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Inner Bay of Fundy (iBoF) Atlantic Salmon (*Salmo salar*) Marine Habitat: Proposal for Important Habitat

T.L. Marshall

Co-chair, iBoF Recovery Team (2002-2007)
19 Sandy Cove Lane, RR 1
Pictou, Nova Scotia
Canada B0K 1H0

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

The inner Bay of Fundy (iBoF) Atlantic salmon (*Salmo salar*) was listed as an endangered species under the *Species at Risk Act* (SARA) when it came into force in 2004. SARA requires the identification of critical habitat for endangered species. A Recovery Strategy for the iBoF salmon was developed and published on the SAR Public Registry in May 2010, but was only able to identify freshwater critical habitat areas. Because Atlantic salmon require both freshwater, estuaries, and marine habitat to complete their life cycle, the Strategy included a Schedule of Studies to help define additional critical habitat.

Previous documentation in support of the estuarine and marine habitats of iBoF salmon reviewed tagging, telemetry and trawling studies of iBoF post-smolts through 2008. The use of Bay habitats by returning/spawning salmon had been and continues to be based on captures of Carlin-tagged fish in now-closed commercial fisheries. These data represent a body of evidence indicating that some areas within the Bay have a long history of use by at least two life stages moving throughout most of the Bay during their marine phase. Unknown was the extent and proportion to which iBoF salmon smolts used the Bay as post-smolt nursery area, their area of occurrence October through winter, and the wintering location of adults and reconditioning kelts. Hence, the probabilities of use for all habitat locations could not be estimated and, therefore, predicted with equal certainty as required under previous guidelines for the identification of Critical Habitat. Recently, however, the guidelines for the identification of critical habitat have been relaxed such that the absence of scientific certainty regarding the function of the Critical Habitat will not preclude its identification to the extent possible using the best available information.

This document reviews:

i) information contributory to past evidence of extended use of the Bay by iBoF salmon,
ii) newly published analyses of the decade-old data from electronically tagged post-smolts and provides
iii) inferred temporal occupancy of estuarine and marine habitats through past smolt, post-smolt and adult monitoring activities and as well, relevant commercial and recreational catch data.

Overwintering habitat of all stages and summer habitats of distant migrating post-smolts and maturing adults of the iBoF salmon remain undocumented, although publication of the migration paths of several iBoF kelts tagged in November/December and May bearing 4- and 6-month duration pop-up satellite tags is expected to reveal their habitats and by corollary, perhaps those of post-smolts and maturing adults.

In the spirit of simplicity and to the extent possible, ‘important habitat’ is identified as the entire Bay of Fundy outward to the northern Gulf of Maine and the Canada-US boundary southward to latitude 43° 46’, May through October. The entire area can, however, be viewed as the sum of eight zones, each having a variation in function, features and attributes for the different life stages documented within. Most recommendations for research outlined in the 2010 Recovery Strategy remain relevant to the further identification of important habitat. The recommendation to further research the migratory behaviour of post-smolts using available geo-referenced data and the identification of the winter habitat of kelts, have been largely addressed but results for kelts are as yet unavailable.

Habitat marin pour le saumon de l'Atlantique (Salmo salar) à l'intérieur de la baie de Fundy : Proposition quant à l'habitat important

RÉSUMÉ

Les populations de saumon de l'Atlantique (*Salmo salar*) de l'intérieur de la baie de Fundy ont été inscrites comme espèce en voie de disparition en vertu de la *Loi sur les espèces en péril* lorsque cette dernière est entrée en vigueur en 2004. La *Loi sur les espèces en péril* exige la désignation de l'habitat essentiel des espèces en voie de disparition. En mai 2010, un programme de rétablissement pour le saumon de l'Atlantique de l'intérieur de la baie de Fundy a été élaboré et publié sur le Registre public des espèces en péril. Ce dernier ne désigne que les zones d'habitat essentiel en eau douce. Puisque le saumon de l'Atlantique a besoin d'eau douce, d'estuaires et d'un habitat marin pour compléter son cycle de vie, la stratégie comprend un calendrier des études afin de définir plus précisément les habitats essentiels supplémentaires.

Les documents publiés précédemment aux fins de soutien des estuaires et des habitats marins du saumon de l'intérieur de la baie de Fundy passaient en revue le marquage, la télémesure et les études du chalutage des post-saumoneaux de l'intérieur de la baie de Fundy au cours de l'année 2008. L'utilisation des habitats dans la baie par les saumons qui effectuent une montaison et les saumons reproducteurs repose toujours sur le nombre de captures de poissons marqués d'étiquettes Carlin dans le cadre de la pêche commerciale dorénavant fermée. Ces données représentent un élément de preuve qui indique que certaines zones de la baie présentent un long historique d'utilisation dans le cadre d'au moins deux stades biologiques à l'échelle d'une grande partie de la baie de Fundy au cours de la phase marine. La portée et la proportion de l'utilisation de la baie de Fundy par les saumoneaux de l'intérieur de la baie de Fundy à titre d'aire de croissance des post-saumoneaux sont inconnues, tout comme la zone d'occupation à partir du mois d'octobre jusqu'en hiver et l'emplacement d'hivernage des adultes et des charognards reconditionnés. Par conséquent, il est impossible d'évaluer la probabilité de l'utilisation de toutes les zones d'habitat ni de la prédire avec le niveau de certitude requis conformément aux lignes directrices précédentes pour la détermination de l'habitat essentiel. Cependant, les lignes directrices récentes pour la détermination de l'habitat essentiel ont été assouplies de sorte que l'absence de certitude scientifique quant à la fonction d'un habitat essentiel n'empêchera pas sa détermination dans la mesure du possible à l'aide des meilleurs renseignements disponibles.

Ce document évalue :

i) les renseignements qui contribuent aux anciens éléments de preuve de l'utilisation prolongée de la baie par le saumon de l'intérieur de la baie de Fundy;

ii) les analyses récemment publiées des données de la dernière décennie à partir des post-saumoneaux marqués de façon électronique;

iii) l'occupation temporelle déduite des estuaires et des habitats marins par l'entremise des activités de surveillance des anciens saumoneaux, des post-saumoneaux et des adultes ainsi que des données des prises de la pêche commerciale et de la pêche récréative.

Il n'existe aucune documentation sur l'habitat d'hivernage pour tous les stades et l'habitat d'été des post-saumoneaux et des adultes arrivant à maturité qui migrent sur une longue distance (saumon de l'intérieur de la baie de Fundy); cependant, on s'attend à ce que la publication des voies de migration de nombreux charognards de l'intérieur de la baie de Fundy qui ont été marqués en novembre, en décembre et en mai à l'aide d'émetteurs détachables (durée de quatre et six mois) révèle les habitats de ces derniers et, par conséquent, les habitats des post-saumoneaux et des saumons adultes.

Aux fins de simplicité et dans la mesure du possible, l'« habitat essentiel » se réfère à la baie de Fundy en entier, jusqu'à la partie nord du Golfe du Maine et la frontière Canado-américaine au sud de la latitude 43° 46', du mois de mai au mois d'octobre. L'aire entière peut cependant être considérée comme la somme de huit zones, qui comptent toutes des différences en matière de fonction, de caractéristiques et d'attributs pour les différents stades biologiques consignés dans le présent document. La plupart des recommandations de recherche décrites dans le programme de rétablissement de 2010 sont pertinentes à la détermination des habitats essentiels. La recommandation visant à mener d'autres recherches sur le comportement migratoire des post-saumoneaux à l'aide des données géoréférencées disponibles et de la détermination de l'habitat hivernal des charognards a été traitée en profondeur, mais les résultats quant aux charognards ne sont pas encore disponibles.

INTRODUCTION

The inner Bay of Fundy (iBoF) Atlantic salmon (*Salmo salar*) was listed as an endangered species under the *Species at Risk Act* (SARA) when it came into force in 2004. SARA requires the identification of critical habitat for endangered species. A Recovery Potential Assessment for iBoF Atlantic salmon was conducted in 2008 (DFO 2008), which includes information on important habitat for iBoF Atlantic salmon available at that time. A Recovery Strategy for the iBoF salmon was developed and published on the SAR Public Registry as 'final' in May 2010 (DFO 2010). The Recovery Strategy identifies only freshwater critical habitat areas for iBoF salmon and includes a Schedule of Studies to help define additional critical habitat. Atlantic salmon require both freshwater, estuaries, and marine habitat to complete their life cycle. The current review provides additional information in support of the identification of estuarine and marine critical habitat for iBoF Atlantic salmon.

Specifically, this document offers to the extent possible and taking account of uncertainties, functional descriptions, features and attributes of the marine and estuarine habitat required for successful completion of all life-history stages of iBoF salmon (Annex 1), including but not limited to:

- 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.

As well, and to the extent possible, the document provides geospatial information on the location and spatial extent of the areas that are likely to have these habitat properties and recommends research or analysis activities necessary to enhance the above provisions where current information is incomplete.

CONTEXT

Critical habitat as defined under section 2 of the SARA is the *"habitat necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species*". Further, habitat for aquatic species is defined as *"spawning grounds, and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where species formerly occurred and have the potential to be reintroduced".* By that definition, the "Science Expert Opinion on Critical Habitat designation for inner Bay of Fundy Atlantic salmon" (DFO 2006) hereafter termed the "Opinion", concluded that habitat can be identified based on the functions it provides, and therefore habitat is sufficiently protected if its capacity to fulfill its functions is protected.

The 'Opinion' (DFO 2006) reviewed tagging and telemetry studies of iBoF post-smolts, and to a lesser extent adult salmon (DFO 2006), showing that there was a body of evidence indicating that some areas within the Bay have a long history of use by specific life-stages and that salmon do move throughout most of the Bay during their marine phase (DFO 2008). The conclusion with respect to 'critical' habitat in the marine environment was that "because not all iBoF salmon smolts are known to migrate and frequent these locations, the probabilities of use for all habitat locations cannot be estimated and therefore predicted with equal certainty", i.e., it was not possible to assess the 'criticality' of all marine areas for iBoF salmon at that time (DFO 2006).

The "Opinion" (DFO 2006) did, however, suggest as a minimum that because iBoF salmon utilized most of the Bay of Fundy for migration and feeding and in order for those functions to be maintained if iBoF salmon were to recover, the areas of known frequent occupation and estuaries proximate to the then 32 iBoF rivers warranted *increased vigilance* (DFO 2006). However, to determine whether there are specific, individual areas of marine habitat that contribute to the persistence or recovery of populations, "additional work must be completed in order to identify the spatial and temporal use of the marine environment by the iBoF salmon throughout the year (particularly in winter)" (DFO 2010). Consequently a 'Schedule of Studies' including research activities, was prepared to ascertain "whether critical habitat areas exist within the marine distribution of iBoF Salmon" (DFO 2010). Since then, DFO has tabled a draft "*Species at Risk Act (SARA) Operational Guidelines for the identification of Critical Habitat for Aquatic Species at Risk"* (DFO 2012). The draft guidelines stress that the absence of scientific certainty regarding the function of the Critical Habitat will not preclude its identification to the extent possible using the best available information. Thus, the predictable concentration or presence of the species could be sufficient to define Critical Habitat when it is accompanied by a Schedule of Studies aimed at better understanding habitat function.

BACKGROUND

REGULARLY FREQUENTED MARINE HABITAT

Atlantic salmon at sea spend the majority of their life near the surface and tend to have a species-specific range of environmental conditions which they select as optimum during their feeding migrations (Dadswell 2004). Environmental conditions include but are not limited to ocean currents, salinity, and water temperature which are addressed below, as well as depth, light regimes and the presence of suitable prey organisms all of which can be influenced by the geographical position of their natal river (Dadswell 2004) and a theoretical 'physiological optimizing strategy' (Leggett 1977) while at sea.

The most recent summary account of the iBoF salmon's marine areas of occupancy and the core of this document was tabled in the "Opinion" (DFO 2006) where [ ] denotes this author's inclusion:

> "The initial marine distribution of iBoF post-smolts and, to a lesser extent, the later distribution of adult salmon, can be inferred from historical distributions of recaptures of tagged salmon (i.e., based on extensive tagging of smolts with conventional external plastic tags as reported by Jessop 1976; Amiro and Jefferson 1996 and Amiro et al. 2003) and from the telemetry of smolts tagged with internal acoustic transmitters (Lacroix et al. 2005). In addition, recent research trawling surveys (2001-2003) provide direct evidence of the distribution of live post-smolts of iBoF origin in the Bay of Fundy and northern Gulf of Maine (Lacroix and Knox 2005).
>
> The tagging and telemetry studies both indicate that some salmon from iBoF rivers, unlike those from other Atlantic coast and outer Bay of Fundy Rivers (e.g., Saint John River), are retained as post-smolts within the Bay of Fundy and northern Gulf of Maine up to and including October. The studies included tagged smolts of wild and hatchery origin and both native and non-native stocks. Migrating post-smolts were initially monitored or recaptured along the New Brunswick (NB) coast, whereas [presumably] resident post-smolts were frequently monitored or recaptured along the Nova Scotia (NS) coast throughout July and August. Many of the traditionally tagged post-smolts were recaptured among the Fundy Isles in August and September. Of the recaptures resulting from the release of 489,898

tagged smolts [more than likely 42,001, Fig. 3 in Amiro (2003)] in Big Salmon River from 1967 to 1973, 1% was captured as [post-] smolts [and adults excl home river returns] in Fisheries Statistical District (FSD) 50, Grand Manan Island; 0.8% in FSD 51[52], Passamaquoddy Bay; 4% in FSD 52 [51], Deer Island; and 9% was captured in FSD 53, the Back Bay and Blacks Harbour area [see Fig. 12 this document for location of FSDs and number of recaptures]. Most of the tag recaptures were in the river [of origin as returning adult salmon]. Telemetry also monitored post-smolts off Grand Manan Island both early and late into the summer, but few post-smolts were monitored entering the Quoddy Region in southwest New Brunswick. The telemetry studies also indicate that the survival of post-smolts in the Bay of Fundy was initially high.

A limitation of both types of tagging studies (i.e., conventional external tags and acoustic transmitters) was the general lack of recaptures or monitoring beyond October. For this reason, they provide no evidence of the over-winter distribution or habitat of iBoF salmon. One tagged smolt was recaptured as an adult salmon in March and as far south as Swampscott Mass., USA, and another was recaptured in July as far north as the southern coast of Newfoundland. Otherwise, tagged smolts were recaptured as adults in April to August in the commercial drift net fisheries that operated in the Bay of Fundy and from the weir fisheries in this area for Atlantic herring. Recaptures were on the southeast side of the Bay (e.g., Morden), Chignecto, Nova Scotia, and the coastal area off the mouth of the Saint John and Big Salmon rivers, New Brunswick, and are indicative of areas where fisheries occurred.

Data from the tagging and telemetry studies as well as from the trawling surveys can also be used to identify migration routes and timing through the Bay of Fundy. They indicate a common migration corridor for iBoF post-smolts along the coast of New Brunswick as they head out of the inner Bay, then heading into the Fundy Channel just northeast of and along the southeast coast of Grand Manan Island in the concentrated southerly flow. Some post-smolts also were monitored crossing the outer bay in the tidal circulation and returning along the Nova Scotia coast. Other post-smolts were monitored exiting the Bay and entered the northern Gulf of Maine, and then returned to the Bay of Fundy most often along the coast of Nova Scotia during the summer. However, not all post-smolts that were monitored leaving the Bay returned during that early marine period. Marked wild smolts of Big Salmon River origin were recently recaptured alive as post-smolts in the northern Gulf of Maine at the same time and in the same location as post-smolts originating from the Saint John River (an outer Bay river), indicating that they may have been migrating to habitat further out in the Atlantic Ocean (Lacroix and Knox 2005).

The traditional tagging, telemetry, and trawling surveys tend to corroborate one another with regards to the early marine distribution of iBoF post-smolts. They indicate that some proportion of the iBoF salmon population establishes a residency within the Bay of Fundy and northern Gulf of Maine from June to October. They also indicate that salmon distribution is often related to major surface currents and temperatures within the Bay of Fundy and coastal areas are important. This stresses the importance of the Bay of Fundy as marine habitat, not only for migrating salmon, but for feeding, growth and survival.

These data suggest that there are areas within the Bay of Fundy that are regularly frequented by iBoF Atlantic salmon at various stages. Some estuaries where fresh and saltwater mix in various proportions, are known to have been frequented by maturing adult salmon for extended times. An example is the Shubenacadie River estuary from the confluence of the Stewiacke River to Maitland, Nova Scotia that supported a commercial drift net fishery for salmon from May to August for some 100 years prior to

> its complete closure in 1985. Another example is the noted higher frequency of tag recaptures of post-smolts from iBoF salmon and elsewhere e.g. Maine USA, in high-head commercial fish trap weirs in areas of persistent cooler summer sea surface temperatures. These weirs were located in areas known to have upwelling and eddying of cooler oceanic currents (Figure 3 in the ‘Opinion’) [reference ‘August’, Figure 7a this document] such as the south shore of the Bay of Fundy in the Morden, Nova Scotia area and in the Fundy Isles area of southern New Brunswick.”

This document reviews materials background to the ‘Opinion’ (DFO 2006) and for post-smolts, embellishes their area and duration of habitat occupancy with insights from the additional analyses of electronically tagged fish in 2001 and 2002 (Lacroix 2008 and 2012) and provides evidence of the timing of smolts and returning adults in inner Bay and estuarine waters. Concrete information on the winter habitat of any life stage was unavailable at the time of writing.

THE GULF OF MAINE

The Gulf has been said to function as a large estuary, i.e., a semi-enclosed coastal body of water which has a free connection with the open sea and within which lighter fresher waters move seaward at the surface and heavier more saline water moves landward at depth (Pritchard 1967 *in* Wells and Pesch 2004). Bigelow (1927) termed the Gulf a mid-latitude marginal sea that is bounded by the coastlines of New England and Atlantic Canada, and (Campbell 1986) the Browns Bank, Georges Bank and Nantucket Shoals. Like other northern-hemisphere marginal seas, the general circulation of the Gulf is cyclonic rather than tidal in nature (Bigelow 1927). The principal cyclonic circulation cell is centered in the eastern Gulf and has accordingly sometimes been referred to as the Jordan Basin Gyre (e.g., Pettigrew et al. 2005).

Circulation Patterns

The surface (<75 m depth) circulation of the Gulf of Maine is characterized by a counterclockwise gyre (Fig. 1: see also Fig. 1 *in* Smith et al. 2012) propelled by incoming cool, fresh Scotian Shelf waters entering in the near-shore region of the Scotian Shelf off Cape Sable. These waters encompass Jordan Basin to the south and west of Grand Manan Island and Georges Basin before veering off the eastern portion of the Jordan gyre with source waters into the Bay of Fundy. The deeper warm, saline, nutrient-rich slope water enters the Northeast Channel to fill the major basins and contribute to mixing and upwelling off southwest Nova Scotia (NS) and in the Grand Manan area (Townsend et al. 1987).

BAY OF FUNDY

The Bay of Fundy is an estuarine embayment about 270 km in length at the northeast end of the Gulf of Maine between the provinces of New Brunswick and Nova Scotia, with a small portion small portion touching the US state of Maine (Fig. 2). The southwest limit of the Bay of Fundy has been described as a line running northwesterly from Cape St. Mary (44°05'N) Nova Scotia, through Machias Seal Island (67°06'W) and on to Little River Head (44°39'N) in the state of Maine, a distance of approximately 80 km. Depths at the western extremity approach 225 m: much of the Bay is < 125 m (Fig. 3).

Geomorphology

The geomorphology of the Bay of Fundy is as well described by Parrott et al. (2008) and is insightful to the Bay’s recent evolution and ecosystem. The following is taken from Parrott et al. (2008); citations within are excluded from ‘Literature Cited’ in this document.

> "The Bay of Fundy is underlain by Triassic sandstones, shales and basalts. Exposed bedrock has been modified by glacial erosion and exhibits a rugged surface. During the late Wisconsinan glacial maximum, culminating in the Gulf of Maine region at approximately 20 ka (20,000 radiocarbon years BP), the Bay of Fundy was covered by a regional ice sheet that terminated to the south on the Scotian Slope (Schnitker et al., 2001; Hundert, 2003). The glacial maximum was followed by a multiphased retreat of the ice front. In the Gulf of Maine, ice-front retreat and glaciomarine deposition began as early as 18 ka. Grounded ice was absent from the Gulf of Maine and Bay of Fundy by approximately 14 ka (King and Fader, 1986; Schnitker et al., 2001; Shaw et al., 2006)."
>
> The Bay "exhibits geomorphologic features formed during the Quaternary glaciation and deglaciation of the area. Moraines and drumlins are topographically prominent. Large icebergs scoured and pitted the seafloor in the waters east and south of Grand Manan Island during this period. The sea level in the Bay of Fundy has varied considerable during, and since, the last glaciation. Approximately 13 ka, relative sea level was 30 m above present levels (Amos et al., 1991, Shaw et al., 2002). After deglaciation, relative sea level fell rapidly to a low stand 25 to 30 m below the present level at c. 7 ka (Amos and Zaitlin, 1985) and then rose to present levels (Grant, 1970). From about 6.3 ka, tidal amplitude started to increase. This effect is continuing today (Godin, 1992). These high tides have resulted in large zones of erosion in areas with high current velocities such as Cape Split, Cape D'Or and Cape Enrage".
>
> "Tidal eddies produced by headlands have created banner banks (Dyer and Huntley, 1999) on both sides of coastal promontories. Coastal erosion is up to 1 m a-1 in many areas (Amos et al., 1991). Sediment transported by this erosion, coupled with sediment from sea floor erosion and sediment delivered by rivers, has contributed to the development of broad intertidal mud flats in the inner Bay of Fundy. The coastlines of the Bay also host salt marshes and dykelands. Seaward of the mud flats in the subtidal zone, the sea floor is variable in character, consisting of exposed bedrock, gravel, sand and mud. In places, strong tidal currents create sand waves several meters in height and hundreds of meters in length (Percy et al., 1997)."

Fader et al. (1977) refers to the seabed at the bottom of the Bay including off St. Mary's Bay and presumably the St. Mary's Bay-Long Island area as being mainly of "Sambro sand", a mixture of sand, silt and clay with varying amounts of gravel, built up into sand waves by tidal action. The seabed of the central and outer parts of the Bay and shoreline consist mainly of coarser material.

Surface Currents

The residual current structure of the Bay of Fundy is depicted in Fig. 4 (Bumpus and Lauzier 1965 and Whitford 2008). However, flow direction and velocity at specific times and locations vary markedly with the tides. Seasonal patterns of surface currents for the Bay of Fundy-Gulf of Maine have also been summarized by Bumpus and Lauzier (1965) and are quoted as follows in Trites and Garrett (1983).

> "The circulation in the Bay of Fundy is related to that of the eastern half of the Gulf of Maine. 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 autumn. 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.
>
> In the Bay itself, the winter surface drift is composed of one large or a few small eddies, that retain within the Bay what has been released there or what has previously drifted

> into it. At that time a definite movement from the northwest to the southeast side of the Bay is observed. During the spring there is an increase in the average speed of the westerly component along the northwest side of the Bay. This is accomplished by a more or less straightforward inflow along the southeast side of the Bay. This "U-turn type of circulation continues during the summer. The autumn circulation is an intermediate one between the 'open' circulation of the summer months and the 'closed' circulation of the winter months."

Whitford (2008; lower panel Fig. 4 herein) illustrates the eddy within the Bay, i.e., within the normal peripheral circulation. A second much larger eddy in the outer Bay/Gulf of Maine is illustrated as being centered on the Canada-US boundary, over the Jordan Basin. This circulation pattern results in a gyre that occupies a large part of the northern outer Bay. Towards the centre of the gyre, turbulence and vertical mixing are suppressed and, with the added influence of freshwater input from the Saint John River this region is susceptible to stratification (Fig. 5) in contrast to the extensive vertical mixing that prevails throughout much of the Bay (Garrett 1977; Trites and Garrett 1983 cited *in* Whitford 2008). Stratification occurs throughout the summer over the northern side of the outer Bay (Fig. 5), but tends to be strongest in the spring and early summer, when river outflow is greatest. Compared with the Nova Scotia side of the Bay, the lack of vertical mixing in this northern portion of the outer Bay leads to warmer surface water temperatures, and higher phytoplankton productivity. A small eddy is also shown in Minas Channel.

Tides

The Bay of Fundy has a resonant period of about 13 hours (Parrott et al. 2008). The resonance is close to the 12 hour and 25 minute dominant lunar tide of the Atlantic Ocean and results in the largest recorded tides in the world, with a range that increases from about 4 m at the mouth of the Bay to a maximum of 17 m at the head of the Bay (Parrott et al. 2008). Dadswell et al. (1983) depicts co-tidal lines of 5 m beginning between Digby Neck and Grand Manan, and increasing to 9, 10 and 11 m through Minas Channel into the Central Minas Basin (Fig. 6 upper panel). These extremely large tides generate strong current velocities that exceed 4.5 m/s in restricted narrow passages at various points in the Bay.

Salinity

Mean annual surface salinities for the Gulf of Maine 1977-1987 ranged from 32.25-32.75 parts per thousand (ppt) (Mountain and Manning 1994). Surface contours for the western portion of the Bay's outflow, i.e., leading from Grand Manan and Grand Manan Basin into the Gulf of Maine in September 1984, were a maximum of 32.7 ppt (Townsend et al. 1987). Average salinities in the outer Bay in late May to early June in 2002 and 2003 were 30.8 ppt (SD $\pm$ 0.4) to 31.0 ppt (SD $\pm$ 0.4) (Lacroix and Knox 2005). In contrast, salinities of the inner reaches of the Bay, e.g., Cumberland Basin are more in the range of 28 ppt (Dadswell 2004). Surface salinities in the Minas Basin between late June and very early August 1958, exhibited declines from 31.0 ppt in the Minas Channel to 30.0 and 29.5 ppt within the Central Minas Basin and 29.3 downwards to 20.0 with progression towards the head of the Cobequid Bay (Parker et al. 2007; Fig. 6 lower panel herein). Dadswell et al. (1984 *in* Parker et al. 2007) identified the 30 ppt isohaline as an approximate division between the oceanic sand beach fish community and the inner estuarine mud-flat fish community in both the Minas Basin and Chignecto Bay. In the Chignecto Bay, the 30 ppt isohaline is near but slightly eastward of a line drawn outwards from Cape Enrage, i.e., salinities proximate to the confluence of the Point Wolfe and Upper Salmon rivers approximate 31 ppt. (Keizer et al. 1984). Depths at low tide within Minas Basin are reported as mostly less than 25 m and averaging 14.5 m (Percy 2001).

However, little information exists concerning salinity selection by ocean-feeding Atlantic salmon (Dadswell 2004). Post-smolts migrate in and out of lower salinities during coastal migration

(Hansen et al. 1987; Hansen and Quinn 1998) but as a rule, continually advance to waters of higher salinity. Holm et al. (1996) *in* Dadswell (*op. cit.*) found that wild post-smolts, after two-three months of ocean migration in the Norwegian Sea [and North Atlantic] were only found in salinities above 35 ppt.

Temperature

Isotherms of monthly mean SSTs for the Bay of Fundy, Gulf of Maine and Scotian Shelf areas derived from satellite imagery spanning the years 1981-2000 are illustrated in Fig. 7a,b (Amiro et al. 2003). Ocean thermal conditions in the Gulf of Maine-Scotian Shelf were as much as 2°C warmer in 1998 as compared to 1986 (Friedland et al. 2003) – an ocean surface warming theme gaining much attention in the Northeast Atlantic (Todd et al. 2008). Bottom temperatures from research vessel survey series in Northeast Atlantic Fisheries Organization (NAFO) Division 4X (most of the Canadian waters from and including the Bay of Fundy to Halifax) have been quite variable in recent years but do not display any long term trends (DFO 2009).

Based on analyses by Reddin and Friedland (1993), of various catch rates and the SSTs at which Atlantic salmon were caught in the North Atlantic, Amiro et al. (2003) ascribed four "preference" categories: *<1°C and >13°C* (unfavorable but not lethal); *1°C to 4°C* (low preference - cool), *>4°C and <10°C* (high preference) and *10°C to 13°C* (low preference - warm) (Fig. 7a-b). SSTs at the outer and inner limits of the Bay in June and August of 2001 and 2002 (Lacroix 2013a), and addressed elsewhere in this document are more consistent with 'low preference warm' than 'high preference' for Atlantic salmon.

Dadswell et al. (1987) relate Gulf of Maine and outer Bay mean isotherms for May and June, 1940-1959, at both 10 m and 50 m depth. At the mouth of the Bay, May temperatures at the surface, and 10 m and 50 m appear quite similar; the temperature at 50 m in June is about 3C less than at the 10 m level and surface.

Productivity

In an effort to characterize the marine benthic habitats of Fisheries and Oceans Canada (DFO) Scotia-Fundy Region, scientists at the Bedford Institute of Oceanography combined metrics for annual bottom temperatures, seasonal and inter-annual temperature variability, oxygen, and food availability (based on spring chlorophyll and summer stratification) into a 'scope for growth' (DFO 2005a). Salinity was thought to play a role but data were limited. Scope for growth was defined as the amount of energy in the environment available for an organisms' growth and maintenance of normal physiological functions, i.e., productivity. Their analysis suggested that the benthic productivity of the middle and outer Bay, and Canadian portion of the Gulf of Maine outwards to Georges, Browns and Baccaro banks far exceeds that of all the rest of the Scotian Shelf waters to the east (DFO 2005a). Waters of the inner Bay were not analyzed.

Prey of Atlantic Salmon

Dadswell (2004) summarized the feeding and prey of salmon as follows (citations not included in "Literature Cited"):

> "Based on the occurrence and weight of food in stomach contents both Lear (1972) and Jacobsen and Hansen (2000) concluded that Atlantic salmon feed almost continuously while at sea and they are voracious and opportunistic feeders that will feed on whatever type of pelagic food item is available in their environment. Prey of ocean-feeding Atlantic salmon consists of pelagic and mesopelagic fishes, crustaceans and squid and varies with salmon age and ocean depth. When they first enter seawater post-smolts feed mainly on insects floating on the surface but they switch to planktonic crustacean after a few weeks at sea (Dutil and Coutu 1988; Jacobsen and Hansen 2000). On the high seas and as they grow older Atlantic salmon progressively switch from a diet dominated by planktonic crustaceans to one dominated by fish and squid (Jacobsen

> and Hansen 2000, 2001). Stomach contents of salmon collected over depths in excess of 1000m consist predominantly of various species of mesopelagic fishes (*Paralepis*, Myctophidae), planktonic crustaceans (*Themisto*, Euphausiidae) and the squid *Gonatus fabricii* (Templeman 1967; Lear 1972; Hansen and Pethon 1985). Over shallower depths salmon stomachs contain planktonic crustaceans, capelin, sand lance and herring (Lear 1972; Jacobsen and Hansen 2000). During homeward migration salmon food organisms in stomachs change from deepwater fishes (mesopelagics), to nearshore fishes (herring, sand lance (*Ammodytes sp*.) and finally they cease to feed before entering freshwater (Lear 1972; Jacobsen and Hansen 2000)".

Whitford (2008) summarized much of the work on zooplanktors in the Bay of Fundy noting that the principal group of smaller zooplankton consists of copepods (Fig. 8 upper panel). Many are common to the Gulf of Maine and Scotian Shelf (Roff 1983) and drift in from the Gulf of Maine (Corey and Milne 1987). The shallow water species, including *Eurytemora herdmani,* and species of *Acartia*, are extremely abundant and dominate the more turbid waters of the inner and upper Bay (Jermolajev 1958; Daborn 1984). Whitford (*op. cit.*) further notes that the most important and one of the larger species of copepod, *Calanus finmarchicus*, dominates the plankton of the outer Bay (Fig. 8 lower panel) during the fall and winter, but is much less abundant in the inner Bay and is rarely encountered in the upper Bay. This species is a fundamental food source for many species of fish (Legaré and MacLellan 1960), birds (Mercier and Gaskin 1985; Chardine 2005), and baleen whales (Woodley and Gaskin 1996) and is thought to be brought to the surface by the upwelling of deeper water at the entrance of the Bay.

The literature on the larger zooplankton, including 'krill' or euphausiids, amphipods, mysids and cumaceans, has been summarized by Corey (1983 *in* Whitford 2008) for the Quoddy Region and Passamaquoddy Bay but not for the greater part of the Bay. The largest and most important species on the Scotian Shelf (Bay of Fundy not treated) is *Meganyctiphanes norvegica* although *Thysanoessa inermis* and *Thysanoessa longicaudate* are also considered important (Breeze et al. 2002). These animals migrate vertically at night from deeper water into the smaller zooplankton and phytoplankton and are important prey of whales, birds and many species of fish. In Passamaquoddy Bay their diversity and abundance is greatest in summer and least in spring (Whitford 2008).

In a herring (*Clupea harengus*) larval survey of the Bay in March of 1979, Scott (1980) found that sand lance were well distributed throughout the survey area *except for* some stations in Chignecto Bay, between the Saint John River estuary and Passamaquoddy Bay, and south of Grand Manan Island at the mouth of the Bay of Fundy (Fig. 9). Concentrations of sand lance larvae were highest in the Sambro sand in the vicinity of Cape Chignecto, especially, near Ile Haute (*ref.* Fig. 6). An increase in mean length of fish from Cape Chignecto outwards to the center of the Bay indicated dispersion of larvae from spawning grounds at the head of the Bay. A second area with a high concentration of larvae was north of Digby Gut where because of the larvae's large size were probably distant to their spawning area. A third area of high concentration and which was thought to be a spawning area from which larvae dispersed was in the vicinity of Long Island (Scott 1980). Pollock larvae (*Pollachius virens*) were also captured in fewer numbers (Fig. 9) and thought to have originated in the Gulf of Maine (Scott 1980).

The importance of the waters of the Bay of Fundy, its' outer reaches and the Canadian portion of the Gulf of Maine to herring is evidenced by landings 1999-2003 (Fig. 10; DFO 2005b) by the predominantly purse seine fishery. The fishing season is year-round off southwest Nova Scotia (west of Baccaro Point, 65°30' west longitude) and in the Bay of Fundy; however, most fishing takes place at times and in areas with aggregations of feeding, overwintering, and spawning fish. Clark et al. (2012) indicate that the German Bank, Scots Bay, Seal Island, and Trinity Ledge are the four main spawning grounds documented for southwest Nova Scotia/Bay of Fundy. Their locations can be inferred through the identification by Stephenson et al. (2009) of spring and autumn spawning components (Fig. 11). Power and Melvin (2011) indicates that the Scots Bay fishery which extends from early July to late-August or early September captured mature herring with ripe and running gonads between July 12 and August 9, 2008. On the German Bank, August 22 to October 21 appeared to be a period over which spawning was constant i.e., individual groups or waves continuously arriving, spawning and then leaving within 10-12 days or less. In the Baltic Sea, the abundance of age-0+ herring in the year of smolt release was found to be a key factor influencing the migration distance, i.e., salmon released in the years of strong herring recruitment in the Gulf of Bothnia had a higher probability of staying in the Gulf of Bothnia for feeding rather than migrating south to the Baltic (Kallio-Nyberg et al. 1999).

FRESHWATER AREAS OF CRITICAL HABITAT

The 'Recovery Strategy' for the iBoF Atlantic Salmon (DFO 2010) noted that not all iBoF salmon freshwater habitat is critical because there is more freshwater habitat available than is required to achieve survival and recovery. Hence the Strategy identified the freshwater habitats of 10 rivers that contain residual native populations and contribute to the Live Gene Bank programs as essential to the current persistence of iBoF salmon, i.e., the Big Salmon, Upper Salmon, Point Wolfe, Economy, Portapique, Great Village, Folly, Debert, Stewiacke and Gaspereau rivers (Fig. 2). The first three rivers on the New Brunswick coast have been referred to as 'intermediate inner BoF' (Lacroix 2008); the last seven are 'distant' inner Bay but better termed rivers of the Minas Basin/Cobequid Bay (Fig. 6). An additional nine rivers identified by DFO Science as necessary to the long term survival of iBoF salmon include New Brunswick's Petitcodiac, and Nova Scotia's Maccan and Apple rivers of the Chignecto and Shepody bays and Nova Scotia's Harrington, Bass (Colchester), Chiganois, North (Colchester), Salmon (Colchester) and Shubenacadie rivers of the Minas Basin (DFO 2010). While data for salmon of only a few of the 19 rivers were available, salmon of the others are assumed to have similar estuarine and marine life strategies, the Gaspereau River excepted.

ESTUARINE AND MARINE AREAS OF OCCUPANCY

SMOLT

Smolt is the term for salmon that have not yet departed from their river of origin for the first time (Allan and Ritter 1975). While smolt tolerance to salt water begins prior to encountering it, their acclimation occurs between the most upstream point of salt water intrusion (sometimes approximated by the high tide mark) and a line drawn between the headlands at the rivers' mouth. This habitat serves importantly as a corridor between the 'critical' freshwater and important bay estuaries and marine habitats where smolt are termed post-smolt. Detailed length and area measures of riverine estuaries were not available for any of the 19 listed rivers. Cursory measures of length (derived using 'Google Earth') range from about 500 m on the Big Salmon River to as much as 43 km for the Stewiacke River (Fig. 2).

Occupancy of these habitats by smolts will vary according the length of the riverine estuaries and could range from one or two to numerous tidal cycles. With some uncertainty, duration can be inferred from the monitoring of wild smolts in a 'rotary screw trap' (RST) near tide-head on the Big Salmon River, 2002-2010 (Flanagan et al. 2006 and Jones pers. comm[1].), a RST located about 20 km above the head-of-tide on the Stewiacke River and bypass facilities at the White Rock Generating Station 2002-2005, roughly 5 km above the head-of-tide on the

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[1] R.A. Jones, DFO, Maritimes Region, Science Branch, Gulf Fisheries Centre, P.O. Box 5030, Moncton, NB, E1C 9B6.

Gaspereau River (Gibson pers. comm.[2]) (Table 1). Mean dates for monitoring 10% and 90% of the Big Salmon River wild smolt runs (n=9) were May 11 and May 30, but more *generally* encompass the 2nd week of May through the 1st week of June (Jones pers. comm[2]. and Table 1). Dates of first and last capture on the Big Salmon River were the last week of April through the last week of June although dates for each year tended to be slightly earlier in the most recent data. Smolts descending through the Stewiacke RST approached the Stewiacke/ Shubenacadie corridor between the 2nd - 3rd week of May (10th percentile) and 1st - 2nd week of June (90th percentile), while smolts descending the Gaspereau River transited the corridor between the 1st - 2nd week of May and 3rd - 4th week of May.

Lacroix (2008) tagged a number of groups of wild and hatchery smolts with ultrasonic transmitters in the Big Salmon, Upper Salmon, Stewiacke and Gaspereau rivers in 2001-2002. Smolts from the Big Salmon and Upper Salmon rivers migrated at rates of 1.0–5.0 km per day (Lacroix, *op. cit.*, one group excepted). Given that the data provided by Flanagan et al. (2006) originated within approximately 500 m of the Big Salmon River outflow to the Bay it is likely that smolts trapped at that location would have left the river within one or two tidal cycles. Run-timing of smolts in the Upper Salmon River is not appreciably different from that of Big Salmon River (Clarke pers. comm.[3]) but electronic-tagged smolts appear in general to have taken a few extra days to descend even short tidal portions of rivers (Lacroix 2008).

Migration rates to and through the longer tidal portions of the Stewiacke and Gaspereau rivers by ultrasonically tagged hatchery smolts were delayed by mean values of 14 and 6 days, respectively, possibly because of an early release date compared to the mid-May to mid-June migration in the Stewiacke River (Lacroix 2008). Gibson (pers. comm.[3]) indicates that some of his ultrasonically tagged smolts on the Stewiacke River reached the head-of-tide within a day, i.e., monitored smolts were probably within a day or two of reaching the high tide mark. Discounting the time for Lacroix's fish to reach the head-of-tide from the total time to reach the estuary (Fig. 5 *in* Lacroix 2008) suggests that the descent of smolts in the Stewiacke and Gaspereau river estuaries may have been extended by about 10 days or into the third week of June (Stewiacke) and 4 days or first week of June (Gaspereau), respectively.

POST-SMOLTS

Post-smolt is the term for salmon that have departed the river for the first time but have not passed a winter at sea (Allan and Ritter 1975). The marine migration pattern of Atlantic salmon originating in the iBoF rivers is as yet not fully understood even though it was hypothesized some 80 years ago to remain within the Bay (Huntsman 1931 *cited in* Amiro 2003).

Historical Tagging: 1963-1990

Jessop (1976) provided the distribution of Carlin–tagged post-smolts recovered from almost 116,000 native (26%) and non-native (74%: Miramichi and Restigouche river origins) tagged smolts released to the Big Salmon River, 1963-1971. Only three tags were returned from outside the Bay (Atlantic coast of south/central Nova Scotia), 50 (0.043%) were returned from fisheries in Passamaquoddy Bay and 101 (0.087%) were returned from fisheries on the Nova Scotia coast of the Bay of Fundy across from the Big Salmon River. (There were no significant differences between the fate of native and non-native fish within the Bay.) With the exception of two post-smolts seined in the Passamaquoddy area herring fishery in January, recaptures were mostly in July and August, at least in part reflective of when fishing activities have been most intense in this area. This distribution is in contrast to outer Bay of Fundy (oBoF) salmon such as

[2] A.J.F. Gibson, DFO, Maritimes Region, Science Branch, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS, B2Y 4A2.
[3] C.N. Clarke, Parks Canada, South Field Unit, Fundy National Park, Alma, NB.

those of the Saint John River which had been recovered in the coastal fisheries of Newfoundland in July and August (Ritter 1989).

In support of his submission to COSEWIC (2006) for status 'designation' of the impoverished iBoF salmon populations, Amiro (2003) referred to more than 50 Big Salmon River (1967 to 1973) and 14 Stewiacke River (1969 to 1990) Carlin-tagged post-smolts being recovered in commercial fisheries of the inner and outer reaches of the Bay in New Brunswick and Nova Scotia. Specific recovery locations included commercial fish weirs along the Nova Scotia coast of the Bay of Fundy [Port George to Hall's Harbour, including Morden and Black Rock (Fig. 2)]. Amiro et al. (2003) further illustrated the seasonal distribution of wild and hatchery tagged post-smolts in Nova Scotia: July (5) and August (18) and, the high weirs of Passamaquoddy Bay and Grand Manan Island in June (1), July (2), August (30) and September (4) (Fig. 12 herein). The distribution of tags, as well as the availability of 'preferred' sea temperatures, i.e., 8-12°C; Friedland et al. (2000); Holm et al. (2004) and 13°C (optimum for growth Handeland et al. 2003), especially in the Morden area of Kings County, Nova Scotia, where weirs were located in areas known to have upwelling and eddying of cooler oceanic currents (Fig. 7a; note yellow, Amiro et al. 2003) and favored prey species of Atlantic salmon, led Amiro et al. (*op. cit.*) to suggest that the Bay and Gulf of Maine may be 'essential' habitat for iBoF salmon.

More recently, monitoring of electronic tags and surface trawling have provided additional insights to the behavior, real time distribution and habitat usage by post-smolts of inner and outer Bay of Fundy origin (Lacroix et al. 2005; Lacroix and Knox 2005; and Lacroix 2008 and 2012) These publications appeared subsequent to the listing of the iBoF populations under Schedule 1 of the SARA in 2003 and the baseline submission to COSEWIC for assignment of 'status' in 2001.

First Electronic Tagging Study: 1999

First trials with electronically tagged iBoF salmon began in 1999, when two groups of captive-reared smolts of Big Salmon River origin were released at the head of tide, 0.5 km inside the Big Salmon River (Lacroix et al. 2005). Group 1 consisted of 24 parr reared to smolts at the Mactaquac Biodiversity Facility while Group 2 comprised 31 fish, first generation offspring of wild Big Salmon River brood-stock, bred in captivity. Release dates were June 1 and June 15, respectively, dates usually encompassed by the wild Big Salmon River smolt run (Table 1). Three coastal monitoring/detecting arrays were deployed: Detecting arrays:

i) enclosed an area of 5 to 10 km around the river mouth through June 29,

ii) formed a line outwards for 13 km from the New Brunswick coast June 12 to the end of August, and

iii) with the removal of the first array, the relocated detectors formed another 25 km array extending from the Nova Scotia coast from June 30 to the end of August (Fig. 13).

Most smolts of both groups entered the Bay during an ebb tide and migrated away from the river rapidly. Ninety-two and 100 percent of Groups 1 and 2 attained a distance of 5 to 10 km within a half day; with 84% of Group 2 were detected 20 km from the Big Salmon River (Group 1 only had short term transmitters and the second array was not established in time to detect Group 1).

Subsequently, two distinct behavior patterns became apparent when comparing transit times and sequential position plots for individual post-smolts:

i) rapid migration along a direct path or common corridor approximately 2.5-5 km from shore (Fig. 14a) away from the areas monitored, and

ii) delayed migration with back-and-forth movements within the areas monitored.

Post-smolts that left rapidly migrated by following a relatively direct path away from the river. A resident behavior pattern was recorded for many of the post-smolts with long term transmitters:16 of the 26 (62%) post-smolts from Group 2 that were moving out of the inner Bay were later monitored returning to one of the arrays extended from either the New Brunswick or Nova Scotia coast (Fig. 14b). The returns were evenly distributed between both sides of the Bay, with an aggregation about 6-8 km from shore on the Nova Scotia side (Fig. 14c). The first behavior pattern, i.e., rapid migration from the area, assumed that these fish were not also prone to back and forth movements but died before returning.

Returning fish, i.e., moving back up the Bay were monitored mostly during July, some 2-22 days after the post-smolts had initially been detected. Post-smolts from Group 2 that returned to the monitoring area instead of continuing their seaward migration continued to be detected in the New Brunswick and Nova Scotia arrays throughout July and August (Fig. 14c,d). As the summer progressed, two to three times more post-smolts were monitored on the Nova Scotia side of the Bay than on the New Brunswick side of the Bay. Post-smolts tended to head out of the Bay during ebb tides and into the Bay on flood tides or during a change from ebb to flood, a behavior that had been previously documented for smolts in estuaries and entering coastal waters (Lacroix et al. 2005).

Lacroix et al. (2005) proposed that the extended presence of some post-smolts inside the Bay of Fundy reflected a resident behavior pattern rather than a slow seaward migration from the area, consistent with earlier proposals based on tagging data. This behavior was observed for post-smolts that were initially slow in leaving and had the least direct migration routes moving out of the Bay. Individual routes revealed common behavior patterns that were related to tidal flow and surface currents.

As a result of the findings, Lacroix et al. (2005) suggested that the area inside the Bay of Fundy, unlike the habitat throughout most of the Gulf of Maine to the south, was favorable to extended post-smolt residency and survival because of the consistently cold water temperature caused by tidal mixing and advection inside the Bay (Smith 1997 *cited in* Lacroix et al., *op. cit.*). Although Saint John River fish (oBoF origin) are distant migrants, Ritter (1989 Table 1b therein) noted that of 56 tag returns from post-smolts tagged and released as smolts from Mactaquac Biodiversity Facility on the Saint John River, 1967 to 1984, 25 were returned from the “lower Fundy shore” of Nova Scotia – mostly in July and August but as well in June (2 tags) and September (1 tag).

Long term mean SSTs (Amiro et al. 2003; ‘low preference-warm’) do indicate that upper temperatures of 12°C (Lacroix 2008) and 14°C (Holm et al. 2000) at which post-smolts have been found, may not have been exceeded in the vicinity of the arrays at any time of the year. Long term mean SSTs of 1°C-3°C in March ‘low preference - cool’ for the Bay of Fundy (Amiro et al. 2003) are consistent with winter temperatures of 1°C-2°C known to be utilized by the aquaculture industry in the Passamaquoddy Bay area (Saunders 1988), i.e., temperatures bordering the categories of Amiro et al. (2003) are compatible if, e.g., other conditions are favorable.

Lacroix et al. (2005) also noted that the movement of post-smolts was consistent with a surface circulation inside the Bay of Fundy that is characterized by an outflow along the New Brunswick coast and a straightforward inflow along the Nova Scotia coast during summer (Trites and Garrett 1983). Some of the outflow (Trites and Garret, *op. cit.*), particularly that on the south side of Grand Manan Island, also made a counter clockwise turn in the outer portion of the Bay joining with the inflow along the Nova Scotia coast. Lacroix et al. (*op. cit.*) suggested that residual currents probably played a role in the initial orientation of post-smolts (i.e., on a course heading straight out of the Bay) and their common use of a departure ‘corridor’ close to the New Brunswick coast. The return of some post-smolts to the area monitored during the summer and their presence along the Nova Scotia coast would also have been consistent with the general circulation in the Bay of Fundy.

Second Electronic Tagging Study: 2001-2002

A second investigation by Lacroix (2008, 2012) in 2001 and 2002 extended the arrays of receivers for the detection of electronically tagged post-smolts from the inner Bay to the western extremities of the outer Bay (Figs. 2 and 15). Smolts (wild and hatchery) were again tagged, now with 3-4 months battery life expectancy (> 4 months realized) and released from the Big Salmon River, as well the Upper Salmon, Stewiacke, Shubenacadie, and Gaspereau rivers of the inner Bay and the Nashwaak tributary of the outer Bay, Saint John River.

Lacroix (2012) provides geo-reference plots of the location of first detection of each post-smolt at an array for 13 groups of post-smolts (Table 2) from those inner and outer Bay rivers (Fig. 15). The encirclement of the Passamaquoddy Bay (Quoddy/Fundy Isles region) with receivers in 2001 (only) was to test the hypothesis that post-smolts entered the region but because of possible adversities caused by the aquaculture industry, failed to exit the area. The outer-most arrays between Grand Manan Island and Digby Neck, Nova Scotia, were to provide insights to post-smolt departure from, or residency within the Bay. Monitoring of tagged smolts from the rivers occurred between late April and late July; the passage of post-smolts with transmitters through the Bay was continuously monitored to “September - October” (Lacroix 2008).

As in 1999, the varied groups of Big Salmon River post-smolts cleared the near-river array within as little as a few hours to a few days. Upper Salmon River smolts took 2 or 3 to 5 or 6 days to exit the river’s outflow to the Bay. Salmon from the Big Salmon and Upper Salmon river groups exhibited the highest proportions of tagged fish (36%-70%) detected at the outer Bay arrays (Fig. 3 *in* Lacroix 2008). On average, these groups of post-smolts cleared the arrays between approximately June 10 and June 27. Average migration rates for the groups were approximately 5-8 km per day for the Big Salmon River fish and 8-17 km/day for the Upper Salmon River fish (Fig. 5c. *in* Lacroix, *op. cit.*).

Lacroix (2012) grouped the migratory behaviour of 274 surviving post-smolts after leaving their rivers (237 from the inner Bay of which 182 were wild (Table 2) as:

i) *distant migrants* - those that left the Bay and were never detected again (n=119),

ii) *coastal migrants-residents* – those left the Bay and returned during the summer (n=93), and

iii)) *strict residents* – those that never completely left the Bay and were repeatedly detected inside the Bay during the summer (n=62).

Post-smolts from the inner Bay groups were predominately coastal migrants and residents (overall 63%, range 29-90%; Fig. 16) that returned to, or remained in the Bay of Fundy. In contrast, most of those from outer BoF groups were considered to be distant migrants (overall 86%, range 77%–100%); they left the Bay of Fundy and did not return during the summer. Post-smolt from inner Bay groups usually had a higher proportion of coastal migrants (overall 41%, range 12%–63%) than strict residents (overall 22%, range 9%–35%). However, there were differences among the inner Bay groups in the extent of coastal migration and residency apparently related to origin, year, migration timing (Lacroix 2013a), and possibly in the case of the Stewiacke and Gaspereau fish, low sample size (Table 2).

Hubley et al. (2008) examined scale circulus spacing patterns in pre-1990 and post-1990 scales of two inner Bay and two Atlantic coast populations and found that narrower bands were characteristic of some iBoF fish, and that wider spacing was characteristic of the known distant migrating fish of the Atlantic coast. Within one of the two iBoF populations (Big Salmon River), it was observed that prior to 1990 there was both a narrow band pattern and a wider band pattern more characteristic of that in the scales from Atlantic coast populations. Post-1990, the narrow band pattern in the Big Salmon River population was absent (no scales were available from the second population, i.e., adult returns were all but non-existent), which suggested to Hubley et al. (2008) that local migration may not presently be a successful strategy for iBoF populations. While this could be suggestive of the Big Salmon River population having two innately different migratory strategies, it is more likely a consequence of post-smolt retention or dispersal from the Bay as a consequence of the timing of their migration, surface currents, temperatures, food availability, etc., and does not discount the possibility that 'local' migrants have more recently experienced habitat and growth comparable to "distant migrants" (i.e., oBoF and Gulf of Maine populations).

Post-smolts that never fully left the Bay often migrated to the mouth of the Bay where they moved across the Bay at the level of the outer Bay array in late June and early July, and returned along the coast of NS (Lacroix 2013a; Fig. 17a,b herein). Some post-smolts that left the inner Bay in June were never monitored at the outer Bay array, but instead spent 2-3 weeks between the arrays before returning to the inner Bay where they circulated and were repeatedly monitored during July and August (Fig. 17c,d).

As with the 1999 tagged post-smolts, out bound post-smolts, especially those from the inner Bay groups, left the inner Bay along the NB coast close to shore (Fig. 15a-c). Once across the outer Bay, salmon from inner Bay groups dispersed over a wide area in Grand Manan Basin, the main outflow from the Bay to the Gulf of Maine, but there was a tendency to be on the Grand Manan Island side of the basin, and often close to the Island's shore. Only 10 post-smolts, [possibly 15% of all post-smolts reaching the outer Bay *ref.* Fig. 3a and Fig. 9 *in* Lacroix 2008] mostly from Big Salmon River, followed the NB coast and entered the Quoddy Region of NB (Fig. 15a), and eight of these rapidly migrated through and out of the area. Only four post-smolts, all of inner Bay origin, left the Bay by the narrow Grand Manan Channel along the coast of Maine (Lacroix 2013a). At the inner Bay array, 51% of out bound post-smolts migrated in a narrow 6-km corridor extending from the NB shore, and 92% of post-smolts were within a broader 14-km corridor along that coast (Fig.18a). The salinity of water in this corridor was the lowest across the Bay at that array location in June of both years (Fig. 19a). The SST was between 6°C and 8°C, and it did not vary much across the Bay at that array location and time (Fig. 19b). At the outer array, 26% of these post-smolts were within 10 km of the east shore of Grand Manan Island and its' salmon cages 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 (Fig. 18a).

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 (Fig. 18b). 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 NS 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 NS coast at the oBoF array (Fig. 18b, dashed line), and more than 80% of post-smolts returned in 10-km wide corridors along the NB and NS coasts at the inner Bay array (Fig.18b, solid line). 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 NS coast at both transects (Fig. 19a,c). The inferred migration routes of several Upper Salmon and Big Salmon River post-smolts leaving and then returning to the Bay are shown in Fig. 20.

The SST experienced by resident post-smolts in the Bay was usually between 10°C and 14°C in August, and the water was coldest at the outer Bay transect on the NS side of the Bay, where many of the post-smolts re-entered the Bay. These temperatures border 'low preference - warm' (Fig. 7a; Amiro et al. 2003).

For coastal migrants, the mean delay between departure from the oBoF and return from the Gulf of Maine was ≤15 days, (*ref.* Fig. 11 *in* Lacroix 2013a). Return of these and resident post-smolts to the iBoF took more than twice as long for each group; the range in mean delay was large (18–33 days), but it did not differ significantly among groups because of high variability in time taken to return to the iBoF array (Lacroix, *op. cit.*).

With respect to occupancy of habitat, Lacroix (2012) indicated that:

- A high proportion of post-smolts of inner Bay origin had a predominantly coastal migration that resulted in i) occupation of habitat in the Gulf of Maine and early return to the Bay and, ii) residency completely inside the Bay during the first summer at sea. This was in contrast to post-smolts from outer Bay populations which likely migrated to the Northwest Atlantic;
- Patterns of post-smolt movement were closely linked to the residual coastal currents of the Bay and Gulf, the northern Gulf of Maine gyre and the Bay of Fundy gyre. Post-smolts monitored in the Gulf of Maine at the NOAA array off Narraguagus Bay were in the cold coastal current close to shore along eastern Maine, which suggests that the area may also be important as suitable habitat for coastal migrants during summer;
- Residency of post-smolts in the Bay of Fundy-Gulf of Maine during initial migration versus those that were distant migrants was predictable given the variables: date of river exit, watershed, and migration speed nested by region within the Bay, i.e., the number of resident post-smolts increased with both a decrease in migration speed, an increase in the date of river exit and distance of the watershed from the outer Bay. The proportion of resident post-smolts to be restricted to the Bay of Fundy versus those that returned from the Gulf of Maine was best predicted by a model in which the timing and speed of migration were nested by year of migration, i.e., the number of resident post-smolts that never left the Bay increased with both a decrease in migration speed, and an increase in the date of river exit;
- Fish that left early and migrated rapidly reached the Gulf of Maine before mid-June, and they had an open migration path with SST <10°C through the Gulf around the southern tip of NS and along the eastern Scotian Shelf (Fig. 21a). This included most post-smolts of oBoF origin and a few of inner Bay origin that did not return. In contrast, by late June and early July, a mass of warming surface water (SST = 10–20°C) reached into the Gulf and on the Scotian Shelf (Fig. 21b). Then, from mid-July onwards, the Bay of Fundy and northern Gulf were effectively encircled by warm water with SST >20°C (Fig. 21c). This pattern suggests that the expanding area of warm surface water could have entrapped or terminated the migration of post-smolts that were late or slow.

Trawling Surveys: 2001-2003

To extend knowledge of the migration routes, condition, habitat and, forage and feeding 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 (Fig. 22). Respective dates of surveys were May 30-June 13, May 26-June 15, and June 4-18, dates which were selected to correspond to the time of peak smolt migration from rivers of the Bay of Fundy. Fish were live captured in an aluminum tank affixed to the net in place of a bag. Total captures numbered 398 post-smolts of which 161 and 237 were of wild and hatchery origin, respectively (Table 3 *in* Lacroix and Knox 2005).

Of 8,195 wild fish marked in the Upper Salmon, Big Salmon, Saint John, Magaguadavic and St. Croix rivers over the three years (Table 1 *in* Lacroix and Knox 2005), eight appear to have been recovered (0.09 % of which seven were from the Big Salmon River). Of almost 1 million potentially identifiable hatchery-reared smolts released to the same rivers, there were approximately 100 recovered (0.01% of 973,052) recoveries. Another 30 hatchery-origin fish were assessed as having originated in rivers of Maine (later determined to be the Penobscot (25) and Denys (5) rivers; (Lacroix et al. 2012), while another 61 hatchery-origin fish were thought to have originated from the aquaculture industry (41 appear to have been ascribed to other US rivers; Lacroix et al., *op. cit.*). The capture location of seven wild marked post-smolts of Big Salmon River origin are shown in Fig. 23 (Lacroix and Knox 2005), five of which extend the southerly distribution limits for iBoF post-smolts into the Gulf of Maine and towards the Scotian Shelf. Aquaculture post-smolts (approximately 15% of the catch) and those of the outer Bay rivers were within the same plume of post-smolts appearing to exit the Bay.

Other fish species captured in the surface trawls included lumpfish (*Cyclopterus lumpus*) (91%-100% of tows with salmon), alewife (*Alosa pseudoharengus*), Atlantic herring, Atlantic mackerel (*Scomber scombrus*), and a variety of larval and age-0 fish (Lacroix and Knox 2005). Crustaceans (amphipods and euphausiids, ctenophores (comb jelly) and cnidarians (jellyfish) were also captured but fish larvae and age-0 fish were usually the most abundant, followed by Atlantic herring, lumpfish, and Atlantic mackerel (Figs. 5 and 6 *in* Lacroix and Knox 2005). Spiny dogfish were caught infrequently but always in company with salmon. Lumpfish, a potential predator of post-smolts were caught very frequently and carried the sea louse *Caligus elongatus*, and occasionally a few were affixed to post-smolts. Post-smolts did not carry the salmon louse *Lepeophtheirus salmonis* and none of the handling mortalities were found to have lesions or other pathologies, or bacterial or viral pathogens (Lacroix and Knox 2005). Lacroix and Knox (*op. cit.*) noted the overlap and potential for bycatch of post-smolts in May and June in commercial purse seine fisheries for herring (Fig. 24) (Lacroix and Knox, *op. cit.*), and DFO (2005b).

The stomachs of 60 post-smolt handling mortalities over the three years indicated that most abundant food items were the crustaceans *Themisto* spp. (Amphipoda, Hyperiidae) and *Megancyctiphanes norvegica* and *Thysanoessa inermis* (Euphausiidae, or krill) (Lacroix and Knox 2005 including Fig. 5 therein). Fish (mostly larval and age-0) occurred in many stomachs, especially sand lance, with lesser frequencies of larval herring and unidentified fish remains. Food items varied in their frequency between years and location of capture. Stomachs of seven post-smolts sampled in the Gulf of Maine in 2003 (see Fig. 23 for plots of all captured post-smolts) were heavily weighted towards a single species of amphipods and krill/euphausiids; some herring larvae and fish remains were of relatively low frequency. Ten samples within the Bay of Fundy in 2001 (two stomachs were empty) yielded a broader cross section of prey: three species of amphipods, krill, sand lance, unidentified fish, copepods and nematodes. The largest sample (43 stomachs) was taken in 2002 in a survey which covered both the Bay and Gulf in 2002. Contents were the most diverse of the three survey years but weighted towards krill.

In general, the food items were consistent with findings reported in the literature for salmon elsewhere, e.g., reviews by Dadswell (2004) and Dadswell et al. (2010). Renkawitz and Sheehan (2011) found that juvenile herring dominated the identifiable teleost fish remains in stomachs of post-smolts sampled in Penobscot Bay, 2001-2005. Renkawitz and Sheehan (*op. cit.*) concurred that the post-smolts feed on a low diversity of prey items, are prey selective and because herring have a high protein and energy content (twice that of sand lance; Lawson et al. 1998) are probably selected for when available. Salminen et al. (1995) noted that in the Bothnian Sea, there is a close relationship between recruitment of herring and production of salmon, with smolt size being the determining factor affecting *their* predation on herring [presumably larvae]. Bryan (2008) did not find a significant correlation between the marine survival of Big Salmon River salmon and herring abundance in the Bay of Fundy. Other studies of salmon in the Baltic Sea and Gulf of Bothnia offer insight into Atlantic salmon adaptation to what is by North American standards an atypical environment.

Salinities during the trawl surveys were approximately 31 ppt and surface water temperatures of approximately 6°C to 9°C (Lacroix and Knox 2005) were consistent with data of Townsend et al. (1987), the 20-year mean SSTs depicted in Amiro et al. (2003) and the 5°C-8°C 'preferred' temperatures of post-smolts (Reddin 2006). Holm et al. (2000) found temperatures to range from 6°C-14°C with the largest number of post-smolts found around a median of 9°C-10°C.

MATURING AND NON-MATURING SALMON

Currently there is no documentation of the location or habitat frequented by iBoF salmon during their first winter at sea, i.e., after the last detections of electronically tagged post-smolt in September or the few recaptures of traditionally tagged post-smolts in nets in October and before their first appearance in former commercial fisheries within the Bay in May/June. To date, iBoF salmon have been characterized as having a more localized migration (staying within the Bay of Fundy and the Gulf of Maine), earlier age at maturity, a greater dependence on repeat spawning for population stability, and until recently a higher survival between spawning events (Amiro 1987; Amiro and Jefferson 1996 *in* DFO 2010). These traits along with temperature conditions (Fig. 7a) and the occurrence of post-smolts in the outer Bay into September suggest that the Bay of Fundy and northern Gulf of Maine could constitute some part of the winter habitat for iBoF salmon. The later age-at-maturity, lesser dependence on repeat spawning and contrasting early run-timing to freshwater by the Gaspereau River population, characterize it more like outer Bay and Southern Upland populations that migrate to the North Atlantic.

RETURNING ADULTS

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 (Fig. 10 *in* Amiro 1998). Of the seven captured at sea, one was captured in a weir in the vicinity of Passamaquoddy Bay, three were returned from net/weir fisheries in the vicinity of Saint John, and three were recovered from weirs located on the Nova Scotia shore in the vicinity of Morden, Kings County, Nova Scotia (Fig. 2). No dates were provided.

Ritter (1989, and Table 3 herein) provides information for a subset of "wild" and "native" Big Salmon River smolts tagged 1967-1973, which were recovered after one or two winters at sea (1SW or 2SW). Five fish were recovered from commercial fisheries in "Middle Fundy", New Brunswick, interpreted here-in as in the vicinity of Saint John, one was taken in "lower Fundy", interpreted as Passamaquoddy Bay and three were from "lower Fundy" Nova Scotia, possibly in the vicinity of Morden, Kings County (Fig. 25 and Ritter, *op. cit.*). One was recovered in Area J2 in Newfoundland and 73 were tallied at the Big Salmon River counting fence (Ritter, *op. cit.*). The paucity of returning adult recaptures in the Bay indicates little about their pathway to the Big Salmon River.

Indirect evidence of high-use marine areas was introduced by Amiro (2003) who treated commercial data for salmon captured in Albert and Westmorland Counties NB (Chignecto Bay, Fishery Statistical Districts [FSDs] 79 and 81 *ref.* Fig. 12), (1870-1984) and from the Central Minas Basin and Cobequid Bay, Nova Scotia (FSDs 42 and 43), 1970-1984, as surrogates for population trends of iBoF salmon. Amiro (*op. cit.*) noted potential uncertainties in the long term data but relied on a treatise by Dunfield (1985) and subsequent analyses to suggest that the data were consistent with declines in abundance in iBoF index rivers during the same time period.

Amiro (2003) further noted that the commercial drift net fishery for salmon in Central Minas Basin and Cobequid Bay was thought to intercept salmon returning to the Shubenacadie/ Stewiacke rivers. This fishery was monitored through a series of reports documenting annual catch, obtained from sales slips and field officer reports prior to 1980 and via individual fisher logbooks from 1980-1984 (Redbook Series MS[4]). Analyses suggested that at a mean weight of 3.24 kg (Amiro 2003), the fishery took an average of 1,062 salmon per year.

Bay of Fundy Commercial/Salmon Fisheries

Former licensed salmon fisheries of the inner Bay, and those of the oBoF, their season of operation and seasonal distribution of landings from FSDs 79, 81, 42 and 43 (Fig. 12), enhance inferences as to where adult salmon are in the one or two months prior to ascending their river of origin. This is built on the premise that historically, species specific fisheries flourished only where and when the species could be found in some abundance, i.e., commercial salmon seasons generally encompassed the traditional duration of the salmon's availability and conditions amenable to fishing.

Commercial salmon fishing in FSDs 79 and 81 in New Brunswick was principally conducted from small boats with salmon *drift nets* of 150 to 200 fathoms in length (one unit was 50 fathoms) in the Petitcodiac estuary (Shepody Bay) between Hopewell Cape and Hillsborough and in the lower part of Cumberland Basin. The season generally extended from May 15 to August 15 with a minimum retention size of 5 lb (Dunfield 1974).

Commercial salmon fishing in FSDs 42 and 43, i.e., Minas Basin, Nova Scotia, was principally conducted with salmon *drift nets* of 200 fathoms length (four 50 fathom units). In the Shubenacadie River estuary, nets were of 35 fathoms in length. In 1971 the season extended from May 1 to August 15. Previous to 1970 the season began on April 15. In Nova Scotia, the minimum retention size was 3 lb (Dunfield 1974).

The largest *drift net* fishery in the Bay was off Saint John in FSDs 48 and 49, which prior to closure in 1972 involved approximately 55 boats (Dunfield 1974). Up to 100 small boats with nets of 30 fathom length also occurred in the Saint John Harbour. The Bay fishery was carried out with nets of up to 500 fathoms (length was not regulated) in the coastal waters of the Saint John River and its outflow between the river's mouth and Point Lepreau and outwards for as much as 16-19 km (Smith 1969 *cited in* Penney 1983). Bases of operation were Saint John, and to the west, Mispec, Lorneville, Dipper Harbour and Chance Harbour. A schematic of the geographic extent of the Bay of Fundy salmon *drift net* fisheries (Dunfield 1974) is provided in Fig. 25 (upper panel).

Salmon were also captured in drifted gill nets licensed for shad and salmon (Dunfield 1974). All Bay of Fundy shad seasons opened on May 1. Of equal interest are the salmon taken from the Bay in *weirs* (Fig. 25 lower panel), i.e., trap nets principally constructed of pickets, brush, and twine or wire netting. Primarily conducted to capture herring, some weirs were designed and licensed to take other species such as shad, salmon, striped bass (*Morone saxatillis)*, sturgeon (*Acipenser* spp.), mackerel, and Gaspereau. In Kings County, NS (FSDs 40 and 41), the principal intention of operation was for salmon. In the Minas Basin (FSD 43) weirs of 8-10 ft height were set up to 2 mi from the high water mark and frequently took shad, striped bass and salmon. Herring weirs, weirs that have a pound of at least 50 pickets (Dunfield, *op. cit.*) and which are located in New Brunswick between Saint John and the Maine border and in Nova Scotia between the Annapolis Basin and Yarmouth area were known to capture post-smolts and only occasionally, adult salmon.

[4] Atlantic Salmon Commercial Catch Statistics. Maritimes Region, Fish. Serv. Res. Develop. Branch, 1967-1971.

Commercial salmon landings, 1967-1971, in (i) FSDs 35 and 40, (ii) 42 and 44 (unknown landings in FSD 41 may have been reported in FSD 40), and (iii) FSDs 79 and 81, i.e., all 'inner' Bay areas from which tagged adults and post-smolts have been returned (Table 3) totaled 140,909 lbs (64 t) (Red Book Series MS) and are suggestive of where iBoF salmon could be found in relative abundance. At a mean weight of 3.24 kg (Amiro 2003) the above landings represented 19,700 salmon. For the five years in question, mean monthly landings (Fig. 26) are suggestive of not only the relative importance of the three fisheries/areas but of a sequential Nova Scotia coastal routing beginning in the Port George to Hall's Harbour area in June (fisheries opened in May, if not mid -April) for presumably of minimally, Minas Basin iBoF adults seeking their natal rivers, i.e., inward migration on the Nova Scotia side of the Bay with the counter clockwise current and cooler upwelling waters of the Bay. The proportion of landings in August may be a consequence of only a half a month of fishing, but a reduction from July would be consistent with the salmon's approach to and entry of estuaries and tidal portions of natal rivers.

Adult salmon tagged and released in the salmon drift net fishery off Saint John in 1962 and 1963 (Smith 1969) and in an experimental drift net fishery conducted May through July in 1970-1973 (Penney 1983 and Fig. 27) rarely appeared at the Big Salmon River counting fence even though up to 25% small mesh (114 mm) netting targeting small salmon/grilse was used 1971-1973 (approximately one-half of Big Salmon River returnees could be labeled as 1SW fish (Legend; Fig. 28 upper panel). Tagged recoveries at the fence in 1972 were 1 out of 621 salmon and 2 of 69 grilse (Penney, *op. cit.*). None of the other 1,324 salmon and 76 grilse tagged in 1970, 1971, or 1973 appeared at the fence although respective counts in 1971 and 1973 were somewhat and largely incomplete (Jessop 1986). The data however led Jessop (1976) to conclude that Big Salmon River fish contributed very little to that fishery. On an ancillary note, only one of the drift net tagged salmon appeared in the NS commercial fishery (FSD 40).

Some salmon originating in the Big Salmon River have, however, been tagged in the Saint John River and appeared later at the Big Salmon River counting fence. These include 15 salmon tagged at Westfield in the lower Saint John River and in the Saint John River Harbour, 1965-1966, (Smith 1969). These however may have been smolts of Miramichi river origin reared at the Saint John Fish Culture Station and released to the Big Salmon River in 1964-1965. Another 10 adults tagged in the Saint John were recaptured in the Petitcodiac, Shediac, and Big Salmon rivers 1966-1974, only a few of which could have originated from age-0 releases of non-native fry and parr in 1966-1967 or Restigouche smolts in 1968-1969, to the Big Salmon River (Gibson pers. comm.) i.e., iBoF salmon have strayed into the Saint John River.

Of 30,542 wild Big Salmon River smolts tagged 1967-1971, four large salmon and two grilse were returned from New Brunswick commercial fisheries, while one large salmon and two grilse were returned from the Nova Scotia commercial fisheries (Ritter 1989). Thus, based on the foregoing, the routing of New Brunswick iBoF salmon in returning to their natal rivers is at best uncertain and possibly at variance with a retracing of a near-shore New Brunswick coastal corridor used by post-smolts or dates of prosecution of the Bay's commercial fisheries.

Outer Bay salmon, specifically those of the Saint John River which exhibit a North Atlantic migration (Amiro 2003) are as maiden fish not known to overwinter in the Bay of Fundy in the winter of their return. Rather they are thought to overwinter off the Grand Banks of Newfoundland (Reddin 2006. Small numbers of tagged kelts (previous spawners) have been reported as recovered December–March (ICES 2008), although the specific recovery locations of these fish were not available for scrutiny. A small early-run component of Saint John River headwaters known as the 'Serpentine Run' (Saunders 1978) returns in the fall of its second year at sea and is thought on the basis of tagging experiments at Westfield in the lower river estuary, to overwinter there before ascending the river as the first salmon arrivals at Mactaquac Dam the following spring - some 140 km upriver of the Bay. February-April SSTs in the Bay are on average 2°C-3°C (Amiro et al. 2003) and are higher than the 1°C-2°C temperatures encountered by the Quoddy Region aquaculture industry (Saunders 1988); temperatures in the ice-covered Saint John River estuary are unknown but even below the halocline are unlikely to be warmer. The adaptation of the Serpentine Run does suggest however, that the Bay of Fundy is not a 'preferred' overwintering habitat of outer-Bay origin salmon.

Dadswell (2004) argues in the absence of data that the overwintering area of iBoF salmon is in fact the North Atlantic Ocean. The hypothesis was based on evidence that:

i) there are no returns of post-smolts in the Bay or Gulf of Maine between the end of October and early May even though there are extensive commercial fisheries that could catch them;

ii) tagged adult salmon have only been caught in the Bay, May to October;

iii) in most cases, the distribution of recaptures in the Bay and seasonal progression of recaptures of post-smolts and returning adults is similar whether the salmon originated from the inner or oBoF or beyond, and

iv) there has never been a commercial fishery for salmon offshore in the Bay or the Gulf of Maine (Dadswell, *op. cit.*).

The undermining rebuttal to the hypothesis is that essentially no tagged iBoF salmon (with the exception of a few possibly misplaced hatchery origin fish) have been returned from the North Atlantic Ocean.

Dadswell (2004) further bases his argument on 'preferred' environmental conditions of Atlantic salmon found in the North Atlantic noting that 'preferred' temperatures [4°C-8°C at the time of his writing] were only available during spring and late fall, that salinities of 35 ppt were never available and that depths in excess of 1,000 m over which to forage are also unavailable in the Bay or Gulf of Maine. He also suggested that except for the Baltic Sea and Ungava Bay populations during years of sea ice, most Atlantic salmon appear to follow ocean currents of the North Atlantic gyre during ocean feeding and if iBoF salmon were to follow those currents of the Gulf of Maine (which Maine stocks do not, Lacroix et al. 2012), rather than those of the Gulf Stream they would only be led into SSTs that are too warm. Reddin (1985), *citing* Lear (1976) suggested on the basis of incidental captures of Atlantic salmon by commercial trawlers, that the waters along the southwestern edges of the Grand Bank and St. Pierre Bank may represent an overwintering or staging area for salmon. There, the merging of the Labrador current and Gulf Stream creates eddies and up-wellings of nutrient-rich water habitat for an abundance of fish species, and SSTs of 3°C-8°C. Reddin (*op. cit.*) suggested, however, that it would have been difficult for southern stocks leaving the area to have completely avoided the fishery along the south coast of Newfoundland.

Much of Dadswell's argument (Dadswell 2004) is based on the absence of post-smolts after October, a generally straight forward departure by some from the Bay along the New Brunswick coast and absence of evidence that they do not stay in the rich upwelling waters off the southern end of Nova Scotia. The concurrent distribution of some iBoF post-smolts with outer Bay post-smolts at the mouth of the Bay of Fundy supports the hypothesis while the historically complete absence of iBoF salmon from distant fisheries of Newfoundland does not.

Inner Bay of Fundy in-River Recreational Fisheries

To bridge the temporal gap between the appearance of significant numbers of salmon in the coastal commercial salmon fisheries, i.e., June to August on the Nova Scotia Coast and July – August in Cobequid Bay and the outer Chignecto Bay, and an October-November spawning in the rivers, the temporal distribution of the recreational catches of salmon in nine rivers (there were no data for the Point Wolfe River) were examined. To establish that recreational catches are generally indicative of the availability of salmon in freshwater, data from the Big Salmon River counting fence (Jessop 1986) and recreational fishery data (O'Neil and Swetnam 1984; Swetnam and O'Neil 1985) were plotted for comparison (Fig. 28 upper panel).

The data (Fig. 28 upper panel) suggest that for the Big Salmon River, staging in the Bay is occurring by July and that the short riverine estuary/corridor is 'essential' July through October. For the Upper Salmon (Alma) river. it is probable that a Bay staging area and the riverine estuary is important between August to October. Assuming that recreational catch of these rivers (season of August 15-31 October) is indicative of their availability, the Basin, Bay and riverine estuaries are important corridors in September and October (Gaspereau excepted). Data for the Gaspereau River, principally a 2SW population (0.16 1SW fish; Legend Fig. 28) believed to have distant migratory tendencies, suggests that the corridor into the Minas channel and the Southern Bight (Fig. 6) of the central Minas Basin is important from May through at least July.

KELTS

Kelt is the term used to describe post-spawning adult salmon. The temporal use by kelts of seemingly important riverine estuaries, river outflow estuaries in the Bay of Fundy or the Cobequid Bay/Central Minas Basin, Chignecto Bay estuaries is largely undocumented although Jones (pers. comm.) reports that for 11 spawners acoustically tagged in the Big Salmon River in mid-Sept. 2008, six left the river in the fall; the other five overwintered and were likely spring kelts. Two- hundred and thirty-eight kelts, possibly of Restigouche river origins (Amiro 2003) were marked and released in the Apple River in the 1930s; none were recovered in the year of marking (Dadswell 2004).

In 2008-2009, Lacroix applied Pop-up Satellite Archival Tags (PSATs) with 4-month pop-off delay to Atlantic salmon kelts leaving the Hammond River (outer Bay) in April, Big Salmon River in November and Gaspereau River in May and Dec. Lacroix (pers. comm.[5], October 2010) indicated that the 'iBoF kelts stay in Bay/Gulf of Maine/Scotian Shelf area' and provided the following overview of findings.

> "Tags from 15 of 20 kelts tagged in 2008-2009 (75%) reported some data. Kelts from one region [Hammond River] migrated thousands of kilometers to the northern edge of the Labrador Sea and as far east as the Flemish Cap, whereas those from the other two regions [Big Salmon and Gaspereau rivers] remained in the Bay of Fundy and Gulf of Maine. Detailed migration tracks were obtained from the archived light data by geo-positioning using sunrise and sunset times. Some common behaviour patterns were revealed by examining the water temperature and depth data archived at 15-min intervals throughout the journey. Although kelts encountered a wide temperature range (-1˚C to 20˚C) they tended to exploit areas within a narrower range (5-10˚C). Kelts spent most of their time near the surface (depth <2 m) while migrating, followed by a diurnal cycle of repeated diving to >50 m during daytime when the feeding grounds were reached. There were also occurrences of deep diving in the 100-500 m range (maximum depth 700 m) along fronts and at the edge of shelves. Mortality was high and the archived parameters revealed that predation was a frequent cause. Marked changes in diving behaviour and temperature indicated that large pelagic fish with thermoregulation capabilities were predators for several tagged kelts in the Gulf of Maine."

[5] G.L. Lacroix, DFO, St. Andrews Biological Station, 531 Brandy Cove Road, St. Andrews, NB, E5B 2L9.

A synthesis of the tagging of eight Big Salmon River kelts in each of 2010 and 2011 (10 tags being of 6-month pop-off delay) and 9 Hammond River kelts with 4-month pop-off delay was not available at the time of writing. The distillate of the available information appears to be that most iBoF kelts released in either November or May remain in the Bay of Fundy and northern Gulf of Maine during the first several months at sea, possibly influenced as are post-smolts, by the residual current structure of those waters.

The deployment of PSATs should fill some of the knowledge gaps in the distribution of iBoF kelts. Publication of the migration paths of several iBoF kelts tagged in November/December and May bearing 4- and 6-month duration pop-up satellite tags (not published at the time of writing, but subsequently published as Lacroix 2013b) is expected to reveal their habitats, and by corollary perhaps those of post-smolts and maturing adults, in late winter/spring (4-6 months from a November/December tag application) and summer (4 months from a May tag application). No information is provided to determine if:

i) November/December-tagged kelts remaining in the Bay had been challenged by 'low preference' SSTs of January/February (Fig. 7b) (Amiro et al. 2003) to retreat to 'high preference' SSTs in US waters of the Gulf of Maine or Shelf waters on either side of the Canada-US boundary,

ii) May-tagged kelts reacted to available 'preferred' SSTs in May and June, and

iii) the presumed 20-year average SSTs mask the annual availability of temperatures used by kelts within the Bay of Fundy or Gulf of Maine.

Eight captive-reared origin kelts fitted with PSATs in 2008 and released from either the Point Wolfe River or a point in the Bay some 2 km offshore, also yielded some information prior to the premature release of their tags (Wissink[6], unpublished data). One kelt was tracked at large in the Bay from mid-December through the third week of January, mostly in surface waters of about 5°C (range of about 4°C-7°C). During that time it moved, to a point off Digby Neck, a straight-line distance of about 140 km. During the second week it made numerous dives, some as much as 40 m. Tag duration data for the remaining fish were not provided but end-point plots indicate that three or four others were descending the Bay. Two tags last transmitted from the Minas Basin and Minas Channel.

SUMMARY: LIFE STAGE USAGE OF ESTUARINE/MARINE HABITAT

In general, the core knowledge of regular and frequent use areas by iBoF salmon was offered in the 'Science Expert Opinion on Critical Habitat Designation for iBoF Atlantic Salmon' (DFO 2006). The additional analyses of iBoF post-smolts electronically tagged in 2001 and 2002 (Lacroix 2008, 2012) have enhanced the understanding of post-smolt residency and its' predictability in the Bay based on drainage location, dates of river exit and migratory speed. Available information which now on the basis of revised operational guidelines (DFO 2012) might be considered adequate for the delineation of the estuarine and some portion of the marine habitat important to iBoF salmon is summarized in Tables 4 and 5.

Smolts

Smolt runs monitored on the Big Salmon River suggest that the essential riverine estuarial/tidal corridors between freshwater and the sea are occupied by 90% of a run, early/mid-May through mid-June; those of the Gaspereau River possibly begin slightly earlier than the Big Salmon River and culminate by about June 1. There is less certainty about the period of occupancy of

[6] R. Wissink, Parks Canada Agency, Pacific Rim National Park Reserve, PO Box 280, 2040 Pacific Rim Highway, Ucluelet, BC. V0R 3A0 *formerly* Fundy National Park, Alma, NB.

the Stewiacke/Shubenacadie estuary because of the early release dates of monitored smolts relative to a natural smolt run but available information suggests mid-May into later June.

Post-Smolts

The observations offered in DFO (2006) on the marine distribution of iBoF post-smolts inferred from historical distributions of recaptures of tagged salmon (i.e., based on extensive tagging of smolts with conventional external plastic tags as reported by Jessop 1976, Amiro and Jefferson 1996; Amiro et al. 2003) and from the telemetry of smolts tagged with internal acoustic transmitters (Lacroix et al. 2005) provided strong evidence that the entire Bay of Fundy and much of its' immediate outflow to the eastern extremities of the northern Gulf of Maine are utilized from the time of their exit from native rivers though September. Based on historical observations, and to a lesser extent recent data, this would include Passamaquoddy Bay. Historical catches suggest that post-smolts prefer pockets of persistent cooler summer SSTs or areas known to have upwelling, eddying of cooler oceanic currents (Fig. 7a,b) and, potentially abundant food supplies such as the south shore of the Bay of Fundy in the Port George, Morden, Hall's Harbour area of Nova Scotia and on the southern flank of the Quoddy Region of south western New Brunswick, especially in July and August. There is however, little evidence as to the location of post-smolts from October into the winter.

Trawl surveys, 2001-2003, provide direct evidence of post-smolts of iBoF origin within Canadian waters of the northern Gulf of Maine southward to a line drawn westward from near Yarmouth to the Canada-US boundary, as well as insights to their habitat and forage (Lacroix and Knox 2005). The more recent analyses by Lacroix (2008 and 2012) of electronically tagged post-smolts in 2001 and 2002 inform of the spatial and temporal bounds of iBoF smolts as they exit the Bay, come and go from the Bay and in particular return to reside within and circulate in the Bay. They as well indicate that some post-smolts from iBoF rivers, unlike those from other Atlantic coast and oBoF rivers, return to and reside within the Bay of Fundy into September; others enter the northern Gulf of Maine and do not return prior to the conclusion of monitoring in 'October'. Telemetry also monitored post-smolts off Grand Manan Island both early and late into the summer, but few post-smolts were monitored entering the Passamaquoddy area/Quoddy Region in southwest New Brunswick. Many however migrated off the east coast of Grand Manan Island.

As largely indicated in DFO (2006) and more recently embellished, the data from the tagging and telemetry studies, as well as from the trawling are highly suggestive that inner Bay salmon are comprised of strict residents, coastal migrants-residents and some distant migrants. The evidence is summarized as follows:

- there is a common migration corridor for iBoF post-smolts along the coast of New Brunswick towards the outer Bay;
- many post-smolts head into the Fundy Channel just northeast of and along the southeast coast of Grand Manan Island in the concentrated southerly flow of the Bay;
- some post-smolts cross into the outer Bay in the tidal circulation and return along the Nova Scotia coast;
- some exit the Bay and enter the northern Gulf of Maine, and then return to the Bay of Fundy most often along the coast of Nova Scotia during the summer;
- not all post-smolts that were monitored leaving the Bay returned during that early marine period;
- some iBoF post-smolts were recaptured along with outer Bay and Maine-origin post-smolts in the Gulf of Maine, suggesting the possibility that iBoF smolts could be migrating to habitat further out in the Atlantic Ocean;
- post-smolt distribution seems related to major surface currents, coastal areas within the Bay and currents exiting the Bay;

- the Bay offers extensive 'favored' temperature regimes for post-smolt growth through July but becomes limiting in August before increasing in September (Fig. 7a);
- surface salinities are acceptable to post-smolts (although not generally associated with feeding adults);
- forage of post-smolts in the Bay includes an array of items including copepods, amphipods, krill, sand lance, and herring larvae common to the forage of populations elsewhere in the North Atlantic; and
- post-smolts migrate in the company of spiny dogfish and lumpfish through areas of significant herring purse-seine fisheries.

Maturing/Non-Maturing Salmon

Most iBoF populations including potentially short and longer distant migrants, first mature as 1SW fish, which in only an occasional circumstance have been recovered in historic salmon fisheries of Newfoundland or Greenland [as were oBoF populations] or even the Atlantic coast of Nova Scotia. This suggests that the first winter at sea is likely spent in an area distinct from other North Atlantic populations, possibly more proximate to their rivers of origin but void of recognized fisheries for salmon.

Overwintering sites of wild maturing salmon are as yet unknown although SSTs and recent data from electronic tagged post-smolts and satellite tracked kelts seem to suggest validity in a Gulf of Maine/Scotian Shelf hypotheses where 'preferred' SSTs (Amiro et al. 2003; Fig. 7b,c) exist. Given evidence that iBoF salmon frequent surface or near-surface waters, they would appear to be challenged in the Bay of Fundy by February and March SSTs in particular (Fig. 7b). Favorable temperatures, i.e., 4°C are evident in the Gulf of Maine but not the Bay of Fundy or on the Scotian Shelf. If the Gulf of Maine was the winter refugia, as suggested by temperature isotherms, much of the area would be outside of Canadian jurisdiction and authority and thus external to identification as Critical Habitat (EC 2009), but still important to discuss in a recovery document. Data obtained from kelts recently deployed with PSATs may offer new insight into these hypotheses (not published at the time of writing, but subsequently published as Lacroix 2013b).

Returning Adults

Historical recaptures of tagged salmon and former commercial landings in salmon gear indicate a migration of iBoF adult salmon within the Bay, June-August approaching, with the possible exception of New Brunswick/Chignecto Bay populations, their natal rivers on the inward flowing current on the Nova Scotia side of the Bay. Waters of the coast of Kings County, and eastern portion of Annapolis County, i.e., Port George to Hall's Harbour, offer SSTs that are somewhat cooler relative to the rest of the Bay, due to persistent upwelling of deeper Bay of Fundy waters (Fig. 7a). The area can be characterized as a temperature refuge supportive of forage such as herring of varied size and sand lance although the feeding intensity of these maturing salmon months and weeks in advance of ascending their rivers of origin is unknown.

The commercial landings in FSDs 35 and 40 where presumably Minas Basin iBoF salmon are first noted upon return to their river of origin, exclude neither a distant (outer Bay, Gulf of Maine, Scotian Shelf or more distant) nor inner Bay winter origin. Overwintering in the Bay if it does occur, would presumably be in 'low preference – cool' (>1 to < 4°C) waters (Amiro et al. 2003) with a moderate abundance of forage such as herring and/or sand lance (which would appear to be in greater abundance on the Nova Scotia side of the Bay (Scott 1980). The closest winter refugia with SSTs $\geq$4°C would primarily be in US waters of the Gulf of Maine (Fig. 7b).

Counts of salmon on the Big Salmon River and recreational catches in both it and the Upper Salmon River support the importance of the immediate estuaries and their riverine estuarial corridor July to October. Recreational catches in tributaries of the Central Minas Basin and

Cobequid Bay estuaries support the importance of those areas and their riverine estuaries, September and October. For the Gaspereau River, it would appear that the Minas Channel, Central Basin and its' Southern Bight are important May through August.

Kelts

The paucity of data on timing of kelt descent from their rivers to the marine environment precludes the ability to describe areas of aggregation, particularly among low gradient rivers with potentially utilizable estuaries. A preview of recent information from satellite tracking has indicated a distribution within the Bay of Fundy and Gulf of Maine although no data were provided with which to assess whether or not those in the Bay were transients or potential residents. The suggestion was that kelts most likely followed their inherent post-smolt routing along the New Brunswick coast towards the outer Bay. Satellite tracked captive-reared kelts released from the Point Wolfe area were not at large long enough to conclude that they were following any particular temperature regime or were disoriented (none of the fish had any previous exposure to the wild). Thus, until data and analyses are available, little can be offered with respect to high use areas or possible corridors of estuarine or marine habitat important to kelt re-conditioning.

PROPOSAL FOR IMPORTANT HABITAT

As reviewed herein, there is a body of evidence indicating that all post-smolts utilize a portion of the Bay for migration to nursery habitat and that some utilize virtually all the Bay for nursery (exclusive of Minas Basin and Chignecto Bay) for at least a portion of the year (DFO 2006). All returning salmon and to some presumed extent, kelts, are known to as well utilize a portion of the Bay for a portion of the year as a migratory corridor to (for spawning) and from (as kelts) their natal rivers. All returning adults and out migrating kelts as well utilize the estuarine portion of their rivers of origin to access spawning habitat and then afterwards, as possible reconditioning habitat. A simple composite of *direct and indirect* evidence of occupancy and therefore important habitat for all life stages is the tidal portions of its' 'inner Bay' rivers, and the entire Bay of Fundy outward to the northern Gulf of Maine and the US-Canada boundary, southward to latitude 43° 46' (Fig. 2) which approximates the southernmost point (in June) that a known inner Bay post-smolt (Fig. 23) has been captured, between May and October.

A disaggregation of that composite suggests eight different zones, each with a variation in function, features and attributes for each of the life stages documented there in (Table 4). Not unexpectedly, many habitats and their use by separate life stages in the Bay are widespread, overlap and are therefore difficult to define geospatially, particularly when most data are unique/non continuous. The duration of occupancy in the various zones by the principle life stages is portrayed separately in Table 5 and illustrates the potential for seasonal protection of a single zone, e.g., zone 8 to benefit more than a single life stage.

RESEARCH RECOMMENDATIONS

Table 3 [Sections 2.6.3 *in* the Recovery Strategy: DFO (2010)] lists research activities for the identification of iBoF salmon Critical Habitat in Canada that was to be incorporated into the ensuing 'Action Plan" for the species. They were:

Description of Activity	Outcome/Rationale	Timeline
1. Investigate habitat used for spawning and by post spawning salmon (kelts) as well as freshwater and estuarine survival of kelts.	Identification of potential areas of estuarine and additional areas of freshwater critical habitat, and potential limiting factors in these habitats.	2008–2010
2. Investigate habitat used by salmon kelts for reconditioning, as well as the location and timing of mortality if it occurs.	Identification of areas of marine critical habitat and potential limiting factors. Repeat spawners are important for the recovery of iBoF salmon.	2009–2011
3. Investigate migration routes for iBoF post-smolts leaving the Bay of Fundy and summer habitat used by resident post-smolts in the Bay of Fundy.	Identification of potential summer areas of marine critical habitat.	2009–2012
4. Investigate marine foraging habitat used by salmon post-smolts and comparison to that used by salmon of oBoF origin.	Identification of potential areas of marine critical habitat.	2009–2011
5. Analyze existing marine distribution data for iBoF salmon.	Identification of potential marine critical habitat areas for iBoF salmon and linkage to environmental factors and habitat activities potentially limiting survival or recovery.	2009–2011

With the exception of Activities 1 and 2 (kelts) elements of the above research recommendations have been completed. Assessments of the progress to date are as follows:

1) No data were apparent describing either the extent or quality of *estuarine* habitat for each iBoF river or its estimated temporal use by aggregates of winter or spring descending kelts. Such descriptions are necessary in order to evaluate the temporal importance of estuarine habitats to kelts. The recent acquisition of data from PSATs in 2008-2009, for some of 28 kelts monitored for up to 4 months (Wissink and Lacroix pers. comm.) may be suggestive of the use of at least one or two iBoF river estuaries and kelt survival therein (not all kelts were released to iBoF rivers or to estuaries and not all iBoF rivers to which they were released had significant estuaries, e.g., Big Salmon and Point Wolfe rivers). A description of estuarine habitats and release of PSAT-kelts into one or two rivers with significant estuaries, e.g., Shubenacadie, would better contribute to moving this 'Activity' forward.

2) The investigation of *marine* habitat used by iBoF kelts for reconditioning has made important strides but is limited herein to data collected from the above mentioned 28 kelts and to a lesser extent, acoustically tagged farm salmon released January and April/May in the Cobscook Bay, Maine (Whoriskey et al. 2006). The application of PSATs in November to kelts of the Big Salmon River and those released in/proximate to the Point Wolfe River are expected to provide insights on winter habitat and mortality (predators), while those tagged in April/May should provide insights to their summer habitat. A manuscript is nearing completion (subsequently published as Lacroix 2013b). Of the few electronically tagged Cobscook Bay farm salmon that survived long enough to find the Bay of Fundy, detections were only made down current as far as the Narraguagus Bay on the Maine coast. The high mortality in Cobscook Bay was suggested to be the result of seal predation (Whoriskey et al. 2006).

Early insights from the satellite archival tags appear to be promising with respect to migratory distribution, preferred temperatures, diving and possible areas of feeding/predation, possible predators and possible location of winter habitat. Thus, a more complete picture of iBoF salmon habitat may soon emerge. These investigations are however constrained by the use of tags with a life of little more than 4-6 months. Conceivably, locations of these first few tagged fish are suggestive of a winter retreat from the Bay to warmer water possibly in US Gulf of Maine.

While a broad approach to the investigation of factors that might explain a decline in survival of salmon was initiated by Bryan (2008), it is not clear that there is an asserted effort to actually describe the features, if any, of the habitat that might be critical to kelt re-conditioning as they remain in, or transit the Bay, e.g., abundance/availability of forage such as, sand lance, herring etc. [*ref.* Dadswell (2004) for summary preferences].

3) The movement of iBoF post-smolts within the Bay, as well as leaving the Bay has been studied both by use of electronic tags (Lacroix 2008 and 2012) and surface trawling (Lacroix and Knox 2005). The recent analysis (Lacroix 2013a) of geo-referenced multiple detection data collected by way of arrays and electronic tags in 2001-02 added considerable insights to the movement, areas of occupation/residency and physical characteristics of the habitat across detection arrays, within and at the outer reaches of the Bay, June into September, but not later. With one exception in which 'some' iBoF origin electronically-tagged fish were detected in coastal arrays within Narraguagus Bay, 85 km southwest of the Maine-NB border (Lacroix 2013a), both techniques leave gaps in the identification of the extent of summer habitat in the Gulf of Maine. Mobile tracking of electronic tags and physical and biological measures of habitat beyond the outer arrays of Lacroix (2008 and 2012) may have been considered but assessed as cost ineffective based on a low probability of tag detection. Surface trawling in Canadian waters of the northern Gulf of Maine was limited by funding and ship time to coverage in only late-May to mid-June 2001-2003, and while characterizing the habitat and food habits of numerous post-smolts outward to Cape Sable, found only five identifiable iBoF-origin fish, only one of which was as far south as Yarmouth.

   Data now being assessed from the deployment of PSATs, along with biophysical data in hand would seem to have the potential to contribute to modeling exercises capable of refining hypotheses as to the location of potential areas of oversummering (adults) and / overwintering (post-smolts and adults).

4) Investigations of early marine foraging habitat used by salmon post-smolts [presumed iBoF origin] and comparison to that used by salmon of oBoF origin were addressed to the extent possible by Lacroix and Knox (2005). Both groups of post-smolts were captured in the trawling surveys although only seven fish were identified as being of iBoF origin and no analyses were attempted or perhaps possible to discern differences in anything more than fish of wild and hatchery origins. Temperatures, salinities and predators were common to both. Post-smolt migration patterns, distribution at sea, conditions selected by foraging salmon during migration, water temperatures, ocean currents, ocean depth and prey of some *North Atlantic* and Baltic populations relative to that currently known for iBoF salmon is available (Dadswell 2004), but less instructive than actual metrics associated with iBoF salmon kelts recently released to iBoF rivers. Literature-based metrics could be corroborative once the habitat of iBoF post-smolts is fully delimited.

   Earlier use of literature-based metrics has been helpful in identifying potential foraging habitat of iBoF salmon. That analyses utilized SSTs associated with varying abundances of captured North Atlantic salmon to develop ranges of temperature utilized for superimposition on 20-year average SSTs of the Bay of Fundy, Gulf of Maine and Scotian shelf (Amiro et al. 2003). Based on these analyses, iBoF post-smolts had the potential of over summering in the Bay (where on average, a small refugia of “low preference – warm” SSTs was available in August) but would be forced to a Gulf of Maine refuge by February independent of the availability of prey. Newly acquired temperature data from habitats of post-smolts and kelts (Lacroix pers. comm.; et al. 2004 and 2006) that broaden the limits utilized by Amiro et al. (2003) by as little as 1°C do however suggest a potential for significant variance in forecasting the more limiting summer and winter habitats, especially if adequate prey were available. August SSTs in 2001 and 2002 at the outer array ranged between 12°C and 14°C (Fig. 19; Lacroix 2013a). Individual tracks of post-smolts there and at the inner array in late July and August (Figs. 17 and 20) appear to be confined to near shore locations where temperatures were 13C or less (Fig. 19) (Lacroix 2013a), i.e., ‘low preference-warm’ (Amiro et al. 2003). The abundance of prey was unknown.

Use of literature based metrics for salinity ‘preference’ of salmon found elsewhere in the North Atlantic as a proxy for iBoF salmon habitat would not seem to be helpful given the evidence that some iBoF salmon appear to reside within the Bay where surface salinities in the summers of 2001-02 seldom exceeded 31.5 ppt and, with some notable exceptions of <30 ppt, were generally between 30 and 31.5 ppt (Lacroix 2013a). Salinities of the North Atlantic where salmon have been found are ≥ 35 ppt (Reddin 2006) while those of the Baltic and Gulf of Bothnia are less than half those of the Gulf of Maine or Bay of Fundy. Similarly, the use of single or a composite of “preferred” prey in describing iBoF habitat is unlikely to have predictive capabilities given the acceptance that salmon are generally described as opportunistic feeders and that copepods, amphipods, euphausiids sand lance and various life stages of herring, the commonly cited favored prey items, appear to be abundant through parts of the Bay and its outer reaches. However there may be promise in the development of overlays of seasonal distributions of densities/abundances of salmon forage within the Bay which could suggest a potential area of occupancy designation beyond the outer Bay array.

Temporal and spatial analyses of stomach contents of post-smolts (Lacroix and Knox 2005) might be instructive in determining whether the year or location effect is driving the forage of equal sized post-smolts. A similar analysis with known river-origin post-smolts detected at the outer arrays and smolts captured in the same year in the same area by surface trawl (Lacroix 2008) might as well be instructive with respect to an opportunistic feeding behaviour of different populations. The ‘opportunistic feeding’ hypothesis of inner and outer Bay origin populations could in fact be tested with data from Lacroix and Knox (2005) by comparing the stomach contents of similar sized wild post-smolts of respective origins in the same tow. This presumes that the sample size for at least one year is adequate to do so. In summary, there are known high use areas that could be described as important habitat on the basis of available forage. Direct assessment (real or desk) of the characteristics of habitat of summer and winter habitat now being suggested by recently acquired data from kelt and post-smolt activities will further contribute to existing knowledge and should better enable the identity of functions which accompany those observations. In this context, the efforts of Renkawitz and Sheehan (2011) and Sheehan et al. (2011) should be useful.

5) Activities 1-4 will yield key information on the marine distribution for iBoF salmon and contribute to new inclusions or an expansion of the here-in proposed zones of important habitat. Evidence of recent concerted efforts to elaborate on environmental factors affecting the distribution of iBoF smolts appears to be limited to the work of Bryan (2008); the results could be termed largely inconclusive. There were no apparent efforts to further investigate anthropogenic threats that might be linked to limiting the survival or recovery of iBoF salmon. Suggestions re: linkages between environmental variables and marine distribution of organisms were made in Activity 4 but linkage between potential ‘important habitat’ and habitat activities that meet existing criteria for limiting survival or recovery will be challenging

and perhaps impossible to identify, i.e., few if any anthropogenic activities are likely to be considered as significantly destructive to the important habitat of iBoF salmon per se, and reason for their decline.

ADDITIONAL RESEARCH

While the focus of research should remain on the foregoing, some lower prioritization activities (DFO 2010) can be regarded as subsets/corollaries of the above five activities, but at a finer scale. However, marine research is costly and resources for same are scarce.

- Investigate marine habitat use, including spatial and temporal use of habitats throughout the year (particularly in winter) with an emphasis on identifying limiting factors.

  [requires results from on-going investigations before meaningful investigations can be designed both inside and outside the Bay]

- Identify which habitat factors are most limiting recovery and which mitigation options would provide the most effective improvement in habitat quantity or quality.

  [requires an understanding of changes in the physical oceanography of the Gulf of Maine such as is being suggested by Smith et al. (2012) and possible changes in the composition of the ecosystem over time through overfishing, method or season of fishing, changes in seal population, etc.. An analysis of change for the western Scotian Shelf or Gulf of Maine on the scale conducted by Choi et al. (2004) for the eastern Scotia Shelf would be informative but perhaps inconclusive]

ADDITIONAL CONSIDERATIONS

- Bryan (2008) investigated the relationship between a large number of physical and indexes of biological abundance data and the decline of salmon. In the absence of definitive conclusions, he suggested that effects are more than likely multiple and although this may not provide information totally relevant to important habitat, could be achieved at little cost relative to ongoing field programs (Activity 5).
- Friedland et al. (2003) noted that ocean thermal conditions on the east coast (SST contours) differed between 1986 and 1998 by as much as 2°C. Amiro et al. (2003) established a 20-year mean contoured map of SSTs for the Bay of Fundy, Gulf of Maine and a portion of the Scotian Shelf. If data were sufficient, 5-year or less ‘mean’ contours through 2012 might provide a better understanding of the variability or lack thereof in SST isopleths and their expansion/contraction, or perhaps trend in habitats defined as ‘preferred’ temperatures of salmon (Activity 5).
- Recent satellite tracking of kelts is currently limited by the six month duration of batteries and will leave significant gaps in their annual distribution. The six months of data would, however, be a starting point for investigators using surface currents, and patterns of SSTs in the Bay of Fundy, Gulf of Maine and Scotian Shelf along with kelt migration speeds to model the trajectories (Booker et al. 2008) and habitat utilized by kelts during reconditioning, overwintering and subsequent return as consecutive repeat spawners (Activity 4).

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TABLES

Table 1. Dates of operation and capture of first, last and 10, 50 and 90% of smolts in rotary screw traps on the Big Salmon and Stewiacke rivers and at a bypass trap at the White Rock Generating Station on the Gaspereau River, 2002-2010. Big Salmon River data for 2002-2005 in Fig. 5 of Flanagan et al. (2006) and for 2006-2010, from R. Jones (pers. comm.); Stewiacke and Gaspereau rivers data from J. Gibson (pers. comm.). Capture efficiency varies with flow but herein is assumed to be constant, i.e., if a large number of smolt emigrated during a flood event when capture efficiency is low, then the dates would be erroneous.

River by Year	Dates of Operation	First Day	Percentiles of Smolt Run (by Dates)			Last Day
			10%	50%	90%	
Big Salmon River						
2002	Apr 30 - Jun 18	May 03	May 10	May 22	May 27	Jun 18
2003	May 07 - Jun 17	May 08	May 21	May 26	Jun 02	Jun 17
2004	May 03 - Jun 29	May 04	May 14	May 23	Jun 16	Jun 28
2005	May 04 - Jun 26	May 04	May 17	May 26	Jun 02	Jun 23
2006	Apr 29 - Jun 15	May 01	May 07	May 13	May 20	Jun 09
2007	May 02 - Jun 20	May 04	May 12	May 26	Jun 05	Jun 17
2008	May 02 - Jun 15	May 02	May 07	May 15	May 28	Jun 07
2009	Apr 27 - Jun 23	Apr 27	May 11	May 18	May 22	Jun 15
2010	Apr 28 - Jun 18	Apr 29	May 03	May 09	May 21	Jun 16
Stewiacke River						
2006	May 04 - Jul 11	May 06	May 12	May 30	Jun 04	Jun 08
2007	May 01 - Jun 28	May 06	May 19	Jun 04	Jun 12	Jun 21
2008[a]	May 08 - Jun 24	May 14	May 20	May 30	Jun 12	Jun 14
Gaspereau River						
2002	May 08 - Jun 02	May 08	May 14	May 19	May 28	Jun 01
2003	May 08 - Jun 06	May 08	May 10	May 20	May 24	May 31
2005	May 04 - May 27	May 04	May 05	May 09	May 16	May 19

[a] Trap was not checked every day.

Table 2. Thirteen groupings of wild and hatchery smolts tagged and subsequently monitored as post-smolts by river and year, dates of release and passage time between entry to and exit from the Bay of Fundy (Lacroix 2013a) where 'days' to outer array are interpolated from Fig. 5 in Lacroix 2008). Lacroix (2008) combined the five Stewiacke and Gaspereau river fish into a single Minas Basin group for analyses and illustration.

River	Location within Bay	Year	Source	Release dates	Number smolts tagged	Number post-smolts monitored	Approx. avg. no. days to outer array
Stewiacke	Distant inner/ Minas Basin	02	Hatch	May 08	40	2	34
Gaspereau	Distant inner/ Minas Basin	02	Hatch	May 08	39	3	26
Upper Salmon	Intermediate / Cobequid Basin	01	Wild	Jun 08 -15	24	19	16
Upper Salmon	Intermediate/ Cobequid Basin	02	Wild	May 24 -31	66	46	25
Big Salmon	Intermediate/ inner Bay NB	01	Wild	May 25 - Jun 15	117	84	12
Big Salmon	Intermediate/ inner Bay NB	02	Wild	May 18 – Jun 10	59	33	18
Big Salmon	Intermediate/ inner Bay NB	02	Hatch	May 29	20	17	21
Big Salmon	Intermediate/ inner Bay NB	02	Hatch	Jun 05	20	15	13
Big Salmon	Intermediate/ inner Bay NB	02	Hatch	Jun 17	36	18	11
Nashwaak	outer Bay NB	02	Wild	May 08 -15	40	15	17
Nashwaak	outer Bay NB	02	Hatch	May 20	20	6	5
Saint John	outer Bay NB	01	Hatch	Jun 7	21	7	3
Saint John	outer Bay NB	02	Hatch	May 21	20	9	9

Table 3. Location and month of recapture of one-sea-winter (1SW) and multi-sea-winter (MSW) adults tagged between 1967 and 1973 as smolts in the Big Salmon River (from Ritter 1989).

		Month of Recovery						
Location	**Sea Age**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
BSR Counting fence	1SW	-	1	11	25	31	4	-
	2SW	-		-	-	1	-	-
NB Middle Fundy	1SW	-	-	-	1	1	-	-
	2SW	-	-	3	-	-	-	-
NB Lower Fundy	1SW	-	-	-	-	-	-	-
	2SW	-	-	-	1	-	-	-
NS Lower Fundy	1SW	-	-	1	1	-	-	-
	2SW	-	1	-	-	-	-	-
Nfld Area J2	1SW	-	-	-	-	-	-	-
	2SW	-	1	-	-	-	-	-

Note: Cells with dash indicate no data.

Table 4. Summary of the location, biophysical functions, features, and attributes of eight zones of estuarine/marine habitat important to iBoF salmon.

Geographic Location of Habitat	Life-Stage	Function	Feature(s)	Attribute(s)
1. Estuarine areas within 19 iBoF rivers	Smolt	-Migration to the sea for growth & maturation (May-June)	-Corridor between freshwater & Bay estuaries	-Sufficient discharge & cool-moderate temperatures for; prey & predators; > salinity
	Adult	-Migration to freshwater for spawning (May-Oct) -Resting/ staging/ fresh-water re-acclimation (May-Oct)	-Corridor between Bay estuaries & freshwater -Holding pools	-Raise in river discharge & moderate- cool temperatures for ascent; < salinity -Depth, volume & overhead cover; cool water
	Kelt	-Migration to the sea for re-conditioning, (winter/spring)	-Corridor between freshwater & Bay estuaries	-Sufficient discharge & cool temperatures for holding/descent; - > salinity
2. Minas Basin, Chignecto Bay & coastal estuaries	p-smolt	-Migration to oBoF (May-Jun) -Feeding (May-Sep)	-Corridor to outer Bay; -Food availability	-Salinity increases to 31 ppt; predators -Pelagic prey inc. copepods, amphipods, euphausiids, fish larvae
	Adult	-Migration to freshwater (May-Oct) -Staging -Feeding (extent unknown)	-Corridor to freshwater -Estuaries -Food availability	-Temperatures ≤14°C while awaiting cues for river entry -< salinity; temperatures <14°C while awaiting cues for river entry -Pelagic prey inc. amphipods, euphausiids, fish larvae
	Kelt	-Migration to the oBoF & re-conditioning, (winter/spring) -Feeding	-Corridor to outer Bay -Food availability	-> salinity for re-acclimation to salt water -Forage: Minas Channel/ Basin with juvenile and adult herring, juvenile white hake, winter flounder, adult & juvenile 3-spine stickle back
3. BoF NB coastal outflow	p-smolt	-Migration (May-Jul) -Feeding (May – Jul) and to Sep)	-Corridor -Food availability thru Sept (for ‘residents circulating in the BoF gyre)	- surface outflow of the BoF gyre to outer Bay & northern Gulf of Maine; SSTs ≤ 14°C; > salinity -Pelagic prey; inc. copepods, amphipods, euphausiids, fish larvae (June-Oct) but unlikely as abundant as on NS coast; SSTs ≤14°C thru Sep
	Adult	-Migration (NB /Chignecto Bay populations probable) (May into Sep) -Feeding (extent unknown)	-Corridor -Food availability	-Surface outflow of the BoF gyre: maintenance of home-river plumes; SSTs ≤14°C, likely cooler at depth -Pelagic prey inc. amphipods, euphausiids, fish larvae & older although herring unlikely as abundant as on NS coast
	Kelt	Unknown		
4. Passamaquoddy Bay/ “Fundy Isles”	p-smolt	-Migration (Jun-Sep) -Feeding (Jun-Sep)	-Estuary -Refugia -Food availability	-SSTs < 14°C -SSTs slightly cooler than outer Bay -Forage of copepods, amphipods, euphausiids, fish larvae & older, esp. herring

Geographic Location of Habitat	Life-Stage	Function	Feature(s)	Attribute(s)
	Adult	Unknown		
	Kelt	Unknown		
5. Middle Bay of Fundy	p-smolt	-Feeding (May-Sep)	-Food availability -Gyre	-Forage inc. copepods, amphipods, euphausiids, fish/ herring larvae & sand lance entrained from inflowing waters to the Bay -Counter clockwise surface currents; some stratification in center leaving cooler waters toward NS coast; passive drift & entrainment within of food & possibly p-smolts recruited from coastal inflow (zone 8); extreme advection on flood and ebb tides; water clarity & SSTs ≤14°C
	Adult	Unknown		
	Kelt	Unknown		
6. Northern Gulf of Maine	p-smolt	-Feeding (Jun into Sep)	-Food availability -Upwelling of Scotian Shelf waters	-Amphipods, copepods, inc. *Calanus* sp., euphausiids, sand lance & fish larvae, esp. larval herring -SSTs <14°C; coolest and richest of all habitats esp. in August
	Adult	Unknown		
	Kelt	Unknown		
7. Bay of Fundy coastal Nova Scotia: Yarmouth to Port George	p-smolt	-Migration (Jul into Sep) -Feeding (Jul-into Sep)	-Corridor -Food availability	-Inflow portion of gyre influenced by Shelf waters; SSTs ≤14°C -Forage of copepods, inc. *Calanus* sp., amphipods, euphausiids, fish larvae, sand lance & larval herring
	Adult	-Migration (Jun-Aug) -Feeding (extent uncertain)	-Corridor -Food availability	-Inflow portion of gyre influenced by Shelf waters; SSTs ≤14°C -Forage: amphipods, euphausiids, fish larvae, sand lance & herring
	Kelt	Unknown		
8. Bay of Fundy coastal NS, Port George-Hall's Harbour	p-smolt	-Feeding (Jul into Sep)	-Food availability -Upwelling of Bay water cooler than center gyre	-Forage of copepods, inc. *Calanus* sp., amphipods, euphausiids, fish larvae, sand lance & larval herring -SSTs <14°C; rich cool waters
	Adult	-Staging (Jun-Aug) -Feeding (extent uncertain) (Jun-Aug)	-Upwelling of Bay water -Food availability	-SSTs <14°C; rich cool waters -Forage: amphipods, euphausiids, fish larvae, sand lance & spawning herring
	Kelt	Unknown		

Table 5. Summary of usage of 8 estuarine/ marine areas by iBoF salmon. '(' = Big Salmon, Point Wolfe and Upper Salmon rivers, i.e., NB rivers ')' = Minas Basin rivers but limited to information from just 5 tagged post-smolts (p-smolt); '()' for NB and Minas Basin rivers, and 'i' for Gaspereau River where it deviates. Shaded cells = no data; open cells = not known to be present; colored cells = riverine estuaries, Bay estuaries and Bay habitats.

Habitats	Life-Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
1. Estuarine portions of salmon rivers	Smolt									(	()	()	)												
	Adult										i	i	i	(i	(i	(	(	()	()	()	()				
	Kelt																								
1. iBoF coastal estuaries, Minas Basin and Chignecto Bay	p-smolt									(	()	()	)												
	Adult										i	i	i	(i	(i	(	(	()	()	()	()				
	Kelt																								
1. BoF NB coastal outflow	p-smolt									(	()	()	()	()											
	Adult																								
	Kelt																								
1. Passamaquoddy / 'Fundy Isles'	p-smolt		(											(	(	(	(	(							
	Adult																								
	Kelt																								
1. Middle Bay of Fundy	p-smolt											()	()	()	()	()	()	()							
	Adult																								
	Kelt																								
1. Northern Gulf of Maine	p-smolt										(	(													
	Adult																								
	Kelt																								
1. BoF coastal SW Nova, Yarmouth to Port George	p-smolt													(	(	(	(								
	Adult																								
	Kelt																								
1. Bay of Fundy coastal NS, Port George-Hall's Harbour	p-smolt													(	(	(	(								
	Adult												()	()	()	()	()								
	Kelt																								

FIGURES

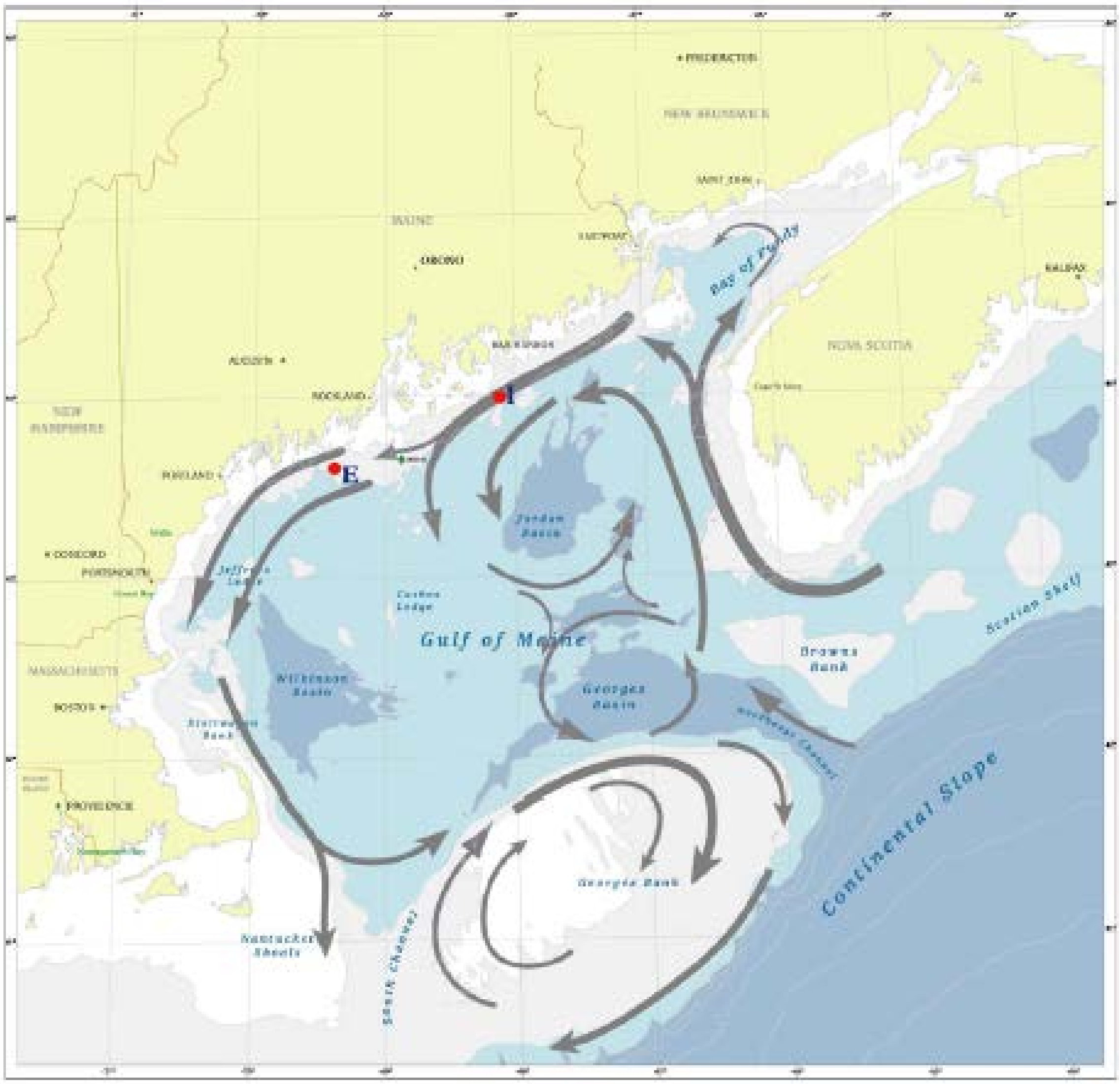

Figure 1. Summer schematic circulation diagram for the upper 40 m in the Gulf of Maine. The red dots marked E and I indicate the locations of real-time GoMOOS (Gulf of Maine Ocean Observing System) buoys that have been measuring currents since the summer of 2001 (Pettigrew et al. 2005).

Figure 2. Bay of Fundy, Northern Gulf of Maine and dividing line (red). Approximate positions of outer Bay arrays in 2001 and 2002 (left; 'mouth' of the Bay), inner Bay arrays in 2001 and 2002 (right) and Fundy Isles array (Lacroix 2008 and 2012); Canada-US boundary; fishing communities of Pt. George, Morden, Harbourville, and Halls Harbour, NS (yellow balloons), and 10 rivers having remnant populations within the Live Gene Bank program (DFO 2010): 1) Big Salmon, 2) Point Wolfe, 3) Salmon, 4) Economy, 5) Portapique, 6) Great Village, 7) Folly, 8) Debert, 9) Stewiacke (at its confluence with the Shubenacadie, and 10) Gaspereau. Symbol by 'Stew' identifies site of Stewiacke adult counting fence (Amiro and Jefferson 1996) proximate to the limit of the highest tides. Lacroix (2012) referred to river (1) as inner Bay coastal, rivers (2) and (3) as those of Chignecto Bay and rivers (9) and (10) as those of Minas Basin.

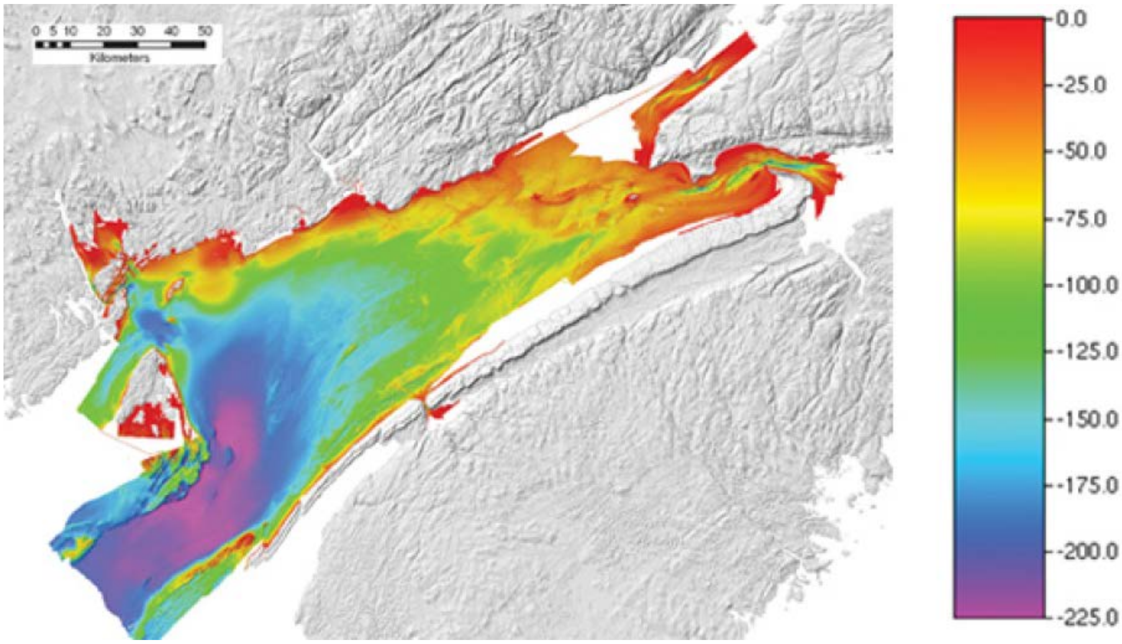

Figure 3. Bathymetry of the Bay of Fundy (data from 1992 to November 2008) with depth in meters.

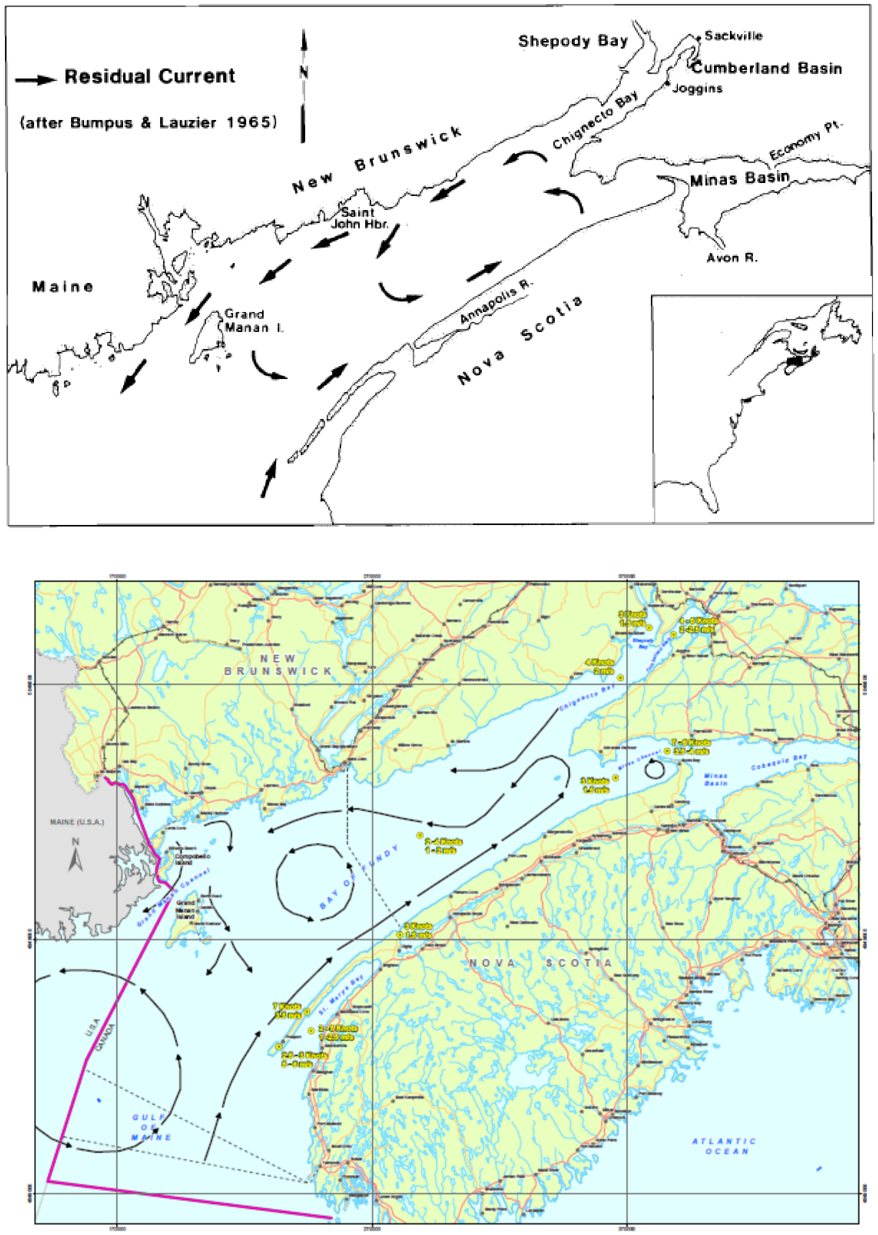

Figure 4. Bay of Fundy showing residual surface currents. Top panel, from Dadswell et al. (1983), based on Bumpus and Lauzier (1965); lower panel given as Fig. 5.2 in Whitford (2008).

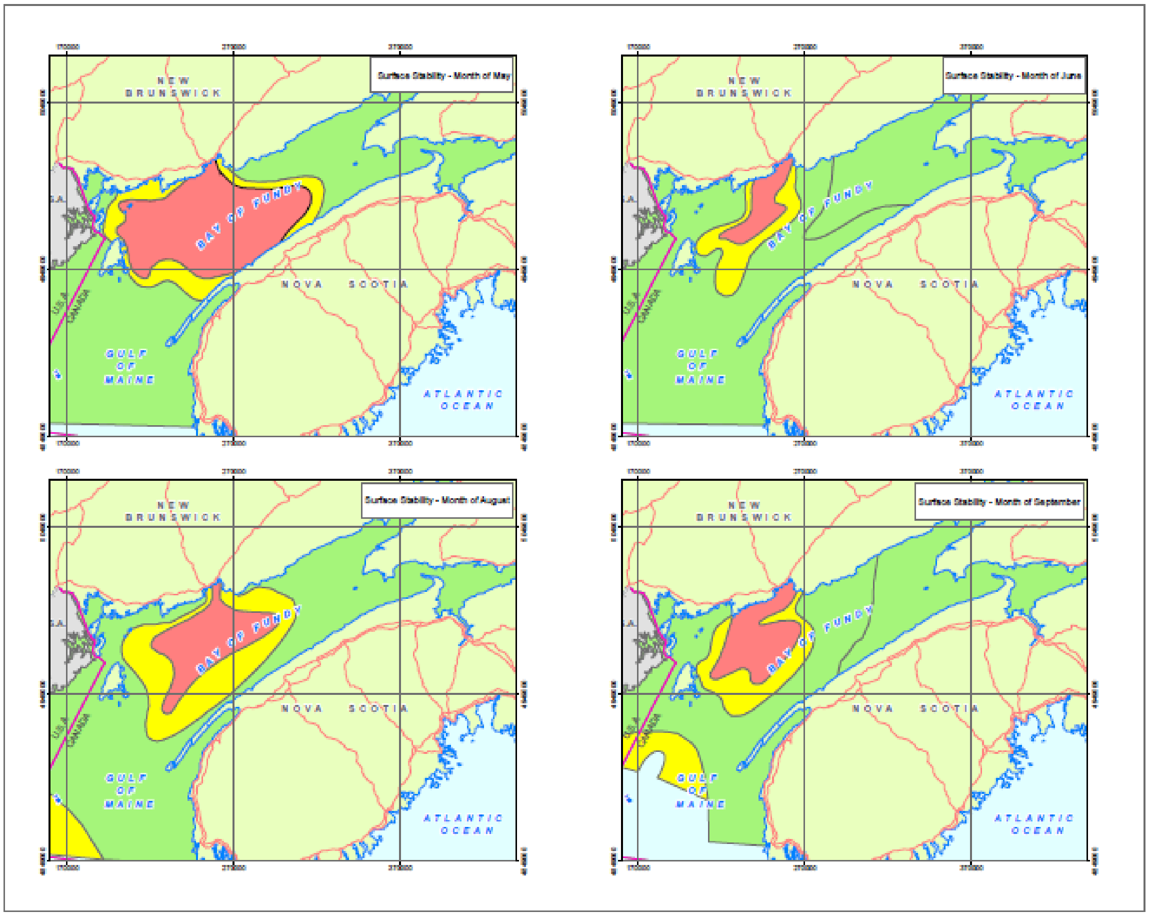

Figure 5. Surface stability (stratification) in the Bay of Fundy in May (upper left panel), June (upper right panel), August (lower left panel) and September (lower right panel). Legend: green is 'well mixed', yellow is 'frontal' and red is 'stratified'. (Fig. 5.12 in Whitford 2008).

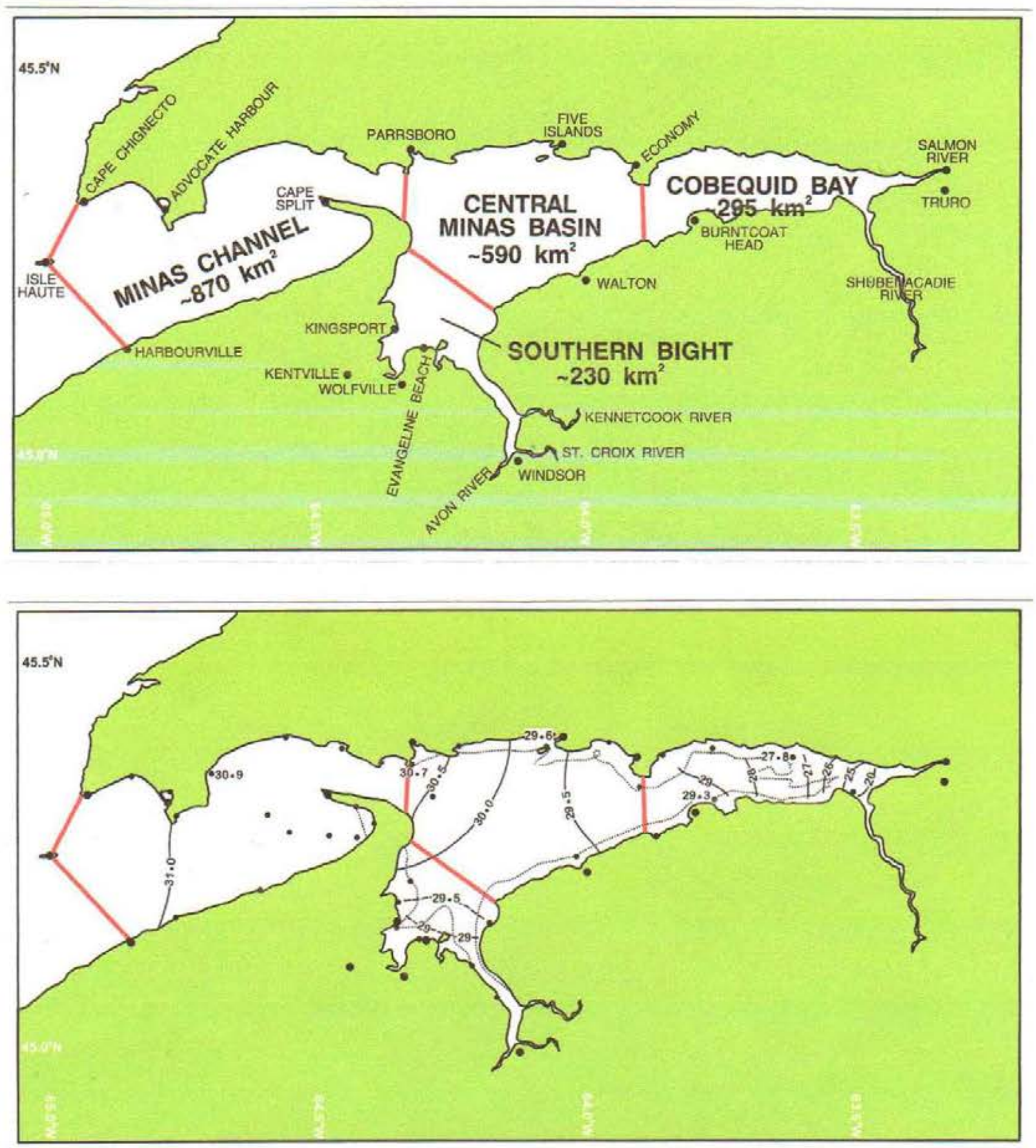

Figure 6. Minas Basin: upper panel – the four eco-regions and their surface areas; lower panel – summer surface salinity (ppt) at low water from June 25 to August 2, 1958 (extracted from Parker et al. 2007).

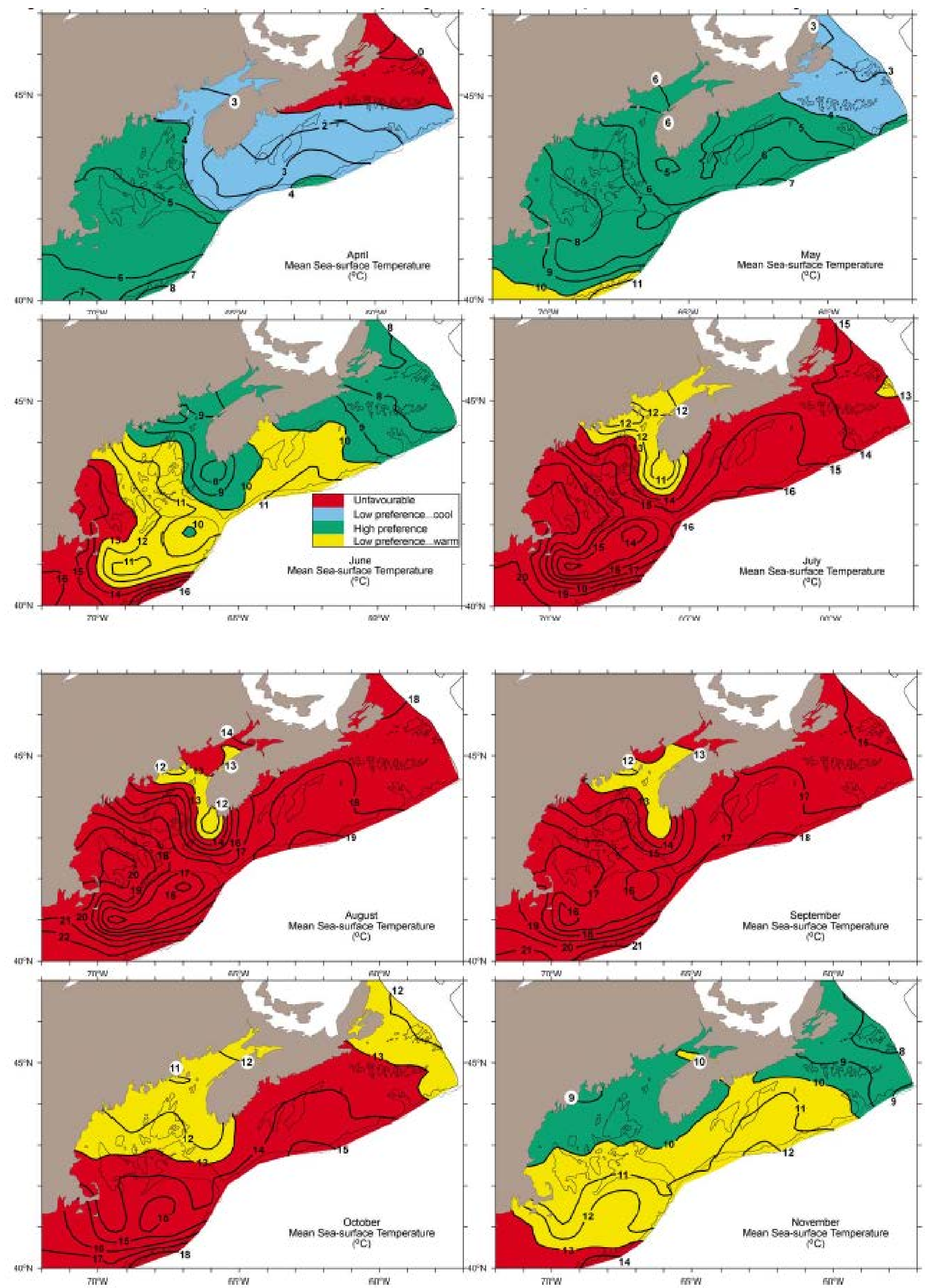

Figure 7a. Average monthly SSTs for April through November as derived from satellite data, 1981-2000. Colour indicates the estimated temperature "preference" regions for salmon where red = unfavourable; blue = low preference (cold); green = high preference; and yellow = low preference (warm). Figure from Amiro et al. (2003).

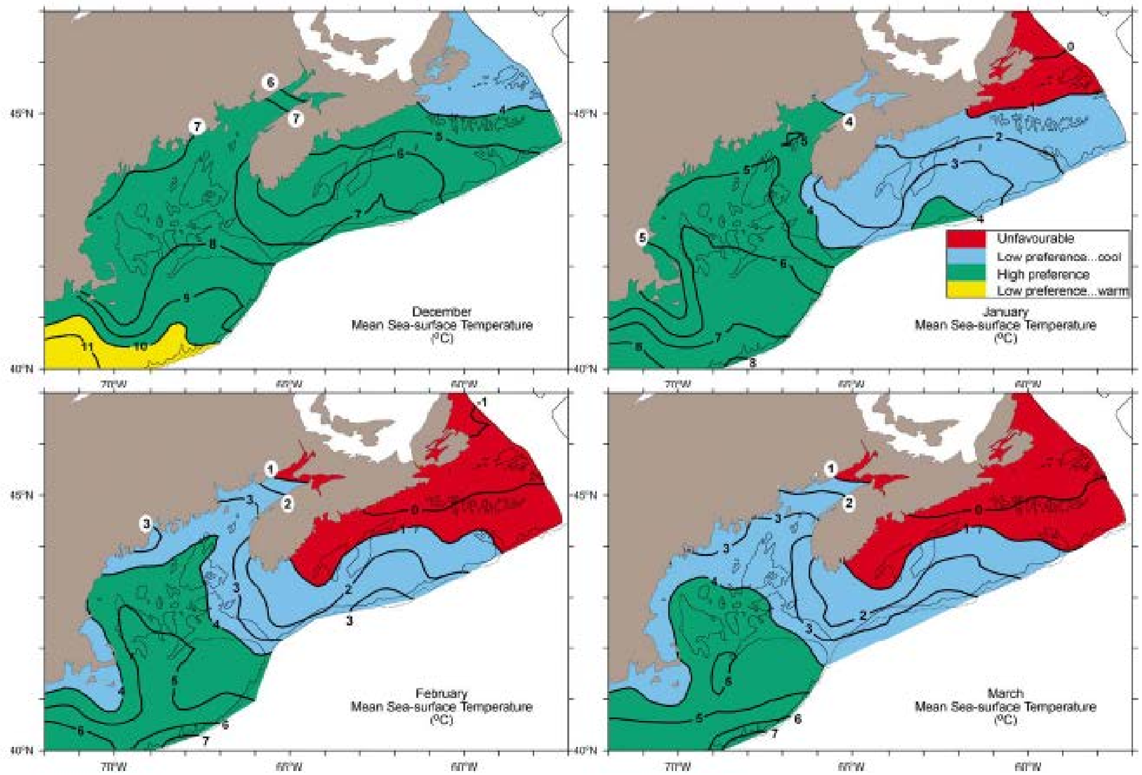

Figure 7b. Average monthly SSTs for December through March as derived from satellite data, 1981-2000. Colour indicates the estimated temperature "preference" regions for salmon where red = unfavourable; blue = low preference (cold); green = high preference; and yellow = low preference (warm). Figure from Amiro et al. (2003).

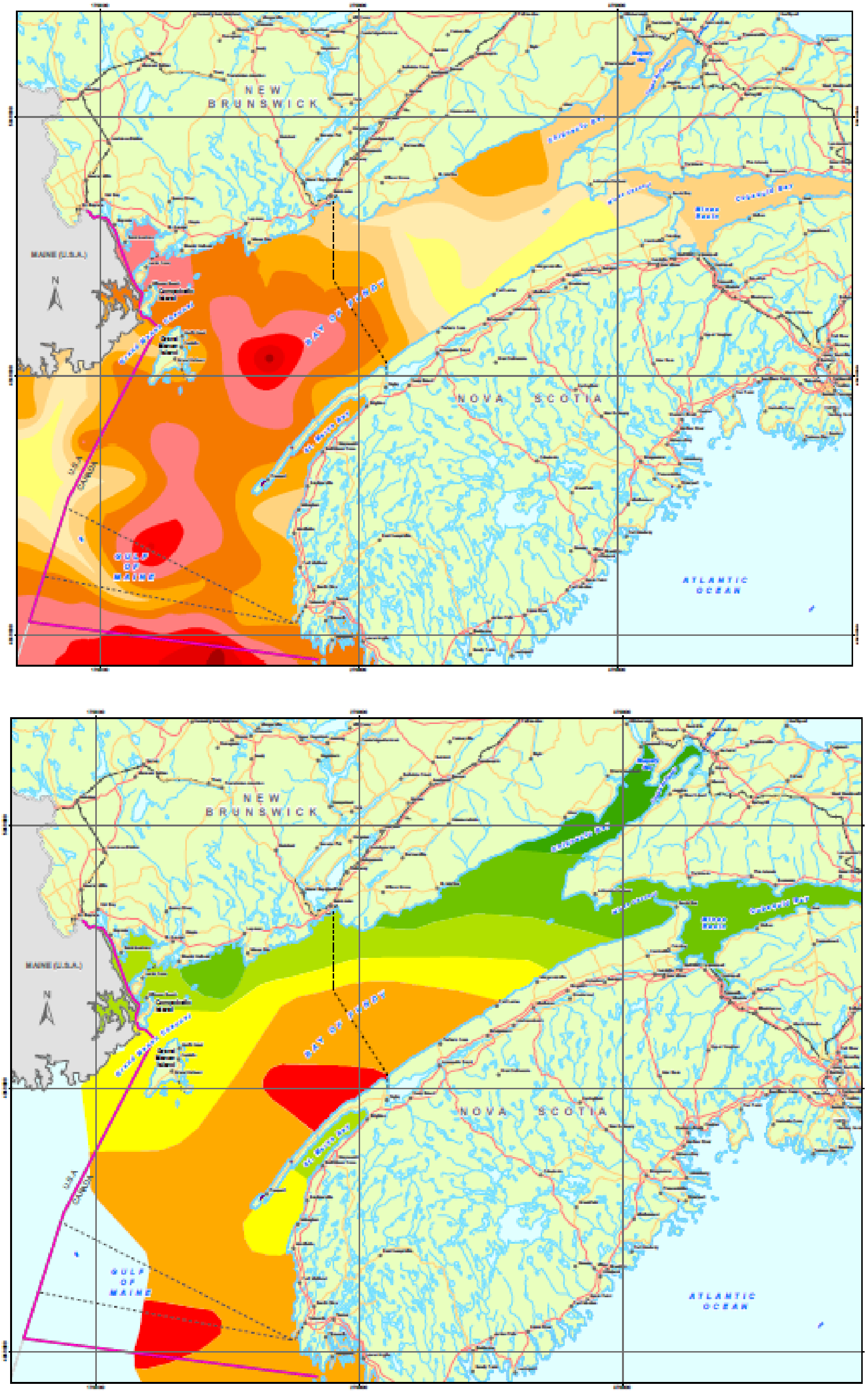

Figure 8. Copepods in the Bay of Fundy. Diversity of copepods (upper panel) increasing from 6.0-7.5 in yellow, through increasingly darker hues to 15.0-16.0 in red and 18.0-19.0 in brown, and distribution of Calanus finmarchicus (lower panel) where numbers per m ^{3} increase from green through red (Figs. 5.14 and 5.15 in Whitford 2008).

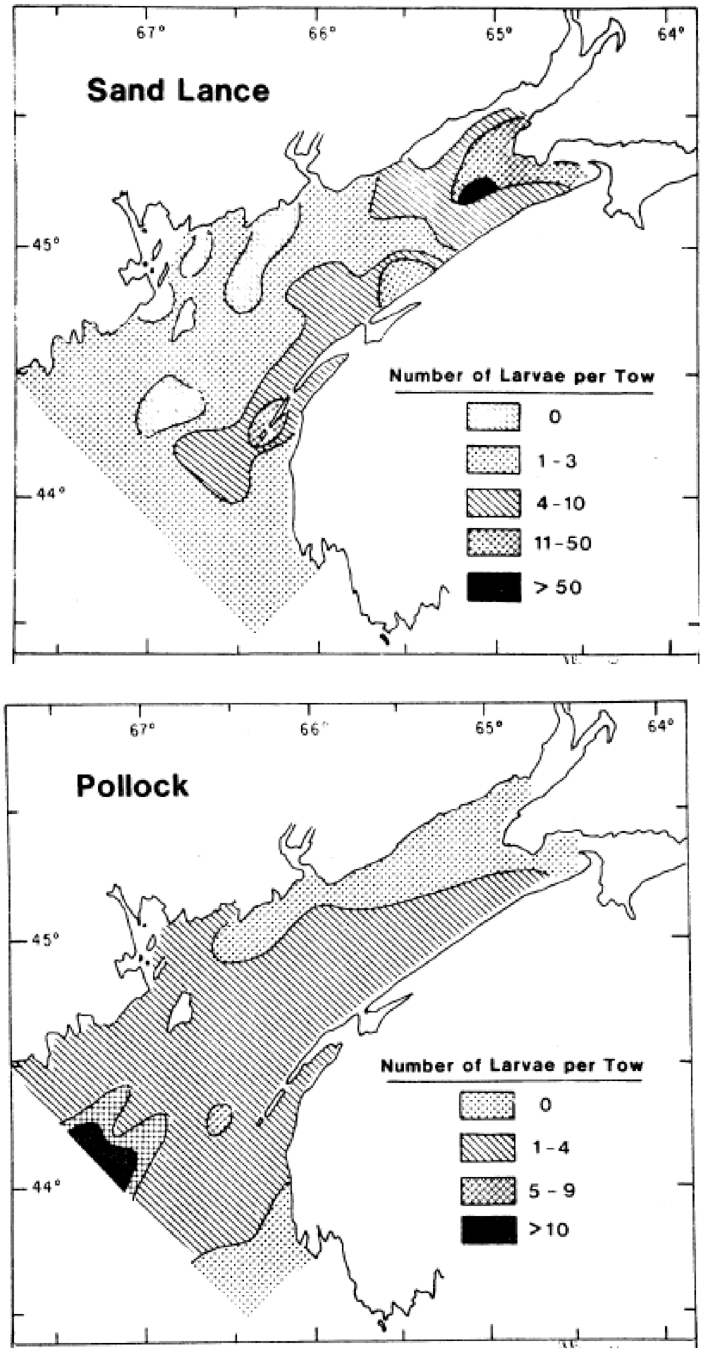

Figure 9. Distribution of sand lance larvae (upper panel) and Pollock larvae (lower panel) in the Bay of Fundy, March 1979 (Scott 1980).

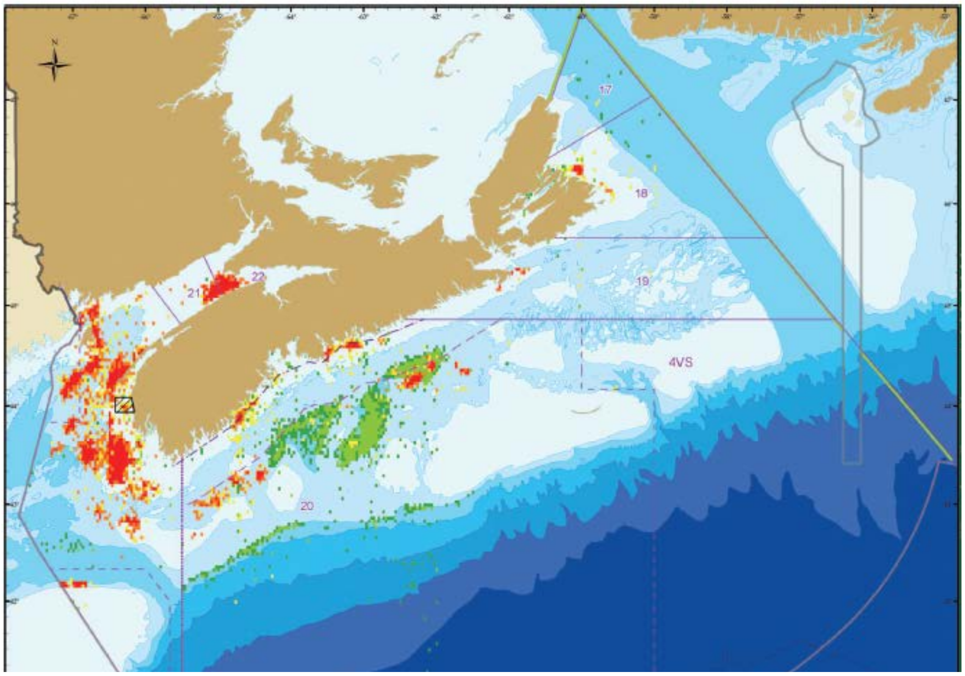

Figure 10. Herring landings (1999-2003) where red represents the highest category (142-27,001 t). (DFO 2005b).

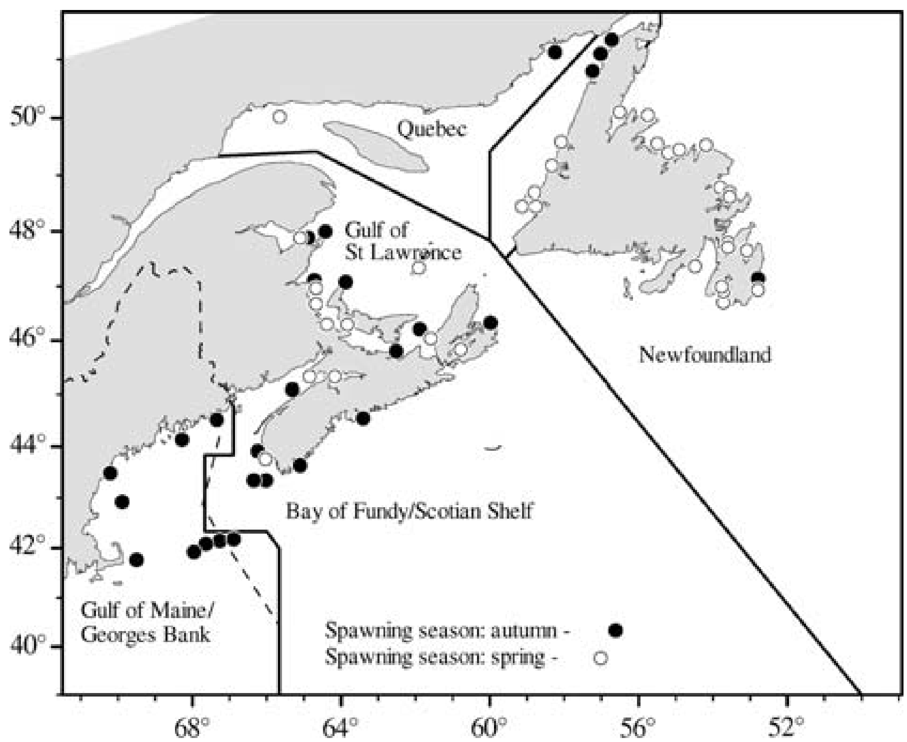

Figure 11. Spawning areas and seasons (dots, autumn; open circles, spring), and management units used for herring in the western Atlantic (Stephenson et al. 2009).

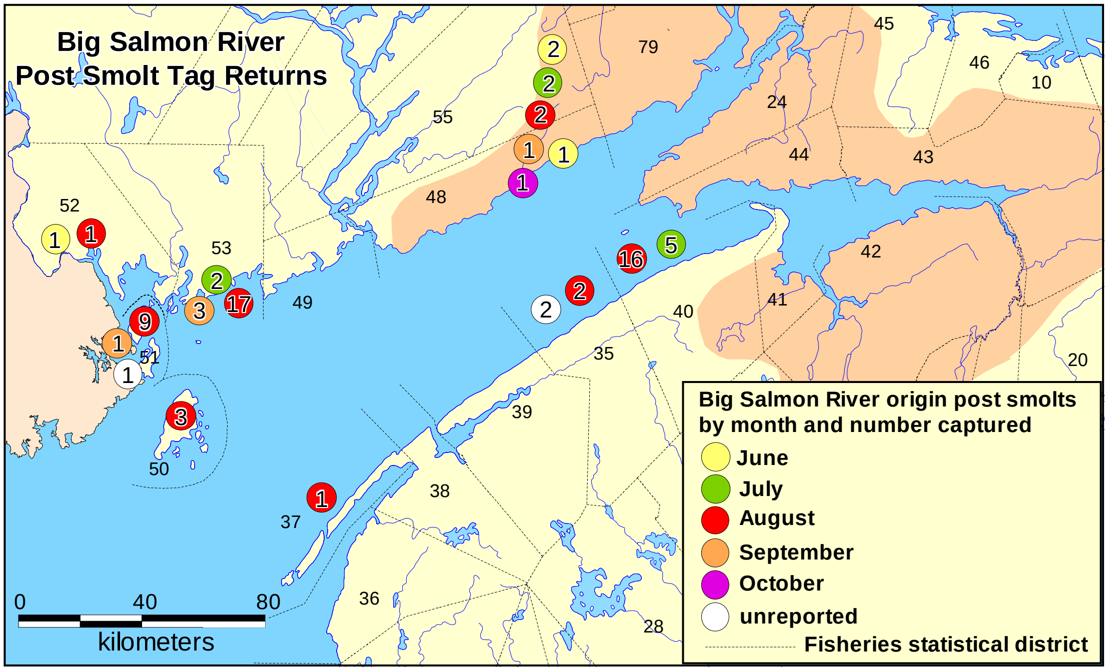

Figure 12. Locations and numbers of recaptures of tagged wild and hatchery Big Salmon River post smolts by month of recapture (Amiro et al. 2003).

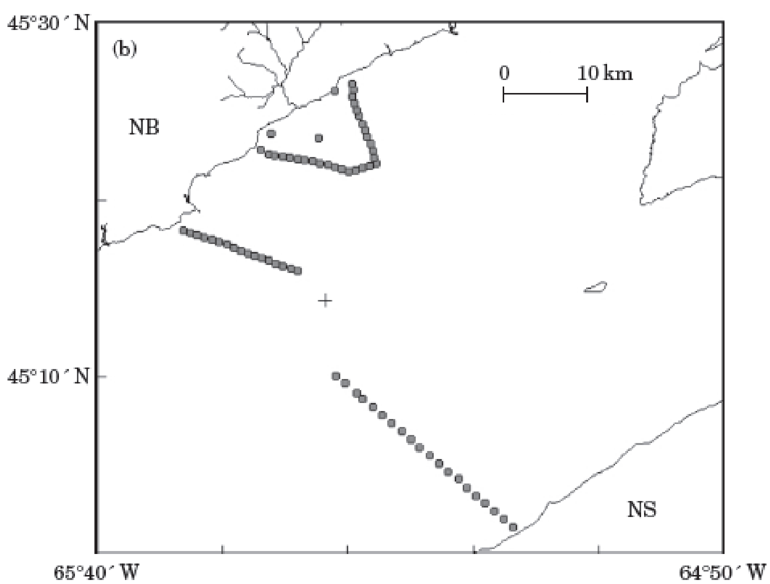

Figure 13. Location of the three coastal monitoring arrays deployed to detect the movements of post-smolts in 1999. The position of Quaco Ledge (+) is shown for cross reference (Fig. 1b in Lacroix et al. 2005).

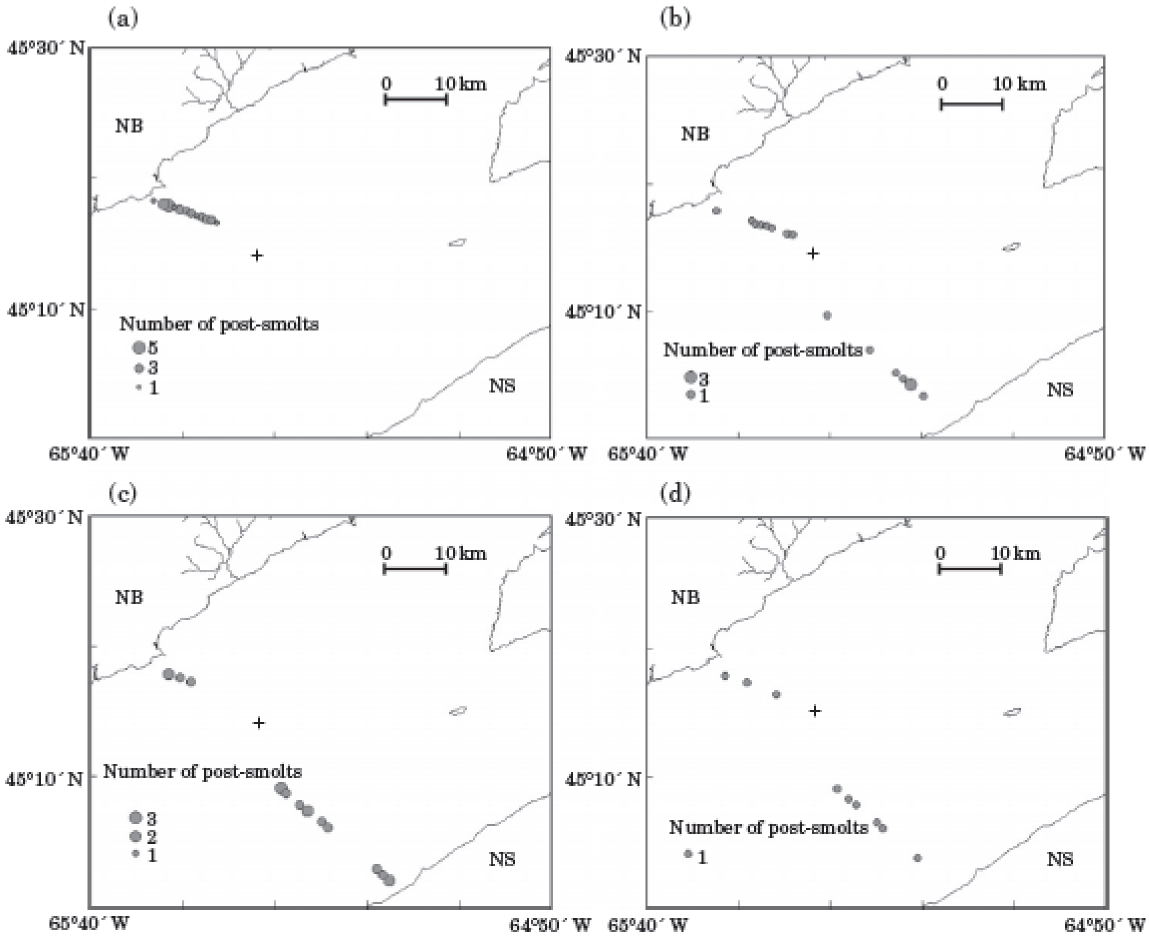

Figure 14. Position of post-smolts from Group 2 along the New Brunswick and Nova Scotia monitoring arrays: upper right panel (a) when they first moved out of the Bay, upper left panel (b) when some post-smolts first moved back to the area monitored, lower panel left (c) when some moved out of the area for a second to fourth time and lower panel right (d) when some moved back to the area for a second to third time. The position of Quaco Ledge (+) is shown in all maps for cross reference (Fig. 3 in Lacroix et al. 2005).

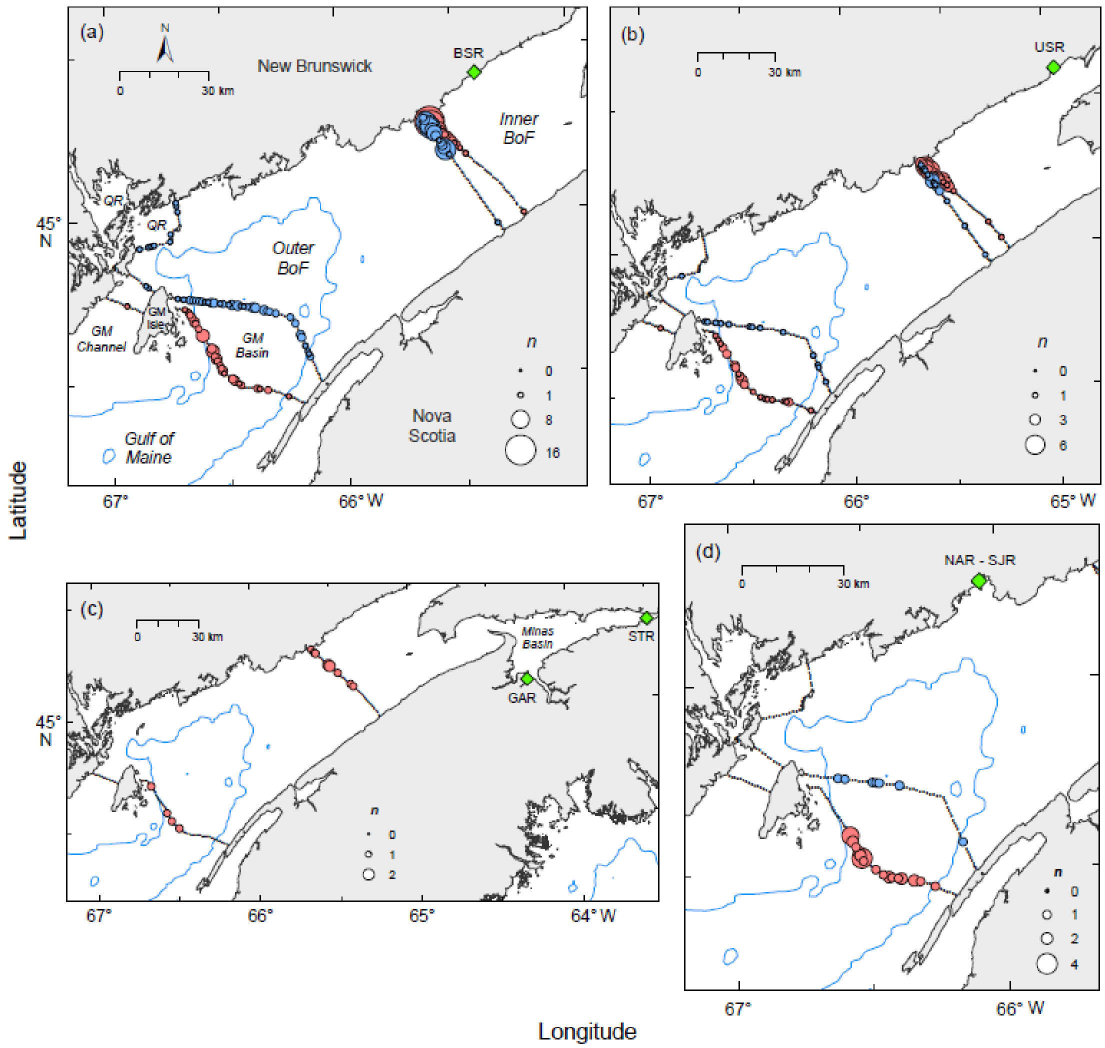

Figure 15. Maps of the monitoring arrays in the Bay of Fundy (BoF) showing the distribution and abundance of migrating Atlantic salmon post-smolts in 2001 (graded blue circles) and 2002 (graded red circles) based on the site of first detection on an array for tagged fish from: (a) the Big Salmon River (BSR) with wild and hatchery fish combined, (b) the Upper Salmon River (USR), (c) the Minas Basin rivers (MBR), and (d) the Nashwaak (NAR) and Saint John (SJR) rivers with wild and hatchery fish and both rivers combined. The scale for number of post-smolts (n) at a site, and the 100 m isobath (blue line) are shown in each panel. The Quoddy Region (QR), and Grand Manan (GM) Island, Channel, and Basin are identified in panel (a) (Fig. 5 in Lacroix 2013a).

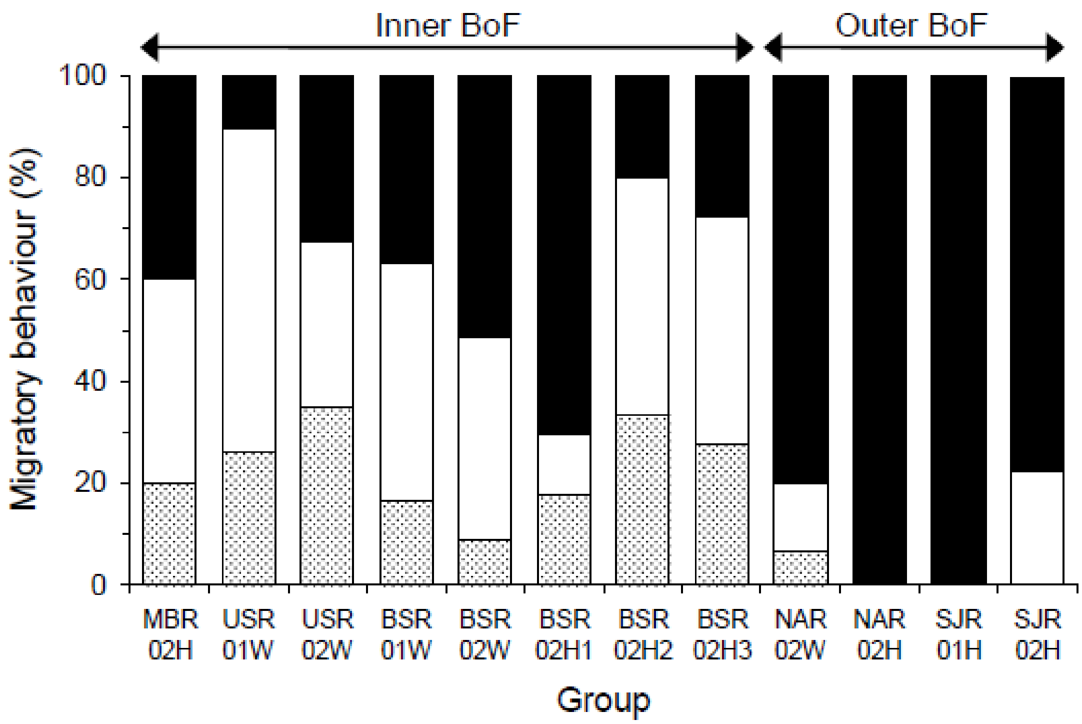

Figure 16. Migratory behaviour of Atlantic salmon post-smolts of inner and outer Bay of Fundy (BoF) origin showing the proportion of each group classified as strict residents of the BoF (shaded), coastal migrants and residents of the BoF and Gulf of Maine (open), and distant migrants (solid). MBR = Minas Basin rivers; USR = Upper Salmon River; BSR = Big Salmon River; NA = Nashwaak River; and SJR = Saint John River; year (01 = 2001; 02 = 2002), origin (H = hatchery; W = wild), and hatchery release sequence of 1, 2 or 3. (Fig. 4 in Lacroix 2012). No account has been taken of mortalities or predation and in the case of all MBR and outer BoF rivers only 5 and 37 post-smolts, respectively, were detected (see Table 2).

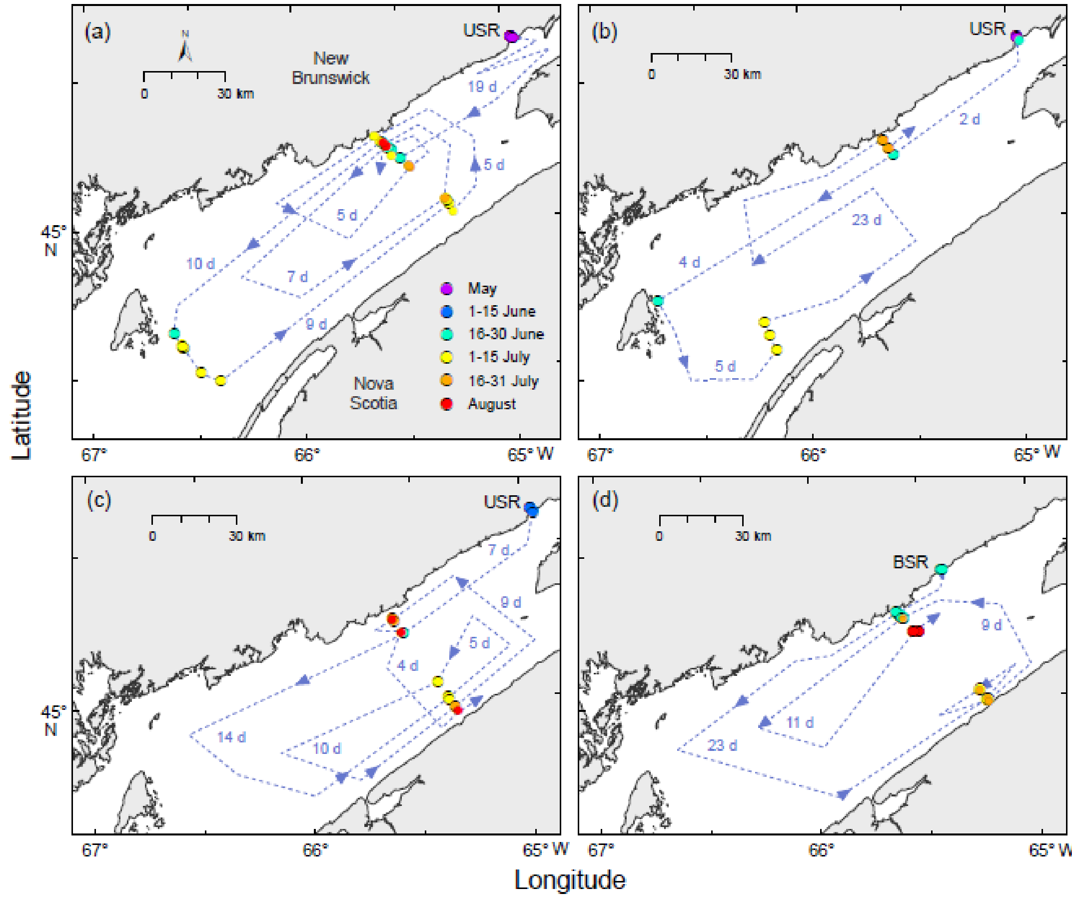

Figure 17. Maps of inferred migration paths (dashed lines) based on sequential sites of detection (circles, color-coded by time period) for individual Atlantic salmon post-smolts of iBoF origin remaining inside the BoF: (a) delayed migration to the mouth of the BoF with return to the inner BoF and repeated circling around the BoF, (b) late migration to the mouth of the BoF and slow return to the inner BoF, (c) and (d) late migration to the outer BoF with return to the inner BoF and repeated circling around the BoF. 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) (Fig. 3 in Lacroix 2013a).

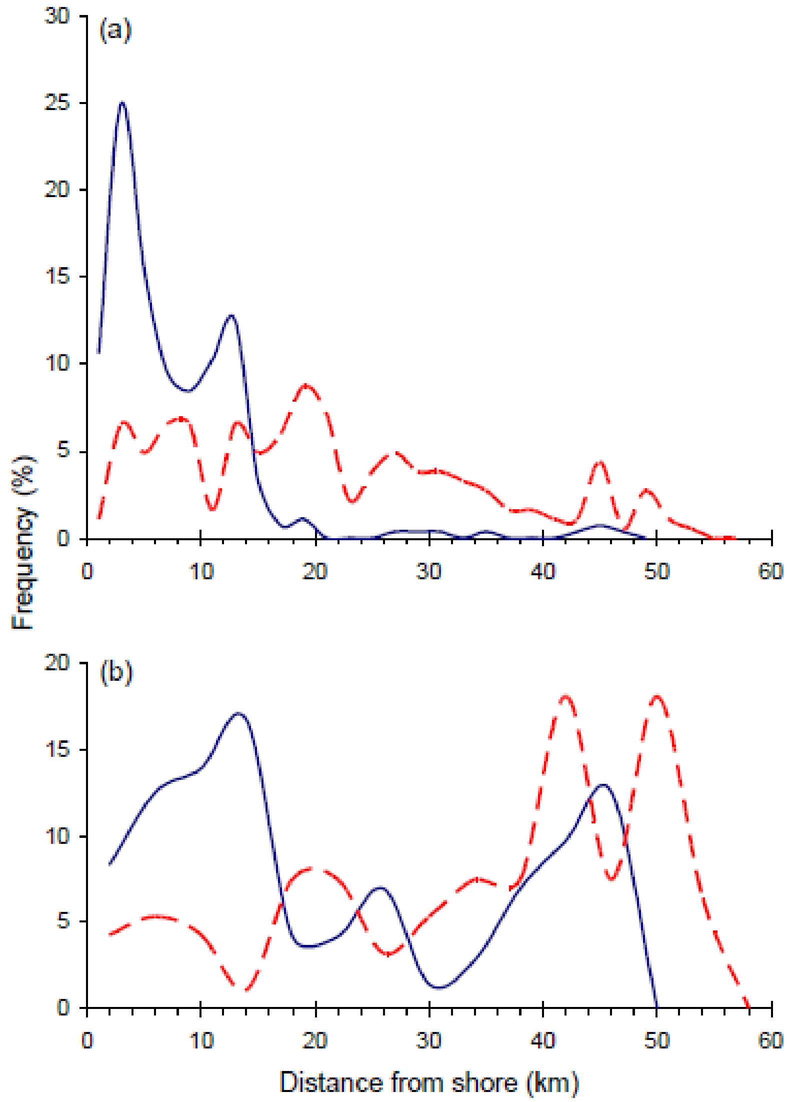

Figure 18. Location of migration corridors for Atlantic salmon post-smolts of iBoF origin monitored (a) leaving the iBoF (solid line, n=272) and oBoF (dashed line, n=183), and then (b) returning to the oBoF (dashed line, n=94) and iBoF (solid line, n=72). Frequency is percent of post-smolts for iBoF groups combined, and distance from shore is from the coast of New Brunswick at the iBoF array and from the east coast of Grand Manan Island at the oBoF array for first exit and return (Fig. 7 in Lacroix 2013a).

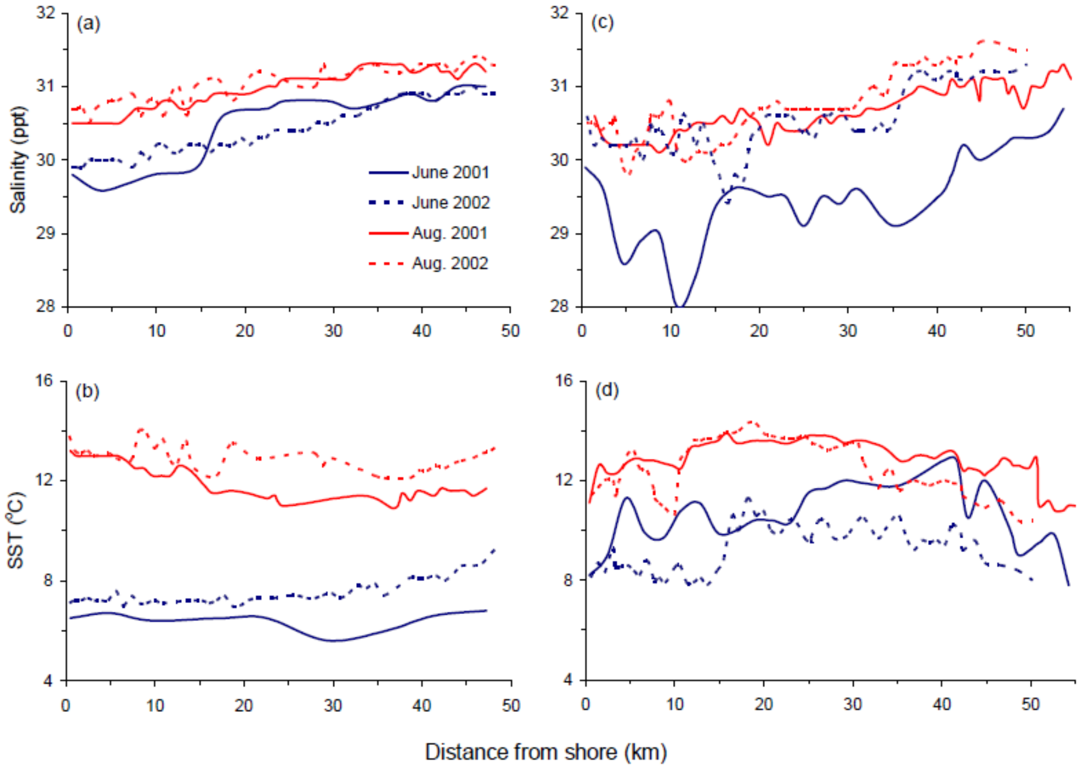

Figure 19. Salinity and SST measured across (a, b) the iBoF) transect and (c, d) the oBoF transect in June (blue lines) and August (red lines) of 2001 (solid lines) and 2002 (dashed lines). Distance from shore on transects is from the coast of New Brunswick at the iBoF transect and from the east coast of Grand Manan Island at the oBoF transect. (Fig. 8 in Lacroix 2013a).

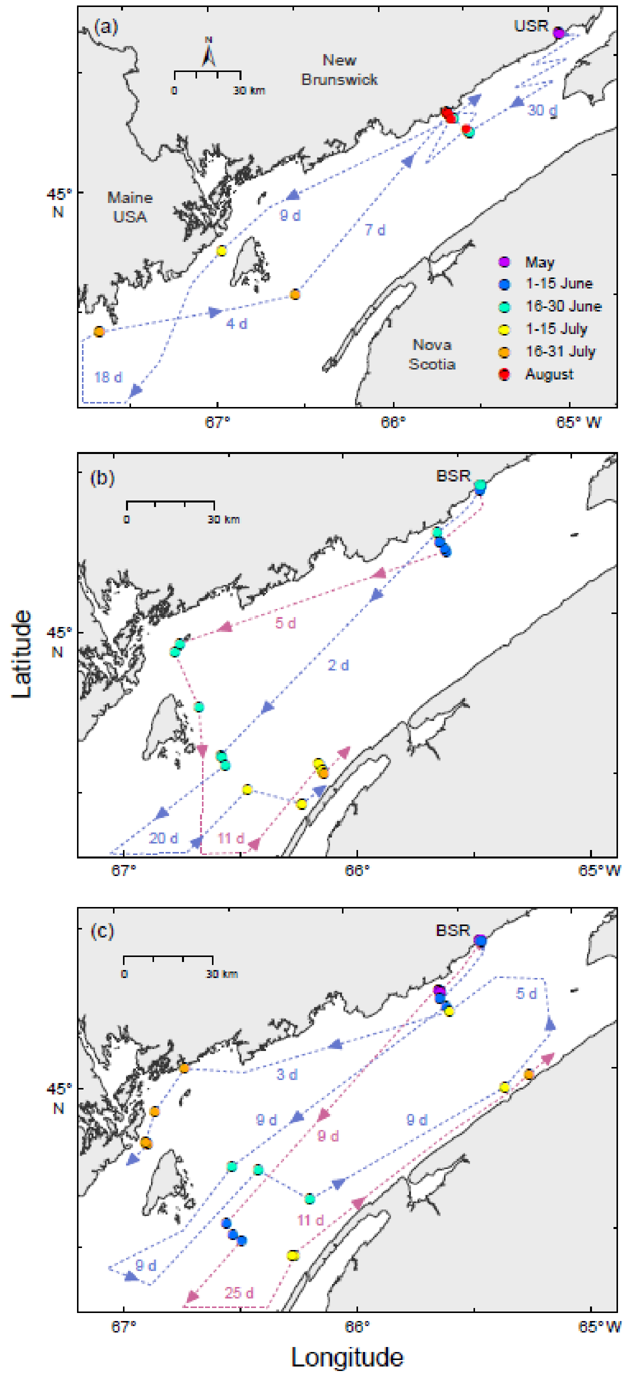

Figure 20. Maps of inferred migration paths (dashed lines) based on sequential sites of detection (circles, color-coded by time period) for individual Atlantic salmon post-smolts of iBoF origin leaving and then returning to the Bay of Fundy from the Gulf of Maine: (a) delayed migration from the iBoF to the coast of Maine and late return to the iBoF, (b) late migration into the Gulf of Maine and return to the oBoF (2 tracks shown), and (c) late migration into the Gulf of Maine and return to the iBoF (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) (Fig. 2 in Lacroix 2013a).

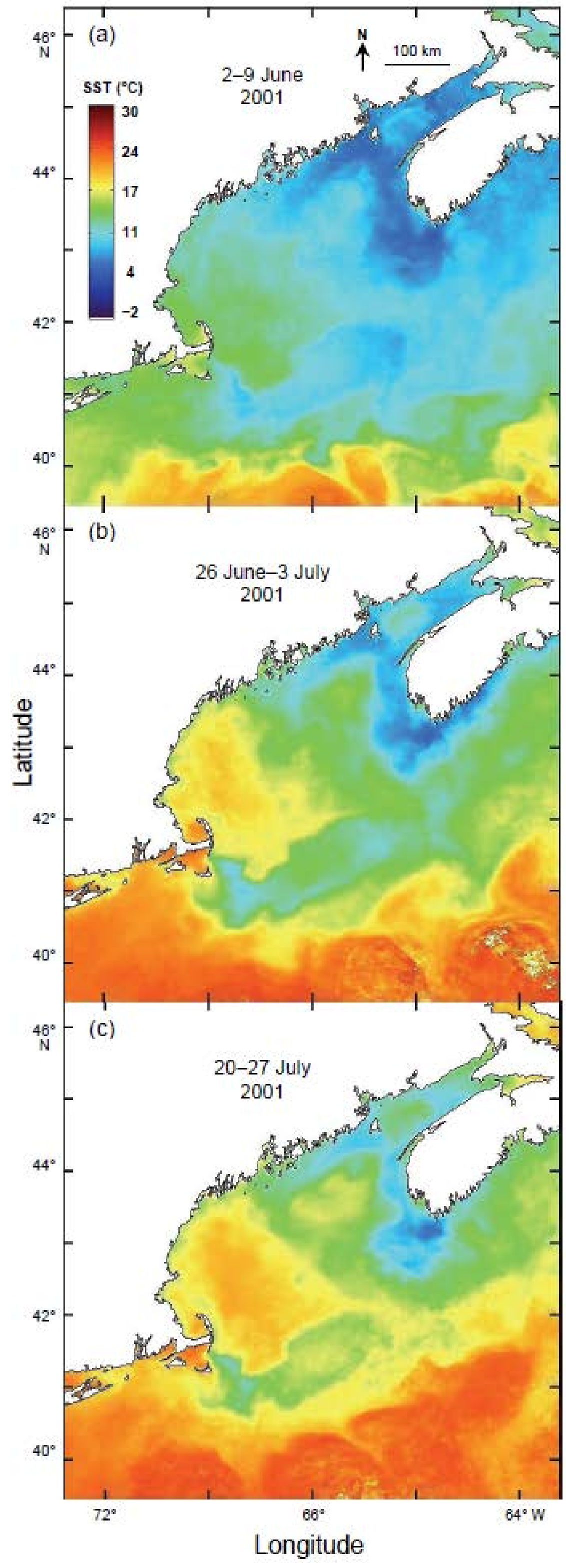

Figure 21. Maps of SST (mean corrected 8-day composite) in the Bay of Fundy and Gulf of Maine during (a) 2–9 June, (b) 26 June–3 July, and (c) 20–27 July of 2001, when Atlantic salmon post-smolts were in the Bay and Gulf. Satellite images are from the [School of Marine Sciences, University of Maine]() (Fig. 12 in Lacroix 2013a).

Figure 22. Distribution of Atlantic salmon (Salmo salar) post-smolts captured during surface trawling surveys in the Bay of Fundy and Gulf of Maine in 2001 (red circles), 2002 (yellow circles), and 2003 (green circles). Circles are graded bycatch size (see legend on map), and trawl sites with no catches marked with open boxes. Source: based on data from Lacroix and Knox (2005) and provided by Lacroix (pers. comm.).

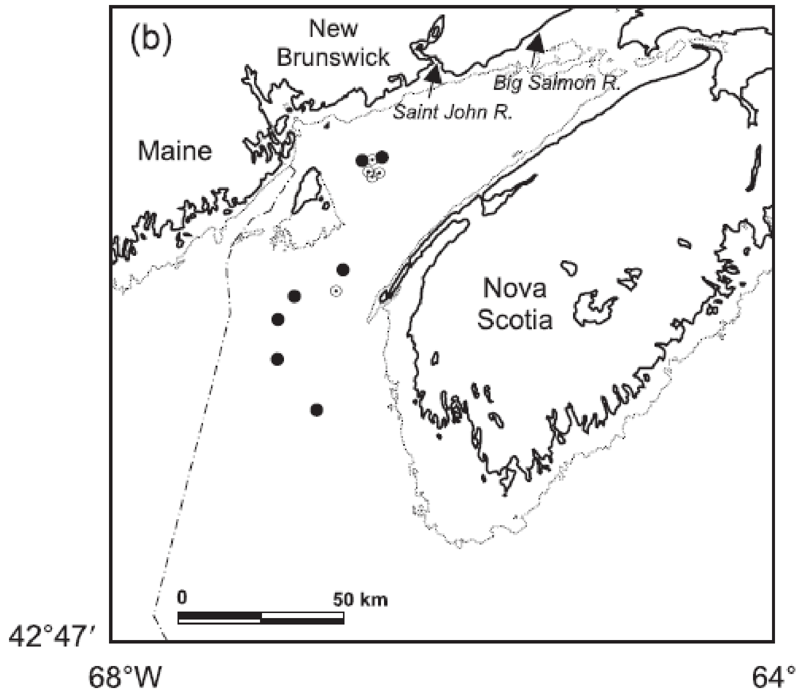

Figure 23. Sites where post smolts from the Big Salmon River (solid circle) and Saint John River system (solid circle within a circle) were recaptured, 2001-2003. The figure includes the 90 m isobath (faint line outward of coast line; ".....") and Canada-US boundary (single dashed line; "_._.__") (Fig. 3b in Lacroix and Knox 2005).

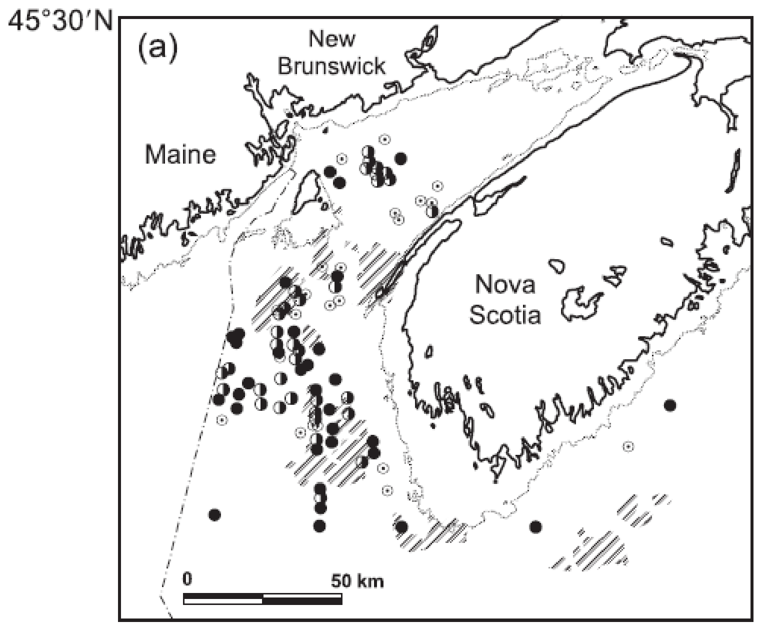

Figure 24. Areas (shaded) of Atlantic herring (Clupea harengus) catches by the purse seine fishery during May and June of 2001-2003 are superimposed on Atlantic salmon post-smolts (circles) captured in the surface trawl, 2001-2003 (Fig. 3a in Lacroix and Knox 2005).

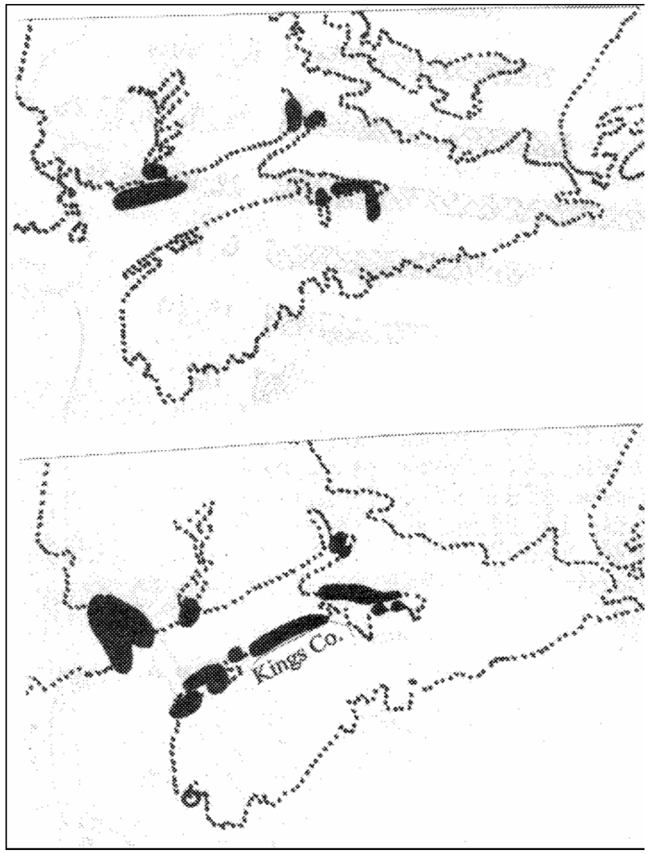

Figure 25. Locations of the historical (1971) Bay of Fundy commercial drift net fisheries for Atlantic salmon (upper), and weir fisheries (lower) which were licensed mostly for herring, but also licensed for other species. Weirs in Kings County were licensed for and focused on Atlantic salmon (adapted from Dunfield 1974).

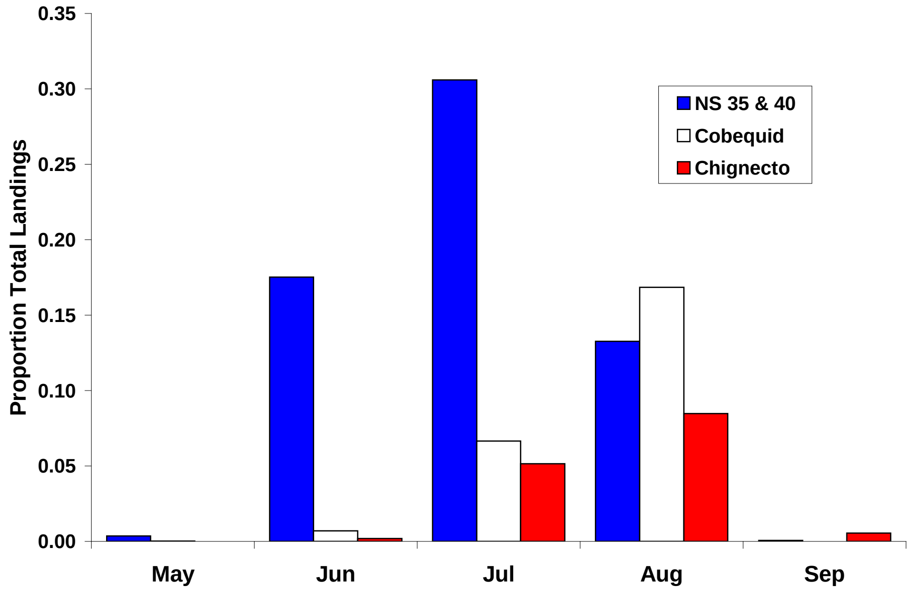

Figure 26. Mean monthly proportion of a possible 19,700 commercially landed salmon on the Nova Scotia coast of the Bay of Fundy (FSDs 35 & 40), in the Minas Basin/Cobequid Bay Nova Scotia (FSDs 42 & 44) and Chignecto Bay (FSDs 79 & 81), New Brunswick, 1967-1971.

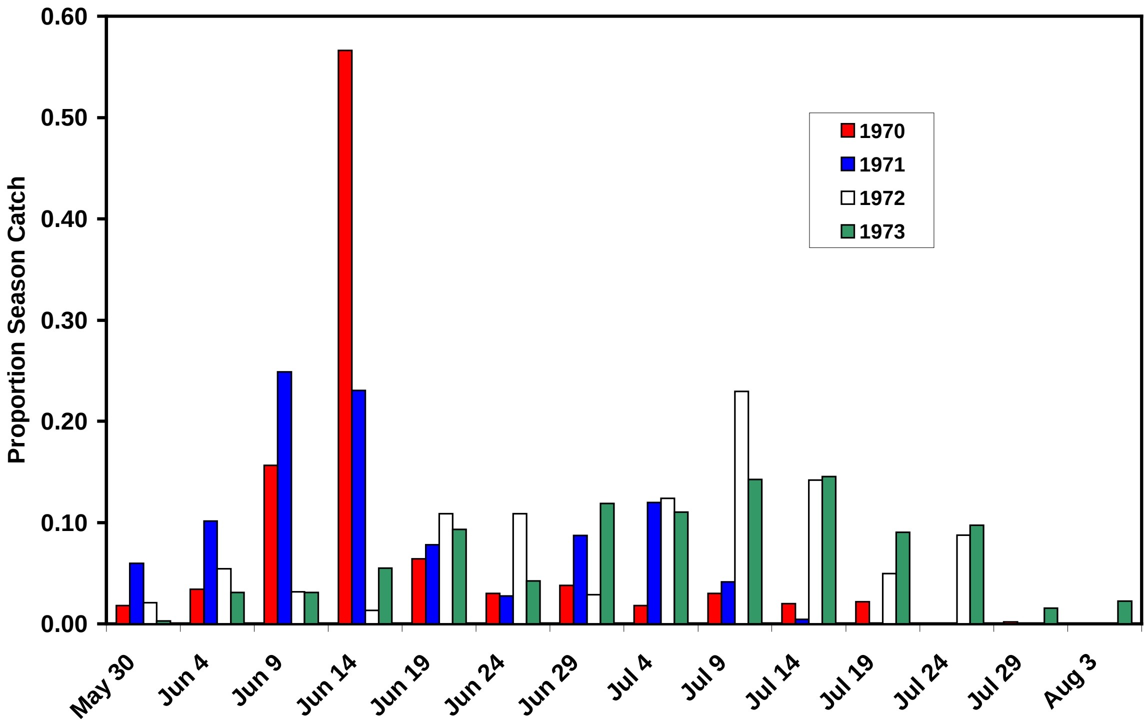

Figure 27. Annual proportions of 2,084 MSW salmon captured in the experimental drift net fishery, off Saint John, NB, late-May to late-July (1970-1972) and late-May to early-August (1973). Data from Penney (1983).

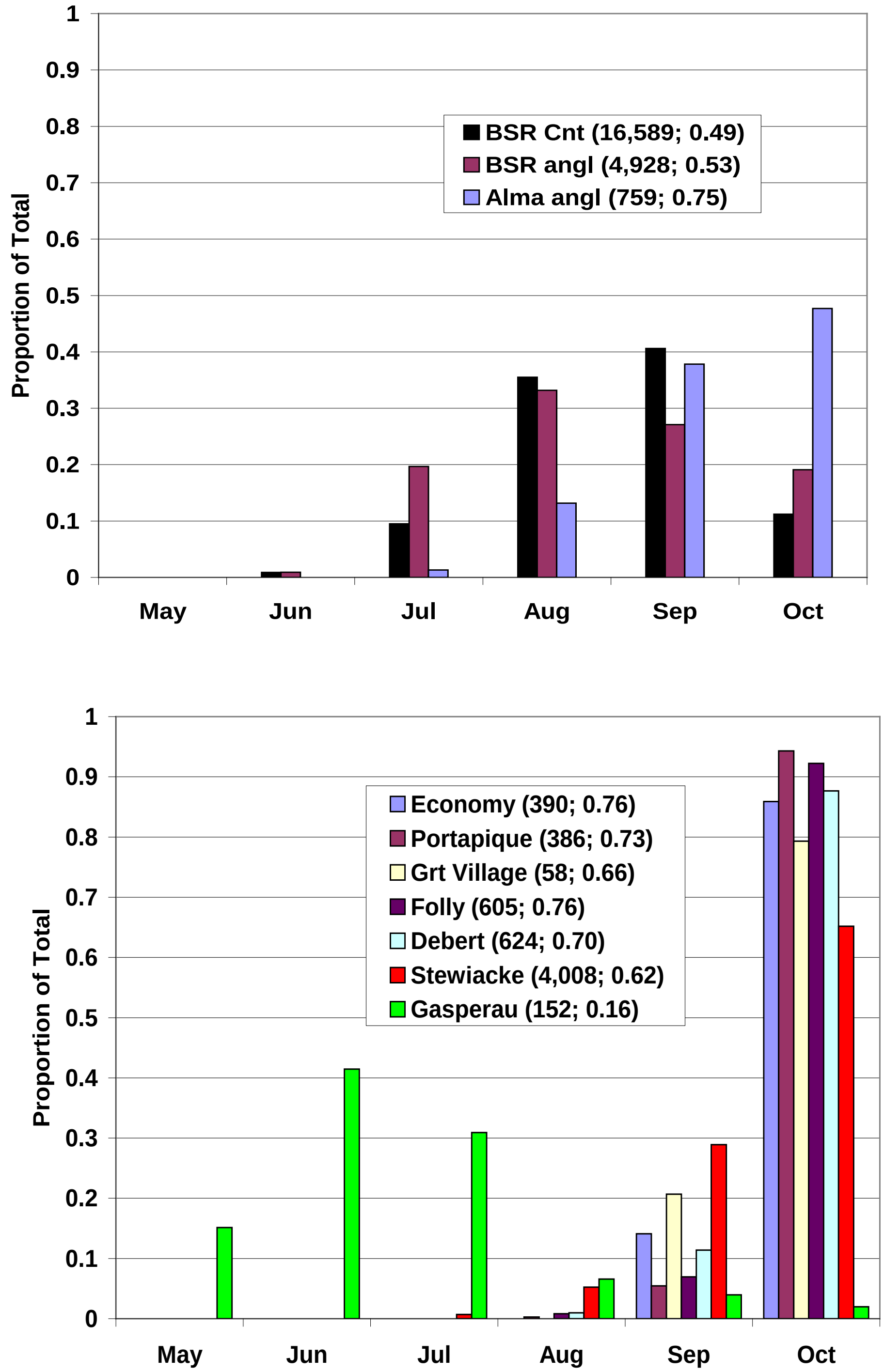

Figure 28. Monthly distribution of adult salmon returns to Big Salmon River counting fence, 1964-1966, 1968-1970 and 1972 (Jessop 1986) and caught by anglers in the Big Salmon and Alma (Upper Salmon) rivers, 1964-1973 (Swetnam and O'Neil 1985; O'Neil and Swetnam 1984) (upper panel) and caught by anglers, 1964-1973, in rivers of Cobequid Basin, NS (Swetnam and O'Neil, op. cit.*; O'Neil and Swetnam,* op. cit.*), 1964-1973. Numbers of fish and proportion 1SW in parenthesis. Salmon of the Gaspereau River are more characteristic of oBoF 2SW populations.*

ANNEX 1

Terms of Reference

Identification of Important Marine and Estuarine Habitat for inner Bay of Fundy Salmon
Regional Peer Review – Maritimes Region

21-22 November 2012
Dartmouth, Nova Scotia

Chairperson: Tana Worcester

Context

The inner Bay of Fundy (iBoF) Atlantic salmon was listed as an endangered species under the Species at Risk Act (SARA) when it came into force in 2004. SARA requires the identification of critical habitat for endangered species. A Recovery Potential Assessment for iBoF Atlantic salmon was conducted in 2008 (DFO 2009), which includes information on important habitat for iBoF Atlantic salmon available at that time. A Recovery Strategy for the iBoF salmon was developed and published on the SAR Public Registry as final in May 2010 (DFO 2010). This recovery strategy identifies freshwater critical habitat areas for iBoF salmon and includes a Schedule of Studies to help define additional critical habitat. Atlantic salmon require both freshwater, estuaries, and marine habitat to complete their life cycle. The current review will provide additional information in support of the identification of marine and estuarine critical habitat for iBoF Atlantic salmon.

Objectives

To the extent possible with the information available, and taking account of uncertainties:

Provide functional descriptions (as well as features and attributes) of the marine and estuarine habitat required for successful completion of all life-history stages of inner Bay of Fundy salmon, including but not limited to:

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

Provide geospatial information on the location and spatial extent of the areas that are likely to have these habitat properties.

Recommend research or analysis activities necessary to complete the above Terms of Reference if current information is incomplete.

Expected Publications

- Science Advisory Report
- Research Document
- Proceedings

Participation

- DFO Science
- DFO Ecosystem Management
- DFO Fisheries and Aquaculture Management
- DFO Policy and Economics
- Provincial (NB and NS) governments
- Aboriginal Communities / Organizations
- Non-governmental organizations
- Fishing Industry
- Aquaculture Industry
- External Reviewers

References

DFO. 2008. Recovery Potential Assessment for inner Bay of Fundy Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/050.

DFO. 2010. Recovery Strategy for the Atlantic salmon (*Salmo salar*), inner Bay of Fundy populations [Final]. *In* Species at Risk Act Recovery Strategy Series. Ottawa: Fisheries and Oceans Canada.