WILD SALMON POPULATIONS IN THE VICINITY OF A PROPOSED FINFISH AQUACULTURE DEVELOPMENT IN ST. MARY'S BAY, NOVA SCOTIA

Context

On December 6, 2010, Fisheries and Oceans Canada's (DFO) Habitat Protection and Sustainable Development (HSPD) Division, Maritimes Region, requested that DFO Science, Maritimes Region, provide advice regarding wild salmon populations in the vicinity of a proposed finfish aquaculture development (two farm sites) in St. Mary's Bay, Nova Scotia, as well as the likelihood of the proposed development project having negative impacts to the wild salmon populations and their habitat. The request for advice is in support of HPSD's review of an environmental assessment (EA) of a proposed aquaculture development project pursuant to the *Canadian Environmental Assessment Act*. Specifically, DFO HPSD asked:

1. What wild salmon populations (and their lifecycle stages) are present in the vicinity of the proposed finfish aquaculture sites in St. Mary's Bay, Nova Scotia.

2. How do the lifecycle stages of wild salmon populations make use of the habitat found in the vicinity of the proposed aquaculture sites?

3. What is the likelihood/probability of any impacts on the survivability and recoverability of the wild salmon populations found in the vicinity of the proposed aquaculture sites?

4. How can mitigation measures reduce any impacts on the wild salmon populations found in the vicinity of the proposed aquaculture sites? and

5. How do the impacts to the wild salmon populations from the proposed aquaculture sites compare to the impacts from other anthropogenic sources?

The Science Special Response Process (SSRP) was based on existing data sources from the St. Mary's Bay area, which are limited in resolution and scale relative to the location and size of the proposed aquaculture site. An SSRP was used due to the short deadline for advice of January 15, 2011.

The conclusions of the SSRP are:

1) A salmon aquaculture development at this site has the potential to impact on salmon populations in three designatable units (DUs): 1) the inner Bay of Fundy (iBoF), 2) the outer Bay of Fundy (oBoF) and 3) the Southern Upland (SU) DUs. IBoF is listed as Endangered pursuant to the *Species at Risk Act*. The oBoF and SU DUs have been recommended for listing as Endangered by the Committee on the Status of Endangered Wildlife in Canada.

2) The general area around the proposed site in St. Mary's Bay is considered to be used as a salmon migratory corridor and feeding grounds in support of growth, maturation, and post-spawning reconditioning.

3) IBoF salmon tend to migrate out along the New Brunswick side of the Bay of Fundy (the Bay) toward the outer Bay and Gulf of Maine, but are also detected on the Nova Scotia side of the outer Bay. Some portion of individuals may leave the Bay, over a period of approximately five months (June through October), but another portion may remain in the Bay during this same period. Post-smolts that remain in the Bay tend to move up into the Bay along the Nova Scotia side.

4) Historically, adult salmon were captured in the vicinity of the proposed St. Mary's Bay sites for extended periods during the spring, summer and fall. Based on tag returns for Saint John River salmon, adults returning to spawn are present in the Bay of Fundy from at least May until November. They are also known to be present near the coastline and to move in and out of estuaries during this time period. Returning adults from at least the iBoF, oBoF and SU DUs would be expected to pass nearby the proposed aquaculture sites, and potentially more than one time.

5) Although a few salmon rivers in the SU region are located in or near the Bay of Fundy (the Annapolis and the Tusket Rivers are the largest), most are located on the Atlantic coast of Nova Scotia and salmon from the Atlantic populations (particularly the northerly rivers) are expected to be in the vicinity of the proposed sites infrequently. Effects on these populations would be expected to occur mainly via interactions with escaped aquaculture salmon.

6) Salmon aquaculture sites can impact wild populations through: the transmission of parasites; pathogens and disease from cage-farmed salmon; potentially increased predation as a result of predator attraction to the cage sites; and through an additional range of pathways that arise from aquaculture escapees. Escapees can hybridize with wild salmon, which has the potential to reduce genetic fitness of wild populations. Salmon in the three DUs are at low abundance relative to past levels and are highly sensitive to increased stress and mortality.

7) A number of mitigation measures have been identified to reduce impacts from aquaculture activities on wild salmon populations, although the likelihood of risk reduction if these measures were implemented is unknown.

8) The relative severity of potential impacts from the proposed aquaculture sites relative to other anthropogenic sources can not be determined. However, these impacts have the potential to undermine the effectiveness of actions to improve the viability of salmon populations and to prevent their extirpation. All commercial and recreational fisheries have been closed in the oBoF, iBoF and SU. Live Gene Banking is currently being used to maintain the genetic diversity of iBoF salmon. Liming activities have been initiated in the SU DU. Fish passage improvements have been undertaken in all three regions. Activities that have the potential to jeopardize the survival of salmon in these regions need to be evaluated in the context of the activities that have been initiated to improve their survivability.

Background

Fisheries and Oceans Canada HPSD, Maritimes Region, is reviewing an EA for a marine finfish aquaculture site to be located at St. Mary's Bay, Nova Scotia, to determine if it is likely to result in negative impacts to fish and fish habitat. One component identified in the DFO HPSD risk assessment of the proposed aquaculture development project is the risk of the proposed development on wild salmon populations in the vicinity of the proposed development sites. As part of the federal EA process, DFO may provide advice to Transport Canada regarding any

impacts that fall under DFO's mandate. In addition, DFO may advise the Nova Scotia Department of Fisheries and Aquaculture on the proposed aquaculture development. Refer to Canadian Environmental Assessment Registry reference number 10-01-55946 for more information regarding the EA of the proposed development project.

Analysis and Response

Most of the information presented in this science response has been synthesized in earlier science advice. For additional detail to that provided below, readers are directed to the 2006 Expert Opinion on offshore aquaculture (DFO, 2006), Research Documents published in support of the Recovery Potential Assessment for iBoF salmon (Amiro et al., 2008a,b; Gibson et al., 2008), to the extensive discussion of threats in the iBoF salmon Recovery Strategy (DFO, 2010a), and to a research document on the pathway of effects of escaped aquaculture organisms or their reproductive material on natural ecosystems in Canada (Leggatt et al., 2010).

1) What wild salmon populations (and their lifecycle stages) are present in the vicinity of the proposed finfish aquaculture sites in St. Mary's Bay, Nova Scotia?

Atlantic salmon show high, but not complete, fidelity to their natal rivers and for this reason, salmon in each river are treated as separate populations for most management and scientific purposes. These populations can be further aggregated for some purposes. When considering the conservation status of wild Atlantic salmon, DFO and MNRF (2008) identified five Conservation units in DFO's Maritimes Region (Figure 1). When evaluating the extinction risk of Atlantic salmon in Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), identified four designatable units (DUs): discrete and evolutionarily significant units of the taxonomic species in the Maritimes Region (where "significant" means that the unit is important to the evolutionary legacy of the species as a whole and if lost would likely not be replaced through natural dispersion). These are identical to the Conservation Units with the exception that the eastern Cape Breton highlands and lowlands were combined into a single DU. It is generally recognized that there is considerable diversity within each of these units and that the maintenance of that diversity is necessary for the long-term conservation of the unit as a whole (e.g. Gibson et al., 2008).

Wild Atlantic salmon populations can be affected by salmon aquaculture either by interaction in the immediate vicinity of the site or by the interactions of escaped aquaculture salmon with salmon in the wild (Leggatt et al., 2010). Escaped aquaculture salmon have been found in rivers at distances greater than 200 km from the nearest aquaculture site (Morris et al., 2008). The proposed aquaculture site is located in St Mary's Bay, Nova Scotia, in the outer Bay of Fundy (Figure 1), in the Southern Uplands DU region. A salmon aquaculture development at this location has the potential to impact on salmon populations in three designatable units: 1) the inner Bay of Fundy (iBoF), 2) the outer Bay of Fundy (oBoF) and 3) the Southern Upland (SU). As described below, salmon from all three DUs are known to be found in close proximity to the site. Salmon from all oBoF and iBoF populations moving in and out of the Bay of Fundy have the potential to migrate in the vicinity of the proposed site, whereas most SU populations are located on the Atlantic coast of Nova Scotia and would not be expected to utilize the Bay of Fundy as habitat. Exceptions include salmon in rivers near the mouth of the Bay of Fundy such as the Annapolis and Tusket Rivers. The potential for interaction with wild salmon extends to the endangered Maine Distinct Population Segment, protected under U.S. legislation, although the extent of this potential is not presently known.

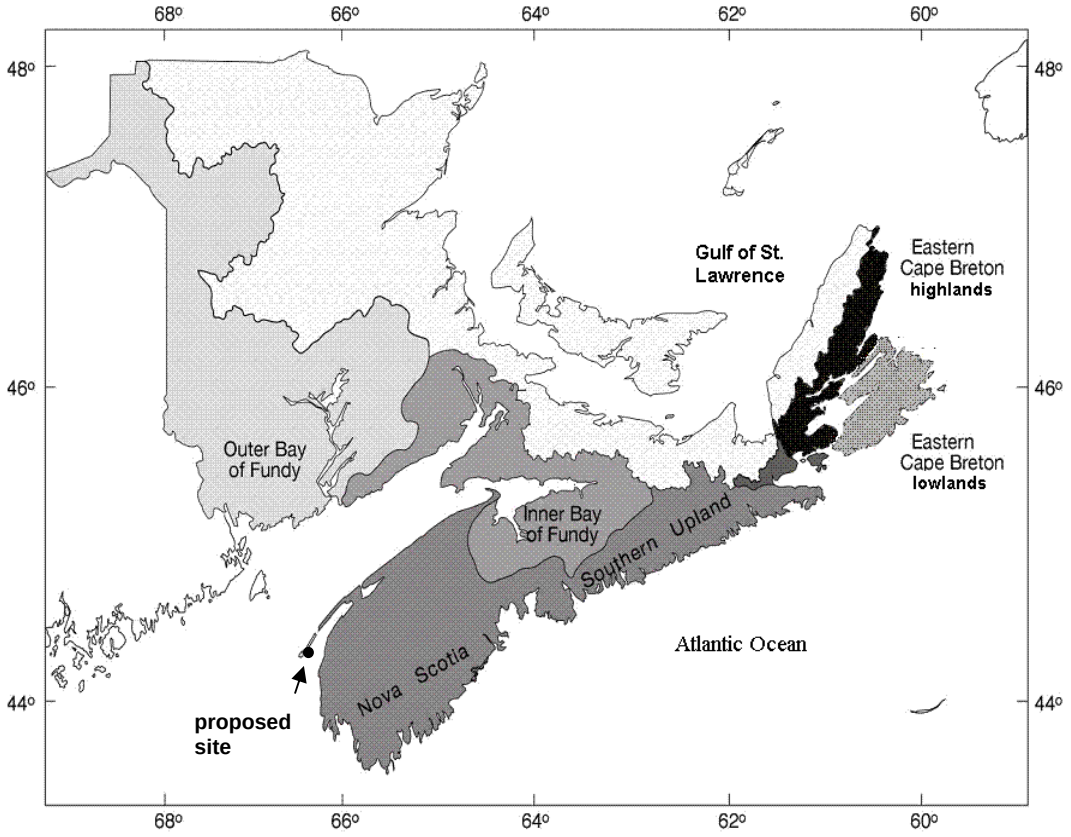

Figure 1. The location of the proposed aquaculture development in St. Mary's Bay (black circle) in relation to the conservation units for Atlantic salmon in the DFO Maritimes Region (Gibson et al., 2011 (In review), adapted from DFO and MNRF, 2008). COSEWIC's designatable units for the outer Bay of Fundy, inner Bay of Fundy and Southern Upland Atlantic salmon are the same as these conservation units.

Atlantic salmon populations in the three DUs are considered at risk of extinction. IBoF salmon are listed as Endangered pursuant to the *Species at Risk Act* (SARA). In the recent past, abundance of adult salmon in the iBoF region is thought to have been roughly 40,000 fish, whereas less than a couple hundred salmon are thought to be returning to rivers in this region now. In the past, river-specific abundances ranged from the tens to the thousands, whereas now, in the few rivers that still have salmon runs, abundance is in the range of less than ten to less than one hundred. Salmon populations in this DU are being maintained via a Live Gene Bank; a genetically-based, supportive-rearing program intended to conserve the remaining genetic diversity within the DU. Salmon in the iBoF DU are expected to rapidly become extinct in the absence of this program (Gibson et al., 2008).

Atlantic salmon in the oBoF and SU DUs have been designated "Endangered" by COSEWIC. Within the SU region, river-specific extirpations of salmon populations have almost certainly occurred and declines in abundance are ongoing. Region-wide electrofishing surveys took place in 2000 and 2008 (DFO, 2009). These surveys were similar in terms of total effort and coverage, although marginally more sites were completed in 2008 (143 sites surveyed in 2008 versus 128 sites surveyed in 2000), but one less river was visited (51 rivers visited in 2008 versus 52 rivers visited in 2000). Approximately one quarter as many juvenile salmon were captured in 2008 (977 salmon) than in 2000 (3733 salmon). In 2000, juvenile Atlantic salmon were found in 54% of the rivers (28 of 52), but were only found in 39% of the rivers (20 of 51) in 2008. The results

of these surveys are consistent with predicted extirpations based on water chemistry (i.e. low pH), further supporting that river specific extirpations have occurred. Adult abundances in the remaining populations are in the range of tens to the hundreds in rivers known to have had abundances in the hundreds to low thousands of salmon in the past (Gibson et al., 2009).

River-specific adult abundances in the oBoF region are currently thought to be in the range of tens to the low thousands. For example, the returns of Atlantic salmon to the Saint John River at the Mactaquac Dam in 2009 was 1171 salmon. This count exceeded 20,000 salmon in some years during the 1980s (DFO, 2010b). River-specific extirpations are thought to have occurred in this DU as well, and it is not presently known if the juveniles found at low abundance in some rivers south of Saint John are progeny of native wild salmon, strays from other rivers or aquaculture escapes.

Evidence for habitat usage by salmon, including post-smolts, returning adults and for previous spawning adults, in the vicinity of the proposed site comes from tag returns, mostly from commercial fisheries in the 1960s to 1980s, as well as from tracking and trawling studies of habitat use and migration patterns in the late 1990s and 2000s. This evidence is summarized below.

The Population Ecology Division (DFO Science, Maritimes region) is completing the recovery of historical tag return data for Atlantic salmon. These data can be used to identify, in part, which salmon populations use habitat in the vicinity of the proposed site, although it can not be used to identify all populations that would use an area because the number of rivers in which tags were applied is limited. Figure 2 shows the locations in the vicinity of the proposed aquaculture sites in St. Mary's Bay from which tags have been returned, and their origin is provided in Table 1. Tagged salmon from all three DUs have been returned from this vicinity. While the selection of the area to include in this analysis is somewhat arbitrary, the conclusion that salmon in the three DUs have been found in this area is not particularly sensitive to this selection (e.g. salmon from all three DUs have been captured at Site 1).

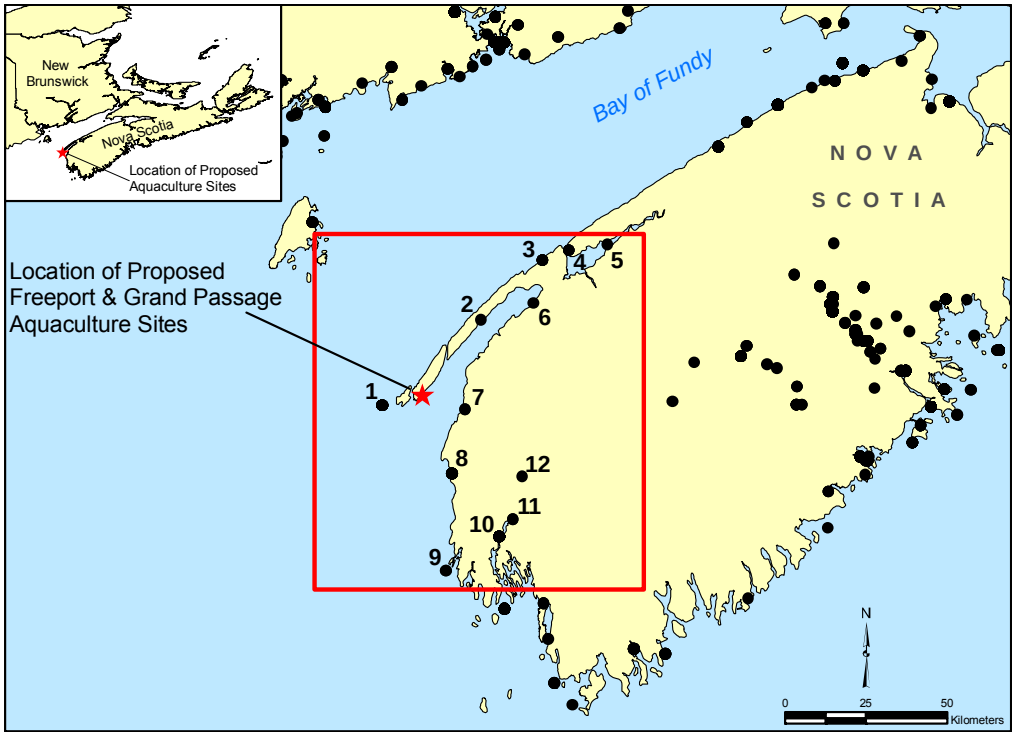

Figure 2. Locations in the vicinity of the proposed aquaculture development in St. Mary's Bay (red star) from which Atlantic salmon tags have been returned (DFO Science tag return database). The origins of salmon from the numbered sites are provided in Table 1.

Table 1. Origins of tagged Atlantic salmon that were captured in the vicinity of St. Mary's Bay. Site IDs refer to the numbered sites in Figure 2.

Site ID	Release River Name (DU)	Total Recaptures	Wild Recaptures	Hatchery Recaptures	Unknown	Recapture Years
1	Big Salmon River (iBoF)	4	1	3		1968-1969
	LaHave River (SU)	1		1		1975
	Saint John River (oBoF)	5	2	3		1970-1974
	Salmon River (Digby)	1		1		1969
	Tusket River (SU)	2		2		1975
2	Big Salmon River (iBoF)	1		1		1966
3	Big Salmon River (iBoF)	2		2		1969
	Saint John River (oBoF)	6	3	1	2	1967-1971
4	Big Salmon River (iBoF)	2		2		1964-1965
	Medway River (SU)	1		1		1972
	Nashwaak River (oBoF)	1			1	1970
5	Annapolis River (SU)	1		1		1988
6	LaHave River (SU)	1			1	1990
7	Saint John River (oBoF)	1	1			1974
	Tusket River (SU)	1		1		1982
8	LaHave River (SU)	1		1		1978
	Salmon River (Digby)	6		6		1967-1986
9	LaHave River (SU)	1		1		1982
	Tusket River (SU)	1		1		1987
10	Carleton River (SU)	1		1		1987
	Tusket River (SU)	38		38		1975-1987
11	Clyde River (SU)	1		1		1986
	Tusket River (SU)	1		1		1980
12	Clyde River (SU)	1		1		1984
	Total	81	7	70	4	

Historical tag return data for iBoF salmon has been summarized by (Jessop, 1976; Amiro and Jefferson, 1996; Amiro, 2003, Amiro et al., 2003). The majority of tagged salmon were released in Big Salmon River, and the majority of returns (as post-smolts) are from the Bay of Fundy (Figure 3). These data led to the conclusion that iBoF salmon have a localized migration strategy remaining primarily in the Bay of Fundy and Gulf of Maine. This is in contrast with the distant migration strategy utilized by salmon from the oBoF and SU DUs, which was determined from tagging studies undertaken in regions such as the oBoF where tags were returned from Newfoundland and Labrador as well as West Greenland.

Life stages that utilize this habitat include post-smolt and adult salmon, the latter including both adults returning to spawn for the first time, as well as post-spawning adults.

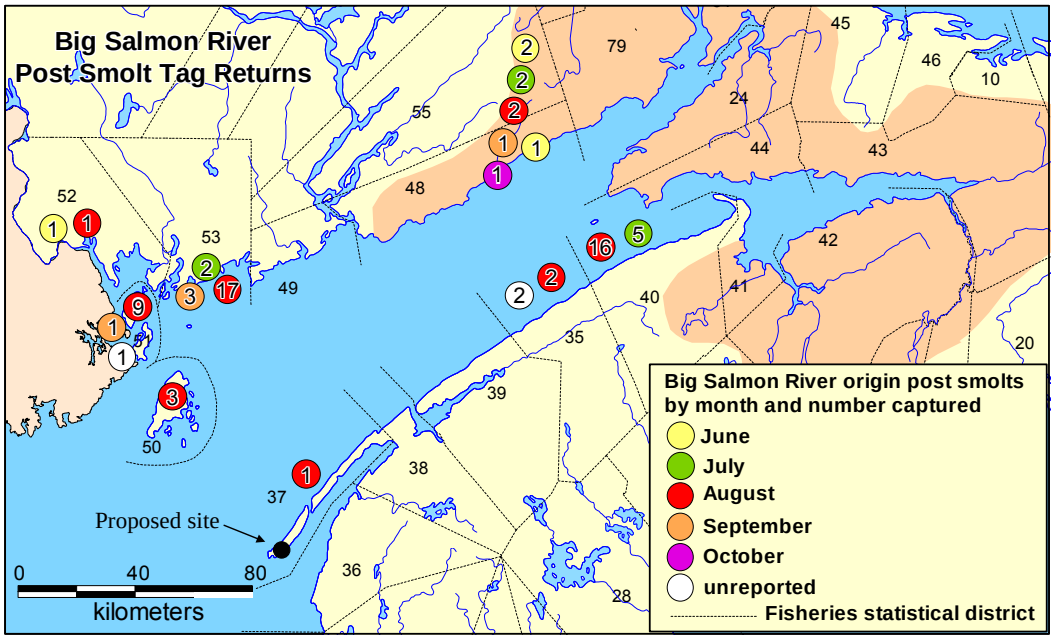

Figure 3. *Locations and numbers of recaptures of tagged wild and hatchery Big Salmon River post-smolts by month of recapture (from Amiro et al., 2003). The proposed aquaculture development in St. Mary's Bay is denoted by the black circle.*

Post-smolts

Post-smolts are the life stage of salmon that have departed the river for the first time but have not passed a winter at sea (Allan and Ritter, 1975). Current knowledge of the distribution and habitat use in the Bay of Fundy is derived from historical distributions of tagged salmon (Jessop, 1975; Amiro and Jefferson, 1996; Amiro, 2003: Figure 3), telemetry of smolts tagged with acoustic transmitters (Lacroix et al., 2005; Lacroix, 2008: Figure 4), research trawling surveys (Lacroix and Knox, 2005), and historical patterns of commercial salmon fisheries (Hutsman and Logie, 2983; Dunfield, 1974). Synthesis of these studies indicates that at the beginning of the marine phase, iBoF salmon tend to migrate along the New Brunswick side of the Bay of Fundy toward the outer Bay and Gulf of Maine, but are also detected on the Nova Scotia side of the outer Bay. Some portion of individuals may leave the Bay, over a period of roughly five months (June through October), but another portion may remain in the Bay during this same period. Post-smolts that remain in the Bay tend to move up the Bay along the Nova Scotia coast. Similar studies have not been undertaken with SU salmon near the location of the proposed aquaculture development sites. Salmon distribution during the winter months is unknown.

In summary, synthesis of available information indicates that at the beginning of the marine phase, iBoF salmon post-smolts tend to begin migration along the New Brunswick side of the Bay of Fundy towards the outer Bay and Gulf of Maine, and then spread across the outer Bay of Fundy. IBoF post-smolts that remain resident within the Bay move up the Bay along the Nova Scotia coast.

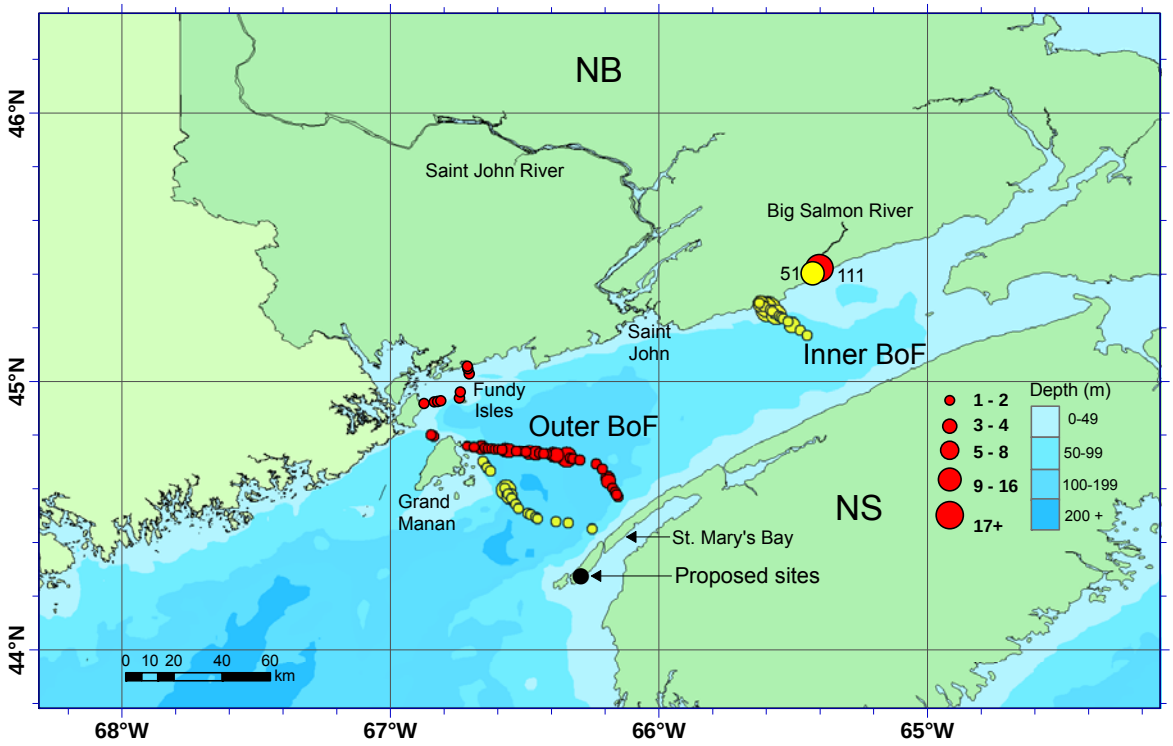

Figure 4. Distribution of migrating post-smolts from the Big Salmon River tagged with acoustic transmitters in 2001 (red circles) and 2002 (yellow circles) based on site of first detections on receiver arrays bounding the inner and outer Bay of Fundy (from Lacroix 2008; Lacroix, pers. comm., DFO Science). The proposed aquaculture development location in St. Mary's Bay is denoted by the black circle.

Adults

Evidence concerning the distribution of adult salmon in the Bay of Fundy is drawn from limited mark-recapture studies, historical commercial salmon fisheries, and current, on-going studies of post-spawning kelts tagged with satellite pop-up transmitters. The use of satellite pop-up archival tags to track the marine migration of kelts indicates that they remain in the Bay for some time (at least weeks) following their return to sea in the late autumn, but the technology lacks the spatial resolution required to determine if individual migration tracks approach the vicinity of the proposed aquaculture development sites.

Although little information is available about the behavior of adults that are returning to spawn, based on tag returns for Saint John River salmon, they are present in the Bay of Fundy from at least May until November (Figure 5). They are also known to be present near the coastline and to move in and out of estuaries during this time period (some of the commercial fisheries utilized weirs that extended from the shoreline out a short distance into the sea). Returning adults from the three DUs would be expected to pass nearby the proposed aquaculture development sites for these reasons and potentially more than one time. Historically, adult salmon have been captured in the vicinity of the proposed St. Mary's Bay aquaculture development sites (as shown in Figure 2) for extended periods from spring to fall, indicating that salmon may be in this general area for at least this time period.

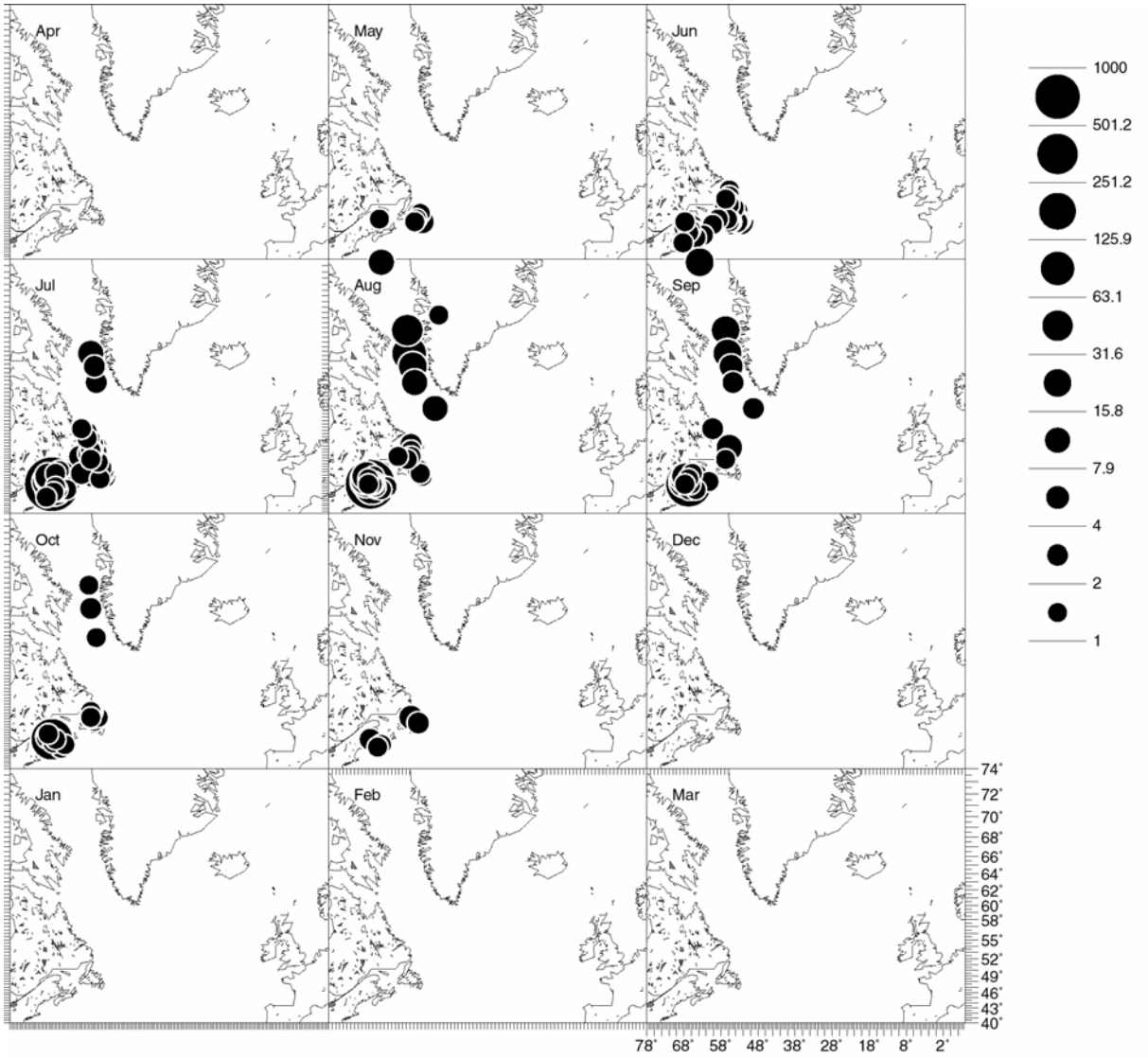

Figure 5. One-sea-year recoveries (captured with 12-24 months of release) from the Saint John River of tagged hatchery smolts aggregated for all available years by 5 minute squares and plotted by month (from ICES, 2008).

2) How do the lifecycle stages of wild salmon populations make use of the habitat found in the vicinity of the proposed aquaculture sites?

As stated earlier, no wild salmon studies have been undertaken in St. Mary's Bay in the immediate area around the proposed aquaculture development sites. Some information does exist for salmon captured farther offshore from the site location. Trawl surveys for salmon post-smolts were conducted in the Bay of Fundy during the late spring for years 2001-2003 (Figure 6; see Lacroix and Knox, 2005, for details). Sampling stations ranged from the inner Bay of Fundy out into the Gulf of Maine. Post-smolts were sampled by surface trawling for a period stretching from end May through June. Sixty-three post-smolts (from a total of 161 live captures) were examined for stomach contents, of which 60 individuals were determined to have food in their stomachs. This result suggests that post-smolts migrating away from their natal rivers feed in the general area offshore (within 1-4 nm) from the proposed aquaculture development site locations. It is not known if or how other life stages may make use of the area. In summary, while it is not possible with available information to determine with confidence how salmon use

the habitat in the vicinity of the proposed aquaculture development sites, the general area is thought to be used as a both a migratory corridor as well as feeding grounds in support of growth, maturation, and post-spawning reconditioning.

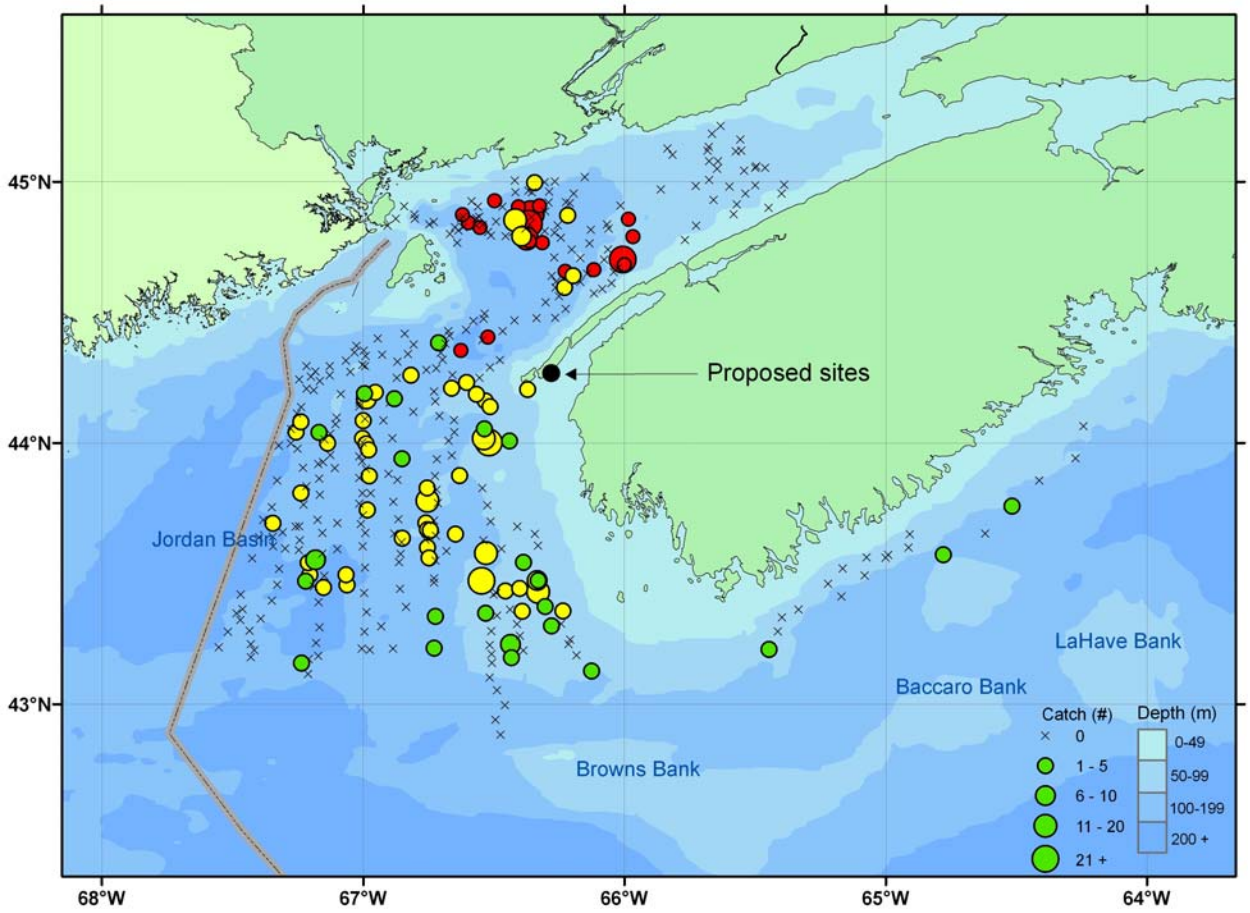

Figure 6. Distribution of post-smolts captured during surface trawling surveys in the Bay of Fundy and Gulf of Maine in 2001 (red circles), 2002 (yellow circles) and 2003 (green circles). Circles are graded by catch size (see legend on map), and trawl sites with no catches are marked (small black x's). (From Lacroix and Knox 2005; Lacroix, pers. comm., DFO Science.) The proposed aquaculture development location in St. Mary's Bay is denoted by the black circle.

3) What is the likelihood/probability of any impacts on the survivability and recoverability of the wild salmon populations found in the vicinity of the proposed aquaculture sites?

In general, aquaculture sites can impact wild populations through several mechanisms and are discussed in detail by several authors (e.g. Amiro et al., 2008b; DFO and MRNF, 2009; DFO, 2010a; Leggatt et al., 2010; Price et al., 2010). These mechanisms include: the transmission of parasites; pathogens and disease from cage-farmed salmon; potentially increased predation as a result of predator attraction to the cage sites; and through an additional range of pathways that arise from aquaculture escapees. Atlantic salmon in three DUs, as well as the Maine DPS, could be potentially be impacted via these mechanisms.

The pathways of effects via escapees are discussed in detail by Leggatt et al. (2010). Thorough discussion of potential impacts from aquaculture sites is provided in a number of

publications. One of the greatest concerns with escaped farmed salmon in the North Atlantic is hybridization with wild populations (Leggatt et al., 2010). Hybridization has the potential to cause a shift in phenotype towards farmed traits, lead to a loss of local adaptation, and lead to a loss of genetic variation that allows for phenotypic plasticity. All of these factors expected to lead to reduced fitness (meaning lower lifetime reproductive rates, lower population growth rates and lower resiliency to environmental perturbations) of the wild populations. Although escaped farmed salmon have lower reproductive success than wild salmon (see review in Leggatt et al., 2010), their success may depend on the abundance of salmon in the wild populations. In areas where small, endangered wild populations are exposed to repeated intrusion by escaped fish (in this instance all iBoF populations as well as many oBoF and SU populations), introgression of genetic material is probable (Leggatt et al., 2010).

Salmon originating from all three DUs are known to occur in the waters offshore of the proposed aquaculture development sites. It is therefore possible that this adjacency to occupied salmon habitat could lead to an increased probability of interaction of the proposed aquaculture development sites with wild salmon, especially through potential disease and parasite transmission, relative to the likelihood of interaction of wild salmon with other aquaculture sites in the lower Bay of Fundy. The absolute likelihood of interaction and resultant impacts has not been determined.

Although the impacts on the survivability or recoverability of salmon cannot be quantified, the proposed development does have the potential to reduce the effectiveness of recovery actions for populations in these DUs. Reduced survival in the marine environment has been identified as a threat to the survival of salmon in the oBoF, SU and iBoF DUs, and if survival is lowered further, recovery becomes more difficult. As discussed by Leggatt et al. (2010), the impacts of aquaculture on wild populations are context-specific, depending on both the magnitude of the stressor, as well as the sensitivity of the ecosystem or ecosystem component. Salmon in the three DUs are at low abundance relative to past levels and, notwithstanding abundance increases in some years, are in overall decline. As such, salmon populations in these DUs are sensitive to increased stress. Activities that increase mortality above current levels would therefore be expected to increase the decline rate and limit the effectiveness of recovery actions focused on other parts of their life cycle.

4) How can mitigation measures reduce any impacts on the wild salmon populations found in the vicinity of the proposed aquaculture sites?

In a 1999 DFO review of the practices used by the aquaculture industry in the Scotia-Fundy region, a series of priority objectives that could reduce the risks of interactions between wild and farmed fish were identified (DFO, 1999). The list of priority objectives to reduce the risk of interactions provided in DFO (1999) was updated by (Amiro et al., 2008b) as follows:

- improving containment, starting with the development and implementation of Codes of Practice, including contingency plans and a reporting system for escapees;
- improving fish health management, beginning with the completion of the major amendments to the Fish Health Protection Regulations and completion and implementation of provincial Codes of Practice, including contingency plans and a reporting system for specified diseases;
- upgrading policy for introductions and transfers of fishes and improving related enforcement;
- enhancing education and training of aquaculture workers, particularly relative to containment and farm/hatchery management;

- ensuring the maintenance of wild stocks at or above their conservation requirements;
- continuing the use of local stocks as donors, where possible, for currently practiced aquaculture, or using other strains if rendered sterile or properly contained; and
- continue incorporating risk analysis into the review process for the location of hatcheries and salmon farms.

Given the available information, it is not possible to quantitatively-assess the likelihood of risk reduction if the above measures were implemented, nor is it possible to rank these measures relatively according to likelihood or magnitude of realized risk reduction.

5) How do the impacts to the wild salmon populations from the proposed aquaculture sites compare to the impacts from other anthropogenic sources?

Thorough evaluations of potential threats to salmon survival have been undertaken several times (e.g. Amiro et al., 2008b; DFO and MRNF, 2009; DFO, 2010a; Leggatt et al., 2010). None of these publications provide a relative ranking of the severity of impacts from known or presumed anthropogenic sources, although DFO and MRNF (2009) does indicate the proportion of salmon populations that are likely to be influenced by a given activity, and the population-level impact of a given activity on spawner abundance. Low at-sea survival is one of the factors limiting population recovery for all three DUs, although it does vary among DUs.

DFO (2010a) provided a succinct list of potential threats to iBoF salmon in the marine environment, which included: interactions with farmed and hatchery salmon, environmental shifts, marine and estuarine fisheries, and depressed population phenomena. Marine survival in this DU is low enough that actions to improve freshwater productivity would not be expected to offset the low survival at-sea (Gibson et al., 2008).

At-sea survival in the SU region is roughly an order of magnitude higher than for iBoF populations, and actions to address freshwater threats have the potential to maintain populations at low abundance. As summarized by Gibson et al. (2009 – see references therein) sulfate deposition in the form of acid rain has lowered the pH of many rivers in the Southern Upland to the point that they may no longer be able to support viable salmon populations. The last region-wide assessment of pH was completed in 1986, where 22 rivers in the Southern Upland were classified as low- or non-acidified (pH > 5.0), 20 rivers were partially acidified (pH ranged from 4.7-5.0) and 14 rivers were heavily acidified (pH < 4.7). At a pH below 5.1, salmon production is considered unstable and only remnant populations may persist. Estimates of the loss in productive potential attributable to acidification for salmon throughout the Southern Upland range from 24-50%.

The loss of productivity related to acidification would likely exacerbate the negative effects of low marine survival and further increase a population's vulnerability to extirpation. Other factors with the potential to impact salmon abundance or distribution in the Southern Upland have been reviewed in a semi-quantitative manner in a recent draft conservation status report (DFO and MNRF, 2009). Habitat alteration and water extraction, through activities such as mining, forestry, agriculture, infrastructure development and maintenance, municipal water use, and hydroelectric power generation, are thought to impact more than 30% of salmon populations in the Southern Upland. However, the impact in terms of spawner loss is not well quantified for individual populations, but cumulatively may be substantial. Invasive species such as smallmouth bass and chain pickerel are becoming increasingly prevalent within the SU region, although their overall impact on salmon in this region is not well understood.

Although low relative to past levels, at-sea survival of oBoF salmon is also about an order of magnitude higher than for iBoF salmon, and as is the case for SU salmon, this higher survival means that recovery actions have a greater chance of increasing abundance and population viability in the outer Bay of Fundy than in the inner Bay. DFO and MNRF (2009) and Jones et al. (2010 – see references therein) provided a summary of potential threats in this region. Of these threats, the effects of agricultural and forestry operations, developing communities of invasive predators (i.e. muskellunge, smallmouth bass, chain pickerel and rainbow trout) and aquaculture escapes are, for the most part, uncertain. Jones et al. (2010) state that juvenile and adult salmon escapes from the Fundy-Isle (New Brunswick) or Cobscook Bay (Maine) aquaculture facilities are the most probable sources of aquaculture origin salmon identified at all primary counting facilities. Although the effect of these aquaculture escapes is uncertain, the numbers and proportions of these identified escapes in relation to total salmon counts on the Magaguadavic and St. Croix rivers were some of the highest observed in eastern North America (Morris et al., 2008).

Directed fisheries on outer Bay of Fundy salmon from recreational and aboriginal users have been closed since 1998. Illegal gillnet fishing in an area below Tobique Narrows Dam still persists by the evidence of net marks on surviving spawners passing through the adult fishway. In 2008, 8% of the salmon counted at the fishway had fresh net marks. Sources of mortality with a predicted spawner loss of 5-0% of the population were associated with hydro facilities (DFO and MNRF, 2009). Based on the return rates of smolts marked with coded nose wire tags and released at numerous locations within the Saint John River, smolt mortality attributable to passage through and between the Tobique Narrows, Beechwood and Mactaquac dams was estimated to be 24.7, 13.6, and 15.9%, respectively (Carr, 2001). At least 42% of the habitat within the outer portion of SFA 23 has hydroelectric facilities that negatively affect the salmon populations within those watersheds.

Although the impacts of the proposed aquaculture site relative to other anthropogenic sources cannot be fully determined, they do have the potential to undermine the effectiveness of actions to reduce impacts from other sources. All commercial and recreational fisheries have been closed in the oBoF, iBoF and SU DUs in response to the decreased abundance of salmon in these regions. Within the iBoF region, Live Gene Banking is currently being used to maintain the genetic diversity of salmon in the few remaining populations. Liming activities have been initiated in the SU region to address the threat posed by river acidification, and further liming activities are being planned. Supportive-rearing, intended to provide a short-term increase in abundance, has been undertaken on SU rivers such as the St. Mary's and Medway Rivers. These programs were intended to reduce extinction risk while threats to populations are being addressed. Fish passage improvements have been made in all three regions including the opening of the causeway on the Petitcodiac River (iBoF) and improved fish passage facilities on the Gaspereau River (iBoF) as two examples. Fisheries and Oceans Canada is currently working with NB Power to improve fish passage on the Saint John River (oBoF) upstream of Mactaquac Dam. Activities that have the potential to jeopardize the survival of salmon in these regions need to be evaluated in the context of the activities that have been initiated to improve their survivability.

Uncertainty

The advice provided in this SSRP is limited in scope and depth due to time constraints to provide science advice by January 15, 2011. With more time allotted to the evaluation, further detail could have been provided about several issues raised herein, although it is unlikely that this detail would have changed the general conclusions provided in this response. A more quantitiative analysis is not likely to have been possible given the paucity of information available. For example, a quantitative analysis of the effects of fitness on populations would

require data about the magnitude and frequency of escape events, information on the proportions of escapees entering rivers, and salmon abundance estimates for these rivers. These data are not being collected in the majority of rivers. Of another point, it is important to note that incidences of escapees are based on self-reporting of escapes by the aquaculture industry; there is no independent system for monitoring escapes. The self-reporting system, and any inherent offset in time between escapes and their reporting, may determine the timing in which escape-events become known to regulatory authorities and their ability to respond in some manner.

Conclusions

1) A salmon aquaculture development at this site has the potential to impact on salmon populations in three designatable units (DUs): 1) the inner Bay of Fundy (iBoF), 2) the outer Bay of Fundy (oBoF) and 3) the Southern Upland (SU) DUs. IBoF is listed as Endangered pursuant to the *Species at Risk Act*. The oBoF and SU DUs have been recommended for listing as Endangered by the COSEWIC.

2) The general area around the proposed site in St. Mary's Bay, Nova Scotia, is considered to be used as a salmon migratory corridor and feeding grounds in support of growth, maturation, and post-spawning reconditioning.

3) IBoF salmon tend to migrate out along the New Brunswick side of the Bay of Fundy (the Bay) toward the outer Bay and Gulf of Maine, but are also detected on the Nova Scotia side of the outer Bay. Some portion of individuals may leave the Bay, over a period of approximately five months (June through October), but another portion may remain in the Bay during this same period. Post-smolts that remain in the Bay tend to move up into the Bay along the Nova Scotia side.

4) Historically, adult salmon were captured in the vicinity of the proposed St. Mary's Bay sites for extended periods during the spring, summer and fall. Based on tag returns for Saint John River salmon, adults returning to spawn are present in the Bay of Fundy from at least May until November. They are also known to be present near the coastline and to move in and out of estuaries during this time period. Returning adults from at least the iBoF, oBoF and SU DUs would be expected to pass nearby the proposed aquaculture sites, and potentially more than one time.

5) Although a few salmon rivers in the SU region are located in or near the Bay of Fundy (the Annapolis and the Tusket Rivers are the largest), most are located on the Atlantic coast of Nova Scotia and salmon from the Atlantic populations (particularly the northerly rivers) are expected to be in the vicinity of the proposed sites infrequently. Effects on these populations would be expected to occur mainly via interactions with escaped aquaculture salmon.

6) Salmon aquaculture sites can impact wild populations through: the transmission of parasites; pathogens and disease from cage-farmed salmon; potentially increased predation as a result of predator attraction to the cage sites; and through an additional range of pathways that arise from aquaculture escapees. Escapees can hybridize with wild salmon, which has the potential to reduce genetic fitness of wild populations. Salmon in the three DUs are at low abundance relative to past levels and are highly sensitive to increased stress and mortality.

7) A number of mitigation measures have been identified to reduce impacts from aquaculture activities on wild salmon populations, although the likelihood of risk reduction if these measures were implemented is unknown.

8) The relative severity of potential impacts from the proposed aquaculture sites relative to other anthropogenic sources can not be determined. However, these impacts have the potential to undermine the effectiveness of actions to improve the viability of salmon populations and to prevent their extirpation. All commercial and recreational fisheries have been closed in the oBoF, iBoF and SU. Live Gene Banking is currently being used to maintain the genetic diversity of iBoF salmon. Liming activities have been initiated in the SU DU. Fish passage improvements have been undertaken in all three regions. Activities that have the potential to jeopardize the survival of salmon in these regions need to be evaluated in the context of the activities that have been initiated to improve their survivability.

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