Wild Atlantic Salmon

Component Study for the Environmental Impact Statement of the Placentia Bay Atlantic Salmon Aquaculture Project

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1.0 Rationale/Objectives

This report and appendices form the Component Study on Wild Atlantic Salmon as required by the Final Environmental Impact Statement (EIS) Guidelines prepared by the Newfoundland and Labrador Department of Municipal Affairs and Environment for the Placentia Bay Atlantic Salmon Aquaculture Project proposed by Grieg NL (NL DMAE 2018). The South Newfoundland population of Atlantic salmon (*Salmo salar*), to which wild salmon in Placentia Bay belong, is currently listed as *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This population has no status under the *Species at Risk Act (SARA)*. Although Atlantic salmon are not fished commercially in Newfoundland and Labrador, the recreational fishery for Atlantic salmon has social, cultural, and recreational value. In addition, the salmon recreational fishery generates revenue and employment for rural communities in Newfoundland, including communities located in Placentia Bay.

Aquaculture operations involving Atlantic salmon introduce the risk of escaped farm fish breeding and/or competing with wild Atlantic salmon, thereby affecting the integrity of the wild population. In addition to the potential genetic and ecological interactions between wild and farmed salmon, mitigation measures and follow-up monitoring intended to protect wild Atlantic salmon from the potential effects of the project are discussed in this report. For the purposes of the EIS, ‘wild Atlantic salmon’ is considered a Valued Environmental Component (VEC).

2.0 Study Area

The boundaries of the Study Area correspond to those of the Placentia Bay Extension Ecologically and Biologically Significant Area (EBSA) (DFO 2012) (Figure 2.1). Within the Study Area, the geographic focus of this component study is on the Bay Management Areas (BMAs), the proposed sea cage sites, and the scheduled and non-scheduled Atlantic salmon rivers and salmon migration corridors that are located closest to the proposed sea cage sites.

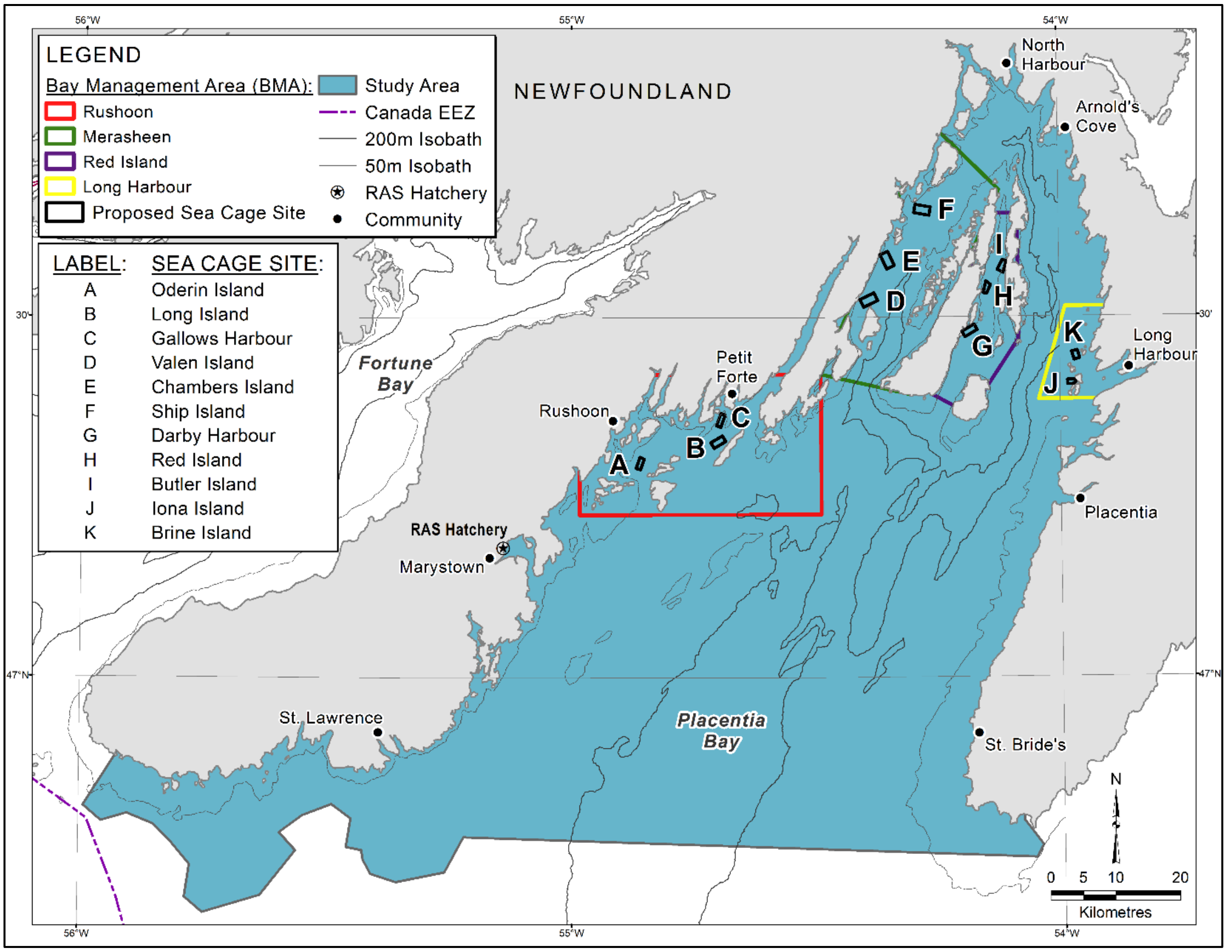

Figure 2.1. The locations of the Study Area, Bay Management Areas, and proposed sea cage sites for Grieg NL's Placentia Bay Atlantic Salmon Aquaculture Project.

3.0 Methodology

This component study is a desktop review of information and literature pertaining to the following topics as required by the Final EIS Guidelines:

- a characterization of the current distribution, abundance, genetic population structure, morphology, health and fitness, and migratory patterns of wild Atlantic salmon in the waters of Placentia Bay;
- genetic and ecological interactions of farmed Atlantic salmon escapees and wild salmon in Placentia Bay;
- literature review of the effects of disease and parasites from farmed salmon on wild Atlantic salmon;
- proximity of the sea cages to scheduled and non-scheduled salmon rivers and potential effects on migrating wild Atlantic salmon;
- oceanographic and meteorological data at the sea cage sites, including water currents, wind and wave action, flood and tidal zones, ice dynamics and storm patterns;

- water-quality data at the sea cage sites including water temperature, salinity and dissolved oxygen;
- aquatic dispersion modeling to predict the biochemical oxygen demand (BOD) material deposition from marine cage sites, as per the guidelines of the Aquaculture Activities Regulations;
- effect of sea cage deposits (i.e. pesticides, therapeutants, and disinfectants), disease, and parasites on the adjacent aquatic environment (i.e. lease area) including possible effects on wild Atlantic salmon; and
- monitoring that will be undertaken to ensure compliance with all federal and provincial regulations related to the use and release of pesticides, therapeutants, and disinfectants in the marine environment.

The information used in this component study was obtained from federal and provincial scientific research documents, academic research papers, technical guidance documents, aquaculture regulations, and consultation with Fisheries and Oceans Canada (DFO) scientists.

4.0 Study Outputs

This section discusses the various topics listed in Section 3.0. Each topic is addressed in its own subsection.

4.1 Characterization of Wild Atlantic Salmon in Placentia Bay

4.1.1 Status

The South Newfoundland population of Atlantic salmon, to which Placentia Bay salmon belong, exhibited a significant net decline in abundance of mature individuals over the last three generations at the time of preparation of the Assessment and Status Report (COSEWIC 2010). Due to the limited information related specifically to wild Atlantic salmon in Placentia Bay (Salmon Fishing Area 10 [SFA 10]), information in this section focuses on the greater demographic of the South Newfoundland population (Designatable Unit 4 [DU 4]). Information that applies specifically to wild Atlantic salmon in Placentia Bay is clearly indicated.

COSEWIC designated the South Newfoundland population of Atlantic salmon as *Threatened* in 2010 (COSEWIC 2010). The Assessment and Status Report referred to the population as “A wildlife species likely to become endangered if limiting factors are not reversed”. It also indicated that “The numbers of small (one-sea-winter) and large (multi-sea-winter) salmon have both declined over the last three generations, about 37% and 26%, respectively, for a net decline of all mature individuals of about 36%.” COSEWIC (2010) identified fisheries, including the commercial fishery in the territorial waters of St. Pierre et Miquelon, illegal fishing, and bycatch mortality, Atlantic salmon aquaculture, and lower survival at sea due to changing marine conditions as some of the potential threats and limiting factors associated with the South Newfoundland population of Atlantic salmon.

A population viability analysis related to conservation spawning requirements for Atlantic salmon in the South Newfoundland population was conducted by Robertson et al. (2013). They concluded that there was low probability (<30%) that Atlantic salmon in DU4 would meet the conservation spawning requirements for population recovery within the following 15 years. A few years later, Robertson et al. (2017) noted that no additional actions had been taken to support recovery of the South Newfoundland population.

4.1.2 Distribution

The range of the South Newfoundland population of Atlantic salmon extends from Mistaken Point on the Avalon Peninsula (~46°38'N, 53°10'W) to Cape Ray at the southwestern extreme of the island of Newfoundland (~47°37'N, 59°19'W); essentially the entire south coast of Newfoundland (COSEWIC 2010). There are 104 rivers identified in DU4, of which 48 are scheduled salmon rivers (COSEWIC 2010; DFO 2017a). In Placentia Bay, there are 20 scheduled salmon rivers and at least four non-scheduled salmon rivers. Non-scheduled salmon rivers are defined as those other than scheduled salmon rivers that are documented as being used by Atlantic salmon.

4.1.3 Migratory Patterns

Most Atlantic salmon are anadromous, meaning that mature fish migrate from the marine environment into freshwater systems to spawn. After hatching, Atlantic salmon spend several months to several years in their natal freshwater habitat, developing through various life history stages. Once development to smolt stage has occurred, salmon migrate downstream to the ocean to begin the marine phase of their life history. Once at sea, Atlantic salmon typically exhibit large-scale migrations, overwintering in feeding grounds off Labrador and western Greenland (COSEWIC 2010). Upon sexual maturation, the salmon return to their natal freshwater habitat to spawn. Some individuals may spawn more than once in their lifetime (i.e., repeat spawners) whereas others may only spawn once. Some stocks have been known to return to spawn after only a few months at sea, whereas others return after spending one winter (i.e., grilse) or more at sea. Low marine survival for overwintering salmon is considered one of the greatest threats to wild Atlantic salmon abundance in Newfoundland and Labrador (DFO 2017a). Mature salmon typically return to freshwater during May–October. Based on data collected at counting fences established on some of the scheduled salmon rivers in Newfoundland, most returning Atlantic salmon migrate upstream during late-June to mid-July (Dempson et al. 2017). Spawning usually occurs in October and November (Scott and Scott 1988; COSEWIC 2010), after which spent salmon will either return to sea or stay in freshwater until the following spring (COSEWIC 2010).

While anadromous and non-anadromous Atlantic salmon typically differ in habitat preference and feeding, there are no significant morphological differences between the two (Riley et al. 1989 *in* Gibson and Haedrich 2006). Some non-anadromous populations occurring in freshwater systems above physical barriers that prevent upstream movement are referred to as 'landlocked'. Atlantic salmon that remain in freshwater for their entire life cycle are termed "resident," whereas anadromous salmon are called "migrants." In Newfoundland, non-anadromous salmon are often called "ouananiche".

Specific Atlantic salmon migratory corridors in Placentia Bay have not been identified in the literature. However, a study planned for Placentia Bay this year will hopefully provide some information on the migratory corridors in the bay (B. Dempson, DFO Research Scientist, pers. comm., 12 April 2018). During migrations between the rivers and the ocean, salmon typically swim in the upper 10 m of the water column, sometimes as close as 2–3 m from the surface (Renkawitz et al. 2012; Thorstad et al. 2012; Godfrey et al. 2015).

4.1.4 Genetic Population Structure

The genetic structure of the South Newfoundland Atlantic salmon population has been described by Verspoor (2005), Adams (2007), and Palstra et al. (2007) *in* COSEWIC 2010). They suggest that there are fewer genetic differences among the fish in the South Newfoundland population compared with other populations on the island. Bradbury et al. (2014) examined genetic spatial structure of wild Newfoundland salmon populations, including the South Newfoundland population, to investigate how habitat and climate have influenced it. They conducted modelling using the input variables watershed size (i.e., basin area, average river width), winter severity (i.e., temperature, annual snowfall), pH, and temperature climate (i.e., temperature, annual precipitation) to determine which factors most influenced genetic divergence among wild salmon populations. Watershed size, in particular freshwater habitat area (i.e, basin area), was found to be the most important factor influencing wild salmon population genetic structure.

In 2013, there was a single large escape event in an aquaculture operation on the south coast of Newfoundland (DFO 2017a). Genetic analyses of juvenile salmon from Fortune Bay and Bay d'Espoir were conducted in 2015 and 2016. In 2015, 159 diploid escapees were detected, but none were detected in 2016. The analyses provided evidence that in 17 of the 18 sampling locations, 35% of all juveniles were either farmed salmon or first- or second-generation hybrids. It was determined that some of the hybrids were capable of reproducing. There were also older individuals (escapees prior to 2013) found among the detected hybrids. In general, smaller stocks of salmon were found to have greater levels of hybridizations than larger stocks (DFO 2017a). DFO (2017a) indicated that further follow-up monitoring will be conducted. Note that these escapes involved sea cages that were not Aqualine Midgard System sea cages proposed for the Grieg NL project.

Verspoor et al. (2015) suggest that there is greater risk of genetic and ecological effects from farmed salmon escapees on wild salmon populations that are considered at risk (e.g., threatened), since smaller depressed stocks (i.e., lower abundances) will be more vulnerable to impacts of genetic contribution (i.e., genetic drift) than larger healthier stocks.

4.1.5 Abundance

Two general methods of estimating Atlantic salmon abundance include: (1) analysis of counting fence data on returning salmon, and (2) analysis of Atlantic salmon recreational fishing data provided by anglers. Only one river in Placentia Bay, specifically the Northeast River, currently has an operating counting fence (G. Veinott, DFO Research Scientist, pers. comm. 5 March 2018). DFO (2017c) recently completed a mid-season review of Atlantic salmon returns to NL rivers in 2017. Northeast River, near the community of Placentia in the eastern part of Placentia Bay, was one of the rivers assessed (Figure 4.1). Projected numbers of returning salmon were compared with mean numbers of returns during the previous five years. Northeast River had particularly low returns in 2017, about 80% fewer salmon returning than what was projected. In a supporting document to the 2016 Newfoundland and Labrador Atlantic salmon stock assessment (DFO 2017a), Veinott et al. (2018) finalized 2016 assessment data for the Atlantic salmon stock returning to Northeast River. There was a counting fence on Northeast River during 1984–2002, but the salmon stock was not assessed again until 2015. Therefore, a five-year mean for total salmon returns could not be calculated for this river. Despite the lack of a five-year mean of returns, it was determined that Northeast River had achieved 438% of its egg conservation requirement, placing it in a "Healthy Zone" in terms of DFO's Precautionary Approach Framework (G. Veinott, DFO, pers. comm., 5 March 2018; Veinott et al. 2018). Nonetheless salmon returns to this river in 2017 declined by approximately 58% compared to returns in 2016 (G. Veinott, DFO, pers. comm., 5 March 2018). Low marine survival is suggested as one of the primary reasons for the low numbers of returning salmon to Northeast River and other rivers in Placentia Bay (Robertson et al. 2017; Veinott et al. 2018).

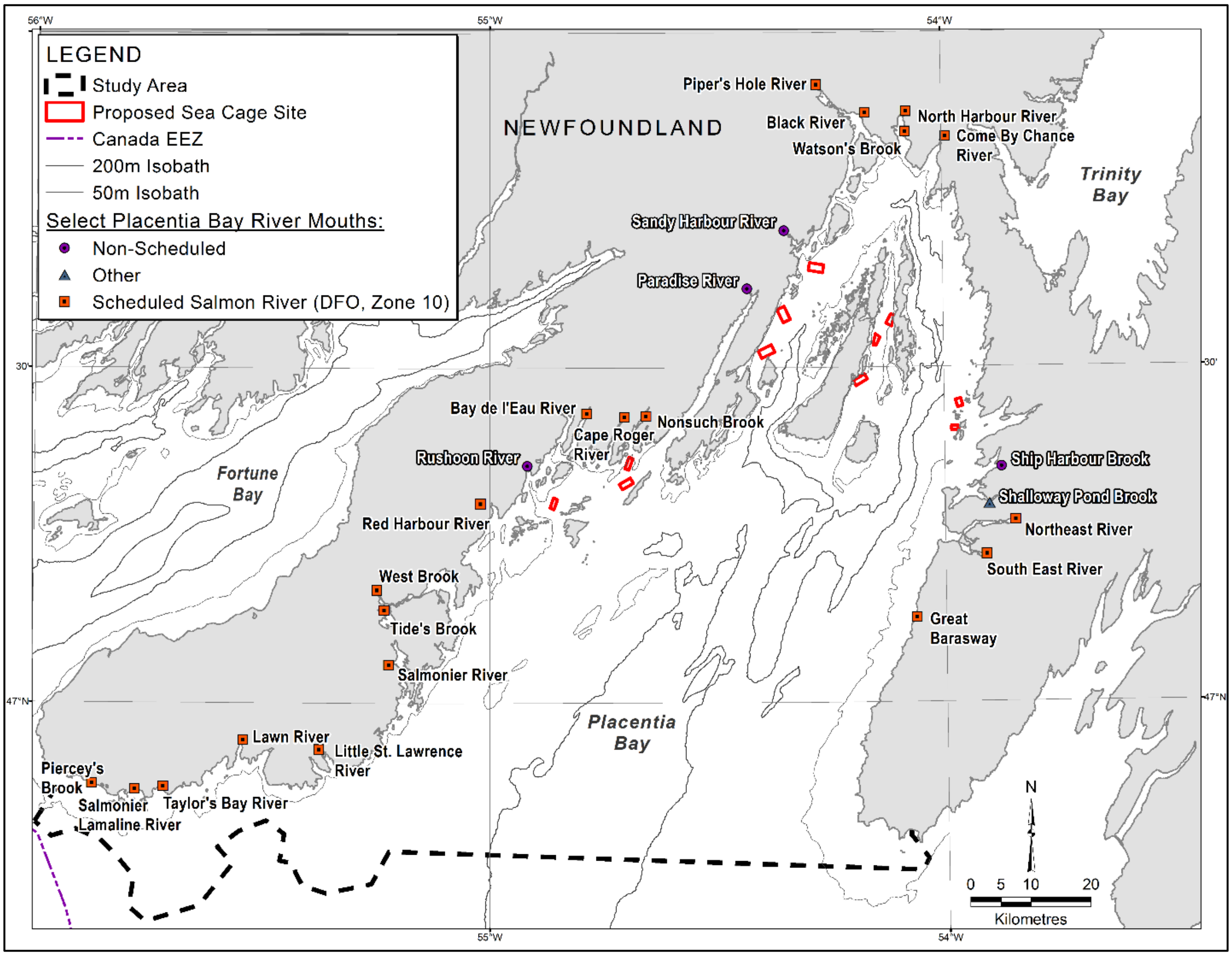

Figure 4.1. Locations of scheduled salmon rivers in Placentia Bay.

According to COSEWIC (2010), the number of mature Atlantic salmon in the South Newfoundland population, as estimated in 2007, ranged between 21,866 and 29,711. The preliminary 2017 estimated range of the number of mature Atlantic salmon in Placentia Bay stocks, which are a component of the South Newfoundland population, is 2,828–5,099. However, these estimates will likely change as DFO processes more of the 2017 angling data and refines its exploitation rates for 2017. The final 2016 estimated range of the number of mature Atlantic salmon in Placentia Bay stocks is 4,981–9,388. Note that these estimated numbers are based on the island wide exploitation rates and angling data from SFA 10. (G. Veinott, DFO Research Scientist, pers. comm. 4 May 2018).

Recreational salmon fishing data for most rivers in Placentia Bay are probably the best available indicator of salmon abundance within the Study Area as a whole. Table 4.1 presents recreational angling data for 18 of the 20 scheduled salmon rivers in Placentia Bay during the 2012–2016 period. During this time, 10,980 salmon were caught, of which 4,429 salmon were retained and 6,461 were caught and released. The locations of these scheduled rivers are shown in Figure 4.1.

Table 4.1. Atlantic salmon recreational fishery statistics for scheduled Atlantic salmon rivers in Placentia Bay (2012–2016).

River Name	Effort (rod days)	Number of Salmon Retained	Number of Salmon Released	Total Number of Salmon Caught	CPUE
Great Barasway*	58	14	8	22	0.38
South East River (Placentia)	5,047	372	690	1,062	0.21
Northeast River (Placentia)	4,063	482	526	1,008	0.25
Come By Chance River	2,961	279	648	927	0.31
North Harbour River	1,641	263	215	478	0.29
Watson’s Brook*	96	3	55	58	0.60
Black River	769	122	92	214	0.28
Piper’s Hole River	5,486	580	1,218	1,798	0.33
Nonsuch Brook*	9	0	0	0	0.00
Cape Rodger River	3,623	606	1,115	1,721	0.48
Bay de l’eau River	5,260	852	1,246	2,098	0.40
Red Harbour River	783	115	45	160	0.20
Tide’s Brook	5,133	546	375	921	0.18
Salmonier River*	127	5	12	17	0.13
Lawn River*	215	19	47	66	0.31
Taylor’s Bay River*	83	18	15	33	0.40
Salmonier Lamaline River	1,589	136	147	283	0.18
Piercey’s Brook*	62	17	7	24	0.39

Source: G. Veinott, Research Scientist, Atlantic Salmon, DFO, pers. comm., 19 February 2018 (unpublished data).

* Denotes that fewer than 5 years of data used to calculate totals and catch per unit effort (CPUE). No data were provided for two other scheduled rivers in Placentia Bay: (1) West Brook; and (2) Little St. Lawrence River.

4.2 Genetic and Ecological Interactions of Farmed Atlantic Salmon Escapees and Wild Salmon

Decades of artificial selection and domestication of farmed salmon have produced fish that are genetically distinct from their wild counterparts (Clifford et al. 1998). Farmed salmon are selected for traits that increase their economic value, including higher growth rate, greater disease resistance and higher fillet quality (Hindar and Fleming 2007). Aquaculture operations on the south coast of Newfoundland have been using New Brunswick's Saint John River strain of farmed salmon since 1991 (DFO 2013). Recently, there has been interest in using European-origin farmed salmon because of their higher growth rates and other attributes that result in more economic benefit (Verspoor et al. 2015). Since European-origin farmed salmon have never been utilised in Newfoundland, there is no available information concerning the genetic and ecological interactions between farmed European salmon and wild Newfoundland salmon.

Mitigating escapes of farmed Atlantic salmon is important because interactions between escapees and wild salmon can result in negative genetic and ecological effects on the wild fish (Naylor et al. 2005; Ferguson et al. 2007; Verspoor et al. 2015; Glover et al. 2017). Morphological, behavioural and ecological traits can be affected as a result of breeding between farmed Atlantic salmon and wild salmon, thereby potentially causing negative impact on the character, abundance, and survivability of wild salmon stocks (Cairns 2001; Ferguson et al. 2007; Jensen et al. 2010; Verspoor et al. 2015).

Hybrid salmon resulting from the breeding of farmed fish with wild fish may have reduced fitness (i.e., outbreeding depression) and ability to adapt to environmental conditions (including resistance to disease) compared to wild Atlantic salmon. This can directly affect survivability (DFO 2013). The effects of interbreeding on the fitness and ability of hybrids to adapt to their local surroundings is unpredictable, however, and may not be fully realized until the arrival of second generation hybrids (Verspoor et al. 2015). Escaped farmed salmon may also compete with wild salmon during spawning in freshwater systems (DFO 2013; Fjelldal et al. 2014), thereby reducing the number of successful wild salmon spawning events and affecting wild salmon stock abundances.

The risks associated with direct genetic interactions between farmed and wild salmon are related to the number of farmed salmon escapees, the number of escape events, the subsequent prevalence of interbreeding over successive generations, the seasonal timing of the escape and the age of escapees (Verspoor et al. 2015; Bridger et al. 2015). In some cases, continuous escapes of a small number of farmed salmon (i.e., chronic releases) can be more harmful than intermittent escapes of a large number of fish (i.e., acute releases) (Baskett et al. 2013; DFO 2013; Verspoor et al. 2015). In any case, the greater the number of escaped salmon, the greater the associated risk of genetic introgression[1] of gene variants to wild salmon stocks (Keyser et al. 2018).

Based on studies of other farmed strains of salmon (e.g., New Brunswick, Norway), there is potential for unpredictable, negative genetic interactions between farmed and wild Atlantic salmon (Hindar et al. 1991; DFO 2013, Verspoor et al. 2015). Note that the farmed salmon discussed here in relation to genetic and ecological interaction are diploid fish (i.e., fish that contain two sets of chromosomes, one from each parent) unless otherwise stated. Diploidy is the natural genetic state of wild salmon. Triploidy, on the other hand, refers to fish with an extra set of chromosomes. This genetic state is induced in salmon eggs to make resultant salmon sterile.

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[1] Introgression is defined as the transference of genes from one species to another resulting in hybridization of offspring.

While triploid male salmon may undergo development of secondary sexual characteristics and subsequently attempt to spawn with diploid wild female salmon in freshwater, sterile female triploid salmon are considered less likely to interact ecologically with diploid wild male salmon (Glover et al. 2016). Most of the offspring that result from spawning between triploid male fish and diploid female wild fish die before first feeding (Benfey 2015). Most of the genetic and ecological interactions observed between farmed and wild salmon involve escaped diploid salmon.

It has been documented that farmed Atlantic salmon escapees sometimes enter rivers that have natural spawning grounds for wild salmon stocks, and mate with wild salmon (Lura and Saegrov 1991; Webb et al. 1991; Carr et al. 1997; Saegrov et al. 1997; Clifford et al. 1998; Fleming et al. 2000; Milner and Evans 2003; Butler et al. 2005; Fiske et al. 2006; Skaala et al. 2006; Hindar and Diserud 2007; Morris et al. 2008; Madhun et al. 2015; Skilbrei et al. 2015). Aquaculture operations on the south coast of Newfoundland have reportedly had high numbers of escaped diploid farmed salmon, with some entering rivers located close to sea cages (Morris et al. 2008; DFO 2017a; Keyser et al. 2018). Specific distances between the sea cages from which farmed salmon escaped and the rivers entered were not provided in these studies. However, Keyser et al. (2018) indicated that the distribution of rivers in which escaped farmed salmon were detected was well within the reported dispersal distance of escaped farmed salmon (Hansen and Youngson 2010). Keyser et al. (2018) indicated that the majority of escaped farmed salmon in their study in Norway were recaptured within 150 km of the release site but that some were recaptured as far as 800 km away. Genetic techniques to trace farmed salmon back to their respective aquaculture operation have also been developed (Norris et al. 1999; Glover 2010), allowing the identification of farmed salmon found in the wild and of the farm from which the fish originated. These techniques can hold aquaculture operators accountable for unreported escapes.

Even with the implementation of the best available containment measures to prevent farmed salmon from escaping from sea cages, it is considered a frequent and inevitable occurrence (Glover et al. 2017). Some potential causes of fish escape from sea cages include severe weather/storm events, holes in the netting of sea cages, predator attacks on the sea cages, and factors related to human/operational error (Jensen et al. 2010; Jackson et al. 2015; Thorvaldsen et al. 2015). Bridger et al. (2015) reviewed aquaculture equipment and standard procedures used to mitigate escapes of farmed fish from sea cages. The primary reasons for escape identified by Bridger et al. (2015) include structural deficiencies of the sea cage and mooring components, human error in fish handling and farm management practices, and predator attacks on sea cages.

The "*Code of Containment for the Culture of Salmonids in Newfoundland and Labrador* (COC)" is a management strategy first developed in 1999 to minimize the escape of farmed salmonids from aquaculture operations. It is a joint effort by the Department of Fisheries and Land Resources (DFLR [formerly DFA]), DFO, and the aquaculture industry aimed at reducing the risk of farmed salmon interacting with wild salmon stocks. In particular, the Code sets standards for the design and operation of sea cage systems. Focus is placed on the infrastructure and equipment used in sea cages such as nets, cages, mesh size, and moorings. However, there are also procedures and monitoring protocols for equipment usage, protection against ice, sea cage inspections, predator control plans, fish handling practices, and measures to recapture fish

(DFA 2014). Any fish escape from a sea cage is considered "significant" and the aquaculture operator must contact DFO to discuss potential recapture methods. An Annual Compliance report is published each year to assess the effectiveness of the management strategies and best industry practices laid out in the Code. Also reported are inspection efforts made by the DFLR, the number of fish escapes, and the effectiveness of recapture methods. The primary recapture methods involve the use of gill nets. "Schedule 1" of the Code (DFA 2014) suggests the minimum gear requirements for recapture efforts, depending on the number of aquaculture sites that report escapes.

In southern Newfoundland, farmed salmon escapes were reported in four of the six years between 2010 and 2015 (DFO 2017b). In August 2015, an unknown number of salmon escaped sea cages that had holes in the netting due to damage caused by predator strikes. Approximately 200 salmon were recovered during this event. In September 2013, there was a single large event involving 20,500 escaped farmed salmon. The escape event was due to extreme weather which resulted in collapsed sea cages. A directed marine recapture fishery and an experimental freshwater fishery were conducted. Small numbers of escapes were reported in 2012 as a result of damage to the netting caused by sharks and tuna. No recapture efforts were conducted during these events in 2012. In 2010, 100–200 farmed salmon escaped due to a harvesting spill. No recapture attempts were made to recover the salmon during this escape event (DFO 2017b).

A proactive method of mitigating the potential effects of genetic interaction of farmed salmon and wild salmon is the use of all-female triploid salmon in aquaculture operations (DFO 2013; Benfey 2015). Triploid females differ from triploid males in that they remain sexually immature throughout their juvenile and adult phases. Triploid males are still capable of mating with wild diploid females (Fjelldal et al. 2014) since they are capable of developing secondary sexual characteristics and exhibiting normal spawning behaviour at the spawning grounds (Benfey 2015). Since male triploids are capable of producing only aneuploid sperm (i.e., possessing an abnormal number of chromosomes), offspring resulting from spawning of a male triploid salmon with a female wild fish typically display poor survivability. The vast majority of the offspring die early in development (Benfey 2015). A number of publications (DFO 2013; Benfey 2015; Fjelldal et al. 2014; Verspoor et al. 2015) recommend the use of all-female triploids as an effective measure to restrict genetic interactions between farmed salmon and wild salmon. Triploidy creates a "genetic containment" thereby minimizing the chances of escaped farmed salmon mating and reproducing with wild salmon (Benfey 1998).

Induced triploidy of Atlantic salmon has been utilized for over 30 years and is currently the only commercially viable method to sterilize large numbers of fish for an aquaculture scale operation (DFO 2013; Benfey 2015). It is commonly conducted by treating newly fertilized eggs with hydrostatic pressure which disrupts the movement of chromosomes during meiosis (Benfey 1998). New improved technology implemented in 2017 has improved the success of induced triploidy from approximately 98% to 100%. DFO (2016) conducted a power analysis to determine the minimum sample sizes required to find at least one non-triploid egg per batch of ~8,000 eggs treated with hydrostatic pressure (see Table 1 in DFO 2016). Stofnfiskur, an egg supplier company in Iceland, has modified the egg pressurization technique by housing the eggs in smaller chambers (i.e., 2 L in volume) when they are subjected to hydrostatic pressurization. By using smaller chambers all eggs are subjected to the same pressure whereas the use of larger chambers in the past resulted in some eggs not receiving the necessary pressure required to induce sterile triploidy. In addition to using smaller chambers for the process, Stofnfiskur has adopted a two-tier testing procedure. A small subset from each batch of eggs is cultured at a slightly higher temperature thereby speeding up the development process. The result is a sample of the batch that can be sent for verification testing at least one week prior. Both the subset and the primary batch must have 100% sterile triploid verification in order to be shipped to a customer. If verification tests indicate less than 100% sterile triploidy, the entire batch of eggs is discarded. This approach to utilize a two-tier testing method increases the probability of detecting failure rates and decreases previous rates that detected 1–2% failure within the batch. The smaller pressure chambers discussed above also allow Stofnfiskur to separate the eggs from each female. Grieg NL will be using triploid sterile all-female Atlantic salmon eggs for the project. More details on the methodology used by Stofnfiskur to induce triploidy are provided in Appendix A.

Triploids, in comparison to diploids, tend to have a higher rate of skeletal deformities and impaired vision from the development of cataracts (Benfey 2015; Verspoor et al. 2015). However, special feed containing phosphorous and the amino acid histidine have helped to alleviate these morphological abnormalities (Sambraus et al. 2017; Smedley et al. 2018; Taylor et al. 2013, 2015).

Competition for food and space is also a potential ecological interaction between escaped farmed salmon and wild salmon, principally in freshwater systems but also, to a lesser degree, in the marine environment. Escaped farmed salmon have demonstrated phenotypic plasticity through their ability to survive in the wild. Several studies have shown that diploid farmed salmon and farm-wild hybrid fish are capable of surviving natural environmental conditions (Fleming et al. 2000; Hamoutene et al. 2015; Lush et al. 2018). Studies conducted by Hislop and Webb (1992), Fleming et al. (2000), Einum and Fleming (1997), McGinnity et al. (2003), and Skaala et al. (2012) determined that escaped farmed salmon have a similar diet to wild salmon which could potentially create competition for food resources (Jensen et al. 2010). Since juvenile farmed salmon grow faster and are more aggressive than juvenile wild salmon (DFO 2013; Verspoor et al. 2015), they could potentially outcompete juvenile wild salmon. Further compounding the size differences between farmed and wild salmon, farmed triploid Atlantic salmon typically grow faster than farmed diploid fish (O’Flynn et al. 1997; Fiskeridirektoratet 2016).

Some studies suggest that the use of sterile triploid salmon in aquaculture will help to prevent genetic and ecological interactions between wild and farmed salmon. Glover et al. (2016) recently examined the ploidy of farmed salmon escapees that were captured in the Norwegian recreational salmon angling fishery during 2007–2014. This was the first study to investigate the frequency of diploid and triploid farmed salmon escapees in rivers. Individual salmon from 17 rivers underwent microsatellite Deoxyribonucleic acid (DNA) genotyping to determine ploidy. Only 7 of the 3,794 (0.18%) Atlantic salmon examined were triploid, five males and two females. Five of the seven triploids were caught in the lower stretches or estuarine sections of the river (i.e., not in the upper areas where the spawning grounds were located). Based on the low ratio of triploids to diploids caught in the rivers, the authors concluded that sterile triploid salmon do not appear to be as motivated to enter freshwater as diploid farmed salmon, particularly the females. If this is indeed the case, then the farming of triploid female salmon could reduce potential genetic and ecological impacts of farmed salmon escapees.

Cotter et al. (2000) conducted an experimental release of diploid and triploid salmon to determine differences in rate of return to freshwater. They found that triploid fish returned at a rate four times lower than that of diploid fish.

4.3 Effects of Sea Lice and Disease Transfer from Farmed Salmon to Wild Atlantic Salmon

Marine sea cage aquaculture of Atlantic salmon may also result in the transfer of sea lice and parasites from the farmed salmon to wild salmon.

4.3.1 Sea Lice

Atlantic salmon stocked in sea cages are initially sea lice-free. However, they can be infected with sea lice from other fish farms or from wild Atlantic salmon that also act as hosts for the parasites. Some studies have examined the parasite loading of farmed fish and wild fish associated with the farms and have found that wild fish actually have higher levels of parasite loading than farmed fish (Sepúlveda et al. 2004; Skov 2009; Fernandez-Jover 2010).

Two of the most common sea louse species that infect farmed and wild Atlantic salmon in Atlantic Canada are the parasitic copepods *Lepeophtheirus salmonis* and *Caligus elongatus*. Sea lice are problematic for fish farmers so controlling them is a high priority area of aquaculture research (Rittenhouse et al. 2016). In addition to the external damage that they cause to salmon, they are capable of facilitating the transfer of pathogens which can lead to disease and increased mortality in both farmed and wild salmon (Jensen et al. 2010; DFO 2014; Verspoor et al. 2015). If not controlled, particularly during infestations, sea lice on farmed salmon can increase the abundance of sea lice in the vicinity of sea cages and the probability of sea lice infesting migrating wild salmon passing through the area (Jensen et al. 2010; DFO 2014; Saksida et al. 2015). It is not necessary that farmed fish escape cages to spread sea lice and/or pathogens and disease to wild salmon (Verspoor et al. 2015). Based on current science information, the free-living stages of sea lice can disperse distances of tens of kilometres (DFO 2014).

Fish farms can therefore function as potential “reservoirs” for the spread of sea lice to wild salmon (DFO 2014, 2016; Johnson and Jones 2015). The extent to which sea lice may proliferate and infect farmed and wild salmon depends on several factors, including environmental conditions such as water temperature, salinity, and hydrological conditions, behaviour and movements of adult sea lice, and the prevalence and abundance of infected salmon (DFO 2014; Johnson and Jones 2015). Rittenhouse et al. (2016) conducted modeling to determine peak timing of sea lice reproduction in southern Newfoundland and demonstrated that abundance is affected by environmental parameters such as temperature and salinity. Their findings indicate that sea lice abundance is greatest in southern Newfoundland in late summer when seawater temperatures and salinities are at their highest levels. While sea lice reproduction peaks in August, it is lowest in December when seawater temperatures are lowest. The abundance and density of sea cages containing farmed salmon infected with sea lice will also influence the abundance and degree of sea lice spread (Jansen et al. 2012; Kristopherson et al.

2013 *in* DFO 2014). The greatest risk of sea lice transfer from farmed salmon to wild salmon occurs during the peak period of juvenile wild salmon migration to sea, between mid-April and early-June (DFO 2014; Johnson and Jones 2015; NASCO 2016). There is little conclusive evidence however to support the belief that escaped farmed salmon may serve as sources of sea lice that could lead to increased mortality in wild fish (Jensen et al. 2010; Verspoor et al. 2015).

Given the common use of chemotherapeutants to treat farmed fish infected with sea lice, the sea lice are becoming increasingly resistant to many of these chemicals. This has prompted the use of "cleaner fish" in aquaculture operations whereby fish species that prey upon sea lice are stocked in the sea cages with farmed salmon. Cleaner fish, such as lumpfish (*Cyclopterus lumpus*), are commonly used in salmon aquaculture in Norway. Currently, a privately-owned lumpfish hatchery in Newfoundland is supplying cleaner lumpfish to the Connaigre Peninsula aquaculture industry.

A study conducted by Imsland et al. (2014) assessed the use of lumpfish to control sea lice infection levels in farmed Atlantic salmon in Norway. Their findings indicate that Atlantic salmon in cages with lumpfish had significantly lower levels of pre-adult and adult sea lice stages than salmon in control cages without lumpfish. Lumpfish sampling conducted at the end of the experiment determined that 28% of the lumpfish had recently ingested sea lice, providing clear evidence that lumpfish will prey on sea lice and can be used as a deterrent to sea lice in sea cages.

Cleaner fish escapees may not cause serious adverse effects on wild lumpfish. Jónsdóttir et al. (2018) examined the genetic diversity and population structure of wild Norwegian lumpfish to determine if previous escapes of lumpfish from sea cages had an impact on wild lumpfish populations. They determined that there were no significant differences in genetic structuring in the wild lumpfish sampled, suggesting that lumpfish escapees may have little or no impact on the genetic composition of wild lumpfish populations.

While cleaner fish remove sea lice from sea cages and thereby reduce sea lice infection rates in farmed Atlantic salmon, they can also carry pathogens which can spread to the salmon (Haugland et al. 2017; Murray 2017). Murray (2017) used a modeling approach to determine the potential for disease spread to salmon stocked in cages with cleaner fish. He found that reusing cleaner fish for consecutive lots of farmed salmon in a sea cage presents more risk to salmon than using new cleaner fish for each lot of farmed fish. Risk of disease transmission is low if only small numbers of cleaner fish are placed in sea cages. Murray (2017) concluded that while cleaner fish do have the potential to infect salmon with pathogens, the risk from the proliferation of sea lice spreading infection in sea cages is greater. Fallowing of sea cages and sourcing cleaner fish from hatcheries with high biosecurity practices are some of the suggested approaches for preventing diseases in cleaner fish.

Aquaculture operators complete weekly sea lice counts during efforts to control and prevent the spread of sea lice among farmed salmon. If sea lice are prevalent, a licensed veterinarian from the Aquatic Animal Health Division (AAHD) may be called in to treat fish (Senate 2016). The use of a range of chemical therapeutants may also be used to eliminate sea lice and other parasites.

Sea lice monitoring programs as well as management and regulatory thresholds have been established for the control of sea lice on farmed fish. Once the thresholds (i.e., number of sea lice per fish) have been reached or exceeded, the use of control treatment measures to reduce the levels of sea lice impacting farmed salmon may be necessary (DFO 2014). Early detection and treatment of sea lice is the main mitigation strategy for sea lice control in aquaculture operations in Atlantic Canada. Generally, sea lice abundance is determined at the cage/farm level by sampling salmon from a number of the cages at a particular site. Sampled fish are anesthetized to allow the enumeration and classification of sea lice life stages (DFO 2014). DFO (2014) provides further advice regarding the sampling of farmed and wild salmon for sea lice assessment.

4.3.2 Pathogens

Although there is little information in the primary literature regarding the resistance of triploid Atlantic salmon to pathogens, anecdotal evidence from fish farmers indicates that triploid fish may be less resistant to pathogens and parasites, potentially resulting in increased disease transmission to wild salmon (DFO 2013; Benfey 2015). Some recent studies have provided new information on the comparable susceptibility and resistance of diploid and triploid Atlantic salmon to viruses. For example, a study conducted by Moore et al. (2017) found that triploid salmon were less susceptible to salmonid alphavirus type 3 (SAV3) than diploid salmon. Herath et al. (2017) compared the susceptibility of triploid and diploid Atlantic salmon to salmonid alphavirus type 1 (SAV1) and found similar rates of mortality in the two groups.

Cases of infectious salmon anemia (ISA) were reported in Atlantic salmon in Newfoundland during 2012–2017, the most recent case occurred in October and November of 2017 (CFIA website 2017a). ISA is a serious disease for salmon and is required to be reported to the Canadian Food Inspection Agency (CFIA) immediately upon discovery. Other diseases which have been reported in Newfoundland (DFLR 2017) include the following.

- bacterial kidney disease;
- enteric red mouth disease;
- vibriosis;
- furunculosis;
- pseudomoniasis;
- saddle back disease;
- winter ulcer disease;
- columnaris disease;
- nocardiosis;
- saprolegniasis;
- nodular gill disease;
- black spot disease;
- infectious pancreatic necrosis;
- nodavirus;
- mycobacteriosis;
- microsporidiosis;
- costiasis;

- trichodiniasis; and
- proliferative kidney disease.

4.3.3 Transfer of Parasites and Pathogens to Non-salmonid Fishes

While parasite and disease transfer between farmed salmon and wild salmon has been identified as an issue with aquaculture, less is known about parasite/disease transmission between farmed salmon and wild non-salmonid fishes (Uglem et al. 2014). Transmission of parasites and pathogens between farmed salmon and wild fishes is likely density-dependent. Generally, the higher the host fish densities, the greater the potential for the spread and persistence of parasites and pathogens to host fishes (Krosek 2017). In addition, parasite and pathogen transfer can be influenced by environmental conditions such as water temperature, salinity and other hydrological parameters, behaviours and movements of adult sea lice, and the prevalence and abundance of salmon that are infected (DFO 2014; Johnson and Jones 2015). Salmon lice (*L. salmonis* and *C. clemensi*) appear to be largely host-specific to salmonid species although they are also known to infect three-spined stickleback (*Gasterosteus aculeatus*) in British Columbia (Jones et al. 2006). In Atlantic Canada, *L. salmonis* has not been observed on any non-salmonid fish species (DFO 2014). Although there are few studies in Atlantic Canada that have examined the transfer of sea lice and other parasites/pathogens from farmed salmon to wild fish species, there is little conclusive evidence of impact; however, it is still thought to be possible (DFO 2014; Verspoor et al. 2015).

4.4 Potential Effect of Proximity of Sea Cages to Salmon Rivers

It has been suggested that the closer sea cages are located to rivers, the higher the potential for escaped farmed salmon to enter the freshwater systems and interact with the wild fish (Carr et al. 1997). However, there is no reason to believe that farmed salmon escapees are not capable of moving to rivers some distance from sea cage sites (Hansen and Youngson 2010; Solem et al. 2013). The likelihood that escaped farmed salmon will enter freshwater systems will depend primarily on the life stage of the fish and the timing of the escape. More mature escaped salmon tend to enter nearby rivers than juvenile salmon (Skilbrei et al. 2015). It is thought that juveniles that escape in the spring are more likely to enter the rivers than those that escape at other times of the year (Skilbrei et al. 2015).

As described previously, at present there are 20 scheduled salmon rivers that empty into Placentia Bay (Figure 4.2). Nineteen of these rivers are designated as Class 2 rivers (one retained fish/season; three catch and release fish/day) and one is designated as a Class 0 river (no retained fish; three catch and release fish/day). These limits regarding fish retention and catch and release for these classes of rivers, which were announced by DFO on 7 May 2018, will be re-examined midway through the 2018 salmon angling season. Four non-scheduled salmon rivers (i.e., non-scheduled rivers with documented occurrences of Atlantic salmon [Porter et al. 1974a,b]) also flow into Placentia Bay (Figure 4.2). In addition, Shalloway Pond Brook in the Argentia vicinity has documented occurrences of Arctic char and rainbow trout (Porter et al. 1974a,b), both salmonid species, so it too was included in Figure 4.2.

DFO (2016) has proposed that sea cages be located at least 20–30 km from the mouths of salmon rivers to minimize the possibility of farmed escapees interacting with wild salmon stocks.

Table 4.2 lists the 20 scheduled salmon rivers, the four non-scheduled salmon rivers (documented occurrence of Atlantic salmon), and one river with documented occurrences of Arctic char and rainbow trout in Placentia Bay, as well as the associated distances (up to a maximum of 50 km) between the river mouths and the sea cage site locations proposed by Grieg NL.

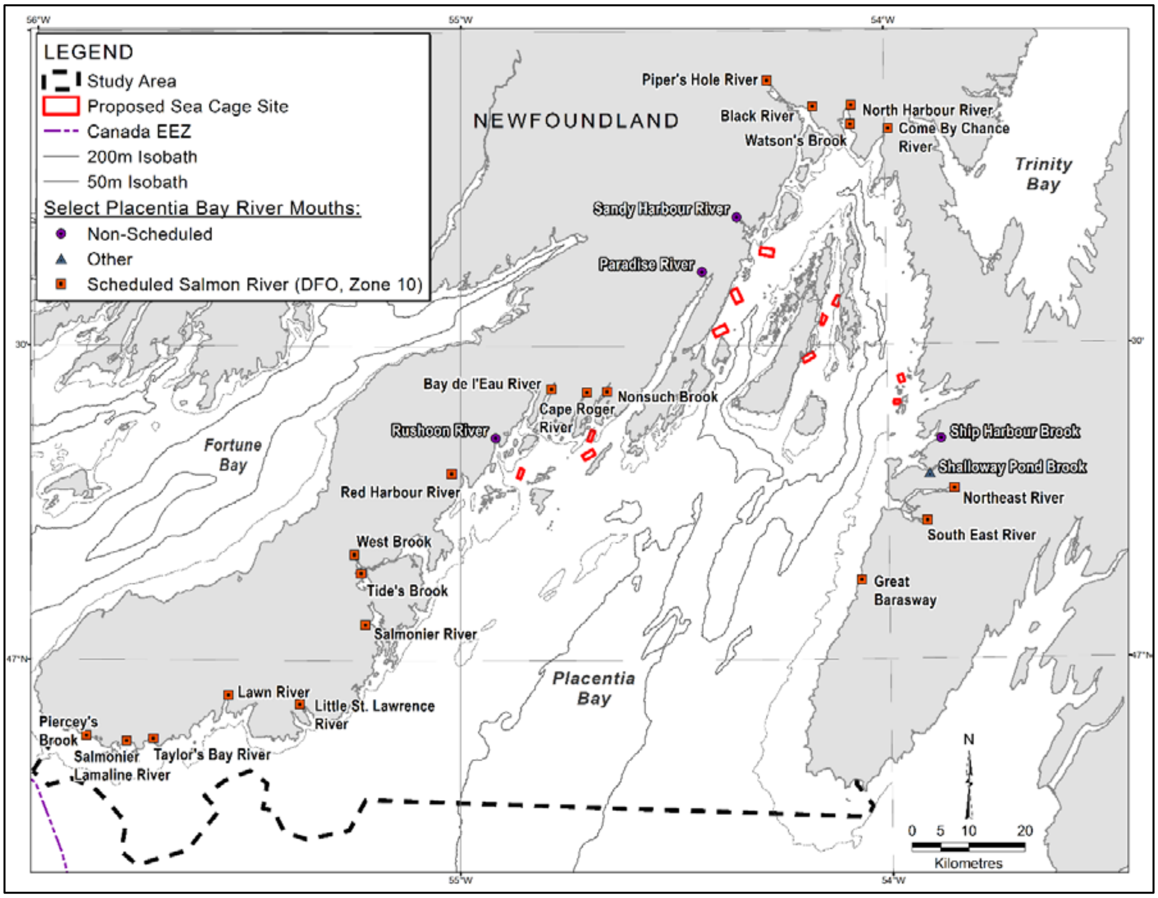


Figure 4.2. Locations of sea cage sites relative to scheduled and non-scheduled salmon rivers in Placentia Bay.

Sea cage sites in the Rushoon BMA are located <20 km from the mouths of scheduled salmon rivers (i.e., Nonsuch Brook, Cape Rodger River, Bay de l'Eau River, and Red Harbour River) and a non-scheduled salmon river (Rushoon River). The sea cage sites at Chambers Island and Ship Island (Merasheen BMA) are both located <20 km from the mouth of Sandy Harbour River, a non-scheduled salmon river. The sea cage sites at Brine Island and Iona Island (Long Harbour BMA) are both located <20 km from the mouths of Ship Harbour Brook (non-scheduled river) and Shalloway Pond Brook (documented occurrences of Arctic char and rainbow trout).

The mouths of the majority of scheduled and non-scheduled salmon rivers in Placentia Bay are located >20 km from a proposed sea cage site.

Table 4.2. Distances between the mouths of Placentia Bay scheduled and non-scheduled Atlantic salmon rivers and the locations of the proposed sea cage sites (only distances ≤50 km are included).

River Name	Latitude	Longitude	RUSHOON BMA			MERASHEEN BMA			RED ISLAND BMA			LONG HR BMA	
			Oderin	Gallows	Long	Valen	Chambers	Ship	Butler	Red	Darby	Brine	Iona
Great Barasway Brook	47.12694	-54.06418							50.0	46.6	40.7	36.3	32.1
South East River	47.22044	-53.91008							46.1	43.6	38.6	32.3	27.9
Northeast River	47.27112	-53.84561							49.0	46.4	41.4	35.2	30.8
Shalloway Pond Brook[1]	47.29588	-53.90283							35.9	33.3	29.7	18.9	14.7
Ship Harbour Brook[2]	47.35093	-53.87539							34.0	31.4	28.4	15.6	12.1
Come By Chance River	47.84405	-53.99102				30.9	40.1	46.6	32.4	36.1	43.2	45.4	49.4
Watson's Brook	47.85175	-54.07990				27.3	36.8	43.5	31.5	35.1	42.3	46.2	
North Harbour River	47.88143	-54.07768				30.5	40.0	46.7	34.8	38.3	45.5	49.6	
Black River	47.88040	-54.16885				43.2	36.5	27.2	36.0	39.5	46.7		
Piper's Hole River	47.92209	-54.27583					44.1	34.8	44.2	47.8			
Sandy Harbour River [2]	47.70454	-54.34960				23.7	17.0	9.2	31.8	35,3	42.6		
Paradise River[2]	47.61809	-54.43211		37.0	39.4								
Nonsuch Brook	47.42857	-54.65585	22.1	8.7	12.1	44.8							
Cape Rodger River	47.42722	-54.70305	18.5	12.3	12.6	48.7							
Bay de l'Eau River	47.43291	-54.78666	16.9	19.8	19.3								
Rushoon River[2]	47.35449	-54.91732	7.8	19.9	19.1								
Red Harbour River	47.29828	-55.01997	11.9	28.7	24.4								
West Brook	47.16920	-55.24673	42.1										
Tide's Brook	47.13911	-55.23086	39.4										
Salmonier River	47.05789	-55.22075											
Little St. Lawrence River	46.93138	-55.37257											
Lawn River	46.94551	-55.53826											
Taylor's Bay River	46.87594	-55.71165											
Salmonier Lamaline River	46.87167	-55.77335											
Piercey's Brook	46.87969	-55.86704											

[1] Denotes non-scheduled river with documented occurrence of Arctic char and rainbow trout; [2] denotes non-scheduled river with documented occurrence of Atlantic salmon.

4.5 Oceanographic and Meteorological Data

This section provides summaries of the data for the oceanographic and meteorological parameters that would most likely have effects on the integrity of farm sea cages. These parameters include the following:

- ice;
- storm frequency and intensity;
- wind and waves; and
- water currents.

The full report on metocean conditions in the northern part of Placentia Bay (Oceans 2018) is contained in Appendix B.

4.5.1 Data Sources

The various data sources used during preparation of the metocean report (Oceans 2018) are as follow:

- MSC50 wave and wind reanalysis data set;
- Environment and Climate Change Canada (ECCC) weather stations;
- SmartBay buoys;
- Red Island wave model;
- Current meters deployed by Memorial University of Newfoundland (MUN), Bedford Institute of Oceanography (BIO) and DHI; and
- Canadian Ice Service.

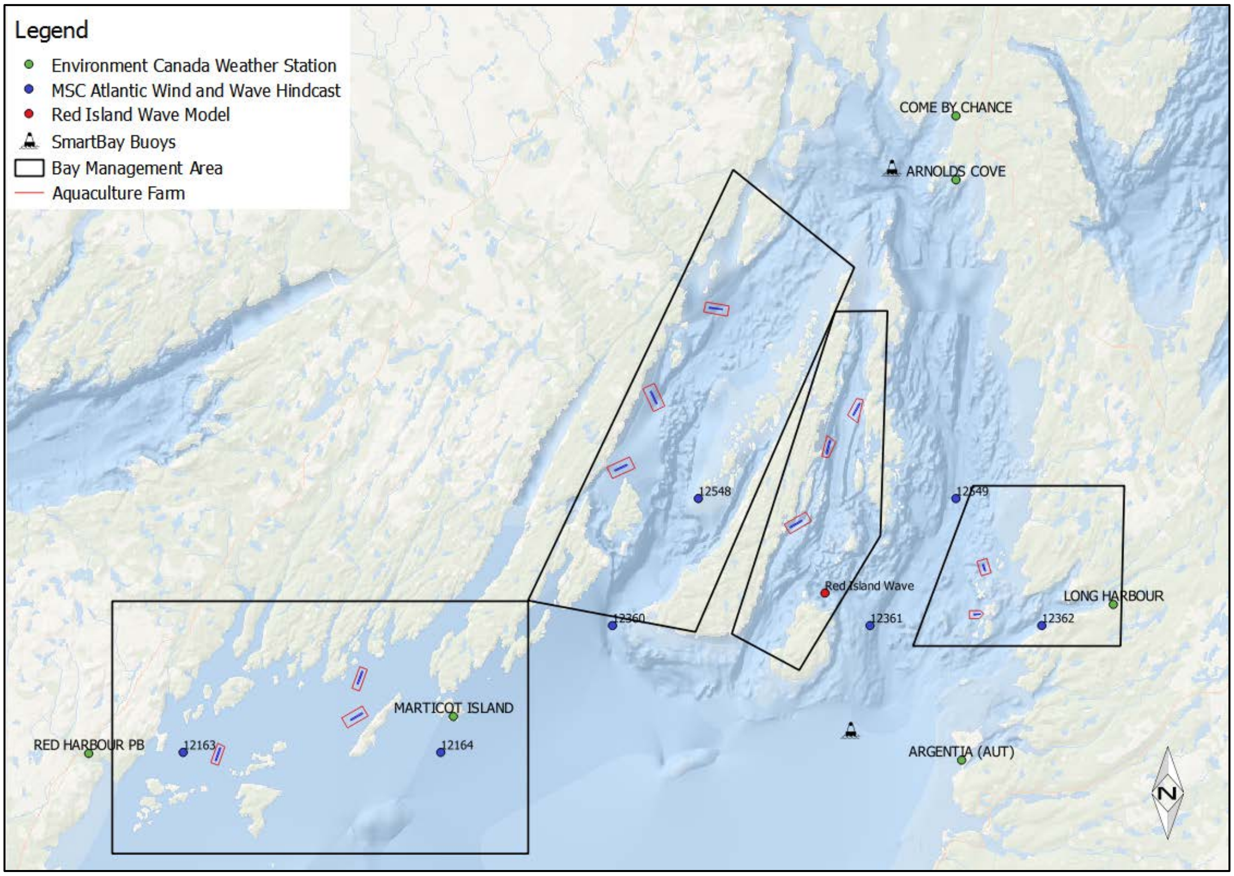
The locations of the MSC50 data set grid points, the ECCC weather stations, the Red Island wave model and SmartBuoys relative to proposed sea cage sites are presented in Figure 4.3. The locations of the MUN and BIO current meters are presented in Figure 4.4.

4.5.1.1 MSC50 Wave and Wind Reanalysis Data Set

Six grid points selected to best represent wind and wave conditions in the northern part of Placentia Bay (Figure 4.3) include:

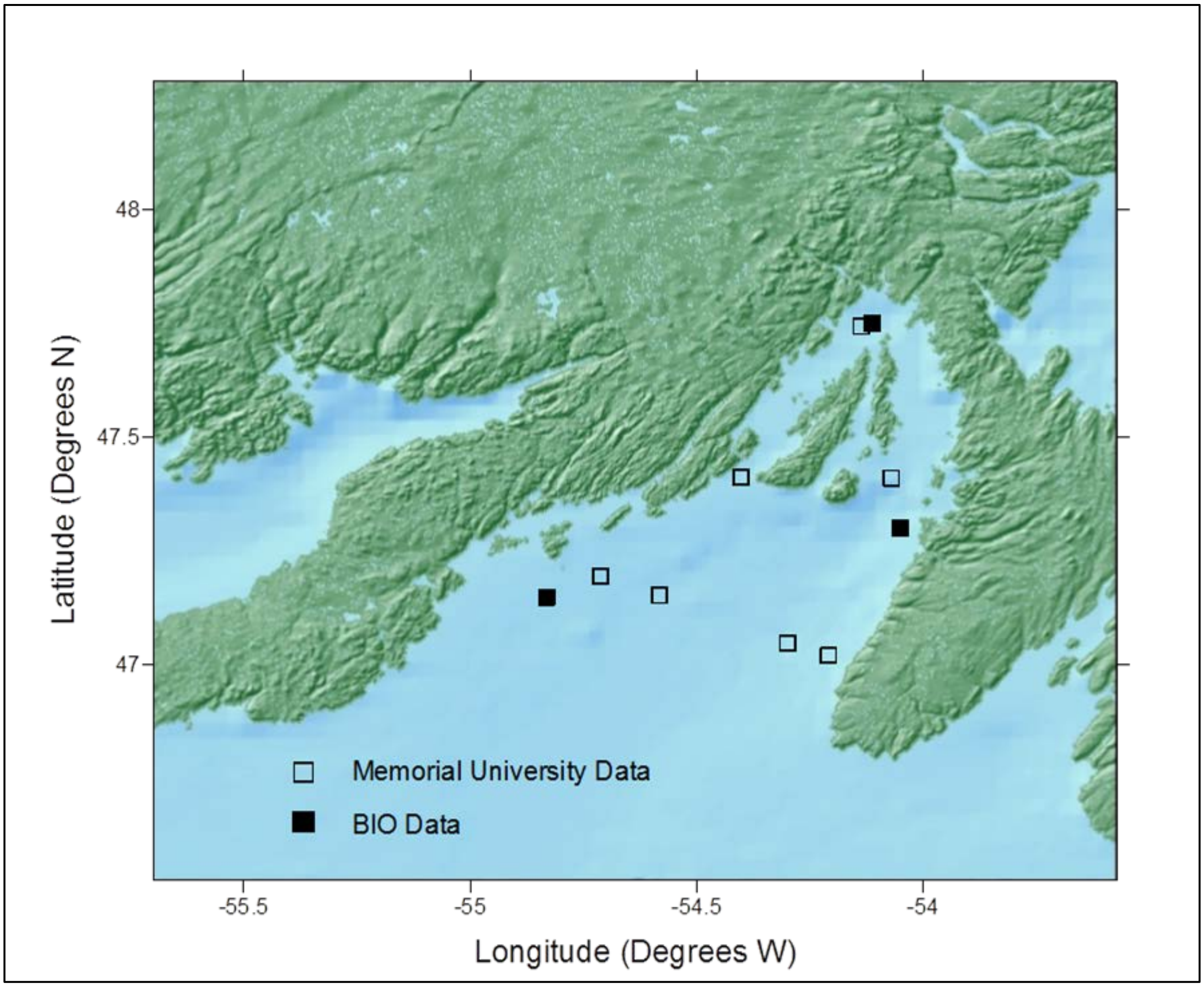
1. Grid point 12163 located approximately 2.5 km W of the Oderin Island sea cage site in Rushoon BMA;
2. Grid point 12164 located approximately 6–7 km ESE of the Long Island sea cage site in Rushoon BMA;
3. Grid point 12360 located approximately 12 km S of the Valen Island sea cage site in Merasheen BMA;
4. Grid point 12548 located approximately 6 km ESE of the Valen Island sea cage site in Merasheen BMA, and ~8 km SE of the Chambers Island sea cage site in Merasheen BMA;

5. Grid point 12361 located approximately 9–10 km SE of the Darby Harbour sea cage site in Red Island BMA, and ~8 km W of Iona Islands sea cage site in Long Harbour BMA; and
6. Grid point 12549 located approximately 5 km NNW of the Brine Island sea cage site in Long Harbour BMA, and ~11–12 km NE of the Darby Harbour sea cage site in Red Island BMA.



Source: Oceans (2018).

Figure 4.3. Locations of the MSC50 data set grid points, the ECCC weather stations, the Red Island wave model and the SmartBuoys relative to proposed sea cage sites.



Source: Oceans (2018).

Figure 4.4. Locations of current meters in Placentia Bay.

4.5.1.2 Environment and Climate Change Canada Weather Stations

The five ECCC weather stations in northern Placentia Bay (see Figure 4.3) used in this analysis are at the following locations:

1. Come By Chance;
2. Arnold's Cove;
3. Long Harbour;
4. Argentia; and
5. Marticot Island (located ~3 km NNE of MSC50 grid point 12164).

4.5.1.3 SmartBay Buoys

The two SmartBay buoys used in this analysis are at the following locations (see Figure 4.3):

1. Northern Placentia Bay, approximately 5–6 km from Come By Chance; and
2. Eastern Placentia Bay, approximately 9 km W of Argentia.

4.5.1.4 Other Sources

There is also a Red Island Wave Model located approximately 5 km SE of the Darby Harbour sea cage site (see Figure 4.3) in Red Island BMA that was used in the analysis.

Water current data were sourced from current meters deployed in Placentia Bay by the Department of Physics and Physical Oceanography at MUN (April–June in 1998 and 1999), and BIO (February–March 1988 and September–October 1998) (see Figure 4.4). There were also water current data collected by DHI, on behalf of Grieg NL, at each of the proposed sea cage sites during January–March 2016.

Ice data were sourced from the Canadian Ice Service.

4.5.2 Ice

In comparison to other bays around Newfoundland, Placentia Bay is a relatively ice-free bay due to its location along the south coast of Newfoundland. A weekly analysis of the Canadian Ice Service's 30-year median of ice in Placentia Bay reveals that ice is typically present in Placentia Bay only from mid-February until mid-April (1981–2010). The likelihood of ice presence in Placentia Bay is highest during the first week in March. During this week, the median of ice concentration in Placentia Bay is 9–9+/10. The frequency of sea ice presence in the four BMAs is 1–15%.

In an effort to provide more up-to-date sea ice information, weekly sea ice charts for Placentia Bay during the past 10 years were analysed for the presence of sea ice within the northern half of Placentia Bay. A table containing the percent frequency of ice conditions within the region is provided below in Table 4.3. The information provided in this table provides a conservative indication of the most severe ice conditions which occurred within the region during the 10-year period. For example, if half of the region was covered in 1/10 ice, and the other half was classified ice free, then cover for the entire region was recorded as 1/10. Most of the sea ice concentrations in northern Placentia Bay reported during 2008–2017 was <1/10. Note that there was one year in which the week beginning February 05 reported 5/10 sea ice coverage.

Definitions for the terms "Ice Free", "Open Water", "Bergy Water" and "Fast Ice", as defined in the ECCC Ice Glossary are provided below.

- **Ice Free -** no ice present (this term not used if ice of any kind is present).
- **Open Water -** a large area of freely navigable water in which ice is present in concentrations less than 1/10. No ice of land origin is present.
- **Bergy Water -** an area of freely navigable water in which ice of land origin is present. Although other ice types may be present, their total concentration is <1/10.
- **Fast Ice -** ice which forms and remains fast along the coast. It may be attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs.

Table 4.3. Percent frequency of weekly sea ice concentration for northern Placentia Bay (2008–2017).

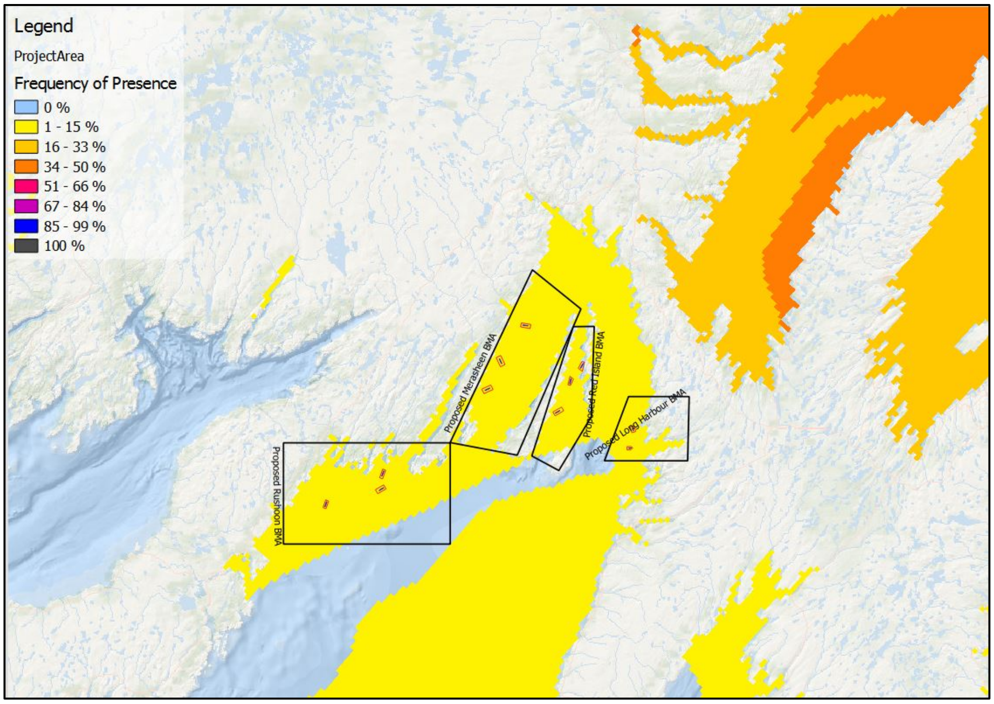
Week	Ice Free	Open Water	Bergy Water	Fast Ice	Tenths									
					1	2	3	4	5	6	7	8	9	9+
Feb-05	70	20	0	0	0	0	0	0	10	0	0	0	0	0
Feb-12	40	50	0	0	0	10	0	0	0	0	0	0	0	0
Feb-19	20	80	0	0	0	0	0	0	0	0	0	0	0	0
Feb-26	30	70	0	0	0	0	0	0	0	0	0	0	0	0
Mar-05	40	60	0	0	0	0	0	0	0	0	0	0	0	0
Mar-12	40	40	10	10	0	0	0	0	0	0	0	0	0	0
Mar-19	50	20	0	20	0	10	0	0	0	0	0	0	0	0
Mar-26	60	20	10	10	0	0	0	0	0	0	0	0	0	0
Apr-02	40	30	20	10	0	0	0	0	0	0	0	0	0	0
Apr-09	40	40	10	10	0	0	0	0	0	0	0	0	0	0
Apr-16	60	10	20	10	0	0	0	0	0	0	0	0	0	0
Apr-23	60	10	10	10	0	10	0	0	0	0	0	0	0	0
Apr-30	70	0	30	0	0	0	0	0	0	0	0	0	0	0

Source: Oceans (2018).

A graphic representation of the weekly analysis of 30-year frequency of ice presence for the four BMAs in the week starting March 5, 1981–2010 is contained in Figure 4.5. There is a 1–15% ice presence during this part of March which is regarded as the time of highest likelihood of presence.

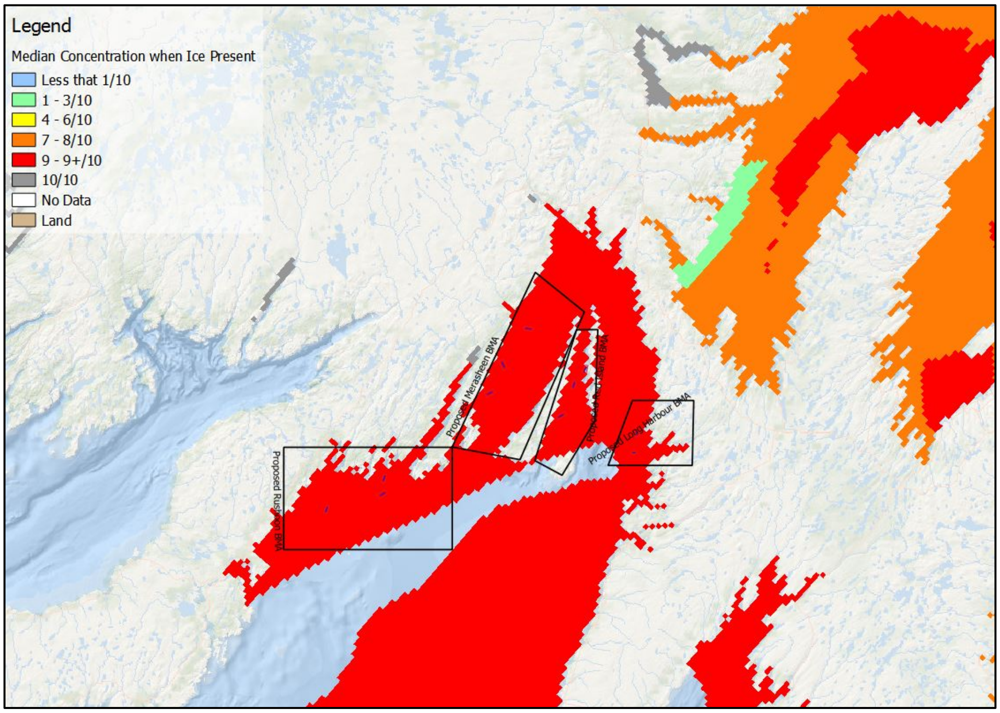
A graphic representation of the weekly analysis of 30-year median of ice concentration when ice is present for the four BMAs in the week starting March 5, 1981–2010 is contained in Figure 4.6. There is a 1–15% ice presence during this part of March, which is regarded as the time of highest likelihood of presence, the 30-year median is 9–9+/10.

Between 1960 and 2015, only six icebergs have been observed in the areas of Placentia Bay where the proposed sea cage sites would be located. Only one iceberg was observed in each of the Long Harbour, Merasheen and Red Island BMAs, while in the Rushoon BMA, which is closer to the outer bay in comparison to the other three areas, three icebergs were sighted over the 55 years, in 1961, 1995, and 2001. Five of the six icebergs ranged in size from ‘growler’ to ‘medium’, and the sixth, which was observed in the Rushoon BMA, was of unknown size.



Source: Oceans (2018).

Figure 4.5. Weekly analysis of 30-year frequency of presence for the four BMAs in the week starting March 5, 1981–2010 (Canadian Ice Service).



Source: Oceans (2018).

Figure 4.6. Weekly analysis of 30-year median of ice concentration when ice is present for the four BMAs in the week starting March 5, 1981–2010 (Canadian Ice Service).

4.5.3 Storm Frequency and Intensity

Despite the increase in the number of tropical storms in the Atlantic Basin during the past 20 years, there has been no appreciable increase in the number of storms which have entered either the Canadian Hurricane Response Zone or through the 150 nm (~275 km) buffer zone surrounding the proposed BMA locations. Between 1961 and 2015, 53 tropical storms have passed within 150 nm of the BMAs, five of which were Category 1, two were Category 2 and one was Category 3.

4.5.4 Wind and Waves

4.5.4.1 Wind

Placentia Bay experiences a predominantly southwest to west flow throughout the year. West to northwest winds which are prevalent during the winter months begin to shift counter-clockwise during March and April, resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominantly westerly again by late fall and into winter.

In addition to mid-latitude low pressure systems crossing the route, tropical cyclones often move northward out of the influence of the warm waters of the Gulf Stream, often passing near the Island of Newfoundland. The tropical cyclone season typically extends from June–November. Once the cyclones move over colder waters they lose their source of latent heat energy and often begin to transform into a fast-moving and rapidly developing extra-tropical cyclone, producing large waves and sometimes hurricane force winds. Low pressure systems crossing the area tend to be weaker during the summer months. As a result, mean wind speeds tend to be at their lowest during this season. Table 4.4 presents some statistics on wind speeds in the general areas of three of the BMAs based on 60+ years of data. Wind speed statistics for the Red Island BMA are unavailable but all three proposed sea cage sites in this BMA should experience lighter winds compared to the other three BMAs due to sheltering effect of the islands in the area.

Table 4.4. Wind speed statistics for the BMAs, 1954–2015.

BMA	Range of Monthly Mean Wind Speed (km/h)	Range of Monthly Maximum Wind Speed (km/h)	Percentage Occurrence of Wind Speed Categories
Rushoon	19.1–38.2	69.8–108.0	Light: 30.5 Moderate: 39.7 Strong: 27.6 Gale: 2.2
Merasheen	19.4–38.2	68.0–101.9	Light: 28.9 Moderate: 41.7 Strong: 27.5 Gale: 1.9
Red Island	na	na	na
Long Harbour	19.8–38.5	57.6–110.9	Light: 28.7 Moderate: 41.5 Strong: 27.8 Gale: 2.0

Source: Oceans (2018).

4.5.4.2 Waves

The wave climate of Placentia Bay is dominated by extra-tropical storms, primarily during October through March. Severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late-August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area but they are still capable of producing storm force winds and high waves.

Table 4.5 presents some statistics on wave heights in the general areas of three of the BMAs based on 60+ years of data. Wave height statistics for the Red Island BMA are unavailable but all three proposed sea cage sites in this BMA should experience lesser wave heights compared to the other three BMAs due to sheltering effect of the islands in the area.

Table 4.5. Wave height statistics for the BMAs, 1954–2015.

BMA	Range of Monthly Mean Significant Wave Height (m)	Range of Monthly Maximum Wave Height (m)	Range of Extreme Significant Wave Height for 50-yr Return Period (m)	Range of Extreme Maximum Wave Height for 50-yr Return Period (m)
Rushoon	0.7–1.6	3.7–7.8	6.1–7.3	11.0–13.2
Merasheen	0.2–1.4	1.3–7.2	2.1–6.8	4.0–12.2
Red Island	0.4–0.7	1.8–3.2	na	na
Long Harbour	0.2–1.9	1.3–7.9	2.2–5.0	4.2–9.0

Source: Oceans (2018).

4.5.5 Water Currents

In general, the near-surface currents in Placentia Bay have been observed to flow counter clockwise around the Bay. This circulation pattern is not consistent at deeper levels. The flow in Placentia Bay is expected to be the result of tides, winds, and the Labrador Current. Since the variability due to tides account for about only 15% of the total variability, other factors are more important. Winds in the area are predominately from the southwest during all seasons and this would contribute to a counter clockwise pattern in the near surface waters. The inshore branch of the Labrador Current follows the bathymetric contours around the Avalon Peninsula. North of Green Bank, the direction of the bathymetric contours shift from an east/west direction to a north/south direction. The Labrador Current probably divides at this location with a portion of the Labrador Current contributing to the flow into Placentia Bay and becoming the major contributor to the overall current variability. Current speeds on the western side of Placentia Bay are typically less than those on the eastern side.

The currents discussed in the following subsections are based on data collected by the eight MUN/BIO current meters deployed proximate to the proposed BMA locations as well as current data collected by DHI on behalf of Grieg NL.

4.5.5.1 Rushoon BMA

The data collected by MUN in the spring of 1999 at locations relevant to the Rushoon BMA showed that the mean current speed at a depth of 20 m was 0.103 m/s, and the maximum current speed was 0.497 m/s. The flow was mainly towards the southwest (i.e., out of Placentia Bay). The semi-diurnal tidal current speed ranged from 0.014–0.059 m/s. The tidal current speed is expected to be approximately 0.08 m/s during spring tide. The BIO data collected in the fall of 1988 showed a similar pattern of the currents; mean current speed of 0.091 m/s and maximum current speed of 0.373 m/s (Oceans 2018).

The data collected by DHI in January and February 2016 indicate variable current direction and a maximum current speed range for the three sea cage sites at a 30 m depth of 0.05–0.15 m/s. The range of current speeds for the three sea cage sites at mid-column (58–87 m) and lower-column (80–135 m) Acoustic Doppler Current Profilers (ADCP) locations was 0.05–0.25 m/s (DHI 2016).

4.5.5.2 Merasheen BMA

The data collected by MUN in the spring of 1999 at locations relevant to the Merasheen BMA showed that the mean current speed at a depth of 36 m was 0.079 m/s, and the maximum current speed was 0.365 m/s. The flow was mainly towards the southwest (i.e., out of Placentia Bay). The semi-diurnal tidal current speed ranged from 0.013–0.040 m/s. The tidal current speed is expected to be 0.05–0.06 m/s during spring tide (Oceans 2018).

The data collected by DHI in February 2016 indicate variable current direction and a maximum current speed range for the three sea cage sites at a 25–30 m depth of 0.11–0.31 m/s. The range of current speeds for the three sea cage sites at mid-column (115–160 m) and lower-column (200–265 m) ADCP locations was 0.10–0.22 m/s (DHI 2016).

4.5.5.3 Red Island BMA

According to Oceans (2018), there are no data from the MUN and BIO ADCP deployments that are directly relevant to the sea cage sites in the Red Island BMA.

The data collected by DHI in February and March 2016 indicate variable current direction and a maximum current speed range for the three sea cage sites at a 30 m depth of 0.15–0.18 m/s. The range of current speeds for the three sea cage sites at mid-column (70–80 m) and lower-column (100–122 m) ADCP locations was 0.12–0.19 m/s (DHI 2016).

4.5.5.4 Long Harbour BMA

The data collected by MUN in the spring of 1999 at locations relevant to the Long Harbour BMA showed that the mean current speed range at a depth of 20 m was 0.11–0.18 m/s, and the maximum current speed was 0.79 m/s. The flow was mainly into Placentia Bay. The semi-diurnal tidal current speed ranged from 0.037–0.06 m/s. The tidal current speed is expected to be approximately 0.10 m/s during spring tide. The BIO data collected in the fall and winter of

1988 showed a similar pattern of the currents; mean current speed of 0.0.125 m/s at 23 m, and maximum current speed of 0.75 m/s (Oceans 2018).

The data collected by DHI in March 2016 indicate variable current direction and a maximum current speed range for the three sea cage sites at a 30 m depth of 0.125–0.25 m/s. The range of current speeds for the three sea cage sites at mid-column (65–76 m) and lower-column (95–115 m) ADCP locations was 0.085–0.16 m/s (DHI 2016).

4.6 Water Quality

4.6.1 Data Collected by Grieg NL

Since early 2016, Grieg NL has regularly collected water temperature and dissolved oxygen (DO) data at all 11 sea cage sites (Grieg NL, unpublished data). The frequency of water quality data collection has been sufficient to provide measures throughout the year (i.e., variability due to seasonality has been captured).

Water temperature data were collected at six water depths; 0, 3, 10, 25, 35, and 50 m. This depth range was selected based on the 45 m vertical dimension of the sea cages to be used in this project. Summary statistics (i.e., mean, minimum, and maximum values) for the water temperature data at each sea cage site are presented in Table 4.6. The highest mean temperatures collected at each water column depth are highest for the sea cage sites in the Long Harbour BMA, while the lowest mean temperatures were observed at the sea cage sites in the Rushoon BMA. The lowest minimum water temperature of -0.5°C was observed at both the 25-m and 35-m depths at the Oderin Island sea cage site (Rushoon BMA) site in March, and at the 50-m depth at the Butler Island sea cage site (Red Island BMA) in April. The maximum water temperatures exceeding 17.0°C were observed in the upper three meters of the water column at the Rushoon, Merasheen and Red Island BMA sea cage sites in August.

Dissolved oxygen data were collected at three water depths: 3, 15 and 35-m. Summary statistics (i.e., mean, minimum, and maximum values) for the DO data at each sea cage site are presented in Table 4.7. The lowest mean DO levels were observed at the sea cage sites of the Long Harbour BMA, while mean levels at the other nine sea cage sites were quite similar. The highest maximum DO levels (i.e., 13.7–15.9 ppm) at 3-m and 15-m depths at all sea cage sites were typically observed during late spring (i.e., May and June). The timing of the highest maximum DO level at 35-m depth was more variable (e.g., in August for both the Merasheen and Long Harbour BMAs; May–July for the other two BMAs). The lowest minimum DO levels were observed at the Oderin Island sea cage site (e.g., 6.5–7.3 ppm). The timing for the lowest minimum DO levels was typically late summer/early fall for the sea cage sites in Rushoon and Merasheen BMAs, but slightly later (i.e., November) in the other two BMAs.

Mansour et al. (2008) examined DO content around salmon farm sea cages and specified a DO content level of <6 ppm as an indicator of hypoxic conditions. All DO measurements taken by Grieg NL at sea cage sites since 2016 have been >6 mg/L (ppm).

The full water quality data set collected to February 2018 by Grieg NL is provided in Appendix C.

Table 4.6. Summary statistics for water temperature data (°C) collected at the proposed sea cage sites, March 2016–February 2018.

BMA/Sea Cage Site	Statistic	Sampling Depth					
		Surface	**3-m**	**10-m**	**25-m**	**35-m**	**50-m**
Rushoon BMA							
Oderin Island	Mean	7.5	6.0	5.6	4.5	3.8	2.7
	Min	-0.2 (Mar)	-0.2 (Mar)	-0.2 (Mar)	-0.5 (Mar)	-0.5 (Mar)	-0.4 (Mar)
	Max	17.2 (Aug)	17.0 (Aug)	15.6 (Aug)	12.3 (Oct)	12.1 (Oct)	10.3 (Oct)
Long Island	Mean	7.5	6.0	5.7	4.8	3.9	2.8
	Min	0.2 (Mar)	0.2 (Mar)	-0.1 (Mar)	-0.2 (Mar)	-0.2 (Mar)	-0.2 (Mar)
	Max	16.7 (Aug)	16.4 (Aug)	16.0 (Aug)	13.1 (Aug)	12.5 (Sept)	10.7 (Oct)
Gallows Harbour	Mean	7.5	6.1	5.7	4.7	3.9	2.8
	Min	0.4 (Mar)	0.3 (Mar)	0.0 (Apr)	0.0 (Apr)	-0.1 (Mar)	-0.1 (Mar)
	Max	17.1 (Aug)	16.6 (Aug)	16.3 (Aug)	12.9 (Aug)	11.8 (Sept)	10.2 (Oct)
Merasheen BMA							
Valen Island	Mean	8.8	7.4	7.2	5.9	5.0	3.6
	Min	-0.1 (Mar)	-0.1 (Mar)	0.0 (Apr)	0.0 (Apr)	-0.1 (Apr)	-0.2 (Apr)
	Max	17.1 (Aug)	17.0 (Aug)	16.7 (Aug)	14.3 (Aug)	13.0 (Sept)	10.9 (Oct)
Chambers Island	Mean	8.0	7.5	7.2	5.9	4.9	3.6
	Min	-0.1 (Mar)	-0.1 (Mar)	0.0 (Mar)	0.0 (Apr)	0.0 (Apr)	-0.2 (Apr)
	Max	17.1 (Aug)	17.1 (Aug)	16.9 (Aug)	13.7(Sept)	13.5 (Sept)	10.8 (Oct)
Ship Island	Mean	8.0	7.5	7.3	5.9	4.9	3.4
	Min	-0.2 (Mar)	-0.2 (Mar)	0.0 (Mar)	-0.1 (Apr)	-0.1 (Apr)	-0.2 (Apr)
	Max	17.3 (Aug)	17.3 (Aug)	17.1 (Aug)	13.8 (Sept)	12.8 (Sept)	10.4 (Oct)
Red Island BMA							
Darby Harbour	Mean	7.6	7.1	7.0	5.8	4.7	3.3
	Min	-0.1 (Apr)	-0.1 (Apr)	-0.1 (Apr)	-0.1 (Apr)	-0.2 (Apr)	-0.2 (Apr)
	Max	17.0 (Aug)	17.0 (Aug)	16.9 (Aug)	13.1 (Sept)	11.8 (Sept)	10.8 (Oct)
Red Island	Mean	7.8	7.4	7.2	5.9	4.7	3.1
	Min	-0.1 (Apr)	-0.1 (Apr)	-0.1 (Apr)	-0.1 (Apr)	-0.2 (Apr)	-0.3 (Apr)
	Max	17.3 (Aug)	17.2 (Aug)	17.2 (Aug)	13.6 (Sept)	11.9 (Oct)	11.3 (Oct)
Butler Island	Mean	7.9	7.4	7.2	5.9	4.7	3.3
	Min	-0.2 (Apr)	-0.2 (Apr)	-0.2 (Apr)	-0.2 (Apr)	-0.3 (Apr)	-0.5 (Apr)
	Max	17.4 (Aug)	17.3 (Aug)	16.8 (Aug)	12.8 (Sept)	12.6 (Sept)	11.3 (Oct)
Long Harbour BMA							
Iona Island	Mean	10.3	10.5	10.0	8.5	6.6	4.3
	Min	2.0 (Dec)	2.0 (Dec)	2.0 (Dec)	1.2 (May)	0.7 (May)	0.4 (May)
	Max	16.3 (Aug)	16.3 (Aug)	15.9 (Aug)	13.5 (Sept)	10.9 (Sept)	9.7 (Oct)
Brine Island	Mean	10.4	10.5	10.0	8.5	6.7	4.7
	Min	2.0 (Dec)	2.1 (Dec)	2.0 (Dec)	1.1 (May)	0.4 (May)	0.2 (May)
	Max	16.4 (Aug)	16.4 (Aug)	15.9 (Aug)	14.8 (Aug)	11.2 (Oct)	9.1 (Oct)

Source: Grieg NL (unpublished data).

Note: Months in which minimum and maximum temperatures were observed are provided in parentheses.

Table 4.7. Summary statistics for dissolved oxygen data (mg/L [ppm]) collected at the proposed sea cage sites, February 2016–February 2018.

BMA/Sea Cage Site	Statistic	Sampling Depth		
		3-m	15-m	35-m
Rushoon BMA				
Oderin Island	Mean	11.7	11.8	11.9
	Min	6.5 (Aug)	6.9 (Aug)	7.3 (Oct)
	Max	15.4 (May)	15.6 (May)	15.0 (July)
Long Island	Mean	11.7	11.7	12.0
	Min	7.5 (Aug)	7.6 (Aug)	8.6 Sept)
	Max	15.5 (May)	15.6 (May)	15.6 (May)
Gallows Harbour	Mean	11.6	11.6	11.9
	Min	8.2 (Aug)	6.7 (Aug)	7.9 (Aug)
	Max	15.6 (May)	15.6 (May)	15.1 (May)
Merasheen BMA				
Valen Island	Mean	11.4	11.4	11.8
	Min	8.2 (Aug)	8.1 (Sept)	8.5 (Sept)
	Max	15.7 (May)	15.5 (May)	19.3 (Aug)
Chambers Island	Mean	11.4	11.3	11.8
	Min	8.5 (Aug)	8.3 (Sept)	8.4 (Sept)
	Max	15.5 (May)	15.3 (May)	15.2 (Aug)
Ship Island	Mean	11.4	11.4	11.8
	Min	8.4 (Sept)	8.3 (Sept)	8.2 (Nov)
	Max	15.3 (May)	15.4 (May)	15.1 (Aug)
Red Island BMA				
Darby Harbour	Mean	11.6	11.5	12.0
	Min	8.7 (Nov)	8.4 (Nov)	8.4 (Sept)
	Max	15.7 (May)	15.3 (May)	15.2 (May)
Red Island	Mean	11.5	11.5	12.0
	Min	8.4 (Sept)	8.3 (Sept)	8.2 (Nov)
	Max	15.9 (May)	15.2 (May)	15.2 (May)
Butler Island	Mean	11.4	11.5	12.0
	Min	8.0 (Nov)	7.8 (Nov)	6.9 (Nov)
	Max	15.7 (May)	15.3 (May)	15.2 (May)
Long Harbour BMA				
Iona Island	Mean	10.5	10.8	11.6
	Min	8.8 (Nov)	8.6 (Sept)	8.7 (Nov)
	Max	13.7 (June)	14.3 (May)	15.2 (Aug)
Brine Island	Mean	10.5	10.8	11.6
	Min	8.6 (Nov)	8.6 (Nov)	8.6 (Nov)
	Max	13.8 (June)	14.2 (Aug)	15.0 (Aug)

Source: Grieg NL (unpublished data).
Note: Months in which minimum and maximum dissolved oxygen levels were observed are provided in parentheses.

4.6.2 Sewage Outfalls

The outfall database of the Water Resources Portal maintained by the Government of Newfoundland and Labrador Department of Municipal Affairs and Environment (GNL n.d.) was used to compile a list of communities within the Study Area with known or possible outfalls for sewage effluent and/or other waste water discharges into the marine environment. In the cases where no outfalls are indicated for a community, it is possible that one or more residences within the community discharge sewage and/or septic tank effluent directly into the sea. Marystown and Placentia have the most known outfalls within the Study Area, the majority of which discharge raw effluent.

There are four Blivet waste water treatment systems installed in the community of Marystown. All four systems discharge their treated effluent to dedicated exfiltration galleries installed in- or nearshore. One of these units is installed in the Marine Industrial Park for treatment of the Park's sanitary sewer. Effluent from this Blivet is discharged to an exfiltration gallery located on the Park's shore. Marystown also has an operational Abydoz engineered wetlands system, which diverts and treats a relatively small portion of its sanitary sewer contents.

The Long Harbour Nickel Processing Plant began operations in 2014 (Vale 2017). This commercial-scale hydrometallurgical ('hydromet') facility releases non-recyclable, treated excess process water (i.e., effluent), storm water and sewage into the marine waters of Long Harbour (Vale 2011). Prior to release, on-site effluent and sewage treatment plants, and polishing and sedimentation ponds are utilized to treat these discharges in accordance with government standards, including the *Metal Mining Effluent Regulations* (Vale 2011). The volume and quality of released effluent are routinely monitored, and effluent can be pumped back through the treatment process repeatedly prior to release if any discharge constituent is not in compliance with regulatory limits (Vale 2011). Treated effluent, which is colourless and transparent, is diverted into a pipeline and released >5 km out into Long Harbour relative to the plant, where the deepwater currents flow out of Long Harbour, assisting in relatively rapid dispersal (Vale 2011). After compliance testing, the effluent is mixed with ≤25% seawater by volume before being released, in order to assist the prevention of gypsum scaling inside the effluent release pipeline (Vale 2011).

4.7 Effects of Deposition from the Sea Cages

Grieg NL has committed to not using pesticides and disinfectants. Therefore, this subsection discusses the potential effects of organic deposits (e.g., feces, feed) and therapeutants released into the marine environment.

The deposition of organic matter from sea cages can impact the benthic habitats occurring beneath and in the vicinity of sea cages. Accordingly, aquatic dispersion modeling is a useful tool for predicting the transport and dispersal of inputs from the cages into the marine environment. To address the federal DFO Aquaculture Activities Regulations (AAR) permitting requirements condition 8.1a, depositional contours representing the rates 1, 5 and 10 g C/m^2/day were modelled for each proposed sea cage site using a specified daily quantity of feed usage. The organics deposited from a sea cage serve as a food source for water-borne bacteria that decompose the organic material using dissolved oxygen, thus reducing the dissolved oxygen for naturally-occurring invertebrates and fishes. The BOD is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions.

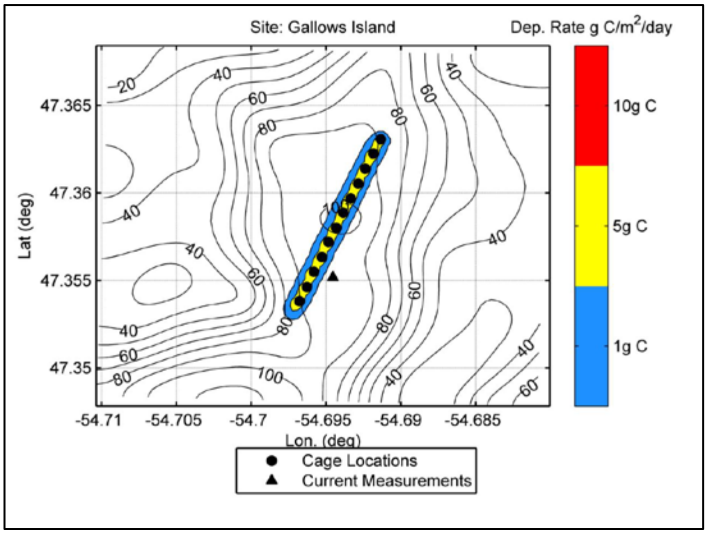
Modelling was conducted by Amec Foster Wheeler Environment & Infrastructure (Amec 2017) at each of the proposed sea cage sites in 2016 (see full report in Appendix D). The DEPOMOD particle tracking model was used to predict carbon flux deposition (g C/m^2/d) of organic inputs (fish feed, feces) onto the seabed, effectively predicting the area on the seabed that may be impacted by aquaculture operations. Model input variables used include bathymetry, water current velocity and layers, particle information (e.g., settling velocity, % carbon in feed and feces), feed specifics, feeding rate and sea cage information (e.g., number, size) (DFO 2014; Amec 2017). Water current velocity and direction data at near-surface, mid-depth and near-bottom were collected using ADCPs deployed at each sea cage site for varying lengths of time during the January–March 2016 period (DHI 2016).

Figures 4.7–4.17 present the modelling results for each of the proposed sea cage sites. The extents of the footprints of three levels of organic deposition are shown. The maximum distance from sea cage to footprint edge is highest for the Chambers Island sea cage site (~150–200 m). This maximum distance is typically 50–100 m for most of the proposed sea cage sites. Overall the majority of depositional contours predicted from the model will not exceed 1g C/ m^2 /day with minimal exceptions at shallower sites.

4.7.1 Rushoon BMA

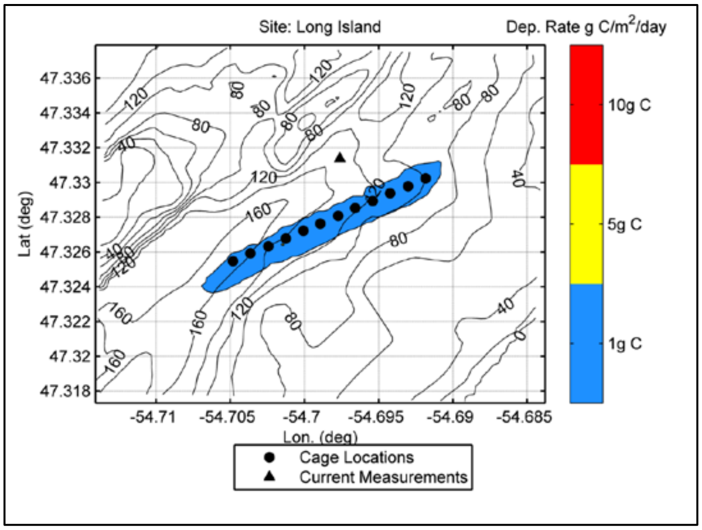
Water current data were collected at the Rushoon BMA sea cage sites in January and February, 2016. The duration of data collection at each sea cage site ranged from 15 hr (Gallows Harbour) to 47 hr (Long Island). Water currents were strongest at the Long Island sea cage site (0.15 m/s @ 30-m; 0.11 m/s @ 87-m; 0.25 m/s @ 135-m), and weakest at Gallows Harbour (0.06 m/s @ 30-m; 0.06 m/s @ 70-m; 0.075 m/s @ 110-m).

Figures 4.7–4.9 display the organic carbon depositional footprints for the three Rushoon BMA sea cage sites. The footprints reflect the water currents measured at each site. The Long Island footprint has the largest area (Figure 4.8) but the greatest homogeneity in terms of the amount of carbon deposited daily (i.e., entire area with a depositional rate of 1 g C/m^2/day). Conversely, the Gallows Harbour site, characterized by the lowest current velocities of the three sea cage sites, has a footprint with the smallest area (Figure 4.7) but the depositional rate below the sea cages is as high as 5 g C/m2/day.



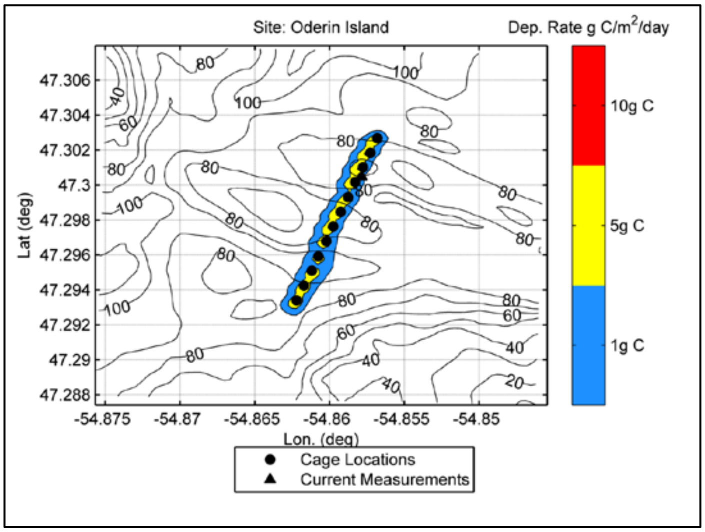
Source: Amec (2017).

Figure 4.7. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Gallows Island sea cage site.



Source: Amec (2017).

Figure 4.8. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Long Island sea cage site.



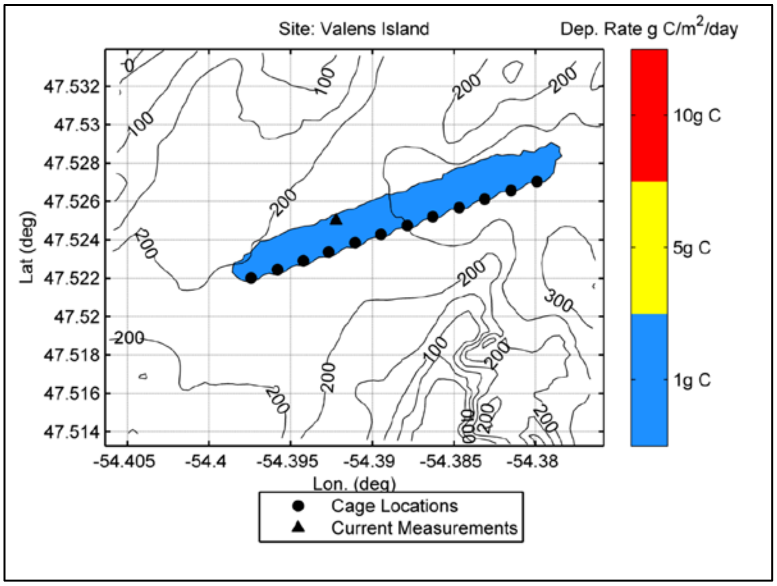
Source: Amec (2017).

Figure 4.9. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Oderin Island sea cage site.

4.7.2 Merasheen BMA

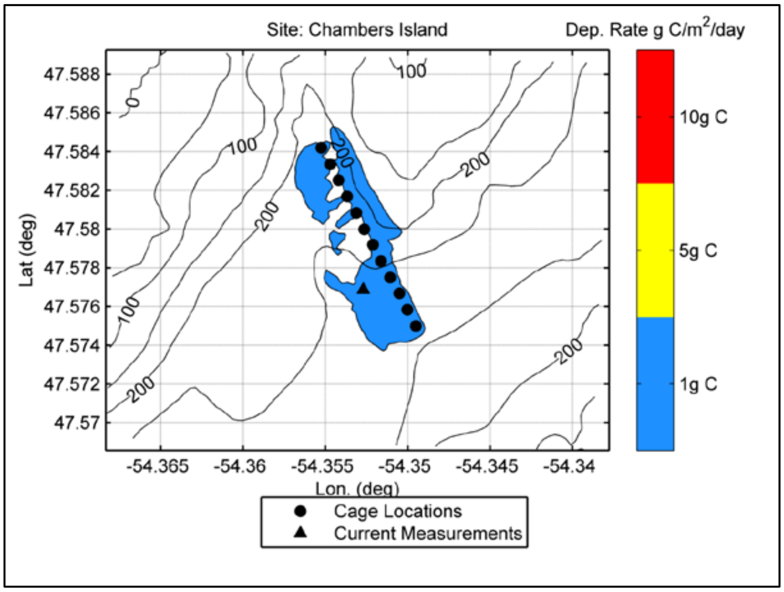
Water current data were collected at the Merasheen BMA sea cage sites in February, 2016. The duration of data collection at each sea cage site ranged from 24 hr (Chambers Island) to 195 hr (Ship Island). Water currents were strongest at the Ship Island sea cage site (0.31 m/s @ 30-m; 0.19 m/s @ 115-m; 0.22 m/s @ 200-m), and weakest at Valens Island (0.11 m/s @ 25-m; 0.10 m/s @ 130-m; 0.135 m/s @ 235-m).

Figures 4.10–4.12 display the organic carbon depositional footprints for the three Merasheen BMA sea cage sites. All three footprints are homogeneous in terms of the amount of carbon deposited daily (i.e., 1 g C/m^2/day). The footprint areas are also quite similar for all three sea cage sites, the irregularly shaped one at Chambers Island perhaps being the largest (Figure 4.11).



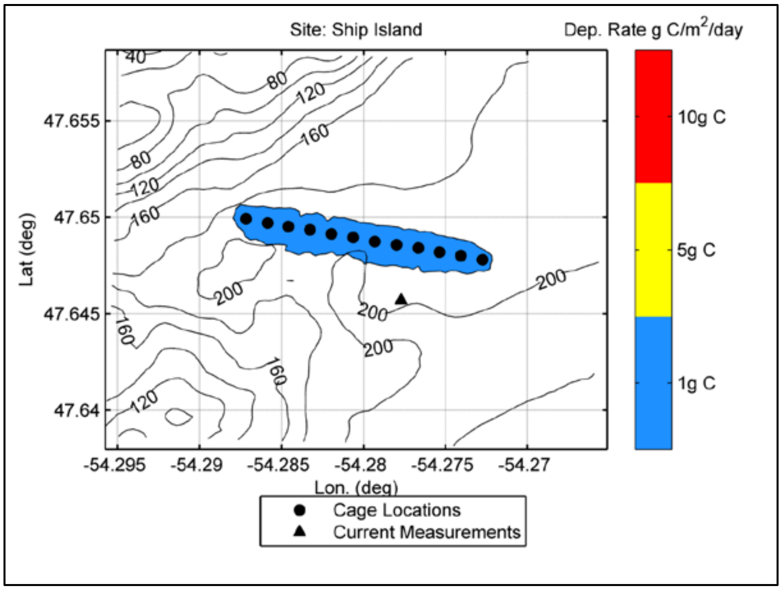
Source: Amec (2017).

Figure 4.10. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Valens Island sea cage site.



Source: Amec (2017).

Figure 4.11. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Chambers Island sea cage site.



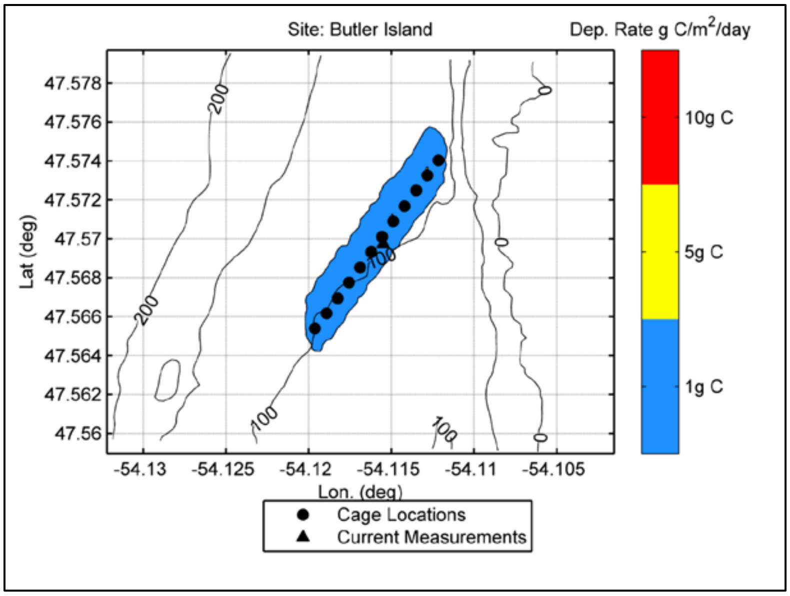
Source: Amec (2017).

Figure 4.12. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Ship Island sea cage site.

4.7.3 Red Island BMA

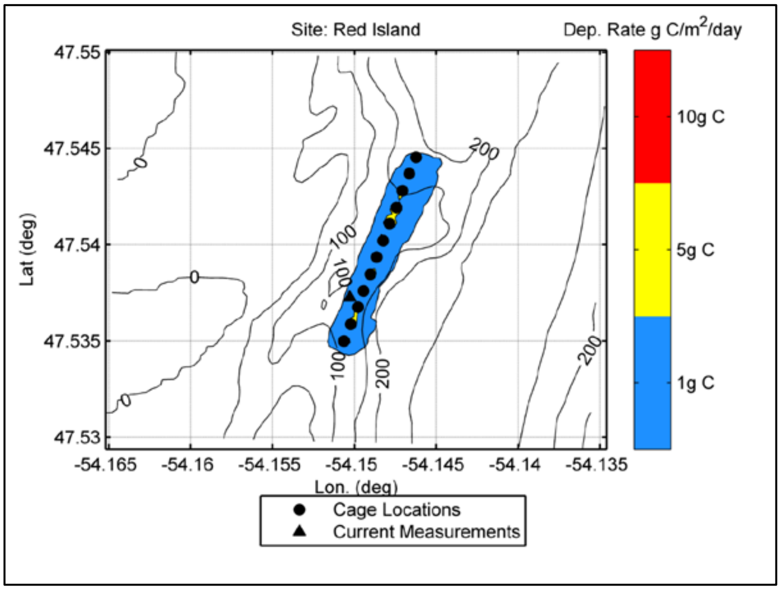
Water current data were collected at the Red Island BMA sea cage sites in February and March 2016. The duration of data collection at each sea cage site ranged from 19 hr (Red Island) to 141 hr (Darby Harbour). Water currents were strongest at the Darby Harbour sea cage site (0.18 m/s @ 30-m; 0.16 m/s @ 80-m; 0.10 m/s @ 122-m). Water currents at the Butler Island and Red island sea cage sites were similar (0.15 m/s @ 30-m; 0.12–0.13 m/s @ 70–75-m; 0.12–0.13 m/s @ 100–105-m).

Figures 4.13–4.15 display the organic carbon depositional footprints for the three Red Island BMA sea cage sites. The footprint areas are quite similar for all three sea cage sites. While the Butler Island depositional footprint is homogenous in terms of the amount of carbon deposited daily (i.e., 1 g C/m^2/day), the footprints at the Red Island and Darby Harbour sea cage sites (Figures 4.14 and 4.15, respectively) have patches of 5 g C/m^2/day depositional rates under the cages.



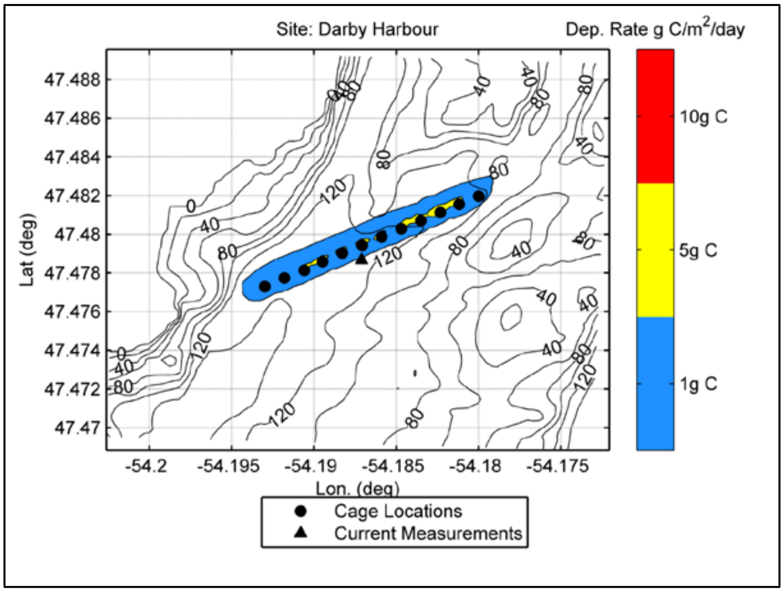
Source: Amec (2017).

Figure 4.13. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Butler Island sea cage site.



Source: Amec (2017).

Figure 4.14. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Red Island sea cage site.



Source: Amec (2017).

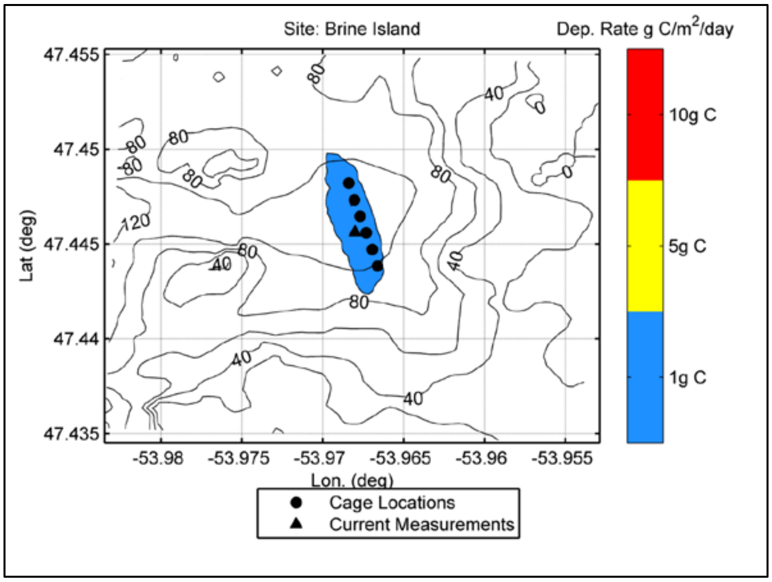
Figure 4.15. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Darby Harbour sea cage site.

4.7.4 Long Harbour BMA

Water current data were collected at the two Long Harbour BMA sea cage sites in March 2016. The duration of data collection at each sea cage site ranged from 48 hr (Iona Island) to 67 hr (Brine Island). At the 30-m depth, water currents were stronger at the Brine Island sea cage site (0.25 m/s compared to 0.125 m/s). Water currents at the mid-column and lower-column depths for both sea cage sites were similar (9–10 m/s @ 65–76-m; 0.09–0.125 m/s @ 95–115-m).

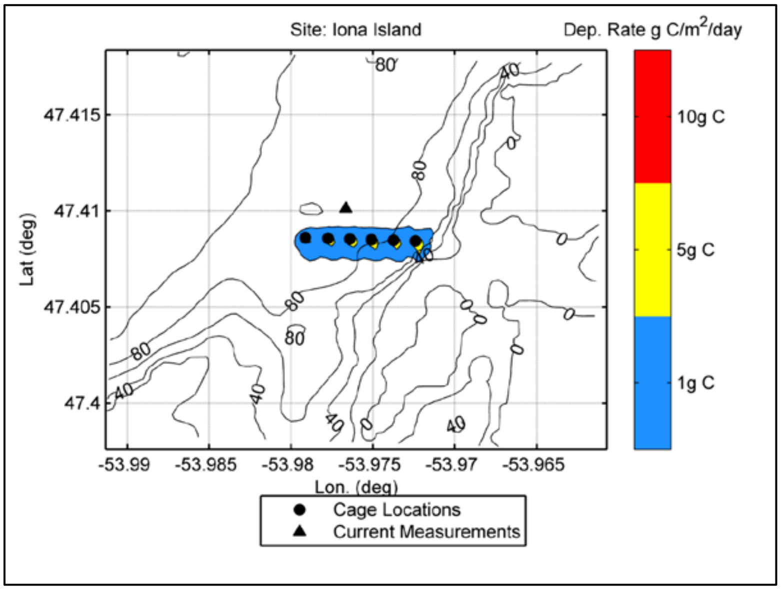
Figures 4.16 and 4.17 display the organic carbon depositional footprints for the two Long Harbour BMA sea cage sites. The footprint areas are quite similar for both sea cage sites. While the Brine Island depositional footprint is homogenous in terms of the amount of carbon deposited daily (i.e., 1 g C/m^2/day) (Figure 4.16), the footprint at the Iona Island sea cage site has patches of 5 g C/m^2/day depositional rates under the cages (Figure 4.17).

The deposition of uneaten fish feed can serve to attract wild fish, including wild salmon to sea cages, which in turn could facilitate the transfer of sea lice and/or pathogens, if infected, from farmed salmon to wild salmon. Wild salmon migration patterns could also be affected as they may choose to travel between fish farms to eat uneaten fish feed instead of actively seeking natural prey. In addition, predators of wild salmon, including seals, tunas, and sharks, may be attracted to sea cages, possibly resulting in higher predation on wild salmon in the vicinity.



Source: Amec (2017).

Figure 4.16. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Brine Island sea cage site.



Source: Amec (2017).

Figure 4.17. Modelled footprint of the deposition of organic matter in the vicinity of the proposed Iona Island sea cage site.

4.8 Mitigation and Monitoring

There are several primary types of effects that may result from Grieg NL Project activities at the sea cage sites, including effects on wild Atlantic salmon. Mitigation and monitoring measures intended to minimize the effects of Project activities on wild Atlantic salmon are described in this section. The planned and unplanned Project activities considered in this section include:

- Fish escapes;
- Attraction of wild Atlantic salmon to the sea cages;
- Pathogen/parasite transfer between farmed salmon and wild salmon;
- Pathogen/parasite transfer between lumpfish cleaner fish and wild salmon;
- Release of unconsumed therapeutants and antibiotics into the marine environment; and
- Deposition of organic material (i.e., feed, feces) from the sea cages onto the seabed.

4.8.1 Fish Escapes

In Canada, there are several primary reasons which have led to the escape of finfish from sea farms including personnel errors made during routine fish handling procedures and net damage caused by weather, ice, and predators[2]. From 2010–2016 in Newfoundland there have been five reported incidents of salmon escapes from sea farms and at least nine breaches in nets with no official report of escapes. Of the five reported incidents two were attributed to personnel errors made during harvesting, two were attributable to extreme weather, and one was attributed to a predator strike (possibly sharks; DFA 2015). The nine net breaches, which were reported in 2012, were attributed to sharks and tunas. The reported salmon escapes in Newfoundland occurred during operation of a different type of sea cage system than the Aqualine Midgard cage system Grieg NL is proposing for use.

Federal and provincial regulators as well as the aquaculture industry recognize the importance of preventing escapes of fish from sea cages and as such, have developed regulations to minimize the chances of such escapes. Since 1999, DFLR (formerly DFA), DFO and the salmonid industry have implemented a management strategy called the *Code of Containment for the Cage Culture of Salmonids in Newfoundland and Labrador* (COC; DFA 2014). Additionally, mitigation measures and monitoring for minimizing the effects of predators and ice on the sea cages are designed to minimize the potential escape of fish.

The mitigation and monitoring measures that will be implemented to minimize the potential of farmed salmon escapes as well as the potential effects of escapes on wild Atlantic salmon of Placentia Bay are described below. The principal potential effects of escapes of farmed Atlantic salmon on the wild Atlantic salmon include:

- Genetic introgression;
- Ecological interaction; and
- Transfer of pathogens and parasites between farmed salmon and wild salmon.

In order for genetic introgression (i.e., the transference of genes from one species to another resulting in hybridization of offspring) involving farmed and wild Atlantic salmon to occur,

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[2] See http://www.dfo-mpo.gc.ca/aquaculture/protect-protege/escape-prevention-evasions-eng html

farmed salmon have to leave the sea cages either by escape through compromised netting or accidental release during handling.

If escaped farmed salmon move into freshwater systems used by wild salmon, then there is potential for competition between the two (e.g., food resources, territory). Ecological interaction between farmed and wild salmon could also occur in the marine environment. In order for ecological interaction between farmed and wild Atlantic salmon to occur, farmed salmon have to escape from the sea cages.

Note that the transfer of pathogens and parasites between farmed salmon and wild salmon can still occur without farmed fish escapes.

The following subsections describe the mitigation measures intended to minimize the potential of farmed salmon escapes and any effects on wild Atlantic salmon resulting from escapes.

1. Code of Containment

The COC is based on internationally recognized principles that focus on procedures which minimize the potential for equipment failures and improve upon handling practices. There are five primary elements to the COC: (1) Equipment; (2) Handling Practices; (3) Inspections; (4) Documentation and Reporting; and (5) Other Mitigations. These elements and how they will be specifically applied to the Project are described below. Grieg NL is using industry best practice where possible.

***(1) Equipment*:** As per the COC, all finfish containment systems (cage structures and nets) must be designed, constructed and installed to withstand local weather and ocean conditions including storms, water currents, and waves. Sea cage systems must also be maintained to control biofouling and ice accretion, which can compromise the system. Predator control measures are also important to minimizing the risk of escapes (see below for more details). In addition to following the COC requirements with regard to the cage structure, nets and moorings, Grieg NL will utilize a Norwegian company, Aqualine, for its cage systems.

The Aqualine Midgard sea cage system, including its dimensions, design, and construction, is based on the Norwegian Standards (NS9415:2009) currently in use in Norway and which are considered industry best practice (Sullivan et al. 2018). The Aqualine sea cage proposed by Grieg NL, weighs 35 tonnes and is constructed of robust materials (netting material is Aqualine Ultima/Ultra SG netting which is made with HDPE material), and the collar structure is certified by DNV GL. Advanced model testing by SINTEF OCEAN, indicated the cages were able to withstand highest wave conditions of 9 m significant wave heights. The Norwegian Standards require cage system and mooring design to minimize the risk of fish escapes due to technical failure. This dimensioning allows for deformations, environmental loads such as wind, waves, currents and ice as well as damage such as puncture. If during extreme situations a rupture or damage occurs to parts of the floating collar, the cage construction will keep its shape and prevent total collapse. The clamps which are connected to a dimensioning main supporting system in the horizontal plane will hold the construction together while the floating collar's remaining capacity will prevent the cage net from collapsing. Aqualine's floating collars are equipped with floater tubes filled with rods made out of expanded polystyrene. Should damage or a puncture occur to the collar, these rods maintain the buoyancy of the cage until repairs can be completed. Tidal variations and storm surges are not critical for the floating collar; however, ice accretion may cause loads on the construction. The load effect from icing is primarily connected to loss of buoyancy. Build-up of ice can readily be removed (see below). Grieg NL will also use a remotely operated vehicle (ROV) to assist in tasks such as net inspections and in-situ net repair, if required.

(2) Handling Practices**:** The COC details Handling Practices and includes appropriate precautions to prevent escapes during all stages of fish handling including transfers, counting, grading, sea lice counts, treatments, harvesting, net changing or cleaning. Additionally, Grieg NL will avoid handling and feeding fish during superchill conditions. As a minimum, Grieg NL will adhere to the best practices included in Appendix 6 of the COC including for grading, weight sampling, sea lice counts, transportation, well boat treatments, and harvesting. A common mitigation measure that reduces the likelihood of escapes during handling is the use of a drop net. Drop nets are placed under the work area and above the sea surface in the event a fish is 'dropped' during routine procedures that require handling of fish. Prior to each use drop nets are inspected for holes, wear and any other damage. Drop nets will be of sufficient size to cover the entire work area and the mesh size will be small enough to contain the smallest fish being handled. In addition to following the COC recommendations to ensure that escapes are minimized, Grieg NL will also be utilizing technology including automatic counters and video monitoring as an added security during handling. Fish counters and video cameras will be utilized during handling procedures including grading, transfers and harvesting to allow careful monitoring of fish numbers and enable a quick response to potential issues. All personnel will receive appropriate training in handling procedures.

(3) Inspections**:** As part of the COC, nets that are over three years old and still in use will be tested every 18 months by a third-party (i.e., Aqualine). Nets are tested for strength (e.g., stress test with a tension scale instrument) and integrity. In addition, as a minimum, nets will be visually inspected every 90 days by an ROV. Cages and surface mooring components will also be inspected as per the COC. Surface components of mooring systems, cages, nets and ropes on each site will be inspected once per week and recorded on Form A.4 of COC. Underwater components of the mooring system, including the anchors, will be inspected based on a schedule developed in consultation with Aqualine and approved by DFO or DFLR. Each year, Grieg NL will be required to submit a "Mooring Maintenance/Replacement Plan" Form A2 for each site occupied with fish. In addition, periodically audits of the cage system as specified in COC Procedures for Compliance will be conducted and DFLR will arrange for audits of net testing procedures. Audits by DFLR will be conducted at a minimum of twice yearly (one in the spring, after fish entry; one audit in fall/early winter). Any identified damaged equipment will be repaired or replaced immediately.

Grieg NL will also comply with the Norwegian Standards (NS9415:2009) for its sea cage system as supplied by Aqualine. The Aqualine sea cage nets which will be used for this Project are issued a service card that is valid for not more than 24 months. These service cards provide information on the condition of the net as well as a period of validity. Nets without a valid service card cannot be used in the cage system. New service cards are issued after an inspection which follows established Aqualine and Norwegian Standards (NS9415:2009) procedures.

(4) Documentation and Reporting**:** Submission of the net testing results every 18 months (for nets over three years old) and annual submission of inventory reconciliation including number of fish stocked, mortalities, removals and explanation of discrepancies is required. The COC includes forms for these reports and all documentation will be maintained by Grieg NL for inspection by DFLR during their routine audits.

(5) Other Mitigation Measures**:** Other mitigation measures to minimize the potential of farmed fish escapes and associated effects include:

- Escape response drills will be performed on site annually. All new employees will also perform an escape response drill as part of their site orientation. Escape response drills will include deploying weighted netting over a "mock" hole in the sea cage, reviewing kit contents and reviewing Standard Operating Procedures (SOPs);
- Should any escape be suspected or known to occur, the COC requires immediate reporting of escape incidents to both DFO and to the DFLR (C. Hendry, Acting Manager of Aquaculture Management, Ecosystems Management Branch, pers. comm., 5 April 2018). Grieg NL will be required to begin discussions with DFO within 24 hours of the incident to determine if recapture efforts should be initiated. Authorization of recapture is at the discretion or direction of DFO in consultation with Grieg NL and stakeholders as needed. Although all escapes are reported, not all escapes incidents may trigger recapture efforts. Factors such as the life history stage of the escaped fish, the time of year, incident-specific factors and conservation objectives for wild fish populations will be considered;
- DFO may deem it necessary to issue a license for recapture. Each BMA will have an escape response kit and all marine personnel will be trained in its use. Once notification has been provided to DFO, and if a recapture response is authorized along with any necessary licenses, Grieg NL will enact their Emergency Response Plan. If conditions permit, it will involve deployment of gill nets and/or dip nets near the sea cage sites where the escape has occurred. Procedures including response details, disposal plan, documenting and reporting on escaped fish are included in Grieg NL’s Emergency Response Plan. If a recapture response is triggered and there is a serious breach in the net, fish will be transferred to a well boat where they will be counted and later returned to a replacement net. This will allow for an accurate assessment of the number of escaped fish.

2. Maintaining Genetic Integrity and Biological Fitness of Wild Salmon

Although mitigation measures and monitoring procedures are in place to prevent fish escapes, it is still possible that some salmon may escape from the sea cages. The concern is that released salmon may affect the genetic integrity and biological fitness (via reproductive interference) of wild Atlantic salmon in Placentia Bay. To minimize this risk, Grieg NL will be using fertilized triploid (sterile and all-female) Atlantic salmon eggs (European strain) supplied from an accredited and approved company called Stofnfiskur (based in Iceland). Triploid organisms have three sets of chromosomes instead of the standard two (diploid). This will be the first time that triploid all-female Atlantic salmon eggs will be used in Canada but triploid Atlantic salmon have been used successfully in cold water aquaculture operations in Norway, Scotland and Tasmania. The gradual ramp up of egg importation and subsequent salmon stocking numbers should allow potential issues with initiating operations to be rectified prior to reaching maximum production. Any technological or procedural improvements arising from ongoing research and development in finfish aquaculture will be considered by Grieg NL during the production ramp up and indeed throughout the Project.

Any finfish egg imports in Canada must be sourced from and received by facilities where robust quarantine measures are followed and which have been approved by regulatory agencies including CFIA, DFO and DFLR. Imports must be approved under the *Health and Animals Act*, and a permit issued, which is the responsibility of the CFIA. The issue of this permit is based on advice received from other regulatory agencies including DFO and DFLR. In 2012, experts from DFO and DFA (now DFLR) visited Stofnfiskur's facility in Iceland as part of the approval process to import sterile/triploid eggs from Stofnfiskur into Canada. This approval process required, in part, extensive review of all Stofnfiskur's permits, procedures and certifications. [See Appendix A for a review of the company's history and accreditations.] Based on this assessment, DFO through the Canadian Science Advisory Secretariat (CSAS) process granted the approval for the importation and use of the European strain triploid Atlantic salmon being produced at Stofnfiskur facilities (DFO 2016). Based on these reviews and assessments, CFIA issued Grieg NL an import permit, recognizing Stofnfiskur as an approved exporter to Canada, in March 2016 (Permit No. Q-2016-00213-4) and Grieg NL has continued to renew this permit every three months as per the regulations.

Induced triploidy of Atlantic salmon has been ongoing for over 30 years and is currently the only commercially viable method to sterilize large numbers of fish species for an aquaculture scale operation (DFO 2013; Benfey 2015). It is commonly conducted by treating newly fertilized eggs with hydrostatic pressure which disrupts the movement of chromosomes during meiosis (Benfey 1998). More specifically, it is based on normal gametogenesis with an extra set of maternal chromosomes (polar body) being retained early in development when the egg is subjected to hydrostatic pressure. Prior to revised techniques currently used by Stofnfiskur, the use of pressure methods to induce triploidy resulted in >98% triploidy induction success (O'Flynn et al. 1997; Devlin et al. 2010 *in* Benfey 2015). One of the concerns highlighted in the CSAS report (DFO 2016) as well as during consultations for the Project, is that the failure rate of inducing triploidy in Atlantic salmon eggs has been 1–2%.

In 2017, Stofnfiskur implemented new improved technology and increased the success rate of inducing triploidy from approximately 98% to 100%. Stofnfiskur also utilizes smaller chambers for the egg pressurization technique (i.e., 2 L in volume) when they are subjected to hydrostatic pressurization. By using smaller chambers, all eggs are subjected to the same pressure whereas the use of larger chambers in the past resulted in some eggs not receiving the necessary pressure required to induce sterile triploidy (resulting in only >98% success). The result of this modification as well as the new improved technology is a process that now will produce 100% triploidy results. Stofnfiskur has also adopted a two-tier testing procedure. A small subset from each batch of eggs is cultured at a slightly higher temperature thereby speeding up the development process. The result is a sample of the batch that can be sent for verification testing at least one week prior. Both the subset and the primary batch must have 100% sterile triploid verification in order to be shipped to a customer. If verification tests indicate less than 100% sterile triploidy, the entire batch of eggs is discarded. This two-tier testing approach increases the probability of detecting failure rates. The smaller pressure chambers discussed above also allow Stofnfiskur to separate the eggs from each female. This enhances biosecurity and permits the eggs from each female to be readily tracked and sampled for all verification testing. Additional details on the Stofnfiskur triploidy (and all-female) induction procedures and verification procedures are provided in Appendix A.

In addition to using triploid all-female eggs there are several additional measures which minimize the risk of affecting the genetic integrity and biological fitness of wild Atlantic salmon. DFO (2016) has proposed that the sea cages be at least 20–30 km from the mouths of salmon rivers in order to reduce the possibility of farmed escapees interacting with wild salmon stocks. The majority of scheduled rivers are located more than 50 km away from the proposed sea cage sites. Only the sea cage sites in the Rushoon BMA are located <20 km from a scheduled salmon river. In this case, the mouths of four scheduled rivers (i.e., Nonsuch Brook, Cape Rodger River, Bay de l'Eau River, and Red Harbour River) are located <20 km (i.e., 8.7–19.8 km) from the Rushoon BMA proposed sea cage sites.

3. Ice Monitoring and Mitigation

The sea cage may accumulate ice during freezing rain events or from sea spray that freezes. All sea cages will be routinely monitored for ice accretion either directly by personnel on site and/or remotely via video camera. Ice accretion will be minimized by personnel removing ice as it accumulates, which is typically done with rubber mallets, as is the practice for vessels.

Based on a review of Canadian Ice Service data (see Appendix B) and discussions with the Placentia Marine Communications and Traffic Services and local stakeholders, sea ice and icebergs are not predicted to pose a threat to the sea cage sites. However, it is recognized that there is a very low probability that sea ice may occur in and near the sea cage site. Grieg NL will routinely (i.e., minimum daily) receive and monitor broadcasts on ice conditions (and/or weather) from the Marine Communications and Traffic Services (MCTS) and receive guidance on the predicted timing and extent of any pack ice (or iceberg) incursions. The Canadian Coast Guard (CCG) holds pre-season meetings with its clients to discuss traffic expectations and service requirements. Grieg NL has submitted an application to “request standing” with the CCG on a committee should the need arise for assistance with ice. A three-tiered approach will be used to manage ice based on the type and size of the ice:

(1) Slush, small patches of drift ice, and ice in general less than 5 cm thick will be mitigated through the robust design of the Aqualine Midgard sea cage as well the deployment of an ice boom and use of Grieg NL operated service vessels.
(2) A multi-purpose vessel (operated by a third-party provider) with ice class capacity will be on standby to mitigate and potentially break-up and/or move 5–15 cm thick ice; more specifically pancake ice, ice cakes, brash ice (<20 m across); small ice floes (20–100 m across); and medium ice floes (100–500 m across).
(3) A CCG ice breaker may assist with large ice floes (>500 m across), solid pack ice, and iceberg(s) in the unlikely event these ice conditions are encountered at or near the sea cage sites.

In the rare circumstance of a major ice incursion which cannot be mitigated through the measures outlined above, Grieg NL’s Emergency Response Plan will detail procedures to either harvest the fish or tow the sea cage(s) to a safe location. The sea cage(s) can only be towed when water temperatures are suitable for the health and welfare of the fish (between 4˚C and 18˚C).

4. Predator Protection and Control

A Predator Control Plan will be required as part of Grieg NL’s aquaculture license application. Methods to monitor, deter and exclude marine predators from the sea cages sites are required because predators such as sharks and tuna can create holes in nets which may contribute to escapement. For example, in fall 2015, DFO reported farm-origin salmon at the mouth of a river in Fortune Bay. It was speculated that sharks, which had been observed in the area, may have created a hole in the bottom of the net (DFA 2015). Several mitigation measures and monitoring tools will be in place to minimize interactions with predators.

Each sea cage will have bird nets which cover the entire top of the cage and prevent birds from entering the sea cage. The bird net and bird poles are part of the Aqualine Midgard sea cage system and are designed to provide sufficient tension to eliminate net sagging. The sides of the bird net can be raised and lowered like a window blind to quickly and easily access the cage. Bird nets will be deployed ensuring mesh size will be sufficient to deter predators but minimize the risk of entanglement. If a bird does become entangled Grieg NL will follow established procedures to release the bird (which will be developed in consultation with ECCC-CWS). Grieg NL will have a Migratory Bird Handling Permit (issued by CWS) in place and will follow reporting requirements.

For waterborne predators several techniques will be used. The bottom of each sea cage will have reinforced netting which minimizes the risk of tears. Also, the daily removal of dead fish from the bottom of sea cages via the automated Mortex system is intended to reduce the attraction of sharks and possibly seals. Each sea cage will have one or two cameras that offer 360° viewing and can be raised and lowered within the water column. These cameras, in addition to an ROV inspection camera, will allow for monitoring of the net integrity and fish behaviour. If a hole is detected in the net, it will be repaired as quickly as possible (estimated to range from <1 hour to several hours) by an ROV. The fish behaviour in sea cages will be monitored by personnel on the feed/accommodation barge and/or at the monitoring control center located at the RAS Hatchery for indications (i.e., crowding in bottom of net, skittish behaviour, change in feeding) that a predator may be nearby. If fish behaviour indicates the presence of a predator and/or a predator is directly observed (via the video or by personnel at the sea cage), the net will be inspected immediately for holes. This may involve a thorough review of video footage and/or dedicated inspection via an ROV and/or diver. If predator incursions are determined to be an issue, Grieg NL in consultation with DFLR and DFO, will determine whether an anti-predator net (i.e., a double net that completely surrounds the sea cage under water) is warranted. There are trade-offs with using an anti-predator net—the primary drawback is that it makes cleaning the primary net much more difficult, which can result in water flow issues and subsequent health risks to the fish.

It is possible that seals and river otters may be attracted to the sea cages but it is unlikely they would gain access to fish from the top of the sea cage. The fencing (and bird netting) on the inside of the gangway would make it difficult for these animals to gain access to the fish. Like sharks, it is possible that seals and perhaps river otters may tear holes in the sea cage netting but to the best of our knowledge this has not happened previously in Newfoundland. However, monitoring should minimize this risk as described above. Of note, Grieg NL will not use acoustic deterrent devices in an attempt to keep marine animals away.

In all circumstances, predator management will be conducted in such a manner as to ensure human safety. Any accidental entanglement of marine mammals, otters, wild fish, and sea turtles will be reported to DFO and action will be taken, in consultation with DFO, to free or remove the animal. In extreme circumstances, if all methods have failed and a marine animal is posing a serious threat to the integrity of the nets (or to personnel safety), lethal measures may be considered. Before such actions are taken (by a third-party; firearms will not be stored at the sea cage sites), DFO will be consulted.

5. Other Mitigation Measures

In addition to the measures in the COC, predator protection and control, and ice monitoring and mitigation, there are other mitigation measures in place to further minimize the likelihood of fish escapes. These include:

- Sea cage sites are selected in areas that provide shelter, have suitable current conditions, and are predominantly ice free;
- Sea cages are oriented to minimize exposure to the prevailing winds and waves; and
- Husbandry practices such as maintaining clean nets and continuous monitoring of fish and nets also serve to minimize the risk of fish escapes.

4.8.2 Attraction of Wild Atlantic Salmon to the Sea Cages

Several mitigation measures and monitoring procedures will be implemented to minimize the potential effects of attraction of naturally-occurring biota including Atlantic salmon to the sea cages. Marine fauna could be attracted to the sea cages for various reasons including the presence of dense concentrations of farmed Atlantic salmon, the build-up of biofouling on the sea cage infrastructure, and the accumulation of organic material, including unconsumed feed, on the seabed in the immediate vicinity of the sea cages.

1. Optimization of Feeding

One reason for the attraction of naturally-occurring biota to sea cages is the deposition of unconsumed feed from the sea cages. Feed wastage will be minimized via the use of established feeding tables/software used to determine feed type and amount and an automatic feeding system which integrates video monitoring in the sea cages. Salmon will be monitored during feeding and once salmon have reached ~80% satiation, feed delivery will be ceased. Cameras mounted in the sea cages will provide staff (located in the control room on the feed barge and/or located remotely) with a view of the feeding behaviour of fish and feed can be stopped as soon as reduced feeding behaviour is noticed. This system reduces nutrient inputs into the environment by optimizing feeding.

2. Husbandry Practices to Minimize Biofouling on the Sea Cages

Another reason for the attraction of naturally-occurring biota to sea cages is accumulation of biofouling on the sea cages. Husbandry practices designed to minimize biofouling will also serve to mitigate effects on the marine environment. Grieg NL will adhere to a schedule to clean its sea cages to minimize biofouling which can add to the depositional load of organic material. The cleaning schedule for cages and nets will be developed based on environmental conditions in Placentia Bay as well as routine monitoring. Nets will typically be cleaned weekly (via a ROV net cleaner equipped with an advanced camera system) and cages will be cleaned once or twice during heavy fouling periods. Cages and nets will also be cleaned after harvesting is completed and prior to cages being transferred to other BMAs. Routine checks of equipment utilizing underwater cameras (e.g., SmartEye Twin 360), ROVs, and inspections by divers (as needed) will be used to confirm the cleaning schedule of the sea cages. Grieg NL will ensure equipment has minimal biofouling.

3. Daily Removal of Dead Salmon from the Sea Cages

Fish mortalities will be removed from each sea cage on a daily basis primarily via the automated Mortex system. Dead salmon in the sea cages could potentially attract naturally-occurring biota. When handling moribund fish from the sea cages, personnel will be required to wear rain gear, gloves, and boots which will be disinfected after each mortality disposal. Once at the surface, the dead fish are transferred to a designated and approved container on the feed barge for ensilaging; there will be limited personnel access to the ensilage container.

4.8.3 Pathogen and Parasite Transfer between Farmed Salmon and Wild Atlantic Salmon

There is risk that disease and parasites may be transferred between farmed and wild Atlantic salmon (as well as other wild fish). There are two primary ways of minimizing this risk.

1. Decrease the Potential for Interactions Between Farmed Salmon and Wild Fishes

Decreasing the potential for interaction between farmed salmon and wild fishes can be accomplished in the following ways.

- Siting of sea cage sites a suitable distance from the mouths of salmon rivers;
- Reducing the attraction of wild salmon to the sea cages by feed optimization and the cleaning of biofouling from the sea cages;
- Removing fish mortalities from the sea cages on a daily basis; and
- Fallowing of the sea cage sites to minimize the accumulation of organic material on the seabed.

2. Maintenance of Farmed Salmon Health

A number of aquatic disease-causing agents (pathogens) such as viruses and bacteria as well as parasites (i.e., sea lice), which occur naturally in the environment, can affect farmed fish. These pathogens can be spread from equipment used to transfer fish as well as through the water by animals releasing the pathogen or from sick or moribund fish. Some known sources of aquatic infections include contaminated equipment or feed and untreated wastewater. A number of tools will be implemented by Grieg NL to eliminate or minimize the spread of disease and sea lice at the sea cage sites and the surrounding aquatic environment. Mitigation measures and regular monitoring will be in place to maintain fish health including (1) biosecurity measures, (2) routine husbandry practices, (3) health checks and procedures, (4) use of specialized feed and feeding procedures, (5) sea lice control procedures, (6) water quality monitoring, (7) vaccinations, and (8) removal and treatment of dead fish. Grieg NL will implement a Fish Health Management Plan and all personnel will be trained in its proper procedures.

(1) ***Biosecurity Measures*****:** BMAs are a strategy that Grieg NL has adopted to enhance biosecurity and mitigate pathogen presence and spread at its proposed sea cage sites.

Grieg NL has proposed four separate BMAs within Placentia Bay (see Figure 2.1). BMAs enhance biosecurity by establishing discreet regions for individual companies and are recognized as an effective approach to disease management, to mitigate pathogen presence and spread (Chang et al. 2007). With the proper use of BMAs, including Grieg NL SOPs that regulate personnel and equipment transfer between and within BMAs, the risk of disease introduction and spread is reduced.

In addition to the use of BMAs, there are federal and provincial regulations, including inspections and permits, that ensure all aquaculture facilities operate in a manner that prevents disease spread while still facilitating market access for Canada’s aquatic resources, both wild and cultured. The CFIA addresses aquatic animal diseases of finfish through the National Aquatic Animal Health Program (NAAHP). The NAAHP is co-delivered by CFIA and DFO. CFIA is the lead agency for program development and implementation while DFO provides the science support for the program (diagnostics, research and advice), and also coordinates and assists with sampling for surveillance purposes. The main objective of NAAHP is to prevent the introduction and spread within Canada of reportable and emerging aquatic animal diseases. The program is consistent with international standards set by the World Organization for Animal Health (OIE). As part of this program, CFIA has a number of regulatory disease response tools including movement controls or “quarantine”, a License to Transport of Animals or Things, and an Order to Dispose.

Domestic movements of aquatic animals or equipment (including nets and cages) may require a Domestic Movement Permit Application to move Finfish and/or Things within Canada (CFIA/ACIA 5743) from CFIA. Whether a permit is required depends on the declarations of the reportable disease status of the areas being transferred from and to. The use of permits for these movements implements a control to contain certain diseases within areas of Canada where they are known to occur. For this reason, CFIA would be contacted by Grieg NL prior to any domestic movements of fish or equipment. In addition to contacting CFIA for domestic movements, Grieg NL would also be required, following the National Code on Introductions and Transfers of Aquatic Organisms, to submit an application to DFLR and DFO, which will address three main risks: genetics, ecosystem and disease prior to any transfer of the fish from the RAS Hatchery to the sea cages for grow-out. The request is submitted to DFLR under a “one stop shop” process. DFLR and DFO review the request under their respective mandates, and if the request is acceptable to both regulators, DFLR forwards both approvals to the applicant. The fish will not be permitted to leave the RAS Hatchery until these approvals are received.

The proposed sea cage sites have been selected based on suitable currents, water temperature, bottom types, and distance from municipal sewage outflows. Consideration of these factors, as well the requirement to fallow sites, all contributes to fish health and mitigating effects on the marine environment.

Other biosecurity measures include ensuring that feed and ensilage stored on the barges at the sea cage sites are physically separated in secure containment units and that procedures for handling these materials minimize the risk of contamination.

(2) *Husbandry Practices*: As in the RAS Hatchery, Grieg NL will employ standard husbandry practices designed to minimize the spread of disease at the sea cage sites. These practices include cleaning/disinfecting of equipment, vessels, and ROVs, and managing personnel and tasks to minimize health risks to fish. The cleaning schedule for cages and nets will be developed based on environmental conditions in Placentia Bay as well as routine monitoring. Nets will typically be cleaned weekly and cages will be cleaned once or twice during heavy fouling periods. Cages and nets will also be cleaned after harvesting is completed and prior to cages being transferred to other BMAs. Routine checks of equipment utilizing underwater cameras, ROVs, and inspections by divers (as needed) will be used to confirm the cleaning schedule of the sea cages. Personnel will be required to change into designated work clothing and boots upon arrival at the sea cage site. Personnel gear will be cleaned and disinfected on a routine schedule. Personnel will be transported from designated crew change sites (i.e., proposed at Petit Fort and Long Harbour). These crew change sites will have designated areas for embarkation and disembarkation to the sea cage sites, which are designed to avoid contamination. The proposed Petit Fort and Long Harbour sites will only be used for crew changes (via dedicated crew vessels). Resupply sites are proposed at two former Ocean Choice International (OCI) premises; one in Marystown and one in Burin. Grieg NL will use these sites for transporting equipment and supplies (primarily via service vessels) to and from the sea cage sites. Additionally, one of the resupply sites will receive waste from the sea cage sites. Service vessels (and the associated movement of equipment, supplies and waste) will not use the Petit Fort or Long Harbour stations. The use of separate resupply sites is designed to avoid contamination.

As discussed below, fish mortalities will be removed from each sea cage on a daily basis. When handling moribund fish from the sea cages, personnel will be required to wear rain gear, gloves, and boots which will be disinfected after each mortality disposal. Once at the surface, the dead fish are transferred to a designated and approved container on the feed barge for ensilaging; there will be limited personnel access to the ensilage container.

(3) *Health Checks and Procedures*: Fish health (salmon and lumpfish) at the sea cage sites will be monitored by Grieg NL personnel following the procedures as prescribed by the Aquatic Animal Health Division. Fish are routinely monitored by staff for not only physical changes such as signs of fin erosion, lesions, pigmentation problems, parasites and deformities but will also include monitoring of fish behaviour changes. As part of Grieg NL's Fish Health Management Plan, an active and passive surveillance program will be implemented in cooperation with a private veterinarian as well as the provincial veterinarian. Grieg NL personnel will be trained and aware of the importance of noticing and reporting to supervisors any noticeable changes (physical and behavioural). This health surveillance program will apply to both farmed Atlantic salmon and the cleaner lumpfish held in the sea cages. Three of the most common types of pathogens that can cause issues with fish at the sea cage sites are viruses, bacteria and parasites (i.e., sea lice). Many of these pathogens are considered to be opportunistic and can create a serious health challenge especially if the fish are exposed to stressful events or prolonged sub-optimal conditions. Care is taken throughout, to ensure the effects of necessary stressful events are kept to a minimum with sufficient recovery time allocated between stressors. Proper husbandry practices are put in place to ensure overall general hygiene is kept up to standard and proper disinfections procedures are put into place. Routine parasite screening will be carried out as well as routine diagnostic testing. All routine parasite screening and active surveillance will be conducted by Grieg NL personnel on a schedule determined in consultation with provincial authorities and a private veterinarian that also considers fish health and welfare. In addition to the active surveillance by Grieg NL, a passive surveillance program along with diagnostic testing will also be performed by provincial veterinarians.

Although Grieg NL will aim to avoid the use of antibiotics, there are some potential diseases that may require treatment, particularly in consideration of the welfare of the fish. An example would be Enteric Red Mouth disease (ERM) that is caused by a bacterium that has a wide host range and a broad geographical distribution but can be treated before it becomes a chronic issue. Grieg NL will only utilize antibiotics as a last resort based on recommendations of health authorities such as the private and provincial veterinarians in consideration of the health and welfare of the fish.

Grieg NL will be using a sea cage net which extends 45 m below the water surface. This relatively deep net has sufficient volume to allow fish to swim to depths that will allow it to avoid unsuitable surface conditions (e.g., water temperature, sea lice, and waves) and thereby decrease stress on the fish. In addition, the grow-out plan is that fish will only spend one winter at sea; this minimizes the risk of fish mortality.

(4) ***Specialized Feed and Feeding Procedures*****:** Grieg NL will use an established feed adjusted to meet the requirement of triploid sterile salmon. More specifically, the feed has been developed to minimize the occurrence of mandible and spinal deformities as well as the development of cataracts in triploid salmon. Grieg NL will utilize a major supplier for all its triploid sterile salmon feed at the sea cages. All the feed will be CFIA and European Union (EU) approved. Feed wastage will be minimized via the use of established feeding tables/software used to determine feed type and amount and an automatic feeding system which integrates video monitoring in the sea cages. Salmon will be monitored during feeding and once salmon have reached ~80% satiation, feed delivery will be ceased. Cameras mounted in the sea cages will provide staff with a view of the feeding behaviour of fish and feed can be stopped as soon as reduced feeding behaviour is noticed. This system optimizes feeding by providing only enough feed to satisfy the fish while reducing nutrient inputs into the environment.

(5) ***Sea Lice Control*****:** Sea lice levels on salmon will be monitored weekly (anaesthetizing a sub-sample of fish and counting the sea lice at various life stages) when water temperatures are above 4˚C and weather conditions allow. In consideration of fish health and welfare, when water temperatures are below 4˚C, physical monitoring as noted above will be less frequent and will be based on advice of a veterinarian; however, weekly monitoring by underwater cameras will be conducted. Grieg NL will use an adaptive management approach involving several methods to control sea lice in a given sea cage site and across BMAs. Lumpfish will be used as a cleaner fish to minimize sea lice occurrence on salmon in all sea cages (Jónsdóttir et al. 2018). Lumpfish naturally exhibit a “scan-and-pick” feeding behaviour and have been successfully used as cleaner fish in other cold-water aquaculture projects (Powell et al. 2017). If monitoring indicates an increase in sea lice levels, guidance will be acquired from private and provincial veterinarians. If sea lice levels require implementation of additional mitigation measures beyond the use of cleaner fish at a given sea cage site, Grieg NL will implement further preventative mitigation measures at other active sea cage sites in all BMAs. These measures could include the use of sea lice skirts and delivering feed through a dispenser located ~6–7 m below the surface (i.e., via a sub-feeder). If implemented, these measures will be done in combination with the use of functional feed (Jensen et al. 2015). Functional feed has been developed to inhibit sea lice by increasing mucous production on the salmon skin, thereby making it more difficult for sea lice to attach to the salmon. The use of a sub-feeder will be considered for use when feeding with functional feed. This will motivate the fish to stay under the main sea lice area by receiving the feed at 6–7 m below the surface. The use of a sea lice skirt will add one more extra barrier for the sea lice, which in combination with the above would reduce the sea lice pressure even further. If the use of all these measures is not successful at controlling sea lice, Grieg NL will once again consult with private and provincial veterinarians. At this stage, three options will be considered: the use of a “Thermolicer”, therapeutants, or harvesting the fish. If required, therapeutants (e.g., SLICE) would be administered in the feed of the fish. The use of SLICE will be considered based on the advice from the private and provincial veterinarian and what stage of the production cycles the affected fish has reached. The Thermolicer® works by exposing fish and sea lice to 30–34°C water for ~25–30 seconds. The sea lice have a much lower tolerance to this warm water than the fish do and fall off and die when exposed to these conditions. The sea lice are collected and removed and the treated fish are sent back to the sea cage[3]. Depending on the size of the fish, it is also possible that the fish will be harvested early to minimize sea lice. Delousing efforts will be balanced against fish welfare, avoiding resistance and with regard to the effects on the environment. Continuous monitoring and response is important to ensure sea lice levels remain low and the use of therapeutants can be minimized or eliminated.

(6) *Water Quality Monitoring*: A routine program will be established for monitoring, measuring, and recording water quality at all active sea cage sites on a daily basis throughout the Project. In-situ data loggers will be installed on the barges at each sea cage site as well as on each individual cage. In addition, sensors can be attached to cameras and buoys located at the perimeter of each sea cage site. These in-situ loggers will collect data on water temperature, oxygen levels, current speed and direction, as well as pH and salinity. Data will be wirelessly transmitted to centralized computer stations on the barges and at the control center in Marystown for real-time viewing or logged for historical collections. Plankton samples will be completed weekly, analyzed and levels

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[3] The Steinsvik Thermolicer was tested by the Norwegian Veterinary Institute and they determined that “thermal de-licing results in a significant reduction in the number of mobile and adult lice” (Viljugrein et al. 2015). They also stated that “Thermal delicing is a new method without chemicals which can be used as an alternative to pharmaceuticals, and should be used together with other measures as an overall strategy against lice” (Viljugrein et al. 2015). Steinsvik has reached an agreement with a third-party supplier in Newfoundland to offer this system. Grieg NL will sign an agreement with Steinsvik to use this system in the future as necessary.

recorded. This will be one of the information sources used to create net cleaning schedules. Data collection will be used to evaluate the severity of any environmental issues such as fouling or changes in physio chemical data, leading to a response. Environmental changes and plankton levels are rated and depending on the results various mitigation responses are initiated. During transport of smolt from the RAS Hatchery to the sea cage sites, water quality in the hold of the well boat will be monitored.

(7) ***Vaccinations*****:** Prior to transfer to sea, salmon will be vaccinated as per the specific recommendations of provincial veterinarians. Typical vaccinations include the standard bacterin with *Aeromonas salmonicida*, *Listonella anguillarum* and *anguillarum* type II, and *Vibrio salmonocida*. Grieg NL will also include the BKD and the ISA vaccine based on consultations and recommendations with health authorities (DFLR and a private veterinarian). The lumpfish will also receive vaccinations as recommended by provincial veterinarians prior to transfer to sea. Currently lumpfish vaccinations can be administered as a dip-vaccine or injected. Lumpfish dip-vaccines are commonly administered to protect against one or more variants of *Vibrio* bacteria. Injection vaccinations for lumpfish target *Aeromonas salmonicida* type V and type VI as well as some *Vibrio* bacteria. Grieg NL will communicate with suppliers of the lumpfish to ensure the appropriate vaccination regime for the lumpfish has been administered prior to accepting delivery of lumpfish to its sea cages.

(8) ***Mortality Removal and Treatment*****:** Grieg NL will use an automatic system (i.e., Mortex system) that removes dead fish from the bottom of the sea cage each day or more frequently as required. Any visible moribund fish or surface mortalities will be retrieved and moribund fish will be euthanized if required. By collecting mortalities daily this will decrease predator attraction to the cages and minimize disease risk. The number of fish mortalities will be recorded daily. When handling moribund fish from the sea cages, personnel will be required to wear rain gear, gloves, and boots which will be disinfected after each mortality disposal. Once at the surface, the dead fish are transferred to a designated and approved container on the feed barge for ensilaging; there will be limited personnel access to the ensilage container. The dead fish are ground into a slurry and acid is added to lower the pH. The silage will be transferred to shore once sufficient quantities are amassed. If a mass mortality occurs, procedures detailed in Grieg NL's Emergency Response Plan will be followed.

4.8.4 Pathogen and Parasite Transfer between Lumpfish Cleaner Fish and Wild Fishes

The same general mitigation measures and monitoring procedures described in Section 4.8.3 are applicable to the minimization of the potential effects of pathogen and parasite transfer between lumpfish cleaner fish and wild fishes.

1. Decrease the potential for interactions between lumpfish cleaner fish and wild fishes; and
2. Maintenance of farmed salmon health.

4.8.5 Release of Unconsumed Therapeutants and Antibiotics into the Marine Environment

Therapeutants and antibiotics will only be used as a final option, based on the advice of health care professionals (private and provincial veterinarians) and in consideration of the health and welfare of the fish. Since therapeutants and antibiotics would be included in the feed should their use be required, the optimization of feeding will be the primary mitigation for this non-routine Project activity to minimize the potential effects on wild Atlantic salmon.

Optimization of Feeding

Feed wastage will be minimized via the use of established feeding tables/software used to determine feed type and amount and an automatic feeding system which integrates video monitoring in the sea cages. Salmon will be monitored during feeding and once salmon have reached ~80% satiation, feed delivery will be ceased. Cameras mounted in the sea cages will provide staff (located in the control room on the feed barge and/or located remotely) with a view of the feeding behaviour of fish and feed can be stopped as soon as reduced feeding behaviour is noticed. This system reduces nutrient inputs into the environment by optimizing feeding.

4.8.6 Deposition of Organic Material from the Sea Cages

Several mitigation measures and monitoring procedures will be implemented to minimize the potential effects of the deposition of organic BOD matter (fish feces, uneaten fish feed, and naturally occurring biofouling material) on wild Atlantic salmon occurring beneath and in the immediate vicinity of the sea cages. These mitigation and monitoring measures are discussed below.

1. Sea Cage Site Selection

One of the first steps is selecting proposed sea cage sites that meet the requirements of the AAR and DFLR’s Aquaculture Licence Application process. Relative to effects on fish and fish habitat, proposed sea cage sites were selected based on sufficient currents and direction necessary to minimize depositional build-up, adequate water depth for sea cages, and suitable bottom type (i.e., >50% hard bottom).

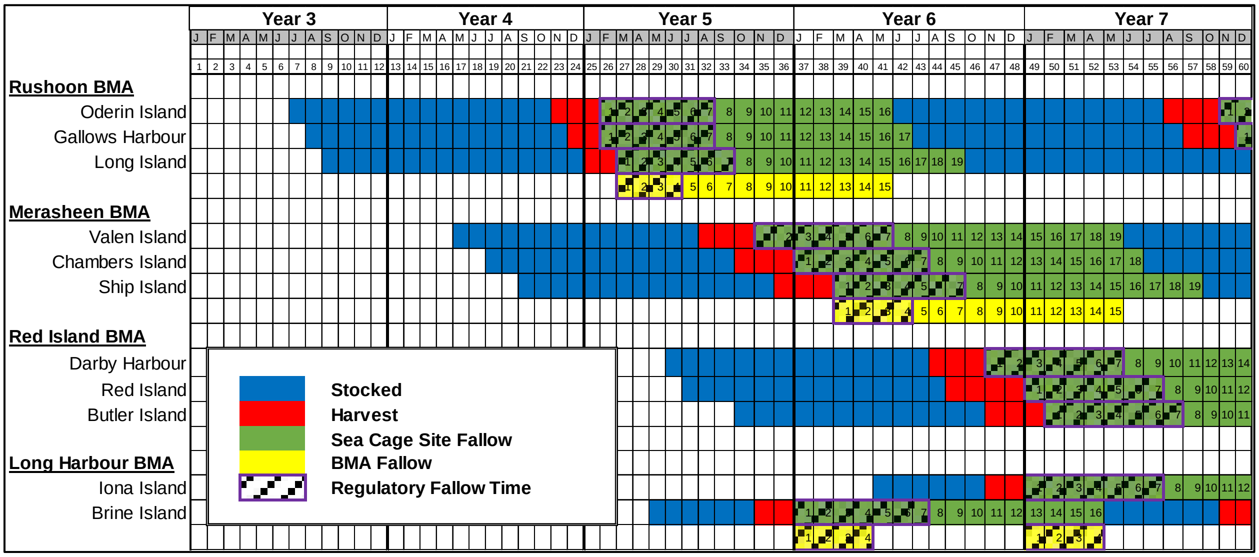
2. Fallowing

Fallowing (leave the site without fish) is another key mitigation measure designed to minimize the effects of aquaculture on marine habitat. Atlantic salmon aquaculture sites in Newfoundland and Labrador are located predominantly over hard bottom substrates where it is difficult to consistently obtain sediment samples. The primary mitigation measure to manage potential effects from uneaten feed and feces is to fallow at the end of each production cycle. In Newfoundland and Labrador, the mandatory fallowing time after harvesting is seven months for a sea cage site and four months for a BMA. Grieg NL will increase this fallowing time for a sea cage site to a minimum of 16 months and a maximum of 19 months after harvesting, increasing the time for the benthic community to recover. A detailed fallowing schedule for each of the proposed sea cage sites and BMAs is provided in Table 4.8. Follow-up monitoring to evaluate nutrification effects from deposition of BOD material will be conducted at each of the sea cage sites. The *Monitoring Protocol for Hard Bottom Benthic Substrates under Marine Finfish Farms in Newfoundland and Labrador* (AAR, Annex 9; GC 2015) will be followed.

3. Optimization of Feeding

Feed wastage will be minimized via the use of established feeding tables/software used to determine feed type and amount and an automatic feeding system which integrates video monitoring in the sea cages. Salmon will be monitored during feeding and once salmon have reached ~80% satiation, feed delivery will be ceased. Cameras mounted in the sea cages will provide staff (located in the control room on the feed barge and/or located remotely) with a view of the feeding behaviour of fish and feed can be stopped as soon as reduced feeding behaviour is noticed. This system reduces nutrient inputs into the environment by optimizing feeding.

Table 4.8. Grieg NL fallowing schedule for each proposed sea cage site relative to the minimum regulatory fallowing schedule. Years 1 and 2 are the Construction Phase of the Project.



4. Husbandry Practices to Minimize Biofouling on the Sea Cages

Husbandry practices designed to minimize biofouling will also serve to mitigate effects on the marine environment. Grieg NL will adhere to a schedule to clean its sea cages to minimize biofouling which can add to the depositional load of organic material. The cleaning schedule for cages and nets will be developed based on environmental conditions in Placentia Bay as well as routine monitoring. Nets will typically be cleaned weekly (via a ROV net cleaner equipped with an advanced camera system) and cages will be cleaned once or twice during heavy fouling periods. Cages and nets will also be cleaned after harvesting is completed and prior to cages being transferred to other BMAs.

Routine checks of equipment utilizing underwater cameras, ROVs, and inspections by divers (as needed) will be used to confirm the cleaning schedule of the sea cages. Grieg NL will ensure equipment has minimal biofouling.

4.9 Follow-up Monitoring

As indicated in Section 7.4 of the EIS Guidelines, Grieg NL will prepare and submit an Environmental Effects Monitoring and Follow-up Plan (EEMP) subsequent to the completion of the EIS but prior to initiation of project construction. The EEMP will provide the details of the proposed follow-up monitoring. Grieg NL anticipates that follow-up monitoring associated with farmed salmon escapes will be designed in cooperation with DFO.

Presented below are the concepts for the follow-up monitoring for the Wild Salmon VEC. As indicated above, the details will be presented in the EEMP. The follow-up monitoring concepts listed below are divided between predictions made regarding the effects of planned project activities on the Wild Salmon VEC, and those made regarding accidental events such as farm fish escapes.

4.9.1 Planned Project Activities

Follow-up monitoring that will be implemented to validate predictions regarding the residual effects of planned Project activities on wild Atlantic salmon include:

- Underwater camera surveys (i.e., drop camera, ROV) of benthic habitat in the vicinities of the sea cages to assess the degree of deposition of organics from the sea cages during regular operations;
- Samples of the deposited organic material will be collected (if possible) and analyzed for various parameters (e.g., sulfide levels);
- If therapeutants and antibiotics are used, samples of the deposited organic material in the vicinity of the sea cages will be collected (if possible) and analyzed for presence of the chemicals; and
- Implementation of a multi-year environmental monitoring program involving the deployment of an ADCP and multiple probes at the Rushoon, Merasheen and Red Island BMAs. Each of the three ADCPs will be deployed at a 40-m depth to collect current profile data in 2-m depth cells in the upper 40 m of the water column. In addition, multiple probes will be installed on the mooring lines at selected depths above the ADCP to collect data on the following parameters.

    - Water temperature;
    - Wave profile;
    - Conductivity;
    - Salinity;
    - pH;
    - Total dissolved solids (TDS); and
    - Dissolved oxygen.

4.9.2 Accidental Events

In the event of an accidental escape of fish from sea cages, Grieg NL must contact DFO before initiating any response effort. Any attempt to recapture escaped fish will have to be approved by DFO first. The principal follow-up monitoring in the event of an accidental escape of farm fish would involve sampling Atlantic salmon in scheduled salmon rivers closest to the location of the escape in order to determine whether escaped farm salmon have entered the freshwater systems. Sampling would involve collecting and analyzing blood samples, which will provide information such as source of the fish (i.e., wild or farm), the broodstock of the fish, and whether or not the fish is triploid. Given DFO's expertise in genetic analysis of Atlantic salmon, Grieg NL would like to design and conduct the follow-up monitoring for farm salmon in the rivers in collaboration with DFO scientists.

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Personal Communication

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