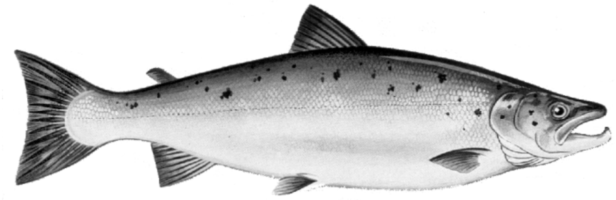
Fisheries and Oceans Canada Pêches et Océans Canada
Science Sciences

Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2013/072

RECOVERY POTENTIAL ASSESSMENT FOR EASTERN CAPE BRETON ATLANTIC SALMON



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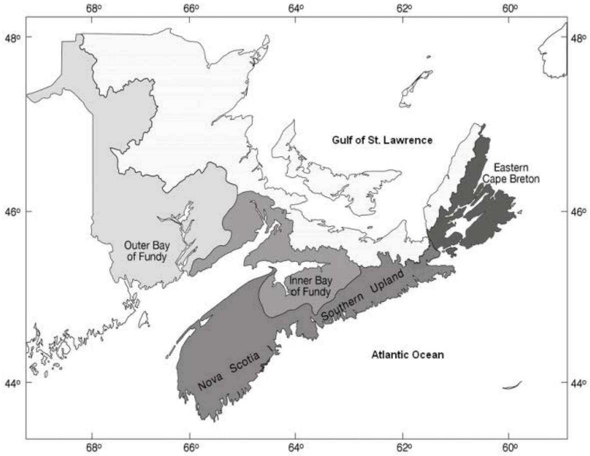

Figure 1. Map showing the location of the Eastern Cape Breton Atlantic Salmon Designatable Unit relative to the three other Designatable Units for Atlantic Salmon in the Maritimes Region.

Context

The Nova Scotia Eastern Cape Breton (ECB) Designatable Unit of Atlantic Salmon was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2010. This population assemblage occupies rivers in Eastern Cape Breton that drain into the Bras d'Or Lakes and Atlantic Ocean south from Salmon River, Victoria County to the Canso Causeway. These rivers (46 of which are known to have historically contained salmon) are within Salmon Fishing Area (SFA) 19, which is the management area used by Fisheries and Oceans Canada (DFO) for salmon fisheries management and assessment purposes. The combination of genetic information, life history patterns, geographic isolation, minimal historical gene flow between eastern Cape Breton and surrounding regions, and the low rates of straying from other regions, support the view that ECB 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 to the Minister 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 the 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 available to assess the recovery potential of ECB Atlantic Salmon, with additional regional-specific Mi'kmaq traditional ecological knowledge (TEK) information provided where available.

This Science Advisory Report is from the January 28 - February 1, 2013, Recovery Potential Assessment for Atlantic Salmon (Eastern Cape Breton Designatable Unit). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

February 2014

SUMMARY

- The Eastern Cape Breton Designatable Unit of Atlantic Salmon (*Salmo salar*) was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada in November 2010.
- There are 46 rivers that are thought to either contain or to have historically contained Eastern Cape Breton Atlantic Salmon populations. It is likely that salmon either presently use, or have in the past used, other rivers, at least on an intermittent basis.
- There is considerable life history and genetic diversity among Atlantic Salmon populations in Eastern Cape Breton, the maintenance of which is considered important for the long term persistence of the Designatable Unit.
- Adult population monitoring for Atlantic Salmon in Eastern Cape Breton has been focused on five river systems: Middle, Baddeck, North, Grand and Clyburn.
- Adult abundance trends during the last three generations (15 years) indicate abundance declines of 97% and 89% in Grand and Clyburn rivers respectively, whereas abundance in North River is thought to have increased by 159% during the same time period. Trends in adult abundance in Middle and Baddeck rivers are less evident.
- Only the North River population is assessed to be above its conservation requirement. During the last ten years, the Middle River and Baddeck River populations have been fluctuating in the vicinity of 20 to 75% of their respective conservation requirements. Abundance in Grand and Clyburn rivers is assessed to be very low relative to their conservation requirements.
- Status of salmon in other rivers is inferred from recreational fisheries and limited electrofishing surveys and with less certainty than in rivers where adult population monitoring has been focused.
- Although there are some exceptions, both the recreational catch and fishing effort have declined to very low levels throughout most of the Designatable Unit.
- The electrofishing data generally indicates that juvenile abundance is low throughout much of the Designatable Unit. However, in contrast with both the Southern Upland and Inner Bay of Fundy DUs, there is no evidence in the surveys that river-specific extirpations have occurred.
- Recommended recovery targets for Atlantic Salmon populations in the Eastern Cape Breton Designatable Unit include both abundance and distribution components. It is proposed that the abundance target for individual river populations be the conservation (egg) requirement. The distribution target should encompass the range of genetic and phenotypic variability among populations and environmental variability among rivers, and it should allow for gene flow between the rivers/populations.
- Taking these principles into consideration, a long term abundance target could be to consistently achieve the conservation (egg) requirements in a suite of watersheds that reflect the population diversity of the Eastern Cape Breton Designatable Unit, with a distribution target of supporting the persistence of salmon in the 46 known salmon rivers. A subset of the 46 rivers could be selected for the distribution target (using the science-based criteria provided) if practical aspects of recovering salmon in a specific river are limiting.

- Recovery targets will need to be revisited as information about the dynamics of the recovering populations becomes available.
- There are only two populations with sufficient data for modeling population dynamics (Middle River and Baddeck River populations, which are considered to be two of the healthier populations). Given the life history variability seen throughout Eastern Cape Breton, these two populations are not considered to be representative of other populations in the Designatable Unit.
- Subject to the uncertainties associated with the limited data available for the analyses, modeling for the Middle River population indicates that productivity (including the combined effects of in-river productivity and at-sea survival) has not declined from the mid-1980s to present. In contrast, productivity for the Baddeck River population is estimated to have declined slightly.
- Population viability analyses for the Middle and Baddeck populations indicate a low probability of extinction if conditions in the future are similar to those in the recent past. Similarly, neither population is expected to reach and remain above their conservation requirements unless overall productivity (including reproduction and/or survival) is improved.
- Freshwater habitat supply is not thought to be limiting salmon abundance in Eastern Cape Breton rivers at present, and evidence of significant habitat loss was not found during this Recovery Potential Assessment.
- While the quantity of habitat currently available in Eastern Cape Breton rivers is considered capable of supporting salmon populations at or above the proposed recovery targets, information is insufficient to determine whether habitat quality may be impeding the survival or recovery of salmon populations in some rivers.
- On the watershed scale, important freshwater habitat can be allocated based on the rivers selected for the distribution component of the recovery target. Within a watershed, sufficient quantities of the habitat types needed to support each life stage are required.
- Estuaries associated with rivers containing important freshwater habitats are also considered to be important habitat for Eastern Cape Breton salmon as successful migration through these areas is required to complete the life cycle.
- The Bras d’Or Lakes are a large and very unique estuary in Eastern Cape Breton. Their role in the life cycle of Atlantic Salmon in the area is not well understood, although regional specific Mi’kmaq traditional ecological knowledge indicates that, in addition to serving as a migratory pathway, they also serve as a staging area for returning adults and as an over-wintering area for kelts.
- While there is likely to be important marine habitat for Eastern Cape Breton Atlantic Salmon, given broad temporal and spatial variation, it is not currently possible to link important life-history functions with specific marine features and their attributes.
- Three dwelling places used by four life stages of Atlantic Salmon were evaluated for their potential consideration as residences. Redds most closely match the criteria for a residence because they are constructed.
- There have been many anecdotal reports of illegal fishing activities (i.e. poaching) for Atlantic Salmon in eastern Cape Breton, both using recreational fishing gear and using gillnets. The magnitude of this threat to specific populations is not possible to quantify.

- Threats in freshwater environments with a medium level of overall concern are (importance not implied by order): infrastructure (roads, power lines, etc.); culverts; genetic effects of small population size; forestry; illegal targeting of Atlantic Salmon while fishing under a general license; stocking of rainbow, brown and brook trout; salmon stocking for fisheries enhancement; changes in predator or prey abundance; non-native fish; silt and sediment; and altered hydrology.
- Threats in estuarine and marine environments identified with a high level of overall concern are (importance not implied by order): salmonid aquaculture; marine ecosystem changes; and diseases and parasites. Threats in estuarine and marine environments identified with a medium level of overall concern are: bycatch in other fisheries and international fisheries.
- In general, estimated status and trends of the five index populations suggests that the North River population would be the most resilient to harm. Under present conditions, North, Middle and Baddeck river populations may be able to sustain existing levels of harm without going extinct. However, existing levels of harm may be impeding recovery for the Middle and Baddeck river populations. The smaller populations that are in decline such as the Grand and Clyburn rivers may not be able to sustain existing levels of harm.

BACKGROUND

Rationale for Assessment

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses 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 Eastern Cape Breton (ECB) DU of Atlantic Salmon (Salmo salar) was assessed as Endangered by COSEWIC in November 2010 (COSEWIC 2010). DFO Science was asked to undertake a RPA for the ECB DU of Atlantic Salmon based on DFO's protocol for conducting RPAs (DFO 2007). Information pertaining to 27 Terms of Reference was reviewed at this meeting.

Eastern Cape Breton DU

The ECB DU of Atlantic Salmon consists of an assemblage of salmon populations that occupy rivers in a region of Nova Scotia extending from the northern tip of Cape Breton Island (approximately 47o 02' N, 60o 35' W) along the Atlantic coast to the Canso Causeway (approximately 45o 39' N, 61o 25' W) (COSEWIC 2010). All populations inhabit rivers within Salmon Fishing Area (SFA) 19, which is a management area used by DFO for salmon fisheries management and assessment purposes.

The exact number of rivers inhabited by ECB Atlantic Salmon is not known, but salmon likely used most accessible habitat in this area at least intermittently in the past (see Sources of Uncertainty). The North Atlantic Salmon Conservation Organization database identifies 45 watersheds with records of Atlantic Salmon, and an additional river (Indian Brook), is also known to contain salmon. Information about these 46 watersheds (Figure 2) is provided in this assessment. During the RPA, a few additional smaller streams, as well as other salmon producing areas, were identified through Mi'kmaq traditional ecological knowledge, consistent with the idea that salmon use or used most of the accessible habitat.

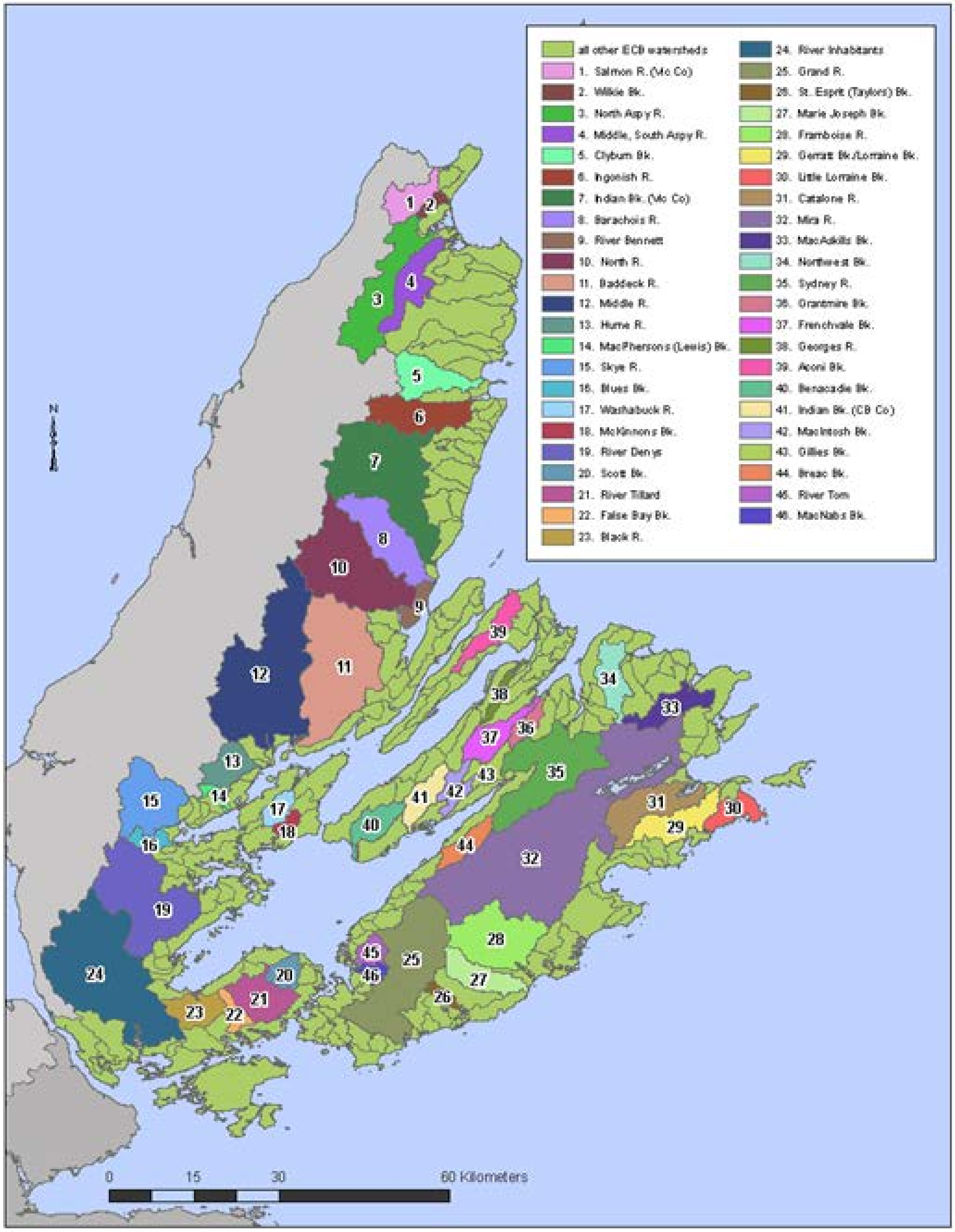

Figure 2. Map of the Eastern Cape Breton region showing 46 watersheds thought to either presently support or to have supported Atlantic Salmon populations, labelled by number and colour. Other Eastern Cape Breton watersheds are shown in light green. The watershed boundaries were obtained from the Secondary Watersheds layer for ArcGIS developed by the Nova Scotia Department of the Environment.

There is considerable life history and genetic diversity among Atlantic Salmon populations in Eastern Cape Breton, the maintenance of which is considered important for the long term persistence of the DU. This diversity likely originates from the diversity of ecosystem types occupied by the DU combined with the relatively complex geography within the region that can lead to the isolation of populations on small spatial scales. This means that populations of Atlantic Salmon within the DU cannot be considered interchangeable. Examples of among-population life history diversity include the ages-of-smoltification, the sea-ages of maturity, the frequency of repeat spawning, and run-timing. Analyses from seven populations indicate there is high genetic diversity among populations in the DU (four or five groups of populations were identified in the analysis of seven populations). It is not known whether including more populations in the genetic analysis would have identified more groups.

Within the ECB populations, salmon mature after either one or two winters at sea (called “one sea-winter salmon” or 1SW, “two sea-winter salmon” or 2SW, respectively), although a small proportion also mature after three winters at sea (called “three sea-winter salmon” or 3SW). The proportion of salmon maturing after a given number of winters at sea is highly variable among populations. In general, rivers flowing off the Cape Breton Highlands contain populations that predominantly mature as 2SW salmon and have a low frequency of repeat spawning, whereas populations in the southeast portion of ECB mature predominantly as 1SW salmon and contain a higher proportion of repeat spawning salmon.

Atlantic Salmon is one of the most-studied fish species in the world. Readers are referred to the supporting research documents, which form part of the advisory package for this DU, for more information than is contained in this summary document.

ASSESSMENT

Status and Trends

Adult population monitoring for ECB Atlantic Salmon has been focused on five river systems: Middle, Baddeck, North, Grand and Clyburn. Middle, Baddeck, North and Clyburn rivers originate in the Cape Breton Highlands and are characterized by relatively steep stream gradients and good water quality. Grand River, situated in the southern portion of Eastern Cape Breton, has the lowest mean stream gradient of the five major river systems assessed and its stream flow and water temperatures are influenced by lakes not present in four rivers. Abundance in other rivers has been inferred from recreational catch data and electrofishing surveys for juveniles, which have occurred intermittently in the past.

Adult Abundance Trends in Index Rivers

Trends in adult abundance in the five index rivers were analyzed for different time periods (10, 15 and 20 years) using both log-linear regression models and by comparison of the five-year mean abundance between two time periods. The results vary among rivers (Figure 3), and, in some cases, also differ among the time periods and between methods. Adult abundance trends during the last three generations (15 years) from the regression models indicate abundance declines of 97% (to 2009) and 89% (to 2011) in Grand River and Clyburn River respectively, whereas the abundance trend in North River indicates an increase of 159% (to 2011). Although adult abundances are variable in Middle and Baddeck rivers, marked abundance declines are not evident in these rivers during the last 15 years. However, abundance in Baddeck River appears to have declined slightly more than in Middle River.

The status of Atlantic Salmon in these rivers is assessed by comparing the estimated egg deposition with their river-specific conservation egg requirement, a reference level considered to be a limit reference point in DFO’s Precautionary Approach fisheries framework. Of these populations, only the North River population is assessed to be above its conservation requirement. During the last ten years, the Middle River and Baddeck River populations have been fluctuating in the vicinity of 20 to 75% of their respective conservation requirements. Abundance in Grand and Clyburn rivers is assessed to be very low relative to their conservation requirements.

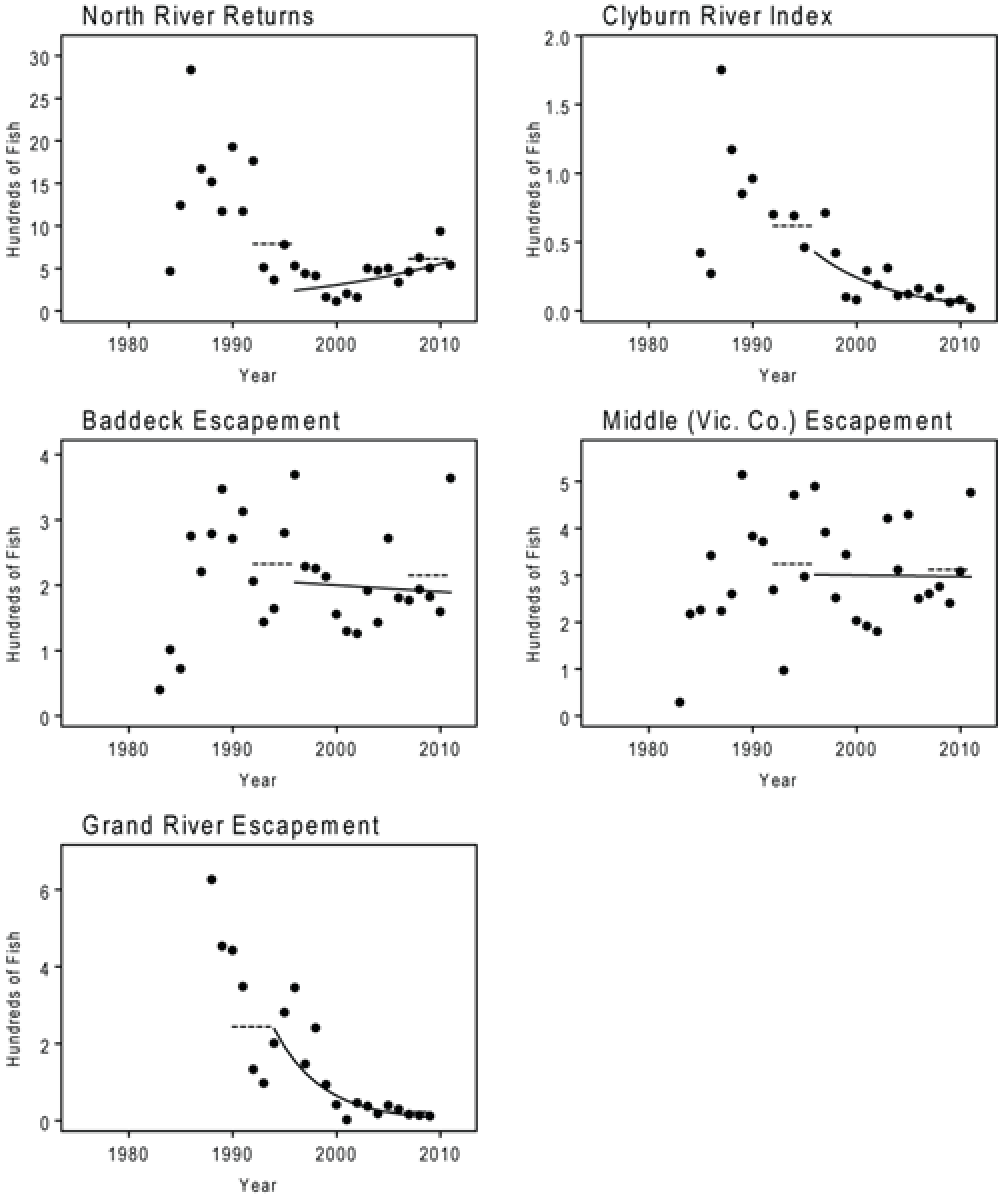

Figure 3. Trends in abundance of adult Atlantic Salmon (size categories combined) in five Eastern Cape Breton rivers. The points are the annual abundance estimates. The solid lines are the predicted abundances from a log-linear model fit by least squares to data for the last 15 years and are indicative of the abundance trends. The dashed line shows the five-year mean abundance for two time periods separated by 10 years.

Abundance in Other Rivers

Comparatively little data exist for Atlantic Salmon populations in other eastern Cape Breton rivers. Status of salmon in these rivers is inferred from the catch and effort data from the Atlantic Salmon recreational fishery's license stub return program and some limited electrofishing data.

Recreational catch and effort estimates from license stub returns are available for a total of 31 rivers in eastern Cape Breton. Although there are exceptions, recreational catches tended to be higher in the 1980s and early 1990s than at present. However, the fishing effort in these earlier years was also higher. Both recreational catch and fishing effort have declined to very low levels for most of the ECB DU. Two of the exceptions are Middle and Baddeck rivers, where the recreational catches during 2009-2011 time period were estimated to be higher than during the previous 10 years. In all rivers, the recreational catch tracks the estimated effort very closely. Little to no fishing effort was reported on most rivers in eastern Cape Breton just prior to recreational fisheries closures in 2010. While this issue makes interpreting the recreational catch statistics as an abundance index difficult, it does suggest that fishing effort had contracted down to those few rivers within the SFA that contained an appreciable number of Atlantic Salmon.

Intermittent electrofishing surveys for juvenile salmon, with relatively limited spatial coverage, have been most recently conducted by DFO in eastern Cape Breton during the 1996 to 2007 time period. During the survey with the widest spatial coverage, conducted during 2001 and 2002, fry densities were estimated to be above Elson’s norm (29 fry/100 m2) in only four of 21 rivers sampled. Similarly, parr (age 1 and older) densities were generally below Elson’s norm for age 1 and older parr (38 parr/100 m2) in rivers sampled from 1998 to 2002. Results were similar during a survey with less spatial coverage conducted in 2006 and 2007. Overall, results of the juvenile electrofishing surveys conducted since 1996 indicate that at least one juvenile life stage (i.e., fry and/or parr) was captured from every river surveyed in eastern Cape Breton since 1996. Although the presence of juveniles was widespread throughout eastern Cape Breton, abundance was generally low relative to reference values reported by Elson. Thus, while the electrofishing data generally indicates low juvenile abundance throughout much of the DU, in contrast with both the Southern Upland and Inner Bay of Fundy DUs, there is no evidence in the juvenile surveys that river-specific extirpations have occurred.

Range and Distribution

In the absence of evidence for river-specific extirpations, the range and present distribution of ECB Atlantic Salmon in fresh water is thought to be, as a minimum, the 46 rivers shown in Figure 2, although salmon are likely present in some other rivers. The extent of the marine range and the use of the Bras d’Or Lakes by ECB Atlantic Salmon are not well known. There is very limited tagging information from the marine environment for salmon in this DU. The limited information indicates that they may be found along the coast of Cape Breton Island, off Newfoundland and along the coast of West Greenland.

Recovery Targets

Recommended recovery targets for the ECB DU of Atlantic Salmon include both abundance and distribution components.

It is proposed that the abundance target for individual river populations be the conservation (egg) requirement, which is based on the estimated amount of juvenile rearing area and an egg deposition rate of 2.4 eggs per m2. This is consistent with the terminology used by Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) when developing the conservation requirement, an assessment of population dynamics relative to several reference levels, as well as past abundance. Attaining the conservation requirement is consistent with the ideas that: the probability of attaining long-term population persistence, the ecological function of the watersheds in which salmon formerly resided, and the potential for human benefits would be increased if populations were recovered to at least this level in as many rivers as possible, and is considered to be consistent with 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 for salmon in the eastern Cape Breton region 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.

The distribution target should encompass the range of genetic and phenotypic variability among populations and environmental variability among rivers, and it should include rivers distributed throughout the DU to allow for gene flow between 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.

Taking these principles into consideration, a long-term abundance target could be to consistently achieve the conservation (egg) requirements in a suite of watersheds that reflect the population diversity of the DU, with a distribution target of supporting the persistence of salmon in the known salmon rivers. It is unknown whether all these rivers are required to ensure the long-term persistence of the ECB Atlantic Salmon DU; however, the greater the number of populations that are maintained, the better the chance of persistence of the DU. Given this uncertainty, a subset of these rivers could be selected for the distribution target if the practical aspects of recovering salmon in some specific rivers are limiting. The following science-based criteria are provided for consideration when prioritizing watersheds for salmon recovery:

1. Current population size. Other factors being equal, larger populations tend to have greater genetic diversity and are at lower risk from random variability in survival and productivity, and therefore should be easier to recover. However, adult population size has only recently been estimated for six rivers: Middle, Baddeck, North, Grand, Clyburn and North Aspy (2009 only). Additional information would be required to apply this criterion more fully.
2. Rearing area. This is an indicator of the potential size of a recovered population. Rearing area has been estimated for the 46 salmon rivers. The rivers with the largest estimated accessible rearing area include Mira River, River Inhabitants, Middle River, and Baddeck River.
3. Representativeness, in terms of population life history, local adaptation and genetic distinctiveness throughout the DU. There is evidence of population and genetic structuring of Atlantic Salmon in the ECB DU. Of the seven salmon populations in the ECB DU for which genetic variation was analyzed, 4-5 genetic groupings were suggested. Populations in the Cape Breton Highlands were found to be more similar to each other, whereas other rivers were suggested to be discrete genetic groupings. There is insufficient genetic information to determine appropriate/specific genetic groupings at this time. However, geographic isolation and environmental variability coupled with the homing behavior of salmon is expected to lead to local adaptation.
    a) A possible basis for characterizing environmental variability within Eastern Cape Breton is the Ecodistricts (i.e., the level of Nova Scotia’s ecological land classification that reflects macroelements of the physical and biological attributes of ecosystems). There are seven Ecodistricts in this area (Figure 4), all of which contain salmon rivers. Including populations from each of these districts in the recovery target would help to ensure the diversity within the region is preserved.
    b) Consideration of geographic isolation when establishing distribution targets could include selecting representative populations of the major basins and bays of the Bras d’Or Lakes, populations representative of those found along each of the south,

central and northern regions of the southeast Atlantic coast, and representation of Atlantic coast rivers flowing off the Cape Breton Highlands. Although other schemes are possible, a proposed geographic grouping (Figure 5) includes: rivers flowing into the Atlantic Ocean between the Canso Causeway and St. Peters (group 1), rivers flowing southeast into the Atlantic that are northeast of St. Peters (group 2), rivers flowing northeast into the Atlantic to the east of the Great Bras d'Or (group 2.1), Highland rivers northwest of White Point (group 3), Highland rivers between White Point and the Great Bras d'Or (group 4), rivers flowing in the Bras d'Or Lakes via St. Patrick's Channel (group 5), and other rivers flowing into the Bras d'Or Lakes (group 6). Other than direction of flow, there is no information for splitting between groups 2 and 2.1.

Revisiting the recovery targets as information about the dynamics of the recovering populations becomes available is recommended.

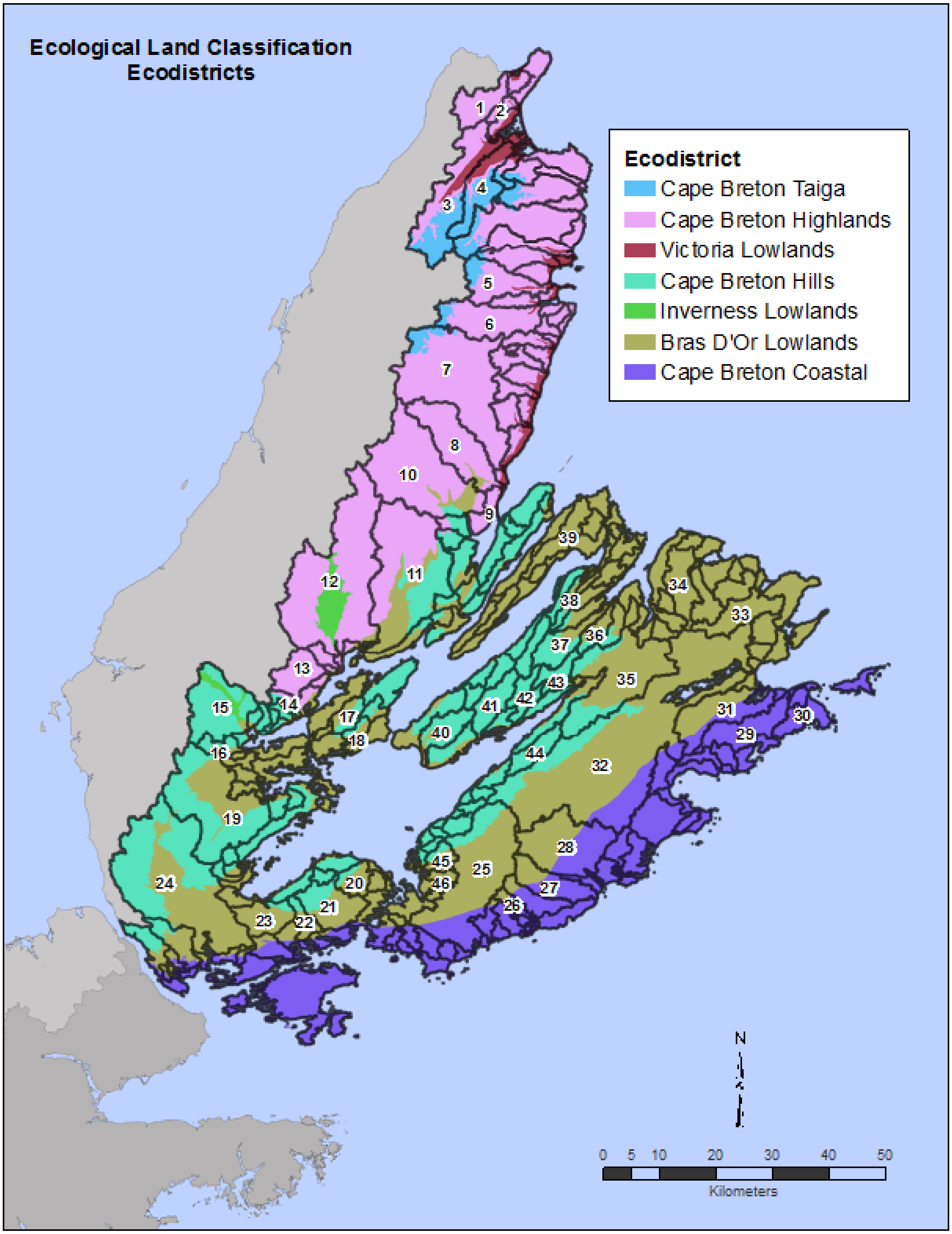

Figure 4. Map of Ecodistricts and the major watersheds associated with known Atlantic Salmon rivers in Eastern Cape Breton.

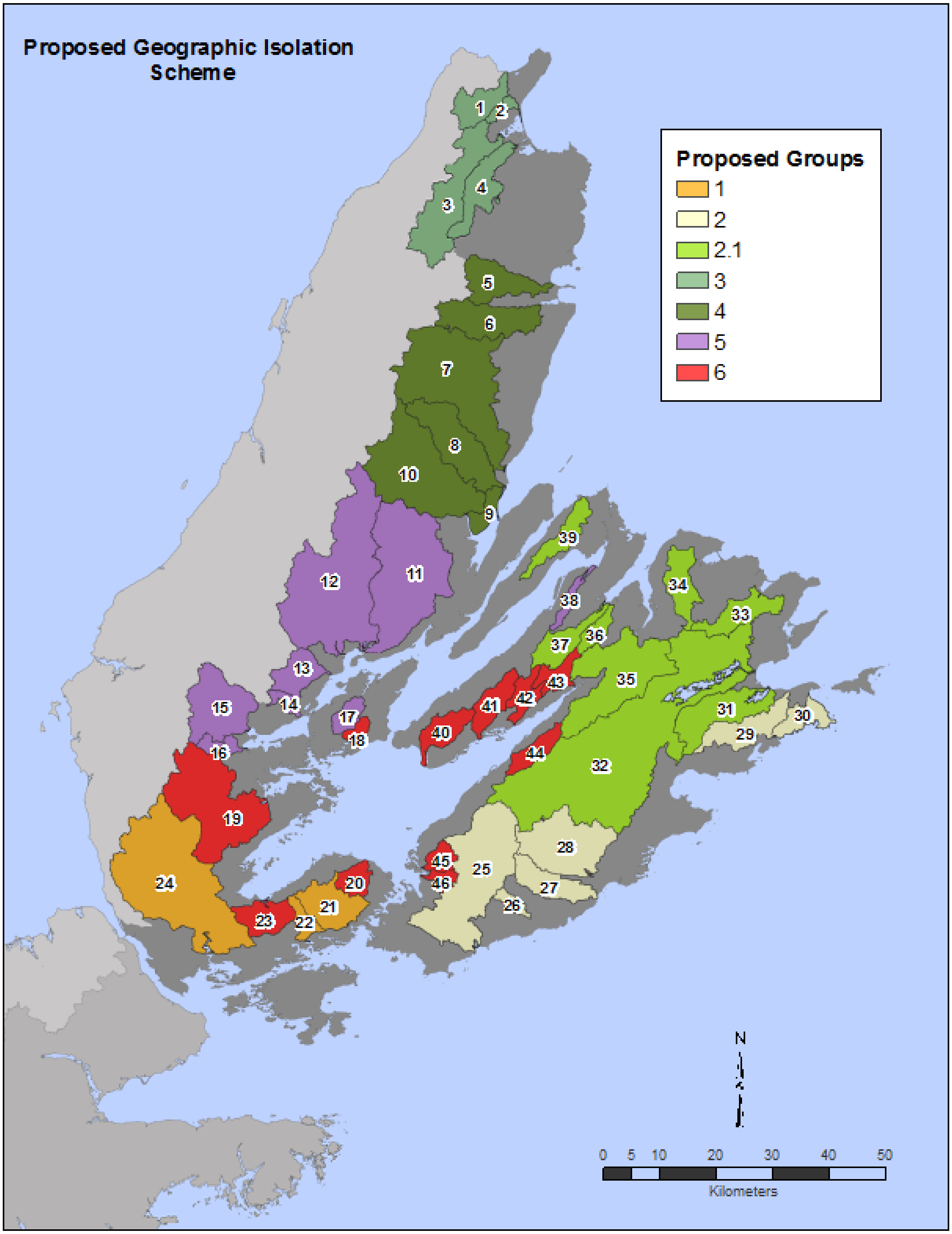

Figure 5. A proposed scheme for grouping rivers by geographic isolation when developing the distribution component of the recovery target. Other schemes are possible.

Life History Parameter Values

Data for characterizing the dynamics of ECB Atlantic Salmon are limited. There are only two populations with sufficient data for modeling their population dynamics (the Middle River and Baddeck River populations), and the available data for these populations is limited. Despite the differences between these populations, they are more similar to each other than to many of the other populations in the ECB DU. Given the life history variability seen throughout Eastern Cape Breton, these two populations are not considered to be representative of other populations in the Designatable Unit. Particularly for those populations with a higher proportion of 1SW salmon and those populations where the abundance is in greater decline. Although extinction and recovery probabilities cannot be estimated for the other populations due to data limitations, the probability of recovery would be expected to be lower and the probability of extinction would be expected to be higher for less healthy populations (those with lower overall productivity) such as those in more rapid decline.

Population dynamics for the Middle and Baddeck populations were analysed using a life history-based model. The population model begins by estimating the total number of first time spawning salmon produced within a cohort as a density-dependent function of its starting egg deposition. These adults are then assigned to the appropriate return year using the estimated proportions-at-age for both the age-at-smoltification and the age-at-maturity. These proportions are estimated in the model and are assumed not to vary through time. A set of annual recruitment deviates (one per cohort year) are estimated thereby allowing for year-to-year variability in the productivity of the populations as would be expected to occur due to changes in environmental conditions. Longer term changes in productivity are evaluated by examining trends in these recruitment deviates. Repeat-spawning dynamics are incorporated into the model using the proportion of salmon in all samples for each population that are repeat spawners (0.034 and 0.048 for the Baddeck and Middle populations, respectively) using the assumption that 50% of repeat spawners are alternate-year repeats and 50% are consecutive-year repeats. Data used in models span the time period 1983 to 2011, and the model is fit to the recreational fisheries data, the dive count data, the mark recapture data for adults and the age composition data using maximum likelihood.

Overall, the analyses indicate the data for the Middle River population are somewhat informative about its productivity; however, the data for the Baddeck River population are less informative, as indicated by the much larger standard errors on the model output for the Baddeck River population (Table 1).

Subject to the uncertainties associated with limited data, population modeling for the Middle River indicates that productivity (including the combined effects of in-river productivity and at-sea survival) has not declined from the mid-1980s to present, i.e., the time series in the recruitment deviates (Figure 6) indicate little or no long term trend in the productivity of the Middle River population. In contrast, productivity in Baddeck River is estimated to have declined slightly. This result is consistent with the long term trends in the populations discussed previously.

The estimated annual recruitments (Figure 6) show variability that can exceed a factor of five annually, consistent with the fluctuations observed in the annual spawning run size. While the general recruitment patterns are similar, there is a marked difference in the recruitment for the 2006 and 2007 year classes between the rivers. Because these year classes are not fully recruited, there is some uncertainty about whether this difference is real.

Notwithstanding the issues with the information content in the data, the parameter estimates do suggest some differences in the dynamics of the populations. First, the age structures of the populations differ. Based on the parameter estimates, there is both a higher proportion of age-2 smolts and a lower proportion of age-3 smolts in Middle River than in the Baddeck River. This implies that a single year class has its smolts more evenly distributed over the three smolt age classes (2 to 4) in the Middle River, whereas there is a greater proportion of age-3 smolts within a cohort in the Baddeck River. Maturity after one winter at sea is similar in the two populations, but there is the potential for a slightly greater proportion of 3SW salmon in the Middle River. Together with the differences in the ages-at-smoltification, this would help to distribute the reproductive effort of a single year class over more years in the Middle River population than in the Baddeck. Additionally, salmon in the Baddeck River tend to be larger and have a higher fecundity. This difference results in a higher lifetime egg production per recruit in the Baddeck River than in the Middle River (Table 1) even though the frequency of repeat spawning (based on the limited available age data) is higher in the Middle River population.

The asymptotic recruitment levels are roughly similar between these populations, but the maximum survival from the egg to the recruit stage is estimated to be lower in the Baddeck River, potentially because productivity appears to be slightly declining for the population. Overall, the maximum lifetime reproductive rates are 3.22 and 1.61 spawners per spawner for the Middle and Baddeck river populations (Table 1), indicating that the Middle River population may have greater resiliency to episodic mortality events than the Baddeck River population.

Based on the dynamics described in this section, both populations have equilibriums that are slightly greater than 50% of their conservation requirement (Table 1), although these are achieved differently in the two populations. The Middle River population produces a greater number of recruits but with a lower lifetime egg production per recruit than does the Baddeck River population (Table 1). The estimated egg depositions and recruitments are scattered around the equilibrium (Figure 7), consistent with the populations having fluctuated in size at about 50% of their conservation requirement during the time period when data are available.

Table 1. Maximum likelihood estimates (M.L.E.'s) and standard deviations for equilibrium values estimated with the productivity models for the Middle River and Baddeck River Atlantic Salmon populations.

	Middle River		Baddeck River	
Parameter	M.L.E.	Std. Dev.	M.L.E.	Std. Dev.
Lifetime egg production per recruit (number of eggs)	3,023	43	4,355	758
Equilibrium egg deposition (number of eggs)	1,180,900	124,620	1,116,600	14,588,000
Equilibrium recruitment (number of first time spawning adults)	390	41	256	3,349
Maximum lifetime reproductive rate (spawners/spawner)	3.22	1.27	1.61	53.01

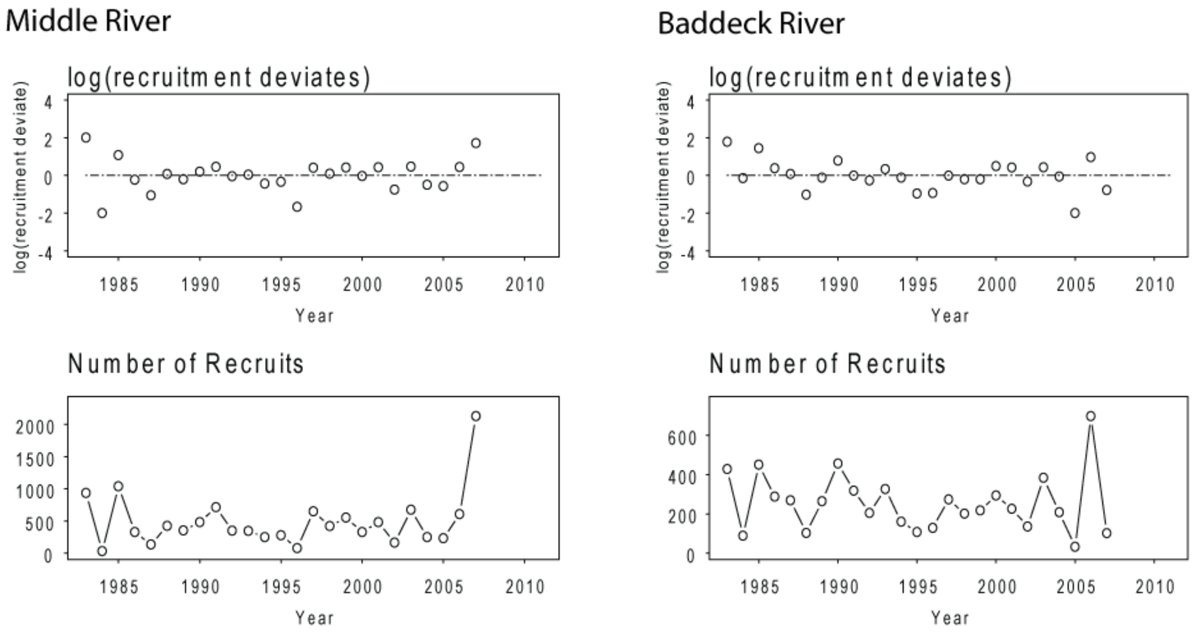

Figure 6. Estimated log-scale annual recruitment deviates (top panel) and estimated number of recruits produced annually by cohort year (bottom panel) for the Middle River (left panels), and Baddeck River (right panels) salmon populations from 1983 to 2007, as estimated with the productivity model.

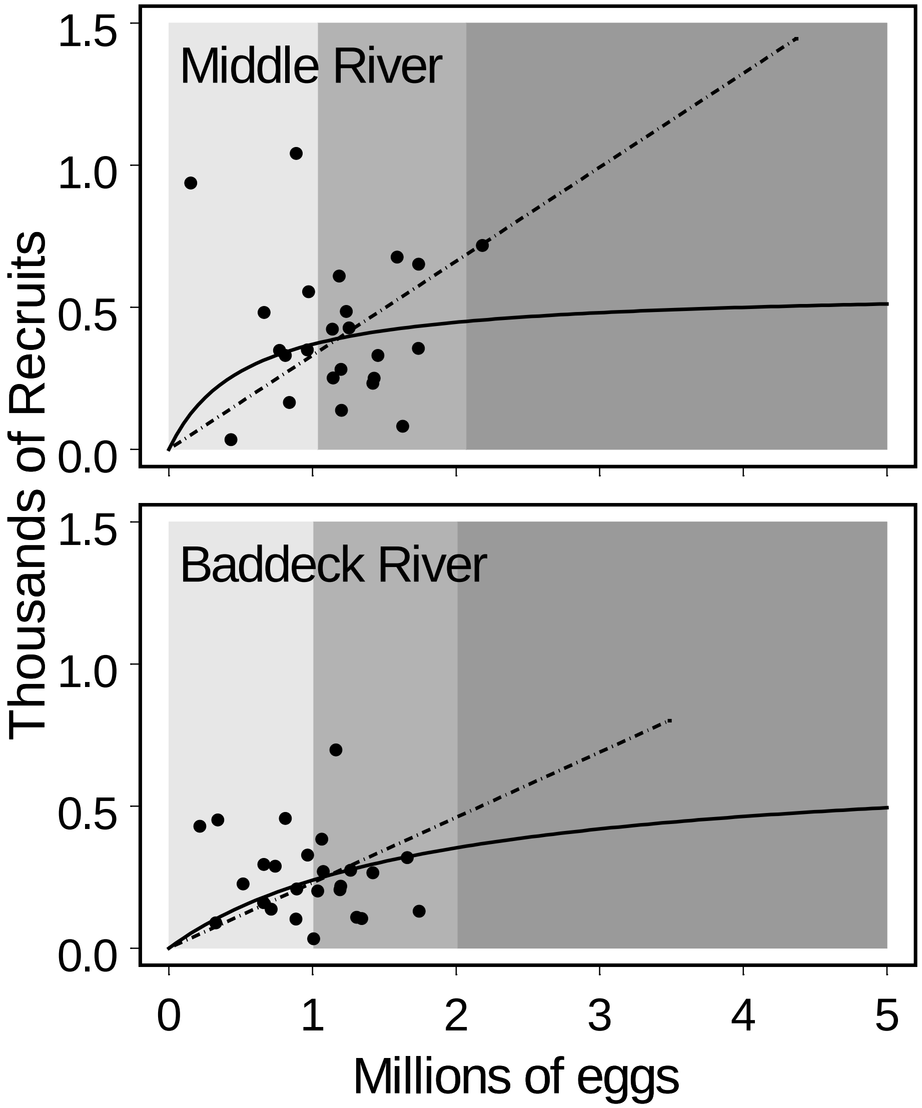

Figure 7. Equilibrium analysis of the dynamics of the Atlantic Salmon populations in the Middle (top) and Baddeck (bottom) rivers. The points are the estimated egg depositions and recruitment (total number of adults produced) for the 1983 to 2007 egg deposition years. The curved, solid lines are the stock recruitment relationships. The straight, dashed lines are the replacement lines that represent the lifetime egg production per recruit. Dark shading indicates egg depositions above the conservation [egg] requirement, medium shading is between 50% and 100% the requirement, and the light shading is below 50% of the requirement.

Population Viability Analysis

Analyses were conducted for the Middle and Baddeck river salmon populations using the population dynamic parameters estimated for the 1983 to 2011 time period. For each river, a total of 1,000 population abundance trajectories were simulated and the extinction and recovery probabilities were calculated as the proportion of the simulations in which the populations go extinct by a specified time. A quasi-extinction threshold of 15 salmon was assumed. When calculating recovery probabilities, the conservation requirement for each river was used as the recovery target, and the probability of recovery was calculated as the proportion of the simulated trajectories that are above the recovery target in a given year. If abundance subsequently declines to a level below the recovery target, the population is no longer considered recovered.

Abundances for each life stage were projected forward for 100 years. Starting abundances were the estimated numbers-at-age and egg depositions for the years 2004 to 2011 for each population. The model includes autocorrelated random variability in the annual productivity (number of recruits produced per cohort), in the smoltification and maturity schedules, and also simulated extreme environmental events which reduce egg survival by two-thirds in the years that they occur.

Population Viability under Present Conditions

The summaries of the 1,000 simulated abundance trajectories for the Middle and Baddeck populations indicate low probability of extinction if conditions in the future are similar to those in the recent past (Figure 8). Similarly, neither population is expected to reach and remain above their recovery targets unless overall productivity (including reproduction and /or survival) is improved. The probability of extinction (Table 2) remains less than one percent for both populations over the 100 year time series, whereas the probability of recovery is in the vicinity of 5% for the Middle River population and of 3% for the Baddeck River population. The median abundance is slightly below the estimated equilibrium because of the way random variability is included. Additionally, these statements are conditional on the modeled dynamics remaining unchanged over the duration of the simulation. If the dynamics change in the future, extinction and recovery probabilities will also change.

Population Viability with Increased and Decreased Productivity

To evaluate how the probability of extinction and probability of meeting the conservation requirement would be expected to vary with increased productivity (which could occur in either fresh-water or at-sea), six scenarios were evaluated for both the Middle River and Baddeck River salmon populations.

Increased productivity was modeled by increasing overall survival from the egg to the first time spawning adult stage by factors of 1.0 (no increase), 1.2 (20% increase), 1.5 (50% increase) and 2.0 (double or 100% increase). Similarly, decreased productivity was modeled by decreasing survival to 90%, 70% and 50% of the base model level.

The results differ between the populations due to the different estimated productivities. For the Middle River population, increasing the productivity by 50% (which could happen if the returns rates increased by 50%, going from 2% to 3% as a hypothetical example), results in one third of the simulated populations exceeding the recovery target after 20 years (Table 3). For the Baddeck River population, despite its lower productivity but due to its slightly higher estimated carrying capacity, this proportion is just over 0.4.

Similarly, the results for the decreasing productivity scenarios also differ between the populations. For the Middle River population, decreasing productivity by 50% only slightly increases the extinction risk over 50 years (Table 3), whereas a 50% decrease in productivity for the Baddeck River population increases its extinction risk to over 95% in 50 years.

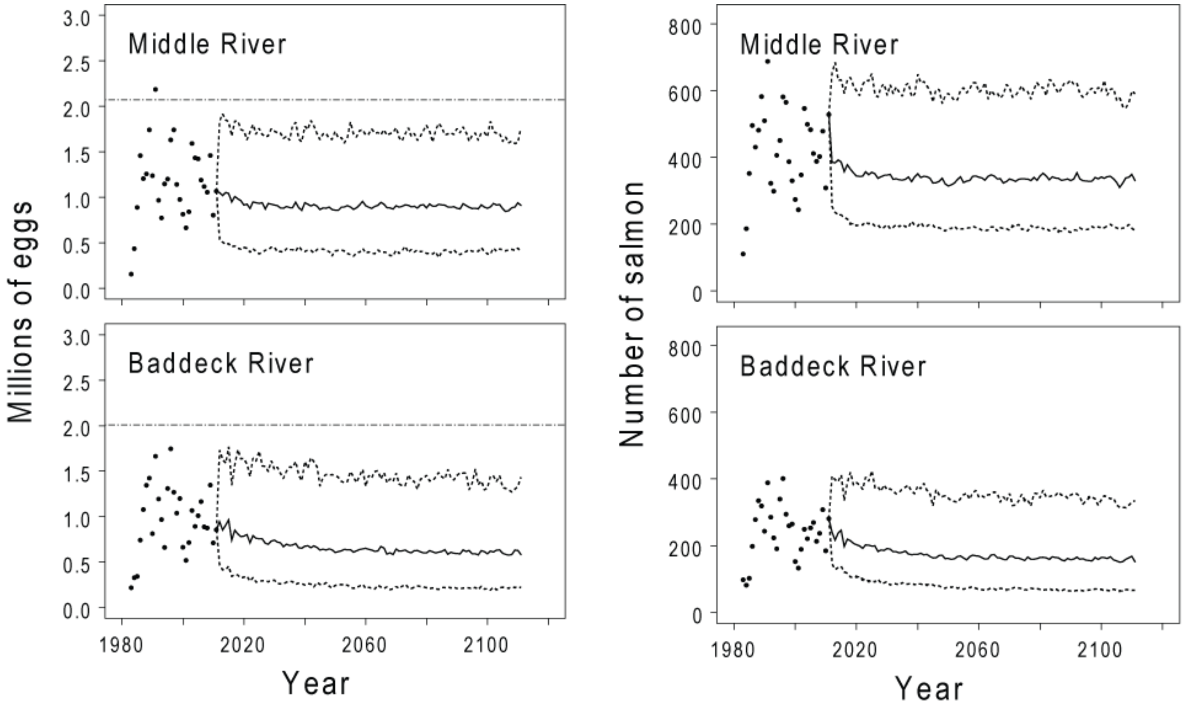

Figure 8. Simulated median abundance (solid line) with the 10th and 90th percentiles (dashed lines) for the egg (left) and adult (right) life stages from Monte Carlo simulations of the Middle River and Baddeck River Atlantic Salmon population viability models using the base model dynamics representative of current conditions. The points show the annual abundance estimates obtained with the productivity model from 1983 to 2011 and the lines show the simulation results from 2012. The graphs summarize 1,000 simulations for each population. The horizontal dashed line in the left panels is the recovery target.

Table 2. Probabilities of extinction and of recovery within 1 to 10 decades for the Middle River and Baddeck River Atlantic Salmon populations. Probabilities are calculated as the proportion of 1,000 Monte Carlo simulations of population trajectories that either became extinct or met the recovery target.

	Probability of Extinction		Probability of Recovery	
Dynamics:	Middle	Baddeck	Middle	Baddeck
Year				
10	0.000	0.000	0.040	0.042
20	0.000	0.000	0.028	0.038
30	0.000	0.000	0.054	0.044
40	0.000	0.000	0.040	0.042
50	0.000	0.002	0.060	0.044
60	0.000	0.000	0.038	0.020
70	0.000	0.002	0.040	0.032
80	0.000	0.004	0.050	0.034
90	0.000	0.004	0.064	0.040
100	0.000	0.002	0.034	0.024

Table 3. Proportions of 1,000 simulated population trajectories that either go extinct or meet the recovery target within 10, 20, 30 and 50 years based on productivity scenarios for the Middle River and Baddeck River Atlantic Salmon populations. The productivity scenarios reflect changes from the present levels estimated with the productivity models and include both increasing and decreasing productivity ranging from one half to twice the productivity estimates.

	Productivity Scenario	% of Base Scenario	Proportion Extinct				Proportion Recovered			
Population			10 yr	20 yr	30 yr	50 yr	10 yr	20 yr	30 yr	50 yr
Middle River	Base	100	0.000	0.000	0.000	0.000	0.040	0.028	0.054	0.060
Middle River	Increasing	120	0.000	0.000	0.000	0.000	0.104	0.140	0.148	0.136
Middle River	Increasing	150	0.000	0.000	0.000	0.000	0.272	0.324	0.338	0.340
Middle River	Increasing	200	0.000	0.000	0.000	0.000	0.578	0.610	0.638	0.606
Middle River	Decreasing	90	0.000	0.000	0.000	0.000	0.026	0.008	0.028	0.036
Middle River	Decreasing	70	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.006
Middle River	Decreasing	50	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.000
Baddeck River	Base	100	0.000	0.000	0.000	0.002	0.042	0.038	0.044	0.044
Baddeck River	Increasing	120	0.000	0.000	0.000	0.002	0.114	0.148	0.170	0.144
Baddeck River	Increasing	150	0.000	0.000	0.000	0.002	0.294	0.414	0.434	0.426
Baddeck River	Increasing	200	0.000	0.000	0.000	0.002	0.622	0.726	0.784	0.746
Baddeck River	Decreasing	90	0.000	0.000	0.000	0.014	0.022	0.010	0.014	0.014
Baddeck River	Decreasing	70	0.000	0.016	0.040	0.274	0.004	0.000	0.000	0.000
Baddeck River	Decreasing	50	0.000	0.258	0.622	0.968	0.000	0.000	0.000	0.000

Habitat Considerations

Functional Descriptions of Habitat Properties

Freshwater Environment

Adults: The timing of the return of adult Atlantic Salmon to rivers in eastern Cape Breton is highly variable. Some populations have spring/summer runs (e.g. the Grand River population), whereas other populations have runs that occur as late as October (e.g. the Middle and Baddeck river populations). Very generally, once in the river the upstream migration of salmon to spawning grounds appears to consist of two main phases: a migration phase with steady progress upriver interspersed with stationary resting periods, and a long residence period called the holding phase. Habitat properties required for the successful migration of adult salmon into rivers are: appropriate river discharge (e.g. it has been suggested that upstream migration will initiate at a river discharge rate of >0.09 m3/s per meter of river width), pools of sufficient depth and proximity in which to hold (salmon can spend weeks to months in a single pool), and unimpeded access throughout the length of the river.

Eggs: Atlantic Salmon in ECB spawn in late fall (November), with eggs incubating in redds through the winter and hatching in April. Successful incubation and emergence of juveniles depends on: river discharge, water depth (e.g. generally between 0.15 to 0.76 m for redd construction) and velocity (e.g. 0.3-0.5 m/s preferred at spawning sites), substrate composition (e.g. coarse gravel and cobble with a median grain size between 15 and 30 mm forms the majority of the substrate of redds, with fine sediments found at low concentrations), water temperature (e.g. stable cold temperatures for egg development), and water quality (e.g. uncontaminated water with a pH >5.0 for development of embryos and alevins).

Juveniles: Juvenile ECB Atlantic Salmon remain in fresh water for one to four years after emergence, with most migrating to the sea two or three years after emergence. Habitat characteristics that are important for the successful rearing of juveniles (fry and parr) include: water depth (e.g. age 0 fry tend to occupy water 15-25 cm deep) and velocity (e.g. fry tend to be found in riffles with surface velocities >40 cm/s, parr are found in a wider range of velocities with an optimum between 20-40 cm/s; juvenile Atlantic Salmon are rarely found at water velocities <5 cm/s or >100 cm/s, and, in the winter juveniles seek out lower velocity water, presumably to minimize energy expenditure); substrate composition (e.g. preferred substrate for age 0 salmon is in the range 16-256 mm diameter (gravel to cobble) and 64-512 mm diameter (cobble to boulder) for age 1 and older parr); the presence of cover; water temperature (typically between 15ºC and 25ºC); and water quality (uncontaminated water of pH > 5.4).

Smolts: Salmon smolts do not have the same freshwater habitat requirements as parr, but rather require the environmental conditions necessary to trigger the changes associated with smoltification as well as to successfully emigrate to salt water. Environmental characteristics influencing the process of smoltification are: photoperiod, water temperature, and river discharge. The main characteristics influencing successful emigration from the river are: unimpeded access throughout the length of the river, suitable water quality and sufficient water discharge.

Kelts: Relatively little is known about freshwater habitat use by post-spawning adult salmon (kelts) in the ECB DU, and variability almost certainly exists among river systems. There is thought to be a component of the kelt population that overwinter in deeper water habitats in the river and descend the river in the spring; however, there may also be a component that exits the river relatively quickly after spawning or that overwinter in estuaries. The proportion of the population that remains in the river during winter likely depends on the availability of pools, lakes, and stillwaters in the watershed.

Estuarine Environment

Smolts: Habitat requirements of ECB smolts have not been studied. In general, once smolts enter estuaries, there does not appear to be a long period of acclimation to salt water given that smolts are actively swimming and tend to move continuously through the estuary (i.e. they do not spend periods resting above the substrate). Migration patterns are not necessarily directly toward the open ocean; a proportion of the population typically moves in various directions over short temporal and spatial scales, leading to various residency times in the estuary. Residency patterns only suggest where and when smolts occupy estuaries, not the physical habitat characteristics that may be required. Given that smolts are thought to swim near the surface within the fastest flowing section of the water column, and use an ebb tide pattern of migration, habitat choice is unlikely to be based on physical habitat characteristics (e.g. substrate type). It is more likely that the oceanographic conditions in estuaries and coastal areas influence movement and, thus, habitat choice in estuaries.

Adults: Adult Atlantic Salmon return to rivers in the ECB DU throughout the spring, summer, and fall months. Their use of estuaries in eastern Cape Breton has not been studied. Based on studies from other areas, similar to smolt use of estuaries, a variety of estuarine residency times for adults have been observed, from moving through estuaries in a matter of days to spending 3.5 months holding in an estuary before moving into the river. Estuaries appear to be mainly staging areas, and movements within them are frequently slow (<0.2 body lengths per second), following the sinusoidal pattern of the tidal currents. While holding in the estuary, adults seem to favour deep water of intermediate salinities ranging from 5 to 20 parts per thousand.

Kelts: Estuary use by kelts in eastern Cape Breton is also unstudied, and there is limited information on residency times or habitat use by kelts in estuaries from other areas. The available evidence suggests that they are used predominantly as staging areas in the spring, or for overwintering, potentially if deep-water habitats are limiting in a particular watershed. In spring, kelts appear to pass relatively quickly through estuaries on their way to open ocean.

The Bras d'Or Lakes are a large and very unique estuary in Eastern Cape Breton. Their role in the life cycle of Atlantic Salmon in the area is not well understood, although regional specific Mi'kmaq traditional ecological knowledge indicates that, in addition to serving as a migratory pathway, they also, as a minimum, serve as a staging area for returning adults and an overwintering area for kelts.

Marine Environment

There is little information about marine habitat use specific to ECB Atlantic Salmon. However, in general, habitat use in the marine environment for immature Atlantic Salmon has been mainly hypothesized based on physiological requirements and tolerances of Atlantic Salmon in the marine environment. At sea, salmon tend to be found in relatively cool (4oC to 10oC) water, avoiding cold water (<2oC), and modifying their migratory route in space and time in response to ocean temperature conditions. For example, in years where coastal water temperatures are warmer, salmon arrive at home rivers earlier. Tagging studies suggest that immature salmon are pelagic, spending the majority of their time in the top few meters of the water column, following the dominant surface currents and remaining in the warmest thermocline. Although movement patterns and distribution have been correlated with water temperature and other abiotic factors, the availability of prey and potential for growth are assumed to determine actual distribution at sea. As such, marine distribution patterns would be expected to vary in space and time as well as among years, based primarily on the distribution of suitable prey items.

Recent studies in the Northeast Atlantic demonstrate that immature salmon begin to feed extensively on marine fish larvae and to a lesser extent on high-energy crustaceans, experiencing a rapid increase in growth in the near-shore environment. Atlantic Salmon are opportunistic feeders, leading to geographical differences in the type and amount of prey consumed. There is some indication that Atlantic Salmon in the Northwest Atlantic have a larger proportion of insects and crustaceans in their diet than those in the Northeast Atlantic, but gadoids, herring and sand lance are also important prey items. Highest marine mortality rates are hypothesized to occur soon after immature salmon reach the open ocean while they are still in the near-shore environment. One hypothesis is that faster growth and lower mortality of immature Atlantic Salmon is associated with entry into the ocean at a time when larval fish prey are abundant and at a consumable size. If so, the environmental factors controlling primary marine production (which would determine prey availability and size) may have a large impact on early marine survival and growth and would largely dictate distribution and habitat use.

After spawning, the majority of adult salmon will exit rivers in the spring of the following year for a period of reconditioning before spawning again. The length of time adults spend in the ocean between spawning events likely determines marine habitat use and distribution patterns for adults. Consecutive spawners return in the same year as their kelt migration and have a relatively short ocean residence period (< 6 months), while alternate spawners return the following year and can spend up to a year and a half in the marine environment. As with immature salmon, marine distribution and habitat use of adult salmon is thought to be determined primarily by the distribution and abundance of suitable prey. Fish form the majority of the diet of adult salmon, and the species consumed include capelin, sand eels, herring, lanternfishes and barracudina. Amphipods, euphausids (krill) and other invertebrates are also consumed, and there is some indication that the proportion of invertebrates consumed increases in more southerly feeding areas. Adult salmon are opportunistic feeders and prey on whatever organisms are most available in the area, so marine habitat use is unlikely to be closely related to temporal or spatial changes in any particular prey. However, major climate or oceanographic events altering the abundance and/or distribution of entire assemblages of suitable prey may have significant effects.

Spatial Extent of Habitat

Freshwater Environment

Freshwater habitat is distributed throughout eastern Cape Breton. The amount of rearing area in the 46 rivers was derived using either map-based measurements of rearing area, or for watersheds for which these measurements were not available, using a linear regression of rearing area on watershed area. A total of 17,942,900 m^2 of rearing area in the 46 rivers was estimated. Wild Atlantic Salmon populations exhibit nearly precise homing behavior to natal rivers, to the extent that each river is thought to contain a distinct population and the amount of habitat available to a specific population is quite variable.

Estuarine Environment

The use of particular habitat types within estuaries by smolts, adults and kelts is mostly unknown for ECB Atlantic Salmon, but estuarine habitat availability is not thought to be limiting.

Marine Environment

Marine distribution patterns for ECB Atlantic Salmon was assessed from historical tagging programs of smolts and adults combined with reported recaptures by commercial and recreational fisheries. In total, there were only 17 recapture events of individuals tagged in eastern Cape Breton, all of which were from hatchery fish. Marine recapture rates from the three groups of tagged fish (for which there was at least one recapture) were extremely low, ranging from 0.05% to 0.24%. Due to the relative scarcity of recapture information, marine distribution patterns of ECB Atlantic Salmon are described as a group, although there are likely differences among populations in marine habitat use patterns as well as year-to-year variation that cannot be characterized with the available data.

The majority of tagged smolts were released in fresh-water in May and June. Only two tags were returned as postsmolts (within 12 months of release), both captured in Fortune Bay, on the south coast of Newfoundland, two months (end of July) and three months (end of August) after release. During the second year-at-sea (as 1SW salmon), the spatial extent of recaptures was larger. In total, 14 tags were returned, 6 of which were released in Grand River and captured north of Neil’s Harbour, Nova Scotia between late June and late September of the year following release (potentially during return migration). An additional 1SW return was reported from the south coast of Newfoundland in June, two from the north coast of Newfoundland (July-August) and the final five returns came from the west coast of Greenland. These Greenland recaptures of 1SW salmon occurred in the early fall (mid-August to late September) and thus potentially represent salmon that were destined to become 2SW spawners. Finally, a single recapture of a 2SW salmon was returned from the northern west Greenland Sea in late September and may potentially represent a salmon destined to return as a 3SW spawner. Given the paucity of returns, it is difficult to formulate hypotheses regarding oceanic migration patterns of salmon from the ECB DU.

Assuming that these data represent general distribution patterns in the marine environment, minimally, ECB Atlantic Salmon use the oceanic and coastal waters of Cape Breton, the south and west coasts of Newfoundland as well as the Labrador Sea. Although it is not possible to explicitly describe the movement patterns of the various life stages of ECB Atlantic Salmon from these data, the spatial extent of recapture locations highlight a crucial point when delineating important habitat in the marine environment. Different life stages may transiently occupy similar habitats and their overall direction of movement can be in opposite directions, potentially leading to a relatively ubiquitous distribution from Nova Scotia to the Labrador Sea and West Greenland throughout much of the year.

Supply of Suitable Habitat

Man-made barriers are not thought to have markedly reduced habitat availability for Atlantic Salmon in eastern Cape Breton. There are 11 watersheds identified that contain man-made barriers, but most of these watersheds are small relative to others in the region. Indian Brook, Sydney River and Northwest Brook have significant amounts of habitat above dams. Both Sydney River and Northwest Brook have fish passage and, in Indian Brook, the dams are above an impassable waterfall.

Freshwater habitat supply is not thought to be limiting salmon abundance in eastern Cape Breton rivers at present. Based on adult counts and recreational fishery catches, adult abundance is considered to be low within the DU, with the expectation that juvenile abundance would also be low. At the current low adult population sizes, it is likely that juvenile production is below what could be supported in the available freshwater habitat.

In contrast with the recovery potential assessment for Southern Upland Atlantic Salmon (DFO 2013), in which habitat loss due to barriers, acidification and other factors was estimated to be at least 40%, this review of habitat availability for ECB Atlantic Salmon has not found evidence of significant habitat loss for this DU. Additionally, there is evidence that freshwater habitat in some eastern Cape Breton rivers can support populations at sizes well above their conservation requirements. While the quantity of habitat currently available in eastern Cape Breton rivers is considered capable of supporting salmon populations at or above the proposed recovery targets, information is insufficient to determine whether habitat quality may be impeding the survival or recovery of salmon populations in some rivers.

Marine habitat quantity is not thought to be limiting abundance of ECB Atlantic Salmon.

Habitat Allocation Considerations

Allocation of important freshwater habitat can occur on at least two scales. On the watershed scale, important freshwater habitat can be allocated based on the rivers selected for the distribution component of the recovery target. Within a watershed, a variety of habitat types are required to support the life stages found in freshwater. Adult Atlantic Salmon need appropriate river discharge conditions and unimpeded access upstream to facilitate spawning migrations, as well as holding pools for staging, and coarse gravel/cobble substrate on which to spawn. Eggs, alevins and juveniles need clean, uncontaminated water with appropriate substrate types, temperature and pH levels for development and growth; and a steady, continuous water flow and areas with appropriate cover. Smolts need appropriate water temperature and river discharge as cues to migrate, as well as unimpeded access throughout the length of the river. All habitat types are required in sufficient quantity to support each life stage.

Estuaries are important habitats known to be used by ECB Atlantic Salmon on an annual basis. The boundaries of an estuary can also be clearly delineated, e.g. using coastlines. There is no information about the duration of estuarine residency periods for either postsmolts or adults in the ECB DU, although simply because of its size, salmon would be expected to be present in the Bras d’Or Lakes for longer periods than in smaller estuaries found at the mouths of rivers flowing directly into the Atlantic Ocean. Estuaries associated with important freshwater habitats are also considered important habitat for ECB Atlantic Salmon as successful migration through these areas is required to complete the life cycle. Additional considerations include the following:
(1) salmon are known to be within or passing through these defined areas during the spring,

summer and fall;
(2) estuaries are areas where significant physiological demands occur as salmon transition between the freshwater and marine environment (and vice versa); and
(3) salmon likely come into direct contact with human activities taking place within estuaries. In terms of increasing the potential for connectivity among the marine and freshwater environments, the estuaries of important watersheds would be high priorities for habitat allocation. Outmigrating smolts and kelts, as well as adult salmon returning to natal rivers to spawn, require unimpeded access to traverse the estuary, and estuarine water of quality (e.g. temperature, contaminants) amenable to survival.

Marine habitats used by ECB Atlantic Salmon populations cannot presently be delineated except on a very coarse scale. Based on tagging data, marine habitats encompass coastal areas from Cape Breton to Greenland. Marine habitat use varies seasonally and is also expected to vary annually depending on factors such as oceanographic conditions or prey distributions. Available tagging data provides only minor insight on the seasonal location of salmon from the ECB DU, and it does not capture annual variability or the true extent of potential movement (e.g. into off-shore areas) due to sampling limitations. While there is likely to be important marine habitat for ECB Atlantic Salmon, given broad temporal and spatial variation, it is difficult to link important life-history functions with specific marine features and their attributes. However, further research into marine distribution patterns is unlikely to delineate distinct areas that should be considered as important marine habitat because salmon are very likely to be widely distributed during most of the year.

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 (*SARA* 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 (DRAFT 2011) 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 four life stages of Atlantic Salmon were evaluated against these criteria. These are spawning redds (used by eggs and alevins), home stones (used by juvenile salmon in fresh water) and holding pools (used by adults). 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. Home stones also match some criteria (they are not created, but are defended or protected), but an individual home stone may be less essential for a life cycle process than a redd because the potential exists for the parr to occupy a different home stone (if not already occupied). Holding pools do not closely match the criteria because they are not created, modified or defended.

Threats

Threats are defined as any activities or processes that have, are, or may cause harm, death or behavioural changes to populations, and/or impairment of habitat to the extent that population-level effects occur. This definition includes natural and anthropogenic sources for threats. Additionally, human activities that impact upon fish and fish habitat often do so in more than one way. In most cases, it is not possible to discuss a specific threat in isolation given the cumulative and correlated nature of the majority of threats. For example, landscape factors controlling hydrology operate at hierarchically nested spatial scales (regional, catchment, reach, in-stream habitat), which means they often override factors controlling salmon abundance at small spatial scales.

In general, there is a lot of information about how threats affect Atlantic Salmon in terms of changes to growth, survival or behaviour of a given life stage (predominantly juveniles) available from other regions, but there is very little research about threats to Atlantic Salmon that is specific to the ECB DU.

A summary of potential threats to ECB Atlantic Salmon and their habitat is provided in Appendix A. The overall level of concern ascribed to a specific threat takes into account the severity of impacts on populations and how often they occur, as well as the spatial scale of the threat in the ECB region.

Threats with a high level of concern are discussed below. The only threat to persistence and recovery in freshwater environments identified with a high level of overall concern is illegal fishing, although there is little information other than anecdotal information to support this evaluation. Threats in freshwater environments with a medium level of overall concern are (importance not implied by order): infrastructure (roads, power lines, etc.); culverts; genetic effects of small population size; forestry; illegal targeting of Atlantic Salmon while fishing under a general license; stocking of rainbow, brown and brook trout; salmon stocking for fisheries enhancement; changes in predator or prey abundance; non-native fish; silt and sediment; and altered hydrology. Threats in estuarine and marine environments identified with a high level of overall concern are (importance not implied by order): salmonid aquaculture; marine ecosystem changes; and diseases and parasites. Threats in estuarine and marine environments identified with a medium level of overall concern are: bycatch in other fisheries and international fisheries (Greenland, St. Pierre – Miquelon).

Illegal Fishing Activities (Poaching)

There have been many anecdotal reports of illegal fishing activities (i.e. poaching) for Atlantic Salmon in eastern Cape Breton, both using recreational fishing gear and using gillnets. The magnitude of this threat to specific populations is not possible to quantify. Poaching would be expected to have the greatest impact when population sizes are small and when population growth rates are low; both of these conditions exist at present.

Salmonid Aquaculture

Commercial aquaculture of salmonids in the marine environment takes place in net pens anchored in coastal estuaries or sheltered near-shore sites. There is an interest in developing the aquaculture industry in Nova Scotia. There are currently nine finfish leases within eastern Cape Breton licensed to raise rainbow trout, eight of which are also licensed to raise Atlantic Salmon. Currently, none of these leases are actively raising Atlantic Salmon.

Detrimental effects on wild Atlantic Salmon populations from aquaculture may occur both in marine and freshwater environments. Impacts in freshwater are largely a result of aquaculture escapes that migrate to freshwater and can introduce pathogens or disease to wild stocks, compete with wild fish for mates, and can reduce the genetic fitness of wild populations via inter-breeding between escapees and wild salmon. In the ocean, impacts include disease and pathogen transfer, habitat degradation near aquaculture sites, contamination by pesticides and chemicals, and transfer of ectoparasites, specifically sea lice (*Lepeophtheirus salmonis*).

Considering the small amount of active salmonid aquaculture operations in eastern Cape Breton, the impact of existing open pen aquaculture is likely minimal. However, should these leases begin active salmon rearing, many of the issues would become more applicable. Further, given that all ECB Atlantic Salmon populations are considered quite small, escape events could produce sizable negative impacts through genetic introgression. The potential also exists that active salmon farming in the Southern Upland or south coast of Newfoundland may impact salmon from the ECB DU (given the potential dispersal range of escapees and potential ECB Atlantic Salmon migration routes near these sites), although the likelihood and magnitude of such impacts is difficult to access with currently available data.

Diseases and Parasites

Relatively little information exists about diseases and parasites in the marine phase of Atlantic Salmon beyond species lists. Most freshwater parasites are lost shortly after entry into the sea, but others have been associated with outbreaks of disease when smolts reach the marine environment. Upon returning to spawn, some tapeworms and other parasites (e.g. sea lice) infecting adult Atlantic Salmon typically die because they cannot complete their life cycle in fresh water. In general, it has been hypothesized that the impact of diseases and parasites would be greater on smolt survival to maturity rather than on adult spawning success because immature salmon are particularly vulnerable to infectious diseases.

Since 2005, several countries, including Canada, have reported salmon returning to rivers with swollen and/or bleeding vents. The condition, known as Red Vent Syndrome (RVS) has been linked to the presence of a nematode worm, *Anisakis simplex*. Although this is a relatively common internal parasite in marine fish, their presence in the muscle and connective tissue surrounding the vents of Atlantic Salmon is unusual. There is no clear indication that RVS affects either the survival of the fish or their spawning success based on the condition of returning spawners. However, if the condition does cause significant mortality, more heavily infected fish would be removed from the study population without the possibility of being sampled (i.e. would die at sea). While there has been a high frequency of infection by the parasite in surrounding regions (i.e. outer Bay of Fundy, Gulf, Southern Upland), and it is likely to be widespread, there are no known observations of RVS in eastern Cape Breton. However, because there are no adult monitoring programs in eastern Cape Breton in which fish are regularly handled, it is unknown how many populations, or which ones, may be impacted by *Anisakis*.

Bacterial kidney disease (BKD) is one of the most widely spread diseases in both fish culture and in the wild. It has been identified in hatcheries throughout Canada, the US and most of Europe. In eastern Cape Breton, BKD has been reported from the North, Middle and Baddeck rivers and St. Anns Bay during the 1970s and 1980s. In these surveys, prevalence within samples ranged from 5.7 to 57.7%. In a study during the 1970s, the impact of BKD on the marine survival of Margaree River salmon, using the ratio of BKD-carrier smolts to BKD-free adults has been estimated to be about a 53% loss of smolt production as a result of the disease. There have not been any recent surveys of BKD prevalence in eastern Cape Breton, although parr collected from Middle and Baddeck rivers for a parr-to-adult captive rearing program did not test positive for the disease.

Sea lice are external parasites that feed on the mucus, skin and body fluids of salmonid species. They were historically observed in low numbers on wild Atlantic Salmon populations with few adverse impacts; however, since the late 1980s there have been epidemics reported in several European countries (Norway, Scotland and Ireland), as well as more recently in Canada. Sea lice infestations have been associated with reduced swimming performance, growth and reproductive rates, impaired immunity, reduced osmoregulatory ability, and acute mortality in salmonid species (Atlantic Salmon, sea trout, Arctic char and some species of Pacific salmon). Linking these physiological effects with increased mortality rates in populations is difficult due to the challenges of capturing wild infected fish. On the east coast of Canada, sea lice infestations spread rapidly among aquaculture sites. Sea lice have been suggested as a potential contributor to the declines in wild Atlantic Salmon populations in Canada, however two recent studies in New Brunswick have not found a link between sea lice from aquaculture and wild population decline. In eastern Cape Breton, anglers have reported sea lice on salmon, however the source and effect of these sea lice is unknown.

Changes in Oceanographic Conditions

Large-scale changes to atmospheric and oceanographic conditions have been observed throughout the marine range of Atlantic Salmon. For example, the Western Scotian Shelf experienced a cold period during the 1960s, was warmer than average until 1998, and then significantly cooled after cold water intrusion from the Labrador Sea. The Eastern Scotian Shelf cooled from about 1983 to the early 1990s and bottom temperatures have remained colder than average since. Sea-ice cover in the Gulf of St. Lawrence and off Newfoundland and Labrador in winter 2009/2010 was the lowest on record for both regions since the beginning of monitoring in 1968/1969. This lack of ice was in part due to warmer temperatures, but also to early season storms breaking up and suppressing new ice growth.

The abundance and distribution of prey species and predators is thought to be an important factor affecting marine growth and survival of Atlantic Salmon populations. Recent evidence of a whole ecosystem regime shift in much of the northwest Atlantic Ocean demonstrates a high likelihood of significant change to the ecological communities experienced by wild Atlantic Salmon populations at sea. The northeast Atlantic Ocean ecosystem has shifted from dominance by large-bodied demersal fish, to small pelagic and demersal fish, and macroinvertebrates. One aspect of this shift is that strong trophic interactions between the remaining top predators, as well as fundamentally altered energy flow and nutrient cycling, appear to be maintaining the new ecological state, making it unlikely that the community will shift back to historical conditions. It has been hypothesized that changes in the abundance and distribution of small pelagic fishes affects food availability and thus marine survival of Atlantic Salmon, and that increased grey seal populations (as seen on the Eastern Scotian Shelf) may lead to significantly higher predation pressure.

There is evidence for bottom-up control of survival to a second spawning event (i.e. kelts in the marine environment) for salmon populations in other regions. A study using time series of return rates to a second spawning for salmon kelts from the Miramichi River, NB and an index of small-bodied fishes in the southern Gulf of St. Lawrence showed that the survival was positively correlated with the abundance of small fishes, presumably representing prey availability.

There is also evidence for top-down control. For example, a study examining the effects of predation demonstrated that following the northeast Atlantic Ocean ecosystem regime shift, predator fields and ocean currents in the Gulf of Maine shifted, resulting in altered migration routes, increased predation and decreased survival of Altantic salmon postsmolts in that area.

Given the mounting evidence of some interaction between climate, prey, predators and salmon, it is likely that the marine survival of salmon are impacted by changes in prey or predator fields. However, the magnitude of this impact, and the mechanism by which marine ecosystem regime shift has affected the marine ecology and survival of Atlantic Salmon from the ECB DU, remains unclear.

Mitigation and Alternatives

A set of mitigation options and alternatives to activities that threaten Eastern Cape Breton Atlantic Salmon were not developed as part of this RPA, although a general discussion (without the intent of reaching consensus about specific mitigation options) did occur at the meeting.

With respect to directed, hook and release recreational fisheries, reducing mortality could occur via the use of time, area, and gear restrictions (e.g. warm water closures, use of barbless hooks, and closures of catch and release fisheries), many of which have already been implemented. Time, area and gear restrictions could also be used to reduce mortality resulting from bycatch in other recreational fisheries if required (this threat was scored “low”). Increased angler education and awareness might also be beneficial. With respect to poaching, increased enforcement and the use of high-tech surveillance gear could increase the number of prosecutions and therefore be a deterrent. Courts could be approached with respect to penalties (causing harm to species listed under SARA as Endangered or Threatened would have higher penalties). Reductions in mortality from high-seas fisheries, if needed, would need to be negotiated in an international forum. Improved information on the extent of mortality from this source would be beneficial.

With respect to salmonid aquaculture in marine and estuarine habitat, site selection criteria could be used to identify areas where impacts on wild salmon would be reduced. Fish health impacts could potentially be reduced with improvements to the National Code on Introductions and Transfers, increased inspections and enforcement, increased education and training, and mandatory reporting and transparency. The impacts of escapes on wild populations could be reduced by improvements to codes of containment, marking of farmed fish so escapes can be more readily identified and removed from the wild and through the use of sterile fish.

With respect to freshwater habitat, suggestions included development of an effective silt and sediment control plan; minimization of hydropower development in Eastern Cape Breton; culvert investigation and improvement; enforcement, compliance monitoring and education; and prioritization of areas for recovery. Based on the discussion of mitigation options, development of river-specific recovery plans and determination of what can be done within a specific location is needed over a general discussion about threats. There is also a need to identify the expected population-level effect associated with each mitigation option or alternative.

Remediation of landscape-level threats to watersheds (e.g. forestry, agriculture, urbanization, roads) requires working at a much larger scale than the stream reach, and typically includes actions that are distant from the actual streambed (e.g. replanting riparian vegetation, revisiting regulations/enforcement on pesticide use, community outreach on invasive species). Although small-scale, in-stream restoration may produce more immediate effects, remediation actions to address land use issues are the more likely to bring about long-term abundance increases because they should have a greater impact on total abundance in the watershed rather than on localized density.

Allowable Harm

Given the population viability analysis is available for only two rivers, which are not representative of the DU, and the variability in population dynamics within the DU, very little scientific advice can be provided in terms of allowable harm. In general, the estimated status and trends of the five index populations suggests that the North River population would be the most resilient to harm, followed by the Middle River population and then Baddeck. The Grand

and Clyburn populations may not be able to sustain existing levels of harm without an increase in productivity or survival rates. Under present conditions, North, Middle and Baddeck may be able to sustain existing levels of harm without going extinct, but existing levels of harm on Middle and Baddeck rivers may be impeding recovery to levels consistently above their respective conservation requirements. Allowable harm for other populations would need to be determined on a case-by-case basis.

Sources of Uncertainty

Most of the information about status and population dynamics comes from three of the index populations (Middle, Baddeck and North), which are considered to be among the healthier populations and are not considered to be representative of the status or dynamics of the DU as a whole.

Data about the age composition of the population, necessary to assign fish returning to the river in a given year to a specific cohort, are only available for a few years, and the number of salmon sampled in some of these years is less than the number of age categories for which proportions-at-age is being estimated. As a result, there is high uncertainty about the dynamics; for example, changes in age-at-smoltification, age-at-maturity and repeat spawning frequency could have changed without being detected, any of which would affect population viability. The resulting uncertainty should be considered when using the results of the population modelling.

Information was compiled about 46 watersheds during this RPA, although salmon likely are found in other watersheds as well. During the review of this assessment, additional salmon rivers were identified through Mi’kmaq traditional ecological knowledge. While the larger watersheds in the region were included in the analyses, estimates of quantities such as the total amount of habitat may be underestimated if salmon are present in other watersheds.

There are only seven ECB Atlantic Salmon populations for which genetics data are available. Although these data do indicate high among-population diversity, they are not sufficient to characterize the spatial scale upon which the diversity occurs. Other information (e.g. ecodistricts, geography) can be used as a proxy for determining groupings.

Salmon in SFA 19 were split into two conservation units during a review of the conservation status of Atlantic Salmon in Eastern Canada: those occupying Cape Breton Highland rivers, and those found in rivers to the east. This split is supported by the genetics and life history diversity from the RPA. It is not known whether this diversity is sufficient to warrant treatment as separate DUs, but these differences do need to be considered in developing recovery plans for the ECB DU as a whole (a different suite of recovery actions may be required for these groups).

There is little information about the dynamics of salmon populations throughout the DU. Specifically, there is insufficient information to be able to evaluate either freshwater productivity or at-sea survival independently.

Although evidence of significant freshwater habitat loss was not found during this RPA, the conclusion that freshwater habitat is sufficient to support recovered populations has not been directly tested.

Marine habitat use, as well as the role of the Bras d’Or Lakes in the life cycle of salmon is not well known.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 28 – February 1, 2013, Recovery Potential Assessment for Atlantic Salmon (Eastern Cape Breton Designatable Unit). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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

DFO. 2007. Revised Protocol for Conducting Recovery Potential Assessments. DFO. Can. Sci. Advis. Sec. Advis. Rep. 2007/039.

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

DFO and MRNF. 2009. Conservation status report, Atlantic Salmon in Atlantic Canada and Quebec: PART II – Anthropogenic considerations. Can. MS Rep. Fish. Aquat. Sci. 2870.

O’Reilly, P., S. Rafferty and A.J.F. Gibson. 2013. Within-and among-population genetic variation in Eastern Cape Breton Atlantic Salmon *(Salmo salar* L.*)*. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/076.

APPENDIX A

Threats tables 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 eastern Cape Breton region.

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 behavioural changes to a species at risk; or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur.

Specific Threat: The specific activity or process causing stress to ECB Atlantic Salmon populations, where stress is defined as changes to ecological, demographic, or behavioural 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 for 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 eastern Cape Breton region 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%. Where possible, the actual proportion of ECB Atlantic Salmon populations affected by a specific threat is given in brackets.

Occurrence and Frequency: Occurrence: Description of the time frame that the threat has affected (H - historical), is (C - current) or may be (A - anticipatory) affecting ECB Atlantic Salmon populations. Historical – a threat that is known or is thought to have impacted salmon populations in the past where the activity is not ongoing; Current – 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 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 <1 year). 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 ECB Atlantic Salmon populations specifically. See Table A2 for definitions/examples of how causal certainty has been evaluated. Note: Does not apply to threats that are anticipatory.

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.

Table A3. Threats to Atlantic Salmon populations in the freshwater environment of the ECB DU.

Threat Category	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	
Freshwater Environment							
Water quality and quantity	Acidification	**Low**	Low	A (potential) Continuous	High	High	Low
	Extreme temperature events	**Low**	Low	H, C and A Seasonal	Low	High	Low
	Altered hydrology	**Medium**	Low (or unknown)	H, C and A Recurrent	Negligible to High (dependent upon timing and magnitude of alteration)	High	Low
	Water extraction	**Low**	Low	H, C and A Recurrent	Negligible to High (dependent upon timing and magnitude of extraction/alteration)	High	Low
	Chemical contaminants	**Low**	Low	H, C and A Seasonal	Negligible to High (dependent upon concentration (dose) and time of exposure (duration)	High	Low
	Silt and sediment	**Medium**	High	H and C Continuous	Negligible to High (dependent upon concentration (dose) and time of exposure (duration)	High	Low
Changes to biological communities	Non-native species (fish)	**Medium**	Medium (15% of assessed populations with invasive fish documented)	H, C and A Continuous	Medium	High	Low
	Non-native species (other)	**Low**	Low	A Continuous	Low to High	Medium	Very Low
	Stocking for fisheries enhancement (Atl. Salmon – using traditional methods)	**Medium**	Medium (two rivers stocked by NSDFA in 2010 and 2011).	H and C Continuous	Low to Extreme (dependent upon number of fish stocked and length of period of stocking)	High (rate of fitness recovery after stocking ends is unknown)	Low

Threat Category	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	
Freshwater Environment							
	Stocking (Atl. Salmon - current)	**Low**	Low (two rivers stocked by DFO in 2011)	C and A Continuous	Low to High	High	Low
	Other salmonid stocking (rainbow – including the Bras d'Or Lakes, brown, and brook trout)	**Medium**	Medium	H, C and A Continuous	Low to High (dependent upon number stocked and type of recipient waterbody (lake vs. river)	Medium	Low
	Salmonid aquaculture (commercial hatcheries)	**Low**	Low	H, C and A Continuous	Medium	High	Low
	Changes in predator or prey abundance	**Medium**	High	C and A Seasonal	Low to High	Medium	Low
	Genetic effects of small population size	**Medium**	Medium	H, C and A Continuous	Negligible to High (dependent upon length of time at small population size, stocking history, and site specific conditions)	High	Low
	Allee (small population size) effects	**Low**	Medium	H, C and A Continuous	High	Medium	Low
	Scientific Activities	**Low**	Low (Five Index Rivers and occasional surveys/ sampling of other rivers)	H, C, A Seasonal	Low	Low	Low

Threat Category	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	
Freshwater Environment							
Physical obstructions	Dams, water diversions and permanent structures	**Low**	Low	H, C and A Continuous	Medium to Extreme (Dependent upon design of structure and location within watershed)	Very High	Low
	Reservoirs	**Low**	Low	H, C and A Continuous	Low to High (Dependent upon size of individual reservoirs and number in series on a system)	High	Low
	Culverts	**Medium**	Very High	H, C and A Seasonal	Low to High (dependent upon design and condition of culvert, and location in watershed)	High	Low
Habitat alteration	Infrastructure (roads, power lines, etc.)	**Medium**	Very High (all rivers)	H, C and A Continuous	Low to High (dependent upon road density within watershed or sub-watershed)	Medium	Low
	Hydro power generation	**Low**	Low	H, C and A Continuous	Low to Extreme (dependent upon facility design and operating schedule)	High	High
	Pulp and paper mills	**Low**	Low	H Continuous	Medium to High (Dependent upon process used and effluent discharge quality)	High	Low
	Urbanization	**Low**	Medium	H, C and A Continuous	Low to High (dependent upon density and infrastructure development)	High	Medium
	Agriculture	**Low**	Medium	H, C and A Seasonal	Low to High (dependent upon extent within watershed and practices used)	Medium	Low
	Forestry	**Medium**	High	H, C and A Continuous	Low to High (dependent upon extent within watershed and practices used)	Medium	Low
	Mining	**Low**	Unknown	H, C and A Continuous	Low to High (dependent upon type of mine, processes used, and susceptibility to acid rock drainage)	Medium	Low
	Habitat alterations	**Low**	High	H, C and A Seasonal	Low (for current fisheries and fishing gears)	Medium	Low

Threat Category	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	
Freshwater Environment							
	from fishing activities						
Directed salmon fishing (current)	Aboriginal fishery	**Low**	Low (at current reported levels)	H, C and A Seasonal	Negligible to Very High	Very High	High
	Recreational fishery (angling)	**Low**	Low	H, C and A Seasonal	Negligible to High	Very High	High
	Illegal fishing / Poaching	**High**	Unknown (but potentially high)	H, C and A Seasonal	Low to Very High (dependent on number of salmon removed and size of impacted population)	Very High	Medium
Bycatch in other fisheries	Aboriginal or commercial fisheries	**Low**	High	H, C and A Seasonal	Low	High	Low
	Recreational fisheries for other species	**Low**	High	H, C and A Seasonal	Low	High	Low
	Recreational fishery: illegal targeting of Atlantic Salmon while fishing under a general license	**Medium**	High	H, C and A Seasonal	Low to High (dependent upon angling pressure)	High	Low

Table A4. Threats to Atlantic Salmon populations in the marine or estuarine environments of the ECB DU.

Threat	**Specific Threat**	**Level of Concern**	**Location or Extent**	**Occurrence and Frequency**	**Severity**	**Causal Certainty**	
Estuarine Environment							
Changes to biological communities	Non-native species	**Low**	High	C and A Continuous	Low	Low	Low
	Salmonid aquaculture	**High**	Very High (because the spatial extent of potential impacts is very large, this can include salmon farms outside the DU)	H, C and A Continuous	Medium to High (dependent upon location of aquaculture facilities and operating practices)	High	Low
	Other species aquaculture	**Low**	Very High (all populations)	H, C and A Seasonal	Negligible to Medium (dependent upon species under culture, location of facility, and operating practices)	Low	Low
	Diseases and parasites	**High**	Very High (all populations)	H, C and A Continuous	Low to High (dependent upon irruptive behavior of disease/parasites resulting in outbreaks)	High	Low
Changes in oceanographic conditions	Marine ecosystem change (including shifts in oceano-graphic conditions and changes in predator/prey abundance)	**High**	Very High (all populations)	H, C and A Continuous	Low to Extreme (dependent upon magnitude of change and sensitivity of salmon to change)	High	Low

Threat	Specific Threat	Level of Concern	Location or Extent	Occurrence and Frequency	Severity	Causal Certainty	
Estuarine Environment							
Physical or abiotic change	Contaminants and spills (land- or water-based)	**Low**	Very High (all populations)	H, C, A Episodic	Low to Extreme (dependent upon identity and magnitude of contamination, and efficacy of cleanup)	Low	Low
	Shipping, transport, noise, seismic activity	**Low**	Very High (all populations)	H, C and A Seasonal	Uncertain; likely Negligible to Low (dependent upon proximity to source of noise/activity)	Low	Low
	Pulp and paper mills	**Low**	Very low (one mill, currently)	H and C Continuous	Medium to High (Dependent upon process used and effluent discharge quality)	High	Low
Directed salmon fisheries	Subsistence fisheries (Aboriginal and Labrador residents)	**Low**	Low	H, C and A Seasonal	Negligible	High	High
	International fisheries (Greenland, St. Pierre – Miquelon)	**Medium**	Very High (all populations)	H, C and A Seasonal	Negligible to High	High	Medium
	Commercial fisheries (Local)	**Low**	Low	H and A Seasonal	Low	High	Low
By-catch in other fisheries	Commercial fisheries	**Medium**	Very High (all populations)	H, C and A Seasonal	Low to High (dependent upon target species, gear and timing)	High	Low
Fisheries on prey species of salmon	Commercial Fisheries	**Low**	Very High (all populations)	H, C and A Seasonal	Low to High (dependent upon reduction of prey species and availability of other forage species)	Low	Low

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