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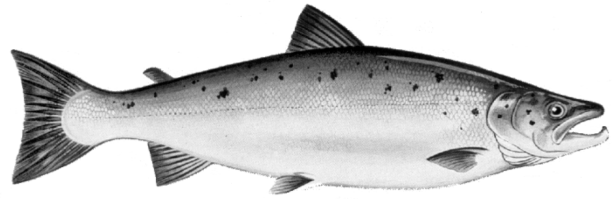
Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/021

RECOVERY POTENTIAL ASSESSMENT FOR OUTER BAY OF FUNDY ATLANTIC SALMON



BIO Technographics

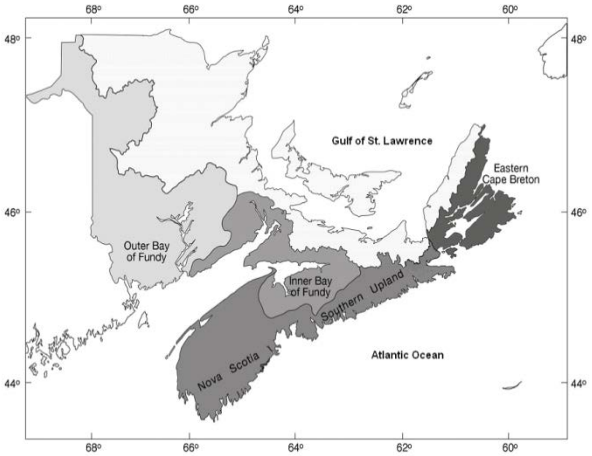


Figure 1. Map showing the location of the Outer Bay of Fundy Atlantic Salmon Designatable Unit relative to the three other Designatable Units for Atlantic Salmon in the Maritimes Region.

Context:

The Outer Bay of Fundy (OBoF) population of Atlantic Salmon (Salmo salar) was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2010. This population assemblage (Designatable Unit) occupies 20 rivers in New Brunswick, including the Saint John River basin and those west to the U.S.A. border, which drain into the outer Bay of Fundy. These rivers are within Salmon Fishing Area (SFA) 23, which is the management area used by the Fisheries and Oceans Canada (DFO) for salmon fisheries management and assessment purposes. The combination of genetic information, life-history patterns, geographic isolation and minimal historical gene flow between OBoF and surrounding regions, and the low rates of straying from other regions, support the view that OBoF salmon differ from salmon in other areas.

A Recovery Potential Assessment (RPA) process has been developed by DFO Science to provide the information and scientific advice required to meet the various requirements of the Species at Risk Act (SARA). The scientific information provided in the RPA serves as advice regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of listing, as well as during subsequent consultations, where applicable. It is also used to evaluate activities that could violate SARA should the species be listed, as well as in the development of a recovery strategy and action plans. This assessment provides a summary of the scientific data and analyses available to assess the recovery potential of OBoF Atlantic Salmon.

This Science Advisory Report is produced from the February 19-22, 2013, Recovery Potential Assessment for Atlantic Salmon (Outer Bay of Fundy Designatable Unit). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

June 2014

SUMMARY

- The Outer Bay of Fundy (OBoF) Designatable Unit 16 (DU 16) of Atlantic Salmon was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada in November 2010.
- There are 20 rivers considered to either contain or to have historically contained OBoF Atlantic Salmon populations. Only the habitat within Canadian boundaries was considered when assessing threats, as well as setting abundance and recovery targets for the OBoF DU. The Saint John River and its tributaries upriver of the Mactaquac Dam are considered a single watershed and one of the 20. All 20 rivers are either influenced by the incursion of tidal waters or directly meet with the Bay of Fundy tides.
- Despite recent declines in population size, measures of within-population genetic variation in the sample populations of OBoF Atlantic Salmon analyzed were relatively high. They were greater than that observed in comparable sample collections from Inner Bay of Fundy and Southern Upland populations, but similar to, or slightly lower than those from Eastern Cape Breton and Northern New Brunswick populations. In among-population comparisons of microsatellite variation, OBoF populations cluster together and separate from all other populations analyzed from the Maritime Provinces (including those from the nearby Inner Bay of Fundy).
- A log-linear (regression) model and a step function (ratio) model were used to predict declines in population abundance over the past 15 years. Analysis of trends for the entire OBoF DU indicates similar declines of 64 and 65% in total adult salmon population abundance over the past 15 years.
- Over the same time period, one-sea-winter (1SW) returns in the DU have declined between 68-73%, slightly more than the decline of 52-68% determined for multi-sea-winter (MSW) returns. MSW salmon include those fish which return following two or more winters at sea and repeat spawners. The greatest decline rates have been observed for total returns to the Magaguadavic River (80-92%).
- In 2012, total (hatchery and wild) estimated 1SW returns were 194 salmon and total estimated MSW returns were 371 salmon for a combined total return of only 565 salmon estimated for the entire DU, which is the lowest in the time-series.
- Record poor adult returns observed in 2012 followed two years of increased adult abundance when the estimated DU returns were about 11,500 (2010) and 8,000 (2011).
- In 2009, electrofishing surveys of 189 sites within most of the rivers or tributaries in the outer Bay of Fundy region indicated that salmon (juveniles) are still present in 15 of the 20 salmon rivers but at low abundance in most rivers.
- The proposed recovery target for OBoF DU salmon has both an abundance and distribution component. The short-term distribution targets were based on seven criteria designed to maintain genotypic, phenotypic, and geographic representation of the DU while offering the best opportunity for recovery. Abundance targets are set using conservation egg requirements of 2.4 eggs per m^2 of productive habitat.
- Short-term distribution target rivers include the Saint John River upriver of Mactaquac Dam (specifically the Tobique, Shikatehawk, and Becaguimec tributaries), five rivers downriver of Mactaquac Dam (Keswick, Nashwaak, Canaan, Kennebecasis, and Hammond), and one river from the outer Fundy complex (Digdeguash). Combined, these rivers represent 56% of the productive salmon habitat in the OBoF region.

- The short-term abundance target for the OBoF DU is to annually achieve the conservation egg requirement in the seven priority rivers selected for distribution targets. This target translates to approximately 54.4 million eggs which could be produced by 23,500 adult salmon (17,000 1SW and 6,500 MSW salmon) within the 22.62 million m² of productive habitat area.
- The long-term abundance target, based on 2.4 eggs per m^2 is 97 million eggs in the currently accessible 40.46 million m² of productive habitat area. This egg deposition could be produced by 41,200 adult salmon (29,700 1SW and 11,500 MSW salmon based on current biological characteristics).
- The maximum lifetime reproductive rate (the maximum number of spawners produced per spawner throughout its life at very low abundance) for the Nashwaak population has decreased from an average of 2.49 in the 1973-1982 time period, to an average of 1.13 during the 2000s. These rates are very low for Atlantic Salmon and are indicative that the Nashwaak population is at risk of extinction due to a reduced capacity to recover from years of low survival that may occur either due to environmental events or due to human activities.
- Population viability analyses indicate that the abundance of the Nashwaak River population, an index of populations in the Saint John River below the Mactaquac Dam, will continue to decline under current conditions. Increases in freshwater productivity are expected to result in an increase in population abundance and a decreased extinction probability. Increases in both freshwater productivity and at-sea survival are required to meet recovery targets with higher probabilities (>90%).
- For the Tobique River population, the number of spawners replaced from one generation to the next, the maximum lifetime reproductive rate was estimated to be 0.18 indicating that spawners are well below replacement and the population is not viable. The Tobique population will be extirpated unless this rate improves. Freshwater production, downstream fish passage survival, and marine survival for the Tobique River population all have to improve to achieve recovery targets.
- Redds have characteristics that meet the residence requirement criteria.
- The seven rivers/tributaries identified in the short-term distribution target and their estuaries are important habitat and are required for OBoF DU salmon to complete their life cycle. Information is not sufficient to determine important marine habitat boundaries other than a general range of occurrence between the OBoF and the Labrador Sea.
- Functional components of freshwater habitat, including their associated features and attributes are well known for OBoF DU salmon.
- There is an estimated 41.75 million m^2 of historically accessible productive freshwater habitat available in the area occupied by OBoF Atlantic Salmon, of which 40.46 million m^2 remain currently accessible. Fish passage facilities provide access to 41.1% of this area. Anthropogenic barriers on the Monquart, Nackawic and Musquash totally exclude salmon from approximately 1.30 million m^2 of productive habitat; other barriers (they number over 200 in the region) and passage issues at some road crossings affect connectivity for habitat in the region.
- Based on tagging information, the marine habitat for OBoF DU salmon includes a wide spatial range and temporal distribution from the Bay of Fundy and Gulf of Maine to the Atlantic coasts of Nova Scotia, Newfoundland and Labrador including the Labrador Sea and west coast of Greenland. There is no evidence that the range in the marine

environment has been reduced. However, the functional components of marine habitat are relatively less well known.

- In freshwater, hydroelectric dams and illegal fishing activities are identified as the threats of highest concern.
- Removal of adult salmon from OBoF rivers constitutes a severe threat to the populations and a direct loss of spawners.
- For many activities, where the level of harm is very low, the effect on extinction risk is likely not measurable. For example, in the case of bridge or culvert construction, only a small portion of the population may be affected by the activity. In other cases, for example scientific activities (e.g. monitoring the juvenile populations by electrofishing), habitat improvement, or recreational fisheries for other species, the small increase in extinction risk may be offset by other benefits, such as improved conditions for salmon or increased knowledge of population status.
- Potential freshwater mitigation measures/actions for high level threats include: implement/improve downstream fish passage, remove or refurbish reservoirs/dams, increase education and awareness activities, public outreach, and increased enforcement in areas of concern.
- Marine threats of high concern (importance not implied by order) are: shifts in marine conditions (which affect temperatures, currents and predator prey interactions), salmonid aquaculture, depressed population phenomenon, and disease and parasites.
- Potential marine mitigation measures/actions for high level threats include: 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.

BACKGROUND

Rationale for Assessment

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) evaluates an aquatic species as Threatened or Endangered, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the *Species at Risk Act* (SARA), is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, population or Designable Unit (DU), threats to its survival and recovery, habitat needs, and the feasibility of its recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted after the COSEWIC assessment. This allows for consideration of peer-reviewed scientific analyses in the SARA processes including listing decisions and recovery planning.

The Outer Bay of Fundy (OBoF) Designatable Unit 16 (DU 16) of Atlantic Salmon (*Salmo salar*) was assessed as Endangered by the COSEWIC in November 2010. DFO Science was asked to undertake an RPA for the OBoF DU of Atlantic Salmon based on DFO’s protocol for conducting RPAs (DFO 2007).

Outer Bay of Fundy DU

Outer Bay of Fundy salmon are unique compared to the adjacent Inner Bay of Fundy populations in that they have a higher incidence of maturation as two-sea-winter (2SW) salmon, a lower incidence of females among one-sea-winter (1SW) salmon, and OBoF post-smolts and adults conduct extensive migrations to the North Atlantic. They also group separately from IBoF salmon and most other populations at multiple allozyme loci and have, therefore, been considered a distinct regional grouping (COSEWIC 2010). One-sea-winter salmon are those which return to spawn following a single winter at sea (also termed Grilse). Multi-sea-winter (MSW) salmon include those fish which return following two or more winters at sea and repeat spawners.

Outer Bay of Fundy salmon live in rivers flowing into the New Brunswick side of the Bay of Fundy between the U.S.A.-Canada border and the city of Saint John (Figure 1). For the purpose of this document, the area occupied by the OBoF Atlantic Salmon DU is considered to have three regions: Saint John River (SJR) above Mactaquac Dam, SJR below Mactaquac Dam, and the outer Fundy complex (Figure 2). There are 20 rivers considered to either contain or to have historically contained OBoF Atlantic Salmon populations. Only the habitat within Canadian boundaries was considered when assessing threats, as well as setting abundance and recovery targets for the OBoF DU. The SJR and its tributaries upriver of the Mactaquac Dam are considered a single watershed and one of the 20. There are 10 rivers below Mactaquac Dam and 9 rivers of the ‘outer Fundy complex’ which independently discharge into the bay. All 20 rivers are either influenced by the incursion of tidal waters or directly meet with the Bay of Fundy tides. All 20 of these rivers (Figure 2) are considered in the current assessment including 16 tributaries and 2 mainstem sections of the SJR upriver of Mactaquac Dam and 10 tributaries of the Jemseg River complex. These rivers are within Salmon Fishing Area (SFA) 23, which is the management area used by the DFO for salmon fisheries management and assessment purposes.

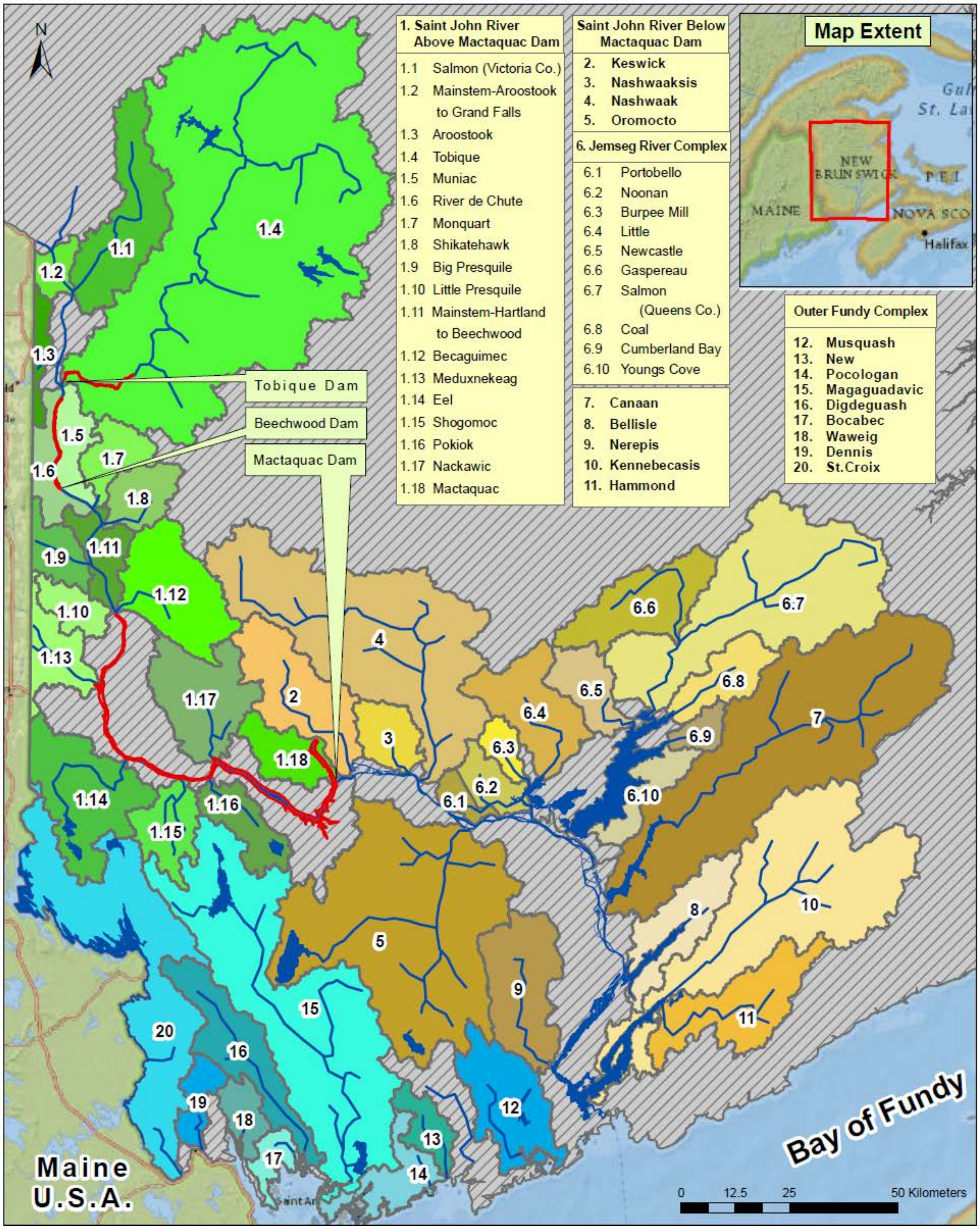


Figure 2. Twenty rivers considered in the OBoF DU including 16 tributary rivers and two mainstem sections of the SJR above Mactaquac Dam and ten tributaries of the Jemseg River complex. SJR tributary rivers above Mactaquac Dam are shaded green, rivers below Mactaquac Dam draining to the SJR are shaded brown and rivers of the outer Fundy complex are shaded blue. Major headpond areas are outlined in red.

ASSESSMENT

Status and Trends

Population status of Atlantic Salmon in the SJR is assessed annually from data collected at the Mactaquac Dam, as well as from the Tobique (index tributary river above Mactaquac) and the Nashwaak (index river below Mactaquac) rivers, the largest salmon-producing tributaries upstream and downstream (respectively) of Mactaquac Dam. Outside of the SJR system, the only other salmon assessment activities are counts of returning adults to the fishway on the Magaguadavic River (conducted by the Atlantic Salmon Federation).

A log-linear (regression) model and a step-function (ratio) model were used to predict declines in population abundance over the past 15 years. Analyses of trends for the entire OBoF DU indicate similar declines of 64 and 65% in total adult salmon population abundance over the past 15 years (Table 1).

Over the same time period, 1SW returns in the DU have declined between 68-73%, slightly more than the decline of 52-68% determined for MSW returns. MSW salmon include those fish which return following two or more winters at sea and repeat spawners. The greatest decline rates have been observed for total returns to the Magaguadavic River (80-92%). In 2012, total estimated (hatchery and wild) 1SW returns were 194 salmon, total estimated MSW returns were 371 salmon, for combined total return of 565 salmon estimated for the entire DU, which is the lowest in the time-series. Record poor adult returns observed in 2012 followed two years of increased adult abundance when the estimated DU returns were about 11,500 (2010) and 8,000 (2011).

Table 1. Summary of rates of declines in adult Atlantic Salmon returns and escapement for the entire DU, SJR upriver of Mactaquac Dam, Nashwaak and Magaguadavic rivers from 1997-2012. The regression method is a log-linear model fit via least squares. The step function (ratio) is the change in the 5-year mean population size ending on 1998 and 2012. An asterisk (*) indicates confidence intervals that include zero (95%) and therefore the possibility of no change or an increase in abundance.

	Log-linear	Log-linear	Ratio
Population	Decline over one year (%)	Decline over time period (%)	Decline over time period (%)
Designable Unit 16			
DU 16 1SW	8*	73*	68*
DU 16 MSW	5*	52*	68
DU 16 Total	7*	64*	65*
SJR Upriver of Mactaquac Dam			
Mactaquac - Total Wild Returns	5*	55*	69
Mactaquac - Total Hatchery Returns	17	94	87
Mactaquac 1SW Returns	14*	90*	84*
Mactaquac MSW Returns	9	76	82
Mactaquac Total Returns	12	86	82
Mactaquac Total Escapement	10	81	83
SJR Downriver of Mactaquac Dam			
Nashwaak 1SW	4*	45*	47*
Nashwaak MSW	1*	19*	50*
Nashwaak Total	2*	27*	41*
Nashwaak Total Escapement	2*	27*	50*
Outer Fundy Complex			
Magaguadavic Total Returns	10	80	92

Adult Abundance in Saint John River Tributaries

Adult salmon counts and estimates of returns to counting facilities (e.g. fishway, counting fence) are evaluated against conservation egg requirements. These are determined for each index river based on accessible productive habitat area and the biological characteristic information of the returning adult salmon.

Saint John River Upriver of the Mactaquac Dam

The Mactaquac Biodiversity Facility (MBF) produces and releases salmon at various life stages to mitigate the effects of hydroelectric development on salmon in the SJR associated with the construction of Mactaquac Dam in the late 1960s. From the early 1970s to the mid-2000s, hatchery broodstock for the program has consisted of 200-300 wild sea-run adults each year. Over the past decade, the program at the MBF has been re-focused with the objective of conserving and restoring a declining resource. Thus, discussion among DFO staff, the Saint John River Management Advisory Committee members, and the Saint John Basin Board members resulted in a program change in 2004. The current program replaces a large portion of the traditional smolt production with production of age-0 fall parr. Additionally, the program utilizes captive-reared adults, originally collected from the wild as juveniles, for both broodstock and adult releases for natural spawning upriver of the Mactaquac Dam. All releases are into tributaries of origin above Mactaquac Dam, mainly in the Tobique River.

Analyses of trends in returns and escapement for the salmon population upriver of Mactaquac Dam from 1SW returns, MSW returns, combined 1SW and MSW returns, and total egg deposition from wild and hatchery 1SW and MSW spawners indicate considerable declines ranging from 76-90% over the past 15 years (Table 1, Figure 3).

Using fishway counts at Mactaquac Dam, the estimated wild origin and hatchery origin returns in 2012 were 81 1SW (a decrease of 92% from 2011 and the lowest estimate since 1970) and 132 MSW fish (a decrease of 76% from 2011 and the lowest since 1970). The estimate of total egg deposition from sea-run returns was 544,300 eggs, which was 2% of the conservation egg requirement (the lowest on record). There was a potential additional contribution of 5.49 million eggs from 1,450 captive reared salmon released in 2012.

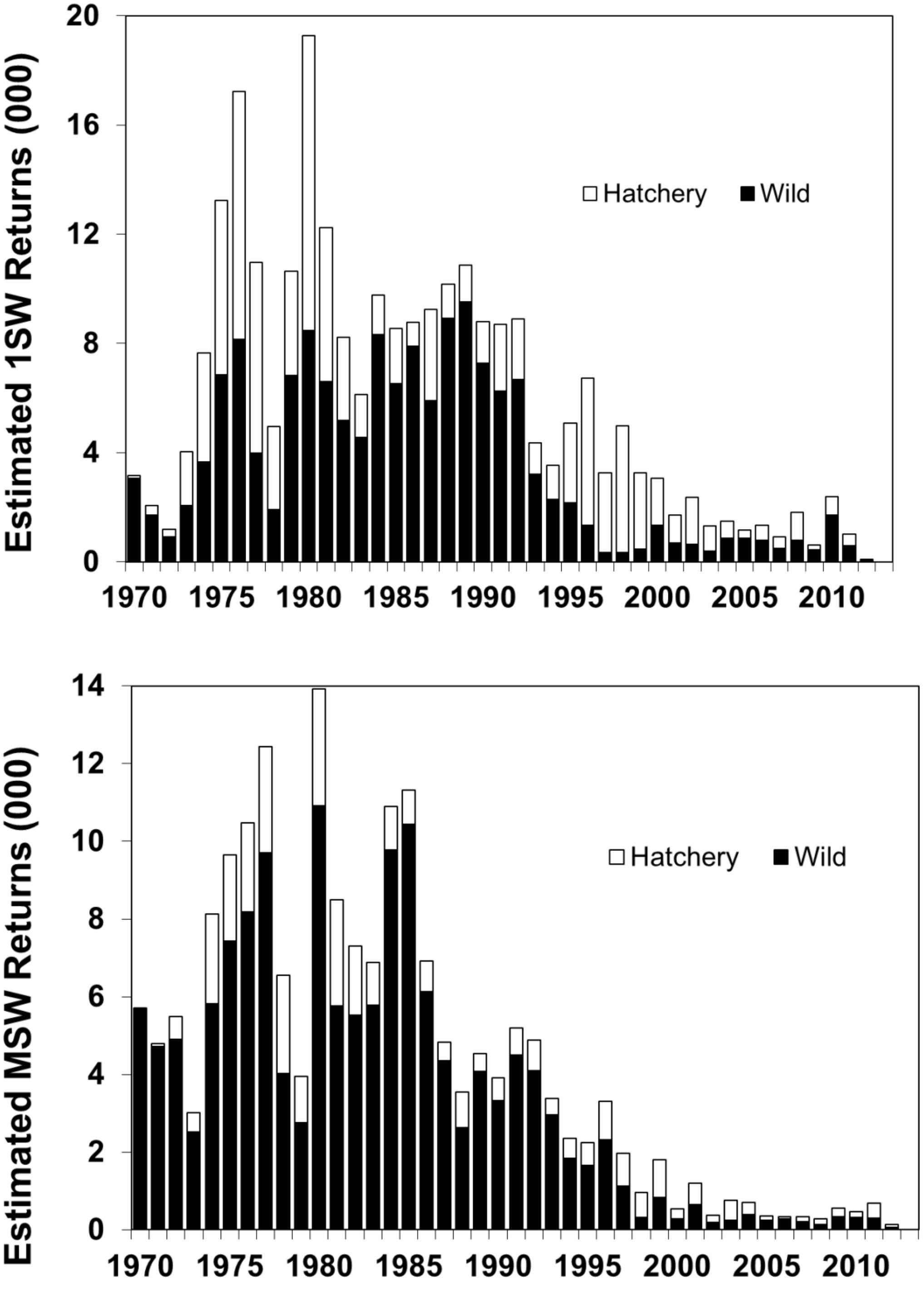


Figure 3. Estimated total returns of wild and hatchery-origin 1SW (top panel) and MSW (bottom panel) salmon destined for upriver of Mactaquac Dam, Saint John River, 1970-2012.

Nashwaak River

Analyses of trends in returns and escapement to the Nashwaak River from 1SW returns, MSW returns, combined 1SW and MSW returns, and total egg depositions from 1SW and MSW spawners indicate declines in the range of 19-50% over the past 15 years (Table 1). However, the confidence intervals on these fits include negative values, indicating that there was no statistically significant change in the past 15 years. This is the result of the high variability in the recent returns.

Estimated returns to a counting fence operated near Durham Bridge on the Nashwaak in 2012, were 29 1SW returns (a decrease of 97% from 2011 and well below the previous 10-year mean), and were 61 MSW returns (a decrease of 89% from 2011 and well-below the previous 10-year mean; Figure 4). The estimate of total egg deposition from sea-run returns was 322,000 eggs, which was 3% of the conservation egg requirement (the lowest on record).

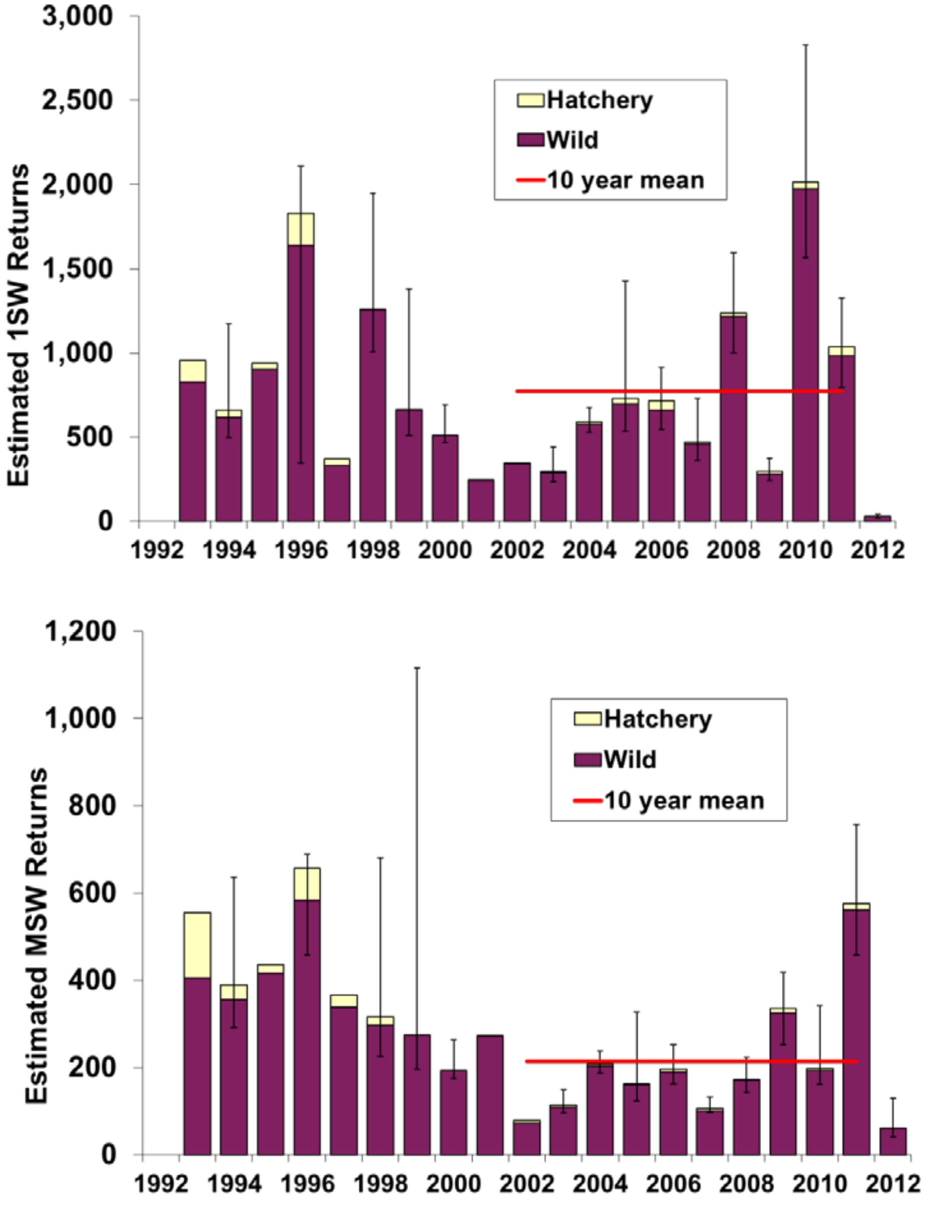


Figure 4. Estimated wild and hatchery 1SW (top panel) and MSW (bottom panel) salmon returns, and 2.5 and 97.5 percentiles, to the Nashwaak River, 1993 - 2012.

Adult Abundance in Outer Fundy Complex Rivers

Magaguadavic River

Analysis of trends in returns for the Magaguadavic River salmon population indicates declines in population abundance in the range of 80-92% (depending on model used) over the past 15 years (Table 1, Figure 5).

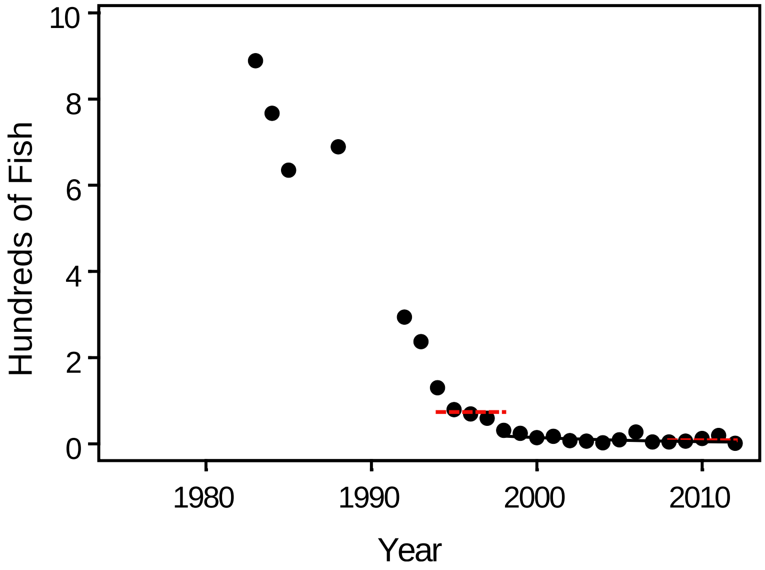


Figure 5. Trends in abundance of Atlantic Salmon returns in the Magaguadavic River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 15-year time period. The dashed red lines show the 5-year mean abundance for 2 time periods ending in 1998 and 2012. The points are the observed data.

A salmon conservation program, coordinated by the Magaguadavic River Salmon Recovery Group and the Atlantic Salmon Federation, has been supplementing the wild population with hatchery releases since 2002. Returns to the St. George fishway and trap located near the head of tide on the Magaguadavic River in 2012 were one female MSW salmon and one re-conditioned male captive-reared broodstock. Both were released upriver of the fishway trap and potentially deposited an estimated 7,160 eggs which is less than 1% of conservation egg requirement. Unlike 2011, there were no captive-reared adults released in 2012 by the Atlantic Salmon Federation staff to augment the potential eggs from the one sea-run return.

Juvenile Abundance Indices

Estimates of emigrating juvenile salmon (i.e., pre-smolt, smolt) are assessed against reference levels using rotary screw traps and mean parr densities obtained by electrofishing on the Tobique and Nashwaak rivers.

Pre-smolt and smolt estimates contributing to the 2012 smolt class for the Tobique River were the highest since monitoring commenced in 2001 and the minimum smolt abundance estimate on the Nashwaak River was higher than 2011 but below the previous 5-year mean. Annual smolt production estimates for both rivers have been less than 0.6 smolts per $100m^2$ of productive habitat (habitat unit). These smolt production estimates are well below the optimal reference levels (3.8 smolt/$100m^2$) determined for rivers meeting or exceeding conservation requirement. Mean fry and parr densities in the Tobique and Nashwaak rivers were considerably below Elson’s ‘norm’ reference values of 29 fry and 38 parr per habitat unit in

2012. Estimated parr densities in both river systems have remained relatively constant (between 5-10 fish per unit) over the last decade.

Range and Distribution

In 2009, electrofishing surveys of 189 sites within most of the rivers or tributaries in the outer Bay of Fundy region indicated that salmon (juveniles) are still present in 15 of the 20 salmon rivers but at low abundance in most rivers. The systems with the highest mean densities were all tributaries of the SJR and included the Shikatehawk, Little Presquile, Keswick, Nashwaak, Canaan and Hammond rivers. No wild juveniles were found in the Magaguadavic and Waweig rivers. The St. Croix, Bocabec, and Musquash rivers were not surveyed. Salmon are thought to no longer be present on the Musquash River and Monquart (tributary of SJR upriver of Mactaquac Dam) due to man-made barriers. Salmon were found in the 0.5km of habitat below the dam on the Monquart during the 2009 electrofishing survey however the remaining river (or productive habitat) is not accessible to salmon.

In addition to the 20 OBoF rivers and their estuaries, tagging information for OBoF salmon indicate that they use the Bay of Fundy, Scotian Shelf, Grand Banks, Newfoundland and Labrador coasts, and the Labrador Sea including the west coast of Greenland during their marine life phase; however, existing data do not provide resolution for more explicit distribution boundaries. The marine habitat range for OBoF Atlantic Salmon is less well known than their range in fresh water. The lack of information is due, in part, to the difficulty in collecting data and tracking salmon at sea.

Genetic Considerations

Overall, levels of allele richness and gene diversity, two commonly used measures of within-population genetic variation in the sample populations of OBoF Atlantic Salmon analyzed were relatively high. They were greater than that observed in comparable sample collections from the Inner Bay of Fundy and Southern Uplands, but similar to, or slightly lower than those from Eastern Cape Breton and Northern New Brunswick. These results suggest that salmon from this region have not experienced the same magnitude of severity and/or duration of genetic bottleneck effects as experienced by Inner Bay of Fundy or Southern Upland Atlantic Salmon. Within the SJR system, levels of gene diversity were quite similar, generally varying by less than 2 percent. Levels of allele richness differed slightly more, generally varying by less than 10 percent. The only significant difference in levels of genetic variation was observed between Tobique and Nashwaak samples that involved a very large number of loci (17), and hence greater statistical power. However, reductions were modest (an approximate 2 percent decline in gene diversity and an approximate 5 percent reduction in allele richness). These declines may reflect the effects of historical stocking above Mactaquac Dam or reduced straying and among-tributary gene flow with increasing distance from the river mouth, as has been observed in studies of other river systems not similarly impacted by dams and stocking effects.

In among-population comparisons of microsatellite variation, OBoF populations cluster together and separate from all other populations analyzed from the Maritime Provinces (including those from the nearby Inner Bay of Fundy). These results are concordant with analyses of other molecular genetic markers, which demonstrate low levels of gene flow from Inner Bay of Fundy and Southern Upland populations into Outer Bay of Fundy populations. Significant genetic structuring was also observed among sample collections obtained from different tributaries, both above and below Mactaquac Dam. Stocking may have reduced the level of divergence between tributaries; however, differences persist. These results indicate that stocking may not have completely homogenized tributary populations above Mactaquac Dam, thus potential local adaptations may exist.

Recovery Targets

The proposed recovery target for OBoF DU salmon has both an abundance and distribution component.

Distribution Target

The distribution target should encompass the range of genetic and phenotypic variability among populations and environmental variability among rivers. It should include rivers distributed throughout the DU to allow for gene flow among the rivers/populations. There is the expectation that including a wide variety of populations in the distribution target will enhance persistence as well as facilitate recovery in the longer term.

Short-Term

The short-term distribution targets were based on seven criteria designed to maintain genotypic, phenotypic, and geographic representation of the DU while offering the best opportunity for recovery. Priority rivers were selected by assessing each OBoF river against criteria 1-6 (below) and assigning a weighted score (higher weights for more important criteria). Following the scoring exercise, rivers were listed by priority and representative geographic variation (criterion 7), was applied by selecting highest priority populations in the three OBoF regions based roughly on each region's proportional amount of productive habitat. Proposed priority rivers include three populations above Mactaquac Dam (23.1% of the total habitat within the Canadian portion of the OBoF region), five from below (31.7%), and one population from the Outer Fundy Complex (1.0%). Distribution target criteria for river prioritization (**in order of importance**) are as follows:

1. No evidence of extirpation
2. Unique and genetically-based traits
3. Recent presence and relative high density of wild Atlantic Salmon
4. Full connectivity between marine and spawning environments
5. High estimated productive capacity
6. Minimal relative impact by known threats.
7. Representative geographic variation/distribution
   - 3 Highest priority SJR tributaries above Mactaquac Dam (1 river)
   - 5 Highest priority rivers from SJR below Mactaquac Dam
   - 1 Highest priority river from Outer Fundy complex

Applying criteria 1-7 resulted in a proposed priority ranking for all OBoF DU rivers. From this list, short-term distribution targets were selected and include:

- SJR above Mactaquac Dam, specific tributaries include:
  - [1]Tobique, Shikatehawk, and Becaguimec
- Rivers from SJR below Mactaquac Dam include:
  - Canaan, Nashwaak, Hammond, Keswick, and Kennebecasis

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[1] Tobique scored for unique traits based on the presence of 'pre-smolt' phenotype and the documented accounts of the unique migration behaviour by the Serpentine River stock (upper tributary of the Tobique).

- Outer Fundy complex include:
    - Digdeguash

The short-term distribution target is to support the persistence of salmon in the 7 priority rivers known to historically contain Atlantic Salmon populations.

Long-Term

The long-term distribution target is to support the persistence of salmon in all 20 rivers known to historically contain Atlantic Salmon populations. It is unknown whether all 20 rivers are required to ensure the long-term persistence of the DU; however, a greater number of populations are expected to increase the chance of persistence of the DU.

Abundance Target

Abundance targets are set using the conservation egg requirement of 2.4 eggs per m^2 of productive habitat. This is consistent with the terminology used by Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) when developing the conservation egg requirement and for a limit reference point in DFO's Precautionary Approach framework. Overall population size is positively related to population persistence for a range of fish species, which suggests that increasing population size is important for recovery. However, population size alone is not an indicator of population viability, and precisely how large populations need to be depends on their dynamics as they rebuild.

Short-Term

The short-term abundance target for the OBoF DU is to annually achieve the conservation egg requirement in all the seven priority rivers selected for distribution targets. Short-term distribution target rivers include the SJR upriver of Mactaquac Dam (specifically, Tobique, Shikatehawk, and Becaguimec tributaries), five rivers downriver of Mactaquac Dam (Keswick, Nashwaak, Canaan, Kennebecasis, and Hammond), and one river from the outer Fundy complex (Digdeguash). Combined, short-term target rivers represent 56% of the salmon habitat in the OBoF region. This target translates to approximately 54.4 million eggs which could be produced by 23,500 adult salmon (17,000 1SW and 6,500 MSW salmon) within the 22.62 million m^2 of productive habitat area.

Long-Term

The long-term abundance target, based on 2.4 eggs per m^2, is 97 million eggs in the currently accessible 40.46 million m^2 of productive habitat area. This egg deposition could be produced by 41,200 adult salmon (29,700 1SW and 11,500 MSW salmon based on current biological characteristics). Currently accessible habitat includes all Canadian OBoF productive habitat area except the estimated 1.3 million m^2 of currently inaccessible habitat due to dams on the Monquart, Nackawic, and Musquash rivers.

Recovery targets will need to be revisited as information about the dynamics of the recovering populations becomes available.

Population Dynamics

A life history-based population dynamics model was used to evaluate population viability. The population dynamics model consists of two parts: a freshwater production model that provides estimates of the expected smolt production as a function of egg deposition, and an egg-per-smolt (EPS) model that provides estimates of the rate at which smolts produce eggs throughout their lives. These components are combined via an equilibrium analysis that provides estimates of the abundance at which the population would stabilize if the input parameters remained unchanged. This combined model is then used to evaluate how equilibrium population size has changed through time, using dynamics from a ‘past’ (1973-1982) and ‘present’ (2000-2009) time period as well as how the population would be expected to change in response to changes in carrying capacity, survival, or life stage transition probabilities. Parameter estimates from the model are used in the population viability analysis (PVA) for the recovery scenarios. Analyses are presented for the two larger index rivers: the Nashwaak River (index river below Mactaquac Dam) and the Tobique River (index tributary river above Mactaquac Dam). Most results are produced from the more complete Nashwaak data set.

Life-History Parameter Estimates

Freshwater Productivity

The analyses for the Nashwaak River population indicate that the maximum number of smolts produced per egg, which occurs at very low abundance in the absence of density dependence, in the past (1973-1982) and present (2000-2009) was 0.007. The carrying capacity for age-1 parr was estimated to be 28.01 parr per 100 m^2, and for smolt to be 104,430 for the entire watershed. For the Tobique River, analyses indicate that the number of smolts produced per egg in the past and present was 0.005. The carrying capacity for age-1 parr was estimated to be 9.31 parr per 100 m^2 and for smolt was estimated to be 27,009 for the entire watershed. This is considered to be low relative to other populations and indicative of freshwater productivity issues.

At-Sea Survival of Smolts and Kelts

Smolts are juvenile salmon migrating to sea for the first time. Kelts are post-spawned adults. One of the causes of OBoF population decline is considered to be a decline in smolt-to-adult return rates. For populations downstream of Mactaquac Dam, estimates of return rates for wild smolts are not available prior to the late-1990s because smolt abundance was not being monitored. However, for the Nashwaak River population, the life history model described above provides estimates of smolt production using time series of estimated egg depositions, age-specific abundances of fry and parr, and the more recent age-specific smolt abundance time series (Figure 6) that can in turn be used to estimate historical return rates. A second issue exists for populations upstream of Mactaquac Dam. It is not possible to determine which fish were bound for the Tobique River to calculate return rates because all salmon bound for any tributary above Mactaquac Dam are collected at the Mactaquac facility and transferred upstream. Thus, return rates to the Nashwaak River, which has full natural access to the Bay of Fundy, are used as a proxy for return rates in Tobique population life history and viability analyses.

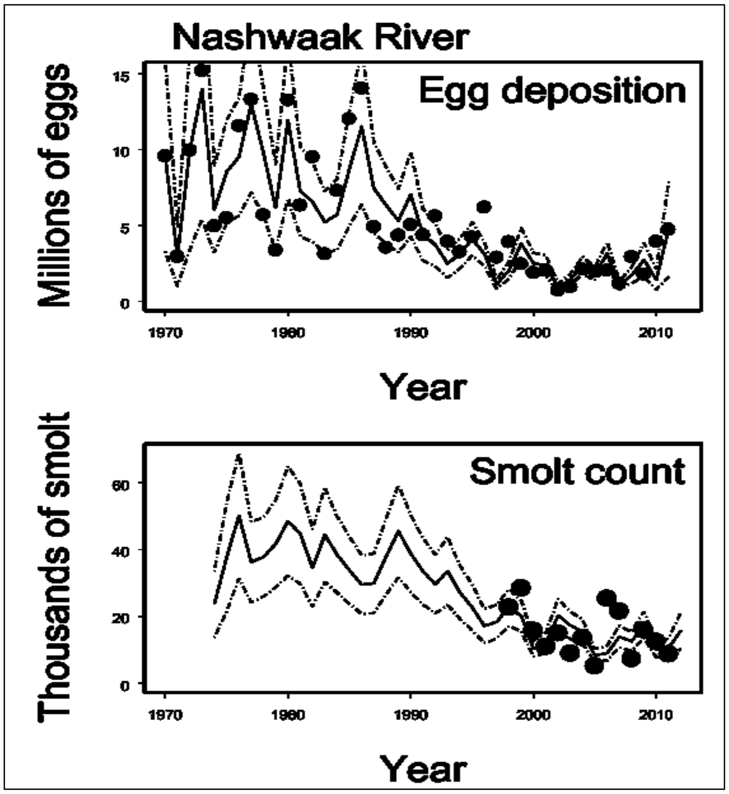

Figure 6. Observed data (points) and fitted (lines) of egg deposition and smolt counts for Atlantic Salmon populations in the Nashwaak River as estimated with the life-history model. The broken lines show 95% confidence intervals based on normal approximations.

The observed and estimated return rates of 1SW and 2SW salmon for the Nashwaak population are shown in Figure 7 and summarized, with fecundity and sex ratio changes from the past to present time periods, in Table 2.

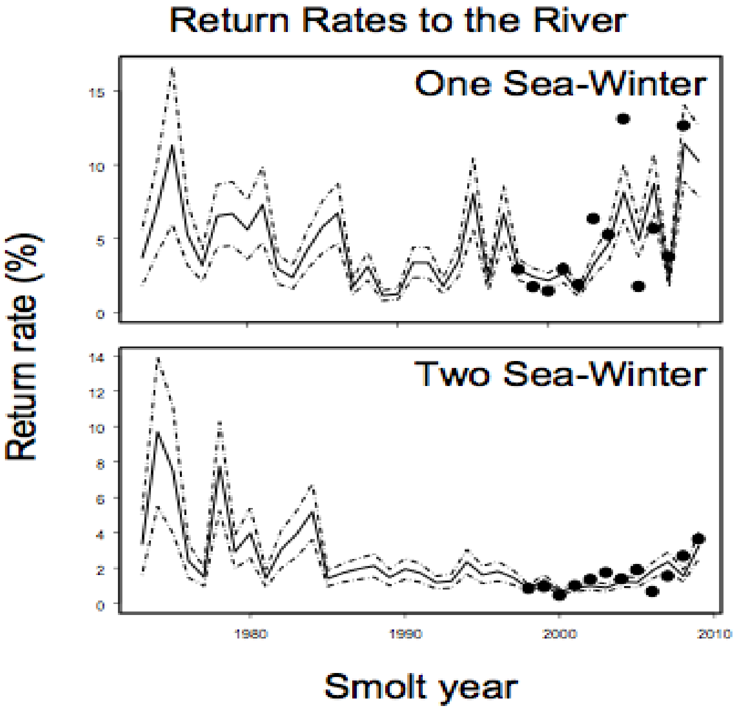

Figure 7. Observed data (points) and estimated (lines) of return rates for 1SW and 2SW wild Atlantic Salmon for the Nashwaak River population, as estimated with the life-history model. The broken lines show 95% confidence intervals based on normal approximations. Return rates are to the mouth of the river.

Table 2. A summary of the average return rates (percent), fecundities, and proportion females for 1SW and 2SW wild Atlantic Salmon for the 1973-1982 and 2000-2009 time periods for the Nashwaak River population.

	Nashwaak River	
	1973-1982	2000-2009
1SW return rate (%)	5.95	4.95
2SW return rate (%)	4.35	1.29
Fecundity (1SW)	3,212	3,430
Fecundity (MSW)	7,142	7,387
Proportion female (1SW)	0.231	0.408
Proportion female (MSW)	0.858	0.796

Population Dynamics Results

Due to the changes in return rates, fecundities, and sex ratios described above for the Nashwaak population, the number of eggs expected to be produced by a smolt through its life (EPS) has decreased. EPS values decreased from 333 eggs/smolt in the past to 151 eggs/smolt in the present.

The estimates of freshwater productivity (the rate at which eggs produce smolts) and the EPS estimates (the rate at which smolts produce eggs throughout their lives) were combined via an equilibrium analysis to provide estimates of the abundance at which the population will stabilize if the input parameters remain unchanged. This combined model was then used to evaluate how equilibrium population size has changed through time, as well as how the population would be expected to change in response to changes in survival.

For the Nashwaak River (Figure 8), the equilibrium egg abundance for this population changed substantially from the past to the present. During the past, the mean equilibrium egg abundance for the population was 20.8 million, a value well above the conservation egg requirement (12.8 million). However the mean equilibrium egg abundance for the present (2000-2009) is 1.7 million eggs, which is only 13% of conservation egg requirement. The equilibrium egg abundance is low enough that the population is expected to be at high risk of extirpation due to the effects of random environmental variability.

The maximum lifetime reproductive rate (the maximum number of spawners produced per spawner throughout its life at very low abundance) for the Nashwaak population has decreased from an average of 2.49 in the 1973-1982 time period, to an average of 1.13 during the 2000s. These rates are very low for Atlantic Salmon and are indicative that the Nashwaak population is at risk of extinction due to a reduced capacity to recover from years of low survival that may occur either due to environmental events or due to human activities.

For the Tobique River population, the number of spawners replaced from one generation to the next, the maximum lifetime reproductive rate was estimated to be 0.18 indicating that spawners are well below replacement and the population is not viable. The Tobique population will be extirpated unless this rate improves. Freshwater production, downstream fish passage survival, and marine survival for the Tobique River population all have to improve to achieve recovery targets.

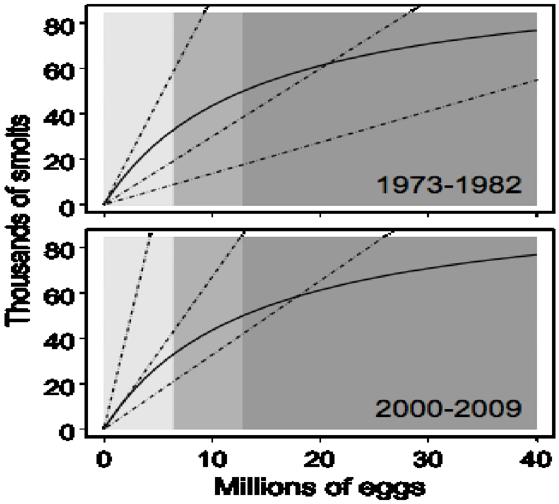

Figure 8. Equilibrium analysis for the Nashwaak River. Solid lines represent freshwater production. Dashed lines represent marine production as calculated from minimum, mean and maximum observed return rates for 1SW and 2SW adults during the two time periods. Dark, medium and light shading indicates egg depositions above, between 50% and 100%, and below 50% of the conservation egg requirement respectively.

Analyses were carried out for the Nashwaak River population using both the past and present dynamics. Populations were modeled as closed populations, meaning that that were not affected by immigration or emigration. However, if either process was occurring it would influence the estimated survival rates. For each PVA scenario, 1000 population trajectories were simulated and the extinction and recovery probabilities were calculated (% populations extinct/recovered at specified time). Populations were considered extinct when adult female abundance was less than 15 for two consecutive years. For both the past and present scenarios, the population was projected forward from a starting abundance of the estimated mean adult population size for the last five years (2008-2012). The numbers of eggs, parr, smolt, and adults, as well as their age, sex, and previous spawning structure, at the start of each simulation were calculated from the adult abundance using the life-history parameter values specific to the simulation.

Population Viability under Present Conditions

Population modeling incorporates random variability for survival estimates and stage transition probabilities. Extreme environmental events are assumed to occur with an annual 10% probability (every 10 years) and have a 20% mortality impact on the population. Population viability analyses indicate that the abundance of the Nashwaak River population, an index of populations in the SJR below the Mactaquac Dam, will continue to decline under current conditions. These results indicate a 28% probability of extirpation over the long term (100 years) in the absence of human intervention or an increase in survival rates for some other reason (Figure 9). This population has zero probability of reaching its recovery target with present dynamics. Past dynamics allow the population to avoid extinction and improve the chances of recovery, with over 50% probability of recovery after 40 years.

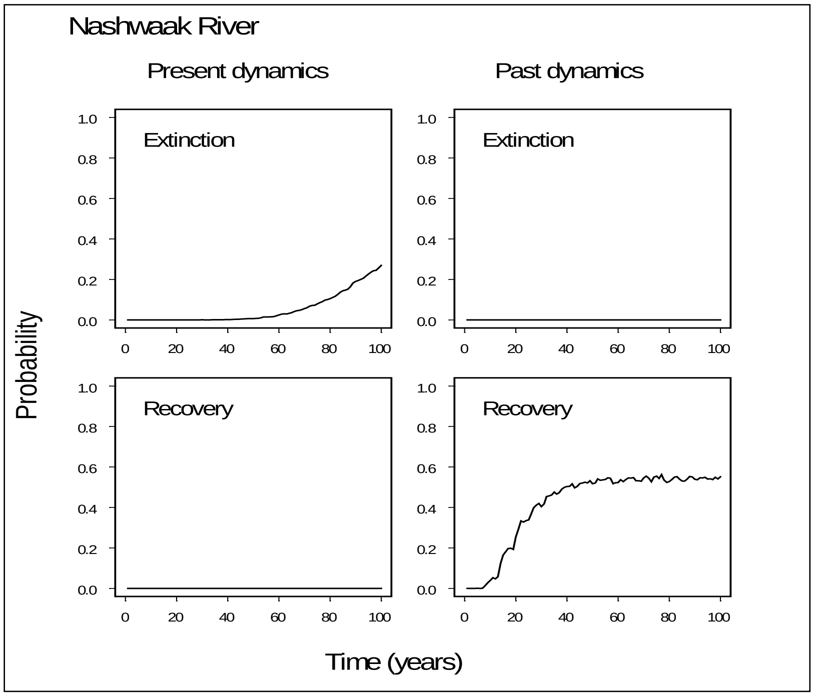

Figure 9. Probabilities of extinction/recovery for the Nashwaak River based on 1973-1982 dynamics (past dynamics) and 2000-2009 dynamics (present dynamics). Probabilities are calculated as the proportion of 1000 Monte Carlo simulations of population trajectories that either became extinct or met the recovery target. Extreme environmental events (one every 10 years) have been incorporated into the model.

Population Viability Scenarios

PVA scenarios were assessed with past, present and two intermediate at-sea survivals, fecundities, and sex ratios (Table 3), potential improvements in the present freshwater productivity (none, 20%, 50%, 100%), and different frequencies and magnitudes of extreme environmental events. For each scenario, 1000 simulated population trajectories, each 100 years in length, were produced (Figure 10). Only current freshwater and marine dynamics lead to a probability of extinction greater than zero (Table 4). Increases in freshwater productivity are expected to result in an increase in population abundance and a decreased extinction probability. Increases in both freshwater productivity and at-sea survival are required to meet recovery targets with higher probabilities (>90%).

Table 3. At-sea survival rates used in the recovery scenario analyses for the Nashwaak River past and present dynamics. The middle columns (Intermediate) show scenarios using values increased by 1/3 and 2/3 of the difference between the Past and Present values.

Life history parameter	Present	Intermediate (+1/3 diff.)	Intermediate (+2/3 diff.)	Past
1SW return rate (%)	4.95	5.29	5.62	5.95
2SW return rate (%)	1.29	2.31	3.33	4.35
Fecundity (1SW)	3,430	3,357	3,285	3,212
Fecundity (MSW)	7,387	7,305	7,224	7,142
Proportion female (1SW)	0.408	0.349	0.290	0.230
Proportion female (MSW)	0.796	0.817	0.838	0.860

Table 4. Summary of proportions of populations simulated trajectories that either recover or go extinct in 50-year time horizons based on recovery scenarios for the Nashwaak River. The marine scenarios reflect changes from the present levels (2000-2009) of at-sea survival to those in the past (1973-1982). The freshwater scenarios reflect increases in freshwater productivity from the present level (1) to 2 times the present level. The lettering for the runs corresponds to those in Figure 10.

			50-year proportions	
Run	Marine	Freshwater	Extinct	Recovered
A	Present	1	0.01	0.00
C	Present	1.5	0.00	0.01
D	Present	2	0.00	0.32
G	1/3	1	0.00	0.00
I	1/3	1.5	0.00	0.44
M	2/3	1	0.00	0.14
O	2/3	1.5	0.00	0.88
S	Past	1	0.00	0.52
U	Past	1.5	0.00	0.97

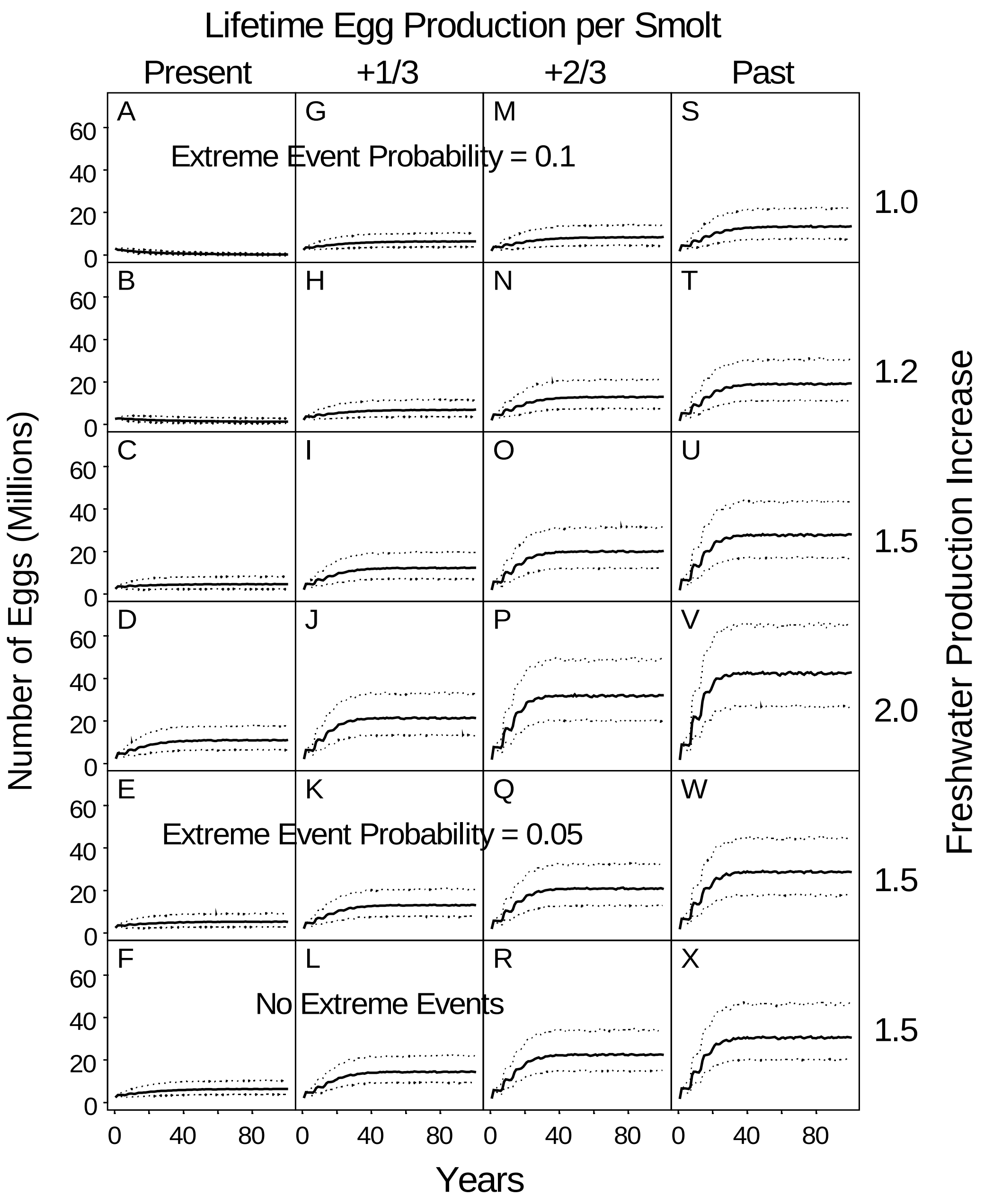

Figure 10. Effects of increasing at-sea survival and freshwater productivity on abundance of eggs for the Nashwaak River population. The median abundance (solid line), and the 10th and 90th percentiles (dashed lines) are shown. Panels on the right and the left are based on the 1973-1982 (past) and 2000s (present) at-sea survival respectively and the middle panels show scenarios using survivals increased by 1/3 and 2/3 of the difference in these values. Return rates for 1SW and 2SW and survival between repeat spawning events are increased. The 2000s freshwater production is used in all scenarios. The top four rows show the effect of increasing freshwater productivity by none, 20%, 50%, and 100%. The bottom two rows show the effect of changing the frequency of extreme events to an average of 1 every 20 years (5th row) and to no extreme events (bottom row). The conservation egg requirement for the Nashwaak River population above the counting fence is 12.8 million.

Sensitivity to Starting Population Size

Recent (2008-2012) mean abundance has been used for base model simulations; however, there is sensitivity to the starting population size used for projections. The effects of a starting population 10%, 25%, 50%, and 100% of this mean were evaluated, as well as the 2012 abundance (Figure 11). The time to extinction decreases with the lower starting population sizes, while the time to recovery is delayed accordingly. The extinction probability is much higher when the 2012 abundance is used rather than the 2008-2012 mean abundance.

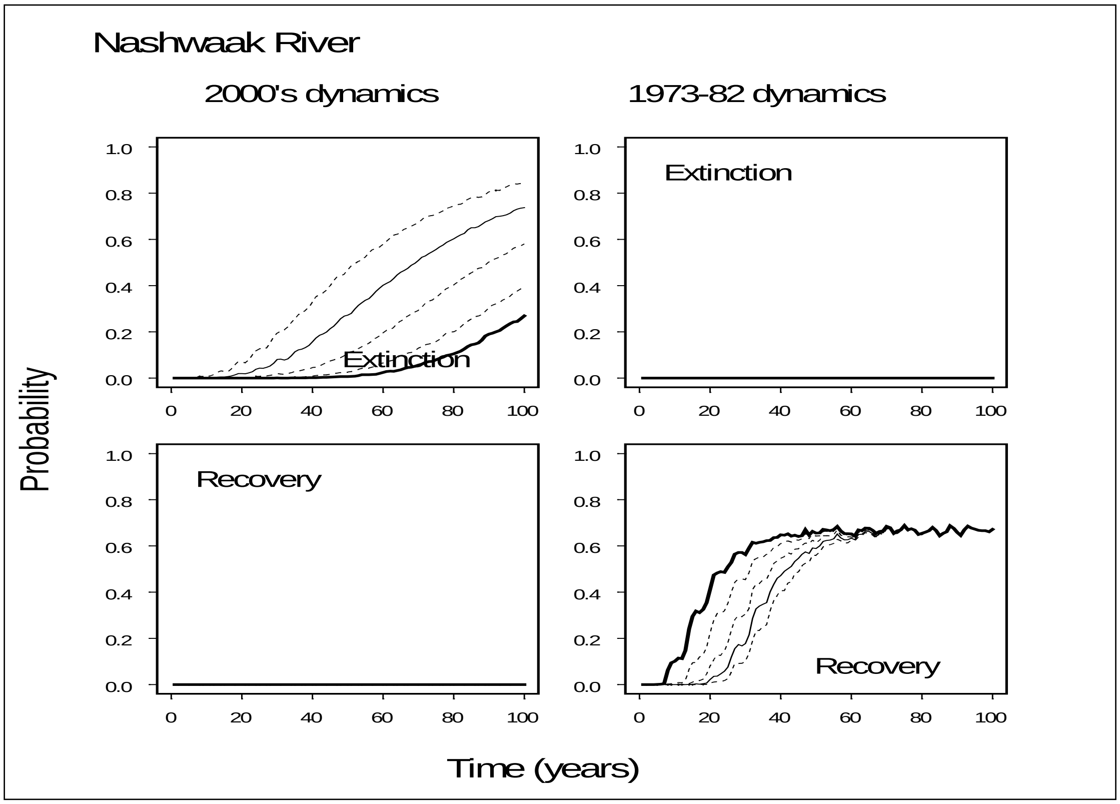

Figure 11. The probability of extinction and recovery for the Nashwaak with reductions in population size. The thick solid lines show the probabilities with current 5-year average abundance (896 1SW salmon and 263 MSW salmon). The other lines show the effects of 50%, 25% and 10% of this abundance (moving away from the solid line, respectively). The 2012 abundance estimates (29 1SW salmon and 63 MSW salmon) produce the thin solid line.

Habitat Considerations

Functional Descriptions of Habitat Properties

Freshwater Environment

Functional components of freshwater habitat, including their associated features and attributes are well known for OBoF DU salmon relative to marine habitat (Table 5). Atlantic Salmon streams are generally clean, cool and well oxygenated, characterized by gradients greater than 0.12%, with bottom substrates composed of assorted gravel, cobble and boulder, pH values greater than 5.3 and low silt loads. Salmon prefer relatively stable stream channels that develop natural riffles, rapids, pools, and flats, which are utilized during different life stages. Highest population densities and productivities are associated with rivers that have moderate summer temperatures (up to 22°C).

Returning adults ascend from the Bay of Fundy to their natal rivers between May and October. When not actively ascending, they typically occupy holding pools where they may spend weeks to months in a single pool. The migration of adults appears to be largely dependent on river discharge and to a lesser degree, temperature. Low flows have been widely observed to delay entry of returning spawners to freshwater environments. High flows generally stimulate upstream movement although responses to changes in discharge are variable.

Atlantic Salmon in the OBoF DU spawn from late October to early November, with eggs incubating in redds through the winter and hatching in April. Spawning redds are often gravel areas with moderate current, a water depth of 0.5–2 m and well oxygenated (>4.5 mg/L dissolved oxygen) continuously flowing cold water. Egg and alevin stages are spent in the interstitial spaces of the gravel within the redd.

Juvenile salmon typically maintain relatively small feeding territories in streams, which can be re-established when individuals undergo larger-scale movements to seek improved foraging conditions, refuge (thermal or seasonal) and/or precocious spawning. Parr frequently establish individual territories in riffle-pool regions of streams in depths of 20-100 cm and feed mainly on drifting invertebrates. Habitat utilized by juveniles varies with discharge and temperature resulting in juveniles occupying a wide range of habitat features.

Home ranges in freshwater are abandoned when pre-smolt and smolt begin to migrate to the marine environment. In the Tobique tributary of the SJR, migrating wild ‘pre-smolts’ from higher in the system are captured lower in the system in October-November while smolts from the lower reaches migrate between late April and early June. Telemetry studies have shown that some pre-smolts from the Tobique River migrate past Tobique Narrows Dam (near the mouth of the Tobique River) and overwinter in the main stem of the SJR. This behaviour is unique among populations of the OBoF DU and contributes to Tobique River’s high priority status for a distribution target. Smolt migration on the Nashwaak River occurs within a similar time frame as those of the Tobique with very little incidence of fall migrating pre-smolts.

Despite a relative lack of explicit knowledge on kelt (overwintered adult salmon) habitat use, observations support the hypothesis that most SJR kelts overwinter in the ice-covered river or estuary. Black salmon or kelt angling data from spring fishery on the Nashwaak River (and other rivers within the DU) in April and May indicate that a number of post spawning adult salmon overwinter within the river. Recent tagging of kelts captured in early April on the Hammond River (Saint John Basin) indicates use of the estuarine habitat in the lower SJR for upwards of four weeks prior to entering the Bay of Fundy.

Estuarine and 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 require little to no acclimation time when moving from freshwater to saltwater thus it is assumed that estuarine habitat is not a requisite for immediate survival. It is generally thought that water temperature is the main controlling environmental variable for smoltification (although photoperiod is also important) as it regulates metabolic rate.

The marine temperature ‘preference’ for Atlantic Salmon ranges between 1-13°C with high preference for 4-10°C areas. Observations of tagged salmon, and analysis of salmon catches, indicate a high incidence of occurrence in the top 5 m however there is also evidence of deeper diving behaviour, potentially associated with feeding. For example, kelts fitted with data logging satellite tags spent most of their time near the surface (depth less than 2 m) while migrating, followed by a diurnal cycle of repeated diving to depths greater than 50 m during daytime once feeding grounds were reached; with occurrences of deep diving in the 100-500 m range along fronts and at the edge of shelves.

Atlantic Salmon feed almost continuously while at sea; they are voracious, opportunistic, and will feed on many types of pelagic food available. Prey of ocean-feeding Atlantic Salmon consists of pelagic and mesopelagic fishes, crustaceans, and squid, a diet that varies with age and ocean depth. When they first enter seawater, post-smolts feed mainly on insects floating on the surface but switch to planktonic crustaceans after a few weeks at sea. In the outer Bay of Fundy and Gulf of Maine, the most abundant food items were the crustaceans *Themisto* spp. (Amphipoda, Hyperiidae), *Megancyctiphanes norvegica* and *Thysanoessa inermis* (Euphausiidae, or krill). Fish larvae are also a common diet item during the early post-smolt stage. On the high seas, salmon progressively switch from a diet dominated by planktonic crustaceans to one dominated by fish and squid. Stomach contents of salmon collected over water depths in excess of 1000 m consist predominantly of various mesopelagic fishes (*Paralepis*, Myctophidae), planktonic crustaceans (*Themisto*, Euphausiidae) and squid (*Gonatus fabricii*). Over shallower depths, salmon stomachs contain planktonic crustaceans, Capelin (*Mallotus villosus*), Northern Sand Lance (*Ammodytes dubius*), and Atlantic Herring (*Clupea harengus*). During homeward migration, salmon food organisms in stomachs change from deepwater fishes (mesopelagics), to nearshore fishes (Herring, Sand Lance), and finally they cease to feed before entering freshwater.

Function, features and attributes of important habitat are provided in Table 5 and are based on the above review of OBoF salmon habitat requirements.

Table 5. Summary of features, functions, and attributes of important OBoF salmon habitat.

Geographic Location	**Life-Stage (age from egg deposition in months)**	**Function**	**Features**	**Attributes**
High Priority Rivers of the OBoF DU include: **SJR above Mactaquac Dam** *(Shikatehawk, Becaguimec, and Tobique),* **Canaan,** **Nashwaak,** **Hammond,** **Keswick,** **Kennebecasis,** and **Digdeguash**	Eggs (0-5 months)	Egg deposition and incubation (Nov-Mar)	Redds	Substrate: loose gravel and cobble (0.6-6.4cm and 6.4-25.0cm in diameter, respectively) Water depth: 0.15 to >1m (generally: 0.15-0.76m) Water velocity: 0.15-0.9m/sec, 0.3-0.5m/sec (preferred) Well oxygenated (>4.5 mg/L DO), continuous, upwelling cold water flow Gradient >0.12% Silt loads <0.02% pH >5.3
	Alevin (6-7 months)	Early development (Apr-May)	Redds	Substrate: loose gravel and cobble (0.6-6.4cm and 6.4-25cm in diameter, respectively) Water depth: 0.15 to >1m (generally: 0.15-0.76m) Water velocity: 0.15-0.9m/sec, 0.3-0.5m/sec (preferred) Gradient >0.12% Silt loads <0.02% pH >5.3
	Fry (7-14 months)	Growth (May-Nov)	Food availability Cover	Substrate: Bed complexity, connectivity among habitat types Temp ≤22°C Depth: 0.2-1m Current: moderate (25cm/sec) Prey: Invertebrate drift Gradient >0.12%, Silt loads <0.02%,

Geographic Location	Life-Stage (age from egg deposition in months)	Function	Features	Attributes
				pH >5.3
	Parr (1+:15-26 months) (2+:27-38 months) (3+:39-50+ months)	Growth (May-Nov)	Food availability Cover Riparian buffer Ice-free pool area	Substrate: bed complexity, connectivity among habitats types Temp ≤22°C Depth: 20-100 cm, Prey: insects Water Current: variable - at high flow, may prefer pools; at lower flow, may prefer riffles Gradient >0.12% Silt loads <0.02% pH >5.3
		Overwintering (Dec-Apr)	Interstitial spaces, Ice free pool areas or lacustrine habitats	Substrate: bed complexity Temp <8-10°C (start of autumnal shift in habitat and behavior) Gradient >0.12%, Silt loads <0.02%, pH >5.3
	Pre-smolt (24, 36 and 48 months)	Migration (Tobique: Oct-Nov)	Corridor to estuary, Cover	Substrate: bed complexity, connectivity among habitats types Flow: high water velocity Temp ≤22°C, 8-10°C (preferred) Gradient >0.12% Silt loads <0.02% pH >5.3
		Overwintering (Dec-Apr)	Interstitial spaces, Ice free pool areas or lacustrine habitats, and available food in early winter	Substrate: bed complexity Prey: fish eggs in early winter Gradient >0.12%, Silt loads <0.02%, pH >5.3
	Smolt (30, 42, and 54 months)	Migration (Tobique/ Nashwaak: Apr-Jun)	Corridor to estuary, Cover	Substrate: bed complexity, connectivity among habitats types Temp ≤22°C, 8-10°C (preferred) Gradient >0.12% Silt loads <0.02% pH >5.3
	Adult (44, 58,70 months)	Upstream Migration and Searching (May-Oct)	Corridor to spawning ground	Substrate: bed complexity, connectivity among habitats types River discharge: Moderate-Higher preferred Obstructions <3.4m Waterfalls: <5m with plunge pool 1.25 times the height Temp ≤22°C Gradient >0.12%
		Resting and residency (May-Oct)	Holding pools Thermal Refugia Cover Riparian buffer	Substrate: boulders (adequate size and density) Overhanging banks and Shading Temp ≤22°C
		Spawning (Oct-Nov)	Gravel bars, upstream side of riffles	Substrate: loose gravel and cobble (0.6-6.4cm and 6.4-25cm in diameter, respectively) Current: moderate (0.15-0.9 m/s) Temp ≤22°C Depth: 0.5-2m (areas of decreasing depth) Well oxygenated (>4.5 mg/L

Geographic Location	Life-Stage (age from egg deposition in months)	Function	Features	Attributes
				DO), continuous, cold water flow Gradient >0.12% Silt loads <0.02% pH >5.3
	Kelt (45, 59, and 71 months)	Overwintering (Winter/Spring)	Ice-free pools, lakes, and still waters	Depth: deep water with sufficient water volume under ice.
		Migration (Winter/Spring)	Corridor to estuary	River discharge: water flow of sufficient volume/depth to allow unimpeded access to estuarine habitat.
Estuaries of high priority rivers. **_(SJR* above Mactaquac Dam,Canaan, Nashwaak, Hammond, Keswick, Kennebecasis, and Digdeguash)._** *SJR Estuary begins at reversing falls in Saint John Harbour covers the main stem approx. 60km upstream to Long Reach NB	Smolts	Downstream Migration (Apr-Jun)	Corridor through the estuary	Water flow: spring flows Depth: in the top 5m of water column Temp ≤22°C, 8-10°C (preferred) Salinity: little acclimation, as brief as 1-2 tidal cycles
		Feeding (pre-oceanic growth)	Available food	Prey: insects floating on surface
	Kelts	Downstream Migration (Winter/spring)	Corridor through the estuary	Water flow: sufficient to allow unimpeded access Temperature: -1-20°C , 5-10°C (preferred) Salinity: increasing salinity, little acclimation, as brief as 1-2 tidal cycles Prey: Not identified
		Overwintering (Winter/spring)	Ice-free pools, lakes, and still waters	Depth: deep water with sufficient water volume under ice.
	Adults	Upstream Migration (May-Oct)	Corridor through the estuary	Connectivity among habitats types Water flow: moderate to high flow (no consistent preferred flow) Volume/depth: not identified Temperature: high temperature can impede migration Salinity: decreasing salinity
		Overwintering (SJR estuary-Serpentine) (fall of second summer at sea (1SW)	Ice-free pools, lakes, and still waters	Depth: deep water with sufficient water volume under ice.
Outer Bay of Fundy-Gulf of Maine	Post-smolts (+7 months from smolt)	Migration	Corridor to feeding grounds	Appropriate spring wind patterns Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: directed along routes of increasing salinity Depth/Light regimes: upper 5m of the water column Ocean currents: interface of Atlantic current and counter coastal current or mid-Fundy gyre
		Feeding	Available food	Prey: planktonic crustaceans, Themisto spp.(Amphipoda, Hyperiidae*), Megancyctiphanes norvegica, Thysanoessa inermis* (Euphausiidae, or krill), and fish (sand lance *Ammodytes* spp.) Temperature: SST 6-14°C, 9-10°C (preferred)
	Kelts (+1 month from	Migration	Corridor to feeding ground	Temperature: SST 0-25°C, 5-15°C (preferred)

Geographic Location	Life-Stage (age from egg deposition in months)	Function	Features	Attributes
	spawning)			Salinity: 35-35.5ppt Depth/Light regimes: <2m with repeat diving up to >50m and between 100-500m along shelves Ocean currents: presume to follow post-smolts in interface of Atlantic current and counter coastal current or mid-Fundy gyre
		Reconditioning	Available food	Prey: shallower depth feeding, planktonic crustaceans, capelin, sand lance and herring Depth/Light regimes: diving to 100-500, 25-50m (preferred)
	1SW adults (+6 months from post-smolt)	Migration to freshwater Migration to sea	Corridor to spawning grounds Corridor to feeding grounds	Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: 35-35.5ppt Depth: up to 5,000, >1,000 (preferred) Ocean currents: Not identified Light regimes: Not identified Prey: homeward migration, switch to nearshore fishes (herring, sand lance)
		Feeding	Available food	Prey: at >1,000m, mesopelagic fishes (*Paralepis*, Myctophidae), planktonic crustaceans (*Themisto*, Euphausiidae), and squid (*Gonatus fabricii*).
	Repeat Spawners (+12 to 16 months from 1SW adult)	Migration to fresh water	Corridor to spawning grounds	Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: 35-35.5ppt Depth: up to 5,000, >1,000 (preferred) Ocean currents: hypothesized to retrace northward movement as post-smolts Prey: homeward migration, switch to nearshore fishes (herring, sand lance)
		Feeding	Available food	Appropriate forage Prey: mesopelagic fishes and squid
Scotian Shelf	Post-smolts	Migration	Corridor to feeding and wintering grounds	Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: directed along routes of increasing salinity Depth/Light regimes: upper 5m of the water column Ocean currents: interface of Atlantic current and counter coastal current
		Feeding	Available food	Prey: mesopelagic fishes and squid
	1SW adults 2SW adults (+18 months from post-smolt) and, Repeat Spawners	Migration (*fish capture in any month likely returning as maturing fish)	Corridor to Spawning grounds Corridor to feeding and wintering grounds	Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: 35-35.5ppt Depth: up to 5,000m, excess of 1,000m (preferred) Ocean currents: kelts-hypothesized to retrace northward movement as post-smolts. Seaward Migration: not identified

Geographic Location	Life-Stage (age from egg deposition in months)	Function	Features	Attributes
				Light regimes: not identified
		Feeding	Available food	Prey: mesopelagic fishes and squid
East coast NL -Grand Banks	Post-smolts,1SW adults, 2SW adults and, Repeat Spawners	Overwintering and Feeding	Available food	Temperature: SST 1-13°C, 4-10°C (preferred) Opportunistic feeder: various pelagic food items
		Migration (1SW- May-Jun- homeward migration as maturing fish and July-Apr- northward migration as non-maturing fish) (2SW- suspected homeward migration in March, April and early May as mature fish)	Corridor to feeding and wintering grounds Corridor to spawning ground	Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: 35-35.5ppt Depth: up to 5,000m, excess of 1,000m (preferred) Ocean currents: northern movement, possibly West Greenland Current of the North Atlantic sub-polar gyre and returning from Greenland in the Labrador Current on westerly side of the sub-polar gyre (hypothesized to retrace northward movement as post-smolts) Light regimes: not identified Appropriate forage
Labrador Sea	Post-smolts,1SW adults, 2SW adults and, Repeat Spawners	Overwintering and Feeding	Available food	Temperature: SST 1-13°C, 4-10°C (preferred) Salinity: not identified Depth/Light regimes: Upper 3m of water column, <1m (preferred) Opportunistic feeder: various pelagic food items
		Migration	Corridor to spawning grounds Corridor to feeding grounds	Ocean currents: northern movement, possibly West Greenland Current of the North Atlantic sub-polar gyre and returning from Greenland in the Labrador Current on westerly side of the sub-polar gyre

Spatial Extent of Habitat

Freshwater Environment

OBoF salmon are thought to utilize accessible habitat of most rivers of Southwest New Brunswick draining into the Bay of Fundy west of and including the SJR. 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 New Brunswick while being fed by tributaries in Eastern Quebec and then flows southeast through New Brunswick to the Bay of Fundy.

For DU 16 there are eleven salmon rivers (considering SJR above Mactaquac Dam as one river with 18 tributaries) within the Saint John River Basin. An additional nine ‘outer Fundy complex’ rivers lie west of the SJR draining into the Bay of Fundy between the city of Saint John and the U.S.A.-Canada boundary. The seven rivers/tributaries identified in the short-term distribution target and their estuaries are considered important habitat and are required for the OBoF DU salmon to complete their life cycle.

Estuarine and Marine Environment

The estuary boundary for the SJR and its tributaries fluctuates with the Bay of Fundy 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 here.

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 Bay of Fundy rapidly from late-May to early-June and directly through Grand Manan Basin. To extend knowledge of the migration routes, condition and habitat of post-smolts from the Bay of Fundy 900,000 hatchery-origin smolts were released from MBF on the SJR and several thousand wild smolts from several Bay of Fundy rivers were captured, marked and released. Subsequent surface trawling surveys in the Bay of Fundy and Gulf of Maine 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.

Unlike the SJR post-smolts, which can directly enter the Bay of Fundy, the St. Croix, Dennis Stream, Waweig, Bocabec, Digdeguash, and Magaguadavic post-smolts in particular, access the Bay of Fundy after encountering the counter-clockwise circulation patterns within the Passamaquoddy Bay. The majority of tagged smolts from Magaguadavic and St. Croix rivers moved quickly as post-smolts through Passamaquoddy Bay (2–6 days) and left by a direct route, usually during an ebb tide. Post-smolts that were slow to leave (7-12 days) moved across the bay from the head of Eastern Passage to Western Passage. Marine temperatures within Passamaquoddy Bay are similar on average to those of the Bay of Fundy and within the ‘preferred’ range for post-smolts.

Tidal currents and wind appear to be factored in the rapid movement of post-smolts tracked away from estuaries towards the Bay of Fundy and the open sea. Post-smolts of OBoF origin likely move, in part, in the interface of southern Atlantic currents in reaching the Outer Bay of Fundy, Scotian Shelf, coasts of Newfoundland, and the Labrador Sea before wintering in the Labrador Sea. In the spring, adult salmon of North American origin concentrate off the eastern slope of the Grand Bank and less abundantly in the Southern Labrador Sea and over the Grand Bank. In summer, feeding 1SW salmon (referred to as non-maturing) move northward, possibly transported by the West Greenland Current of the North Atlantic sub-polar gyre, off the West Greenland coast and, in less abundance, to the Northern Labrador Sea and occasionally the Irminger Sea. Based on tag recoveries, salmon returning from West Greenland appear in Labrador and Newfoundland fisheries consistent with transport in the Labrador Current on the westerly side of the sub-polar gyre. Information is not currently sufficient to determine important marine habitat boundaries other than a general range of occurrence between the OBoF and the Labrador Sea.

Supply of Suitable Habitat, Including Barriers and other Constraints

Freshwater Environment

The larger rivers of the OBoF DU have had a century or more of industrial development that has severely impacted Atlantic Salmon habitat. Dams, regulated flows, headponds, other habitat alteration, as well as inputs of 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.

In total, there is an estimated 41.75 million m^2 of historically accessible productive freshwater habitat available in the area occupied by OBoF Atlantic Salmon of which, 40.4 million m^2 remain currently accessible. Fish passage facilities provide access to 41.1% of the habitat considered currently accessible. Productive habitat estimates in the Canadian portion of the OBoF region, include 14.4 million m^2 (36%) upriver of Mactaquac Dam and 23.2 million m^2 (57%) downriver of

Mactaquac Dam. Only 2.8 million m^2 (7%) of productive habitat are found in outer Fundy complex rivers. Anthropogenic barriers on the Monquart, Nackawic, and Musquash rivers totally exclude salmon from approximately 1.30 million m^2 of productive habitat; other barriers (they number over 200 in the region) and passage issues at some road crossings affect connectivity for habitat in the region.

The occurrence of juveniles in most tributaries of the SJR suggests an element of habitat suitability, particularly on the Tobique, Shikatehawk, and Becaguimec tributary rivers above Mactaquac Dam and the Keswick, Nashwaak, Canaan, Kennebecasis, and Hammond rivers below Mactaquac Dam. However from the perspective of Elson's 'norm', reference levels, mean fry and parr densities on the Tobique River (19% of accessible habitat within Canadian boundaries to OBoF salmon) have achieved Elson 'norm' for fry density only once and never for parr since 1993. The lower values for the Tobique may well have been the result of habitat alteration in the 1950s, including construction of the Tobique Narrows Dam and controlled discharges for power generation from storage reservoirs. Some smaller and relatively pristine streams, such as the Shikatehawk, have yielded much higher densities than the 'norms'. With the exception of the Nashwaak River, less is known about habitat suitability downstream of Mactaquac. In the decade preceding 1993, fry densities in the Nashwaak River achieved Elson's 'norm' but have generally failed to meet 50% of the 'norm' in the last 15 years. From 1982 to present, parr densities largely failed to achieve >50% of the 'norm'.

In general, the supply and suitability of freshwater habitat is not considered to be presently limiting the persistence of OBoF Atlantic Salmon but may limit the recovery of OBoF Atlantic Salmon to target levels due to apparent low productivity relative to the habitat occupied by other DUs.

Estuarine and Marine Environment

Estuarine and marine habitat availability is not thought to be limiting population persistence at present but there may be less suitable habitat available now than in the past. Survival (to adults) of smolts released from the MBF and those estimated to have naturally migrated from the Nashwaak River is considerably less than what it was two and three decades ago. This suggests that suitable habitat in estuaries or at sea has diminished. However, the possibility that perceived declines in marine survival are driven by or linked to threats (such as exposure to contaminants which lower marine survival) in the freshwater environment cannot yet be ruled out.

Tagging results suggest that the presence of salmon farms both in the St. Croix estuary and along the migration route from the Magaguadavic River outflow did not delay salmon migration, but most losses of smolts and post-smolts from that river occurred in areas near the salmon farms where potential predators were abundant.

The influence of warming sea temperatures in recent years may be a constraint on salmon. The fish may encounter altered amounts or timing of predators or pathogens when accessing traditional feeding areas.

Habitat Allocation Considerations

Freshwater Environment

Habitat allocation in freshwater should be focused on protecting the functional characteristics of habitats and within DU population variability so as to minimize extinction risk for OBoF Atlantic Salmon populations. Highest priority should be accorded to those rivers selected for the short-term distribution target. These rivers include; the SJR above Mactaquac Dam (specifically the SJR tributary rivers Tobique, Shikatehawk, and Becaguimec), Keswick, Nashwaak, Canaan, Kennebecasis and Hammond (below Mactaquac Dam), and the Digdeguash (outer Fundy complex). The Keswick River contained relatively high densities of juveniles but this may reflect a mix of stocks originating upriver of the Mactaquac Dam which ‘dropped back’ from the dam. A similar situation may be present on the Shikatehawk River (below Beechwood Dam). The Tobique and its tributaries have unique phenotypic traits and offer extensive allocation opportunities. For the representation of the Outer Fundy complex rivers, the Digdeguash River is recommended due to full connectivity with the marine environment, relative larger size and productivity in that region.

Estuarine Environment

A potentially important consideration in allocating tributary rivers and rivers of the SJR is that all are dependent on a single functional lengthy tidal estuary for safe passage of smolts and kelts migrating to the Bay of Fundy and adults returning to spawn. The estuary is believed to serve as an area of extended residency for adults and smolts. In addition to the presence of a major city (Saint John) on estuarine waters of the SJR, long-standing industrial activities (oil refinery and paper mill) occur at the mouth of the SJR and intensive aquaculture operations occur in the estuarine habitat of the outer Fundy complex river in the Passamaquoddy Bay region with both known and unknown impacts on the aquatic systems.

Marine Environment

Based on tagging information, the marine habitat for OBoF DU salmon includes a wide spatial range and temporal distribution from the Bay of Fundy and Gulf of Maine to the Atlantic coasts of Nova Scotia, Newfoundland and Labrador including the Labrador Sea and the west coast of Greenland. There is no evidence that range in the marine environment has been reduced. However, the functional components of marine habitat are relatively less well known (Table 5).

Residence Requirements

Under *SARA*, a residence is defined as a dwelling-place that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating (*SAR*A section 2.1). DFO’s Draft Operational Guidelines for the Identification of Residence and Preparation of a Residence Statement for an Aquatic Species at Risk (unpublished report) uses the following four conditions to determine when the concept of a residence applies to an aquatic species:

1. there is a discrete dwelling-place that has structural form and function similar to a den or nest,
2. an individual of the species has made an investment in the creation, modification or protection of the dwelling-place,
3. the dwelling-place has the functional capacity to support the successful performance of an essential life-cycle process such as spawning, breeding, nursing and rearing, and
4. the dwelling place is occupied by one or more individuals at one or more parts of its life cycle.

Three dwelling places used by five life stages of Atlantic Salmon were evaluated against these criteria. These were; spawning redds (used by eggs and alevins), home stones (used by parr), and holding pools (used by kelts and returning adults).

Based on the guidelines above, redds most closely match the criteria for a residence because they are constructed. Redds have a structural form and function of a nest, the female has invested energy in its creation, redds are essential for successful incubation and hatching of the eggs, and redds can contain hundreds to several thousand eggs from a female salmon.

Redds therefore have characteristics that meet the residence requirement criteria. Although they satisfy some criteria (they are protected), home stones are not created. Holding pools do not closely match the criteria because they are not created, modified or protected.

Threats

Threats are defined as any activity or process (both natural and anthropogenic) that has caused, is causing, or may cause harm, death, or behavioral changes to a species at risk or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur.

A summary of potential threats to OBoF Atlantic Salmon and their habitat (in no particular order) is provided in Appendix A, including a relative ranking of importance to the persistence of the OBoF salmon population.

In fresh water, hydro dams and illegal fishing activities are identified as the threats of highest concern.

Freshwater threats with an assessed medium level of concern (importance not implied by order) include: silt and sedimentation, contaminants, invasive species (fish), historical stocking practices (adult collection, spawning and juvenile release), other dams and obstructions, crossing infrastructure, urbanization, agriculture, forestry, and commercial salmonid aquaculture hatcheries.

Freshwater threats with an assessed low level of concern (importance not implied by order) are: extreme temperature events, water extraction, other power generation, other native salmonid stocking (i.e. Brook Trout and landlocked salmon), current salmon stocking practices (juvenile collection and rearing to adult release), mining, acidification, military activities, invasive species (non-fish), recreational or aboriginal or commercial fishing by-catch, and scientific activities/research.

Marine threats of high concern (importance not implied by order) are: shifts in marine conditions (which affect temperatures, currents and predator prey interactions), salmonid aquaculture, depressed population phenomenon; and disease and parasites.

High-seas fisheries are assessed as a medium level of concern.

Marine threats with an assessed low level of concern (importance not implied by order) are: shipping traffic and spills, commercial fisheries by-catch, fisheries on prey species of salmon, non-salmonid aquaculture, and scientific activities/research.

Threats assessed as a high level of concern are discussed in more detail below.

Hydro Dams

Based on available information, hydro-power generation dams (hydro dams) are considered to be the most limiting threat to OBoF salmon population persistence. In general, dams can alter the river flow, temperature, hydraulics, the stability and availability of substrate, channel morphology, and riparian vegetation, which affects the structure and function of the aquatic communities.

Hydro dams also create other identified threats in the OBoF DU including invasive species prevalence (because of reservoir habitat) and the effects of extensive long-term hatchery supplementation (to mitigate effects of dams). Indeed, the increase in abundance and distribution of invasive fish predators of Atlantic Salmon in the OBoF DU such as Muskellunge (*Esox masquinongy*) and Smallmouth Bass (*Micropterus dolomieu*) have been facilitated by habitat alteration caused by major dams. The SJR, particularly populations above Mactaquac Dam, has been subjected to intensive hatchery stocking for over 40 years to mitigate effects of hydro dams as well as the transfer of adult salmon above Mactaquac Dam to upstream tributaries without knowledge of natal tributary of origin. A wide range of depressed population fitness measures, as a result of hatchery supplementation practices, are documented by an established body of research.

There is increasing evidence that the restoration of diadromous fish populations in coastal rivers of eastern North America, including Atlantic Salmon, may well depend on the restoration of the entire diadromous fish community that co-evolved in those watersheds. Prior to the construction of the Mactaquac Dam, American Shad (*Alosa sapidissima*), Alewife (*Alosa pseudoharengus*), Blueback Herring (*Alosa aestivalis*), American Eel (*Anguilla rostrata*), Striped Bass (*Morone saxatilis*) and Sea Lamprey (*Petromyzon marinus*) had access to the headwater areas of the SJR. Shad historically ascended the SJR upstream to Grand Falls. Since the construction of Mactaquac Dam, access to areas upstream has only been provided for Atlantic Salmon and limited numbers of Alewife and Blueback Herring. American Eel and Sea Lamprey have only had accidental access to the waters above Mactaquac Dam.

Hydro dams, even those equipped with upstream fish passage facilities; reduce the connectivity and production of salmon habitat by restricting/delaying mature fish from reaching spawning habitat. Most dams in the OBoF DU range lack downstream, passage which causes delays in salmon migration through head pond reservoirs above dams, direct mortality in descending spillways or through turbines, and predation in head ponds and tail races during migration.

As a result of three major hydro dams (Mactaquac, Beechwood, and Tobique Narrows) (Figure 2), 145 km of the SJR used by Atlantic Salmon, primarily for migration between spawning grounds and the Bay of Fundy, has been compromised by flooding riverine habitat to create headpond reservoirs. The cumulative mortality rate for smolts on the Tobique River (the largest single basin in the DU) is 45% as they pass through three major headponds and dams. Considering the Tobique has the largest quantity of productive habitat of any river accessible to the DU, less than 2% of salmon eggs deposited survive to smolt. Given the recent declines in marine returns rates, this level of additive smolt mortality is concerning. The Mactaquac Dam is a complete barrier to upstream migration and requires handling of each migrating adult salmon to pass fish (by trucking) upstream to spawn, potentially after ascending up to two additional major hydro dams.

Dams on the Musquash River, built without fish passage measures in 1922, effectively ended the Atlantic Salmon run on the river. There are also dams with no passage measures on the Monquart and Nackawic rivers, which are tributaries of the SJR above the Mactaquac Dam.

The Magaguadavic River had a 13.4 m high dam and hydroelectric station located at the head-of-tide, which was replaced with a new hydroelectric station in 2004. Upstream passage in the newest facility is provided by a pool and weir fishway and there is a downstream bypass.

The first dam was built on the St. Croix River in 1860. There are three power dams (at Milltown, Woodland and Grand Falls) and three others to control water levels on the St. Croix River. All dams provide upstream fish passage.

Illegal Fishing

All OBoF salmon populations in the OBoF region have a high exposure to illegal fishing (e.g. poaching). Any removal of adult salmon from OBoF rivers constitutes a severe threat to the population and a direct loss of spawners as they have survived maximal sources of mortality at that stage. Based on net and jig/hook markings recorded at Mactaquac and Tobique salmon counting facilities, illegal fishing activities has and continues to occur on the SJR system. Accurate tracking of illegal fishing losses are inherently difficult to estimate however in 2010, conservation officers reported increased illegal fishing activity and a few seizures within the season; 58 MSW salmon (or 12.6% of the total MSW returns) were estimated to have been lost to illegal gillnet activities in 2010.

Marine Ecosystem Changes

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. Alone or in combination, these factors will likely impact on Atlantic Salmon production and survival.

Marine predators of Atlantic Salmon include seals, Spiny Dogfish (*Squalus acanthias*), sharks, and tunas. Grey Seal (*Halichoerus grypus*) abundance in Eastern Canada has increased substantially over the last 25 years. Spiny Dogfish populations in the Northwest Atlantic showed increases from 1980 - 1990, but have since declined. Spiny Dogfish or Blue Shark (*Prionace glauca*) predation on post-smolts, even at low levels, could have a significant effect on populations due to the relative high abundance of these predators. Present abundance of Porbeagle Shark (*Lamna nasus*) in the Northwest Atlantic is approximately 25% of 1961 levels but is 95-103% of 2001 abundance. Bluefin Tuna (*Thunnus thynnus*) abundance in the Atlantic region is estimated to have had a sharp (approximately 70%) decline from 1970 to the mid-1980s but has since been relatively stable.

Atlantic Herring and Northern Sand Lance have been documented as an important and preferred prey species for wild Atlantic Salmon. Herring abundance has been positively correlated with marine survival in other Atlantic Salmon populations. Northwest Atlantic Herring stocks have shown notable declines preceding the recent declines in OBoF salmon abundance. Further, there is evidence of the potential for prey competition for salmon where Grey Seals, currently near or surpassing 100 year-high abundance in the Maritime Provinces region, have been documented to be using Sand Lance as a significant prey source. Sand Lance stock abundance along the Scotian Shelf, a feeding corridor for migrating OBoF salmon, was variable 1970-1996 although did show lower relative abundance through the 1980s.

Salmonid Aquaculture

All OBoF salmon populations pass within 100 km of the intensive aquaculture activities of the Passamaquoddy Bay region in Southwest New Brunswick. In 2011, N.B. farmed salmon harvest was approximately 20,000 mt, representing approximately 4.5 million fish. Currently, there are 95 licensed Canadian aquaculture sites in the Passamaquoddy Bay region, although approximately one third are fallowed (intentionally not stocked) each year in efforts to support fish health and environmental management practices. Interactions between wild Atlantic Salmon populations and aquaculture operations can occur in the immediate vicinity of the net-pens or through interactions between escaped aquaculture salmon and wild salmon.

Escape of cultured salmon occurs through small ‘leaks’ and isolated larger events, such as storms, which can cause containment pen breaches. The potential impacts of aquaculture escapes on wild populations of Atlantic Salmon include: reduction of the genetic fitness of wild populations via inter-breeding between escapes and wild salmon, loss of local adaptations, introduction of pathogens or disease to wild stocks, competitive displacement of wild salmon, and increased uncertainties in wild stock assessment (where escaped fish are counted as wild).

Monitored OBoF rivers most impacted by suspected aquaculture escapes are the Magaguadavic and St. Croix rivers, which both empty into Passamaquoddy Bay. On the Magaguadavic, escaped salmon have been identified every year from 1992 - 2012. Wild-origin sea-run salmon were distinguished from aquaculture escapees by using external morphology and scale circuli characteristics. Since then, escapees have comprised over 75% of the cumulative total of returning salmon and have made up more than 90% of the adult run in some years. Research has shown that aquaculture escapees have interbred with wild salmon resulting in losses of local adaptations for the wild Magaguadavic River population. On the St. Croix River, escaped salmon were identified every year from 1994 to 2006 (when monitoring ended), and escapees comprised between 13 and 85% (39% median) of the total run of salmon. Suspected aquaculture escapes have also been reported on the Bocabec River.

Suspected aquaculture escapes have been captured on the SJR at the Mactaquac Dam (approximately 150 km from the Bay of Fundy) since 1990 though potentially misidentified as hatchery returns before then. Since then, suspected escapees were detected in all but 6 years with counts as high as 229 salmon (in 1990). Occurrence of escapes is positively related to a river's proximity to farm operations. Since 1993, very few suspected escapes have been captured at the counting fence that is annually operated on the Nashwaak River, about 20 km above the confluence with the main SJR at Fredericton N.B. (approximately 20 km downstream of Mactaquac Dam). No regular monitoring of suspected escapes is carried out in any of the other lower SJR tributaries (below Mactaquac Dam) which contains over 40% of the OBoF DU habitat and SJR populations nearest (for migrating salmon) aquaculture operations of the Passamaquoddy Bay region.

Based largely on research from Europe and Western Canada, potential impacts to migrating wild salmon in the immediate vicinity of net-pens include those related to waste production, altered predator-prey dynamics, and disease transfer. Predator attraction to net pens has not been directly linked to increased mortality in wild populations. However, recent research in Newfoundland showed significantly higher frequency and density of wild fish in bays containing farm operations, demonstrating potential for altered predator-prey dynamics.

Disease and Parasites

Several naturally occurring diseases have been documented in the OBoF region in wild and/or farmed fish. Major diseases and parasites affecting the Atlantic maritime aquaculture industry are: bacterial kidney disease (BKD- *Renibacteriumsalmoninarum*), furunculosis (*Aeromonas salmonicid*), vibriosis (*Vibrio anguilarum*), sea lice (*Caligus* and *Lepeophtheirus salmonis*), and infectious salmon anemia (ISA). All these diseases are found in the wild, but the most frequently affecting wild salmon are furunculosis and BKD. The size of the farmed population in Southwest N.B. presents an unnaturally high spatial and temporal density of hosts which could threaten any susceptible wild hosts (including salmon) in the event of disease/pathogen outbreak. However, there are no proven cases in Canada where disease or sea-lice outbreak in wild populations can be directly linked to aquaculture sites, although research in epidemiology demonstrates that exposure and the frequency of exposure are important contributing factors to the spread of disease.

ISA was first detected in aquaculture cages in the Bay of Fundy in New Brunswick in 1996. In 1999, 4 of 58 escaped farmed salmon captured and 14 of the 15 wild fish collected for broodstock in the Magaguadavic River tested positive for ISA. Although transmission from net pens to wild stocks has been shown in other areas, a 2005 study in the outer Bay of Fundy and Gulf of Maine did not find evidence of aquaculture sites infecting post-smolts during migration through the aquaculture corridors following disease testing and observations of post-smolt collections.

To date, Red Vent Syndrome (RVS) is restricted to wild Atlantic Salmon and may negatively affect spawning ability, fecundity, migratory behaviour, growth rate, and ability of the fish to endure changing oceanic conditions. RVS occurences are observed on SJR salmon sorted at the MBF (Figure 12), although concerted efforts to note presence/absence and describe severity did not start until 2009. Recent RVS occurrences do not appear to correlate with lower corresponding 2011/2012 pre-smolt/smolt production estimates (i.e. no observed decline in spawning success or survival to smolt), on the Tobique River however the effects of RVS in parents on marine survival of offspring are not yet known (earliest returns due in 2013).

Infectious Pancreatic Necrosis (IPN) is endemic in both marine and freshwater environments in N.B., although only a few epizootic outbreaks in trout fry in freshwater hatcheries were associated with this viral infection. The disease agent (IPNv) was detected in salmonid 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.

Ectoparasitic copepods (*Lepeophtheirus salmonis* and *Caligus sp.*), commonly referred to as ‘sea lice’, feed on salmon skin, flesh, and mucus. The MBF research program has been monitoring sea lice on returning salmon since 1992. Between 1992 and 2002, 21 and 17% of the wild and farmed salmon caught respectively, were observed to have sea lice. Presence of ectoparasites on returning adult salmon is observed at MBF sorting facilities (Figure 12). These observations suggest parasites have been present on a higher proportion of returning salmon over the last decade. Despite the known presence of at least one species of freshwater (*Argulus stizostethii*) and salt water (*Lepeophtheirus salmonis*) parasitic louse on salmon returning to the MBF sorting facility in recent years, regular identification has not been carried out to determine parasite species composition over time. 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 N.B. 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.

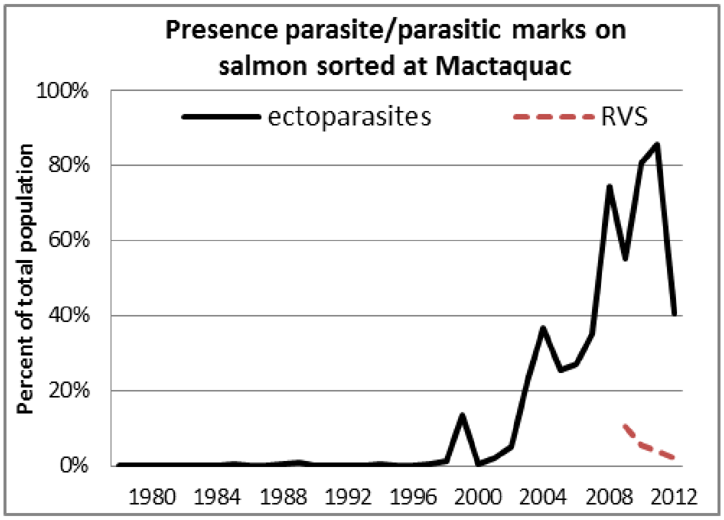

Figure 12. Observation of ectoparasite and RVS presence on adult salmon sampled at the MBF sorting facility 1980-2012.

Depressed Population Phenomenon

When populations decline to very low levels as a result of individual or compounding threats, mechanisms driven simply by low population numbers can act to maintain low levels or prohibit recovery independent of original threats. For fish, the consequences of very low abundance can include inbreeding depression, behavioral shifts, inability to find mates, and ineffective school sizes to adequately defend against predators. These effects are often described as depressed population phenomenon.

For the OBoF DU, dramatic declines in abundance may be sufficient for depressed population phenomenon to limit recovery. With the continued decline of population abundance it has become increasingly difficult to detect sources of mortality. It is possible that current populations are too small to determine if original causes of decline would also limit the recovery of a larger population or rather, are currently limiting recovery because populations are so small. To answer this, populations in the OBoF DU and possibly adjacent DUs (depending on the effect of metapopulation size on recovery), would need to at least temporarily reach near pre-decline abundance so current sources of mortality (threats) could be assessed to determine whether they are limiting a normal size population.

Genetic bottlenecks have been demonstrated in the adjacent Inner Bay of Fundy population; however, analyses of OBoF samples suggest genetic variation is less of a concern for populations of the OBoF. OBoF post-smolts have been sampled during trawl surveys and were suggested to be at densities too small to effectively defend against predation.

Mitigation and Alternatives

A number of measures are already in place to attempt to address threats to salmon identified in Appendix A, though the effectiveness of these measures has not been evaluated. An inventory of additional potential mitigation measures and alternatives to address threats to OBoF salmon are outlined below. It is expected that implementation of many of these approaches would require collaboration between multiple departments, agencies, and groups. Prioritization of these mitigation options has not been attempted.

Fisheries – High, Medium, and Low Threats

Potential mitigation measures to address fisheries-related threats are described below.

Illegal Fishing – High Threat

- Increase education, awareness, and public outreach.
- Promote reporting of illegal activities through available toll-free numbers.
- Increase enforcement in areas of concern.
- Use of high-tech surveillance equipment for monitoring.
- Increase penalties for illegal fishing.

Labrador Resident Subsistence and Greenland Fisheries – Medium Threat

- Maintain current restrictions or further refine restrictions if there is evidence that OBoF salmon are intercepted in that fishery.
- Maintain funding that would keep the Greenland fishery at subsistence levels (currently provided by NGOs).
- Work towards suspension of all Atlantic Salmon harvesting within Greenland territorial waters.

Recreational Salmon Fishery – Low Threat

- Maintain current salmon season closures.

Aboriginal, Food, Social, and Ceremonial Fishery – Low Threat

- Maintain the status quo.

By-catch in Recreational, Aboriginal, and Commercial Fisheries – Low Threat

- Increased compliance monitoring and enforcement in areas of potential concern.
- Further refine time/area/gear restrictions when salmon are present.

Salmonid Aquaculture (Marine Environment) - High Threat

Potential mitigation measures to address threats from salmonid aquaculture include the following measures or improvements to current measures:

- Application of science-based siting criteria for aquaculture operations.
- Improved escape management regime for use by the industry that includes further measures for escape prevention, reporting, and recapture (e.g. genetic or physical marking programs to readily identify and remove aquaculture fish from the wild and/or for owner/site identification of aquaculture escapes).
- Improved fish health management including prevention, policy (e.g. mandatory fish health/sea lice management plans), reporting (e.g. mandatory reporting of sea lice levels), contingency plans and auditing. Full implementation of animal health regulations. Investment in the development of new disease management tools, including therapeutants.
- Enhanced education and training of aquaculture site workers, particularly relative to containment and fish health/pest management.
- Renew the National Code on Introductions and Transfers and increase compliance and enforcement.

Freshwater Habitat – High and Medium Threats

Potential mitigation measures to address threats to freshwater habitat are listed below.

Hydro Dams – High Threat

- Implement or improve downstream fish passage and spill regimes.
- Remove or refurbish reservoirs/dams.

Silt and Sediment – Medium Threat

- Increased compliance monitoring and enforcement for projects/activities that alter/impact sedimentation rates.
- Increased use of best management practices.

Contaminants – Medium Threat

- Increased monitoring and enforcement of current regulations (federal and provincial).

Other Dams and Obstructions – Medium Threat

- Work with proponents to provide fish passage.
- Support for programs to inventory obstructions to facilitate prioritized use of mitigation resources.

Crossing infrastructure – Medium Threat

- Work with province and partners to bring poor installations into compliance.
- Support for programs to inventory crossings to facilitate prioritized use of mitigation resources (for removals and repairs).

Urbanization, Agriculture, Forestry – Medium Threats

- Increased enforcement and monitoring of current regulations (federal and provincial).
- Certification systems could be expanded to other land use practices.

General Population-Level – High, Medium, and Low Threats

Potential mitigation measures to address other threats to OBoF salmon are listed below.

Depressed Population Phenomenon – High Threat

- Any actions to increase population abundance.
- Support for studies to quantify genetic diversity of populations to identify bottleneck concerns and establish baseline.

Disease and Parasites – High Threat

- Implementation of regular standardized monitoring of wild 'indicator' populations to improve understanding in trends and detection speed.
- Develop, continue or increase collaborative efforts with aquaculture industry aimed at reducing risk of outbreaks in farmed salmon population due to its high temporal and spatial host density. These include proactive measures such as operational protocols, best practices, early detection, etc.
- Develop, continue or increase collaborative efforts with aquaculture industry and regulators aimed at reducing hazard (damage sustained) of outbreaks in farmed salmon population should they occur such as rapid quarantine protocols or culls.

Marine Ecosystem Changes – High Threat

- No potential mitigation measures were identified at the meeting.

Invasive Fish Species – Medium Threat

- Maintain and improve measures and associated enforcement on the intentional and accidental transfer of invasive/non-native aquatic species (including collaboration with U.S. departments).
- Improve communications strategy to inform public on the hazards for wild salmon posed by the continued spread of invasive species.

Extreme Temperature Events – Low Threat

- Increased enforcement of current regulations for activities known to affect stream temperature (riparian zone removal, water extraction or storage, etc.).
- Increased monitoring coverage to improve extreme temperature trends detection and understanding.

Allowable Harm

Both the equilibrium analyses (Tobique River population) and the PVA (Nashwaak River population) indicate that, with current dynamics, there is zero probability that the populations will recover and a high probability that populations will extirpate. The effects of small decreases in survival in the marine and freshwater environments were explored using the PVA for the Nashwaak population. To mimic the effects of reduced survival in the marine environment, return rates were reduced by 1, 5, and 10% of the values used in the base PVA run. To mimic reduced survival in the freshwater environment, smolt production was reduced by 0.5, 1, 2, and 5%. While recovery probabilities remained at essentially zero in all of these scenarios, the probability of extinction increased with increases in mortality. In cases where the increase in mortality is small, the increase in extinction risk is also small.

Although not explored for the Outer Bay of Fundy populations, analyses for Inner Bay of Fundy populations indicate that the supportive rearing program does reduce extinction risk, although the longer the supportive rearing program is in place, the greater the potential for genetic effects that would reduce survival in the wild. Therefore, the supportive rearing program for populations above Mactaquac Dam should be an interim measure to reduce extinction risk in the short-term while threats are being addressed.

For populations below the Mactaquac Dam, extinction risk does increase with increased mortality although for many activities this increase may be very low. For example, in the case of bridge or culvert construction, only a small portion of the population may be affected by the activity. In similar cases, the effect on extinction risk is likely not measurable. In other cases, for example scientific activities (e.g. monitoring the juvenile populations by electrofishing), habitat improvement, or recreational fisheries for other species, the small increase in extinction risk may be offset by other benefits. These benefits could include improved conditions for salmon or increased knowledge of population status which is required to prioritize recovery actions.

Sources of Uncertainty

DU Structure

There are 20 considered rivers in the OBoF region however the eleven on the SJR system comprise more than 90% of the habitat accessible to the OBoF salmon population. Following the definition that states a river drains to tidal waters, the SJR and tributaries above Mactaquac Dam, 35.7% of the productive habitat accessible to OBoF salmon, is considered one river. This river contains the Tobique River which represents the habitat above Mactaquac and the largest single river utilized by this DU representing 19.4% of the total habitat). Based on habitat area, and monitoring of population status and dynamics, the Tobique may be the best index river for the area above the Mactaquac Dam. However apparent independent dynamics of other tributaries (such as the Shikatehawk's high productivity) suggests Tobique index measures may not be representative of all area above the Mactaquac Dam. Further, true trends in wild population dynamics may be complicated by the intended contributions from captive reared adults in the Tobique River.

Relative to other salmon DUs in the Maritimes, the OBoF DU is well studied and has long-term data sets, particularly on adults returning to the Mactaquac Dam (est. 1968). Approximately 60% of the productive habitat within Canadian boundaries in the SJR occurs below the Mactaquac Dam and aside from monitoring on the Nashwaak system since the early 90s, much less is known about the dynamics of the lower SJR populations. Thus, indices derived from above the Mactaquac Dam (or Nashwaak) may not represent the significant remaining area in the lower SJR.

Even with a long-term dataset, there is little information on population structure for the SJR prior to the 1960s. With a clear understanding of historic populations, the recent decline in abundance (20,000 returning adults to Mactaquac in the early 1980s to current levels less than

2,000) could be put in perspective. Historic accounts of annual commercial SJR harvests exceeding 500,000 lbs (approximately 226 mt) of adult salmon and reports of some lower SJR rivers being nearly extirpated by the mid-1800s suggests at least the potential for SJR populations being compromised (from natural state) even before major dam building began on the SJR in the 1950s.

Estimates of Productive Rearing Habitat and Conservation Egg Requirement

In order to calculate the conservation egg requirement of 2.4 eggs/m^2 of habitat, the supply of productive habitat must be estimated and, in this case, generally relies on gradient (>0.12%) to indicate productive habitat.

Productive habitat estimates based only on gradient and area may not always quantify suitable habitat. Factors such as obstructions and impact by other threats reduce quantity of suitable habitat even where gradients are appropriate. Further, accessible productive habitat estimates for some of the SJR tributaries and the outer Fundy complex rivers are derived without gradient information and thus are likely over estimated. Although, the rivers without gradient information still only make up about 20% of the habitat that is potentially utilized by this DU.

The 2.4 eggs/m^2 of productive habitat reference point is expected to sustain viable populations but is derived from research conducted when productivities were apparently higher than current dynamics. Thus, it is unclear whether future conditions (i.e. further reductions in marine survival) and associated population dynamics would result in population viability at that reference point. This stresses the need to reconsider abundance and distribution targets as populations begin to recover.

Perceived Low Marine Survival

Current understanding of causes for OBoF population declines suggests that marine survival has decreased. The number of returning adult salmon from a given smolt cohort is generally considered as the marine survival however this measure does not account for the possible effects freshwater life may have on the animal's ability to survive the marine migration. In this sense, a freshwater threat could be affecting survival at sea and be inappropriately reported as a marine environment threat. Research has shown that certain threats, such as exposure to toxic chemicals, in freshwater have lowered salmon's ability to survive marine migration.

Known Genetic Variation

Genetic analyses suggests OBoF population cluster separately from the other DUs and that populations above Mactaquac Dam cluster separately from those below. Thus the unique characteristics exhibited by the Tobique River population appear to have a genetic basis. Analyses did not indicate a biologically significant genetic distinction for Serpentine River stock despite that stock's reported unique migration strategy. Historic samples of this suspected stock could address the genetic basis for the Serpentine's reported unique migration phenotype. The limited number and time-span of samples from OBoF populations analyzed could result in current or past genetically unique populations being undetected and possibly not prioritized for recovery efforts.

Marine Habitat Use

Features, functions and attributes of marine habitat are still largely unknown for OBoF Atlantic Salmon. This knowledge gap poses significant challenges for the design of effective recovery efforts, especially because there has been an apparent decline in marine survival during the recent OBoF population decline.

Reporting of By-catch in Legal Fisheries

Commercial and recreational gillnet/trapnet fishermen are required to report the by-catch of Atlantic Salmon in their logbooks as part of their license agreement. Based on the timing and gear used in these fisheries, it is felt that juvenile and adult salmon are likely regularly captured. Likely not all salmon caught are being reported and are therefore a source of uncertainty when assessing these fisheries as a threat.

SOURCES OF INFORMATION

This Science Advisory Report is produced from the February 19-22, 2013, Recovery Potential Assessment for Atlantic Salmon (Outer Bay of Fundy Designatable Unit). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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

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Marshall, T.L., C.N. Clarke, S.M. Ratelle, and R.A. Jones. 2014. Assessment of the Recovery Potential for the Outer Bay of Fundy Population of Atlantic Salmon: Habitat Considerations. DFO Can. Sci. Advis. Sec.Res Doc 2014/007.

APPENDIX A

A threats table for the freshwater, estuarine and marine environments, summarizing human activities or sources of environmental change that either negatively impact Atlantic Salmon populations (i.e. cause reduced abundance) or cause reduced quality and/or quantity of habitat in the OBoF region is provided in Table A4. Definitions for terms contained within this table as well as the approach assigning the overall Level of Concern for each Threat are provided below.

Definition of Table Headings and Column Values

Threat Category: The general activity or process (natural and anthropogenic) that has caused, is causing, or may cause harm, death, or behavioral changes to a species at risk; or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur.

Specific Threat: The specific activity or process causing stress to Atlantic Salmon populations in the OBoF DU, where stress is defined as changes to ecological, demographic, or behavioral attributes of populations leading to reduced viability.

Level of Concern: Signifies the level of concern for species persistence if a threat remains unmitigated; where a High level of concern reflects threats that are likely to lead to substantial declines in abundance or loss of populations in the absence of mitigation, a Medium level of concern reflects threats that are likely to limit populations to low abundance and thus increase extinction risk, while a Low level of concern reflects threats that might lead to slightly increased mortality but are expected to have a relatively small impact on overall population viability. This criterion is based on the evaluation of all other information in the table with an emphasis on the extent of the threat in the DU and the number of populations likely to be affected at each level of Severity (see definition below).

Location or Extent: The description of the spatial extent of the threat in the DU was largely based on the criteria developed for the Conservation Status Report Part II (DFO and MRNF 2009), where Low corresponds to < 5% of populations affected, Medium is 5-30%, High is 30-70% and Very High is > 70%.

Occurrence and Frequency: Occurrence: Description of the time frame that the threat has affected, is, or may be affecting Atlantic Salmon populations in the Outer Bay of Fundy DU. Historical (H) – a threat that is known or is thought to have impacted salmon populations in the past where the activity is not ongoing; Current (C) – a threat that is known or thought to be impacting populations where the activity is ongoing (this includes situations in which the threat is no longer occurring but the population-level impacts of the historical threat are still impacting the populations); Anticipatory (A) – a threat that is not presently impacting salmon populations but may have impacts in the future (this includes situations where a current threat may increase in scope). Frequency: Description of the temporal extent of the threat over the course of a year (Seasonal, Recurrent, Continuous).

Severity: Describes the degree of impact a given threat may have or is having on individual Atlantic Salmon populations subjected to the threat given the nature and possible magnitude of population-level change. See Table A1 for definitions/examples of how severity has been evaluated.

Table A1. Definitions/examples of how severity has been evaluated.

Category	**Definition/Examples**
Negligible	• Habitat alteration within acceptable guidelines that does not lead to a reduction in habitat quality or quantity. • No change in population productivity.
Low	• Minor or easily recoverable changes to fish habitat (e.g. seasonal or changes <12 months). • Little change in population productivity (< 5% decline in spawner abundance)
Medium	• Moderate impact to fish habitat with medium term for habitat recovery (3-5 years). • Moderate loss of population productivity (5-30% decline in spawner abundance)
High	• Substantial damage to fish habitat such that the habitat will not recover for more than 5 years. • Substantial loss of population productivity (> 30% decline in spawner abundance)
Extreme	• Permanent and spatially significant loss of fish habitat • Severe population decline with the potential for extirpation.

Causal Certainty: Two-part definition. Part 1: Reflects the strength of the evidence linking the threat (i.e. the particular activity) to the stresses (e.g. changes in mortality rates) affecting populations of Atlantic Salmon in general. As such, evidence can come from studies on any Atlantic Salmon population. Part 2: Reflects the strength of the evidence linking the threat to changes in productivity for populations in the OBoF DU specifically. See Table A2 for definitions/examples of how causal certainty has been evaluated.

Table A2. Definitions/examples of how causal certainty has been evaluated.

Causal certainty	**Description**
Negligible	Hypothesized.
Very Low	< 5%: Unsubstantiated but plausible link between the threat and stresses to salmon populations.
Low	5% - 24%: Plausible link with limited evidence that the threat has stressed salmon populations.
Medium	25% - 75%: There is scientific evidence linking the threat to stresses to salmon populations.
High	76% - 95%: Substantial scientific evidence of a causal link where the impact to populations is understood qualitatively.
Very High	> 95%: Very strong scientific evidence that stresses will occur and the magnitude of the impact to populations can be quantified.

Procedure for consistently assigning Level of Concern ranking for OBoF DU

Following suggestions from the OBoF Atlantic Salmon RPA meeting to consistently assess the Level of Concern (LoC) for each threat, a ranking matrix was developed with threat Severity and Extent as inputs. Numbers were assigned to each of the levels (described above) of severity and level of extent. This allows the level of each category to be multiplied together to produce a score from 1-16 as demonstrated in Table A3.1 below. As the LoC category has 3 levels, the nine scores in Table A3.1 were divided as follows: 1,2,3 (Low); 4,6,8 (Medium); and 9,12,16 (High). Threats assigned a ‘Negligible’ Severity, as defined above, were assigned a LoC of Low, regardless of the Extent. Applying the scored categories of Table A3.1 allows LoC rankings to be made as shown in Table A3.2. This approach offers a consistent approach for assigning the overall LoC for each threat based on the definitions for the Extent and Severity categories. Other threat table categories (i.e. causal certainty, Frequency, and Rationale) provide additional context of the LoC ranking within the OBoF DU.

Table A3.1. Level of Concern scoring matrix.

			Severity				
			Neg.	**Low**	**Medium**	**High**	**Extreme**
		Multiplier	**n/a**	**x1**	**x2**	**x3**	**x4**
Extent	**Low**	**x1**		1	2	3	4
	Med	**x2**		2	4	6	8
	High	**x3**		3	6	**9**	**12**
	V.High	**x4**		4	8	**12**	**16**

*Note: Low Scores= 1,2,3; Medium Scores= 4,6,8; and **High Scores= 9,12,16**.*

Table A3.2. Level of Concern rank assignment matrix (based on scoring from Table A3.1).

		Severity				
		Negligible	**Low**	**Medium**	**High**	**Extreme**
Extent	**Low**	LOW	LOW	LOW	LOW	MEDIUM
	Med	LOW	LOW	MEDIUM	MEDIUM	MEDIUM
	High	LOW	LOW	MEDIUM	**HIGH**	**HIGH**
	V.High	LOW	MEDIUM	MEDIUM	**HIGH**	**HIGH**

Table A4. Summary of threats to, and rating of effects on, the recovery and/or persistence of Outer Bay of Fundy Atlantic Salmon. Threats with the same level of concern are not ranked in order of importance.

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**		**Rationale**
		Overall DU	% of DU Population affected	**C**urrent, **H**istoric, **A**nticipated	Population Impacts	Evidence in general on A. Salmon	Evidence on OBoF Salmon	Context for DU
Freshwater								
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.
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.
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.

Threat	Specific Threat	Level of Concern	Extent	Occurrence and Frequency	Severity	Causal Certainty		Rationale
		Overall DU	% of DU Population affected	**C**urrent, **H**istoric, **A**nticipated	Population Impacts	Evidence in general on A. Salmon	Evidence on OBoF Salmon	Context for DU
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.
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
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.

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**		**Rationale**
		Overall DU	% of DU Population affected	**C**urrent, **H**istoric, **A**nticipated	Population Impacts	Evidence in general on A. Salmon	Evidence on OBoF Salmon	Context for DU
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.
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)	Aboriginal 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, Aboriginal or Commercial	Low	High	H, C and A Seasonal	Low	Medium	Medium	Shad, Gaspereau, Eel have by-catch but is suspected to be low
Marine/ Estuarine Environment								
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).

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**		**Rationale**
		Overall DU	% of DU Population affected	**C**urrent, **H**istoric, **A**nticipated	Population Impacts	Evidence in general on A. Salmon	Evidence on OBoF Salmon	Context for DU
	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.
	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
	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
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.

Threat	**Specific Threat**	**Level of Concern**	**Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**		**Rationale**
		Overall DU	% of DU Population affected	**C**urrent, **H**istoric, **A**nticipated	Population Impacts	Evidence in general on A. Salmon	Evidence on OBoF Salmon	Context for DU
Applicable to Freshwater, Estuarine and Marine Environments								
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.

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