WILD SALMON POPULATIONS IN THE VICINITY OF A PROPOSED FINFISH AQUACULTURE DEVELOPMENT AT LITTLE MUSQUASH COVE, NEW BRUNSWICK

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 site at Little Musquash Cove, New Brunswick, 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 development site at Little Musquash Cove, New Brunswick?

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

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 development site?

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

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

The Science Special Response Process (SSRP) was based on existing data sources from the Little Musquash Cove area, which are limited in resolution and scale relative to the location and size of the proposed aquaculture development 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 the proposed aquaculture development site has the potential to impact on salmon populations in three designatable units (DU): the inner Bay of Fundy (iBoF); the outer Bay of Fundy (oBoF); and the Southern Upland (SU) DUs. The IBoF DU is listed as Endangered under the *Species at Risk Act* (SARA) and the oBoF and SU DUs have been recommended for listing as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The iBoF and oBoF DUs are known to be found in close proximity to the proposed site; whereas, although it is likely that SU salmon are at times present near the site (some populations are located in Nova Scotia directly across the Bay of Fundy), effects on SU salmon may occur via interactions with escaped salmon.

2) The general area around the proposed site at Little Musquash Cove is considered to be used as a migratory corridor and feeding grounds in support of growth, maturation, and post-spawning reconditioning.

3) Synthesis of available information indicates that at the beginning of the marine phase, iBoF salmon post-smolts tend to migrate along the New Brunswick side of the Bay of Fundy (the Bay), at least within 4-6 nautical miles of the site, and may circulate within the inner Bay.

4) Historically, adult salmon were captured in the area just offshore of the proposed Little Musquash Cove development site for extended periods during the late spring. 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 and oBoF DUs would be expected to pass nearby the proposed aquaculture site, and potentially more than one time.

5) Salmon aquaculture operations 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 return to freshwater, mature and reproduce with wild conspecifics. The resulting wild farm-wild hybrids have the potential to reduce fitness of wild populations through an increased risk of outbreeding depression. Salmon in the three DUs are at low abundance relative to past levels and are highly sensitive to increased stress and mortality.

6) 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.

7) The relative severity of potential impacts from the proposed aquaculture development site relative to other anthropogenic sources cannot be determined. However, these impacts have the potential to reduce 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 proposed marine finfish aquaculture development site to be located at Little Musquash Cove, New Brunswick, 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 project. 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 New Brunswick Department of Agriculture, Aquaculture and Fisheries on the proposed aquaculture development. Refer to Canadian Environmental

Assessment Registry reference number 08-01-38158 for more information regarding the EA of the proposed development project.

Analysis and Response

Most of the information presented in this 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), the extensive discussion of threats in the iBoF salmon Recovery Strategy (DFO, 2010a), and a research document (and references therein) on the pathways 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 development site at Little Musquash Cove, New Brunswick?

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). Escapees have been detected in rivers at distances greater than 200 km from their sites of origin (Morris et al., 2008). The proposed aquaculture site is located near the coast in the outer Bay of Fundy (Figure 1). A salmon aquaculture development at this site 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) DUs. As described below, salmon from the iBoF and oBoF DUs are known to be found in close proximity to the site, whereas, although it is likely that SU salmon are at times present near the site (some populations are located in Nova Scotia directly across the Bay of Fundy), effects on SU salmon may occur via interactions with escaped salmon. Analogously, 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.

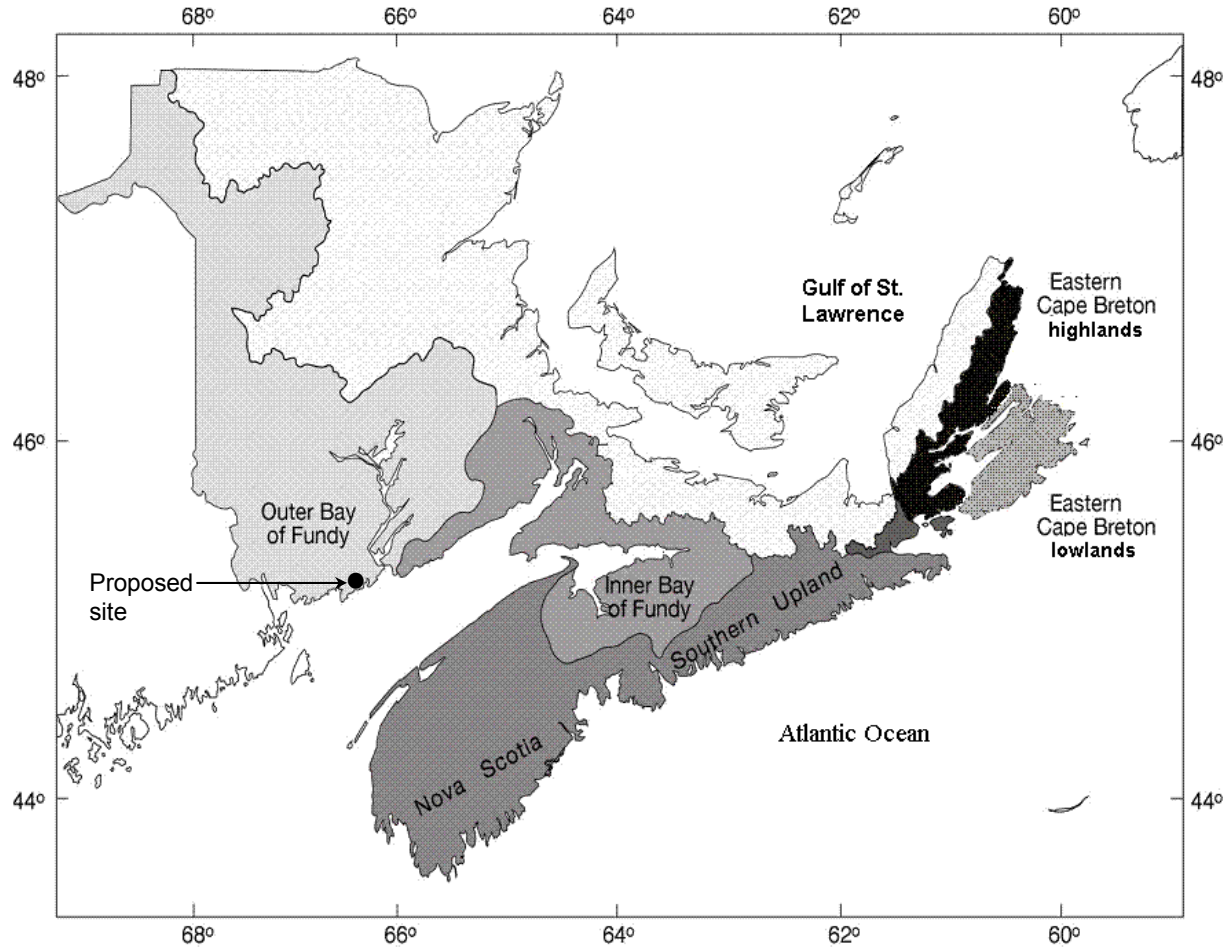

Figure 1. The location of the proposed Little Musquash aquaculture development site (black circle) in relation to the conservation units for Atlantic salmon in the Scotia-Fundy region (Gibson et al., 2011 (In review); adapted from DFO and MNRF, 2008). COSEWIC's designatable units for the outer Bay of 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 under the *Species at Risk Act* (SARA). In the recent past, abundance of adult salmon in this 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 thousands, whereas presently in the few rivers that still have salmon runs abundance is in the range of less than ten to less than one hundred individuals. 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. River-specific extirpation of salmon populations are known to have occurred in the SU region and adult abundances in the remaining populations are in the range of tens to hundreds in rivers known to have contained 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 were 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, for post-smolts, returning adults and for previous spawning adults, in the vicinity of the proposed aquaculture development 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) 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 aquaculture development 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 quite limited. Figure 2 shows the locations in the vicinity of the proposed aquaculture development site from which tags have been returned. Their origin is provided in Table 1. Tagged salmon from both the iBoF and oBoF regions have been returned from this vicinity. A few tagged salmon from East River (Sheet Harbour, Nova Scotia) have also been returned from this area, but the origin of the parents of these hatchery-raised salmon has not yet been verified, but likely is not within the SU region. The selection of the area shown in Figure 2 is arbitrary. Selecting a larger area extending into the Saint John River estuary increases the number of tag returns from the releases in East River (Sheet Harbour, Nova Scotia), and increasing the area to include the upper portion of Passamaquoddy Bay brings in very low numbers of tag returns of hatchery-raised salmon from other SU rivers (e.g. the Medway River, Nova Scotia).

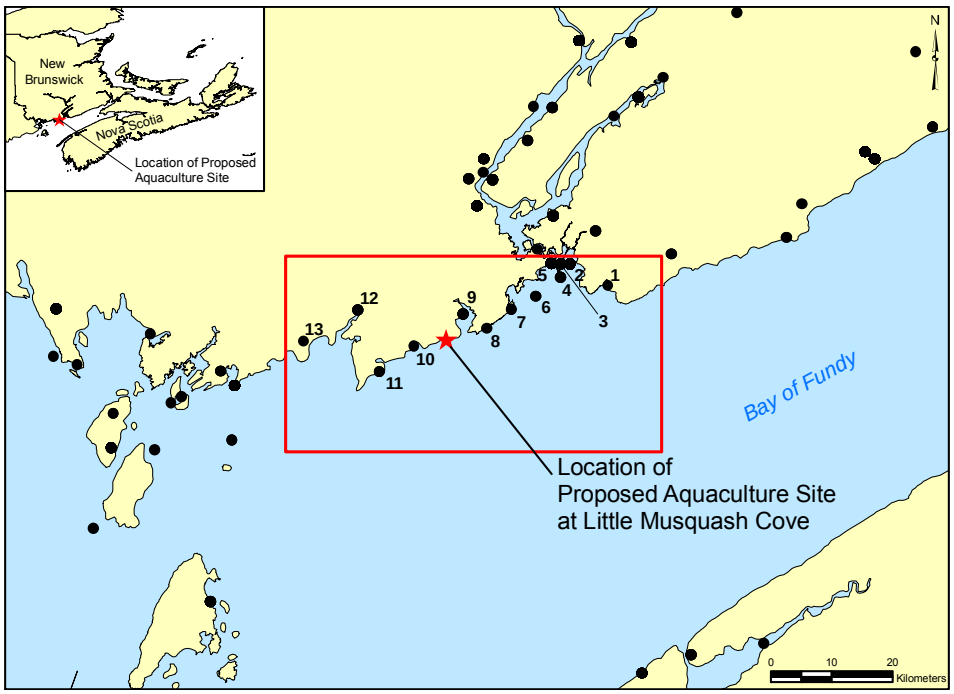

Figure 2. Locations in the vicinity of the proposed aquaculture development site at Little Musquash Cove (red star) from which Atlantic salmon tags have been returned (DFO Science tag return database). The origin of salmon from the numbered sites are provided in Table 1.

Historical tag return data for iBoF salmon have been summarized in several reports (Jessop, 1976; Amiro and Jefferson, 1996; Amiro, 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 DU, which was determined from tagging studies undertaken in regions such as the oBoF wherein tags were returned from Newfoundland and Labrador as well as West Greenland.

Table 1. Origin of tagged Atlantic salmon that were captured in the vicinity of proposed aquaculture development site at Little Musquash Cove. Site IDs refer to the numbered sites in Figure 2.

Site ID	Release River Name	Designatable Unit	Total Recaptures	Wild Recaptures	Hatchery Recaptures	Unknown	Recapture Years
1	Big Salmon River	iBoF	1		1		1964
2	Big Salmon River	iBoF	3	2	1		1964-1968
	East River (Sheet Harbour)	SU*	1		1		1977
	Nashwaak River	oBoF	11			11	1968-1971
	Saint John River	oBoF	298	70	104	124	1966-1997
	Tobique River	oBoF	9	1	6	2	1968-1982
3	Saint John River	oBoF	12	2	9	1	1966-1982
	Tobique River	oBoF	1		1		1982
4	Nashwaak River	oBoF	1		1		1983
	Saint John River	oBoF	2		2		1983
5	East River (Sheet Harbour)	SU*	2		2		1977
	Nashwaak River	oBoF	25		4	21	1968-1988
	Saint John River	oBoF	406	101	156	149	1966-1994
	Tobique River	oBoF	1			1	1968
6	Saint John River	oBoF	2		2		2001
7	Big Salmon River	iBoF	1		1		1968
	Saint John River	oBoF	1		1		1983
8	Saint John River	oBoF	1			1	1983
9	Big Salmon River	iBoF	1		1		1965
	Saint John River	oBoF	3		3		1983
10	Big Salmon River	iBoF	1		1		1965
11	Saint John River	oBoF	1			1	1966
12	Saint John River	oBoF	3		3		1983
13	Big Salmon River	iBoF	1		1		1965
Total			**788**	**176**	**301**	**311**	

*See text.

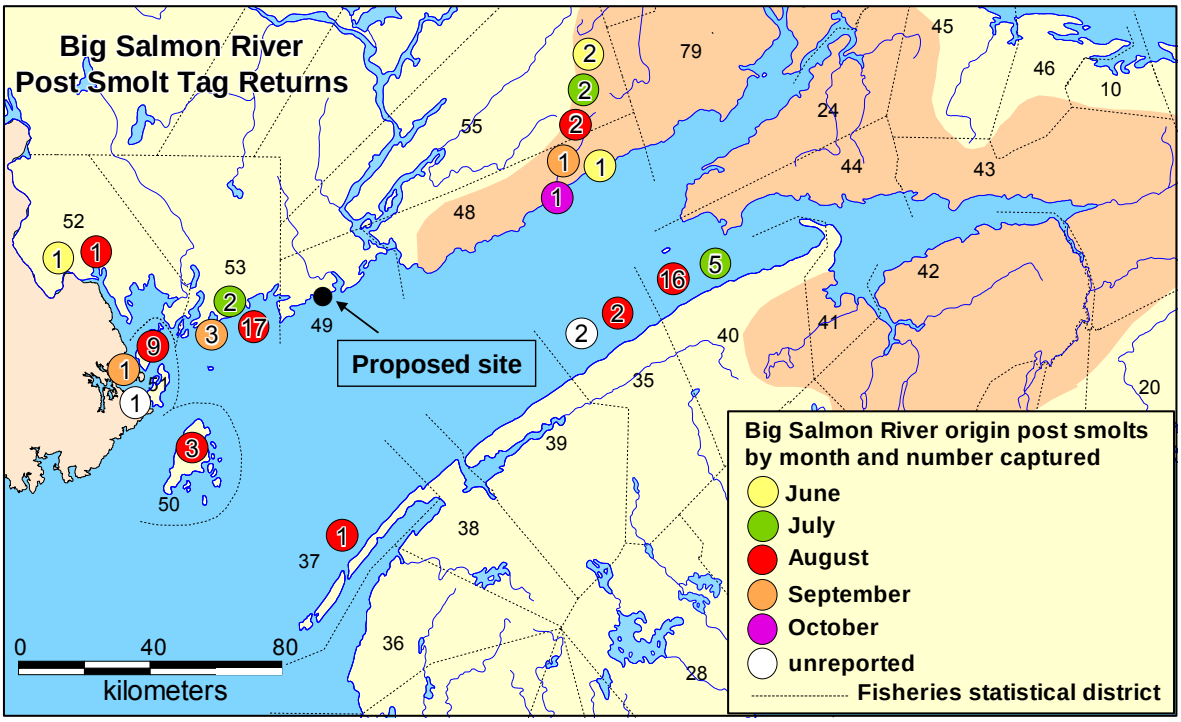

Figure 3. Locations and numbers of recaptures of tagged wild and hatchery Big Salmon River post-smolts by month of recapture (from Amiro et al., 2003). The proposed aquaculture development site at Little Musquash Cove is denoted by the black circle.

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.

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 distribution and habitat use in the Bay of Fundy is derived from historical distributions of tagged salmon (Jessop, 1976; 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 (Huntsman and Logie, 1938; 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. Telemetry data indicate that outgoing post-smolts of iBoF origin and from Saint John River populations (oBoF) migrate through the area adjacent to Musquash, New Brunswick (Lacroix et al., 2005; Lacroix, 2008). Some portion of individuals may leave the Bay of Fundy, over a period of roughly five months (June through October), but another portion may remain in the Bay during this same period. Salmon distribution during the winter months is unknown.

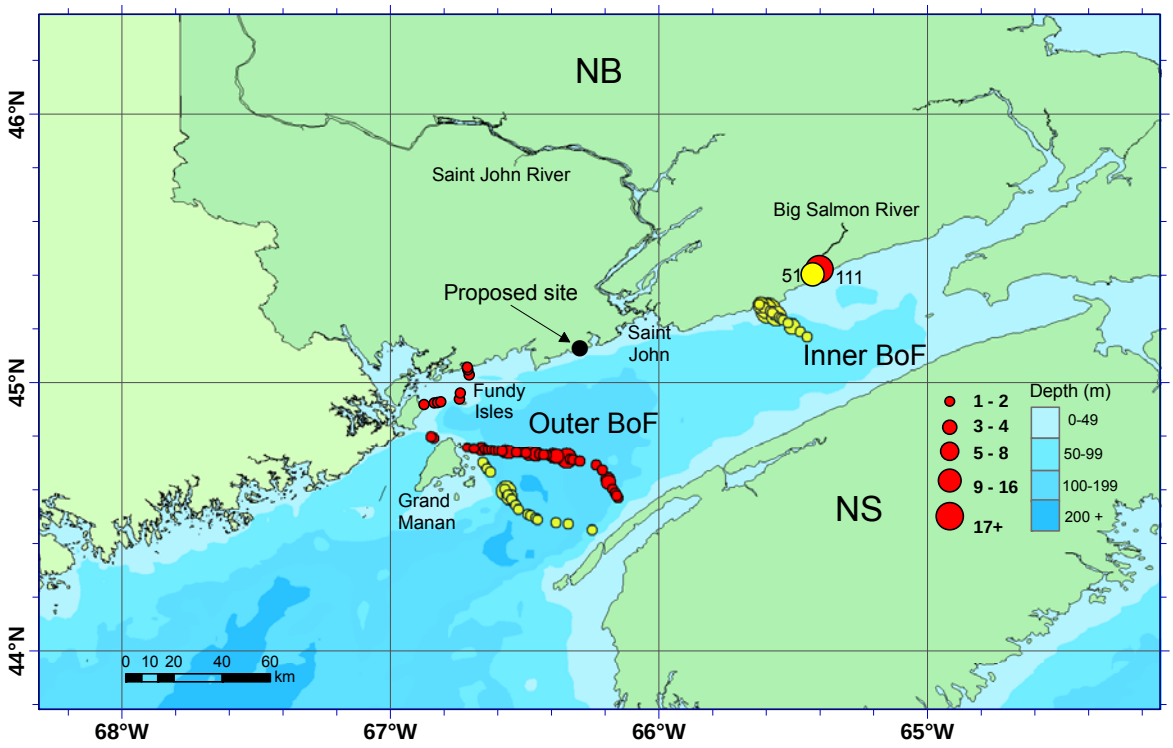

Figure 4. Distribution of migrating post-smolts from the Big Salmon River, New Brunswick, tagged with acoustic transmitters in 2001 (red circles) and 2002 (yellow circles) based on site of first detections on receiver arrays bounding the inner and outer Bay of Fundy (from Lacroix, 2008; Lacroix pers. comm., DFO Science). The proposed aquaculture development site at Little Musquash Cove 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. Jessop (1976) reported that of 147 smolts tagged in the Big Salmon River, New Brunswick, during 1966-1974, three of seven fish recaptured as adults were returned by net/weir fisheries located in Fishery Statistical Districts 48 and 49 around Saint John, New Brunswick (Figure 3). Ritter (1989) reported on a subset of these data (1967-1973), wherein five fish were captured in commercial fisheries in the area of “Middle Fundy”.

The largest historical fishery for salmon in the Bay of Fundy was prosecuted off of Saint John, in Fishery Statistical Districts 48 and 49 (Huntsman and Logie, 1938; Dunfield, 1974: Figure 5). The fishery concentrated in an area that extended from the mouth of the Saint John River to Point Lepreau, New Brunswick, and out into the Bay for nearly 20 km (see Penney, 1983). The bulk of salmon catch occurred during the late spring and summer. Due to lack of returns, Jessop (1976) hypothesized that the Big Salmon River population (iBoFs DU) contributed very little to the fishery. It is more likely that these landings consisted of oBoF salmon, mainly runs from the Saint John River.

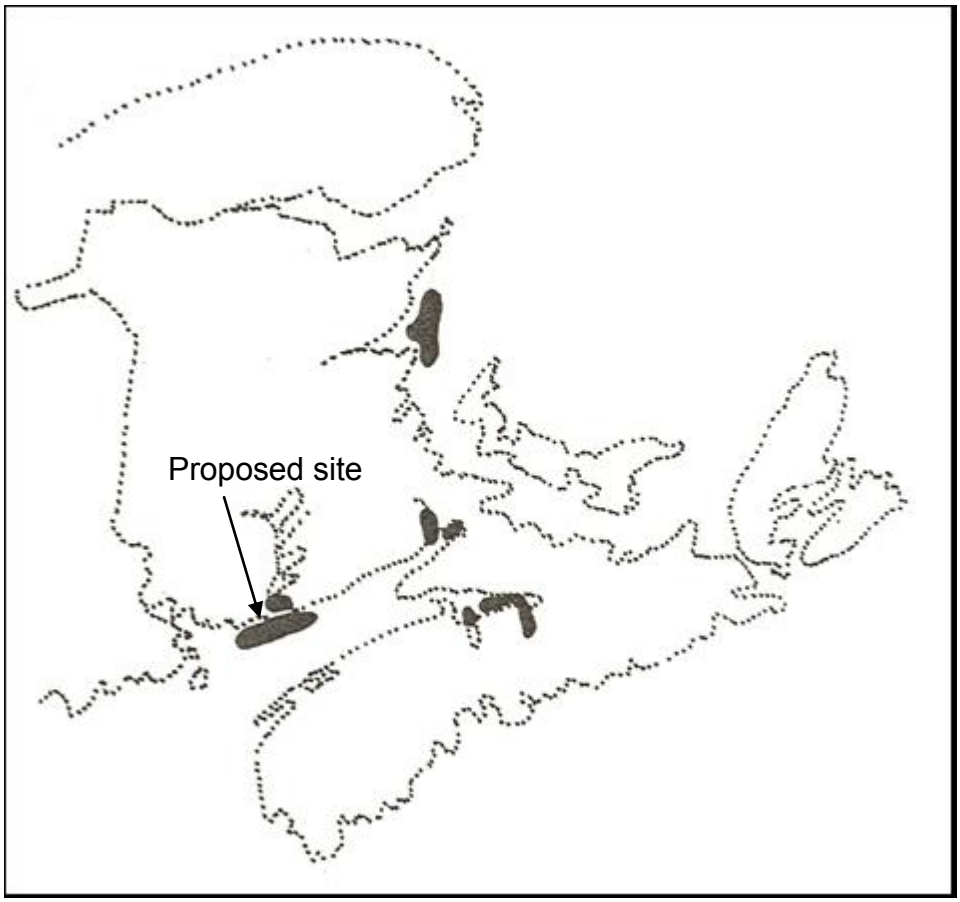

Figure 5. Locations of the Bay of Fundy commercial drift net fisheries for Atlantic salmon (adapted from Dunfield, 1974).

The use of satellite pop-up archival tags to track the marine migration of kelts indicates that they remain in the Bay of Fundy 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 site.

In summary, synthesis of available information indicates that at the beginning of the marine phase, iBoF and oBoF salmon post-smolts tend to migrate along the New Brunswick side of the Bay of Fundy towards the outer Bay and Gulf of Maine, and that, at least historically, adult salmon were captured in the area offshore of the proposed Little Musquash Cove aquaculture development site for extended periods during the late spring.

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 6). 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 at least the iBoF, oBoF and SU DUs would be expected to pass nearby the proposed aquaculture development site for these reasons and potentially more than one time.

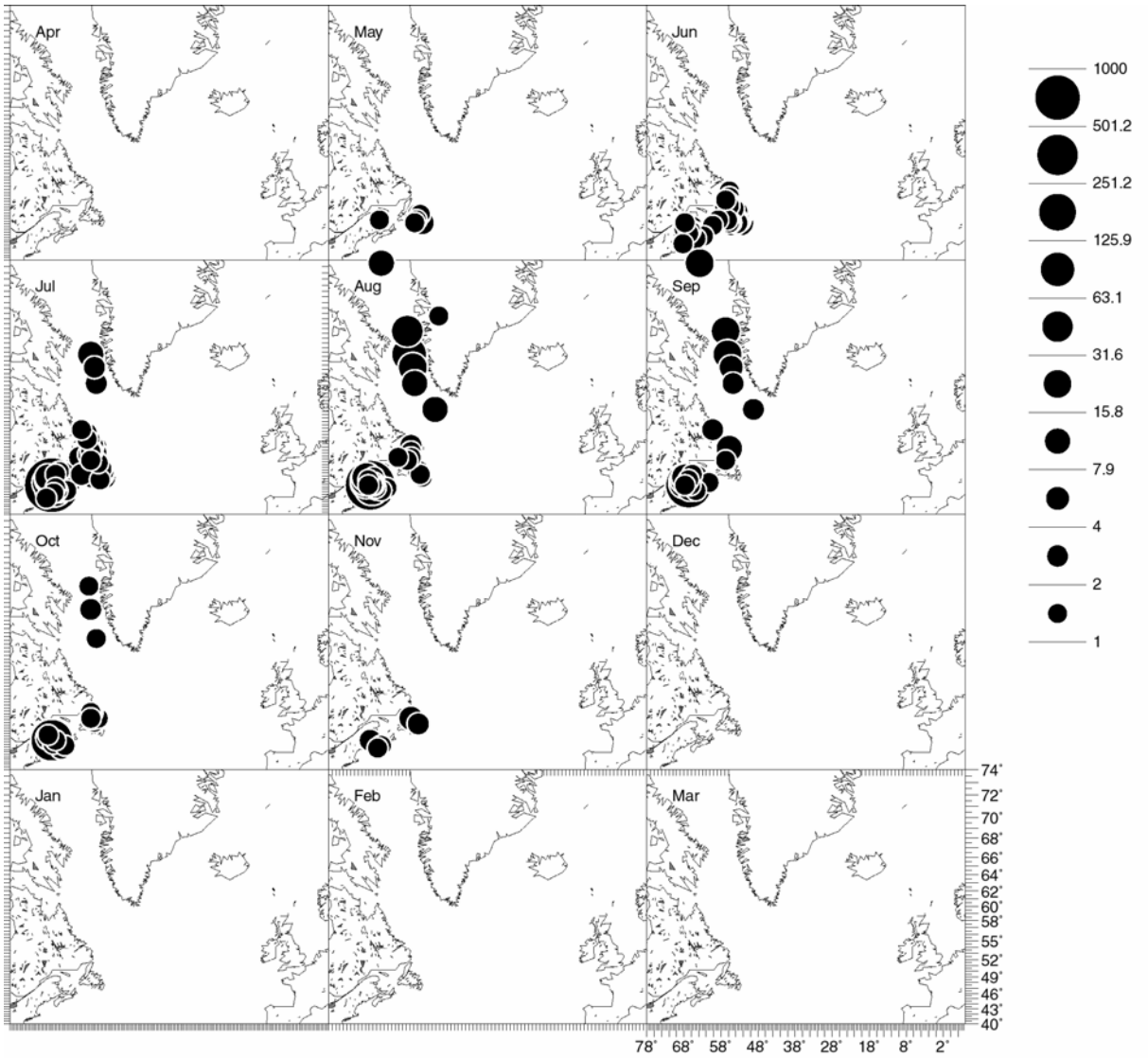

Figure 6. One-sea-year recoveries (captured with 12 to 24 months of release) from the Saint John River of tagged hatchery smolts aggregated for all available years by 5 minute squares and plotted by month (from ICES, 2008).

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

As stated earlier, no wild salmon studies have been undertaken in the immediate area around the proposed aquaculture development site. 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 (see Lacroix and Knox, 2005, for details: Figure 7). 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 the end of 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 4-6 nautical miles) from the proposed site location. It is not known if or how other life stages may make use of the area although, as stated earlier, the region off of Saint John supported historically a relatively large commercial salmon fishery. 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 site, the general area is thought to be used both as a migratory corridor and feeding ground in support of growth, maturation, and post-spawning reconditioning.

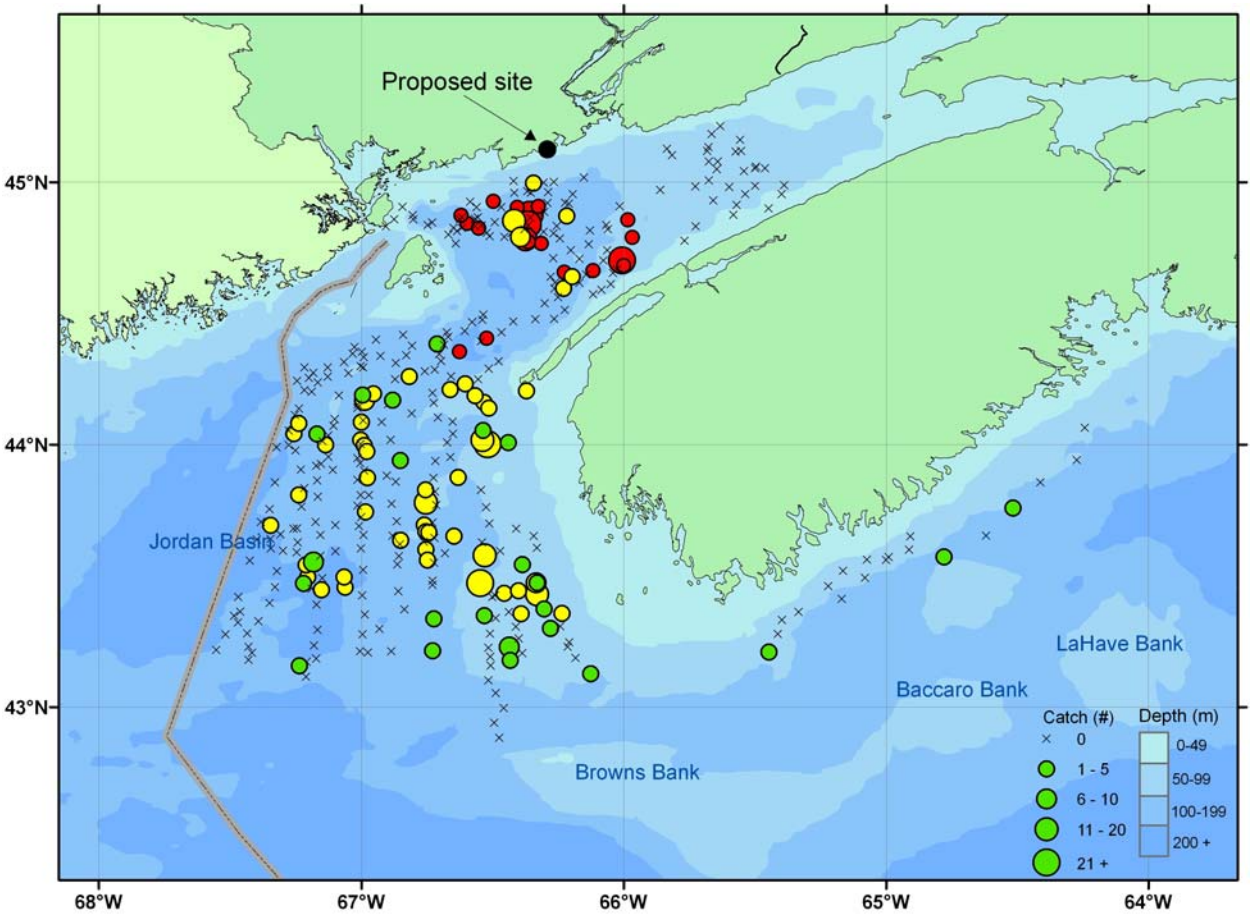

Figure 7. Distribution of post-smolts captured during surface trawling surveys in the Bay of Fundy and Gulf of Maine in 2001 (red circles), 2002 (yellow circles), and 2003 (green circles). Circles are graded by catch size (see legend on map), and trawl sites with no catches are marked (small black x's) (from Lacroix and Knox, 2005; Lacroix pers. comm., DFO Science). The proposed aquaculture development site at Little Musquash Cove is denoted by the filled 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 development site?

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, potentially could 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 development 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 are 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 of both inner and outer Bay of Fundy origin are known to occur in the waters offshore of the proposed aquaculture development site. It is therefore possible that this adjacency to occupied salmon habitat could lead to an increased probability of interaction of the proposed site 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 BoF. The absolute likelihood of interaction and resultant impacts has not been determined.

Although the impacts on the survivability or recoverability salmon cannot be quantified or compared directly to potential impacts from existing salmon aquaculture sites, 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 development site?

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 development site compare to the impacts from other anthropogenic sources?

Thorough evaluation of potential threats to salmon survival has been undertaken several times (e.g. Amiro et al., 2008b; DFO and MRNF, 2009; DFO, 2010a; Leggatt et al., 2010). None of these 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. None of these peer-reviewed publications provide a relative ranking of the severity of impacts from known or presumed anthropogenic sources. However, the presence of a salmon aquaculture cage site can alter the habitat in the vicinity of the farm. Also, the proposed aquaculture development site at Little Musquash Cove substantially extends the geographical range of salmon cage aquaculture in the Bay of Fundy.

Although the impacts of the proposed aquaculture development 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. Fish passage improvements have been made in all three regions including the opening of the causeway on the Petitcodiac River, New Brunswick, and improved fish passage facilities on the Gaspereau River, Nova Scotia, as two examples. DFO is currently working with NB Power to improve fish passage on the Saint John River 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.

Sources of 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 quantitative 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 the proposed aquaculture development site has the potential to impact on salmon populations in three designatable units (DU): the inner Bay of Fundy (iBoF); the outer Bay of Fundy (oBoF); and the Southern Upland (SU) DUs. The IBoF DU is listed as Endangered under the *Species at Risk Act* (SARA) and the oBoF and SU DUs have been recommended for listing as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The iBoF and oBoF DUs are known to be found in close proximity to the proposed site; whereas, although it is likely that SU salmon are at times present near the site (some populations are located in Nova Scotia directly across the Bay of Fundy), effects on SU salmon may occur via interactions with escaped salmon.

2) The general area around the proposed site at Little Musquash Cove is considered to be used as a migratory corridor and feeding grounds in support of growth, maturation, and post-spawning reconditioning.

3) Synthesis of available information indicates that at the beginning of the marine phase, iBoF salmon post-smolts tend to migrate along the New Brunswick side of the Bay of Fundy (the Bay), at least within 4-6 nautical miles of the site, and may circulate within the inner Bay.

4) Historically, adult salmon were captured in the area just offshore of the proposed Little Musquash Cove development site for extended periods during the late spring. 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 and oBoF DUs would be expected to pass nearby the proposed aquaculture site, and potentially more than one time.

5) Salmon aquaculture operations 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 return to freshwater, mature

and reproduce with wild conspecifics. The resulting wild farm-wild hybrids have the potential to reduce fitness of wild populations through an increased risk of outbreeding depression. Salmon in the three DUs are at low abundance relative to past levels and are highly sensitive to increased stress and mortality.

6) 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.

7) The relative severity of potential impacts from the proposed aquaculture development site relative to other anthropogenic sources cannot be determined. However, these impacts have the potential to reduce 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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