Fisheries and Oceans Canada | Pêches et Océans Canada
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Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2013/054

IMPORTANT MARINE AND ESTUARINE HABITAT OF INNER BAY OF FUNDY ATLANTIC SALMON

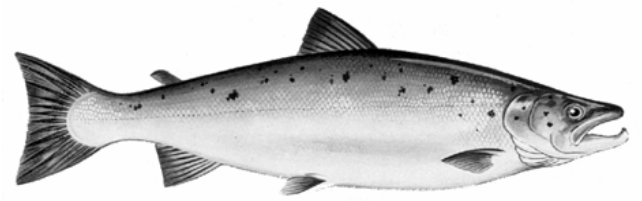

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Figure 1. Map showing the region within the Maritimes Provinces where inner Bay of Fundy (iBoF) Atlantic salmon are found. Highlighted area location of iBoF Designatable Unit (DU).

Context

The inner Bay of Fundy (iBoF) populations of Atlantic salmon (Salmo salar) were listed as Endangered under the Species at Risk Act (SARA) when it came into effect in 2003. SARA requires the identification of Critical Habitat for Endangered species. Information on important habitat, including freshwater and marine habitat, for iBoF Atlantic salmon was provided for a Recovery Potential Assessment in 2008 (DFO 2008). A Recovery Strategy for iBoF salmon was published on the SARA Public Registry in May 2010 (DFO 2010), which identified freshwater Critical Habitat only due, to uncertainties about the distribution and habitat use of iBoF Salmon in the marine environment, as well as a Schedule of Studies to help refine the identification of Critical Habitat for iBoF salmon.

Recent, operational guidelines for the identification of Critical Habitat for aquatic species at risk now provide standards and approaches for identifying Critical Habitat and stress that the absence of scientific certainty regarding the function of the Critical Habitat should not preclude its identification to the extent possible using the best available information. Guidelines state that the predictable concentration or presence of the species could be sufficient to define Critical Habitat when accompanied by a schedule of studies aimed at better understanding habitat function. The current science review aims to provide an update and synthesis of information, in addition to what was provided in the Recovery Potential Assessment in 2008, to support the identification of marine and estuarine Critical Habitat for iBoF salmon.

This Science Advisory Report is from the November 21-22, 2012, review of the Identification of Important Marine and Estuarine Habitat for Inner Bay of Fundy Salmon. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Using the Bounding Box approach, important marine and estuarine habitat of inner Bay of Fundy (iBoF) Atlantic salmon is proposed as: the tidal portions of 19 inner Bay of Fundy salmon rivers and the entire Bay of Fundy outward to the northern Gulf of Maine and the US/Canada boundary, southward to latitude 43°46'51.
- The 19 iBoF rivers for which the tidal portions have been identified as important estuarine habitat are the Gaspereau, Shubenacadie, Stewiacke, Salmon (Colchester), North (Colchester), Chiganois, Debert, Folly, Great Village, Portapique, Bass (Colchester), Economy, Harrington, Apple, Maccan, Petitcodiac, Upper Salmon, Point Wolfe, and Big Salmon. These are the same rivers identified as the long-term recovery target in the iBoF salmon Recovery Strategy; 10 of these rivers are identified as containing freshwater Critical Habitat.
- This recommendation is consistent with the initial focus of the long-term recovery target for iBoF salmon and is primarily based on information on iBoF salmon that mature after one year at sea (the most common life-history strategy).
- The description of important marine and estuarine habitat includes information on the important biophysical functions, features, and attributes for each relevant iBoF salmon life-history stages (smolts, post-smolts, mature adults, and kelts).
- Important functions identified for the marine and estuarine habitat of iBoF salmon are migration, feeding, and staging.
- Important features identified for the marine and estuarine habitat of iBoF salmon are migration corridors, estuarine holding pools, surface waters, upwellings, and food availability.
- Important attributes of these features include temperature, salinity, water flow, depth/volume, forage species, (e.g. sandlance, herring, euphausiids, amphipods), and predator abundance.
- The area identified as important marine and estuarine habitat for iBoF salmon was disaggregated into eight smaller areas (the boundaries of which are only roughly defined) in order to more clearly describe the spatial distribution of important functions, features and attributes by life-history stage. These areas are: Area 1 - the tidal portions of 19 iBoF rivers; Area 2 - the Minas Basin and Chignecto Bay; Area 3 - Bay of Fundy New Brunswick coastal outflow; Area 4 - Passamaquoddy Bay/Fundy Isles; Area 5 - middle of the Bay of Fundy; Area 6 - northern Gulf of Maine; Area 7 - coastal southwest Nova Scotia: Yarmouth to Port George; and Area 8 - coastal southwest Nova Scotia: Port George to Hall's Harbour.
- It was suggested that these areas could be prioritized using the following criteria: number of life-history stages using the area, importance to the life-history stage, and whether there were alternative habitats available. Based on a cursory evaluation of these criteria, Areas 1, 2 and 8 were identified as the highest priority areas; Areas 3, 4, 5, and 7 were identified as the next highest priority areas; and Area 6 was considered to be data deficient.
- The most complete information to assess important marine and estuarine habitat for iBoF salmon is for post-smolts from the May to August period. The greatest uncertainty is in the fall and winter period.
- Overwintering habitats of all life-stages are as yet unknown, but are hypothesized to be off the Scotian Shelf or in the southern portion of the Gulf of Maine.

INTRODUCTION

Fisheries and Oceans Canada (DFO) Science was asked to review and evaluate available information in support of the identification of important marine and estuarine habitat required for successful completion of all life-history stages of inner Bay of Fundy salmon (iBoF), specifically:

- spatial and temporal high-use areas based on existing marine distribution data;
- post-smolt marine foraging habitat, migration routes, and summer resident habitat;
- kelt re-conditioning habitat and areas where mortality occurs;
- potential overwintering habitat as described in the Recovery Potential Assessment (DFO 2008); and
- estuaries of importance to iBoF salmon, such as those associated with the freshwater critical habitat (i.e. rivers) that have already been identified in the Recovery Strategy (DFO 2010).

Science was asked, to the extent possible, to provide geospatial information on the locations and spatial extent of the areas that are likely to have these properties and recommend research or analysis where current information is incomplete. This Science Advisory Report comprises information extracted from the more comprehensive Marshall (2013).

Inner Bay of Fundy Salmon

The iBoF populations of Atlantic salmon are considered a Designatable Unit (DU) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006). The entire iBoF DU exists within Eastern Canada. It includes the salmon populations that spawn in all rivers draining into the inner Bay of Fundy, starting with the Mispec River (northeast of the Saint John River in New Brunswick) to the Pereaux River (in the Minas Basin). Adult Atlantic salmon are reported to have inhabited from 32 to 42 rivers in that area. The Recovery Strategy for iBoF Salmon (DFO 2010) identified 10 of these rivers that contained residual native populations essential to the current persistence of iBoF salmon as containing freshwater Critical Habitat: the Big Salmon, Upper Salmon, Point Wolfe, Economy, Portapique, Great Village, Folly, Debert, Stewiacke, and Gaspereau rivers.

IBoF salmon are genetically distinct from other Atlantic salmon population groups and have some unique life history traits, including maturity after one winter at sea (referred to as a 1SW salmon) that is higher than other populations in the Maritimes and a localized migration strategy. An exception to this pattern is the Gaspereau River population, which has a high proportion of two-sea-winter (2SW) salmon and is thought to have a migration pattern more similar to outer Bay of Fundy salmon populations.

IBoF salmon are anadromous, i.e. they hatch and typically spend two to four years as juveniles in fresh water before descending as smolts to the sea in the spring of the year. There, first as post-smolts and then, after the first winter, as maturing adults, they feed and grow for one and sometimes two years before returning to their natal river where they spawn, late October-early November. After spawning, the adults are termed ‘kelts’ and either that fall, or in the ensuing spring, descend to the sea where they re-condition for a subsequent return and spawning. Adult run timing is variable. Some populations return to the rivers during late spring or early summer; whereas, other populations return primarily during the fall.

The Bay of Fundy/Gulf of Maine

The Bay of Fundy is an estuarine embayment at the eastern end of the Gulf of Maine. The circulation in the Bay of Fundy is related to that of the eastern half of the Gulf of Maine and is also counterclockwise. At all times, there is an inflow along the southern entrance of the Bay. This inflow reaches a minimum during the winter months and a maximum during summer and

fall. Flow direction and velocity at specific times and locations vary markedly with the tides. The outflow from the Bay to the northern Gulf of Maine also exhibits a seasonal variation, being minimal during the winter and maximal during the spring and summer.

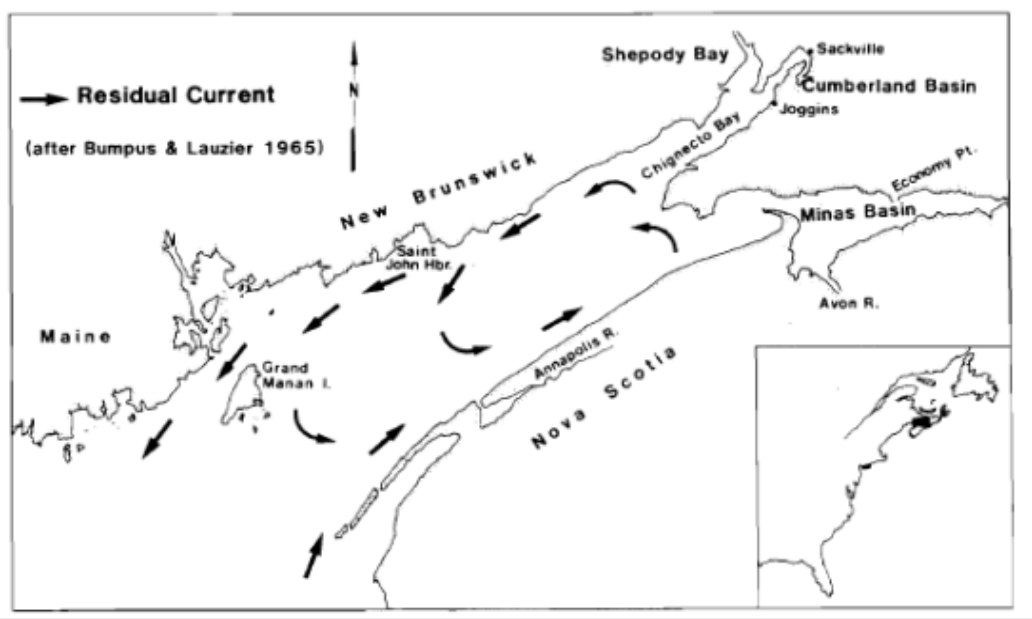

Figure 2. Bay of Fundy showing residual current structure (from Dadswell et al. 1983, based on Bumpus and Lauzier 1965).

Salinities in the Bay of Fundy are lowest in the Minas Basin and Cobequid Bay (29.5 parts per thousand (ppt) and downwards to 20.0 ppt, respectively). Salinity gradually increases towards the outer Bay (approximately 31.0 ppt) to the Gulf of Maine (approximately 32.5 ppt). All salinities within the Gulf and Bay are significantly less than the 35.0 ppt in which post-smolts and maturing adults of most North American populations are found. For the purposes of this document, the term estuary is defined as waters with a salinity $\leq$30.0 ppt.

National Guidance on Identification of Critical Habitat

The *Species at Risk Act* (*SARA*) defines Critical Habitat as, "… the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species." This Science Advisory Report does not identify Critical Habitat, but provides information on important habitat and its features and functions to support the identification of Critical Habitat. The Species at Risk Management Division will consider this Science advice, the requirements of *SARA*, and National policies and guidance on Critical Habitat identification to complete the identification of Critical Habitat in the Recovery Strategy.

National Guidance suggests that the identification of Critical Habitat is comprised of several components: biophysical functions, features and attributes, and their geographic locations.

Functions – Critical Habitat serves one or more biological functions, which support a life-cycle process requirement of the listed species. A function is the result of a biophysical feature and its attributes**,** which together provide the capacity for the function to occur.

Features – Features are the biophysical components of the habitat, e.g., eelgrass beds, macrophytes, riffles, pools, and acoustic environment. Features are the aspects of the habitat that support the functional capacity for a life-cycle processes necessary for survival or recovery. Features must be described in terms of their temporal use and/or availability.

Attributes – Every feature is comprised of many attributes, such as temperature, water depth, velocity, gravel size, and oxygen level that operate within optimal ranges and together provide the functional capacity of the feature to support a life-cycle process. Attributes are measurable and indicate why one feature is essential whereas another similar feature is not. Only those attributes deemed essential to a feature and the function it supports should be described.

Geographic location – Can be identified through a variety of approaches include the Bounding Box Approach, in which the functions and features of the habitat can be described, but their exact location cannot.

ASSESSMENT

Data Sources

Primary data sources used in this assessment were as follows:

1) Smolt run monitoring on the Big Salmon (Flanagan et al. 2006), Gaspereau, and Stewiacke (Gibson, pers. comm) rivers using rotary screw traps.
2) Conventional tagging of smolts (wild and hatchery origin) from the Big Salmon and Stewiacke rivers, with subsequent recapture (e.g., in fisheries) as post-smolts or adults (Jessop 1976; Amiro and Jefferson 1996; Amiro et al. 2003).
3) Acoustic tagging of smolts and detection along acoustics arrays as post-smolts (Lacroix et al. 2005; Lacroix 2008, 2013).
4) Research trawl surveys of post-smolts, including stomach content analysis (Lacroix and Knox 2005).
5) Information derived from catch of salmon (post-smolts and adults) in commercial (e.g., drift nets and weirs) and recreational fisheries (Amiro et al 2003).
6) Monitoring of adults at the Big Salmon River counting fence (Jessop1986).

Some preliminary information was provided on results of pop-up satellite tags applied to kelts from the Big Salmon and Gaspereau rivers (Lacroix, pers. comm.). Oceanographic information from a variety of sources was also used to help interpret available data on iBoF salmon marine and estuarine distribution.

Important Marine and Estuarine Habitat for Inner Bay of Fundy Salmon

All sources of information available to date on the marine and estuarine distribution of iBoF salmon support the conclusion that iBoF salmon populations migrate through, and some portion establishes a residency within, the Bay of Fundy and northern Gulf of Maine (including migration through estuaries of natal rivers) from May to October (at a minimum), as the majority of catches, recaptures, and detections of iBoF salmon to date have been contained within this area. Compared to other Atlantic salmon populations in the Maritimes Region, a relatively small number of recaptures of tagged iBoF salmon have come from more distant locations during these months. However, data from kelts and 2SW salmon (e.g., from the Gaspereau River) are limited, as are data from the November-April period, and it is likely that additional habitats of importance to a distant migrating component of iBoF salmon, as well as overwintering habitats, are not captured with the existing information.

Estuarine habitat of iBoF Atlantic salmon (particularly tidal portions of natal rivers) is relatively easily defined; however, marine habitats and their use by the various life stages in the Bay of Fundy are widespread, ill-defined, overlap and are, therefore, difficult to define geospatially.

On the basis of existing direct and indirect evidence, and using the Bounding Box approach, important marine and estuarine habitat of iBoF Atlantic salmon is proposed as:

> *the tidal portions of 19 inner Bay of Fundy salmon rivers and the entire Bay of Fundy outward to the northern Gulf of Maine and the US/Canada boundary, southward to latitude 43°46'51.*

The southern boundary was determined based on trawl recaptures of wild post-smolts of Big Salmon River in the Gulf of Maine in June. The furthest southward recapture was about 30 km due west of Yarmouth, Nova Scotia (Figure 8).

The 19 iBoF salmon rivers for which the tidal portions have been identified as important estuarine habitat are the Gaspereau, Shubenacadie, Stewiacke, Salmon (Colchester), North (Colchester), Chiganois, Debert, Folly, Great Village, Portapique, Bass (Colchester), Economy, Harrington, Apple, Maccan, Petitcodiac, Upper Salmon, Point Wolfe, and Big Salmon. These are the same rivers identified as the long term target in the iBoF salmon Recovery Strategy; 10 of these rivers are currently identified as containing freshwater Critical Habitat in the iBoF salmon Recovery Strategy.

This recommendation is consistent with the initial focus of the long-term recovery targets for iBoF salmon (once at sea survival is improved, recovery efforts in a greater number of rivers will become increasingly valuable for long term population self-sustainability) and is primarily based on information on iBoF salmon that mature after one year at sea (the most common life-history strategy). It includes important habitat used by smolts, post-smolts, mature adults, and kelts but it does not include additional important habitat used by distant migrating salmon, e.g., kelts and Gaspereau River fish that spend two winters at sea.

Functions, Features, and Attributes of Important Habitat Areas

Available data sources provide information on the spatial and temporal distribution of iBoF salmon within the area identified as important estuarine and marine habitat, as well as information on oceanographic conditions, feeding of salmon, and some limited information on salmon predation within this area. This, in conjunction with iBoF salmon life-history information and relevant information on Atlantic salmon available from other areas, allows for characterization of some of the functions of the area identified as important estuarine and marine habitat, as well as its biophysical features and attributes (as defined in the National Guidance).

Based on available information, important functions identified for the marine and estuarine habitat of iBoF salmon were migration, feeding, and staging. Important features identified for the marine and estuarine habitat of iBoF salmon were migration corridors, estuarine holding pools, surface waters, upwellings, and food availability. Important attributes of these features include temperature, salinity, water flow, depth/volume, forage species (e.g., sandlance, herring, euphausiids, amphipods), and predator abundance. When attributes of different relative importance were used to describe the features, they were classified as either primary (attributes with the most influence on the functional capacity of the feature) or secondary (attributes that influence the functional capacity of the feature, but to a lesser degree).

The area identified as important marine and estuarine habitat for iBoF salmon was disaggregated into 8 smaller areas. Despite the challenges in delineating these areas geospatially, roughly defined boundaries are provided (Figure 3) in order to help describe the spatial distribution of important functions, features, and attributes by life-history stage. However, these boundaries should be considered as approximate. Details on the delineation of each of the 8 areas are included in their respective sections below. These areas are: Area 1 - the tidal portions of iBoF salmon rivers; Area 2 - the Minas Basin and Chignecto Bay; Area 3 - Bay of Fundy New Brunswick coastal outflow; Area 4 - Passamaquoddy Bay/Fundy Isles; Area 5 - middle of the Bay of Fundy; Area 6 - northern Gulf of Maine; Area 7 - coastal southwest Nova

Scotia: Yarmouth to Port George; and Area 8 - coastal southwest Nova Scotia: Port George to Hall's Harbour.

Appendix 1 provides summary information on the functions, features, and attributes of each of these eight areas by life-history stage. The timing and duration of occupancy within each of the eight areas, by life-history stage, is provided in Appendix 2.

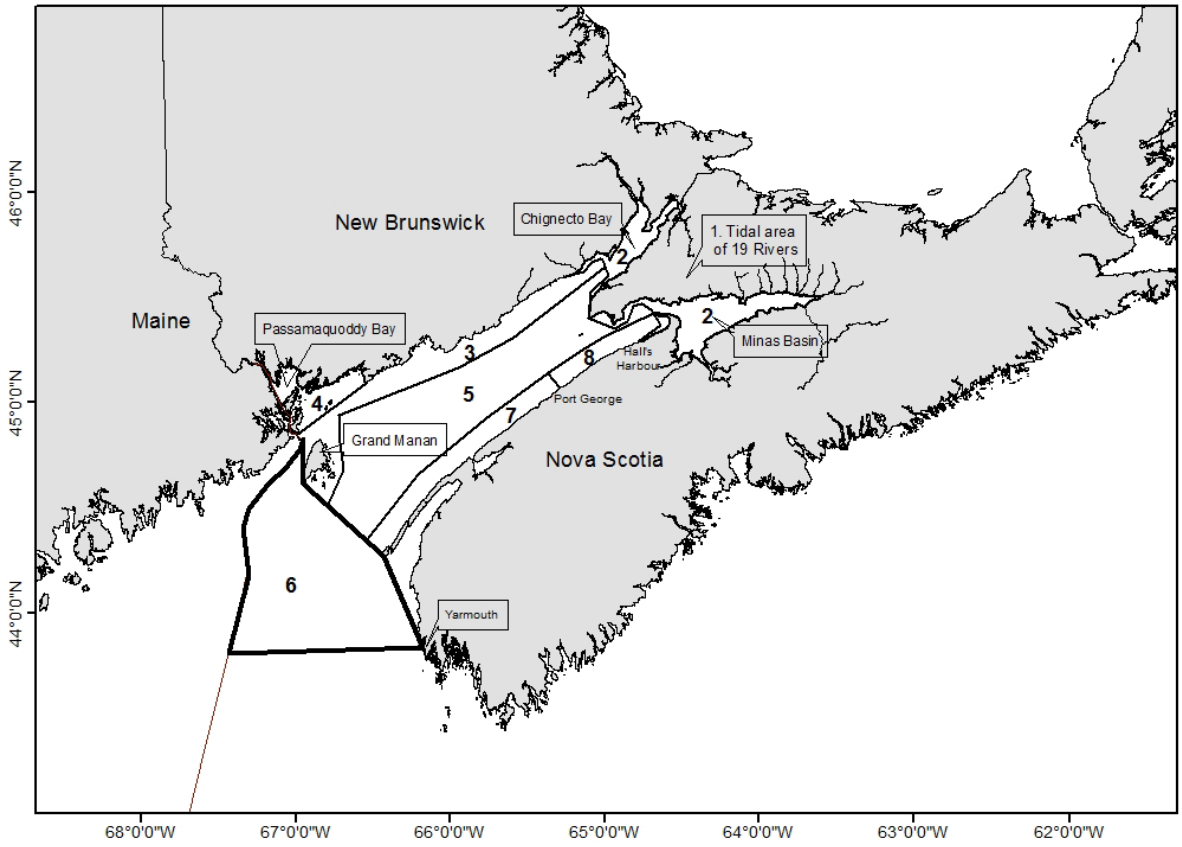

Figure 3. Areas identified within the important habitat bounding box for iBoF Atlantic salmon: Area 1 - tidal portions of 19 iBoF salmon rivers, Area 2 - Minas Basin and Chignecto Bay, Area 3 - Bay of Fundy New Brunswick coastal outflow, Area 4 - Passamaquoddy Bay/Fundy Isles, Area 5 - middle of the BoF, Area 6 - northern Gulf of Maine, Area 7 - coastal southwest Nova Scotia: Yarmouth to Port George, and Area 8 -.coastal southwest Nova Scotia: Port George to Hall's Harbour. The red line is the Canada/US International Boundary Line.

A narrative description of each of these areas, including the information available on its use by iBoF salmon, is provided below.

Area 1 - Tidal Portions of iBoF Salmon Rivers

The tidal portions of 19 iBoF salmon rivers were identified as important estuarine habitat for migration of smolts, adults, and kelts, as well as for staging of adults.

The 19 iBoF salmon rivers considered here are those identified in the long term recovery targets of the Recovery Strategy (DFO 2010): the Gaspereau, Shubenacadie, Stewiacke, Salmon (Colchester), North (Colchester), Chiganois, Debert, Folly, Great Village, Portapique, Bass (Colchester), Economy, Harrington, Apple, Maccan, Petitcodiac, Upper Salmon, Point Wolfe, and Big Salmon rivers (Figure 4).

The tidal portions of iBoF salmon rivers are considered here to be the lower reaches of the rivers between the high tide mark and a line drawn between the headlands at the river mouth. In the case of the Big Salmon River and, to a slightly greater extent, the Point Wolfe and Upper Salmon rivers, the tidal portion of the river is a few kilometers or less. In the Minas Basin and Cobequid Bay, the tidal portions of rivers vary from 'short' on the north shore, 'intermediate' on the Gaspereau, to 'long', an estimated 43 km for the Stewiacke/Shubenacadie river system.

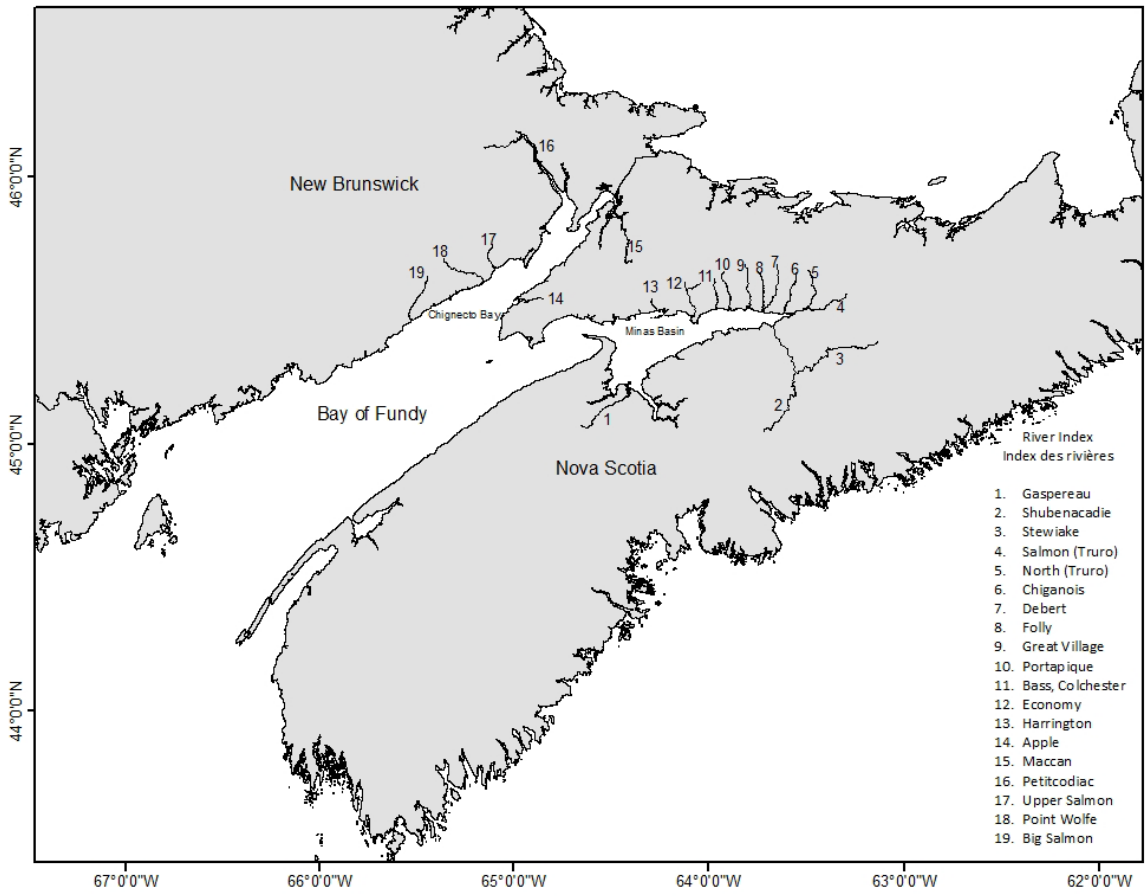

Figure 4. The 19 iBoF rivers for which important estuarine habitat was identified – used for migration of smolts, adults, and kelts, as well as for staging of adults.

Smolt

Migration: The tidal portions of iBoF salmon rivers serve as migration corridors and salt water acclimation areas for smolts migrating to sea. In the case of the Big Salmon River and, to a slightly greater extent, the Point Wolfe and Upper Salmon rivers, acclimation is thought to be rapid given the short estuarine areas of these rivers. Duration of occupancy in the tidal portions of iBoF salmon rivers by smolts can be inferred from the recent monitoring of rotary screw traps on the Big Salmon and Stewiacke rivers, as well as by-pass facilities at the White Rock Generating Station on the Gaspereau River. Accounting for distances and speed of travel from the smolt monitoring facilities to the headlands, it is suggested that the bulk of the runs, on average, would be in the tidal portions of rivers for approximately five to six weeks in May/June: from the first/second week of May to mid-June for the three New Brunswick rivers, from the first week of May to the beginning of June in the Gaspereau River, and mid-May to the third week of June for the Stewiacke/Shubenacadie rivers. The most important attribute of these migration corridors for smolts is thought to be water flow of sufficient volume and depth to allow for

unimpeded access. Other attributes that are potentially important include temperature, salinity, and the abundance of predators.

Adult

Migration: The same tidal portions of iBoF salmon rivers are important as migration corridors (and acclimation areas) to freshwater by adults returning to spawn. Counts of salmon on the Big Salmon River and recreational catches in both the Big Salmon and Upper Salmon rivers support the importance of their estuaries from July to October. Recreational catches in tributaries flowing into the Central Minas Basin and Cobequid Bay support the importance of their estuaries in September and October. Staging in the Gaspereau starts in May, possibly earlier, based on counts at the fish ladder. The most important attributes of these migration corridors for adults are thought to be water flow of sufficient volume and depth to allow for unimpeded access and temperature, as high temperatures are known to impede migration. Secondary attributes include salinity and predator abundance.

Staging: Staging pools within the tidal portions of some iBoF salmon rivers are considered to be important resting/staging habitat for ascent to freshwater by maturing adults. Timing of the use of these areas is likely river specific. Based on the monthly distribution of salmon returns to the Big Salmon River counting fence 1964-1967, 1968-1970, and 1972 (Jessop 1976), and those caught by anglers in the Big Salmon and Upper Salmon rivers 1964-1973 (Swetnam and O'Neil 1985), the Big Salmon River staging occurs by July and the short riverine estuary is used July through October. For the Upper Salmon River, it is probable that staging is occurring August-October. The most important attributes of these staging pools for adults is thought to be depth, volume, and temperature. Other potentially important attributes include salinity, abundance of predators, and distance to the head of tide.

Kelt

Migration: The tidal portions of iBoF salmon rivers are known to serve as migration corridors for kelts, which use them in the winter/spring to return to the sea for reconditioning. However, limited data are available to evaluate or describe their use by kelts.

Area 2 - Minas Basin and Chignecto Bay

Minas Basin and Chignecto Bay (Figure 3) were identified as important estuarine habitat for migration of post-smolts, adults, and kelts; feeding areas for post-smolts and kelts; and staging areas for adults. All but one (Big Salmon River) of the 19 iBoF salmon rivers identified as having important estuarine habitat flow into these two larger estuaries.

Post-smolt

Migration: Minas Basin and Chignecto Bay are inferred to be used as a migration corridor for post-smolts to the rest of the Bay of Fundy in May and June. The important attributes of these migration corridors for smolts are thought to be temperature, salinity, and predator abundance.

Feeding: Minas Basin and Chignecto Bay are also inferred to be used as feeding areas for post-smolts from June through September. Key forage species (primary attribute) are not known specifically for this area, but in other areas include small pelagic prey, such as amphipods, euphausiids, and fish larvae.

Adult

Migration: Information on the migration of adults through the Minas Basin and Chignecto Bay into their natal rivers is inferred primarily from historical catches in commercial fisheries and subsequent catches in freshwater recreational salmon fisheries. This information suggests that these estuaries are used by adults from May to October. The important periods of former commercial salmon fisheries in Central Minas Basin and Cobequid Bay/estuary were July and

August, which is consistent with the progression of adults returning to natal rivers of the Minas Basin from the cooler sea surface temperature (SST) off Kings County (see description of Area 8). For Gaspereau River salmon populations, it would appear that the Minas Channel, Central Basin, and Southern Bight are important May through August. Temperatures of <14°C while salmon await appropriate river discharges is considered to be an important factor in the use of these estuaries as migration corridors (primary attribute), as is the presence of decreasing salinity and an absence of predators (secondary attributes).

Staging: Minas Basin is important for adult staging, acclimation to fresher waters, and possibly feeding for the period July through October. For Gaspereau River salmon populations, this period would encompass at least June through August. Chignecto Bay staging areas, presumably proximate to natal salmon rivers, appear to be important August and September for the Upper Salmon River. The temporal distribution of former recreational catches of salmon suggests that, for the Upper Salmon River, it is probable that a Bay of Fundy staging area is important August to October. Temperatures of <14°C while salmon await appropriate river discharges is considered to be an important factor in the use of these estuaries as staging areas (primary attribute), as is the presence of decreasing salinity (secondary attribute).

Kelt

Migration: Kelts of rivers flowing into the Minas Basin and Chignecto Bay are thought to migrate through these waters in the winter/spring to access the rest of the Bay of Fundy for reconditioning. The primary attribute of importance for kelts is increasing salinity to enable acclimation, with secondary attributes of depth/volume and predator abundance.

Feeding: Kelts are also thought to feed in these areas in order to recondition post-spawning. Forage species include juvenile herring, white hake, winter flounder, and adult and juvenile three spine sticklebacks (Minas Basin).

Area 3 - Bay of Fundy New Brunswick Coastal Outflow

For the purpose of this assessment, the Bay of Fundy New Brunswick coastal outflow area is considered to extend along the New Brunswick side of the Bay of Fundy from approximately 44^{o}49' to 45^{o}31' (about 210 km), and to extend outwards from shore approximately 10-15 km (on average), excluding Passamaquoddy Bay. This area is characterized by average depths of less than 50 m. The extreme westerly edge between Grand Manan and the Fundy Isles reaches depths closer to 150 m. Surface salinity in this area is lowest near shore, due to fresh water plumes from river drainages, and increases towards the middle of the Bay of Fundy. This area includes the mouth of the Big Salmon River, one of the 19 identified important iBoF salmon rivers.

The Bay of Fundy New Brunswick coastal outflow (Figure 3) was identified as important marine migration habitat for post-smolts and adults, as well as important feeding habitat for post-smolts. Use of this area by kelts for migration, or by kelts and adults for feeding has not been studied.

Post-smolt

Migration: Information on post-smolt migration in this area is primarily derived from conventional and acoustics tagging results. The majority of post-smolt migration information in the Bay of Fundy was collected by Lacroix (2008, 2013) in 2001 and 2002 using acoustically tagged smolts. Tagged smolts were detected at arrays of receivers placed across the Bay of Fundy at approximately the separation of the inner and outer Bay (inner array) and between Grand Manan, New Brunswick, and Nova Scotia (outer array), the latter approximating the bounds between the outer bay and the Northern Gulf of Maine (Figure 5).

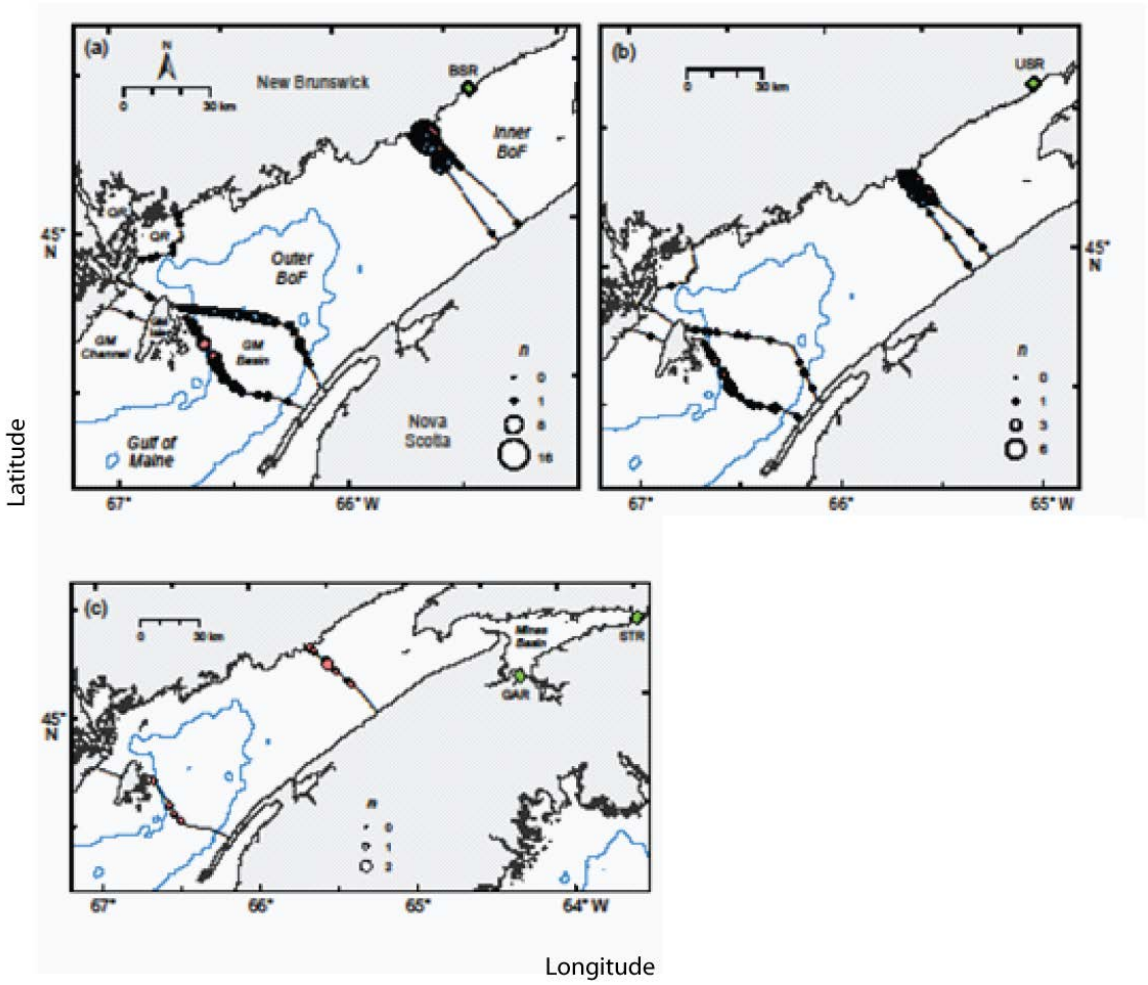

Figure 5. Maps of the monitoring arrays in the Bay of Fundy (BoF) showing the distribution and abundance of migrating Atlantic salmon post-smolts in 2001 (graded blue circles) and 2002 (graded red circles) based on the site of first detection on an array for tagged fish from: (a) the Big Salmon River (BSR) with wild and hatchery fish combined, (b) the Upper Salmon River (USR), and (c) the Minas Basin rivers (MBR). The scale for number of post-smolts (n) at a site, and the 100-m isobath (blue line) are shown in each panel. Reproduced with permission from Lacroix (2013).

Data indicate that the majority of tagged post-smolts migrated along the coast of New Brunswick as they headed out of the inner Bay in May-June, then headed into the Fundy Channel just northeast of and along the southeast coast of Grand Manan Island in the concentrated southerly flow of May-July (Figure 6).

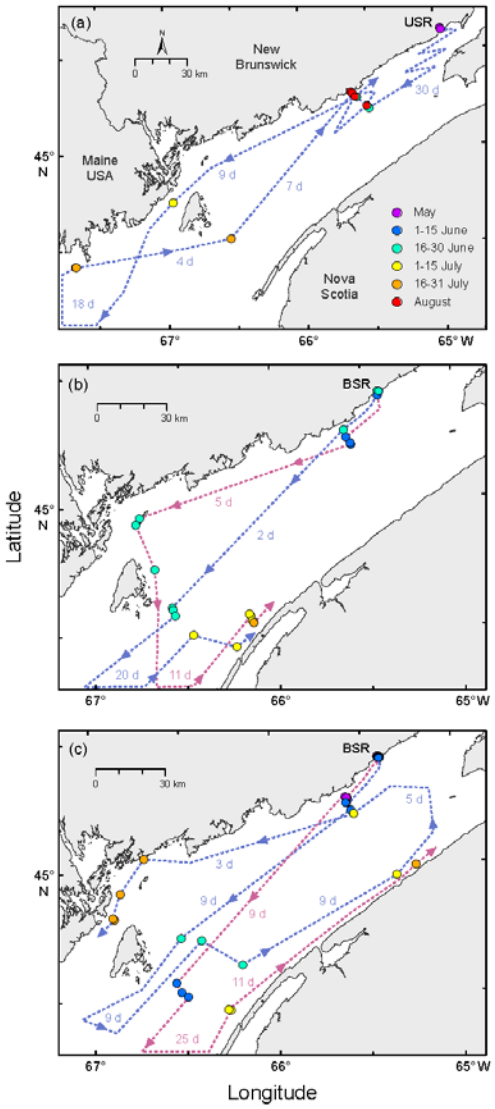

Figure 6. Maps of inferred migration paths (dashed lines) based on sequential sites of detection (circles, color-coded by time period) for individual Atlantic salmon post-smolts of inner Bay of Fundy (BoF) origin leaving and then returning to the BoF from the Gulf of Maine (GoM): (a) delayed migration from the inner BoF to the coast of Maine and late return to the inner BoF, (b) late migration into the GoM and return to the outer BoF (2 tracks shown),and (c) late migration into the GoM and return to the inner BoF (2 tracks shown). The number of days between sequential detections is shown for some track segments. Rivers of origin are Upper Salmon River (USR) and Big Salmon River (BSR). Reproduced with permission from Lacroix (2013).

Fifty-one percent of 237 outbound acoustically tagged iBoF post-smolts migrated within a 6 km corridor extending from the New Brunswick shore; 92% of post-smolts were within a 14 km corridor along that coast. The salinities in this area were higher in June than in August for both 2001 and 2002, and the SST varied between 6-8°C (Figure 7). At the outer array, 26% of post-smolts were within 10 km of the east shore of Grand Manan Island and 61% were in a broader corridor extending 22 km from the east coast of the Island with a peak in post-smolts monitored at 18–20 km.

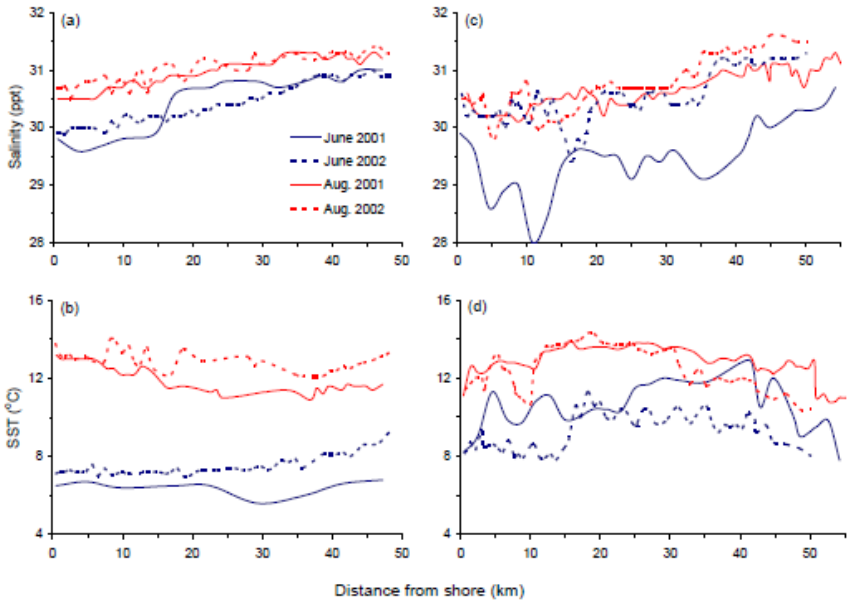

Figure 7. Salinity and sea surface temperature (SST) measured across (a, b) the inner Bay of Fundy (BoF) transect and (c, d) the outer BoF transect in June (blue lines) and August (red lines) of 2001 (solid lines) and 2002 (dashed lines). Distance from shore on transects is from the coast of New Brunswick at the inner BoF transect and from the east coast of Grand Manan Island at the outer BoF transect. (Reproduced with permission from Lacroix (2013).

The role of water current (outflow current from the main circulation gyre) is considered to be important for the migration of post-smolts (primary attribute). Visual cues, salinity, and SST (less than 14^{o}C refugia) are also likely to play a role in post-smolt migration (secondary attributes).

Feeding: Based on work done in Norway and other areas, there is some information on the feeding of post-smolts in near shore environments. The period of sea entrance and the first few months of marine life are considered a high point for marine mortality for Atlantic salmon. During this time, post-smolts begin feeding extensively on marine fish larvae, gadoids, and crustacean prey. Near-shore feeding is also considered to be a period of rapid growth. This feeding area is, therefore, inferred to be important to post-smolt growth and survival. Forage species availability is expected to play an important role in feeding (primary attribute).

Adult

Migration: Direct evidence of the routing of iBoF salmon to their natal river following their first or more winters at sea is limited to captures of adults that were tagged as smolts. Amiro (2003), in reviewing the database of Jessop (1976), noted that of 147 Big Salmon River adults tagged as smolts (1966-1974), seven were captured at sea and 140 were recovered at a counting fence installed at the mouth of the Big Salmon River (Amiro 1998). Of the 7 captured at sea, one was captured in a weir in the vicinity of Passamaquoddy Bay and 3 were returned from net/weir fisheries in the vicinity of Saint John. Ritter (1989) provides information for a subset of “wild” and “native” Big Salmon River smolts tagged 1967-1973, which were recovered (as adults) after one or two winters at sea. Five fish were recovered from commercial fisheries in “Middle Fundy”, New Brunswick, interpreted as in the vicinity of Saint John; one was taken in “lower Fundy”, interpreted as Passamaquoddy Bay. These captures of adults are interpreted as being within the Bay of Fundy, New Brunswick, coastal outflow area. As with post-smolts, water current is expected to be an important factor in adult migration (primary attribute), as are visual cues, salinity, temperature (e.g. <14^{o}C), and predator abundance (secondary indicators).

Area 4 - Passamaquoddy Bay/Fundy Isles

Encompassing the Canadian waters of the Quoddy Region, the area described here as Passamaquoddy Bay/Fundy Isles extends from Point Lepreau to just south of Liberty Point on Campobello Island (the US/Canada border) and encompasses the Passamaquoddy Bay, the Deer Island Archipelago, Campobello Island, and the Wolves. The area contains several estuaries, the largest being that of the St. Croix River extending between St. Stephen and St. Andrews, New Brunswick. The southern flank of the Quoddy region exhibits cooler summer SSTs due to upwelling and eddying of cooler oceanic currents.

This area was identified as important marine migration and feeding habitat (possible thermal refuge) for post-smolts. Use of this area by iBoF kelts and adults has not been studied.

Post-smolt

Migration: Information on post-smolt migration through this area is primarily derived from conventional and acoustics tagging and subsequent recapture/detection results. Of the approximately 42,000 wild and hatchery smolts tagged with conventional tags in the Big Salmon River from 1967 to 1973, 73 were recaptured as post-smolts in the inner Bay of Fundy (Figure 9). Of these 73, 38 (52%) were recovered in the Passamaquoddy Bay/Fundy Isles area (June-September). In 2001, an array to detect acoustically tagged smolts was placed around the Passamaquoddy Bay/Fundy Isles area (Figure 5a). Ten post-smolts, mostly from Big Salmon River, entered the array and 8 of these rapidly migrated through and out of the area (Lacroix 2008). Temperatures (<14^{o}C) and predator abundance are expected to be important factors in the migration of post smolts (potential primary attributes).

Feeding: No data exists on the feeding behavior of post-smolts in this area. However, this area is considered to have suitable temperature (<12^{o}C) and forage species (amphipods, euphausiids, fish larvae) for this life stage. Information regarding near-shore feeding behavior of post-smolts presented in the New Brunswick Coastal Outflow section of this document would also be applicable here.

Area 5 – Middle of the Bay of Fundy

The ‘middle of the Bay of Fundy’ is described here as the area of the Bay of Fundy beginning at approximately 10-15 km from shore on the New Brunswick side to approximately 10-15 km from shore on the Nova Scotia side (bounded by the New Brunswick coastal outflow Area 3 and coastal Southwest Nova Scotia Areas 7 and 8), from Grand Manan to Cobequid Bay/Minas Basin. This area has higher salinities (approximately 30-31 ppt) than the coastal waters and greater depths from approximately 25-250 meters.

The use of the middle of the Bay of Fundy by iBoF salmon is not well understood. Some limited data support the use of the area by post-smolts, potentially as feeding habitat, but there is no data available on the use of this area by adults and kelts.

Post-smolt

Feeding: To extend knowledge of the migration routes, conditioning habitat and forage and feeding behaviour of post-smolts, Lacroix and Knox (2005) captured, marked, and released several thousand wild smolts migrating in several rivers of the Bay of Fundy, including the Upper Salmon and Big Salmon rivers, and subsequently conducted surface trawling surveys in the Bay of Fundy and Gulf of Maine 2001-2003. Dates of surveys were May 30 – June 13 (2001), May 26 – June 15 (2002), and June 4 -18 (2003), dates which were selected to correspond to the time of peak smolt migration from rivers of the Bay of Fundy. Total captures numbered 398 post-smolts, of which 161 and 237 were of wild and hatchery origin, respectively. Of 8,195 wild smolts marked in the Upper Salmon, Big Salmon, Saint John, Magaguadavic, and St. Croix rivers over the 3 years, 7 post-smolts of Big Salmon River origin were recovered, 3 of

them were in the middle of the Bay of Fundy area (Figure 8), the 4 other were recovered in the northern Gulf of Maine area).

Lacroix also analyzed the stomach contents of 60 post-smolt handling mortalities during these surveys. The post-smolts captured in the trawling surveys and used for food analysis were separated into wild and hatchery origins. As few of the post-smolts captured had river specific ID tags, they were not separated into inner and outer BoF groups for analysis; however, salmon from inner and outer Bay of Fundy origins were captured in similar areas during trawling surveys with similar depth, temperature, and salinity preferences. Forage items included euphausiids, amphipods, herring larvae, and sandlance, which are common to the forage of salmon populations elsewhere in the North Atlantic.

Presence of forage and SST (<14^{o}C) are considered to be important factors (primary attributes) for post-smolt feeding in this area, with water clarity as another potential factor (potential secondary attribute).

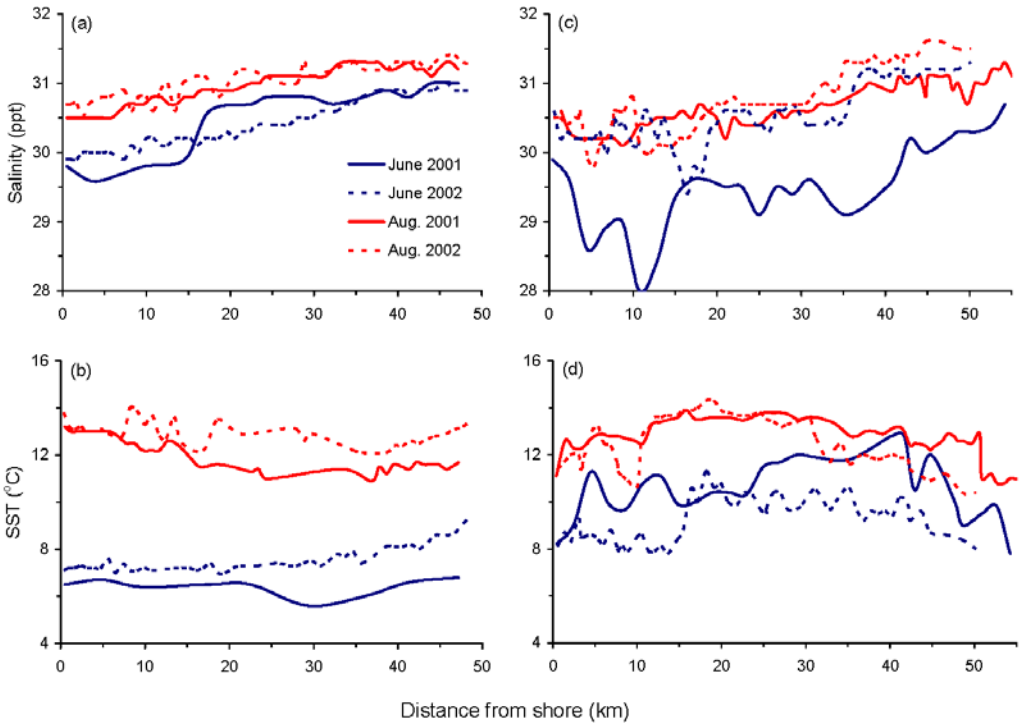

Figure 8. Sites where post-smolts from the Big Salmon River (solid circle) and Saint John River systems (solid circle within a circle) were recaptured, 2001-2003. (Figure 3b in Lacroix and Knox 2005).

Area 6 - Northern Gulf of Maine

The area described here as the 'northern Gulf of Maine' encompasses Canadian waters from approximately Grand Manan Island south to latitude 43^{o}46'51, and from the US/Canada border on the west to approximately 10-15 km from the coast of Nova Scotia to the east. The northeastern boundary is considered to be approximately the location of the outer acoustic array referenced in previous sections.

The northern Gulf of Maine area is inferred to be used as feeding habitat by post-smolts. There is no information available on the use of this habitat by adults and kelts.

Post-smolt

Feeding: As mentioned above, Lacroix and Knox (2005) captured, marked, and released several thousand wild smolts migrating in several rivers of the Bay of Fundy, including the Upper Salmon and Big Salmon rivers and subsequently conducted surface trawling surveys in the Bay of Fundy and Gulf of Maine 2001-2003. Of 8,195 wild smolts marked in the Upper Salmon, Big Salmon, Saint John, Magaguadavic, and St. Croix rivers over the 3 years, 7 of Big Salmon River origin were recovered, with 4 captured in the northern Gulf of Maine area (Figure 8). Based on analysis of the stomach contents of post-smolt handling mortalities, diets were the least diversified when surveys were confined to the Gulf of Maine, where they were comprised of single species of amphipods and euphausiids, as well as herring and unidentified fish remains. Presence of forage species and cooler SST in summer (<14°C) are potentially important factors in the feeding of post-smolts in this area.

Area 7 - Coastal Southwest Nova Scotia: Yarmouth to Port George

The area described has as 'coastal Southwest Nova Scotia: Yarmouth to Port George' extends from Yarmouth to Port George, and from shore to a distance of approximately 10-15 km into the Bay of Fundy to create a corridor of approximately 190 km in length.

This area was identified as an important migration area for adults and post-smolts, and a feeding area for post-smolts. Use of this area by kelts is unknown.

Post-smolt

Migration: Some of the acoustically tagged post-smolts that crossed the outer Bay of Fundy array returned to the Bay of Fundy during the summer, most often along the coast of Nova Scotia. The return route to both the outer and inner Bay array differed from the initial exit route for post-smolts classified as coastal migrants and residents of the Bay of Fundy. When post-smolts first returned to the Bay, they were widely dispersed from shore to shore across Grand Manan Basin, but more fish were monitored on the Nova Scotia side of the Bay and close to that shore. The mean return position of all groups across the outer Bay array was, in most cases, >30 km from Grand Manan Island. More than 50% of post-smolts returned via a 12-km wide corridor starting 4 km off the Nova Scotia coast at the outer Bay of Fundy array, and more than 80% of post-smolts returned in 10-km wide corridors along the coasts at the inner Bay array. The inferred migration routes of several Upper Salmon and Big Salmon River post-smolts leaving and then returning to the Bay are shown in Figure 6c. The pronounced plume of fresher water seen in June off Grand Manan Island disappeared by August, and salinity across the Bay of Fundy increased slightly towards the Nova Scotia coast at both transects. Water current and SST (e.g. <14^{o}C) are considered to be important factors in the migration of post-smolts through this area (primary attributes).

Feeding: Post-smolt feeding near shore has been documented in Norwegian waters and is considered to be important for growth and survival of post-smolts in their first few months at sea (refer to text in the Bay of Fundy New Brunswick coastal outflow section above). Availability of forage species is considered to be an important factor (primary attribute) in the use of this area for feeding by post-smolts.

Adult

Migration: Historical recaptures of adult tagged salmon and former commercial landings in salmon gear indicate a migration of iBoF adult salmon within the Bay of Fundy June through August, approaching their natal rivers on the inward flowing current on the Nova Scotia side of the Bay. Water current is expected to play an important role in adult migration through this area (primary attribute).

Area 8 - Coastal Southwest Nova Scotia: Port George to Hall's Harbour

The area described here as 'coastal Southwest Nova Scotia: Port George to Hall's Harbour' extends from Port George (latitude 45°00') to Hall's Harbour (latitude 45°12'), Nova Scotia (approximately 65 km long), from the shoreline into the Bay of Fundy approximately 10-15 km. This area roughly corresponds to the waters off Kings County, Nova Scotia, and Fisheries Statistical Districts 35 and 40 (Figure 9).

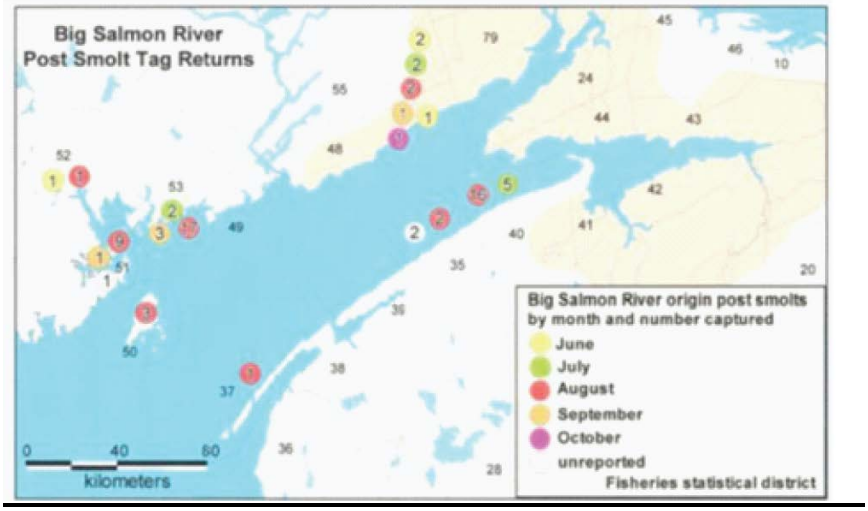

Figure 9. DFO Fisheries Statistical Districts (FSDs) of the Maritime Provinces and locations and numbers of recaptures of Carlin tagged wild and hatchery Big Salmon River post-smolts by month of recapture (Amiro et al. 2003).

Analysis of SSTs indicates that this area is somewhat cooler (≤13°C) relative to the rest of the Bay of Fundy, Chignecto Bay, Central Minas Basin, and the Cobequid Bay due to persistent upwelling and eddying of deep, cooler waters, and is considered a potential temperature refuge.

This area is suspected to be marine staging habitat for adults and feeding habitat (summer residency) for post-smolts.

Post-smolt

Feeding: Use of this area by post-smolts is derived primarily from acoustic and conventional tagging of post-smolts, including inferences from detections on the Nova Scotia side of the inner acoustic array (Figures 5 and 9) and historical recaptures in coastal fisheries. A component of the acoustically tagged post-smolts demonstrated a residency behavior within the Bay of Fundy (Jul-Aug), with 2-3 times more detections on the Nova Scotia side of the array (within this area) as the summer progressed. A small number of conventionally tagged post-smolts have also been re-captured in fisheries in this area in July and August. There is limited information on the feeding behavior of post-smolts in the Bay of Fundy, and no specific data from this area. However, given the suspected use of other coastal areas of the Bay of Fundy for feeding by post-smolts, there is also the potential for this area to be used by post-smolts for feeding. Forage species availability and SST (summer thermal refuge, <14°C) are potential important factors in the use of this area for feeding (primary attribute). Water current is also expected to play a role in the use of this area by post-smolts.

Adult

Staging: Salmon were historically captured in the Bay of Fundy in drifted gill nets licensed for shad and salmon, as well as herring weirs. In Kings County, Nova Scotia, weirs were licensed for and mainly targeted Atlantic salmon. Commercial salmon landings, 1967-1971, indicate that

Fisheries Statistical Districts 35 and 40 (Figure 9) were a significant contributor to total landings and suggest a sequential Nova Scotia coastal routing starting in the Port George to Hall's Harbour area in June for presumably iBoF salmon adults seeking their natal rivers, and continuing into August. While the area is known to support Atlantic salmon forage species such as herring and sandlance, the feeding intensity of maturing salmon in advance of ascending their rivers of origin is unknown. Temperature is expected to play an important role in the use of this area as staging habitat for adults.

Overwintering Marine Habitat

To date, the marine habitats occupied during the winter months by any life stage of iBoF salmon (overwintering marine habitat) are undocumented. Under the assumption that preferred temperature range reported by Amiro et al. (2003) applies to iBoF salmon, the Recovery Potential Assessment (RPA) for iBoF Atlantic Salmon (DFO 2008) noted that suitability of habitat within the Bay of Fundy and northern Gulf of Maine varies seasonally. The infusion of cold oceanic water into the Bay of Fundy and Gulf of Maine maintains temperatures within the preferred range for much of the year. However, mean SST mapping indicates that during August and September when water temperatures are warm, suitable habitat is limited to the Fundy Isles, outer Bay of Fundy, and off Southwest Nova Scotia. The RPA noted that the habitat availability is even more limited from February to April, when mean SSTs are at the low end of the temperature range. It further suggested that colder temperatures likely occur, which would further reduce habitat suitability within those months.

Substantive information on overwintering marine habitat of kelts has been collected, and documentation is imminent. Early suggestions are that iBoF salmon kelts move out of the Bay of Fundy into the Gulf of Maine. While their locations within the Gulf of Maine have not been revealed, it is noteworthy that preferred temperatures of 4°C are available on the Scotian Shelf and in US waters of the southern Gulf. It is generally thought that adults returning from ocean feeding and overwintering habitat tend to retrace the routing by which they went to sea as post-smolts. Similarly, it is thought that kelts would return to overwintering/feeding areas from which they came and, thereby, reveal with reasonable probability an overwintering area common to all marine life stages of iBoF salmon.

Prioritization of Areas Within the Bay of Fundy

At the review meeting, it was suggested that the relative importance of the eight smaller areas within the broader Bay of Fundy bounding box identified as important marine and estuarine habitat for iBoF salmon could be prioritized using the following criteria: number of life-history stages using the area, importance to the life-history stage, and whether there were alternative habitats available. Based on a cursory evaluation of these criteria, the tidal portions of 19 inner Bay of Fundy salmon rivers (Area 1), Minas Basin and Chignecto Bay (Area 2), and coastal Southwest Nova Scotia: Port George to Hall's Harbour (Area 8), were identified as the highest priority areas. The Bay of Fundy New Brunswick coastal outflow (Area 3), Passamaquoddy Bay/Fundy Isles (Area 4), the middle of the Bay of Fundy (Area 5), and coastal Southwest Nova Scotia: Yarmouth to Port George (Area 7), were identified as the next highest priority areas. The Canadian portion of the Gulf of Maine (Grand Manan southward to latitude 43°46'51) was considered to be data deficient.

Research Recommendations

The following recommendations expand upon those provided in the Recovery Strategy for iBoF Atlantic salmon (DFO 2010) and which were not fully addressed by this process:

1) Investigate habitat and months used by post spawning salmon (kelts) in river and coastal estuaries and sources of mortality. *Outcome/Rationale:* identification of months when kelts descend from freshwater and potential additional areas of important habitat and mortality.
2) Investigate habitat used by salmon kelts for reconditioning, as well as the location and timing of mortality if it occurs. *Outcome/Rationale:* Repeat spawners, identification of areas of marine important habitat, and potential limiting factors are important for the recovery of iBoF salmon.
3) Re-analyze existing marine distribution data for iBoF salmon once existing kelt data are available and link to environmental factors (SSTs), changes in the physical oceanography of the Gulf of Maine, possible changes in the composition of the ecosystem over time through overfishing, potentially available prey and predators and, threats to habitat potentially limiting survival or recovery. *Outcome/Rationale*: Refinement of potentially important marine habitat for iBoF salmon and identification of possible necessity for listing.
4) Re-investigate SSTs analyzed by Amiro et al. 2003 from the perspective of a) variability in thermal conditions over the 20-year data set, and b) similarities/ differences with the most recent 10 years and their impact on inferences of iBoF habitat from existing contoured maps of monthly SSTs for the Bay of Fundy, Gulf of Maine, and a portion of the Scotian Shelf. Outcome/Rationale: Refinement of potential areas marine critical habitat areas for iBoF salmon.
5) Model trajectories and habitat utilized by tagged kelts during reconditioning, overwintering, and subsequent return as consecutive repeat spawners using migration speeds, surface currents, and patterns of SSTs in the Bay of Fundy, Gulf of Maine, and Scotian Shelf. *Outcome/Rationale*: Refinement of potentially important marine habitat for iBoF salmon.

Sources of Uncertainty

While efforts have been made here to characterize the use of the Bay of Fundy by various life-history stages of iBoF salmon to the extent possible, this has been done based on very limited data (sometimes just a few samples). Any boundaries described should be considered as approximate, and, as new information is gathered, refinements to the areas used by salmon, including the important attributes of these areas, are expected.

Uncertainty with respect to the priority distinction between Areas results from a prioritization based on a literature review.

Uncertainty with respect to the likelihood of salmon to use alternative habitats available was not documented during the discussion on area priorities.

Inferences have been made on some aspects of the timing of marine and estuarine habitat use by iBoF salmon, e.g. based on sampling/captures in adjacent areas.

CONCLUSIONS

Using the Bounding Box approach, important marine and estuarine habitat of iBoF Atlantic salmon is proposed as:

> *the tidal portions of 19 IBoF salmon rivers and the entire Bay of Fundy outward to the northern Gulf of Maine and the US/Canada boundary, southward to latitude 43°46'51.*

The 19 iBoF salmon rivers mentioned above are the Gaspereau, Shubenacadie, Stewiacke, Salmon (Colchester), North (Colchester), Chiganois, Debert, Folly, Great Village, Portapique, Bass (Colchester), Economy, Harrington, Apple, Maccan, Petitcodiac, Upper Salmon, Point Wolfe, and Big Salmon.

These are the same rivers identified as the long-term recovery target in the iBoF salmon Recovery Strategy; ten of these rivers are identified as containing freshwater Critical Habitat.

This recommendation is consistent with the initial focus of the long-term recovery targets for iBoF salmon and is primarily based on information on iBoF salmon that mature after one year at sea (the most common life-history strategy).

It includes important habitat used by smolts, post-smolts, mature adults, and kelts but does not include additional habitat used by distant migrating salmon, e.g. kelts and salmon that spend two winters at sea.

Important functions identified for the marine and estuarine habitat of iBoF salmon were migration, feeding, and staging. Important features identified for the marine and estuarine habitat of iBoF salmon were migration corridors, estuarine holding pools, surface waters, upwellings, and food availability. Important attributes of these features include temperature, salinity, water flow, depth/volume, forage species (e.g. sandlance, herring, euphausiids and amphipods), and predator abundance.

The area identified as important marine and estuarine habitat for iBoF salmon was disaggregated into eight smaller areas (the boundaries of which are only roughly defined) in order to more clearly describe the spatial distribution of important functions, features, and attributes by life-history stage. These areas are: Area 1 - the tidal portions of iBoF salmon rivers; Area 2 - the Minas Basin and Chignecto Bay; Area 3 - Bay of Fundy New Brunswick coastal outflow; Area 4 - Passamaquoddy Bay/Fundy Isles; Area 5 - middle of the Bay of Fundy; Area 6 - northern Gulf of Maine; Area 7 - coastal southwest Nova Scotia: Yarmouth to Port George; and Area 8 - coastal southwest Nova Scotia: Port George to Hall's Harbour.

These areas were prioritized using the following criteria: number of life-history stages using the area, importance to the life-history stage, and whether there were alternative habitats available. Based on these criteria, Areas 1, 2 and 8 were identified as the highest priority areas; Areas 3, 4, 5, and 7 were identified as the next highest priority areas; and Area 6 (Grand Manan southward to latitude 43°48') was considered to be data deficient.

The most complete information to assess important marine and estuarine habitat for iBoF salmon is for post-smolts from the May-August period. The greatest uncertainty is in the fall and winter period. Overwintering habitats of all stages are as yet unknown, but are hypothesized to be off the Scotian Shelf or in the southern portion of the Gulf of Maine.

SOURCES OF INFORMATION

This Science Advisory Report is from the November 21-22, 2012, review of the Identification of Important Marine and Estuarine Habitat for Inner Bay of Fundy Salmon. Additional publications from this meeting will be posted on the *Fisheries and Oceans Canada (DFO) Science Advisory Schedule* as they become available.

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APPENDIX 1

Summary of the biophysical functions, features, attributes and location of marine and estuarine habitat important to iBoF salmon. Attributes used to describe the features were classified as either primary (attributes with the most influence on the functional capacity of the feature) or secondary (attributes that influence the functional capacity of the feature, but to a lesser degree).

Geographic Location	Life-Stage	Function	Features	Attributes
Area 1.Tidal portions of 19 iBoF salmon rivers	Smolt	Migration to salt water (May-Jun)	Corridor through the estuary	Primary: • Water flow of sufficient volume/depth to allow unimpeded access Secondary: • Temperature • Salinity • Predator abundance
	Adult	Migration to fresh water (May-Oct)	Corridor through the estuary	Primary: • Water flow of sufficient volume/depth to allow unimpeded access. Peak flow needed for assent • Temperature – high temperature can impede migration Secondary: • Salinity – decreasing salinity • Predator abundance
		Staging for fresh-water conditions	Pools in the estuary (may be river specific, e.g. Stewiacke River)	Primary: • Depth • Volume Temperature Secondary: • Salinity • Predator abundance • Distance to head of tide
	Kelt	Migration (winter/spring)	Corridor through the estuary	Primary: • Water flow of sufficient volume/depth to allow unimpeded access • Temperature Secondary: • Salinity – increasing salinity to enable acclimation to salt water

Geographic Location	Life-Stage	Function	Features	Attributes
				• Predator abundance
Area 2. Minas Basin and Chignecto Bay	Post-smolt	Migration to Outer Bay of Fundy (May-Jun)	Corridor through the estuaries	Secondary: • Temperature Salinity - Increases to 31 ppt • Predator abundance
		Feeding (Jun-Sep)	Food availability	Forage species: not known for this area
	Adult	Migration to fresh water (May-Oct)	Corridor through the estuaries	Primary: Temperature - <14°C while awaiting appropriate river discharges Secondary: • Salinity – increasing salinity • Predator abundance
		Staging	Estuaries	Primary: Temperature – <14°C while awaiting appropriate river discharges Secondary: Salinity – decreasing salinity
	Kelt	Migration to the Bay of Fundy for re-conditioning, (winter/spring)	Corridor through the estuary	Primary: Salinity - acclimation to increasing salinity Secondary: • Depth / Volume • Predator abundance
		Feeding	Food availability	Forage species: juvenile herring, White hake, Winter flounder, adult and juvenile Three spine stickle backs (Minas Basin)

Geographic Location	Life-Stage	Function	Features	Attributes
Area 3. BoF NB coastal outflow	Post-smolt	Migration	Corridor	Primary: Water Current -outflow current from main circulation gyre Secondary: • Visual cues • Salinity • Temperature - SSTs <14°C • Predator abundance
		Feeding	Food availability	Forage species - amphipods, euph-ausiids, fish larvae
	Adult	Migration (May-Oct)	Corridor	Primary: Water Current -outflow current from main circulation gyre Secondary: • Visual cues • Salinity - maintenance of freshwater plumes • Temperature - <14°C, likely cooler at depth • Predator abundance
	Kelt	No information		
Area 4. Passamaquoddy Bay/"Fundy Isles"	Post-smolt	Migration (Jun-Sep)	Estuary / Bay	• Temperature - SSTs variable but cooler toward NS coast, <14°C • Predator abundance
		Feeding	Food availability	Forage species - amphipods, euphausiids, fish larvae
	Adult	No information		
	Kelt	No information		
Area 5. Middle of the BoF	Post-smolt	Feeding (May-Aug)	Food availability	Primary: • Forage - sandlance, herring larvae and euphausiids • Temperature - SSTs <14°C (Jun-Aug); Secondary: Water clarity
	Adult	No information		
	Kelt	No information		
Area 6. Northern Gulf of Maine	Post-smolt	Feeding (Jul-Sep)	Food availability	Primary: • Forage – amphipods and euphausiidsTemperature - SSTs <14°C, coolest sea surface temp in August
	Adult	No information		
	Kelt	No information		

Geographic Location	**Life-Stage**	**Function**	**Features**	**Attributes**
Area 7. Coastal southwest Nova Scotia: Yarmouth to Port George	Post-smolt	Migration	Corridor	Primary: • Water current - inflow current from main circulation gyre • Temperature - <14^{o}C
		Feeding (Jul-Sep)	Food availability	Primary: Forage species
	Adult	Migration (Jun-Aug)	Corridor	Primary: Water current - inflow current from main circulation gyre
	Kelt	No information		
Area 8. Coastal southwest Nova Scotia: Port George to Hall's Harbour	Post-smolt	Feeding (Jul-Sep)	Food availability	Primary: • Forage - sandlance and herring • Temperature – SSTs <14°C Secondary: Water current - inflow current from main circulation gyre
	Adult	Staging (Jun-Aug)	Upwelling	Primary: Temperature – <14°C
	Kelt	No information		

APPENDIX 2

Summary of monthly usage by IBoF salmon life stage of the 8 estuarine and marine habitat areas. '(' = Big Salmon, Point Wolfe and Upper Salmon rivers; ')' = Minas Basin rivers but limited to information from only 5 tagged post-smolts; '()' for all 19 rivers, and 'i' for Gaspereau River where it deviates. Shaded cells = no data; open cells= not present; colored cells = riverine (yellow), estuaries (pink) and marine (orange) habitats.

Areas	Life-Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept		Oct		Nov		Dec	
1.Tidal portions of IBoF salmon rivers	Smolt									(	()	()	)												
	Adult										i	i	i	(i	(i	(	(	()	()	()	()				
	Kelt																								
2. Minas Basin and Chignecto Bay	post-smolt									(	()	()	)												
	Adult										i	i	i	(i	(i	(	(	()	()	()	()				
	Kelt																								
3.BoF NB coastal outflow	post-smolt									(	()	()	()	()											
	Adult																								
	Kelt																								
4.Passamaquoddy / "Fundy Isles"	post-smolt		(											(	(	(	(	(							
	Adult																								
	Kelt																								
5.Middle of the BoF	post-smolt											()	()	()	()	()	()	()							
	Adult																								
	Kelt																								
6. Northern Gulf of Maine	post-smolt										(	(													
	Adult																								
	Kelt																								
7. Coastal Nova Scotia: Yarmouth to Port George	post-smolt													(	(	(	(								
	Adult																								
	Kelt																								
8. Coastal Nova Scotia: Port George to Hall's Harbour	post-smolt													(	(	(	(								
	Adult												()	()	()	()	()								
	Kelt																								

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