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Updated Information on Atlantic Salmon (*Salmo salar*) Inner Bay of Fundy Populations (IBoF; part of Salmon Fishing Areas 22 and 23) 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 provide an update of Fisheries and Oceans Canada (DFO) information for the Inner Bay of Fundy (IBoF) Atlantic Salmon (*Salmo salar*) population (Designatable Unit 15) to support the development of a second status report of Atlantic Salmon in eastern Canada by the Committee on the Status of Endangered Wildlife in Canada. Information pertaining to IBoF Atlantic Salmon populations within Salmon Fishing Areas 22 and 23 is compiled in this review, including population status, trends, life history characteristics, habitat and threats.

Abundance of IBoF Atlantic Salmon are presently at critically low levels, listed as endangered and protected under the federal Species at Risk Act. Persistence of the populations is currently maintained through a Live Gene Bank (LGB) program focused on three rivers: the Stewiacke and Gaspereau in Nova Scotia, and the Big Salmon in New Brunswick. IBoF salmon assessment and monitoring activities undertaken by DFO Science primarily on the Big Salmon and Gaspereau rivers over the last 20 years have been in association with the LGB program and all incorporate genetic analyses. Estimated adult abundance on the Big Salmon River is presently below 4% of its conservation requirement and estimated egg deposition has declined at a rate greater than 60% over the last three generations (13 years). Since 2006, annual egg depositions from sea-run returns to the Gaspereau River have never exceeded 10% of the conservation requirement. A great majority of adults returning to the Big Salmon River continue to mature as small salmon (<63 cm fork length) after one-sea-winter and include a high percentage of females but the occurrence of repeat spawners is much less prevalent than in earlier years (1960s and 1970s). The Gaspereau River population is comprised of a higher proportion of maiden two-sea-winter salmon compared to the Big Salmon River adult returns. Most adults returning to the Gaspereau are progeny of LGB releases whereas more than 75% of returns to the Big Salmon are from the residual wild population or of unknown origin. The mean return rate of combined origin small salmon to the Big Salmon River over the past 13 years is extremely low at 0.29%.

Overall, the recent available DFO data for IBoF Atlantic Salmon indicates that population abundance has not improved and may have further declined over the past three generations despite significant conservation and supplementation efforts. Given the current lack of recruits from natural spawning and very high marine mortality, the LGB program remains critical to population recovery when marine survival rates increase to a level where these populations can be self-sustaining.

INTRODUCTION

The Inner Bay of Fundy (IBoF; Designatable Unit [DU] 15) Atlantic Salmon (*Salmo salar*) population assemblage was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in May 2001 (COSEWIC 2001). Furthermore, this population was listed as Endangered on Schedule 1 of the Canadian Species at Risk Act (SARA) when it came into effect in June 2003. COSEWIC later reviewed and confirmed this status in 2006 (COSEWIC 2006) and again in 2010 as the population has declined to less than 200 mature individuals from the 40,000 individuals estimated earlier in the 20th century (COSEWIC 2010). As required by SARA, section 37, a Recovery Strategy (DFO 2010) and an Action Plan (DFO 2019) were completed. The COSEWIC status report, the Recovery Strategy, and the Action Plan are a series of documents that are linked and should be taken into consideration together.

The IBoF Atlantic Salmon DU range consists of all rivers draining into the Bay of Fundy (BoF) starting with the Pereaux River [Nova Scotia (NS)] and extending around the Bay to the Mispec River (New Brunswick [NB]) (Figure 1). This geographic area was labelled as Conservation Unit 16 in the Conservation Status Report (CSR) (DFO and MRNF 2008). Although this region contains many rivers, note that only 50 rivers are depicted in Figure 2 as per the Recovery Strategy (DFO 2010).These rivers are within Salmon Fishing Area (SFA) 22, the BoF area of NS and SFA 23 east of the Saint John River (SJR), which are two of the five the management areas used by the Department of Fisheries and Oceans Canada (DFO) in Maritimes Region for salmon fisheries management and assessment purposes (Figure 1).

The purpose of this document is to provide an update of DFO information for the IBoF Atlantic Salmon population (DU15) to support the development of a 2nd status report of Atlantic Salmon in eastern Canada by COSEWIC. Information pertaining to IBoF salmon populations in SFA 22 and 23 is compiled in this review, specifically data from DFO Science-led efforts in the Big Salmon (NB), Stewiacke (NS), and Gaspereau rivers (NS) (Figure 3, 4, 5). This document updates and summarizes the latest IBoF population monitoring and assessment activities extensively reviewed in Jones et al. (2020) in supporting the development of a Science Advisory Report (SAR) for the Review of the Science Associated with the IBoF Atlantic Salmon Live Gene Bank (LGB) Program (DFO 2018). Updated returning adult population abundance information that incorporates data since the 2008 RPA (DFO 2008b) is also reviewed (DFO 2020).

IBoF Atlantic Salmon, like most populations in Atlantic Canada, is an anadromous species utilizing both freshwater and marine environments in different parts of its lifecycle. Young-of-the-year develop until May or June in gravel redds, emerge as fry, and grow as parr feeding on invertebrate drift (COSEWIC 2006). Wild produced parr eventually undergo physiological change for ocean migration (termed smoltification) after 2 to 4 years where they grow to maturity. Adult IBoF salmon return to their natal rivers from May to November and spawning occurs from October to December. Spawning adults consist of small salmon (fork length [FL] <63 cm, also referred to as grilse) and large salmon (FL ≥63 cm). Small salmon are maiden one-sea-winter (1SW) fish that have returned to the river to spawn for the first time or repeat-spawning 1SW salmon that have spawned previously. Large salmon consist of maiden spawners that return after two-sea-winters (2SW) or more, or repeat-spawning fish. Collectively large salmon are also referred to as multi-sea-winter (MSW) salmon.

The IBoF Atlantic Salmon population has been in decline since the 1980s and has historically experienced periods of low abundance and recovery (Amiro and Jefferson 1997, Amiro 2003, Gibson and Amiro 2003, Gibson et al. 2003c, DFO 2008b). Although, in comparison to the reduction in IBoF salmon recruitment during the years 1958 to 1965, the current decline is more severe (Amiro 2003). Gibson and colleagues reported declines in abundance of IBoF salmon of greater than 95–99% since the early 1970s (Gibson and Amiro 2003, Gibson et al. 2003a, 2003b). All commercial salmon fisheries in the Maritime Provinces' (NB, NS, and Prince Edward Island) were closed in 1985, and in the years following, recreational fisheries for salmon in IBoF rivers were subjected to successive in-season restrictions to further reduce exploitation. All recreational and Indigenous salmon fisheries have been closed in IBoF rivers of SFA 22 and SFA 23 since 1990, except for the Gaspereau River which was closed after the 1997 season (Amiro 2003, DFO 2010).

Initiated in 1998, prior to the listing under SARA, persistence of the IBoF Atlantic Salmon population is currently maintained through the DFO developed LGB program using individuals from three principle rivers (Big Salmon, Stewiacke, and Gaspereau) (DFO 2018). The objective of the LGB program is to use pedigree informed captive spawning and rearing technologies specifically designed to conserve genetic diversity and maintain populations until recovery can occur (DFO 2008a). The IBoF LGB program is part of the larger IBoF salmon recovery program that also includes population supplementation involving the release of juveniles and adults into native river habitat (Figure 6). In 2008, the RPA concluded with very high probability that, under current conditions without human intervention and the support of the LGB program, IBoF Atlantic Salmon would be extinct (DFO 2008b, Gibson et al. 2009).

LIFE HISTORY CHARACTERISTICS

The IBoF Atlantic Salmon population was typically assessed using data from two index rivers, the Big Salmon River and the Stewiacke River. Historically, biological information necessary for assessment purposes and obtained from salmon sampled in these rivers exhibited similarities in characteristics such as smolt age, age at maturity, size at age, frequency of repeat spawning, and run time of seaward migrating smolts and returning adult spawners (Jessop 1975, 1986, Amiro and McNeill 1986). Except for the Gaspereau River and the Black, Mosher, and Irish rivers in NB, all IBoF salmon populations were thought to have similar life history traits (Amiro 2003). More recently (2001–19), IBoF salmon monitoring and assessment activities have been undertaken by DFO Science in association with the LGB program (DFO 2018, Jones et al. 2020). All of the assessment activities incorporate genetic analyses to evaluate the success of the LGB and various recovery strategies. To facilitate the collection of smolts for each of the LGB programs and to estimate smolt abundance by origin (wild versus LGB), annual smolt assessments were initiated on the Big Salmon, Gaspereau, and more recently, Stewiacke rivers. This smolt monitoring data is also used to assess freshwater and marine survival for the progeny of the LGB program and any remnant wild adult spawners (Jones et al. 2020). The two index rivers currently monitored for adult abundance within the IBoF DU are the Big Salmon and Gaspereau rivers, with both populations being supported by supplemental releases from their respective LGB programs (Table 1, 2; DFO 2018).

SMOLT CHARACTERISTICS

Big Salmon River

Emigrating smolts are captured on the Big Salmon River using a Rotary Screw Trap (RST) (Flanagan et al. 2006) that is annually (since 2001) installed near the mouth of the river in Amateur Pool (N45.42240°, W-65.40984°) and operated from early May until mid-June (Table 3, Figure 3).

The objective of the Big Salmon River smolt assessment is to both estimate annual smolt abundance and collect non-adipose clipped smolts to be integrated into the LGB at the Mactaquac Biodiversity Facility (MBF). Smolt and parr releases from the LGB program were easily discernable from wild or LGB fry releases by the absence of the adipose fin. However, the origin (from adult spawners or LGB unfed fry) of the non-adipose clipped smolts could only be determined through the use of genetics. Genetic analysis (or parentage assignment) of tissue samples randomly collected from outgoing non-adipose clipped smolts, in combination with assessment data, provides smolt abundance estimates by origin (Table 4; Figure 7). The non-adipose clipped smolts that did not assign to the parents of the LGB program are grouped as 'adult spawners' and would include progeny from the remnant wild population (Table 5; Figure 8). Genetic considerations for the years 2001 to 2016 are described in Jones et al. (2020). Smolt abundance estimates and genetic analysis results from 2001–05 are summarized in Flanagan et al. (2006) and biological characteristic comparisons between smolts of different origins from the 2003 smolt class were preliminarily assessed by de Mestral et al. (2013).

The annual mean length of wild/LGB_{FRY} smolts (age classes combined, genetic origin not considered) sampled during the spring RST operations has ranged from 14.6 cm (2009) to 15.9 cm (2016) since monitoring began in 2001 (Figure 9). The mean length of wild/LGB_{FRY} or non-adipose clipped smolts sampled on the Big Salmon River in 2018 and 2019 was 14.9 cm, only 0.3 cm less than the previous 5-year mean. The greater mean length of smolts in 2016 is likely reflective of the larger proportion of age-3 and age-4 smolts in the cohort compared with earlier or 'younger' emigrating smolts observed in 2009 (Table 4; Figure 10) when the smallest value (14.6 cm) in the time series was observed (Figure 9).

The age distribution has fluctuated over the past 19 years, although the Big Salmon River smolt runs remain primarily age-2 dominant (Table 4; Figure 10). In 2019, analyses of scale samples (n = 410) collected from wild/LGB_{FRY} smolts in the Big Salmon River indicated that 81.0% were age-2, which is only 1.1% less than previous 5-year mean (82.1%, 2014–18). The remainder was age-3 (19.0%) as no age-4 smolts were sampled in 2019. Age-2 smolts have comprised 70% or more of the total non-adipose clipped smolts sampled in all but three years since 2001: 2011 (52.4%), 2012 (63.6%), and 2016 (63.9%) (Table 4; Figure 10).

Stewiacke River

In 2014, a smolt assessment program that involves the operation of a RST was reestablished in the Stewiacke River by Mi'kmaw Conservation Group (MCG), supported by DFO. Due to logistical interruptions (e.g., high flow, tidal flooding, change in location), low capture efficiency and low catches, a reliable smolt estimate has only been derived in one of six years of operation (2017). In the majority of those years, the RST was installed below the Little River confluence at the Rock Pile Pool (N45.162362°, W-63.286669°; Figure 4) and operated from mid-May to late June.

Biological characteristics were collected for the majority of smolts captured between 2014 and 2019. The annual mean length of wild/LGB_{FRY} smolts (age classes combined, genetic origin not considered) sampled during the spring RST operations since 2014 was 13.7 cm, ranging from 12.7 cm (2019) to 15.1 cm (2014) (Figure 11).

The age distribution of smolts remained consistent over the first four years of sampling where it is primarily age-2 dominant. The analysis of scale samples (n = 358) collected from wild/LGB_{FRY} smolts in the Stewiacke River in 2014–17 indicated that, on average, 93.6% (range: 85.7–95.8%) were age-2. The remainder were age-3 smolts (4.5%; range: 1.7–14.3%) and a few smolts were age-1 (2.0%; range 0–3.4%). All age-1 smolts were observed in 2015, two years after the last release of LGB age-0 fall parr into the Stewiacke River.

Gaspereau River

The Gaspereau River is a hydroelectric controlled watershed comprised of the Black and Gaspereau river systems with five generating stations (Amiro and Jefferson 1996) (Figure 5). Downstream fish passage at White Rock Dam (Figure 5) is provided for smolts via three surface bypass structures that contain assessment traps, which are typically monitored (smolts enumerated) between April 15 to May 31, although dates are adjusted to the smolt 'emigration window' based on water temperatures and seasonal flows. Sampling has occurred at this site since 2002 (DFO-MAR- 2012-07 2012-Notice of Permit from Species at Risk) where smolts are enumerated and finally transferred to the Coldbrook Biodiversity Facility (CBF) for tagging (PIT tag), tissue sampling, measurements, and inclusion into the Gaspereau River LGB program. Either marked LGB-origin smolts (released upriver of White Rock Dam) or wild-produced (i.e., non-adipose clipped or unmarked) smolts (captured in bypasses and recycled upriver of White Rock Dam) have been used since 2007 (except in 2011) to evaluate the capture efficiencies of the three bypasses and estimate smolt abundance (Table 6). Genetic analysis (or parentage assignment) of tissue samples randomly collected from outgoing non-adipose clipped smolts in combination with assessment data provide smolt abundance estimates by origin (LGB juvenile releases and/or adult spawners [non-targeted LGB or anadromous returns]) (Table 7; Figure 12). The non-adipose clipped smolts that did not assign to the parents of the LGB program are categorized as progeny of adult spawners, and include progeny of the remnant wild salmon and a small number of mature LGB adult salmon released upriver of White Rock Dam to spawn naturally (Table 8). Since 2008, all of the LGB fall parr releases have been marked with an adipose fin clip, making it possible to estimate smolt output separately for the LGB unfed fry and fall parr emigrating as smolts starting in 2011 (Table 7; Figure 12).

A sampling program for smolts was initiated on the Gaspereau River in 2014. In most years prior to 2014, biological characteristics of smolts caught in the bypasses were not collected at the time of capture, as these fish were primarily collected for the LGB program, thus minimal handling was ensured with efforts to reduce stress and mortality. From 2014 to 2019, the mean length of wild/LGB_{FRY} smolts (age classes combined, genetic origin not considered) sampled from the bypasses was 18.6 cm, ranging from 18.2 cm (2016) to 19.1 cm (2018). The average percentage of age-2 wild- or LGB_{FRY}-origin sampled smolts was 80.8% (range: 68.5–90.0%) and age-3 wild or LGB_{FRY} smolts was 18.4% (range: 11.1–30.7%) with only a few age-4 (0.7%, range: 0–2.2%) smolts (Figure 13).

IBoF Salmon Smolt Run Timing

With some uncertainty, smolt migration timing of IBoF Atlantic Salmon can be inferred from the monitoring of wild produced smolts in RSTs near head of tide on the Big Salmon and Stewiacke rivers (Figure 3, 4) and bypass facilities at the White Rock Generating Station, roughly 5 km above the head of tide on the Gaspereau River (Figure 5). From 2010 to 2019, mean dates for monitoring 10% and 90% of the Big Salmon River wild produced smolt runs (10-year mean) were May 12 and May 27, but more generally encompass the first week of May through the first week of June (Table 9). Dates of first and last capture on the Big Salmon River were predominately first week of May through the second week of June. Date of first capture has tended to be slightly later in recent years compared to the previous 10 years in the time series (see Marshall 2014). Smolts descending through the Stewiacke RST approached the head of tide between the third week of May (10^{th} percentile) and second week of June (90^{th} percentile) (Table 9). Smolts descending the Gaspereau River bypassed White Rock Dam between the first (10^{th} percentile) and third (90^{th} percentile) week of May (Table 9).

ADULT CHARACTERISTICS

Big Salmon River

Adult abundance assessments on the Big Salmon River have occurred annually since 2000 using methods described in Gibson et al. (2009) (Table 10). The methodological approach includes an early season (August) diver count of salmon holding in the largest pools, a mid-season count (September) usually of those same pools followed by a seining/marking activity of captured adults, and finally a three-section swim survey in October. Typically, during the early September count, the pools holding schools of adults are identified, and then if these pools can be efficiently seined, captured salmon are sampled for biological characteristics data (Table 11), marked, and then released for identification or recapture in the late-season diver swim.

The relative proportion of small salmon (age classes combined, genetic origin not considered) sampled in the Big Salmon River during the past twenty years is greater than 90% (Table 11). When applied to the modeled annual abundance estimate, the mean percentage of small salmon is slightly less than 80% of the total estimated salmon return (Table 12). The proportion of females make up 58.5% and 81.0% of small and large salmon, respectively (Table 11, 12). Mean lengths of sampled adult female salmon captured in the Big Salmon River are 55.1 cm for small salmon and 69.2 cm for large salmon (Table 11, 12).

Egg deposition estimates for the Big Salmon River population were determined from a length-fecundity relationship established for Atlantic Salmon in the Stewiacke River (eggs = $431.3*e^{0.0368*FL}$; Amiro and MacNeill 1986); an IBoF index river that best represents salmon of the IBoF DU. Therefore, fecundity of small and large salmon returns to the Big Salmon River respectively average 3,276 and 5,505 eggs. To estimate the total egg contribution from the non-target LGB adult releases in 2003 to 2005, Jones et al. (2006) developed a length-fecundity relationship from 29 female, two-year captive-reared Atlantic Salmon from the SJR broodstock (compensation) program at MBF in 2005.

From 2003 to 2019 (no adults were sampled in 2004, 2012, 2013, and 2017), 196 small salmon have been captured (either by net or angling) and tissue sampled on the Big Salmon River (Table 13). Based on parentage analysis of the small salmon sampled, 49 of 196 samples processed can be attributed to LGB releases. Thirty-eight (38) were released as unfed fry, while the remaining 11 were returns released as adipose clipped fall parr. Another 37 small salmon were progeny of previously sampled adult returns. Two adipose clipped small salmon did not assign to the Big Salmon River LGB program and, therefore, were likely hatchery-origin strays from a nearby river (Table 13). The number of small salmon sampled annually has averaged about 25%, but it varied between 0% and 66% of the total abundance estimates (Table 13). Taking the annual proportion of the total actual returns (small and large salmon) into account and adjusting the genetic results to the total small salmon returns, the actual returns since 2005 breakdown is as follows: 106 LGB fry releases, 22 LGB parr releases, 120 wild spawner adult returns and three adipose clipped strays (Table 14). From 2005 to 2019, when LGB-origin small salmon were expected based on previous LGB releases to the Big Salmon River, progeny of LGB fry and parr releases represented 24% of the total small salmon returns (Table 14). From the samples of large salmon analyzed (n = 22), another three adults can be assigned to the LGB (2 fry and 1 parr) and another adipose clipped stray was observed (Table 15). Given the small number of samples, no attempt was made to apply the genetic results to the total large salmon returns.

An analysis of 220 scale samples collected from wild- or unknown-origin small and large salmon captured on the Big Salmon River from 2000 to 2019, indicate that the majority of returning adults continue to mature after 1SW (98.2%), but repeat spawners are much less prevalent (9.5%) than during the late 1960s and 1970s (Jessop 1986, Amiro 2003). Only four large salmon matured as maiden 2SW salmon (Table 16). Similar to the historical samples summarized by Amiro (2003), there was a high percentage (58.3%) of females among the 1SW salmon sampled since 2000. The data collected from the 50 small and large LGB salmon during the more recent time period indicated similar results (94.0% 1SW of which 59.6% were females) as wild- or unknown-origin salmon (Table 16).

Proportionally more wild salmon of smolt age-2 years are found in the 1SW maiden salmon group compared with smolt age-3 years (Table 16). Over all the years sampled, 2000 to 2019, the proportions of 1SW at smolt age-2 and age-3 for 1SW maiden returns are 80.4% and 18.9%, respectively. In the Big Salmon River, 2000 to 2019, the mean generation time, defined as the average age of salmon returns from a year class (egg deposition to egg deposition), is 4.3 years for wild returns. For comparison purposes, mean generation time of LGB_{FRY} returns was also 4.3 years whereas mean generation time of total LGB origin (LGB release life stages combined) was lower at 3.8 years (Table 16).

Gaspereau River

Adult salmon ascending the Gaspereau River encounter several migration barriers (Figure 5), although both upstream and downstream passage exists at the White Rock Hydro Station, Lanes Mills (Gaspereau Lake), and at Aylesford Lake (Meade 2000). Since 1995, salmon have been enumerated at the White Rock Dam, which now includes an assessment trap after retrofitting in 2002 (Table 17). Scale and tissue samples, sex, and lengths are obtained from the individuals caught in the trap at the fishway and a PIT tag is injected for individual identification.

Since the LGB program was initiated on the Gaspereau River, adult returns captured in the pool and weir fishway at the White Rock Dam have been tissue sampled to determine origin of returns. Based on the genetic analysis, and for those years when LGB-origin adults were expected, most of the returning adults assign via parentage analysis to LGB salmon either from captive spawning in the LGB program at CBF or through natural spawning of LGB adults released in the Gaspereau River and are, therefore, LGB in origin. Salmon that do not assign to LGB parents are assumed to be either from the residual wild population or un-genotyped LGB adult releases in the Gaspereau River. From 2005 to 2019, 3.5% and 18.6% of the small returns and 3.2% and 16.1% of the large returns were progeny of wild or non-genotyped LGB adults.

Egg deposition of sea-run releases is calculated using the length-fecundity curve, where the number of eggs = $446.54 * e^{0.0362 * FL}$ (Cutting et al. 1987), and was derived from LaHave River adults. The length-fecundity curve (eggs = $309.8 * e^{0.045 * FL}$) for the Gaspereau River captive-reared adult releases was developed based on a 2006 egg count of 14 females broodstock ranging from 44 to 85 cm in length (B. Lenentine, DFO Science, unpublished data).

Based on biological characteristics data collected from wild, unknown, and LGB-origin adult returns to the Gaspereau River from 2001 to 2016, mean length and mean fecundity (number of eggs) of 1SW maiden female spawners are 53.6 cm and 3,100 eggs, respectively (Jones et al. 2020; Table 18). Mean length (68.6 cm) and fecundity (5,385 eggs) of wild and unknown origin 2SW maiden are both slightly less than those respective values for 2SW maiden returns of LGB origin (Table 18).

An analysis of 125 scale samples collected from wild- or unknown-origin small and large salmon captured on the Gaspereau River from 2001 to 2016, indicate about 60% were maiden 1SW, 36% maiden 2SW and 3% repeat spawning salmon (Table 18). Scale analysis of the LGB and hatchery-origin small and large salmon were very similar (63% 1SW; 33% 2SW; 3% repeat spawners) to the wild-origin fish with the addition of one 3SW salmon. The Gaspereau River population is comprised of a higher proportion of maiden 2SW salmon compared to the Big Salmon River adult returns (Table 16, 18). Given that these data have not been updated since 2016, an important difference noted by Jones et al. (2020) is still evident, that being a lower proportion of females comprise the LGB-origin small salmon group compared to both recent (Table 18) and historical wild-origin small salmon returns (Amiro and Jefferson 1996).

In the Gaspereau River, 2000 to 2016, the mean generation time (egg deposition to egg deposition) is 4.7 years for returns of wild or unknown origin. For comparison purposes, mean generation time of LGB origin returns was 4.0 years.

IBoF Salmon Adult Run Timing

Most IBoF Atlantic Salmon maiden and repeat spawners enter rivers in the late summer and fall of the year (Amiro 1987, Amiro and Jefferson 1996) as historical recreational fisheries opened in August and closed in October (Amiro 2003). Notable exceptions are the Gaspereau River and the Big Salmon River (Amiro and Jefferson 1997). Gaspereau salmon enter freshwater earlier in the year (May and June) and are considered to have distant migratory tendencies with a higher incidence of 2SW recruitment (Amiro and Jefferson 1997). The Big Salmon River population has biological characteristics typical of the DU, but some portion of the run ascends the river in July and August and possibly earlier as a recreational fishery historically occurred in June and July (Amiro 2003). Marshall (2014) used data from the Big Salmon River counting fence (Jessop 1986) and recreational fishery data (O’Neil and Swetnam 1984, Swetnam and O’Neil 1985) to establish the temporal distribution of Big Salmon River, Upper Salmon (Alma) River, and Gaspereau River salmon in coastal and riverine estuary corridors of the BoF, outer Chignecto Bay, Cobequid Bay, Minas channel and Minas Basin (Figure 14).

REVIEW OF DESIGNATABLE UNIT 15 – INNER BAY OF FUNDY

COSEWIC considers the IBoF Atlantic Salmon population as a unique DU, distinct from neighbouring regional groupings, specifically Outer Bay of Fundy (OBoF) and NS Southern Upland (SU), based on a review of genetic, phylogeographic, local selection, life history, behavioural, and demographic evidence (COSEWIC 2006, 2010). IBoF salmon populations are genetically distinct (Verspoor et al. 2002, Verspoor 2005, Moore et al. 2014, O’Reilly et al. 2014, Jeffery et al. 2018) and possess some unique life history traits compared to OBoF salmon, including an earlier age at maturity with a high proportion of females among individuals that mature after 1SW, a hypothesized local marine migration, a greater incidence of repeat spawning (typically consecutively), and until recently a higher survival between spawning events (Amiro 1987, Amiro and Jefferson 1996, Amiro 2003, DFO 2008b). There is also limited evidence of demographic uncoupling with other nearby DUs (Amiro 1987, 1990, 2003). A notable exception is the Gaspereau River, which despite being genetically similar to populations in the Minas Basin (Verspoor et al. 2002, Verspoor 2005), displays life history traits more characteristic of OBoF and SU populations that migrate to distant oceanic areas in the North Atlantic (Amiro and Jefferson 1996, Amiro 2003, DFO 2008b). However, the Big Salmon River has also had higher incidences of 2SW salmon possibly as a result of hatchery introductions (Amiro and Jefferson 1997).

COSEWIC (2006) interpretively reviewed measures of genetic divergence between IBoF salmon and other regions based on the combined results of studies attempting to resolve population structure across the species North Atlantic distribution. Allozyme, mitochondrial DNA, and microsatellite data suggest divergence among DUs 14,15,16 (Verspoor 2005, Verspoor et al. 2005, O'Reilly 2006, COSEWIC 2010). Mitochondrial DNA analysis identified a genetic haplotype unique to the Minas Basin (including the Gaspereau River) populations and a rare haplotype shared by salmon populations throughout IBoF rivers (Verspoor et al. 2002). Accordingly, the Minas Basin and Chignecto Bay groupings of salmon populations, collectively known as IBoF salmon, may be considered genetically and geographically separated (DFO 2008b). The microsatellite and single nucleotide polymorphism (SNP) analysis of Moore et al. (2014) was also consistent with previous studies suggesting IBoF populations were evolutionarily distinct (McConnell et al. 1997, Verspoor et al. 2002, Vandersteen Tymchuk et al. 2010) and that differentiation existed between Chignecto Bay and Minas Basin populations (Verspoor et al. 2002, Vandersteen Tymchuk et al. 2010). A SNP panel developed by Jeffery et al. (2018) was also able to differentiate IBoF, western NS, and SJR populations at a high level of accuracy.

The RPA (DFO 2008b) raised concerns that the rapidly developing Atlantic Salmon farming industry in the BoF was potentially limiting recovery of IBoF salmon because of the negative genetic impacts of cultured escapees on the fitness of wild salmon through interbreeding. European farm salmon ancestry, the proximate source of which appears to be the local BoF/Gulf of Maine (GoM) industry, has been detected in salmon collected from the Upper Salmon and other IBoF rivers (DFO 2018). These and other results reported in O’Reilly et al. (2019) indicate that local farm salmon escapes exhibiting European ancestry, or their European farm/North American farm hybrid offspring, appear to have been spawning in nearly all IBoF rivers during all or most years within the period of examination spanning 1997 to 2012. Additionally, results from several analyses are all consistent with the genetic structuring between OBoF and Big Salmon River populations decreasing over time which could represent a risk to the conservation of IBoF genetic characteristics in the Big Salmon River LGB population (DFO 2018).

The approach used to conserve genetic variation and minimize loss of fitness in the IBoF LGB program has been reviewed in O’Reilly and Doyle (2007), O’Reilly and Harvie (2010) and O’Reilly and Kozfkay (2014). A comprehensive analysis and review of the IBoF Atlantic Salmon science associated with the LGB program was recently conducted (DFO 2018). Its purpose was to primarily evaluate the success of conserving genetic characteristics of the IBoF salmon population across three generations of captive breeding and rearing. Other published studies resulting from the review assess some of the effects of captive breeding and rearing on IBoF salmon performance in the wild and phenotypic trait characteristics (Harvie et al. 2020) and describe genetic change (loss of genetic variation, including accumulation of inbreeding, and drift-induced changes in allele frequency distributions) associated with neutral processes over the course of the program (O’Reilly et al. 2019).

POPULATION STATUS AND TRENDS

Evaluation of the status of Atlantic 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 the returning adult salmon population) relative to a reference point known as the Conservation Egg Requirement (CER). The river-specific CER is based on an egg deposition of 2.4 eggs/m^2 (Elson 1975, CAFSAC 1991) multiplied by the amount of accessible fluvial rearing habitat that is of suitable gradient (Amiro 1993). An egg deposition of 2.4 eggs/m^2 is considered a limit reference point in the context of DFO’s Precautionary Approach Framework (DFO 2009, DFO 2012, Gibson and Claytor 2013) for DFO’s Maritimes Region.

Conservation requirements for many of the rivers in the IBoF DU are reported in Gibson et al. (2009). River specific adult abundance monitoring in all IBoF rivers that receive LGB support are not feasible due to the size of the program and the extent of the geographic area between release rivers in the DU. Throughout the lifespan of the LGB program, there have been at least 15 LGB supported rivers that have not had annual adult assessments. Currently, DFO conducts adult salmon assessment and monitoring annually on two of three principal LGB rivers, the Big Salmon and Gaspereau. Since the LGB program was initiated, most of the adult returns captured on either river have been tissue sampled to determine origin.

STATUS UPDATE RELATIVE TO CONSERVATION REQUIREMENTS

Big Salmon River

Each year, the number of adult salmon returning to the Big Salmon River is estimated by diver counts using mark-recapture methods (Gibson et al. 2004). If sufficient numbers of salmon are tagged, an abundance estimate is generated (i.e., 2007 and 2010) using an aggregated Bayesian model assuming a binomial distribution. If not, a single census mark-recapture value (0.57 from Gibson et al. 2004) is applied to the largest observed count for that season. A good representative sample of returning adults was not captured through seining activities in every year, therefore the annual adult abundance estimates were divided into small and large spawners based on the diver observations (i.e., ratio of small to large).

Since 2003, the first year in which adult returns from the LGB program were expected, combined small and large salmon abundance estimates have averaged 44 fish, ranging from 11 (2013) to 118 (2011) (Table 10; Figure 15). The biological characteristics data (i.e., sex ratio and mean length) collected since 2000 was used to calculate the annual egg deposition estimates, although sufficient samples for each size category were not obtained each year (Table 12). For those years with less than six fish (per size group), the mean data for the time-series was used. For small salmon, the minimum sample size was collected for 11 of the 20 years, while there were no years in which at least six large salmon were captured and subsequently sampled for biological characteristics (Tables 11, 12).

Approximately 280 small salmon and 420 large salmon are required to achieve the CER of 2.2 million eggs established for the Big Salmon River by Marshall et al. (1992). Based on the length-fecundity relationship from Amiro and MacNeill (1986), and using the mean sex ratio and female length (2000 to 2019), the egg deposition estimates in 2019 were 49,828 eggs for the small and 31,213 eggs for the large salmon returns (Table 12). Combined, this represents 3.7% of the CER for the Big Salmon River in 2019. Since 2000, the annual egg deposition estimates on the Big Salmon River have been below 10% of the CER in 18 of the 20 years assessed and averaging 4.4% over the time series (Figure 16). Based on the length-fecundity relationship for captive-reared adults (Jones et al. 2006) and using the annual sex ratio and mean length (female) data, the egg deposition estimates from 2003 to 2005 for the non-targeted LGB adult releases ranged from 138,814 to 283,646 (Table 13). Estimated egg depositions from these LGB adults released in the headwaters of the Big Salmon River more than doubled overall estimated egg depositions in those years (Figure 16).

Gaspereau River

Adult returns to the Gaspereau River are monitored by counting the small and large salmon ascending the pool and weir fishway that provides upstream passage above White Rock Dam. Since 2002, individuals caught in the fishway assessment trap were held for incorporation into the Gaspereau LGB program or released upriver to spawn naturally if catches were greater than 10 adults. In 2019, 14 small salmon and eight large salmon were captured in the fishway trap and transported to CBF for possible inclusion into the LGB program (Table 17). However, the large salmon count in 2019 included eight LGB returns that were released in the spring of the year as reconditioned kelts equipped with two types of acoustic transmitters to determine coastal and oceanic distribution and survival (Table 17). The mean count since initiation of the Gaspereau LGB program in 2005 has been eight fish ranging from two to 22, and recent annual counts remain amongst the lowest in the time series (Table 17; Figure 17).

The area above White Rock and below Lane Mills (including Trout River) represents 86% of available salmon habitat in the Gaspereau River system. The required egg deposition for this 332,500 m^2 of habitat is 798,216 eggs in order to reach conservation requirements (Gibson et al. 2009). The available habitat and conservation target estimates exclude the habitat above Lanes Mills, as the current management arrangement limits salmon to downstream of Lanes Mills to avoid turbine mortality in other areas of the watershed (Gibson et al. 2009). Spawning escapement from 1997 to 2001 was estimated by Gibson et al. (2004). No spawners were released above White Rock from 2002 until 2005 and egg deposition for those years since 2006 was estimated when either anadromous returns, any ‘retired’ repeat spawning broodstock (no longer used in the LGB program), and/or any non-targeted LGB adults from the Gaspereau LGB program were released to spawn naturally (Jones et al. 2020). If available, the biological data (i.e., female sex and length) from the individual fish handled and released upriver was used to estimate egg deposition. In the case of the non-targeted LGB adults, a sub-sample of the total number of fish released was used. Using the length-fecundity curve eggs = $446.54*e^{0.0362*FL}$ (Cutting et al. 1987) for anadromous spawners and the length-fecundity curve (eggs = $309.8*e^{0.045*FL}$) for LGB adult releases, the egg deposition estimates since 2006 have ranged from 33,821 to 513,649 eggs for the three groups of spawners combined (Figure 18). Since 2006, egg depositions from anadromous returns have never exceeded 80,000 eggs or 10% of the CER. In 2006, 2007, and 2012, the estimated eggs from the non-targeted LGB adults released above White Rock Dam have been close to the CER (Figure 18).

IBoF Atlantic Salmon DU 15

A full assessment of the status of the IBoF Atlantic Salmon DU has not been conducted since 2008 (Gibson et al. 2009, DFO 2008b). Returning adult population estimates for the LGB supported rivers within DU 15 from 2013 to 2017 were reported in DFO (2020). The authors concluded that, even with the uncertainty in the annual population estimates, recent abundance of adult Atlantic Salmon in the IBoF DU has consistently remained below the 1999 estimate of less than 250 returning adults despite the contribution of the LGB program and associated supplementation efforts. Furthermore, the 1999 population estimate was comprised primarily of wild-origin fish, whereas the current estimates (adult returns less than 105 in 4 of 5 years) predominantly originate from LGB supplementation. IBoF rivers remain well below conservation requirements due to poor marine survival (DFO 2008b, 2018, 2020, Jones et al. 2020) (see Other Indicators).

TRENDS IN ABUNDANCE AND ESCAPEMENT

Trends in adult abundance were analyzed for the Big Salmon River Atlantic Salmon population from total combined small and large returns as well as total egg deposition from wild and LGB origin spawners (Table 12). Using a method similar to that described by Gibson et al. (2011), trends in returns and escapement of combined sea-age and origin were analyzed over the past three generations or most recent 13-year period using a log-linear model:

$$N_t = N_0 e^{zt} ,$$

Where N_0, the estimated population size at the start of the time series, and z, the instantaneous rate of change in abundance, are estimated parameters. For a given value of z, the percent change in the population size over a given number of years, t, is $(e^{z*t}-1)*100$. This model was fit using least squares after transformation of the data to log scale.

Plots of abundance and the log-linear fit for total returns and total egg deposition both indicate declines over the past three generations or 13 years (Figure 19, 20), with predicted decline rates of 59% and 61%, respectively (Table 19). Despite contributions from an average of 46 anadromous spawners (Table 10), as well as substantial juvenile releases from the LGB program (Table 1) that resulted in smolt outputs in the vicinity of 10,000 fish annually between 2006 and 2019 (Table 4, Figure 7), the Big Salmon River continues to remain well below conservation levels and this appears to be due to poor marine survival (see Other Indicators).

Trends in returns and escapement to the Gaspereau River were analyzed using the log-linear model described for the Big Salmon River population. The two data sets analyzed for the Gaspereau River were total returns (small and large salmon combined) and total egg deposition from wild and LGB origin spawners (Table 9). Plots of abundance and the log-linear model fit for total adult returns suggests an increasing population size over the past 10 years as evident from the negative value for the decline rate (-29.95%) (Table 19; Figure 21). The predicted decline rate from the log-linear model over the past 10 years for spawning escapement was 43.73% (Table 19). However, the confidence intervals on this model fit includes a negative, indicating the regression is not significant and it is possible that there was no change or even an increase in egg deposition in the past 10 years (Figure 22). This is likely a result of the relatively higher egg deposition estimate in 2012 with greater than 95% of eggs in that year being contributed by mature adult LGB releases (Figure 18), assuming they spawn successfully. It is also important to consider that the sea-run Gaspereau returns are probably influenced by the hydro dam facilities located throughout the river, which alter various hydrological conditions (e.g., water flow, level and temperature) predominately below White Rock.

AREA OF OCCUPANCY

The IBoF Atlantic Salmon Recovery Strategy (DFO 2010) identifies 10 rivers that contained residual native populations essential to the persistence of IBoF salmon: Big Salmon, Upper Salmon, Point Wolfe, Economy, Portapique, Great Village, Folly, Debert, Stewiacke, and Gaspereau rivers. Of these 10 critical rivers, only the Portapique does not receive support from the LGB program. Since 2010, there have been at least 15 LGB supported rivers where juvenile and adult Atlantic Salmon have been released (Table A1, A2).

The first broadscale electrofishing surveys of juvenile Atlantic Salmon in IBoF rivers were carried out in 2000, 2002, and 2003 (Gibson et al. 2003a, 2004). These authors suggested that, while densities were increasing (yet remained low) in rivers with LGB support, river-specific extirpations in non-supported LGB rivers were ongoing. The interest for updated electrofishing surveys of juveniles in the IBoF region in 2013 and 2014 was to address specific objectives of the LGB program review and its contribution to IBoF salmon population recovery (DFO 2018). Both the directed Stewiacke River electrofishing survey (2013) and the broadscale IBoF electrofishing survey (2014) were designed to evaluate recent status of juvenile abundance and investigate the return and reproductive success of sea run spawners into rivers of both LGB-supported (Stewiacke in 2013 and Salmon River [Colchester] in 2014) and, most importantly, currently unsupported rivers (33 IBoF rivers).

For the 2013 Stewiacke River survey, a total of 40 sites were electrofished of which 11 were historical reference sites previously sampled for monitoring trends in juvenile abundance. A total of 402 juveniles were collected and tissue sampled. The genetic analysis of the juveniles caught detected an estimated presence of only two ‘unknown’ (wild or un-genotyped LGB releases) female spawners in the parentage assignment. A detailed summary and analysis of the results are presented in Appendices 9 and 10, Figures 32 and 33, and Tables 28–30 of Jones et al. (2020).

During the 2014 broadscale survey, a total of 34 rivers and 85 sites comprised of accessible prime salmon habitat were electrofished. Juvenile salmon were detected in only seven rivers (range: one to 31 salmon caught per river, one to six sites fished per river). Only five non-LGB supported rivers had juvenile salmon present and at low densities: four NB rivers (Irish, Mosher, Black, and Mispec rivers) and the Portapique River in NS. Genetic analysis of the salmon caught in the North Chignecto portion of the IBoF, in proximity to the SJR (OBoF DU) indicated that those fish are not likely IBoF origin (O'Reilly et al. 2019, Jones et al. 2020).

Considering LGB distributions within the past 10 years and the results of the directed and broadscale electrofishing surveys in 2013–14, the freshwater distribution of remaining IBoF salmon populations is probably restricted to 20 rivers (15 LGB supported, five non-LGB supported) with minimal or lack of contribution from truly wild spawners.

The extent of marine occupancy and occurrence includes at least the BoF and outlying oceanic waters (COSEWIC 2006). DFO (2013) proposed that important marine and estuarine habitat for IBoF salmon included the tidal portions of 19 IBoF salmon rivers and the entire BoF outward to the northern GoM and the Canada/U.S. boundary, southward to latitude 43°46'51.

HABITAT CONSIDERATIONS

FUNCTIONAL PROPERTIES

Freshwater Environment

Freshwater habitat use by Atlantic Salmon has been thoroughly reviewed (e.g., Bjornn and Reiser 1991, Gibson 1993, Bardonnet and Bagliniere 2000, Armstrong et al. 2003, Rosenfeld 2003, Amiro 2006, Bowlby et al. 2014, Marshall et al. 2014). Salmon require several different habitats to complete a life cycle, and as a salmon grows to maturity, habitat requirements change. Connectivity among habitat types is an important determinate of growth, survival and lifetime reproductive success. Gibson (1993) identified three major freshwater habitat types

1. feeding habitat,
2. winter habitat, and
3. spawning habitat.

Armstrong et al. (2003) further separated the habitat requirements of early life stages into nursery and rearing habitat, and identified habitat that was used during upstream migration. Habitat quality can be affected by:

1. seasonal temperatures,
2. stream discharge,
3. water chemistry (e.g., pH, nutrient levels, oxygen concentration),
4. turbidity,
5. invertebrate abundance, and
6. physical perturbations (e.g., impoundments, deforestation), as well as many other factors (Gibson 1993, Armstrong et al. 2003).

IBoF salmon habitat preferences and requirements assumed common for all types of freshwater habitat (i.e., temperature, gradient, etc.) have been addressed in Amiro et al. (2008a) and DFO (2008b). Critical habitat for IBoF salmon has been identified to the extent possible in Section 2.5 of the Recovery Strategy (DFO 2010). Critical habitat as defined under section 2 of SARA is the "habitat necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species". The Gaspereau, Stewiacke, Debert, Folly, Great Village, Portapique, Economy, Upper Salmon, Point Wolfe and Big Salmon rivers contain freshwater critical habitat for IBoF salmon. Freshwater critical habitat consists of riffles, runs and staging or holding pools found below complete natural barriers (i.e., waterfalls) in these 10 rivers (and their tributaries). The Recovery Strategy (DFO 2010) contains details about this identified critical habitat including its geographical location and biophysical functions, features and attributes.

Estuarine/Marine Environment

Marine habitat requirements for IBoF DU Atlantic Salmon are less well known than those for freshwater. In part, the lack of information is due to the challenges associated with collecting data and tracking salmon during their migrations in the marine phase. Nonetheless, DFO (2006a) reviewed conventional tagging (Jessop 1976, Amiro and Jefferson 1996, Amiro et al. 2003) and acoustic telemetry (Lacroix et al. 2005) studies of post-smolts, and to a lesser extent adult salmon, showing that there is a body of evidence indicating that some areas have a long history of use by specific life-stages and that IBoF salmon do move throughout most of the BoF during their marine phase (DFO 2008b). Trawl surveys and monitoring of acoustically tagged smolts of wild and hatchery origin provides direct evidence that some post-smolts of IBoF origin utilize habitat in the BoF and northern GoM from May to October (Lacroix and Knox 2005, Lacroix et al. 2005, Lacroix 2008, 2013a). However, some proportion of ultrasonically tagged smolts of Big Salmon River origin were shown to leave the BoF early and rapidly without returning, a similar behaviour noted for post-smolts of OBoF origin considered to be distant migrants (Lacroix 2013a). Hubley et al. (2008), on the basis of post-smolt scale circulus spacing patterns, determined that all Big Salmon River fish sampled between 1999 and 2005 exhibited wider spacings similar to distant migrating salmon populations from DU 14 – NS SU.

DFO (2013) identified important functions for the marine and estuarine habitat of all IBoF salmon life history stages (smolts, post-smolts, mature adults, and kelts) to be migration, feeding, and staging. Important features identified were migration corridors, estuarine holding pools, surface waters, upwellings, and food availability. Important attributes of these features include temperature, salinity, water flow, depth/volume, forage species, and predator abundance. Marshall (2014) reviewed in more detail these functional descriptions, features and attributes of IBoF marine and estuarine habitat.

Overwintering habitat of all stages and summer habitats of coastal resident and distant migrating post-smolts and maturing adults of IBoF origin largely remain undocumented. Although, the migration paths of IBoF kelts tagged with 4- and 6-month duration pop-up satellite archival tags (PSATs) revealed their fall–winter and spring habitats and by corollary, perhaps mimicked those of post-smolts and maturing adults of similar origin (Lacroix 2013b, 2014).

SPATIAL EXTENT AND CONSTRAINTS

Freshwater Environment

The freshwater habitats used by Atlantic Salmon from the IBOF DU range across southeastern NB and north central NS (Figure 1) and includes all rivers (50 named rivers; DFO 2010) draining into the BoF, from the Mispec River (the first river northeast of the SJR in NB) to the

Pereaux River (the first river northeast of the Annapolis River in NS) (Figure 2). Recreational catch data since 1970 and historical electrofishing surveys indicate that at least 32 IBoF rivers supported self-sustaining salmon populations (Amiro 2003, COSEWIC 2006). Another 10 rivers and streams are reported to have produced salmon at least intermittently in the past (National Recovery Team 2002, COSEWIC 2006). These include the Avon River in NS and nine river systems in NB (i.e., Memramcook, Weldon, Goose, Quiddy, Little Salmon, Tynemouth/Bains Brook, Gardner, Emmerson and Mispec).

Within a given watershed, spawning locations, adult holding pools, as well as juvenile rearing habitat, are distributed throughout the system, with habitat quality varying due to factors such as stream discharge, substrate type, temperature, and food availability (see Bowlby et al. 2014 for details), all of which may be influenced by human activities. Stream gradient is a habitat parameter known to influence water flow characteristics, channel morphology, sediment sorting processes, and the amount of energy required to occupy a habitat (Gibson et al. 2008). Gradients greater than 0.12% and less than 25% are considered to be productive salmon habitat (Amiro 1993, O'Connell et al. 1997). From available remote-sensed habitat data (gradient, stream width, and distance from the mouth measured from ortho-photo maps and aerial photographs), productive capacity of habitat in 22 IBoF rivers was estimated to be greater than 9,000,000 m^2 (Amiro 1993, Amiro et al. 2003). Of the 22 IBoF rivers for which habitat measurements are available, four rivers have less than 1,000 habitat units (100 m^2) in the gradient categories greater than 0.12% and less than 5% and 12 rivers have more than 3,000 habitat units (Amiro et al. 2003).

Spatial constraints on freshwater habitat in the IBoF Atlantic Salmon DU includes factors related to human activities such as forestry, agriculture, road development, and barriers (dams, dykes, and causeways) (Amiro et al. 2008a). Barriers exist on at least 25 major rivers in the BoF and have caused or are thought to have caused a wide range of ecological effects on rivers and their estuaries (Wells 1999). Construction of the Petitcodiac River causeway in 1968 (the gates of the Petitcodiac Causeway in Moncton, NB have been open since spring 2010) largely obstructed the passage of adult salmon and smolt and is estimated to have reduced the total IBoF salmon production by at least 20 percent (National Recovery Team 2002, Locke et al. 2003). In turn, this decrease in production may have affected the persistence of the entire IBoF, particularly if straying and mixing of wild salmon among rivers is important for population viability (COSEWIC 2006, Fraser et al. 2007, references therein).

While anthropogenic sources of freshwater degradation have certainly impacted access to spawning and rearing areas and reduced salmon production capacity of the IBoF region for over a century, the timing of occurrence does not correspond with the greater than 95%–99% decline rate for these populations during the last 30 years (Gibson and Amiro 2003, Gibson et al. 2003c). A critical habitat case study of IBoF Atlantic Salmon conducted by Trzcinski et al. (2004) concluded that population viability and specifically recovery to conservation limits could not realistically be achieved by increasing the quantity or quality of freshwater habitat under current marine survival conditions. They noted that the presence of salmon in rivers with LGB support indicates that these rivers contain habitat capable of supporting salmon at least from the fry to the smolt stage. This is to say, freshwater habitat is not limiting recovery at present (Amiro et al. 2008a). Accordingly, freshwater habitats in the 10 rivers that contain residual native populations and contribute to the LGB program are considered critical to recovery. Appendix IVa of the Recovery Strategy (2010) provides a detailed view of the critical habitat boundaries for these 10 watersheds.

Estuarine/Marine Environment

As reviewed in DFO (2013) and Marshall (2014), best available sources of information on the estuarine and marine distribution of Atlantic Salmon populations in DU 15 support the conclusion that IBoF salmon of all life stages migrate through (including migration through estuaries of natal rivers), and some portion establishes a residency within, the BoF and northern GoM from May to October (at a minimum). Compared to other Atlantic Salmon populations in the Maritimes Region, including the neighbouring OBoF DU, a relatively small number of recaptures of tagged IBoF salmon have come from more distant oceanic areas (Ritter 1989, Amiro 2003, ICES 2007). All IBoF salmon post-smolts utilize a portion of the BoF and GoM for migration to nursery habitat and that in some years the majority of post-smolts remain in the Bay throughout the entire summer growth season (DFO 2013, Marshall 2014). All returning adults and to some extent, post-spawn kelts, are known to utilize coastal habitats near their rivers of origin for a portion of the year as a migratory corridor to access spawning habitat (Amiro 2003) and then afterwards, as possible reconditioning habitat (Lacroix 2013b). However, data from 2SW salmon (e.g., Gaspereau River) are limited, as are data from the November-April period for any life stage (Marshall et al. 2014). Therefore, it is likely that additional habitats of importance to a distant migrating component of IBoF salmon, as well as overwintering habitats, are not contained to coastal areas in the BoF and GoM (DFO 2013).

On the basis of a simple composite of direct and indirect evidence of occupancy, Marshall (2014) postulated that important habitat for all IBoF Atlantic Salmon life stages is the tidal portions of its' 'inner Bay' rivers, and the entire BoF outward to the northern GoM. Estuarine habitat of IBoF Atlantic Salmon (particularly tidal portions of natal rivers) is relatively easily defined; however, not unexpectedly, many marine habitats and their use by the various life stages in the BoF are widespread, overlap and are therefore difficult to define geospatially, particularly when most occupancy data are non-continuous. Using a bounding box approach, important estuarine and marine habitat of IBoF Atlantic Salmon is proposed as: the tidal portions of 19 IBoF salmon rivers and the entire BoF outward to the northern GoM and the US/Canada boundary, southward to latitude 43°46'51 (DFO 2013). The southern boundary was determined based on research trawl recaptures of wild post-smolts of Big Salmon River origin in the BoF and GoM during May and June of 2001–03 (Lacroix and Knox 2005). The 19 IBoF salmon rivers for which the tidal portions have been identified as important are the same rivers identified as the long term distribution target in the Recovery Strategy; ten of these rivers are currently identified as containing freshwater critical habitat (DFO 2010). This large area of important marine and estuarine habitat was further subdivided into eight smaller areas of the BoF. Based on a cursory evaluation of three criteria (number of life-history stages using the area, importance to the life-history stage, and whether there were alternative habitats available), the tidal portions of 19 IBoF salmon rivers (Area 1), Minas Basin and Chignecto Bay (Area 2), and coastal Southwest NS: Port George to Hall's Harbour (Area 8), were identified as the highest priority areas. An inclusive approach to the delineation of IBoF salmon marine critical habitat boundaries in Minas Basin and Chignecto Bay is provided in DFO (2016a).

Notwithstanding the uncertainties of characterizing the extent of estuarine and marine habitat use of the BoF by various life-history stages of IBoF DU Atlantic Salmon based on very limited data, observed temperature conditions in relation to tag recovery and detection information suggest that suitability within the BoF and northern GoM varies seasonally (Amiro et al. 2003, Lacroix 2013a). Spatial analysis of potential marine habitat based on salmon temperature preferences and average monthly sea surface temperatures (SST) derived from satellite data for 1981–2000 indicated that suitable habitat was constrained to the Fundy Isles, OBoF, and off the southwestern coast of NS from August to September (Amiro et al. 2003). Rapidly changing SSTs in the BoF and GoM during June and July of 2001 (this SST pattern was replicated again in 2002), when Atlantic Salmon post-smolts were migrating and residing in the area, greatly reduced the habitat area with cold water suitable for salmon (SST <15 °C) and it was limited to several pockets where resident post-smolts were found during the summer (Lacroix 2013a). Coastal marine habitat availability is also limited from February to April, when mean SSTs are at the low end of the temperature range (Amiro et al. 2003, Marshall 2014). Results from PSAT tagging of kelts from IBoF populations indicated avoidance of marine habitat with SSTs >15 °C in spring and summer and the supercooled surface layer in fall and winter suggesting seasonal water temperature-related habitat constraints (Lacroix 2013b). Still, temperature is only one component of marine habitat and there are a number of threats affecting conditions in the marine environment that may be contributing factors to the continued decline of the IBoF salmon population (DFO 2006a, Amiro et al. 2008a).

THREATS

Since the previous COSEWIC status assessment in 2010, there has not been a new Recovery Potential Assessment for the IBoF DU. Therefore, much of the information on threats to the IBoF DU relies on information provided in Amiro et al. (2008b) and DFO and MRNF (2008, 2009) and is similar to the COSEWIC assessment in 2010 except when updated information was available. In Amiro et al. (2008b) and DFO and MRNF (2008, 2009) threats were assessed based on the extent and severity of the threat but the level of concern rating was not implemented at this time. Therefore, using the extent and severity ratings provided in Amiro et al. (2008b), this report has updated threats to include level of concern (Table A3) following the procedure for consistently assigning level of concern rankings (see DFO 2014).

Amiro et al. (2008b) concludes that the freshwater environment is likely not currently impeding the IBoF population recovery and freshwater threats may only become of concern if marine threats can be reduced or mitigated and marine survival improved. Within the marine environment, only ecosystem change was assigned a high level of concern. However, the severity and extent of these threats may have changed since the assessment of Amiro et al. (2008b).

RESIDENTIAL AND COMMERCIAL DEVELOPMENT

Housing & Urban Areas

The effects of urbanization is discussed in terms of altered hydrology (see section Dam & water management/use).

Commercial and Industrial Areas

No DFO data.

Tourism and Recreation

No DFO data.

AGRICULTURE AND AQUACULTURE

Annual & Perennial Non-Timber Crops

Although agriculture was identified as a threat to habitat within IBoF rivers (Amiro et al. 2008b), the National Recovery Team concluded that freshwater habitat was still of sufficient quality to support IBoF salmon populations (DFO 2006b).

Livestock Farming and Ranching

No DFO data.

Marine & Freshwater Aquaculture

The development of salmonid aquaculture within the BoF and GoM over the last 20 years has increased the likelihood of wild and aquaculture salmon interactions (Amiro et al. 2008b). These interactions can lead to negative effects on populations via, habitat alterations, competition, predator attraction, disease transfer and genetic introgression. Aquaculture occurs in both the marine and freshwater environments with the former likely being a higher threat to population persistence as it predominantly effects older salmon and has a higher chance of leading to genetic introgression.

In the freshwater environment, aquaculture threats stem from contamination and escapees. Most aquaculture facilities use a flow-through system that diverts river/stream water through tanks within the facility and discharges the waste water downstream (Michael 2003). The wastewater is a source of elevated nitrogen and phosphorus, chemical residues (antibiotics) and solid organics that can lead to increased siltation and reduced oxygen content downstream of the facility (Michael 2003, Camargo et al. 2011. Salmon can also escape from the facilities resulting in increased competition, predator attraction and facilitate the transfer of disease (Krueger and May 1991). The negative effects would also vary with the size and production capacity of the facility, and the size and morphology of the downstream environment (Bonaventure et al. 1997). As other maritime DUs have reported escapee salmon from freshwater facilities (Marshall et al. 1999, Bowlby et al. 2014), it is likely that similar events occur in the IBoF DU. However, as the vast majority of freshwater facilities only produce juvenile salmon, escape events would need to be sufficiently large with high survival to reproduction to cause high rates of competition and genetic introgression.

In comparison to freshwater aquaculture, marine aquaculture is likely to have more severe threats to populations as it is predominantly carried out in net pens more open to the environment, focused on grow-out to reproductive adults and interacts with more mature wild Atlantic Salmon. Atlantic Salmon populations in closer proximity to aquaculture sites are likely to more impacted via increased interactions with sites/escapees, however, even distant populations can be affected via escapees straying into distant rivers or wild fish interacting with sites during migration.

Post-smolts from the IBoF have been shown to migrate close to aquaculture sites near the eastern and southern shores of Grand Manan, however, recaptured individuals were free of diseases and parasites (Lacroix and Knox 2005). Within the Magaguadavic River in the OBoF, ISA was found in four escapees and one wild salmon ascending the river in 1999 (Carr and Whoriskey 2002), however, strong evidence for the effects of disease and parasites on IBoF populations is lacking (Amiro et al. 2008b). Predators surrounding aquaculture net pens has been suggested (Lacroix et al. 2004, Lacroix 2013a) and predation on post-smolts and repeat spawners could be limiting and/or destabilizing IBoF populations (Amiro 1998, Lacroix 2014). However, the BoF has numerous predators and there is insufficient data to determine the impact of predation in coastal habitat on persistence and recovery (Amiro et al. 2008b, Lacroix 2014).

During the time the aquaculture industry was growing within the BoF, IBoF populations were declining (Amiro 1998, Chang 1998) and there is concern that genetic introgression may have impacted wild populations (Amiro et al. 2008b). In the Upper Salmon River within the IBoF, genetic assessments indicated that 10% of juveniles had markers consistent with European descent (P.T O'Reilly, DFO, personal communication), and considering that approximately 10%

of BoF farmed stock is of European ancestry, this finding suggests that a much larger proportion of wild fish may at least be partially descended aquaculture escapee fish (Amiro et al. 2008b). However, the magnitudes of impacts remain undetermined (Amiro et al. 2008b).

More recently, there is genetic evidence that European farm salmon or European/North American hybrid farm salmon have successfully reproduced in many IBoF rivers (Big Salmon, Upper Salmon, Gaspereau and Stewiacke rivers), and in many instances, spawned with IBoF Atlantic Salmon (DFO 2018). Detection rates of alleles from smolts emigrating from Big Salmon River indicated that between 10% to 25% of in river produced smolts may exhibit some level of European farm ancestry (DFO 2018). The occurrence and frequency of European farm salmon also appears to be higher in Chignecto Bay compared to Minas Basin (DFO 2018).

Currently there are no marine salmonid aquaculture sites within the IBoF DU, however, in the surrounding DUs there is substantial aquaculture occurring. The vast majority of NB Atlantic Salmon aquaculture occurs within the southwest portion of the OBoF DU. Average yearly aquaculture salmon production within NB between 2015 and 2019 was 24,988 t and there is currently 93 active sites. Compared to NB, NS Atlantic Salmon aquaculture production is much smaller with average yearly production (2015 to 2019) of 7,589 t with the majority of sites occurring on the western and southwestern coast. Between 2010 and 2019, it was estimated that over 225,000 and 44 aquaculture Atlantic Salmon escaped from marine net pens within the OBoF and SU DUs, respectively and due to the proximity of NB and NS aquaculture, there is still a substantial threat to the IBoF DU.

ENERGY PRODUCTION AND MINING

Mining and Quarrying

Mining was identified as a threat to habitat quality within IBoF rivers (Amiro et al. 2008b), however the National Recovery Team concluded that freshwater habitat was not limiting IBoF salmon populations (DFO 2006b).

Transportation and Service Corridors

No DFO data.

Roads and Railroads

No DFO data.

Utility and Service Lines

No DFO data.

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). The extent of shipping within IBoF estuaries is limited and the effects of these activities on IBoF populations is uncertain (Amiro et al. 2008b). However, there are higher amounts of shipping along the Atlantic coast of NS and NB up to the southern coast of Newfoundland (Bowlby et al. 2014). As this traffic is concentrated in coastal environments likely within IBoF marine migration routes, there could be potential for negative effects.

BIOLOGICAL RESOURCE USE

Logging and Wood Harvest

Although forestry was identified as a threat to habitat quality within IBoF rivers (Amiro et al. 2008b), The National Recovery team determined that IBoF populations were not limited by the freshwater environment (DFO 2006b).

Fishing and Harvesting Aquatic Resources

Fisheries have the ability to affects populations through either direct removal of individuals from populations or causing stress to individuals resulting in less reproductive output. As IBoF populations remain in low abundance, removal of individuals have potential to limit population persistence and recovery.

Indigenous and Labrador Resident's Food Fishery

Three Indigenous groups take part in the Labrador subsistence food fishery. This fishery occurs in estuaries and coastal bays using gillnets (ICES 2011) and the majority of catches from all Indigenous fisheries occurs in Labrador (Bowlby et al. 2014). Reporting rates for this fishery is thought to be over 85% (DFO and MRNF 2009). Since 2010, harvest has ranged from 52.5 t to 70.4 t with 54.0 t in 2019 (ICES 2020). It is estimated that 95% of this harvest is from Labrador fisheries and due to the fishery predominantly occurring in local river estuaries (ICES 2011), this fishery is expected to have little effect on IBoF populations.

Labrador residents also participate in the food fishery. Regulations minimize the capture of large MSW salmon, which could originate from IBoF populations. Since 2010, the harvest has decreased from 2.3 t to 1.6 t with 47% of harvest being large salmon in 2019 (ICES 2020). As this fishery also occurs within Labrador waters, the impact on IBoF populations is low.

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 was nine and 57 professional and recreational, respectively, licenses issued (Bowlby et al. 2014). Recreational licenses are permitted to use one gillnet measuring 180m 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 (Bowlby et al. 2014), and given its location there is potential that this fishery is removing MSW IBoF Atlantic Salmon. 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 1.3 t in 2019 (ICES 2020). In 2017, 2018 and 2019, it was estimated that 0.2%, 0.3% and 0.0%, respectively, of large salmon harvested were from IBoF populations (ICES 2019, ICES 2020), however confidence intervals of these estimated extended to 0.0% in all years.

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 in 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 (2012–18) to seven years where factory landings were set to 0 t (2005–11), total harvest has increased to 290 t (2012–18) from 182 t (2005–11) marking a 59% increase. In 2019, it was estimated that approximately 29.8 t were landed within Western Greenland with 0% of total harvest originating from IBoF.

Commercial Fisheries

Local commercial fisheries have been closed since 1984 and therefore have little effect on current populations (Amiro et al. 2008b).

Recreational Fisheries

All rivers within the IBoF have been closed to recreational Atlantic Salmon fishing. Therefore, recreational fisheries pose little threat to Atlantic Salmon populations.

Illegal Fisheries

There a limited amounts of reports/incidences of illegal poaching of Atlantic Salmon within IBoF rivers, however, as populations remain at low levels, any removals could have significant effects (Amiro et al. 2008b).

Bycatch in Other Fisheries

In local commercial fisheries within the BoF, Atlantic Salmon have been historically caught in Atlantic Herring (*Clupea harengus harengus*) weirs (Jessop 1976, Lacroix et al. 2004), however, harvesting of salmon caught was prohibited in 1983 (Amiro et al. 2008b). Lacroix et al. (2005) found that Atlantic Salmon post-smolts distribution within the BoF and GoM did overlap with a commercial purse seine herring fishery in May and June, however no bycatches were ever reported (Amiro et al. 2008b). Loch et al. (2004), reviewed over 100 licensed fisheries in the BoF and identified American shad (*Alosa sapidissima*), herring gillnet, and certain Alewife (*Alosa pseudoharengus*) and Blueback Herring (*Alosa aestivalis*), collectively referred to as gaspereau, and Atlantic Mackerel (*Scomber scombrus*) fisheries as posing risks to IBoF populations. American Eel (*Anguilla rostrata*) fyke net and weir, smelt gill net, and gaspereau trap net fisheries were deemed to be moderate to high threats (Loch et al. 2004). More recently, DFO (2016b) reviewed the threat of bycatch on IBoF Atlantic Salmon populations, however, data was insufficient to perform a quantitative analysis and a qualitative approach was used. Gaspereau, shad and eel fyke nets/weirs, along with the gaspereau trap net, fisheries were all identified as having a moderate to high likelihood of harming IBoF populations (DFO 2016b). Dissimilar to Loch et al (2004), mackerel and smelt gillnet fisheries were assigned an uncertain and low level of concern, respectively (DFO 2016b). However, DFO (2016b) notes that bycatch data is insufficient and an actual level of impact on IBoF populations cannot be determined but reaffirms a precautionary approach is advised.

In other maritime DUs, concerns have been expressed about distant off shore fisheries removing salmon (Bowlby et al. 2014) as smolt and post-smolt distributions overlap with herring and mackerel during certain times of year (ICES 2000), however, no data supports this hypothesis (DFO and MRNF 2009).

Atlantic Salmon are caught as bycatch in fisheries in Ungava Bay for Brook Trout (*Salvelinus fontinalis*), 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, since these are distant fisheries that would likely comprise of MSW fish, the expectation is that the effect on IBoF populations is low.

Atlantic Salmon bycatch also occurs during recreational angling. Recreational angling occurs within most rivers within the DU and juveniles, smolts and adults have been reported as being caught, however, live release is mandatory and minimize impacts on populations (Amiro et al. 2008b).

HUMAN INTRUSIONS AND DISTURBANCES

Recreational Activities

Almost all salmon within the DU are handled as part of scientific activity via husbandry and stocking protocols during the LGB program, however, mortality is expected to be minimal from these activities (Amiro et al. 2008b).

NATURAL SYSTEMS AND MODIFICATIONS

Fire & Fire Suppression

No DFO data.

Dam & Water Management/Use

The BoF has 25 barriers on 44 of its major rivers (Amiro et al. 2008b). Within the IBoF, the most substantial causeway-dam type barriers are on the Petitcodiac, Shepody, Great Village, Chiaganois and Parrsboro rivers and have caused a variety of ecological impacts; altered freshwater discharges, reduced estuary length, altered hydrodynamics, increased and/or redistributed sedimentation, reduced open salt marsh, reduced nutrient transfer, interfered with anadromous fish movement, and modified nursery habitat (Wells 1999, DFO 2007). Tidal barriers within the BoF (dykes, aboiteau, causeways, bridges, culverts, dams and wharves) have also been inventoried and mapped by multiple sources (McCallum 2001, Koeller 2002, Proosdij and Dobek 2005; DFO 2007) and identified over 400 smaller tidal barrages or gates. Documented effects of these processes are unavailable and remain unquantified (Amiro et al. 2008b). However, the Petitcodiac causeway is estimated to have reduced IBoF Atlantic Salmon production by at least 20% (National Recovery Team 2002; Locke et al. 2003) and could have been impacting the persistence of the entire IBoF population (Hutchings 2003). A recent study showed genetic evidence that migration from neighbouring rivers was historically substantial and that populations likely depended on immigration from nearby rivers and the obstruction within the Petitcodiac River was an important factor in nearby river declines (Fraser et al. 2007). If the IBoF does indeed have a meta-population structure, then restoration of a significant source population could be beneficial to the recovery and viability of the IBoF DU (Amiro et al. 2008b). However, in 2010 the Petitcodiac causeway gates were opened and removed the associated fish passage issues (DFO 2018).

More direct methods of mortality can occur when Atlantic Salmon migrate through turbines of hydropower dams or over spillways of dams. Mortality associated with these types of facilities are highly variable and dependent on facility design and mitigations made for fish passage (Amiro et al. 2008b). Recently, an acoustic telemetry study in the Gaspereau River analyzed Atlantic Salmon survival through a hydropower dam from smolts released above the dam that migrated downstream via bypasses, a spillway or through the dam turbines compared to smolts released immediately below the dam. Preliminary results show that although cumulative survival (from release to the bay) of smolts released below the dam tend to be slightly higher compared to smolts that migrate through the turbines, via bypasses or over the spillway, confidence intervals are large and negate firm conclusions. It is also expected that if some of these barriers were to be removed, the increase in production rate would still not be above replacement rates at current marine mortality rates (Amiro et al. 2008b).

Other Ecosystem Modifications

No DFO data.

NEGATIVE INTERACTIONS WITH OTHER SPECIES AND GENETIC INTERACTIONS

Invasive Non-native/Alien Species

No DFO data.

Negative Interactions with Native Species

Atlantic Salmon smolts experience high mortality rates during outmigration and predation is believed to account for majority of these mortalities (LaCroix 2008, Thorstad et al. 2012). Predation events occurring during migrations can have a significant, negative impact on salmon population numbers, especially for endangered populations (Grout 2006, LaCroix 2008). The rate of predation on salmon smolts can vary between years and rivers, as well as between different areas within a single river, with the majority of mortality events often occurring at the head-of-tide or estuary (LaCroix 2008, Thorstad et al. 2012, Halfyard et al. 2013). Striped Bass (*Morone saxatilis*) are common predators of Atlantic Salmon smolts and have been observed to aggregate in rivers during the smolt migration (Blackwell and Jaunes 1998, Daniels et al. 2019). Striped Bass are highly abundant in the IBoF and annually use the tidal portion of the Stewiacke River as spawning habitat (Bradford et al. 2015). In this river, the Striped Bass spawning migration and Atlantic Salmon smolt migration coincide in both space and time. Predation by Striped Bass has been shown to account for 13 to 32% of smolt mortality in the Stewiacke River in previous years (Gibson et al. 2015). Here we use novel acoustic predation tags to quantify the rates of smolt predation in the Stewiacke River over three years.

Sampling of smolts occurred within the Stewiacke River watershed in 2017–19, during the annual smolt run beginning in mid-May and ending in mid-June. Smolts were captured via rotary screw trap just downstream of the Stewiacke River head-of-tide in 2017 and just upstream of the head-of-tide in 2018 (Figure 23). In 2019, smolts were captured using a barrier fence on the Pembroke River, approximately 56 km upstream of the head-of-tide. Smolts were tagged and released at the site of capture. Fifty smolts were tagged in both 2017 and 2018; 56 smolts were tagged in 2019 (total n=156). Only smolts longer than 12 cm in fork length were chosen for tagging to ensure that the recommended tag-to-body size ratio was not exceeded (<8% for Atlantic Salmon; LaCroix et al. 2004). Smolts were tagged with V5D-180 kHz predation acoustic transmitters (12.7 x 5.6 mm, 0.68 g in air; Innovasea Systems Inc., Bedford, NS). These tags have a biopolymer coating that triggers a change in transmitter ID (from an even number to the next odd number) when dissolved by the stomach acids of a predator, thus indicating that a predation event has occurred.

Prior to tagging, an array of VR2W-180 kHz acoustic receivers (Innovasea Systems Inc.) was deployed along the migration route from the release/tagging site to the mouth of the Shubenacadie River (n=16 in 2017, n=15 in 2018, n=24 in 2019; Figure 23). Supplemental detection data were provided by additional receivers (VR2W-180 kHz and HR2; Innovasea Systems Inc.) deployed in the Minas Basin. Tags in 2017 had an estimated battery life of 47 days, while tags in 2018 and 2019 had a battery life of approximately 24 days due to dual programming for both types of receivers.

After analysis of telemetry data, smolts were classified into one of three fate groups: successful migrants, mortalities, or predations. A smolt was considered to be a successful migrant if the last detection was from a receiver at the mouth of the Shubenacadie River or in the Minas

Basin. Smolts were presumed to be a mortality if detections ceased upstream of the Shubenacadie River mouth. Predations were identified by the change in tag ID.

Total smolt mortality rates were 86% in 2017, 54% in 2018, and 37.5% in 2019. Of these mortalities, predations accounted for at least 55.8% in 2017 and 66.7% in both 2018 and 2019 (Table 20). The predation rates observed here are greater than those estimated by Gibson et al. (2015) where predation of smolts in the Stewiacke River by Striped Bass accounted for 13% of mortalities (7.3% of all smolts) in 2008 and 32% (27.3% of all smolts) in 2011. Gibson et al. (2015) used a cluster analysis to differentiate live smolts from smolts predated by Striped Bass based on differences in movement metrics between the two species. The predation rates presented here were obtained from predation tags where additional analyses are required to identify the potential predator species. In 2017 and 2018, 79 to 89% of predation events occurred within known Striped Bass spawning grounds, indicating these smolts were likely consumed by Striped Bass. Further evidence for Striped Bass predation was given by post-consumption detections displaying behaviours that more closely resembled Striped Bass movement (i.e., several reversals in up and downstream movement) than smolt movement. In 2019 only half of the detected predations occurred on Striped Bass spawning grounds while the other half were in freshwater. Freshwater predators of smolts include invasive Smallmouth Bass (*Micropterus dolomieu*) and Chain Pickerel (*Esox niger*). Additional predations by avian or semi-aquatic predators may not have been detected but instead classified as mortalities due to the removal of the tag from the study site.

Changes in the timing of migrations by smolts, Striped Bass, or other migratory prey fishes may have resulted in the variability in predation rates between years. Fluctuations in salmon or Striped Bass population numbers may have also contributed. There are indications that over the last 20 years, Striped Bass numbers have increased in the Shubenacadie River (Bradford et al. 2015) while the IBoF Atlantic Salmon population has declined by over 90% since 1970 (Gross and Robertson, 2006). Additionally, the cumulative stress of surgery to insert tags and immediate entry into saltwater and Striped Bass spawning grounds after release may explain the higher mortality rates seen in 2017 and 2018 compared to 2019 (Table 20) where smolts travelled through over 50 km of freshwater before reaching the head-of-tide. Previous studies in several river systems have found that majority of smolt predations by both piscine and avian predators occur upon entry into saltwater likely due to osmotic stress reducing anti-predator behaviour (Dieperink et al. 2002, Halfyard et al. 2013, Daniels et al. 2019).

These results provide evidence that Striped Bass are preying upon IBoF Atlantic Salmon smolts in the Stewiacke River at rates that vary between years. Predation by Striped Bass and other predators has accounted for a larger proportion of total smolt mortalities in the past three years compared to previous years. Striped Bass predation was not the sole source of smolt mortality during outmigration, further studies are required to investigate other sources of mortality especially in iBoF rivers that are not heavily used by Striped Bass.

Diseases and Parasites

Federally reportable diseases are reported yearly for each province. Between 2015 and 2019, a total of 79 cases of Infectious salmon anaemia were 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 is also reported yearly in other finfish species (Brook Trout, Rainbow Trout [*Oncorhynchus mykiss*] and Arctic Char) and from 2015 to 2019, a total of 12 occurrences were reported in NB (n= 3), NS (n= 7) and QC (n= 2).

Introduced Genetic Material

The IBoF population is at extremely low numbers and relies on supplementation programs and all stocking is through an LGB program that reduces the loss of genetic diversity and fitness (Amiro et al. 2008b). A comprehensive analysis and review of the science associated with the LGB program and related IBoF salmon population maintenance and monitoring activities and considerations for the future management of the program are summarized in DFO (2018). O'Reilly et al. (2019) reviews in more detail the genetic change in IBoF salmon associated with captive breeding and rearing processes over 15 years (across 3 Salmon generations) of LGB program operations and possible introgression of non-native wild and aquaculture genetic material into IBoF LGB populations. Overall, the river populations in the LGB program are losing some genetic variation, but the loss is limited. Gene diversity changed little over the duration of the program, ranging from 0.990 to 0.995 for different spawner-year groups, possibly increasing slightly in the early years (pre-2005), and potentially slightly declining thereafter to approximately 0.992 (O'Reilly et al. 2019). A goal of retaining greater than 95% of gene diversity through 20 Salmon generations (G20) is realistically achievable following several possible paths to maintaining large effective population size in IBoF LGB programs, each involving different levels of expenditures of three key resources: genotyping capacity; hatchery space; and human resource capacity (DFO 2018). With respect to introgression of non-native wild and aquaculture genetic material into the IBoF population, recent collections of IBoF salmon do reflect the presence of European ancestry of suspected farm origin in all three IBoF LGB populations (DFO 2018; O'Reilly et al. 2019), but with different levels of introgression. Some limited suspected European farm genes associated with the original founder generation (G0) still persist in the Stewiacke River LGB population, but there are ongoing efforts to detect and remove them (O'Reilly et al. 2019). Introgression of European farm ancestry is somewhat more extensive in the Gaspereau River LGB population, and removal may not be possible without an unacceptable loss of native GAK genes (DFO 2018). The overall percentage of European farm genes in the Big Salmon River LGB population is likely less than 3%, however, the prevalence of European farm ancestry in existing BSR LGB broodstock may be too extensive to remove without significant loss of BSR founder genetic variation (DFO 2018). Additionally, extensive and ongoing introgression of OBoF genes into the BSR gene pool over time could be expected for several reasons and may represent a risk to the conservation of IBoF genetic characteristics in the BSR LGB population (DFO 2018).

POLLUTION AND CONTAMINANTS

Household Sewage & Urban Wastewater

The amount of populations within the DU affected by waste water is estimated as high with over 30% of the population being affected (Amiro et al. 2008b). However, although there are some indications that waste water alters Atlantic Salmon survival, these effects on IBoF populations is uncertain (Amiro et al. 2008b).

Industrial & Military Effluents

There is limited military activity within the DU and the severity of this threat is uncertain for IBoF populations (Amiro et al. 2008b).

Agricultural & Forestry Effluents

There has been growing evidence that chemical contaminants are negatively affecting Atlantic Salmon at sea survival (Amiro et al. 2008b). Atlantic Salmon smolts exposed to 4-nonylphenol (found in pesticides) and the pesticide atrazine (commonly used in herbicides) leads to significant increases in mortality of smolts when transferred to sea-water (Moore et al. 2003, Waring and Moore 2004). Agriculture exists in numerous IBoF watersheds and in particular the Petitcodiac, Stewiacke, Salmon and Cornwallis rivers (Amiro et al. 2008b). High levels of copper have also been documented in lobsters within Shepody Bay, Cobequid Bay and the Cumberland Basin which suggest metal contamination may also be a threat to IBoF populations (Chou et al. 2000). However, contamination surveys within the IBoF are limited and it is uncertain if the contaminants are influencing IBoF Atlantic Salmon survival (Amiro et al. 2008b).

Garbage & Solid Waste

No DFO data.

Air-Borne Pollution

Most rivers within the DU (some tributaries within the Avon and Gaspereau rivers are exceptions) are rich in base cations and have the ability to neutralize acidification and acidification is considered a low threat to IBoF populations (Amiro et al. 2008b).

Excess Energy

No DFO data.

GEOLOGICAL EVENTS

Volcanoes

No DFO data.

Earthquakes & Tsunamis

No DFO data.

Avalanches & Landslides

No DFO data.

CLIMATE CHANGE

Habitat Shifting & Alteration

The North Atlantic has experienced the highest increase in sea surface temperature of anywhere around the globe and resulted in a decrease in primary productivity (Gregg et al. 2003) and Friedland et al. (2003) has suggested that global warming may be the cause of the current declines in Atlantic Salmon in the North Atlantic. However, more local environmental conditions within the BoF and the GoM suggest that conditions are not likely to have caused an increase in mortality (Amiro et al. 2008b). However, IBoF Atlantic Salmon marine over-wintering habitat is unknown and therefore, it is not possible to determine how environmental effects are impacting populations (Amiro et al. 2008b). 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 hypothesis is that decreased larval prey availability and grey seal predation rates could be limiting SU populations within these areas (Bowlby et al. 2014) and if IBoF populations also use these areas, similar mechanisms could be limiting IBoF populations also.

Droughts

No DFO data.

Temperature Extremes

No DFO data.

Storms & Flooding

No DFO data.

OTHER

Depressed Population Phenomena

Low population abundance can lead to inbreeding depression and the accumulation of deleterious alleles within the population while other, perhaps beneficial, alleles are lost. For IBoF populations, the founder effect could be potentially influencing the loss of genetic diversity (Amiro et al. 2008b) where significantly reduced populations are repopulated by few individuals from adjacent rivers or hatchery stocks which likely have less genetic diversity than the original population (Elliot and Reilly 2003). The greater the decrease in abundance and the longer the time that abundances remain low, populations are more likely to suffer the effects of inbreeding (Amiro et al. 2008b). IBoF populations appear to be below the critical threshold where evolutionary potential is lost and the loss of genetic diversity is likely a key factor in recovery (Amiro et al. 2008b). Amiro et al (2008b) also suggests that IBoF may be part of a meta-population in which local extinctions and recoveries have been typical. Evidence shows that there are three distinct lineages in the BoF (Minas Basin, Chignecto Bay and OBoF) (COSEWIC 2006) but microsatellite mtDNA suggests that there may also be gene flow between the OBoF and Chignecto Bay and given this structure, the meta-population may not be impacted for many years if the IBoF was to lose a major source population (Amiro et al. 2008b, Hutchings 2003).

The LGB program was reviewed in 2018 (DFO 2018). Genetic analyses showed that approximately 24% of small salmon returns to the Big Salmon River and the majority of adult returns to White Rock Dam (Gaspereau River) resulted from the program (DFO 2018). They also note that had the Stewiacke founder population been collected two years prior, the levels of genetic variation would have been much higher, however, they also note that the effective number of Stewiacke breeders is probably sufficiently large that genetic loss due to genetic drift and rates of accumulation of inbreeding are not expected to be high (DFO 2018). As it is highly unlikely that adult returns to IBoF rivers can be maintained without the support from the LGB program (DFO 2020), this program is instrumental in maintaining genetic variation should marine survival rates improve in the future.

Amiro et al. (2008b) also suggests that low population sizes can result in altered behaviour. At low population sizes, smolts and post-smolts may not be able to effectively school together in large enough numbers and experience higher predation rates, however there is no evidence supporting this hypothesis (Amiro et al. 2008b).

MANIPULATED POPULATIONS

IBoF Atlantic Salmon rivers have a history of enhancement activities through the release of hatchery reared fish with the objective of increasing yields in commercial and recreational fisheries that typically generate economic benefits. Records compiled by Gibson et al. (2003b) document the release of just over 40 million salmon of various life stages into 33 IBoF rivers from 1900 to 2002. The vast majority of these fish were stocked as fry prior to 1960. Since 1970, the majority of stocking events involved the release of progeny of broodstock collected from IBoF rivers to rebuild populations that were at low levels. Despite extensive stocking of fish originating from outside the IBoF DU, it has maintained a strong genetic differentiation from nearby DUs (Verspoor 2005, Jeffery et al. 2018), particularly populations from the geographically isolated Minas Basin rivers (King et al. 2001, Verspoor et al. 2002).

Since the IBoF Atlantic Salmon are phenotypically and genetically distinct, efforts were made to prevent the imminent extirpation of this population assemblage beginning in 1998–2001 (prior to listing under SARA) with the development of the LGB program at DFO's biodiversity facilities in Maritimes Region. The LGB program, and associated juvenile and adult supplementation efforts (as schematically depicted for the Stewiacke River LGB in Figure 6), has been in operation for a little over 15 years (across 3 salmon generations) and has recently undergone a comprehensive analysis and review to primarily evaluate the science associated with the development and ongoing modification of the program (DFO 2018). It is the principal activity being undertaken to prevent, at least temporarily, the extinction of salmon in this DU (Gibson et al. 2009). The objective of the LGB program is to use captive breeding and rearing technologies to conserve genetic characteristics of IBoF salmon and maintain populations through adult and juvenile supplementation until recovery can occur (DFO 2008b). The program involves: the captive rearing of wild-exposed broodstock, genetic pedigree-based selective mating strategies to maximize genetic variability, early stocking of progeny to prolong exposure to natural selection in freshwater rivers and, finally, collection of wild-exposed juveniles (parr/smolt) to maintain a large effective population size for each of the principal LGB populations (DFO 2018).

The MBF maintains the Big Salmon River LGB program, whereas the CBF (and prior to closure in 2013, the Mersey Biodiversity Facility) facilitates the NS LGB program with the Stewiacke River and, in 1999, added the Gaspereau River program (Gibson et al. 2004). Preliminary numbers of LGB unmarked (non-adipose clipped) and marked (adipose clipped or garment tagged) juvenile salmon distributed to the Big Salmon and Gaspereau rivers from 2001 to 2019 are respectively presented in Tables 2 and 3. A summary of the MBF LGB distributions and the NS LGB distributions (cumulative for CBF and Mersey Biodiversity Facility) from 2001 to 2019 are tabled in Appendices 1 and 2.

OTHER INDICATORS

MARINE SURVIVAL

Big Salmon River

The annual small salmon abundance estimates from the Big Salmon River (Table 14) from 2002 to 2019 combined with the smolt abundance estimates (Table 4) from 2001 to 2018 were used to determine the annual smolt-to-small salmon return rates (Table 21). Combining smolts and small salmon produced from wild spawners, LGB fry, and LGB parr, the smolt-to-small salmon return rate has averaged 0.32% ranging from (0.05% to 0.69%) over the time series (Figure 24).

The long-term mean smolt-to-small salmon return rate for the smolts that originated from wild spawners is 0.83%, a value more than four times greater than the mean return rate for LGB fry

(0.18%). The mean return rate of combined origin small salmon over the past three generations (0.29%; 2005–18) is only slightly less than the long-term mean (0.32%; 2001–18). However, for smolts produced from wild origin spawners, mean return rate of small salmon over the past 13 years (three generations) has decreased approximately 33% relative to the smolt-to-small return rate over the entire 18-year time series (Table 21).

Gaspereau River

The annual smolt abundance estimates from the Gaspereau River upriver of White Rock Dam (Table 6) from 2007 to 2018 combined with the small salmon returns to the fishway (Table 17) from 2008 to 2019 were used to determine the annual smolt-to-small salmon return rates (Table 22). Combining smolts and small salmon by origin, the mean smolt-to-small salmon return rate has averaged 0.23% while ranging from 0% (2012 smolt year) to 0.68% (2018 smolt year) (Table 22; Figure 25). With the addition of the large salmon returns the following year, the mean value increases to 0.29%, ranging from 0.00% (2012 smolt year) to 0.64% (2008 smolt year) (Table 22; Figure 25). These smolt-to-adult survival rates should be considered minimum estimates as on average greater than 59% (i.e., bypass efficiencies; range: 13.5%–66.7%; Table 6) of smolts produced from habitat above White Rock Dam are exposed to possible spillway and turbine mortality in their seaward migration.

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TABLES

Table 1: Numbers of Live Gene Bank (LGB) unmarked (non-adipose clipped) and marked (adipose clipped or garment tagged) juvenile salmon distributed to the Big Salmon River from 2001 to 2019.

Year	Fry (0+) Unmarked	Parr (0+) Unmarked	Parr (0+) Adipose Clipped	Parr (1+) Adipose Clipped	Parr (1+) Tagged	Smolt (1 year) Unmarked	Smolt (1 year) Adipose Clipped	Smolt (2 year) Unmarked	Smolt (2 year) Adipose Clipped
2001	185,523	0	77,718	0	0	0	0	0	0
2002	138,682	0	34,062	0	0	0	19,725	0	0
2003	296,818	0	54,000	21,025	0	0	13,360	0	0
2004	369,109	0	90,843	7,009	0	0	11,663	0	0
2005	258,873	0	69,862	892	0	0	1,295	0	0
2006	413,413	0	72,556	665	0	0	1,413	50	0
2007	370,605	0	87,088	0	0	0	0	0	0
2008	265,126	0	87,786	0	0	0	0	0	0
2009	177,971	0	56,984	0	0	0	1,243	0	829
2010	200,378	0	43,140	0	0	382	0	1,695	0
2011	401,486	3,137	12,000	13	0	102	0	330	0
2012	97,209	50	0	0	0	0	0	0	0
2013	341,995	0	0	0	0	0	0	0	0
2014	255,386	0	0	0	0	0	0	0	0
2015	302,307	0	0	0	0	0	0	259	0
2016	404,398	0	0	0	0	0	0	0	0
2017	352,055	0	0	0	0	0	0	0	0
2018	222,241	0	0	0	0	0	0	0	0
2019	241,437	0	0	0	0	0	0	0	0
Total	**5,295,012**	**3,187**	**686,039**	**28,926**	**0**	**382**	**43,384**	**2,025**	**829**

Table 2: Preliminary numbers of Live Gene Bank (LGB) non-adipose clipped and adipose clipped juvenile salmon distributed to the Gaspereau River upriver of the White Rock Dam from 2001 to 2019.

Year	Non-Adipose Clipped Unfed Fry (0+)	Non-Adipose Clipped 6 Week Post-Feeding Fry (0+)	Non-Adipose Clipped Fall Parr (0+)	Non-Adipose Clipped Spring Parr (1+)	Non-Adipose Clipped Smolt (1 Year)	Adipose Clipped Fall Parr (0+)	Adipose Clipped Spring Parr (1+)	Adipose Clipped Smolt (1 Year)	Adipose Clipped Smolt (2 Year)
2001	0	0	0	0	0	31,404	0	2,172	0
2002	0	4,033	0	0	0	0	0	0	0
2003	0	0	0	0	0	18,105	18,600	9,372	0
2004	0	0	0	0	0	5,878	0	0	0
2005	0	18,997	0	0	0	9,000	0	0	0
2006	0	0	37,501	0	6,480	0	0	0	0
2007	0	0	19,662	189	0	0	0	0	1,034
2008	275,000	0	0	0	3,302	23,628	0	0	0
2009	117,700	0	0	0	0	22,023	0	0	0
2010	86,511	0	0	0	0	20,003	0	0	0
2011	221,000	0	0	0	0	0	0	0	0
2012	220,000	0	0	0	0	0	0	300	0
2013	191,700	0	0	0	0	0	0	0	0
2014	182,750	0	0	0	0	0	0	0	0
2015	153,000	0	0	0	0	0	0	0	0
2016	188,187	0	0	0	0	0	0	0	0
2017	185,186	0	0	0	0	0	0	0	0
2018	159,204	0	0	0	0	0	0	0	0
2019	211,078	0	0	0	0	0	0	0	0
Total	**2,594,962**	**23,030**	**57,163**	**189**	**9,782**	**130,041**	**18,600**	**11,844**	**1,034**

Table 3: A summary of the Big Salmon River rotary screw trap (RST) operation in Amateur Pool from 2001 to 2019. "Temp." = temperature, "LGB" = Live Gene Bank produced fish, "FC" = fin clip, "BD" = blue dye, "LC"= Lower caudal fin, "MUC/MLC" = mid-upper caudal/mid-lower caudal fin clips/punch, "ST" = streamer tag, "Recap." = recaptured, "Eff." = efficiency, "Morts." = mortalities, "N/A" = smolts were not recycled in that given year.

Year	RST Timing Install Date	RST Timing Temp. (°C)	RST Timing 1st Smolt Catch Date	RST Timing RST Removal Date	RST Catches Wild/ LGB_{FRY}	RST Catches LGB_{PARR}	RST Catches Total # Smolts	RST Efficiency from Smolt Recycles Total # Recycled Smolts	RST Efficiency from Smolt Recycles Type Mark Applied	RST Efficiency from Smolt Recycles Total # RST Fish Recap.	RST Efficiency from Smolt Recycles Efficiency	LGB Total # LGB Smolts	LGB PIT Tags	LGB Morts.
2001	May 9	7.0	May 10	Jun 21	692	1	693	377	BD (LC), ST, FC (LC)	22	5.8%	0	0	26
2002	Apr 29	3.0	May 3	Jun 19	439	207	646	118	BD (LC)	13	11.0%	0	0	6
2003	May 6	8.0	May 8	Jun 17	1,071	458	1,529	1,301	ST	133	10.2%	204	0	9
2004	May 3	8.5	May 4	Jun 29	361	156	517	271	ST	28	10.3%	130	49	2
2005	May 3	5.0	May 4	Jun 27	444	429	873	603	ST	63	10.4%	77	77	7
2006	Apr 28	9.5	Apr 29	Jun 15	900	725	1,625	1,192	ST	115	9.6%	198	197	4
2007	May 1	6.0	May 4	Jun 20	1,104	1,145	2,249	1,599	ST, FC	303	18.9%	342	51	8
2008	May 1	5.0	May 2	Jun 15	1,007	203	1,210	895	ST	85	9.5%	194	187	2
2009	Apr 16	4.0	Apr 27	Jun 23	1,128	450	1,578	901	ST	84	9.3%	242	242	7
2010	Apr 26	8.9	Apr 29	Jun 22	1,474	853	2,427	1,780	ST	222	12.5%	300	300	4
2011	Apr 26	6.8	May 4	Jun 16	1,069	310	1,379	1,081	ST, MUC	114	10.5%	204	200	1
2012[a]	Apr 30	4.0	May 1	Jun 6	755	133	888	N/A	N/A	N/A	N/A	203	199	4
2013[a]	Apr 30	11.0	May 1	Jun 19	735	78	813	287	MUC	29	10.1%	302	302	10
2014[a]	May 6	6.0	May 7	Jun 26	411	4	415	120	MUC	15	14.2%	149	149	9
2015	May 12	6.5	May 13	Jun 26	1,013	0	1,013	498	MUC	52	10.4%	395	395	10
2016	Apr 28	7.5	May 3	Jun 14	1,328	0	1,328	384	MUC/MLC	71	18.5%	395	395	24
2017	May 1	7.0	May 4	Jun 16	1985	1	1986	788	MUC/MLC	167	21.2%	570	571	6
2018	May 8	11.0	May 9	Jun 15	1530	0	1530	595	MUC/MLC	131	22.0%	589	589	10
2019	May 1	5.5	May 6	Jun 20	2370	0	2370	687	MUC	163	23.7%	853	0[b]	1

[a] RST operated from Sunday night to Friday morning during these years.
[b] PIT tagging of LGB collections was conducted by Mactaquac Biodiversity Facility staff at a later date to minimize handling mortalities.

Table 4: Annual abundance estimates for Big Salmon River-emigrating non-adipose clipped smolts [either Live Gene Bank (LGB) or wild-origin] by age from 2001 until 2019. "–" = assessment data not available, "N/A" = assessment completed, emigrating smolt data not available for given age class.

Year	Abndnc Estimate	% LGB FRY	Abndnc by Age: Age-2	Abndnc by Age: Age-3	Abndnc by Age: Age-4	Abndnc by Age: Total	Non-Adipose Clipped Smolts Proportion by Age: Age-2	Non-Adipose Clipped Smolts Proportion by Age: Age-3	Non-Adipose Clipped Smolts Proportion by Age: Age-4	Adult Spawner Abndnc by Age: Age-2	Adult Spawner Abndnc by Age: Age-3	Adult Spawner Abndnc by Age: Age-4	Adult Spawner Abndnc by Age: Total	Live Gene Bank Unfed Fry Abndnc by Age: Age-2	Live Gene Bank Unfed Fry Abndnc by Age: Age-3	Live Gene Bank Unfed Fry Abndnc by Age: Age-4-	Live Gene Bank Unfed Fry Abndnc by Age: Total
2001	5,290	N/A	160	8	1	169	0.95	0.05	0.01	5,008	250	31	5,290	N/A	N/A	N/A	-
2002	4,295	N/A	59	21	1	81	0.73	0.26	0.01	3,128	1,114	53	4,295	N/A	N/A	N/A	-
2003	9,200	44.7%	194	23	2	219	0.89	0.11	0.01	4,510	966	84	5,560	3,640	N/A	N/A	3,640
2004	5,970	50.8%	90	38	0	128	0.70	0.30	0.00	2,063	871	0	2,934	2,134	901	N/A	3,036
2005	4,550	73.0%	86	24	1	111	0.77	0.22	0.01	953	266	11	1,230	2,572	718	30	3,320
2006	17,355	51.6%	196	75	9	280	0.70	0.27	0.03	5,880	2,250	270	8,401	6,268	2,399	288	8,954
2007	6,400	36.9%	271	83	2	356	0.76	0.23	0.01	3,073	941	23	4,037	1,799	551	13	2,363
2008	10,750	36.4%	162	34	1	197	0.82	0.17	0.01	5,626	1,181	35	6,841	3,215	675	20	3,909
2009	11,960	54.9%	210	33	0	243	0.86	0.14	0.00	4,660	732	0	5,392	5,676	892	0	6,568
2010	12,620	43.3%	253	76	3	332	0.76	0.23	0.01	5,453	1,638	65	7,156	4,164	1,251	49	5,464
2011	10,135	44.8%	119	107	1	227	0.52	0.47	0.00	2,931	2,636	25	5,592	2,382	2,142	20	4,543
2012	11,120	38.1%	117	67	0	184	0.64	0.36	0.00	4,376	2,506	0	6,881	2,695	1,543	0	4,239
2013	9,840	54.4%	264	30	0	294	0.90	0.10	0.00	4,032	458	0	4,490	4,804	546	0	5,350
2014	4,470	33.1%	144	25	2	171	0.84	0.15	0.01	2,517	437	35	2,988	1,248	217	17	1,482
2015	9,690	66.4%	364	42	1	407	0.89	0.10	0.00	2,911	336	8	3,255	5,755	664	16	6,435
2016	7,180	79.9%	310	170	5	485	0.64	0.35	0.01	922	506	15	1,443	3,667	2,011	59	5,737
2017	9,380	84.0%	502	59	2	563	0.89	0.10	0.00	1,338	157	5	1,501	7,026	826	28	7,879
2018	7,310	65.3%	483	93	1	577	0.84	0.16	0.00	2,121	408	4	2,534	3,998	770	8	4,776
2019	9,990	83.4%	332	78	0	410	0.81	0.19	0.00	1,339	315	0	1,654	6,750	1,586	0	8,336
Mean (2003 to 2019)		**55.36%**	**-**	**-**	**-**	**-**	**0.78**	**0.21**	**0.01**	**-**	**-**	**-**	**4,229**	**-**	**-**	**-**	**5,061**

Table 5: Parentage analysis of Big Salmon River non-adipose clipped smolts (either Live Gene Bank [LGB] or wild-origin) from 2003 to 2019. Other parents include: research, LGB unknown sire or dam, Point Wolfe LGB adult or unfed fry release. " – " = assessment data not available. N/A = not applicable.

Year	Live Gene Bank Unfed Fry (0+) Releases	Adult Spawners Live Gene Bank Adult	Adult Spawners Other Parents	Adult Spawners Wild Adults Previous Adult Return	Adult Spawners Wild Adults Unknown Parents	Total	% Unfed Fry	% LGB Adult
2003	92	0	0	0	114	206	44.70%	N/A
2004	60	0	0	0	58	118	50.80%	N/A
2005	54	0	0	1	19	74	73.00%	N/A
2006	97	11	1	16	63	188	51.60%	5.90%
2007	48	10	1	9	62	130	36.90%	7.70%
2008	68	11	2	57	49	187	36.40%	5.90%
2009	134	1	12	38	59	244	54.90%	0.40%
2010	113	0	36	42	70	261	43.30%	N/A
2011	91	0	4	48	60	203	44.80%	N/A
2012	77	0	1	49	75	202	38.10%	N/A
2013	112	0	0	35	59	206	54.40%	N/A
2014	59	0	4	28	87	178	33.10%	N/A
2015	261	0	11	23	98	393	66.40%	N/A
2016	163	0	1	7	33	204	79.90%	N/A
2017	126	0	4	13	7	150	84.00%	N/A
2018	98	0	1	24	27	150	65.33%	N/A
2019	126	0	2	4	19	151	83.44%	N/A
Mean	-	-	-	-	-	-	**50.60%**	-

Table 6: Bypass catch, mark-recapture estimate, bypass efficiency estimate, and smolt abundance estimate (non-adipose clipped and adipose clipped) available data on the Gaspereau River from 2002 to 2019. " – " = assessment data not available, "N/A" = fish were not marked in the given year, "Unknown" = no mark-recapture experimental data.

Year	Bypass 1, 2 & 3 Catch Non-Adipose Clipped	Bypass 1, 2 & 3 Catch Adipose Clipped	Bypass 1, 2 & 3 Catch Total	Marks	Recaps	Bypass 1, 2 & 3 Efficiency	-	Abundance Estimate Non-Adipose Clipped	Abundance Estimate Adipose Clipped Fall Parr	Abundance Estimate Adipose Clipped Smolt	Abundance Estimate Adipose Clipped Unknown[1]	Abundance Estimate Adipose Clipped 95% CL's		-
2002	219	1,354	1,573	1,500	606	40.40%	3,973	542	-	-	3,431	3,718	4,091	-
2003	180	2,074	2,254	1,500	446	29.70%	7,581	605	-	-	6,976	7,088	8,140	-
2004	-	-	2,341	-	-	-	-	-	-	-	-	-	-	-
2005	-	-	440	-	-	-	-	-	-	-	-	-	-	-
2006	-	-	324	-	-	-	-	-	-	-	-	-	-	-
2007	1,743	600	2,343	1,033	599	58.00%	4,040	3,005	-	1,035	-	3,780	4,340	3
2008	734	2,201	2,935	3,300	2,201	66.70%	4,400	1,100	-	3,300	-	4,312	4,496	3
2009	1,019	1,245	2,264	264	106	40.20%	5,635	2,536	3,099	-	-	4,750	6,910	3
2010	605	1,662	2,267	55	17	30.90%	7,354	1,963	5,391	-	-	5,017	13,135	3
2011	1,317	1,124	2,441	N/A	-	-	5,719	3,085	2,634	-	-	N/A	N/A	-
2012	591	373	964	300	147	49.00%	1,968	1,207	461	300	-	1,712	2,312	3
2013	1,502	-	1,502	48	24	50.00%	3,000	3,000	-	-	-	2,150	4,900	3
2014	212	-	212	28	-	Unknown [6]	1,174	1,174	-	-	-	N/A	N/A	
2015	541	-	541	139	23	16.50%	3,268	3,268	-	-	-	2,350	5,325	3
2016	2366	-	2366	524	238	45.40%	5,212	5,212	-	-	-	4,640	5,920	3
2017	415	-	415	171	23	13.45%	3,090	3,090	-	-	-	2,220	4,995	3
2018	671	-	671	233	73	31.33%	2,070	2,070	-	-	-	1,546	3,226	3
2019	1,261	-	1,261	373	191	51.21%	2,462	2,462	-	-	-	2,180	2,801	3

[1] Abundance estimate includes smolts from LGB parr and LGB smolt releases.
[2] LGB-origin smolts released upriver of White Rock Dam to determine efficiencies of the bypasses.
[3] 2.5-97.5 percentiles.
[4] Non-adipose clipped wild origin smolts marked, recycled and released upriver of White Rock Dam to determine efficiencies of the bypasses.
[5] Smolt abundance estimate was determined by dividing total bypass catch by the mean bypass efficiency (42.7%).
[6] Near the end of the smolt migration period it was noticed that wooden floor of bypass # 1 was rotten and smolts were passing the assessment facility unaccounted for.
[7] Smolt abundance estimate was determined by dividing bypass 2 & bypass 3 catch by the combined bypass 2 & bypass 3 efficiency (9.54%) determined in 2016.

Table 7: Smolt abundance estimates by origin for Gaspereau River-emigrating salmon from 2007 to 2019.

Year	Non-Adipose Clipped Adult Spawner	Non-Adipose Clipped LGB Juvenile Release	Adipose Clipped LGB Fall Parr Release	Adipose Clipped LGB Smolt Release	Adipose Clipped Total Smolts
2007	71	2,934	0	1,035	4,040
2008	67	1,033	0	3,300	4,400
2009	1,459	1,077	3,099	0	5,635
2010	902	1,061	5,391	0	7,354
2011	2,153	932	2,634	0	5,719
2012	585	622	461	300	1,968
2013	228	2,772	0	0	3,000
2014	162	1,012	0	0	1,174
2015	1,295	1,973	0	0	3,268
2016	645	4,567	0	0	5,212
2017	399	2,691	0	0	3,090
2018	291	1,779	0	0	2,070
2019	277	2,185	0	0	2,462

[1] Combination of unfed fry/6 week post-feeding fry/unclipped fall parr releases.
[2] Unfed fry releases only.

Table 8: Parentage analysis summary for Gaspereau River non-adipose clipped smolts from 2003 to 2019. " – " = assessment data not available, N/A = not applicable.

Year	LGB Release Juvenile	LGB Release Unfed Fry	Wild or LGB Adult Spawners	Total	% Adult	% Juvenile
2003	2	-	49	51	96.10%	3.90%
2004	2	-	88	90	97.80%	2.20%
2005	27	-	107	134	79.90%	20.10%
2006	167	-	6	173	3.50%	96.50%
2007	124	-	3	127	2.40%	97.60%
2008	153	-	10	163	6.10%	93.90%
2009	45	-	61	106	57.50%	42.50%
2010	127	-	108	235	46.00%	54.00%
2011	N/A	45	104	149	69.80%	30.20%
2012	N/A	103	97	200	48.50%	51.50%
2013	N/A	207	17	224	7.60%	92.40%
2014	N/A	119	19	138	13.80%	86.20%
2015	N/A	125	82	207	39.60%	60.40%
2016	N/A	177	25	202	12.40%	87.60%
2017	N/A	7	12	93	12.90%	7.53%
2018	N/A	177	29	206	14.08%	85.92%
2019	N/A	252	32	284	11.27%	88.73%
Mean	**-**	**-**	**-**	**-**	**36.42%**	**58.90%**

[1] Wild exposed in the genetics database.
[2] Wild produced in the genetics database.

Table 9: Dates of operation and capture of first, last and 10, 50 and 90% of smolts in rotary screw traps on the Big Salmon (2010–2019) and Stewiacke (2014–2019) rivers and at a bypass trap at the White Rock Generating Station on the Gaspereau River (2010–2019). Capture efficiency varies with flow but herein is assumed to be constant, i.e., if a large number of smolt emigrated during a flood event when capture efficiency is low, then the dates would be erroneous.

River by Year	Dates of Operation	First Smolt	Percentiles of Smolt Run (by Dates) 10%	Percentiles of Smolt Run (by Dates) 50%	Percentiles of Smolt Run (by Dates) 90%	First Smolt Last Smolt
Big Salmon River	**-**	-	-	-	-	-
2010	Apr 28 - Jun 18	Apr 29	May 03	May 09	May 21	Jun 16
2011	Apr 26 - Jun 16	May 04	May 07	May 22	May 31	Jun 14
2012[a]	Apr 30 - Jun 6	May 01	May 09	May 10	May 17	Jun 06
2013[a]	Apr 30 - Jun 13	May 01	May 07	May 10	May 20	Jun 10
2014[a]	May 6 - Jun 15	May 07	May 16	May 21	May 27	Jun 10
2015	May 12 - Jun 19	May 13	May 21	May 27	Jun 09	Jun 15
2016	May 1 - Jun 14	May 03	May 08	May 15	May 27	Jun 10
2017	May 1 - Jun 15	May 04	May 17	May 20	May 28	Jun 13
2018	May 8 - Jun 15	May 09	May 11	May 16	May 24	Jun 15
2019	May 1 - Jun 17	May 06	May 21	May 26	Jun 03	Jun 17
Stewiacke River	**-**	-	-	-	-	-
2014[a]	May 21 - Jun 19	May 23	May 29	Jun 04	Jun 19	Jun 19
2015[a, b]	May 4 - Jun 26	May 26	Jun 01	Jun 05	Jun 15	Jun 26
2016	May 17 - Jun 29	May 19	May 19	Jun 01	Jun 07	Jun 20
2017	May 4 - Jun 23	May 04	May 20	Jun 02	Jun 11	Jun 17
2018	May 15 - Jun 22	May 15	May 23	May 31	Jun 08	Jun 14
2019[c]	May 13 - Jun 21	May 26	Jun 05	Jun 06	Jun 19	Jun 21
Gaspereau River	**-**	-	-	-	-	-
2010	Apr 24 - May 21	Apr 25	Apr 30	May 05	May 10	May 20
2011[d]	Apr 29 - May 26	Apr 29	May 02	May 06	May 17	May 24
2012	Apr 18 - May 22	Apr 19	Apr 27	May 08	May 15	May 21
2013	Apr 26 - May 10	Apr 26	May 03	May 07	May 09	May 10
2014	Apr 30 - May 29	May 06	May 10	May 17	May 19	May 22
2015	May 4 - Jun 2	May 14	May 17	May 21	May 28	Jun 02
2016	Apr 22 - Jun 5	Apr 23	May 03	May 11	May 19	Jun 05
2017	Apr 18 - May 26	Apr 22	May 05	May 12	May 19	May 24
2018	Apr 24 - May 26	Apr 29	May 05	May 14	May 21	May 26
2019[e]	Apr 26 - June 2	May 04	May 07	May 12	May 24	Jan 00

[a] Trap was not checked every day.
[b] RST initially installed 110 m below Rock Pile Pool and was moved upriver on May 25.
[c] Dates are based on RST only and do not include Pembroke Fence data.
[d] Screens pulled from Bypass 2 & 3 on May 15, data after is based on Bypass 1 data.
[e] Percentile dates are based on Bypass 1 only.

Table 10: Big Salmon River adult Atlantic Salmon counts by stream-side observation and dive surveys from 1988 to 2019. Data sources and spawning escapement estimates (1988 to 2003) are also provided and can be found in Gibson et al. (2004). Underlined date = count for specified year, "N/A" = assessment not completed for given year, " – " = assessment data not available, References for counts or estimates from 1988 to 2005 (see Jones et al. 2006).

Year	Date	Count Technique	-	Count	Estimated Spawners Small	Estimated Spawners Large	Estimated Spawners Total
1988	Fall	Diver	-	300-400 fish [11]	-	-	350
1989	Fall	Diver	-	975 fish [11]	-	-	975
1990	Oct. 18	Diver	1	64 small / 169 large	-	-	235
1991	Aug. 16	Diver	-	49 small / 115 large	-	-	-
1991	Sept. 12, 17	Diver	2	105 small/151 large	-	-	300
1992	Aug. 21	Visual	-	-	-	-	-
1992	Sept. 29	Diver	-	150 fish (45% small)	-	-	150
1993	Aug. 27	Visual	-	165 fish (69% small)	-	-	300
1994	Sept. 27	Visual	3	225 fish (60% small)	-	-	225
1995	Aug. 22	Visual	4	10 small / 23 large	-	-	-
1995	Sept. 26	Visual	4,5,8	18 small / 53 large	-	-	110
1996	-	Visual	6	100-150 fish [11]	-	-	125
1997	-	Visual	-	50 fish [11]	-	-	50
1998	-	Visual	-	25-50 fish [11]	-	-	38
1999	N/A	N/A	-	N/A	N/A	N/A	N/A
2000	Oct. 16-18	Diver	7,8	23 small / 5 large	34	7	41
2001	Oct. 22, 23	Diver	7,8	12 small / 8 large	18	12	30
2002	Aug. 27, Sept. 3	Diver	7,8	16 small / 5 large	24	7	31
2003	Oct. 2	Diver	9	10 small / 2 large	18	3	21
2004	Oct. 20	Diver	10	4 small / 5 large	7	9	16
2005	Sept. 7, 8, 14	Diver	7,10	23 small / 11 large	41	19	60
2006	Aug. 30, Oct. 11	Diver	7,10	34 small / 10 large	60	17	77
2007	Aug. 1, Sept. 5, Oct. 10	Diver	7,12	26 small / 2 large	44	3	47
2008	July 15, Sept. 15, Oct. 8	Diver	7,10	20 small / 8 large	35	14	49
2009	Aug. 5, Sept. 3, Oct. 21	Diver	7,10	20 small / 1 large	35	2	37
2010	July 6, Sept. 13, Oct. 12	Diver	7,12	44 small / 5 large	78	9	87
2011	July 27, Sept. 7, Oct. 13	Diver	7,10	63 small / 4 large	111	7	118
2012	July 23, Sept. 12, Oct. 25	Diver	7,10	6 small / 3 large	11	5	16
2013	Aug. 8, Sept. 9, Oct. 19	Diver	7,10	4 small / 2 large	7	4	11
2014	Aug. 7, Sept. 8, 9, Oct. 21	Diver	10,13	26 small / 2 large	46	3	49
2015	Aug. 11, Sept. 16, Oct. 20	Diver	7,10	16 small / 2 large	28	4	32
2016	Aug. 8, Sept. 7, Oct. 18	Diver	10	8 small / 3 large	14	5	19
2017	July 25, Sept 6, Oct. 19	Diver	10	9 small / 4 large	16	7	23
2018	July 25, Sept. 5	Diver	10	24 small / 1 large	42	2	44
2019	Aug. 2, Oct. 2, 3, 4, 16	Diver	10	15 small / 4 large	26	7	33

[1] High water (count is a minimum estimate), [2] Complete river surveyed, except one pool, [3] Diver observations on Oct. 19 indicated escapements could have been less than 225, [4] 15 pools surveyed representing 74% of the total river based on the 1991 complete river survey, [5] Streamside survey on Oct. 19 indicated no new fish in the river, [6] Counts were hindered by high water, estimated number is based on two partial surveys and a count for Catt and Rody pools, [7] counts for each survey can be found in Appendix 4 of Jones et al. (2014), [8] Adjusted counts = counts / (proportion of river surveyed / (estimated observation rate) – based on calculation by Amiro and Jefferson (1996), [9] Mark recapture estimate (Gibson et al. 2004), [10] Borrowed observation rate (0.57) from 2003 survey (Gibson et al. 2004), [11] Unknown size composition, [12] total estimate is derived from Bayesian model, [13] the small salmon estimate includes 33 LGB returns that were released as pre-grilse in 2014.

Table 11: Summary of the Big Salmon River small and large salmon biological characteristics collected from 2000 to 2019. "Prop." = proportion, " – " = assessment data not available.

Year	Small Total	Small Male Count	Small Female Count	Small Female Mean Length	Small Prop. Female	Large Total	Large Male Count	Large Female Count	Large Female Mean Length	Large Prop. Female	Total Salmon	Prop. Small Sampled
2000	10	7	3	53	0.300	1	-	1	73.5	1	11	0.909
2001	0	-	-	-	-	0	-	-	-	-	0	-
2002	2	-	2	53.5	1	3	2	1	70.4	0.330	5	0.400
2003	6	4	2	55.1	0.333	1	-	1	65.7	1	7	0.857
2004	0	-	-	-	-	1	-	1	80.4	1	1	0
2005	17	12	5	54.8	0.294	2	-	2	64	1	19	0.895
2006	17	9	8	56.5	0.471	3	1	2	66	0.670	20	0.850
2007	14	5	9	54.7	0.643	0	-	-	-	-	14	1
2008	23	7	16	55.7	0.696	1	-	1	80	1	24	0.958
2009	9	4	5	57.2	0.556	4	1	3	69	0.750	13	0.692
2010	45	13	32	55.7	0.711	2	-	2	72.5	1	47	0.957
2011	23	8	15	54.7	0.652	0	-	-	-	-	23	1
2012	0	-	-	-	-	0	-	-	-	-	0	-
2013	0	-	-	-	-	0	-	-	-	-	0	-
2014	3	-	3	53.7	1	1	-	1	80	1	4	0.750
2015	13	3	10	56.3	0.769	0	-	-	-	-	13	1
2016	3	3	-	-	0	1	-	1	64.3	1	4	0.750
2017	0	-	-	-	-	0	-	-	-	-	0	
2018	13	5	8	55.1	0.615	0	-	-	-	-	13	1.000
2019	7	5	2	54.8	0.286	1	-	1	65.5	1	8	0.875
Total	**205**	**85**	**120**	**55.1**	**0.585**	**21**	**4**	**17**	**69.2**	**0.810**	**226**	**0.907**

Table 12: Counts, biological characteristics, and estimated number of eggs for small and large salmon returning to the Big Salmon River and LGB adults released to the Big Salmon River, as well as overall percent egg conservation requirement from 2000 to 2019. "CER" = conservation egg requirement, " – " = assessment data not available.

Year	Small Salmon Returns Mean Female Length	Small Salmon Returns Fecundity	Small Salmon Returns Proportion Female	Small Salmon Returns Spawner Count	Small Salmon Returns Small Eggs	Large Salmon Returns Mean Female Length	Large Salmon Returns Fecundity	Large Salmon Returns Proportion Female	Large Salmon Returns Spawner Count	Large Salmon Returns Large Eggs	Total Eggs	% CER
2000	53	3,033	0.300	34	30,937	-	-	-	7	31,213	62,150	2.82%
2001	-	-	-	18	34,496	-	-	-	12	53,509	88,005	4.00%
2002	-	-	-	24	45,995	-	-	-	7	31,213	77,208	3.51%
2003	55.1	3,276	0.333	18	19,636	-	-	-	3	13,377	33,013	1.50%
2004	-	-	-	7	13,415	-	-	-	9	40,131	53,547	2.43%
2005	54.8	3,240	0.294	41	39,055	-	-	-	19	84,722	123,777	5.63%
2006	56.5	3,450	0.471	60	97,497	-	-	-	17	75,804	173,301	7.88%
2007	54.7	3,228	0.643	44	91,327	-	-	-	3	13,377	104,704	4.76%
2008	55.7	3,349	0.696	35	81,582	-	-	-	14	62,427	144,008	6.55%
2009	57.2	3,540	0.556	35	68,888	-	-	-	2	8,918	77,807	3.54%
2010	55.7	3,349	0.711	78	185,729	-	-	-	9	40,131	225,860	10.27%
2011	54.7	3,229	0.652	111	233,617	-	-	-	7	31,213	264,830	12.04%
2012	-	-	-	11	21,081	-	-	-	5	22,295	43,376	1.97%
2013	-	-	-	7	13,415	-	-	-	4	17,836	31,251	1.42%
2014	-	-	-	13	24,914	-	-	-	3	13,377	38,291	1.74%
2015	56.3	3,424	0.769	28	73,726	-	-	-	4	17,836	91,562	4.16%
2016	-	-	-	14	26,830	-	-	-	5	22,295	49,126	2.23%
2017	-	-	-	16	30,663	-	-	-	7	31,213	61,877	2.81%
2018	55.2	3288	0.615	42	84,929	-	-	-	2	8,918	93,847	4.27%
2019	-	-	-	26	49,828	-	-	-	7	31,213	81,041	3.68%
Mean[3]	**55.1**	**3,276**	**0.585**	**-**	**-**	**69.2**	**5505**	**0.810**	**-**	**-**	-	-
-	**Small Salmon LGB Releases**	**Small Salmon LGB Releases**	**Small Salmon LGB Releases**	**Small Salmon LGB Releases**	**-**	**Large Salmon LGB Releases**	**Large Salmon LGB Releases**	**Large Salmon LGB Releases**	**Large Salmon LGB Releases**	**-**	**-**	**-**
2003	-	-	-	-	-	78.7	10,448	1	15	156,720	156,720	7.10%
2004	-	-	-	-	-	79.2	10,678	1	13	138,814	138,814	6.30%
2005	47.8	2,716	0.686	35	65,184	65	5,749	0.776	49	218,462	283,646	12.90%

[1] Time-series mean values (small or large salmon treated separately) applied to spawner count to calculate eggs in that year,
[2] The 33 LGB pre-grilse were excluded from the estimated egg calculation, [3] Mean values are calculated using all fish sampled from 2000 to 2019 (see Table 11).

Table 13: Summary of the Big Salmon River small salmon parentage analysis results for individuals sampled from 2000 to 2019. "N/A" = parental analysis is not applicable as no returning adults of this category were expected for that year, " – " = assessment data not available.

Year	# Tissue Sampled	Live Genk Bank Origin Unfed Fry	Live Genk Bank Origin Fall Parr (Adipose Clipped)	Adult Spawners Progeny of Wild Adult Returns (Genetically Analyzed)	Adult Spawners Adipose Clipped Stray	Adult Spawners Unknown	Small Salmon Escapement	Proportion of Total Return Sampled
2000	0	N/A	N/A	N/A	N/A	0	34	0
2001	0	N/A	N/A	N/A	N/A	0	18	0
2002	0	N/A	N/A	N/A	N/A	0	24	0
2003	6	N/A	1	N/A	0	5	18	0.33
2004	0	-	-	N/A	-	-	7	0
2005	19	2	0	N/A	0	17	41	0.46
2006	17	2	1	N/A	0	14	60	0.28
2007	14	5	2	2	0	5	44	0.32
2008	23	4	1	3	0	15	35	0.66
2009	9	1	0	3	0	5	35	0.26
2010	45	9	6	11	2	19	78	0.58
2011	23	4	0	11	0	8	111	0.21
2012	0	-	-	-	-	-	11	0
2013	0	-	-	-	-	-	7	0
2014	3	0	0	0	0	3	13	0.23
2015	13	3	0	0	0	10	28	0.46
2016	4	3	0	0	0	1	14	0.29
2017	0	-	-	-	-	-	16	0
2018	13	4	0	3	0	6	42	0.31
2019	7	1	0	4	0	2	26	0.27
Totals	**196**	**38**	**11**	**37**	**2**	**110**	-	-

[1] This LGB return could be from the spring smolt release in 2005 or fall parr release in 2004 (age 1.1).
[2] Age 2.1 – confirmed by genetics that the individual is from the 2002 spawning class, thus a fall parr release.

Table 14: Estimated Big Salmon River small salmon returns by origin based on the parentage analysis from 2000 to 2019. "N/A" = parental analysis is not applicable as no returning adults of this category were expected for that year, " – " = assessment data not available.

Year	Live Genk Bank Origin Unfed Fry	Fall Parr (Adipose Clipped)	Adult Spawners Progeny of Wild Adult Returns (Genetically Analyzed)	Adult Spawners Adipose-Clipped Stray	Adult Spawners Unknown
2000	N/A	N/A	N/A	N/A	34
2001	N/A	N/A	N/A	N/A	18
2002	N/A	N/A	N/A	N/A	24
2003	N/A	3	N/A	0	15
2004	-	-	N/A	-	-
2005	4	0	N/A	0	37
2006	7	4	N/A	0	49
2007	16	6	6	0	16
2008	6	2	5	0	23
2009	4	0	12	0	19
2010	16	10	19	3	33
2011	19	0	53	0	39
2012	-	-	-	-	-
2013	-	-	-	-	-
2014	0	0	0	0	13
2015	6	0	0	0	22
2016	11	0	0	0	3
2017	-	-	-	-	-
2018	13	0	10	0	19
2019	4	0	15	0	7
Totals 2005 to 2019	**106**	**22**	**120**	**3**	**280**
% of Total	**19.96%**	**4.14%**	**22.60%**	**0.56%**	**52.73%**

Table 15: Summary of the Big Salmon River large salmon parentage analysis results from 2000 to 2019. "N/A" = parental analysis is not applicable as no returning adults of this category were expected for that year, " – " = assessment data not available.

Year	# Tissue Sampled	Live Genk Bank Origin Unfed Fry	Live Genk Bank Origin Fall Parr (Adipose Clipped)	Adult Spawners Progeny of Wild Adult Returns (Genetically Analyzed)	Adult Spawners Adipose Clipped Stray	Adult Spawners Unknown	Small Salmon Escapement	Proportion of Total Return Sampled
2000	0	N/A	N/A	N/A	N/A	0	7	0
2001	0	N/A	N/A	N/A	N/A	0	12	0
2002	0	N/A	N/A	N/A	N/A	0	7	0
2003	1	N/A	0	N/A	0	1	3	0.33
2004	0	-	-	N/A	-	-	9	0
2005	4	0	0	N/A	0	4	19	0.21
2006	3	0	0	N/A	0	3	17	0.18
2007	2	0	0	N/A	0	2	3	0.67
2008	2	1	0	0	0	1	14	0.14
2009	4	0	1	0	1	3	2	2
2010	4	0	0	0	0	4	9	0.44
2011	0	-	-	-	-	-	7	0
2012	0	-	-	-	-	-	5	0
2013	0	-	-	-	-	-	4	0
2014	1	1	0	0	0	0	3	0.33
2015	0	-	-	-	-	-	4	0
2016	0	-	-	-	-	-	5	0
2017	0	-	-	-	-	-	7	0
2018	0	-	-	-	-	-	2	0
2019	1	-	-	-	-	1	7	0.14
Totals	**22**	**2**	**1**	**0**	**1**	**19**	-	-

Table 16: Summary of Big Salmon River a) Live Gene Bank (LGB) origin and b) wild or unknown origin small and large adult salmon returns by total age after smoltification between 2000 and 2019 (n = 220 scale samples). "Unknown" = data not known, " – " = assessment data not available, N/A – Not applicable.

Total Years After Smoltification	Spawning History 1st	Spawning History 2nd	Spawning History 3rd	'	Individual Count	Mean Female Length (cm)	Mean Fecundity (# of Eggs)	% Female	% Sample
a) Live Gene Bank Origin	-	-	-	-	-	-	-	-	-
Small salmon	-	-	-	-	-	-	-	-	-
1	0	N/A	N/A	[1]	47	55.2	3,288	59.57%	94.00%
Large salmon	-	-	-	-	-	-	-	-	-
2	0	N/A	N/A	[2]	1	80	8,191	100.00%	2.00%
2	1	N/A	N/A	[3]	1	-	-	0.00%	2.00%
3	2	N/A	N/A	[3]	1	80	8,191	100.00%	2.00%
b) Wild or Unknown Origin	-	-	-	-	-	-	-	-	-
Small salmon	-	-	-	-	-	-	-	-	-
1	0	N/A	N/A	[1]	147	55.6	3,342	58.33%	86.47%
2	1	N/A	N/A	[3]	3	62	4,223	66.70%	1.76%
Large salmon	-	-	-	-	-	-	-	-	-
1	0	N/A	N/A	[1]	3	-	-	0.00%	1.76%
2	1	N/A	N/A	[3]	9	65.1	4,734	62.50%	5.29%
3	1	2	N/A	[3]	4	68.6	5,385	100.00%	2.35%
4	1	2	3	[3]	2	75	6,814	100.00%	1.18%
2	0	N/A	N/A	[2]	1	73.5	6,449	100.00%	0.59%
3	2	N/A	N/A	[3]	1	-	-	Unk.	0.59%

[1] Maiden 1SW salmon, [2] Maiden 2SW salmon, [3] Repeat spawner.

Table 17: Summary of small and large Atlantic Salmon returns captured at the White Rock Dam fishway on the Gaspereau River from 1995 to 2019. "Unknown" = unknown origin, either origin could not be determined by parentage analysis or tissue sample were not collected. "LGB" = returns from Live Gene Bank program – confirmed by genetic analysis, "Hatchery" = hatchery returns prior to the LGB program, and "Wild" = wild-origin from previous adult spawners, " – " = assessment data not available, N/A = not applicable.

Year	Small Salmon Hatchery	Small Salmon LGB	Small Salmon Wild	Small Salmon Unknown	Small Salmon Total	Large Salmon Hatchery	Large Salmon LGB	Large Salmon Wild	Large Salmon Unknown	Large Salmon Total	Grand Total
1995	29	N/A	33	0	62	0	N/A	19	0	19	81
1996	75	N/A	41	0	116	29	N/A	33	0	62	178
1997	30	N/A	12	0	83	7	N/A	12	0	19	102
1998	62	N/A	8	0	78	12	N/A	9	0	21	99
1999	0	N/A	3	0	3	13	N/A	25	0	38	41
2000	35	N/A	5	0	56	13	N/A	7	0	20	76
2001	11	N/A	12	0	23	13	N/A	20	0	33	56
2002	2	N/A	8	0	10	4	N/A	0	0	4	14
2003	3	N/A	3	0	6	0	N/A	2	0	2	8
2004	6	N/A	5	7	18	1	N/A	0	0	1	19
2005	N/A	2	0	0	2	0	N/A	0	0	0	2
2006	N/A	2	1	0	3	N/A	1	0	0	1	4
2007	N/A	0	0	3	3	N/A	0	0	0	0	3
2008	N/A	11	0	1	12	N/A	4	0	0	4	16
2009	N/A	4	0	0	4	N/A	0	0	1	1	5
2010	N/A	2	1	3	6	N/A	3	0	0	3	9
2011	N/A	5	0	3	8	N/A	4	0	1	5	13
2012	N/A	1	0	1	2	N/A	1	0	0	1	3
2013	N/A	0	0	0	0	N/A	0	1	1	2	2
2014	N/A	2	0	0	2	N/A	0	0	0	0	2
2015	N/A	5	0	0	5	N/A	3	0	2	5	10
2016	N/A	3	0	2	5	N/A	0	0	0	0	5
2017	N/A	10	0	1	11	N/A	1	0	0	1	12
2018	N/A	6	1	2	9	N/A	0	0	0	0	9
2019	N/A	14	0	0	14	N/A	8 [1]	0	0	8 [1]	22
Total	**0**	**67**	**3**	**16**	**86**	**0**	**25**	**1**	**5**	**31**	**116**
% Total	**N/A**	**77.91%**	**3.49%**	**18.60%**	**N/A**	**N/A**	**80.64%**	**3.23%**	**16.13%**	**N/A**	**N/A**

[1] The large salmon estimate includes 8 LGB returns that were released as acoustic tagged kelts in May 2019.

Table 18: Summary of a) Live Gene Bank (LGB) origin and b) wild or unknown origin small and large salmon by total age after smoltification, spawning history, mean length (cm), fecundity (number of eggs), percent female, and percentage of salmon in the Gaspereau River. Values were determined from 125 aged scale samples collected from wild, hatchery and LGB-origin adult returns captured in the White Rock Dam fishway from 2001 to 2016. " – " = assessment data not available, N/A = not applicable. Reproduced from Jones et al. (2020).

Total Years After Smoltification	Spawning History 1st	Spawning History 2nd	Spawning History 3rd	'	Individual Count	Mean Female Length (cm)	Mean Fecundity (# of Eggs)	% Female	% Sample
a) Live Gene Bank Origin	-	-	-	-	-	-	-	-	-
Small salmon	-	-	-	-	-	-	-	-	-
1	0	N/A	N/A	[1]	42	53.6	3,100	11.90%	62.70%
Large Salmon	-	-	-	-	-	-	-	-	-
2	0	N/A	N/A	[2]	21	70.4	5,753	85.70%	31.30%
3	0	N/A	N/A	[3]	2	69	5464	50.00%	3.00%
3	1	N/A	N/A	[4]	2	N/A	N/A	0.00%	3.00%
b) Wild or Unknown Origin	-	-	-	-	-	-	-	-	-
Small salmon	-	-	-	-	-	-	-	-	-
1	0	N/A	N/A	[1]	34	53.6	3,100	70.60%	58.60%
2	0	N/A	N/A	[2]	1	57.5	3,579	100.00%	1.70%
Large Salmon	-	-	-	-	-	-	-	-	-
2	0	N/A	N/A	[2]	21	68.6	5385	95.20%	36.20%
3	1	N/A	N/A	[4]	2	75	6,814	50.00%	3.40%

[1] Maiden 1SW salmon, [2] Maiden 2SW salmon, [3] Maiden 3SW salmon, [4] Repeat spawner.

Table 19: Summary of declines in adult Atlantic Salmon returns and escapement for two river populations in IBoF DU 15 from a log-linear model fit via least squares. The standard errors (SE) and 95% confidence intervals (C.I.) are shown. 13 years corresponds to three generations for the Big Salmon River population. A negative value for the decline rate indicates an increasing population size. Model fits are shown in Figures 19-22.

Population	Time Period	No. of Years	Slope	(SE)	Log-linear Model 1 Yr. decline rate (%)	Log-linear Model 95% C.I.	Log-linear Model 95% C.I.	Log-linear Model Decline over time period (%)	Log-linear Model 95% C.I.	Log-linear Model 95% C.I.
Big Salmon River Total Returns	2006–2019	13	-0.07	0.04	6.63	-1.24	13.90	59.01	-17.42	85.70
Big Salmon River Total Escapement	2006–2019	13	-0.07	0.04	6.90	-0.74	13.97	60.52	-10.03	85.85
Gaspereau River Total Returns	2009–2019	10	0.07	0.07	-2.65	-22.78	6.59	-29.95	-678.77	49.43
Gaspereau River Total Escapement	2009–2019	10	-0.06	0.07	5.59	-8.46	17.82	57.79	-238.18	94.74

Table 20: Percent of Stewiacke smolts belonging to each fate group in the three study years.

-	2017	2018	2019
Successful migrants	14%	46%	62.5%
Mortalities	38%	18%	12.5%
predations	48%	36%	25%

Table 21: Estimated smolt-to-small salmon return rates for Big Salmon River Live Gene Bank (LGB) origin fry and parr, as well as adult spawners. N/A =not applicable, " – " = assessment data not available.

Smolt Year	LGB Smolt Release	Combined LGB Unfed Fry	Combine d LGB Parr	Combined Adult Spawners	Smolt-to-Small Salmon Return Rate by Origin LGB Unfed Fry	Smolt-to-Small Salmon Return Rate by Origin LGB Parr	Smolt-to-Small Salmon Return Rate by Origin Adult Spawners	% Combined [1]
2001	-	-	-	5,290	NA	NA	0.45%	0.45%
2002	19,725	-	2,035	4,295	NA	0.15%	0.35%	0.28%
2003	13,650	3,640	6,120	5,560	-	-	-	0.05%
2004	11,663	3,036	1,691	2,934	0.13%	0.00%	1.26%	0.54%
2005	1,296	3,320	4,175	1,230	0.21%	0.10%	3.98%	0.69%
2006	1,413	8,954	8,940	8,401	0.18%	0.07%	0.26%	0.17%
2007	-	2,363	5,855	4,037	0.25%	0.03%	0.69%	0.29%
2008	-	3,909	2,110	6,841	0.10%	0.00%	0.45%	0.27%
2009	2,072	6,568	4,756	5,392	0.24%	0.21%	0.96%	0.47%
2010	2,077	5,464	6,840	7,156	0.35%	0.00%	1.29%	0.57%
2011	432	4,543	2,939	5,592	-	-	-	0.08%
2012	NA	4,239	1,900	6,881	-	-	-	0.05%
2013	NA	5,350	1,050	4,490	0.00%	0.00%	0.29%	0.12%
2014	NA	1,482	40	2,988	0.40%	0.00%	0.74%	0.62%
2015	NA	6,435	NA	3,255	0.17%	NA	0.09%	0.14%
2016	NA	5,737	NA	1,443	-	-	-	-
2017	NA	7,879	NA	1,501	0.05%	NA	0.60%	0.45%
2018	NA	4,776	NA	2,534	0.02%	NA	0.24%	0.36%
2019	NA	8,336	NA	1,654	-	-	-	-
Mean (2004 to 2010)	**Mean (2004 to 2010**	-	-	-	**0.21%**	**0.06%**	**1.27%**	**0.43%**
Mean (2005 to 2018)	**Mean (2005 to 2018)**	-	-	-	**0.18%**	**0.05%**	**0.87%**	**0.33%**
Mean (2001 to 2018)	**Mean (2001 to 2018)**	-	-	-	**0.18%**	**0.06%**	**0.83%**	**0.32%**

[1] Combined excludes LGB smolt releases.

Table 22: Estimated smolt-to-small and large salmon return rates for Gaspereau River Live Gene Bank (LGB) origin fry and parr, as well as adult spawners. " – " = assessment data not available.

Smolt Year	LGB Smolt Release	LGB Unfed Fry	LGB Parr	Adult Spawners	% Small	% Small + Large
2007	1,035	2,934 [1]	**-**	71	0.40%	0.43%
2008	3,300	1,033 [1]	**-**	67	0.36%	0.64%
2009	-	1,077 [1]	3,099	1,459	0.11%	0.21%
2010	-	1,061 [1]	5,391	902	0.10%	0.12%
2011	-	932	2,634	2,153	0.02%	0.05%
2012	300	622	461	585	0.00%	0.00%
2013	-	2,772	-	228	0.07%	0.23%
2014	-	1,012	-	162	0.43%	0.43%
2015	-	1,973	-	1,295	0.15%	0.18%
2016	-	4,567	-	645	0.21%	0.21%
2017	-	2,691	-	399	0.29%	0.29%
2018	-	1,779	-	291	0.68%	-
2019	-	2,185	-	277	-	-
Mean	**-**	**-**	**-**	**-**	**0.23%**	**0.29%**

FIGURES

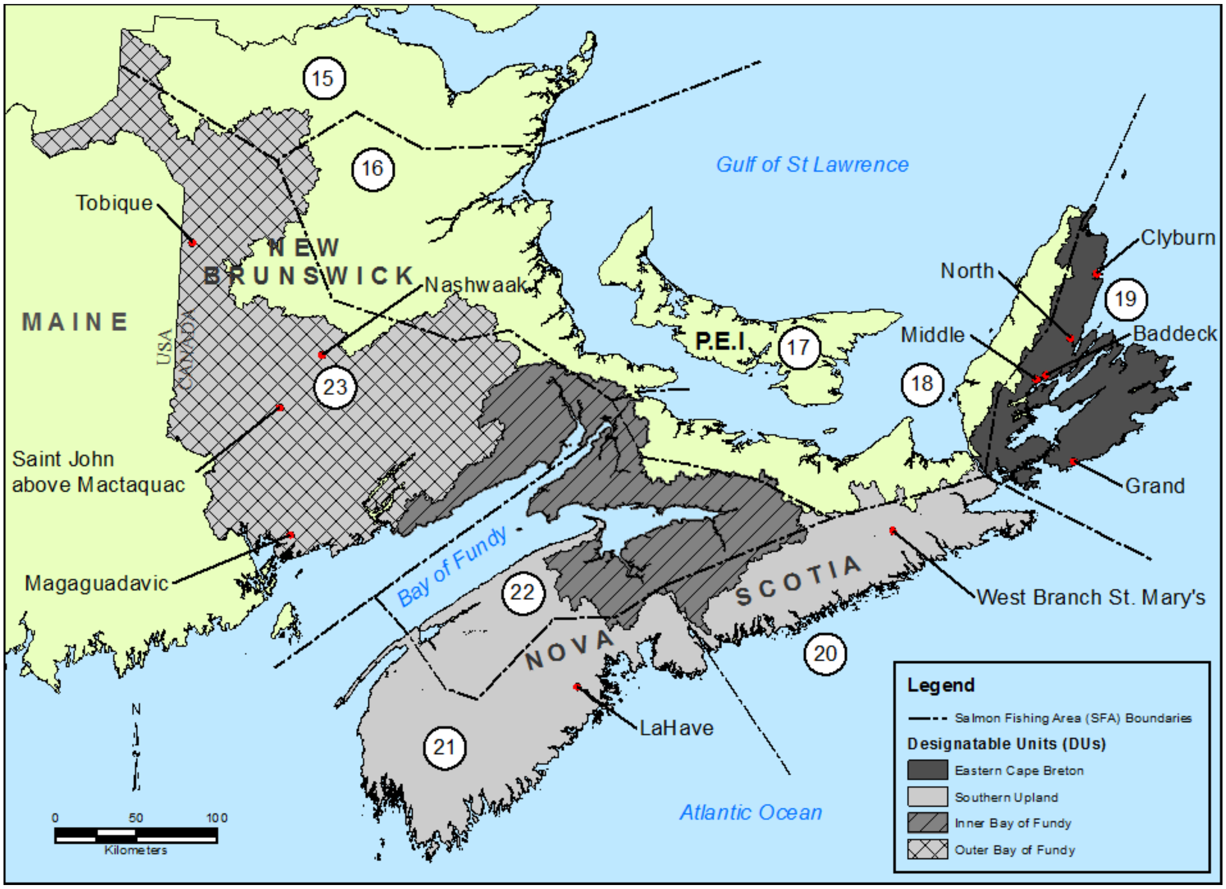

Figure 1: Map showing the locations of Salmon rivers where monitoring predominately occurred, Salmon Fishing Areas (SFAs), and Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Designatable Units (DUs) mentioned in this update. SFA numbers are labeled inside the white circles. Data Source for DUs derived from NS Secondary Watershed Layer (NS Dept. of Environment) and NB Watershed Level 1 Layer (NB Dept. of Natural Resources).

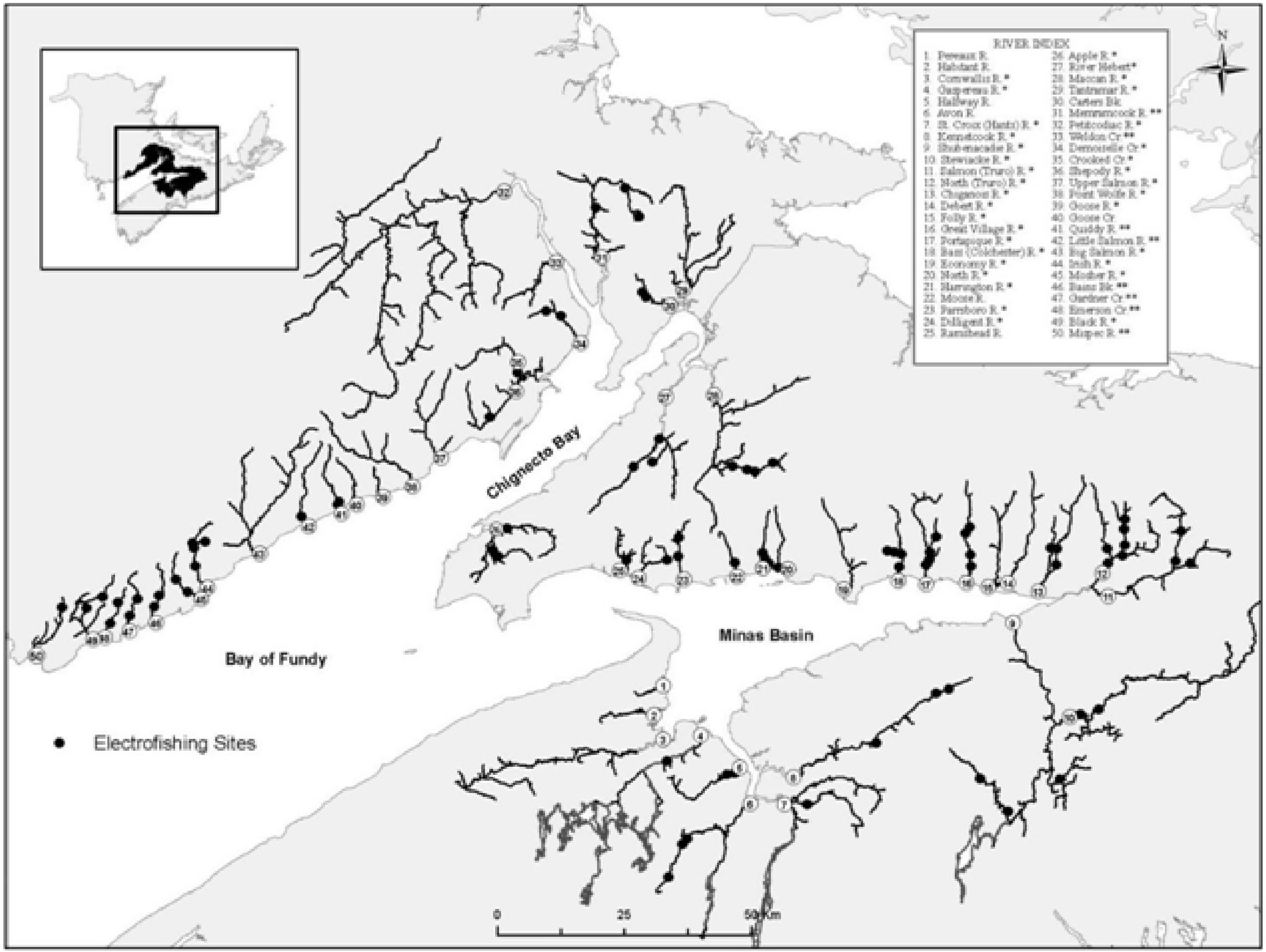

Figure 2: The locations of the Inner Bay of Fundy (IBoF) Atlantic Salmon designatable unit (DU) and the fifty (50) IBoF rivers in the Recovery Strategy (DFO 2010). The rivers marked with an asterisk (*) supported self-sustaining Atlantic Salmon populations, as suggested by recreational catch and historical electrofishing data. The double asterisk (**) identified rivers are reported to have produced salmon.

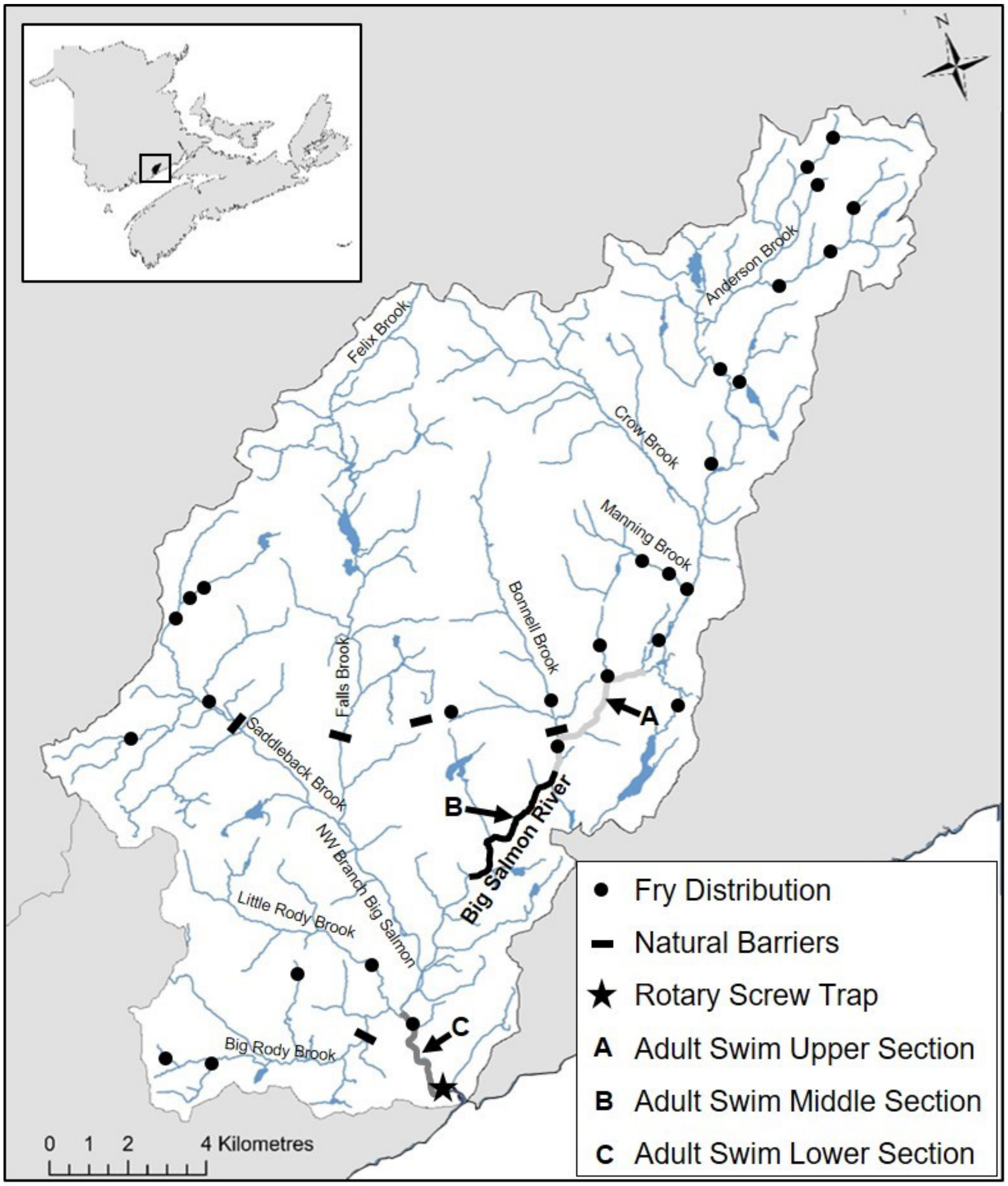

Figure 3: Map of assessment efforts on the Big Salmon River, New Brunswick (NB) showing locations of fry distribution sites (solid black circle), natural barriers (solid black rectangle), rotary screw trap operations (black star), adult swim surveys [upper (bold A, solid light grey line), middle (bold B, solid black line), lower (bold C, solid grey line).

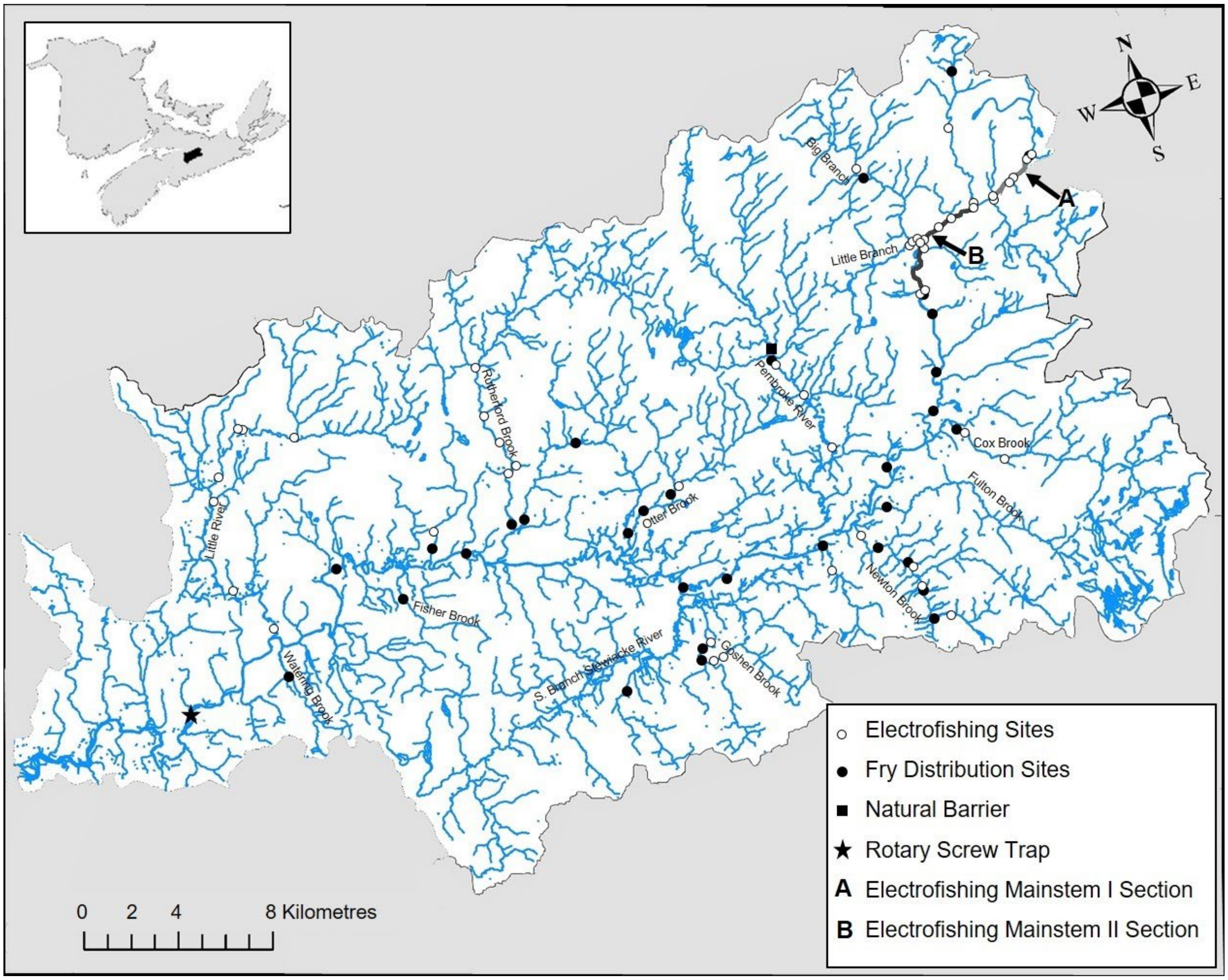

Figure 4: Map of assessment efforts on the Stewiacke River, Nova Scotia (NS) showing locations of fry distribution sites (solid black circle), natural barriers (solid black square), rotary screw trap operations (black start), and electrofishing sites (white circle) and surveys (section I [bold A, dark grey line] and section II [bold B, dark grey line]).

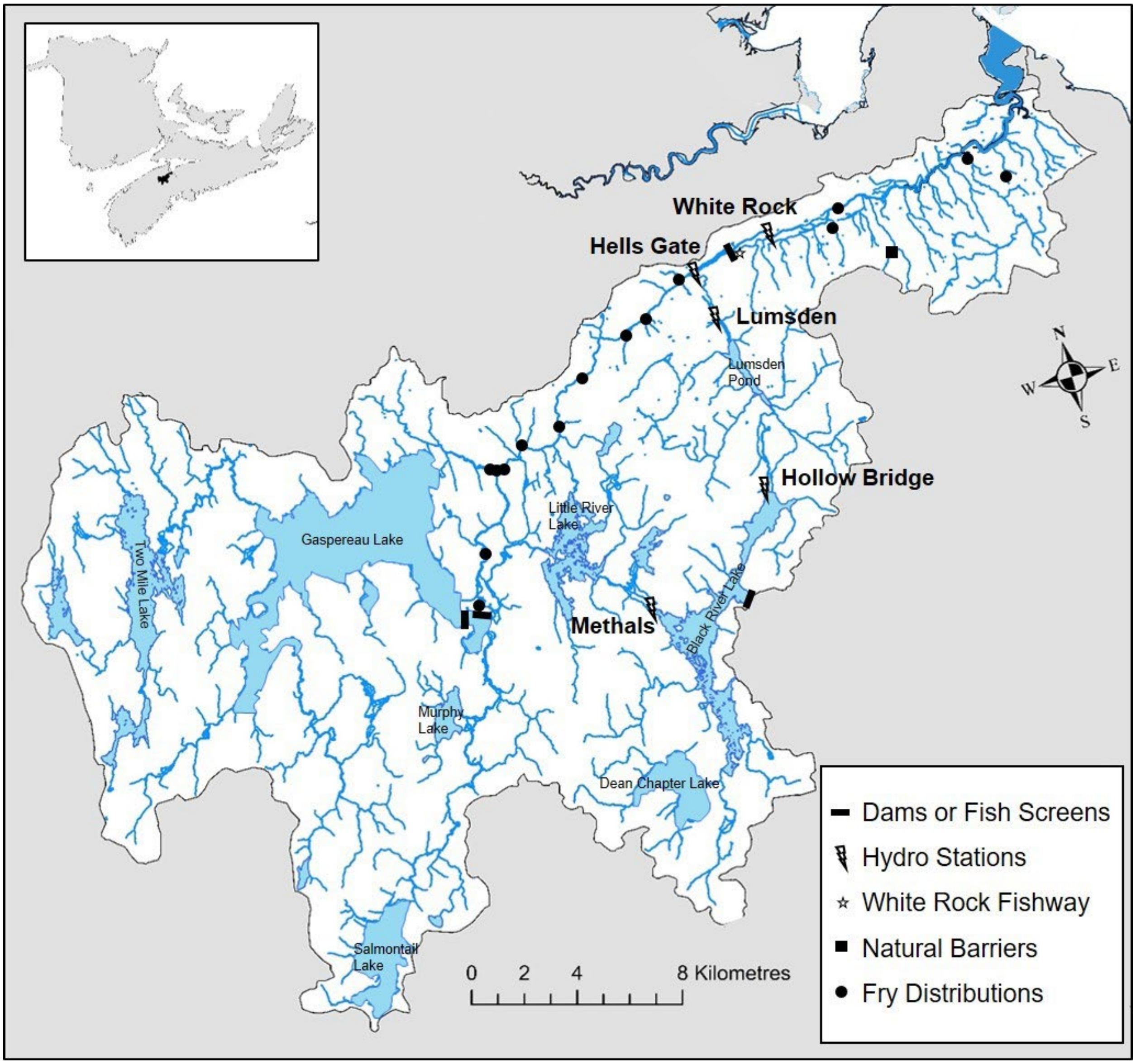

Figure 5: Map of assessment efforts on the Gaspereau River, Nova Scotia (NS) showing locations of hydroelectric landmarks [dams/fish screen (solid black rectangle), hydro station (white with black outline zigzag), and White Rock fishway (white star)], fry distribution sites (solid black circle), and natural barriers (solid black square).

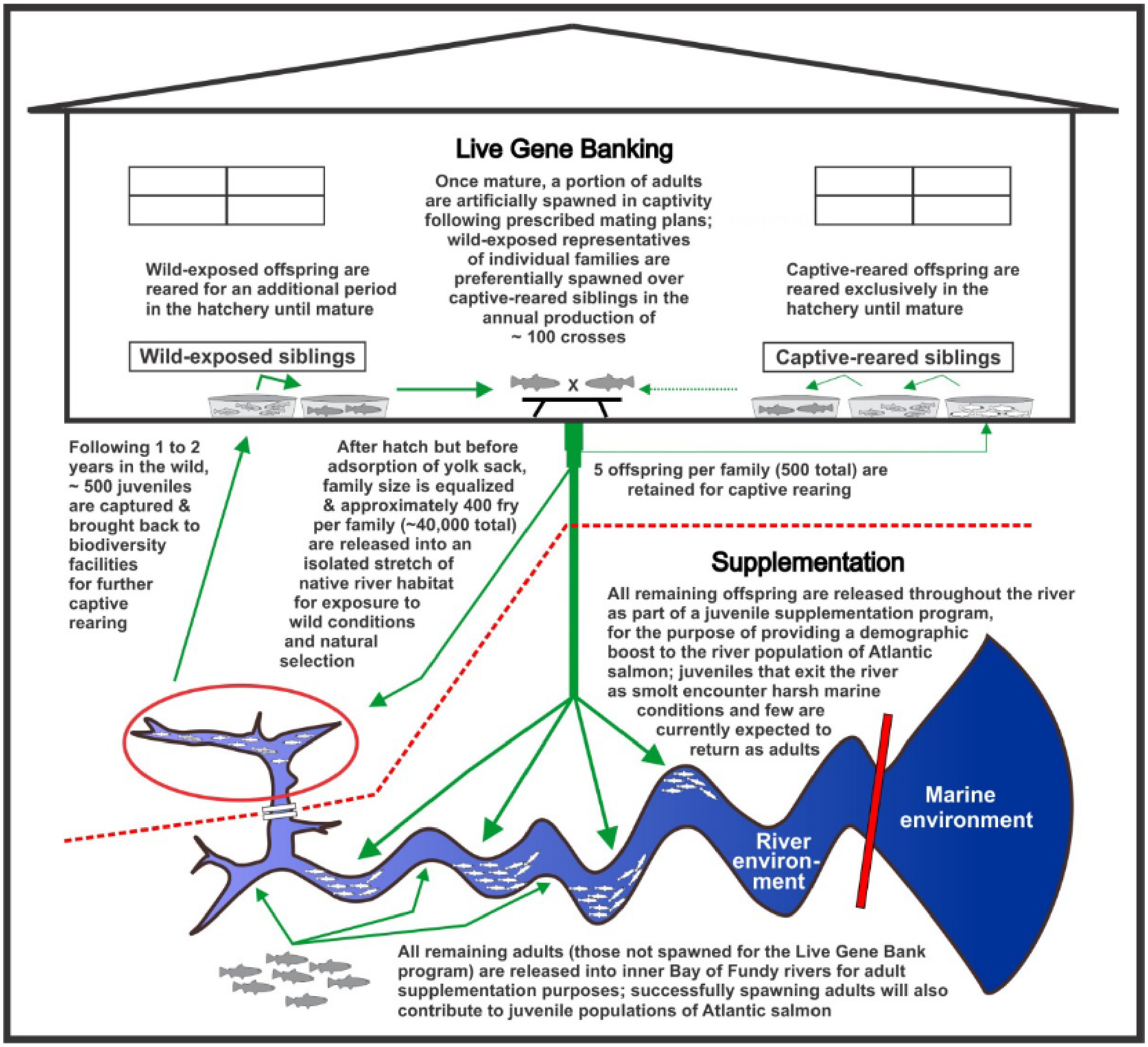

Figure 6: Schematic of the current Stewiacke River Inner Bay of Fundy conservation program, including Live Gene Banking (above red dotted line) and supplementation (below red dotted line) components. Reproduced from DFO (2018).

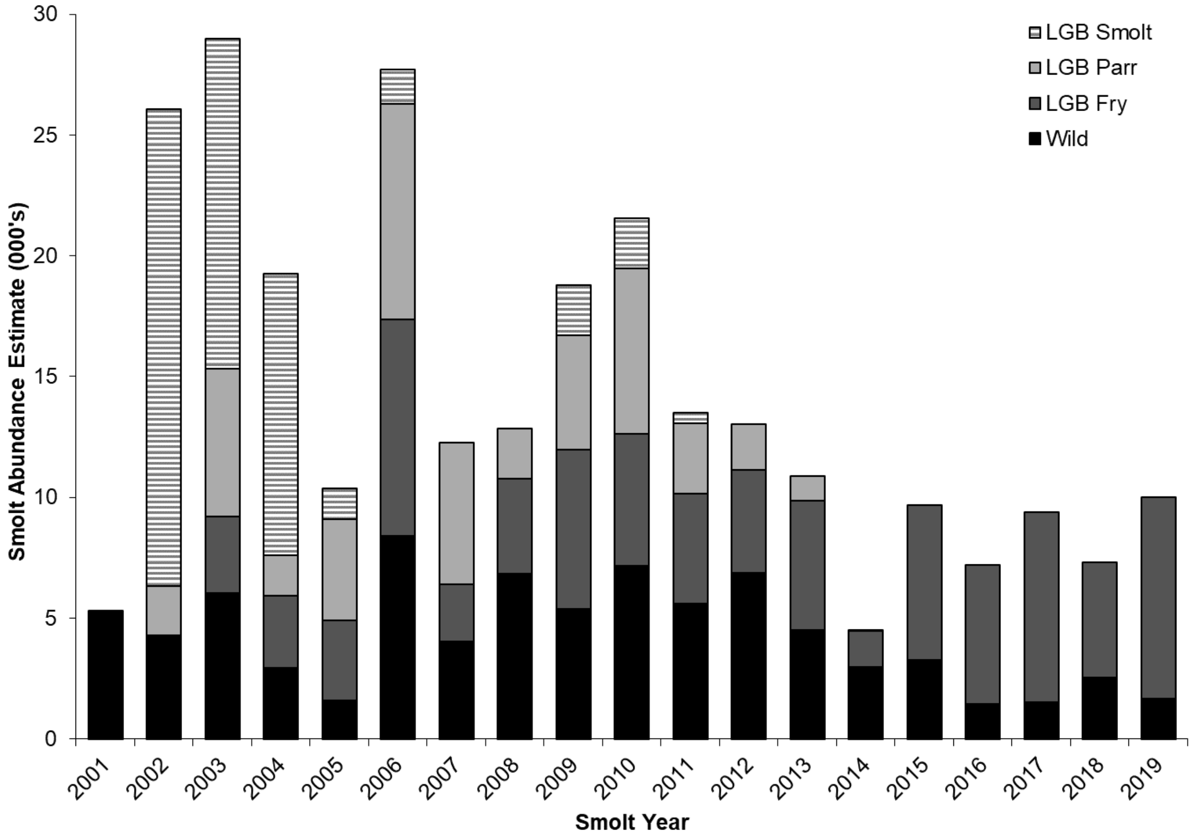

Figure 7: Estimates of Big Salmon River smolt abundance (000's) by origin from 2001 to 2019.

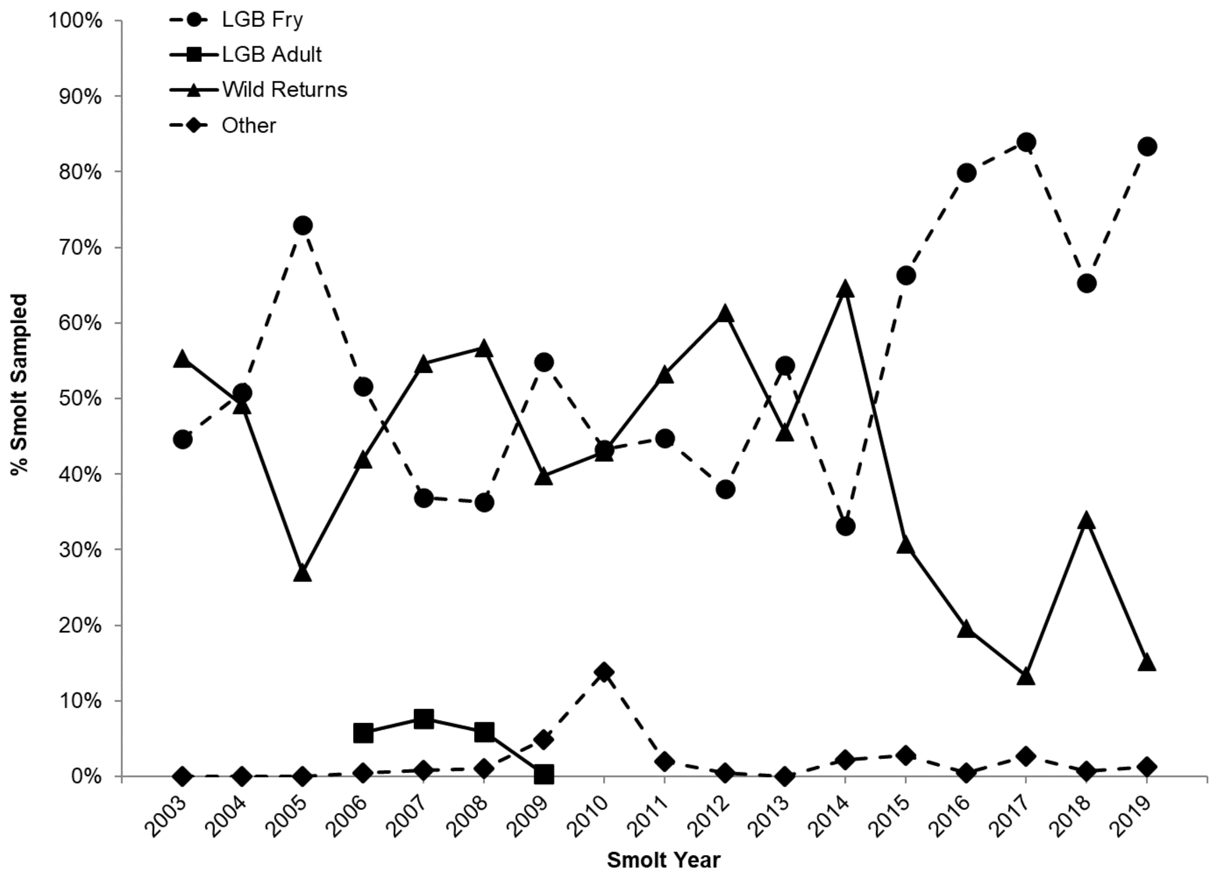

Figure 8: Genetic parentage analysis to determine origin of the Big Salmon River-emigrating non-adipose clipped smolts sampled from 2003 to 2019. 'Wild returns' are a combination of those smolts that assign to previous adult returns (i.e., sampled during assessment activities) and those that do not assign to any parents in the Live Gene Bank database.

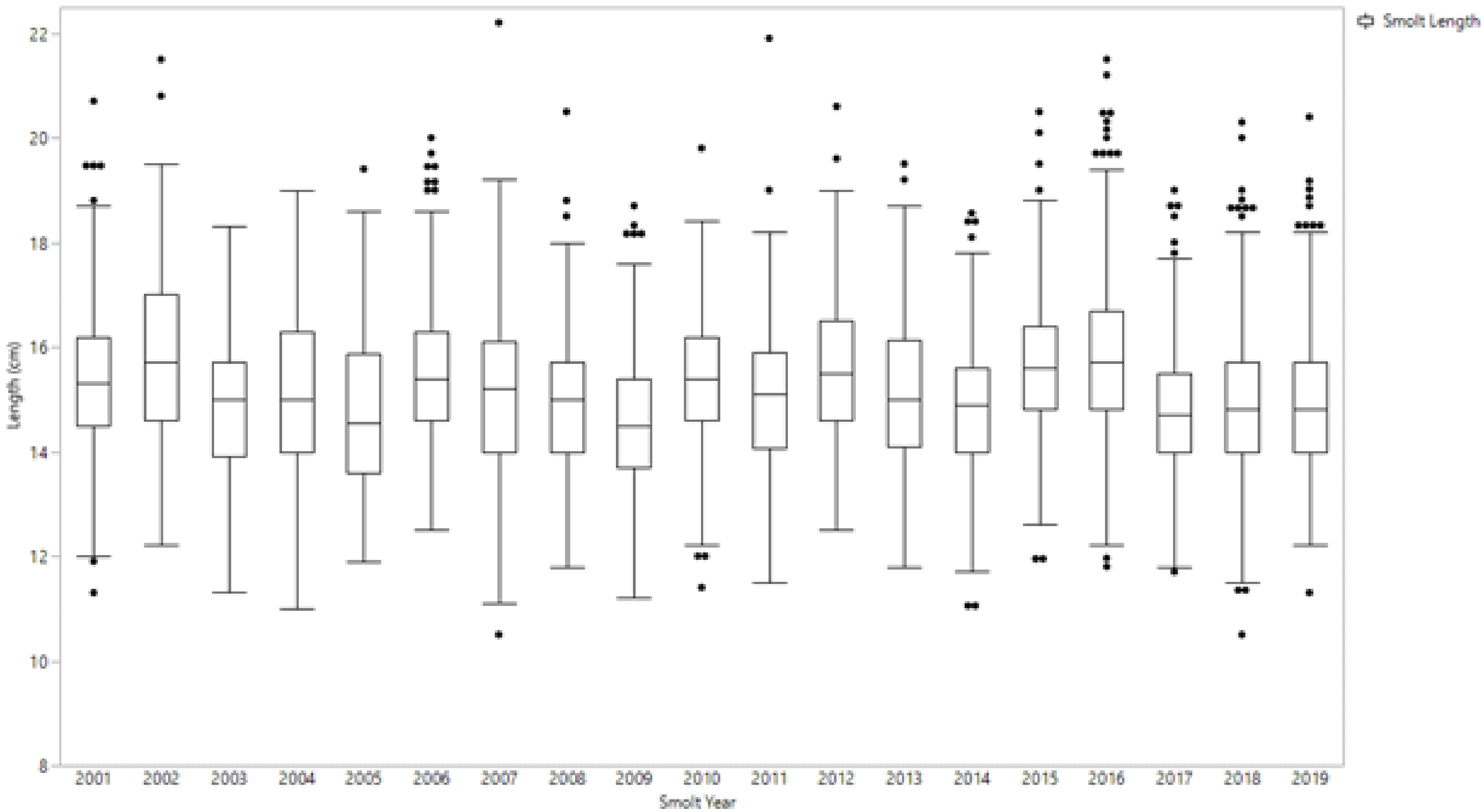

Figure 9: Box plot summarizing the variation in wild/LGB$_{FRY}$ smolt lengths measured at the Big Salmon River Rotary Screw Trap from 2001 to 2019, showing the median and the 25th and 75th percentiles. Error bars represent the 10th and 90th percentiles, with outliers denoted as circles.

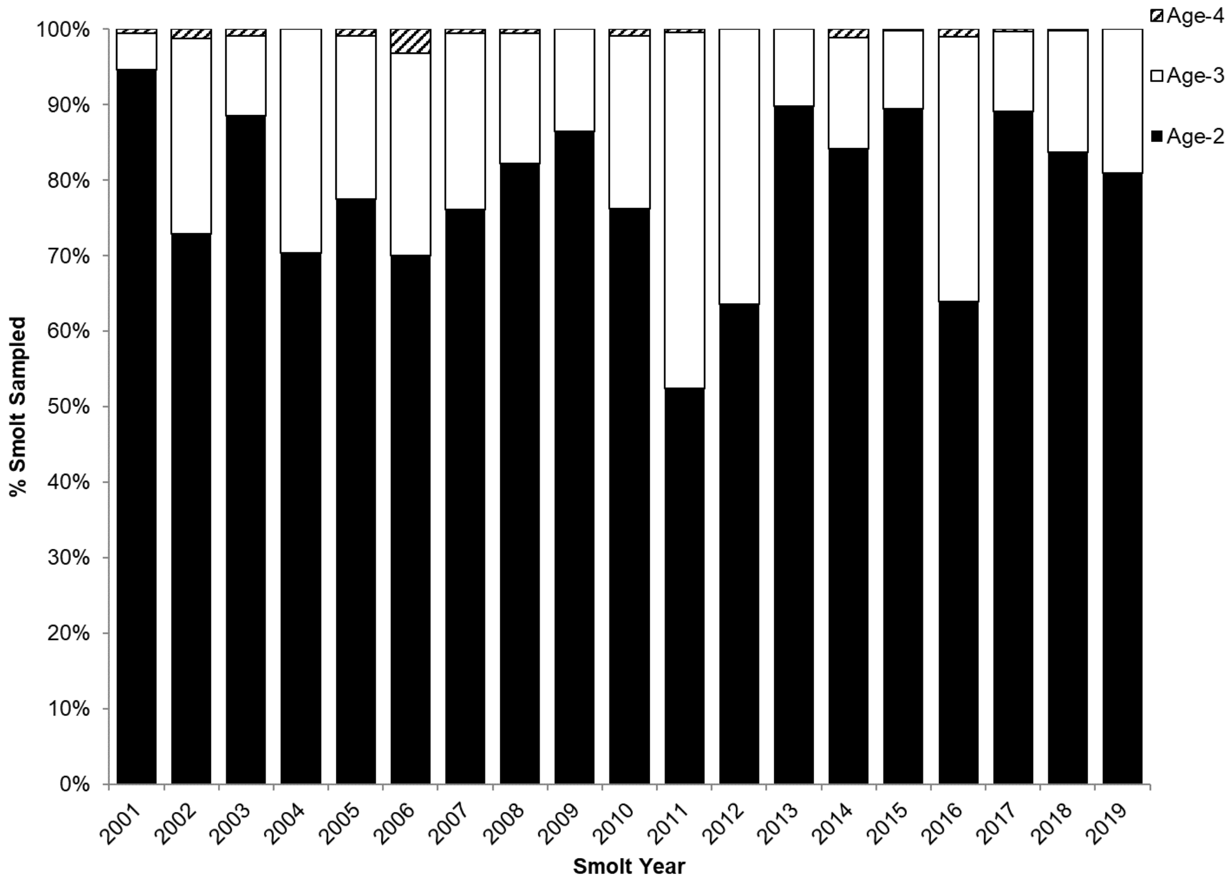

Figure 10: Big Salmon River wild and/or Live Gene Bank fry-origin smolt age proportions as determined by scale analysis from 2001 to 2019. Scale sampling at the Big Salmon River includes all smolt collected for the LGB (wild/LGB$_{FRY}$ origin), as well as a proportion of LGB$_{PARR}$.

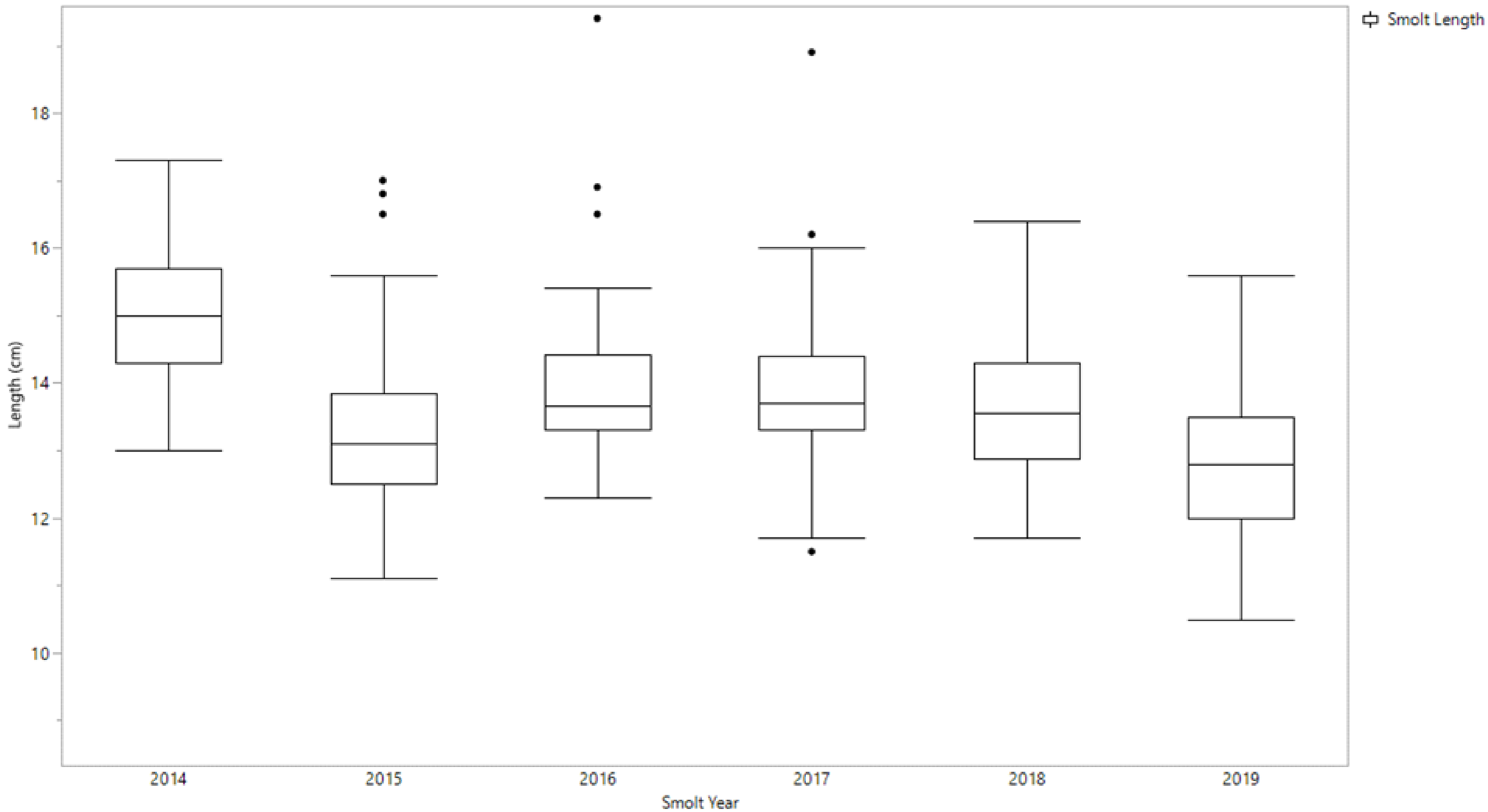

Figure 11: Box plot summarizing the variation in wild/LGB$_{FRY}$ smolt lengths measured at the Stewiacke River Rotary Screw Trap from 2014 to 2019, showing the median and the 25th and 75th percentiles. Error bars represent the 10th and 90th percentiles, with outliers denoted as circles.

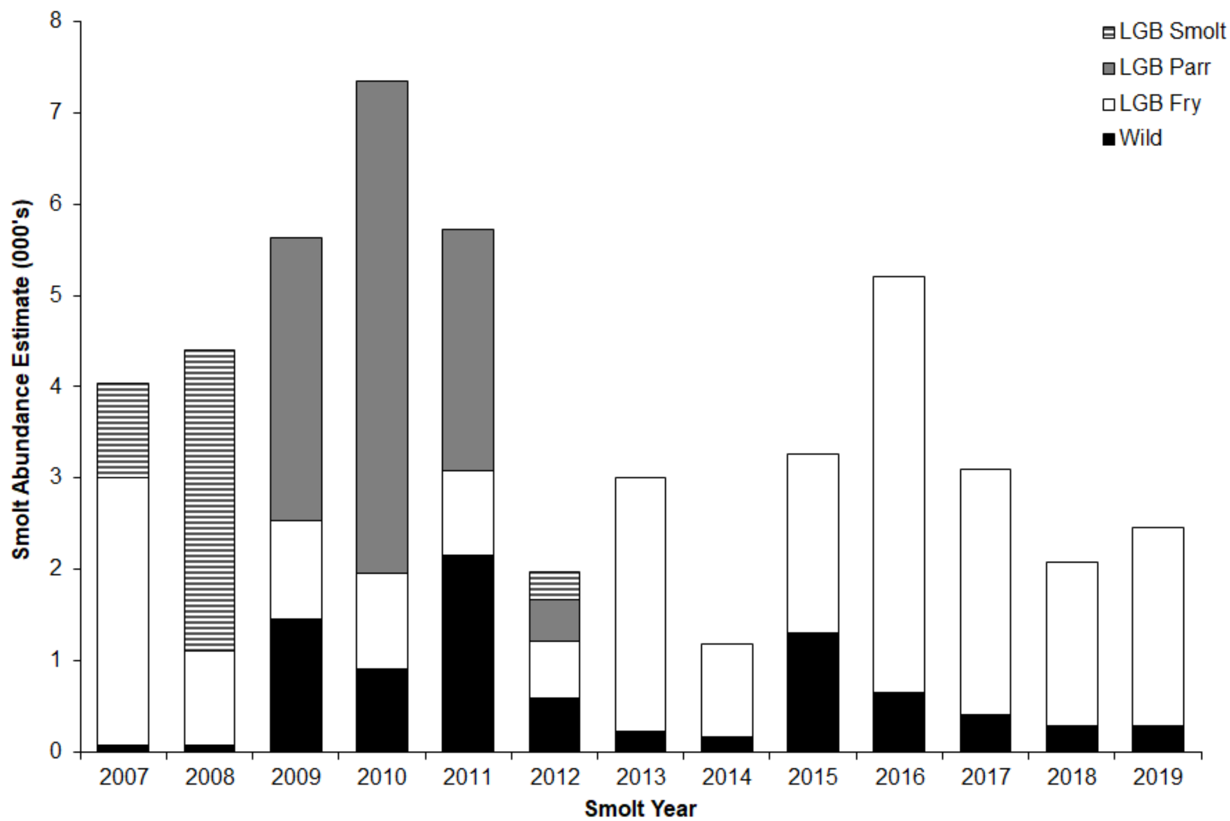

Figure 12: Estimates of Gaspereau River smolt abundance (000's) by origin from 2001 to 2019.

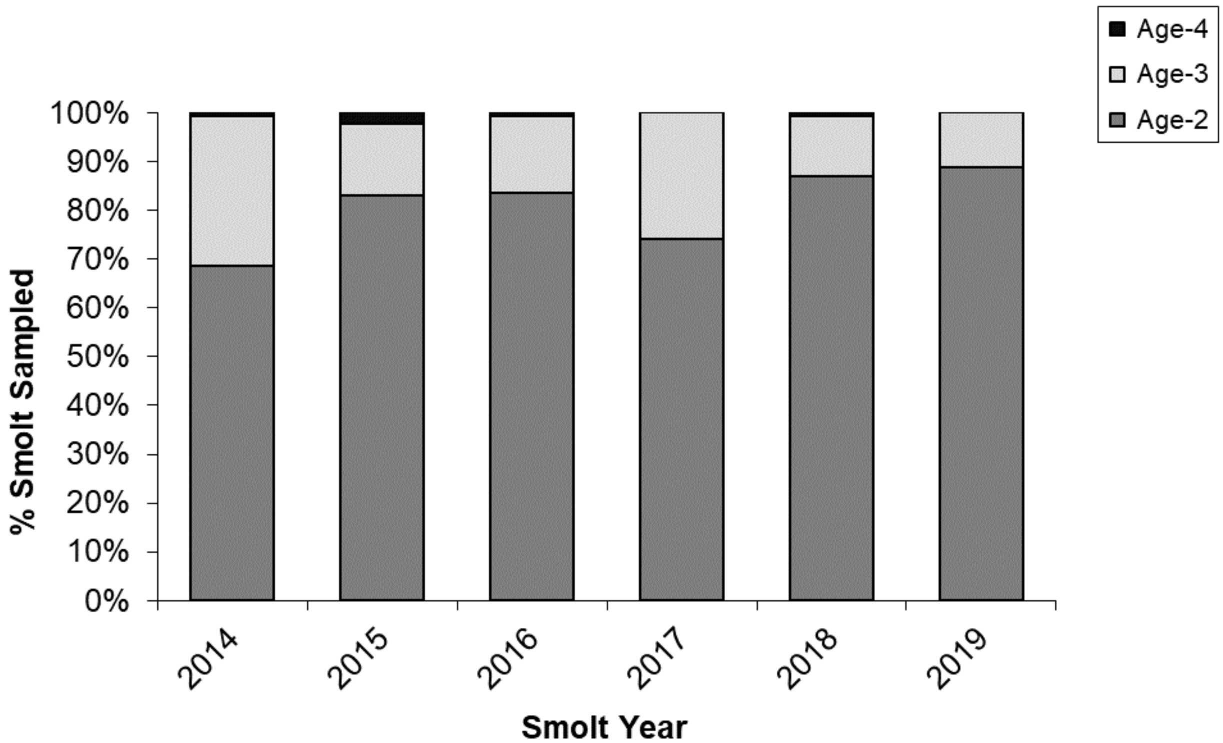

Figure 13: Summary of the age proportions for sampled Gaspereau River wild-or LGB_{FRY}-origin smolt, as determined by scale analysis, from 2014 to 2019.

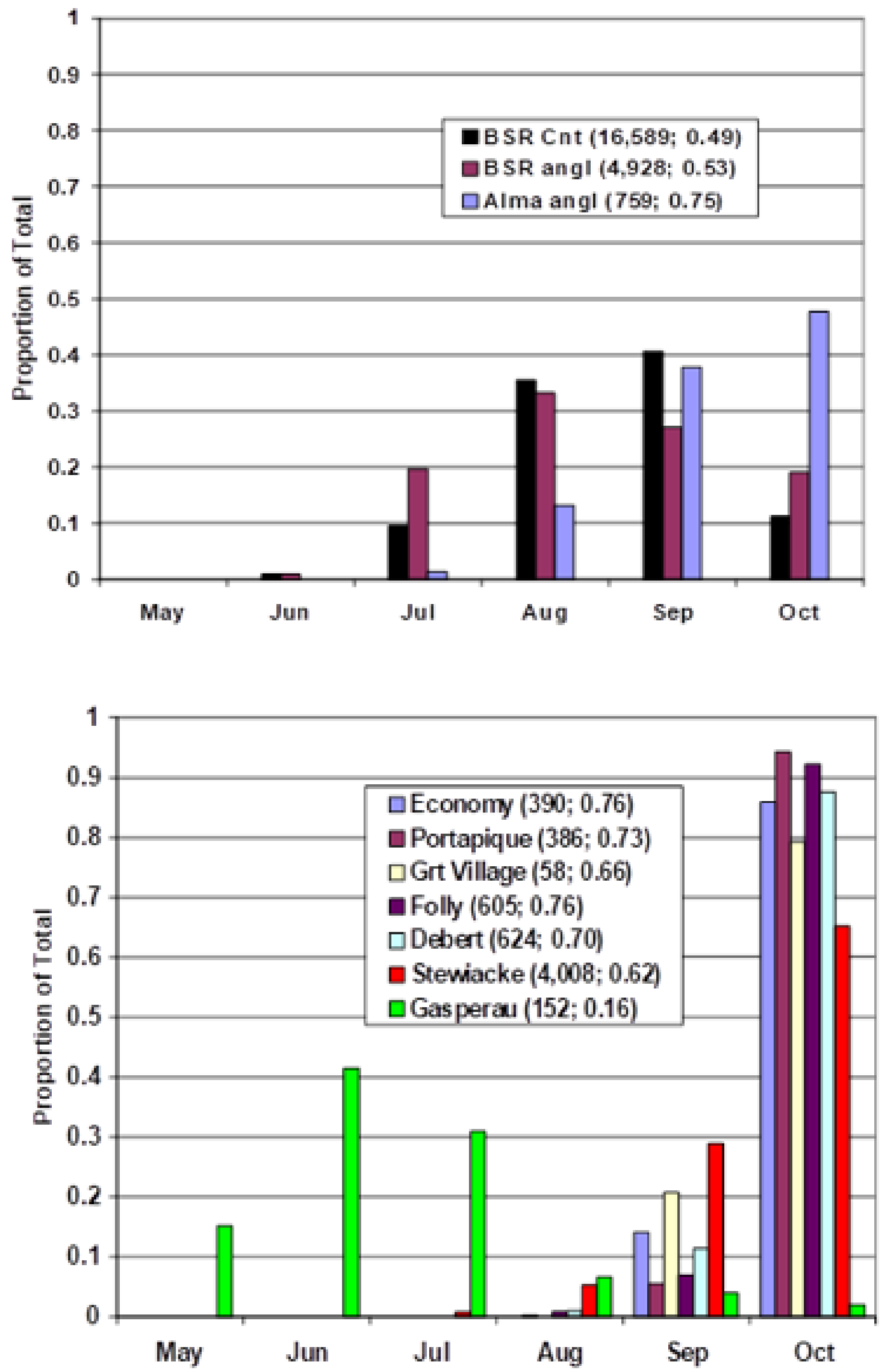

Figure 14: Monthly distribution of adult salmon returns to Big Salmon River counting fence, 1964-1966, 1968-1970 and 1972 (Jessop 1986) and caught by anglers in the Big Salmon and Alma (Upper Salmon) rivers, 1964-1973 (Swetnam and O'Neil 1985, O'Neil and Swetnam 1984) (upper panel) and caught by anglers, 1964-1973, in rivers of Cobequid Basin, NS (Swetnam and O'Neil, op. cit., O'Neil and Swetnam, op. cit.), 1964-1973. Numbers of fish and proportion 1SW in parenthesis. Reproduced from Marshall (2014).

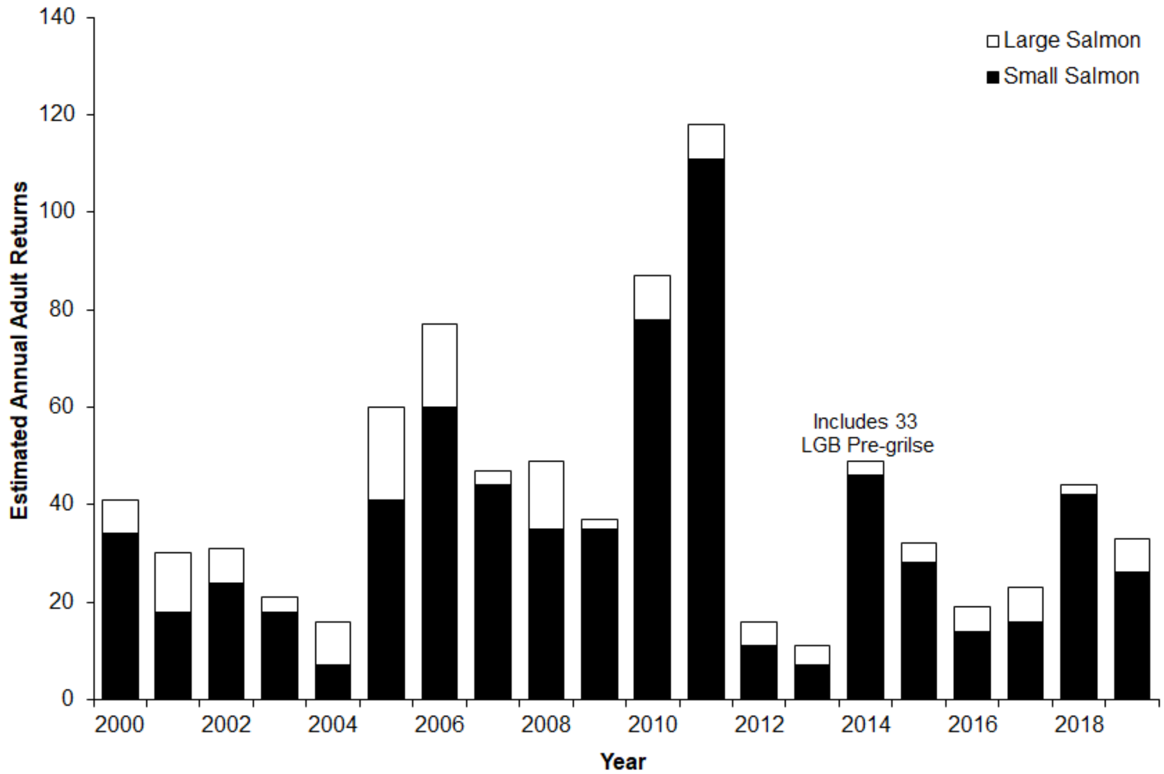

Figure 15: Estimated Big Salmon River small (solid black) and large (solid white) adult salmon returns from 2000 to 2019.

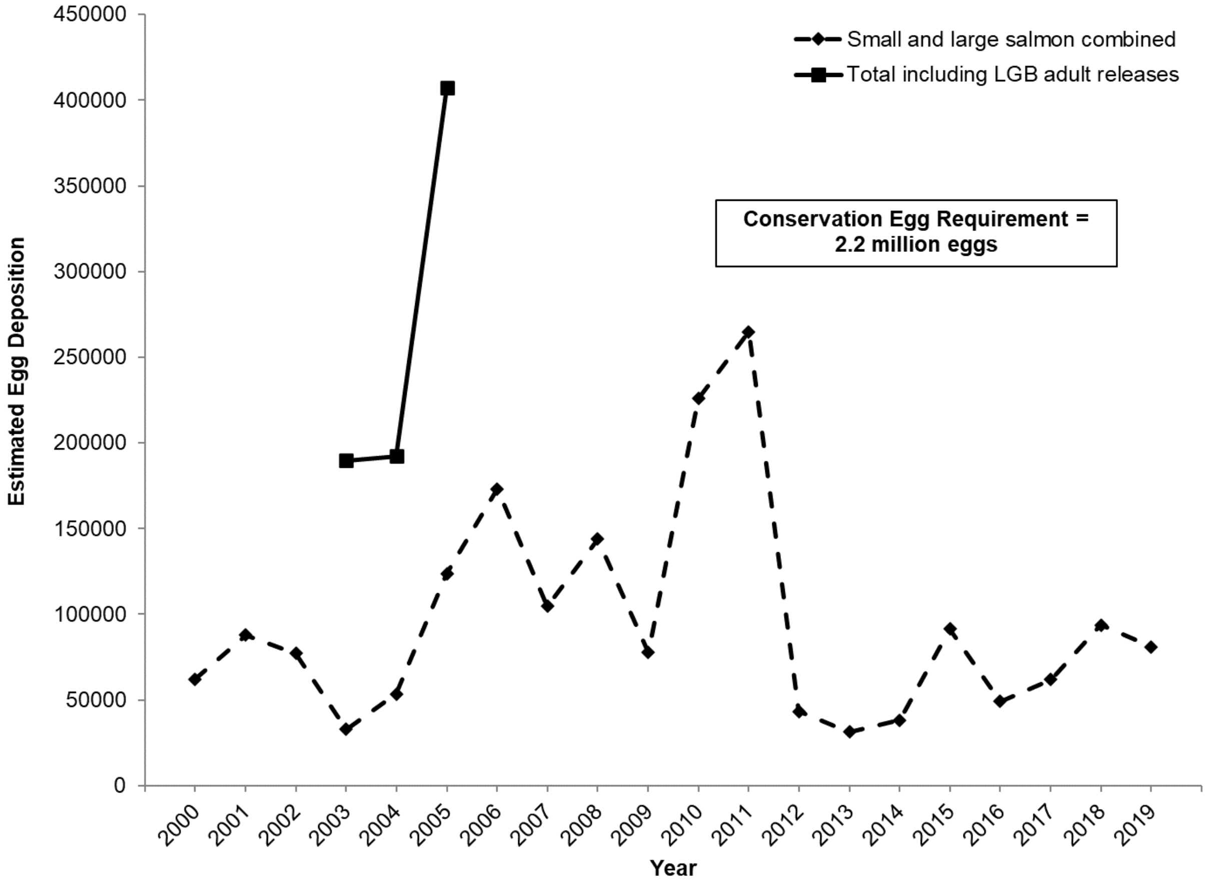

Figure 16: Estimated egg deposition on the Big Salmon River from 2000 to 2019.

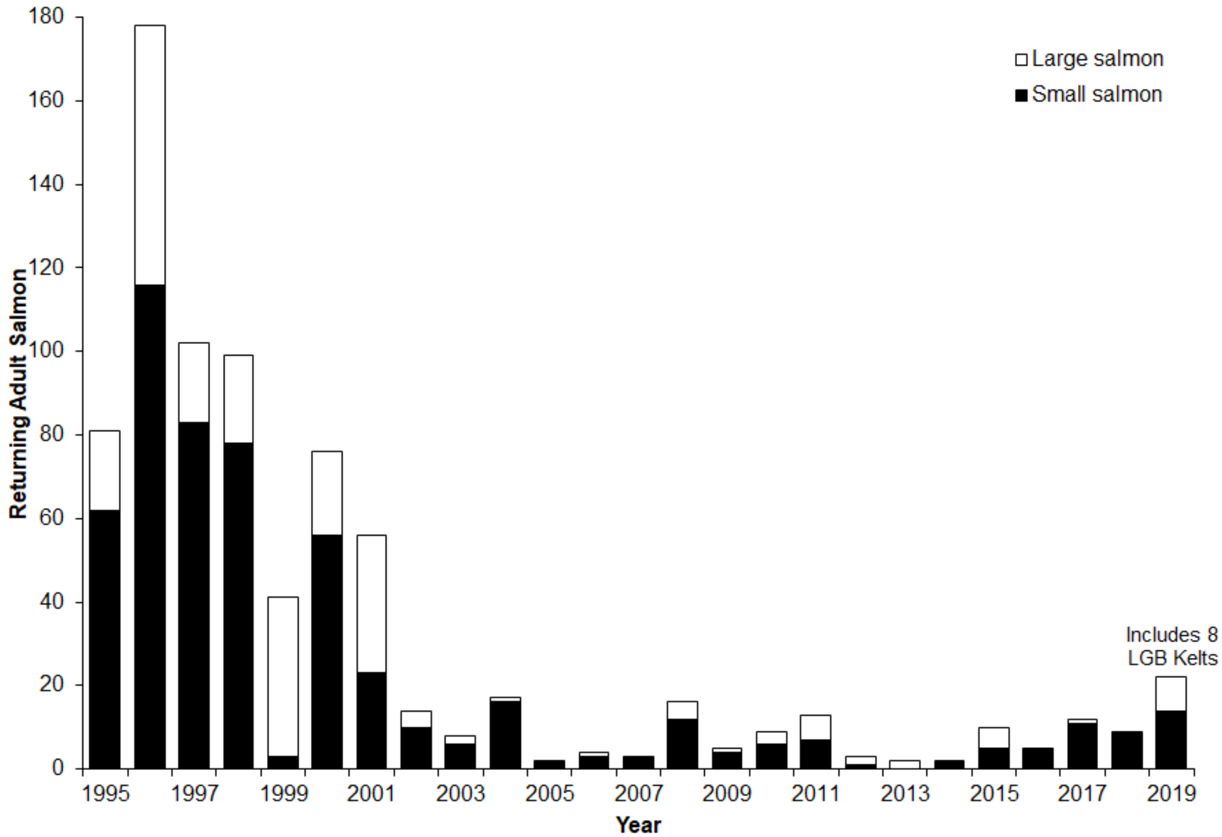

Figure 17: Gaspereau River small and large salmon counts to the White Rock Dam fishway from 1995 to 2019.

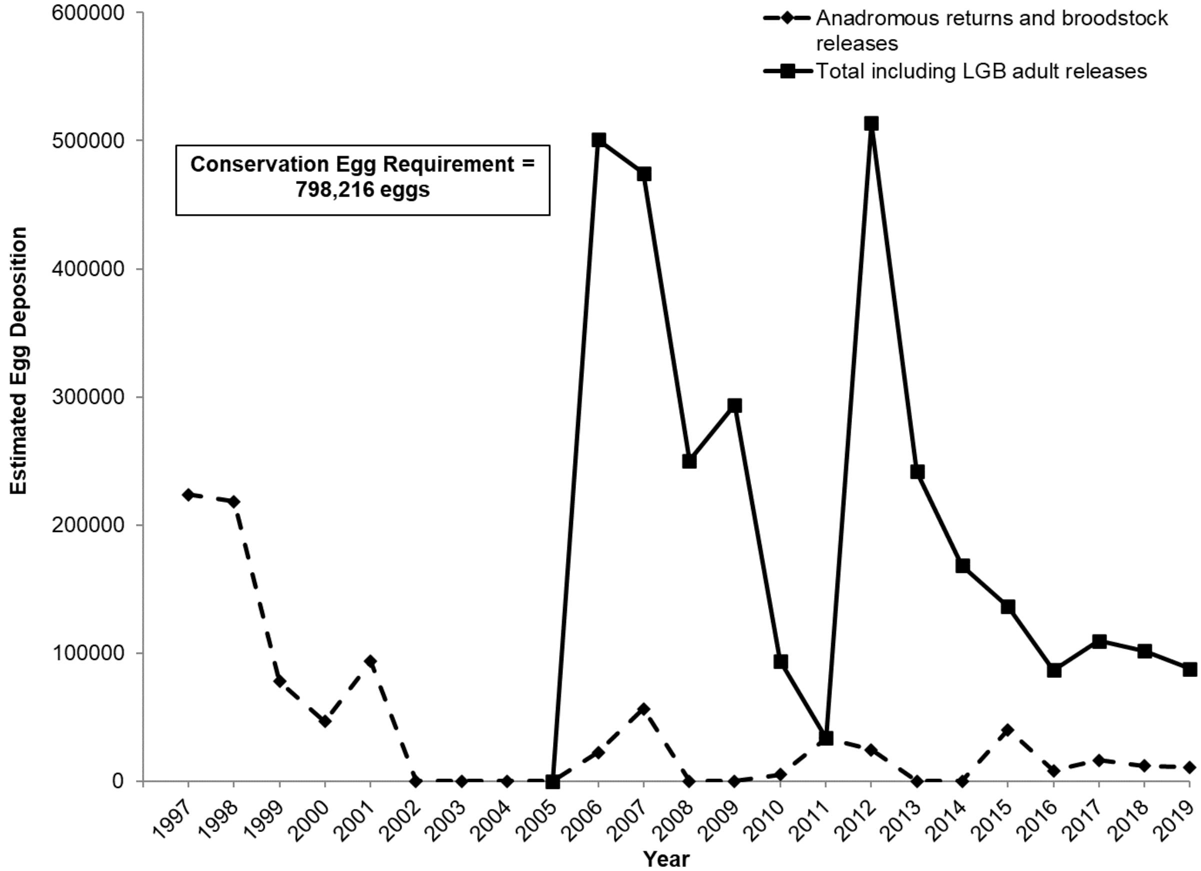

Figure 18: Estimated Gaspereau River salmon egg deposition with contributions from anadromous returns, surplus anadromous broodstock and non-targeted Live Gene Bank adults released upriver of the White Rock Dam from 1997 to 2019.

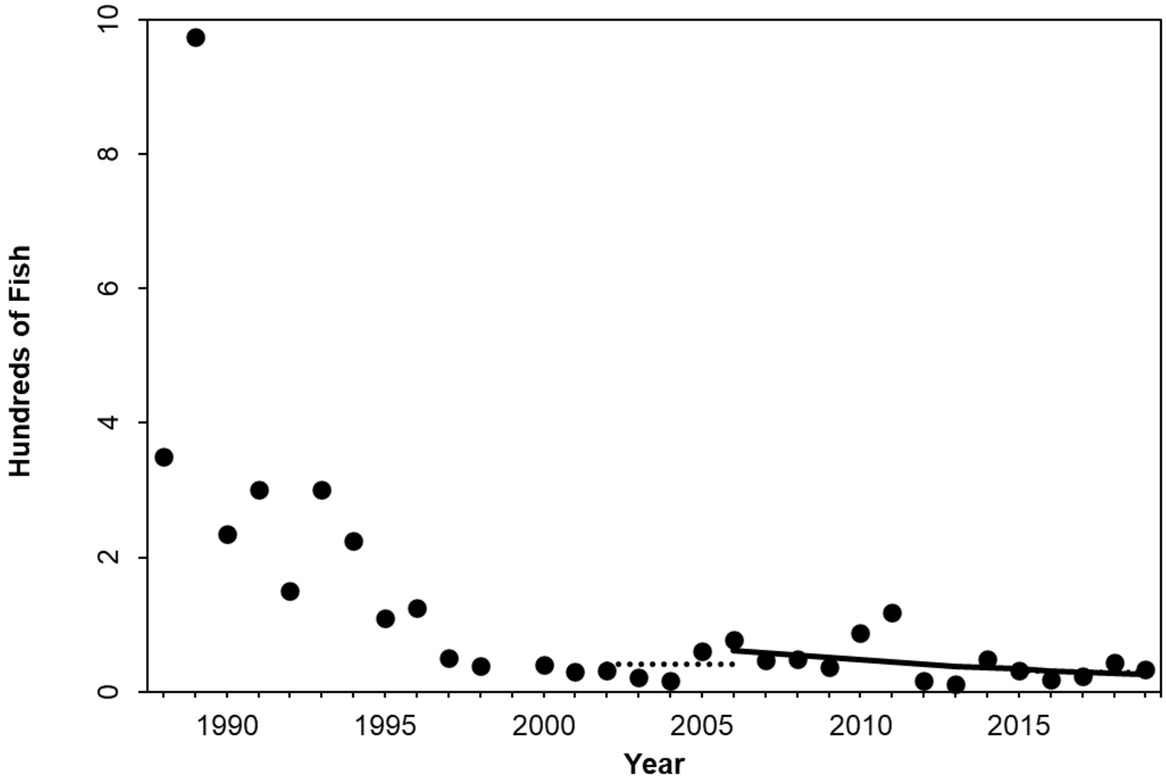

Figure 19: Trends in abundance of small and large Atlantic Salmon returns in the Big Salmon River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 13-year time period. The dashed lines show the 5-year mean abundance for two time periods ending in 2006 and 2019. The points are the observed data. Model coefficients are provided in Table 19.

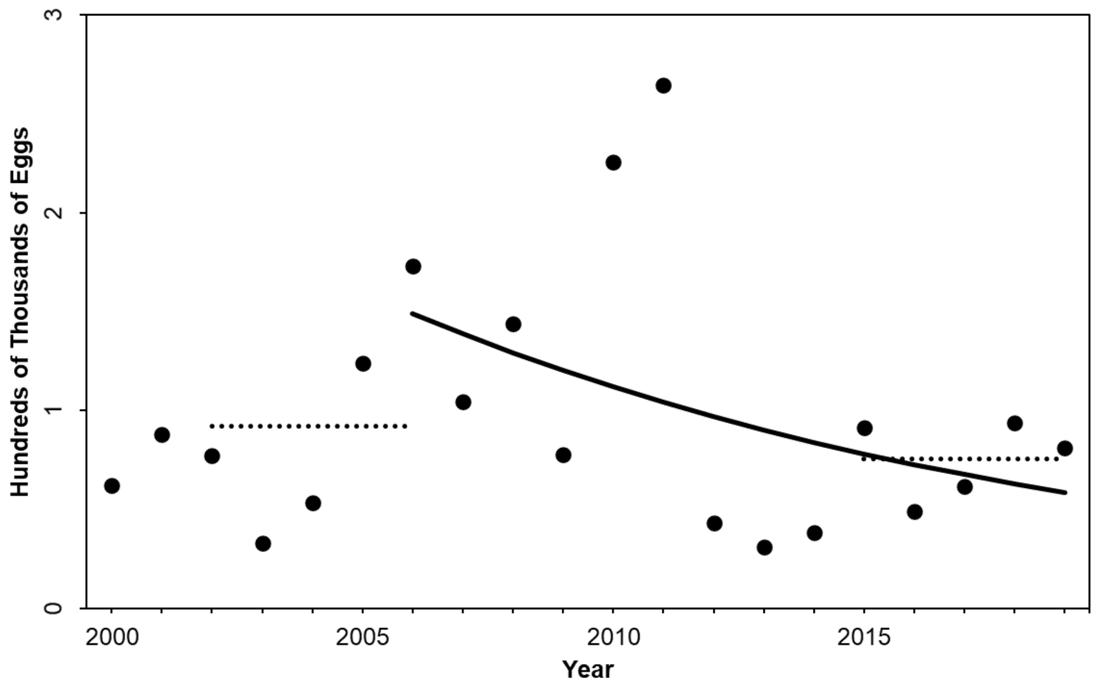

Figure 20: Trends in escapement (egg deposition) of small and large Atlantic Salmon returns in the Big Salmon River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 13-year time period. The dashed lines show the 5-year mean abundance for two time periods ending in 2006 and 2019. The points are the observed data. Model coefficients are provided in Table 19.

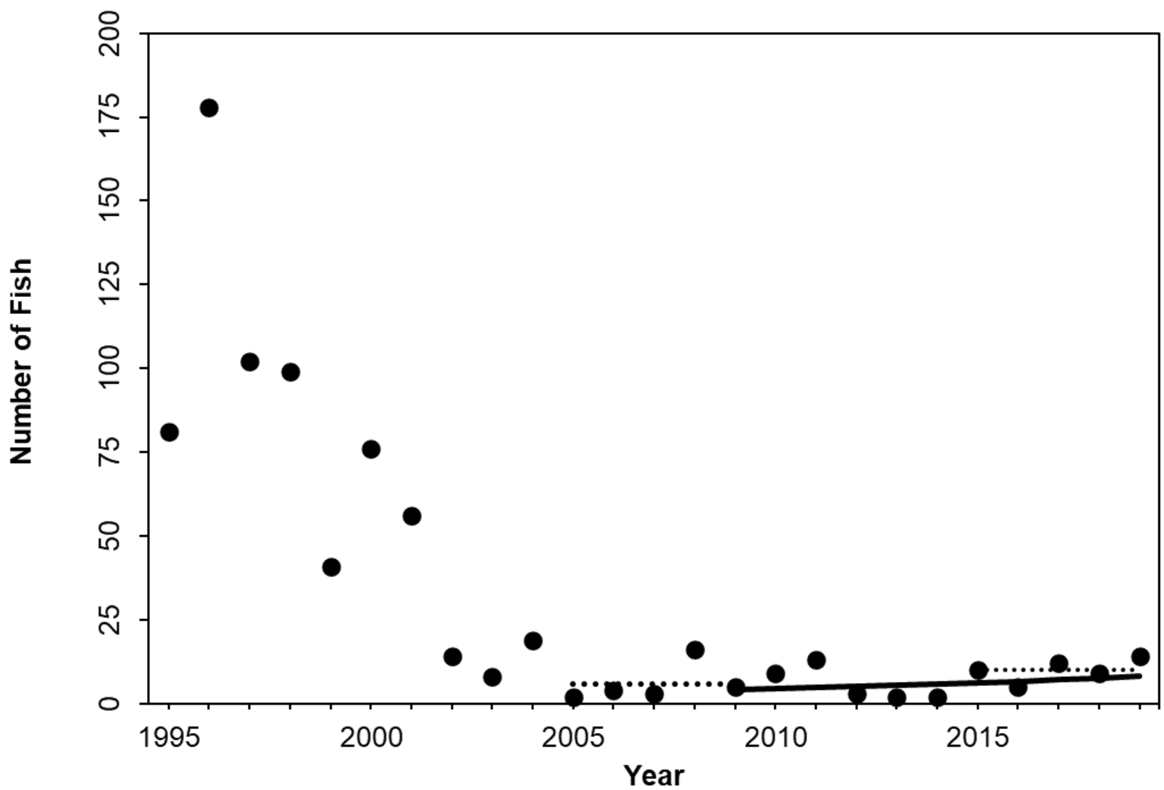

Figure 21: Trends in abundance of small and large Atlantic Salmon returns in the Gaspereau River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 10-year time period. The dashed lines show the 5-year mean abundance for two time periods ending in 2009 and 2019. The points are the observed data. Model coefficients are provided in Table 19.

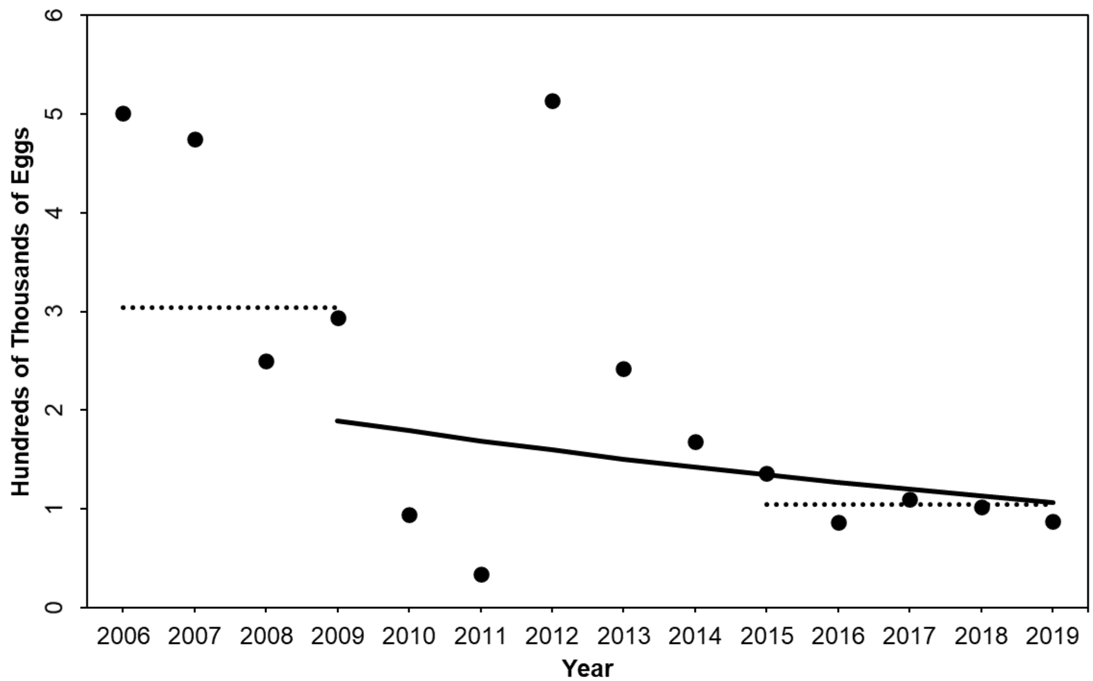

Figure 22: Trends in escapement of small and large Atlantic Salmon returns in the Gaspereau River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 10-year time period. The dashed lines show the 5-year mean abundance for two time periods ending in 2009 and 2019. The points are the observed data. Model coefficients are provided in Table 19.

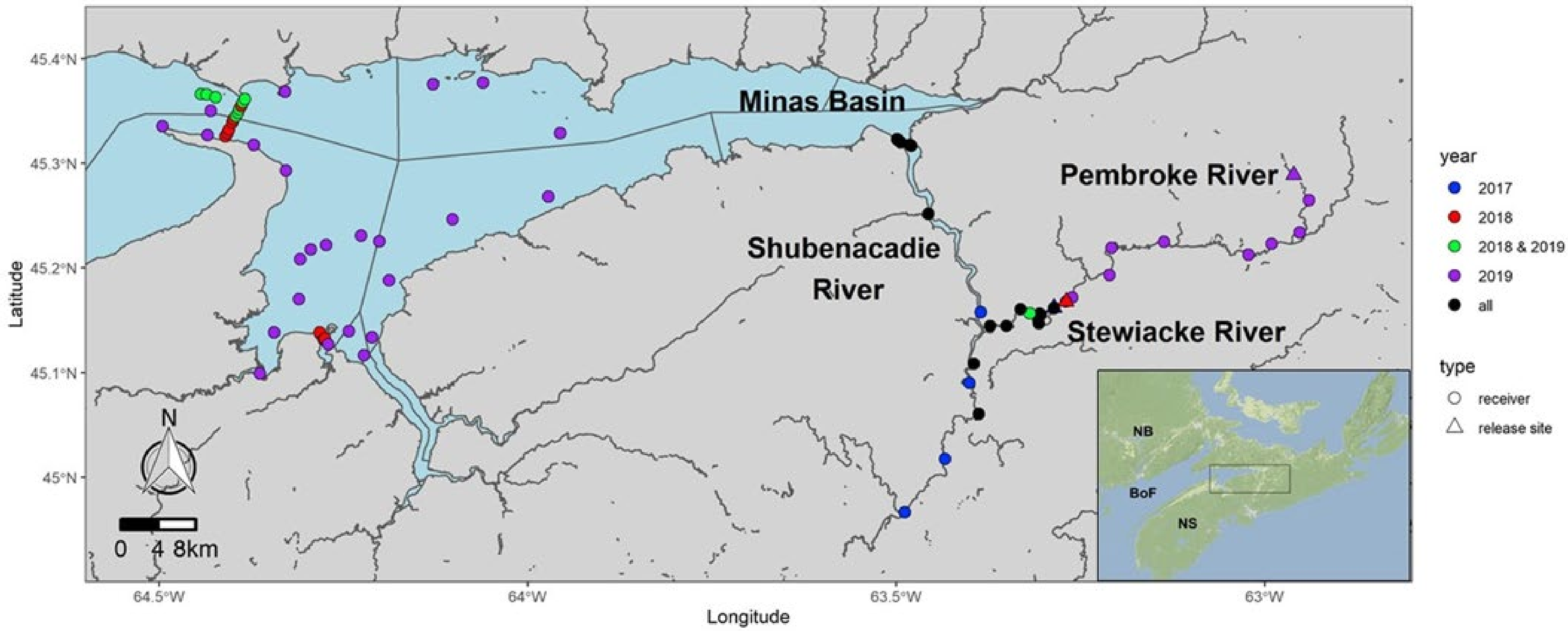

Figure 23: Map showing receiver and release site locations in the Stewiacke River watershed and Minas Basin, Nova Scotia, Canada. Inset shows location of study area (box) in relation to Nova Scotia (NS), New Brunswick (NB), and the Bay of Fundy (BoF).

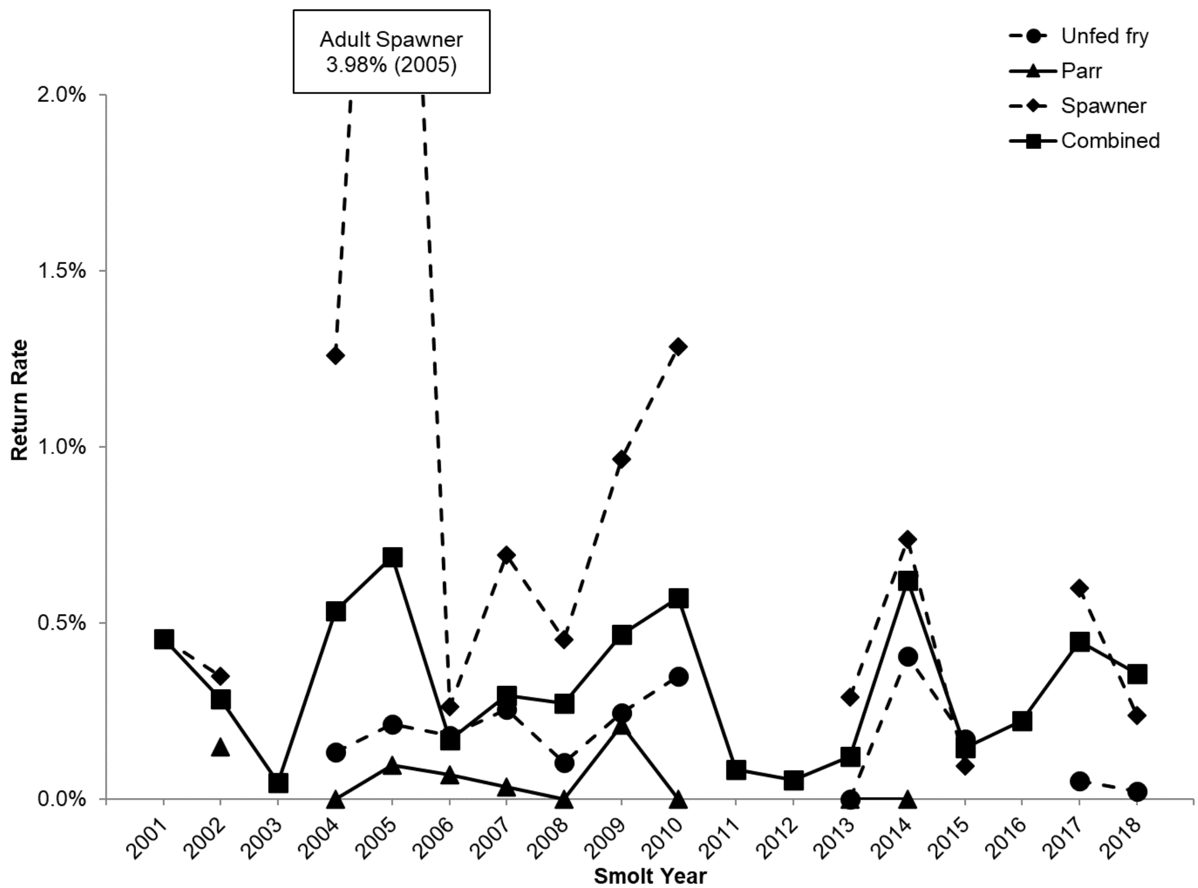

Figure 24: Big Salmon River smolt-to-small salmon return rates from 2001 to 2019.

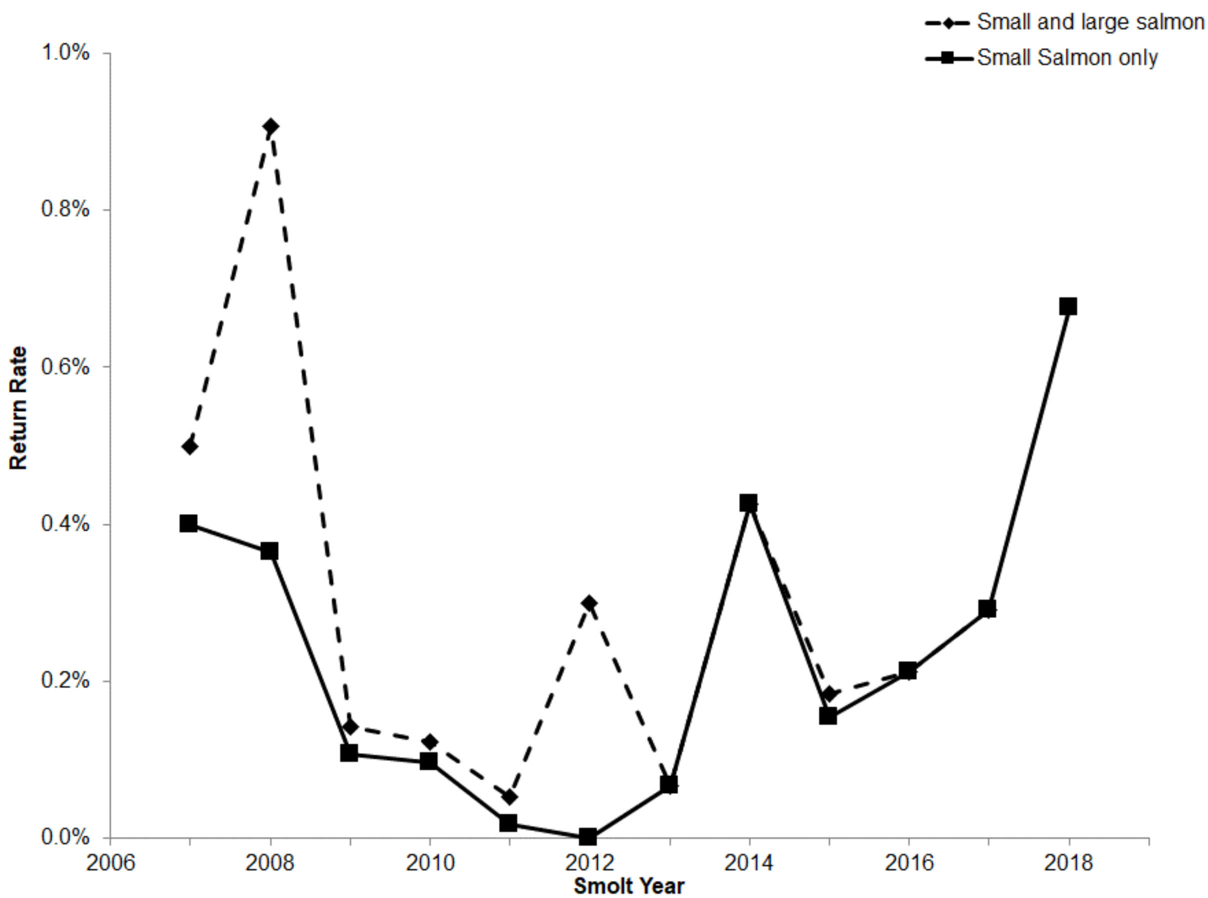

Figure 25: Gaspereau River smolt-to-adult return rates from 2007 to 2019.

APPENDIX

Table A1: Summary of the Mactaquac Live Gene Bank distributions from 2001 to 2019. This excludes distributions to Fundy National Park rivers. "MSW" = multi-sea winter spawners, " – " = assessment data not available.

Distribution River	Year	Unfed Fry	Fall Parr (0+)	Spring Parr (1+)	Smolt (1 yr.)	Smolt (2 yr.)	Pre-Grilse	Grilse	MSW Spawners
Big Salmon	2001	185,523	77,718	-	-	-	-	-	-
Big Salmon	2002	138,682	34,062	-	19,725	-	-	-	-
Big Salmon	2003	296,818	54,000	21,025	13,650	-	-	-	15 [1]
Big Salmon	2004	369,109	90,843	7,009	11,663	-	-	-	13 [1]
Big Salmon	2005	258,873	69,862	892	1,295	-	-	28	56
Big Salmon	2006	413,413	72,556	665	1,413	50	-	-	-
Big Salmon	2007	370,605	87,088	-	-	-	-	-	-
Big Salmon	2008	265,126	87,786	-	-	-	-	-	-
Big Salmon	2009	177,971	56,984	-	1,243	829	-	-	-
Big Salmon	2010	200,378	43,140	-	382	1,695	-	-	-
Big Salmon	2011	401,486	15,137	13	102	330	-	-	-
Big Salmon	2012	97,209	50	-	-	-	1,270	-	-
Big Salmon	2013	341,995	-	-	-	-	1,012	-	-
Big Salmon	2014	255,386	-	-	-	-	288	-	-
Big Salmon	2015	302,307	-	-	-	259	-	-	-
Big Salmon	2016	404,398	-	-	-	-	-	-	-
Big Salmon	2017	352,055	-	-	-	-	-	-	-
Big Salmon	2018	222,241	-	-	-	-	-	-	-
Big Salmon	2019	371,437	-	-	-	-	-	-	-
Petitcodiac	-	-	-	-	-	-	-	-	-
Pollet River	2002	56,159	-	-	-	-	-	-	-
Pollet River	2005	120,094	-	-	-	-	-	-	-
Pollet River	2008	-	-	-	-	-	-	3	4
Pollet River	2009	63,550	-	-	-	-	-	-	-
Pollet River	2011	337,622	-	-	-	-	-	-	-
Pollet River	2012	37,246	-	-	-	-	-	-	-
Pollet River	2015	-	-	-	-	-	-	204	-
Pollet River	2016	50,000	-	-	-	-	-	-	-
Pollet River	2017	47,000	-	-	-	-	-	434	-
Pollet River	2018	73,000	-	-	-	-	-	434	-
Pollet River	2019	-	-	-	-	-	-	163	-
Little River	2002	-	-	-	-	-	-	-	53
Little River	2003	-	-	-	-	-	549	-	-
Little River	2012	-	-	-	-	-	-	340	549
Little River	2013	-	-	-	-	-	-	330	7
Little River	2014	-	-	-	-	-	-	403	160

Distribution River	Year	Unfed Fry	Fall Parr (0+)	Spring Parr (1+)	Smolt (1 yr.)	Smolt (2 yr.)	Pre-Grilse	Grilse	MSW Spawners
Little River	2015	-	-	-	-	-	-	733	56
Little River	2016	-	-	-	-	-	-	355	-
Little River	2017	-	-	-	-	-	-	297	179
Little River	2018	-	-	-	-	-	-	163	364
Little River	2019	-	-	-	-	-	-	412	-
Demoiselle	2001	16,222	-	-	-	-	-	-	-
Demoiselle	2002	10,080	-	1,078	-	-	-	-	-
Weldon Creek	2004	130,197	-	-	-	-	-	-	-
Irish River	2017	-	-	-	-	-	-	-	20
Irish River	2018	-	-	-	-	-	-	-	25
Irish River	2019	-	-	-	-	-	-	-	31
Black River	2004	53,482	-	-	-	-	-	-	49
Black River	2005	17,915	-	-	-	-	-	-	28

[1] Female spawners

Table A2: Summary of Nova Scotia (cumulative for Coldbrook and Mersey Biodiversity facilities) Live Gene Bank distributions from 2001 to 2019. " – " = assessment data not available.

Distribution River	River of Origin	Year	Unfed Fry	6-week Fry	Fall Parr (0+)	Spring Parr (1+)	Smolt (1 yr.)	Smolt (2 yr.)	Adult Spawners
Stewiacke River	Stewiacke	2001	12,700	29,400	34,000	-	-	-	-
Stewiacke River	Stewiacke	2002	24,000	42,000	88,300	-	6,000	-	-
Stewiacke River	Stewiacke	2003	34,700	-	27,000	-	17,600	-	-
Stewiacke River	Stewiacke	2004	13,900	10,000	2,800	-	7,400	-	737
Stewiacke River	Stewiacke	2005	150,400	158,100	178,100	-	4,500	1,290	-
Stewiacke River	Stewiacke	2006	156,000	45,000	35,000	-	9,000	-	44
Stewiacke River	Stewiacke	2007	197,500	120,000	120,000	-	10,000	1,000	112
Stewiacke River	Stewiacke	2008	135,000	99,000	75,000	-	10,000	1,450	-
Stewiacke River	Stewiacke	2009	70,000	60,000	42,000	-	10,000	350	-
Stewiacke River	Stewiacke	2010	112,000	65,000	50,000	6,000	10,000	700	-
Stewiacke River	Stewiacke	2011	166,800	-	64,000	-	10,000	-	396
Stewiacke River	Stewiacke	2012	157,000	-	36,000	-	10,000	-	125
Stewiacke River	Stewiacke	2013	260,400	-	437	-	-	-	212
Stewiacke River	Stewiacke	2014	242,050	-	-	170	-	30	270
Stewiacke River	Stewiacke	2015	244,000	-	-	-	-	150	870
Stewiacke River	Stewiacke	2016	253,371	-	-	-	-	93	702
Stewiacke River	Stewiacke	2017	253,479	-	-	-	-	15	578
Stewiacke River	Stewiacke	2018	212,611	-	-	-	-	70	593
Stewiacke River	Stewiacke	2019	284,009	-	-	-	-	229	354
Chiganois River	Stewiacke	2002	24,000	27,000	37,000	-	-	-	-
Chiganois River	Stewiacke	2003	42,600	46,500	32,900	-	-	-	-
Chiganois River	Stewiacke	2004	-	-	-	-	8,150	-	-
Chiganois River	Stewiacke	2005	15,100	-	15,900	-	-	-	-
Chiganois River	Stewiacke	2006	-	37,000	-	-	-	-	-
Chiganois River	Stewiacke	2008	16,000	640	5,000	-	-	-	130
Chiganois River	Stewiacke	2009	16,000	-	3,000	-	-	-	-
Chiganois River	Stewiacke	2010	51,000	-	-	-	-	-	-
Debert River	Stewiacke	2002	10,000	27,000	45,500	-	-	-	-
Debert River	Stewiacke	2003	49,800	34,000	47,800	-	-	-	-
Debert River	Stewiacke	2004	9,100	-	-	-	8,150	-	-
Debert River	Stewiacke	2005	43,000	16,000	-	-	-	-	-
Debert River	Stewiacke	2006	20,000	-	40,000	-	5,000	-	-
Debert River	Stewiacke	2007	37,500	-	25,000	-	-	-	138
Debert River	Stewiacke	2009	16,000	-	21,000	-	-	-	-
Debert River	Stewiacke	2010	10,000	-	18,500	-	-	-	30
Debert River	Stewiacke	2011	37,000	-	41,300	-	-	-	92
Debert River	Stewiacke	2012	45,000	15,000	42,600	-	-	-	169
Debert River	Stewiacke	2014	113,550	-	-	-	-	-	-

Distribution River	River of Origin	Year	Unfed Fry	6-week Fry	Fall Parr (0+)	Spring Parr (1+)	Smolt (1 yr.)	Smolt (2 yr.)	Adult Spawners
Debert River	Stewiacke	2015	43,800	-	-	-	-	-	-
Debert River	Stewiacke	2016	13,784	-	-	-	-	-	-
Debert River	Stewiacke	2017	57,764	-	-	-	-	-	-
Debert River	Stewiacke	2018	82,560	-	-	-	-	-	-
Debert River	Stewiacke	2019	84,868	-	-	-	-	-	-
Folly River	Stewiacke	2002	32,000	27,000	24,500	-	-	-	-
Folly River	Stewiacke	2003	9,700	35,000	43,700	-	-	-	-
Folly River	Stewiacke	2004	13,000	9,100	-	-	4,640	-	-
Folly River	Stewiacke	2005	15,100	35,600	16,000	-	-	-	-
Folly River	Stewiacke	2006	20,000	-	50,000	-	5,000	-	-
Folly River	Stewiacke	2007	37,500	-	25,000	-	-	-	71
Folly River	Stewiacke	2008	38,000	-	4,000	-	-	-	40
Folly River	Stewiacke	2009	16,000	-	21,000	-	-	-	-
Folly River	Stewiacke	2010	22,500	-	18,500	-	-	-	30
Folly River	Stewiacke	2011	37,000	-	30,000	-	-	-	-
Folly River	Stewiacke	2012	45,250	-	37,700	-	-	-	-
Folly River	Stewiacke	2013	15,000	-	-	-	-	-	-
Folly River	Stewiacke	2014	96,950	-	-	-	-	-	-
Folly River	Stewiacke	2015	41,975	-	-	-	-	-	-
Folly River	Stewiacke	2016	55,136	-	-	-	-	-	-
Folly River	Stewiacke	2017	28,882	-	-	-	-	-	-
Folly River	Stewiacke	2018	41,280	-	-	-	-	-	-
Folly River	Stewiacke	2019	42,434	-	-	-	-	-	-
Great Village River	Stewiacke	2004	300	-	-	-	24,810	-	-
Great Village River	Great Village	2005	-	-	8,000	-	-	-	-
Great Village River	Unknown	2007	16,000	-	-	-	-	-	461
Great Village River	Stewiacke	2008	-	-	-	-	-	-	109
Great Village River	Stewiacke	2010	-	-	45,000	-	-	-	-
Great Village River	Stewiacke	2011	30,000	-	-	-	-	-	-
Great Village River	Stewiacke	2012	-	-	-	-	-	-	49
Economy River	Economy	2004	600	-	-	-	-	-	-
Economy River	Economy	2006	34,000	-	24,000	-	-	-	-
Economy River	Economy	2007	10,000	-	2,500	-	-	-	-
Economy River	Stewiacke	2010	-	-	800	-	-	-	280
Economy River	Stewiacke	2011	-	-	12,500	-	99	-	294
Economy River	Stewiacke	2012	-	-	-	-	-	-	156
Salmon River	Stewiacke	2002	-	-	-	-	-	-	190

Distribution River	River of Origin	Year	Unfed Fry	6-week Fry	Fall Parr (0+)	Spring Parr (1+)	Smolt (1 yr.)	Smolt (2 yr.)	Adult Spawners
(Colchester)	Stewiacke	2003	-	-	-	-	-	-	132
Salmon River	Stewiacke	2005	-	-	200	-	-	-	116
Salmon River	Stewiacke	2006	15,000	-	16,500	-	-	-	281
(Colchester)	Stewiacke	2007	12,500	-	-	-	-	-	428
Salmon River	Stewiacke	2008	-	-	-	-	-	-	253
Salmon River	Stewiacke	2009	-	-	-	-	-	-	-
Salmon River	Stewiacke	2010	25,000	-	-	-	-	-	316
Salmon River	Stewiacke	2011	-	-	-	3,000	-	-	235
Salmon River	Stewiacke	2012	-	-	-	-	-	-	362
Salmon River	Stewiacke	2013	-	-	-	-	-	-	221
Salmon River	Stewiacke	2014	-	-	-	-	-	-	256
Salmon River	Stewiacke	2016	189,530	-	-	-	-	-	59
Salmon River	Stewiacke	2017	16,504	-	-	-	-	-	46
Salmon River	Stewiacke	2018	-	-	-	-	-	-	95
Salmon River	Stewiacke	2019	-	-	-	-	-	-	37
Gaspereau River	Gaspereau	2001	-	-	42,700	-	10,900	-	-
Gaspereau River	Gaspereau	2002	-	7,400	-	-	16,500	-	-
Gaspereau River	Gaspereau	2003	-	-	21,700	18,600	27,400	-	-
Gaspereau River	Gaspereau	2004	-	-	8,400	-	11,500	-	-
Gaspereau River	Gaspereau	2005	77,000	19,000	18,000	-	1,700	-	-
Gaspereau River	Gaspereau	2006	70,000	-	45,000	-	6,500	-	251
Gaspereau River	Gaspereau	2007	400,000	-	46,000	190	10,000	1,030	276
Gaspereau River	Gaspereau	2008	350,000	-	54,000	-	10,000	750	362
Gaspereau River	Gaspereau	2009	160,000	-	48,800	-	12,000	-	-
Gaspereau River	Gaspereau	2010	100,000	42,000	20,000	-	10,000	750	69
Gaspereau River	Gaspereau	2011	248,500	-	13,500	-	7,600	-	163
Gaspereau River	Gaspereau	2012	232,500	-	22,100	-	3,200	-	236
Gaspereau River	Gaspereau	2013	302,600	1,100	-	-	-	-	282
Gaspereau River	Gaspereau	2014	245,150	-	-	-	-	-	130
Gaspereau River	Gaspereau	2015	151,500	-	-	-	-	-	293
Gaspereau River	Gaspereau	2016	219,075	-	-	-	-	-	178
Gaspereau River	Gaspereau	2017	200,235	-	119	-	-	65	40
Gaspereau River	Gaspereau	2018	159,204	-	167	-	-	41	33
Gaspereau River	Gaspereau	2019	211,078	-	212	-	-	69	42
Bass River	Stewiacke	2008	320,000	-	-	-	-	-	-
Cornwallis River	Gaspereau	2005	-	-	-	-	-	2,700	-
Cornwallis River	Gaspereau	2006	-	-	-	-	-	633	-
Cornwallis River	Gaspereau	2010	-	-	68,000	71	-	344	68
Cornwallis River	Gaspereau	2011	-	-	23,000	-	-	-	387
Cornwallis River	Gaspereau	2012	15,500	-	20,300	-	-	-	216

Distribution River	River of Origin	Year	Unfed Fry	6-week Fry	Fall Parr (0+)	Spring Parr (1+)	Smolt (1 yr.)	Smolt (2 yr.)	Adult Spawners
Cornwallis River	Gaspereau	2013	-	-	1,182	-	-	-	109
Cornwallis River	Gaspereau	2014	143,100	-	-	-	-	-	203
Cornwallis River	Gaspereau	2015	-	-	-	-	-	-	138
Cornwallis River	Gaspereau	2016	-	-	-	-	-	-	-
Cornwallis River	Gaspereau	2017	16,500	-	-	-	-	-	46
St. Croix River	Gaspereau	2014	-	-	-	-	-	-	349
St. Croix River	Gaspereau	2015	76,000	-	-	-	-	-	437
St. Croix River	Gaspereau	2016	115,830	-	-	-	-	-	350
St. Croix River	Gaspereau	2017	96,589	-	-	-	-	-	340
St. Croix River	Gaspereau	2018	72,953	-	-	-	-	-	281
St. Croix River	Gaspereau	2019	143,828	-	-	-	-	-	275

Table A3: Summary of threats and rating of effects on recovery and/or persistence for Conservation Unit (CU) 16 (inner Bay of Fundy) Designatable Unit (DFO-MRNF 2008). Table has been adapted to include the level of concern for each threat according to the procedure for consistently assigning level of concern ranking found in DFO (2014). "NA" = not applicable, " – " = data and/or information not available.

Potential sources of mortality/harm Permitted and un-permitted activities	**Source (with examples)**	**Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)**	**Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)**	**Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)**	**Management Alternatives/ mitigation (relative to existing actions)**	**Level of concern**
Directed Salmon Fishing	Indigenous	NA closed.	H – closed since 1991.	None	NA closed.	NA closed.
Directed Salmon Fishing	Recreational: retention and release	NA closed.	H – closed since 1991.	None	NA closed.	NA closed.
Directed Salmon Fishing	Commercial (domestic)	NA closed.	H – closed since 1984.	None	NA closed.	NA closed.
Directed Salmon Fishing	High Seas (West Greenland / St. Pierre – Miquelon)	High - All rivers in the CU produce 2SW salmon.	C - No tags recovered from distant fisheries for all but one stock.	Low - Estimated catch of CU 16 non-maturing salmon in West Greenland fishery is extremely low.	Reductions to domestic food fisheries.	Low
Directed Salmon Fishing	Illegal (poaching)	High - All populations are exposed to illegal fishing.	C – Fishery Officer reports.	Uncertain - Reports, investigations, and prosecutions for illegal fishing of salmon are low and, therefore, one assumes that the take is low, but the numbers of salmon are also low, so any removal of pre-spawning salmon could be significant.	Additional enforcement, specifically in rivers where adult salmon are released from the living gene bank.	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Bycatch of Salmon in Fisheries for Other Species	Indigenous	Low – Indigenous fisheries management has initiated restrictions on salmon catches similar to DFO regulations.	C	Low – Small catches of salmon caught.	–	Low
Bycatch of Salmon in Fisheries for Other Species	Recreational	High – Recreational fisheries for other species occur in most rivers of the CU. Juveniles, smolts, and adults have been reported captured during various fisheries. Live release is mandatory.	C	Low - Bycatch of salmon is illegal, seasons are adjusted or closed to avoid bycatch, live release of incidental catch of salmon is effective.	Additional monitoring and enforcement of bycatch regulations in recreational fisheries known to capture CU 16 salmon and known to have a high potential for live release.	Low
Bycatch of Salmon in Fisheries for Other Species	Commercial nearshore	Low – Limited gaspereau and low weir fisheries occur in near shore and in some estuarial environments for varying periods of time exposing two principal stages: smolt and adult. Shad gillnet fishery is closed.	C	Uncertain – Reports, investigations, and prosecutions for illegal fishing of salmon in estuaries and in near-shore gear are low and, therefore, one assumes that the take is low, but the numbers of salmon are also low, so any removal of pre-spawning salmon could be significant.	Additional monitoring and enforcement of bycatch regulations in commercial fisheries known to have captured or have the potential to capture CU 16 salmon and are known to have a high potential for live release. Close a commercial fishery if salmon have been recently captured.	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Bycatch of Salmon in Fisheries for Other Species	Commercial distant	Low – Few rivers in the CU produce distant migrating 2SW and 3SW salmon.	H and C – Low numbers tag recoveries from historical commercial fisheries indicate most stocks are not exposed to interceptory fisheries.	Uncertain – Reports, investigations, and prosecutions for illegal fishing of salmon in distant fisheries including Newfoundland and coastal Nova Scotia is low and, therefore, one assumes that the take is low, but the numbers of salmon are also low, so any removal of maturing salmon at sea could be significant.	Advise commercial monitoring programs to report any Atlantic Salmon observations and provide samples of mortalities.	–
Salmon Fisheries Impacts on Salmon Habitat	Indigenous	NA	H	None	NA	NA
Salmon Fisheries Impacts on Salmon Habitat	Recreational	NA	H	None	NA	NA
Salmon Fisheries Impacts on Salmon Habitat	Commercial	NA	H	None	NA	NA
Salmon Fisheries Impacts on Salmon Habitat	Illegal	High – - Based on report rates proportion of salmon affected is likely low.	C	Uncertain - Based on reported cases impact is likely low.	Additional enforcement.	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Mortality Associated with Water Use	Power generation at dams and tidal facilities (turbine morts, entrainment, stranding)	Medium – Hydroelectric dams occur on three rivers in the CU including the Gaspereau, Avon, and St. Croix, some with no or ineffective fish passage.	H and C	Low – Ineffective fish passage areas were long ago extirpated or had limited habitat available below natural barriers; fish passage improvements continue in the most affected river, Gaspereau River, Kings Co., NS.	Continue to improve fish passage efficiency. Operational management changes.	Low
Habitat Alterations	Municipal waste water treatment facilities	High – Waste water discharge is generally into rivers and estuaries.	C	Uncertain – Some indication that waste water chemicals alter survival.	Tertiary treatment of all wastewater to reduce chemical effects.	–
Habitat Alterations	Pulp and paper mills	Low – Halfway River, Kings Co., NS. Dammed to provide water.	C	Low - Fish passage only recently re-established, but river was already extirpated.	–	Low
Habitat Alterations	Hydroelectric power generation (dams and reservoirs, tidal power): altered behaviour and ecosystems	Medium – Hydroelectric dams occur on three rivers in the CU including the Gaspereau, Avon, and St. Croix, some with no or ineffective fish passage.	C	Low – Populations were extirpated long ago in two locations and fish passage improvements have been initiated and continue in the Gaspereau River.	Improve fish passage facilities. Spill regimes to match run timing of smolts and adults.	Low
Habitat Alterations	Water extractions	Unknown	C	Uncertain – The extent and impact of water extraction/ diversion on the production of salmon is unknown.	Flow releases to emulate natural flows.	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Habitat Alterations	Urbanization (altered hydrology)	High – Many rivers have complete or partial fish passage resultant of water control structures in support of urban or agriculture flood relief. Effective passage and delays in downstream and upstream migration limits populations in many rivers known to have provided salmon habitat and production, e.g., Petitcodiac, Avon, Shepody, Great Village, Parsboro, Chiginois.	C and P	Uncertain – No known positive effects; possibility for long term metapopulation reduction and loss of population resilience.	Urban planning that incorporates hydrology. Alternative flood control measures.	–
Habitat Alterations	Infrastructure (roads/culverts) (fish passage)	High – All rivers have structures of one form or another.	C and P	Uncertain	Ensure compliance with construction and installation standards for fish habitat. Conduct regular compliance monitoring and reporting. Provide increased exposure and education for best design and construction practices.	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Habitat Alterations	Aquaculture siting	High – Proximity of industry in a known marine habitat area; water is a vector for disease and parasites transmission.	C and P	Uncertain – Exposure may not equal mortality; limited survival of escapes results in low straying to CU 16 rivers.	Therapeutic application of vaccines and treatment of infections of farmed salmon to control outbreaks of disease and parasites. License sites away from wild populations. License only land-based operations.	–
Habitat Alterations	Agriculture / Forestry / Mining, etc.	High – Most watersheds have agricultural and/or forestry and many habitat deficiencies as the result of poor design, construction, and operations have been noted.	C	Uncertain – Altered flow regimes, increased water temperatures, and siltation can result from extensive cutting and poor operational practices, which increases vulnerability of fish during increasing drought events associated with climate change.	Increase education and awareness of best management practices. Ensure compliance with best management practices for design, construction, and operations. Increased monitoring and enforcement of habitat procedures. Habitat restoration and /or compensation for harmful alteration or destruction of fish habitat or its function. Increased greenbelt applications including fencing for agriculture and no cut areas for forestry in prime habitats for fish. On site filtering of contaminated water before release.	–
Habitat Alterations	Municipal, provincial, and federal dredging.	Low	C	Low	Timing to reduce impact.	Low

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Shipping, Transport, and Noise	Municipal, provincial, federal, and private transport activities (incl. land and water based contaminants/spills)	Low – Limited shipping in major estuaries.	C	Uncertain	–	–
Fisheries on Prey of Salmon (For ex., capelin, smelt, shrimp, …)	Commercial, recreational, Indigenous fisheries for species a, b, c, etc.	Medium – Smelt are fished both commercially and recreationally throughout the CU; herring are fished extensively throughout the CU and known marine habitat areas; commercial harvest of Sand Lance outside Canadian waters but within the Bay of Fundy occurs.	C	Unknown - Complete distribution of CU 16 salmon in the marine habitat is unknown; returns of putatively local migrating salmon is too low to examine any condition factor.	–	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Aquaculture (Salmon and Other Species)	Escapes from fresh water, marine facilities, disease, parasites, competition, effects on behaviour, and migration, genetic introgression	Medium – Observed incidence of escapes is low however some escapes migrate to CU 16 rivers and are known to have spawned leading to genetic introgression and loss of local fitness; predator attraction to escapes and collateral mortality of wild salmon in the marine habitat likely occurs.	C and P	Uncertain - threat to genetic diversity, increased transmission or once rare diseases, potential for increased parasite transmission, predator attraction and increased collateral mortality of proximate wild salmon.	Increase retention of farmed fish in cages through increased performance based standards and controls and mandatory reporting of losses. Treat effluents from fish culture operations. Direct removal of farmed salmon at counting facilities. Screen all live gene bank salmon for farmed salmon. Control or limit predators in the vicinity of fish farms. Move to land based operation for salmonids. Prevent fish's ability to reproduce if escape occurs.	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Fish Culture /Stocking (Noncommercial, including Private, NGO, Government)	Impacts on effective population size, over representation of families, domestication	Medium – While marine survival is intolerably low the population is dependent on supportive rearing and breeding; all stocking is through a pedigree based live gene bank program designed to reduce the loss of diversity and fitness to the wild; commercial hatcheries operate within the CU growing imported salmon under strict retention licensees.	C	Uncertain - Completely neutral supportive rearing and breeding programs are not possible; escapes from hatcheries within the area or adjacent to the area or from salmon farms receiving products from these hatcheries have been reported; only 3 rivers have the opportunity (fishway or traps) to remove escapes and none have the ability to completely genetically identify escapes or external stock strays; funding for genetic identification is limited to live gene bank components.	Ensure compliance with the fish culture genetic program and introductions and transfer protocols within government hatcheries. Increased regulation and enforcement of existing regulations for industry hatcheries on both escapes and distributions. Ensure transparency of industry and government hatcheries.	–
Scientific Research	Government, university, community, and Indigenous groups	High – Until marine survival rebounds, almost all salmon with the CU are handled at some stage.	C	Low – Some delays, minimal mortality.	Ensure research likely to benefit the recovery of the species. Best handling practices.	Low
Military Activities	Field operations, shooting ranges	Low – Limited military activity in the area.	H	Uncertain	–	–

Potential sources of mortality/harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)	Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ mitigation (relative to existing actions)	Level of concern
Air Pollutants	Acid rain	Low – Most rivers are rich in base cations and have high acid neutralizing capacity; Avon and Gaspereau rivers have some tributaries that are exceptions.	C	Low – Drainages in CU are not particularly vulnerable to acid precipitation and pH is generally suitable for salmon.	Support enforcement of the Clean Air Act. Precautionary manage the residual salmon rivers/stocks. Mitigate key watersheds through liming to prevent extirpation of rare genetic stocks.	Low
Introductions of Non-native /Invasive Species	Smallmouth Bass, Chain Pickerel, Muskellunge, Rainbow Trout, invertebrates, plants, algae	Low – Some Smallmouth Bass, Brown Trout (*Salmo trutta*), and Rainbow Trout are known in the CU.	H and C	Uncertain – Bass noted as significant predator on juvenile/smolts populations in Eastern Canada.	Direct removals in selected drainages and facilities. Increase regulations and enforcement concerning transfers of fish. Increase or make mandatory harvests in all directed fisheries or bycatch of exotic fish species. Increase education programs concerning the expansion of exotic species.	–
International High Seas Targeted	Flags of convenience?	Low - Few distant migrating salmon.	C	Uncertain – The extent and origin of high seas salmon catch is unknown; migration strategy switching of CU 16 salmon may have been a viable alternative that is now unsuccessful for unknown reasons.	–	–

Potential sources of mortality/harm Permitted and un-permitted activities	**Source (with examples)**	**Proportion of salmon in CU affected (LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN)**	**Cause/Time frame Historical and completed (H) Current (C) Potential increase (P)**	**Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)**	**Management Alternatives/ mitigation (relative to existing actions)**	**Level of concern**
Ecotourism and Recreation	Private Co's and public at large (water crafts, swimming, etc) effects on salmon behaviour and survival	Low	C	Uncertain	Determine any potential for negative impacts and mitigate.	–
Ecosystem Change	Climate change, changes in relative predator / prey abundances, disease	High – All drainages are vulnerable to low flow and high flow events as well as exposed to increased predation associated with increased fish, bird and mammal populations has reduced marine survival.	C	High – marine survival and returns are less than 99% of past values.	Direct research to address climate change and related ecosystem change issues on Atlantic Salmon.	High