DFO NEWFOUNDLAND AND LABRADOR REGION SCIENCE REVIEW OF FIVE PROPOSED GRIEG AQUACULTURE MARINE FINFISH AQUACULTURE FACILITIES IN PLACENTIA BAY, NEWFOUNDLAND

Context

Grieg Aquaculture (GA) has submitted applications for five Atlantic Salmon aquaculture licenses in Placentia Bay located on the south coast of Newfoundland (Channel Harbour, Gilbert's Cove, Jude Island, Paradise Sound, St. Leonard's). The Proponent's site applications were submitted to the Province of Newfoundland and Labrador (NL) and referred to Department of Fisheries and Oceans Canada (DFO) for siting advice. DFO Science has been asked for a review of the predicted exposure zones associated with the range of aquaculture activities and the predicted impacts on species and the habitats that support them. The proponent has submitted a site application package for each site that includes a Baseline Assessment Report in accordance with the *Aquaculture Activities Regulations* (AARs).

DFO is developing a siting framework to promote a consistent approach to aquaculture site reviews. This framework will include four standardized questions the Regional Aquaculture Management Office (RAMO) uses to ensure a comprehensive review of site applications and inform DFO advice to the Province:

1. Based on the available data for the site and scientific information, what is the expected exposure zone from the use of approved fish health treatment products in the marine environment, and the predicted consequences to susceptible species?
2. Based on available data, what are the Ecologically and Biologically Significant Areas (EBSAs); Species At Risk (SAR); fishery species; and ecologically significant species (ESS) and their associated habitats that are within the predicted benthic exposure zone and vulnerable to exposure from the deposition of organic matter? How does this compare to the extent of these species and habitats in the surrounding area (i.e. are they common or rare)? What are the anticipated impacts to these sensitive species and habitats from the proposed aquaculture activity?
3. To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic species at risk make use of the area, and for what duration and when?
4. Which populations of conspecifics are within a geographic range where escapes are likely to migrate? What are the size and status trends of those conspecific populations in the escape exposure zone for the proposed site? Are any of these populations listed under Schedule 1 of the *Species At Risk Act* (SARA)?

In relation to these particular site applications, significant scientific advice has previously been provided for many elements of the above four questions (DFO 2016, DFO 2018). The RAMO is seeking science advice, as a priority, in particular on questions one and two, as well as any new scientific information relevant to the other questions that may now be available.

This Science Response Report results from the Regional Science Response Process of June 29-30, 2021 Request for Aquaculture Siting Advice for Provincial Site Licence Applications from Grieg Aquaculture in Placentia Bay, Newfoundland.

Background

Grieg Aquaculture (GA, Grieg NL Seafarm Ltd.) has submitted applications to develop five new marine finfish aquaculture sites in Placentia Bay, on the south coast of Newfoundland, for the production of sterile triploid Atlantic Salmon (all female; *Salmo salar*). The location of the five sites is shown in Figure 1. The Channel Harbour, Paradise Sound and Gilbert’s Cove sites are all located in Paradise Sound with 1 km between lease boundaries. None of these sites have a previous history of aquaculture activities.

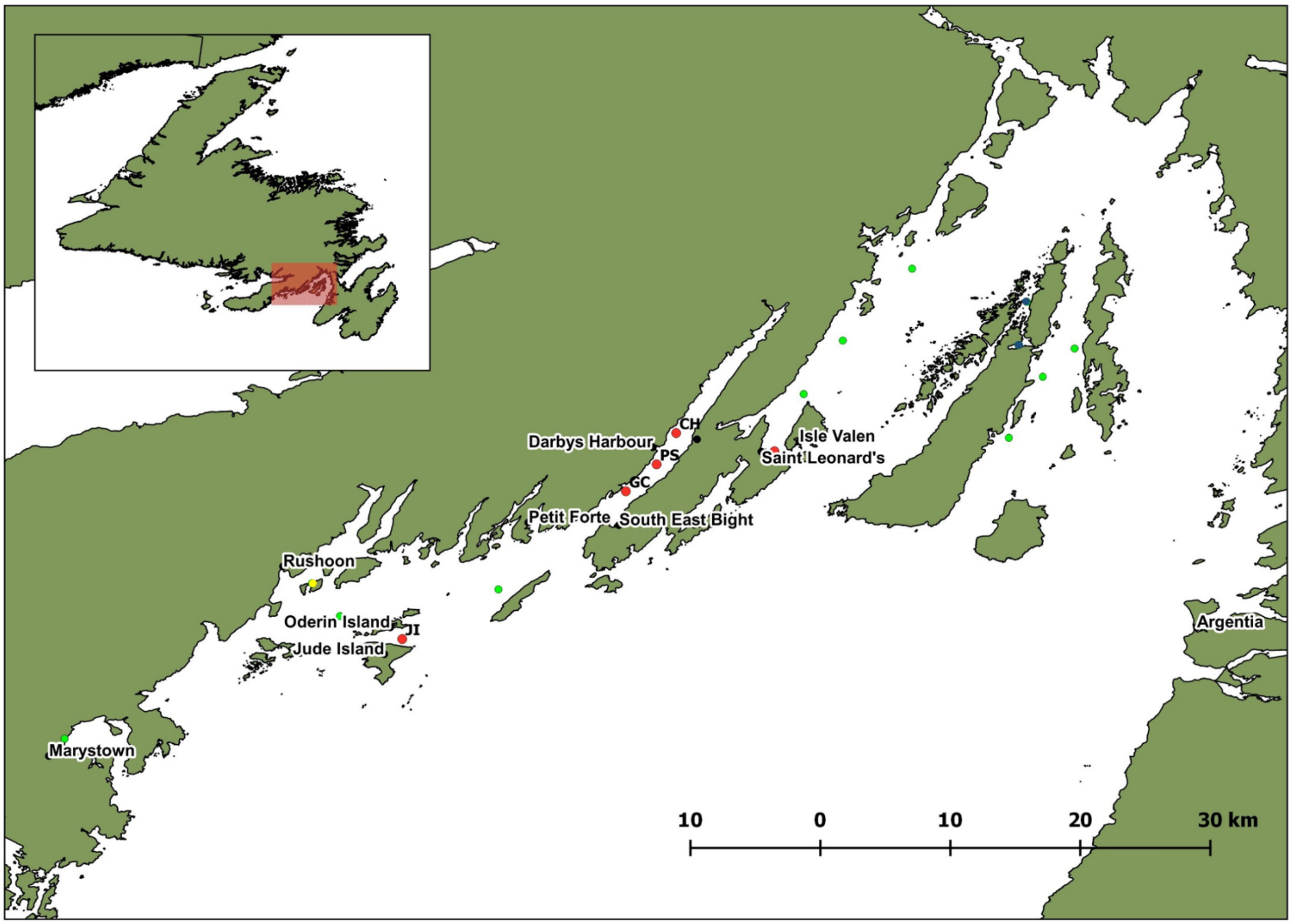

Figure 1: Location of the proposed aquaculture sites in Placentia Bay, NL. Red dots represent proposed sites Channel Harbour (CH), Gilbert’s Cove (GC), Paradise Sound (PS), Jude Island (JI) and St. Leonard’s (SL). Green dots represent currently licensed finfish sites and blue dots represent currently licensed shellfish sites in Placentia Bay; yellow dot represents seasonal cod ranching site.

General Description of Sites

The five proposed sites are located on the northwestern side of Placentia Bay; three of the sites (Channel Harbour, Paradise Sound and Gilbert's Cove) are located in Paradise Sound while Jude Island and St. Leonard's are located outside of the sound. Visual benthic surveys were used to characterize the flora, fauna, and substrate types within the lease boundaries of the proposed sites. In these surveys, a station is defined as the area of the seafloor surveyed during one minute of video collection. No hard-bottom benthic indicator of organic enrichment (Beggiatoa-like bacteria, opportunistic polychaete complexes (OPC), or barrenness caused by aquaculture) was observed within the surveyed area at Channel Harbour, Gilbert's Cove, Paradise Sound and St. Leonard's; at Jude Island, Beggiatoa-like bacteria was observed at 24 of the 317 stations sampled, most often forming over or near algal debris (likely due to natural deposition in the area). Benthic substrate monitoring, based on the AAR Monitoring Standard, was conducted at the soft bottom sites (Channel Harbour, Gilbert's Cove, Paradise Sound and Jude Island) to determine the concentration of free sulfide; this analysis revealed oxic conditions at all proposed sites where samples were collected. The description of sites is based on the documentation provided by the proponent, unless explicitly noted. Key oceanographic, farm infrastructure and grow-out information for each of the proposed site are summarized in Table 1.

The proposed Channel Harbour aquaculture site is in the Rushoon Bay Management Area (BMA), Placentia Bay, NL, in Paradise Sound, approximately 12.9 km north northeast of the mouth of the sound and 925 m west of Channel Harbour (Figure 1). It is approximately 16.6 km (by water) from the community of Petit Forte, 66 km (by water) from the community of Marystown. The site is exposed to Placentia Bay and the open sea to the southwest and it is relatively exposed to winds from NE, S and SW. Bottom sediments consisting of mostly silt/mud soft substrate. Of the 263 stations surveyed by video, 183 were characterized as soft seafloor (70%); a benthic characterization report (Wood Environment & Infrastructure Solutions 2020) classified 54% of the lease area as a soft-bottom deep-water muddy seascapes, 19% as deep-water bedrock seascapes, 1% as sub-littoral bedrock seascapes; the remaining 25% of the lease area had no data.

The proposed Gilbert's Cove aquaculture site is in the Rushoon BMA, Placentia Bay, NL, in Paradise Sound, approximately 5.0 km north northeast of the mouth of the sound and 2.5 km north of South East Bight (Figure 1). It is approximately 9.4 km (by water) from the community of Petit Forte, 57 km (by water) from the community of Marystown. The proposed site is relatively exposed to winds from the NE, SE, S and SW. Bottom sediments consisting of mostly silt/mud soft substrate. Of the 240 stations surveyed by video 165 were characterized as soft seafloor (69%); a benthic characterization report (Wood Environment & Infrastructure Solutions 2020) classified 54% of the lease area as soft-bottom deep-water muddy seascapes, 33% as deep-water bedrock seascapes, 1% as sub-littoral bedrock seascapes; the remaining 12% region of this lease area had no data.

The proposed Paradise Sound aquaculture site is in the Rushoon BMA, Placentia Bay, NL, in Paradise Sound, approximately 8.5 km north northeast of the mouth of the sound and just south of Darbys Harbour (Figure 1). It is approximately 13 km (by water) from the community of Petit Forte, 58 km (by water) from the community of Marystown. The site is relatively exposed to winds from the northeast and south-southwest. Bottom sediments consisting of mostly mud/silt soft substrate. Of the 369 stations surveyed by video 283 were characterized as soft seafloor (77%); a benthic characterization report (Wood Environment & Infrastructure Solutions 2020) classified 49% of the lease arear as deep-water muddy, 37% as deep-water bedrock; the remaining 14% region of this lease area had no data.

The proposed Jude Island aquaculture site is in the Rushoon BMA, Placentia Bay, NL, just north of Jude Island and approximately 450 m south of Oderin Island (Figure 1). It is approximately 12 km (by water) from the community of Rushoon, 27 km (by water) from the community of Marystown, The area is relatively exposed to winds from most directions, but especially from the NE, E, SE and W, as well as winds from the S for the eastern part of the lease area. Bottom sediments consisting of hard substrate. Of the 317 stations surveyed by video, 157 were characterized as soft seafloor (49.5%); a benthic characterization report (Wood Environment & Infrastructure Solutions 2020) classified 41% of the lease area as soft-bottom deep-water muddy seascapes, 16% as sub-littoral bedrock seascapes, 8% as deep-water bedrock seascapes; the remaining 35% region of this lease area had no data.

The proposed St. Leonard’s aquaculture site is located in the Merasheen BMA, Placentia Bay, NL, between Isle Valen and St. Leonard’s (Figure 1). It is approximately 34 km (by water) from the community of Petit Forte, 72 km (by water) from the community of Marystown. The site is relatively exposed to winds from the north and southeast. Bottom sediments consisting of hard substrate. Of the 195 stations surveyed by video, 124 were characterized as hard seafloor (64%); a benthic characterization report (Wood Environment & Infrastructure Solutions 2020) classified 47% of the lease area as deep-water bedrock seascapes, 23% as sub-littoral bedrock seascapes, 21% as soft-bottom deep-water muddy seascapes; the remaining 9% region of this lease area had no data.

The most widely distributed organisms noted in all proposed sites were arrow worms, krill and shrimp. The most common commercial species noted in surveys included shrimp (*Pandalus borealis*), Snow Crab (*Chionoecetes opilio*), Toad Crab (*Hyas araneus*). Scallops were noted in small numbers (maximum count of three) at all sites except for Gilbert Cove. Large concentrations or schools of commercially important species were not noted. No species identified as at risk by *Canada’s Species at Risk Act* were noted during the survey. Snow Crab, Atlantic Cod (*Gadus morhua*), and herring (*Clupea harengus*) are the main commercial fish species that are present in Placentia Bay; with an estimated landed value for 2019 of $13 million, $3.3 million and $937,000 (herring and Capelin [*Mallotus villosus*]) respectively (DFO Policy and Economics Branch). Lobster (*Homarus americanus*) are also fished, with an estimated landed value in 2019 of $3,900,000.

In the proponent surveys for Jude Island, Paradise Sound and St. Leonard’s various types of macroalgae and kelp beds (including Agarum sp. and Laminaria sp.) were observed, typically in shallow, near shore waters, outside of the proposed cage array, within lease boundaries. In addition, mussel beds were also observed.

Among non-commercial benthic invertebrate species, the taxa reported in the proponent’s surveys include soft corals (Nephtheidae Family), Hormathia sp. and Stomphia sp. anemones, cerianthid anemones, geodiid sponges, brittle stars and crinoids (reported as feather stars).Concentrations of Nephtheidae soft corals were identified at the Paradise Sound site (n = 271), and in lower concentrations at all other sites (Channel Harbour, Gilbert’s Cove, Jude Island and St. Leonard’s). Brittle stars were found in concentrations at several stations across the sites, but were mostly dominant at St. Leonard’s, where sponges, sea anemones and corals were less common or not reported. Sea anemones (Hormathia sp.) were frequently found in high concentrations at all sites besides St. Leonard’s. Based on the counts provided by the proponent, and mapping by the reviewers concentrations of corals, sponges, cerianthids, anemones, or crinoids were generally not identified directly under the proposed cage arrays at most sites. Soft corals can be indicators of vulnerable marine ecosystems (VMEs: FAO 2020, Long et al. 2020). They can provide habitat to other species and enhance local diversity (Baillon et al. 2012, Long et al. 2020, Neves et al. 2020). Sponges can also be VME indicators; the taxa observed at high densities were identified in the proponent's survey as geodiid sponges (Family Geodiidae); however, sponge species identification from imagery is challenging, and the confirmation of these taxa as geodiid sponges would require collecting samples for physical examination.

For aquatic Species at Risk potentially found in the Placentia Bay area, the proponent's submission lists Blue Whale (*Balaenoptera musculus*), Fin Whale (*Balaenoptera physalus*), Northern bottlenose whale (*Hyperoodon ampullatus*), North Atlantic Right Whale (*Eubalaena glacialis*), Sowerby's beaked whale (*Mesoplodon bidens*), Leatherback Sea Turtle (*Dermochelys coriacea*), Loggerhead sea turtle (*Caretta caretta*), Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*Anarhichas minor*), Atlantic Wolffish (*Anarhichas lupus*), American eel (*Anguilla rostrata*), Newfoundland population of the banded killifish (*Fundulus diaphanus*), and White Shark (*Carcharodon carcharias*).

The five proposed sites fall within the Placentia Bay Ecologically and Biological Significant Area (EBSA; Figure 2). This EBSA has important salmon rivers, Capelin spawning beaches (concentrated on east side of the bay, with few also found on the west side and on the southern tip of the Burin Peninsula), eelgrass habitat (throughout the bay in coves and harbors), high concentrations of ichthyoplankton (along the western side of Placentia Bay and at the head of the Bay near Swift Current/Come By Chance area) and seabird colonies. Within the boundaries of this EBSA several important spawning areas for Atlantic Cod can be found; near Bar Haven Island near the head of the bay, at Oderin Bank in the center of the bay, and just off Cape St. Mary's (Wells et al. 2019). Furthermore, Placentia Bay was identified as containing important habitat for Leatherback Turtles, which are known to frequent the entire bay (DFO 2012; Wells et al. 2019). This EBSA also captures part of a larger area denoted as important for Blue Whales. In addition, large gorgonian coral, soft coral and sponge important areas (IAs) are found near the seaward boundary of the Placentia Bay EBSA (Halibut Channel, St. Pierre Channel and in Placentia Bay nearshore region; Wells et al. 2019).

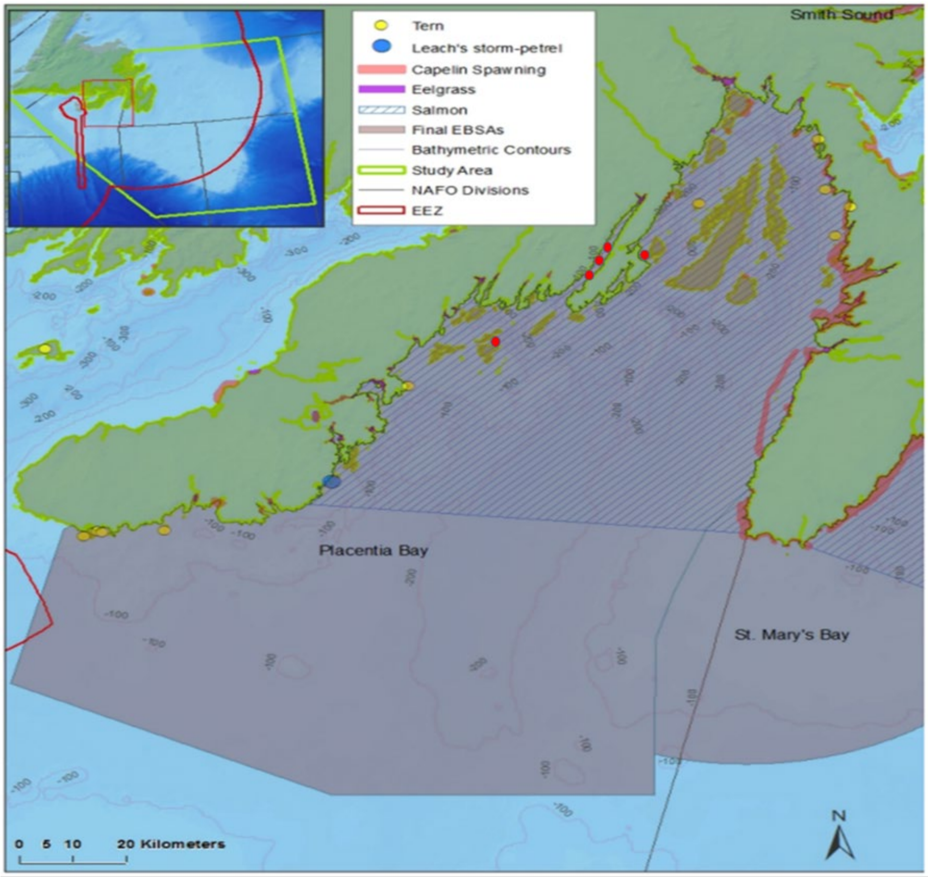

Figure 2: Placentia Bay EBSA; red dots represent the five proposed sites.

Table 1: Key oceanographic, farm infrastructure and grow-out information for the proposed sites. All information was extracted from the reports provided by the proponent for the site licence applications.

<table>
<tr><th>Characteristic</th><th colspan="3">Channel Harbour</th><th colspan="3">Gilbert's Cove</th><th colspan="3">Jude Island</th><th colspan="3">Paradise Sound</th><th colspan="3">St. Leonard's</th></tr>
<tr><td>Dimension [m](3)</td><td colspan="3">2,550 x 1,200</td><td colspan="3">2,550 x 950</td><td colspan="3">2,600 x 1,400</td><td colspan="3">2,850 x 1,270</td><td colspan="3">2,300 x 1,030</td></tr>
<tr><td>Area [ha](1)</td><td colspan="3">225</td><td colspan="3">205</td><td colspan="3">290</td><td colspan="3">324</td><td colspan="3">173</td></tr>
<tr><td>Predominant substrate type(3)</td><td colspan="3">Soft bottom</td><td colspan="3">Soft bottom</td><td colspan="3">Soft bottom</td><td colspan="3">Soft bottom</td><td colspan="3">Hard bottom</td></tr>
<tr><td>Net-pen array configuration(1)</td><td colspan="3">1 x 12</td><td colspan="3">1 x 12</td><td colspan="3">1 x 12</td><td colspan="3">1 x 12</td><td colspan="3">1 x 12</td></tr>
<tr><td>Individual net-pen circumference/depth [m](1)</td><td colspan="3">160/37</td><td colspan="3">160/37</td><td colspan="3">160/37</td><td colspan="3">160/37</td><td colspan="3">160/37</td></tr>
<tr><td>Net-pen volume [m^3](1)</td><td colspan="3">660,048</td><td colspan="3">660,048</td><td colspan="3">660,048</td><td colspan="3">660,048</td><td colspan="3">660,048</td></tr>
<tr><td>Depth under the lease area [m](3)</td><td colspan="3">6–222</td><td colspan="3">4–263</td><td colspan="3">12–179</td><td colspan="3">1–255</td><td colspan="3">8–307</td></tr>
<tr><td>Depth under the cage array [m](2)</td><td colspan="3">80–160</td><td colspan="3">150–180</td><td colspan="3">60–110</td><td colspan="3">~190</td><td colspan="3">70–150</td></tr>
<tr><td>Current measurement period(1)</td><td colspan="3">15-Jan-2020 to 25-Feb-2020</td><td colspan="3">08-Jan-2020 to 25-Feb-2020</td><td colspan="3">08-Jan-2020 to 25-Feb-2020 (upper layer)

16-Sept-2019 to 31-Oct-2019 (deeper layer)</td><td colspan="3">18-Nov-2019 to 20-Dec-2019</td><td colspan="3">16-Sept-2019 to 30-Oct-2019</td></tr>
<tr><td rowspan="2">Current speed [cm/s](1)</td><td rowspan="2">Depth [m]</td><td colspan="2">Speed [cm/s]</td><td rowspan="2">Depth [m]</td><td colspan="2">Speed [cm/s]</td><td rowspan="2">Depth [m]</td><td colspan="2">Speed [cm/s]</td><td rowspan="2">Depth [m]</td><td colspan="2">Speed [cm/s]</td><td rowspan="2">Depth [m]</td><td colspan="2">Speed [cm/s]</td></tr>
<tr><td>Mean</td><td>Max</td><td>Mean</td><td>Max</td><td>Mean</td><td>Max</td><td>Mean</td><td>Max</td><td>Mean</td><td>Max</td></tr>
<tr><td>Surface</td><td>Upper 25</td><td>6</td><td>42</td><td>Upper 19</td><td>10</td><td>66</td><td>0-20</td><td>7</td><td>49</td><td>0-20</td><td>8</td><td>56</td><td>0-20</td><td>7</td><td>37</td></tr>
<tr><td>Midwater</td><td>42</td><td>4</td><td>24</td><td>35</td><td>6</td><td>39</td><td>39</td><td>4</td><td>34</td><td>38</td><td>7</td><td>38</td><td>37</td><td>6</td><td>27</td></tr>
<tr><td>Bottom</td><td>142</td><td>2</td><td>20</td><td>99</td><td>3</td><td>23</td><td>88</td><td>3</td><td>12</td><td>188</td><td>4</td><td>17</td><td>87</td><td>2</td><td>14</td></tr>
<tr><td>Grow-out period [month](1)</td><td colspan="3">17</td><td colspan="3">17</td><td colspan="3">17</td><td colspan="3">17</td><td colspan="3">17</td></tr>
<tr><td>Maximum number of fish on site(1)</td><td colspan="3">2,000,000</td><td colspan="3">2,000,000</td><td colspan="3">2,000,000</td><td colspan="3">2,000,000</td><td colspan="3">2,000,000</td></tr>
<tr><td>Initial stocking number [fish/pen](1)</td><td colspan="3">166,667</td><td colspan="3">166,667</td><td colspan="3">166,667</td><td colspan="3">166,667</td><td colspan="3">166,667</td></tr>
<tr><td>Initial stocking weight [kg](1)</td><td colspan="3">0.35</td><td colspan="3">0.35</td><td colspan="3">0.35</td><td colspan="3">0.35</td><td colspan="3">0.35</td></tr>
<tr><td>Average planned harvest weight [kg](1)</td><td colspan="3">5</td><td colspan="3">5</td><td colspan="3">5</td><td colspan="3">5</td><td colspan="3">5</td></tr>
<tr><td>Expected maximum biomass [kg](1)</td><td colspan="3">8,000,000</td><td colspan="3">8,000,000</td><td colspan="3">8,000,000</td><td colspan="3">8,000,000</td><td colspan="3">8,000,000</td></tr>
<tr><td>Maximum stocking density [kg/m^3](1)</td><td colspan="3"><15</td><td colspan="3"><15</td><td colspan="3"><15</td><td colspan="3"><15</td><td colspan="3"><15</td></tr>
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[1] Values taken from "Aquaculture License Application" document and rounded to the nearest cm/s (i.e. significant figure)
[2] Appendix 16 Deposition Modeling – Section 2.2.
[3] Appendix 14 AAR Baseline Report Grieg NL Seafarms Ltd. Part I.

Analysis and Response

Sources of Data

Information to support this analysis includes data and information provided by the proponent, data holdings within DFO, publicly available literature, and registry information from the SARA database. DFO Multi-species Research Vessel (RV) Survey database was referenced to supplement commercial fisheries information provided in the proponent's submissions. Supporting information files submitted to DFO for consideration and used in its review are shown in Table 2.

Table 2: Summary table of information files submitted to DFO.

Description	File Name
Proposed development plan package Baseline survey data submission	1. Channel Harbour Application Package 2. Channel Harbour AAR Baseline Video Files
Proposed development plan package Baseline survey data submission	1. Gilberts Cove Application Package 2. Gilberts Cove AAR Baseline Video Files
Proposed development plan package Baseline survey data submission	1. Paradise Sound 2. Paradise Sound AAR Baseline Video Files
Proposed development plan package Baseline survey data submission	1. Jude Island Application Package 2. Jude Island AAR Baseline Video Files
Proposed development plan package Baseline survey data submission	1. St. Leonard's Application Package 2. St Leonard's Baseline Video Files

Benthic Predicted Exposure Zones

The Benthic Predicted Exposure Zone (benthic-PEZ) is computed using physical processes to provide an order of magnitude of the potential benthic area that could be impacted by the deposit of waste feed and feces associated with aquaculture activities (Page et al. In press[1]). It is, in various ways, a conservative estimate used to determine the size and location of areas that may be exposed to a substance introduced into or released from a site (waste feed and feces). The exposure zone associated with the release of in-feed drugs is assumed to be dominated by the waste of medicated feed and feces; benthic exposure can also occur in relation to the use of bath pesticides particularly at shallow depths, however, this will be considered in the Pelagic Predicted Exposure Zones section of this review.

The calculation of the benthic-PEZ was carried out with a conservative approach as we could while retaining its simplicity. Key assumptions are: constant settling velocity of the particles, constant ocean current speed during the particles descent, constant depth (i.e. flat bathymetry) and no resuspension mechanism. The parameter used were: slow sinking velocities (the minimum sinking rate obtained from the literature), fast water currents (the maximum water current speed observed at the site averaged over the sinking or dilution period of particles), and deep bottom topography (the maximum depth over the lease area). Sinking rates were obtained

[1] Page, F., Haigh, S., and O'Flaherty-Sproul, M. In Press. Potential Exposure Zones for Proposed Newfoundland Marine Finfish Salmon Aquaculture Sites: Initial First Order Triage Scoping Calculations and Consistency Comparisons. DFO Can. Sci. Advis. Sec. Res. Doc.

from previously reported values (Findlay and Watling 1994; Chen et al. 1999; Cromey et al. 2002; Chen et al. 2003; Sutherland et al. 2006; Law et al. 2014; Bannister et al. 2016; Law et al. 2016; Skoien et al. 2016). Release of waste feed and feces are considered to happen at the bottom of the net pen; since particles sink from the net-pens to the seabed and the available currents data show slowly decreasing speed towards the seabed, currents near or right below the depth of the bottom of the net pen were selected for the calculation. The benthic-PEZ is then represented by a circle centered on the cage array; however, the benthic footprint is likely to be more complex due to bathymetry and hydrodynamic effects. The zones for each site were estimated by adding the horizontal transport distance to the length of the proposed net-pen array.

The benthic-PEZ does not provide an estimate of the intensity of organic loading within the site, and the zones do not imply that everywhere within the zone has the same exposure level (i.e. any location within a PEZ has the potential to see one or more particles of interest or even none if any of the key assumptions stated above fails). The intensity of exposure is expected to be highest near the net-pen arrays and decrease as distance from the net-pens increases, except for areas of anticipated overlaps where cumulative exposure may occur. Accumulation over sheltered areas, where ocean currents may decrease, can be expected as well.

Table 3 outlines the parameters used in the calculation and the results of the benthic-PEZ. A map showing the estimations of the benthic-PEZ using waste feed particles for the five sites is provided in Figure 3.

Important points need to be taken into consideration when interpreting PEZ analysis:

- PEZ analysis provides estimates only, which are sensitive to data input. The results should be interpreted as order of magnitudes (Appendix A).
- The proponent did not collect full profiles of currents which limited its use for the determination of a conservative current speed value. In addition, the available currents data do not correspond to the desired season (maximum daily quantity of feed usage; summer-fall season). As a result, the PEZ presented correspond to the conditions that would be experienced during fall or winter (i.e. seasons when data were collected). Based on DFO research and data collection in the region, an uncertainty of a factor 2 of PEZ radius can be expected.
- Current- and wave-induced bottom resuspension is not considered in PEZ analysis. However, bottom currents with speed over 9 cm/s were observed at various sites suggesting potential for resuspension. The overall potential impacts of redistribution and flocculant deposition is unknown.

Table 3: Parameters and result of the benthic-PEZ calculation for the proposed sites. Sinking rates correspond to the slowest rate to ensure conservative results.

Particle Type	Min. Sinking Rate [cm/s]	Sinking period [h]	Max. calculated speed during sinking period [cm/s]	PEZ Radius [km]
Channel Harbour (maximum lease depth 222 m)				
Feed	5.3	1	22	2
Feces	0.3	21	12	10
Fines and Flocs	0.1	62	6	13
Paradise Sound (maximum lease depth 255 m)				
Feed	5.3	1	36	2
Feces	0.3	24	21	19

Particle Type	Min. Sinking Rate [cm/s]	Sinking period [h]	Max. calculated speed during sinking period [cm/s]	PEZ Radius [km]
Fines and Flocs	0.1	71	11	28
Gilbert's Cove (maximum lease depth 263 m)				
Feed	5.3	1	33	2
Feces	0.3	24	13	12
Fines and Flocs	0.1	73	9	26
Jude Island (maximum lease depth 160 m)				
Feed	5.3	1	32	2
Feces	0.3	17	14	10
Fines and Flocs	0.1	50	6	12
St. Leonard's (maximum lease depth 307 m)				
Feed	5.3	2	22	2
Feces	0.3	28	11	12
Fines and Flocs	0.1	85	8	25

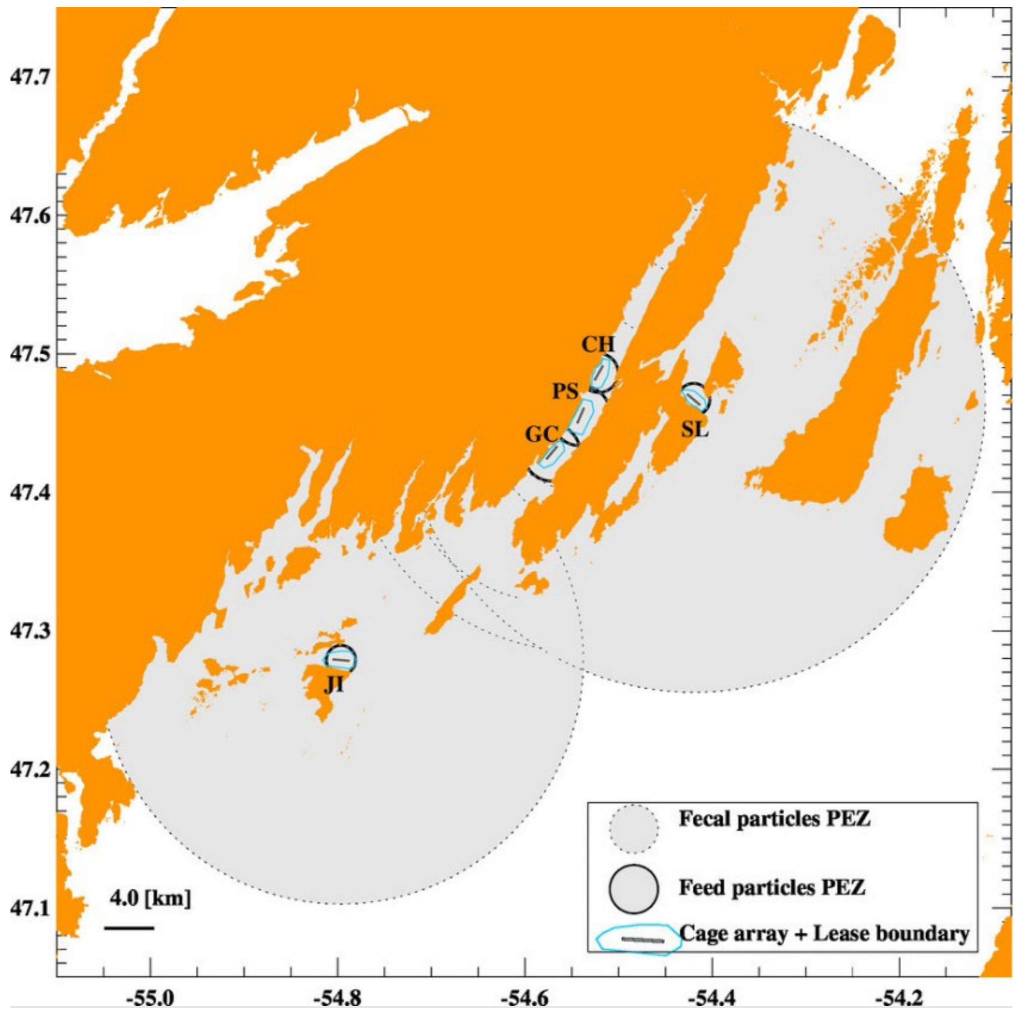

Figure 3: Benthic-PEZ calculated for each site. Black circles delimit the PEZ associated to feed particles; shaded grey areas represent the PEZ associated to fecal particles.

Susceptible Species Interactions

Species are considered to be susceptible within the benthic-PEZ if they are sessile at any life stage and are sensitive to either low oxygen levels, smothering, loss of access to the site, or exposure to in-feed drugs (DFO In Press.[2]). Specific consideration is given to whether or not there is evidence in the baseline survey, scientific literature, and Departmental holdings for presence of certain sensitive sessile species, such as sponges, corals and eelgrass, and critical habitat for SARA-listed species. When the available data are limited, consideration as to whether the benthic substrate type is suitable for the growth of these species is considered.

There are overlaps between the feed-based benthic-PEZ within Paradise Sound (Channel Harbour, Gilbert's Cove, and Paradise Sound) where smothering and oxic-state changes are anticipated to occur due to organic loading. No feed related PEZ overlap is expected with Jude Island and St. Leonard's sites. Overlaps in areas of feces deposition are predicted (Figure 3). The spatial extent of the PEZs based on feces provides also an indication of the full area that could be exposed to any in-feed drugs used. The presence of shrimp, Toad Crabs, Snow Crabs and mussels within the benthic-PEZ show a potential for these species to be impacted by the deposition of feed/medicated feed (when applicable).

The proponent's Fish Health and Biosecurity Management Plan indicates that the potential usage of chemical treatments will be prescribed in case when the series of alternative treatments (cleaner fish, the installation of sea lice skirts, functional feeds, mechanical or thermal treatments) fail to keep parasite infestation under control. The drugs listed are SLICE® (Emamectin Benzoate; EMB) as well as approved pesticides (Azamethiphos, Hydrogen Peroxide). Specific considerations have to be given to the potential for interactions with crustaceans due to their susceptibility to EMB and Azamethiphos (Burridge 2013, Burridge et al. 2014, Environment Canada 2005).

Placentia Bay itself is part of a large EBSA (called Placentia Bay); all five sites are found within such EBSA and all species and associated habitats therein are vulnerable to exposure from the deposition of organic matter. As part of the application package, the proponent provided video files and analysis including species and habitat identification for sampling stations within the predicted benthic exposure zone. The video files were also reviewed by Aquaculture Management and DFO Science for accuracy and to identify any sensitive habitat or species; this review highlighted the presence of corals and sponges and other sessile organisms (e.g. sea anemones), of varying density and distribution, at most of the sites, which can be vulnerable to the exposure of organic matter deposition (e.g. due to smothering). Both corals and sponges are considered "sensitive and susceptible to anthropogenic activities, including direct (e.g. removal or damage) and indirect (e.g. smothering by sedimentation) fishing impacts" (DFO 2010). Analysis of the baseline video shows soft corals were identified at all sites, with Paradise Sound being the one with the highest total counts (n = 271). Soft corals of variable sizes were observed, indicating the presence of both young and adult colonies. There is no available data on growth rates and longevity (i.e. proxy for recovery time) of most sponge species and Nephtheidae soft corals. However, early growth in *Gersemia fruticosa* and *Duva florida* (family Nephtheidae) was shown to be slow, while *Gersemia rubiformis* showed faster growth rates (Henry et al. 2003; Sun et al. 2011); therefore, early growth rates seem variable. The Ecologically Significant Species (ESS) eelgrass, which has characteristics which meet the criteria of an EES (DFO 2009), has not been reported at any of the sites. No SARA-listed species were identified at any of the five proposed sites.

[2] DFO. In Press. Review Of The Marine Harvest Atlantic Canada Inc. Aquaculture Siting Baseline Assessments For The South Coast Of Newfoundland. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.

If dispersion predictions are accurate, the potential loss of these benthic assemblages due to aquaculture impacts might be localized. However, the Benthic-PEZ estimates indicate a potential for both food and feces to reach all surveyed stations and sometimes overlap amongst sites (i.e. Channel Harbour, Gilbert's Cove and Paradise Sound), and therefore all the fauna herein may be subject to increased organic enrichment and feed chemical residues. In addition, cumulative effects among nearby aquaculture sites it is likely.

Video Analysis and Benthic Substrate Monitoring – General Comments

The proponent has made an effort to summarize the fauna at each site (Table 4, AAR Baseline Reports); however, the spreadsheet format is made for reading. It would be preferable for the proponent to provide the data in a format that can be analyzed without the need to reformat. The proponent provided abundances of the benthic fauna observed during the seafloor surveys. Abundances represent the count of organisms over one minute of video at specific stations, generally 100 m apart; it is unclear what one minute means, and if the distance covered is the same. It is also suggested to provide the field of view area and fauna densities so that those numbers are actually comparable. When organisms were very abundant, the proponent classified counts as >20; however, this could represent 25 or 50, and there is no mention of whether at a particular station >20 means a much larger amount.

Using the data available in the proponent's AAR Baseline Reports, a summary of the fauna counts for some groups of benthic invertebrates was created (Figure 4), focusing on taxa that have potential as indicators of vulnerable marine ecosystems (e.g. corals, sponges - Geodiids, cerianthids, crinoids), and gregarious potential (e.g. sea anemones). However, the identification of the taxonomically challenging sponges as Geodiid (or Geodia sp.) and soft corals as Gersemia sp. should be seen as tentative, as no voucher samples were collected. These organisms were also the focus of the review of the video analyses per site.

Using the data available in the proponent's AAR Baseline Reports on the counts of faunal presence, taxa richness per station was calculated, using the taxonomic resolution provided in the report (high level, species in sp.) and reported for each proposed site in the following sections. Organisms were also mapped to facilitate the review, but maps are not shown. In this exercise, if no organism was reported by the proponent at a specific station, a value of zero was attributed to it, however zero does not necessarily mean absence. Organisms with abundances >20 per station were considered as a count of 20 (likely underestimating the diversity in the area). As a note, taxa absences and abundance counts need to be taken with caution, as counts do not reflect relative counts (i.e. in relation to surveyed area) and camera distance from the seafloor might be slightly different between stations.

Arrow worms and krill are listed as the most common organisms at several sites; while this is worth mentioning, most arrow worms are pelagic organisms . Their widespread presence in the water column indicates grazing, likely due to high productivity in the area during the surveys (August/September). This high abundance also at several times has hampered imagery. Furthermore, "arrow worms" is the common name of Chaetognatha worms, and this should be mentioned in the report as to avoid confusion with mainly benthic worms such as annelids (including polychaetes).

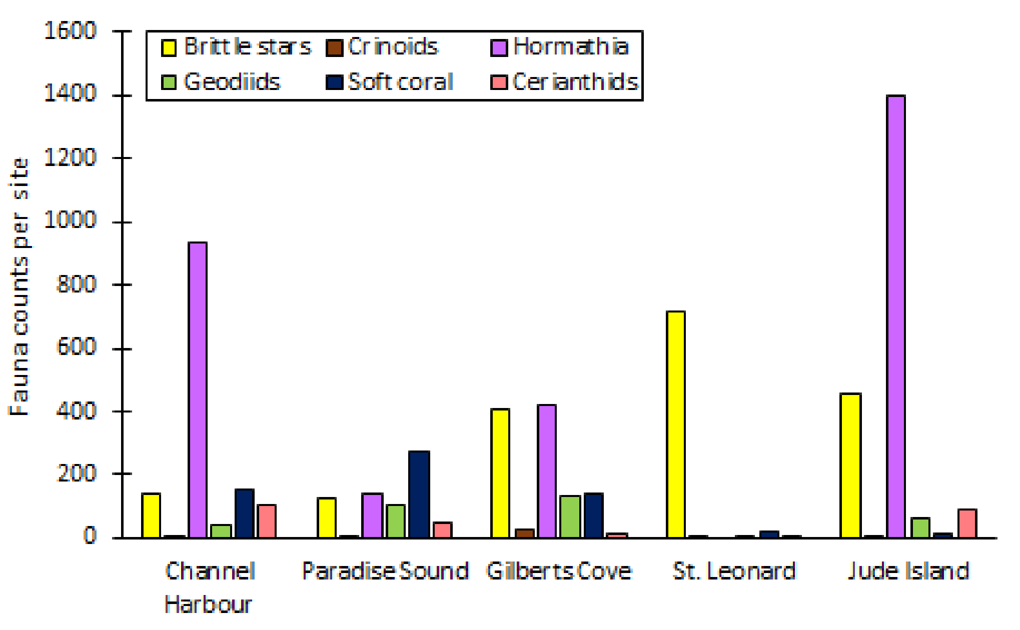

Figure 4: Summary of total specimen counts (sum) for some taxa reported in the AAR Baseline reports (data are raw counts and do not consider area).

Video Analysis – Channel Harbour

Maximum reported taxa richness per station was 14; The highest taxa richness was identified at transect T23–850 at 46 m depth. Maximum reported taxa richness per station inside the cage array boundaries was 14, including several sea anemones and sponges, sea stars, and soft corals.

Mapping of the seafloor observations reported by the proponent indicates two clusters of geodiid sponges , between 87–155 m. These clusters represent n>20 sponges/station; only one of these is found within the lease area. Geodiid and other sponge taxa were reported at low abundances at other areas for this site. Unidentified sponges represented ~80% of the sponges found at this site.

Large concentrations of soft corals were reported near the Northwest end of the lease area, representing between 14–>20 soft coral colonies per station. Soft corals were identified in the area underneath the proposed cage arrays, in at least one case as 17 colonies in a single station (T8–700, 74 m).

The sea anemone Hormathia sp. was identified in high concentrations at this site (n>20 individuals/station at several stations), including in the area under the proposed cage array. Video observations indicate that in some areas these sea anemones are the dominant megabenthos.

Ophiuroids were reported in the northern portion of the lease area, sometimes in high concentrations (n>20 individuals/station), including in the area under the proposed cage array.

Video Analysis – Gilbert's Cove

Maximum reported taxa richness per station was 12. Maximum reported taxa richness per station inside the cage array boundaries was 8 at two stations 800 m apart.

Mapping of the seafloor observations reported by the proponent indicates a few clusters of geodiid sponges.

Large concentrations of *Hormathia* anemones were identified throughout the area (west of the lease), with at least three instances of n>20 Hormathia anemones per station. Crinoids (n=5) were identified at one station under the cage array.

Large concentrations of soft corals were identified at several stations through the lease area, (at least one instance of n>20 colonies/station under the cage array). This site had several basket stars identified (Gorgonocephalus sp.); soft corals make habitat for juveniles of this taxon (see Neves et al. 2020).

Video Analysis – Paradise Sound

Maximum reported taxa richness per station was 12. Maximum reported taxa richness inside the cage array boundaries was four. Poor visibility was reported at this site, including the stations inside the cage array boundaries.

The following commercial species were reported: scallops (rare), flounder, Atlantic Cod, and Redfish. Shrimp, Snow Crab and Toad Crabs were also documented.

Mapping of the seafloor observations reported by the proponent indicates clusters of geodiid sponges to the west of the proposed cage array, but not inside its boundaries.

Cerianthids were reported at 31 stations at this site, and ophiuroids were present at most of the lease area, and at high concentrations at one station. Concentrations of Hormathia anemones and soft corals were also identified, but none of these organisms were reported as present underneath the proposed cage array area.

Video Analysis – Jude Island

Maximum reported taxa richness per station was 13 Maximum reported taxa richness inside the cage array boundaries was 10, at a depth of 58 m (station T8–800).

The following commercial species were reported: Acadian Redfish, scallops (rare), flounder and other flatfishes, hake. The most numerous commercial species were shrimp. Snow Crab and Toad Crab were also observed.

Mapping of the seafloor observations reported by the proponent indicates three clusters of geodiid sponges in the lease area. However, no geodiid sponges were reported at the stations under the proposed cage array.

Cerianthids were reported at 38 stations at this site, with a maximum of nine individuals per station; five was the maximum number of cerianthids under the cage array area. Large concentrations of Hormathia anemones were common at this site, particularly at the northeast of the lease. At three stations under the cage array there were n>20 individuals reported. Brittle stars were identified throughout the lease area, including the area under the proposed cage array.

Crinoids were only reported at two stations at this site, both outside of the cage array boundaries, and for a maximum of five individuals (T19–1000).

Soft corals were found at this site, but outside of the cage array boundaries, for a maximum of four colonies per station.

Video Analysis – St. Leonard's

Maximum reported taxa richness was 11. Maximum reported taxa richness inside the cage array boundaries was seven.

The following commercial species were reported: scallops, flounder, Atlantic Cod, shrimp, and Snow Crab.

Fan bryozoan was reported at this site (e.g. ST–21); however, reviewers had difficulty observing these organisms where indicated.

Geodiid sponges cerianthids and crinoids (n=1) were reported in low numbers. Hormathia anemones were not reported at this site.

This site seems to be distinguished from the other sites by the dominance of ophiuroids in relation to the other fauna commonly reported at the other sites (e.g. sponges, soft corals, sea anemones). Three stations inside and several others surrounding the proposed cage array boundaries had concentrations of ophiuroids. Maximum soft coral concentrations per station at this site was five, and two stations within the boundaries of the cage arrays had soft corals reported.

Pelagic-Predicted Exposure Zone

The Pelagic Predicted Exposure Zone (pelagic-PEZ) is computed using physical processes to provide an order of magnitude of the potential pelagic area where interactions between registered pesticides used in finfish aquaculture and susceptible species are likely. It is, in various ways, a conservative estimate used to determine the size and location of areas that may be exposed to a potentially harmful substance.

The two pesticides available for use in bath treatments (e.g. tarp bath and well-boat) are azamethiphos and hydrogen peroxide. The size of the pelagic-PEZ depends on the decay and/or dilution rate of the pesticide, a chosen concentration threshold, and choice of horizontal water current speed. The computation of pelagic-PEZ uses information on the known toxicity of the most toxic of the registered pesticides (i.e., azamethiphos), the predicted dilution and dispersion of the pesticides, and the water currents. Health Canada's Pest Management Regulatory Agency (HCPMRA) has assessed that the two registered pesticides (hydrogen peroxide and azamethiphos) and their breakdown products are expected to remain in suspension since they do not bind with organics or sediments and do not accumulate in organisms' tissues. The half-lives of the pesticides range from days to weeks, suggesting that they can persist in the environment for some time (HCPMRA 2014, 2016a, 2016b, 2017).

The pelagic-PEZ was calculated assuming the use of tarp bath treatments, regardless of whether all cages would meet the HCPMRA treatment conditions for application, given the larger exposure zone anticipated to result from a tarp treatment versus a well boat. The near-surface current speed was used since the application of tarp bath treatments occurs in the surface waters. The pelagic-PEZ for azamethiphos was calculated first by computing the running sum of the near-surface current vectors for the dilution period and finding the maximum current speed computed from the running sum, the PEZ is then calculated as the maximum current speed times the duration of dilution. The duration of the maximum azamethiphos target treatment concentration of 100 µg/L to dilute to the HCPMRA environmental effect threshold (1 µg/L) is used as the decay and dilution time. For tarp treatment, it is in the range of 3 h (DFO 2013a, 2013b).

The pelagic-PEZ was estimated by adding the horizontal transport distance to the length of the proposed net-pen array. The pelagic-PEZ does not quantify the intensity or duration of exposure, nor does it include a frequency of exposure. The zones do not imply that areas within the pelagic-PEZ have the same exposure risk. The intensity of exposure is expected to be highest near the net-pen arrays and decrease as the distance from the net-pens increases, except for in areas of anticipated overlaps where cumulative exposures may occur (e.g. the three sites located within Paradise Sound - Channel Harbour, Gilbert's Cove, and Paradise Sound).

The exposure is expected to primarily occur in the pelagic zone; however, areas within the pelagic-PEZ where the bathymetry is less than 10 m may also be at risk of exposure to toxic pesticide concentrations. This will be the case for the various shores close to the sites.

Within Paradise Sound if treatment is used at more than one site simultaneously, exposure overlaps associated with pesticide releases from the proposed sites are predicted (Figure 5). More sites have been requested within the area (included in previous license requests), thus overlaps associated with pesticide release will greatly depend on which sites are active and treated. Should various sites within the same BMA be active and treated simultaneously, a large part of the BMA might be exposed to releases from the sites.

Figure 5 illustrates the estimated PEZ for each site. As expected, the faster the current speed, the greater the advection distance of toxic levels. Under the assumptions used in the calculation, shallow areas along the shore may be at risk of exposure to toxic products released and transported from the proposed sites during the three hours of evaluation. There is a significant overlap of the pelagic-PEZ in Paradise Sound (Channel Harbour, Paradise Sound and Gilbert's Cove) related to the usage of bath pesticides.

Table 4: Pelagic-PEZ estimates of the potential horizontal distances travelled by azamethiphos treatment water before the 3-hour dilution.

Site	Max. calculated speed during dilution period [cm/s]	PEZ Radius [Km]
Channel Harbour	24	3
Paradise Sound	34	4
Gilberts Cove	43	5
Jude Island	25	3
St. Leonard's	27	4

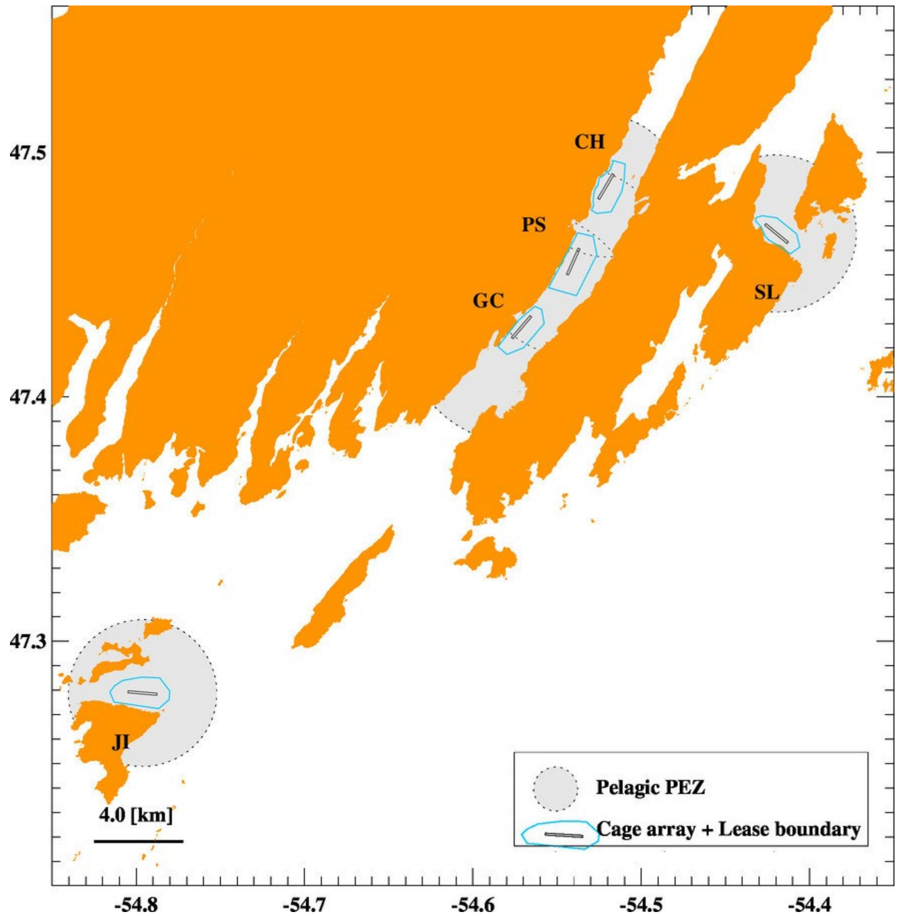

Figure 5: Pelagic-PEZs calculated for each site. Shaded grey areas represent the pelagic-PEZ.

Susceptible Species Interactions

Species are considered to be susceptible within the pelagic-PEZ if they are CRA fisheries species (Commercial, Recreational or Aboriginal), are SARA-listed species, or have known sensitivities to pesticide exposures. Specific consideration is given to the potential for interactions with crustaceans due to their higher relative susceptibility to the pesticides used in aquaculture.

The PEZ outputs indicate a potential of exposure of the intertidal and coastal zones. Although industry and internal holdings are limited in their ability to observe all susceptible species in the coastal zone, available data indicate that lobster and crab are present within the pelagic-PEZs for azamethiphos. The effects of pesticides on SARA-listed species such as White Shark and Wolffish species are unknown and will likely be limited to individuals and habitats present within the PEZ.

The proponent’s Fish Health and Biosecurity Management Plan indicates that preferred treatment routes are: the use of cleaner fish, the installation of sea lice skirts, feeding with functional feeds, mechanical or thermal treatments and finally if the previous non-chemical methods fail the usage of SLICE (Emamectin Benzoate; EMB) as well as approved pesticides (Azamethiphos, Hydrogen Peroxide). Based on the potential products to be used, we have summarized some of the information regarding modes of action of the anti-sea lice chemicals and known sensitive groups in the following section:

- EMB has low water solubility and relatively high octanol-water partition coefficient (KoW = 5 at pH:7) indicating that it has the potential to be absorbed to particulate material and that it will be tightly bound to marine sediments with little mobility (SEPA 1999; Environment Canada 2005). However, the fate and behaviour data also suggest that, although levels in the seawater are very low, they may form equilibrium with the emamectin benzoate in the sediment (SEPA 2017). EMB mode of action such as other avermectins is not specific to parasitic nematodes and arthropods and may potentially affect other non-target invertebrates when it reaches the environment (Garric et al. 2007). In invertebrates, they generally open glutamate-gated chloride channels at inhibitory synapses resulting in an increase in chloride concentrations, hyperpolarization of muscle and nerve tissue, and inhibition of neural transmission (Roy et al. 2000, Grant 2002).
- Azamethiphos is soluble in water (1.1 g/L) and has a low octanol-water partition coefficient (log KoW = 1.05) (PMRA 2016). Azamethiphos is likely to remain in the aqueous phase (exposure through the water column) on entering the environment and is not expected to bioaccumulate considering its solubility (PMRA 2016). Azamethiphos acts by inhibition of the cholinesterase activity with toxicity towards a wide range of non-target organisms (Ernst et al. 2014) with crustaceans being the more sensitive group (Burridge et al. 2014).
- Hydrogen peroxide does not have a targeted mode of action. The suggested mechanisms of action of hydrogen peroxide are mechanical paralysis through peroxidation by hydroxyl radicals of lipid and cellular organelle membranes, and inactivation of enzymes and DNA replication (Robbins et al. 1989). Due to the rapid degradation of hydrogen peroxide, the hazard posed by the proposed end-use product is mostly of an acute nature. Hydrogen peroxide is very short lived in natural aquatic environments with reported half-lives ranging from 1 hour to 10 days (PMRA 2014). Algal groups have been identified as among the most sensitive group (Hamoutene et al. 2021[3]; PMRA 2014); any negative impacts to algal communities from hydrogen peroxide are expected to be transient (PMRA 2014).

For both pesticides (hydrogen peroxide, azamethiphos), there is a potential risk of exposure of intertidal communities (invertebrates, algae, and other non-target species) especially for the three sites in the Rushoon BMA. to prevent plumes of pesticides to be washed into the littoral zone, treatments should be performed at outgoing tide or during periods with a local outgoing current. Table 5 summarize the potential exposure of sensitive species in case of usage of Azamethiphos and EMB.

A post-deposit monitoring program is being developed to assess, monitor and remediate potential impacts to fish and fish habitat resulting from the deposit of drugs and pesticides at aquaculture sites.

[3] Hamoutene, D., Ryall, E., Porter, E., Page, F. H., Wickens, K., Wong, D., Martell, L., Burridge, L., Villeneuve, J., and Miller, C. In Press. Discussion of Environmental Quality Standards (EQS) and their development for the monitoring of impacts from the use of pesticides and drugs at marine aquaculture sites. DFO Can. Sci. Advis. Sec. Res. Doc.

Table 5: Main information regarding the potential presence and exposure of sensitive species in case of usage of Azamethiphos and EMB.

Site	Potentially sensitive species present as per PEZ outputs	Notes on potential exposure	Intertidal zone exposure	Mitigation considerations
Azamethiphos (pelagic exposure)				
Gilbert's Cove (GC) Channel Harbour (CH) Paradise Sound (PS)[1]	GC: Krill and shrimp present at 173, and 132 stations out of 240. CH: Krill and shrimp were present at 211 and 198 stations out of 263. PS: Krill and shrimp were present at 299 and 191 stations out of 369. Snow Crabs and Toad Crabs were observed at the three sites; dilution of the product in the water column (depths >20m; PMRA 2016) might limit the concentrations of the plumes in the bottom. Arrow worms[2] present. While not looked for in surveys, pelagic copepods and amphipods are likely present at all sites. Copepods are ubiquitous in marine environments as are amphipods.	Typically, deep water species (confirmed by AAR report at site at depths >100m), krill and shrimp juveniles can aggregate in coastal areas during post spawning in summer. There is potential for exposure of krill, shrimp and Snow Crab in deep water for adults and in shallower areas for juveniles/larvae. Based on 2016–18 open data, the NL drugs and pesticides treatments happen mostly in summer-fall (Chang et al. in press[4]) Many types of copepods and amphipods pelagic species and are present throughout the water column including directly adjacent to and within aquaculture pens. Burridge and Van Geest (2014) report that the copepod, *Temora longicornis*, has a 24 hour LC50 >10 µg L^{-1} while amphipods have a 48-hour EC50 of ~3 µg L^{-1}.	There is potential for invertebrates of the intertidal zone to be exposed. No significant presence of crustaceans was noted in the shallower stations surveyed however timing of surveys can have an influence on observations (larvae).	To prevent toxic effects on local organisms and waste of azamethiphos into the littoral zone, treatment should be performed at outgoing tide or during periods with a local outgoing current (PMRA 2016). Modelling of concentrations should better inform on risk (new regulatory framework being established). Copepods are a key prey species for the early life-stages of fish such as Capelin, herring, and cod. Release of pesticides should be avoided during periods when larvae are present in order to ensure a sufficient supply of prey for first-feeding larvae, typically spring through summer. In the case of Capelin this would be during June and July and in the

[4] Chang, B.D., Page, F.H., and Hamoutene, D. In Press. Use of drugs and pesticides by the Canadian marine finfish aquaculture industry in 2016-2018. DFO Can. Sci. Advis. Sec. Res. Doc.

Site	Potentially sensitive species present as per PEZ outputs	Notes on potential exposure	Intertidal zone exposure	Mitigation considerations
				case of cod in July – September.
St. Leonard's (SL) Jude Island (JI)	SL: Krill and Snow Crab present at 69 and 37 stations out of 195. Arrow worms[2] present as well. JI: Shrimp and Snow Crabs present at 56 and 42 stations out of 317. Arrow worms[2] present. Same notes as previous three sites.	Both sites have little occurrence of crustaceans especially in comparison with the first three sites in the table.	Considering the sites configuration, the intertidal zone exposure is possible, however the sites are also open to offshore water masses; this can allow to potentially infer dilution and a minimal risk on intertidal communities when currents are towards the offshore.	Considerations similar to the first three sites with less concern in the light of the site configuration. Use of pesticides at SL and JI may be of particular concern with respect to the potential for copepod mortality as Bar Haven is a key spawning location for cod in Placentia Bay and eggs and larvae are transported along the western edge of the Bay and the highest densities of larval cod have been observed around Jude Island in some years (Bradbury et al. 1999).
EMB (benthic exposure mostly)				
Gilbert's Cove-Channel Harbour-Paradise Sound[1]	Snow Crabs and Toad Crabs have potential to be exposed to EMB in sediments because of their benthic habitat. Benthic arrow worms[2] have a potential to be exposed due to their benthic habitat and burrowing behavior, although the lack of accumulation of the product in the sediment might further limit exposure. Shrimp and krill can be exposed through some water diffusion/equilibrium of EMB (though not a significant route of exposure) but another	Worms[2] and crustaceans are sensitive to EMB (avermectins) through benthic (and potential pelagic) exposures. Considering the potential for cumulative exposures (PEZ overlaps) and persistence of EMB in sediments (Benskin et al. 2016) the risks have to be managed according to the new AAR framework.	Feces transport to intertidal areas could expose littoral communities. Effects on these communities: echinoderms, bivalves, anemones and sponges of EMB through potential exposure of EMB in sediments is not known. Direct toxicity linked to EMB in sediments on macroalgae and or encrusting algae	Modelling of concentrations should better inform on risk

Site	Potentially sensitive species present as per PEZ outputs	Notes on potential exposure	Intertidal zone exposure	Mitigation considerations
	route is intermittent contact with sediments and presence at the sediment interface.		in intertidal zones is improbable considering EMB mode of action.	
St. Leonard's Jude Island	Snow Crab, Toad Crabs, and arrow worms[2] have potential to be exposed to EMB in sediments due to their benthic habitat. Krill can be exposed through some water diffusion/equilibrium of EMB (though not a significant route of exposure) but another route is intermittent contact with sediments and presence at the sediment interface.	Worms and crustaceans are sensitive to EMB through benthic (and potential pelagic) exposures (Hamoutene et al. In Press[3]). The sites have little occurrence of crustaceans.	Feces transport to intertidal areas could expose littoral communities. The open water location of the sites might minimize significant deposition with expected more deposition in deeper areas.	Modelling of concentrations should better inform on risk especially for feces dispersion

[1] Considering the potential for cumulative exposures (PEZ overlaps) and dispersion patterns including intertidal zones, timing of treatments will have to be carefully considered for these three sites. Mitigation strategies might need to be recommended (example: treating fish outside of the area/passage through well boat usage, etc.).
[2] Most arrow worm species are pelagic, and review of some sections of the videos indicates their presence in the water column (sometimes even described by the proponent as causing poor visibility along with krill and marine snow). However, there is a possibility of benthic worm species present that have not been accounted for, as these were identified at broad taxonomic levels by the proponent.

Physical Interactions

Benthic Species Interactions

The baseline reports did not record any observations of lobster in the video footage; however, the proposed aquaculture sites are located in an area where fishing takes place for American Lobster (*Homarus americanus*). The absence of lobster in the baseline videos may be due to their cryptic nature (especially during the day) and the unlikelihood to observe them during this type of video survey. The baseline assessment identified suitable American Lobster habitats at the proposed sites (i.e., boulders, bedrock, cobble, kelp, mud and silt; Dinning and Rochette 2019). In Newfoundland, lobster commonly frequent shallow depths (within 20 meters) in the spring and summer months and move into deeper waters in the fall. On average, cage arrays are located at water depths more than 80 m. Expansion of aquaculture development at the proposed sites increases the risk of anoxic or hypoxic conditions beneath cages that could potentially impact lobster in the area. Exposure to pesticides that target sea lice could threaten lobster at all life stages. Timing of treatment, given the presence of crustacean larvae in the pelagic environment and juveniles in shallower waters, is also a factor to consider to reduce potential impact on crustaceans recruitment (DFO 2019, DFO In Press[5]). Concern about pesticide exposure is greatest at shallow sites with lower dispersion patterns and more prevalent juvenile lobster presence (Lawton and Lavalli 1995). It was noted that pesticides may have negative impacts on lobster, even in non-lethal exposure events; behavioral changes,

[5] DFO. In Press. Proceedings of the Regional Peer Review of the Marine Harvest Atlantic Canada Aquaculture Siting Baseline Assessments. DFO Can. Sci. Advis. Sec. Proceed. Ser.

including reduced female reproductive success, have been reported after exposure to sub-lethal doses of sea lice pesticides (Burridge 2013). Research conducted in New Brunswick also found that sub-lethal pesticide exposure resulted in higher shipping mortality for lobsters, raising market concerns (Couillard and Burridge 2015). A recent study found no impact of salmon aquaculture on lobster abundance through an eight year before-after-control study at a production site in the Bay of Fundy (Grant et al. 2019); however, this work is likely not applicable to Newfoundland conditions.

Scallop were rarely observed in the baseline surveys of the proposed sites. However, there is scallop fishing activity in Placentia Bay. Potential exposure to pesticides that target sea lice and deposition under the cages could affect scallop species as observations in other areas where aquaculture operations exist have shown evidence of lower meat to shell ratios (lower meat quality) in scallop and thinner shells (Wiber et al. 2012).

The SARA-listed marine fish species (MFSAR) Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*Anarhichas minor*), and Atlantic Wolffish (*Anarhichas lupus*) could be found in Placentia Bay. Atlantic Wolffish is the most commonly found wolffish species in coastal shallow Newfoundland waters, while Spotted and Northern Wolffish are less frequent in inshore waters and tend to be found at greater depths. Atlantic Wolffish move from offshore waters and undergo inshore spawning migrations in spring and summer and eggs have been observed on boulders and rocky crevices at depths <40 m (late summer-fall). Seasonal movements, spawning behaviour and site characteristics are unknown for Northern and Spotted Wolffish in NL waters. Although the fish habitat surveys conducted by the proponent did not detect MFSAR, it is likely that wolfish (particularly Atlantic Wolffish) are present in the vicinity of the proposed sites. Thus, the accumulation of waste materials from the cages has the potential to negatively impact benthic habitats used by Wolffish, if such habitats overlap with the proposed sites and PEZ (e.g. nesting sites, feeding grounds). Wolffish tend to be found in low densities, have low mobility, and a generally solitary life style; the three Wolffish species are widespread in Canadian waters, and are considered as single Designatable Units (DU). Under the scenario of single DUs, and life history traits as described above, the anticipated impacts to these species and their habitats will likely be low and limited to the surrounding areas of the proposed aquaculture activities.

Atlantic Cod are known to be present in Placentia Bay in all seasons (Lawson and Rose 2000) and for all life stages and are known to use the area for both spawning and as a nursery ground (e.g. Bradbury et al. 2000, Gregory et al. 1997, Rose et al. 2008). There is a protected area for spawning cod located near Bar Haven, NL, but there are other spawning locations throughout the Bay. This is potentially of concern for cod with respect to the new aquaculture sites as the mean circulation in Placentia Bay is counter-clockwise and is likely to transport cod eggs and larvae along the western edge of Placentia Bay (Bradbury et al. 1999). Bradbury et al. (1999) found that the highest densities of cod larvae were located along the western and south western edges of Placentia Bay in August of 1997 and 1998. In August of 1997, some of the highest densities of cod larvae were observed near Jude Island which is the proposed location of one of the aquaculture sites. Acoustic surveys over multiple seasons in 1997 and 1998 showed significant numbers of cod using the western edge of Placentia Bay (Lawson and Rose 2000), an area where finfish aquaculture sites may already exist and/or are planned, indicating that there is likely to be spatial overlap between wild cod and farmed salmon. Further, there is evidence from multiple studies in both Newfoundland and elsewhere showing that the presence of Atlantic Salmon aquaculture is likely to alter the spatial distribution of wild fish (e.g. Fortune Bay: Goodbrand et al. 2013; Norway: Dempster et al. 2009, Uglem et al. 2014; Multiple countries: Callier et al. 2018) with many types of gadoids, including Atlantic Cod, being attracted to finfish aquaculture sites by their excess feed (see for example Dempster et al. 2009, and McAllister et al. 2021). Work by Goodbrand et al. (2013) found that an acoustic index of the biomass of biological organisms in the water column were two to three times higher in bays with aquaculture sites compared to bays without them in Fortune Bay. Further, work by McAllister et al. In Press[6] collected juvenile and adult cod and Redfish that were present at aquaculture sites in Fortune Bay, NL, and using stable isotope analysis found that juvenile cod had elevated $\delta^{13}C$ and $\delta^{15}N$ levels and proportions of vegetable oil-based fatty acids that suggests that they were receiving an energy subsidy from the farm. The data for adult cod and Redfish suggested that they weren't receiving an energy subsidy from the farm. In Norway, Atlantic Cod and other gadoids were often found aggregated in the water column directly adjacent to and below aquaculture nets (reviewed in Uglem et al. 2014 and in Callier et al. 2018). The fish biomass aggregated around aquaculture sites included a mix of gadoids including cod and was generally on the order of 10s of tonnes of fish. Fish aggregating adjacent to the nets potentially represents a vertical shift in the spatial distribution of cod as the maximum depth of the proposed aquaculture nets is 37 m while Lawson and Rose (2000) found that the median depth of cod was 60 m in April and as high as 38 m in October in Placentia Bay. Shifts in the vertical distribution of cod may alter the temperature regimes they are exposed to which could have metabolic effects on the cod as metabolic processes tend to increase at higher temperatures (to some maximum temperature at which point metabolic rates slow and may end in death) which could alter growth rates (Baudron et al. 2013; Gillooly et al. 2001). Cod are known to consume aquaculture feed (Dempster et al. 2009; McAllister et al. In Press[6]), and this has the potential to affect the quality and taste of cod; there have been anecdotal reports by Newfoundland harvesters of cod from bays with aquaculture facilities having soft flesh and undesirable flavour. Changes in distribution if cod are attracted to cages may also impact the availability of cod to harvesters. The aggregation of cod in the area of aquaculture activities may also increase density dependent impacts on the local population (e.g. increased predation, cannibalism) which may have implications for natural mortality on this stock. This is of particular concern for 3Ps cod as the stock is currently in the critical zone, and is experiencing high natural mortality.

There are also concerns that the use of a general invertebrate pesticides or pesticides targeting sea lice at the aquaculture sites may kill off copepods and other invertebrates that are the prey of larval cod in the waters immediately downstream of the cod spawning grounds. This could be of particular issue at the proposed Jude Island site which is in the immediate area of where the highest densities of larval cod were observed in August of 1999 (Bradbury et al. 1999). We further note that there is a strong potential that larval cod could be transported by local currents into the proposed salmon pens at Jude Island or through surrounding areas which would have increased predator densities due to juvenile and adult fish being attracted to the pens. Larval fish experience extremely high mortality rates and even small changes in their growth and mortality rates (e.g. due to reduced availability of prey) can have tenfold or greater effects on their recruitment (e.g. Houde 1987).

Pelagic Species Interactions

Pelagic species data in Placentia Bay are moderately limited; there is a lack of biomass estimates for Capelin and mackerel, and a biomass estimate from 2016 for herring. In 2016, an acoustic survey for Atlantic Herring estimated biomass at 19,834 t; it is important to note that the main distribution areas for herring were in nearshore waters that are somewhat similar to those used for aquaculture facilities (Figure 6); therefore is likely that herring will use areas where aquaculture facilities are sited. In Placentia Bay spawning Capelin are known to be seasonally abundant (spring to Fall), initially as spawning adults and later as eggs, and larvae; overwintering populations of juvenile Capelin may also be present. Mackerel use Newfoundland waters seasonally during summer and fall, and therefore they may be seasonally present in Placentia Bay.

It is likely that aquaculture facilities will promote the growth of phytoplankton and potentially zooplankton (Suikkanen et al. 2013) through eutrophication due to the increased nutrient loads (Bonsdorff et al. 1997, Callier et al. 2018). This may serve to aggregate pelagic fish such as herring around the proposed sites; additionally, any lighting used at the aquaculture facility may act to concentrate zooplankton, larval fish, and adult herring to the waters surrounding the facility (e.g. Stickney 1970). The aggregation of both piscivorous fish and small pelagic forage species such as herring and Capelin is likely to result in increased mortality rates; the use of lighting at night, particularly when larvae are abundant, may act to expose larval herring and Capelin to increased predation rates as they are drawn to the lights (e.g. Stickney 1970, Keenan et al. 2007). There are likely to be additive, cumulative effects from each new aquaculture site. Effects are likely to be heavier on herring than Capelin as herring may be present year-round in coastal waters (Bourne et al. 2018) while Capelin spend much of their lives in deeper offshore waters (Mowbray et al. 2019) and mackerel migrate to Newfoundland waters on a seasonal basis (Parsons and Hodder 1970). However, all three species have the potential for significant numbers of early life-stage individuals to be exposed to increased predation pressure if they pass by waters occupied by fish farms. The number of fish consumed is likely to vary by season. Consumption rates may be substantially higher for periods when larval and juvenile fish are abundant, but are likely to be substantially lower during periods when wild fish in the pens are scarce or when water temperatures are cooler and salmon metabolic rates lower. In addition, there is the possibility that younger farmed salmon may feed on planktonic fish larvae and shellfish larvae, having a potential effect on the reproductive success of wild fish and shellfish living in the Bay.

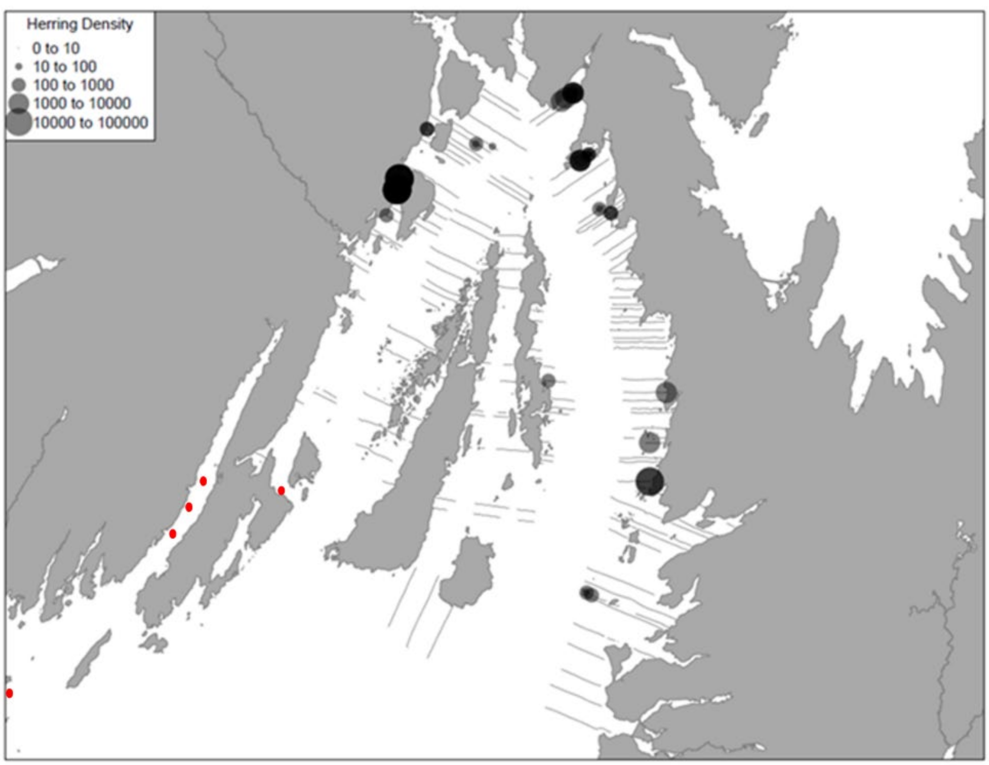

Figure 6: Surveyed transect lines and estimated herring density in Placentia Bay during 2016 inshore acoustic survey. Red dots represent proposed sites.

Northeast River on the eastern side of Placentia is monitored for adults Atlantic Salmon returns (total returns averaged ~836 salmon annually since 1992); the population has been assessed as in the healthy zone, although it declined to the critical zone in 2020 after a record low return of Atlantic Salmon. Adult abundance information is lacking for most of the other populations in Placentia Bay; however, many of these are thought to be relatively small in size (a few hundred fish or less returning annually).

Placentia Bay is within Salmon Fishing Area (SFA) 10, and contains several Atlantic Salmon rivers which are targeted annually in the recreational fishery, with some of the more heavily targeted being in close proximity to the proposed sites (e.g. Bay de L'eau River, Cape Roger River, and Pipers Hole River). Any long term impact from escaped farmed salmon interacting with wild conspecifics and/or transmission of disease/parasites to wild smolts could have negative impacts on the abundance for each of these populations with long term implications on recreational angling activities. In addition, the proposed sites proximity to several salmon rivers could impact smolt behavior, residency and survival in the early phase of their marine migration. DFO NL Salmonid section acoustic-tagged Atlantic Salmon smolts in two rivers near the five proposed sites (Bay de L'eau River and Rushoon River); from this study it appears juvenile salmon use the small islands in the region for 6-8 weeks (May-July) prior to moving further south or east into the bay (Figure 7; Nicholas Kelly, unpublished data). It is plausible that the addition of the proposed sites, particularly Jude Island, will attract salmon smolts and potentially have impacts on the local wild populations.

Both past commercial Atlantic Salmon catch data and tag returns indicate that salmon from all over the south coast and Atlantic Canada are present in the region of southern Newfoundland and potentially exposed to the five sites. Reddin and Lear (1990) describe the tag returns from the commercial fishery. For salmon tagged within Placentia Bay, the results suggest that salmon were largely recaptured within Placentia and St. Mary's Bays, although recaptures did occur around the Island and in two rivers of the Gulf of St. Lawrence. This is further substantiated by the historical data on commercial and recreational catches in southern Newfoundland (May and Lear 1971; Lear 1973; Reddin and Short 1981; Ash and O'Connell 1987). Recent genetic assignments from the St Pierre-Miquelon mixed stock fishery (ICES WGNAS 2020 Report) indicate that the fishery was dominated by contributions from Gulf and Gaspe Peninsula regions and as well as Newfoundland. It seems likely that although exposure will be highest for salmon from within Placentia Bay and St. Mary's Bay, individuals from a variety of southern Newfoundland populations, and from elsewhere, migrate through Placentia Bay and may be exposed to these sites both as migrating smolts and returning adults.

As a note, the proponent addresses potential impacts of the proposed sites to lobster and crab fishing recreational activities (cod, lobster and crab fishing) within a few kilometers; however, Atlantic Salmon are a highly migratory species and previous escape events have resulted in known movements of farmed fish larger than 1-5 km from the location of the escape.

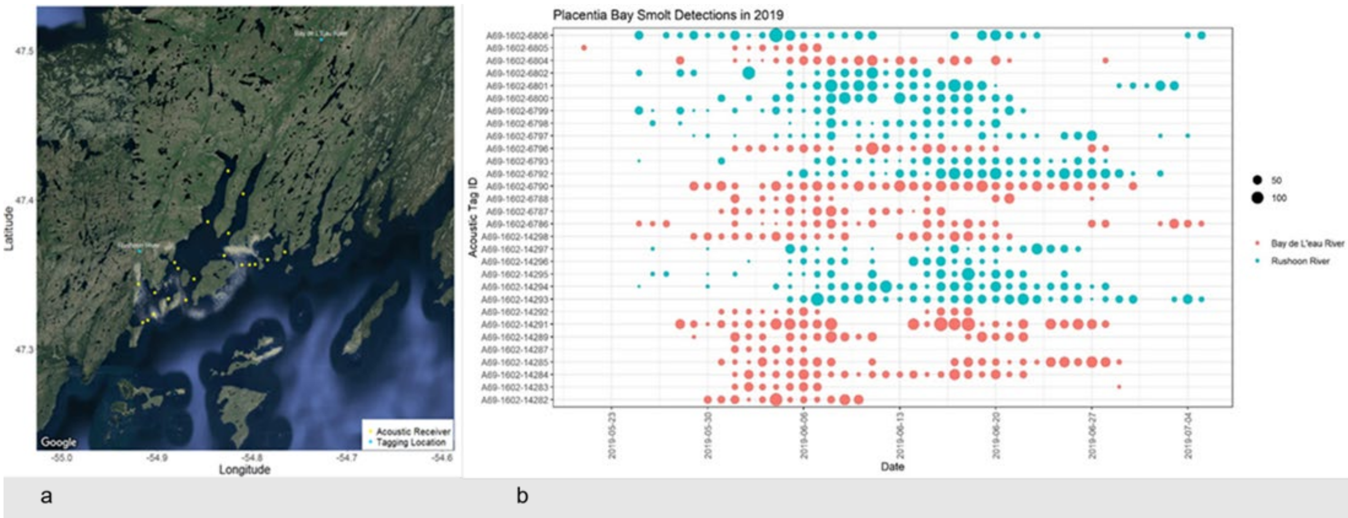

Figure 7: a) Map of acoustic receivers deployed (2018–2019) to track nearshore residency and survival of Atlantic Salmon smolts tagged in Rushoon River and Bay de L'eau River. b) Count plot showing detections per day for acoustic-tagged Atlantic Salmon smolts from Bay de Leau River and Rushoon River (2019). Detections were pooled for each day across all receivers in the array.

Aquaculture Escapees

In Placentia Bay there are twenty-one scheduled salmon rivers and ten non-scheduled salmon rivers. In the event of an escape from the proposed sites, any of these rivers' populations could be impacted as documented previously in the Bay d'Espoir region.

The proponent will be using European (origin: Norwegian salmon, Icelandic hatchery) triploid salmon; the possible impact of European-origin salmon escapees on wild NL Atlantic Salmon is uncertain and the use of all-female triploid population was recommended in a previous CSAS (DFO 2016). While the interbreeding between wild and farmed salmon has been shown to have negative effect on the fitness and population abundance (Sylvester et al. 2018), the commercial production of all-female triploid (sterile) salmon was considered to be an effective means of significantly reducing direct genetic impacts to wild Atlantic Salmon populations. However, it was uncertain whether it would reduce the indirect genetic, ecological and/or fish health impacts. This advisory process identified several recommendations and mitigations to minimize ecological and genetic consequences of wild-farmed salmon interactions: production of all-female triploids; testing of the cage system (Aqualine Midgard), viewed as effective at reducing escape incident rates, in the NL environment prior to stocking; review of Code of Containment to identify gaps; use of DNA methods to identify families and investigate escapes back to the farm of origin; maintaining regular Fish health through all life history stages prior to authorization of entry to sea cages, with additional confirmatory triploid validation testing prior to authorization of entry to sea cages; submission of Standard Operating Procedures (SOPs) for triploid induction and verification from the egg supplying facility to DFO as part of the information required in applications for transfer licences so that they may reviewed as part of the application review process; conducting scientific investigations of triploid performance and triploid-wild salmon interactions prior to commencement of commercial operations. The Proponent has implemented some of the mitigation measures that have been suggested (switched to all-female triploids, confirmatory triploid validation testing prior to entry in sea cages, sample sizes increase).

Recent genetic studies have documented widespread hybridization between wild salmon and aquaculture escapees both in southern Newfoundland and in the Maritimes. Across the North

Atlantic, the magnitude of genetic impacts due to escaped farmed Atlantic Salmon on wild populations has been correlated with the biomass of farmed salmon in nearby cages and the size of wild populations (Glover et al. 2017; Keyser et al. 2018). Here the potential genetic interactions resulting from the proposed finfish expansion involving 5 sites (2M individuals/site) in the Rushoon BMA in Paradise Sound, Newfoundland (BMA 4) and on the western side of Placentia Bay in the Merasheen BMA (BMA 1) was considered using a combination of empirical data (North American and European), and both individual-based and dispersal modeling following Bradbury et al. (2020). The distribution of escapees in the wild under the proposed production regime (existing and proposed expansion) for Placentia Bay were modelled using a recently published spatial model of dispersal and survival (Bradbury et al. 2020; Jóhannsson et al. 2017). Model predictions for individual rivers were evaluated against a 10% threshold, above which demographic decline and genetic changes have been predicted (Bradbury et al. 2020). In contrast to previous assessments, triploid female salmon are being employed within this bay and under the proposed expansion (DFO 2016). As the goal here is to specifically quantify direct genetic interactions resulting from interbreeding between wild salmon and escapees, we evaluate the number of diploid or reproductively viable salmon potentially present. Recent results suggest triploidy induction success is likely high (Glover et al. 2020). The only published examination of triploidy success in Norwegian salmon farms using triploids from this hatchery (i.e., Stonfiskur) indicates levels of induction success ranging from 90%–100% with an average of 97.8% (Stien et al. 2019). However, it is important to note that sample sizes were small (n = 20–40) so accurate estimates may not be possible. Here we varied the proportion of triploid salmon in production from 0%, 50%, 95%, 97%, 99% and 100% of total production.

Under a scenario where all farmed fish in the bay were diploid (i.e., no triploid), the model predicts ~1,014 escapees entering rivers within the Placentia and St. Mary's Bays, and that 23 rivers will exceed 10% escapees relative to wild salmon, hence genetic and demographic impacts are predicted to be likely (Figure 8b). For the scenario where 50% of all farmed fish in the region are diploid (i.e., 50% triploid) the model predicts ~507 escapees entering rivers within the two bays, and 21 rivers exceed 10% escapees relative to wild salmon (Figure 8c). For the scenarios where 5%, 3% and 1% of all farmed fish in the region are diploid (i.e., 95%, 97%, and 99% triploid) the model predicts 51, 30, and 10 escapees entering rivers within the two bays respectively (Figure 8 d-f). For each of these simulations, no rivers exceed the 10% threshold for escapees relative to wild salmon.

Several sources of uncertainty exist, most importantly the size of wild populations and the level of triploidy achieved. Although significant uncertainty exists in the size of wild populations, recent analysis of trends in the abundance of salmon in the region suggests a decline over the last decade but no significant trend when modelled over the period 1992–2019 (Nicolas Kelly, pers. comm.). Interestingly, Watson (2020) reconstructed trends in effective population size over the recent past, using a large panel of genetic markers and observed a consistent similar pattern of decline across all rivers, over the last six generations (1989–2013). As such, it is possible that predictions of population size used here are overestimates, but in the absence of accurate population size data it is difficult to evaluate this hypothesis. The level of triploidy present in the proposed expansion will ultimately determine the direct genetic impacts on wild salmon in the region. The best available data suggests levels of triploidy success are high (Glover et al. 2020) and likely >90%, and on average 97% (Stien et al. 2019). Our simulations centre on this range of values and suggest little impact at values of 97% triploidy or greater given predicted population sizes. Finally, it is important to note, these simulations only consider direct genetic interactions resulting from interbreeding with escapees. Indirect genetic or ecological interactions due to predation, competition, disease, or parasites would not be considered here.

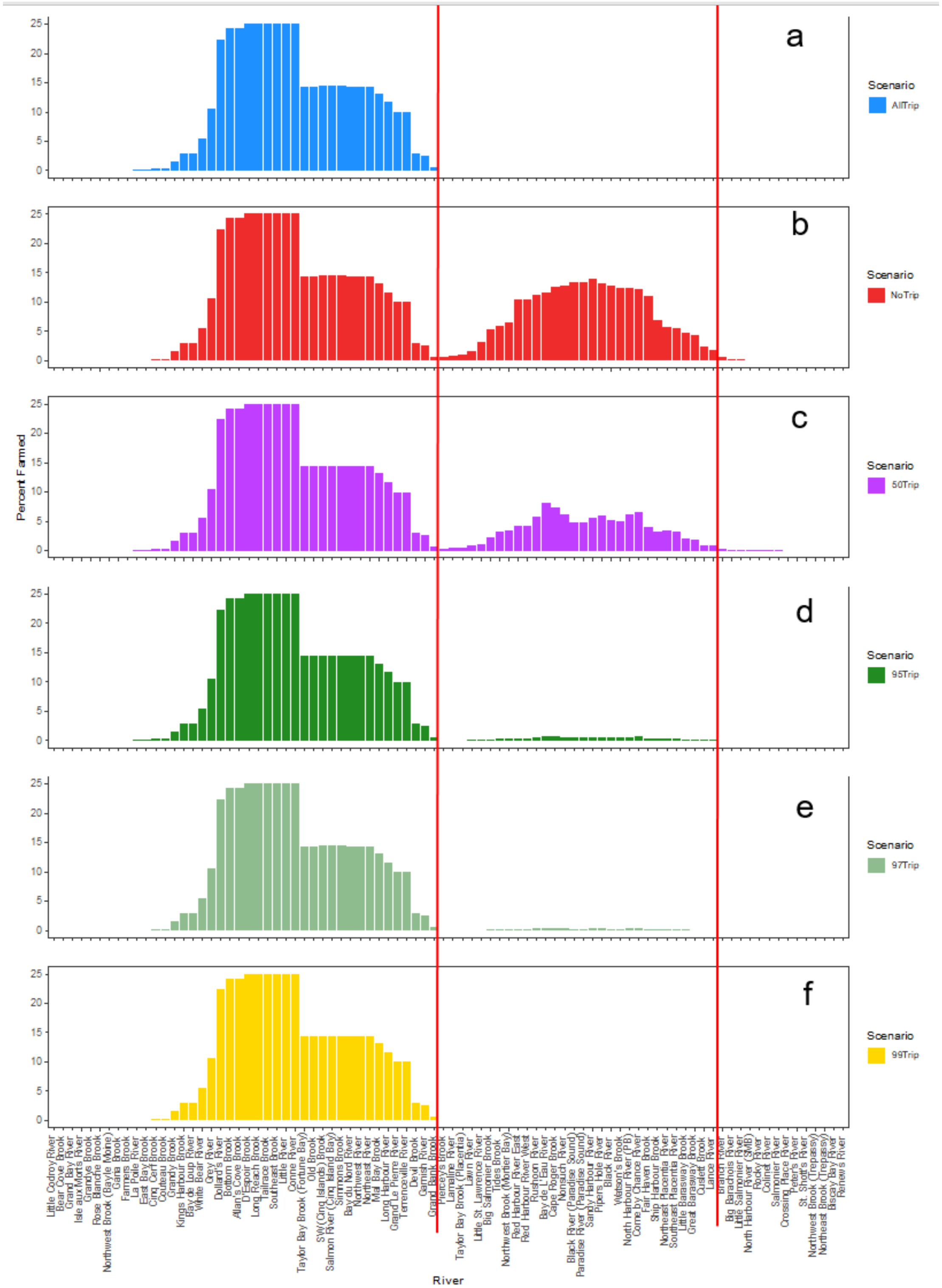

Figure 8: Percentage farmed escaped salmon relative to wild salmon present following the proposed expansion under varying levels of triploidy induction success a) 100% triploid b) 0% triploid c) 50% triploid d) 95% triploid e) 97% triploid f) 99% triploid. Simulations include all salmon populations in southern Newfoundland; Placentia Bay is bounded by Piercey's Brook to the west and Lance River to the east (graph area delimited between two red lines).

Cleaner Fish Escapees

Integrated pest management and the continued threat of sea lice represents one of the most significant challenges facing the Atlantic Salmon aquaculture industry worldwide. This threat and the potential ecological impacts are poised to increase as common therapeutants become increasingly ineffective due to the evolution of resistance (Fjørtoft et al. 2020). Cleaner fish such as wrasse and Common Lumpfish are used in aquaculture as a biological control for sea lice in other countries, such as Norway (Blanco Gonzalez and de Boer 2017) and Ireland (Bolton-Warberg 2018). In Atlantic Canada, the industry has begun investigating the use of Common Lumpfish as cleaner fish with much of the preliminary development work underway in Newfoundland. However, as with Atlantic Salmon (e.g., Wringe et al. 2018), research suggests reproductive interactions between cleaner fish and wild populations warrant consideration as negative impacts are likely (e.g., Faust et al. 2018, Blanco Gonzalez et al. 2019).

Wild Common Lumpfish nest in nearshore bays around the island (Simpson et al. 2016). DFO-NL spring multispecies surveys in Subdiv. 3Ps indicate declines in abundance of about 58% between 1996 and 2014 (Simpson et al. 2016). Accordingly, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Common Lumpfish as Threatened in Canadian waters in 2017 (COSEWIC 2017). Although Lumpfish in Canadian waters were assessed as a single designatable unit (COSEWIC 2017), recent genetic analysis (Ian Bradbury, pers. comm.) suggests significant subdivision is warranted with the presence a northern population which includes southern Newfoundland. There remains considerable uncertainty regarding the potential impact of the proposed expansion on local Common Lumpfish populations. However, given the status of this species in the NL Region, and evidence of negative genetic impacts of cleaner fish on wild populations elsewhere, the potential exists for increased negative interactions due to the proposed expansion in southern Newfoundland.

Pests and Pathogens

Marine finfish aquaculture conducted in net pens have no barriers to pathogen and pest exchange with the environment. Water flows freely through the net pens and potential pathogens may come in contact both with wild fish and other farmed fish populations (Johansen et al. 2011).

Information about pests and pathogens on salmon farms in Newfoundland and Labrador is scarce. The Government of Newfoundland and Labrador Aquatic Animal Health Division published a one-page aquatic animal health summary providing a brief description of the audits and site visits on aquaculture leases in Newfoundland and Labrador. The summary included diseases, Canadian Food Inspection Agency (CFIA) reportable viruses and parasites identified during the aquatic animal health inspections conducted in 2015 and a list of 20 historically detected diseases in Newfoundland and Labrador wild and farmed finfish.

Reportable diseases

Of significant importance to aquatic animal health are reportable diseases. Anyone who owns or works with aquatic animals and knows of or suspects a reportable disease is required by law to notify the CFIA. To date, two reportable diseases have been reported in finfish in Newfoundland: infectious salmon anemia (ISA; total of 25 entries) and viral hemorrhagic septicemia (VHS; total of 3 entries; CFIA, 2021a; 2021b).

ISA is a finfish infectious disease caused by the ISA virus. It is considered an endemic disease in Atlantic Canada and is commonly detected in marine Atlantic Salmon aquaculture at levels not known to cause disease (non-virulent; DFO 2020a). In Newfoundland, some Atlantic salmon have been confirmed to be infected with ISA, the virulent or the non-virulent form, in at least in one instance every year between 2012–2021 (CFIA 2021a). This includes the recent positive detection of ISA in two fish on an Atlantic Salmon farm along the south coast of NL that required removal of fishes raised in the same cage to mitigate risks of viral spread (ASF 2020). Some research indicates that ISA can propagate in Atlantic Herring (*Clupea harengus*) and they may be an asymptomatic carrier of the virus (Nylund et al. 2002); herring could potentially contribute to the spread of the virus among farms, since they are known to travel large distances.

VHS is a finfish infectious disease caused by the VHS virus (VHSV). Infections with VHSV have been reported in over 80 species including Salmoniformes (salmon, trout, whitefish) (reviewed in Garver and Hawley 2021). Despite VHSV's capacity to infect a broad range of hosts, not all species are universally susceptible to all genotypes of VHSV (Garver and Hawley 2021). In Newfoundland, since 2013, some Atlantic Herring have been confirmed to be infected with VHS in at least one instance in three years (2016, 2019 and 2020) and there has been no detections reported in Atlantic Salmon (CFIA 2021b). Due to the positioning of the proposed cages in narrow fjords, the relative position of the water column occupied by herring and the relative abundance of herring in the ecosystem, it is likely that wild herring will swim past or interact with cages during the production cycle and potentially increase the transmission of such virus.

Sea lice

Salmon lice are small, naturally occurring ectoparasites that can pose a significant health risk to farmed and wild Atlantic Salmon when present at certain host density threshold levels (Krkosek 2010). Prevalence and abundance of *L. salmonis*, the most common sea lice infesting farmed Atlantic Salmon (Saksida et al. 2015), vary among origin of fish (e.g. farmed vs. wild); sea lice can spread from farm to farm and from farmed to wild salmon; the effects of sea lice infestation on wild salmon population productivity and the consequent control management for salmon aquaculture have been the subject of many studies in the past 10–20 years (e.g. Brooks 2009; Krkošek et al. 2011, 2012; Torrissen et al. 2013).

Wild salmon smolt survival can be impacted by exposure to sea lice; migrating smolts have been shown reduced one sea-winter returns to natal rivers and a shift in relationships between ocean climate and returns; rivers with aquaculture showed lesser returns in years following high lice levels on nearby salmon farms (Shephard and Gargan 2021). The magnitude of wild population decline in years of sea lice outbreaks in salmon farms has been reported to be between 12–50% (Shephard and Gargan 2017, Thorstad and Finstad 2018). Moreover, prophylactically treating out migrating smolts for sea lice has been shown to improve survival by 50X (Bøhn et al. 2020). Although no data exists on sea lice-induced mortality in Placentia Bay, the addition of 10,000,000 (2M per site) farmed fish to Placentia Bay can reasonably be expected to amplify both endemic pathogens and sea lice in the area, due to the significant increase in the number of host fish Placentia Bay.

A substantial and growing body of research (Dionne et al. 2007, Dionne et al. 2009, Tonteri et al. 2010, Consuegra et al. 2011, Kjaerner-Semb et al. 2016, Pritchard et al. 2018, Zueva et al. 2018, Lehnert et al. 2020) indicates that wild salmon populations are adapted to common pathogens and that the introduction of new pathogens could drive population decline. Several recent studies in Europe clearly document evidence supporting the transfer of pathogens from aquaculture to wild salmon (Garseth et al. 2013, Madhun et al. 2015, Madhun et al. 2018, Nylund et al. 2019).

Increased disease susceptibility of triploid fish

Data for southern Newfoundland indicates disease outbreaks associated with salmon aquaculture are a common occurrence, but no study has examined the impacts on wild salmon to date. The proponent acknowledged the potential for triploid fish to be less resistant to pathogens and parasites in their applications and included a list of key mitigation measures for fish health maintenance for each site. However, given recent data from Norway suggests significant increases in disease susceptibility of triploid Norwegian salmon (Stien et al. 2019), additional measures to (1) detect any increase in disease or infection susceptibility on the proposed sites and (2) additional mitigation measures if applicable are recommended. Higher rates of disease susceptibility, if present in triploid salmon in southern Newfoundland, could elevate risks to wild salmon in the region.

Summary

Placentia Bay, as previously stated, contains several Atlantic Salmon rivers targeted annually in the recreational fishery, with some of the more heavily targeted being in close proximity to the proposed sites (e.g. Bay de L'eau River, Cape Roger River, and Pipers Hole River). Any long-term impact from transmission of disease/parasites to wild smolts could have negative impacts on the abundance for each of these populations with long term implications on recreational angling activities. Juvenile salmon from Bay de L'eau River and Rushoon River appeared to use the small islands in the region for 6–8 weeks prior to moving further south into the bay (Nicolas Kelly, unpublished data); therefore, It is plausible that the addition of the proposed sites, particularly Jude Island, will potentially impact the local wild populations, increasing disease and parasites transmission.

Ultimately, the fish health impact of farmed Atlantic Salmon sites on wild susceptible fish species will depend on health status of farmed Atlantic Salmon, the duration and proportion of wild susceptible exposure to the new farm sites, the concentration of pathogens and parasites on and in proximity of farms and the wild fish susceptibility to infection and disease within the environmental conditions found in Placentia Bay.

Entanglements

Bycatch or entanglement of wild species (e.g. wild fish, marine mammals, turtles, sharks) associated with the placement of infrastructure is another potential interaction associated with aquaculture sites.

There is a lack of information regarding the distribution of cetaceans and pinnipeds provided in the aquaculture lease applications; in addition, few scientific surveys have been completed in the coastal, sheltered areas of Placentia Bay. In this situation Local and Traditional Ecological Knowledge collected from consultations would be valuable to assess the potential for entanglements and/or vessel strikes. It is not clear, however, if the consultations conducted by the proponent included this topic. However, there is overlap with the distribution of several species of whales (Blue Whale, Humpback Whale [*Megaptera novaeangliae*], Minke Whale [*B. acutorostrata*], North Atlantic Right Whale, sperm whale [*Physeter microcephalus*]), dolphins, and Harbour Porpoise (*Phocoena phocoena*). In addition, Placentia Bay was identified as containing important habitat for Leatherback Sea Turtles, which are known to frequent the entire bay. While entanglement and subsequent drowning are the main concerns for marine mammal species which do not echolocate (e.g., baleen whales), and sea turtles, the risk of entanglement is considered low at the proposed sites. Nationally, there have been reports of humpbacks found entangled at finfish sites in British Columbia in 2013 and 2016 over the period of 1990-2019 (Price et al. 2016; DFO 2021). The cause of death was unknown for the solitary humpback found at a finfish site in 2013 while accidental drowning was confirmed for entangled solitary humpbacks at two separate finfish sites in 2016. To date, there have been no reported incidents of entanglement of cetaceans or sea turtles at finfish aquaculture sites in the NL Region. Seals species such as Harbour Seals (*Phoca vitulina*; year-round) and Grey Seals (*Halichoerus* *grypus;* seasonal from spring to fall) occur in Placentia Bay regularly and may have haul-outs in the lease areas, particularly near islands and rocks. The potential attraction to the proposed sites and the potential reduction of haul out space in the area are concerns for pinnipeds. The number of accidental drownings from entanglement of pinnipeds at NL finfish aquaculture sites is not known. From 2011 to present, there were 236 reported marine mammal interactions at British Columbia marine finfish aquaculture sites (DFO 2021). Of these interactions, 60 were reported as accidental drownings from entanglements of 32 Harbour Seals, California Sea Lions (*Zalophus californianus*), and one Northern Fur Seal (*Callorhinus ursinus*). According to DFO (2021), improved anti-predator netting, improved anchoring, and the prompt removal of attractants (i.e., dead fish). dramatically reduced the interactions that resulted in the death of megafauna over the past two decades. The proponent mentions the possible use, if deemed necessary in consultation with Department of Fisheries, Forestry and Agriculture (Newfoundland and Labrador, DFFA) and DFO, of an anti-predator net (i.e., a double net that completely surrounds the sea cage under water). However, the proponent monitoring plan for entanglements/holes in the anti-predator net is not clear. As a note, the proponent's application states that any dead or distressed (i.e. entangled) SAR species will be reported immediately to DFO or Environment and Climate Change Canada's, Canadian Wildlife Service ECCC-CWS; however, it is not clear if dead or distressed non-SAR species will be reported to DFO or other applicable departments or agencies. All dead or distressed animals should be reported to the relevant agency for a potential response.

White Shark (*Carcharodon carcharias*) move into Canadian waters seasonally, including the south coast of Newfoundland and Placentia Bay, predominately in shallow waters (<50 m) and mesopelagic depths (200–500 m). The potential attraction and entanglement of large pelagic fish to the sea cages (e.g. tunas and sharks) have been documented previously; an increased presence of White Sharks have been observed along the south coast in recent years, including in Placentia Bay. White Sharks are opportunistic predators, feeding on a variety of prey, hence the potential for entanglement of White Sharks to sea cages cannot be discarded. However, the presence of White Sharks in coastal Newfoundland waters is deemed rare, and the pelagic habitat occupied by the species is extensive (i.e. Ocean Basin scale), suggesting that any impact resulting from the proposed aquaculture activities at species or population levels, and their habitat, is negligible.

AAR Guidelines

DFO Science suggests more prescriptive regional guidelines to be implemented in the AAR, in order to improve the information being provided by the proponent(s). These guidelines should include:

- Collection of temperature and salinity profiles at the site of interest during expected maximum feeding season. Collection of ocean currents observations at the site of interest, preferably using a current profiler, or, if using single points instruments, at depths representative of the water structure (i.e. water masses) during expected maximum feeding season for at least 3 months. This would provide with the necessary information for a depositional and dispersion of drugs and pesticides models to be run with more reasonable confidence. Ideally, a full year of temperature, salinity and current profiles collected at the site of interest, would provide a more complete picture and lead to more reliable estimates.
- Provision of a suitable model description including variables input details, justified site-specific depths of current series input (if the model requires such depths to be provided; e.g. DEPOMOD) and the use of a complete range of settling velocities (note: fraction loss on the slowly settling flocs might need to be determined).

- Provision of a climatological representation of temperature conditions that occur at the site of interest to ascertain potential risks of extreme temperature events (e.g. using combination of available data consultation of from DFO MEDS (Marine Environmental Data Section) archive with additional observations).
- Provision of an estimate of oxygen demand from the proposed sites and its environment availability (e.g. using dissolved oxygen (DO) measurement over the course of a year). i.e. a carrying capacity estimate to frame more robust mitigation measures in case of heat waves/low availability of dissolved oxygen.
- Provision of an estimate for nutrients loading (nitrogen and phosphorous) from the proposed sites.
- Provision of a description, which can be based on available literature, of potential, site/region specific risks associated with climate change (e.g. expected temperature changes and DO availability).
- The AAR baseline report submitted by the proponent is somewhat misleading on number of fish and benthic animals reported, since it provides absolute counts for specific sampling points; these numbers should be converted to densities and then used to estimate overall numbers for the total area covered. Currently, the results reported underestimate the number of animals present at each site and make these not properly comparable.

It is also suggested for DFO to request, archive and make available the physical environment data for each site application (including the review) to increase transparency and social acceptance.

Sources of uncertainty

Oceanographic data and model output

The calculation of PEZ is evolving as more oceanographic data are available, in particular the selection of the current series used to compute the dispersion of particles released from the farms necessitates further validation.

The proponent has made an effort to collect current data at various depth at all proposed sites; however, the means used to measure the currents do not provide a clear picture of the variability within the water column. The proponent used current profilers only in the upper 20–25 m near the sea surface and point measurements at 3 deeper depths using current meters. On the other hand, current measurements were only collected for a part of a season (less than 50 days) and not always carried out at the same period (e.g. Winter 2020 for Channel Harbour, Gilberts Cove and the surface layer of Jude Cove, late Summer/early Fall 2019 for deeper layer in Jude Island and all measurements in St. Leonard’s and late Fall 2019 for Paradise Sound, Table 1); this does not allow to assess seasonal variability. In addition, the ocean currents observations were not collected during the season of maximum daily quantity of feed usage (AAR requirement for modeling simulation), while the seasons of maximum daily quantity of feed usage (summer to late summer) was used for the modeling. As a result, the hydrodynamic model used for Biological oxygen demand (BOD) matter dispersion could not be validated against observations and those observations have a very limited use for direct estimate of dispersion (e.g. PEZ). Uncertainties regarding the estimated deposits can be important; they are basically unknown for the proponent’s dispersion results and they could be on the order of a factor 2 with PEZ based on statistical estimates the department made over the years in NL south coast areas.

In term of modeling the deposition, the proponent used the 3-D circulation model Delft3D-flow with a nested version at higher spatial resolution around the site to better capture the spatial variability near and around the proposed sites. The hydrodynamic model used is suitable and the method is relevant, however, it is unclear if the model was used in barotropic mode (i.e. 2D depth-averaged) or baroclinic mode (fully 3D). The latter would be appropriate but the former would not; given the strong seasonal stratification that the region experiences. In order to use the output of the circulation model to simulate deposition, it is necessary to validate it with observations; a comparison of time series of currents at various depths for the same period is crucial and gives a better idea of how well the circulation model reproduces the currents at the site of interest. Comparison of the modelled water structure (distribution of temperature and salinity) with observation is also a requirement (Ma et al. 2017 for instance discusses about the importance of stratification on the circulation in the bay). Only upon such validation should the model output be used for waste dispersion calculation. The proponent provided some comparison of model output with observation. However, the proponent states that it is not possible to do a direct comparison between the two as they do not cover the same period. With the possibility of running the model for the periods when the observation data were available, it is rather surprising that such run was not performed. As a consequence, stating that the model reproduces the currents at the sites and can be used to compute deposition around the site is overstating.

Time series of the wind used to force the model could be included in the document. A plot illustrating the stratification (e.g. temperature and salinity profiles) and how it evolved along the simulation (e.g. start and end of the run) would help getting more confidence in the results presented (e.g. no or limited overmixing). Validating the temperature and salinity fields with observations would have been valuable also. It seems that this could have been possible using the data presented/described in the application (monthly collection of temperature and salinity data). Alternatively, comparing with available data such as the ones from smartatlantic and/or archived data (then only/mostly useful to get monthly climate) would have helped getting more confidence; especially in the absence of appropriate ocean currents data.

The proponent does not describe the particle tracking model used to simulate the dispersion using the hydrodynamic model results, making it difficult to assess the results appropriately. Recent studies show that slow settling particle velocities (1 mm/s) should be considered for aquaculture waste deposition modeling (Law et al. 2014) but this settling velocity type was not considered, increasing uncertainty on the potential size of the patch.

The method used to calculate extreme values of currents provided is not appropriate; extreme values analyses (Gumbel type) need site-specific data to be valid, using coefficients determined in what could be very different environment cannot be representative. Knowing that the region is generally subject to storm and hurricane events every year and considering that current measurements were only performed for a short period, the validity of the 10- and 50-year currents calculation will need further verification for the south coast of Newfoundland (the proponent stated that this calculation is based on the Norwegian Standard NS 9415:2009 for currents). Wave analyses are also questionable as only 2 years of data were used for the calculation of extremes (10-yr & 50-yr return period); such a limited dataset, increases the uncertainty, which was not provided. The use of such short time series is surprising since a much better dataset is available for the region and was used in the proponent’s Environmental Impact Study (EIS) for a preliminary analysis. This same dataset (MSC50: 1954-2018 hindcast) could have been used to refine the estimates using the same approach as presented in this application (i.e. using a higher resolution bathymetry and shallow-water wave model [SWAN] to propagate swell and generate wind-waves using the wind).

Depositional model maps in most cases were challenging to understand; in particular, it was difficult to appreciate the resulting deposition inside the lease, as the maps have a broader scale (e.g. Figure 4.4 of Channel Harbor report). Due to this issue, reviewers were not able to examine the distribution of fauna in relation to the predicted deposition.

The proponent's application often refers to the EIS of June 2018 (Science Response 2018/045, DFO 2018); however, the proposed sites were not considered in the EIS and three of those sites are located in Paradise Sound (a long [30 km], and narrow [~2 km or less] fjord) an area arguably different from the other areas described in the EIS. Site specificities of Paradise Sound might therefore preclude the direct use of EIS findings when it comes to its physical description. In addition, a number of inaccurate statements, not supported by data or existing information, are presented when discussing the physical environment. For instance stating that the water exchange at the proposed sites is "good", without presenting any water exchange calculations and when the ocean currents series collected are too short to deduce such exchanges reasonably (since the environment is not dominated by astronomical tides).

Potential effects of global warming are not presented; these could be important with respect to mass mortality risks, for instance, such as summer heat waves or winter superchill events. It could also be important with respect to potential pest and disease outbreaks (e.g. sea lice). In addition, the mitigations measures against potential extreme temperature events (warm or cold) are lacking details; in particular, no quantitative estimate are provided on the oxygen demand from the cage/farm and its effect on the environment availability (a heat wave issue). Also, with respect to superchill events, there is a lack of convincing evidence of warmer water at depth to support the claim that deeper net would mitigate this issue (section 3.6.1). DFO Science experience within the region indicate that this will likely not be the case; cooling in the winter affect a large portion of the water column (order of 100 m or more).

Cumulative effects

DFO's Fisheries and Aquaculture Management (FAM) has been identified by Murray et al. (2020) as an area that would benefit from cumulative effects research and assessment due to its broad application to resource management decisions and policy development. While this science review is focused on the siting of five new aquaculture sites in Placentia Bay, it is important to note that the addition of these five sites is not happening in isolation. There are numerous other human activities going on in the Placentia Bay ecosystem and its surrounding watershed, including other finfish aquaculture sites, which all have some degree of effects on the ecosystem. Additionally, there are also broad scale processes affecting the Placentia Bay ecosystem including global climate change and ocean acidification. The interactions between many of these effects can be multiplicative which may result in seemingly minor perturbations to the system having substantial impacts on the ecosystem.

Placentia Bay in general is becoming at risk of cumulative effects of finfish aquaculture activities in addition to other anthropogenic activities, which are not being currently considered during site application reviews.

As of 2001, the Placentia Bay region has ~60 communities and a population of ~25,060 (Placentia Bay Integrated Management Planning; IMP). Ocean related economic activities in the region averaged $545 million from 2001 to 2004. Some of the key uses of Placentia Bay include commercial and recreational fisheries, aquaculture, scientific research and monitoring, marine tourism and recreation, oil production, development and support services, shipbuilding and ship repair, marine transportation and infrastructure and ocean technologies. The IMP identifies several pollution concerns within Placentia Bay. A main concern is pollution associated with marine traffic and related activity which could result in oil pollution in the form of both spills and chronic discharges.

There are also concerns about the potential for pollution associated with onshore and near-shore sources. The main onshore and near-shore pollution sources include sewage discharge, by-products from fish processing and aquaculture operations, and the discharge of toxic chemicals by fish processing, industrial and mining activities. The former two are focused on nutrient pollution, which is a global problem in coastal waters (Cloern 2001, Breitburg et al. 2018) as excess rates of nutrient loading can lead to coastal eutrophication, and in many cases the formation of seasonal or year-round hypoxic and anoxic zones. This is already an issue in some estuaries in the Southern Gulf of St. Lawrence (e.g. Thibodeau et al. 2006; Schein et al. 2013). There is the potential for global climate change to exacerbate the effects of coastal eutrophication through higher water temperatures which may strengthen stratification and increase the inflows of freshwater and nutrients to coastal waters (Rabalais et al. 2009). While low levels of eutrophication can be beneficial, potentially leading to increased production of phytoplankton and potentially zooplankton (Cloern 2001, Suikkanen et al. 2013), at higher levels it can be quite destructive to marine ecosystems and can be very costly to deal with (e.g. Breitburg et al. 2018).

The level of nutrient loadings from aquaculture facilities is not small. In the Åland Archipelago in Finland, 35–40 fish farms collectively producing ~5,000 tonnes year-1 of rainbow trout resulted in the production of nutrient loads that are comparable to the amount of treated wastewater from a city with ~370,000 people for phosphorous (~40 tonnes year-1) and 90,000 people for nitrogen (~270 tonnes year-1; Bonsdorff et al. 1997). If the levels of nutrient production by the proposed aquaculture sites are comparable, the initial nutrient loading increase from the proposed salmon farms at their initial combined production rate of ~20,000 tonnes of salmon per cycle would be the equivalent of adding a city of ~1.5 million people to Placentia Bay's water shed in terms of treated sewage for phosphorus and 360,000 in terms of treated sewage for nitrogen to the Bay's watershed. At full production (~40,000 tonnes of salmon per cycle), this would be the equivalent of adding ~3 million people for phosphorus and 720,000 for nitrogen to the watershed. It seems plausible that the scales of these estimates are reasonable or perhaps even an underestimate as the proponents are planning to use 4,707 tonnes of feed/site to increase the biomass of the stocked fish by 3,650 tonnes (growing from an average stocked weight of 0.35 kg to an averaged harvested weight of 5 kg) which suggests that 1,057 tonnes of feed/site (5,285 tonnes total across five sites) will remain in the Bay as either waste feed or metabolic wastes. At a production level of 8,000 tonnes of salmon, 3,262 tonnes of feed/site (16,310 tonnes total) would remain in the Bay as either waste feed or metabolic wastes. This is in addition to the already existing nutrient loads from sewage discharge, the by-products from fish processing, existing salmon aquaculture facilities, and runoff from agriculture operations (e.g. pig and chicken farming; IMP) in the Bay's watershed. Estimating/modelling the expected amount of phosphorous and nitrogen, on both a seasonal and annual basis, that will be released by aquaculture farms in a Newfoundland context seems like an essential part of understanding the potential impacts of this activity in the region. To try and avoid the potential for ecological damages from eutrophication and the potential formation of dead zones (volumes of water with low levels of oxygen, typically less than 2–3 mg L^{-1}), it would be advisable to conduct a water quality modeling analysis of the Bay to determine the Bay's capacity for additional nutrient loading before eutrophication will have significant negative effects.

An examination of the computed pelagic and benthic PEZs presented in this document showed that the PEZs of individual sites overlapped, suggesting that there was the potential for cumulative effects to occur within the zones of overlap. We were unable to examine the spatial overlap of PEZs from the current process with those from sites that were previously proposed in the region. A combined analysis would be necessary should various sites in the same BMA be simultaneously active. Although there is some indication of benthic fauna recovery/partial recovery from the fallout of aquaculture activities (e.g. Macleod et al. 2004, Lin and Bailey-Brock 2008, Aguado-Giménez et al. 2012, Zhulay et al. 2015), there is also evidence of incomplete (Salvo et al. 2017) or little recovery of benthic diversity even after long periods of time (e.g. Verhoeven et al. 2018). Sediment geochemical recovery in soft bottom areas is another concern. In sites where PEZ zones overlap spatially – even if they do not overlap temporally – the activity in one site might still have effects on a fallow site which may influence the site's recovery.

Intertidal zones near the proposed aquaculture sites are expected to be impacted by the proposed sites through multiple pathways. As both the benthic and the pelagic PEZs include the coastline adjacent to the sites, they are expected to be exposed to waste feed, fecal material and pesticides coming from the aquaculture sites. Primarily in the case of the proposed Paradise Sound sites, there is overlap in the PEZs across sites which suggests that the coastlines adjacent to these sites has the potential to receive 2–3 times the pesticides and waste materials of sites that are more isolated from one another. Further, it changes the nature of the pesticide exposure that commercially important species such as lobster (e.g. Hamoutene et al. In press[3]), which are known to be susceptible to the pesticides being used at these sites, from a temporary exposure to a chronic exposure if it takes several days for treatment baths for sea lice to be completed across all of the pens within each of the sites and increases the overall amount of pesticides being deposited in the sediments. Additionally, the proponents note in the proposal that the shorelines adjacent to the aquaculture are likely to receive debris from the facilities (e.g. rope, netting, other gear and debris), despite their efforts to minimize it. While they intend to mitigate this by periodic shoreline clean-ups, this may not result in the removal of debris that settles below the water line.

The proposed aquaculture sites create some new potential challenges for the Atlantic Cod stock in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps which is currently considered to be in the critical zone. The Subdivision has undergone a series of structural changes since 2010 that have been linked to an ongoing warming trend (DFO 2020b). These include an increasing dominance of warm water species such as silver hake (*Merluccius bilinearis*), increases in the estimated natural mortality rate of cod and shifts in cod diets which are suggestive of a change in species composition in the region. The addition of aquaculture sites in areas of high larval abundance for cod represents a further source of stress to a stock that is already struggling. The potential aquaculture sites at Jude Island and St. Leonard's may increase larval cod mortality rates through both direct predation on cod larvae by both farmed salmon and fish being aggregated to the proposed aquaculture sites and by indirect mortality through reduced zooplankton availability, a key prey for larval fish, due to the aggregation of wild fish in the vicinity of the aquaculture site and through the use of pesticides to control sea lice which also has effects on other zooplankton such as the copepod *Temora longiforms* (Burridge and Van Geest 2014).

Other Considerations

The following considerations have been highlighted for video surveys and should be evaluated. Video surveys conducted by the proponent often have suboptimal camera quality; although it is possible to determine the main fauna at most frames, the low-quality hampers more specific identifications; in many cases it is difficult to understand how animals could be identified at the low taxonomic levels at which they were identified in the application. To solve the issue, it is suggested to add an auxiliary camera to the drop camera frame; some low-cost GoPro cameras can have better quality than what is shown in the reports (i.e. use the live camera during the survey as the main camera, adding a smaller high-resolution camera to support species identification). Some images are covered with sediment due to the impact of the camera on the seafloor; since the camera had a live fed to surface, during deployment operators should wait until turbidity lowers down before capturing the image. In addition, a better timing for surveys may be needed, if high turbidity caused by organic matter in the water and zooplankton can hamper the video quality. As mentioned in previous Science Reviews for site applications, the low quality of the videos will challenge future comparative analysis of before and after aquaculture activities; therefore, there is a need for the proponents to improve the quality of the seabed videos.

Another concern is direct predation on wild fish by farmed salmon which has potential cumulative effects on herring stocks in the region. Making some simple assumptions, it is possible to derive an annual estimate of the number of wild fish being consumed by farmed salmon in pens. Work from British Columbia showed that the incidence of feeding on wild fish by farmed salmon was around 0.08% (typically only one wild fish consumed/event; Wild Fish Predation Project). The aquaculture license application notes that salmon will be fed 2–4 times per day and that there will initially be one million farmed fish at the site with the potential to go to two million farmed fish. If we assume salmon feed twice a day on wild fish at the observed incidence rate and there are a million fish in the pens, over a one year period, the expected consumption of wild fish would be:

1,000,000 fish × 0.08% incidence rate of wild fish being consumed × 2 feeding period/day × 365 days/yr = 584,000 fish/yr/million farmed salmon.

Across the five sites, this would equate to ~2.92 million wild fish per year being consumed at the low stocking level and ~5.84 million wild fish per year being consumed at the high stocking level. We note that this is a very rough estimate and that farmed salmon are supply limited, meaning they are only able to feed on wild fish that are able to enter their pens.

The use of eDNA to detect species, in addition to baseline surveys, may be beneficial to detect species which tend to be more cryptic and those that might avoid the camera.

The potential interactions of the proposed sites with Aquatic Invasive Species (AIS) has been noted as a topic which should be discussed during aquaculture siting applications reviews.

The predation and consumption of wild fish and/or shellfish larvae by farmed salmon may be an issue to consider during the regional assessment for herring and potentially other stocks as a new additional source of removals.

Potential effects of climate change were not assessed by the proponent and could not be assessed by the current Science Response Process due to the limited timeline. Those effects could be very important and should be considered in future site applications as well as future science work undertaken by the department. In particular, effects of and potential for heat waves, oxygen depletion and winter superchill should be studied and addressed.

Conclusions

Question 1: Based on the available data for the site and scientific information, what is the expected exposure zone from the use of approved fish health treatment products in the marine environment, and the predicted consequences to susceptible species?

- The Benthic predicted exposure zones (benthic-PEZ) associated with the use of in-feed fish health treatment products are within a radius of the order of 2 and 19 km from the site location when related to settling of feed and feces particles, respectively.
- There is an overlap of both feed and feces benthic-PEZ among the sites within Paradise Sound (Channel Harbour, Gilbert's Cove, and Paradise Sound). Any overlap between these anticipated zones suggests the potential for cumulative exposure to organic enrichment and feed chemical residues. While located more towards the PEZ limits, thus associated with higher uncertainty, there are some feces related overlaps between sites located within Paradise Sound and the other two proposed sites.
- The Pelagic predicted exposure zone (pelagic-PEZ) associated with the use of approved pesticides is within a radius of the order of 5 km from the site location.
- There is a significant overlap of the pelagic-PEZ related to the usage of bath pesticides for the three sites within Paradise Sound (Channel Harbour, Gilbert's Cove, and Paradise Sound). Considerations of the cumulative impacts of these pesticides in relation to the timing of their usage within the three sites to mitigate impacts on sensitive species is advised.
- Snow Crab, Toad Crab, shrimp, and lobster are present in Placentia Bay and therefore the sensitivity of larvae in the pelagic environment and juveniles in shallower waters to drugs and pesticides should be carefully considered during the application phase of operations to reduce potential impact on crustaceans recruitment.

Question 2: Based on available data, what are the Ecologically and Biologically Significant Areas (EBSAs); Species At Risk (SAR); fishery species; and ecologically significant species (ESS) and their associated habitats that are within the predicted benthic exposure zone and vulnerable to exposure from the deposition of organic matter? How does this compare to the extent of these species and habitats in the surrounding area (i.e. are they common or rare)? What are the anticipated impacts to these sensitive species and habitats from the proposed aquaculture activity?

- The benthic-PEZ of organic matter associated with falling particles from the farm can be characterized in three categories depending on the size (and the sinking rate) of the particles: the PEZ due to feed particles is within a radius of ~2.5 km from the site location with overlap between sites within Paradise Sound, the PEZ due to feces particles is within a radius of the order of 10 km from the site location with significant overlap among proposed sites, while the finest particles show associated PEZ that spans tens of km (similar scale as the bay). These sites have a benthic habitats with concentrations of corals, sponges, and other sessile organisms, and for which baseline data on vulnerability sand recovery, as well as on the connectivity with populations within and outside of these areas (possible limiting factor in the recovery) is lacking.
- Sessile or sedentary benthic taxa, including the soft corals, sponges, and other sessile organisms present at all five sites are expected to be more vulnerable to aquaculture wastes, as they cannot relocate to another environment when under stress. Although these species were usually identified outside of the proposed cage arrays (but inside the lease areas), the overlap of the benthic-PEZ among the sites within Paradise Sound (Channel Harbour, Gilbert's Cove, and Paradise Sound) has the potential to further loss of these benthic assemblages due to cumulative impacts of aquaculture effects on these nearby areas.
- The proposed sites fall within the Placentia Bay EBSA.

Question 3: To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic species at risk make use of the area, and for what duration and when?

- Leatherback Sea Turtles can be found in the area from June to November, suggesting the potential for entanglements from mid-summer to late fall.
- The general area overlaps the distribution of several species of whales, dolphins, porpoises, and sharks including SARA-listed species (Blue Whale, North Atlantic Right Whale, White Shark). The occurrence of cetaceans in Placentia Bay are generally highest in summer to fall and lowest in winter and spring based on sightings (opportunistic, systematic) and acoustics data. While entanglement and subsequent drowning are the main concerns for cetacean species, such as baleen whales which do not echolocate, the risk of entanglement is considered low at the proposed sites.
- The risk of entanglement may be higher for pinniped species, such as harbour seals and grey seals, that may be attracted to the cage netting for potential prey. Harbour seals occur year-round while grey seals are seasonal visitors that arrive in late spring and depart in late fall.
- In general, the risk of entanglement of marine mammals and sea turtles in the proposed lease areas is likely highest in the summer to fall period and lowest in winter to spring period based on seasonality of occurrence.

Question 4: Which populations of conspecifics are within a geographic range where escapees are likely to migrate? What are the size and status trends of those conspecific populations in the escape exposure zone for the proposed site? Are any of these populations listed under Schedule 1 of the Species At Risk Act (SARA)?

- Local populations of Atlantic Salmon are present within the geographic range where escapes are likely to migrate.
- COSEWIC (2010) designated the South Newfoundland Atlantic Salmon population as Threatened. There have been longstanding and continuous population declines of wild salmon in southern Newfoundland as compared to other regions of the province.
- An assessment of the potential genetic impacts of the proposed expansion on Atlantic Salmon populations within Placentia Bay and St. Mary's Bay was completed based on the best available scientific data (North American and European) and the size and location of the existing and proposed sites. The proposed scale of expansion is predicted to result in no direct genetic impacts to wild salmon, assuming the predicted wild population sizes are accurate and the levels of triploidy induction success are equal to or greater than 95%. Sensitivity analyses suggest that reductions in the levels of triploidy achieved below those proposed (i.e., increased numbers of non-sterile salmon) are predicted to have significant genetic and demographic impacts on wild salmon within Placentia Bay. There remains significant uncertainty as to indirect genetic and ecological impacts on wild salmon from this proposed expansion. Moreover, recent reports of increased disease susceptibility of triploid salmon in Norway warrant further consideration.

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Appendix I

PEZ Order of Magnitude Calculation

Given the following parameters:

- Mean sites depth (all five proposed sites are comparable): 100–200 m
- Settling velocity feed: 10 cm/s
- Settling velocity faeces: 1 cm/s
- Settling velocity flocs: 1 mm/s
- Maximum current speed: 50 cm/s

The following settling times for particles (100–200 m depth) are obtained:

- Feed: ~17–33 min
- Faeces: ~3–6 hrs
- Flocs: ~28–56 hrs

Estimated PEZ radius (100–200m depth):

- Feed: 500–1,000 m
- Faeces: 5–10 km
- Flocs: 50–100 km

Note: the further away, the less the initial assumptions hold (e.g. constant depth, constant current speed and direction, etc.).

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