



DFO NEWFOUNDLAND AND LABRADOR REGION SCIENCE REVIEW OF THE PROPOSED GRIEG MARINE FINFISH AQUACULTURE FACILITIES AT GOAT ISLAND IN PLACENTIA BAY, NEWFOUNDLAND

CONTEXT

The Proponent, Grieg Marine NL Ltd., has submitted an application for an Atlantic Salmon aquaculture licence for a new site (Goat Island) in Placentia Bay located on the south coast of Newfoundland. The application was 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 new aquaculture activity and the predicted impacts on species and the habitats that support them. In accordance with the *Aquaculture Activities Regulations (AARs)*, the Proponent's site application package includes a Baseline Assessment Report.

DFO has implemented a siting framework to promote a consistent approach to aquaculture site reviews. This framework includes 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)?

This Science Response Report results from the regional peer review of September 20-21, 2022, Aquaculture Siting Advice for Provincial Site Licence Applications from Cold Ocean Salmon in Connaigre Bay and Grieg Aquaculture in Placentia Bay.

BACKGROUND

The Proponent submitted an application to develop and operate a new finfish aquaculture site to produce sterile triploid Atlantic Salmon (all female; *Salmo salar*) in Placentia Bay. The location of the site is east of Goat Island in the Red Island Bay Management Area (shown in Figure 1). This is the fourteenth proposed marine salmon aquaculture site in Placentia Bay and the fourth within the Red Island BMA. There have been no previous aquaculture activities at the Goat Island site.

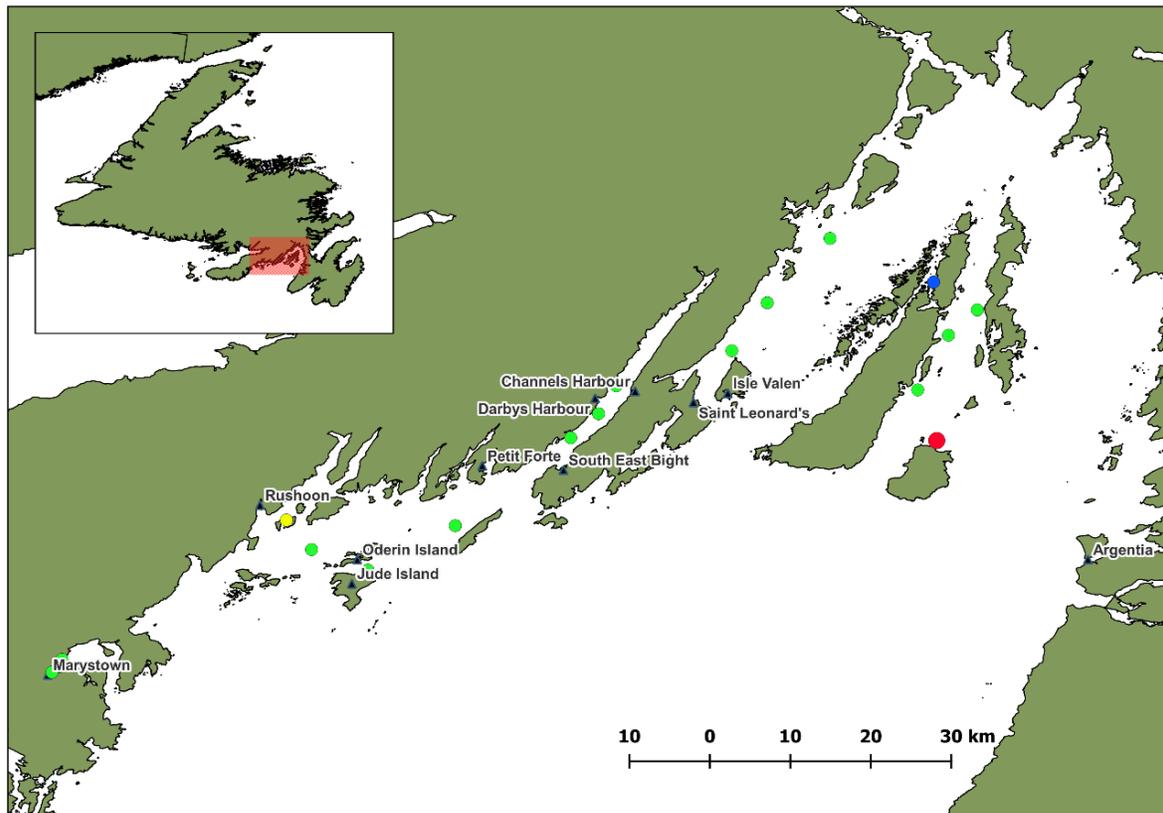


Figure 1: Location of aquaculture sites in Placentia Bay, NL. The red dot represents the proposed Goat Island site, green dots represent currently licensed finfish sites, blue dots represent currently licensed shellfish sites, and the yellow dot represents a seasonal cod ranching site.

General Description of Site

The baseline environmental report for the Goat Island proposed aquaculture site¹, following the *Aquaculture Activities Regulations (AAR) Monitoring Standard* includes the site description, bathymetric survey, visual benthic survey, and fish habitat survey conducted for the entire proposed lease area. The general description of site section of this Science Response is based on this, and other documentation provided by the Proponent.

The proposed lease area (2.73 km²) is located on the eastern side of Placentia Bay, within the Red Island BMA. The bathymetric survey reports that depth ranges from approximately 7 m on the western side (near the shoreline), to 232 m on the northern portion of the lease area. While

¹ Aquaculture Activities Regulations: Baseline Environmental Assessment Report.

this is the case for the entire lease area polygon, the depths directly beneath the planned cage array area range from 110 m to 170 m. The seabed within the area is primarily (76%) deep-water bedrock. The remaining 24% is sublittoral bedrock, concentrated closest to shore in shallower parts of the lease area.

A visual benthic survey to characterize flora, fauna, and substrate type was conducted at 294 stations spaced along a 100 m grid. 278 (98%) of the benthic stations were classified as hard bottom. Stations classified as hard bottom contained a mixture of cobble and gravel, often mixed with mud/silt, or hard-packed fine substrates. Hard bottom was indicated when the camera frame impacted the substrate rather than sinking into it. Only visual benthic sampling procedures are required for hard bottom sites according to the AARs; thus, no sediment samples were collected. As this site has not previously hosted aquaculture facilities, evidence of benthic indicators for aquaculture activity was not expected. Consistent with this, observations from the benthic survey did not show any indications of aquaculture disturbance such as the presence of *Beggiatoa*-like bacteria, opportunistic polychaete complexes, and/or barrenness caused by aquaculture.

No aggregations of commercially important species were observed during the survey. This statement is followed by an important caveat: a visual benthic survey using a drop camera would not be expected to detect aggregations of fish. A better indicator would be the nearby fishing activities. Several commercial species are known to be present in the area and are harvested in Placentia Bay (Northwest Atlantic Fisheries Organization [NAFO] Subdivision 3Ps). Snow Crab (*Chionoecetes opilio*), Atlantic cod (*Gadus morhua*), and Atlantic herring (*Clupea harengus*) are the main commercial species present in Placentia Bay; with an estimated landed value for 2020 of \$9.5 million, \$1.9 million, and \$213,000 respectively (DFO Policy and Economics Branch). Other fished species include: Haddock (*Melanogrammus aeglefinus*), Redfish (*Sebastes spp.*) Atlantic Halibut (*Hippoglossus hippoglossus*), American Plaice (*Hippoglossoides platessoides*), Yellowtail Flounder (*Limanda ferruginea*), Witch Flounder (*Glyptocephalus cynoglossus*), Winter Flounder (*Pseudopleuronectes americanus*), Greenland Halibut (*Reinhardtius hippoglossoides*), Skate species, Pollock (*Pollachius pollachius*), White Hake (*Urophycis tenuis*), Monkfish (*Lophius americanus*), Bluefin Tuna (*Thunnus thynnus*), Mako Shark (*Isurus spp.*), scallop (*Placopecten magellanicus* and *Chlamys islandica*), Sea Cucumber (*Cucumaria frondosa*), and Whelk (*Buccinum undatum*), worth a total combined landed value of \$654,000 in 2020 (DFO Policy and Economics Branch).

Commercial species encountered during the video survey included: 388 Northern shrimp (*Pandalus borealis*), 107 Toad Crab (*Hyas araneus*), 40 Snow Crab, six flatfish, four Acadian Redfish (*Sebastes fasciatus*), and two Atlantic cod.

The most widely distributed fauna observed in the proposed sites were non-commercial invertebrates. Brittle Stars (*Ophiurida*) and Green Sea Urchins (*Strongylocentrotus droebachiensis*) were observed in 190 (64%) and 186 (63%) of the 294 stations, respectively. Brittle stars and arrow worms were the most numerous, often observed in clusters of >20 individuals. Soft corals (*Gersemia spp.*) were noted at 2 (<1%) of the stations surveyed, 6+ species of anemone were observed as well as 4+ sponge species. One bed of Ascidian tunicates was observed.

Encrusting algal species (*Hildenbrandia spp.*, *Lithothamnion spp.*) were observed at 74 (25%) stations. A kelp bed with *Agarum spp.* (Sea Colander) and *Laminaria spp.* was observed. Kelps and other macroalgae beds (made up of *Chondrus crispus*, *Desmarestia*, and other mixed macroalgae) were observed in the shallower stations nearshore, outside of the proposed cage array. For some of the deeper sites, allochthonous algal material (detritus) mixed within fine sediments was observed over the deepwater bedrock.

No species identified as at risk by Canada's *Species at Risk Act* (SARA) were observed during the surveys. Based on general distribution maps, DFO Research Vessel (RV) survey data, and/or DFO marine mammal sightings/survey data in general, the following Species at Risk (SAR) can potentially occur in the application site: 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*), Harbour Porpoise (*Phocoena phocoena*), 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*), the Newfoundland population of the Banded Killifish (*Fundulus diaphanus*), and White Shark (*Carcharodon carcharias*). White Shark have been tracked into the south coast of Newfoundland through satellite telemetry and are increasing in frequency (Bastien et al. 2020).

The SARA-listed marine fish species at risk (MFSAR) Northern Wolffish, Spotted Wolffish, and Atlantic Wolffish can be found along the south coast of Newfoundland. 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 eggs have been observed on boulders and rocky crevices at depths <40 m (late summer-fall).

The proposed site falls within the Placentia Bay Ecologically and Biologically Significant Area (EBSA; Figure 2). This EBSA contains important salmon rivers, Capelin spawning beaches (concentrated on the east side of the bay, with a few also found on the west side and the southern tip of the Burin Peninsula), eelgrass habitat (throughout the bay in coves and harbours), 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 2011, 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 the Placentia Bay nearshore region; Wells et al. 2019).

DFO's spring RV survey does not sample the shallow waters of Placentia Bay. Corals and sponges have however been observed in adjacent offshore areas in DFO research surveys and are shown in Figure 3. This in combination with observations at this and other proposed sites indicates that corals and sponges are present in the general area.

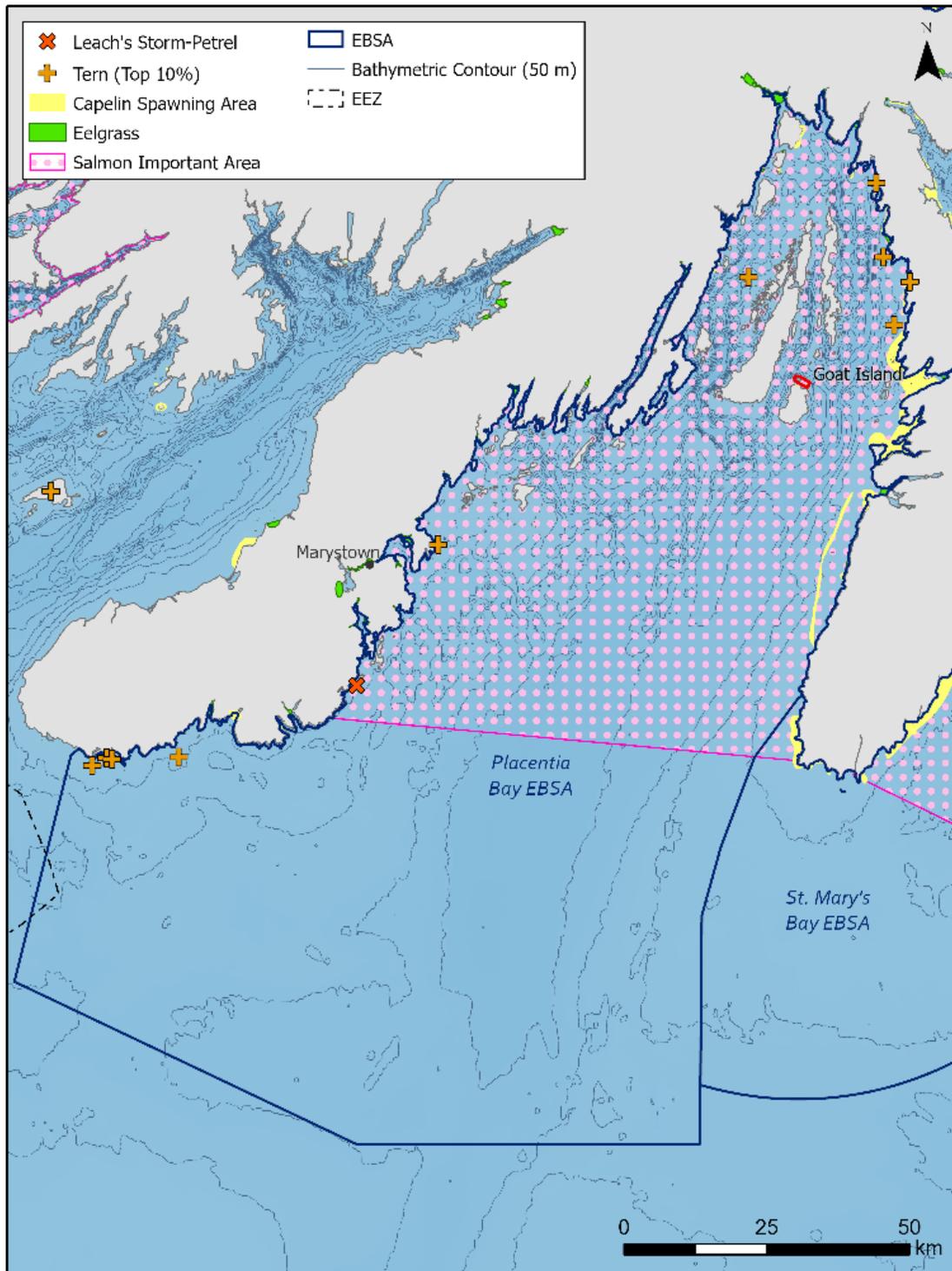


Figure 2: Placentia Bay EBSA; proposed site outlined in red.

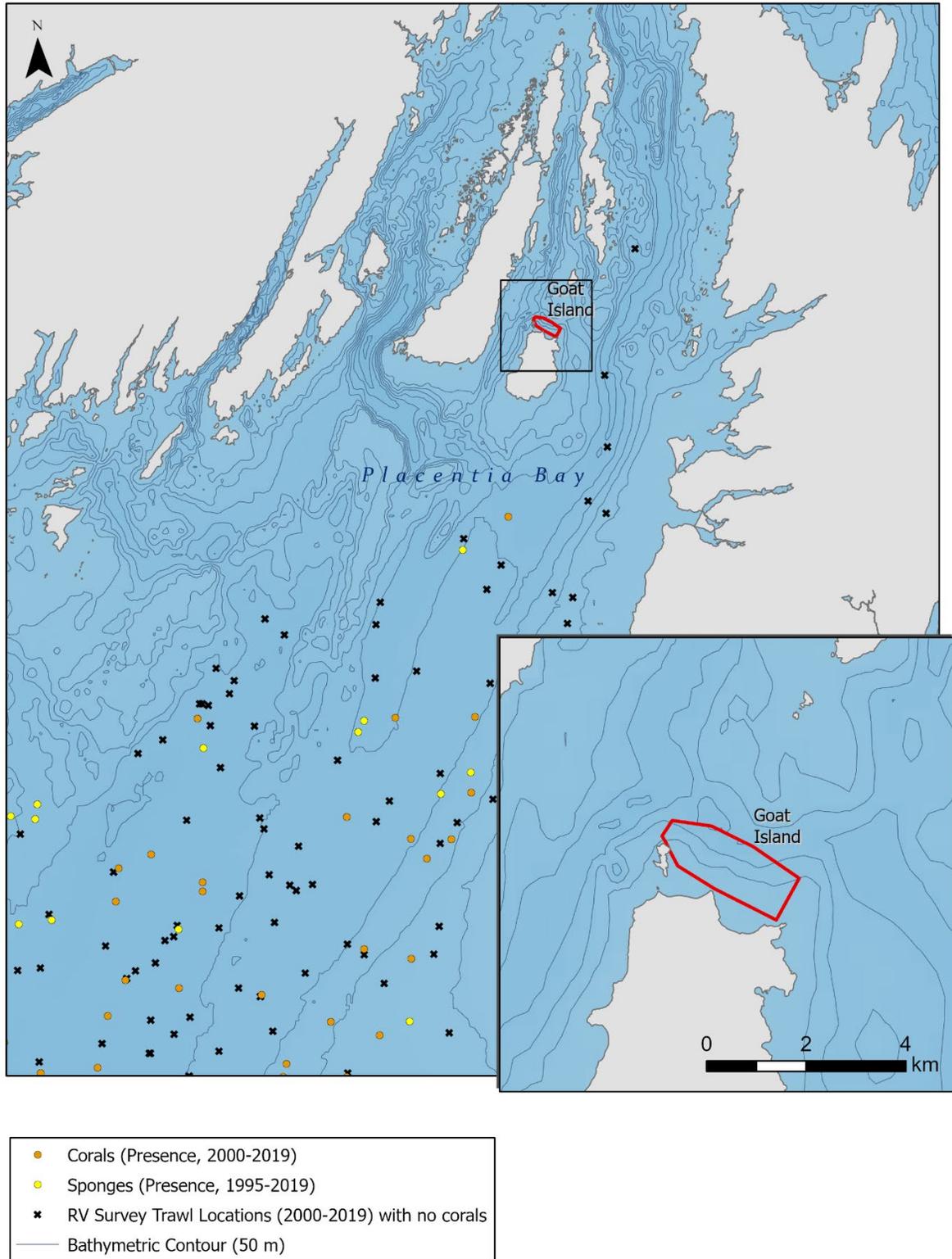


Figure 3: Set locations of DFO’s spring RV survey data from 2000–19 (for corals) and 1995–2019 (for sponges) indicating presence of corals (orange circles) and sponges (yellow circles). Sets that lacked corals and sponges are indicated with a black “x”.

Oceanographic, farm infrastructure, and grow-out information for the proposed Goat Island site is summarized in Table 1.

Table 1: Oceanographic, farm infrastructure and grow-out information for the proposed Goat Island site. All information was extracted from the reports provided by the Proponent for the site licence applications.

Characteristic	-		
⁽²⁾ Dimension [m]	2,830 x 1,120		
⁽¹⁾ Area [ha]	205		
⁽²⁾ Predominant substrate type	hard bottom		
⁽¹⁾ Net-pen array configuration	1 x 12		
⁽¹⁾ Individual net-pen circumference/depth [m]	160/37		
⁽¹⁾ Net-pen volume [m ³]	660,048		
⁽²⁾ Depth under the lease area [m]	7–232		
Depth under the cage array [m]	110–170		
⁽¹⁾ Current measurement period	16-Sept-2019 to 30-Oct-2019		
Current speed [cm/s]	Depth [m]	Speed [cm/s] Mean Max	
	5	7.8	30.2
	15	7.2	31.8
	45	5.7	25.7
	81	5.6	20.2
	114	4.3	20.8
Current measurement type	5, 15 m current profiler 45, 81, 114 m point measurements		
⁽¹⁾ Grow-out period [month]	17		
⁽¹⁾ Maximum number of fish on site	2,000,000		
⁽¹⁾ Initial stocking number [fish/pen]	166,667		
⁽¹⁾ Initial stocking weight [kg]	0.35		
⁽¹⁾ Average planned harvest weight [kg]	5		
Expected maximum biomass [kg]	8,000,000		
⁽¹⁾ Maximum stocking density [kg/m ³]	10		

¹ Values taken from “Aquaculture License Application” document and rounded to the nearest cm/s (i.e., significant figure)

² Appendix 14 AAR Baseline Report Grieg NL Marine Ltd. Part I.

ANALYSIS AND RESPONSE

Sources of Data

Information to support this analysis includes data and information provided by the Proponent, holdings within DFO, publicly available literature, and registry information from the SARA database. The DFO multispecies 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 files submitted to DFO.

Description	File Name
Proposed development plan package Baseline survey data submission	1. Goat Island Application Package 2. Goat Island AAR Baseline Video Files

Current Analysis

Ocean current data were provided by the industry Proponent. The Proponent used two types of measurements, a current profiler for the upper 28 m and point measurement using current meters for three deeper depths (45, 81, and 114 m). The available data from the Proponent do not capture the full water structure vertically. Ocean current data were recorded between 16 Sept 2019 and 30 Oct 2019 and thus do not capture sufficient temporal variability (seasonal and annual). The deepest ocean currents were recorded at depth ~114 m while the maximum depth within the cage area is 170 m and 232 m within the lease area.

Although limited in detail, based on the Proponent's data, Figure 4 shows that higher maximum ocean current speeds were observed near the surface, slightly higher maximum speeds were also observed in the lower part measured by the profiler. Median ocean current speeds show a slight decrease with depth.

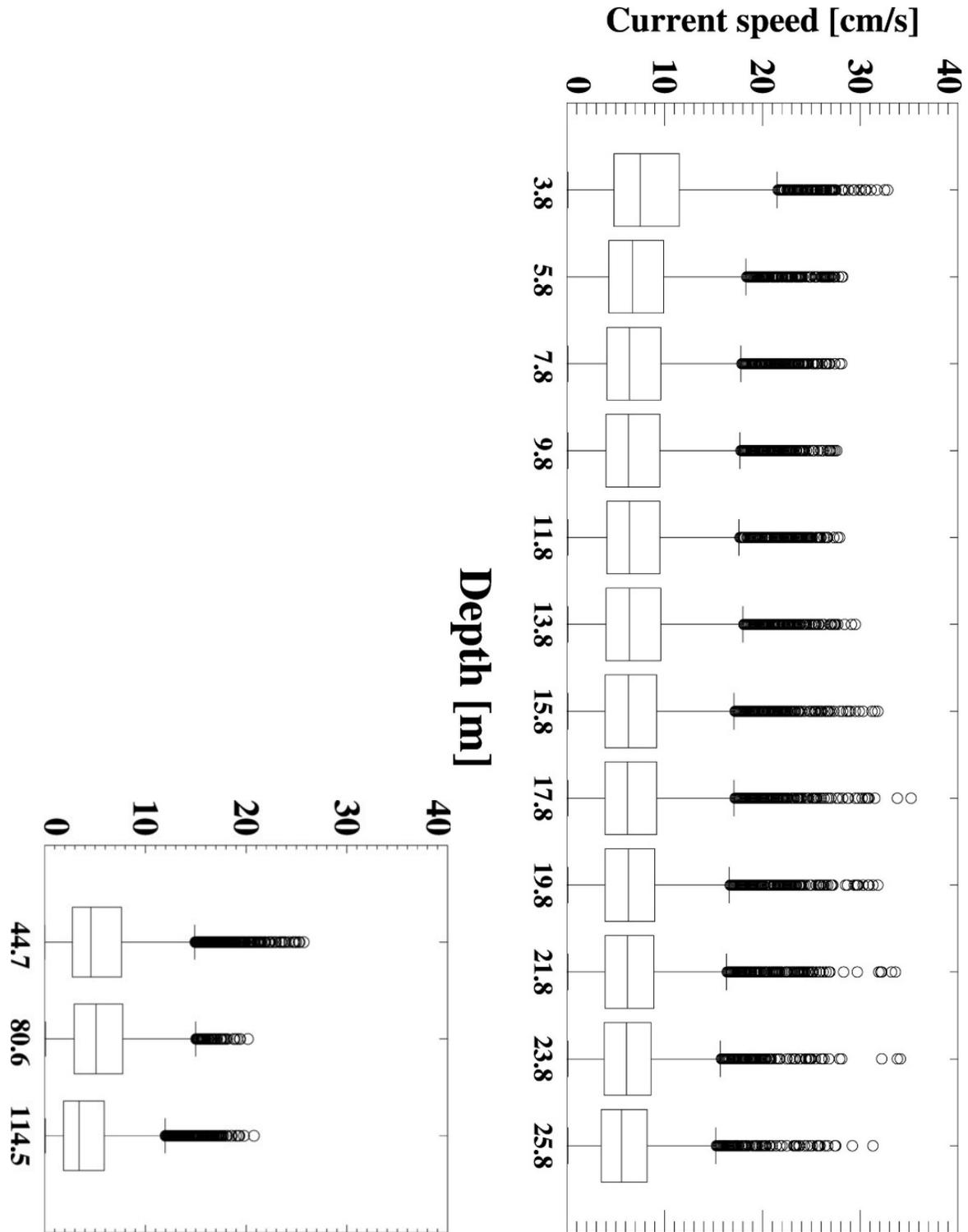


Figure 4: Boxplot of current speed at Goat Island for the period of 16 Sept. 2019 to 30 Oct. 2019 and for all available current profiler data. The boxplot provides information on median and interquartile range (IQR) of data, current speeds above the upper fence (values above 1.5xIQR from the third quartile) are represented with open circles.

Benthic Predicted Exposure Zone

Predicted exposure zones (known as PEZs) are a tool for identifying, albeit at a broad spatial scale, areas of potential exposure for sensitive species and habitats.

The Benthic Predicted Exposure Zone (benthic-PEZ) is an estimate of the size and location of benthic area that may be exposed to the deposit of waste feed and feces released from a site, which can result in organic loading. The PEZ potentially exposed to the deposit of medicated waste feed is known as the waste feed-PEZ, and feces is the fecal-PEZ. The benthos may also be exposed to pesticides released into the water, particularly at shallow depths, however, this impact is addressed through the calculation of the Pelagic Predicted Exposure Zone (pelagic-PEZ). Dominant factors that affect benthic-PEZ are farm layout, feeding practices, and oceanographic conditions (i.e., bathymetry and water currents).

The benthic-PEZ calculation is carried out with as conservative approach as can be achieved while retaining its simplicity. It is calculated by first computing the transport distance (ocean current speeds multiplied by the period of sinking of the particles, feed, and feces individually), and adding half the length of the cage array. Key assumptions for the model include: constant settling velocity of the particles, constant ocean current speed during the particle descent, constant depth (i.e., flat bathymetry), and no resuspension mechanism. The parameters used are: slow sinking velocities (the minimum sinking rate obtained from the literature), fast water currents (the maximum persisting water current speed observed at the site during the sinking or dilution period of particles), and deep bottom topography (the maximum depth over the lease area). The sinking rates for different particulate materials released from farmed fish (i.e., waste feed and feces) vary, although little is known about the distribution of the sinking speeds in relation to the characteristics of the released particles. The rates were obtained from literature 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, Skøien et al. 2016).

Ocean current data were obtained from the Proponent. The current data show slowly decreasing speed towards the seafloor (Figure 4). Since the release of waste particles is considered to happen at the bottom of the cages, the available ocean currents just below the cage depth (~44.7 m) were selected for the calculation of maximum current speed during the sinking period. The selected minimum sinking rate for each category and the corresponding maximum current speed as well as the first-order estimates of the spatial extent of the benthic-PEZ related to organic effluent and in-feed drugs from the proposed Goat Island site are given in Table 3.

Table 3: First order benthic-PEZ estimates of the potential horizontal distances travelled by sinking particles such as waste feed pellets, fish feces and in-feed drugs released from the Goat Island fish farm (settling rates obtained from literature; Findlay and Watling 1994, Chen et al. 1999, Chen et al. 2003, Cromey et al. 2002, Sutherland et al. 2006, Law et al. 2014, Bannister et al. 2016, Law et al. 2016, Skøien et al. 2016).

Particle type	Min. sinking rate [cm/s]	Sinking period [h]	Max. calculated current speed during sinking period [cm/s]	PEZ radius [km]
Feed	5.3	1.2	24.9	1.7
Feces	0.3	21.5	17.	13.8
Fines and Flocs	0.1	64.4	13.1	31.0

The benthic-PEZ is represented by a circular zone centered on the middle of the proposed cage array and represents the outer limit for potential exposure; however, the benthic footprint is

more likely a curved ellipse with a major axis length scale due to current directionality. The zones were estimated by adding the horizontal transport distance to the length of the proposed net-pen array. The spatial extent of exposure is illustrated in Figure 5.

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 risk. The intensity of exposure is expected to be highest near the net-pen arrays and decrease with distance. The waste feed-PEZ is anticipated to have the greatest intensity of exposure given that it happens closer to the net-pens.

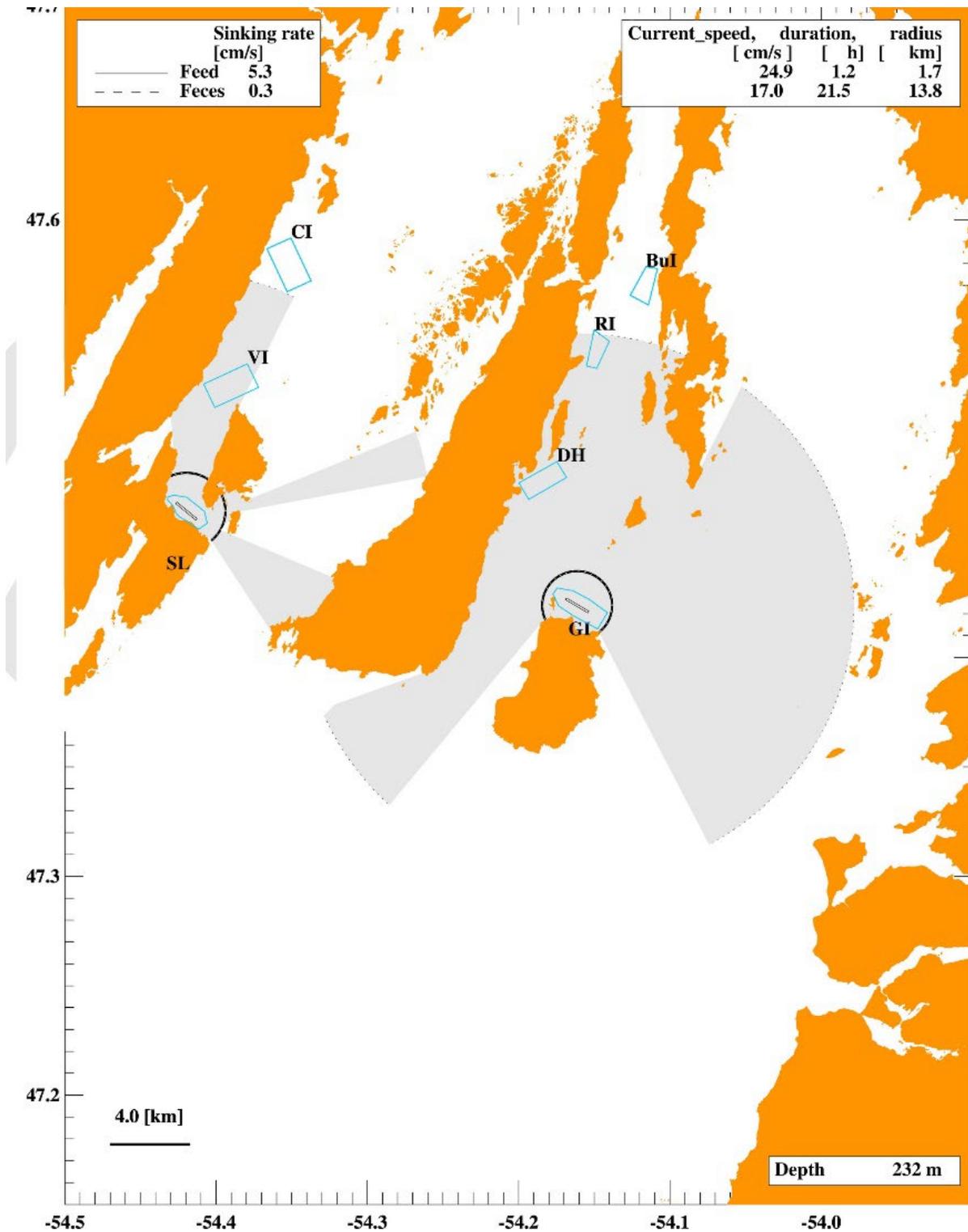


Figure 5: Benthic-PEZ for the proposed Goat Island site. Net-pen arrays (dark grey line) within lease boundaries (light blue polygons) are shown. Black circle delimits the waste feed-PEZ and shaded grey areas the fecal-PEZ. Darby Harbour (DH), Red Island (RI), Butler Island (Bul), Valen Island (VI), Chamber Island (CI), St. Leonards (SL) are licensed sites. Note that benthic-PEZ for SL (calculated by DFO in previous siting documents) is also shown.

Calculation of the fecal-PEZ uses a similar method but uses the maximum current speed for the period of sinking of fecal particles (Table 3). The spatial extent of the fecal-PEZ provides an indication of the full area that could be exposed to any in-feed drugs used. The benthic-PEZ associated with the feed (waste feed-PEZ) and feces particles (fecal-PEZ) covers the region outside the lease area with the latter reaching farther distance.

Current- and wave-induced bottom resuspension is not explicitly considered for these first-order estimates of exposure. However, assuming the ocean current information at 114 m provided by the Proponent also applies to near bottom conditions, ocean currents with speeds over 9.5 cm/s (the critical value for resuspension for the deposition model DEPOMOD, Chamberlain and Stucchi 2007) were observed, suggesting potential for sediment resuspension. The overall impacts of redistribution and flocculant deposition is unknown.

The presented benthic-PEZ does not overlap with a calculated PEZ for any other site. For finfish aquaculture sites that were approved in the original environmental assessment, no PEZs have been calculated. The benthic-PEZ of the Goat Island site does overlap with other finfish aquaculture sites in the same BMA (e.g., the Darby Harbour site). A combined analysis would be necessary should multiple sites in the same BMA be simultaneously active. Each BMA is stocked by year class. (e.g., Red Island BMA 2022, Merasheen BMA 2023, Rushoon BMA 2024, Red Island BMA 2025).

For the interpretation of the PEZ, one needs to consider that PEZ analyses provide estimates only, which are sensitive to data input. The results should be interpreted as an order of magnitude.

Susceptible Species Interactions

Species are considered susceptible within the benthic-PEZ if they are sessile at any life stage and are sensitive to low oxygen levels, smothering, loss of access to the site, or exposure to in-feed drugs (DFO 2022a, 2022b). This includes any species that spends time on the benthos (and has limited vagility), during any life stage. Expansion of aquaculture development at the proposed site increases the risk of anoxic or hypoxic conditions that could potentially impact benthic species (this includes important commercial species such as American Lobster, Snow Crab, and scallop) in the lease area (and benthic-PEZ). This may also impact eggs of fish species.

Special consideration must be given when there is evidence of certain highly sensitive sessile species (such as sponges and corals), and critical habitat (such as eelgrass; DFO 2009) for SARA-listed species in the baseline survey, scientific literature, and Departmental biological data holdings. When the available data are limited, consideration as to whether the benthic substrate type is suitable for the growth of these species is considered instead.

The video survey indicates that the site is a hard bottom characterized by a mixture of cobble and gravel, often mixed with mud/silt, or hard-packed finer substrates. Some stations indicate the presence of crustose algae (*Hildenbrandia* spp., *Lithothamnion* spp), kelp (*Laminaria* spp., *Agarum* spp.), Ascidians and soft corals (*Gersemia* spp.); these species might be susceptible to smothering by finfish wastes. These organisms were present at 32% of the survey stations and often near the shoreline. Cerianthid anemones were also found at ~30% of stations. Certain soft corals, ascidians, and cerianthids are considered indicators of vulnerable marine ecosystems (VMEs) when found in high densities (Murillo et al. 2011). As the specimens reported from the video surveys were not identified to species, it is difficult to say if VME indicator species are present in this area.

Considering the size and location of the estimated benthic-PEZ (1.7 km and 13.8 km radius from the center of the proposed cage array location for waste feed and feces particles falling

from the cage, respectively) the risk of exposure (i.e., smothering, exposure to in-feed drugs) is high from both feed and feces waste.

The most common commercial species noted in the video surveys included Northern shrimp and crabs (*Chionoecetes opilio*; *Hyas araneus*; *Pagurus spp.*), with presence at 98 and 106 stations, respectively. Overall surveys show the presence of benthic and pelagic crustaceans (Table 4 copied from the AAR baseline report).

Table 4: Recorded observations of crustaceans during AAR baseline video surveys.

Crustaceans	# Individuals	# Stations
Hermit Crab (<i>Pagurus spp.</i>)	3	3
Krill (<i>Meganyctiphanes norvegica</i>)	>681	35
Northern shrimp (<i>Pandalus borealis</i>)	338	98
Snow Crab (<i>Chionoecetes opilio</i>)	40	35
Toad Crab (<i>Hyas Araneus</i>)	107	71
Unidentified crab	2	2
Unidentified crustacean	1	1

The presence of the abovementioned commercial species within the benthic-PEZ lends to the potential for these species to be affected by the deposition of feces/medicated feed. The Proponent's Fish Health and Biosecurity Management Plan indicates that the usage of chemical treatments will be prescribed only in cases 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 emamectin benzoate (EMB, an in-feed treatment known commercially as SLICE®), as well as approved pesticides (azamethiphos and hydrogen peroxide; discussed in the pelagic-PEZ section).

In a review of 4 years of publicly available data (2016–19) on chemical usage at salmon sites in NL, results show that sequential chemical treatments are the prevalent approach, EMB with azamethiphos being the most used combination with a decrease in ivermectin usage. There was no usage of teflubenzuron in NL as per the consulted dataset. Relatively high rates of usage of EMB per fish biomass were noted (Hamoutene et al. 2022).

Exposure to in-feed pest control drug EMB through deposition of medicated waste feed and/or fecal excretion is documented to have impacts on crustaceans (e.g., Burrige et al. 2000, Waddy et al. 2002, Burrige et al. 2008, Hamoutene et al. 2023a). These studies report deleterious effects on lobsters (adults and larvae) as well as shrimp species, with less data on crabs. Their presence within the lease area (Figure 6) with potential benthic deposits from the farm activity suggests a potential risk associated with the usage of medicated feed (EMB, ivermectin, teflubenzuron).

How in-feed drugs impact bottom dwelling fish, is unknown but species such as wolffish, would be potentially exposed to contaminated seabed within the PEZ. Although the fish habitat survey and benthic video sampling did not detect MFSAR, it is likely that wolffish are present in the vicinity of the proposed aquaculture site. Thus, the accumulation of waste materials from the cages has the potential to negatively impact benthic habitats (e.g., habitat degradation, mortality of prey species) used by wolffish, for any such habitats within the benthic-PEZ (e.g., nesting sites, feeding grounds).

Wolffish tend to be found in low densities, have low mobility, and a solitary lifestyle; the three wolffish species are widespread in Canadian waters, and each is considered a single Designatable Unit (DU). Under the scenario of single DUs, and life history traits as described above, the anticipated impacts to these species and habitats will be low and limited to the

surrounding areas of the proposed aquaculture activities. Otherwise, if evidence of local populations can be established, then the potential for spatial erosion of those populations should be assessed.



Figure 6: Map summarizing the presence of both pelagic and benthic crustaceans at the Goat Island site (data extracted from AAR baseline reports). Pelagic crustaceans include krill (*M. norvegica*) and shrimp (*P. borealis*) while benthic crustaceans are crabs (mostly snow [*C. opilio*] and toad [*H. araneus*] with some hermit [*Pagurus spp.*] crabs).

Pelagic Predicted Exposure Zone

The Pelagic Predicted Exposure Zone (pelagic-PEZ) is computed 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 a conservative estimate used to determine the spatial pelagic area that may be exposed to a potentially harmful substance.

The two Health Canada authorized pesticides available for use in bath treatments, tarp bath and well-boat, are azamethiphos and hydrogen peroxide (Pest Management Regulatory Agency [PMRA]). The pelagic-PEZ is calculated conservatively, assuming use of tarp bath treatment, regardless of whether all cages would meet the PMRA treatment conditions for application, given the larger exposure zone anticipated to result from the tarp treatment versus a well-boat. Tarp baths involve enclosing the salmon net-pens with tarps and adding bath treatment medicine, where the well-boat method is a more contained environment; fish are pumped into well-boats containing the pesticide (Shen et al. 2019).

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. Health Canada's PMRA has assessed that the pesticides 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 at toxic concentrations for some time (PMRA 2014, 2016a, 2016b, 2017).

For both azamethiphos and hydrogen peroxide, the decay rate of the active ingredient is low compared to the dilution rate. Hence a dilution time scale was used to calculate the pelagic-PEZ. The pelagic-PEZ is estimated using toxicity information of azamethiphos, considered the more toxic of the two pesticides at the time of registration (PMRA 2014, 2016a, 2016b, 2017). A three-hour dilution time scale was used to estimate the time required for the maximum azamethiphos target treatment concentration of 100 µg/L to dilute to the PMRA environmental effects threshold of 1 µg/L (DFO 2013a, b).

The dilution time scale, and hence the size of the pelagic-PEZ, increases as the ratio of the treatment to the threshold concentration increases. The values of threshold concentrations for both bath pesticides were recently discussed in a Canadian Science Advisory Secretariat (CSAS) meeting (Hamoutene et al. 2022), and will continue to be reviewed within DFO. Recent literature indicates that hydrogen peroxide is not as benign as initially assumed (Bechmann et al. 2019, Escobar-Lux and Samuelsen 2020, Escobar-Lux et al. 2020, Mill et al. 2022) and may remain above suggested threshold concentrations. The threshold values for azamethiphos discussed in Hamoutene et al. (2022; 2023b) and available internationally (SEPA 1999) are lower than the threshold used in this modelling exercise. When new thresholds are adopted, new pelagic-PEZs for azamethiphos and hydrogen peroxide will be generated for site applications.

The tarp bath treatments occur in the surface layer thus near surface currents (3.8 m depth) were analyzed and pelagic-PEZ was calculated first by computing the maximum persisting current speed during the period of dilution and multiplying it by the dilution period (3 hour). It 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.

As shown in Table 5, treatment particles can reach a distance of 3.4 km away from the center of the cage array during the three-hour dilution period. The pelagic-PEZ for the proposed Goat Island site is illustrated in Figure 7. The exposure is expected to primarily occur in the pelagic zone; however, since it reaches areas near the shoreline, shallow areas (less than 10 m depth) may also be at risk of exposure to toxic pesticide concentrations.

Table 5: First order pelagic-PEZ estimates associated to the potential horizontal distances travelled by non-sinking particles for a dilution period of 3 h.

Dilution period [h]	Max. calculated speed during dilution period [cm/s]	PEZ radius [km]
3	25.7	3.4

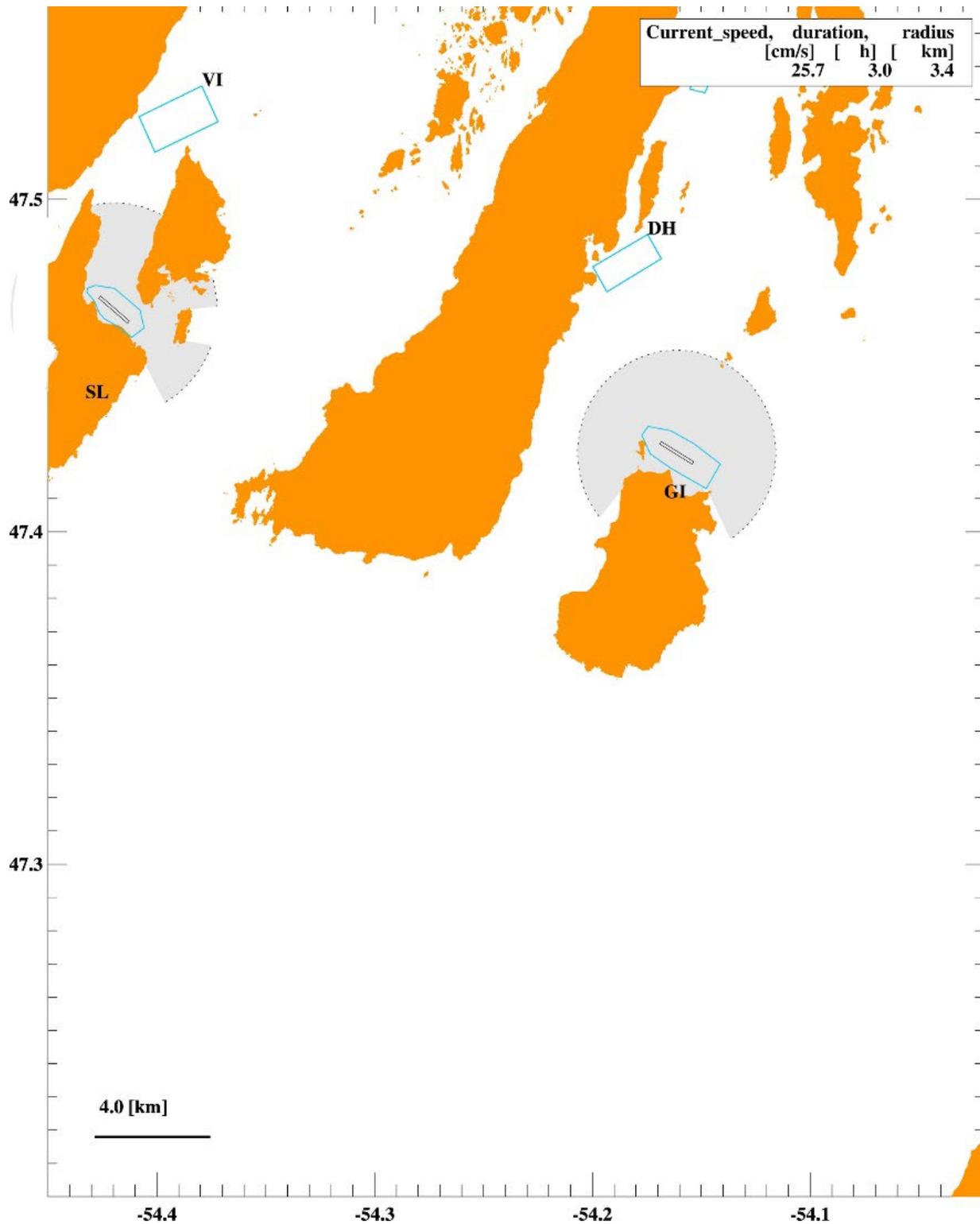


Figure 7: Pelagic-PEZ (shaded grey areas) for the proposed Goat Island (GI) site. Net-pen arrays (grey rectangles) within lease boundaries (light blue polygons) are shown. St. Leonards (SL), Darby Harbour (DH) and Valen Island (VI) are licensed sites. Note that pelagic-PEZ for SL is also shown.

Susceptible Species Interactions

Species are considered susceptible within the pelagic-PEZ if they are known to have sensitivities to pesticide exposures. Specific consideration must be given to the potential for interactions with crustaceans due to their higher relative susceptibility to the pesticides used. Survey data indicate, as stated above, that shrimp, crabs, and krill are present within the pelagic-PEZ for pesticides. Due to their cryptic nature, American Lobster are difficult to detect via the survey, however due to the suitable habitat and presence of a commercial fishery, they are expected to also occupy the PEZ.

Azamethiphos is known to be toxic to crustaceans (e.g., Burrige 2013, PMRA 2016b, 2017). Recent acute toxicity studies have included hydrogen peroxide and azamethiphos and have documented morbidity and mortality effects on a variety of shrimp species (Bechmann et al. 2019, Escobar-Lux and Samuelsen 2020, Mill et al. 2022, Hamoutene et al. 2023a). This risk might be more prevalent for the pelagic stages of the crustacean lifecycle but there is also a risk of exposure to benthic stages (newly settled instars, juveniles, or adults) to toxic concentrations of pesticides that may come into contact with the seabed in the shallow areas of the pelagic-PEZ.

While there are limited toxicity studies directly related to crabs (Hamoutene et al. 2023a), predicted impacts are similar to those on lobster and shrimp given the targeted mode of action of substances like azamethiphos. In addition, tests for both pesticides have documented delayed effects on crustaceans (shrimp and lobster larvae) at concentrations that are lower than recommended treatment concentrations (Bechmann et al. 2019, Escobar-Lux and Samuelsen 2020, Escobar-Lux et al. 2020, Parsons et al. 2020). Although dilution is a factor for the use of pelagic pesticides, active ingredients such as azamethiphos and hydrogen peroxide are proven to be more stable in the formulations used which contain additives, and therefore may lead to prolonged exposures for non-target crustaceans.

Exposure to pesticides could threaten commercial lobster and Snow Crab at all life stages (throughout the pelagic-PEZ). Concern about pesticide exposure for lobster is greatest at shallow sites with lower dispersion patterns and higher juvenile lobster prevalence (Lawton and Lavalli 1995).

Due to risks to seabed crustaceans, the PMRA guidelines restrict azamethiphos usage at shallow sites (i.e., no application to tarped net pens in water depths ≤ 10 m). In addition, any crabs that are in shallow areas are at risk of exposure to pesticides that come into contact with the seabed. A better understanding of the pelagic-PEZ concentrations and timing of dispersion in shallow areas of the bay remains a priority to better characterize risk.

It was noted that pesticides may have negative impacts on commercial crustaceans even in non-lethal exposure events. Behavioural changes, including reduced female reproductive success, have been reported after lobster exposure to sub-lethal doses of sea lice pesticides (Burrige 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 Burrige 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).

There are few studies on the potential effects of pesticides on mussels. An earlier study conducted in 2007 shows that azamethiphos can modulate haemocyte function and immune defense in *Mytilus edulis* at environmentally relevant concentrations after only a few hours (Canty et al. 2007). More recent work on exposure with the giant mussel *Choromytilus chorus*

larvae suggest that azamethiphos can modulate the transcriptome signatures related to early development (Núñez-Acuña 2022).

Bivalve mollusks important from a fishery and aquaculture perspective in the area may be affected within the pelagic-PEZ. For example, other areas where aquaculture operations exist have shown evidence of lower meat to shell ratios (lower meat quality) and thinner shells in scallop (Wiber et al. 2012).

The potential threats of pesticides as they disperse throughout the water currents on large pelagic fish are unknown. However, there are concerns that the use of invertebrate pesticides targeting sea lice at aquaculture sites may kill off copepods and other invertebrates that are the prey of many pelagic species and early life-stage organisms.

Physical Interactions

Groundfish Species Interactions

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 (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. The mean circulation in Placentia Bay is counterclockwise 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 southwestern edges of Placentia Bay in August of 1997 and 1998. 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).

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 (with many types of gadoids, including Atlantic cod, being attracted to finfish aquaculture sites by their excess feed (Dempster et al. 2009, McAllister et al. 2021). Work by Goodbrand et al. (2013) in Fortune Bay, NL found that an acoustic index of the biomass of biological organisms in the water column was two to three times higher in bays with aquaculture sites compared to those without. Further, work by McAllister et al. (2021) collected juvenile and adult cod and Redfish that were present at aquaculture sites in Fortune Bay, NL, and, using stable isotope and terrestrial-based fatty acid analysis, found evidence suggesting that juvenile cod were receiving an energy subsidy from the farm. The data for adult cod and Redfish suggested that they were not receiving an energy subsidy. In Norway, Atlantic cod and other gadoids were often found aggregated in the water column directly adjacent to and below aquaculture nets (Uglem et al. 2014, 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 up to 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. 2014, Gillooly et al. 2001).

Cod are known to consume aquaculture feed (Dempster et al. 2009, McAllister et al. 2021), 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 due to cod being attracted to cages may also impact the availability of cod to harvesters. Aggregations of cod around 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 NAFO Subdivision 3Ps cod as the stock is currently in the Critical Zone and is experiencing high natural mortality.

There is a potential that larval cod could be transported by local currents into the proposed salmon pen from surrounding areas which would have increased predator densities due to the presence of farmed fish in the pens and juvenile and adult fish that are 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 and/or increased predation) can have tenfold or greater effects on their recruitment (Houde 1987).

Pelagic Species Interactions

Pelagic species data in Placentia Bay are moderately limited. Biomass data for Capelin (*Mallotus villosus*) are not available, but it is known that Capelin are seasonally abundant in Placentia Bay from the spring through fall, initially as spawning adults and then later as eggs and larvae. There may also be overwintering populations of juvenile Capelin. Though biomass data for mackerel (*Scomber scombrus*) in Placentia Bay are not available, it is known that mackerel use Newfoundland waters seasonally during summer and fall.

An acoustic survey for Atlantic herring was performed in Placentia Bay in February 2016 that allowed the calculation of a biomass estimate of 19,834 t (DFO In prep²). The main distribution areas for herring were in nearshore waters similar to those used for aquaculture facilities (Figure 8) and herring are likely to use areas where aquaculture facilities are sited.

Aquaculture facilities promote the growth of phytoplankton and potentially zooplankton (Suikkanen et al. 2013) through eutrophication due to increased nutrient loads (Bonsdorff et al. 1997, Callier et al. 2018). Increasing nutrient loading rates to Newfoundland's coastal bays in combination with climate change has the potential to lead to coastal eutrophication and the formation of coastal hypoxic zones (Justić et al. 1996, Laurent et al. 2018). These zones are known to impact benthic productivity and could affect the survival of the eggs and larvae of pelagic fish, depending on the water column structure of hypoxic zones and the vertical distribution of eggs and larvae (Breitburg et al. 2003, Adamack et al. 2012).

The presence of elevated phytoplankton and zooplankton concentrations may serve to aggregate pelagic fish such as herring in bays with salmon farms. Additionally, any lighting used at the aquaculture facility (e.g., for navigation or security purposes) may act to concentrate zooplankton, larval fish, and adult herring to the waters surrounding the facility (Stickney 1970). Use of lighting at night, particularly when larvae are abundant, may expose larval herring and Capelin to increased predation rates as they are drawn to the lights (Stickney 1970, Keenan et al. 2007) which are also areas with higher predator concentrations (both wild fish and farmed salmon).

The aggregation of both piscivorous fish and small pelagic forage species is likely to result in increased mortality rates of the latter (versus their spatial distribution when not aggregated by attraction to salmon farms). Effects are likely to be greater on herring than Capelin and mackerel 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

² DFO. In prep. Assessment of Atlantic Herring in NAFO Div. 3KLPs to 2021. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.

migrate to Newfoundland waters on a seasonal basis (Parsons and Hodder 1970). However, all three species have the potential for increased predation pressure on early life-stage individuals if they pass through waters occupied by fish farms. Work on farmed Atlantic Salmon in British Columbia (BC) has shown predation incidence rates of 0.14 to 1.1% (Hay et al. 2004, Johannes and Hay 2006).

Aggregation of fish by aquaculture facilities may also promote the spread of disease and parasites to and from wild fish stocks. The development of new sites has the potential to increase the ease of spread of diseases between aquaculture sites as it shortens the travel distance/time between sites for wild fish who may move frequently between farm sites (Uglem et al. 2009). The spread of disease is of particular concern as there have been more than 50 incidents of infectious salmon anemia in Newfoundland waters since 2012³ although 18 of the outbreaks involved strains that were not known to cause disease. However, the impact on wild susceptible fish species will depend on the duration and extent of their exposure to the proposed site, the increased concentration of pathogens and parasites, and their relative susceptibility to infection and disease within the environmental conditions found in the area.

Due to the positioning of the proposed cages adjacent to coastline, the relative position of the water column occupied by pelagic forage fish, and their high relative abundance in the ecosystem, it is likely that they will move past or interact with salmon aquaculture cages during their production cycles. Some research indicates infectious salmon anemia (ISA) virus is able to propagate in Atlantic herring and they may be an asymptomatic carrier of the virus (Nylund et al. 2002). Herring are known to move between bays and offshore areas, traveling tens or hundreds of kilometres (Wheeler and Winters 1984).

Recent work by Bouwmeester et al. (2021) identified several potential means by which farmed fish populations may affect the disease dynamics of wild fish stocks. Specifically, farmed fish may co-introduce parasites to the new environment which may infect conspecifics and may or may not infect other wild species, potentially leading to emerging disease. Farmed fish may play host to parasites from wild host species, with the potential to amplify parasite numbers and increase the frequency of parasite infections in wild hosts when the parasite infections spill back to wild populations. Finally, the presence of farmed fish has the potential to alter the transmission of parasites between wild host species, potentially altering wildlife disease dynamics. Collectively, these effects of farmed fish populations have the potential to degrade fish health in an ecosystem through increased rates of disease and parasitism.

³ Canadian Food Inspection Agency. [Locations infected with infectious salmon anaemia.](#)

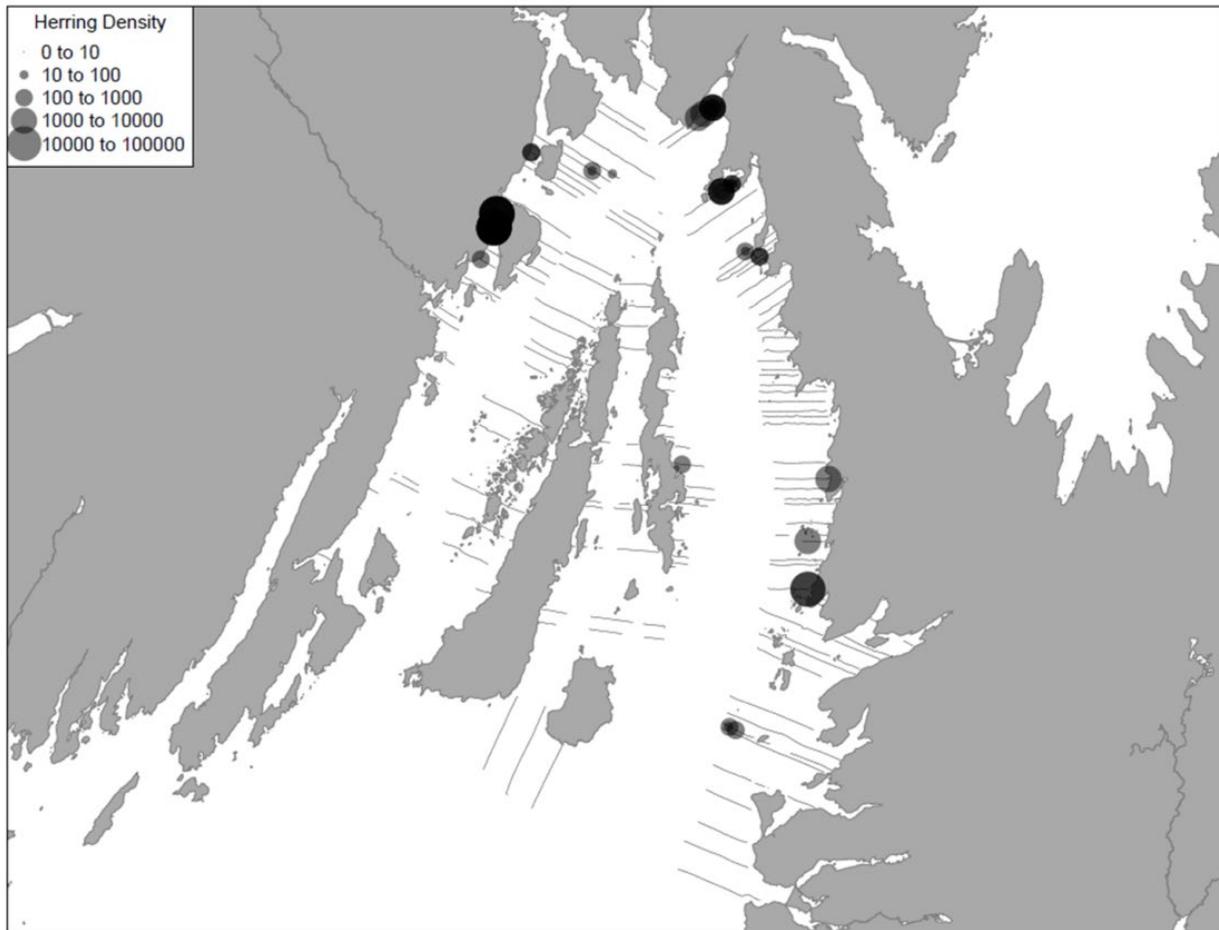


Figure 8: Surveyed transect lines and estimated herring density in Placentia Bay during 2016 inshore acoustic survey.

Salmonid Species Interactions

Placentia Bay is within Salmon Fishing Area (SFA) 10 and contains 31 Atlantic Salmon rivers, several of which are targeted annually in the recreational fishery. Salmon returns on two of these rivers have been monitored in recent decades: Northeast River (Placentia) and Come By Chance River. Since the commercial moratorium in 1992, Atlantic Salmon returns to Northeast River have averaged 827 salmon annually (range: 298–1655). However, more recently (2016–21), returns have averaged 556 salmon annually. This population has been assessed in the Healthy Zone in all years aside from 2020 when it was assessed in the Critical Zone (DFO 2022c). Atlantic Salmon returns to Come By Chance River were monitored in 2021, however, the count of 78 salmon was incomplete due to environmental conditions (DFO 2023). As of September 11, 2022, preliminary counts suggest that at least 187 salmon have entered Come By Chance River this year.

In recent years, DFO Science (Salmonids Section) has used acoustic telemetry to understand the residency, survival, and movements of Atlantic Salmon smolts from two rivers in northwest Placentia Bay (Figure 9). During the three-year study, a total of 132 smolts (51 in 2018, 39 in 2019, and 42 in 2021) were tagged with acoustic transmitters. All smolts tagged in 2021 were from Bay de l'eau River. In all years, several tagged smolts moved throughout the primary study area from mid-May to early July and typically remained within the receiver array for 6–8 weeks

(Figure 9, Figure 10). In 2021, 5 of 42 tagged smolts were detected on acoustic receivers deployed by DFO Science (Groundfish Section) to study Atlantic cod movements in the western channel off Merasheen Island and the eastern side of Placentia Bay during the last week of June and first week of July (Figure 9). In 2021, an acoustic tag with temperature and depth sensors was inserted into one smolt on Bay de l'eau River which was detected almost 3,000 times in the receiver array. This smolt predominantly occupied water temperatures of 5–10°C (mean=7.8°C) and depths less than 10 m (mean=5.0 m). Together, these data may indicate that the islands in the northwest and northeast regions of Placentia Bay are a rearing habitat used by wild Atlantic Salmon smolts during the first few months of their marine migration prior to moving south and leaving Placentia Bay later in the summer/fall. The potential for migrating wild Atlantic Salmon smolts from Placentia Bay populations to be exposed to cage sites in that region, including the proposed Goat Island location, is high.

Both past commercial 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. Reddin and Lear (1990) describe the tag returns from the commercial fishery. Salmon tagged within Placentia Bay were largely recaptured within Placentia and St. Mary's Bays, although some recaptures did occur around Newfoundland and in two rivers in the Gulf of St. Lawrence. Salmon tagged in locations like St. Lawrence (1973), Placentia Bay (1975), and throughout the east coast were recaptured across the south coast (e.g., Burgeo, Port aux Basques) and throughout the Maritimes (Reddin and Lear 1990). 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 data from the St Pierre-Miquelon mixed stock fishery analysis (ICES WGNAS 2020 Report) was dominated by contributions from Gulf and Gaspé Peninsula regions and had a smaller contribution from the northeast coast of Newfoundland. These historical datasets indicate that salmon that occupy Placentia Bay at one or more periods of their migration/life history may interact with populations outside their management unit (SFA 10). Pathogens and parasites can potentially be transmitted to migrating fish and represent a significant source of potential impact that does not require escape events.

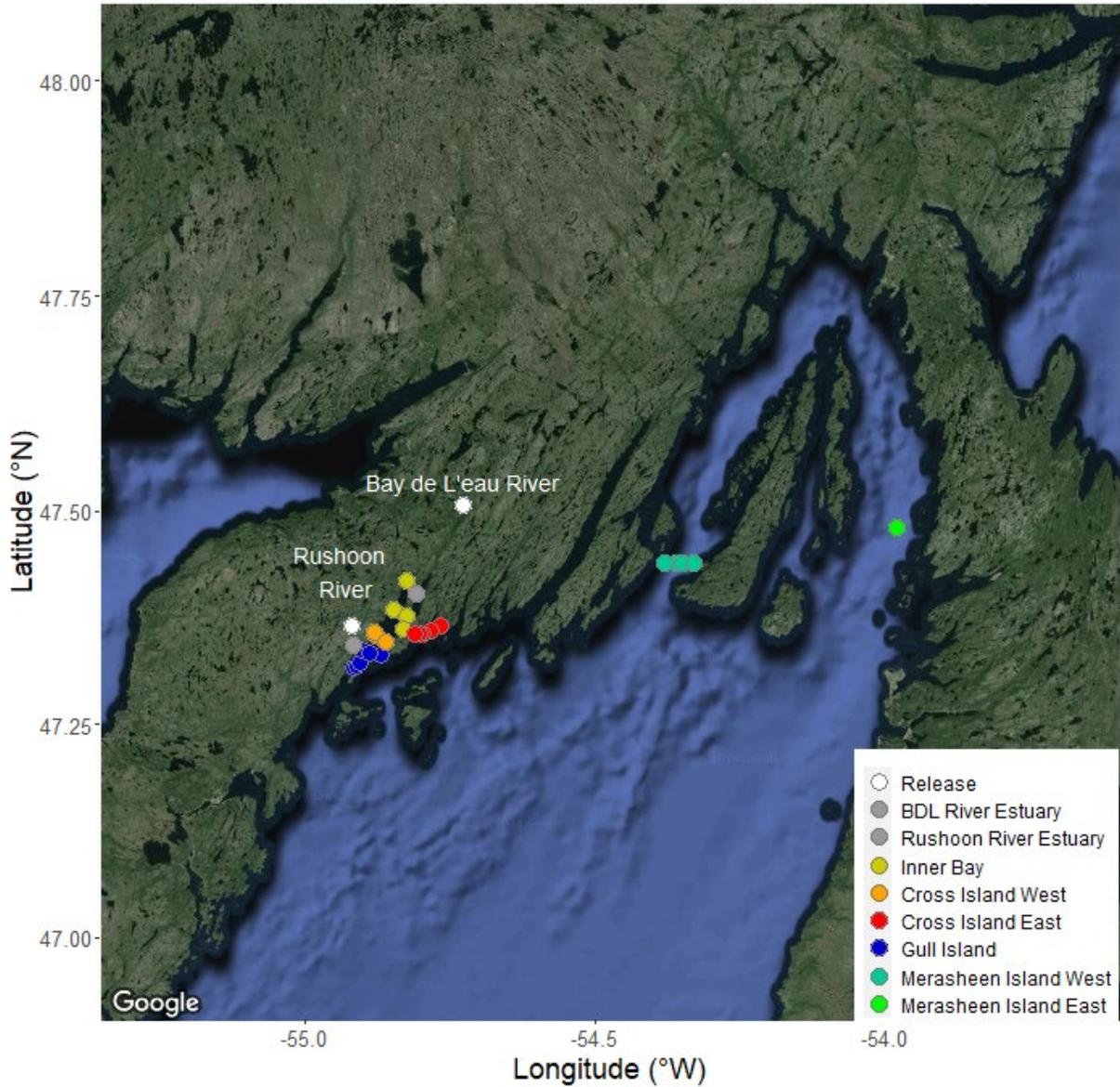


Figure 9: Map of acoustic receivers deployed (2018, 2019, and 2021) to track where tagged Atlantic Salmon smolts were detected, including 20 deployed in northwest Placentia Bay by DFO Science Salmonids Section and 5 deployed near Merasheen Island and eastern Placentia Bay by DFO Science Groundfish Section.

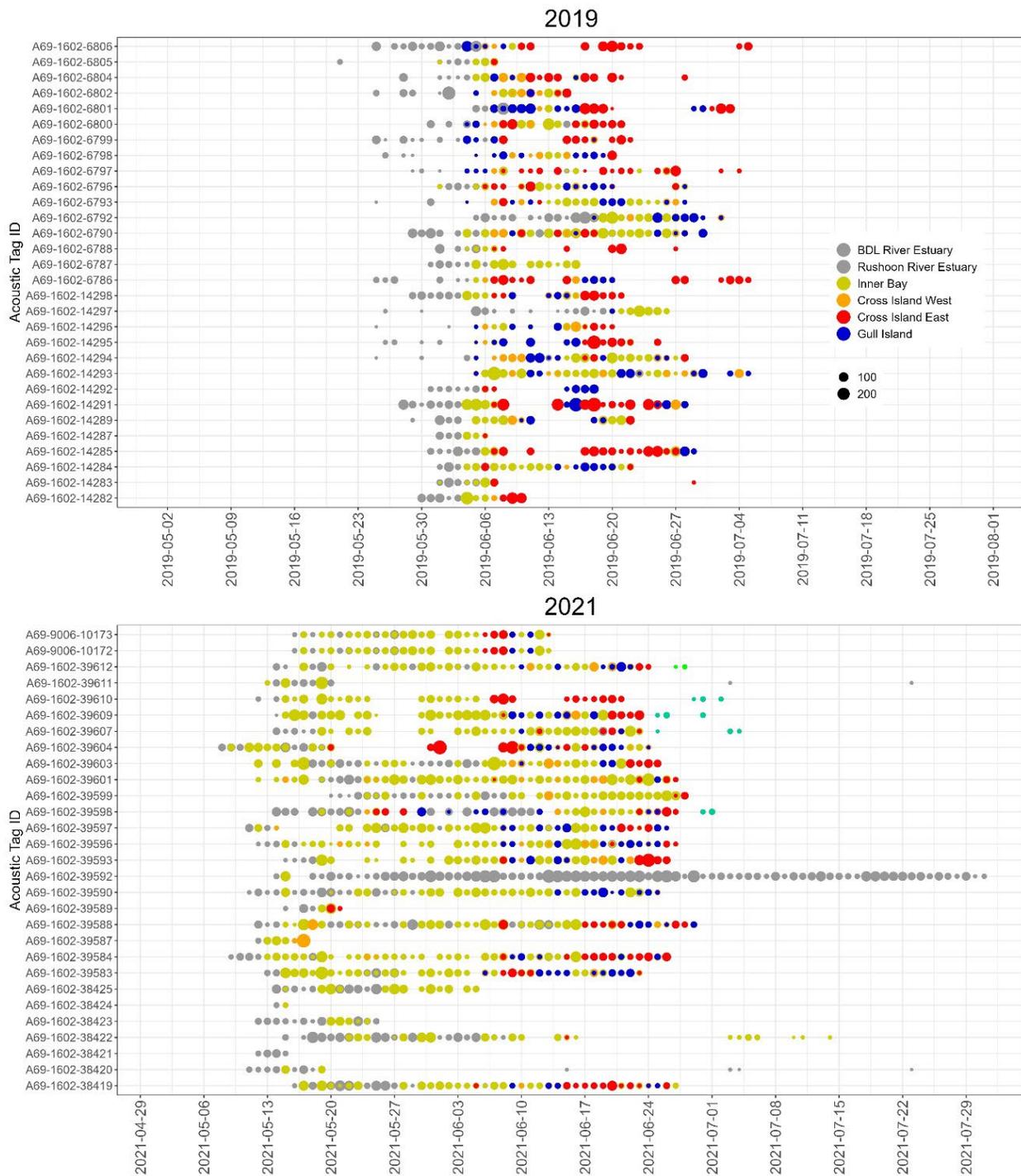


Figure 10: Count plot showing detections per day for acoustic-tagged Atlantic Salmon smolts from Bay de l’Eau River (2019 and 2021) and Rushoon River (2019 only). Detections were pooled for each day across all receivers in the array. Points are coloured to represent area within the receiver array where detections occurred (see Figure 9).

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).

A substantial and growing body of research (Dionne et al. 2007, 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, 2018, Nylund et al. 2019).

Information about pests and pathogens on salmon farms in NL is limited to regulatory and licensing public reporting requirements. The Government of NL licensing requirements for incident reporting are outlined in its 'Aquaculture Operator Incident Reporting Guidelines', and state reporting requirements for abnormal mortality, disease events, and suspected or confirmed escapes. Aquaculture operators fulfill these requirements with industry statements posted on the Newfoundland Aquaculture Industry Association (NAIA) website. Further to this, as a condition of licensing, aggregated monthly sea lice abundance numbers must be reported publicly, and the website is used to satisfy this requirement.

The Government of NL 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 NL. The summary included diseases, Canadian Food Inspection Agency (CFIA) reportable viruses, and parasites identified during the aquatic animal health inspections conducted in 2015, plus a list of 20 diseases historically detected in NL wild and farmed finfish.

Reportable diseases

Of significant importance to aquatic animal health are reportable diseases. Individuals, organizations, and businesses who own or work with aquatic animals and know of or suspect a reportable disease is required by law to notify the CFIA. To date, two such diseases have been reported in finfish in Newfoundland: infectious salmon anemia virus (ISA; total of 25 entries) and viral hemorrhagic septicemia (VHS; total of 3 entries; CFIA 2021a, 2021b).

ISA is considered endemic in Atlantic Canada and is commonly detected in marine Atlantic Salmon aquaculture at levels not known to cause disease (non-virulent; DFO 2020a). There has been at least one confirmed case of virulent or non-virulent infection annually between 2012–21 in Newfoundland Atlantic Salmon (CFIA 2021a). This includes the recent positive detection of ISA in two fish on an Atlantic Salmon farm along the south coast of Newfoundland that required removal of fishes raised in the same cage to mitigate the risk of viral spread (ASF 2020).

Infections with VHS virus (VHSV) have been reported in over 80 species including Salmoniformes (salmon, trout, whitefish; 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 VHSV in at least one instance in each of three years (2016, 2019, and 2020) and there have been no detections reported in Atlantic Salmon (CFIA 2021b). Due to the positioning of the proposed cages, 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 the 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). The prevalence and abundance of *Lepeophtheirus salmonis*, the most common sea lice infesting farmed Atlantic Salmon (Saksida et al. 2015), vary based on the origin of fish (i.e., farmed versus 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 recent decades (Brooks 2009, Krkošek et al. 2011, Torrissen et al. 2013).

Wild salmon smolt survival can be impacted by exposure to sea lice. Migrating smolts have been shown to have reduced one sea-winter returns to natal rivers and a shift in relationships between ocean climate and returns; rivers 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 resulted in a 55 times higher likelihood of survival (Bøhn et al. 2020). Although no data exist on sea lice-induced mortality in Placentia Bay, the addition of 2,000,000 farmed fish to the bay can be expected to amplify both endemic pathogens and sea lice in the area, due to the increased abundance of host fish.

Increased disease susceptibility of triploid fish

There are currently 13 aquaculture sites licensed in three BMAs within Placentia Bay. Each site is licensed for a maximum of 2,000,000 fish. However, each BMA will have a maximum of 7,000,000. There is potential for a maximum of 14,000,000 farmed fish present in Placentia Bay if the BMAs containing the two grow-out year classes are fully stocked.

Data for southern Newfoundland indicate 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. However, given recent data from Norway suggest significant increases in disease susceptibility of triploid Norwegian salmon (Stien et al. 2019), additional measures to detect any increase in disease or infection susceptibility and mitigations, 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

Several Atlantic Salmon rivers targeted annually in the recreational fishery drain into Placentia Bay. Any long-term impact from transmission of disease/parasites to wild smolts could have negative impacts on the abundance 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 to 8 weeks prior to moving further south into the bay (Nicolas Kelly, unpublished data); therefore, it is plausible that the addition of the proposed site will potentially impact the wild populations, increasing disease and parasite transmission.

The fish health impact of farmed Atlantic Salmon sites on wild susceptible fish species will depend on the 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 to farms, and the wild fish susceptibility to infection and disease within the environmental conditions found in Placentia Bay.

Aquaculture Escapees

Escaped farmed salmon interacting with wild conspecifics can result in decreased fitness for wild populations through ecological and genetic interactions. In addition, transmission of disease/parasites to wild smolts can also have negative impacts on the abundance of local populations. The proposed site's proximity to several salmon migration rivers could impact smolt behavior, residency, and survival in the early phase of their marine migration.

Genetic studies over the last decade have documented widespread hybridization between wild salmon and aquaculture escapees both in southern Newfoundland and the Maritimes (Holborn et al. 2022, Keyser et al. 2018, Sylvester et al. 2019, Wringe et al. 2018). 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. Recent work in the region suggests that smaller populations in accessible rivers may be most at risk (Sylvester et al. 2019). In southern Newfoundland, the precocial maturation of male wild-farm hybrid parr has been documented, likely fast-tracking introgression (i.e., transfer of genetic material from farmed escapees to wild populations) and subsequent genetic impacts (Holborn et al. 2022). Overall, research over the last decade indicates that genetic impacts of farmed escaped salmon are present in southern Newfoundland though significant uncertainty exists as to the magnitude. In the context of this site evaluation, the use of European origin salmon or individuals with European ancestry adds significant uncertainty and could elevate the potential impact of escapees on wild populations (Bradbury et al. 2022), though the use of triploid/sterile salmon at the Goat Island site significantly mitigates this risk and uncertainty with respect to direct genetic interactions (DFO 2016).

The distribution of escapees in the wild under the proposed production regime (existing and proposed expansion) were modelled using a spatial model of dispersal and survival (Bradbury et al. 2020). Model predictions for individual rivers were evaluated against a 10% threshold for the proportion of escapees relative to wild population size, above which demographic decline and genetic changes have been predicted in wild populations (Bradbury et al. 2020). Wild population sizes were estimated based on habitat area and corrected for recent population declines through comparison with recent salmon assessment data (DFO 2022). The number of expected escapees per unit production was estimated using both Norwegian (2011–21) and Newfoundland data on licensed maximum production and escape events as ~0.2 escapees per tonne production and compared with a corrected value (i.e., 0.4) for unreported escape events following Skilbrei et al. (2015). The model accounts for periods of fallowing and production losses as stated by the Proponent, and assumes a 5 kg harvest weight.

The potential direct genetic interactions resulting from this proposed finfish expansion site (2 million individuals/site) on the eastern side of Placentia Bay 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 use of European-origin salmon by the Proponent here likely elevates the genetic impact of escapees on wild NL Atlantic Salmon and as such the use of all-female sterile triploids was previously recommended (DFO 2016). Based on the available literature and testing results, it seems likely that a 98% success rate is expected for triploidy/sterility induction, so we assume 2% farmed salmon at this site are diploid individuals. 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 (i.e., 2% of total production number). The model here assumes the stated 20% production losses included in the application. Under the likely scenario where the farmed fish in the Placentia Bay are 2% diploid, escapee dispersal simulations suggest there is no significant increase in the number of escapees (<1% increase). Under these conditions, none of the southern Newfoundland salmon rivers east of the Burin

Peninsula (Southern Newfoundland East DU) are predicted to exceed 10% diploid escapees both prior to and with the inclusion of the proposed site (Figure 11). At the regional level (east of the Burin Peninsula), the proportion of diploid escapees does not exceed 10% and is predicted to be less than 1% at both 0.2 and 0.4 diploid escapees per tonne production. The stated inclusion of an escapee monitoring program within Placentia Bay and the capacity for traceability of escapees provide additional means to evaluate and mitigate risk to wild salmon in the region associated with this site.

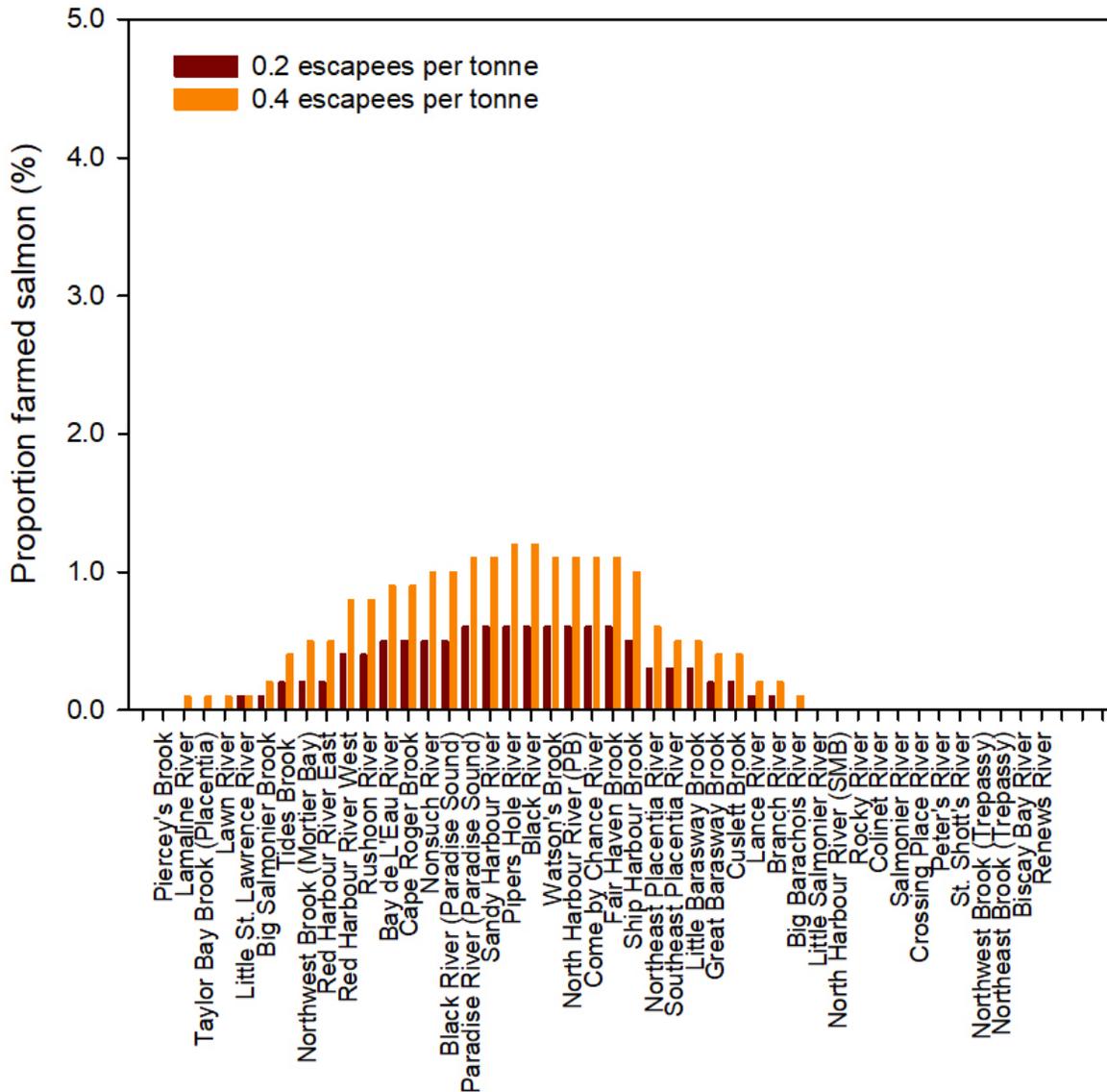


Figure 11: Predicted proportion of escaped farmed salmon in rivers of southern Newfoundland relative to wild population size with the inclusion of the Goat Island site. Brown bars indicate simulations using 0.2 escapees per tonne production and orange bars indicate 0.4 escapees per tonne production, see text and Bradbury et al. 2020 for details.

Cleaner Fish Escapees

Cleaner fish such as wrasse and Common Lumpfish (*Cyclopterus lumpus*) are increasingly 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 using Common Lumpfish as cleaner fish in salmon aquaculture. The Proponent includes this in their application for the proposed site. However, as with Atlantic Salmon, research suggests genetic interactions between escaped cleaner fish and wild populations warrant consideration as negative impacts are likely (Blanco Gonzalez et al. 2019, Faust et al. 2018, 2021). DFO-NL spring multispecies surveys in Subdivision 3Ps indicated declines in Lumpfish 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 DU (COSEWIC 2017), recent genetic analysis (Ian Bradbury, pers. comm.) suggests the presence of a distinct northern population which includes southern Newfoundland, and further structuring within that group around the island of Newfoundland. There remains considerable uncertainty with regards to the potential impact of the proposed expansion on local Common Lumpfish populations. However, given the status of this species in the Region, and evidence of negative genetic impacts of cleaner fish on wild populations elsewhere, the potential exists for negative interactions in southern Newfoundland.

Entanglements

Entanglement of megafauna (e.g., wild fish, marine mammals, turtles, and sharks) associated with the placement of infrastructure is another potential interaction associated with aquaculture sites. Entanglement can cause drowning, direct injury from ropes and nets, fatigue, and starvation. Interactions that result in the death of megafauna have reduced dramatically over the past two decades due to improved anti-predator netting, improved anchoring, and the prompt removal of attractants, such as dead fish (DFO 2022d).

Whales

There is a lack of information regarding the distribution of marine mammals in the aquaculture lease area under review as few scientific surveys have been completed in the coastal area of Placentia Bay. In this situation, Local and Traditional Ecological Knowledge collected from consultations would be valuable to assess the potential for entanglements. There is overlap with the distribution of several species of whales (Blue Whale, Fin Whale, Humpback Whale, Minke Whale, Sei Whale, North Atlantic Right Whale, Sperm Whale), several species of dolphins, and Harbour Porpoise. Based on opportunistic and systematic sightings data, these cetaceans can occur in Newfoundland waters year-round with seasonal peaks in abundance occurring typically in summer and fall.

Data on cetacean entanglement associated with aquaculture infrastructure are largely not available in Canada. BC provides data on marine mammal fatalities at marine finfish aquaculture sites from 1990 to 2022 (DFO 2022d). From 1990 to 2015, there were two reports of cetacean fatalities that included one Harbour Porpoise and one Humpback Whale found dead at an aquaculture site, but cause of death was unknown. Between 2016 and 2021, there were five reported Humpback Whale entanglements at aquaculture sites in BC, and two of these entanglements were fatal. DFO (2022d) noted that Humpback Whales, like other baleen whales, are more prone to entanglement because they do not use echolocation for navigation and have become more numerous in BC coastal waters in recent years. In Newfoundland there have not been any reported cetacean entanglements with finfish aquaculture net pens to date; however, in 2018 a Humpback Whale was entangled in a gillnet deployed to capture escaped farmed salmon in Hermitage Bay. It was freed later the same day.

Seals

Seal species such as Harbour Seals (*Phoca vitulina*) and Grey Seals (*Halichoerus grypus*) occur in Connaigre Bay regularly and may have haul-outs in the lease area, particularly near islands and rocks. Compared to cetaceans and sea turtles, the risk of entanglement may be higher for pinniped species 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.

Similar to cetaceans, data on pinniped entanglement associated with aquaculture infrastructure are largely not available in Canada. In BC, the most common marine mammal fatalities at aquaculture sites were Harbour Seal and California Sea Lion (*Zalophus californianus*); however, the vast majority are authorized fatalities that were permitted prior to March 2020. DFO (2022d) publicly provided data on marine mammal fatalities (authorized and accidental) for 2011–22. Over that period, 78 authorized fatalities and 50 accidental drownings were reported for Harbour Seal. In Newfoundland, there have not been any reported pinniped entanglements with finfish aquaculture net pens to date.

Turtles

Leatherback and Loggerhead Sea Turtles are known to frequent Newfoundland waters during summer and fall to forage, but do not nest in Canada. Placentia Bay was identified as containing important habitat for Leatherback Sea Turtles, which are known to frequent the entire bay (DFO 2012, Wells et al. 2019). Loggerhead Sea Turtles typically occur offshore along the continental shelf break and beyond, from Georges Bank to the southern Grand Banks in summer (DFO 2020a) and are not expected to occur in the proposed aquaculture lease area. In Newfoundland there have been no reported turtle entanglements with finfish aquaculture net pens to date. While entanglement and subsequent drowning are concerns, the risk of entanglement is considered low at the proposed site.

Sharks

White Shark 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) has been documented previously, and an increased presence of White Sharks has 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 in sea cages cannot be disregarded. 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. To date, there have been no reports of White Shark entanglements in marine finfish aquaculture gear in Atlantic Canada.

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. These guidelines should include:

- Collection of temperature and salinity profiles at the site of interest during the expected maximum feeding season for the whole water column, as well as dissolved oxygen (DO) within the upper layer. Collection of ocean current observations at the site of interest, preferably using a current profiler, or, if using single point instruments, at depths

representative of the water structure (i.e., water masses) during the expected maximum feeding season for at least 3 months. This would provide the necessary information for a depositional model to be run with 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 variable input details, justified site-specific depths of current series input (if the model requires such depth 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, if available, or for the Region where the site is located to ascertain potential risks of extreme temperature events (e.g., consultation of DFO Marine Environmental Data Section archive).
- Provision of an estimate of oxygen demand from the cage/farm and its environmental availability (e.g., using DO measurements over the course of a year). This would provide a carrying capacity estimate to frame more robust mitigation measures in case of heat waves/low availability of DO.
- Provision of an estimate for nutrient loading (nitrogen and phosphorous) from the proposed site.
- Provision of a description, which can be based on available literature, of potential site/Region specific risks associated with climate change.

It is also suggested that DFO 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 PEZs are computed based on water current data provided by the Proponent. The Proponent made an effort to collect current data at various depths at the proposed site; however, the means used to measure the currents do not allow for a clear understanding of the variability within the water column. The Proponent used current profilers in the upper 28 m near the sea surface and point measurements at 3 deeper depths using current meters which prevented the provision of a more detailed description of the structure of the whole water column. This is a limitation in the determination of a conservative current speed value. Thus, only limited data, covering a portion of the water column, could be used in the calculation. Further, current measurements were only collected at a single location for a part of a season (less than 60 days); this does not allow for the assessment of seasonal variability. The available current data do not correspond to the desired maximum feed period season (summer-fall). As a result, the PEZs presented correspond to the conditions that would be experienced during late fall (i.e., the season when data were collected). The first-order PEZ calculation assumes that the current is spatially homogeneous and seasonally consistent. This may influence the estimates of exposure, deposition zones, and intensities over the area of interest and over the period of the year. Validation and sensitivity analysis of the transport and deposition models is ongoing for the NL Region. Uncertainties regarding the estimated deposits can be important; they are unknown for the Proponent's dispersion results.

In terms of modeling the deposition, the Proponent used the coastal hydrodynamic 3-D circulation model, Delft3D-FLOW (Deltares 2022) with a nested version at higher spatial resolution around the site, to better capture the spatial variability near and around the proposed site; the hydrodynamic model used is suitable and the method is relevant. To use the output of the circulation model to simulate deposition, it is necessary to validate it with observation (e.g., comparison of the current speed timeseries between observation and model output); the comparison of statistics between observation and model output shows some discrepancy which may indicate the need for tuning of the model (e.g., measured currents show lower mean speed and lower standard deviation than the model output near the surface and near the bottom). Comparison of the modelled water structure (distribution of temperature and salinity) with observation is also a requirement; Ma et al. (2017) discusses the importance of stratification on the circulation in the bay. Only upon such validation and tune-up of the model should the output be used for waste dispersion calculation.

A plot illustrating the stratification (temperature and salinity profiles) and how it evolved along the simulation (start and end of the run) would improve confidence in the results presented (no or limited overmixing). Validating the temperature and salinity fields with observations would have been valuable. This could have been possible using the data presented/described in the application. Alternatively, available data comparisons (i.e., from smartatlantic and/or archived data [BIO climate⁴]) may be useful to increase confidence, especially in the absence of appropriate ocean current data.

The method used to calculate extreme values of currents may not be appropriate. A reference is needed to understand the parameters used in the calculation. Extreme values analyses (Gumbel type) need site-specific data to be valid. Using coefficients determined in what could be a quite different environment cannot be representative. Knowing that the Region is 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 current calculations will need further verification for the south coast of Newfoundland.

Potential effects of global warming are not presented; these could be important with respect to mass mortality risks (e.g., summer heat waves, winter superchill events, the susceptibility of the system to the formation of hypoxic zones). It could also be important with respect to potential pest and disease outbreaks (e.g., sea lice). In addition, the mitigation measures against potential extreme temperature events (warm or cold) are lacking in detail; in particular, no quantitative estimates are provided for the oxygen demand from the cage/farm and its effect on the environmental availability (a heat wave issue).

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 a new aquaculture site in Placentia Bay, it is important to note that the addition of this site is not happening in isolation. There are many other human activities occurring in the Placentia Bay ecosystem and its surrounding watersheds, including other finfish aquaculture sites, which all have some effect on the ecosystem. Additionally, there are broad-scale processes affecting the Placentia Bay ecosystem including global climate change and ocean acidification. The interactions between many of these effects can be

⁴ [Bedford Institute of Oceanography](#).

multiplicative, which may result in seemingly minor perturbations having disproportionately large impacts on the ecosystem.

Increases in aquaculture activity in Placentia Bay are likely to result in accumulating effects on the bay's ecosystem, and those additional effects are accumulating in combination with other stressors on the system such as anthropogenic climate change and marine shipping, which are not being currently considered during site application reviews.

The Placentia Bay region has ~60 communities and a population of ~25,060 (Placentia Bay Integrated Management Planning [IMP]). 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 shipping 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 (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 (Breitburg et al. 2018).

The level of nutrient loadings from aquaculture facilities requires discussion. In the Åland Archipelago in Finland, 35–40 fish farms producing ~5000 tonnes year⁻¹ of rainbow trout produced nutrient loads comparable to the amount of treated wastewater from a city with ~370,000 people for phosphorous and ~90,000 people for nitrogen (Bonsdorff et al. 1997). Assuming that feed use patterns are similar between Rainbow Trout and Atlantic Salmon aquaculture facilities, the Goat Island facility in Placentia Bay would initially produce ~4,000 tonnes of year⁻¹ Atlantic Salmon growing to 8,000 tonnes at maximum production. This would initially be comparable to cities of ~296,000 people and ~72,000 people in terms of phosphorous and nitrogen emissions respectively, doubling at maximum production. At the BMA level, the maximum amount of salmon that can be raised at one time is 6 million, while bay-wide, it is allowable to have two year-classes of salmon growing at any one time, resulting in a maximum total of 12 million farmed fish in the Bay at any one time. Based on aquaculture production estimates for these stocking levels, this would translate into 24,000 tonnes of salmon production at a BMA level and 36,000 tonnes on a bay-wide basis. In terms of nutrient pollution, salmon aquaculture facilities in a BMA would release an amount of phosphorous equivalent to a city of ~1.78 million people and nitrogen equivalent to a city of ~0.43 million while the bay-wide salmon aquaculture phosphorous and nitrogen releases would be equivalent to cities of ~2.66 million and ~0.65 million people respectively. These nutrient releases are in addition to the already existing nutrient loading from sewage discharge, by-products from fish processing, and runoff from agriculture operations (e.g., pig and chicken farming; IMP) in the bay's watersheds.

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 and examining their potential impacts on oxygen demand is 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 2–5 mg L⁻¹ depending on the region being considered), conducting a water quality modeling analysis of the bay could be considered to determine its capacity for additional nutrient loading.

In prior siting advice for salmon aquaculture sites, the analysis of pelagic- and benthic-PEZs focused on currently proposed sites. It is now possible to consider the PEZs of the site currently being considered in relation to previously reviewed aquaculture sites and associated PEZs. The closest PEZ to the Goat Island site is St. Leonards, however no overlap in PEZ (benthic or pelagic) occurred (Figure 5 and 6). The Goat Island site's benthic-PEZ overlaps with the previously proposed Darby Harbour and Red Island lease areas (for both of these sites PEZs have not been calculated).

The pelagic-PEZ for the proposed Goat Island site is much smaller than the benthic-PEZ and doesn't overlap with the proposed sites at Darby Harbour and Red Island, and doesn't overlap with the pelagic-PEZ for the proposed St. Leonard site. Similar to the benthic-PEZ, the overlapping of pelagic-PEZs would likely magnify the effect of aquaculture on the affected waters, but the amount of magnification is not known as the computed PEZs for Goat Island do not include zones that might be exposed by other previously requested sites in the same BMA.

Although there is some indication of benthic fauna recovery/partial recovery from the fallout of aquaculture activities (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 extended periods of time (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 site are expected to be impacted by the proposed site through multiple pathways. As both the benthic and the pelagic-PEZ include the coastline adjacent to the site, they are expected to be exposed to waste feed, fecal material, and pesticides coming from the aquaculture site. Additionally, the Proponent notes that the shorelines adjacent to the aquaculture site 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 site creates some new potential challenges for the Atlantic cod stock in 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 that overlap with larval cod represents a further source of stress to a stock that is already struggling. The potential aquaculture site 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 longiformis* (Burridge and Van Geest 2014).

Other Considerations

The following considerations have been highlighted for video surveys and should be evaluated. Video surveys conducted on behalf of 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 feed to surface, operators should wait until turbidity lowers down before capturing the image during deployment. In addition, 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 earlier Science Responses for site applications, the low quality of the videos will challenge future comparative analyses of before and after aquaculture activities; therefore, there is a need for Proponents to improve the quality of the seabed videos.

Another consideration is direct predation on wild fish by farmed salmon which has potential cumulative effects on pelagic stocks in the region. Making some simple assumptions, it is possible to derive an annual estimate of the number of wild fish that could potentially be consumed by farmed salmon in pens. Work from BC (Hay et al. 2004, Johannes and Hay 2006) showed that the incidence of feeding on wild fish by farmed salmon was around 0.14% (typically only one wild fish consumed/event). 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:

$1,000,000 \text{ farmed salmon} \times 0.14\% \text{ incidence rate of wild fish being consumed} \times 2 \text{ feeding period/day} \times 365 \text{ days/yr} = 1,022,000 \text{ wild fish/yr/million farmed salmon.}$

We note that this is a rough estimate, and that farmed salmon are supply limited, meaning they are only able to feed on wild fish and invertebrates that are able to enter their pens. 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.

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 not be detected by video surveys.

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

The Proponent acknowledges the risks of adverse environmental conditions without specifically mentioning the potential effects of climate change and submitted plans to address the potential issue. Those effects could be especially important and should be considered in all future site applications as well as future science work undertaken by the Department. Effects of and potential for heat waves, oxygen depletion, and winter superchill events 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 zone (benthic-PEZ) associated with the use of in-feed fish health treatment products resulting in potential exposure is within a radius of 1.7 km from the site location for drugs present in feed waste (higher concentration of active ingredients) and 13.8 km for those found in feces waste (lower concentration of active ingredients).
- The pelagic predicted exposure zone (pelagic-PEZ) associated with the use of approved pesticides is within a radius of 3.4 km from the site location.
- Crustaceans are present within the pelagic-PEZ 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 impacts.

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 associated with the greatest intensity of potential impacts is within a radius of 1.7 km from the site location, while the lightest particles could extend up to 31.0 km from the site. This site has benthic habitats with sessile organisms (including corals and sponges) and a likely presence of fish eggs and larvae for which baseline data on vulnerability and recovery, as well as connectivity within and outside these areas, are lacking.
- Sessile or sedentary benthic taxa present at the site are expected to be vulnerable to aquaculture wastes, as they cannot relocate to another environment when under stress.
- The proposed site falls within the Placentia Bay EBSA, which was identified based on several taxonomic groups fitting the criteria of uniqueness, aggregation, fitness consequences, and the presence of at-risk species.

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 is generally highest in summer to fall and lowest in winter and spring based on sightings (opportunistic, systematic) and acoustics data. White Shark are present in the area seasonally between June and October, with the highest number of individuals detected in July and August based on tagging and telemetry 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 site.

- 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 White Shark, marine mammals, and sea turtles in the proposed lease area is 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 wild Atlantic Salmon are present within the geographic range where escapees are likely to migrate. Tagging studies indicate that waters surrounding the islands in the northwest and northeast regions of Placentia Bay are likely rearing habitat used by wild Atlantic Salmon smolts during the first few months of their marine migration.
- 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.
- Simulations of diploid escapees and escapee dispersal associated with the proposed expansion predict no direct population-level genetic impacts to wild salmon in the region, assuming the predicted wild population sizes are accurate and the levels of triploidy induction success are high (i.e., $\geq 98\%$).
- There remains significant uncertainty as to the magnitude of indirect genetic and ecological impacts on wild salmon in the region. Moreover, ongoing concerns of triploid Atlantic Salmon health and welfare in Norway warrant further consideration here.

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