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Updated Information on Atlantic Salmon (*Salmo salar*) Populations in Southwest New Brunswick (Outer Portion of Salmon Fishing Area 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 Outer Bay of Fundy (OBoF) Atlantic Salmon (*Salmo salar*) population [Designatable Unit (DU) 16] 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 OBoF Atlantic Salmon populations in southwest New Brunswick, corresponding to the outer part of Salmon Fishing Area 23, is compiled in this review, including population status, trends, life history characteristics, habitat and threats.

Evaluation of the status of Atlantic Salmon in the OBoF is based on adult abundance monitoring for a number of index populations. For the Saint John River (SJR) upriver of Mactaquac Dam, the Nashwaak River (a tributary to the SJR downriver of Mactaquac Dam), and the Magaguadavic River, adult salmon counts and estimates of returns to enumeration facilities (e.g., fishway, counting fence) and subsequent spawners are assessed using a comparison of the estimated egg deposition (calculated from the estimated abundance and biological characteristics of Atlantic Salmon stocks) relative to a reference point known as the conservation egg requirement. Overall, the recent available data for OBoF Atlantic Salmon indicates that populations are persisting at low abundance levels and continuing to decline. Estimated adult abundance on the SJR upriver of Mactaquac Dam and on the Nashwaak River is presently 4% and 5% of their respective conservation requirements, and estimated egg deposition has declined at rates in excess of 75% over the last 3 generations (15 years) for both index populations. Adult returns to the Magaguadavic River were two MSW salmon in 2019, and have annually averaged less than two fish for the past decade. Small (one-sea-winter) and large (multi-sea-winter) salmon returning to rivers in the OBoF have both declined over the last 3 generations, approximately 81% and 79%, respectively. Moreover, these declines represent continuations of declines greater than 70% extending back over 25 years to 1993.

Within the OBoF DU, threats of highest concern include the operation of hydro facilities in freshwater and unfavourable conditions in the marine environment linked with depressed population phenomena, along with aquaculture operations. To compensate for additive mortalities associated with hydroelectric dams and low marine survival, the salmon enhancement program at the Mactaquac Biodiversity Facility is currently being adaptively managed to produce captive spawning adults from wild-caught juvenile salmon and distribute to tributaries above Mactaquac Dam surplus offspring as unfed fry for supplementation purposes. However, freshwater threats, combined with low marine survival, still appear to be limiting recovery of the salmon populations in the SJR.

INTRODUCTION

The Outer Bay of Fundy [OBoF; Designatable Unit (DU) 16] Atlantic Salmon (*Salmo salar*) population assemblage was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2010 (COSEWIC 2010). This DU occupies 20 rivers in New Brunswick (NB), including 11 rivers within the Saint John River (SJR) basin and nine river basins in southwest NB discharging into the Bay of Fundy (BoF) between the SJR and the USA-Canada border (Figure 1). This geographic area was labelled as Conservation Unit 17 in the Conservation Status Report (DFO and MRNF 2008). These rivers are within Salmon Fishing Area (SFA) 23, which is the management area used by the Department of Fisheries and Oceans Canada (DFO) for salmon fisheries management and assessment purposes (Figure 1).

The purpose of this document is to provide an update of DFO information for the OBoF Atlantic Salmon population (DU16) to support the development of a 2nd status report of Atlantic Salmon in eastern Canada by COSEWIC. DFO Science information pertaining to populations in NB's western part of SFA 23 is compiled in this review, including the SJR upriver of Mactaquac Dam, the Tobique River (index river above Mactaquac Dam), the Nashwaak River (a tributary to the SJR downriver of Mactaquac Dam), the Magaguadavic River and the St. Croix River (Figure 2). This document updates some of the status, trends, distribution, and life history characteristics information that was provided in Jones et al. (2014) as part contribution to the development of a Recovery Potential Assessment (RPA) Science Advisory Report (SAR) for the OBoF DU of Atlantic Salmon (DFO 2014).

Atlantic Salmon are an anadromous species with a complex life history that involves residence in both freshwater and marine habitats over a life span of four, five, and six or more years. Adult OBoF salmon spawn in their natal rivers in October and November. Young develop until May or June in gravel redds, emerge as fry, and grow as parr feeding on invertebrate drift. After two or three years in freshwater, most parr will undergo smoltification and migrate downriver in spring, entering the ocean as post-smolts where they grow rapidly to maturity. Adults first return to spawn in their natal rivers after one, two and occasionally three winters at sea. Some survive after reproduction and return to sea the subsequent spring; a portion of which will return again to spawn in consecutive and/or alternating years as repeat spawners.

Population status of Atlantic Salmon in the SJR is assessed annually from data collected at the Mactaquac Dam, as well as from the Tobique and the Nashwaak rivers, the largest salmon-producing tributaries upstream and downstream of Mactaquac, respectively. Adult salmon counts and estimates of returns to counting facilities (i.e., at Mactaquac Dam and in the Nashwaak River) are evaluated against conservation egg requirements (CER) that were determined for each index river based on the area of accessible habitat and the biological characteristics of the returning adults. Programs based on mark-recapture methods to estimate smolt production take place on the Tobique and Nashwaak river systems. For the Tobique River, this includes an estimate of the fall pre-smolt migration in the year previous, in addition to a spring smolt estimate. Electrofishing surveys, from which the density of age-0, age-1, and age-2 and older juveniles are estimated and assessed against reference levels, also take place on the Tobique and Nashwaak rivers. Outside of the SJR system, the only other assessment activities in DU 16 are counts of returning adult salmon to the fishway on the Magaguadavic River. The fishway on the St. Croix River has not been monitored since 2006. The status of Atlantic Salmon stocks in the Maritimes Region, including OBoF corresponding to the western part of SFA 23, are evaluated and reported annually using established methods (DFO 2020 and references therein).

The Maritime Provinces’ commercial salmon fishery has been closed since 1984. Due to the persistent failure of populations to achieve the conservation requirement, the Food, Social and Ceremonial (FSC) fisheries and the recreational fisheries have been closed on the SJR system since 1998. Similarly, FSC and recreational fisheries have been closed since 1998 on the Magaguadavic and St. Croix rivers. However, there is some by-catch of salmon in net fisheries in the SJR estuary, as well as some illegal fishing taking place throughout the SJR system.

Many of the OBoF river populations face a multitude of habitat constraints and threats. These include hydroelectric dams (with upriver passage facilities but most are devoid of safe downstream passage), artificial flow regimes, headponds, significant industrial and municipal effluents, run-off from intensive agricultural and forestry operations, and communities of invasive predators (Clarke et al. 2014, Marshall et al. 2014). Marine threats of highest concern include: depressed population phenomena, salmonid aquaculture operations and shifts in oceanic conditions (abiotic and biotic) caused by changes in climate (Clarke et al. 2014).

RECENT ABUNDANCES AND LIFE HISTORY CHARACTERISTICS

The most complete information on life history characteristics of OBoF Atlantic Salmon is available for the SJR (Jones et al. 2004, 2006, 2010, 2014, Chaput and Jones 2006, Chaput et al. 2006, Gibson et al. 2016). Biological characteristics of adult Atlantic Salmon returning to counting facilities in the SJR at the Mactaquac Dam and in the Nashwaak River are collected annually as part of DFO projects to monitor and assess the status of populations within the DU. Early life history characteristics of juveniles emigrating from the Nashwaak and Tobique rivers have been obtained annually in spring (smolt) and fall (pre-smolt; specific to the Tobique) monitoring programs ongoing since 1998 and 2001, respectively. Population characteristics data for salmon from rivers in this DU were previously presented in detail by Jones et al. (2010) for the COSEWIC (2010) review and updated in Jones et al. (2014) for the development of a RPA Science Advisory Report for OBoF populations (DFO 2014). Gibson et al. (2016) also contributed information on the RPA for OBoF salmon by presenting population viability analyses for the two larger index rivers, Tobique and Nashwaak, using a life history-based population dynamics model.

ADULT RETURNS DESTINED FOR THE SAINT JOHN RIVER UPRIVER OF MACTAQUAC DAM

Atlantic Salmon adult returns destined for the SJR upriver of Mactaquac Dam are captured and counted at the fish collection facilities at the dam and at an adult trap operated in the migration channel at the Mactaquac Biodiversity Facility (MBF) (Ingram 1980). In most years, both fish trapping facilities operate from early-May until late-October. Adult run timing is variable, but the majority of fish arrive at Mactaquac during the month of July. Few salmon have been observed prior to mid-June in the last 10 years further adding to the uncertainty regarding the current existence of the phenotypically unique Serpentine stock (DFO and MRNF 2008). Adult salmon captured at the fish collection facilities are sampled at the MBF sorting facility before being transported and released at various sites upriver. Salmon sampled at the sorting facility are identified as either wild origin, hatchery origin, captive-reared origin, aquaculture escape, or landlocked salmon; measured for fork length and classified as small (< 63 cm) or large (≥ 63 cm); sex, determined on the basis of external characteristics, is recorded; and a portion are scale sampled (Jones et al. 2014). All fish classified as wild origin could include returns from hatchery origin unfed and feeding fry as well as progeny from captive-reared spawners (released primarily to the Tobique River since 2003). Both of these groups are indistinguishable from wild origin fish. Hatchery returning salmon originate from a smolt release program just below Mactaquac Dam or from stockings of age-0 parr upriver of Mactaquac (Table A1, A2).

Captive-reared origin salmon returning to Mactaquac Dam as reconditioned adults were previously collected from the wild as juveniles and released as mature adults to spawn naturally in the Tobique River (Table A3). Ages were determined from scale samples. Additionally, the proportion of wild and hatchery origin in the count was adjusted based on interpretation of these scales. The procedures used to adjust counts are described in Marshall and Jones (1996) and have been consistently applied since 1995. The adjusted counts at Mactaquac Dam were used to estimate the returns and return rates for hatchery fish released as age-1 smolts and as age-0 parr.

Adjusted wild origin and hatchery origin returns in 2019 to Mactaquac Dam were 502 one-sea-winter (1SW) and 197 multi-sea-winter (MSW) (Table 1; Figure 3). Adjusted returns of wild origin 1SW salmon decreased by 33% from those of 2018, and were the second lowest annual estimate since 1970 (Table 2). Returns of wild origin MSW salmon increased by 52% in 2019, but were the second lowest estimate in the 50-year time series (Table 2). Estimated total (wild and hatchery combined) returns in 2019 for both 1SW and MSW were less than the previous 10-year means (Table 2; Figure 3). The return rate to Mactaquac of hatchery origin 1SW fish released as 1-year old smolts was 0.15%, a 39% decrease from the previous year and the sixth lowest value observed in the time series (Table 3; Figure 4). The return rate of the 2017 age-1 hatchery smolts as maiden two-sea-winter (2SW) salmon (Table 4; Figure 4) was 0% for a second consecutive year.

The adjusted counts proportioned by age composition among hatchery and wild components of Atlantic Salmon adults returning to Mactaquac from 1992 to 2019 are presented in Table 5. For the time series, wild 1SW and MSW adult returns are comprised of mainly 2 and 3-year old smolts with age-2 dominating both return groups over the past 15 years, or 3 generations (Table 5). From 1985 to 2017, the hatchery program has encompassed accelerated rearing and release of age-1 smolts below Mactaquac and of age-0 parr above Mactaquac (Table A1, A2). The resulting returns of hatchery fish are predominantly 1 and 2-year old smolts for both the 1SW and 2SW components (Table 5). Total mean age or generation time (egg deposition to egg deposition) of all wild returns during 1992 to 2019 ranged from a minimum of 4.3 in 2010 to a maximum of 5.4 in 1997 (mean=4.6; Table 5). In terms of sea age for both wild and hatchery returns combined, most of the large salmon are maiden 2SW (Table 5). With the exception of four years in the time series (1996, 1997, 1999, 2012), 1SW fish made up greater than 50% of the wild returns to Mactaquac (Table 5; Figure 5). In the last 15 years, previous (i.e., repeat) spawners have represented less than 3% of the total returns with a veritable absence of any 3SW maiden salmon (Table 5; Figure 5).

Biological characteristics of primarily females (female mean length, proportion female) from 1996 to 2019 have been summarized for 1SW and MSW salmon by origin (Table 6, 7). Notable differences in 2019 biological characteristics from 2018 were an increased proportion of females among wild 1SW salmon (+0.04) and a reduction in mean length of hatchery MSW (-0.7 cm). The proportion of females among wild and hatchery MSW fish increased by 0.03 and 0.02, respectively, from 2018 (Table 7). Mean lengths of wild (-3.4 cm) and hatchery (-4.3 cm) 1SW spawners have decreased similarly relative to their respective previous 10-year means. On average, female 1SW salmon are close to 60 cm, carry about 3,700 eggs, and represent less than 10% of the total 1SW returns. However, female MSW salmon average about 77 cm, bear approximately 7,000 eggs and represent close to 90% of the MSW returns. Using the length-fecundity relationship calculated for SJR salmon (eggs = $430.19 * e^{0.03605 * FL}$; Marshall and Penney 1983), as well as the mean lengths and estimated escapement in 2019 upriver of Mactaquac Dam, the total estimated egg deposition was 1.32 million eggs (0.1 eggs per m^2), or 4% of the CER (Gibson and Claytor 2012). This is triple the value estimated for wild female spawners in 2018 and the highest estimate in eight years (Figure 6). Estimated eggs from wild and hatchery

1SW fish comprised 15% of the total deposition. Eggs from hatchery origin 1SW and MSW salmon potentially contributed 80% of the total deposition in 2019 (Table 7).

ADULT RETURNS TO THE NASHWAAK RIVER (INDEX RIVER DOWNRIVER OF MACTAQUAC DAM)

The Nashwaak River is the largest single salmon-producing tributary of the SJR downriver of Mactaquac Dam (Marshall et al. 2014). The amount of accessible fluvial productive (gradient > 0.12%) rearing habitat area in the Nashwaak River has been estimated from orthophoto measurements (Amiro 1993) at 5.69 million m^2 (Marshall et al. 1997) or 14.1% of the total productive habitat area within the OBoF region (Marshall et al. 2014). An adult salmon counting fence 23 km upriver from the confluence with the SJR (Figure 7) was operated by DFO in 1972, 1973 and 1975, and by DFO in cooperation with Indigenous peoples from 1993–2019. In 2019, the fence was jointly operated by Kingsclear and Oromocto First Nations.

Adult counts at the Nashwaak River fence in 2019 were 122 1SW and 43 MSW salmon (DFO 2020). The start and finish dates were similar to previous years (Table 8). However, the counting fence was temporarily lowered in early and mid-July (4 days) and then again in September (12 days) and October (2 days) due to exceedingly high water levels. Therefore, the fence counts are considered only a sub-sample of the total returns in 2019 (Table 8). After scale analysis, 1SW and MSW salmon components of the fence counts in 2019 were left unadjusted (Table 9). There were no aquaculture escapes, landlocked salmon, or hatchery origin fish identified among the final 1SW and MSW unadjusted counts. The five high water events that necessitated the temporary removal of the fence prevented any meaningful comparison of the run timing in 2019 to previous years but generally the majority of 1SW and MSW salmon were counted during the month of July (Figure 8, 9). Similar to the previous three years, in 2019 very few 1SW (8%) and MSW (13%) were counted during the month of August and the first half of September when river discharge was relatively low (Figure 8, 9). Scale samples revealed that the age composition of wild adults in 2019 was 67% 1SW fish, 32% maiden 2SW fish and 1% previous spawners. The proportion of 1SW and 2SW salmon returns is similar to values observed in 23 of the last 27 years; the exceptions being 1997, 2001, 2009, and 2012 (Figure 10). The sea age breakdown of Nashwaak River wild salmon returns has been very similar to those of wild salmon returning to Mactaquac Dam since 2000 (Figure 5). Previous spawners have represented less than 10% of the estimated total annual returns since 2015. The return rate of maiden 1SW and 2SW salmon to spawn a second time has been variable since 1993 but has generally been declining throughout the time series (Figure 11). Very few maiden 3SW salmon have been observed in the Nashwaak population (Figure 10). For 1993 to 2019, the mean generation time has varied from 4.3 to 5.0 years.

In 2019, estimated wild returns to the Nashwaak totaled 238 1SW and 68 MSW salmon (Figure 12). Estimated 1SW returns increased almost 3-fold from 2018 but were still 50% less than the 10-year mean. MSW returns more than doubled from the 2018 returns and yet were 57% less than the 10-year mean. Smolt-to-adult return rates for 1SW and 2SW salmon on the Nashwaak River were not possible to calculate in 2019 (Table 10). Smolt-to-1SW (2.84) and 2SW (0.41) return rates for the 2016 smolt cohort, the most recent year for which return data is available, were lower than the long-term means (1998–2015; 4.28 and 1.05) and the previous 10-year means (2006–2015; 4.31 and 1.11) shown in Figure 13.

As in previous assessments, egg deposition and the number of spawners in 2019 were estimated on the basis of length, external sexing and interpretation of age from scales collected from fish captured at the fence. Numbers of 1SW and MSW spawners were 12% and 3% of the conservation requirements, respectively (Table 9). Egg deposition was estimated to be 649,729 eggs or 5% (0.12 eggs per m^2) of the CER (Table 10; Figure 14). One-sea-winter females contributed 47% of the total estimated egg deposition.

NASHWAAK RIVER SMOLT PRODUCTION

To provide a basis for evaluating marine survival and freshwater production rates of the Nashwaak River, an index river for other SJR tributaries below Mactaquac Dam, a smolt population assessment has been conducted annually since 1998. In 2019, two rotary screw traps (RSTs) were installed and operated from May 1 until June 5 in the main stem of the river just downstream of Durham Bridge (Figure 7). Similar to earlier years from 1998 to 2001, a portable counting fence was also operated on the Tay River from which smolts were marked and released (Figure 7). A total of 399 wild smolts were captured during RST and fence operations. The timing of the smolt migration appeared to be delayed similar to 2014 and 2015 (Figure 15). Jones et al. (2004) provided evidence that at least in the first five years of the time series, water temperatures and not discharge appeared to influence peak smolt movements. In 18 of 20 years when the population could be estimated, at least 50% of the cumulative smolt catch had occurred by May 14, including 2019 (Figure 15). Only 10 smolt were captured during the last 12 days of operation.

Marked smolts captured and released at the counting fence and those ‘recycled’ upriver of the RST resulted in similar estimates of smolt wheel capture efficiency (3.2% and 5.2%). Based on mark-recapture data, an aggregated Bayesian model assuming a binomial distribution for the catches resulted in an estimate of 8,710 fish (95% C.I. 5,960 to 17,815) emigrating from the Nashwaak River in 2019 (Table 10; Figure 16). This represents an increase of 22% from 2016 and an 8% decrease from the previous 5-year mean for when a population estimate could be calculated (2012–2016). It was the fifth lowest estimated total since smolt assessments on the Nashwaak commenced in 1998 (Table 10; Figure 16).

Since the initial year of monitoring, the annual mean fork length of wild smolts emigrating from the Nashwaak River has ranged from 14.3 cm (2015 and 2019) to 15.8 cm (2016) with a mean of 15.0 cm (Figure 17). O’Connell et al. (2006) compared the annual mean fork length values of smolts from 10 Atlantic Salmon populations in Eastern Canada and only two Newfoundland populations (Western Arm Brook and Campbellton) were consistently larger than the Nashwaak. Wild smolts have been predominately age-2 with the remainder being age-3 since monitoring began (Figure 18). In 2019, age-2 smolts represented 95% of total juvenile emigrants, which was greater than the long-term mean, and likely contributed to it being one of the smallest annual mean length values observed in the time series. For all years, mean fork length values for age-2 smolts and age-3 smolts have averaged 14.6 cm and 16.3 cm, respectively.

TOBIQUE RIVER (INDEX RIVER UPRIVER OF MACTAQUAC DAM) PRE-SMOLT AND SMOLT PRODUCTION

Fall pre-smolt and spring smolt collections upriver of Mactaquac Dam (Tobique River; Figure 19) have been conducted since 1998 and 2000, respectively. Several sampling techniques and assessment methods have been used and are described in Jones et al. (2004, 2006, 2010, 2014). In the Tobique River, there is a component of the juvenile population that begins downstream migration in the fall past Tobique Narrows Dam and overwinters in the main stem of the SJR (Carr 2001, Jones and Flanagan 2007). These fish, commonly termed pre-smolts, were estimated in 2001 to comprise 64% of the total juvenile salmon contributing to the 2002 smolt class (Jones et al. 2004). From 2002 until 2005, all wild pre-smolts were retained for the captive-reared program at MBF. Beginning in 2006, a population assessment component was added. In the years following, approximately two thirds of the wild pre-smolts were retained for the captive-reared program and the remaining one-third of the wild origin, and all hatchery origin pre-smolts, were marked and released in the main stem near Plaster Rock; approximately 3.5 km upriver of the Three Brooks RST location (Figure 19). RSTs have been consistently used to capture juvenile migrating salmon at two different locations (Nictau and Three Brooks; Figure 19). In fall 2018 and spring 2019, pre-smolts and smolts were also collected from a downstream fish passage surface bypass structure at the Tobique Narrows Dam. The downstream bypass passage structure contained assessment screens, which are operated and monitored by Tobique First Nation personnel, typically during the fall and spring emigration periods based on water temperature and seasonal flows. Since 2006 and 2007, wild origin pre-smolt and smolt could include progeny from sea-run and captive-reared spawners (releases began in 2003).

In fall 2018, four RSTs operated for five weeks at the Three Brooks location captured a total of 1,254 pre-smolts (85% wild) and 182 parr (87% wild) (Table 11). To estimate pre-smolt production from the river, a total of 520 wild and hatchery pre-smolts were marked (caudal punch) and released upriver at Plaster Rock (Figure 19). Of the 520 fish that were marked and released 3.5 km upstream, 80 were recaptured, resulting in an efficiency of 16.3% and an estimated population of 7,689 pre-smolts (2.5 and 97.5 percentiles; 6,359–9,722); 6,524 wild and 1,165 hatchery pre-smolts using the Bayesian estimation procedure (Table 11). The 2018 pre-smolt estimate was the second lowest in the time series and 39% less than the previous 10-year mean (Table 11; Figure 20).

In spring 2019, a total of 128 and 47 unmarked wild and hatchery smolts, respectively, were captured during the six weeks of operation at Three Brooks (Table 12). The first smolt was captured on May 3 while 50% of the total catch had occurred by May 13 (Figure 21). Only 57 smolts were marked (caudal punch) and released at Plaster Rock. Seven of the tagged smolts were recaptured in the RST at Three Brooks, resulting in an overall efficiency of 12.3%. This mark-recapture data resulted in a Bayesian estimate of 1,426 combined wild and hatchery origin smolts (2.5 and 97.5 percentiles; 852–3,904). Separate estimates for wild and hatchery fish could not be calculated using this data because of the small sample sizes. The 2019 smolt estimate was the second lowest in the time series and 75% less than the previous 10-year mean (Table 12; Figure 20).

The mean length of wild smolts (all age classes combined) sampled during spring operations on the Tobique River has varied annually between 13.8 cm (2017) and 15.6 cm (2018) since monitoring began in 2000 (Figure 22). The mean length of wild smolts sampled in 2019 was 14.7 cm, a value only slightly less than the long-term mean (14.8 cm; 2000–2019). Analysis of scale samples (n=128) collected from wild smolts indicated that the majority (91%) were age-2 (Figure 23). The remainder were age-3 smolts; no age-4 smolts or older have been observed in the Tobique smolt population since 2006 (Figure 23). Age-2 smolts have comprised more than 70% of the total wild smolt estimate in all but three years occurring between 2001 and 2005 (Figure 23).

REVIEW OF DESIGNATABLE UNIT 16 – OUTER BAY OF FUNDY

OBoF Atlantic Salmon are unique compared to the adjacent Inner Bay of Fundy (IBoF) populations in that they have a higher incidence of maturation as 2SW salmon, a lower incidence of females among 1SW fish, and they conduct extensive migrations to the North Atlantic (DFO 2014, Marshall et al. 2014). They also group separately from IBoF salmon and most other populations at multiple allozyme loci and have, therefore, been considered a distinct regional grouping (DFO and MRNF 2008, COSEWIC 2010). Analyses of microsatellite genetic variation carried out by O’Reilly et al. (2014) are largely in agreement with the identification of OBoF salmon as an important component of within-species biodiversity, and their resolution as a DU of Atlantic Salmon. Among-population comparisons of microsatellite variation show that

OBoF populations cluster together and separate from all other populations analyzed from several other nearby DUs in the Maritime Provinces, including IBoF, Southern Upland (SU), Eastern Cape Breton (ECB), and Gaspé-Southern Gulf of St. Lawrence (GSGL) (O'Reilly et al. 2014). These results are consistent with analyses of other molecular genetic markers, which demonstrate low levels of gene flow between OBoF salmon and the next geographically proximate populations in the IBoF and SU DUs (O'Reilly 2006, O'Reilly et al. 2012)

O'Reilly et al. (2014) also report on results of analyses of two molecular genetic datasets, one involving several small sample collections obtained from the OBoF and analyzed at a limited set of seven microsatellite loci, and another involving only two OBoF locations, but analyzed at a larger set of 17 microsatellite loci. Both datasets include at least one tributary of the SJR above and one below Mactaquac Dam, and multiple reference populations from other DUs. Overall, levels of allele richness and gene diversity in the sample populations of OBoF Atlantic Salmon analyzed were relatively high. Levels of genetic variation within OBoF sample collections overall are comparable to those obtained from large populations in the GSGL DU and elsewhere, and considerably greater than many sample collections obtained from the IBoF and the SU DUs. The only significant difference in levels of genetic structuring was observed between tributaries above Mactaquac Dam (Tobique) and tributaries below Mactaquac (Nashwaak). However, reduced gene diversity and allele richness for the Tobique was modest indicating that genetic patterns observed in the SJR system could reflect the impact of dams and stocking effects but also natural biological processes such as decreased straying among upper river tributaries.

The OBoF Atlantic Salmon DU is geographically positioned to be affected by aquaculture operations as all populations must pass within 100 km of the intensive aquaculture activities of the Passamaquoddy Bay region in the BoF during migration to and from freshwater (Marshall et al. 2014). The Magaguadavic, St. Croix and some other outer Fundy complex rivers drain directly to Passamaquoddy Bay and surrounding region in southwestern NB where Atlantic Salmon is currently the only finfish species commercially grown in marine cages. In 2012 there were 92 marine finfish leases with 59 actively growing salmon commercially on site for an average of approximately 20 months (minimum two months) during 2010–2012 (Change and Page 2014). Change and Page (2014) also estimated farmed salmon production in southwestern NB in 2012 to be 30,217 t. The Magaguadavic River salmon population is affected by both freshwater aquaculture (Morris et al. 2008) and marine aquaculture (Bouret et al. 2011). Despite the precipitous and consistent reduction in number of wild and hatchery adult returns to the Magaguadavic River in recent years (Table 1), estimates of genetic diversity in Magaguadavic samples were very similar to those observed in other contemporary OBoF populations, and similar to the sample collection obtained from the Magaguadavic River the year the decline of the wild population began (O'Reilly et al. 2014). Based on further genetic data and additional analyses carried out by Bourett et al. (2011), these authors attributed observed genetic diversity and allele richness in the more recent samples collected on the Magaguadavic River to the likely introgression of new alleles from genetically divergent aquaculture salmon.

POPULATION STATUS AND TRENDS

In November 2010, COSEWIC assessed the OBOF Atlantic Salmon population as Endangered (COSEWIC 2010). DFO Science held a RPA for the OBoF DU in February 2013 (DFO 2014, 2015). Since this time, DFO Science has provided annual updated advice on the status of Atlantic Salmon stocks within the Maritimes Region, including OBoF (corresponding to the western part of SFA 23), using established methods (DFO 2020 and references therein). In 2019, the status of populations in SFA 23 was assessed using the following indicators: adult abundance relative to reference levels (Gibson and Claytor 2012), juvenile densities (Elson 1967); and smolt production estimates (Symons 1979).

Returns to the three SFA 23 index rivers in 2019 were all estimated to contribute less than 6% of their CERs (Table 2, 9; Figure 6, 14). Although egg depositions from spawners in the SJR upriver of Mactaquac Dam and Nashwaak rivers increased slightly from record low values in 2018, estimates in 2019 for each of the three OBoF DU index rivers remained below 8% of their CER for the eighth consecutive year (DFO 2020). Assuming the captive-reared adults spawn successfully, spawners released upriver of Mactaquac Dam in 2019 potentially increased the estimated egg depositions to 11% of the requirement on that section of the SJR.

TRENDS IN RETURNS

Trends in abundance were analyzed for the Atlantic Salmon population upriver of Mactaquac Dam from total 1SW returns, total MSW returns, combined 1SW and MSW returns, as well as total egg deposition from wild and hatchery-origin 1SW and MSW spawners (Table 2). Prior to analyses, estimated total (adjusted) returns of wild and hatchery origin salmon were combined because of the difficulty of distinguishing origin due to the increasing numbers of unmarked hatchery age-0 parr released upriver of Mactaquac Dam since 2004 (Table A1, A2). Using a method similar to that described by Gibson et al. (2011), trends in these four groups of combined origin were analyzed over the past three generations or most recent 15-year time 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 1SW, MSW, and total returns all indicate substantial declines in population abundance over the past three generations or 15 years (Figure 24), with predicted decline rates of 80.0%, 81.5%, and 80.1%, respectively (Table 13). The predicted decline rate for egg deposition was slightly less, at 76.7%. The decline rate for both 1SW and MSW salmon is synchronous, which is consistent with both cohorts experiencing similar ocean conditions during the post-smolt phase or some time period before the second summer at sea. It is also important to note that the 1SW (2008–19) and MSW (2009–19) returns have been influenced by progeny from the captive-reared releases of salmon since 2004.

Trends in returns and escapement to the Nashwaak River were analyzed using the log-linear model described for the salmon population upriver of Mactaquac. The four data sets analyzed for the Nashwaak River were 1SW returns, MSW returns, total returns (1SW and MSW combined), and total egg deposition from 1SW and MSW spawners (Table 9). Plots of abundance and the log-linear fit for 1SW, MSW, total returns, and total egg deposition, all suggest considerable declines in population abundance over the past 15 years (Figure 25). The log-linear model predicted similar decline rates (82.8%, 79.1%, 82.2%, 82.7%) for all adult abundance indicators over the 3- generation time period.

Decline rates for the Magaguadavic River salmon population have been updated since those presented in Jones et al. (2014). The rates were calculated using combined wild and hatchery 1SW and MSW returns (Table 1) with the log-linear model described above. Plots of abundance and the log-linear fit for total returns predict large declines (76.9%) in population abundance over the past 15 years (Table 13; Figure 26). However, the lower confidence interval on this model fit included a negative value, indicating a greater level of uncertainty in the direction of population change. This is likely a result of the relatively larger numbers of wild 1SW and hatchery fish which returned in the beginning and middle years of the time series.

Calculations completed to provide updated totals for 1SW and MSW returns to the DU from 1993 to 2019 are described below (Table 14). Total 1SW and MSW returns to the SJR from 1993 to 2019 were calculated from the estimated returns to the Nashwaak River (upriver of the counting fence, Table 9) multiplied by the amount of habitat assessed (Total Nashwaak * proportion above fence; 0.245 * 0.90 = 0.221) plus the total returns destined for Mactaquac (Table 2). Updated habitat estimates reported by Marshall et al. (2014) were used. This slightly increased (1–3%) total return estimates for 1993–2012 reported in Jones et al. (2014) but did not affect the decline rates.

Jones et al. (2010) estimated 1SW and MSW returns to other OBoF rivers using the total returns to both the Magaguadavic and St. Croix rivers, divided by the proportion of the habitat area assessed on the St. Croix and Magaguadavic in relation to the total amount of habitat for the entire outer Fundy complex of rivers, and then added to the estimated SJR returns to provide the total estimated 1SW and MSW returns to the DU. However, the fishway on the St. Croix has not been monitored since 2006. Therefore, returns to other outer Fundy complex rivers (including the St. Croix River) in 2007–2019 were estimated based only on returns to the Magaguadavic River and its accessible productive habitat area as a percentage (0.198) of outer Fundy rivers in DU 16 (Canada only). Updated habitat estimates for the St. Croix River and other rivers west of the SJR in DU 16 were used in these calculations. The methods used in updating productive salmon habitat estimates in DU 16 are provided in Marshall et al. (2014).

Total estimated 1SW returns to the entire OBoF DU in 2019 was 1,584 fish (Table 14). The estimated 1SW returns in 2019 were 54% lower than the previous 15-year mean. The total estimated MSW returns to DU 16 was 524 fish, 50% less than the previous 15-year mean. Total estimated returns (1SW and MSW combined) in 2019 were 53% lower than the previous 15-year mean and the sixth lowest estimate in the 27-year time series. Overall, estimated returns to the OBoF region for both 1SW and MSW salmon have been less than 15% of the conservation requirement since 2011.

Similar to the three index populations in DU 16 [i.e., SJR upriver of Mactaquac, Nashwaak (SJR downriver of Mactaquac), Magaguadavic (outer Fundy complex)] trends in 1SW returns, MSW returns, and combined 1SW and MSW returns (Table 13) were analyzed for the entire DU over the last 15 years with the log-linear model. Plots of abundance and the log-linear fit for the groups indicate significant declines in population abundance over the past 15 years (Figure 27). The decline rates from the log-linear model for 1SW, MSW and total returns were 81.3%, 79.4%, and 81.0%, respectively (Table 13).

AREA OCCUPANCY

The total amount of drainage area, wetted habitat, as well as the amount of productive habitat for the OBoF population or DU 16 was updated in Marshall et al. (2014) and are identical to those reported in Jones et al. (2014). These accessible habitat estimates, primarily on the SJR tributaries, are based on digital spatial data from the NB Department of Natural Resources, width measurements from air photos and length measurements from orthophotographic maps. Areas of productive habitat (> 0.12%) are partitioned based on stream gradient (Amiro 1993). The bases for estimates of productive habitat for other rivers are provided in Appendix 2 of Marshall et al. (2014).

An extensive electrofishing survey to assess the presence/absence (area of occupancy) and relative density (fish per 100m^2) of juvenile salmon in rivers containing accessible habitat in the OBoF DU was last conducted in 2009 by DFO and partners. Results of these collaborative efforts are detailed in Jones et al. (2014). In total, 189 sites equivalent to more than 137,000 m^2 of habitat within the DU were electrofished. Wild juvenile salmon (combined age classes) were captured at 69%, 65%, and 33% of sites surveyed in tributaries above Mactaquac Dam, in tributaries below Mactaquac, and within six rivers of the outer Fundy complex, respectively.

HABITAT CONSIDERATIONS

FUNCTIONAL PROPERTIES

Freshwater Environment

Freshwater habitat use by Atlantic Salmon is diverse, widely documented and the subject of substantial reviews (e.g., Bjornn and Reiser 1991, Gibson 1993, Bardonnet and Baglinière 2000, Armstrong et al. 2003, Rosenfeld 2003, Amiro 2006, Bowlby et al. 2014). Functional components of freshwater habitat for OBoF DU Atlantic Salmon, including their associated features and attributes are well known relative to marine habitat (DFO 2014). Marshall et al. (2014) provided functional descriptions of aquatic habitat properties required for successful completion of freshwater life-history stages. Major freshwater habitat types identified included: feeding, wintering, spawning, early life-stage nursery and rearing, and upstream migration habitat (Gibson 1993, Armstrong et al. 2003). Freshwater habitat quality can be affected by seasonal temperatures, stream discharge, water chemistry (e.g., pH, dissolved oxygen), turbidity, invertebrate abundance, physical perturbations (e.g., impoundments, deforestation), and connectivity. Of these, connectivity generally continues to be the most debilitating and subsequently, best quantified impact on salmon habitat in DU 16 (Clarke et al. 2014, DFO 2014, Marshall et al. 2014). Other factors, such as those caused by climate change (e.g., water temperatures, stream discharges), agriculture, forestry and increasing urbanization, are also recognized as debilitating but their impacts on OBoF salmon freshwater habitat remain largely unquantified.

Tidal/Estuarine/Marine Environment

Virtually all salmon rivers of the SJR are of low gradient where they meet tidal waters and the spatial extent of the estuary can vary daily with the magnitude of the tides and their incursion into rivers. Smolts encountering extensive estuaries such as the lower SJR where passage can last up to 10 days (means of six to seven days) (Lacroix 2008) before reaching the BoF may benefit by way of some pre-oceanic growth and the potential for reduced predation once at sea (Marshall et al. 2014).

Marine habitat requirements for OBoF Atlantic Salmon are less well known than those for freshwater. The lack of information is due, in part, to the challenges associated with collecting data and tracking salmon during their migrations in the marine phase. Nonetheless, there is a body of tag data (Ruggles and Ritter 1980, Penney 1983, Ritter 1989, ICES 1990, 2007, Lacroix et al. 2004, Lacroix and Knox 2005, Whoriskey et al. 2006, Lacroix 2008, 2013a, 2013b, 2014, Ó Maoiléidigh et al. 2018) that places OBoF salmon in the BoF, Scotian Shelf, Grand Banks, Newfoundland and Labrador coasts, and Labrador Sea where other researchers have described preferred habitats and prey of Atlantic Salmon (Dadswell 2004, Reddin 2006, Dadswell et al. 2010, Reddin et al. 2011, Lacroix et al. 2012, Sheehan et al. 2012, Renkawitz et al. 2015, Strøm et al. 2020). Stable isotope analysis of archival OBoF salmon scales has also been used in recent years to infer ocean conditions and feeding strategies driven by diet composition, foraging location, or both (Soto et al. 2018, Kelly et al. 2019). Marshall et al. (2014) generalized attributes of important marine habitat for different life stages of most Atlantic Salmon populations (OBoF DU Atlantic Salmon included), specifically water temperature, salinity, depth, ocean currents, light regimes and the presence of suitable prey organisms.

SPATIAL EXTENT AND CONSTRAINTS

Freshwater Environment

OBoF DU Atlantic Salmon are thought to utilize accessible habitat of most southwest NB rivers draining into the BoF west of and including the SJR (Figure 1). The SJR is the second longest river in northeastern North America and has a basin area of over 55,000 km^2. It begins in northern Maine, travels northeast into northern NB while being fed by tributaries in eastern Quebec and subsequently flows southeast through NB to the BoF (Figure 2). Fifty-one percent of the SJR Basin is in NB, 36 percent is in Maine, and 13 percent is in Quebec (Kidd et al. 2011). Approximately 16,000 km^2 of the basin is above Grand Falls, NB and has historically been inaccessible to Atlantic Salmon (Cunjak and Newbury 2005). There are 11 salmon rivers in DU 16 (considering the SJR above Mactaquac Dam as one river with 18 tributaries) within the SJR Basin. An additional nine rivers (outer Fundy complex rivers), with spawning and rearing habitat potentially available to Atlantic Salmon, lie westward of the SJR draining into the BoF between the city of Saint John and the Canada-USA boundary. Estimates of productive capacity for habitat within 16 tributaries, two mainstem sections of the SJR upriver of Mactaquac Dam, and 10 tributaries to the Jemseg River downstream of Mactaquac Dam are provided in Table 1 of Marshall et al. (2014). Marshall et al. (1997) documented the extent of much of the productive habitat for Atlantic Salmon in DU 16 (Canada) on the basis of gradients > 0.12%, as determined by Amiro (1993). Current temperature and stream discharge regimes, impacts due to obstructions, agriculture, urbanization, etc., affect the productive capacity of the SJR, St. Croix and Magaguadavic rivers habitat relative to what it was (Clarke et al. 2014). In total there is an estimated 49.7 km^2 of productive habitat available to Atlantic Salmon within DU 16 in Canada and USA; 81% is within Canada. Of the combined Canada-USA area, 90% is within the SJR Basin. Within the SJR, 21.5 km^2 is upriver of Mactaquac Dam and 23.1 km^2 is downriver of Mactaquac Dam. Only 5.0 km^2 (10%) is found in rivers west of the SJR.

The major spatial constraint on Atlantic Salmon in DU 16 is connectivity resultant of large hydroelectric dams and headponds in the SJR as well as the St. Croix and Magaguadavic rivers. The larger rivers of the OBoF DU have had a century or more of industrial development that has constrained the connectivity of Atlantic Salmon populations and their habitat. Habitat alterations associated with dams, headponds, regulated flows, and other ecosystem impacts such as point-source pollutants have limited the accessibility and reduced the connectivity on the main stem SJR (and some tributaries) between Mactaquac Dam and Grand Falls (Kidd et al. 2011). They are also largely accountable for degradation of major sections of the St. Croix and to a lesser extent the Magaguadavic river basins. Major dams and headponds affect 48% of the estimated accessible productive freshwater habitat on the SJR; 52% of that in the entire OBoF DU. There are also three water storage dams (Serpentine, Trousers and Long) on the ‘Right Hand Branch’ of the Tobique River with a combined water storage capacity of 130 million m^3 (Carr 2001). The location of major dams in the SJR are shown in Figure 2. The critical impact of these dams, headponds, and storage reservoirs on the connectivity of habitat in each of the aforementioned basins are summarized in Marshall et al. (2014). Concise descriptions of these and additional dams and obstructions in DU 16 are addressed in Clarke et al. (2014).

Tidal/Estuarine/Marine Environment

The estuary boundary for the SJR and its tributaries fluctuates with the BoF tides but is generally considered as the main stem area from Reversing Falls at the head of the Saint John

Harbour upstream to an area near Long Reach, NB. Similarly, estuaries of outer Fundy complex rivers are considered as the area at the mouth of each river influenced by salt water but are not explicitly defined.

Based on releases of 40 wild-origin and 20 hatchery-origin Nashwaak River smolts and 41 hatchery-origin smolts from MBF, post-smolts of OBoF origin tended to exit the BoF rapidly from late-May to early-June and swim directly through Grand Manan Basin (Lacroix 2008); although a small proportion of slow migrants (range 9–35 days) were observed (Lacroix et al. 2013a). To extend knowledge of the migration routes, condition and habitat of post-smolts from the BoF, Lacroix and Knox (2005) marked and released approximately 900,000 hatchery-origin smolts from MBF on the SJR; captured, marked and released several thousand wild smolts migrating from several rivers of the BoF; and conducted surface trawling surveys in the BoF and Gulf of Maine (GoM) between 2001–2003. Subsequent surface trawling surveys in the BoF and GoM captured 161 wild-origin and 237 hatchery-origin post-smolts. No captures from these releases were made either to the east of the SJR or in the vicinity of Passamaquoddy Bay. Based on post-smolt captures and sea-surface temperatures (SSTs) during trawling in the last days of May and first half of June, Lacroix (2013a) suggested an area of suitable habitat in the OBoF and eastern GoM extending to the Scotian Shelf that was characterized by SSTs in the 4–10°C range and which contracted with the onset of summer.

Post-smolts of OBoF origin likely move, in part, in the interface of ocean currents in reaching the OBoF, Scotian Shelf, coasts of Newfoundland, and the Labrador Sea where they possibly overwinter as suggested by Reddin (2006). In the following spring and summer, 1SW salmon captured along the south and southeast coast of Newfoundland or off Nova Scotia (NS) likely maturing and returning to North American natal rivers. Whereas, 2SW salmon (non-maturing 1SW) can be found in late summer and autumn feeding inshore along the northeast Newfoundland and Labrador coasts, at West Greenland, in the Labrador Sea and in the Irminger Sea including the East Greenland coast (Reddin 2006). Based largely on the spatial and temporal overlap of archival and electronic tagging data (ICES 2007, Reddin et al. 2012, Lacroix 2013b, Ó Maoiléidigh et al. 2018), OBoF repeat spawning salmon can be surmised to generally trace the route of post-smolts towards the Labrador Sea and thereafter, depending on life history strategy (i.e., consecutive or alternate repeat spawner), be exposed to similar marine habitat of 1SW and 2SW fish. Dadswell et al. (2010) proposed an alternative model for the distribution of salmon in the North Atlantic whereby some proportion of populations from both continental stocks use the North Atlantic Subpolar Gyre (NASpG) to migrate among seasonal feeding habitats in the northwest and northeast Atlantic. Regardless, information is not currently sufficient to determine critical marine habitat boundaries of OBoF DU Atlantic Salmon other than a general range of occurrence between the BoF and the main axis of the NASpG.

Spatial constraints of Atlantic Salmon from DU 16 in the marine environment are not thought to be limiting population persistence (Marshall et al. 2014). Acoustic telemetry monitoring of hatchery-reared and wild smolts migrating from two rivers of Passamaquoddy Bay indicated the presence of salmon farms both in the estuary and along the migration route of fish from one of the rivers did not delay migration, but most losses of smolts and post-smolts from that river occurred in areas near the salmon farms where potential predators were abundant (Lacroix et al. 2004).

The influence of warming SSTs in recent years may be diminishing habitat suitability in estuaries or at sea. Both post-smolts and kelts may be encountering altered amounts or timing of predators or pathogens when accessing historical feeding areas (Lacroix et al. 2004, Lacroix 2013b).

THREATS

The Recovery Potential Assessment for OBoF salmon defined threats as any activity or process (both natural and anthropogenic) that has caused, is causing, or may cause harm, death, or behavioural changes to a species at risk or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur (DFO 2014). A summary of potential threats to OBoF salmon were tabled along with a ranking of relative importance to the persistence of salmon in this DU (Table A4 and A5). Only threats assessed as high risk were discussed in detail. In freshwater habitat these included hydro dams and illegal fishing. The removal of adult salmon from OBoF rivers was identified as a particularly severe threat to the populations and a direct loss of spawners. In the marine environment, shifts in marine conditions (which affect temperatures, currents and predator prey interactions), salmonid aquaculture, depressed population phenomenon, and disease and parasites were assessed as high risk threats. Potential freshwater mitigation measures/actions for high level threats included: implementation/improvement of downstream fish passage, removal or refurbishment of reservoirs/dams, increased education and awareness activities, public outreach, and increased enforcement in areas of concern. Potential marine mitigation measures/actions for high level threats included: application of science based siting criteria for aquaculture operations, escape management regimes, improved fish health management, increased compliance and enforcement of best management practices, and enhanced education and training for industry.

RESIDENTIAL AND COMMERICAL DEVELOPMENT

Housing & Urban Areas

Urbanization has been identified as a medium threat to OBoF salmon (DFO 2014). Clarke et al. (2014) summarized populations sizes for notable urban developments throughout the OBoF. Most census numbers used derived from 2010–2011. Although a site-by-site update is not provided herein, the overall population of NB has remained relatively stable in the past decade and changes are unlikely to represent a change in the threat assessment of urbanization for OBoF Atlantic Salmon.

Commercial and Industrial Areas

No DFO data.

Tourism and Recreation

No DFO data.

AGRICULTURE & AQUACULTURE

Annual & Perennial Non-Timber Crops

Agriculture has been identified as a medium threat to OBoF salmon (DFO 2014). Clarke et al. (2014) summarized the footprint and diversity of agricultural practices in the OBoF, highlighting potato production and processing in the SJR basin as the most notable contribution to this threat to salmon.

Livestock Farming and Ranching

No DFO data.

Marine & Freshwater Aquaculture

Given correlations between the proximity and density of aquaculture sites and negative effects on wild salmonids (e.g., Ford and Myers 2008), and the fact that all OBoF salmon populations have to pass within 100 km of an intensive aquaculture area in the Quoddy region, it's not surprising that salmonid aquaculture and diseases and parasites have been identified as high threats to OBoF salmon (DFO 2014, Clarke et al. 2014). As of 2011, NB farmed salmon harvest was 20,000 mt, or 4.5 million fish with 95 licenses in in Passamaquoddy Bay region (1/3 intentionally fallow).

Clarke et al. (2014) broke down aquaculture threats to OBoF salmon into four themes: freshwater hatcheries, escapees, wild salmon interactions with farms and surrounding areas, and aquaculture of non-salmonids. Interactions between wild Atlantic Salmon and aquaculture operations can occur in the immediate vicinity of the net-pens or through interactions between escaped aquaculture salmon and wild salmon. Aquaculture escapes can impact wild Atlantic Salmon populations via reduction of genetic fitness via inter-breeding, loss of local adaptations, introduction of pathogens or disease, competitive displacement of wild salmon and increased uncertainties in wild stock assessment (DFO 2014).

Freshwater hatcheries can threaten habitat quality through contaminated outflows and the escape of cultured individuals or disease (Bowlby et al. 2014). Clarke et al. (2014) review several instances in which both smolts and returning adults in OBoF rivers were found to have derived from freshwater juvenile salmon escape events. In the Magaguadavic River, 9% of the adult returns from the 1996 smolt cohort were smolts escaped from domestic commercial hatcheries upstream as juveniles (Lacroix and Stokesbury 2004). The fact that this same study estimated that these hatchery escapee smolts had only 20% the survival rate of wild smolts through the marine migration reveals relatively high potential input of escape of farmed juveniles into freshwater environments, to say nothing of the genetic effects of introgression. In another instance, over 20% of the smolt captures in a counting fence on the Tay River in 1998 were escapees from a private hatchery (Marshall et al. 1999).

The threat posed by interactions between farmed salmon escaped from marine cages and wild salmon populations depends, among other things, on farm size, escape rate, and frequency of escape events (Morris et al. 2008). In the OBoF, where the abundance of adult farmed salmon (millions) is many orders of magnitude higher than the total OBoF adult salmon population (circa 1000), the potential threat from even low frequency and extent escape events is severe. Between 2010 and 2019, there have been multiple reported large scale aquaculture escape events including containment breaches that released 184,000, over 100, between 1,000 and 1,500, 40,000 and approximately 1,225 aquaculture salmon in 2010, 2012, 2013, 2015 and 2019, respectively. On the Magaguadavic River, escaped salmon have been identified every year from 1992–2019 with over 1,000 individuals ascending the river in 1994. Since then, escapees have comprised over 75% of the cumulative total of returning salmon and have made up more than 90% of the adult salmon run in some years and 100% of the run in 2017. On the St. Croix River, escaped salmon were identified from 1994–2006 (when monitoring ended) and escapees comprised between 13–85% of the total run of salmon. Suspected escapees have been identified in the Bocabec River and have been captured on the SJR at the Mactaquac Dam since 1990. Since then, suspected escapees were detected in all but six years with counts as high as 229 salmon (1990). See Clarke et al. (2014) for an extensive review of aquaculture escape events in the OBoF DU, including evidence that escaped salmon have introgressed with wild salmon.

When wild salmon interact with farm areas they can be exposed to effects of nutrient loading and chemical inputs including antibiotics, as well as altered predator-prey dynamics when wild fish congregate around sea-cages (Goodbrand et al. 2013). In the case of Passamaquoddy Bay, most OBoF origin smolts that entered the area were detected exiting (Lacroix et al. 2004, Lacroix 2008), although the latter study noted lower survival of smolts in areas where predators were prevalent. Clarke et al. (2014) highlighted that documented evidence of effects of aquaculture operations on salmon populations in Atlantic Canada were sparse compared to Europe or Western Canada. They recommended that continued research and collaboration with the aquaculture industry was necessary to define and monitor the industry's effects in this region. To date, predator attraction to net pens has not been directly linked to increased mortality in wild OBoF salmon populations (DFO 2014). Clarke et al. (2014) considered non-salmonid aquaculture to have a negligible impact on the persistence of wild OBoF salmon.

There are currently 93 marine aquaculture sites within the OBoF DU licensed to grow finfish species (Figure 28). As of January 2021, there were also an additional three sites currently under review. The majority of marine sites occur in the southwest portion of the DU in the Passamaquoddy Bay and surrounding area and off Grand Manan Island. Between 2015 and 2019 the average yearly production of aquaculture salmon in NB was 24,988 t (Figure 29).

ENERGY PRODUCTION & MINING

Oil & Gas Drilling and Renewable Energy

Non-hydro generating stations in the OBoF DU include the Lepreau Nuclear Generating Station, which continuously circulates 300 gallons of seawater per minute resulting in discharges as much as 20 °C higher than ambient temperature (Clarke et al. 2014). Other associated emission risks include gaseous and liquid radioactive products as well as anti-fouling biocides (Nelson et al. 2001). The Coleson Cove thermal generating station, which represents about 25% of the electricity production capacity for NB (NB Department of Environment and Local Government, 2019) has been cited as the largest single point source of air pollution and greenhouse gases in the region (Clarke et al. 2014).

Mining & Quarrying

Clarke et al. (2014) reviewed existing and developing potash, metal (various) and shale gas mining activities in the OBoF. They document a potash brine line breakage that resulted in salmon mortalities in the Hammond River in the 1980s, as well as subsequent spills in 1994,1995 and 2009. At the time of that writing, the Sisson Brook Tungsten and Molybdenum mine in the Nashwaak watershed was thought set to begin operation in 2014. In a news release (December 3, 2020), Northcliff Resources announced the approval of a 2-year extension of the construction commencement timeline. At the same time, they announced that:

> "…*review of Sisson Fisheries Act Authorization application and Off-setting/Fish Habitat Compensation Plan was completed and approved. Pursuant to paragraph 35(2)(b) of the Fisheries Act the Minister of Fisheries and Oceans Canada has authorized the proposed work that will result in impacts to fish and fish habitat arising from the construction and operation of an open pit and tailing storage facility that will result in impacts to fish and fish habitat*."

Clarke et al. (2014) also pointed out that a large portion of NB contains gas-bearing shale, and that a number of companies are exploring or actively producing gas from shale by fracturing.

TRANSPORTATION AND SERVICE CORRIDORS

Roads and Railroads

The National Research Council (2003) ranked roads as the second most significant impediment to Atlantic Salmon recovery. Each road crossing has the potential to create a barrier to fish movement, to influence sedimentation, to be a chronic source of pollutants, and to increase human access resulting in alteration of aquatic habitat and the spread of non-native species (Bowlby et al. 2014 and references therein). Crossing infrastructure has been identified as a medium threat to OBoF salmon (DFO 2014). Clarke et al. (2014) showed that the density of unpaved crossings was particularly high in the Nashwaak, Keswick and Tobique watersheds due to the extensive history of forestry operations, which has been shown to contribute significantly to sediment input in streams.

Utility and Service Lines:

No DFO data.

Shipping Lanes

Shipping traffic is concentrated in the city of Saint John at the mouth of the SJR, where shipping itself (avoidance behaviour) as well as the biotic and abiotic contents of ballast water and the potential for spills of transported goods all represent potential but undocumented threats to OBoF salmon (DFO and MRNF 2009). The Irving oil refinery outside of Saint John, NB as well as the Irving Canaport facility results in high shipping traffic and heightened potential for spilling oil products, which could be potentially devastating to OBoF marine life, including salmon (Clarke et al. 2014). There is also high degree of ship traffic along the Atlantic coast of NS up to the southern coast of Newfoundland with is highest amount exiting the Gulf of St. Lawrence through the Cabot Strait (Bowlby et al. 2014). As this traffic is concentrated in coastal environments and within potential OBoF salmon marine migration routes, there may be a high degree of interaction.

BIOLOGICAL RESOURCE USE

Logging & Wood Harvest

Forestry has been identified as a medium threat to OBoF salmon (DFO 2014). The main threats from forestry stem from the removal of vegetation, road infrastructure and the application of chemicals, resulting in altered stream flow and structure, sediment and chemical loading and altered thermal regimes. Clarke et al. (2014) describe the large extent of forestry throughout most OBoF watersheds, including the extent of clearcutting and the use of glyphosate spraying, and conclude although it is not possible to determine many of the effects of past forest activities on OBoF salmon populations, current implementation and auditing of operational standards is presumed to result in less aquatic impact per unit of operation than past practices. Importantly, they point out that intensive forestry also takes place on the American side of the SJR basin, where a 1.4 million ha section of the north Maine woods is largely managed as industrial forest land. This highlights the possibility that forestry effects on OBoF salmon could originate from outside Canadian jurisdiction, so international cooperation and collaboration will be important for threat identification and recovery action planning.

Fishing & Harvesting Aquatic Resources

Directed Fisheries – Freshwater

Annual harvests as large as 550,000 lbs of salmon were reported from the SJR and its tributaries as late as 1860, decreasing thereafter to 200,000 lbs or less by 1890 (Kidd et al. 2011). Clarke et al. (2014) reviewed sources of information documenting Indigenous, recreational, commercial and illegal fishing records. All directed salmon fishing has been closed to domestic commercial fishing since the early 1980s (Jones et al. 2010) and to Indigenous and recreational fishing since the late 1990s, as salmon populations persistently failed to meet conservation requirements.

However, Clarke et al. (2014) highlighted the high exposure to illegal fishing and that any removal of adult salmon from OBoF rivers constitutes a severe threat. As recently as 2010, DFO estimated that poaching accounted for as much as 12.6% of the total MSW returns (DFO 2011). However, DFO (2011) also notes that illegal fishing cannot be quantified for the Maritimes Region and there were only seven confirmed salmon removals from illegal poaching which occurred on the Nashwaak River which would account for 0.3% of returns. It also appears that the 12.6% estimate is partially based on net and jig marks on salmon counted at the Mactaquac and Tobique facilities. However, the SJR has legal net fisheries which could be the cause of these net marks in which the cause would be fishing by-catch and not necessarily poaching. Regardless, quantifying the severity and extent of the illegal fishing/poaching threat is difficult with the limited and anecdotal information. Clarke et al. (2014) also points out that although losses due to poaching and intentional hook and release of salmon under authority of licensed trout angling is difficult to quantify, precautionary measures have been put in place to reduce these threats such as increasing patrols and closing angling in holding pools below dams and near salmon distribution/release sites.

By-Catch – Freshwater

Clarke et al. (2014) reviewed commercial fisheries in the OBoF DU that were thought to potentially intercept salmon as by-catch. American Shad (*Alosa sapidissima*), certain Alewife (*Alosa pseudoharengus*) and Blueback Herring (*Alosa aestivalis*), collectively referred to as Gaspereau, and American Eel (*Anguilla rostrata*) fisheries in the mainstem SJR as well as in the Oromocto River and Grand Lake/Jemseg River complex using both trap-nets and gill nets were identified as potential threats, although unreliable by-catch reporting make the estimation of impacts to the population difficult. Jones et al. (2010) estimated that 1% 1SW and 2.4% MSW by-catch in the shad and Gaspereau nets in the lower SJR. Small salmon by-catches in the Indigenous Striped Bass (*Morone saxatilis*) fishery below Mactaquac Dam are also probable (DFO and MRNF 2009).

Directed Fisheries and By-catch – Marine

Interceptory drift-net fisheries for salmon ended in 1967, although salmon were also caught in gillnets and weirs set to catch other marine and diadromous species (DFO and MRNF 2009). Atlantic Herring (*Clupea harengus harengus*) weirs, also used for Atlantic Mackerel (*Scomber scombrus*) fishing, as well as the extensive pelagic fishery in the coastal Passamaquoddy region in the OBoF, have the potential to capture migrating adult and post-smolt salmon (Lacroix 2008).

Clarke et al. (2014) reviewed extrapolated catches in the West Greenland fishery using run-reconstruction for 2001–2010 as varying from 49–184 2SW salmon, representing losses of 4.2–15.0% of potential returns in those years. Some losses may still occur in the Labrador resident food fisheries and the fishery at St. Pierre and Miquelon (Clarke et al. 2014). The Indigenous fishery in Labrador varied from 6–17 t in 2001–2010, but most were expected to be destined for Labrador rivers (DFO and MRNF 2009).

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 180 m while professional licenses are permitted three nets of 360 m each (ICES 2011). All sizes of salmon are allowed to be retained and in 2010 a total of 2.8 t was reported (ICES 2011). Genetic analyses show that 98% of this fishery consists of Canadian origin fish and, given its location, has potential to effect OBoF populations. More recently, the amount of professional licenses issued is similar to 2011 with seven being issued in 2019, however, the amount of recreational licenses has steadily increased to 80 in 2019 (ICES 2020). Since 2011, the highest harvest amount occurred in 2013 at 5.3 t but has since decreased to 1.29 t in 2019 (ICES 2020). In 2017, 2018 and 2019, it was estimated that 0.2%, 0.3% and 0.0%, respectively, of MSW fish harvested were of SJR or aquaculture origin (ICES 2019, ICES 2020), however confidence intervals in 2017 and 2018 overlapped with 0.0%. Based on the proximity of the fishery, it is possible this fishery could impact OBoF populations, however, negative effects are likely minimal.

Within Labrador, three Indigenous groups take part in the subsistence food fishery that occurs in estuaries and coastal bays using gillnets (ICES 2011) and account for the majority of catches from all Indigenous fisheries (Bowlby et al. 2014). Reporting rates for this fishery is thought to be over 85% (DFO and MRNF 2009). In 2010, total harvest estimate was 59.3 t which is similar to harvest estimates within the previous five years (Bowlby et al. 2014). Since 2010, total harvest has ranged between 52.5 t and 70.4 t with 54.0 t in 2019. As it is estimated that 95% of this harvest is from Labrador fisheries, due to the fishery predominantly occurring in local river estuaries (ICES 2011), this fishery is expected to have little effect on OBoF populations. Labrador residents also participate in the food fishery with an estimated catch of 2.3 t in 2010 (ICES 2011). Regulations minimize the capture of large MSW salmon, which could originate from OBoF populations, in this fishery and only 25% of total catch in 2010 were large salmon (ICES 2011). Since 2010, the harvest has decreased to 1.6 t with 47% of harvest being large salmon in 2019 (ICES 2020). In 2017, 2018 and 2019, 0.0% of catches were of SJR or aquaculture origin in both Indigenous and Labrador residents fishery (ICES 2019, ICES 2020) and likely has little effect on OBoF populations.

HUMAN INTRUSIONS & DISTURBANCE

Recreational Activities

No DFO data.

NATURAL SYSTEMS MODIFICATIONS

Fire & Fire Suppression

No DFO data.

Dam & Water Management/Use

Hydropower dams and other obstructions, and the threats stemming from them, are the most limiting threat to the persistence of OBoF Atlantic Salmon (Clarke et al. 2014, DFO, 2014). Clarke et al. (2014) review diverse ways in which dams can affect Atlantic Salmon. They discuss alterations in the riverine habitat structure and function, reductions or delays in connectivity and production, ecosystem effects of declines in other diadromous species caused by impeded access, predator-prey interactions and other factors.

Clarke et al. (2014) highlight the particular importance of the Mactaquac Dam on the SJR to the upstream and downstream migration of Atlantic Salmon, but also that only Atlantic Salmon and Gaspereau have been provided access to upstream areas since the construction of the Mactaquac Dam. Historically, American Shad, Striped Bass, Atlantic Sturgeon (*Acipenser oxyrinchus*), Shortnose Sturgeon (*Acipenser brevirostrum*), American Eel and Sea Lamprey (*Petromyzon marinus*) would also have had access to the headwater area, so the upstream biotic community has been dramatically altered, and a more fulsome restoration of these co-evolved species may be required as part of salmon restoration efforts. The Mactaquac Dam had an original 100 year life expectancy until 2068, however, structural damage via alkaline aggregate reactions has caused concrete portions to swell and crack requiring yearly maintenance since the 1980s. A recent decision was made to maintain the dam for continued power generation through 2068. The work will involve major structural repair to the concrete, electrical components, replacing six turbines and include installation of new multi-species fish passage facilities. Work is expected to be completed by 2035.

Clarke et al. (2014) discuss the history, impacts, and current status of many of the more than 200 dams on the SJR, as well as the importance of the headpond reservoirs that occupy more than 11,000 ha over 145 km of Atlantic Salmon migration routes. These discussions are not repeated herein, except where DFO data and updates are known. Other important references on the impacts of dams on salmon in the SJR and other OBoF rivers include Jones et al. (2010, 2014) and Marshall et al. (2014).

Other Ecosystem Modifications

No DFO data.

NEGATIVE INTERACTIONS WITH OTHER SPECIES AND GENETIC INTERACTIONS

Invasive Non-Native/Alien Species

Clarke et al. (2014) highlight the sensitivity of Atlantic Salmon to predation by native and non-native fish species alike. For the SJR especially, the creation of headponds and the damaging/disorienting effects of passage through turbines and spillways can exacerbate predation risk by native and non-native fish and bird species (e.g., Carr 2001, Blackwell and Juanes 1998).

Smallmouth Bass (*Micropterus dolomieu*) are a species of concern for OBoF Atlantic Salmon due to the juvenile predation and the occupation of salmon habitat. The expansion of the range of Smallmouth Bass by natural and unauthorized human introductions since their initial introduction in 1969 is documented in Clarke et al. (2014). Chain Pickerel (*Esox niger*) are also known predators on juvenile salmon and are now established in several OBoF rivers in southwestern NB (Clarke et al. 2014 and references therein).

Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) have better competitive abilities than Atlantic Salmon (Van Zwol et al. 2012a, Houde et al. 2017), and the deleterious effects (on salmon) of competition between invasive/introduced Rainbow Trout and wild Atlantic Salmon are quite well documented (see select references below). There is a growing body of evidence linking low marine survival to delayed effects from the physical and biological interactions experienced by juvenile salmon in rivers (Russell et al. 2012). For example, Atlantic Salmon have been shown to undertake riskier (daytime) feeding in the presence of Rainbow

Trout than they do in similar densities of conspecifics (Blanchet et al. 2008). At the individual level, behavioural strategies and dominance hierarchies of salmon are strongly disrupted by invasive Rainbow Trout such that growth trajectories are affected (Blanchet et al. 2007). Atlantic Salmon in natural streams have been shown to have reduced fitness related traits that were associated with suboptimal microhabitats in the presence of Rainbow Trout, but used optimal microhabitats in their absence (Houde et al. 2014). Rainbow Trout have been shown to displace Atlantic Salmon out of preferred habitat and into increased competition with other native salmonids, even at low trout densities (Hearn and Kynard 1986, Thibault and Dodson 2013). In a study using experimental stream channels, the presence of Rainbow Trout and Brown Trout was found to reduce aggression, dominance and food consumption of Atlantic Salmon by a factor of two, which resulted in a cessation of growth or even weight-loss by salmon over a seven day period, compared to controls when no trout were present (Van Zwol et al. 2012b). These effects were linked to elevated stress hormones in salmon when invasive trout were present (Van Zwol et al. 2012c). Other studies on the impacts of invasive or introduced Rainbow Trout on Atlantic Salmon show that the severity varies with habitat differences such as temperature (e.g., Jones and Stanfield 1993), between salmon lineages (Van Zwol et al. 2012a and 2012c) and when multiple invasive salmonid species are present (Korsu et al. 2010).

Clarke et al. (2014) describe observations and reports of Rainbow Trout in rivers or sub-drainages of the SJR in the OBoF region, including the Magaguadavic, Big Presquile, Becaguimec, Shikatehawk, Tobique, Whitemarsh Creek, Muniac, and on main stem of the SJR in Mactaquac Dam and Beechwood Dam fishways. The progenitors of reproducing Rainbow Trout populations in the Big Presquile, Shikatehawk, and Becaguimec rivers may derive from licensed freshwater aquaculture sites in the upper SJR (Clarke et al. 2014). At present, the New Brunswick Rainbow Trout Aquaculture Policy (NB Department of Agriculture, Aquaculture and Fisheries, 2016) prescribes that only sterile triploid or all-female Rainbow Trout be used in NB aquaculture operations.

Although there is no authorized stocking of Brown Trout or other non-native fish species in the OBoF DU, Brown Trout were introduced into NB in 1921 and are found in the SJR and other rivers in the OBoF region (Clarke et al. 2014 and references therein).

Muskellunge (*Esox masquinongy*) have now been present in the SJR watershed for 50 years. Clarke et al. (2014) cite studies that model annual predation by Muskellunge on salmon smolts migrating past the Mactaquac Dam to be as low as 7,400 smolts based on a bio-energetic model to as high as 73,000–154,000 smolts based on an isotope mixing model (Curry et al. 2007). Although the same study concluded that low Muskellunge numbers and minimal habitat overlap with salmon suggest that it was improbable that Muskellunge were having a significant impact on SJR salmon, Jones et al. (2014) highlighted even the more conservative predation estimate as a concern given low juvenile salmon densities upriver of Mactaquac Dam. The lack of safe downstream passage for salmon smolts is likely to result in more severe predation at the tailrace of Mactaquac Dam as smolts would be concentrated and potentially stressed as they fall over the spillway or pass through the turbines (Carr 2001, Curry et al. 2007).

Largemouth Bass (*Micropterus salmoides*) were illegally introduced and detected in the Magaguadavic River in 2006 (Brown et al. 2009), and have more recently been confirmed to be present and reproducing in the St. Croix (MDIFW, 2013). Since that time, Largemouth Bass have also been caught in Meduxnekeag and Mactaquac Arm (Gautreau et al. 2018). They can be voracious predators on juvenile salmonids and other native fish species (Clarke et al. 2014).

Diseases and parasites associated with salmonid aquaculture has been identified as high threat to OBoF salmon. These are reviewed in DFO (2014) and updated herein where DFO data are available.

Infectious Salmon Anemia (ISA) was first detected in cages in the BoF in 1996. In 1999, four of 58 escaped farmed salmon and 14 of 15 wild salmon collected in the Magaguadavic River tested positive for ISA. Transmission of ISA from net pens to wild stocks is known in other areas, a 2005 study in the OBoF and GoM did not find evidence of aquaculture sites infecting post-smolts during migration.

Infectious Pancreatic Necrosis (IPN) infectious agent was detected in salmon samples from Muniac Stream (1995–1996), Baker Brook (1987), Grand Reed Brook (headwater of SJR, 1995–1996), Passamaquoddy Bay (1989), SJR (1989, 1994), Oromocto Lake (1990), and the Magaguadavic River (1998) although this sample was suspected to be an aquaculture escape (DFO 2014).

ISA and IPN are both federally reportable diseases. From 2015 to 2019, a total of 79 cases of ISA were reported in NB (all strains=55; disease strains=18), NS (all strains=5; disease strains=2) and Newfoundland (all strains=19; disease strains=10). IPN has also been in other species [Brook Trout (*Salvelinus fontinalis*), Rainbow Trout and Arctic Char *(Salvelinus alpinus*)] and from 2015 to 2019, a total of 12 occurrences were reported in NB (n=3), NS (n=7) and Quebec (n=2).

Red Vent Syndrome (RVS) may negatively affect spawning ability, fecundity, migratory behaviour, growth rate and ability of the fish to endure changing oceanic conditions (DFO 2014). RVS and other evidence of parasitic infection or disease are recorded from salmon sorted at the MBF. Although trends in RVS occurrence rates did not appear correlated to lower corresponding 2011–2012 pre-smolt/smolt production rates (i.e., no concomitant decline in spawning success or survival to smolt) on the Tobique River (DFO 2014), the effects of RVS in parents on the marine survival of offspring were not yet known (earliest returns due in 2013).

Ectoparasitic copepods (‘sea lice’; *Lepeophtheirus salmoni*s and *Caligus sp*.) feed on salmon skin, flesh and mucous. Sea lice on returning salmon has been monitored since 1992. Major pathogen outbreaks in salmon farms have not been linked to wild salmon in Atlantic Canada although research in epidemiology demonstrates that exposure rate and host density are important contributing factors to the spread of disease. Using the harvested population of farmed salmon in NB alone, farmed salmon outnumber wild OBoF salmon at least 1000:1, and wild populations pass relatively close by during parts of their migration. Thus disease outbreaks in dense farm populations are a concern for salmon growers and wild populations alike (DFO 2014). Between 1992 and 2002, 21% and 17% of the wild and farmed salmon caught, respectively, were observed to have sea lice.

A study by Teffer et al. (2020) examined the infectious agent profiles in escapee salmon entering the Magaguadavic River in comparison to wild fish ascending the SJR (close proximity to aquaculture) and Restigouche River (distant proximity to aquaculture). Contrary to their expectation, Restigouche River salmon had higher infection loads and infection richness in comparison to SJR salmon. However, aquaculture escapees had a unique infection profile compared to other groups, the highest prevalence of viruses with Piscine reovirus and Atlantic Salmon calcivirus occurring in over half of the 17 sampled individuals (Teffer et al. 2020). Within SJR fish, infectious agents (% of fish detected in) were *Flavobacterium psychrophilum* (63%), *I. hoferi* (33%), *Ca. P. salmonis* (30%), *P. theridion* (13%), *P. pseudobranchicola* (10%), and *Aeromonas salmonicida* (10%) (Teffer et al. 2020).

Negative Interactions with Native Species

Although Brook Trout are extensively stocked in the OBoF DU, and competitive and predatory interactions between salmon and native Brook Trout are known to occur (Henderson and Letcher 2003, Mookerji et al. 2004), Clarke et al. (2014) did not identify any clear evidence whether extensive stocking of non-anadromous salmonids impacts OBoF salmon populations. They did note that Atlantic Salmon outnumbered Brook Trout in most instances during an extensive electrofishing survey in 2009.

Clarke et al. (2014) reviewed trends in abundance and distribution of several known salmon predators, highlighting the significant increase in Grey Seal (*Halichoerus grypus*) populations as well as trends in Spiny Dogfish (*Squalus acanthias*) abundance as being potentially relevant to predation on adult salmon and post-smolts, respectively. The abundance of several other marine salmon predators [e.g., pelagic sharks, Bluefin Tuna (*Thunnus thynnus*)] either decreased or varied in ways not obviously related to the recent collapse of salmon populations. Although Atlantic Herring and Sand Lance (Ammodytes spp.) abundance decreased in the decades preceding recent severe declines in salmon populations, there was no evidence that current krill abundance was a factor limiting salmon survival.

Introduced Genetic Material

Clarke et al. (2014) limited their summary of Atlantic Salmon stocking activities to aspects that could contextualize ways in which hatchery and stocking programs could pose a threat to the OBoF salmon DU. Not all are repeated herein, but their approach divides hatchery practices into “past” and (1967–2004) and “present” (2001–2012).

For example, past practices from 1968 to the mid-1990s, the retention of wild run adults derived from spring, summer and fall seasons, and from unknown tributaries, as broodstock for the Mactaquac Dam compensation program could have resulted in tributary specific adaptations being homogenized or lost. The circumvention of the entire natural freshwater life stage for spawning-to-smolt released salmon is now known to exclude periods when Atlantic Salmon develop important characteristics for homing. The relaxation (or re-direction) of selective pressures as a result of hatchery operations may have led to decreases in fitness. Clarke et al. (2014) also identified the lack of passive upstream fish passage at the Mactaquac Dam as a potential source of physical damage and reduction in survival and reproduction due to trapping, handling and transport stress, which are compounded for Tobique or Aroostook salmon that must navigate fish lifts or other fishways on those rivers.

An important delineation in the transition to the “present” period in Clarke et al. (2014) is the cessation of most adult broodstock collection and artificial spawning around 2004. Since that time, the majority of the program focusses on tributary-specific smolt collections with hatchery-reared adults being released back to the wild to spawn is based on evidence that these approaches are more likely to maintain wild fitness than previous approaches (Fraser 2008, Fraser et al. 2011).

POLLUTION AND CONTAMINANTS

Clarke et al. (2014) reviewed extensive literature concerning pollutants, chemicals and wastewater effects on OBoF rivers. They cite an inventory of potential effluents into the SJR watershed (USA and Canada) that identified over 70 non-municipal waste water discharges, over 100 municipal waste water discharges, at least 19 fish hatcheries, 21 food processing plants, approximately 40 waste and rock handling facilities, and 15 pulp and paper or lumber mills (Kidd et al. 2011). Many specific examples were provided that apply across the subcategories below. Most are not repeated herein (see Clarke et al. 2014 and references therein).

Household Sewage & Urban Wastewater

No DFO data.

Industrial & Military Effluents

General effects of terrestrial military activities on Atlantic Salmon were recently described in DFO and MRNF (2009):

> "*Military training activities conducted by the Department of National Defence, as well as those activities in support of training (construction and maintenance of infrastructure), can have varied effects on fish, including Atlantic Salmon. Training activities have the potential to directly harm fish through such actions as the crossing of watercourses (fording), whereby a vehicle driving on the substrate could crush and kill eggs or juveniles present in the substrate. This outcome could also occur during an exercise that would require a large scale crossing of soldiers on foot. Military exercises using explosives could lead to direct mortality if used too close to watercourses with fish present. The same is possible for unknown experimental chemicals, which in the past included 'Agent Orange'. Support activities also have the potential for impact. Many military training areas have numerous roadways, and these roadways would require bridge or culvert installations and maintenance, ditching, and road resurfacing and grading. These activities could lead to the deposit of sediment into nearby watercourses.*"

Specifically documented military activities that may affect OBoF salmon (at Canadian Forces Base Gagetown) include the use of herbicides to control vegetation, various live fire training activities, chemical releases from ordinance and sedimentation (Clarke et al. 2014).

Agricultural & Forestry Effluents

Clarke et al. (2014) cite extensive and long-term occurrence of forestry, agriculture, industry and damming activities on the SJR and its tributaries as the basis for considering sediments as important threat. However no specific data are discussed other than generally low juvenile salmon productivity in the Tobique and Nashwaak Rivers relative to other Maritime DUs, and discrepancies in relative fry and parr abundance within a cohort (Marshall et al. 2014). Extensive road crossing and forestry have historically and currently affected the Tobique and Nashwaak rivers (Kidd et al. 2011).

Aluminum levels in the SJR are thought to be mainly non-anthropogenic (i.e., geology, Kidd et al. 2011), and none of the three OBoF rivers surveyed (Dennis et al. 2012) had elevated measurements.

Garbage & Solid Waste

No DFO data.

Air-Borne Pollution

Clarke et al (2014) reviewed available information from NB Department of Environment Water Quality Survey as well as results of extensive provincial testing and concluded that with a few exceptions, acidity levels are generally low throughout the majority of the OBoF DU, and does not appear to be a limiting factor in the SJR or its major tributaries. Exceptions to this include the Canaan and Gaspereau rivers which were found to have lower pH (DFO and MRNF 2009) with the former also being reported to have a low pH (5.9) in another study (Hunt et al. 2011).

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

No DFO data.

Droughts

No DFO data.

Temperature Extremes

Effects of climate warming are anticipated in both freshwater and marine environments and will particularly affect northern North America and the North Atlantic. Some of the most marked increases in surface air temperatures in Atlantic Canada are predicted for areas containing the majority of OBoF salmon freshwater habitat (Western NB, DFO and MRNF 2009). Clarke et al. (2014) reviewed the literature concerning stream temperature modelling that predicted warming summer temperatures in SJR tributaries, including increases in the duration of summer water temperatures above the thermal threshold for Atlantic Salmon. They cited that the constriction of the Tobique dam is thought to have compromised cold water refugia near the confluence with the SJR, and that a current inventory of cold water refuges in OBoF rivers would provide critical information for habitat allocation decisions. Temperature has been monitored at select locations in the SJR basin by DFO since 1995 and these data suggest no apparent trends in the frequency of days in the year with minimum water temps above 20 °C, a commonly reported metric to describe salmon’s ability to recover from extreme temperatures.

DFO and MRNF (2009) describe the effects of changes in the ocean on wild Atlantic Salmon populations:

> *“Changes in temperatures, salinities, currents, and species composition and distribution (including predators and prey of salmon) are all anticipated as a result of climate change. In combination, these factors will impact on Atlantic Salmon production and survival in fresh water and at sea. The population trajectories associated with these changes are difficult to model as the anticipated conditions are outside the range of values observed in the relatively short time frame during which salmon have been studied. Marine and estuarine conditions are believed to exert important influences on*

> *Atlantic Salmon, their ecology and survival. Climate induced changes, for example in sea surface temperature and salinity, may be some of the key factors affecting natural salmon mortality through changes in the distribution of plankton assemblages and associated dependent prey species, as well as predators (Cairns 2001). Regardless, projecting stock-specific effects of climate change on Atlantic Salmon will be problematic owing to differences in stock characteristics and local geography. To date, three approaches have been used to draw inferences: physiological approaches, empirical approaches using local weather and climate data related to salmon population dynamics, and distributional approaches linking projected climate change effects to presumed changes in fish species distributions."*

Marshall et al. (2014) reviewed data that showed that SSTs could be unfavourably high for OBoF salmon returning to natal rivers in mid-late summer. Understanding the degree to which ongoing changes in oceanic conditions threaten the persistence or recovery of OBoF salmon is hampered by challenges in tracking salmon at sea.

Storms & Flooding

No DFO data.

OTHER

Depressed Population Phenomena

Clarke et al. (2014) reviewed studies that suggested that OBoF smolts and post-smolts occurred at densities too low to support natural schooling (Lacroix and Knox 2005), which they suggested could result in a lessened ability to avoid predation. Genetic bottlenecks due to depressed population size appear to be less of a concern for OBoF than in the adjacent IBoF (O'Reilly et al. 2014).

Saint John and Nashwaak River Smolt Survival

In 2017, 2018 and 2019, hatchery and wild smolts were acoustically tagged in the Nashwaak River and survival was measured to the mouth of the SJR. In 2017, 2018 and 2019, 75 smolts (70 hatchery and 5 wild), 75 smolts (41 hatchery and 34 wild) and 50 wild smolts were acoustically tagged, respectively. Smolts were detected by acoustic receivers placed throughout the Nashwaak and SJR and along the Scotian Shelf near Halifax, NS. Survival was estimated by using raw detection data and if a smolt was not detected by receivers at the mouth of the SJR or along the Scotian Shelf, it was considered to have died within the river. Preliminary results on survival to the mouth of the SJR was 47.1%, 60.0% and 48.0% for hatchery, wild and all smolts combined, respectively, in 2017. In 2018, wild smolt survival was 64.7% but only 2.4% for hatchery smolts. However, hatchery smolts suffered extremely high mortality within the first 17 km after release and is likely due to a much higher than expected degree of tagging related mortality. In 2019, survival to the mouth of the SJR was 72.0%.

Lacroix et al. (2008) also acoustically tagged Atlantic Salmon smolts from the SJR and Nashwaak River and determined survival to the mouth of the SJR and into the BoF. Hatchery smolts were tagged and released in the SJR in 2001 (n=21) and 2002 (n=20). Hatchery (n=20) and wild smolts (n=40) were released in the Nashwaak River in 2002. Survival to the mouth of the SJR for smolts released in the SJR was approximately 44% and 59% in 2001 and 2002, respectively. Nashwaak River smolts survival to the mouth of the SJR was approximately 60% and 58% for wild and hatchery smolts, respectively.

Aside from the high degree of mortality in hatchery smolts in 2018, survival was on average similar in recent years in comparison to the study performed by Lacroix et al. (2008). Given the similarities in results, it appears that acoustically tagged smolt survival has not changed in the last 15 to 17 years. However, it is important to note that these results are for acoustically tagged individuals and do not necessarily represent what is occurring in the un-manipulated population.

FRESHWATER THREATS SUMMARY

In summary, habitat obstruction overall is the most important freshwater threat to the OBoF salmon populations. Smolt mortality through three dams on the SJR has been documented at 45% cumulatively, with turbine related mortality inferred as the main cause, which is further compounded by the deleterious effects of alterations of flow, temperature and non-native predatory fish abundance. The Mactaquac Dam necessitates stressful trap and truck operations to provide access for migrating adult salmon to upstream spawning habitat. Stocking efforts to offset these effects are likely the only reason OBoF salmon persist upstream of Mactaquac Dam, although these same stocking efforts may have compromised their persistence and recovery in other ways. Due to low population levels, any illegal removals of salmon have increasingly severe effects on population persistence and recovery potential.

MARINE THREATS SUMMARY

Bowlby et al. (2014) clarified that return rate trends should not be considered synonymous with marine survival because the former include mortality and other survival effects on adult and smolt while in freshwater. Nonetheless, return rates of OBoF salmon populations have recently declined (Jones et al. 2014) and this trend is at least in part indicative as a decline in marine survival. Clarke et al. (2014) found little direct evidence of specific threats arising from aquaculture operations in the OBoF. However, they pointed out that the effects of altered predator, parasite and disease dynamics as well as effects of interbreeding with escaped domesticated salmon have been demonstrated to be occurring elsewhere, and concluded that aquaculture should be considered an important threat to OBoF salmon until directed research suggests otherwise. Clarke et al. (2014) identified the lack of understanding of marine salmon habitat as an important obstacle in determining causes of population decline. Low contemporary salmon abundance not only heightens the severity of all threats but makes it difficult to study this question and detect effects. They concluded that unfavourable marine conditions, linked with depressed population phenomena, remain a vague but important threat to OBoF population persistence.

MANIPULATED POPULATIONS

Rivers in DU 16 considered to either contain or to have historically contained wild Atlantic Salmon populations have undergone various manipulations since likely prior to 1880 including one or more of: 1) river escapements of mature fish from the aquaculture industry (Clarke et al. 2014), 2) hatchery introductions of Atlantic Salmon originating peripheral to DU 16 (Clarke et al. 2014, 3) homogenization by long time hatchery practices (O'Reilly et al. 2014), and 4) misplacement through practices of trucking spawners long distances around multiple dams (Marshall et al. 2014).

The SJR has experienced a century or more of intensive hatchery stocking and populations above Mactaquac Dam have been subjected to over 40 years of trapping and trucking of adults to upstream tributaries without knowledge of natal tributary of origin (DFO 2014). Details of hatchery stockings between 1880 and 1984 related to the SJR are summarized in annual reports of various federal departments responsible for fish culture. Marshall et al. (2014)

approximates that more than 180 million salmon age-0 (mostly “fry”), age-1 parr (2.2 million) and smolts of all ages (4.2 million) of SJR lower watershed mixed stock, possibly Serpentine River stock (high Tobique tributary), Miramichi, Restigouche, and a few non-NB river origins were widely distributed through the entire SJR system. The high natural mortality rate of the early fry stage probably limited the impact of mixed stock distributions occurring before 1968 on river/tributary specific populations. Although, this may not be the case for older-aged juveniles (age-0 fall parr and older-aged smolts) of mixed stock origins released below Mactaquac Dam (but also to upriver tributaries, mainly the Tobique River) from the MBF commencing in the early 1970s. That being said, results presented in O’Reilly et al. (2014) suggest that, despite an established body of literature documenting various potential and realized reduced population fitness measures associated with captive-breeding/supplementation (Fraser 2016), even large-scale, long-term stocking-mediated gene flow, involving local and/or non-local salmon, may not have effectively homogenized wild populations above Mactaquac Dam relative to other large (and less impacted) river systems.

Atlantic Salmon were also stocked in most of the outer Fundy complex rivers. Records from the National Archives of Canada Volume 813, through various files, indicate that the falls at the mouth of the Magaguadavic River has always been a barrier to the passage of salmon. Historical documents would appear to provide evidence then that those salmon stocks of the Magaguadavic River were in fact introduced through stocking from the SJR or other Maritime rivers (Marshall et al. 2014).

Clarke et al. (2014) discuss past (1967–2004) and recent (2001–2012) stocking strategies on the SJR system focusing on the long term DFO stocking and manipulation of the OBoF population upriver of the Mactaquac Dam including general strategy, numbers of fish, and time periods, to provide context on the magnitude of program components. Generally, past stocking actions refers to those which collect and spawn wild adults, rear eggs in captivity and release juveniles at a later stage (mostly as smolts). Recent practice generally refers to those which capture juveniles from the wild, rear to maturity in captivity and release adults to the wild to spawn naturally. Recent ‘Revisions to the Mactaquac Fish Culture Program’ and justifications have been previously documented in Jones et al. (2004, 2010). More comprehensive details of Atlantic Salmon collected for the captive-reared program at MBF (juveniles since 2013; Table A3) and released in the SJR upriver of Mactaquac Dam, including Tobique River, are provided in this report (Table A1, A2). Numbers of salmon distributed to the Nashwaak, St. Croix and Magaguadavic rivers and collected from the SJR above Mactaquac for the Tobique captive-reared program up to 2012 are provided in Jones et al. (2014).

The MBF has been involved in mitigating the effects of hydroelectric development on Atlantic Salmon in the SJR since its construction following the completion of the large Mactaquac Dam in 1968. From the early 1970s to the mid-2000s, the facility emphasized artificial propagation of smolts as a method of augmenting natural recruitment lost from hydroelectric infrastructure at Mactaquac and to sustain and restore commercial, recreational, and FSC fisheries. As part of the Mactaquac Fish Culture Program, MBF selected and retained several hundred wild sea-run adult Atlantic Salmon trapped at the Mactaquac fish collection facilities for use as broodstock. Following discussion among DFO and the Saint John River Management Advisory Committee (SJRMAC), the program was refocused to the singular objective of conserving tributary populations in the SJR upriver of Mactaquac Dam. Beginning in 2001, the program began to utilize captive-reared adults, originally collected from the wild as juveniles, for both broodstock and adult releases for natural spawning upriver of Mactaquac Dam. Additionally, between 2004 and 2017, smolt production below Mactaquac was reduced and replaced with increased releases of age-0 fall parr into tributaries above Mactaquac. In 2018, further adaptive management of the program occurred as the juvenile release strategy then began to prioritize the distribution of unfed fry in order to decrease the effects of domestication selection. Releases of unfed fry and captive-reared adults continue to be directed to SJR tributaries above Mactaquac Dam, mainly the Tobique River (Table A1, A2).

In 2019, captive-reared adults were distributed to sites in the Tobique River and at one site just downriver of the confluence with the main SJR near Perth-Andover. Using the mean length for each life history type (wild-exposed juvenile vs captive-reared broodstock) and a length-fecundity relationship (eggs = $430.19 * e^{0.03605 * FL}$; Jones et al. 2006), the sexually mature females potentially produced another 3.65 million eggs, or an additional 7% of the conservation requirement (Figure 6).

OTHER INDICATORS

JUVENILE DENSITIES

To evaluate status and trends of juvenile abundance above and below Mactaquac Dam, electrofishing survey data from 1970 until 2019 on the Tobique and Nashwaak rivers was used. Changes in electrofishing techniques over the five decades of sampling and corresponding adjustment factors are described in Jones et al. (2014).

Tobique River

The density calculations reported in Francis (1980) are adjusted from 12 of 15 sites to account for expanded sampling and technique changes. Three of the 15 sites were no longer surveyed after the mid-1980s because of significant changes in habitat. No electrofishing took place at any of these sites on the Tobique in 1980, 1987, 1990–91. The densities presented are for wild parr only. Since 2004, wild parr could be progeny from either sea-run or captive-reared adults. Because sampling at each site has not occurred consistently each year, a generalized linear model (GLM) was used to predict values for individual sites prior to calculating the annual mean densities for each age-group in order to develop a standardized time series of juvenile abundances (Gibson et al. 2009).

The mean density of wild fry at these 12 sites on the Tobique River in 2019 was 0.2 fish per 100 m^2. This value is the lowest in the 50-year time series (Table 15; Figure 30). Since 1995, mean densities at these 12 sites have been well below the ‘Elson norm’ of 29 fry per 100 m^2 (Elson 1967) and adjusted mean densities observed in the 1970s–80s (Figure 30).

Mean density of age-1 and older wild parr at the 12 index sites was 3.1 parr per 100 m^2 in 2019 (Figure 30). The annual mean density of age-1 and older wild parr in 2015 to 2019 was slightly lower than the most recent decadal mean. These values are well below Elson’s (1967) ‘normal index’ of 38 parr per 100 m^2 (Figure 30). However, only the 1979 adjusted mean value approaches the ‘normal’ index. The mean density of age-1 and older parr in the 1970s and 1980s was 12.2 parr per 100 m^2 and decreased to approximately nine and four parr per 100 m^2 in the 1990s and 2000s, respectively (Figure 30).

Nashwaak River

Similar to the Tobique River, the density calculations reported in Francis (1980) for seven of 10 sites were adjusted to account for expanded sites and technique changes. Three of the 10 sites were not included in the analysis due to significant changes in habitat or having been less frequently surveyed. No electrofishing occurred at any of these sites in 1980. The densities presented are for wild parr only. There have been no hatchery releases since 2010. Because not all sites were electrofished in all years, the same approach as taken for the Tobique was used, and a standardized time series of juvenile densities was developed by fitting a GLM to the data to predict values for each site. The GLM included site and year effects and was used to calculate the annual mean densities for each age-group separately (Gibson et al. 2009).

Mean density of wild fry at the seven historical sites in 2019 (one downriver and six upriver of the counting fence) was 1.0 fry per 100 m^2, the lowest value in the time series and 78% below the most recent 10-year mean (Table 16; Figure 31). Since 1993, mean densities at the seven sites have been below the ‘Elson norm’ (Elson 1967), and ranging between 1.0 (2019) and 17.6 (2002) fry per 100 m^2. Mean annual densities from the 1970s and 1980s were 46.5 and 45.0 fry per 100 m^2, respectively.

Mean density of age-1 and older wild parr at the seven sites in 2019 was 2.4 fish per 100 m^2, the second lowest value in the time series and 40% below the mean density observed for the most recent decade (Table 16; Figure 31). Despite mean fry densities in the 1970s and 1980s that exceeded Elson’s norm, this failed to translate into mean parr densities that exceeded or even approached the ‘normal index’ of 38 small and large parr per 100 m^2 (Elson 1967) during the same time period (Figure 31). Mean densities of age-1 and older wild parr in the 1970s and 1980s were 15.7 and 11.4 fish per 100 m^2, respectively.

REFERENCES CITED

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

Amiro, P.G. 2006. A synthesis of fresh water habitat requirements for Atlantic Salmon (Salmo salar). DFO Can. Sci. Advis. Sec. Res. Doc. 2006/017.

Armstrong, J.D., Kemp, P.S., Kennedy, G.J.A., Ladle, M. and Milner, M. 2003. Habitat requirements of Atlantic Salmon and Brown Trout in rivers and streams. Fish. Res. 62: 143-170.

Bardonnet, A. and Baglinière, J.L. 2000. Freshwater habitat of Atlantic Salmon (Salmo salar). Can. J. Fish. Aquat. Sci. 57: 497-506.

Bjornn, T.C. and Reiser, D.W. 1991. Habitat requirements of salmonids in streams. Amer. Fish. Soc. Spec. Publ. 19: 83-138.

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

Blanchet, S., Loot, G., Grenouillet, G., Bernatchez, L. and Dodson, J.J. 2008. The effects of abiotic factors and intraspecific versus interspecific competition on the diel activity patterns of Atlantic salmon (Salmo salar) fry. Can. J. Fish. Aquat. Sci. 65: 1545-1553.

Blanchet, S., Loot, G., Grenouillet, G. and Brossse, S. 2007. Competitive interactions between native and exotic salmonids: a combined field and laboratory demonstration. Ecol. Freshw. Fish. 16: 133-143.

Bourret, V., O’Reilly, P.T., Carr, J.W., Berg, P.R. and Bernatchez, L. 2011. Temporal change in genetic integrity suggests loss of local adaptation in a wild Atlantic Salmon (Salmo salar) population following introgression by farmed escapees. Heredity 106: 500-510.

Bowlby, H.D., Horsman, T., Mitchell, S.C. and Gibson, A.J.F. 2014. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Habitat requirements and availability, threats to populations, and feasibility of habitat restoration. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/006.

Brown, T.G., Runciman, B., Pollard, S., and Grant, A.D.A. 2009. Biological synopsis of Largemouth Bass (Micropterus salmoides). Can. Manuscr. Rep. Fish. Aquat. Sci. 2884: v + 27 p.

Cairns, D.K. (ed.). 2001. An evaluation of possible causes of the decline in pre-fishery abundance of North American Atlantic Salmon. Can. Tech. Rep. Fish. Aquat. Sci. 2358: 67 p.

Carr, J. 2001. A review of downstream movements of juvenile Atlantic Salmon (Salmo salar) in the dam-impacted Saint John River drainage. Can. Manuscr. Rep. Fish. Aquat. Sci. 2573: 76 p.

Chang, B.D. and Page, F.H. 2014. Historical and spatial trends in selected aspects of the finfish aquaculture industry in southwestern New Brunswick, Bay of Fundy, 1978-2012. Can. Tech. Rep. Fish. Aquat. Sci. 3112: iv + 70 p.

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

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

Clarke, C.N., Ratelle, S.M. and Jones, R.A. 2014. Assessment of the recovery potential for the Outer Bay of Fundy population of Atlantic Salmon: Threats. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/006.

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

Cunjak, R.A. and Newbury, R.W. 2005. Atlantic coast rivers of Canada; pp. 939-980. In: A.C. Benke and C.E. Cushing [eds.]. Rivers of North America. Academic Press, Elsevier Inc., San Diego, CA.

Curry, R.A., Doherty, C.A., Jardine, T.D. and Currie, S.L. 2007. Using movements and diet analyses to assess effects of introduced Muskellunge (Esox masquinongy) on Atlantic Salmon (Salmo salar) in the Saint John River, New Brunswick. Environ. Biol. Fish. 79: 49-60.

Dadswell, M.J. 2004. Migration of Inner Bay of Fundy Atlantic Salmon. Acadia University, Wolfville, NS: 41 p.

Dadswell M.J., Spares, A.D., Reader, J.M. and Stokesbury, M.J.W. 2010. The North Atlantic subpolar gyre and the marine migration of Atlantic Salmon Salmo salar: the ‘Merry-Go-Round’ hypothesis. J. Fish Biol. 77: 435-467.

Dennis, I.F, Clair, T.A. and Kidd, K. 2012. The distribution of dissolved aluminum in Atlantic Salmon (Salmo salar) rivers of Atlantic Canada and its potential effect on aquatic populations. Can. J. Fish. Aquat. Sci. 69: 1174-1183. doi:10.1139/F2012-053.

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

DFO. 2014. Recovery Potential Assessment for Outer Bay of Fundy Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/021.

DFO. 2015. Proceedings of the Maritimes Region Regional Peer Review on the Recovery Potential Assessment for Atlantic Salmon (Salmo salar) Outer Bay of Fundy Designatable Unit; February 19-22, 2013. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2015/038.

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

DFO and MRNF. 2008. Conservation status report, Atlantic Salmon in Atlantic Canada and Québec: PART I - Species information. Can. Manuscr. Rep. Fish. Aquat. Sci. 2861: 208 p.

DFO and MRNF. 2009. Conservation status report, Atlantic Salmon in Atlantic Canada and Québec: PART II – Anthropogenic Considerations. Can. Manuscr. Rep. Fish. Aquat. Sci. 2870: 175 p.

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

Ford, J.S. and Myers, R.A. 2008. A global assessment of salmon aquaculture impacts on wild salmonids. PLoS Biol. 6(2): e33. doi:10.1371/journal.pbio.0060033.

Francis, A.A. 1980. Densities of juvenile Atlantic Salmon and other species, and related data from electroseining studies in the Saint John River system, 1968-78. Can. Data Rep. Fish. Aquat. Sci. 178. 102 p.

Fraser, D.J. 2008. How well can captive breeding programs conserve biodiversity? A review of salmonids. Evol. Applic. 1: 535-586. doi:10.1111/j.1752-4571.2008.00036.x.

Fraser, D.J. 2016. Risks and benefits of mitigating low marine survival in wild salmon using smolt-to-adult captive-reared supplementation. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/030. v + 31 p.

Fraser, D.J., Weir, L.K., Bernatchez, L., Hansen, M.M. and Taylor, E.B. Taylor. 2011. Extent and scale of local adaptation in salmonid fishes: Review and meta-analysis. Heredity 106: 404-420.

Gautreau, M., B. Wallace, and R.A. Curry. 2018. “Fish Community in the Mactaquac Reservoir: 2016-2017” Mactaquac Aquatic Ecosystem Study Report Series 2018-056. Canadian Rivers Institute, University of New Brunswick, 31 p.

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

Gibson, A.J.F., Bowlby, H.D., Hardie, D.C. and O’Reilly, P.T. 2011. Populations on the brink: Low abundance of Southern Upland Atlantic salmon in Nova Scotia, Canada. North Am. J. Fish Manage. 31: 733-741.

Gibson, A.J.F., Jones, R.A. and Bowlby, H.D. 2009. Equilibrium analyses of a population's response to recovery activities: A case study with Atlantic salmon. North Am. J. Fish. Manage. 29: 958-974.

Gibson, A.J.F., Jones, R.A. and MacAskill, G.J. 2016. Recovery Potential Assessment for Outer Bay of Fundy Atlantic Salmon (*Salmo Salar*): Population Dynamics and Viability. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/032. v + 87 p.

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

Goodbrand, L., Abrahams, M.V. and Rose, G.A. 2013. Sea cage aquaculture affects distribution of wild fish at large spatial scales. Can. J. Fish. Aquat. Sci. 70: 1289-1292. doi:10.1139/cjfas2012-0317.

Hearn, W.E. and Kynard, B.E. 1986. Habitat utilization and behavioral interaction of juvenile Atlantic salmon (Salmo salar) and rainbow trout (S. gairdneri) in tributaries of the White River of Vermont. Can. J. Fish. Aquat. Sci. 43: 1988-1998.

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

Houde, A.L.S., Wilson, C.C. and Neff, B.D. 2014. Competitive interactions among multiple non-native salmonids and two populations of Atlantic salmon. Ecol. Freshw Fish. doi:10.1111/eff.12123

Houde, A.L.S, Wilson, C.C. and Neff, B. 2017. Performance of four salmonid species in competition with Atlantic salmon. J. Great Lakes Res. 43: 211-215.

Hunt, C.W., Salisbury, J.E. and Vandemark, D. 2011. Contribution of non-carbonate anions to total alkalinity and overestimation of pCO2 in New England and New Brunswick rivers. Biogeosci. 8: 3069-3076.

Ingram, J.H. 1980. Capture and distribution of Atlantic salmon and other species at Mactaquac Dam and Hatchery, Saint John River, N.B., 1972-76. Can. Data Rep. Fish. Aquat. Sci. No. 181. 74 p.

ICES. 1990. Report of the study group on the North American salmon fisheries. 26 February – 2 March 1990. Halifax, Nova Scotia, Canada. ICES CM 1990/M:3. 111 p.

ICES. 2007. Report of the Workshop on the Development and Use of Historical Salmon Tagging Information from oceanic areas (WKDUHSTI), 19–22 February 2007, St. John's, Canada. ICES CM 2007/DFC:02. 64 pp.

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

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

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

Jones, M.L. and Stanfield, L.W. 1993. Effects of exotic juvenile salmonines on growth and survival of juvenile Atlantic salmon (*Salmo salar*) in Lake Ontario tributary. In: Gibson, R.J. & Cutting, R.E., eds. Production of juvenile Atlantic salmon, Salmo salar, in natural waters. Canadian Special Publication of the Journal of Fisheries and Aquatic Sciences 118. Ottawa: National Research Council Canada, pp. 71–79.

Jones, R.A. and Flanagan, J.J. 2007. A description and assessment of the Atlantic Salmon (Salmo salar) fall pre-smolt migration in relation to the Tobique Narrows hydroelectric facility, Tobique River, New Brunswick using radio telemetry. Can. Tech. Rep. Fish. Aquat. Sci. 2735: ix + 41 p.

Jones, R.A., Anderson, L. and Goff, T. 2004. Assessments of Atlantic Salmon stocks in southwest New Brunswick, an update to 2003. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/019.

Jones, R.A., Anderson, L. Flanagan, J.J. and Goff, T. 2006. Assessments of Atlantic Salmon stocks in southern and western New Brunswick (SFA 23), an update to 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/025.

Jones, R.A., Anderson, L., Gibson, A.J.F. and Goff, T. 2010. Assessments of Atlantic Salmon stocks in South Western New Brunswick (outer portion of SFA 23): An update to 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/118.

Jones, R.A., Anderson, L. and Clarke, C.N. 2014. Assessment of the Recovery Potential for the Outer Bay of Fundy Population of Atlantic Salmon (*Salmo salar*): Status, Trends, Distribution, Life History Characteristics and Recovery Targets. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/008. vi + 94 p.

Kelly, B., Benoît, H.P, Chaput, G., Jones, R.A. and Power, M.A. 2019. Spawning-strategy-dependent diets in two North American populations of Atlantic salmon Salmo salar. J. Fish. Biol. 94: 40-52.

Kidd, S.D., Curry, A. and Munkittrick, K.A. [eds.]. 2011. The Saint John River: A state of the environment report. Canadian Rivers Institute, University of New Brunswick, Fredericton, NB. ISBN 978-1-55131-158-6: 175 p.

Korsu, K., Huusko, A. and Muotka, T. 2010. Impacts of invasive stream salmonids on native fish: using meta-analysis to summarize four decades of research. Boreal Environment Research 15: 491-500.

Lacroix, G.L. 2008. Influence of origin on migration and survival of Atlantic Salmon (Salmo salar) in the Bay of Fundy, Canada. Can. J. Fish. Aquat. Sci. 65: 2063-2079.

Lacroix, G.L. 2013a. Migratory strategies of Atlantic salmon (Salmo salar) postsmolts and implications for marine survival of endangered populations. Can. J. Fish. Aquat. Sci. 70: 32-48.

Lacroix, G.L. 2013b. Population-specific ranges of oceanic migration for adult Atlantic salmon (Salmo salar) documented using pop-up satellite archival tags. Can. J. Fish. Aquat. Sci. 70: 1011-1030.

Lacroix, G.L. 2014. Large pelagic predators could jeopardize the recovery of endangered Atlantic salmon. Can. J. Fish. Aquat. Sci. 71: 343–350.

Lacroix, G.L. and Knox, D. 2005. Distribution of Atlantic Salmon (Salmo salar) postsmolts of different origins in the Bay of Fundy and Gulf of Maine and evaluation of factors affecting migration, growth, and survival. Can. J. Fish. Aquat. Sci. 62: 1363-1376.

Lacroix, G.L. and Stokesbury, M.J.W. 2004. Adult return of farmed Atlantic salmon escaped as juveniles into freshwater. Trans. Am. Fish. Soc. 133: 484-490.

Lacroix, G.L., Knox, D., Sheehan, T.F, Renkawitz, M.D. and Bartron, M.L. 2012. Distribution of U.S. Atlantic salmon postsmolts in the Gulf of Maine. Trans. Am. Fish. Soc. 141: 934-942.

Lacroix, G.L., McCurdy, P. and Knox, D. 2004. Migration of Atlantic Salmon postsmolts in relation to habitat use in a coastal system. Trans. Amer. Fish. Soc. 133: 1455-1471.

Maine Department of Inland Fisheries And Wildlife (MDIFW). 2013. Research & Management Report 2013.

Marshall, T.L. 1989. Assessment of Atlantic Salmon of the Saint John River, N.B. 1988. CAFSAC Res. Doc. 89/77.

Marshall, T.L. and Jones, R. 1996. Status of Atlantic Salmon stocks of southwest New Brunswick, 1995. DFO Atl. Fish. Res. Doc. 96/40.

Marshall, T.L. and Penney, G.H. 1983. Spawning and river escapement requirements for Atlantic Salmon of the Saint John River, New Brunswick. CAFSAC Res. Doc. 83/66.

Marshall, T.L., Clarke, C.N., Jones, R.A. and Ratelle, S.M. 2014. Assessment of the recovery potential for the Outer Bay of Fundy population of Atlantic Salmon (Salmo salar): Habitat considerations. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/007.

Marshall, T.L., Jones, R.A. and Anderson, L. 1999. Follow-up assessments of Atlantic Salmon in the Saint John River drainage, N.B., 1998. DFO Can. Stock Assess. Sec. Res. Doc. 99/109.

Marshall, T.L., Jones, R.A. and Pettigrew, T. 1997. Status of Atlantic Salmon Stocks of Southwest New Brunswick, 1996. DFO Can. Stock Assess. Sec. Res. Doc. 97/27: iii + 67 p.

Massachusetts Division of Fisheries and Wildlife (MDIFW). 2013. Research and Management Report 2013. (Accessed on January 18, 2021).

Mookerji, N., Weng, Z. and Mazumder, A. 2004. Food partitioning between coexisting Atlantic Salmon and Brook Trout in the Sainte-Marguerite River ecosystem, Quebec. J. Fish Biol. 64: 680-694.

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

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

Nelson, R.P., Ellis, K. and Smith, J.N. 2001. Environmental monitoring report for the Point Lepreau N.B. nuclear generating station - 1991 to 1994. Can. Tech. Rep. Hydrogr. Ocean Sci. 0.211: v + 125.

New Brunswick Department of Agriculture, Aquaculture and Fisheries. 2016. New Brunswick Rainbow Trout Aquaculture Policy. (Accessed on January 18, 2021).

New Brunswick Department of Environment and Local Government. 2019. New Brunswick Power Corporation for the Coleson Cove thermal generating station. (Accessed on January 18, 2021).

O'Connell, M.F., Dempson, J.B. and Chaput, G. 2006. Aspects of the life history, biology, and population dynamics of Atlantic Salmon (Salmo salar L.) in Eastern Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/014.

Ó Maoiléidigh, N., White, J., Hansen, L. P., Jacobsen, J. A., Potter, T., Russell, I., Reddin, D., et al. 2018. Fifty years of marine tag recoveries from Atlantic salmon. ICES Cooperative Research Report No. 343. 121 pp.

O'Reilly, P. 2006. Towards the identification of Conservation Units in Atlantic Salmon from Eastern Canada. DFO Can. Sci. Adv. Sec. Res. Doc. 2006/012.

O'Reilly, P.T., Jones, R. and Rafferty, S. 2014. Within- and among-population genetic variation in Outer Bay of Fundy Atlantic Salmon (Salmo salar L.), with special emphasis on the Saint John River system in the context of recent human impacts. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/069. vi + 34 p.

O'Reilly, P.T., Rafferty, S. and Gibson, A.J.F. 2012. Within- and among-population genetic variation in the Southern Upland Designatable Unit of Maritime Atlantic Salmon (Salmo salar L.). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/077.

Penney, G.H. 1983. Recaptures of Atlantic Salmon tagged and released in the Bay of Fundy near the Saint John River, New Brunswick, 1970-1973. Can. Manuscr. Rep. Fish. Aquat. Sci. 1737: vii + 12 p.

Reddin, D.G. 2006. Perspectives on the marine ecology of Atlantic Salmon (Salmo salar) in the Northwest Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/018.

Reddin, D.G., Downton, P., Fleming, I.A., Hansen, L.P. and Mahon, A. 2011. Behavioural ecology at sea of Atlantic salmon (Salmo salar L.) kelts from a Newfoundland (Canada) river. Fish. Oceanogr. 20: 174-191.

Reddin, D.G., Hansen, L.P., Bakkestuen, V., Russell, I., White, J., Potter, E.C.E., Dempson, J.B., Sheehan, T., Ó Maoiléidigh, N., Smith, G.W., Isaksson, A., Jacobsen, J.A., Fowler, M., Mork, K.A. and Amiro, P. 2012. Distribution and biological characteristics of Atlantic Salmon (Salmo salar L.) at Greenland based on analysis of historical tag recoveries. ICES J. Mar. Sci. 9: 589-1597.

Renkawitz, M.D., Sheehan, T.F., Dixon, H.J. and Nygaard, R. 2015. Changing trophic structure and energy dynamics in the Northwest Atlantic: implications for Atlantic salmon feeding at West Greenland. Mar. Ecol. Prog. Ser. 538: 197-211.

Ritter, J. 1989. Marine migration and natural mortality of North American Atlantic Salmon (Salmo salar L.). Can. Manuscr. Rep. Fish. Aquat. Sci. 2041. 136 p.

Rosenfeld, J. 2003. Assessing the habitat requirements of stream fishes: An overview and evaluation of different approaches. Trans. Amer. Fish. Soc. 132: 953-968.

Ruggles, C.P. and Ritter, J.A. 1980. Review of North American smolt tagging to assess the Atlantic Salmon fishery off West Greenland. Rapp. P.-v. Réun. Cons. Int. Explor. Mer. 176: 82-92.

Russell, I, Aprahamian, M., Barry, J., Davidson, I., Fiske, P., Ibbotson, A., Kennedy, R., Maclean, J., Morse, A., Otero, J., Potter, T. and Todd, C. 2012. The influence of the freshwater environment and the biological characteristics of Atlantic salmon smolts on their subsequent marine survival. ICES J. Mar. Sci. 69: 1563-1573.

Sheehan, T.F., Reddin, D.G., Chaput, G. and Renkawitz, M.D. 2012. SALSEA North America: a pelagic ecosystem survey targeting Atlantic salmon in the Northwest Atlantic. ICES J. Mar. Sci. 69: 1580-1588.

Soto, D.X., Trueman, C.N., Samway, K.M., Dadswell, M.J. Cunjak, R.A. 2018. Ocean warming cannot explain synchronous declines in North American Atlantic salmon populations. Mar. Ecol. Prog. Ser. 601: 203-213.

Strøm, J.F., Thorstad, E.B., and Rikardsen, A.H. 2020. Thermal habitat of adult Atlantic salmon Salmo salarin a warming ocean. J. Fish. Biol. 96: 327-336.

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

Teffer, A.K., Carr, J., Tabata, A., Schulze, A., Bradbury, I., Deschamps, D., Gillis, C.A., Brunsdon, E.B., Mordecai, G. and Miller, K.M. 2020. A molecular assessment of infectious agents carried by Atlantic salmon at sea and in three eastern Canadian rivers, including aquaculture escapees and North American and European origin wild stocks. FACETS 5(1): 234-263.

Thibault, I. and Dodson, J. 2013. Impacts of exotic rainbow trout on habitat use by native juvenile salmonid species at an early invasive stage, Trans. Am. Fish. Soc. 142: 1141-1150.

Van Zwol, J.A., Neff, B.D. and Wilson, C.C. 2012a. The effect of competition among three salmonids on dominance and growth during the juvenile life stage. Ecol. Freshw. Fish. 21: 533–540.

Van Zwol, J.A., Neff, B.D. and Wilson, C.C. 2012b. The effect of nonnative salmonids on social dominance and growth of juvenile Atlantic salmon. Trans. Am. Fish. Soc. 141: 907-918.

Van Zwol, J.A., Neff, B.D. and Wilson, C.C. 2012c. The influence of non-native salmonids on circulating hormone concentrations in juvenile Atlantic salmon. Anim. Behav. 83: 119-129

Whoriskey, F.G., Brooking, P., Doucette, G., Tucker, S. and Carr, J.W. 2006. Movements and survival of sonically tagged farmed Atlantic Salmon released in Cobscook Bay, Maine USA. ICES J. Mar. Sci. 63: 1218-1223.

TABLES

Table 1: Counts of wild (W), hatchery (H), landlocked (LL) and aquaculture (A) origin Atlantic Salmon (as identified by fishway technicians) trapped at fishways/ fences in four rivers in southwest and central New Brunswick: Saint John (SJR), Nashwaak (NSH), Magagdavic (MAG), and St. Croix (SCR) rivers. Period (.) equals no data; (n/a) equals no monitoring.
KEY: a - small numbers of aquaculture fish; b - aquaculture; c - hatchery designation to be reviewed (aquaculture fish could be among hatchery fish prior to 1994); d - corrected by scale analysis; e - partial count; f - breakdown changed from Jones et al. 2004.

Year	SJR W 1SW	SJR W MSW	SJR H 1SW	SJR H MSW	SJR LL	KEY	NSH W 1SW	NSH W MSW	NSH H 1SW	NSH H MSW	NSH LL	KEY	MAG W 1SW	MAG W MSW	MAG H 1SW	MAG H MSW	MAG A 1SW	MAG A MSW	KEY	SCR[c] W 1SW	SCR[c] W MSW	SCR[c] H 1SW	SCR[c] H MSW	SCR[c] A 1SW	SCR[c] A MSW	KEY
1967	1,181	1,271	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1968	1,203	770	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1969	2,572	1,749	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1970	2,874	2,449	94	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1971	1,592	2,235	336	37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1972	784	4,831	246	583	.	.	259	859	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1973	1,854	2,367	1,760	475	.	.	596	1,956	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1974	3,389	4,775	3,700	1,907	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1975	5,725	6,200	5,335	1,858	.	.	1,223	1,036	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1976	6,797	5,511	7,694	1,623	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1977	3,504	7,257	6,201	2,075	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1978	1,584	3,034	2,556	1,951	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1979	6,234	1,993	3,521	892	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1980	7,555	8,157	9,759	2,294	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1981	4,571	2,441	3,782	1,089	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1982	3,931	2,254	2,292	728	34	.	.	.	.	.	.	.	.	.	.	.	.	.	.	53	15	27	3	.	.	df
1983	3,613	1,711	1,230	299	37	.	.	.	.	.	.	.	282	607	.	.	21	30	.	33	62	2	28	.	.	df
1984	7,353	7,011	1,304	806	26	.	.	.	.	.	.	.	255	512	.	.	.	.	.	120	40	63	17	.	.	df
1985	5,331	6,390	1,746	571	6	.	.	.	.	.	.	.	169	466	.	.	.	.	.	36	250	12	46	.	.	df
1986	6,347	3,655	699	487	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	31	128	29	130	.	.	df
1987	5,106	3,091	2,894	344	19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	43	147	181	21	.	.	df
1988	8,062	1,930	1,129	670	310	.	.	.	.	.	.	.	291	398	.	.	.	.	.	45	22	55	274	.	.	df
1989	8,417	3,854	1,170	437	128	.	.	.	.	.	.	.	.	.	.	.	.	.	.	46	19	95	73	.	.	df
1990	6,486	3,163	1,421	756	681	a	.	.	.	.	.	.	.	.	.	.	.	.	.	11	40	4	54	.	.	df
1991	5,415	3,639	2,160	587	190	a	.	.	.	.	.	.	.	.	.	.	.	.	.	30	83	42	52	.	.	df
1992	5,729	3,522	1,935	681	0	a	.	.	.	.	.	.	155	139	.	.	83	62	bd	.	.	.	.	.	.	.
1993	2,873	2,601	1,034	379	0	a	72	113	11	42	.	de	112	125	.	.	96	52	bd	3	30	5	66	.	.	d
1994	2,133	1,713	1,180	493	83	a	376	251	27	23	.	de	69	61	.	.	1,059	81	bd	24	19	23	18	97	.	.

Year	SJR W 1SW	SJR W MSW	SJR H 1SW	SJR H MSW	SJR LL	KEY	NSH W 1SW	NSH W MSW	NSH H 1SW	NSH H MSW	NSH LL	KEY	MAG W 1SW	MAG W MSW	MAG H 1SW	MAG H MSW	MAG A 1SW	MAG A MSW	KEY	SCR[c] W 1SW	SCR[c] W MSW	SCR[c] H 1SW	SCR[c] H MSW	SCR[c] A 1SW	SCR[c] A MSW	KEY
1995	2,429	1,681	2,541	598	50	a	544	294	25	14	.	de	49	30	.	.	491	168	bd	7	14	7	19	7	6	d
1996	1,552	2,413	4,603	726	24	a	854	391	86	38	.	de	48	21	.	.	174	20	bde	10	32	13	77	15	5	d
1997	380	1,147	2,689	629	44	a	332	339	38	27	.	d	35	24	.	.	59	23	bd	7	8	26	2	11	16	d
1998	476	367	4,413	624	28	a	464	142	1	9	.	de	28	3	.	.	211	3	bd	12	6	20	3	14	11	df
1999	700	1,112	2,511	680	22	a	303	84	2	0	.	de	19	5	.	.	80	10	bd	7	2	1	3	23	0	df
2000	1,408	393	1,573	200	24	a	428	161	0	0	.	de	13	1	.	.	25	2	bd	0	0	15	5	30	0	df
2001	730	680	942	521	39	a	242	271	2	1	3	d	8	9	.	.	120	4	bd	0	0	13	7	33	23	df
2002	709	212	1,616	178	19	a	342	73	1	6	0	d	7	0	.	.	29	0	bd	0	0	14	6	2	4	d
2003	443	279	838	464	1	a	181	82	7	3	2	de	3	3	.	.	14	2	bd	0	0	13	2	3	3	df
2004	863	446	562	296	2	a	473	168	13	4	1	de	2	0	.	.	0	17	bd	1	0	5	4	0	4	d
2005	862	269	264	94	2	.	405	94	20	3	2	ade	5	0	4	0	62	1	bd	0	0	2	4	30	3	d
2006	823	303	467	68	6	a	376	116	29	2	1	de	14	3	9	1	4	2	bd	0	0	2	2	4	3	d
2007	574	204	334	111	3	.	218	95	3	6	0	de	4	0	0	0	4	1	bd	n/a	.	.	.	.	.	.
2008	886	163	871	137	.	.	516	77	10	1	0	de	4	0	0	0	2	4	bd	n/a	.	.	.	.	.	.
2009	449	361	162	179	1	.	188	206	11	7	0	de	1	2	2	1	13	1	bd	n/a	.	.	.	.	.	.
2010	1,870	321	499	105	7	a	836	142	18	3	1	de	0	0	12	0	23	0	bd	n/a	.	.	.	.	.	.
2011	580	288	408	394	5	.	396	226	21	6	1	de	0	0	8	11	17	0	bd	n/a	.	.	.	.	.	.
2012	48	69	33	59	350	.	16	39	0	0	6	de	0	1	0	0	18	0	bd	n/a	.	.	.	.	.	.
2013	212	98	79	34	96	ad	57	35	0	0	1	de	3	3	0	0	53	37	bd	n/a	.	.	.	.	.	.
2014	111	45	22	23	32	d	49	14	0	0	3	de	9	2	1	1	19	8	bd	n/a	.	.	.	.	.	.
2015	396	58	215	37	18	d	200	31	0	0	0	de	5	4	0	0	5	8	.	n/a	.	.	.	.	.	.
2016	193	63	311	121	15	d	319	59	0	1	0	de	2	0	0	0	17	24	.	n/a	.	.	.	.	.	.
2017	131	81	192	98	14	d	80	38	0	0	0	de	0	0	0	0	4	13	.	n/a	.	.	.	.	.	.
2018	159	25	287	36	7	ad	89	31	0	0	0	de	0	1	0	0	2	1	.	n/a	.	.	.	.	.	.
2019	107	38	395	159	5	ad	122	43	0	0	0	de	0	2	0	0	38	40	bd	n/a	.	.	.	.	.	.

Table 2: Estimated total returns and egg depositions of wild, hatchery and aquaculture 1SW and MSW Atlantic Salmon destined for Mactaquac Dam, Saint John River, 1970–2019. Period (.) equals no data.

Year	Wild 1SW	Wild MSW	Hatchery 1SW	Hatchery MSW	Total (W+H) 1SW	Total (W+H) MSW	Aquaculture 1SW	Aquaculture MSW	Total Egg Deposit
1970	3,057	5,712	100	0	3,157	5,712	.	.	6,743,577
1971	1,709	4,715	365	77	2,074	4,792	.	.	9,686,229
1972	908	4,899	285	592	1,193	5,491	.	.	25,380,372
1973	2,070	2,518	1,965	505	4,035	3,023	.	.	15,326,312
1974	3,656	5,811	3,991	2,325	7,647	8,136	.	.	39,357,968
1975	6,858	7,441	6,374	2,210	13,232	9,651	.	.	54,684,280
1976	8,147	8,177	9,074	2,302	17,221	10,479	.	.	36,292,706
1977	3,977	9,712	6,992	2,725	10,969	12,437	.	.	50,883,354
1978	1,902	4,021	3,044	2,534	4,946	6,555	.	.	28,813,466
1979	6,828	2,754	3,827	1,188	10,655	3,942	.	.	18,023,742
1980	8,482	10,924	10,793	2,992	19,275	13,916	.	.	58,362,594
1981	6,614	5,766	5,627	2,728	12,241	8,494	.	.	17,778,521
1982	5,174	5,528	3,038	1,769	8,212	7,297	.	.	18,882,016
1983	4,555	5,783	1,564	1,104	6,119	6,887	.	.	9,686,229
1984	8,311	9,779	1,451	1,115	9,762	10,894	.	.	40,216,241
1985	6,526	10,436	2,018	875	8,544	11,311	.	.	41,197,125
1986	7,904	6,128	862	797	8,766	6,925	.	.	26,483,866
1987	5,909	4,352	3,328	480	9,237	4,832	.	.	24,276,877
1988	8,930	2,625	1,250	912	10,180	3,537	.	.	14,835,870
1989	9,522	4,072	1,339	469	10,861	4,541	.	.	27,955,192
1990	7,263	3,329	1,533	575	8,796	3,904	8	221	25,135,151
1991	6,256	4,491	2,439	700	8,695	5,191	56	24	25,748,203
1992	6,683	4,104	2,223	778	8,906	4,882	34	16	23,786,435
1993	3,213	2,958	1,156	425	4,369	3,383	0	6	15,081,091
1994	2,276	1,844	1,258	503	3,534	2,347	0	28	11,402,776
1995	2,168	1,654	2,907	599	5,075	2,253	4	102	13,477,345
1996	1,326	2,309	5,394	1,002	6,720	3,311	3	10	18,277,454
1997	343	1,128	2,912	843	3,255	1,971	0	0	9,780,394
1998	341	320	4,641	647	4,982	967	0	4	5,912,196
1999	472	837	2,785	967	3,257	1,804	7	13	10,087,002
2000	1,343	277	1,725	267	3,068	544	3	3	3,564,850
2001	686	644	1,014	562	1,700	1,206	12	2	6,482,071
2002	634	199	1,724	177	2,358	376	5	8	1,867,321
2003	381	240	921	511	1,302	751	2	1	3,912,005
2004	864	400	623	312	1,487	712	0	1	4,067,287
2005	863	254	296	96	1,159	350	0	0	1,916,912
2006	797	283	536	64	1,333	347	1	0	1,840,252
2007	492	205	411	131	903	336	0	0	1,550,959
2008	796	143	1005	138	1,801	281	0	0	1,528,238
2009	437	337	176	221	613	558	0	0	2,769,173
2010	1,708	312	686	148	2,394	460	0	27	2,448,140
2011	582	294	437	384	1,019	678	0	0	4,107,234
2012	48	71	33	61	81	132	0	0	544,251
2013	214	101	80	35	294	136	2	1	783,071
2014	112	46	22	24	134	70	0	0	490,747
2015	400	59	217	38	617	97	0	0	701,282
2016	195	65	314	124	509	189	0	0	1,166,382
2017	132	83	194	101	326	184	0	0	1,272,091
2018	161	26	290	37	451	63	0	1	416,717
2019	108	39	399	163	507	202	0	3	1,325,003

(a) Excludes 3 CR MSW fish (2006), 1 CR 1SW fish (2007), 6 CR MSW fish (2009), 2 1SW and 2 MSW CR fish (2010), 5 MSW CR fish (2011), 4 MSW CR (2013), 9 MSW CR (2014), 23 CR (2015), 8 MSW CR (2016), and 2 MSW CR (2018).

(b) 2003–2005, count raised by estimated removals downstream of Mactaquac and adjusted according to ages from scale samples.

Table 3: Estimated total number of 1SW returns to the Saint John River, 1975–2019, from hatchery-reared smolts released at Mactaquac Dam, 1974–2018. Prop 1-yr = proportion of total releases age-1. Period (.) equals no data.

Releases Year	Releases Smolts	Releases Prop 1-yr	Returns Year	Returns Mactaquac Mig ch (combined)	Returns Mactaquac Dam (combined)	Returns Indigenous fishery	Returns Angled main SJ	Returns By-catch	Returns Com-mercial	Returns Total[a]	Returns % return Unadj	Returns % return Adj[bcf]
1974	337,281	0.00	1975	1,771	3,564	28	977	34	.	6,374	1.890	.
1975	324,186	0.06	1976	2,863	4,831	219	1,129	32	.	9,074	2.799	.
1976	297,350	0.14	1977	1,645	4,533	36	708	70	.	6,992	2.351	.
1977	293,132	0.26	1978	777	1,779	49	369	70	.	3,044	1.038	.
1978	196,196	0.16	1979	799	2,722	100	186	20	.	3,827	1.951	.
1979	244,012	0.09	1980	3,072	6,687	335	640	59	.	10,793	4.423	.
1980	232,258	0.12	1981	921	2,861	139	350	.	1,356	5,627	2.423	.
1981	189,090	0.08	1982	828	1,464	64	267	.	415	3,038	1.607	.
1982	172,231	0.06	1983	374	857	39	69	.	225	1,564	0.908	.
1983	144,549	0.22	1984	476	828	36	63	48	.	1,451	1.004	0.976
1984	206,462	0.28	1985	454	1,288	82	128	66	.	2,018	0.977	0.920
1985	89,051	1.00	1986	64	635	53	93	17	.	862	0.968	0.868
1986	191,495	1.00	1987	152	2,063	74	222	52	.	2,563	1.338	1.170
1987	113,439	1.00	1988	(717)	(717)	15	46	16	.	794	0.700	0.672
1988	142,195	1.00	1989	(1,018)	(1,018)	0	107	23	.	1,148	0.807	0.763
1989	238,204	0.98	1990	(903)	(903)	0	57	20	.	980	0.411	0.401
1990	241,078	0.98	1991	(1,490)	(1,490)	88	108	35	.	1,721	0.714	0.649
1991	178,127	0.97	1992	(1,132)	(1,132)	26	135	26	.	1,319	0.740	0.688
1992	204,836	1.00	1993	(779)	(779)	11	60	17	.	867	0.423	0.406
1993	221,403	1.00	1994	(841)	(841)	37	0	18	.	896	0.405	0.393
1994	225,037	1.00	1995	(1,509)	(1,509)	15	.	15	.	1,539	0.684	0.661
1995	251,759	1.00	1996	(2,649)	(2,649)	215	0	29	.	2,893	1.149	1.140
1996	286,400	1.00	1997	(1,543)	(1,543)	58	0	16	.	1,617	0.565	0.558
1997	286,485	1.00	1998	(2,112)	(2,112)	0	0	21	.	2,133	0.745	0.745
1998	297,012	1.00	1999	(1,672)	(1,672)	0	0	17	.	1,689	0.569	0.468
1999	305,073	1.00	2000	(1,403)	(1,403)	0	0	14	.	1,417	0.464	0.464
2000	311,825	1.00	2001	(839)	(839)	0	0	8	.	847	0.272	0.272
2001	305,321	1.00	2002	(1,358)	(1,358)	0	0	14	.	1,372	0.449	0.449
2002	241,971	1.00	2003	(815)	(815)	0	0	8	.	823	0.340	0.340
2003	155,701	1.00	2004	(499)	(499)	0	0	5	.	504	0.324	0.324
2004	52,178	1.00	2005	(197)	(197)	0	0	2	.	199	0.381	0.381
2005	77,271	1.00	2006	(426)	(426)	0	0	4	.	430	0.556	0.384
2006	113,847	1.00	2007	(273)	(273)	0	0	3	.	276	0.242	0.213
2007	84,088	1.00	2008	(686)	(686)	0	0	7	.	696	0.828	0.703
2008	55,253	1.00	2009	(97)	(97)	0	0	1	.	98	0.177	0.125
2009	27,314	1.00	2010	(444)	(444)	0	0	5	.	448	1.640	1.435
2010	35,050	1.00	2011	(51)	(51)	0	0	0	.	51	0.146	0.120
2011	24,135	1.00	2012	(4)	(4)	0	0	0	.	4	0.017	0.017
2012	4,953	1.00	2013	(33)	(33)	0	0	0	.	33	0.666	0.666
2013	9,159	1.00	2014	(10)	(10)	0	0	0	.	10	0.109	0.109
2014	14,741	1.00	2015	(35)	(35)	0	0	0	.	35	0.237	0.237
2015	21,033	1.00	2016	(22)	(22)	0	0	0	.	22	0.105	0.105
2016	2,779	1.00	2017	(15)	(15)	0	0	0	.	15	0.540	0.540
2017	3,624	1.00	2018	(9)	(9)	0	0	0	.	9	0.248	0.248
2018	6,575	1.00	2019	(10)	(10)	0	0	0	.	10	0.152	0.152
2019	20	1.00	2020	(.)	(.)	.	.	.	.	.	.	.

(a) Includes some returns from smolts stocked downriver of Mactaquac or escaped from sea-cages (Table 1: as determined from erosion of margins of upper and lower caudal fins).

(b) Adjusted return rates exclude smolts stocked downriver from Mactaquac (Marshall 1989) and fish of probable sea-cage origin. (Marginal numbers of returns from approx. 5,000 age 2.1 smolts, 1989–1991 are not included; no returns from tagged smolts released to the Nashwaak River, 1992 or 1997; 1997 count yielded 2 tagged 1SW fish from among 2,000 tagged smolts released to the Nashwaak in 1996 (9,017 smolts total).

(c) 1997 adjustment to return years 1995–97, based on adipose-clipped age1.1 returns from age-0 fall fingerlings stocked above Mactaquac, 1993–95. Total estimated returns number 22, 22 and 10 in 1995, 1996 and 1997, respectively.

(d) Revised "smolts released" includes 11,177 age-1 smolts released to the migration channel from Saint John Hatchery.

(e) Smolts were from the Tobique River captive-reared program.

(f) 2006–08 adjustment to return year based on adipose-clipped age 1.1 returns from age-0 fall fingerlings stocked above Mactaquac in 2004–06. Total estimated returns numbered 133 fish in 2006, 34 fish in 2007 and 105 fish in 2008.

(g) 2008 smolts were 36,394 from sea-run crosses and 18,859 from captive-reared crosses.

Table 4: Estimated total number of maiden 2SW returns to the Saint John River, 1976–2019, from hatchery-reared smolts released at Mactaquac Dam, 1974–2017. Period (.) equals no data.

Releases Year	Releases Smolts	Releases Prop 1-yr	Returns Year	Returns Mactaquac Mig ch (combined)	Returns Mactaquac Dam (combined	Returns Indigenous fishery	Returns Angled main SJ	Returns By-catch	Returns Com-mercial	Returns Total[a]	Returns % return Unadj	Returns % return Adj[bcf]
1974	337,281	0.00	1976	310	1,313	392	267	20		2,302	0.683	.
1975	324,186	0.06	1977	341	1,727	206	417	34	.	2,725	0.841	.
1976	297,350	0.14	1978	223	1,728	368	165	50	.	2,534	0.852	.
1977	293,132	0.26	1979	145	747	210	65	21	.	1,188	0.405	.
1978	196,196	0.16	1980	302	1,992	506	146	46	.	2,992	1.525	.
1979	244,012	0.09	1981	126	963	252	125	.	1,262	2,728	1.118	.
1980	232,258	0.12	1982	88	640	462	181	.	398	1,769	0.762	.
1981	189,090	0.08	1983	44	255	76	17	.	712	1,104	0.584	.
1982	172,231	0.06	1984	84	722	201	5	103	.	1,115	0.647	0.560
1983	144,549	0.22	1985	73	492	189	5	116	.	875	0.605	0.553
1984	206,462	0.28	1986	16	471	266	4	40	.	797	0.386	0.346
1985	89,051	1.00	1987	4	338	110	4	24	.	480	0.539	0.453
1986	191,495	1.00	1988	(511)	(511)	150	0	35	.	696	0.363	0.354
1987	113,439	1.00	1989	(379)	(379)	0	0	20	.	399	0.352	0.330
1988	142,195	1.00	1990	(480)	(480)	0	0	25	.	505	0.355	0.170
1989	238,204	0.98	1991	(359)	(359)	62	0	46	.	467	0.196	0.173
1990	241,078	0.98	1992	(590)	(590)	58	0	32	.	680	0.282	0.256
1991	178,127	0.97	1993	(242)	(242)	16	0	11	.	269	0.151	0.145
1992	204,836	1.00	1994	(303)	(303)	10	0	23	.	336	0.164	0.159
1993	221,403	1.00	1995	(398)	(398)	5	0	11	.	414	0.187	0.187
1994	225,037	1.00	1996	(567)	(567)	18	0	15	.	600	0.267	0.267
1995	251,759	1.00	1997	(412)	(412)	45	0	12	.	469	0.186	0.186
1996	286,400	1.00	1998	(229)	(229)	0	0	6	.	235	0.082	0.082
1997	286,485	1.00	1999	(554)	(554)	0	0	14	.	568	0.198	0.198
1998	297,012	1.00	2000	(173)	(173)	0	0	4	.	177	0.060	0.060
1999	305,073	1.00	2001	(462)	(462)	0	0	12	.	474	0.155	0.155
2000	311,825	1.00	2002	(142)	(142)	0	0	4	.	146	0.047	0.047
2001	305,321	1.00	2003	(443)	(443)	0	0	11	.	454	0.149	0.149
2002	241,971	1.00	2004	(265)	(265)	0	0	7	.	272	0.112	0.112
2003	155,701	1.00	2005	(78)	(78)	0	0	2	.	80	0.051	0.051
2004	52,178	1.00	2006	(44)	(44)	0	0	1	.	45	0.086	0.086
2005	77,271	1.00	2007	(89)	(89)	0	0	2	.	91	0.118	0.110
2006	113,847	1.00	2008	(71)	(71)	0	0	2	.	73	0.064	0.052
2007	84,088	1.00	2009	(139)	(139)	0	0	4	.	143	0.170	0.137
2008	55,253	1.00	2010	(76)	(76)	0	0	2	11	89	0.161	0.148
2009	27,314	1.00	2011	(34)	(34)	0	0	1	.	35	0.128	0.128
2010	35,050	1.00	2012	(22)	(22)	0	0	1	.	23	0.066	0.066
2011	24,135	1.00	2013	(4)	(4)	0	0	0	.	4	0.017	0.017
2012	4,953	1.00	2014	(5)	(5)	0	0	0	.	5	0.101	0.101
2013	9,159	1.00	2015	(2)	(2)	0	0	0	.	2	0.022	0.022
2014	14,741	1.00	2016	(13)	(13)	0	0	0	.	13	0.088	0.088
2015	21,033	1.00	2017	(9)	(9)	0	0	0	.	9	0.043	0.043
2016	2,779	1.00	2018	(0)	(0)	0	0	0	.	0	0.000	0.000
2017	3,624	1.00	2019	(0)	(0)	0	0	0	.	0	0.000	0.000
2018	6,575	1.00	2020	(.)	(.)	.	.	.	.	.	.	.
2019	20	1.00	2021	(.)	(.)	.	.	.	.	.	.	.

(a) Includes some returns from smolts stocked downriver of Mactaquac or escaped from sea-cages (Table 1: erosion of margins of upper and lower caudal fins).

(b) Adjusted return rates exclude smolts stocked downriver from Mactaquac (Marshall 1989) and fish of probable sea-cage origin. (Marginal numbers of returns from approx. 5,000 age 2.1 smolts, 1989–1991 are not included; no returns from tagged smolts released to the Nashwaak River, 1992; possibly 3 returns from 12,516 smolts >12 cm to Nashwaak in 1993; no returns from 15,059 stocked in the Nashwaak in 1994 and 2 returns from 3,989 tagged [13,283 total] in 1995.

(c) 1997 adjustment to return year 1997 based on adipose-clipped age 1.2 returns from age-0 fall fingerlings stocked above Mactaquac in 1994. Total estimated returns numbered 9 fish in 1997.

(d) Revised "smolts released" includes 11,177 age-1 smolts released to the migration channel from Saint John Hatchery.

(e) Smolts were from the Tobique River captive-reared program.

(f) 2007–08 adjustment to return year based on adipose-clipped age 1.2 returns from age-0 fall fingerlings stocked above Mactaquac in 2006–07. Total estimated returns numbered 6 fish in 2007 and 14 fish in 2008.

(g) 2008 smolts were 36,394 from sea-run crosses and 18,859 from captive-reared crosses.

(h) Estimated to have been removed by poachers (not commercial fishers) below Mactaquac Dam.

Table 5: Adjusted counts by age of wild and hatchery 1SW and MSW Atlantic Salmon to Mactaquac Dam, 1992–2019.

Category Origin	Smolt Sea Age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1SW Salmon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild	2.1	2573	1865	993	957	601	150	147	150	823	485	368	270	404	549
Wild	3.1	3075	883	1035	1154	585	146	185	290	459	191	258	103	415	285
Wild	4.1	80	74	42	43	28	32	7	27	48	3	2	4	36	20
Wild Total	-	**5728**	**2822**	**2070**	**2154**	**1214**	**328**	**338**	**467**	**1330**	**679**	**628**	**377**	**855**	**854**
Hatchery	1.1	1132	779	841	1509	2649	1543	2112	1672	1403	839	1358	815	499	197
Hatchery	2.1	527	240	214	834	1354	521	968	480	207	129	263	83	98	79
Hatchery	3.1	259	52	227	483	867	627	1459	569	66	35	86	13	19	14
Hatchery	4.1	17	1	13	2	69	88	56	36	32	1	0	1	1	3
Hatchery Total	-	**1935**	**1072**	**1295**	**2828**	**4939**	**2778**	**4595**	**2757**	**1708**	**1004**	**1707**	**912**	**617**	**293**
1SW Salmon	**Total**	**7663**	**3894**	**3365**	**4982**	**6153**	**3106**	**4933**	**3224**	**3038**	**1683**	**2335**	**1289**	**1472**	**1147**
MSW Salmon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild	*2.2*	1897	1156	1098	976	1128	428	64	359	137	507	124	160	348	149
Wild	*3.2*	1297	1247	413	523	925	473	145	412	58	91	29	55	38	87
Wild	*4.2*	17	38	8	35	13	26	1	16	2	1	0	0	0	0
Previous Spawners and 3SW	-	181	112	105	59	114	68	101	28	73	29	41	19	4	12
Wild Total	-	**3392**	**2553**	**1624**	**1593**	**2181**	**995**	**312**	**816**	**270**	**628**	**194**	**234**	**390**	**248**
Hatchery	1.2	590	242	303	398	567	412	229	554	173	462	142	443	265	78
Hatchery	2.2	136	76	142	95	221	143	120	209	57	49	22	38	32	13
Hatchery	3.2	82	97	19	47	137	158	177	158	19	9	2	10	5	1
Hatchery	4.2	1	6	0	2	10	4	13	3	1	0	0	0	0	0
Previous Spawners and 3SW	-	3	19	66	30	13	26	92	19	10	28	7	7	2	2
Hatchery Total	-	**812**	**440**	**530**	**572**	**947**	**744**	**631**	**943**	**260**	**548**	**173**	**498**	**304**	**94**
MSW Salmon Total	-	**4204**	**2993**	**2154**	**2165**	**3128**	**1739**	**943**	**1759**	**530**	**1176**	**367**	**732**	**694**	**342**
TOTALS	-	**11867**	**6887**	**5519**	**7147**	**9281**	**4845**	**5876**	**4983**	**3568**	**2859**	**2702**	**2021**	**2166**	**1489**
Total Mean Age- Wild only	-	**4.9**	**5.0**	**4.9**	**4.9**	**5.2**	**5.4**	**5.3**	**5.3**	**4.6**	**4.7**	**4.7**	**4.7**	**4.8**	**4.6**
Prop of MSW that are 2SW	-	**0.96**	**0.96**	**0.92**	**0.96**	**0.96**	**0.95**	**0.79**	**0.97**	**0.84**	**0.95**	**0.87**	**0.96**	**0.99**	**0.96**

Table 5 (cont.). Adjusted counts by age of wild and hatchery 1SW and MSW Atlantic Salmon to Mactaquac Dam, 1992–2019.

Category Origin	Smolt Sea Age	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1SW Salmon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild	2.1	553	396	554	279	1384	358	36	172	76	301	126	76	127	93
Wild	3.1	232	91	232	143	307	209	12	40	35	91	67	55	32	14
Wild	4.1	4	0	2	11	0	9	0	0	0	4	0	0	0	0
Wild Total	-	**789**	**487**	**788**	**433**	**1691**	**576**	**48**	**212**	**111**	**396**	**193**	**131**	**159**	**107**
Hatchery	1.1	426	273	686	97	444	51	4	33	10	35	22	15	9	10
Hatchery	2.1	65	116	213	55	187	216	16	38	6	141	167	128	223	296
Hatchery	3.1	40	15	96	19	48	158	7	8	6	39	122	49	51	87
Hatchery	4.1	0	3	0	3	0	8	6	0	0	0	0	0	4	2
Hatchery Total	-	**531**	**407**	**995**	**174**	**679**	**433**	**33**	**79**	**22**	**215**	**311**	**192**	**287**	**395**
1SW Salmon	**Total**	**1320**	**894**	**1783**	**607**	**2370**	**1009**	**81**	**291**	**133**	**611**	**504**	**323**	**446**	**502**
MSW Salmon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild	*2.2*	249	148	113	280	223	251	54	74	45	44	50	59	13	33
Wild	*3.2*	25	52	21	40	39	36	4	24	0	12	13	17	12	5
Wild	*4.2*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Previous Spawners and 3SW	-	2	0	5	9	6	0	11	0	0	2	0	5	0	0
Wild Total	-	**276**	**200**	**139**	**329**	**268**	**287**	**69**	**98**	**45**	**58**	**63**	**81**	**25**	**38**
Hatchery	1.2	44	89	71	139	76	34	22	4	5	2	13	9	0	0
Hatchery	2.2	14	33	61	57	37	292	32	24	11	26	92	47	28	131
Hatchery	3.2	2	6	3	9	9	48	5	3	2	9	14	40	8	26
Hatchery	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Previous Spawners and 3SW	-	2	0	0	10	5	0	0	3	5	0	2	2	0	2
Hatchery Total	-	**62**	**128**	**135**	**215**	**127**	**374**	**59**	**34**	**23**	**37**	**121**	**98**	**36**	**159**
MSW Salmon Total	-	**338**	**328**	**274**	**544**	**395**	**661**	**128**	**132**	**68**	**95**	**184**	**179**	**61**	**197**
TOTALS	-	**1658**	**1222**	**2057**	**1151**	**2765**	**1670**	**209**	**423**	**201**	**706**	**688**	**502**	**507**	**699**
Total Mean Age- Wild only	**-**	**4.5**	**4.5**	**4.4**	**4.7**	**4.3**	**4.6**	**5.0**	**4.5**	**4.5**	**4.4**	**4.6**	**4.8**	**4.4**	**4.4**
Prop of MSW that are 2SW	**-**	**0.99**	**1.00**	**0.98**	**0.97**	**0.97**	**1.00**	**0.91**	**0.98**	**0.93**	**0.98**	**0.99**	**0.96**	**1.00**	**0.99**

Table 6: Number, biological characteristics and estimated number of eggs from wild 1SW and MSW Atlantic Salmon released upriver of Mactaquac Dam, 1996–2019.

Sea-Age Origin	Year	Female Mean Length (cm)	Estimated Fecundity	Prop Female	Total (M+F) Counts Escape	Total Eggs	Prop Total
Wild 1SW	1996	58.8	3,587	0.132	1,082	512,310	0.03
Wild 1SW	1997	61.3	3,927	0.061	313	74,979	0.01
Wild 1SW	1998	58.5	3,550	0.135	311	148,573	0.03
Wild 1SW	1999	62.3	4,066	0.109	432	192,076	0.02
Wild 1SW	2000	59.8	3,717	0.177	1,208	795,471	0.22
Wild 1SW	2001	59.6	3,692	0.112	548	225,894	0.03
Wild 1SW	2002	59.9	3,728	0.126	544	254,698	0.14
Wild 1SW	2003	59.7	3,701	0.137	281	142,091	0.04
Wild 1SW	2004	59.2	3,635	0.120	759	330,803	0.10
Wild 1SW	2005	58.2	3,506	0.068	804	190,824	0.08
Wild 1SW	2006	60.2	3,767	0.064	736	178,759	0.10
Wild 1SW	2007	56.0	3,239	0.048	440	67,731	0.04
Wild 1SW	2008	60.5	3,810	0.038	716	103,005	0.07
Wild 1SW	2009	60.6	3,825	0.079	394	118,412	0.04
Wild 1SW	2010	60.1	3,748	0.040	1,664	250,008	0.10
Wild 1SW	2011	61.0	3,879	0.034	546	73,033	0.02
Wild 1SW	2012	60.0	3,741	0.019	46	3,247	0.01
Wild 1SW	2013	61.5	3,949	0.073	207	59,451	0.08
Wild 1SW	2014	57.1	3,374	0.090	108	32,878	0.23
Wild 1SW	2015	57.0	3,358	0.075	385	97,206	0.14
Wild 1SW	2016	53.6	2,971	0.041	185	22,550	0.02
Wild 1SW	2017	57.3	3,391	0.171	127	73,828	0.06
Wild 1SW	2018	54.8	3,096	0.081	152	37,999	0.09
Wild 1SW	2019	54.9	3,112	0.120	106	39,707	0.03
Wild 1SW	**Mean**	**58.8**	**3,599**	**0.090**	-	-	**0.07**
Wild MSW	1996	78.6	7,313	0.861	1,700	10,704,039	0.59
Wild MSW	1997	77.0	6,896	0.949	786	5,143,823	0.53
Wild MSW	1998	79.7	7,617	0.929	188	1,330,139	0.22
Wild MSW	1999	78.0	7,146	0.953	582	3,963,315	0.39
Wild MSW	2000	77.9	7,131	0.953	129	877,003	0.25
Wild MSW	2001	78.0	7,149	0.947	470	3,181,509	0.49
Wild MSW	2002	79.5	7,557	0.896	92	623,097	0.33
Wild MSW	2003	77.3	6,981	0.946	161	1,063,337	0.27
Wild MSW	2004	78.9	7,395	0.816	343	2,070,079	0.62
Wild MSW	2005	77.1	6,930	0.900	193	1,203,131	0.71
Wild MSW	2006	78.2	7,206	0.965	182	1,265,022	0.69
Wild MSW	2007	76.6	6,807	0.821	150	838,424	0.54
Wild MSW	2008	76.4	6,758	0.974	91	599,074	0.39
Wild MSW	2009	77.4	6,996	0.765	277	1,482,541	0.54
Wild MSW	2010	77.4	6,996	0.928	233	1,511,948	0.62
Wild MSW	2011	77.0	6,906	0.941	264	1,715,191	0.42
Wild MSW	2012	76.3	6,733	0.917	57	351,800	0.65
Wild MSW	2013	76.4	6,758	0.869	91	534,224	0.70
Wild MSW	2014	77.7	7,074	0.915	39	252,407	0.51
Wild MSW	2015	78.0	7,159	0.914	56	366,344	0.52
Wild MSW	2016	77.7	7,082	0.938	57	378,445	0.32
Wild MSW	2017	79.2	7,476	0.880	79	519,447	0.42
Wild MSW	2018	77.2	6,943	0.880	20	122,197	0.29
Wild MSW	2019	77.4	7,003	0.868	35	212,855	0.16
Wild MSW	**Mean**	**77.7**	**7,084**	**0.905**	-	-	**0.47**

Table 7: Number, biological characteristics and estimated number of eggs from hatchery 1SW and MSW Atlantic Salmon released upriver of Mactaquac Dam, 1996–2019.

Sea-Age Origin	Year	Female Mean Length (cm)	Estimated Fecundity	Prop Female	Total (M+F) Counts Escape	Total Eggs	Prop Total
Hatchery	1996	58.8	3,584	0.118	4,394	1,858,276	0.10
1SW	1997	62.0	4,021	0.092	2,429	898,565	0.09
1SW	1998	58.6	3,551	0.113	4,311	1,734,600	0.29
1SW	1999	59.5	3,672	0.101	2,530	940,495	0.09
1SW	2000	58.0	3,486	0.089	1,587	493,507	0.14
1SW	2001	60.8	3,855	0.041	915	144,907	0.02
1SW	2002	60.2	3,769	0.047	1,621	287,235	0.15
1SW	2003	58.1	3,494	0.073	855	218,951	0.06
1SW	2004	59.6	3,688	0.062	580	132,273	0.02
1SW	2005	61.4	3,935	0.037	256	37,589	0.03
1SW	2006	60.5	3,803	0.041	522	82,202	0.04
1SW	2007	56.2	3,262	0.050	392	63,748	0.04
1SW	2008	60.6	3,823	0.046	958	167,199	0.11
1SW	2009	61.3	3,925	0.060	165	38,550	0.01
1SW	2010	61.0	3,879	0.006	675	15,048	0.01
1SW	2011	62.2	4,046	0.029	402	47,145	0.01
1SW	2012	62.0	4,021	0.103	25	10,400	0.02
1SW	2013	64.0	4,322	0.113	63	30,681	0.04
1SW	2014	52.0	2,804	0.100	21	5,889	0.01
1SW	2015	55.7	3,204	0.057	209	37,904	0.05
1SW	2016	60.4	3,796	0.072	304	82,967	0.07
1SW	2017	56.1	3,254	0.202	191	125,662	0.09
1SW	2018	54.6	3,082	0.102	275	86,242	0.21
1SW	2019	54.6	3,081	0.131	391	157,791	0.12
1SW	**Mean**	**59.1**	**3,640**	**0.079**	-	-	**0.08**
Hatchery	1996	77.0	6,906	0.921	818	5,202,829	0.28
MSW	1997	77.8	7,102	0.931	554	3,663,027	0.37
MSW	1998	77.3	6,976	0.881	439	2,698,884	0.46
MSW	1999	77.5	7,021	0.940	756	4,991,116	0.49
MSW	2000	77.6	7,051	0.982	202	1,398,869	0.39
MSW	2001	77.0	6,903	0.895	474	2,929,761	0.45
MSW	2002	78.4	7,263	0.826	117	702,291	0.38
MSW	2003	76.7	6,831	0.924	394	2,487,626	0.64
MSW	2004	77.9	7,133	0.785	274	1,534,132	0.26
MSW	2005	76.3	6,733	0.901	80	485,368	0.17
MSW	2006	77.0	6,898	0.949	48	314,269	0.17
MSW	2007	76.6	6,807	0.783	109	581,056	0.37
MSW	2008	76.8	6,856	0.829	116	658,960	0.43
MSW	2009	77.4	7,003	0.827	195	1,129,670	0.41
MSW	2010	77.4	7,003	0.848	113	671,136	0.27
MSW	2011	77.4	7,006	0.924	351	2,271,865	0.55
MSW	2012	75.3	6,495	0.706	39	178,804	0.33
MSW	2013	77.1	6,928	0.818	28	158,715	0.19
MSW	2014	76.1	6,685	0.857	21	120,330	0.25
MSW	2015	77.7	7,082	0.784	36	199,828	0.28
MSW	2016	76.2	6,700	0.878	116	682,420	0.59
MSW	2017	78.9	7,398	0.771	97	553,155	0.43
MSW	2018	77.6	7,046	0.833	29	170,279	0.41
MSW	2019	76.9	6,871	0.853	156	913,843	0.69
MSW	**Mean**	**77.2**	**6,946**	**0.860**	-	-	**0.39**

Table 8: Start and finish dates for the operation of an adult salmon counting fence on the Nashwaak River, as well as the assessment technique used to estimate the total returns upriver of the fence site. The fence count as a proportion of the total estimated 1SW and MSW Atlantic Salmon and a mean (min., max.) fence capture efficiency. Period (.) equals no data.

Year	Start and Finish Date	Dates fence was not fishing 100%	Assessment Technique	Estimate up to	Year	Fence count as proportion of total estimate 1SW	Fence count as proportion of total estimate MSW
1972	Aug 18-Oct 29	Sept 4-6, Oct 8-9, Oct 25-28	.	.	.	.	.
1973	June 10-Nov 5	July 5-11, Aug 3-7	.	.	.	.	.
1975	June 28-Oct 29	Oct 21-22	.	.	.	.	.
1993	Aug 19-Oct 12	.	Historical Run Timing	.	~~1993~~	~~0.09~~	~~0.28~~
1994	July 15-Oct 25	.	Seining; Mark Recap	Oct 25	1994	0.61	0.71
1995	July 12-Oct 18	.	Historical Run Timing	.	~~1995~~	~~0.61~~	~~0.71~~
1996	June 13-Oct 18	July 9-10, July 14-31	Seining; Mark Recap	Oct 18	1996	0.51	0.65
1997	June 18-Nov 2	.	Count; No Washouts	Nov 01	~~1997~~	~~1.00~~	~~1.00~~
1998	June 8-Oct 27	Aug 12-14, Oct 2-5	Seining; Mark Recap	Oct 27	1998	0.37	0.48
1999	June 3-Oct 13	Sept 17-20, Sept 23-28	Seining; Mark Recap	Oct 13	1999	0.46	0.31
2000	June 19-Oct 26	Oct 10-11	Seining; Mark Recap	Oct 26	2000	0.84	0.84
2001	June 21-Nov 1	Aug 3-17 [a]	Count; No Washouts	Nov 01	~~2001~~	~~1.00~~	~~1.00~~
2002	June 10-Oct 28	.	Count; No Washouts	Oct 28	~~2002~~	~~1.00~~	~~1.00~~
2003	June 5-Oct 26	Aug 6-8, Oct 15-17, Oct 21-23	Seining; Mark Recap	Oct 15 [b]	2003	0.63	0.75
2004	June 3-Oct 26	Aug 31- Sept 2, Sept 9-12	Seining; Mark Recap	Oct 26	2004	0.82	0.83
2005	June 9-Oct 7	June 18-19, Aug 30-Sept 2, Sept.17-20 & 27-28	Seining; Mark Recap	Oct 07	2005	0.58	0.59
2006	June 1-Oct 20	June 4-5, 9-26, July 5-6	Seining; Mark Recap	Oct 20	2006	0.57	0.61
2007	May 30-Oct 30	Oct 13-14, Oct 21 [c]	Seining; Mark Recap	Oct 30	2007	0.47	0.95
2008	May 30-Oct 22	June 29-July 4, Aug 2-7, 9-14, Sept 28-Oct 10	Seining; Mark Recap	Sept 28 [d]	2008	0.43	0.45
2009	May 29-Oct 4	June 12-15, 20-23, June 29-July 1, July 4-6, 25-26, 30-31, Aug 8, Sept 29	Seining; Mark Recap	Oct 4 [e]	2009	0.67	0.63
2010	May 28-Oct 27	June 5-8, Sept 4, Oct 1-3, 7-12, 16-19 [f]	Seining; Mark Recap	Oct 15	2010	0.42	0.74
2011	June 3-Oct 16	June 10-12,14,18-22, 25-27, July 13,22-23,28, July 31- Aug 1, Aug 23-24, Aug 29-Sept 19, Oct 5	Seining; Mark Recap	Oct 16	2011	0.40	0.40
2012	June 1-Oct 12	June 26-July 2, Sept 30-Oct 2, Oct 7-8	Mean Fence Efficiency	Oct 12	2012	0.56	0.62
2013	June 21-Oct 7	June 21-23, July 27-Aug 13, Sept 3-26	Seining; Mark Recap	Oct 9 [g]	2013	0.32	0.32
2014	June 11-Oct 10	June 19, 27, July 6-14, 17-18, Aug 14-19	Seining; Mark Recap	Oct 10	2014	0.30	0.29
2015	June 1-Sept 30	June 10, 22-23, Sept 11-12, 14-15	Seining; Mark Recap	Sept 30	2015	0.63	0.65
2016	June 2-Oct 17	June 8-10, 11-14, July 2-3, 7-8, Aug 15, 18, 23-24	Seining; Mark Recap	Oct 17	2016	0.80	0.80
2017	June 1-Oct 16	.	Seining; Mark Recap	Oct 16	2017	0.39	0.38
2018	June 1-Oct 18	Aug 18-20, Oct 11-15, 17-18	Seining; Mark Recap	Oct 18	2018	1.00	1.00
2019	June 7-Oct 17	July 7-8, 13-14, Sept 7-11, 24-30, Oct 8-9	Seining; Mark Recap	Oct 17	2019	0.51	0.62
~~years~~ not used calculations	**~~years~~ not used calculations**	**~~years~~ not used calculations**	**~~years~~ not used calculations**	**~~years~~ not used calculations**	**~~years~~ not used calculations**	**~~years~~ not used calculations**	**~~years~~ not used calculations**
-	-	-	-	-	Mean	0.56	0.62
-	-	-	-	-	Min	0.30	0.29
-	-	-	-	-	Max	1.00	1.00

(a) Fence was removed and base crib was raised 45 cm.
(b) Only two 1SW salmon were counted after Oct. 15, 2003.
(c) A couple holes large enough for a 1SW salmon to pass though were discovered in the fence around July 19, 2007.
(d) Only four 1SW and one MSW salmon were counted after Sept. 28, 2008.
(e) Continued rainfall/highwater after Oct 4 did not allow for further operation. Fence was dismantled beginning on Oct. 13, 2009.

(f) Four to five holes large enough for a 1SW salmon to pass though were discovered in the fence after seining on Oct. 6, 2010.
(g) Removal of fence panels began Oct 7; one salmon found in trap on Oct 9, 2013, and was included in population estimate.

Table 9: Estimated returns, escapement, eggs deposited and percent of Conservation Egg Requirement (CER) attained for the Nashwaak River, 1993–2019.

Year	Estimated Returns 1SW	Estimated Returns MSW	Escapement 1SW	Escapement MSW	% of Requirement 1SW	% of Requirement MSW	Total Egg Deposition Eggs Deposited	Total Egg Deposition % CER
1993	954	555	866	555	42%	27%	3,947,841	31%
1994	661	388	610	349	30%	17%	3,264,340	26%
1995	940	436	940	436	46%	21%	4,222,157	33%
1996	1829	657	1804	641	88%	31%	6,202,877	48%
1997	370	366	364	362	18%	18%	2,888,199	23%
1998	1259	315	1238	309	61%	15%	3,917,071	31%
1999	665	275	658	269	32%	13%	2,468,024	19%
2000	509	192	489	189	24%	9%	1,886,981	15%
2001	244	272	224	266	11%	13%	2,034,132	16%
2002	343	79	320	69	16%	3%	725,198	6%
2003	297	113	280	109	14%	5%	950,300	7%
2004	590	207	569	201	28%	10%	2,116,130	17%
2005	731	162	712	155	35%	8%	2,007,482	16%
2006	716	195	681	186	33%	9%	2,044,636	16%
2007	469	106	442	98	22%	5%	1,166,495	9%
2008	1237	173	1217	168	60%	8%	2,931,693	23%
2009	297	336	274	328	13%	16%	1,780,154	14%
2010	2016	197	2008	195	98%	10%	3,942,271	31%
2011	1034	576	1033	575	51%	28%	4,739,127	37%
2012	29	61	29	61	1%	3%	322,084	3%
2013	180	110	180	110	9%	5%	829,284	6%
2014	163	48	162	48	8%	2%	470,544	4%
2015	318	48	213	48	16%	2%	704,286	6%
2016	398	76	398	76	20%	4%	927,897	7%
2017	203	100	203	97	10%	5%	832,659	7%
2018	89	31	89	31	4%	2%	276,336	2%
2019	238	69	238	68	12%	3%	649,729	5%

Table 10: Estimates of wild smolt emigration from upriver of Durham Bridge (and 2.5 and 97.5% percentiles), production per unit area of habitat (smolts/100 m^2) and the smolt-to-adult return rates for the Nashwaak River, 1998–2019. Period (.) equals no data.

Year	Wild Smolt Estimate Mode	Wild Smolt Estimate 2.50%	Wild Smolt Estimate 97.50%	Production per unit area (smolts/100 m^2)	Return Rate (%) 1SW	Return Rate (%) 2SW
1998	22,750	17,900	32,850	0.43	2.91	0.67
1999	28,500	25,300	33,200	0.54	1.79	0.84
2000	15,800	13,400	19,700	0.3	1.53	0.28
2001	11,000	8,100	17,400	0.21	3.11	0.9
2002	15,000	12,300	19,000	0.28	1.91	1.26
2003	9,000	6,800	13,200	0.17	6.38	1.58
2004	13,600	10,060	20,800	0.26	5.13	1.28
2005	5,200	3,200	12,600	0.10	12.73	1.52
2006	25,400	21,950	30,100	0.48	1.81	0.62
2007	21,550	16,675	30,175	0.41	5.63	1.26
2008	7,300	5,500	11,200	0.14	3.86	2.05
2009	15,900	12,150	22,850	0.30	12.41	3.31
2010	12,500	9,940	16,740	0.24	7.86	0.35
2011	8,750	7,130	11,300	0.17	0.33	0.98
2012	11,060	8,030	17,745	0.21	1.63	0.29
2013	10,120	8,840	11,800	0.19	1.61	0.45
2014	11,100	8,150	17,200	0.21	2.86	0.60
2015	7,900	6,520	9,980	0.15	5.04	1.18
2016	7,150	5,575	9,925	0.13	2.84	0.41
2017*	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
2018*	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
2019	8,710	5,960	17,815	0.16	Not Applicable	Not Applicable

*A smolt estimate was attempted but was not successful due to a high flow event that prevented operation of the Rotary Screw Trap during the full smolt migration period.

Table 11: Dates of operation and smolt catches at RSTs (Three Brooks location only), and data used to estimate emigrating fall pre-smolts on the Tobique River from 2001 to 2018. Period (.) equals no data.

Details	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Operation	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Start Date	24-Sep	02-Oct	29-Sep	24-Sep	29-Sep	25-Sep	01-Oct	01-Oct	29-Sep	28-Sep	04-Oct	01-Oct	02-Oct	07-Oct	07-Oct	03-Oct	02-Oct	10-Oct
End Date	13-Nov	16-Nov	09-Nov	14-Nov	21-Nov	01-Dec	12-Nov	16-Nov	01-Dec	19-Nov	21-Nov	27-Nov	20-Nov	14-Nov	24-Nov	23-Nov	11-Nov	11-Nov
Lost Fishing Days	0	8	9	3	5	6	4	4	1	2	7	7	0	1	0	1	4	4
# of RST's Fished	2	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	4	4
Estimated Efficiency	12.0%	.	.	.	.	8.3%	9.7%	7.4%	16.8%	12.7%	8.0%	10.2%	12.1%	10.1%	8.3%	12.1%	6.0%	16.3%
Catches	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pre-smolt (Wild)	1,317	1,453	566	222	338	944	675	1,251	1,379	1,025	1,927	1,218	1,997	900	388	993	435	1,064
Pre-smolt (Hatchery)	64	101	34	26	47	638	99	102	133	223	171	68	165	79	42	77	64	190
Parr (Wild)	233	255	222	62	77	300	138	202	489	252	181	362	421	107	169	181	60	158
Parr (Hatchery)	11	6	1	9	7	38	13	5	360	26	10	13	12	0	4	12	3	18
Fry	957	941	76	86	130	168	291	20	188	1,056	36	140	46	11	5	61	94	6
Population Estimates	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pre-smolt (Wild)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marked	1,496	.	.	.	.	558	21	386	505	310	565	331	416	139	110	260	132	323
Recap	189	.	.	.	.	68	24	32	85	41	52	36	60	15	11	32	11	51
Catch	1,319	.	.	.	.	1,510	774	1,353	1,512	1,248	2,098	1,286	2,162	979	430	1,070	499	1,254
Estimate	**[a]10,400**	**[b]5,740**	**[b]9,760**	**[b]7,050**	**[b]18,500**	**[c]11,560**	**[c]6,920**	**[c]16,770**	**[c]8,190**	**[c]8,075**	**[c]24,180**	**[c]11,930**	**[c]16,506**	**[c]8,880**	**[c]4,692**	**[c]8,217**	**[c]7,079**	**[c]6,524**
2.5th percentile	9,200	.	.	.	.	9,389	5,107	12,624	6,905	6,521	19,220	9,042	13,306	5,957	3,032	6,318	4,516	5,396
97.5th percentile	12,000	.	.	.	.	15,033	10,650	24,479	10,021	10,508	32,102	17,374	21,494	16,768	9,853	11,669	15,133	8,249
Pre-smolt (Hatchery)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marked	98	.	.	.	.	558	85	86	119	196	150	22	113	9	35	71	47	168
Recap	3	.	.	.	.	68	6	3	20	23	6	-	4	0	1	8	0	29
Catch	63	.	.	.	.	1,510	774	1,353	1,512	1,248	2,098	1,286	165	979	430	1,070	499	1,254
Estimate	**[a]2,100**	**[b]1,290**	**[b]904**	**[b]1,550**	**[b]3,700**	**[c]7,480**	**[c]1,020**	**[c]1,350**	**[c]790**	**[c]1,800**	**[c]2,145**	**[c]670**	**[c]1364**	**[c]780**	**[c]508**	**[c]637**	**[c]1,041**	**[c]1,165**
2.5th percentile	1,100	.	.	.	.	6,076	753	1,016	666	1,454	1,705	508	1099	523	328	490	664	963
97.5th percentile	14,100	.	.	.	.	9,727	1,570	1,971	967	2,342	2,848	976	1,776	1,472	1,067	905	2,227	1,473
Pre-smolt (Wild and Hatchery)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total estimates	.	.	.	.	.	**19,040**	**7,940**	**18,120**	**8,990**	**9,875**	**26,325**	**12,600**	**17,870**	**9,660**	**5,200**	**8,854**	**8,120**	**7,689**
2.5th percentile	.	.	.	.	.	15,465	5,860	13,640	7,580	7,975	20,925	9,550	14,405	6,480	3,360	6,808	5,180	6,359
97.5th percentile	.	.	.	.	.	24,760	12,220	26,450	11,000	2,850	34,950	18,350	23,270	18,240	10,920	12,574	17,360	9,722

(a) Wild and hatchery pre-smolt estimates calculated separately using the mark and recapture data by origin.

(b) Pre-smolt estimates are estimated from the ratio of fall pre-smolts in 2001, 2006 to the spring smolts in 2002, 2007.

© Wild and hatchery data (marked, recap, catch) combined and proportion of catches used to split estimate into wild and hatchery.

Table 12: Dates of operation and smolt catches at RST(s) (Three Brooks location only), and data used to estimate emigrating smolts on the Tobique River from 2001 to 2019. Period (.) equals no data. No spring smolt monitoring occurred in 2013–2015.

Details	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Operation	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Start Date	04-May	24-Apr	07-May	23-Apr	04-May	25-Apr	29-Apr	05-May	04-May	14-Apr	02-May	26-Apr	.	.	.	27-Apr	12-May	15-May	01-May
End Date	28-May	05-Jun	28-May	09-Jun	08-Jun	30-May	30-May	02-Jun	03-Jun	25-May	09-Jun	23-May	.	.	.	31-May	31-May	08-Jun	05-Jun
Lost Fishing Days	0	0	0	0	1	5	4	5	0	0	0	0	.	.	.	2	0	0	0
# of RST's Fished	2	3	2	2	1	2	2	2	3	4	4	4	.	.	.	3	4	4	4
Estimated Efficiency – recycled wild/hff	7.4%	5.2%	4.3%	6.2%	1.6%	6.6%	6.4%	1.8%	7.6%	8.7%	4.8%	5.3%	.	.	.	2.2%	0.0%	0.0%	12.3%
Estimated Efficiency – hatchery garment	.	4.1%	1.4%	.	1.1%	3.1%	1.6%	1.0%	0.4%	7.0%	3.4%	2.0%	.	.	.	.	2.5%	0.7%	.
Catches	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Smolt (Wild)	176	318	119	291	63	591	303	40	74	410	61	89	.	.	.	84	31	19	128
Smolt (Hatchery)	86	176	50	49	25	214	289	36	98	538	31	34	.	.	.	92	3	7	47
Population Estimates	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Smolt Wild/Hatchery	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marked	149	422	139	275	62	784	575	55	132	762	62	76	.	.	.	92	3	6	57
Recap	11	22	6	17	1	52	37	1	10	66	3	4	.	.	.	2	0	0	7
Catch	262	494	169	340	88	805	592	76	172	948	92	123	.	.	.	176	34	26	175
Smolt (Hatchery) Garment Tag	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marked	.	2,357	1,483	.	1,400	991	1,996	1,969	1,988	1,836	996	1,949	.	.	.	.	200	448	.
Recap	.	97	21	.	15	31	32	20	8	129	34	39	.	.	.	.	5	3	.
Catch	.	494	169	.	88	805	592	76	172	948	92	123	.	.	.	.	34	26	.
Smolt (Wild and Hatchery)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total estimates	**3,560**	**9,500**	**3,900**	**5,500**	**4,750**	**12,140**	**9,210**	**3,400**	**6,740**	**10,960**	**2,700**	**6,140**	**.**	**.**	**.**	**8,200**	**1,360**	**3,850**	**1,426**
2.5th percentile	2,280	6,770	2,250	3,785	3,640	9,520	7,040	2,910	5,520	8,880	1,000	4,940	.	.	.	3,800	800	2,050	852
97.5th percentile	7,960	15,870	12,755	9,875	7,120	16,200	13,270	4,330	8,840	14,240	12,400	8,400	.	.	.	101,000	4,900	24,650	3,904

Table 13: Summary of declines in adult Atlantic Salmon returns and escapement for three populations and DU 16 from a log-linear model fit via least squares. The standard errors (SE) and 95% confidence intervals (C.I.) are shown. Fifteen years corresponds to three generations. A negative value for the decline rate indicates an increasing population size. Model fits are shown in Figures 24–27.

Population	Time Period	No. of Years	Slope	(SE)	Log-linear Model 1 Yr. decline rate (%)	Log-linear Model 1 Yr. decline 95% C.I.	Log-linear Model 1 Yr. decline 95% C.I	Log-linear Model 15 Yr. decline rate (%)	Log-linear Model 15 Yr. decline 95% C.I.	Log-linear Model 15 Yr. decline 95% C.I.
Mactaquac 1SW Returns	2004–2019	15	-0.11	0.04	10.17	2.27	17.44	80.00	29.16	94.36
Mactaquac MSW Returns	2004–2019	15	-0.11	0.03	10.63	5.11	15.84	81.47	54.44	92.48
Mactaquac Total Returns	2004–2019	15	-0.11	0.03	10.21	3.88	16.13	80.12	44.77	92.85
Mactaquac Total Escapement	2004–2019	15	-0.10	0.03	9.25	3.57	14.61	76.70	42.07	90.64
Nashwaak 1SW Returns	2004–2019	15	-0.12	0.05	11.06	1.78	19.45	82.76	23.66	96.10
Nashwaak MSW Returns	2004–2019	15	-0.10	0.03	9.91	3.80	15.64	79.11	44.10	92.20
Nashwaak Total Returns	2004–2019	15	-0.12	0.04	10.85	3.52	17.64	82.16	41.58	94.56
Nashwaak Total Escapement	2004–2019	15	-0.12	0.04	11.02	4.48	17.12	82.66	49.75	94.02
Magaguadavic Total Returns	2004–2019	15	-0.10	0.05	9.32	-1.00	18.48	76.94	-13.71	95.33
DU 16 1SW	2004–2019	15	-0.11	0.05	10.56	1.94	18.43	81.25	25.45	95.29
DU 16 MSW	2004–2019	15	-0.11	0.03	10.00	4.28	15.38	79.42	48.14	91.84
DU 16 Total	2004–2019	15	-0.11	0.04	10.49	3.69	16.80	81.02	43.15	93.67

Table 14: Total 1SW and MSW Atlantic Salmon returns to the rivers of DU 16 (OBoF population) from 1993 to 2019. Period (.) equals no data.

Year	1SW Returns Nashwaak	1SW Returns Saint John River Downriver	1SW Returns Saint John River Upriver	1SW Returns Magaguadavic	1SW Returns St. Croix	1SW Returns Mag + St. C	1SW Returns Other Fundy rivers	DU 16	MSW Returns Nashwaak	MSW Returns Saint John River Downriver	S MSW Returns Saint John River Upriver	MSW Returns Magaguadavic	MSW Returns St. Croix	MSW Returns Mag + St. C	MSW Returns Other Fundy rivers	MSW Returns DU 16	TOTAL (1SW + MSW) Mature Individuals
1993	954	4,317	4,369	112	8	120	157	8,843	555	2,511	3,383	125	96	221	289	6,183	15,026
1994	661	2,991	3,534	69	47	116	152	6,677	388	1,756	2,347	61	37	98	128	4,231	10,907
1995	940	4,253	5,079	49	14	63	82	9,415	436	1,973	2,253	30	33	63	82	4,308	13,723
1996	1,829	8,276	6,723	48	23	71	93	15,092	657	2,973	3,311	21	109	130	170	6,454	21,546
1997	370	1,674	3,255	35	33	68	89	5,018	366	1,656	1,971	24	10	34	44	3,672	8,690
1998	1,250	5,656	4,982	28	32	60	78	10,717	315	1,425	967	3	9	12	16	2,408	13,125
1999	665	3,009	3,257	19	8	27	35	6,301	275	1,244	1,804	5	5	10	13	3,061	9,363
2000	510	2,308	3,068	13	15	28	37	5,412	190	860	544	1	5	6	8	1,412	6,824
2001	244	1,104	1,700	8	13	21	27	2,832	272	1,231	1,206	9	7	16	21	2,458	5,289
2002	343	1,552	2,358	7	14	21	27	3,937	79	357	376	0	6	6	8	741	4,679
2003	297	1,344	1,302	3	13	16	21	2,667	113	511	751	3	2	5	7	1,269	3,936
2004	590	2,670	1,487	2	6	8	10	4,167	207	937	712	0	4	4	5	1,654	5,821
2005	731	3,308	1,159	9	2	11	14	4,481	162	733	350	0	4	4	5	1,088	5,569
2006	716	3,240	1,333	23	2	25	33	4,605	195	882	347	4	2	6	8	1,237	5,843
2007	469	2,122	903	4	NA	4	20	3,045	106	480	336	0	.	0	0	816	3,861
2008	1,237	5,597	1,801	4	NA	4	20	7,418	173	783	281	0	.	0	0	1,064	8,482
2009	297	1,344	613	3	NA	3	15	1,972	336	1,520	558	3	.	3	15	2,094	4,066
2010	2,016	9,122	2,394	12	NA	12	61	11,577	197	891	460	0	.	0	0	1,351	12,928
2011	1,034	4,679	1,019	8	NA	8	40	5,738	576	2,606	678	11	.	11	56	3,340	9,078
2012	29	131	81	0	NA	0	0	212	61	276	132	1	.	1	5	413	625
2013	180	814	294	3	NA	3	15	1,124	110	498	136	3	.	3	15	649	1,773
2014	163	738	134	10	NA	10	51	922	48	217	70	3	.	3	15	302	1,224
2015	318	1,439	617	5	NA	5	25	2,081	48	217	97	4	.	4	20	334	2,416
2016	398	1,801	509	2	NA	2	10	2,320	76	344	197	0	.	0	0	541	2,861
2017	203	919	326	0	NA	0	0	1,245	100	452	184	0	.	0	0	636	1,881
2018	89	403	451	0	NA	0	0	854	31	140	65	1	.	1	5	210	1,064
2019	238	1,077	507	0	NA	0	0	1,584	69	312	202	2	.	2	10	524	2,108

Note 1: Assessed portion of the Nashwaak represents 0.221 (0.245*0.9) of downriver habitat (Table 1; Marshall et al. 2014). Nashwaak returns are included in the Downriver SJR totals.

Note 2: Magaguadavic and St. Croix rivers represent 0.765 of the outer Fundy complex river habitat (Table 1; Marshall et al. 2014). The St. Croix and Magaguadavic returns are included in the other Fundy rivers totals for the years 1993–2006.

Note 3: Magaguadavic River represents 0.198 of the outer Fundy complex river habitat (Table 1; Marshall et al. 2014). The Magaguadavic returns are included in the other Fundy rivers totals for the years 2007–2019.

Table 15: Annual means (calculated using GLM) of fry (age-0), age-1, and age-2 and older parr Atlantic Salmon densities (number per 100 m^2) in the Tobique River, upriver of Mactaquac Dam, estimated during electrofishing surveys between 1970 to 2019. No surveys in 1980, 1987, 1990, and 1991. Period (.) equals no data.

Year	No.	Age-0 density LSMEAN	Age-1 density LSMEAN	Age-2 density LSMEAN
1970	12	10.93	0.14	1.11
1971	12	15.67	3.13	4.43
1972	10	15.51	0.86	2.51
1973	12	54.53	0.78	8.56
1974	12	15.40	4.45	2.60
1975	12	49.42	10.98	3.53
1976	12	89.68	8.34	6.14
1977	12	44.75	13.58	2.37
1978	12	69.48	9.39	3.39
1979	7	38.73	26.37	9.08
1980	0	.	.	.
1981	8	87.73	12.61	3.54
1982	12	44.90	16.88	0.94
1983	12	16.54	7.54	1.60
1984	11	28.99	4.65	1.50
1985	11	58.87	6.85	2.52
1986	11	21.47	15.60	1.66
1987	0	.	.	.
1988	4	94.57	6.53	1.55
1989	4	32.57	11.93	1.58
1990	0	.	.	.
1991	0	.	.	.
1992	7	12.09	7.04	2.03
1993	5	36.12	10.50	3.24
1994	4	27.69	6.93	1.21
1995	5	38.36	10.38	3.72
1996	12	6.08	4.98	1.51
1997	12	12.13	4.67	1.38
1998	12	10.93	8.25	0.94
1999	12	9.67	5.60	1.48
2000	12	13.27	3.79	0.61
2001	12	8.42	6.57	0.74
2002	12	4.61	2.98	0.39
2003	12	0.70	5.93	0.58
2004	12	5.90	2.28	0.84
2005	12	6.92	5.26	0.47
2006	12	3.99	3.73	0.23
2007	12	8.87	4.08	0.43
2008	12	1.91	2.76	0.43
2009	11	1.71	1.79	0.60
2010	12	12.81	1.90	0.63
2011	12	2.83	4.76	0.95
2012	12	4.90	5.54	1.21
2013	11	6.54	2.09	0.49
2014	12	1.98	4.02	0.72
2015	12	2.60	1.52	1.08
2016	11	3.30	1.59	1.13
2017	12	4.83	2.51	1.19
2018	12	3.78	2.68	0.89
2019	12	0.16	2.54	0.52

Table 16: Annual means (calculated using GLM) of fry (age-0), age-1, and age-2 and older parr Atlantic Salmon densities (number per 100 m^2) in the Nashwaak River, downriver of Mactaquac Dam, estimated during electrofishing surveys between 1970 to 2019. No survey took place in 1980. Period (.) equals no data.

Year	No.	Age-0 density LSMEAN	Age-1 density LSMEAN	Age-2 density LSMEAN
1970	3	22.33	3.76	7.41
1971	7	58.43	7.43	7.86
1972	7	28.11	2.49	15.83
1973	7	32.69	0.13	12.39
1974	7	68.94	2.29	9.14
1975	7	63.21	15.10	11.81
1976	7	42.14	10.91	2.91
1977	7	28.59	12.37	2.63
1978	7	55.46	7.73	3.71
1979	5	65.60	15.87	4.79
1980	0	.	.	.
1981	6	59.64	15.36	4.51
1982	7	41.87	10.50	3.23
1983	7	22.89	6.97	2.87
1984	7	38.43	5.61	1.73
1985	7	40.34	6.27	2.49
1986	7	42.13	7.89	2.19
1987	7	59.61	11.21	0.79
1988	7	52.27	9.47	0.69
1989	7	47.67	9.04	1.63
1990	7	38.24	9.14	0.86
1991	7	32.57	8.97	1.11
1992	7	29.06	13.84	0.79
1993	7	14.03	6.49	1.39
1994	7	4.61	3.07	0.64
1995	7	11.60	8.09	1.51
1996	7	9.83	3.91	0.69
1997	7	15.19	5.39	0.83
1998	7	3.36	4.30	0.70
1999	7	8.66	4.10	1.34
2000	7	14.89	4.63	0.13
2001	7	12.14	11.09	1.47
2002	7	17.63	6.17	1.33
2003	7	4.13	4.70	0.71
2004	7	4.19	2.36	0.50
2005	7	6.13	4.64	0.50
2006	6	5.03	3.40	0.51
2007	7	4.74	3.44	0.49
2008	7	5.01	5.27	0.94
2009	7	5.23	3.13	0.70
2010	7	14.53	4.93	0.81
2011	6	1.80	3.91	0.07
2012	7	12.93	2.53	1.49
2013	6	1.26	7.04	0.63
2014	7	4.04	2.54	1.21
2015	7	1.16	1.45	1.10
2016	7	2.81	0.41	0.70
2017	7	4.03	1.97	1.03
2018	7	1.21	3.60	0.25
2019	7	1.00	1.71	0.67

FIGURES

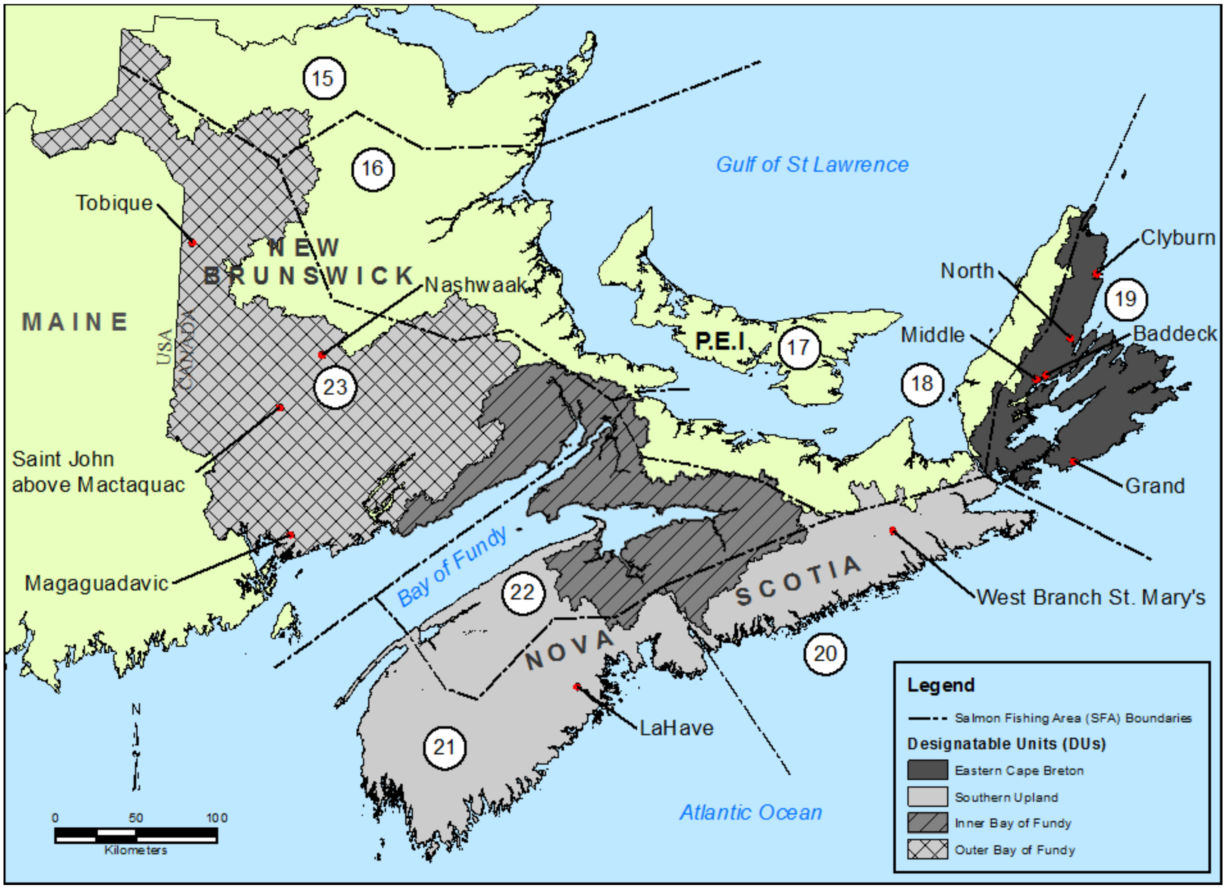


Figure 1: Map showing the locations of Atlantic Salmon rivers where monitoring predominately occurred, Salmon Fishing Areas (SFAs), and Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Designatable Units (DUs) mentioned in this update. SFA numbers are labeled inside the white circles. 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).

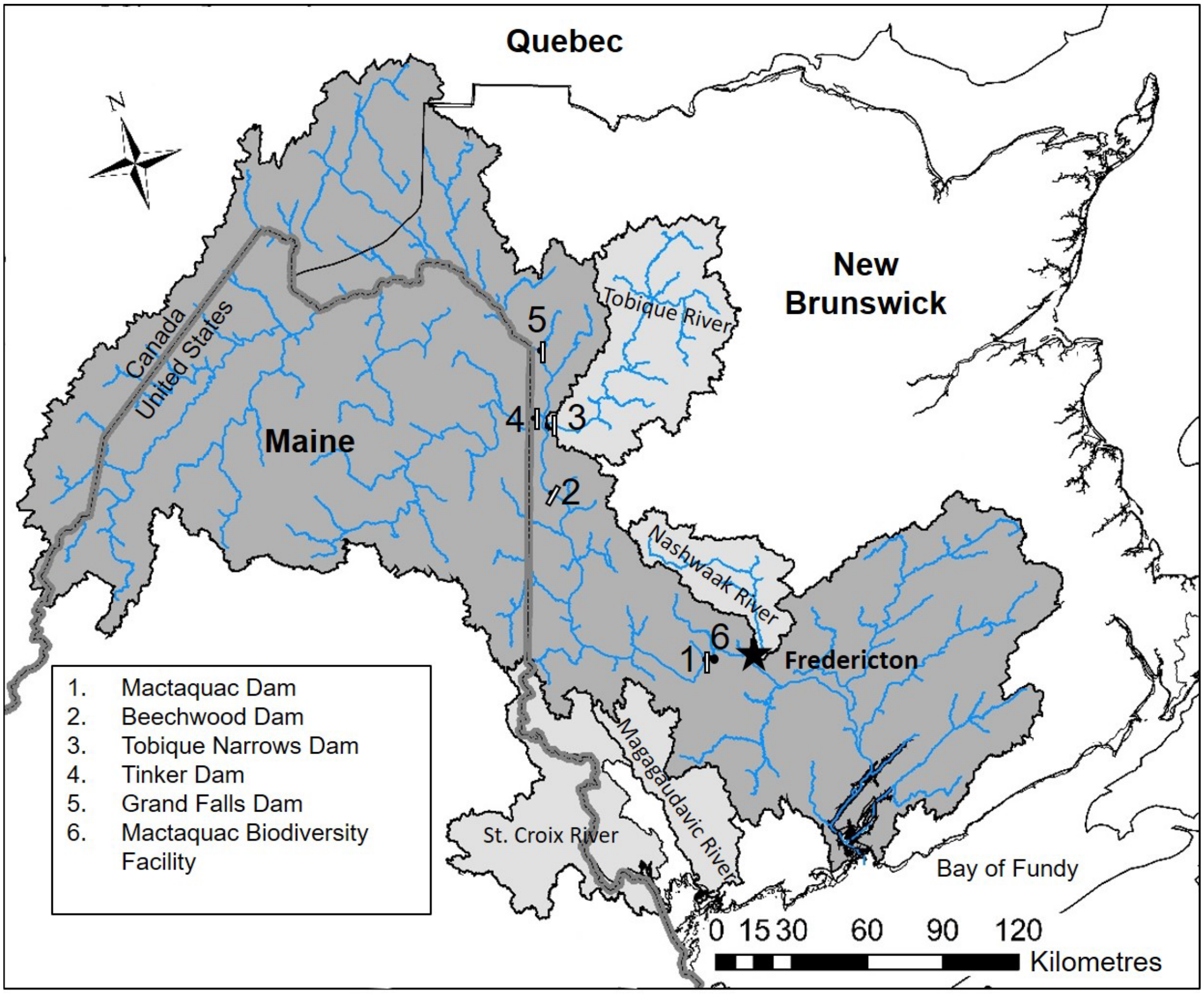


Figure 2: Map of the Magaguadavic, St. Croix and Saint John rivers' drainages including: Tobique and Nashwaak rivers and the location of five major hydroelectric dams on the Saint John River and DFO's Mactaquac Biodiversity Facility.

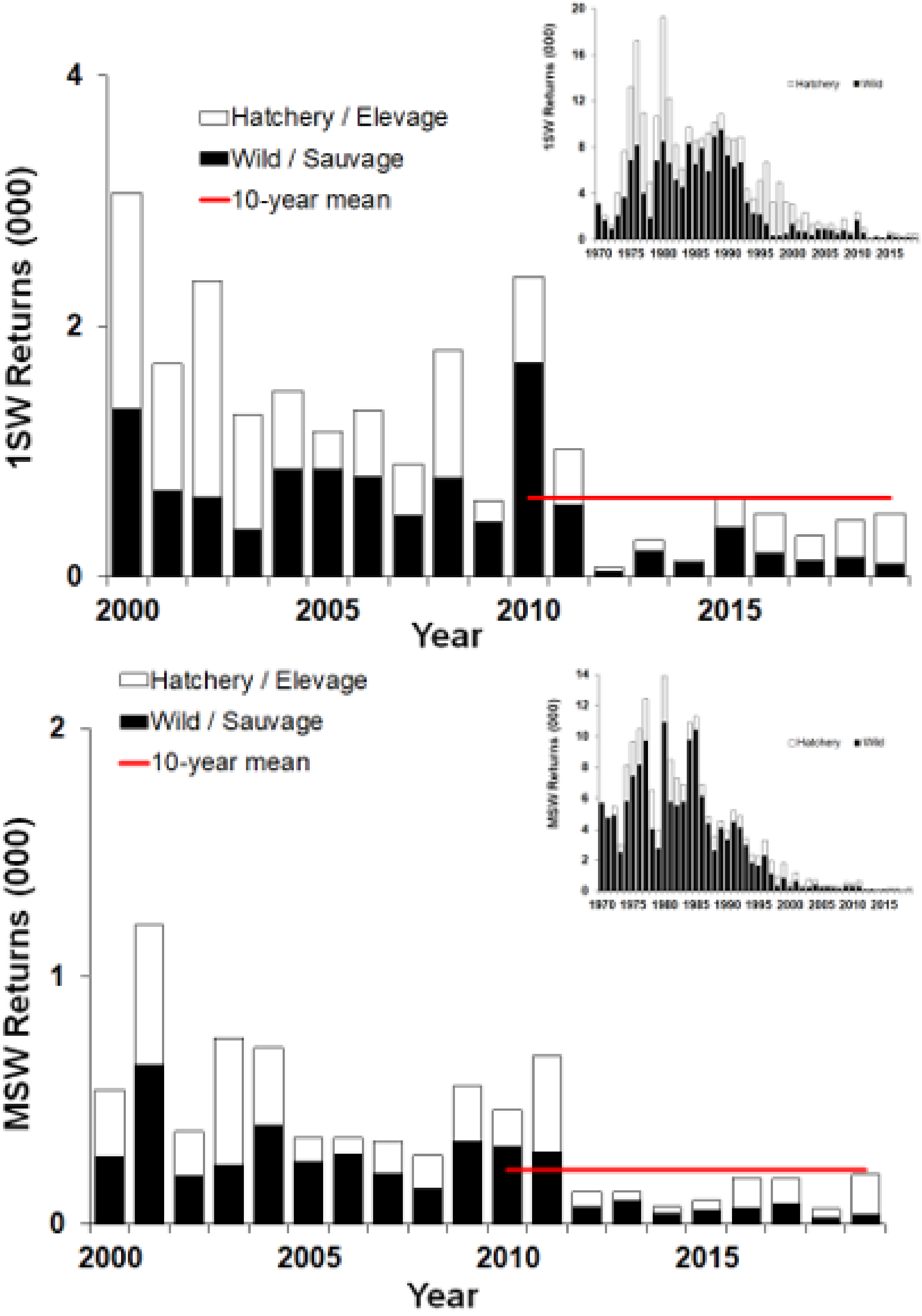


Figure 3: Estimated wild and hatchery-origin one-sea-winter (1SW) and multi-sea-winter (MSW) Atlantic Salmon returns destined for upriver of Mactaquac Dam, Saint John River, 1970–2019. The 'wild-origin' 1SW (since 2008) and MSW (since 2009) returns are progeny from sea-run and captive-reared spawners (releases began in 2004).

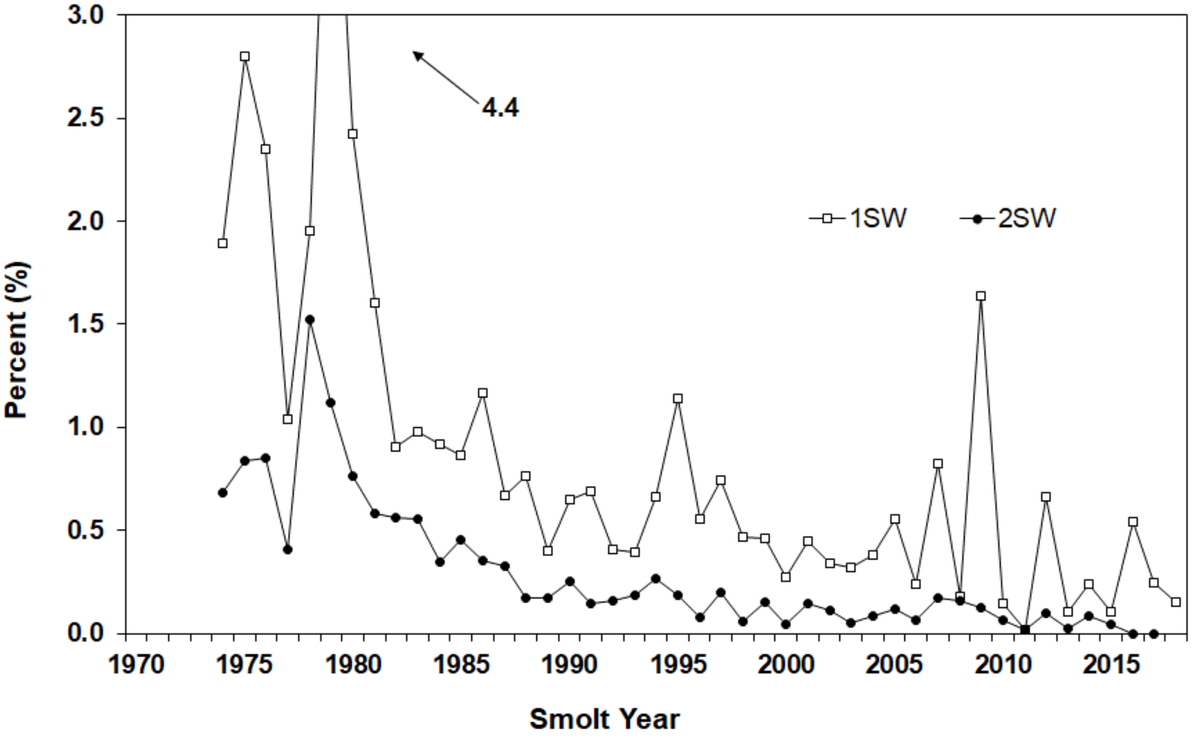


Figure 4: Return rates of hatchery reared smolts to maiden 1SW and maiden 2SW salmon destined for Mactaquac Dam on the Saint John River by smolt year, 1974–2018. Since 2006 (except 2008), all hatchery origin smolts released were progeny of captive broodstock originating in the Tobique River.

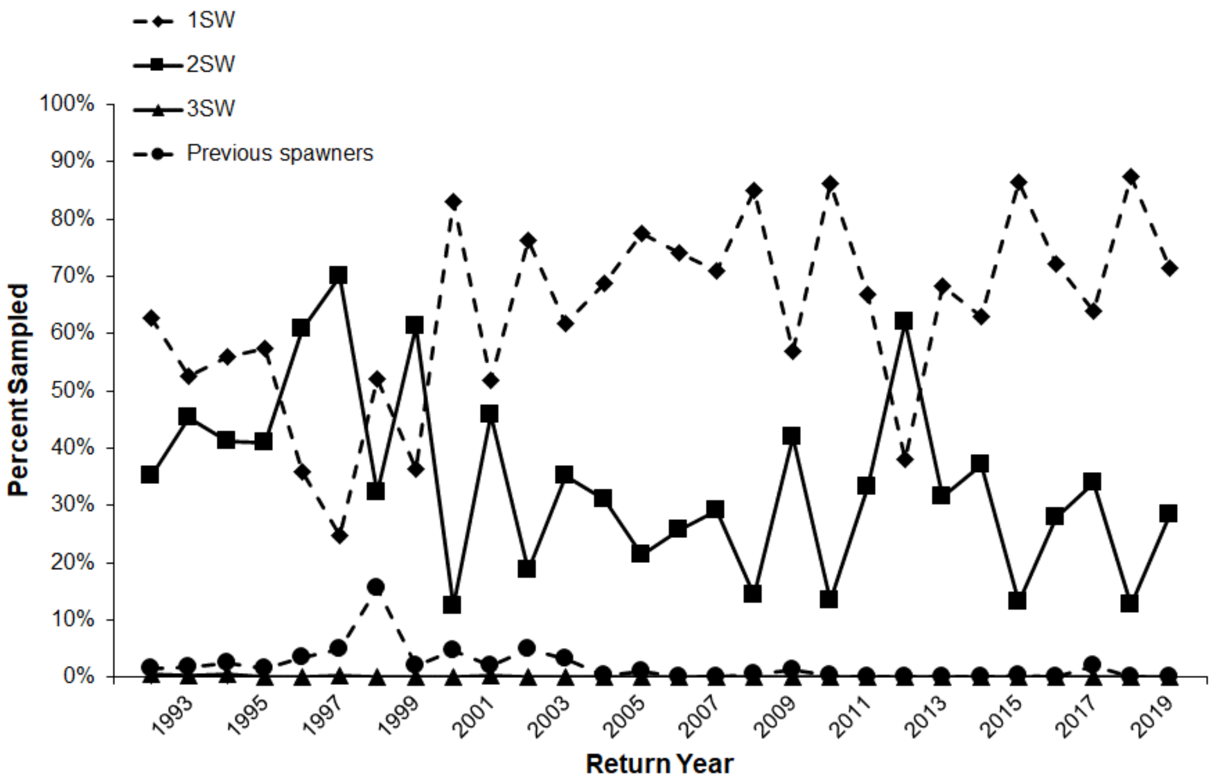


Figure 5: The percentages of wild maiden 1SW, 2SW, 3SW and previous spawning (repeat spawning) Atlantic Salmon in the total returns to the Mactaquac Dam, 1992–2019.

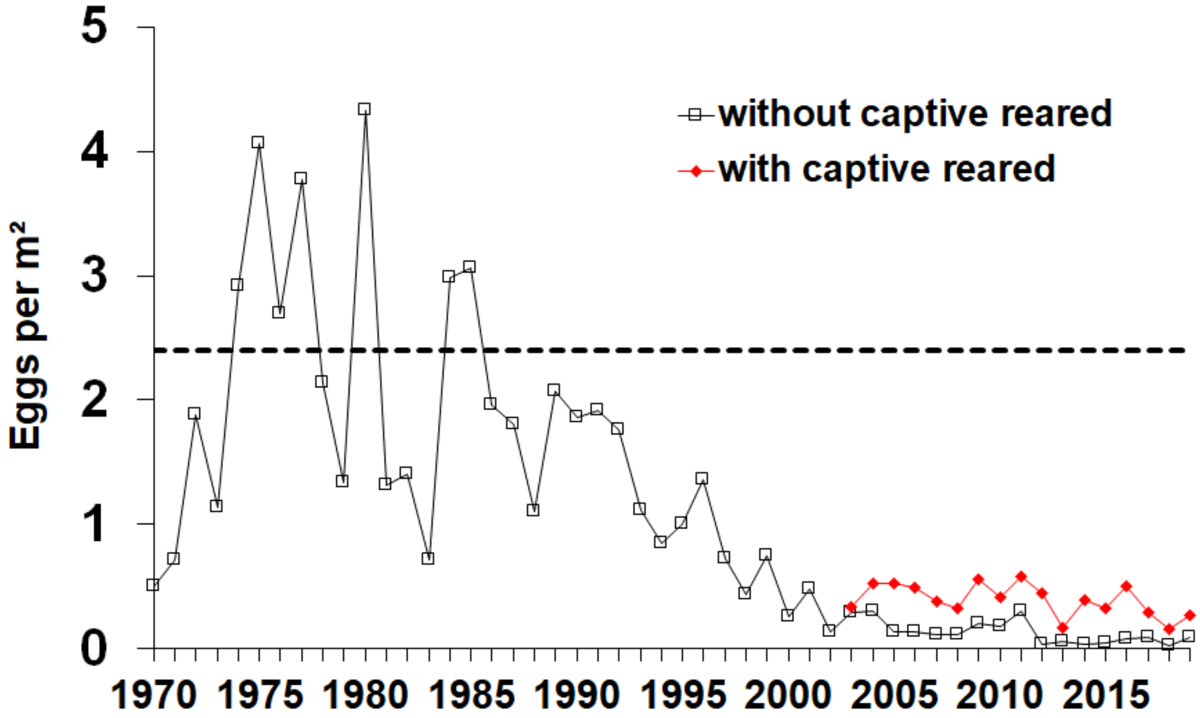


Figure 6: Estimated egg deposition upriver of Mactaquac Dam on the Saint John River, 1970–2019.

Figure 7: Map of the Nashwaak River, indicating the adult counting fence site (rectangle), RST site (triangle), smolt fence (rectangle), holding pools seined in adult recap activities (circles), and electrofishing sites (#'s).

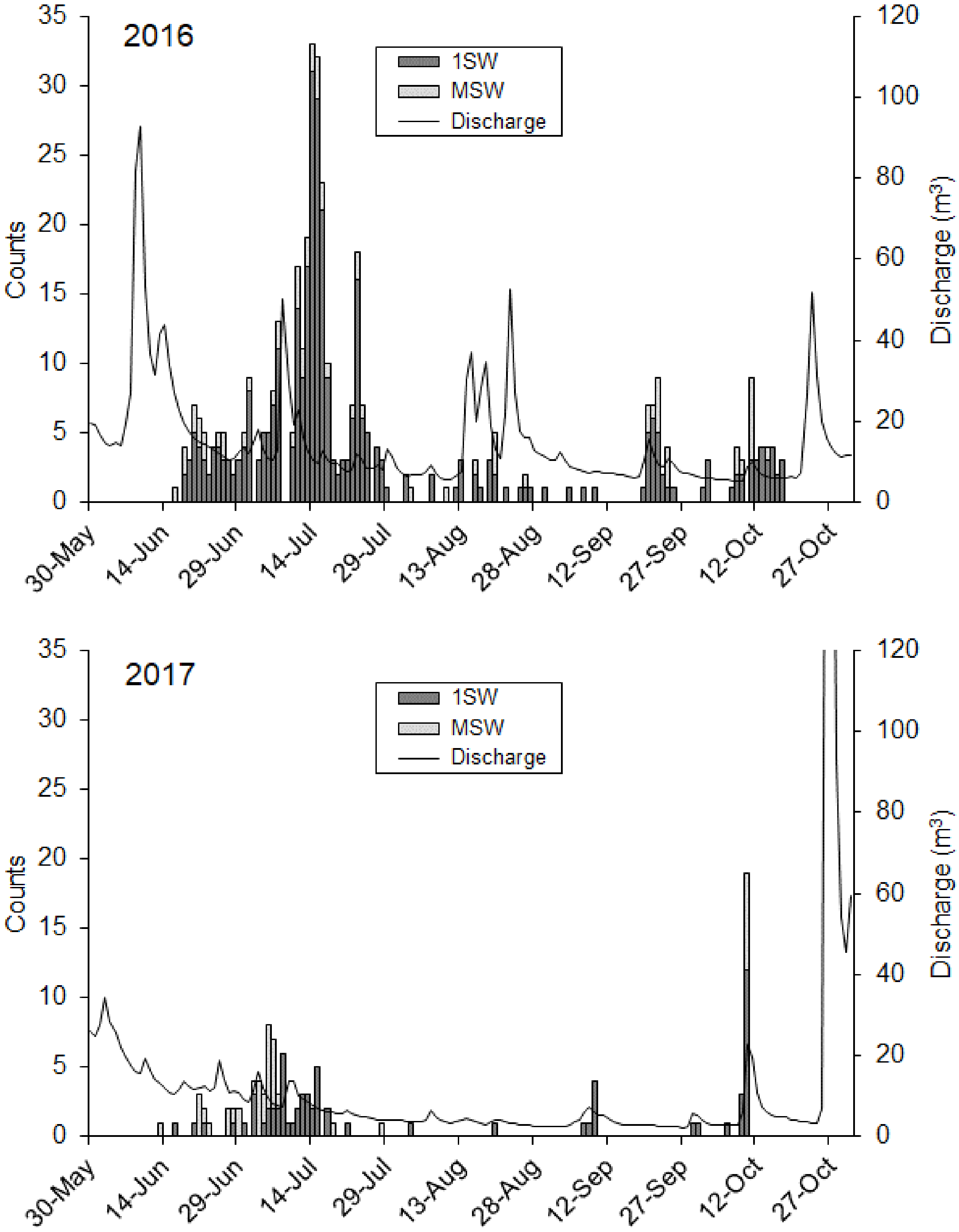
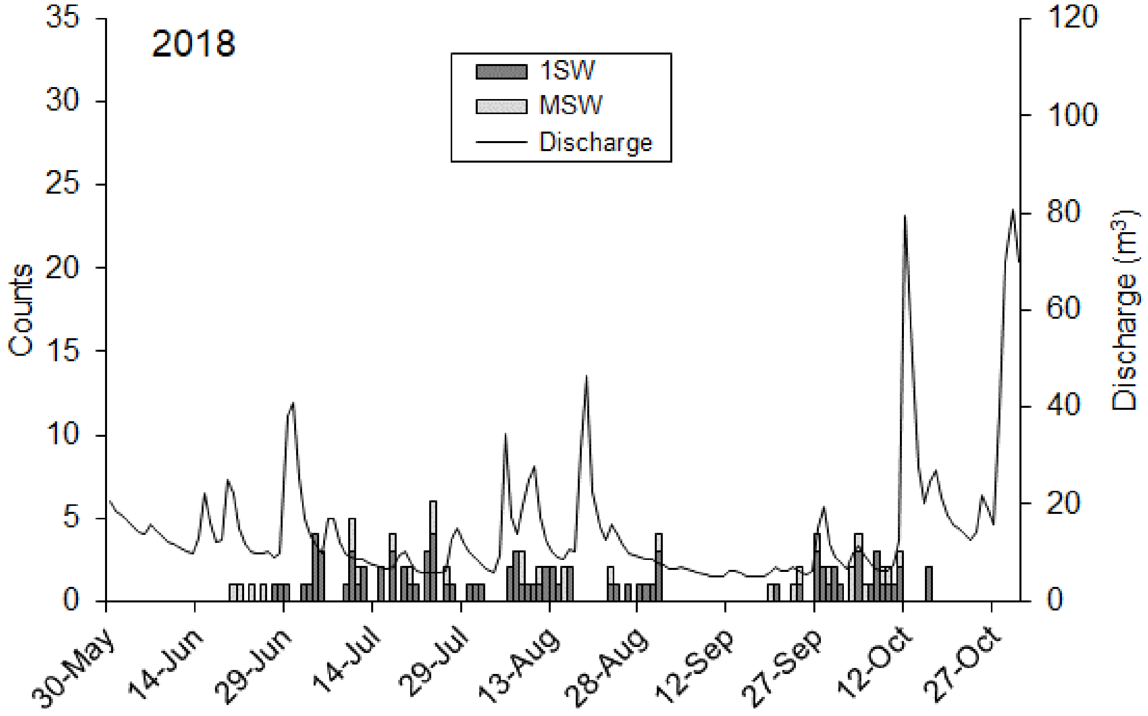


Figure 8: Average daily discharge (m³/sec) at Durham Bridge and adjusted fence counts of 1SW and MSW Atlantic Salmon on the Nashwaak River, 2016–2017.



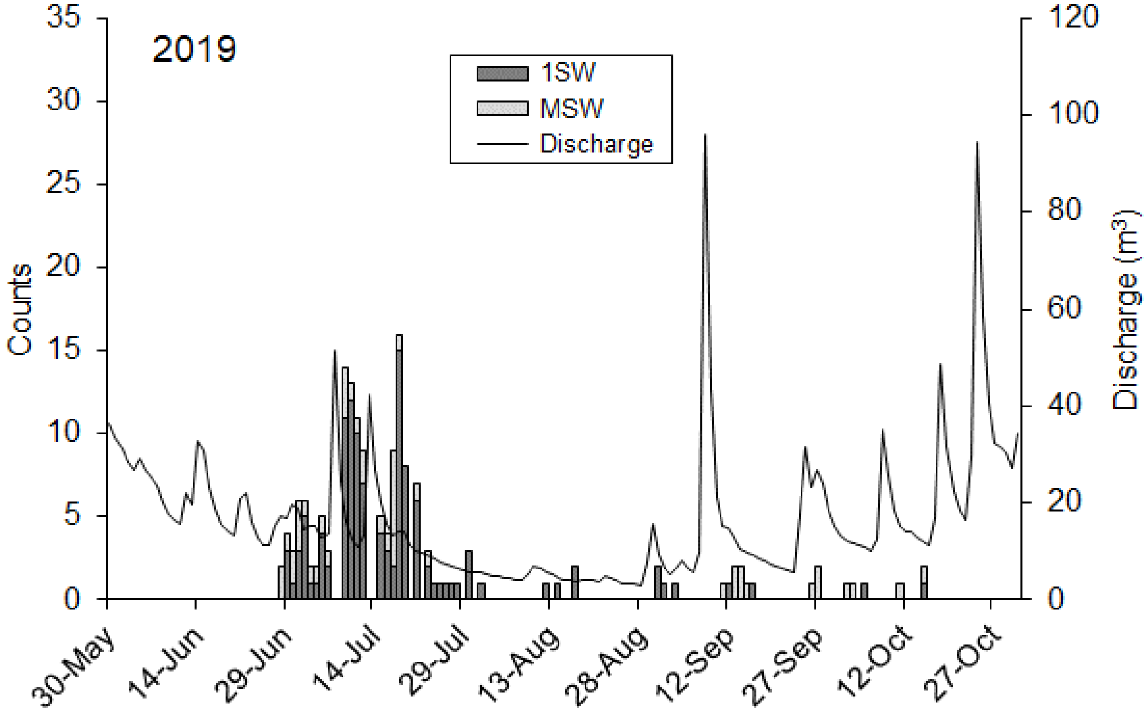


Figure 9: Average daily discharge (m³/sec) at Durham Bridge and adjusted fence counts of 1SW and MSW Atlantic Salmon on the Nashwaak River, 2018–2019.

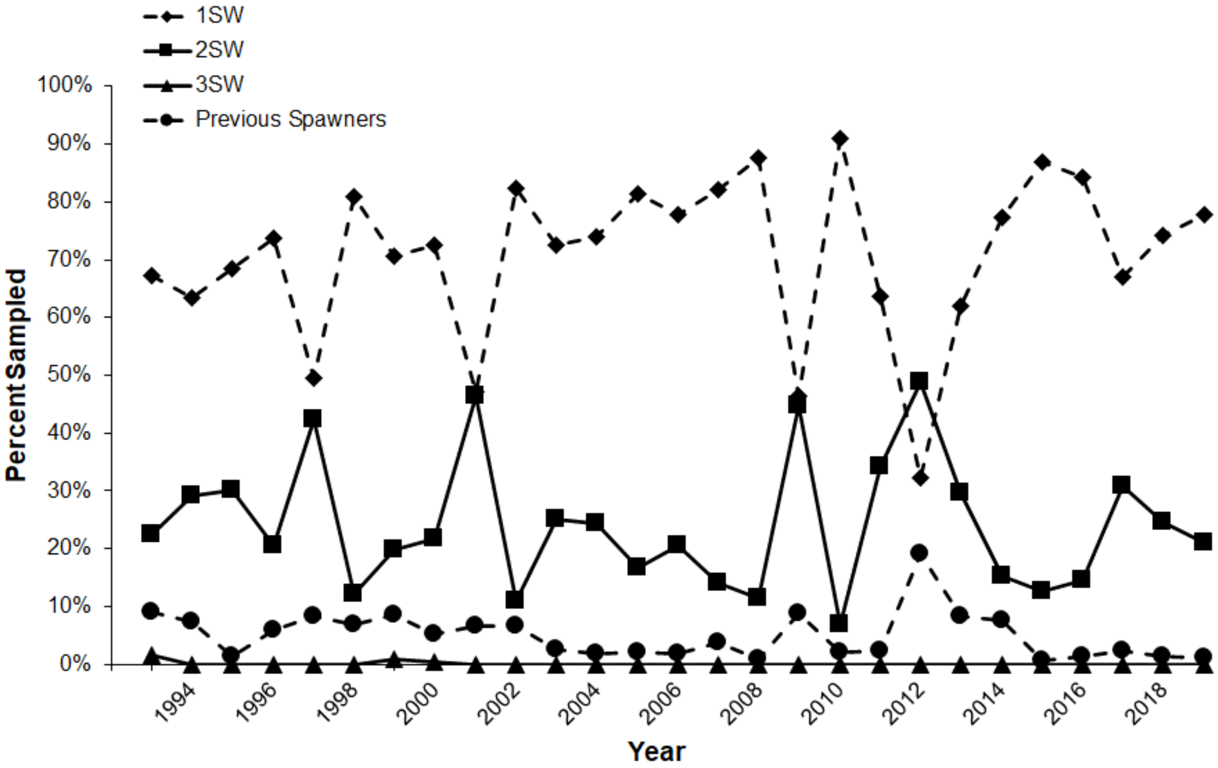


Figure 10: The percentages of wild maiden 1SW, 2SW, 3SW and previous spawning (repeat spawning) Atlantic Salmon in the total returns to the Nashwaak River, 1993–2019.

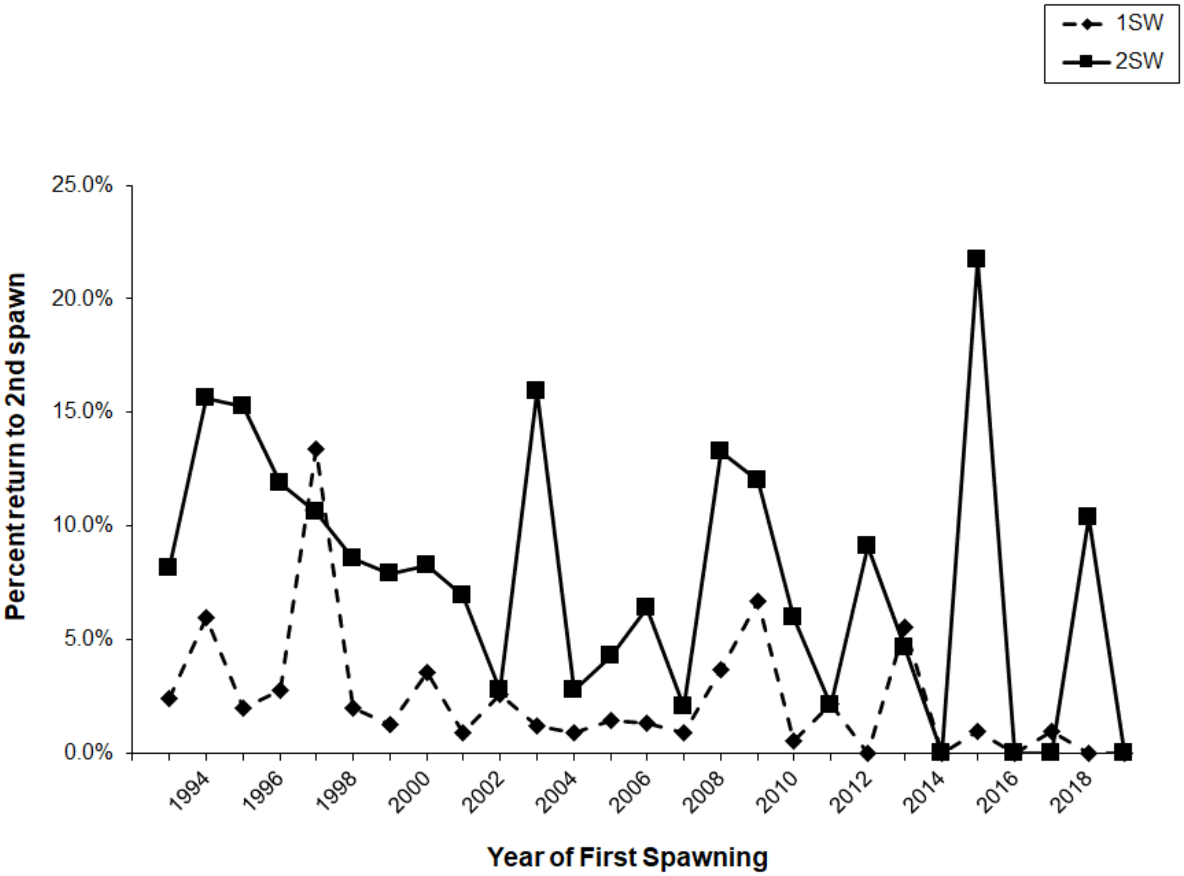


Figure 11: Percentage of maiden 1SW and 2SW Atlantic Salmon surviving to spawn as a consecutive (one year later) or alternate (two years later) repeat spawners on the Nashwaak River, 1993–2019.

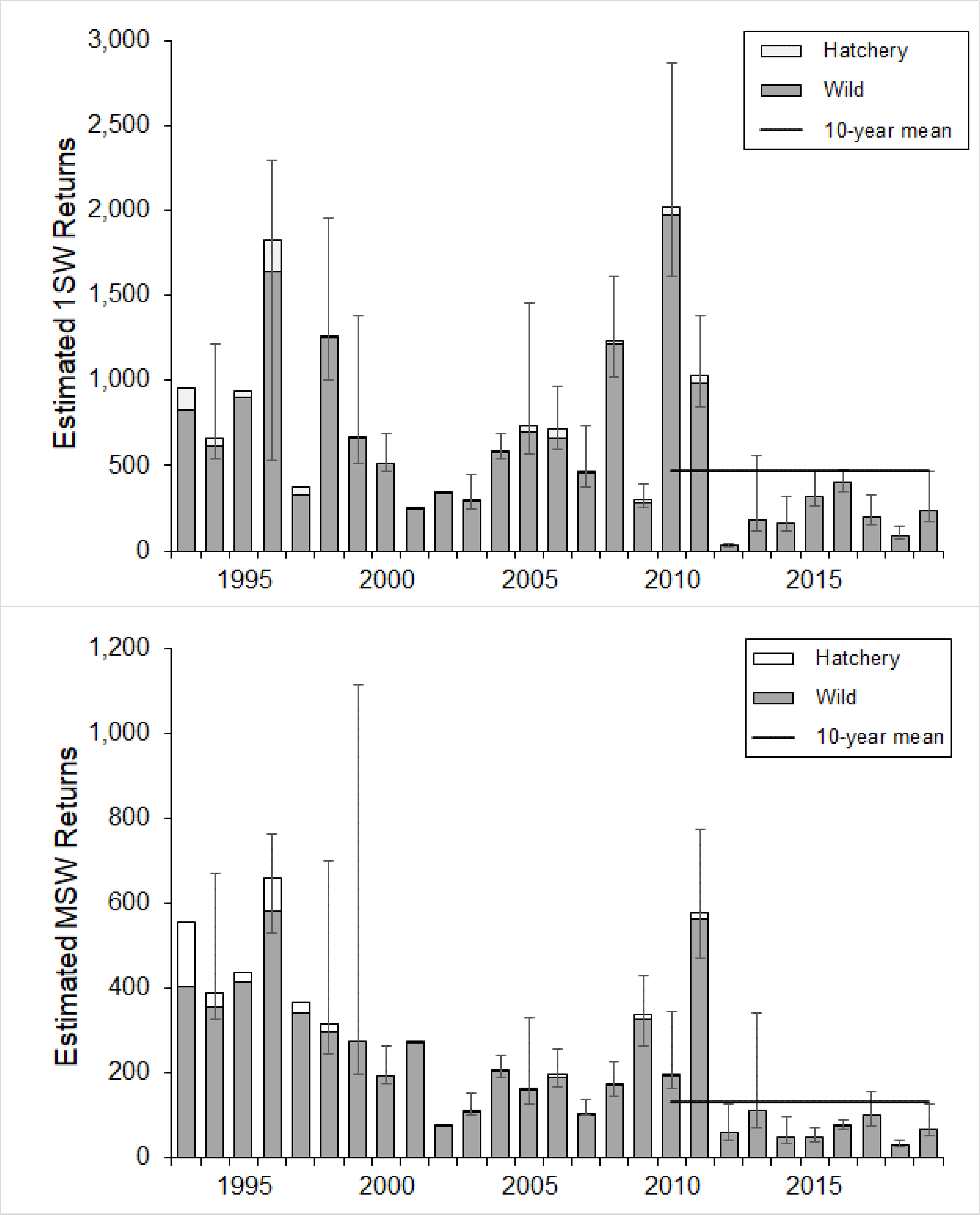


Figure 12: Estimated wild and hatchery 1SW and MSW Atlantic Salmon returns (and 2.5 and 97.5 percentiles) to the Nashwaak River, 1993–2019.

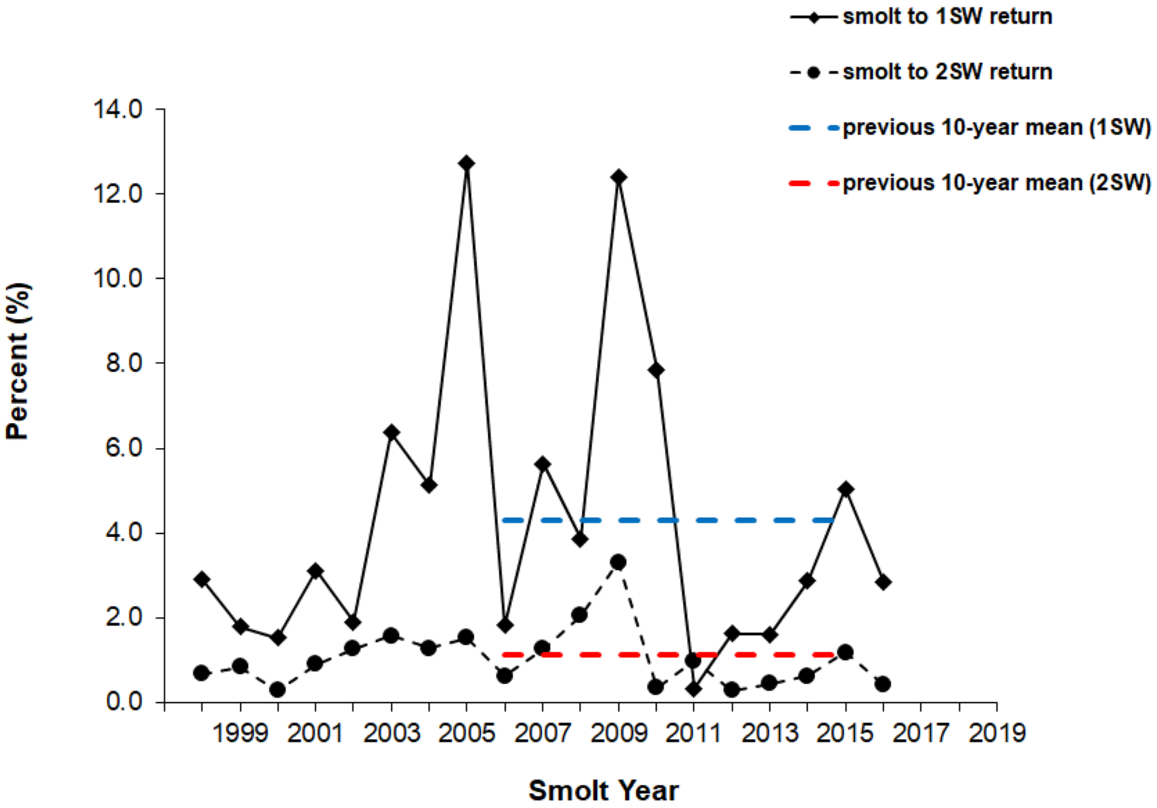


Figure 13: Estimated smolt-to-adult return rates for one-sea-winter (1SW) and maiden two-sea-winter (2SW) Atlantic Salmon on the Nashwaak River (above Durham Bridge), 1998–2019.

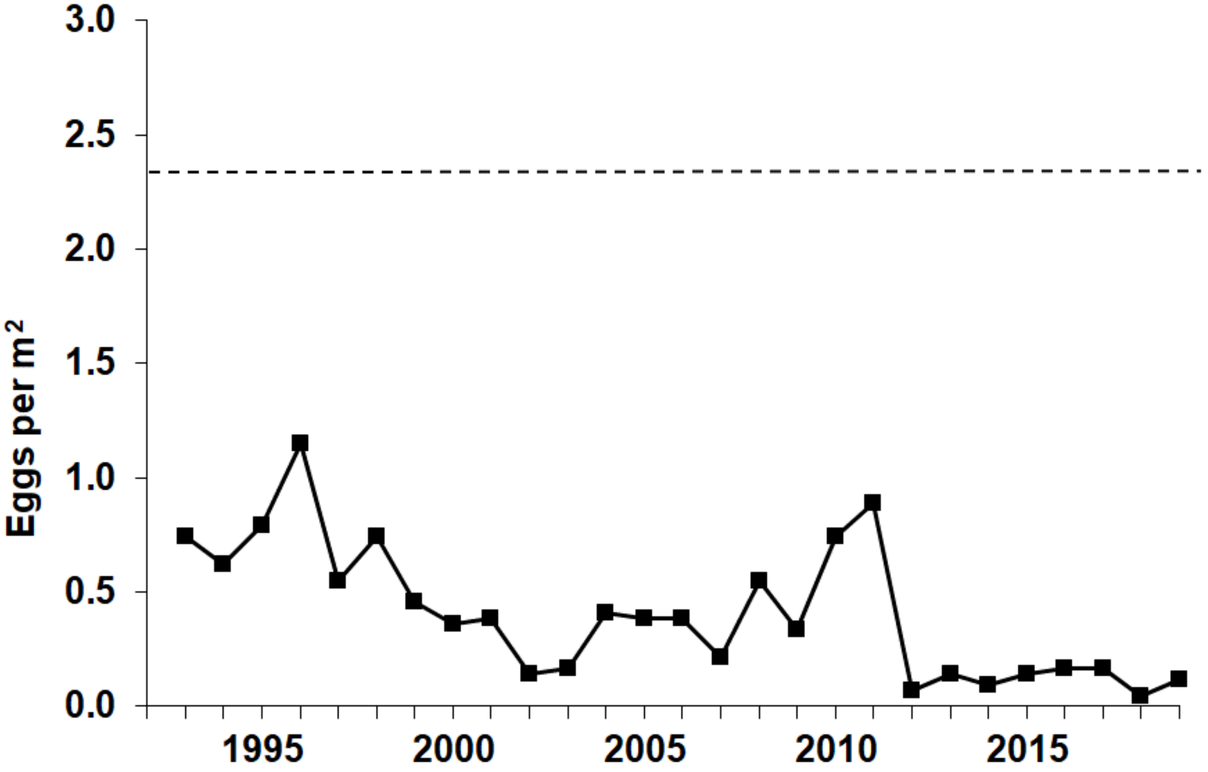


Figure 14: Estimated egg deposition per m^2 upriver of the counting fence operated just below Durham Bridge, Nashwaak River, 1993–2019. The horizontal dashed line is the conservation egg requirement (2.4 eggs per m^2).

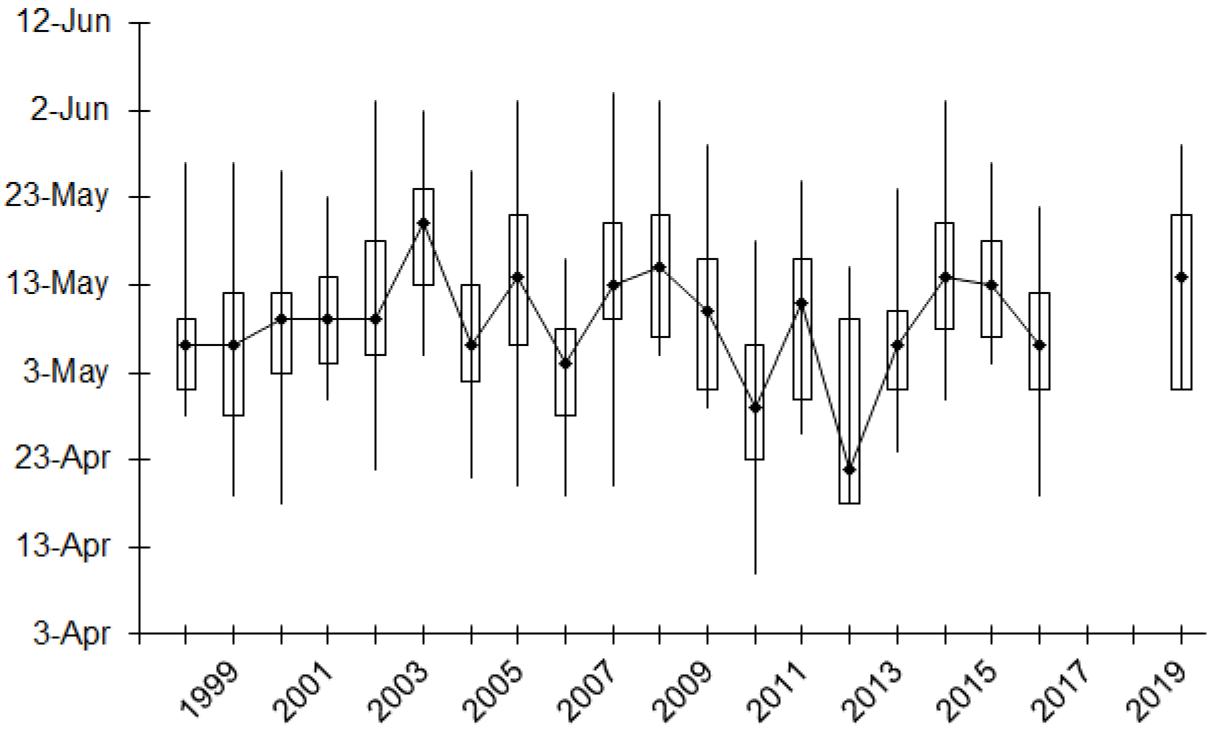


Figure 15: Distribution of smolt RST captures on the Nashwaak River by date and year; showing the first and last smolts captured, as well as the 10%, 50% and 90% cumulative proportion of catch from 1998 to 2019.

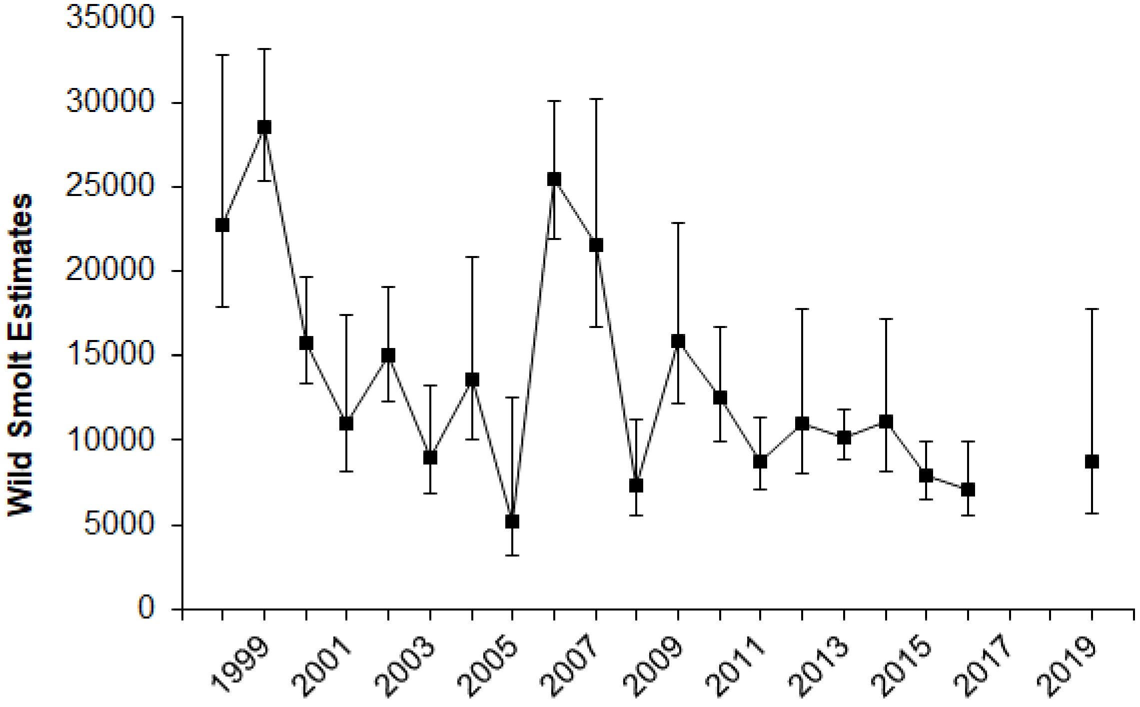


Figure 16: Estimated numbers of wild smolts (± 95% C.I.) emigrating from the Nashwaak River, 1998–2019.

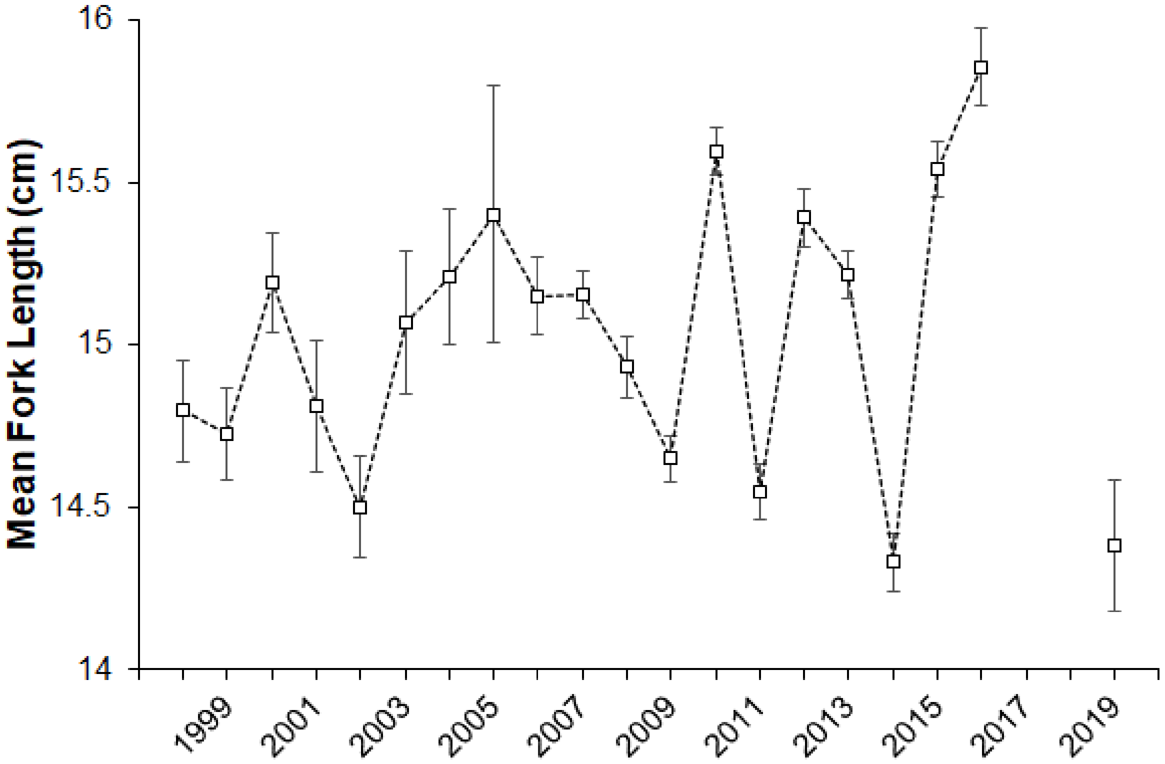


Figure 17: Mean fork length (+/- 2 times standard error) for wild smolts sampled during assessment projects on the Nashwaak (1998–2019).

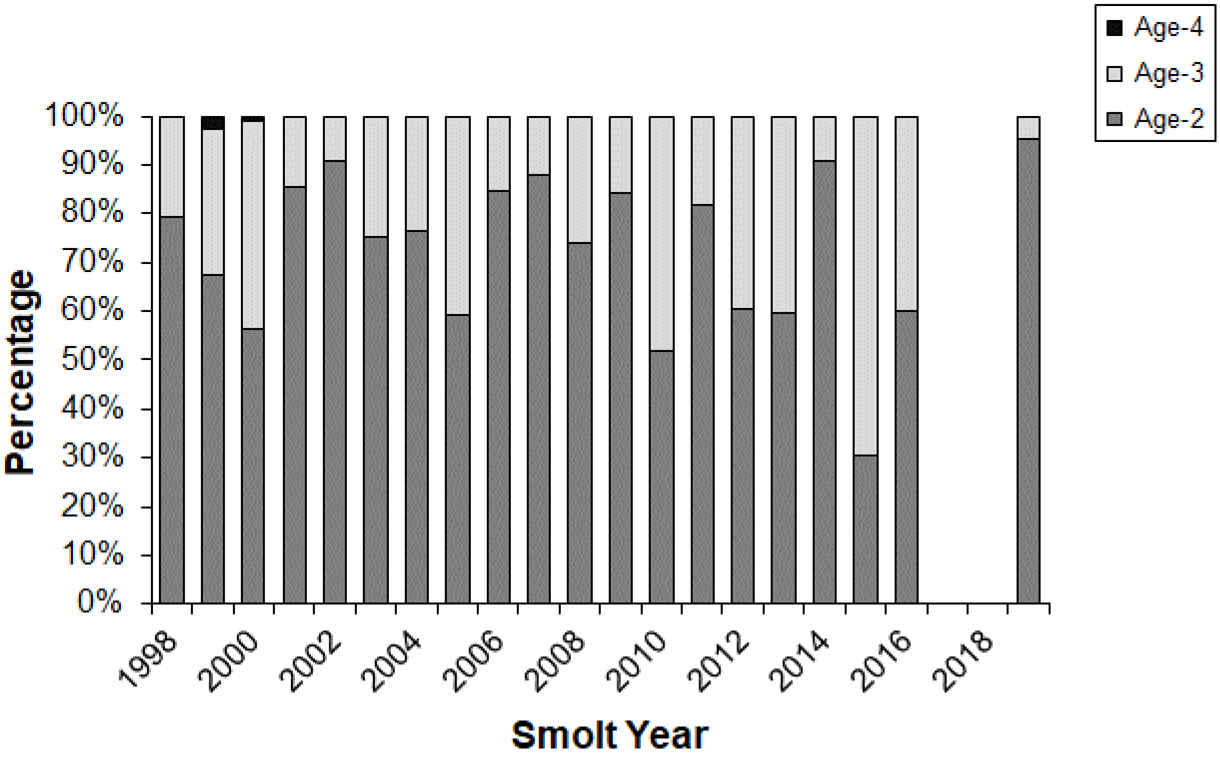


Figure 18: Percentages of age-2, age-3 and age-4 wild smolts emigrating from the Nashwaak River, 1998–2019.

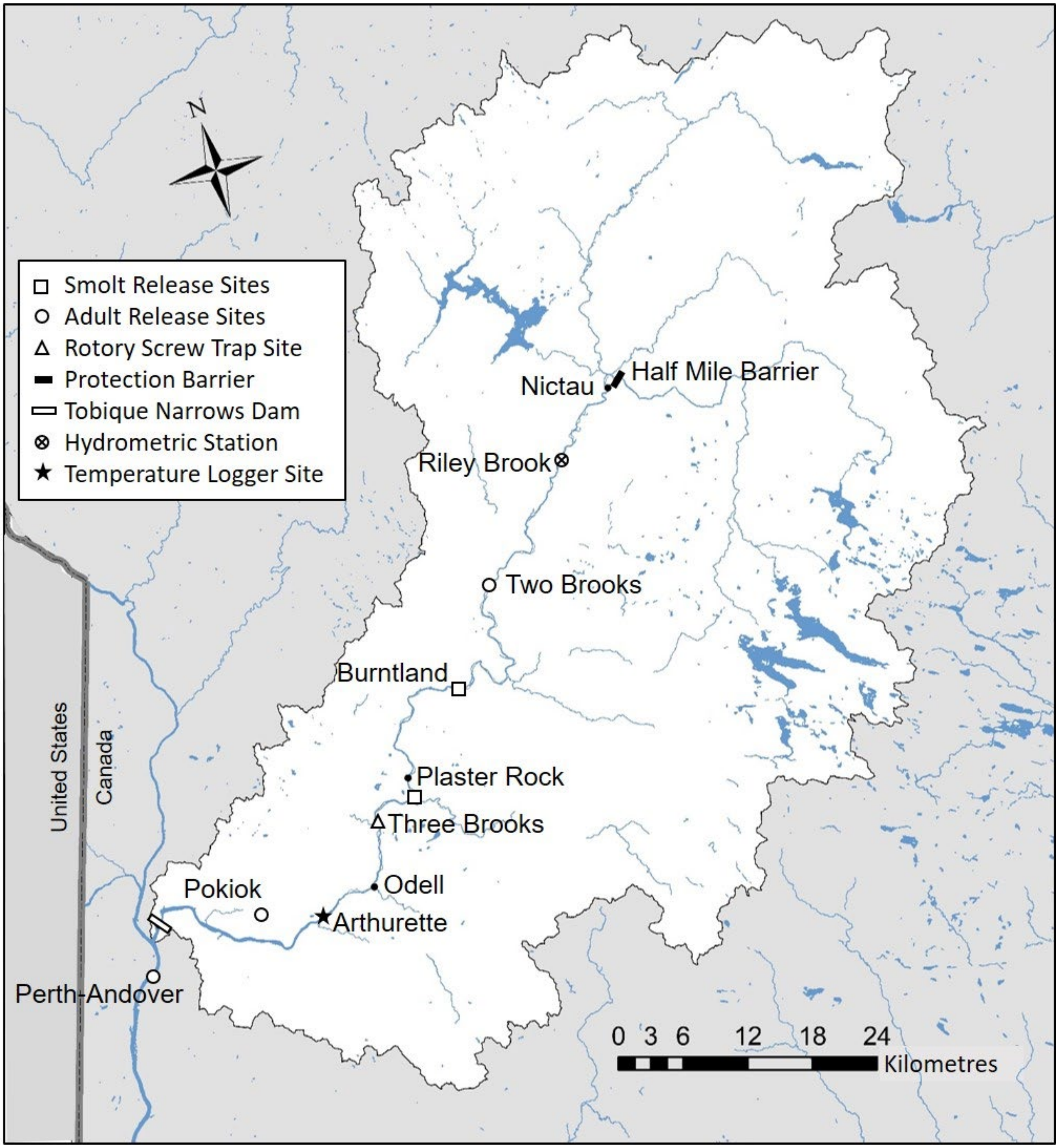


Figure 19: Map of Tobique River showing the location of the RSTs (triangle), release sites for smolts (squares) and adults (circles), the temperature recorder (star), and the half mile fish protection barrier (black rectangle).

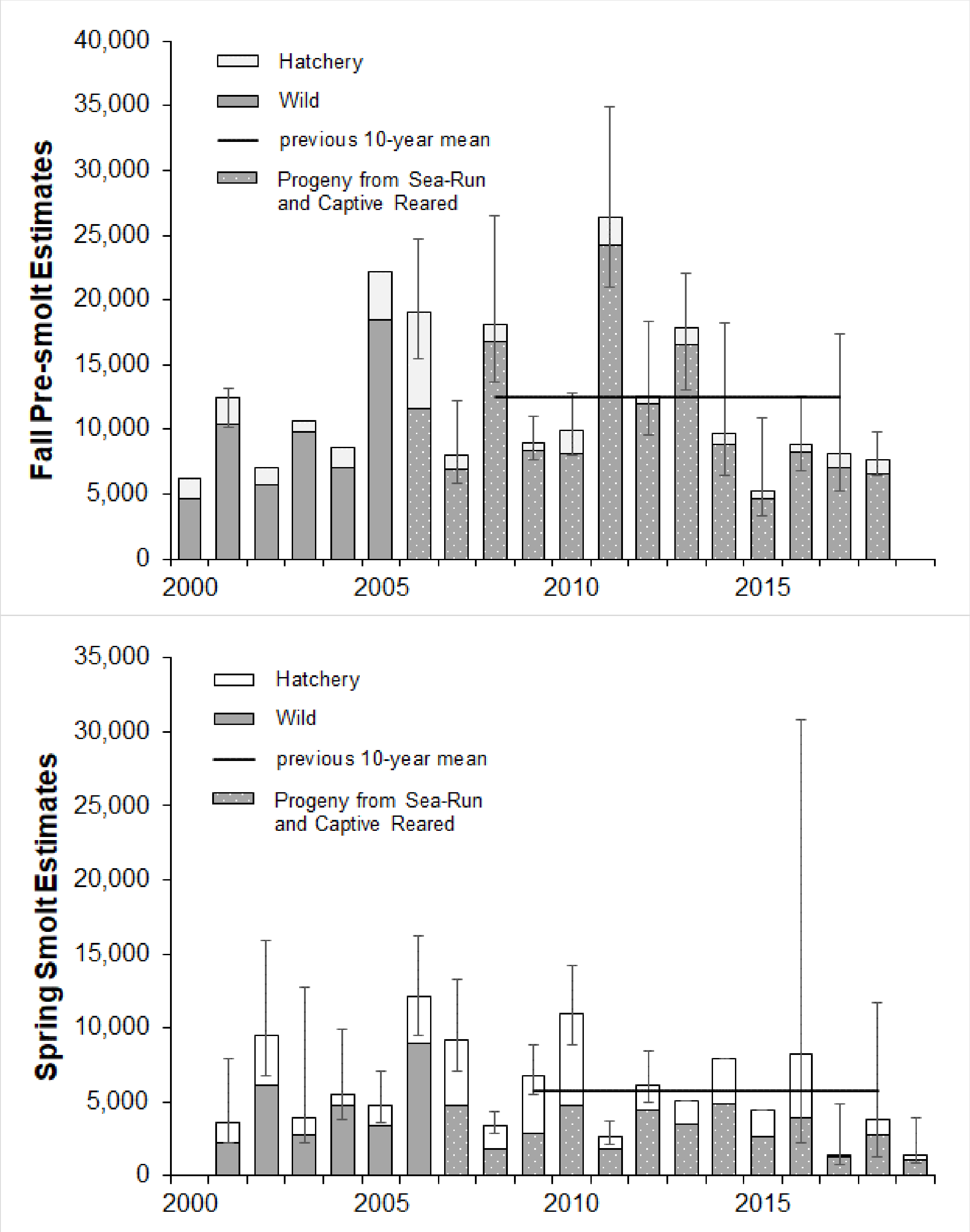


Figure 20: Estimated number (and 2.5 and 97.5 percentiles) of wild (or sea-run adults), hatchery (released as fall fingerlings) and sea-run adults/captive reared adults fall pre-smolt (upper) and spring smolts (lower) emigrating from the Tobique River, 2001 to 2019.

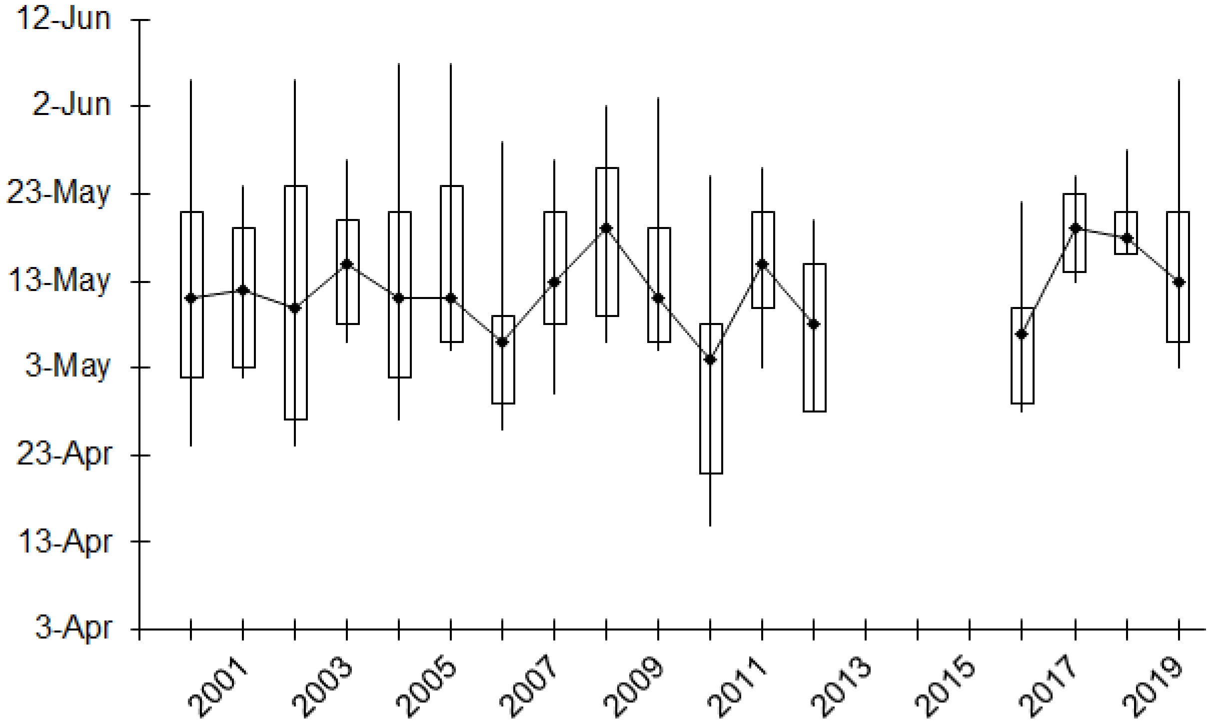


Figure 21: Distribution of wild smolt RST captures on the Tobique River (Odell: 2000 and Three Brooks: 2001–2019) by date and year; showing the first and last smolts captured, as well as the 10%, 50% and 90% cumulative proportion of catch from 2000 to 2019.

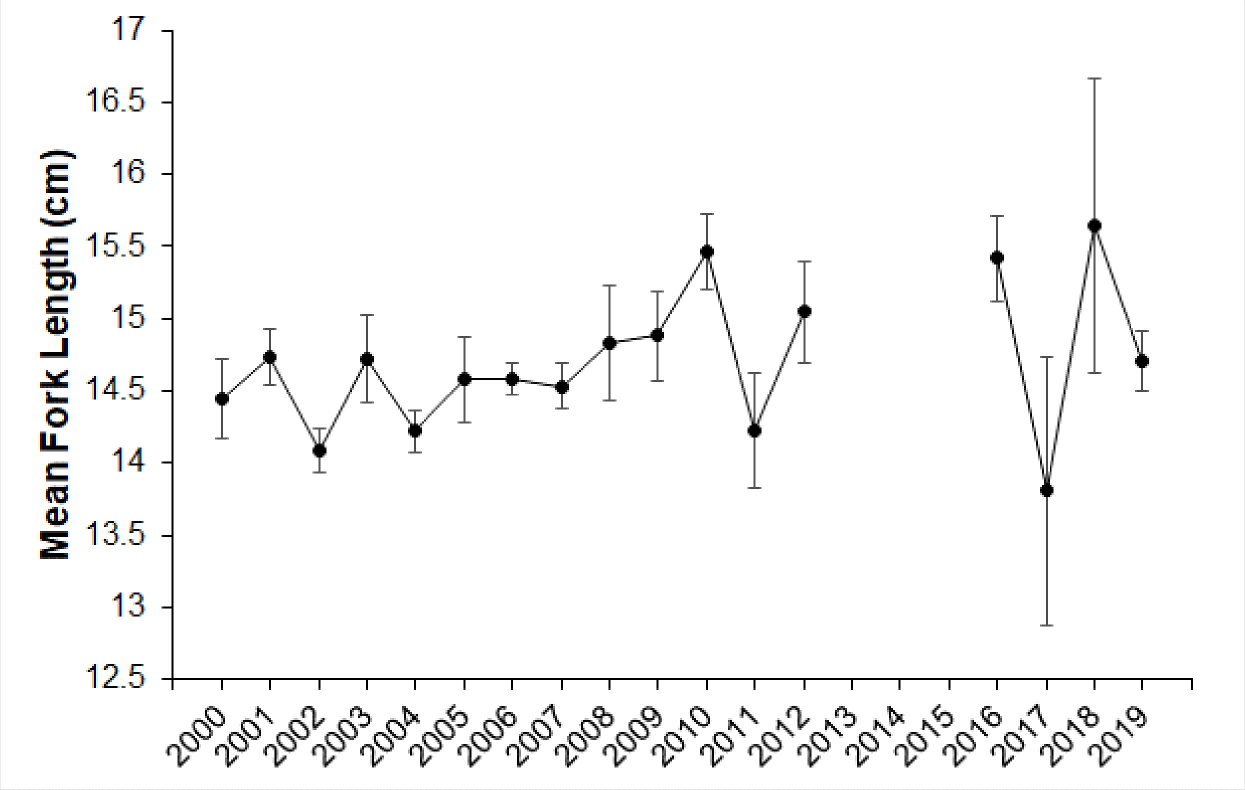


Figure 22: Mean fork length (+/- 2 times standard error) for wild smolts sampled during assessment projects on the Tobique River (2000–2019).

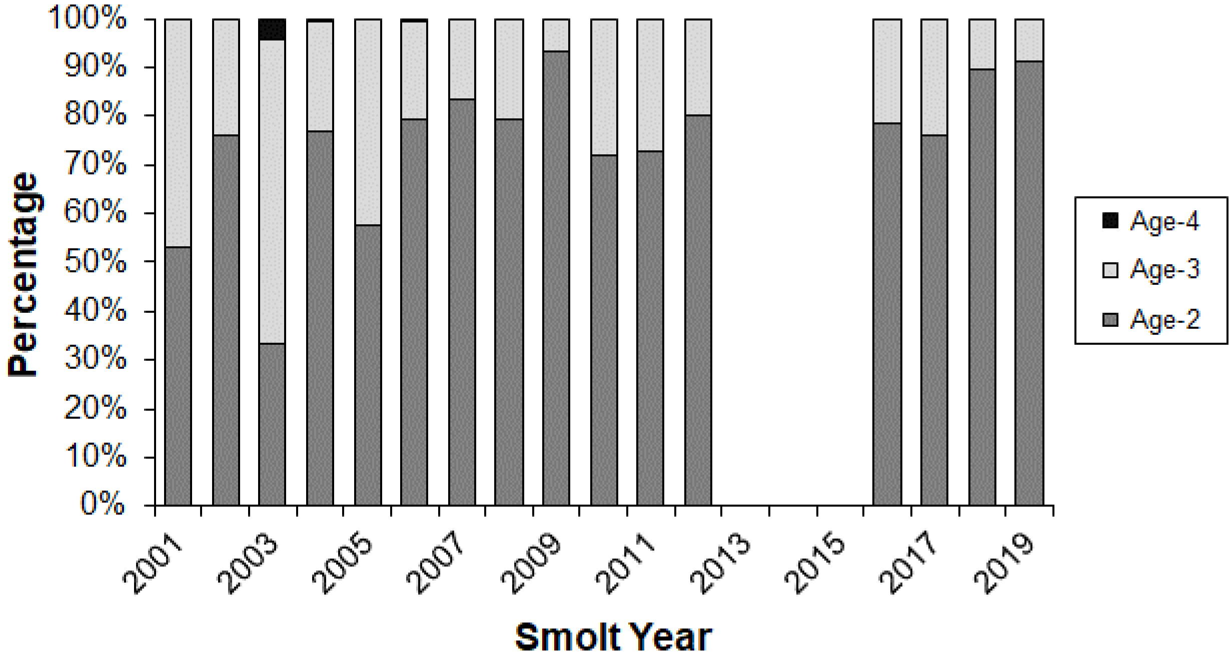


Figure 23: Percentages of age-2, age-3 and age-4 wild smolts emigrating from the Tobique River from 2001 to 2019.

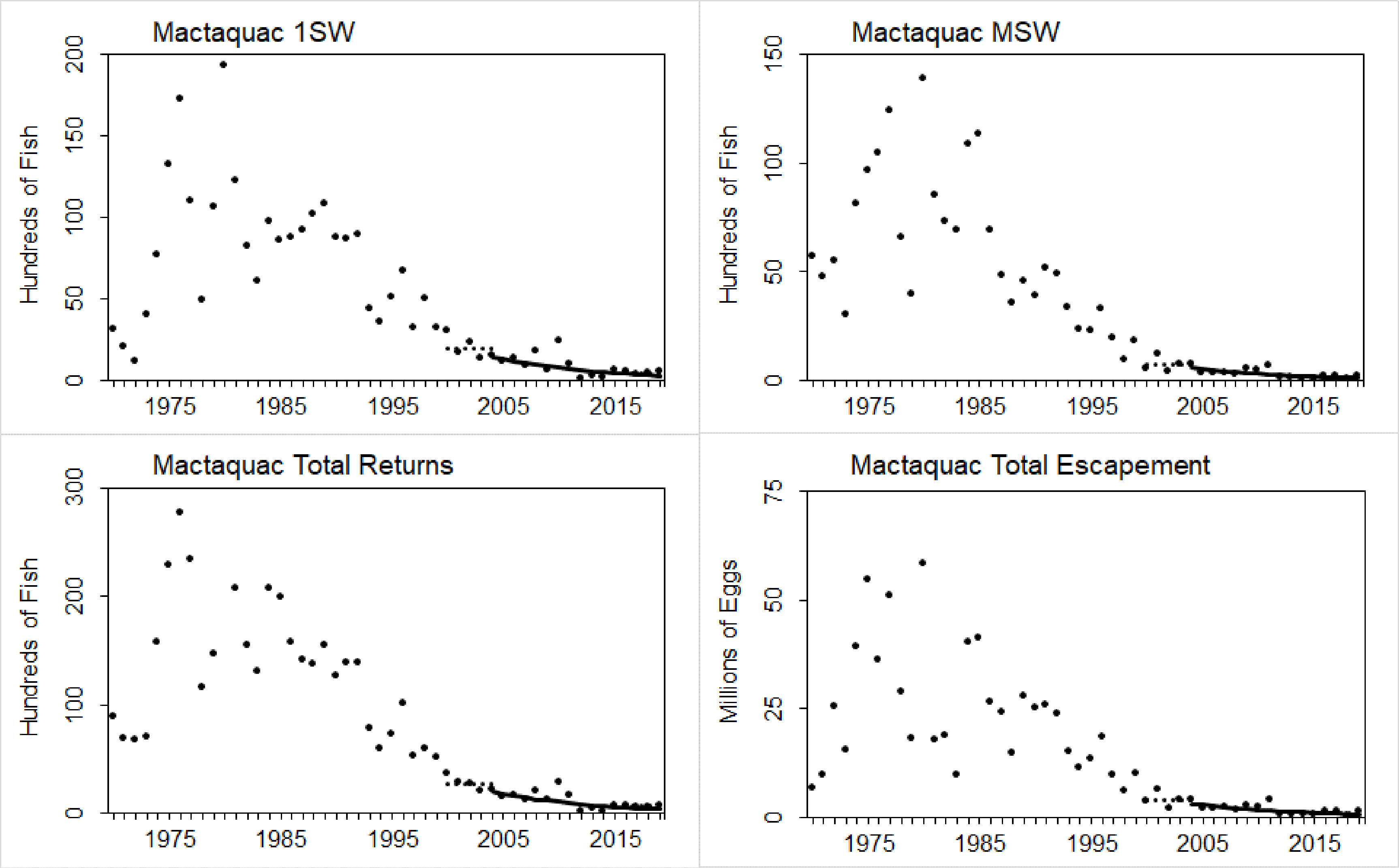


Figure 24: Trends in abundance of adult Atlantic Salmon in the Saint John River, upriver of Mactaquac Dam, during the last 15 years. The solid line is the predicted abundance from a log-linear model fit by least squares. The dashed lines show the 5-year mean abundance for two time periods ending in 2004 and in 2019. The points are the observed data. Model coefficients are provided in Table 13.

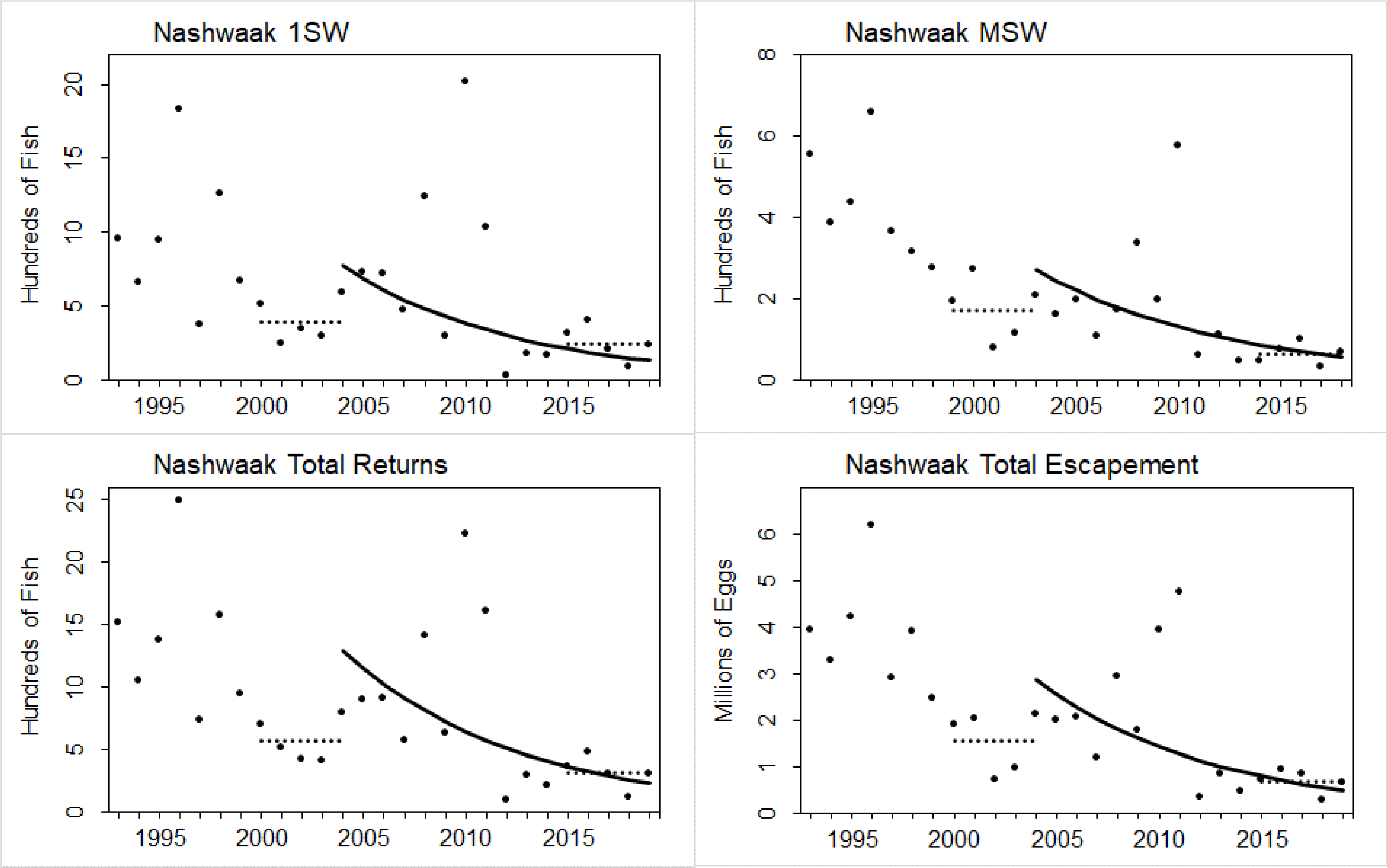


Figure 25: Trends in abundance of Atlantic Salmon returns in the Nashwaak River during the last 15 years. The solid line is the predicted abundance from a log-linear model fit by least squares over a 15- year time period. The dashed lines show the 5-year mean abundance for two time periods ending in 2004 and 2019. The points are the observed data. Model coefficients are provided in Table 13.

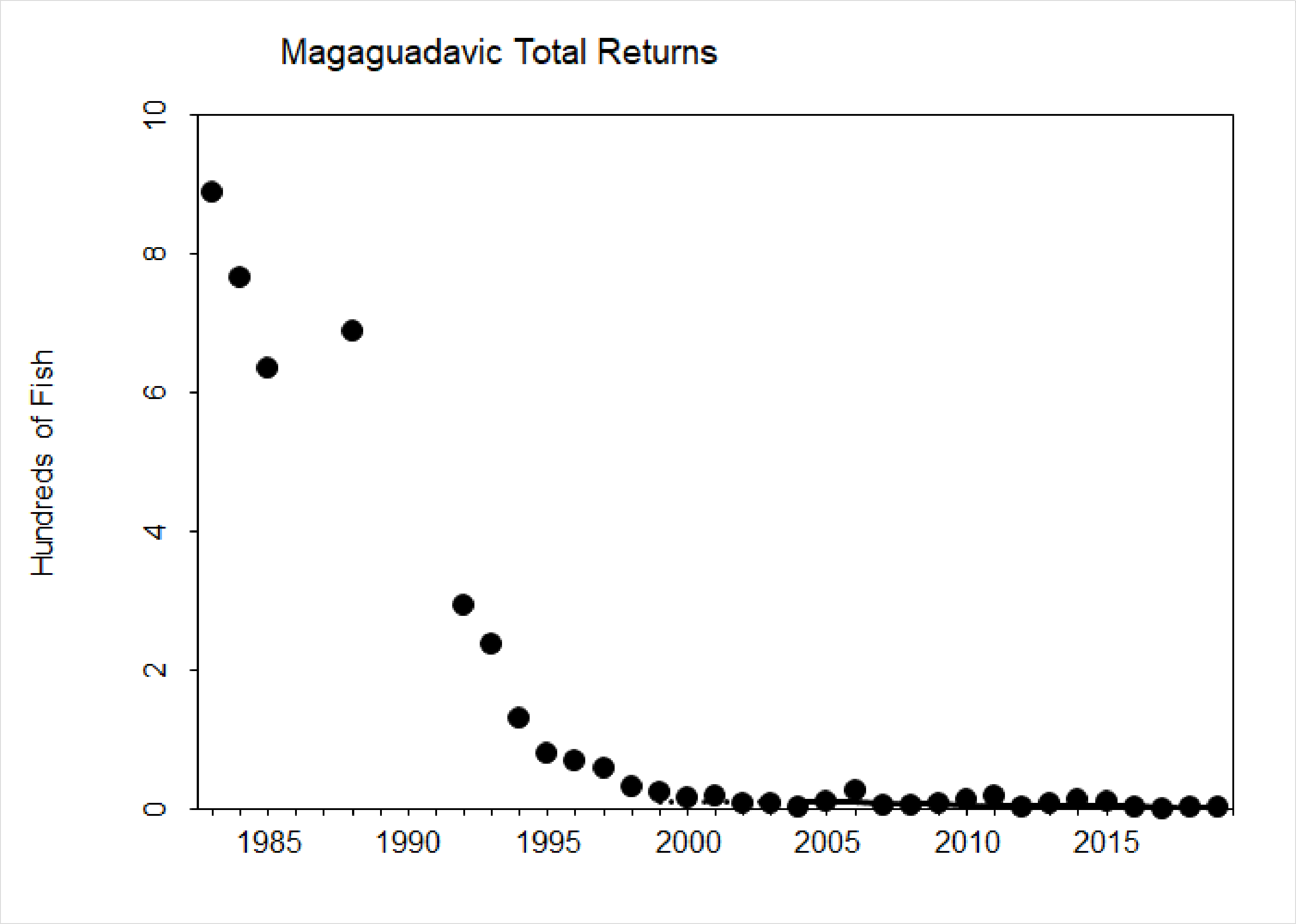


Figure 26: Trends in abundance of Atlantic Salmon returns in the Magaguadavic River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 15-year time period. The dashed lines show the 5-year mean abundance for two time periods ending in 2004 and 2019. The points are the observed data. Model coefficients are provided in Table 13.

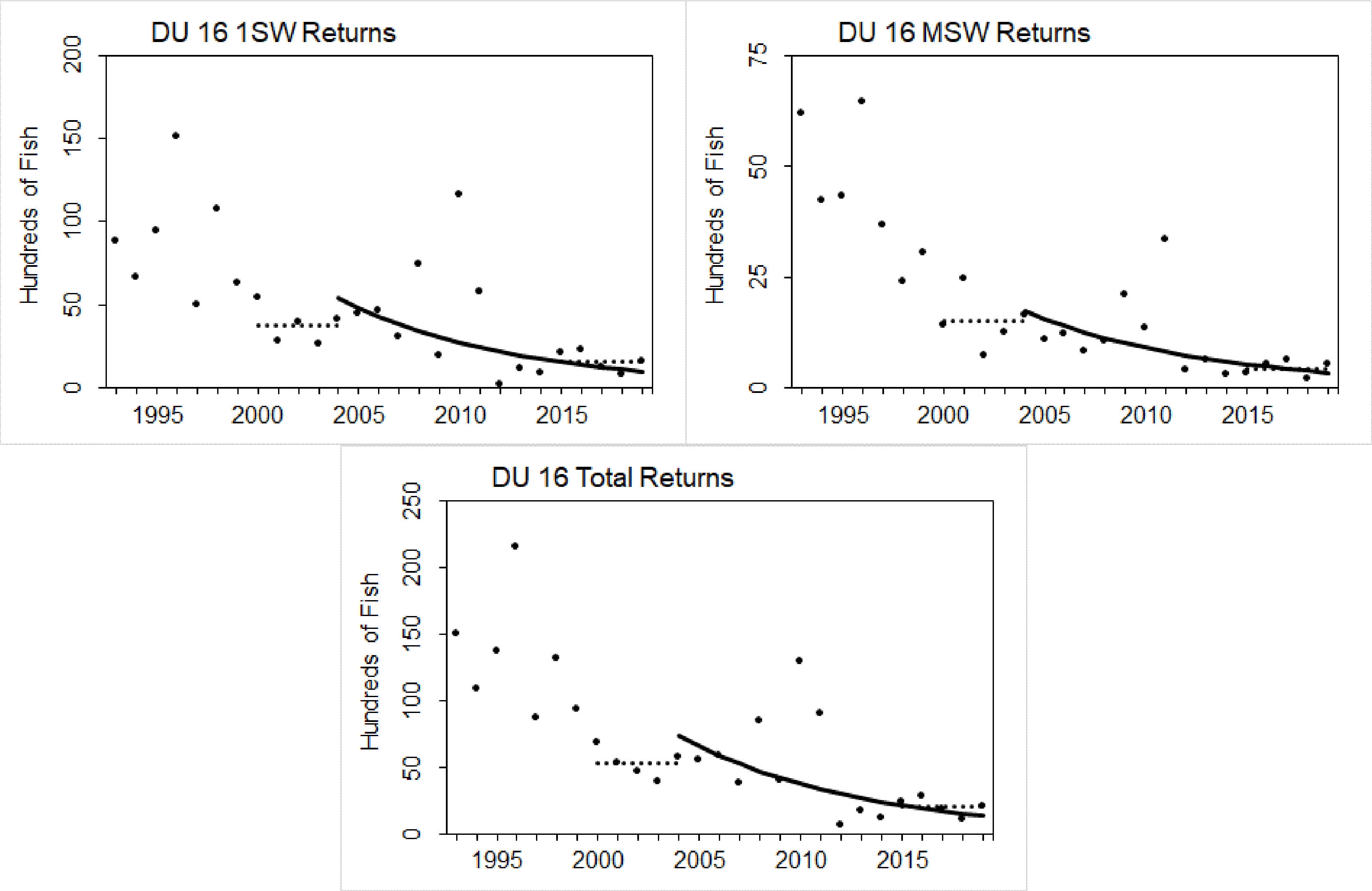


Figure 27: Trends in abundance of Atlantic Salmon returns in DU 16. The solid line is the predicted abundance from a log-linear model fit by least squares for the last 15 years. The dashed lines show the 5- year mean abundance for two time periods ending in 2004 and 2019. The points are the observed data. Model coefficients are provided in Table 13.

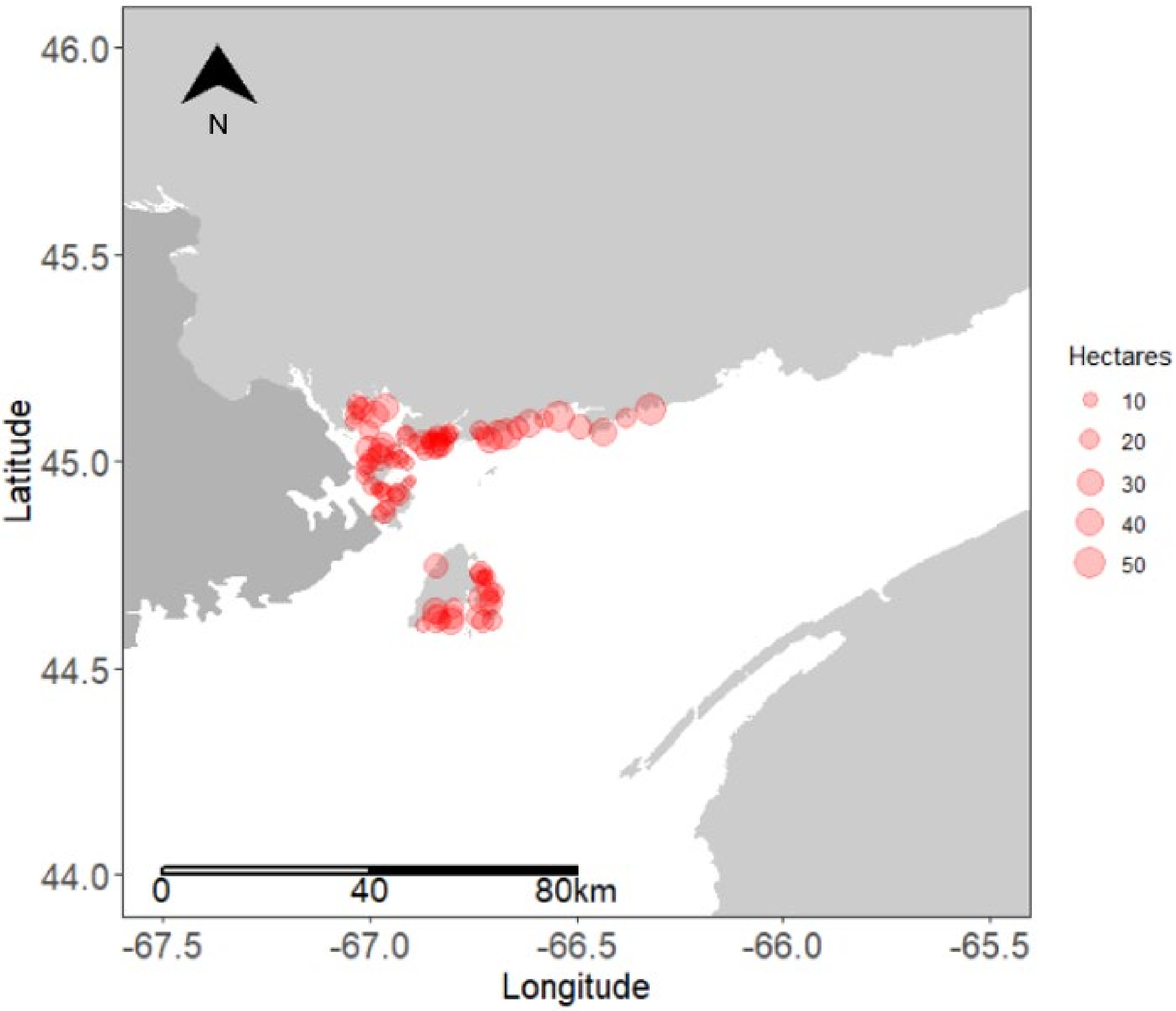


Figure 28: Locations and sizes of finfish aquaculture sites within the Outer Bay of Fundy DU.

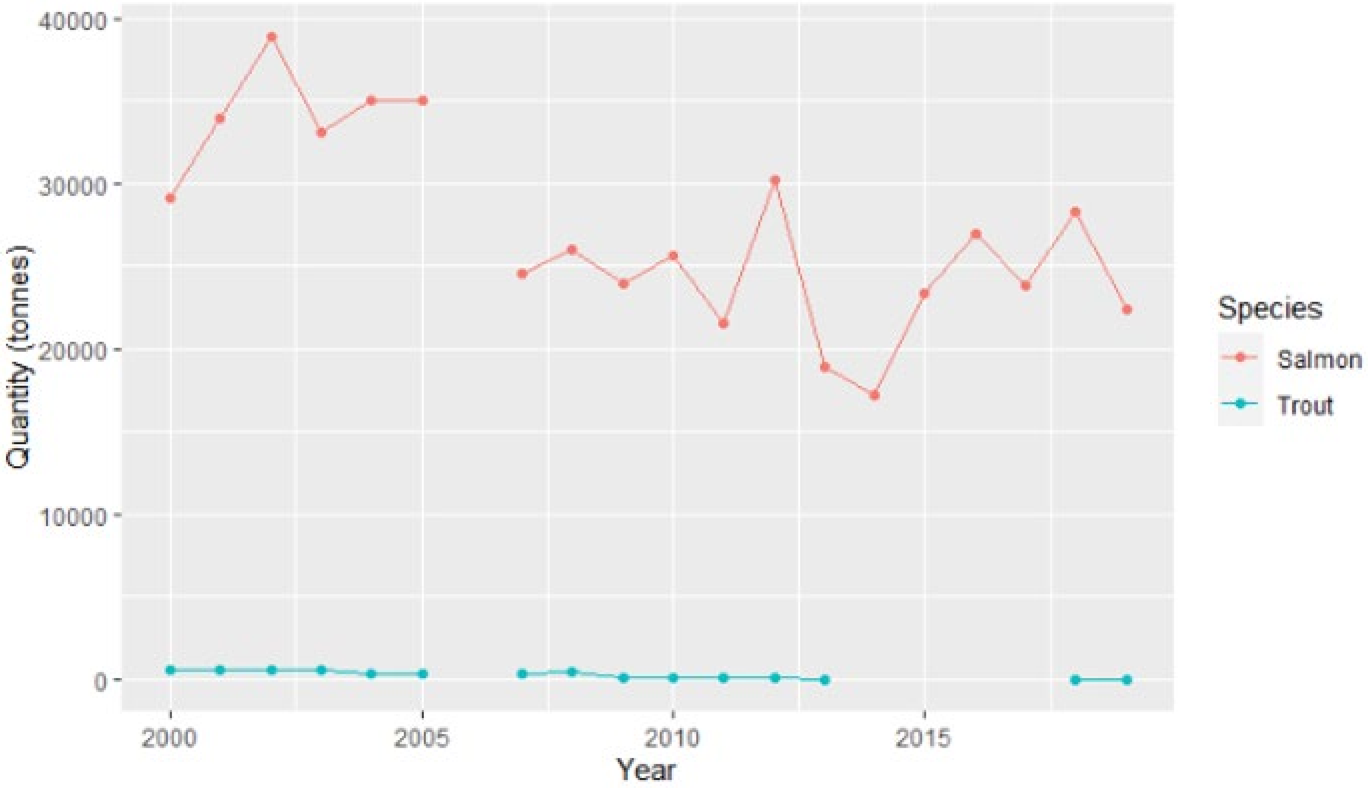


Figure 29: Aquaculture production of salmon and trout species for the province of New Brunswick from 2000 to 2019.

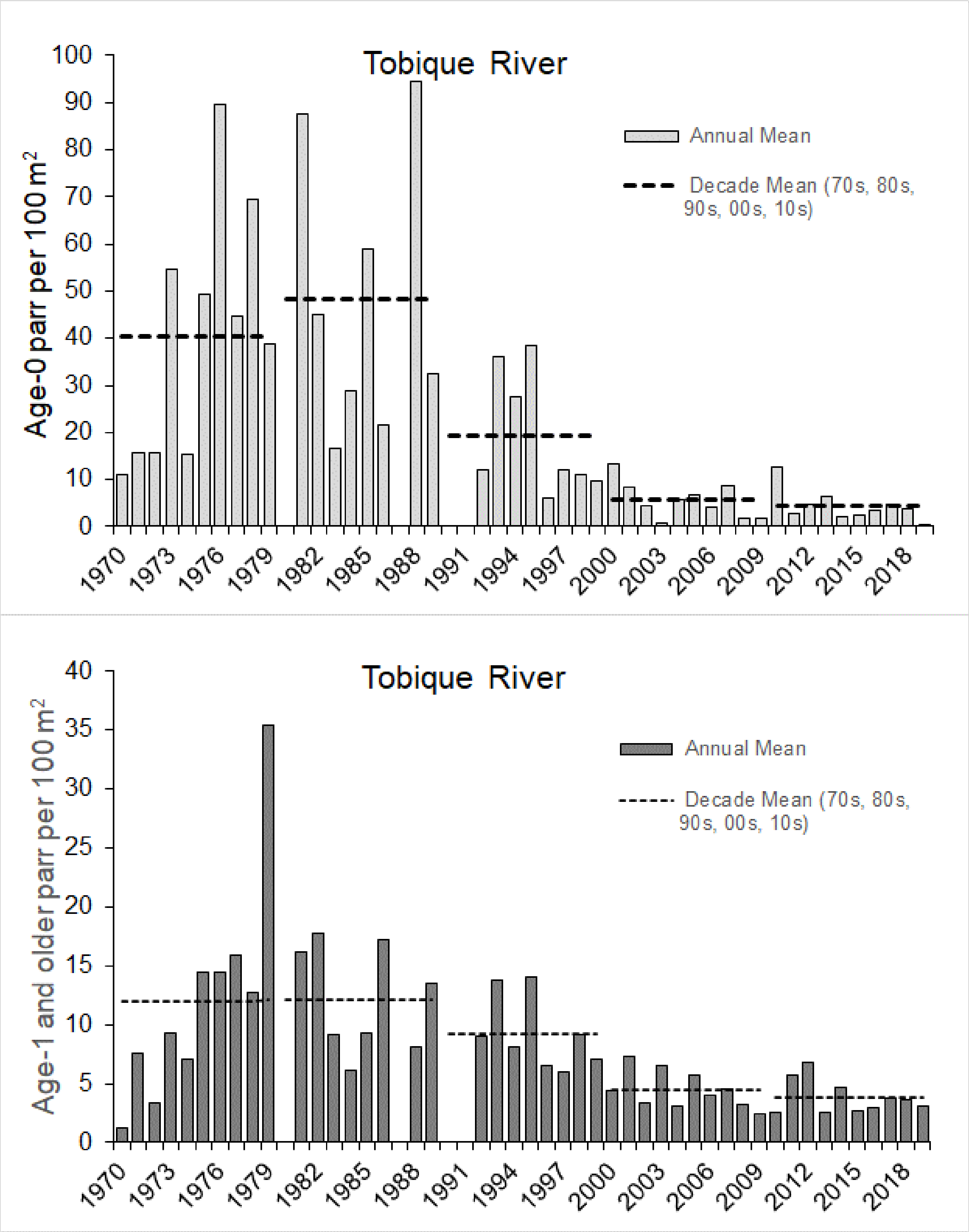


Figure 30: Annual mean densities of age-0 (fry) (upper panel) and age-1 and older parr (lower panel) from electrofishing sites on the Tobique River from 1970 to 2019. Dashed lines represent 10-year mean values for each decade (1970s, 1980s, 1990s, 2000s, 2010s). No electrofishing sites were surveyed in 1980, 1987, 1990 and 1991.

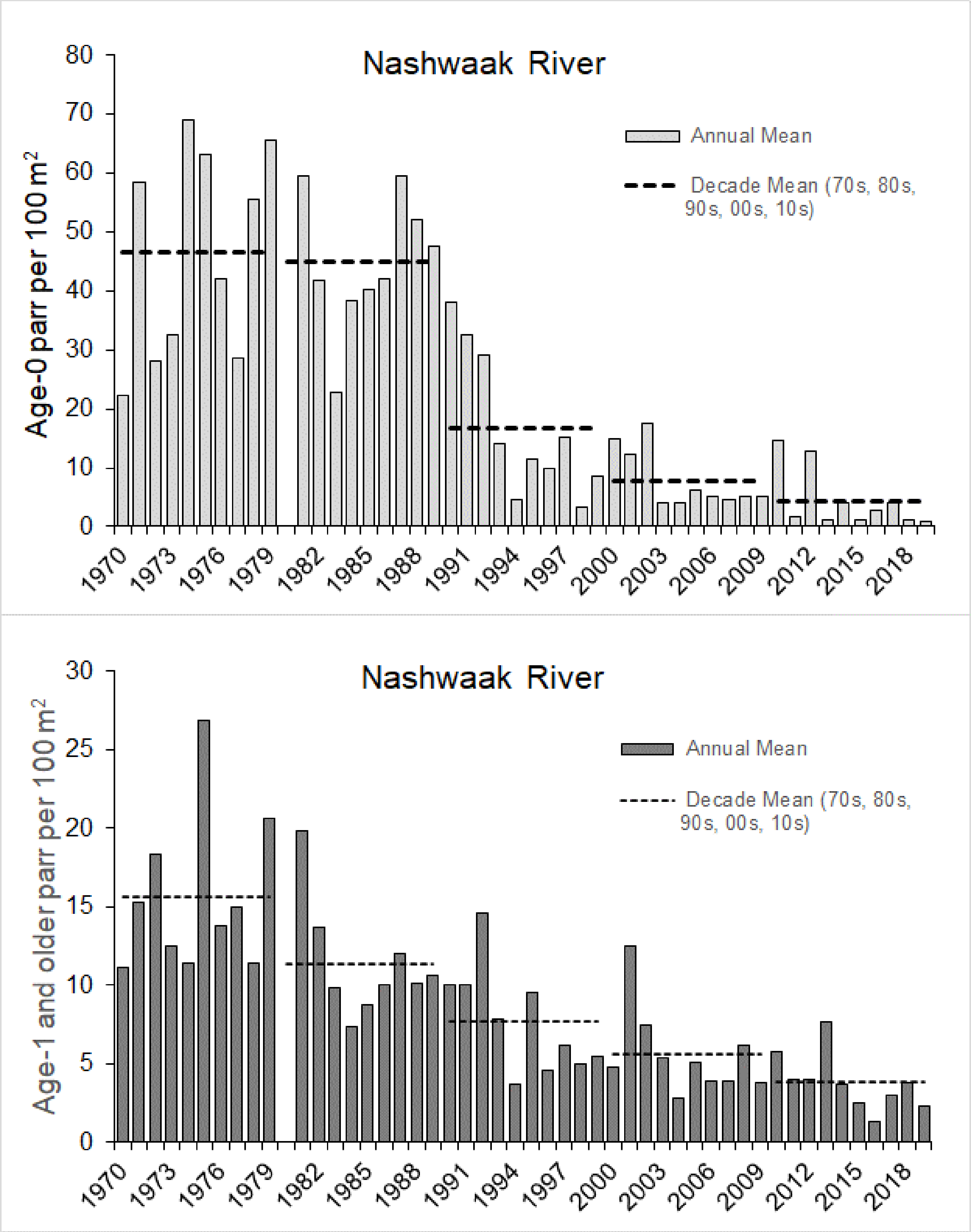


Figure 31: Annual mean densities of age-0 (fry) (upper panel) and age-1 and older parr (lower panel) from electrofishing sites on the Nashwaak River from 1970 to 2019. Dashed lines represent 10-year mean values for each decade (1970s, 1980s, 1990s, 2000s, 2010s). No electrofishing surveys were conducted in 1980.

APPENDIX

Table A1: Numbers of juvenile hatchery Atlantic Salmon and wild captive-reared adults distributed to sites up river of Mactaquac Dam (excluding distributions to the Aroostook River), 1976–2019. Fry are between zero and 14 weeks old, age-0 parr are at least 14 weeks old but less than one year old, and age-1 parr are at least one year old but less than two years old. Period (.) equals no data.

Year	Age-0 (Fry) No Mark	Age-0 (Fry) Ad Clip	Age-0 (Parr) No Mark	Age-0 (Parr) Ad Clip	Age-1 (Parr) No Mark	Age-1 (Parr) Ad Clip	Age-1 (Parr) Tagged	1 year smolt No Mark	1 year smolt Ad Clip	1 year smolt Tagged	2 year smolt No Mark	2 year smolt Ad Clip	2 year smolt Tagged	Captive Reared Adults 1 year	Captive Reared Adults 2 year	Captive Reared Adults 3 year	Captive Reared Adults Repeats
1976	.	.	.	.	.	52,662	5,000	.	.	.	.	.	.	.	.	.	.
1977	.	.	6,042	44,021	.	.	.	.	.	.		.	.	.	.	.	.
1978	.	.	9,163	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1979	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1980	.	.	.	.	.	.	.	.	.	.	.	.	5,995	.	.	.	.
1981	.	.	.	.	.	.	.	.	.	.	.	.	5,998	.	.	.	.
1982	.	.	75,210	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1983	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1984	.	.	123,757	8,517	.	.	.	.	.	.	.	.	.	.	.	.	.
1985	.	.	164,947	110,569	24,544	.	.	.	.	.	.	.	.	.	.	.	.
1986	17,300	.	126,692	91,808	.	.	.	.	.	.	.	.	.	.	.	.	.
1987	266,257	.	101,052	50,283	.	.	.	.	.	.	.	.	.	.	.	.	.
1988	79,948	.	107,478	60,472	.	.	.	.	.	.	.	.	.	.	.	.	.
1989	150,384	.	151,562	.	.	.	.	4,680	30,011	.	20,000	.	.	.	.	.	.
1990	164,005	.	232,291	.	.	.	.	2,877	24,026	.	.	17,140	.	.	.	.	.
1991	227,535	.	499,130	.	.	.	.	.	30,181	.	.	19,646	.	.	.	.	.
1992	600,408	.	514,662	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1993	672,797		272,824	99,939	.	.	.	819	.	.	.	.	.	.	.	.	.
1994	983,549	30,000	285,988	253,730	.	.	.	.	.	.	.	.	.	.	.	.	.
1995	642,830	.	193,208	226,391	.	.	.	.	.	.	.	.	.	.	.	.	.
1996	940,962	.	511,771	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1997	504,488	.	391,860	20,991	.	.	.	.	.	.	.	.	.	.	.	.	.
1998	213,973	.	.	282,491	.	.	.	.	.	.	.	.	.	.	.	.	.
1999	172,220	.	.	356,635	.	.	.	.	.	.	.	.	.	.	.	.	.
2000	609,802	.	.	371,751	.	.	.	.	1,996	.	.	.	.	.	.	.	.
2001	8,330	.	.	344,618	.	.	.	.	.	.	.	.	.	.	.	.	.
2002	500	.	.	342,176	.	.	.	.	.	2,357	.	.	.	.	.	.	.
2003	2,723	.	.	261,852	.	.	.	.	.	1,483	.	.	.	387	.	.	.
2004	87,936	.	122,196	129,147	.	.	.	.	.	.	.	.	.	240	847	.	.

Year	Age-0 (Fry) No Mark	Age-0 (Fry) Ad Clip	Age-0 (Parr) No Mark	Age-0 (Parr) Ad Clip	Age-1 (Parr) No Mark	Age-1 (Parr) Ad Clip	Age-1 (Parr) Tagged	1 year smolt No Mark	1 year smolt Ad Clip	1 year smolt Tagged	2 year smolt No Mark	2 year smolt Ad Clip	2 year smolt Tagged	Captive Reared Adults 1 year	Captive Reared Adults 2 year	Captive Reared Adults 3 year	Captive Reared Adults Repeats
2005	.	.	2,500	206,533	.	.	.	1,400	.	.	.	.	.	202	847	128	39
2006	1,294	.	.	310,947	.	.	.	.	.	1,986	.	.	.	224	803	143	119
2007	.	.	.	157,142	.	.	.	.	.	1,999	.	.	.	268	413	114	195
2008	.	.	59,185	121,299	.	.	.	.	.	1,968	.	.	.	69	617	141	88
2009	12,061	.	2,500	178,096	.	.	.	.	.	1,988	.	.	.	156	458	322	412
2010	.	.	2,500	188,895	.	4,253	1,004	.	.	1,818	.	.	.	381	404	79	170
2011	.	.	183,041	.	.	.	2,879	996	.	.	.	.	.	331	398	135	232
2012	3,487	.	158,220	.	78	.	.	2,000	.	.	.	.	.	0	1,056	232	162
2013	.	.	150,260	.	32,396	.	.	.	.	.	.	.	.	168	13	144	64
2014	.	.	64,905	182,288	.	26,110	.	.	.	.	.	.	.	419	760	.	.
2015	.	.	74,142	162,921	.	.	.	.	.	.	.	.	.	512	284	217	.
2016	.	.	196,788	82,973	.	.	.	.	.	.	.	.	.	482	889	73	.
2017	34,543	.	10,806	154,009	.	.	.	200	.	.	.	.	.	162	264	183	.
2018	133,436	.	.	.	.	.	.	.	.	500	.	.	.	278	374	141	.
2019	262,719	.	.	.	.	.	.	.	.	.	.	.	.	149	249	184	.
Total	**6,793,487**	**30,000**	**4,794,680**	**4,800,494**	**57,018**	**83,025**	**8,883**	**12,972**	**86,214**	**14,099**	**20,000**	**36,786**	**11,993**	**4,428**	**8,676**	**2,236**	**1,481**

Table A2: Numbers of juvenile hatchery Atlantic Salmon and wild captive-reared adults distributed to sites on the Tobique River, 1976–2019. Fry are between zero and 14 weeks old, age-0 parr are at least 14 weeks old but less than one year old and age-1 parr are at least one year old but less than two years old. Period (.) equals no data.

Year	Age-0 (Fry) No Mark	Age-0 (Fry) Ad Clip	Age-0 (Parr) No Mark	Age-0 (Parr) Ad Clip	Age-1 (Parr) No Mark	Age-1 (Parr) Ad Clip	Age-1 (Parr) Tagged	1 year smolt No Mark	1 year smolt Ad Clip	1 year smolt Tagged	2 year smolt No Mark	2 year smolt Ad Clip	2 year smolt Tagged	Captive Reared Adults 1 year	Captive Reared Adults 2 year	Captive Reared Adults 3 year	Captive Reared Adults Repeats
1976	.	.	.	.	.	.	5,000	.	.	.	.	.	.	.	.	.	.
1977	.	.	6,042	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1978	.	.	9,163	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1979	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1980	.	.	.	.	.	.	.	.	.	.	.	.	5,995	.	.	.	.
1981	.	.	.	.	.	.	.	.	.	.	.	.	5,998	.	.	.	.
1982	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1983	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1984	.	.	.	8,517	.	.	.	.	.	.	.	.	.	.	.	.	.
1985	.	.	43,211	38,687	.	.	.	.	.	.	.	.	.	.	.	.	.
1986	17,300	.	46,563	53,782	.	.	.	.	.	.	.	.	.	.	.	.	.
1987	52,882	.	33,505	21,950	.	.	.	.	.	.	.	.	.	.	.	.	.
1988	.	.	28,723	40,038	.	.	.	.	.	.	.	.	.	.	.	.	.
1989	80,012	.	83,846	.	.	.	.	2,255	9,995	.	.	.	.	.	.	.	.
1990	68,707	.	83,075	.	.	.	.	534	9,944	.	.	.	.	.	.	.	.
1991	.	.	194,173	.	.	.	.	.	4,995	.	.	4,953	.	.	.	.	.
1992	119,987	.	257,732	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1993	203,950	.	98,738	99,939	.	.	.	819	.	.	.	.	.	.	.	.	.
1994	317,996	30,000	46,376	253,730	.	.	.	.	.	.	.	.	.	.	.	.	.
1995	337,080	.	101,900	207,683	.	.	.	.	.	.	.	.	.	.	.	.	.
1996	651,045	.	333,320	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1997	302,000	.	256,578	20,991	.	.	.	.	.	.	.	.	.	.	.	.	.
1998	83,995	.	.	193,756	.	.	.	.	.	.	.	.	.	.	.	.	.
1999	101,204	.	.	209,358	.	.	.	.	.	.	.	.	.	.	.	.	.
2000	360,390	.	.	254,473	.	.	.	.	1,996	.	.	.	.	.	.	.	.
2001	.	.	.	221,014	.	.	.	.	.	.	.	.	.	.	.	.	.
2002	500	.	.	184,349	.	.	.	.	.	2,357	.	.	.	.	.	.	.
2003	2,723	.	.	181,630	.	.	.	.	.	1,483	.	.	.	339	.	.	.
2004	.	.	78,052	129,147	.	.	.	.	.	.	.	.	.	213	797	.	.
2005	.	.	2,500	179,713	.	.	.	1,400	.	.	.	.	.	202	577	128	39
2006	.	.	.	310,947	.	.	.	.	.	1,986	.	.	.	224	720	115	119

Year	Age-0 (Fry) No Mark	Age-0 (Fry) Ad Clip	Age-0 (Parr) No Mark	Age-0 (Parr) Ad Clip	Age-1 (Parr) No Mark	Age-1 (Parr) Ad Clip	Age-1 (Parr) Tagged	1 year smolt No Mark	1 year smolt Ad Clip	1 year smolt Tagged	2 year smolt No Mark	2 year smolt Ad Clip	2 year smolt Tagged	Captive Reared Adults 1 year	Captive Reared Adults 2 year	Captive Reared Adults 3 year	Captive Reared Adults Repeats
2007	.	.	.	157,142	.	.	.	.	.	1,999	.	.	.	230	380	114	195
2008	.	.	59,185	121,299	.	.	.	.	.	1,968	.	.	.	69	358	94	88
2009	.	.	2,500	178,096	.	.	.	.	.	1,988	.	.	.	156	458	322	412
2010	.	.	2,500	188,895	.	4,253	1,004	.	.	1,818	.	.	.	381	404	79	170
2011	.	.	183,041	.	.	.	.	996	.	.	.	.	.	302	362	96	232
2012	.	.	150,166	.	.	.	.	2,000	.	.	.	.	.	0	928	214	0
2013	.	.	150,260	.	32,396		.	.	.	.	.	.	.	168	13	144	64
2014	.	.	64,905	160,846	.	26,110	.	.	.	.	.	.	.	419	760	.	.
2015	.	.	74,142	162,921	.	.	.	.	.	.	.	.	.	512	284	217	.
2016	.	.	196,788	82,973	.	.	.	.	.	.	.	.	.	482	889	73	.
2017	34,543	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2018	21,401	.	.	.	.	.	.	.	.	500	.	.	.	267	273	141	.
2019	38,719	.	.	.	.	.	.	.	.	.	.	.	.	149	222	164	.
Total	**2,794,434**	**30,000**	**2,586,984**	**3,661,876**	**32,396**	**30,363**	**6,004**	**8,004**	**26,930**	**14,099**	**0**	**4,953**	**11,993**	**4,113**	**7,425**	**1,901**	**1,319**

Table A3: Number of wild and hatchery juvenile Atlantic Salmon collected during the spring and fall seasons for the captive-reared broodstock program at MBF, from the Tobique River and at Beechwood Dam 2013–2019. Period (.) equals no data.

Collection Year	Location	Pre-Smolt Wild	Pre-Smolt Hatchery[a]	Parr Wild	Parr Hatchery[a]	Fry Wild	Total
2013	Nictau	500	.	.	.	.	500
2013	Three Brooks	1,512	.	.	.	.	1,512
2013	Beechwood	.	.	.	.	.	0
Smolt Class 2014	.	**2,012**	**.**	**.**	**.**	**.**	**2,012**
2014	Nictau	552	.	128	.	.	680
2014	Three Brooks	771	.	94	.	.	865
2014	Beechwood	.	.	.	.	.	0
Smolt Class 2015	.	**1,323**	**.**	**222**	**.**	**.**	**1,545**
2015	Nictau	356	.	259	.	.	615
2015	Three Brooks	168	.	165	.	.	333
2016	Beechwood[b]	270	.	.	.	.	270
2016	Three Brooks[b]	44	.	.	.	.	44
2016	Trap Net	5	.	.	.	.	5
Smolt Class 2016	.	**843**	**.**	**424**	**.**	**.**	**1,267**
2016	Nictau	116	.	183	.	.	299
2016	Three Brooks	764	.	161	.	.	925
2017	Beechwood[b]	206	.	.	.	.	206
2017	Three Brooks[b]	30	.	.	.	.	30
Smolt Class 2017	.	**1,116**	**.**	**344**	**.**	**.**	**1,460**
2017	Nictau	51	.	96	.	.	147
2017	Three Brooks	246	.	57	.	.	303
2017	Bypass	781	.	76	.	.	857
2018	Beechwood[b]	26	.	.	.	.	26
2018	Three Brooks[b]	19	.	.	.	.	19
2018	Bypass[b]	10	.	.	.	.	10
Smolt Class 2018	.	**1,133**	**.**	**229**	**.**	**.**	**1,362**
2018	Nictau	149	.	195	.	.	344
2018	Three Brooks	674	.	156	.	.	830
2018	Bypass	639	.	112	.	.	751
2019	Beechwood[b]	0	.	.	.	.	0
2019	Three Brooks[b]	114	.	.	.	.	114
2019	Bypass[b]	200	.	.	.	.	200
Smolt Class 2019	.	**1,776**	**.**	**463**	**.**	**.**	**2,239**
2019	Three Brooks	119	.	115	.	.	234
2019	Bypass	515	.	127	.	.	642
2019	Odell[c]	.	.	.	705	.	705
Smolt Class 2020	.	**634**	**.**	**242**	**705**	**.**	**1,581**
Grand Total	.	**8,203**	**.**	**1,924**	**705**	**.**	**11,466**

(a) Stocked previous year as fall fingerling.
(b) Collected from spring projects at "smolt" stage.
(c) Stocked previous years as unfed fry, and collected as 1+ and 2+ wild exposed parr.

Table A4: Threats to Atlantic Salmon populations in the freshwater environment of the OBoF DU (Clarke et al. 2014).

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Physical obstructions	Hydro dams	High	High	C,H, A Continuous	Extreme	Very High	Very High	Direct mortality. Eight major hydro dams in DU. Some require handling all fish. Affects migration, cumulative mortality through dams on the SJR up to 45%, headponds and tailraces harbour predators.
Directed salmon fishing (current)	Illegal Fishing (poaching)	High	High	H, C and A Seasonal	High	High	High	Direct spawner loss; population-level impact dependent on level of illegal fishing and overall population size. Evidence of salmon H&R or retention angling in trout fishery.
Water quality and quantity	Silt and sediment (Also see Agriculture, forestry, mining)	Medium	High	C, H, A Seasonal /Continuous	Medium	High	Medium	Road crossings, industrial run-off. Affects juvenile survival & physiology. Reduces habitat. Extensive forestry and agriculture in DU.

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Water quality and quantity	Contaminants (Chemical and waste water)	Medium	High	C, H, A, Recurrent	Medium	High	Med	Reduces survival (freshwater and& marine); causes physiological changes. Some inadequate waste handling facilities in DU, extensive agriculture, mills, plants etc. >50% of NB citizens live in OBoF Watersheds.
Changes to biological communities	Invasive species (Fish)	Medium	High	C,H, A Seasonal	Medium	High	Medium	Head ponds provide habitat for some invasive predators. Increasing non-native predator diversity and abundance in SJR. Potential for increased predation rates at low population level.
Changes to biological communities	Historic Stocking (Adult collection, captive spawn, rear to smolt, release)	Medium	High	H,A	Medium	High	Low	Declines in fitness associated with captive matings and juvenile captive exposure. but little evidence of non-stocked rivers out-performing stocked.

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Physical obstructions	Other dams and obstructions (see Hydro dams and obstructions)	Medium	High	C, H, A Recurrent	Medium	High	Medium	> 200 known in SJR system. Form temporary or permanent reductions in passage or habitat quantity. Water storage dams on Tobique reduce egg - smolt survival.
Physical obstructions	Crossing Infrastructure (roads/culverts)	Medium	High	H,C, A recurrent	Medium	High	Low	Can form full or partial barriers to migration. Crossings can be point sources of pollution, sediments, and invasives.
Habitat alteration	Urbanization	Medium	High	H, C, A Continuous	Medium	Medium	Low	Aggregate of many threats. Salmon population viability is lower in more populated areas.
Habitat alteration	Agriculture	Medium	High	H, C, A Recurrent	Medium	Medium	Low	Altered flow, increases in temperatures and siltation, chemical run-off, loss of cover, reduces habitat productivity and can reduce growth and survival of juveniles.

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Habitat alteration	Forestry	Medium	High	H,C,A Recurrent	Medium	Medium	Low	Altered flow, forestry is dominant land use of DU (> 80%). Significant past clear cutting in Salmon (Vic Co.), Tobique and Nashwaak basins.
Changes to biological communities	Salmonid aquaculture commercial hatcheries (see aquaculture)	Medium	High	C,H,A Recurrent	Medium	Medium	Medium	Known escapes from commercial facilities; known reduction in fitness, potential competition, disease transfer and introgression.
Water quality and quantity	Extreme temperature events	Low	High	C, A Seasonal	Low	High	Medium	Some cool refuge lost to regulated flow. Western NB expected to be highly affected by climate warming.
Water quality and quantity	Water extraction (See extreme temperature, mining)	Low	High	C Continuous	Low	Medium	Low	Reduces flow which impacts survival. > 50% of NB citizens live in OBoF Watersheds.
Water quality and quantity	Non-hydro power generation (Nuclear, thermal and Tidal applies to estuarine threats)	Low	High	C, H, A Continuous	Low	Low	Low	Threats occur in SJR with potential to affect all SJR populations. Tidal generation being explored in Passamaquoddy Bay

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Changes to biological communities	Native salmonid stocking	Low	High	C, H, A Recurrent	Low	Medium	Low	Brook Trout and Landlocked salmon stocking is prevalent in lakes. Potential for competition, pathogen transfer, and predation.
Changes to biological communities	Current Stocking (Smolt collection & adult release, limited captive spawning)	Low	Medium	C, A Recurrent	Low	Medium	Low	Natural mate-choice, juveniles wild exposed for lifetime.
Habitat alteration	Mining	Low	Medium	C, A, H Recurrent	Low	Medium	Low	Sedimentation; contaminant source; water extraction. Potential for increased hazard on Nashwaak (Tungsten mine) and Kennebecasis (Shale gas)
Water quality and quantity	Acidification	Low	Low	C Continuous	Low	High	Medium	Hammond, St. Croix, Digdeguash and Magaguadavic have had a few acidic samples but overall not considered limiting.

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Water quality and quantity	Military activities (also see silt and sediments)	Low	Low	H, C and A Periodic	High	Low	Low	Two rivers in DU on CFB Gagetown training areas. One suspected to be severely affected by sedimentation. Population-level impacts are unpublished.
Changes to biological communities	Invasive Species (other)	Low	Medium	C, A Recurrent	Low	Medium	Low	E.g., Didymo; forms mats that alter the composition of aquatic insect communities. Confirmed to be present on Tobique and Shikatehawk.
Directed salmon fishing (current)	Recreational fishing	Low	High	H, C	Low	Very High	High	No permitted fishery at present. If reopened for H&R, low mortality rates associated with regulated gear types and seasons.
Directed salmon fishing (current)	Indigenous or commercial fishing	Low	Low	H, C	Negligible	Very High	High	No permitted food, social, ceremonial or commercial harvest in OBoF rivers.
By-catch in other fisheries	Recreational, Indigenous or Commercial	Low	High	H, C and A Seasonal	Low	Medium	Medium	Shad, Gaspereau, Eel have by-catch but is suspected to be low

Table A5: Threats to Atlantic Salmon populations in the marine/estuary environment of the OBoF DU (Clarke et al. 2014).

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Biotic and abiotic shifts	Marine Ecosystem Changes (climate and predator-prey)	High	Very High	C, H, A Continuous	Unknown	Medium	Low	Lower marine survival thought to limit recovery. Climate change affecting SST; currents and ice cover. Correlation of some predators increasing during OBoF decline (Grey Seals). Some prey species have declined (herring).
Biotic and abiotic shifts	Salmonid aquaculture	High	High	C, H, A Continuous	High	High	Medium	High host density presents potential altered dynamics for predators, prey and pathogens. Documented occurrence of escapes and wild fitness loss with introgression.
Biotic and abiotic shifts	Diseases and parasites	High	High	C,H, A Continuous	High	Medium	Medium	Several naturally occurring diseases documented in OBoF in wild and/or cultured fish. Linked to aquaculture through high spatial and temporal density of hosts

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Biotic and abiotic shifts	Depressed Population Phenomenon	High	Very High	C,A Current	Unknown	Medium	Low	Smolt may be at densities too low to support schooling. Genetic bottleneck concerns with current low abundance.
Directed salmon fisheries	High seas fisheries (Greenland Labrador, St Pierre)	Medium	Very High	C, H Seasonal	Medium	High	High	Three relatively small fisheries would increase mortality in the 2SW component f populations including OBoF. Estimates of OBoF portion of harvest > 5% < 30% of returns.
Biotic and abiotic shifts	Shipping, transport, spills	Low	High	C, H, A Continuous	Low	Low	Low	Extensive shipping traffic during near-shore migrations could disrupt migration and impact marine habitats and prey distributions. Largest North American oil refinery near mouth of SJR serviced by sea.
By-catch in other fisheries	Commercial fisheries	Low	High	C, H Seasonal	Low	Low	Low	Mortality is low from permitted gear types and seasons. Herring weirs (including Mackerel). Little by-catch from offshore fisheries

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency (C =Current, H=Historic, A=Anticipated)**	**Severity**	**Causal Certainty – Evidence linking the threat to stresses in general**	**Causal Certainty – Evidence for changes to viability of OBoF salmon populations**	**Rationale and Context for Designatable Unit**
Directed fisheries	Fisheries on prey species of salmon (see shifts in marine conditions)	Low	High	C, A, H Continuous	Low	Medium	Low	Prey availability or changes in prey distribution may be linked to increased marine mortality. Evidence suggests food not limiting survival.
Biotic and abiotic shifts	Other species aquaculture (see aquaculture)	Low	Low	C, H, A Recurring	Low	Low	Low	All NB commercial finfish sites are salmon and only one site leased for non-finfish.
Scientific Research	Monitoring, Assessments, Collections, and other Research	Low	High	C, A, H Continuous	Low	Medium	Low	Documented cases of negative impacts from certain sampling methods. Generally, activities compensate for harm by contributing to population persistence.