Placentia Bay Atlantic Salmon Aquaculture Project Environmental Effects Monitoring Plan (EEMP):

Climate and Weather

GRIEG NL

December 2019

Placentia Bay Atlantic Salmon Aquaculture Project Environmental Effects Monitoring Plan:

Climate and Weather

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1.0 Introduction

As part of the environmental assessment (EA) process for the proposed Placentia Bay Atlantic Salmon Aquaculture Project, Grieg NL was required to prepare and submit Environmental Effects Monitoring Plans (EEMP) subsequent to the completion of the Environmental Impact Statement (EIS) but prior to initiation of Project construction (see Section 7.4 in EIS Guidelines, Department of Municipal Affairs and Environment [DMAE] 2018). Additionally, the release of the Placentia Bay Atlantic Salmon Aquaculture Project from further environmental assessment by DMAE on 5 September 2018 was subject to Grieg NL meeting a series of terms and conditions including eight components requiring an EEMP. The required EEMP for Climate and Weather is presented in this document. This EEMP is designed to monitor select meteorological and physical oceanographic conditions at the Grieg NL sea cage sites and at other sites in Placentia Bay. In addition, this Plan is designed to examine these data to potentially offer insight into climatic conditions in the Study Area over time.

Grieg NL is committed to implementation of this EEMP as a component of its Placentia Bay Atlantic Salmon Aquaculture Project. The organization of this document generally follows the requirements outlined in Section 7.4 of the EIS Guidelines (DMAE 2018). However, we have not included a section on Cumulative Effects in this EEMP given that it is not applicable. The EEMP will be reviewed on an annual basis and updated as needed throughout the Project life.

2.0 Objectives and Scheduling of Monitoring

The EEMP for 'Climate and Weather' is designed to collect meteorological and physical oceanographic data. These data will be used by Grieg NL personnel when making operational decisions for certain Project activities in the marine environment. Of direct relevance to this EEMP are operational decisions that influence how the Project may affect the marine environment. Weather also has direct influence on operational decisions regarding personnel safety; however, this is considered outside the scope of the EEMP. The primary objectives of this EEMP are to monitor weather data, document its influences on relevant Project activities, and to have mechanisms in place for adaptive management procedures if required. A secondary objective is to examine collected weather data on a longer time scale to possibly ascertain if climatic changes are occurring and what influence these changes may have on Project activities and associated mitigation measures.

The Climate and Weather EEMP has three main monitoring components: (1) collection of meteorological and physical oceanographic data; (2) monitoring of weather forecasts, ice conditions, and water temperatures for operational purposes; and (3) climate analysis. Monitoring design and methods are detailed in Section 3.0. In terms of scheduling, meteorological and physical oceanographic data collection will occur daily as will the monitoring of weather forecasts. Ice conditions at and near the sea cages will be monitored daily during the seasonal pack ice periods. Following five years of select meteorological and physical oceanographic data collection, Grieg NL will examine the data to provide a short-term climatic "history" for its sea cage sites.

3.0 Monitoring Design/Methodology

Meteorological and physical oceanographic data will be collected at each of Grieg NL's active sea cage sites (Figure 3.1). Other sources of data are available from Environment and Climate Change Canada (ECCC) weather stations as well as SmartBay buoys in Placentia Bay. These data will be used to examine potential climatic changes.

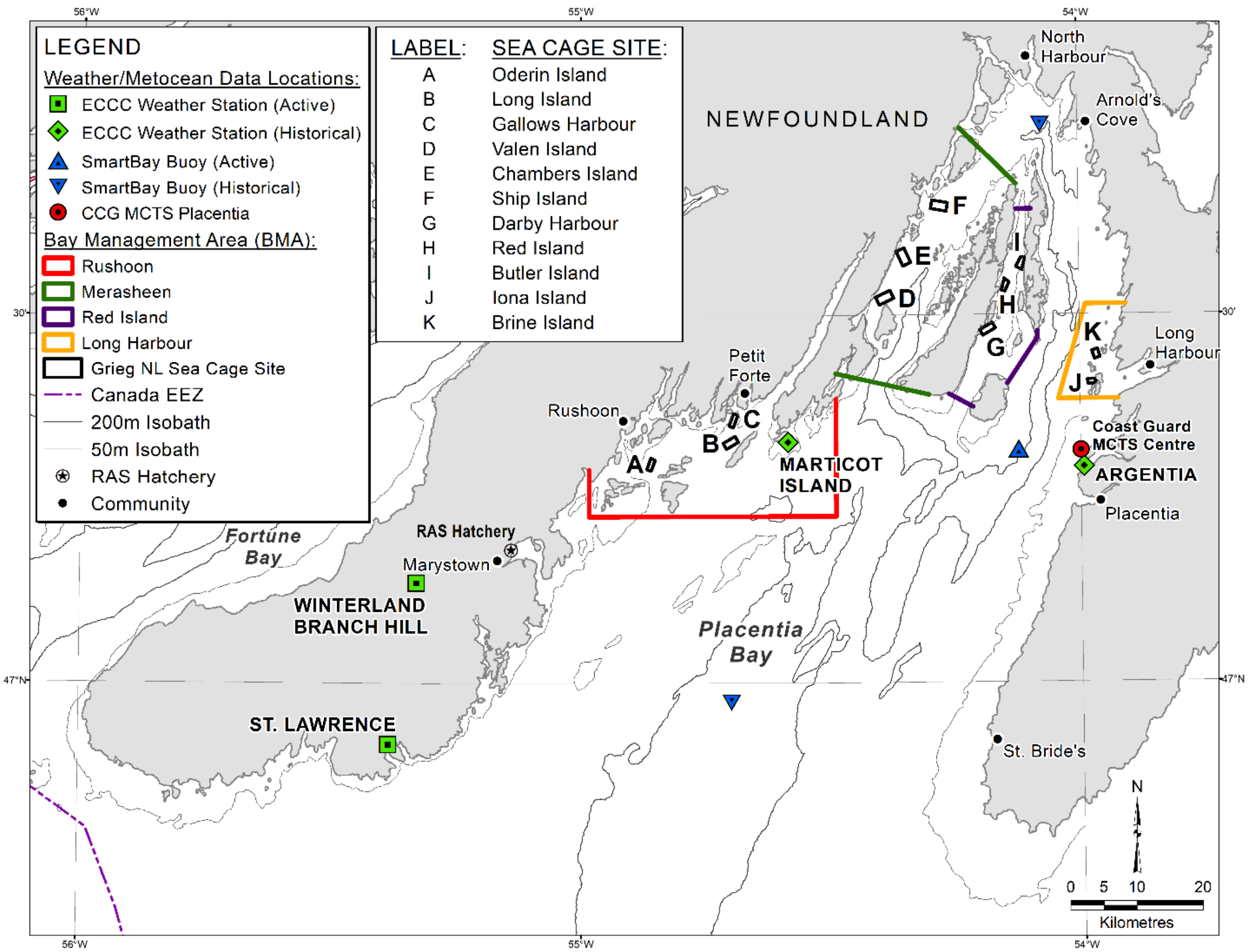

Figure 3.1. Locations of Grieg NL sea cage sites, ECCC weather stations, SmartBay buoys, and the MCTS Centre in Placentia Bay.

3.1 Meteorological and Physical Oceanographic Data Collection

Meteorological and physical oceanographic data will be collected at each of Grieg NL's active sea cage sites. Additionally, Grieg NL will acquire data from ECCC weather stations and SmartBay buoys in Placentia Bay. Note that the EEMP is not designed to address broader scientific questions on regional currents (which could be obtained with drifters and drogues).

3.1.1 Sea Cage Sites

Meteorological and physical oceanographic data will be collected at each active Bay Management Area (BMA) via a weather station, Acoustic Doppler Current Profiler (ADCP; or similar system), and observations made by Grieg NL personnel.

3.1.1.1 Weather Stations

An automatic weather station (AWS) will be mounted on the primary feed/accommodation barge at each active sea cage site. The AWS and sensors will include a weather-proof enclosure for housing a data logger, sensors, rechargeable battery (for back-up purposes) and possibly telemetry electronics. The AWS will collect air temperature, wind speed, wind direction, and atmospheric pressure data. It is anticipated that these data will be collected at one-minute intervals but the sampling interval may vary. Grieg NL plans to have data collected by the AWS displayed on a monitor in the barge in real time. Weather data from each AWS will also be transmitted for display in a central console room (in near real-time).

3.1.1.2 ADCP or Similar System

Wave profile data (e.g., height, direction, and period) will be collected via probes of an ADCP system (or similar system like an oceanographic buoy) deployed in each active BMA. As part of this system, probes will be installed to collect data on the current profile up to the surface and on other parameters. Of direct relevance to this EEMP are data collected on wave profiles and water temperature as these environmental parameters can affect Project activities. The exact sampling regimes of the probes have not yet been determined.

3.1.1.3 Observations by Personnel

Meteorological and oceanographic variables which are difficult to acquire through automation, including precipitation, visibility (estimate in km), sea state (Beaufort Wind Force), ice type/presence and, if required, estimates of sea ice concentration, will be recorded by personnel daily at each active sea cage site. A designated Grieg NL employee at the primary feed/accommodation barge will collect these data three times per day—early morning, mid-day, and late afternoon. This will be done in conjunction with observations for marine wildlife (see Fish, Marine Mammals, Sea Turtles, and Seabirds EEMP) to minimize data recording duties of personnel. [However, it should be recognized that effort to collect data on meteorological variables will have to be balanced with the requirements of Grieg NL personnel to conduct their primary job duties, i.e., the operation, maintenance and eventual decommissioning of sea cage sites.] Meteorological and oceanographic data will be recorded onto a data sheet and later entered into an electronic database (e.g., Microsoft Excel). Grieg NL will explore the possible use of recording data directly into a handheld tablet device or computer with dedicated software. The device will automatically record Global Positioning System (GPS) location, date/time and facilitate data entry via pre-filled menus. In the event that the AWS malfunctions at a given sea cage site, Grieg NL personnel will also collect data on air temperature, wind speed, and wind direction three times per day.

3.1.2 Regional Sites

Grieg NL will acquire weather data and physical oceanographic data at regional sites from ECCC weather stations and SmartBay buoys. The following meteorological data are publicly available from ECCC for active weather stations in Placentia Bay (see Figure 3.1): air temperature, wind speed, wind direction, precipitation, relative humidity, and atmospheric pressure. These data will be downloaded on a monthly basis for the Marystown (Winterland Branch Hill) and St. Lawrence weather stations by Grieg NL personnel. Data are provided at an hourly interval by ECCC. The following physical oceanographic and meteorological data are available publicly from Smart Atlantic Alliance for each active SmartBay buoy in Placentia Bay (see Figure 3.1): wind speed (average, peak) and direction, wave height (significant, maximum), wave direction, peak wave period, and sea surface temperature. These data are collected at 30-minute intervals and will be downloaded on a monthly basis for active SmartBay buoys in Placentia Bay by Grieg NL personnel. These data will be incorporated into the climate analysis (see Section 3.3). Additional data sources, namely data from historical weather stations and recording buoy logs will be acquired and utilized for longer-term climate analyses, following five years of Project operation (see Figure 3.1; Section 5.3).

3.2 Monitoring Weather Forecasts, Ice Conditions, and Water Temperatures for Operational Purposes

Grieg NL will use local forecasts for weather and ice for many aspects of its operations. Additionally, Grieg NL will routinely monitor water temperatures at its active sea cage sites. Of direct relevance to this EEMP, are meteorological and ice conditions as well as decreases in water temperature that may lead to a superchill event.

3.2.1 Local Weather Forecasts

Grieg NL personnel at each primary feed/accommodation barge will monitor ECCC publicly-issued forecasts as the primary source of information for weather conditions. The weather forecast will be monitored daily, a minimum of three times per day (early morning, mid-day, and evening) and more frequently depending on the Project activity and forecast. The Beaufort Wind Force Scale, in addition to any forecasted (near-shore [land] weather advisories, watches, or warning alerts and marine [South Coast of Newfoundland]: small craft, gale, and storm) warnings issued by ECCC will be used as the basis for proactive decisions related to environmental conditions that would initiate changes to normal operational procedures. Wind force and wave heights from storm events are of primary concern.

3.2.2 Ice Conditions

As described in Section 4.2.2.6 of the EIS, Placentia Bay is relatively ice-free compared to other bays of Newfoundland. Sea ice is sometimes present in Placentia Bay from mid-February until mid-April, with the highest likelihood of ice presence during early-March. The frequency of sea ice presence within the BMAs during early-March is 1–15%. Icebergs in the BMAs are considered rare.

During the sea ice season, broadcasts and reporting on ice occurrence and distribution will be facilitated by daily communication from Grieg NL personnel with the Canadian Coast Guard (CCG) Marine Communications and Traffic Services (MCTS), Placentia. Regular communication with the CCG MCTS will occur daily during the seasonal sea ice periods. Broadcasts and reporting on ice occurrence and distribution will be monitored, as well as guidance and advice related to predicted timing and extent of any sea ice (or iceberg) incursions will be sought. Additionally, Grieg NL personnel will also have access to the ECCC Canadian Ice Service (CIS) products website for updated ice forecasts and warnings for Placentia Bay.

Sea cage components above the water surface may accumulate ice during freezing rain events or from sea spray that freezes. Ice accretion may cause loads on the construction of the sea cage. The load effect from icing is primarily connected to loss of buoyancy. All sea cages will be routinely monitored for ice accretion by either personnel on site or video camera. Ice accretion will be minimized by personnel removing ice as it accumulates, which is typically done with rubber mallets and/or frequent disruption of temporary tarpaulin coverings to dislodge surface ice.

3.2.3 Water Temperature

Fishes have thermal tolerances with upper and lower temperature limits that are species-specific. Atlantic salmon have a lower temperature limit of approximately -0.75˚C (Elliott and Elliott 2010) and an upper thermal limit range of approximately 22.3-27.5˚C (Anttila et al. 2013). A study by Anttila et al. (2013) suggests that there is substantial variation in both thermal and hypoxia (deficiency of oxygen reaching tissues) tolerance among families of Atlantic salmon due to genetic differences. Regardless, extremes in water temperature can result in mortality in Atlantic salmon, primarily due to a depletion in available oxygen in the case of extreme high temperatures.

The concentration of dissolved oxygen (DO) in water is influenced by a number of factors, including water temperature, salinity and atmospheric pressure. Storm events can also affect how DO varies in the water column. The DO level in water is typically inversely related to temperature and salinity, and directly related to pressure. Generally, warmer, highly saline water near surface contains less dissolved oxygen than cold, lower salinity water at depth (Fondriest Environmental, Inc. 2013).

A routine program will be established for monitoring, measuring, and recording biophysical data at all active sea cage sites on a daily basis throughout the Project, as per Aquaculture Policy 2. *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, 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. This daily collected biophysical data will be submitted to the Aquaculture Development and AAHD of DFLR on a quarterly basis. These data will also be available to DFLR upon request in the event of an extreme water temperature event. .

3.2.3.1 Superchill

Although Atlantic salmon can survive temperatures below freezing, if the salmon contact ice crystals in the water mortality may occur. Superchill occurs when the water temperatures fall below freezing and ice nuclei form in the water and then develop across the epidermis of the fish (Speare 2003). This can be detrimental to the health of the fish and result in high mortalities. In Newfoundland, a superchill event resulted in farmed Atlantic salmon mortalities in 2014 (DFA 2015). Superchill can occur in Placentia Bay and affect the Project.

Grieg NL will implement measures to reduce the possibility of fish being affected by a superchill event. Temperature profiles during winter months in Placentia Bay are negatively correlated with water depth (see LGL 2018 in Volume 3 of the EIS). Salmon position themselves vertically in relation to water temperature within sea cages (Oppedal et al. 2011). Therefore, providing the fish with deep nets (i.e., 37 m below surface) will allow the fish to descend deeper into the water that is warmer than the colder surface water. Other mitigation measures which will be implemented by Grieg NL to minimize the effects of a superchill event include the cessation of feeding and other activities that require the fish to come to the surface. Additionally, water temperatures will be monitored daily (as a minimum at surface, mid-cage, and bottom cage), and personnel will be trained to recognize when a superchill event may occur.

3.2.3.2 Extreme High Temperature Events

Grieg NL has and/or will implement the following mitigation measures to minimize the likelihood of a mass mortality event occurring at its Placentia Bay sea cage sites as a result of extreme high temperature events.

Project Planning—Site Selection: Placentia Bay was selected because it provides deep-water sites that have ideal water temperatures, stratification, and currents to support salmon growth. Grieg NL's sea cage sites are located in the deep channels that run the longitudinal axis and are characteristic of Placentia Bay. Ma et al. (2012) modelled currents and temperature in Placentia Bay and discovered that wind-induced coastal upwelling pumped low temperature water from a deeper layer up to the surface on the west coast of the bay. As a result of the southwesterly winds, surface water temperature along the east coast warmed up. Observations in Placentia Bay support this cooler water temperature along the west coast of the bay where Grieg NL sea cages are located. Grieg NL has been collecting water temperature and DO data in its BMAs since 2016. Maximum water temperature observed at the sea cage sites was 18.4˚C, which occurred in the upper 10 m of the water column for a relatively brief period in August 2019. Below 10 m, maximum water temperatures from 2016-2019 have ranged from 14°C to 17.5°C and at 25 m below 15° C. Water sampled was predominately near or above 100% oxygen saturation and measured DO concentrations were consistently greater than 6 mg/L, typically considered the indicator value below which hypoxic conditions occur for farmed salmon (Mansour et al. 2008). ,

Project Planning—Production Plan: A stocking density of <15 kg/m^3 will be used in each sea cage, which allows adequate net volume for fish to descend lower in the net if necessary. All-female triploids will be used instead of diploids and the smolt will be graded by size prior to transfer to sea which will allow for more accurate assessment of oxygen requirements.

Selection of Sea Cages, Associated Equipment, and Husbandry Practices: Grieg NL will be using deep (37 m) and large sea cages (50 m diameter) to house its farmed salmon. This will allow salmon to descend lower in the water column to avoid warmer surface temperatures if necessary. Grieg NL's barges are equipped with large generators which can power aeration devices for deployment into the sea cages should DO decrease to levels which are deemed to put salmon health at risk. Additionally, Grieg NL is considering equipping its sea cages with a "lock' system, which will allow the entire net to be lowered deeper into the water column. Nets will be cleaned by a service provider approximately every 10 days during periods when water temperatures would be highest. Maintaining a consistent cleaning program will ensure there is minimal fouling on the nets and ultimately allows for optimum water flow within the sea cage. Each sea cage will be equipped with a LiftUp mortality removal system that will be operated/monitored daily; it is anticipated that there will be no accumulation of fish mortalities. [Note that the LiftUp system is designed to handle a mass mortality event and has a maximum mortality removal capacity of 60 ton/hour (J. Ragnhildstveit, Production Manager, LiftUp, pers. comm., 29 October 2019).]

Visual Monitoring of Fish Behaviour: Salmon behaviour will be monitored during feeding and will provide early warning signs of potential issues with high water temperatures. This will allow Grieg NL to implement modified operational activities (see below) in a more timely fashion and complements the water temperature and DO monitoring at each sea cage.

Water Temperature and DO Monitoring: Water temperature and DO will be monitored continuously in each sea cage at select depths in the water column (i.e., as a minimum at surface, mid-cage, and bottom cage). If water temperatures increase and/or oxygen levels decrease to levels deemed to put salmon health at risk, modified operational activities will be implemented (see below).

Modified Operational Activities: Activities that require the fish to come to surface will be ceased during periods of high water temperatures and/or low oxygen levels. Feeding regimes will be adjusted based on environmental conditions and fish behaviour in consultation with the company veterinarian. Feed will either be reduced, ceased, or alternatively fish may be fed through a sub-feeder. Aeration devices will be available for deployment. If net locks are employed, sea cages in the affected high water temperature areas will be lowered into the water column to minimize exposure of salmon to hypoxic conditions.

If a mass mortality event does occur, Grieg NL will implement its mass mortality response plan.

3.3 Climate Analysis

Following five years of data collection, Grieg NL will examine the data to provide a short-term climatic "history" for its sea cage sites and adjacent areas in Placentia Bay. More specifically, minimum, maximum, and mean values (monthly, annual) for precipitation, air temperature, wind speed, wind direction, wave profiles as well as data on ice and storm events will be analyzed. This information may allow Grieg NL to provide some insight into potential changes in weather. However, it should be recognized that the relatively short-term scale of data collection may not be sufficient to detect trends. The analysis of meteorological and physical oceanographic data will be conducted every five years throughout the operations phase of the Project.

4.0 Frequency, Duration and Geographic Extent of Monitoring

The frequency, duration, and geographic extent of climate and weather monitoring are summarized in Table 4.1. Figure 3.1 shows the locations of the sea cage sites as well as the locations of ECCC weather stations, SmartBay buoys, and the MCTS Centre in Placentia Bay.

Table 4.1. Summary of frequency, duration, and geographic extent of climate and weather monitoring.

Climate and Weather	Frequency	Duration[b]	Geographic Extent
A. Meteorological and Physical Oceanographic Data Collection			
Sea Cage Sites: Weather Stations	Hourly[a]	Operations Phase	Primary feed/accommodation barge
Sea Cage Sites: ADCP or Similar System	Hourly[a]	Operations Phase	Location in each active BMA
Sea Cage Sites: Personnel Observations	Daily	Operations Phase	Visible area around active sea cages
Regional Sites	Monthly[c]	Operations Phase	Placentia Bay[d]
B. Monitoring for Operational Purposes			
Local Weather Forecasts	Daily	Operations Phase	Placentia Bay
Sea Ice and Icebergs	Daily during "Ice Season"	Operations Phase	Placentia Bay
Ice Accretion	As Required	Operations Phase	Sea Cages
Water Temperature	Hourly[a]	Operations Phase	Sea Cages
C. Climate Analysis	Every 5 Years	Operations Phase	Placentia Bay[d]

[a] Sampling will likely occur more frequently; however, the exact sampling frequency has not yet been determined.

[b] This EEMP is focused on the operations phase because it is during this period that weather and physical oceanographic conditions can affect Project activities that may lead to effects on the marine environment. Weather and ice conditions will also be monitored during construction and decommissioning phases but monitoring will be related to safety (personnel, equipment), which is considered outside of the scope of this EEMP.

[c] Data will be downloaded on a monthly basis, but the data sampling regime is more frequent.

[d] The ECCC weather stations and SmartBay buoys in Placentia Bay where data will be acquired are shown in Figure 3.1.

5.0 Reporting and Response Mechanisms

Reporting, and in some cases data submission, procedures for each of Grieg NL's climate and weather monitoring components are provided below. For monitoring components which are designed to support mitigation measures, response mechanisms are also included as appropriate. An adaptive management approach will be employed to monitor and mitigate potential influences of weather and ice on those marine project activities which may affect the marine environment. Available data will also be used to verify EIS predictions as appropriate.

5.1 Meteorological and Physical Oceanographic Data Collection

As described in Section 3.1, Grieg NL will collect meteorological and physical oceanographic data at each of its active sea cage sites. In the Technical Report (Section 5.4) prepared for this EEMP, Grieg NL will compile and analyze these data including monthly and annual values (minimum, mean, and maximum) for air temperature, wind speed, wind direction, sea state (Beaufort Wind Force), wave profile data (e.g., height, direction, and period), water temperature, atmospheric pressure, visibility (in-air), ice type/presence and estimates of sea ice concentration (if required). These data can be provided on an annual basis to ECCC if requested.

5.2 Monitoring Weather Forecasts, Ice Conditions, and Water Temperatures for Operational Purposes

Of direct relevance to this EEMP are the influences of weather, ice conditions, and water temperatures on the risk of releasing farmed fish into the environment. Grieg NL will only conduct Project activities including fish transfers during suitable conditions. Transfer of fish from the RAS Hatchery to a well boat (and from a well boat to sea cage sites) will only occur under acceptable sea conditions of wave heights less than 2–2.5 m. Grieg NL will summarize the influences of weather on Project activities directly relevant to effects on the marine environment in the technical report for this EEMP.

Although sea ice and icebergs are not considered a particular risk to sea cage operations, Grieg NL will routinely (i.e., minimum daily during the sea ice season) receive and monitor broadcasts on ice conditions (and/or weather) from the MCTS and receive guidance on the predicted timing and extent of any sea ice (or iceberg) incursions. Grieg NL's application for "standing" with the CCG on the Placentia Bay Traffic Committee should the need arise for assistance with ice is being processed. A three-tiered approach will be used to adaptively 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 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 details procedures to harvest the fish. In the unlikely event mitigation measures for sea ice management are required they will be described in the technical report for this EEMP. This report will also include a discussion of the potential need for changes in the adaptive ice management approach.

A summary of ice accretion levels and removal at active sea cages will also be included in the technical report for this EEMP.

In the rare circumstance of a superchill event that leads to mass fish mortality, Grieg NL's Emergency Response Plan details procedures to harvest the fish. The technical report for this EEMP will describe any superchill events and measures taken to minimize effects on the caged fish and the environment.

5.3 Climate Analysis

As outlined in Section 3.3, following five years of meteorological and physical oceanographic data collection, Grieg NL will examine the data to provide a short-term climatic "history" for its sea cage sites and adjacent areas in Placentia Bay. Climate information will be reported for Placentia Bay as a whole and at finer resolution(s) of BMA or sea cage sites. Temporal statistics will be generated at five-year intervals from start of the operations phase to assess relative change. Given that climate studies aimed at trend analyses require large time windows (e.g., 30+ years) to account for variability, our approach will be simple with comparison of five-year results to the statistical means for the preceding 30 years (i.e., 'moving window') to detect anomalies from mean meteorological parameters. Climate analyses will be included in the technical report for this EEMP.

5.4 Technical Report

An annual technical report will be prepared on or before 31 March which presents the findings of the Climate and Weather EEMP as outlined in Sections 5.1–5.3.

6.0 Procedures to Assess Effectiveness of Monitoring and Follow-up Programs, Mitigation Measures, and Recovery Programs

The efficacy of monitoring and mitigation measures for meteorological influences on Project activities and the marine environment primarily relate to mechanisms to reduce the risk of farmed fish escapes. As described in Section 5.0, Grieg NL will employ an adaptive management approach for mitigation measures. Recovery programs directly related to this climate and weather EEMP are not applicable.

Grieg NL will continuously look to use the most reliable and advanced weather and ice forecasts to assist with predicting environmental conditions relevant to its Project activities.

7.0 Communication Plan to Describe the Results

As outlined in Section 5.0, an annual technical report will be prepared on or before 31 March of each year. This report will present an overview of meteorological and physical oceanographic conditions for the preceding year of operations.

As per 'Condition c' in the Government of Newfoundland and Labrador's Project release letter, Grieg NL will include the results of the climate and weather monitoring program within its annual report on EEMPs. This report will be publicly available on the Grieg NL website.[1]

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[1] In addition, Grieg NL will publicly release all confirmed reports of disease and fish escapes within 24 hours and the use of chemotherapeutants (i.e., antibiotics, vaccinations, and anesthetics) and pesticides on an annual basis.

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