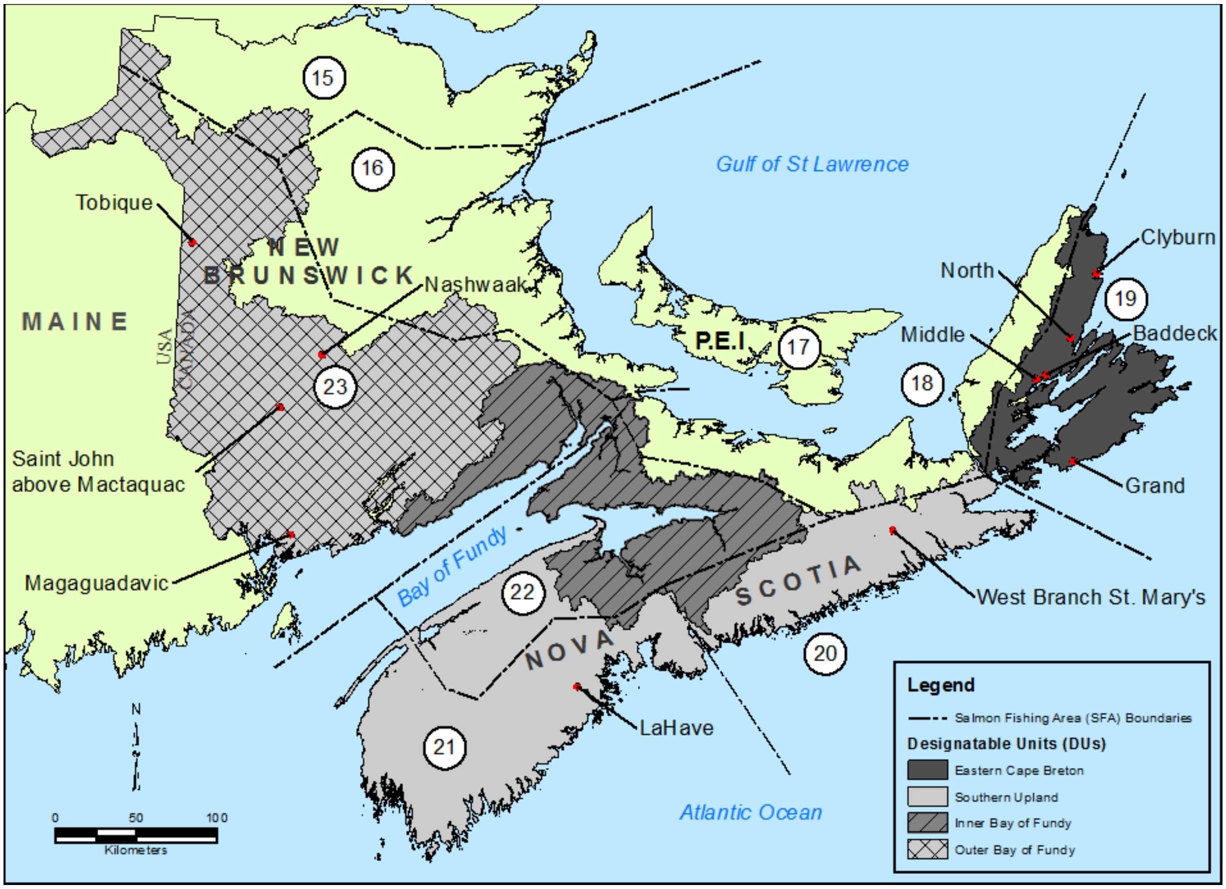

Figure 2. Map showing the boundaries of Salmon Fishing Areas (SFAs) within Maritimes and Gulf regions, and Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Designatable Units (DUs). SFA numbers are labeled inside the white circles. Data Source for DUs derived from NS Secondary Watershed Layer (NS Dept. of Environment) and NB Watershed Level 1 Layer (NB Dept. of Natural Resources).

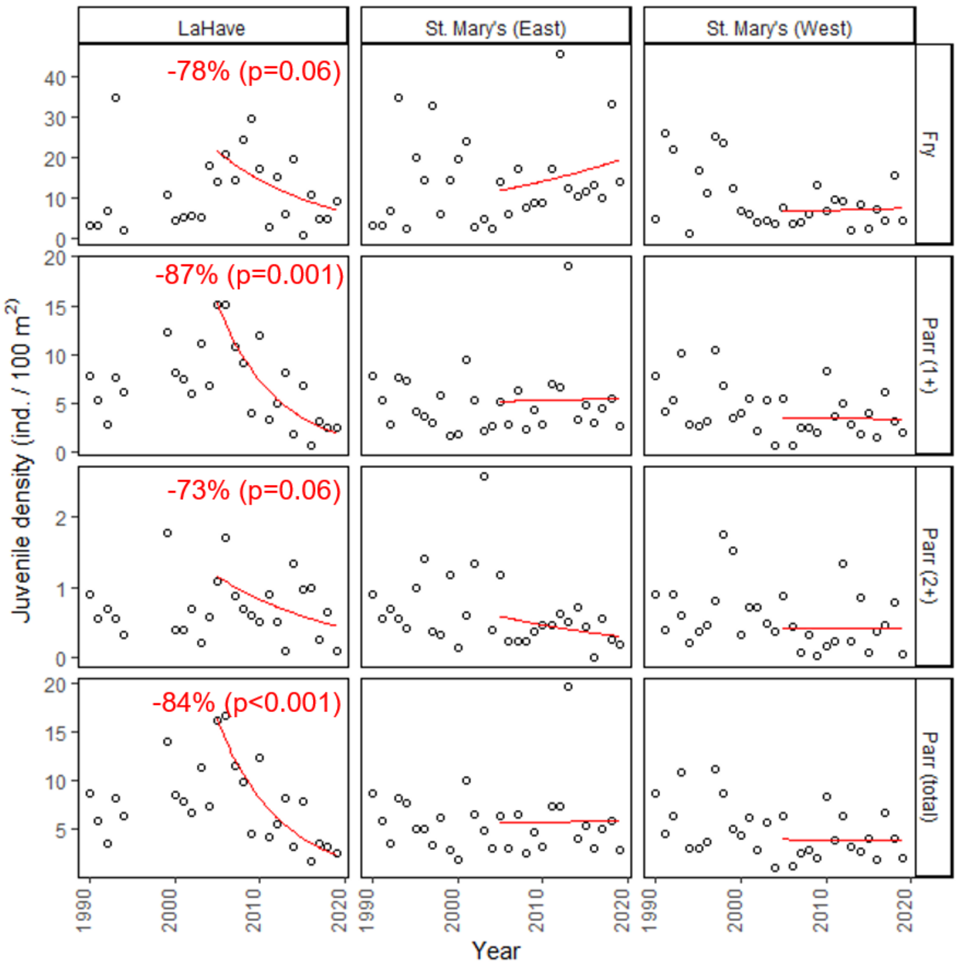

Figure 3. Annual juvenile Atlantic Salmon (fry and parr) estimates from electrofishing surveys on LaHave River and St. Mary's River (East and West branches), 1990–2019. Points are average densities (n = 3–22 sites per year). Solid lines are 14 year (3 generation) log-linear trends. Where significant, percent declines are indicated on plot panels.

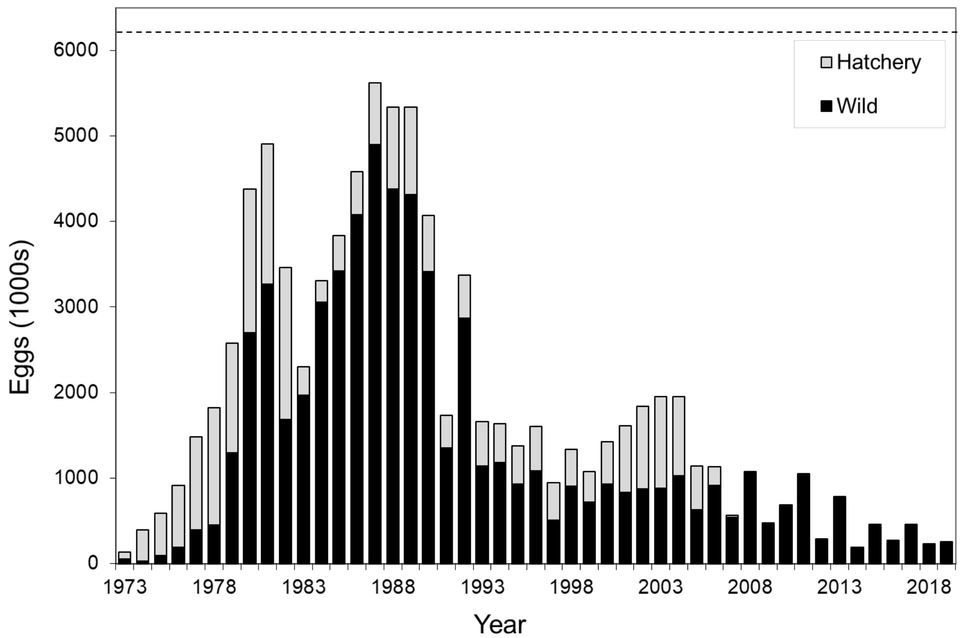

Figure 4. Estimated egg deposition (1000's) relative to the conservation egg requirement by wild- and hatchery-origin Atlantic Salmon at the Morgan Falls fishway on the LaHave River, from 1973 to 2019. The horizontal dashed indicates the conservation egg requirement above Morgan Falls.

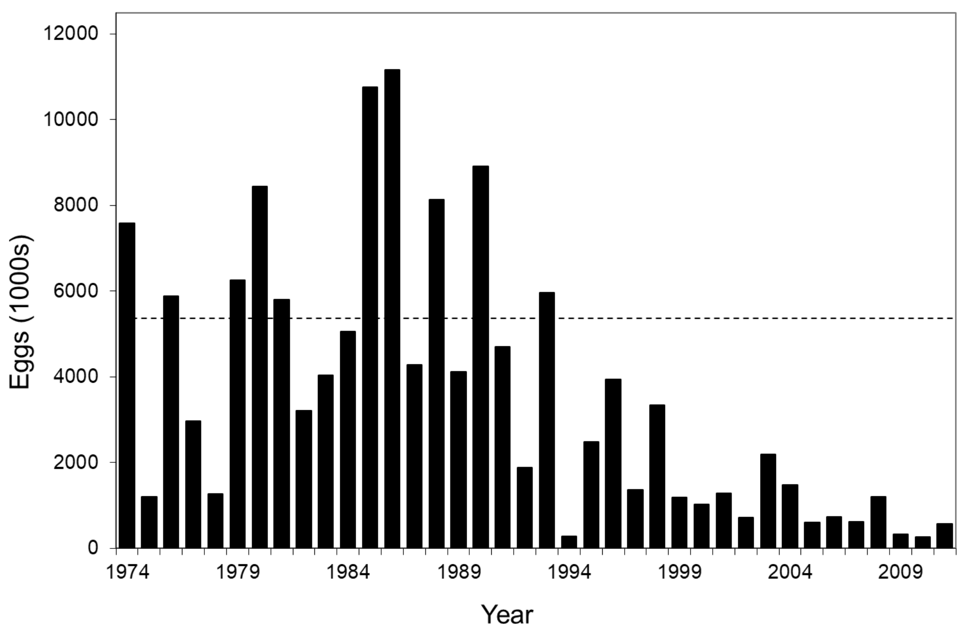

Figure 5. Estimated egg deposition (1000's) relative to the conservation egg requirement by wild- and hatchery-origin Atlantic Salmon on the St. Mary's River (West Branch), from 1974 to 2011. The horizontal dashed indicates the conservation egg requirement for the West Branch.

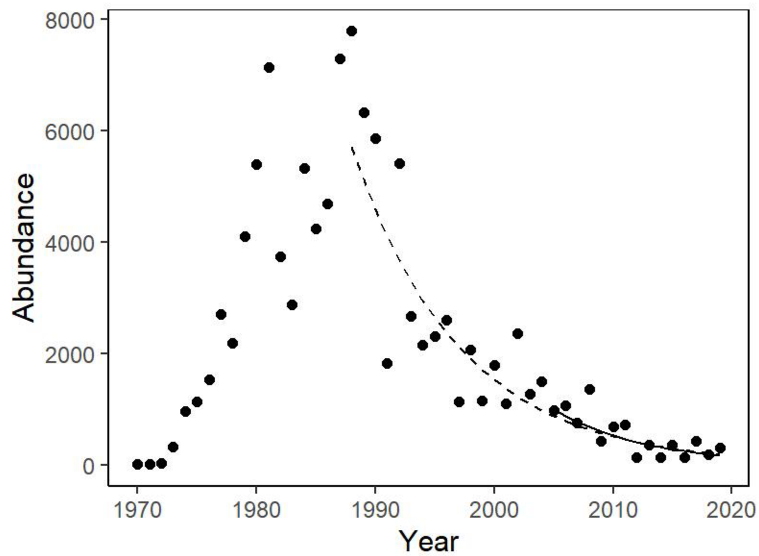

Figure 6. Observed adult escapement from 1970 to 2019 (points) and the log-linear model-predicted declines over the past 3 generations (14-years; solid line) and from maximum abundance (dashed line) for the LaHave River (above Morgan Falls).

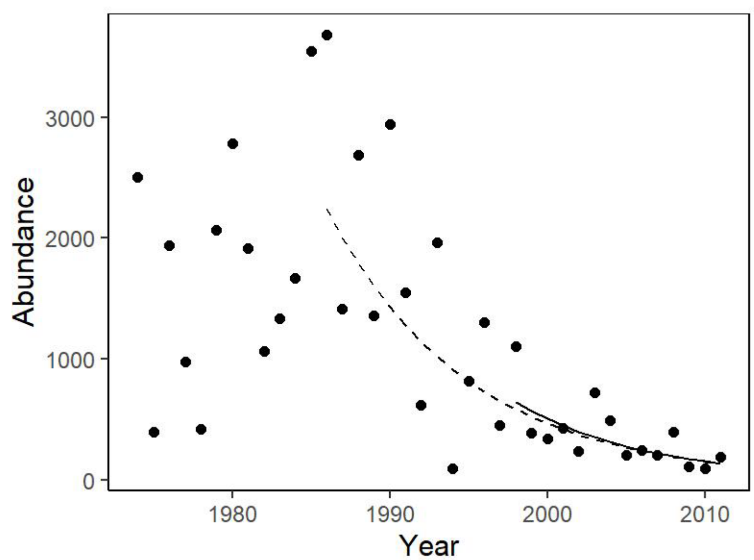

Figure 7. Observed adult escapement from 1974 to 2011 (points) and the log-linear model-predicted declines over the past 3 generations (13-years; solid line) and from maximum abundance (dashed line) for the St. Mary's River (West Branch).

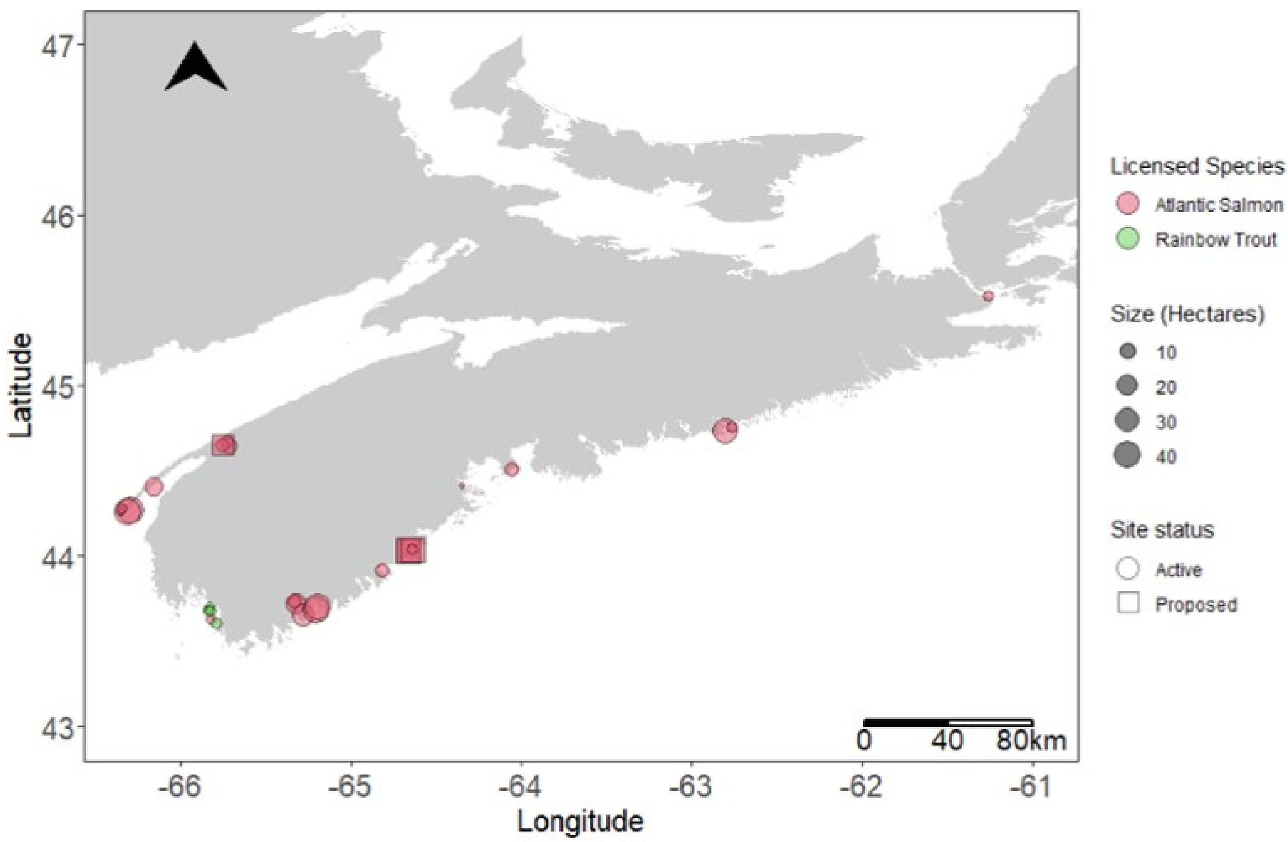

Figure 8. Locations, sizes, licensed species and site status of finfish aquaculture sites within the Southern Upland Designatable Unit. Sites licensed for Atlantic Salmon may also be licensed for other finfish species.

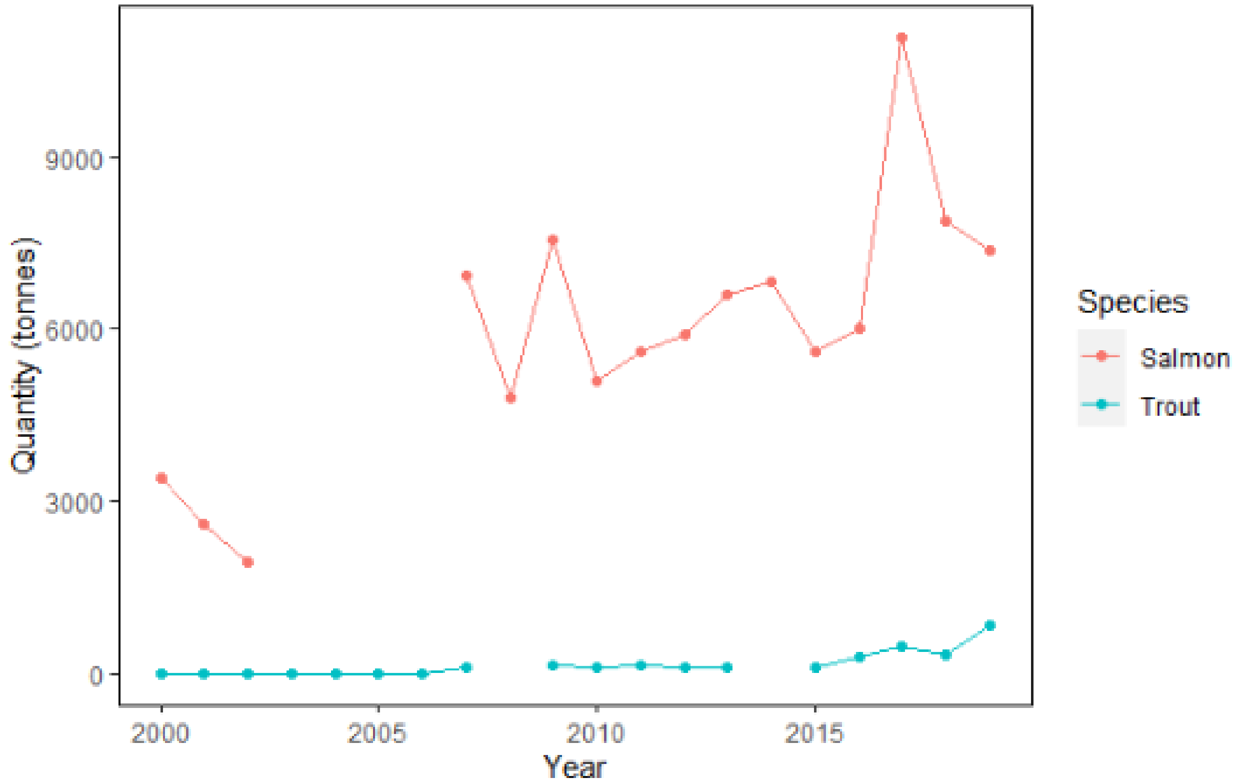

Figure 9. Aquaculture production of salmon and trout species for the province of Nova Scotia from 2000 to 2019.

APPENDIX

Table A1. Threats to Atlantic Salmon populations in the freshwater environment of the SU DU (DFO 2013b).

Threat Category	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	**Causal Certainty**
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
Freshwater Environment	Freshwater Environment	Freshwater Environment	Freshwater Environment	Freshwater Environment	Freshwater Environment	Freshwater Environment	Freshwater Environment
Water quality and quantity	Acidification	High	Very High (78% of assessed populations affected)	H, C and A Continuous and recurrent	Extreme	Very High	Very High
Water quality and quantity	Extreme temperature events	Medium	High to Very High (anecdotal information suggests the majority of rivers are affected)	H, C and A Seasonal	High	High	Medium
Water quality and quantity	Altered hydrology	High	High to Very High	H, C and A Seasonal	High	High	Medium
Water quality and quantity	Water extraction	Low	Low	H, C and A Recurrent	Negligible to High (dependent upon timing and	High	Low

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
					magnitude of extraction/alteration)		
Water quality and quantity	Chemical contaminants	Low	Unknown (anecdotal information suggests the majority of populations affected)	H, C and A Seasonal	Negligible to High (dependent upon concentration (dose) and time of exposure (duration))	High	Low
Water quality and quantity	Silt and sediment	Medium	Very High (100%)	H and C Continuous	Negligible to High (dependent upon concentration (dose) and time of exposure (duration))	High	Low
Changes to biological communities	Invasive species (fish)	High	Medium (22% of assessed populations)	H, C and A Continuous	High	High	Medium

Threat Category	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	**Causal Certainty**
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
Changes to biological communities	Invasive species (other)	Low	Low	A Continuous	Low to High	Medium	Very Low
Changes to biological communities	Stocking for fisheries enhancement using traditional methods	Medium	Very High	H and C Continuous	Medium to Extreme (dependent upon number of fish stocked and length of period of stocking)	High (rate of fitness recovery after stocking ends is unknown)	Low
Changes to biological communities	Stocking (current)	Low	Low (several Fish Friends projects; educational programs)	C and A Continuous	Low to High (dependent upon number of juveniles stocked and size of recipient population)	High	Low
Changes to biological communities	Other salmonid stocking (rainbow, brown, & Brook Trout)	Low	Medium	H, C and A Continuous	Low to High (dependent upon number stocked and type of recipient waterbody	Medium	Low

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
					(lake vs. river))		
Changes to biological communities	Salmonid aquaculture (commercial)	Low	Low	H, C and A Continuous	Medium	High	Low
-	Avian predators	Medium	High	C and A Seasonal	High	Medium	Medium
-	Genetic effects of small population size	Medium	Medium (mostly focused in southwest area of DU)	H, C and A Continuous	Negligible to High (dependent upon length of time at small population size, stocking history, and site specific conditions)	High	None (Not evaluated)
-	Allee (small population size) effects	Medium (abundance specific)	Very High (abundance is low in all rivers)	H, C and A Continuous	Low to High (dependent on population-specific abundance)	Medium	Low

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
-	Scientific activities	Low	Low (Two Index Rivers and occasional surveys/sampling of other rivers)	H, C, A Seasonal	Low	Low	Low
Physical obstructions	Habitat fragmentation due to dams, culverts and other permanent structures	High	Medium to Very High	H, C and A Continuous	Low to Extreme (Dependent upon design of structure and location within watershed)	Very High	Very High
-	Reservoirs	Medium	Medium	H, C and A Continuous	Low to High (Dependent upon size of individual reservoirs and number in series on a system)	High	Medium
Habitat alteration	Infrastructure (roads)	Medium	Very High (all rivers)	H, C and A Continuous	Low to High (dependent upon road density within	Medium	Low

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
					watershed or sub-watershed)		
Habitat alteration	Pulp and paper mills	Low	Low (only two known pulp mills in DU)	H and C Continuous	Medium to High (Dependent upon process used and effluent discharge quality)	High	Low
Habitat alteration	Hydro power generation	Medium	Medium	H, C and A Continuous	Medium to Extreme (dependent upon facility design and operating schedule)	High	Medium
Habitat alteration	Urbanization	Medium	Medium	H, C and A Continuous	Low to High (dependent upon density of urbanization and infrastructure development)	High	Medium

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
Habitat alteration	Agriculture	Medium	High	H, C and A Seasonal	Low to High (dependent upon extent within watershed and practices used)	Medium	Low
-	Forestry	Medium	High	H, C and A Continuous	Low to High (dependent upon extent within watershed and practices used)	Medium	Low
-	Mining	Medium	Unknown	H, C and A Continuous	Low to High (dependent upon type of mine, processes used, and susceptibility to Acid Rock Drainage)	Medium	Low
Directed salmon fishing (current)	FSC fishery	Low	Low	H, C and A Seasonal	Negligible	Very High	High

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
-	Recreational fishery (angling)	Low	Low	H and A Seasonal	Negligible	Very High	High
-	Illegal fishing and poaching	High	Unknown (but potentially high)	H, C and A Seasonal	Low to High (dependent on number of salmon removed and size of impacted population)	High	High
By-catch in other fisheries	Indigenous or commercial fisheries	Low	Low	H, C and A Seasonal	Low	High	High
-	Recreational fisheries	Low	High	H, C and A Seasonal	Low	High	High
-	Recreational fishery: illegal targeting of Atlantic Salmon while fishing under	Medium	High	H, C and A Seasonal	Low to High (dependent upon angling pressure)	High	High

Threat Category	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat Category	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
	a general license						

Table A2. Threats to Atlantic Salmon populations in the estuarine and marine environment of the SU DU (DFO 2013b).

Threat	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
Marine or Estuarine Environment	Marine or Estuarine Environment	Marine or Estuarine Environment	Marine or Estuarine Environment	Marine or Estuarine Environment	Marine or Estuarine Environment	Marine or Estuarine Environment	Marine or Estuarine Environment
Changes to biological communities	Invasive species	Low	Very High (all populations)	C and A Continuous	Low	Low	Low
Changes to biological communities	Salmonid aquaculture	High	Very High	H, C and A Continuous	Medium to High (dependent upon location of	High	Low

Threat	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
					aquaculture facilities and operating practices)		
Changes to biological communities	Other species aquaculture	Low	Very High (all populations)	H, C and A Seasonal	Negligible to Medium (dependent upon species under culture, location of facility, and operating practices)	Low	Low
Changes to biological communities	Diseases and parasites	Medium	Very High (all populations)	H, C and A Continuous	Low to High (dependent upon irruptive behavior of disease/para sites resulting in outbreaks)	Low	Low
Changes in oceanographic conditions	Marine ecosystem change (including shifts in oceano-graphic	High	Very High (all populations)	H, C and A Continuous	Low to Extreme (dependent upon magnitude of change and sensitivity of	Medium	Low

Threat	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
	conditions and changes in predator/prey abundance)				salmon to change)		
Physical or abiotic change	Shipping, transport, noise, seismic activity	Low	Very High (all populations)	H, C and A Seasonal	Uncertain; likely Negligible to Low (dependent upon proximity of salmon to source of noise/activity)	Low	Low
-	Contaminants and spills (land- or water-based)	Low	Very High (all populations)	H, C, A Episodic	Low to Extreme (dependent upon identity and magnitude of contamination, and efficacy of cleanup)	Low	Low
-	Tidal power	Low	Low	C and A	Medium to High	High	Medium

Threat	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
				Seasonal	(dependent upon facility design and operating schedule)		
Directed salmon fisheries	Subsistence fisheries (Indigenous and Labrador residents)	Low	Low	H and A Seasonal	Negligible	High	High
Directed salmon fisheries	International fisheries (Greenland; St. Pierre-Miquelon)	Medium	Very High (MSW component of all populations)	H, C and A Seasonal	Negligible to High	High	Medium
By-catch in other fisheries	Commercial fisheries	Low	Very High (all populations)	H, C and A Seasonal	Low	High	High
Fisheries on prey species of salmon	Commercial fisheries	Low	Very High (all populations)	H, C and A Seasonal	Low to High (dependent upon reduction of prey species and availability of	Low	Low

Threat	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	Causal Certainty
Threat	**Specific Threat**	for the DU as a whole	of the threat in the DU	of the threat in the DU	of population level impacts	evidence linking the threat to stresses in general	evidence for changes to viability of SU salmon populations
					other forage species)		