DFO NEWFOUNDLAND AND LABRADOR REGION SCIENCE REVIEW OF SIX PROPOSED FINFISH AQUACULTURE SITES ON THE SOUTH COAST OF NEWFOUNDLAND

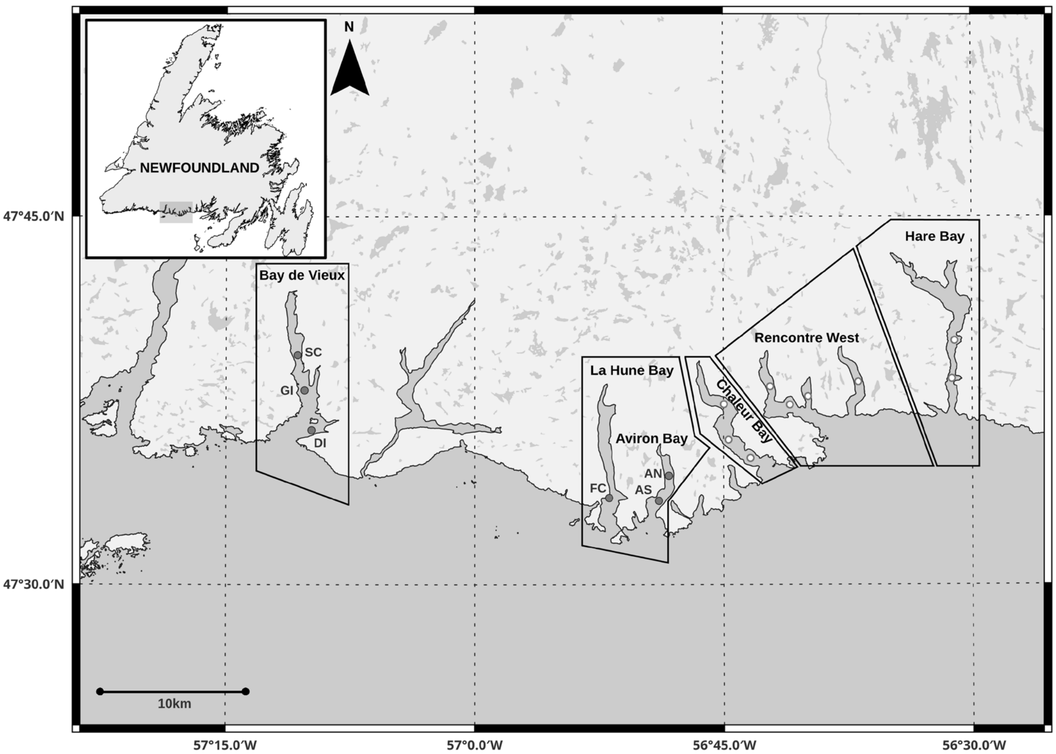

Figure 1: Location of the proposed aquaculture sites in Bay de Vieux, Aviron Bay and La Hune Bay. Solid dots represent proposed sites Shoal Cove (SC), Gnat Island (GI), Denny Island (DI), Aviron North (AN), Aviron South (AS) and Foots Cove (FC). White dots indicate other licenced aquaculture sites in the area. Stars indicate nearby communities. Solid lines indicate separation of aquaculture management areas. Dashed lines indicate latitudinal and longitudinal grid.

Context:

*MOWI Canada East Incorporated submitted applications to the Province of Newfoundland and Labrador (NL) for six new finfish aquaculture sites for Atlantic Salmon (*Salmo salar*), on Newfoundland's south coast. As per the Canada-Newfoundland Memorandum of Understanding on Aquaculture Development, the Newfoundland and Labrador Department of Fisheries, Forestry and Agriculture has forwarded these applications to Fisheries and Oceans Canada (DFO) for review and advice in relation to DFO's legislative mandate. In accordance with the Aquaculture Activities Regulations (AAR), the Proponent submitted a Baseline Assessment Report and Addendum for each site/licence.*

SUMMARY

- MOWI Canada East Incorporated submitted applications to the Province of Newfoundland and Labrador to develop and operate six new finfish aquaculture sites for Atlantic Salmon on the south coast of Newfoundland split among three fjords within two proposed aquaculture management areas, Bay de Vieux and Aviron/La Hune Bays.
- Estimates of benthic-Potential Exposure Zone (PEZ) for feed waste for each site showed no overlap. Estimates of benthic-PEZ for feces overlapped at adjacent sites within the same bay. Feed waste and feces can potentially contain bound substances such as medications.
- Pelagic-PEZ, which estimates the spatial extent across which exposure to registered pesticides may result in adverse effects, overlaps between sites within the same aquaculture management areas. These pelagic-PEZs extend to water masses beyond the bays and reach shorelines which may impact the shallow areas adjacent to each site.
- Chemotherapeutant sea lice treatments could affect non-target crustaceans through the exposure of adults in the benthos to in-feed residues, and/or their larval stages through pelagic exposure to pesticides. For primarily pelagic krill species, pesticide exposure might represent a risk at most sites.
- Treatments that occur at adjacent sites may result in cumulative impacts at sites where benthic and pelagic-PEZs overlap. For the Foots Cove and Shoal Cove sites, high densities of crustaceans that are in close proximity to cage areas might be at a higher risk.
- Soft corals and sea pens were identified at five of the sites. At Gnat Island, the sea pen *Pennatula aculeata* was detected in high concentrations adjacent to the proposed cage array. Lack of data on the density, distribution, and effects on these species and habitats in the surrounding area limit understanding of the potential impacts.
- There are 55 Atlantic Salmon rivers along the southwest coast of Newfoundland. Monitoring data from recent decades suggests that all three monitored rivers in the region have shown evidence of multi-generational population declines, with Bay d’Espoir showing declines exceeding 90%.
- Widespread hybridization between wild salmon and aquaculture escapees, and resulting genetic changes, have been documented in southern Newfoundland over the past decade. The continued observations of European ancestry in escaped farmed salmon in Atlantic Canada increases the direct genetic risk to wild populations.
- Empirical data and dispersal modeling analyses showed that for Designatable Unit 4b, the area of the proposed expansion, the number of escapees in the rivers is predicted to increase by 10% under the proposed expansion, with most occurring in White Bear River and Grey River. Ongoing impacts are predicted on both the abundance and genetic character of wild salmon in the region, and the risk of impacts is predicted to increase under the proposed expansion.
- An increase in aquaculture infrastructure increases the potential for entanglement for some Species at Risk. These include White Shark, Blue Whale, Fin Whale, North Atlantic Right Whale, and Leatherback Sea Turtles which occur in the general area, particularly from spring to autumn. Nonetheless, there are no reports of entanglement of these species in finfish aquaculture gear in the Newfoundland and Labrador Region.

- Two benthic fecal-PEZs (Denny Island, Gnat Island) minimally overlap (<1 km^2) the current South Coast Ecologically and Biologically Significant Area (EBSA). Benthic waste feed-PEZs do not overlap this EBSA.
- The Canadian Science Advisory Secretariat (CSAS) review process for aquaculture siting would greatly benefit from a framework process that refines guidelines for science input.

BACKGROUND

The Proponent, MOWI Canada East Incorporated (MOWI), submitted applications to develop and operate six new finfish aquaculture sites for the production of Atlantic Salmon (diploid *Salmo salar*, Saint John River strain) on the south coast of Newfoundland.

The Newfoundland and Labrador (NL) provincial Department of Fisheries, Forestry and Agriculture (FFA) is responsible for aquaculture licencing under the *Aquaculture Act*. This licencing process includes a review focusing on the applicant's ability to farm responsibly and comply with regulatory requirements. As per the Canada-Newfoundland Memorandum of Understanding on Aquaculture Development, the FFA has forwarded these applications to Fisheries and Oceans Canada (DFO) NL Region for review and advice in relation to DFO's legislative mandate. While aquaculture is managed amongst federal, provincial and territorial governments, there are federal regulations in place under the Aquaculture Activities Regulations (AAR) that build on the federal and provincial regimes to clarify conditions in which aquaculture companies may install, operate, maintain or remove an aquaculture facility. This includes measures to treat fish for disease and parasites, and regulatory thresholds for deposit of organic matter, under Sections 35 and 36 of the *Fisheries Act*. The AAR allow aquaculture operators to do so within specific restrictions to avoid, minimize and mitigate any potential detriments to fish and fish habitat. The regulations also impose specific environmental monitoring and sampling requirements on the industry. The AAR encompasses all stages of operation from siting to fallow. In accordance with the AAR, the Proponent submitted a Baseline Assessment Report and Addendum for each site/licence.

To guide DFO's review of these applications, the Regional Aquaculture Management Office (RAMO) requested DFO Science advice on the potential exposure zones (PEZs) associated with the proposed aquaculture activities and the potential impacts on susceptible fish and fish habitat.

Specifically, DFO Science has been asked the following questions:

- Based on the available data for the sites and the scientific information, what are the PEZs from the use of approved fish health treatment products in the marine environment, and the potential consequences to susceptible species?
- Based on available information, what are the Ecologically and Biologically Significant Areas (EBSAs), Species listed under Schedule 1 of the *Species at Risk Act* (SARA), fishery species, Ecologically Significant Species (ESS), and their associated habitats that are within the benthic-PEZ and vulnerable to exposure from the deposition of organic matter? How does this distribution 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(ies)?
- To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic Species at Risk (SAR) listed under Schedule 1 of SARA make use of the area, for what duration, and when?

- What populations of conspecifics are within a geographic range that escaped farmed fish are likely to migrate into? What are the size and status trends of those populations in the escape exposure zone for the proposed sites? Are any of these populations listed under Schedule 1 of SARA? What are the potential impacts and/or risks to these wild populations from direct genetic interactions associated with any escaped farmed fish from the proposed aquaculture activity?

To respond to the above questions, the process considered the following:

1. Estimate the PEZs associated with:
   a. The deposition of feed and feces
   b. Use of regulated drugs
   c. Use of regulated pesticides
2. Identify the species and habitats within each PEZ that would be susceptible to interactions/impacts associated with each exposure/pathway type. For example:
   a. Effect of smothering from the deposition of waste feed and feces
   b. Toxicity of approved drugs used in aquaculture
   c. Toxicity of approved pesticides
   d. Disease associated with pests and pathogens
3. Assess the consequences of these exposures including:
   a. Temporal/spatial extent of site-specific impacts
   b. Importance of the exposure area to life processes of susceptible fish species
   c. Relative to population-level impacts, considering status (SARA status, relative to reference points) and management regime
   d. Proximity to EBSAs and ESS, fisheries species, and their habitats
4. Beyond the PEZ, identify other possible interactions with fish and fish habitat, associated with the proposed sites, specifically:
   a. Entanglement and displacement of wild species (e.g., marine mammals, turtles, sharks, tunas)
   b. Smothering of habitat or species associated with placement of infrastructure
   c. Attraction of wild species to the site (e.g., sharks, marine mammals)
   d. For conspecifics, genetic interactions between farmed and wild Atlantic Salmon

DFO has developed a consistent approach for the review of marine finfish aquaculture site applications (DFO 2024a). This approach includes a first order triage analysis that estimates exposure zones, and the potential for physical and genetic interactions at the proposed sites. This Science Advisory Report provides scientific information on the PEZs and physical and genetic interactions but does not evaluate risk or impact to species and/or habitats as a result of these zones and interactions. Based on feedback and experience from over four years of DFO aquaculture siting reviews, there is a recognized need to review and refine guidelines for science input to the siting process which could be done through a science framework process.

ANALYSIS

Sources of Data

Information to support these analyses include documents from the Proponent, data holdings within DFO, registry information from the SARA database, publicly available literature, and industry practices and mitigation measures.

The following supporting information was submitted to DFO for each of the six proposed sites, and was used in this review:

- MOWI Canada East Aquaculture Licence Application-Finfish Cage Culture;
- Baseline Assessment Report, including Benthic Videos;
- Appendix 1: Logistical & Benefits;
- Appendix 2: Site Diagrams;
- Appendix 3: Site Development Plans;
- Appendix 4: Fishing and Recreational Activities;
- Appendix 5: Environmental Management and Waste Management Plan;
- Appendix 6: Water Quality;
- Appendix 7: Consultation Report;
- Appendix 8: Site Restoration Plan.

Industry Practices and Mitigation Measures

The location of an aquaculture site significantly impacts production, requiring careful consideration of biological requirements, environmental conditions, regulations, and socio-economic factors. According to the Environmental Management and Waste Management Plan (Proponents Appendix 5: Environmental Management and Waste Management Plan), the Proponent is required to assesses site suitability before and after the licencing process. Sites are selected for their shelter from major wind storms, temperatures suitable for salmon culture, orientation for optimal current flow and particle dispersion, and hard bottom substrates to manage localized effects of fish and feed waste.

The application indicates that the finfish cages will comply with the Newfoundland and Labrador Code of Containment (Newfoundland and Labrador Department of Fisheries and Aquaculture 2022). Regulatory requirements under the AAR and provincial regulations set regulatory thresholds and require the Proponent to conduct seafloor monitoring. Annual monitoring of benthic deposition and sensitive habitats and species is required by the AAR. Industry practices in relation to husbandry and environmental monitoring will occur. The application also outlined management strategies that align with the Code of Containment to reduce the farmed salmon escapes and potential interactions with wild salmon populations.

Identification charts are provided at all sites to facilitate the identification and recording of sightings of SAR. Entanglement mitigation measures such as removal of unnecessary lines and ensuring all lines are taut, are employed to reduce the risk of entanglements.

General Description of Sites

The six proposed sites are distributed across three different bays: Shoal Cove, Gnat Island, and Denny Island in Bay de Vieux; Aviron North and Aviron South in Aviron Bay; and Foots Cove in La Hune Bay. Nearby communities include Grey River, Ramea, and Francois. The locations of the six sites are shown in Figure 1. None of these bays have a previous history of aquaculture activities within the proposed lease sites. The proposed sites are within two separate aquaculture management areas with sites at Aviron Bay and La Hune Bay having a different year class (stocked with finfish year classes 2026, 2029, and 2032) than those sites at Bay de Vieux (stocked with finfish year classes 2027, 2030, and 2033). Currently there are approved aquaculture sites east of the proposed sites, in separate aquaculture management areas, in Chaleur Bay (three sites), Rencontre Bay (four sites), and Hare Bay (two sites) (Figure 1). No sites owned by other companies operate in the aquaculture management areas where the proposed sites are located, and other sites owned by the Proponent are located more than 1 km away from the proposed sites.

The aquaculture management area system (i.e., Bay Management Areas [BMAs]) is designed to reduce disease and parasite impacts to improve the health of cultured salmon and reduce environmental impacts. Every aquaculture management area is stocked with a single generation of farmed salmon, with each site having a minimum fallow period of seven months and a minimum of four months for the entire aquaculture management area, or until benthic analysis indicates re-stocking is permitted.

The six proposed sites have a 2x5 cage array (total of 10 cages per site) with each net having a circumference of 140 m and a depth of 30 m. The maximum number of fish per site is 1 million with a maximum stocking density of 15 kg/m^3. Baseline environmental reports for the six proposed sites follow the AAR Monitoring Standard and include site descriptions, bathymetric surveys, visual benthic surveys, and fish habitat surveys for the lease areas. General descriptions of the proposed sites are provided in Table 1.

Remotely operated vehicle (ROV) video surveys were used to characterize flora, fauna, and substrate types along transects within the area of the proposed lease. These surveys covered the lease area for each site using transects (ranging 10 to 20 transects per site) spaced 100 m apart. Surveys were conducted for 2–3 days depending on the site from mid-June to the end of July. At each station, organisms were counted for 1 minute. The ROV footage and still images were reviewed and analyzed for substrate type, fauna, and flora at stations and used to conduct fish habitat surveys. A summary of sensitive, commercial, and SARA-listed species in the Proponent's Baseline Reports are provided in Appendix A, Table A1.

Shoal Cove

The Shoal Cove aquaculture site is located approximately 14.4 km northwest of the town of Grey River, 22.7 km northeast of the town of Ramea, and 46.2 km west northwest of the town of Francois (all distances by waterway). The proposed lease, as indicated in the aquaculture licence application, is located ~5.7 km north northeast of the mouth of Bay de Vieux and is 1,900 m long by 900 m wide (Table 1). The water depth below the proposed lease area ranges from 0–234 m, with bottom sediments consisting of mixed substrates. From the total of 217 stations analyzed, 147 stations (68%) were classified as hard substrate and 70 stations (32%) were classified as either soft or fine substrate or a layer of fine substrate over hard bottom, for an overall site classification of hard bottom. No benthic indicators of aquaculture activity (*Beggiatoa*-like bacteria or opportunistic polychaete complexes) were observed at any of the transects analyzed within the lease boundaries. Three kelp beds were observed near shore consisting of brown algae species of the genus *Agarum*, present as fringing patches along the top rim of the rock wall between 1 m and 11 m depths. In addition, two brown algae beds were observed near shore on the west ends of transects 7 and 19 in 20 to 25 m depths. Six sea anemone beds (*Metridium senile*, *Stomphia* sp. *Hormathia* sp.), three beds of feather stars or Crinoid stars (*Heliometra glacialis*), and four beds of brittle stars (*Ophiolepidae*) were observed. The application states that the cage array will not be positioned over the location of the observed species.

Neither eelgrass (*Zostera marina*) beds, nor sponge (*Porifera*) complexes were observed within the proposed lease sites during the ROV survey. Some encrusting and standalone sponges were noted, however, not in sufficient quantities to be considered a complex. For species targeted in Commercial, Recreational, and Aboriginal (CRA) fisheries, the ROV survey detected Snow Crab (*Chionoecetes opilio*) and Sea Scallop (*Placopecten magellanicus*). In addition, seven schools (greater than 20 individuals) of Acadian Redfish (*Sebastes fasciatus*) were observed and individual Acadian Redfish were observed on most transects. One school and fifteen individual Atlantic Cod (*Gadus morhua*) were observed as well as one school and nine individuals of Atlantic Pollock (*Pollachius pollachius*).

Gnat Island

The Gnat Island aquaculture site is located approximately 11.5 km northwest of the town of Grey River, 20.6 km northeast of the town of Ramea, and approximately 42.6 km west northwest of the town of Francois (all distances by waterway). The proposed lease, as indicated in the aquaculture licence application, is located approximately 3.5 km northeast of the mouth of Bay de Vieux and is approximately 1,500 m long by 1,000 m wide (Table 1). The water depth below the proposed lease area ranges from 0–370 m, with bottom sediments consisting of mixed substrates. From the total of 163 stations analyzed at depths less than 300 m, 124 stations (76%) were classified as hard substrate and 39 stations (24%) were either soft or fine substrate or a layer of fine substrate over hard bottom, for an overall site classification of hard bottom. It is important to note that the substrate type is not known for a section of the lease area that is greater than 300 m as this was not surveyed by underwater video surveillance, due to the depth limitations of the available equipment. Benthic indicators, present as a patch of *Beggiatoa*-like bacteria, were observed on one transect at 390 to 400 m in approximately 72 to 81 m depth of water and were likely a result of natural deposition at this location. Nine brown algae beds were observed, consisting of brown algae species of the genera *Agarum* and *Desmarestia*, present as fringing patches along the top rim of the rock wall between 3 m and 22 m depths. In addition, six red algae beds were observed. Three sea anemone beds (*Metridium senile* and *Stomphia* sp.), one bed of feather stars or crinoid stars, one bed of green sea urchins (*Strongylocentrotus droebachiensis*), an individual Atlantic wolffish (*Anarhichas lupus*), and sea pens or Pennatulacean corals were observed. The application states that the cage array will not be positioned over the location of the observed species. Survey results indicated individual Acadian Redfish on most transects, while six and one Atlantic Cod were observed on separate transects. In addition, three individual Snow Crabs and two individual Sea Scallops were observed.

Denny Island

The Denny Island aquaculture site is located approximately 9.7 km northwest of the town of Grey River, 18.9 km northeast of Ramea, and 40.4 km west northwest of the town of Francois (all distances by waterway). The proposed lease, as indicated in the aquaculture licence application, is located approximately 1.0 km northeast of the mouth of Bay de Vieux and is approximately 1,000 m long by 692 m wide (Table 1). The water depth below the proposed lease area ranges from 0–173 m, with bottom sediments consisting of mixed substrates. From the total of 88 stations analyzed, 76 stations (86%) were classified as hard substrate and 12 stations (14%) were either soft or fine substrate or a layer of fine substrate over hard bottom, for an overall site classification of hard bottom. No benthic indicators (*Beggiatoa*-like bacteria or opportunistic polychaete complexes) were observed at any of the transects analyzed within the lease boundaries. Four kelp beds were observed near shore and were minimal, consisting of brown algae species of the genus *Agarum*. In addition, two brown algae beds were observed near shore on the south end of transect 10 at depths of 6 to 14 m. One bed of green sea urchins, two beds of Blue Mussels (*Mytilus edulis*) and five beds of feather stars or Crinoid stars were observed. The application states that the cage array will not be positioned over the location of the observed species. Survey results indicated individual Acadian Redfish were observed. A single Snow Crab and individual scallops (species unidentified) were also observed.

Aviron North

The Aviron North aquaculture site is located approximately 14.6 km west of the town of Francois, 28.8 km east of Grey River, and 47.6 km east northeast of Ramea (all distances by waterway). The proposed lease is located approximately 4.5 km north northeast of the mouth of Aviron Bay and is approximately 1,200 m long by 710 m wide (Table 1). The water depth below the proposed lease area ranges from 0–135 m, with bottom sediments consisting of mixed substrates. From the total of 99 stations analyzed, 55 stations (56%) were classified as hard substrate and 44 stations (44%) were either soft or fine substrate or a layer of fine substrate over hard bottom, for an overall site classification of hard bottom. Benthic indicators, present as a small patch of *Beggiatoa*-like bacteria, were observed on one transect (transect 5) at 500 m in approximately 95 m water depth and was likely a result of natural deposition at this location. Kelp beds were observed near shore and were minimal, consisting of brown algae species of the genera *Saccharina*, *Agarum* and *Laminaria*. In addition, four mixed brown algae beds were observed as fringing patches along bedrock and boulder substrates between 1 m and 33 m depths. Five sea anemone beds (*Stomphia* sp.), one green sea urchin bed and an individual sea pen or Pennatulacean coral were observed. The application states that the cage array will not be positioned over the location of the observed species. Survey results indicated one individual American Lobster (*Homarus americanus*), two individual Snow Crab and a few individual Acadian Redfish were observed.

Aviron South

The Aviron South aquaculture site is located approximately 12.3 km west southwest of the town of Francois, 26.6 km east southeast of the town of Grey River, and 45.5 km east northeast of the town Ramea (all distances by waterway). The proposed lease, as indicated in the aquaculture licence application, is located approximately 2.5 km north of the mouth of Aviron Bay and is approximately 913 m long by 821 m wide (Table 1). The water depth below the proposed lease area ranges from 0–144 m, with bottom sediments consisting of mixed substrates. Benthic indicators, present as patches of *Beggiatoa*-like bacteria, were observed on three transects (transects 1, 8, and 10) in approximately 117 to 141 m water depth. The bacteria observed were typically covering unattached algae present on the seafloor, which was likely a result of natural deposition at this location. From the total of 101 stations analyzed, 59 stations (58%) were classified as hard substrate and 42 stations (42%) were either soft or fine substrate or a layer of fine substrate over hard bottom, for an overall site classification of hard bottom. Seven mixed brown algae beds consisting of species of the genera *Desmarestia, Laminaria*, *Saccharina*, *Phylaiella,* and *Agarum* and two sea colander kelp beds (*Agarum* sp.) were observed near shore as fringing patches along boulder, rubble and cobble substrates between 1 m and 29 m depths. Seven beds of green sea urchins three sea anemone beds (*Metridium* *senile* and *Hormathia* sp.), two beds of sand dollars (*Echinarachnius* sp.), and one bed of brittle stars (*Ophiolepidae* sp.) were observed. The application states that the cage array will not be positioned over the location of the observed species. Survey results indicated one individual American Lobster, an individual Acadian Redfish, and an individual Sea Scallop were also observed.

Foots Cove

The Foots Cove aquaculture site is located approximately 15.1 km southwest of the town of Francois, 21.9 km southeast of Grey River, and 40.4 km east of Ramea (all distances by waterway). The proposed lease, as indicated in the aquaculture licence application, is located approximately 200 m north of the mouth of La Hune Bay and is approximately 1,200 m long by 1,300 m wide (Table 1). The water depth below the proposed lease area ranges from 0–177 m, with bottom sediments consisting of mixed substrates. Benthic indicators, present as very small patches of *Beggiatoa*-like bacteria, were observed on two transects, at 600 m along transect 7 in approximately 145 m water depth and at 720 m along transect 9 in 120 m water depth on algae debris, and were likely a result of natural deposition at these locations. From the total of 183 stations analyzed, 111 stations (61%) were classified as hard substrate and 72 stations (39%) were either soft or fine substrate or a layer of fine substrate over hard bottom, for an overall site classification of hard bottom. Five kelp beds were observed near shore and were minimal, consisting of brown algae species of the genera *Agarum* and *Laminaria*. In addition, one mixed brown algae (Phaeophyta) and one mixed red algae (Rhodophyta) bed were observed as fringing patches along bedrock and boulder substrates between 1 m and 23 m depths. Four beds of green sea urchins and two sand dollar beds were observed. Additionally, Moon Snail (*Naticidae*) sand collars, which are the snail egg masses, were observed and may potentially indicate moon snail nursery or juvenile habitat. The application states that the cage array will not be positioned over the location of the observed species. Survey results indicated two individual Snow Crab, individual Sea Scallops, and individual Acadian Redfish were also observed.

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

Characteristic	Shoal Cove	Gnat Island	Denny Island	Aviron North	Aviron South	Foots Cove
Dimension [m]	1,900 x 900	1,500 x 1,000	1,000 x 692	1,200 x 710	913 x 821	1,200 x 1,300
Area [ha]	132.4	130.4	69.2	81.0	83.1	159.0
Predominant substrate type	Hard bottom	Hard bottom	Hard bottom	Hard bottom	Hard bottom	Hard bottom
Net-pen array configuration	2 x 5	2 x 5	2 x 5	2 x 5	2 x 5	2 x 5
Individual net-pen circumference/depth [m]	140 / 30	140 / 30	140 / 30	140 / 30	140 / 30	140 / 30
Net-pen volume [m^3]	390,000	390,000	390,000	390,000	390,000	390,000
Depth under the lease area [m]	0 – 234	0 – 370	0 – 173	0 – 135	0 – 144	1 – 177
Depth under the cage array [m]	146-220	101 – 275	40 – 110	104 – 120	94 – 140	112 – 150
Current measurement period	14-Jun-2018 to 21-Jul-2018	13-Jun-2018 to 21-Jul-2018	13-Jun-2018 to 21-Jul-2018	10-May-2018 to 14-Jun-2018	10-May-2018 to 14-Jun-2018	10-May-2018 to 13-Jun-2018
Current speed [cm/s]	*Depth [m]* / *Speed [cm/s]*: *Mean* / *Max*	*Depth [m]* / *Speed [cm/s]*: *Mean* / *Max*	*Depth [m]* / *Speed [cm/s]*: *Mean* / *Max*	*Depth [m]* / *Speed [cm/s]*: *Mean* / *Max*	*Depth [m]* / *Speed [cm/s]*: *Mean* / *Max*	*Depth [m]* / *Speed [cm/s]*: *Mean* / *Max*

Characteristic	Shoal Cove			Gnat Island			Denny Island			Aviron North			Aviron South			Foots Cove		
	5.1	*8.1*	*34*	*4.9*	*6.6*	*38*	*5.1*	*5.4*	*22*	*4.8*	*4.5*	*29*	*5.1*	*6.1*	*35*	*5.1*	*5.9*	*45*
	9.2	*7.6*	*35*	*9.7*	*5.5*	*29*	*10.7*	*4.5*	*20*	*10.0*	*3.7*	*17*	*11.0*	*4.5*	*20*	*10.5*	*4.8*	*40*
	15.7	*6.4*	*36*	*15.7*	*4.4*	*25*	*14.7*	*4.1*	*24*	*16.0*	*3.2*	*15*	*15.0*	*3.6*	*20*	*14.5*	*4.3*	*30*
	101.2	*4.7*	*25*	*106.4*	*3.3*	*17*	*55.6*	*2.9*	*17*	*54.2*	*2.5*	*12*	*68.9*	*3.3*	*14*	*63.4*	*2.3*	*11*
	197.9	*3.8*	*15*	*209.9*	*2.1*	*9*	*104.9*	*3.1*	*16*	*105.0*	*2.8*	*13*	*130.4*	*3.4*	*12*	*124.0*	*2.2*	*15*
Current measurement type	*current profiler*			*current profiler*			*current profiler*			*current profiler*			*current profiler*			*current profiler*		
Grow-out period [month]	28			28			28			28			28			28		
Maximum number of fish on site	1,000,000			1,000,000			1,000,000			1,000,000			1,000,000			1,000,000		
Initial stocking number [fish/pen]	100,000			100,000			100,000			100,000			100,000			100,000		
Initial stocking weight [kg]	0.150			0.150			0.150			0.150			0.150			0.150		
Average planned harvest weight [kg]	6.67			6.67			6.67			6.67			6.67			6.67		
Expected maximum biomass [kg]	4,876,840			4,876,840			4,876,840			4,876,840			4,876,840			4,876,840		
Maximum stocking density [kg/m^3]	15			15			15			15			15			15		

Oceanographic Conditions

The waters on the south coast of Newfoundland are strongly, seasonally stratified and subject to a spatially uneven freshwater runoff (Donnet et al. 2018a, 2018b). Data available from Hermitage Bay and Bay d'Espoir show that the water column is characterized by a two to three layer system from spring to fall (Richard and Hay 1984, Donnet et al. 2018b). Ocean stratification is fundamental to current dynamics (e.g., Gill 1982, Pond and Pickard 1983, Cushman-Roisin and Beckers 2011). In this region, currents are complex, with large temporal and spatial (including vertical) variability (Ratsimandresy et al. 2019), and dominated by atmospheric events (i.e., strong winds or storms) rather than tidal forcing (Salcedo-Castro and Ratsimandresy 2013, Ratsimandresy et al. 2019).

Bathymetry

The proposed sites occupy long, narrow bays, exposed to the south with steep walls and deep water, though Aviron Bay has a relatively shallow sill. The sites are located within inlets at the mouth or middle of an inlet, in small coves or along the coastline. The water depth below the proposed lease areas ranges from 0–370 m, with bottom sediments consisting of mixed substrates. All sites were classified with the majority having hard substrates with some mixed substrates.

Currents

Water currents are a critical input to estimations of the zone of exposure associated with the release of biological oxygen demanding (BOD) organic matter, pesticides and drugs from any farm site. The Proponent provided water current data over a period of 35 to 39 days and followed the requirements of the AAR. Acoustic Doppler Current Profilers (ADCPs) were deployed at a single location and configured to measure ensemble average horizontal currents at 15-minute intervals (Table 1). Most of the current meter moorings were near the center of the proposed cage arrays.

Currents were reported at near surface, upper, mid-water, and near bottom depths (Table 1). There is vertical variation in the maximum current speed and this variation is larger than for the mean speeds. Current directions vary with depth; however, the main current directions are either parallel to the isobaths or coastline. This observation is consistent with the results from Ratsimandresy et al. (2019), which highlighted the variability of the currents in the region.

Species and Habitats

The main commercial pelagic fish species in the south coast region where the sites are being proposed are Atlantic Herring (*Clupea harengus*), Atlantic Mackerel (*Scomber scombrus*), and Capelin (*Mallotus villosus*). However, there is little to no commercial fishing for these pelagic species in the proposed region. Biomass data for pelagic species are not available, however, it is known that these species are seasonally abundant in Newfoundland waters. The proposed sites include habitat for several groundfish, including, but not limited to Atlantic Cod, Witch Flounder (*Glyptocephalus cynoglossus*), and Redfish. Data on groundfish and pelagic species are limited for the project area. The DFO multispecies survey (MSS) is typically used to describe the distribution and abundance of species in the NL Region, including the south coast. This survey does not extend into the bays where the new sites are proposed.

The commercial benthic invertebrate species in the general area are American Lobster, Snow Crab and Sea Scallop. The baseline assessment identified one observation from ROV footage of suitable lobster habitat, however, lobsters are cryptic (especially during the day) and are unlikely to be directly observed in the survey. Snow Crab were identified in small numbers in the baseline assessment. The early life stages of Snow Crab are also cryptic, but they could be susceptible to activities associated with aquaculture at all life stages. The Snow Crab life cycle features a release of larvae in spring followed by a pelagic larval period in the surface layers that involves several stages before settlement in the fall (Comeau et al. 1999, Sainte-Marie 1993). Habitat use through ontogeny follows a general pattern of distributions occurring in shallow/cold/coarse habitats during early ontogeny and deeper/warm/softer habitats during later ontogeny, with vertical exchanges for some groups of crab, particularly large males, during seasonal breeding migrations (Mullowney et al. 2018). Scallop were rarely observed in the baseline surveys of the lease area for the proposed aquaculture sites. Scallop fishing occurs along the southwest coast area.

Among non-commercial benthic invertebrate species, the taxa reported in the Proponent's surveys include sea pens, soft corals (families *Alcyoniidae* and *Capnellidae*), cerianthid anemones, *Hormathia* sp. and *Stomphia* sp. anemones, geodiid sponges, brittle stars, and crinoids (reported as feather stars), which are all indicators of Vulnerable Marine Ecosystems (VMEs). Stations containing high concentrations of sea pens (>20 colonies per station) were identified at Gnat Island with colonies of variable sizes, indicating the presence of both young and adult colonies whereas one sea pen was reported at Aviron North. Soft corals were identified at Aviron North, Aviron South, Denny Island, and Shoal Cove, with maximum concentrations of eight colonies per station (at Shoal Cove). Other taxa with high densities that were identified at some sites include geodiid sponges, cerianthid anemones, sea anemones (e.g., *Hormathia* sp.), brittle stars, and crinoids (reported as feather stars). Brittle stars were found in high concentrations at several stations across all sites but were mostly dominant at Aviron South and Foots Cove.

EBSAs are identified through formal scientific assessments as having biological or ecological significance when compared with the surrounding marine ecosystem. These are areas where regulators and marine users should practice risk aversion to maintain healthy and productive ecosystems (Government of Canada 2023). In identifying EBSAs, knowledge of an area is assessed against five criteria: uniqueness, aggregation, fitness consequence, naturalness, and resilience. The NL Region has identified 29 EBSAs (Wells et al. 2017, 2019) (Appendix D, Figure A2). Three of the proposed sites are found in an area adjacent to the South Coast EBSA: Shoal Cove; Gnat Island; and Denny Island (the closest lease boundary to the EBSA is at Denny Island, which is 2.4 km away).

In terms of ESS, eelgrass has not been reported at any of the sites. Although criteria for the identification of other ESS exist (DFO 2006), assessments have been rare. Several benthic invertebrate taxa might be included under the ESS umbrella (e.g., Cobb et al. 2020). Sea pens fields, which are indicators of Significant Benthic Areas (SiBAs) and VMEs, have been identified at Gnat Island. At least 35 distinct taxa were identified by the Proponent across the proposed sites.

With the exception of one individual Atlantic Wolffish, no SARA-listed species were observed during the survey. Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*Anarhichas minor*), Atlantic Wolffish and White Shark (*Anarhichas denticulatus*) are SARA-listed marine fish species found in Newfoundland waters, with Atlantic Wolffish being the most commonly observed wolffish species in coastal shallow Newfoundland waters, and as bycatch in inshore fisheries.

Wild Atlantic Salmon migrate along the south coast and, as a result of declining populations, are currently designated as threatened by the Committee on the Status of Endangered Wildlife in

Canada (COSEWIC 2010). After further declines in the NL Region (DFO 2022a, DFO 2023a) the designation is currently being re-evaluated. Common Lumpfish (*Cyclopterus lumpus*) are also present and have shown declines in abundance of about 58% between 1996 and 2014 (Simpson et al. 2016). Accordingly, Common Lumpfish was designated as Threatened in Canadian waters in 2017 (COSEWIC 2017).

Based on general species distribution, DFO survey data, and DFO marine mammal sightings/survey data, the following cetaceans can potentially occur in the proposed sites: Blue Whale (*Balaenoptera musculus*), Fin Whale (*Balaenoptera physalus*), Sei Whale (*Balaenoptera borealis*), Minke Whale (*Balaenoptera acutorostrata*), Humpback Whale (*Megaptera novaeangliae*), North Atlantic Right Whale (*Eubalaena glacialis*), Sperm Whale (*Physeter macrocephalus*), and several species of dolphins and Harbour Porpoise (*Phocoena phocoena*). Based on opportunistic and systematic sightings data, these cetaceans can occur in the proposed areas with seasonal peaks in abundance occurring typically in the summer and fall. Additionally, seal species such as Harbour Seals (*Phoca vitulina*) and Grey Seals (*Halichoerus grypus*) occur along the Newfoundland south coast regularly and may have haul-outs in the lease areas, particularly near islands and rocks. While Leatherback Sea Turtles (*Dermochelys coriacea*) and Loggerhead Sea Turtles (*Caretta caretta*) frequent Newfoundland waters during summer and fall to forage, they do not nest in Canada. While they frequent inshore waters and offshore along the continental shelf respectively, they are not expected to commonly occur in the proposed aquaculture lease areas.

Site Classification and Depths

Baseline video summary tables were provided by the Proponent to document species communities, and these tables demonstrate that large concentrations of corals, sponges, cerianthids, anemones or crinoids are generally not located directly under the proposed cage arrays at most sites, with the exception of high sea pen concentrations identified near the cage array at Gnat Island. At the proposed Aviron South site, benthic indicators of organic enrichment, present as patches of *Beggiatoa*-like bacteria covering unattached algae, were observed on three transects (transects 1, 8 and 10) from approximately 117 to 141 m water depths. *Beggiatoa*-like bacteria were also observed on a single transect at Gnat Island and Aviron North and on two transects at Foots Cove. These bacterial mats likely result from natural deposition at this location but suggests that low oxygen conditions may occur (Hamoutene 2013). Taxa absences and abundance counts should be considered with caution considering relative counts to surveyed area, camera distance from sea floor, and video quality specifications.

Pesticide and Drug Use

The Proponent’s Environmental Management and Waste Management Plan (included in Appendix 5 of the application package) indicates that the use of chemical treatments will be prescribed in cases when the series of alternative treatments (mechanical or thermal treatments) fail to keep parasite infestation under control. The AAR requires the Proponent to consider alternative, non-chemical methods first. Canada allows only the use of products that are registered under the Pest Control Products Act and the Food and Drugs Act, and are regulated by the Pest Management Regulatory Agency (PMRA) and Health Canada Veterinary Drugs Directorate. Any intervention therapy must be chosen by a licenced veterinarian, in consultation with the provincial Fish Health and Welfare Director. 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). While not currently approved for use in Canada, Lufeneron (an in-feed treatment used in freshwater hatcheries known commercially as Imvixa®) is also available under Emergency Drug Release from the Veterinary Drugs Directorate (Health Canada). Antibiotics are not listed in the application, however they might be administered in case of infectious bacterial diseases. Under the AAR, the Proponent is required to report on the usage of drugs and pesticides at each marine finfish cage on an annual basis.

Drugs

The use of in-feed antibiotics raises concern about the potential development of antimicrobial resistance (AMR), a process whereby bacteria become insensitive to one or multiple antibiotics over time (Baquero et al. 2008). Many uncertainties still exist with respect to these indirect impacts of antibiotics on marine organisms; however, direct toxicity to marine organisms has been deemed unlikely for the amounts used. The lack of information on AMR in marine organisms, means that this review cannot address potential effects. However, it is important to highlight the potential of the presence of other compounds to influence AMR patterns through a co-selection/enhancement process (Jonah et al. 2024). EMB has very low water solubility (Mushtaq et al. 1996) and is predicted to persist in the water column for short durations and subsequently partition into solid environmental matrices (Jacova and Kennedy 2022, Strachan and Kennedy 2021). Thus, EMB should not occur in high concentrations in water, and is unlikely to cause harmful effects on pelagic organisms through continuous aqueous exposures (Mill et al. 2021).

Pesticides

Hydrogen peroxide and azamethiphos are currently the only approved pesticides for use by the finfish aquaculture industry in Canada (2017) and Health Canada provides regulatory guidelines for their use (PMRA 2016a, 2016b, 2017). The release of pesticides can impact susceptible habitats and species at various life stages in both the water column and on the seafloor.

POTENTIAL EXPOSURE ZONES

Accumulation of feed waste and feces can alter benthic habitat resulting in decreased oxygen levels (i.e., hypoxia), increasing sulfide levels and increases in indicator organisms such as *Beggiatoa* sp., opportunistic polychaete organisms, and flocculant matter. PEZs are a scoping tool for identifying areas of potential exposure for sensitive species and habitats, albeit at a broad spatial scale. This initial estimate of size and location of areas that might be subject to exposure to releases depends upon multiple factors such as ocean current speed, bathymetry, and particle settling velocity. The PEZ gives an order of magnitude estimate of the sizes and locations of exposure and provides initial understanding. A detailed description of the PEZ model can be found in Page et al. (2023a); however, it is important that the PEZs are understood as an initial step in identifying potential concerns to the decision maker. They are not zones of impact.

Benthic Potential Exposure Zone

The benthic-PEZ estimates the size and location of the benthic area potentially exposed to the deposition of waste feed and feces released from a site, which can result in organic loading. There are two categories of benthic-PEZ:

1. The zone potentially exposed to the deposition of waste feed is known as the waste feed-PEZ; and,
2. the zone potentially exposed to the deposition of feces is the fecal-PEZ.

The benthos may also be exposed to pesticides released into the water, particularly at shallow depths; however, this concern is addressed through the calculation of the pelagic Potential Exposure Zone (pelagic-PEZ), discussed in a subsequent section of this document.

The benthic-PEZ calculation takes a conservative approach in that it calculates a very broad area whereby particles could potentially distribute, even at a low level. It is a simple approach. The benthic-PEZ is represented by a circular zone centered on the middle of the proposed cage array and represents the inferred outer limit for potential exposure. The spatial extent of exposure of the benthic-PEZ associated with feed particles is illustrated in Figure 2. The benthic-PEZ associated with the feed (waste feed-PEZ) is similar in scale to the lease area, of the order of various hundreds of meters.

It is calculated by first computing the transport distance (ocean current speed multiplied by the period of sinking of the particles, feed and feces respectively), and adding half the length of the cage array. This calculation determines whether or not there are species or habitats within a larger area of concern that warrant further refinement (i.e., more comprehensive study of the spatial extent, intensity and/or duration of anticipated interaction). The benthic-PEZ does not provide an estimate of the intensity of organic loading within the site, and the zones do not imply the same potential exposure everywhere within the zone. The intensity of the exposure is expected to be highest near the net-pen arrays and decreases with distance.

Key assumptions for the model include constant settling velocity of the particles, constant ocean current speed during 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 and deep bottom topography (the maximum depth over the lease area). Current speed is obtained by analyzing the maximum progressive vector diagram (PVD) based on the timeseries of current velocities at each depth over the period of sinking of particles; see Appendix B for explanation of PVD. 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 previously reported values (Findlay and Watling 1994, Chen et al. 1999, Cromey et al. 2002, Chen et al. 2003, Sutherland et al. 2006, Reid et al. 2009, Law et al. 2014, Bannister et al. 2016, Skøien et al. 2016, DFO 2020a).

For each location, timeseries of ocean currents at various depths within the water column were provided by the Proponent to carry out the above analysis and calculation. Table 2 provides 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 sites.

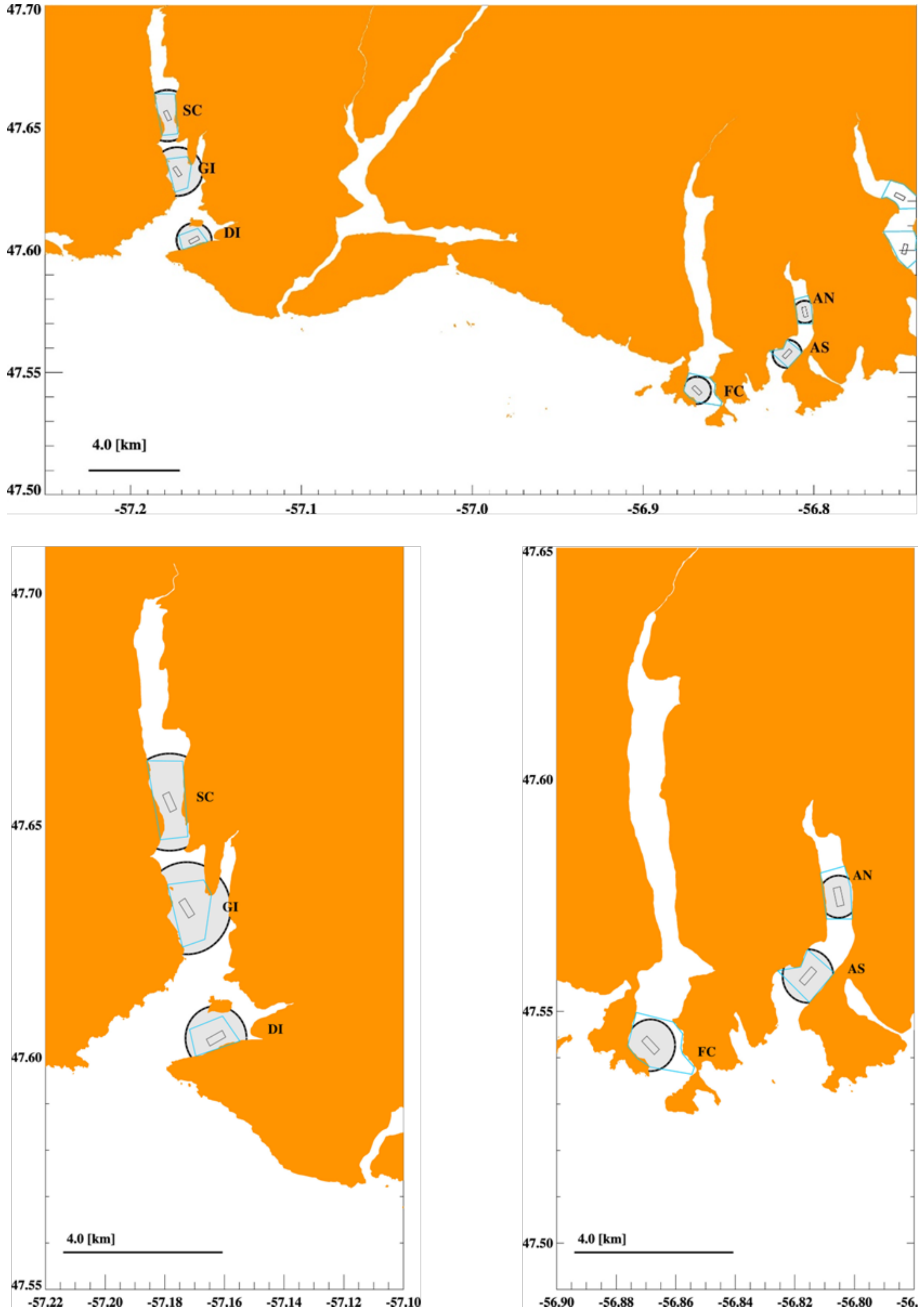

Figure 2: Top panel illustrates the benthic-PEZ (grey area delimited by black circle) associated with feed particles for the proposed sites. Black rectangles delimit the cage areas and blue polygons the lease area for each site. The sites in Bay de Vieux are Shoal Cove (SC), Gnat Island (GI), and Denny Island (DI) and the sites in the other bays are Foots Cove (FC), Aviron South (AS), and Aviron North (AN). Bottom left panel illustrates a zoom in on Bay de Vieux showing the DI, GI, SC sites. Bottom right panel illustrates a zoom in on FC site and Aviron Bay (AS and AN).

Table 2: First order benthic-PEZ estimates associated with the potential horizontal distances travelled by sinking particles such as waste feed pellets and fish feces released from the proposed fish farms (settling rates correspond to the slowest rate obtained from literature to ensure conservative result). Numbers in brackets following site names (shown in bold font) are the maximum site depths.

Particle type	Min. sinking rate [cm/s]	Sinking period [h]	Current speed during sinking period [cm/s]	PEZ radius [km]
Shoal Cove (234 m)				
Feed	5.3	1.2	20.8	1.1
Feces	0.3	21.7	7.3	5.9
Gnat Island (370 m)				
Feed	5.3	1.9	12.3	1.0
Feces	0.3	34.2	3.5	4.5
Denny Island (173 m)				
Feed	5.3	0.9	16.1	0.7
Feces	0.3	16.0	4.8	3.0
Aviron North (135 m)				
Feed	5.3	0.7	10.3	0.5
Feces	0.3	12.5	4.4	2.2
Aviron South (144 m)				
Feed	5.3	0.7	14.6	0.6
Feces	0.3	13.3	6.9	3.5
Foots Cove (177 m)				
Feed	5.3	0.9	11.2	0.6
Feces	0.3	16.4	4.0	2.6

The waste feed-PEZ is anticipated to have the greatest intensity of exposure at positions closer to the net-pens. Calculation of the fecal-PEZ is carried out with the same method but using the period of sinking for fecal particles (Table 2). The spatial extent of the fecal-PEZ provides an indication of the full area that could be exposed to any in-feed drugs as computed using the maximum distance from the PVD. Figure 3 illustrates the benthic-PEZ associated with the fecal particles. These benthic-PEZs cover the whole channels, outside of the lease, where the sites are located, and out towards the mouth of the bays. The size of the PEZ is of the order of few kilometers. Overlap between sites is not expected for the benthic-PEZ associated with feed particles at the proposed sites. For the fecal-PEZ, overlaps occur for PEZ from sites within the same bay suggesting potential for accumulation.

Some important points to consider when interpreting PEZ results:

- PEZ analysis provides estimates only, which are sensitive to data input. It is a spatial scoping tool to identify potentially sensitive marine features. The results should be interpreted as an order of magnitude, acknowledging the complex flow field within the bay and offshore and that current measurement at a single location is an insufficient representation of the full flow field in the area.
- These first-order estimates of exposure do not consider current- and wave-induced bottom resuspension. However, assuming the deepest ocean current speeds information provided by the Proponent also apply to near-bottom conditions, ocean currents with speed over

9.5 cm/s (the critical value for resuspension for the deposition model [DEPOMOD], Chamberlain and Stucchi 2007) were observed in all but the Gnat Island site, suggesting potential for sediment resuspension. The overall impacts of redistribution and flocculant deposition are unknown.

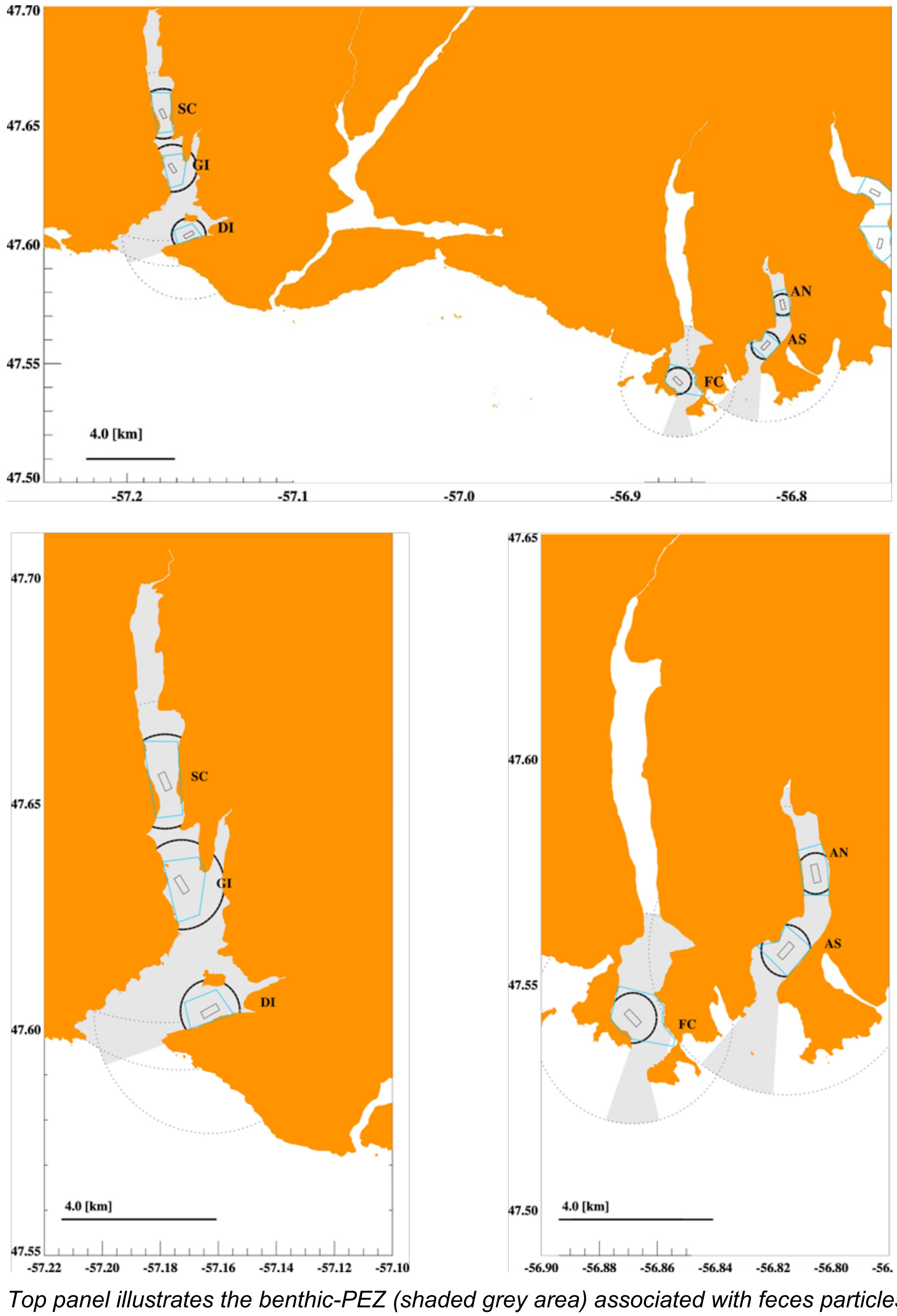

Figure 3: Top panel illustrates the benthic-PEZ (shaded grey area) associated with feces particles for the proposed sites. Each circle (dotted lines) delimits the benthic-PEZ associated with and centered at a specific site. The sites in Bay de Vieux are Shoal Cove (SC), Gnat Island (GI), and Denny Island (DI) and the sites in the other bays are Foots Cove (FC), Aviron South (AS), and Aviron North (AN). Note that offshore areas have different current regime, introducing high uncertainty in the PEZ calculation. Bottom left panel illustrates a zoom in on Bay de Vieux showing the DI, GI, SC sites. Bottom right panel illustrates a zoom in on FC site and Aviron Bay (AS and AN).

Spatial Extent of Drug Exposure

Drugs are administered as in-feed medications, and exposure to drugs can occur through uneaten medicated feed as well as drug residues excreted in feces. Given the overlap in benthic-PEZ associated with feces deposition, the calculation suggests that benthic areas directly underneath and beyond the cages and leases within the bays may be subject to increased organic enrichment and feed chemical residues, in some cases encompassing the entire bay due to overlap across sites within bays. This overlap suggests a potential interaction with the benthic species inhabiting these areas.

In-feed product effect

Most concerns from in-feed product exposure arise from adverse effects on bottom-dwelling organisms, particularly due to the persistence of the avermectin compound EMB in sediment (Benskin et al. 2016, Strachan and Kennedy 2021, Hamoutene et al. 2023b). Avermectins, a series of drugs and pesticides used to treat infections with ectoparasitic copepods, disrupt electrical impulses by binding to invertebrate-specific chloride channels, causing paralysis (e.g., Burridge et al. 2008). Perturbations in other pathways may affect a broader range of taxa, including benthic organisms (Garric et al. 2007). The combined effects of feces containing in-feed residues and medicated feed wastage can result in deposits around sites, as evidenced by measurements from Kingsbury et al. (2023). Additionally, unknowns remain regarding the confounding effects of EMB and organic matter deposition on the benthos (Bloodworth et al. 2019).

The use of in-feed drugs in finfish aquaculture poses a potential threat to SARA-listed marine fish species, particularly bottom-dwelling fish such as wolffish, due to potential exposure to seabed habitat contaminated with persistent compounds like EMB. The effects of drugs or pesticides targeting mostly invertebrates on SARA-listed marine fish species are unknown but are likely limited to individuals and habitats within the PEZ and surrounding areas.

Invertebrates at the proposed sites are among the most susceptible taxa to some in-feed products identified for potential use. These taxa include shrimp, some crab species, lobster, krill, cnidarians, bryozoans, polychaetes, echinoderms, sponges, and tunicates.

In Bay de Vieux, the benthic-PEZs (feces particles) overlap among sites and, combined with the channel configuration, could result in cumulative effects on susceptible species to active ingredients of in-feed compounds. This also applies to the Aviron North and South sites. In La Hune Bay, at the proposed Foots Cove site, the proximity of the cages to high observations of crustacean species represents a higher potential for exposure, given that the highest residue concentrations of in-feed products are expected near the net-pens (Kingsbury et al. 2023). EMB exposure has documented impacts on crustaceans, such as lobsters (adults and larvae) and shrimp species, with limited data on crabs (Burridge et al. 2000, Waddy et al. 2002, Burridge et al. 2008, Daoud et al. 2018, Mill et al. 2021, Hamoutene et al. 2023a; Kingsbury et al. 2023).

Smothering and Hypoxia

Any sessile stages of species are susceptible within the benthic-PEZ and thus vulnerable to low oxygen levels, smothering, or exposure to in-feed drugs, if and when used (DFO 2022b, 2022c). This group may include species such as crustaceans and bivalves during particular life stages. The presence of certain sensitive sessile species requires special consideration, such as sponges, corals, and eelgrass, and critical habitat for SARA-listed species identified in the baseline survey data, scientific literature, and Departmental biological data holdings. When the available data are limited, experts consider whether the benthic substrate type is suitable for the growth of these species. Aquaculture development at the proposed sites increases the risk of anoxic or hypoxic conditions that could potentially impact benthic species including commercially important species such as American Lobster, Snow Crab, and Scallop in the lease areas.

Corals and sponges are considered sensitive taxa susceptible to anthropogenic activities, including direct (e.g., removal or damage) and indirect (e.g., smothering by sedimentation) fishing impacts (DFO 2010). Stations containing high concentrations of sea pens (>20 colonies per station) were identified at Gnat Island. Colonies of variable sizes were observed, indicating the presence of both young and adult colonies. Soft corals were identified at Aviron North, Aviron South, Denny Island, and Shoal Cove, but with maximum concentrations of eight colonies per station (at Shoal Cove). Sponges can also be VME indicators and high densities of geodiid sponges (family *Geodiidae*) were identified at some sites.

Elevated fluxes of particulate matter associated with salmon farms in Norway significantly affected epifaunal community composition, including increased abundances of the predatory sea star *Asterias rubens* in locations with elevated fluxes, and decreases in sponges (e.g., *Polymastia* sp. and *Phakellia* sp.) and the soft coral *Duva florida* (Dunlop et al. 2021). Epifaunal sea stars, sponges, and soft corals were observed in Newfoundland, including some specifically at the proposed sites. Kutti et al. (2022) showed that corals (*Desmophyllum pertusum*, published as *Lophelia pertusa*) exhibited decreased metabolic rates, reduced growth and reduced energy reserves compared to those outside the main depositional footprint of salmon aquaculture farms in Norway.

Pelagic Potential Exposure Zone

Spatial Extent of Pesticide Exposure

The pelagic-PEZ provides an order of magnitude estimate of the pelagic area where susceptible species may be exposed to registered pesticides. This conservative estimate determines the broadest spatial pelagic area that may be exposed to a potentially harmful substance, thus aiding decision makers in identifying overlap with sensitive species and habitats. The release of pesticides can impact susceptible habitats and species at various life stages in both the water column and on the seafloor.

The size of the pelagic-PEZ depends on various parameters including the decay and/or dilution rate of the pesticide, a chosen concentration threshold, and estimate of horizontal water currents that drive the dispersion of the pesticide. 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).

The two Health Canada authorized pesticides available for use in bath treatments (tarp bath and well-boat) are azamethiphos and hydrogen peroxide (PMRA). The conservative pelagic-PEZ calculation uses the tarp bath treatment, given the larger exposure zone anticipated to result from the tarp treatment versus a well-boat. Tarp baths enclose the salmon net-pens with tarps and add bath treatment medicine, whereas the more contained well-boat method pumps fish into well-boats containing the pesticide (Shen et al. 2019). Although both methods disperse pesticides in the environment, previous studies and models indicate that pesticides released from a well-boat treatment dilute more quickly than those released from a tarp treatment (Page et al. 2015, Page et al. 2023b). The release of pesticides presumably produces a patch containing the treatment pesticide, which expands and moves with time.

Azamethiphos and hydrogen peroxide both yield a low decay rate of the active ingredient compared to the dilution rate. Hence a dilution time scale from a target treatment concentration to an environmental quality standard (EQS) was used to calculate the pelagic-PEZ. The PEZ was calculated using a conservative EQS value that ensures a level of protection of 95% of the species (as per the data available) as inferred using HC5 values (i.e., the hazardous concentration for which 5% of species are affected or potentially affected) (TGD 2018). It should be noted; however, that EQS limits for aquaculture treatment products have not yet been established in Canada.

The EQS values for both pesticides include assessment factors of 2 and 5 for azamethiphos and hydrogen peroxide, respectively (Hamoutene et al. 2023a). Using these new values, the treatment patch contains toxic concentrations for a longer period than previously considered. Hamoutene et al. (2023a) inferred an EQS for azamethiphos lower than the previously used value of 1 µg/L, with an updated value of 0.1 µg/L; furthermore 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. 2021) and may remain above suggested threshold concentrations for longer than azamethiphos. The EQS for hydrogen peroxide is 150 µg/L (Hamoutene et al. 2023a). Page et al. (2023b) provided the method to compute the time required for the pesticide concentration within the treatment patch to achieve dilution below the EQS (dilution time thereafter) for the above therapeutants, as well as the potential maximum patch depth reached by the plume containing a toxic concentration of pesticide. The time required depends on various parameters including the size of the cages, the depth of the tarp within which treatment is performed, the water depth, and the initial treatment concentration of the therapeutants, as well as the EQS. Considering a treatment depth of 18 m (information provided by the Proponent), the dilution time for azamethiphos is 15.5 h, and that of the hydrogen peroxide is 39.5 h. The half-life in seawater of azamethiphos is 8.9 days and hydrogen peroxide ranges from 7 to 28 days, and depends on multiple chemical (formulation, stabilization) and environmental factors (Burridge and Holmes 2023). For both compounds these dilution times fall within the half-lives as evaluated so far whether as active ingredients or formulations. Azamethiphos breaks down by hydrolysis (PMRA 2016b) and hydrogen peroxide degrades to oxygen and water (Haya et al. 2005; Lyons et al. 2014). The maximum patch depth is 42 m and 56 m, for azamethiphos and hydrogen peroxide, respectively.

Given the information on the potential maximum depth of the treatment patch, evaluation of the pelagic-PEZ used the ocean current information covering this maximum patch depth. Current speed is obtained as the average of all maximum PVD (Appendix B) computed within the layer of the maximum patch depth which multiplied by the period of dilution gives the total transport distance. The PEZ is then estimated as the distance plus half the length of the proposed net-pen array.

While the intensity of exposure is expected to be highest near the net-pen arrays and decrease as the distance from the net-pens increases, the pelagic-PEZ does not quantify the intensity or duration of exposure, nor does it quantify frequency of exposure. The zones do not imply that areas within the pelagic-PEZ have the same exposure risk.

Given the large difference between the decay rate necessary to reach EQS for azamethiphos and hydrogen peroxide (1,000 fold for azamethiphos and 10,000 fold for hydrogen peroxide) and assuming a treatment concentration of 100 µg/L for the former and $1.5x10^6$ µg/L (1.5 g/L) for the latter, two different pelagic-PEZs were computed. Table 3 shows the potential distance travelled by particles representing azamethiphos and similarly, Table 4 for hydrogen peroxide, during the respective dilution period. As shown in the tables, the treatment particles can reach a distance of 5–13 km and 7–16 km away from the center of the cage array during the 15.5 and

39.5 hour dilution of azamethiphos and hydrogen peroxide, respectively. The pelagic-PEZ is illustrated in Figures 4 and 5 for the proposed sites. Most exposure is expected in the pelagic zone; however, since the pelagic-PEZ reaches areas near the shoreline, shallow areas (less than 42 m and 56 m depth, for azamethiphos and hydrogen peroxide, respectively) may also be exposed to toxic pesticide concentrations should the ocean currents move plumes toward the shore. Note that in a channel with various sites where individual PEZs overlap, the PEZ defined by the most shoreward current data should be used to describe the potential exposure when assessing the overall offshore-PEZ; particle movement is subject to ocean currents closest to its location. Because the pelagic-PEZ extends into offshore areas, the different current regime increases uncertainty in the calculation. The figure shows overlap of the PEZs from different sites and from sites within neighboring bays (Figures 4 and 5). This overlap illustrates the additive nature of potentially toxic pesticides should successive treatments occur in the same area within that period. This overlap will result in a longer dilution time from the first treatment, and thus a potentially wider exposure area.

Similar to the benthic-PEZ, the interpretation of the pelagic-PEZ results should consider that they provide only an order of magnitude based on the available data input, in particular the current information at one location near the respective site locations.

Table 3: First order pelagic-PEZ estimates associated with the potential horizontal distances travelled by non-sinking particles (representing azamethiphos) for a dilution period of 15.5 h and a maximum patch depth of 42 m. (outside of the bay, information from Denny Island should delimit the overall PEZ, ** and PEZ from Aviron South should define the zone in the offshore area).*

	Shoal Cove	Gnat Island	Denny Island	Aviron North	Aviron South	Foots Cove
Max. current speed during dilution [cm/s]	22.5	11.2	9.0	9.4	10.7	11.6
PEZ radius [km]	12.8*	6.5*	5.0	5.4**	6.3	6.7

Table 4: First order pelagic-PEZ estimates associated with the potential horizontal distances travelled by non-sinking particles (representing hydrogen peroxide) for a dilution period of 39.5 h and a maximum patch depth of 56 m. (outside of the bay, information from Denny Island should delimit the overall PEZ, ** and PEZ from Aviron South should define the zone in the offshore area).*

	Shoal Cove	Gnat Island	Denny Island	Aviron North	Aviron South	Foots Cove
Max. current speed during dilution [cm/s]	11.3	6.3	5.0	5.0	6.3	6.6
PEZ radius [km]	16.3*	9.2*	7.4	7.4**	9.2	9.6

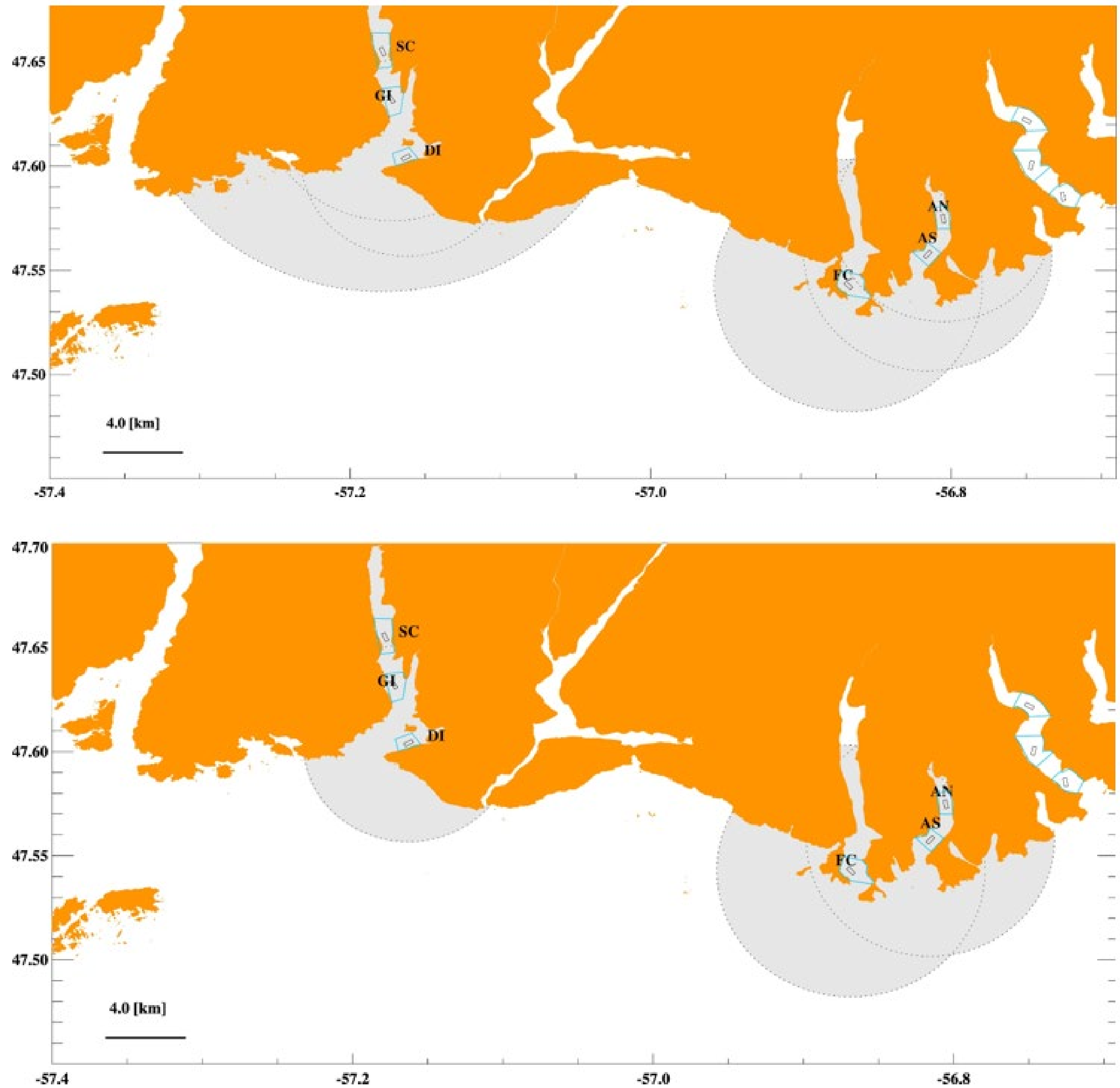

Figure 4: Pelagic-PEZ (shaded grey areas) for the proposed sites associated with treatment by azamethiphos: the sites are Shoal Cove (SC), Gnat Island (GI), Denny Island (DI), Foots Cove (FC), Aviron South (AS), and Aviron North (AN). Dotted circles delimit the pelagic-PEZ for each site. Note that the pelagic-PEZ covers the entirety of the arms where the sites are located and that the offshore-PEZ area bears greater uncertainty due to the unknown current regime. Alongshore seabed shallower than 42 m may be at risk of exposure to toxic pesticide concentrations. While top panel shows PEZ computed for each proposed site, the delineation of PEZ outside of the channel should be assessed with only the information from the current measurement closest to the mouth of the channel (bottom panel).

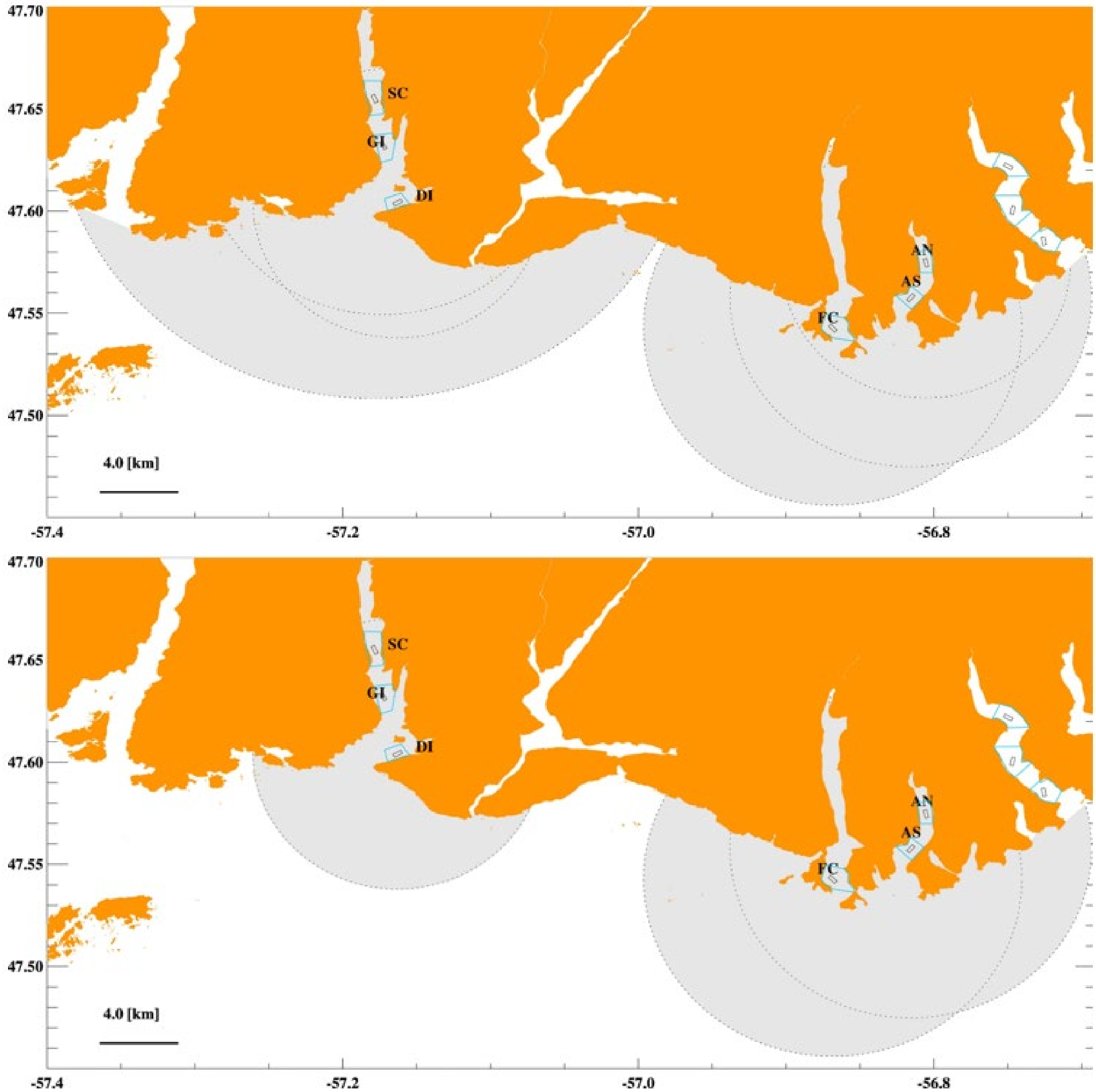

Figure 5: Pelagic-PEZ (shaded grey areas) for the proposed sites associated with treatment by hydrogen peroxide: the sites are Shoal Cove (SC), Gnat Island (GI), Denny Island (DI), Foots Cove (FC), Aviron South (AS), and Aviron North (AN). Dotted circles delimit the pelagic-PEZ for each site. Note that the pelagic-PEZ covers the entirety of the arms where the sites are located and the greater uncertainty of the offshore-PEZ due to the unknown current regime. Alongshore seabed shallower than 56 m may be at risk of exposure to toxic pesticide concentrations. While top panel shows PEZ computed for each proposed site, the delineation of PEZ outside of the channel should be assessed with only the information from the current measurement closest to the mouth of the channel (bottom panel).

Effects of Pesticides Exposure

Exposure to pesticides that target sea lice could threaten lobster at all life stages. Concern about pesticide exposure is greatest at shallow sites with lower dispersion patterns and more prevalent juvenile lobster presence (Lawton and Lavalli 1995, Wahle et al. 2013). It was noted that pesticides may have negative impacts on lobster, even in non-lethal exposure events. Behavioural changes, including reduced female reproductive success, have been reported after exposure to sub-lethal doses of sea lice pesticides (Burridge 2013). Research conducted in New Brunswick also found that sub-lethal pesticide exposure resulted in higher shipping mortality for lobsters, raising market concerns (Couillard and Burridge 2015). A recent study found no impact of salmon aquaculture on lobster abundance through an eight year before-after-control study at a production site in the Bay of Fundy (Grant et al. 2019). Exposure to pesticides that target sea lice could potentially affect scallop species given that observations in other areas where aquaculture operations exist have shown evidence of lower meat to shell ratios (lower meat quality) in scallop and thinner shells (Wiber et al. 2012). Effect(s) of pesticides or drugs targeting mostly invertebrates on non-target species are unknown but will likely be limited to individuals and habitats present within the PEZ and surrounding areas.

Susceptible Species Interactions

Crustaceans are the group with the most toxicity data available for both approved bath pesticides (Hamoutene et al. 2023b). With respect to azamethiphos, crustaceans are known to have high sensitivity (e.g., Burridge et al. 2014, Ernst et al. 2014). For hydrogen peroxide, toxicity data related to crustacean sensitivity were acquired more recently. Recent toxicity data indicates that crustaceans have a lower tolerance for lethal concentrations compared to other species, placing them at the more sensitive end of the Species Sensitivity Distribution (SSD) curve. However, when considering sublethal effects crustaceans are evenly distributed across the SSD curve (Hamoutene et al. 2023b).

In Aviron Bay, where the Aviron North and Aviron South sites are proposed, crustaceans and krill were observed at 48.5% and 57.4% of all stations sampled, respectively. The map below (Figure 6) indicates the potential exposure of these sensitive species to both benthic and pelagic use of anti-sea lice compounds.

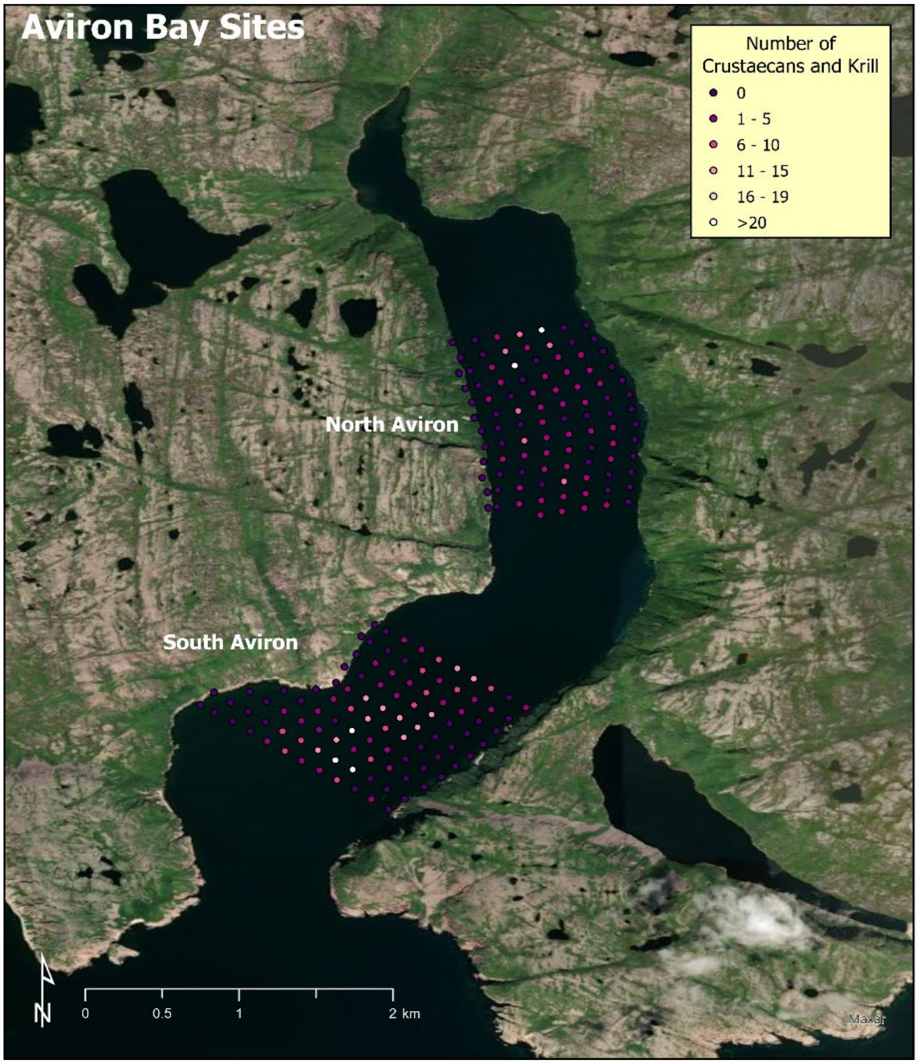

Figure 6: Representation of crustacean and krill presence at sites in the Aviron Bay. Dots are not to scale as per the limitations of the video sampling and therefore counts can be used only as partially indicative of spatial density.

Despite the overlap of the azamethiphos and hydrogen peroxide PEZs, the differences in expected dispersion, timelines between usage, and half-lives of compounds result in low likelihood of potential cumulative effect of both pesticides. An overview of bath pesticide usage of NL sites between 2018 and 2022 (DFO 2023c) indicates that most sites used azamethiphos only and that, among the sites using both (25.6% of sites), 70% of those had an interval of more than one week between pesticide use. It is difficult to comment on whether concurrent presence of azamethiphos and hydrogen peroxide could occur in shallow areas considering the lack of details of timelines for the PEZ, especially in terms of vertical dispersion and the potential residency of water masses in these shallow zones. Concurrent exposure would happen in the case of a persistent current towards the shore resulting in exposure of intertidal species to plumes of both pesticides, however, such a scenario is very speculative at this stage. A review of four years of publicly available data (2016–19) on chemical usage at salmon sites in NL, shows that sequential chemical treatments are commonly used, with EMB and then azamethiphos as the most used combination with a decrease in ivermectin usage (Hamoutene et al. 2022a). Therefore, any multi-chemical cumulative effect would occur mostly through both exposure of adults in the benthos (EMB usage as per the benthic-PEZ), and larval stage pelagic exposure to bath pesticides (pelagic-PEZ). For krill species and sand shrimp that mostly and/or intermittently occupy the pelagic zone, exposure to bath pesticides might represent a risk (pelagic-PEZ Figure 4 and Figure 5).

At the Foots Cove proposed site in La Hune Bay, krill were observed at 15 of 183 stations of the surveyed area (8.2% of stations) as illustrated in Figure 7. Given the close proximity of these sensitive species to the cage area (within the PEZ), they could experience a higher likelihood of exposure to chemotherapeutants after tarp treatment. This exposure might constitute a risk for krill and pelagic larval stages of some benthic species, as well as some shrimp species because of proximity to cages. Similarly, proximity to cage area of the highest counts of crustaceans might constitute a greater risk for these species given higher expected residue concentrations in water following tarp treatment.

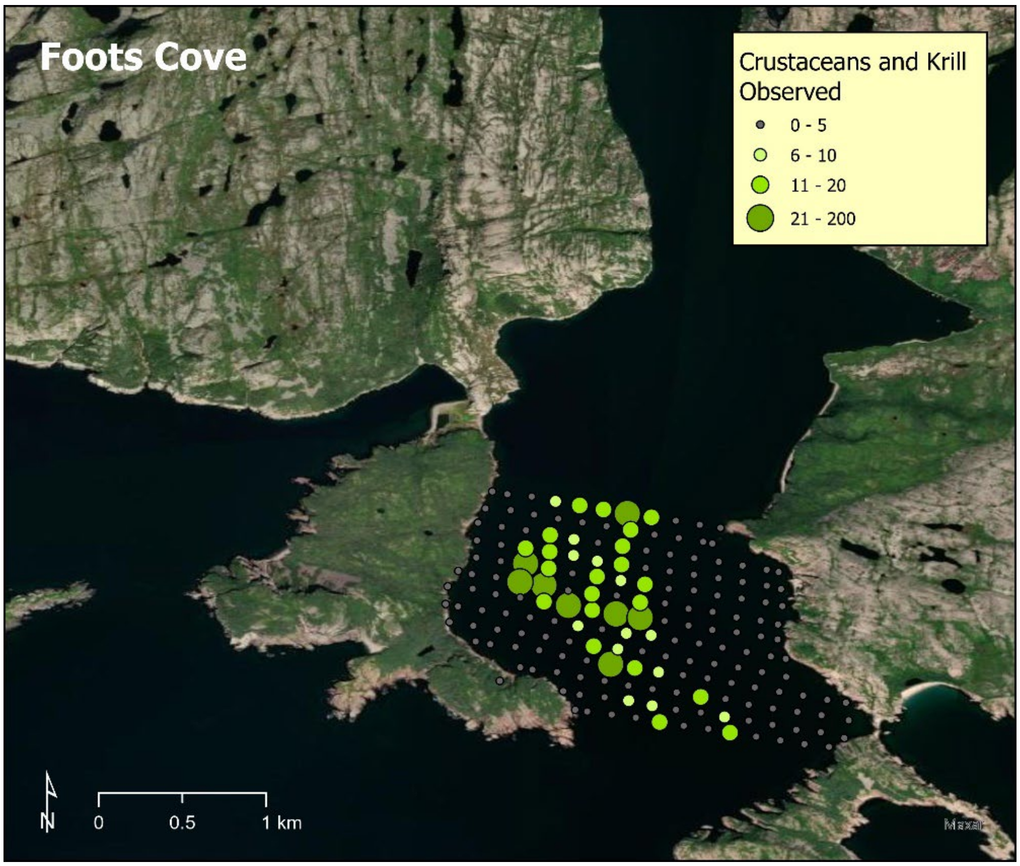

Figure 7: Representation of crustacean and krill presence at sites in the Foots Cove site. Dots are not to scale as per the limitations of the video sampling and therefore counts can be used only as partially indicative of spatial density.

In Bay de Vieux, where the Gnat Island, Shoal Cove, and Denny Island sites are proposed, crustaceans and krill were observed at 35%, 40.5% and 4.5% of all stations sampled, respectively. Figure 8 indicates the potential exposure of these sensitive species to both benthic and pelagic use of anti-sea lice compounds.

On the one hand, as stated above for all proposed sites, the likelihood of cumulative effects of azamethiphos and hydrogen peroxide pelagic-PEZs is low. On the other hand, there is a likely effect on crustaceans through both the exposure of adults in the benthos (EMB usage as per the benthic-PEZ), and the larval stages through a pelagic exposure to bath pesticides (pelagic-PEZ). For krill species and some shrimp occupying the pelagic zone, exposure to bath pesticides might represent a risk.

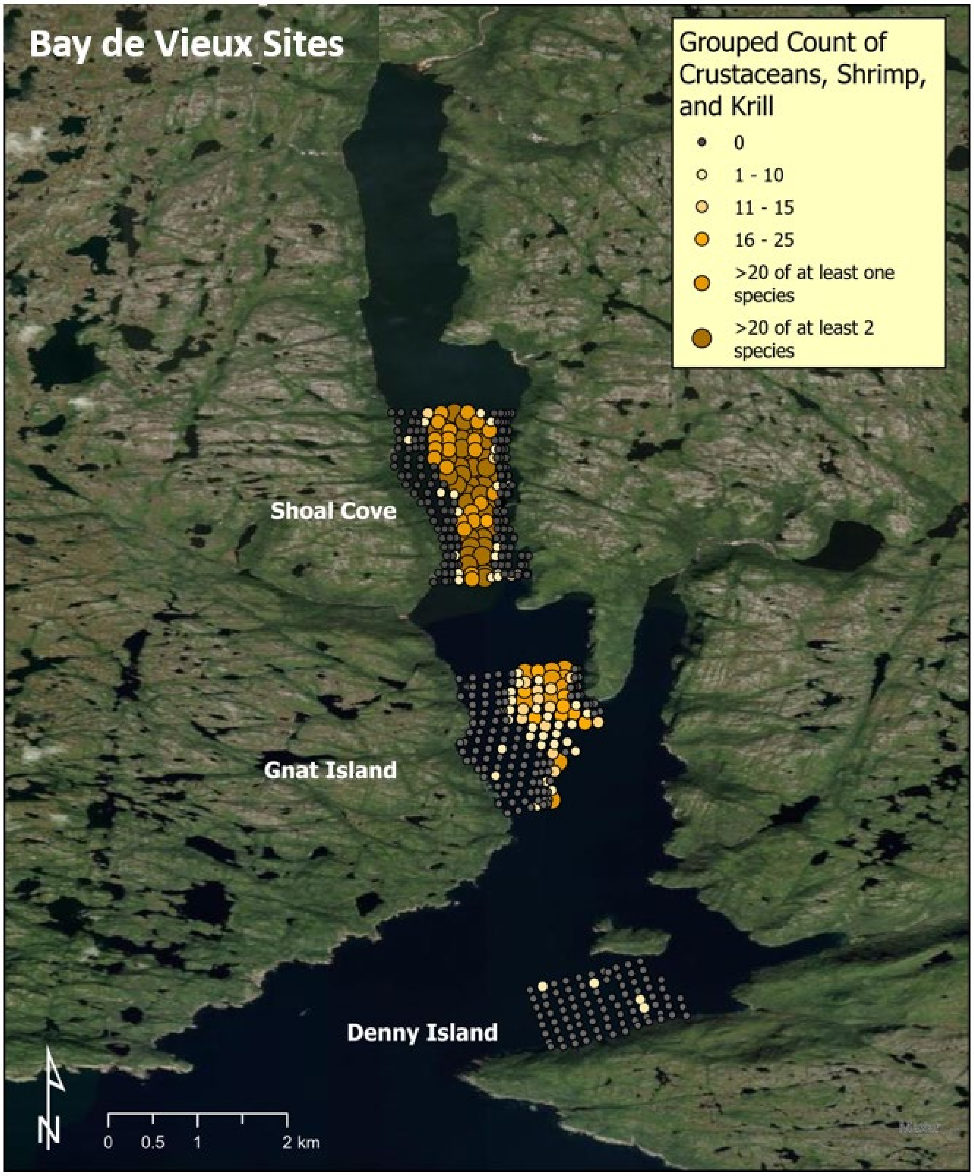

Figure 8: Representation of crustacean and krill presence at sites in Bay de Vieux. Dots are not to scale as per the limitations of the video sampling and therefore counts can be used only as partially indicative of spatial density.

Ecologically and Biologically Significant Areas

The South Coast EBSA (Appendix D, Figure A2 and A3) is located along the south coast of Newfoundland from Cape Ray to east of Ramea and extends 35–40 km seaward from the coast. Key features used to delineate this EBSA include important habitat for Blue Whale and other marine mammals; important areas for Atlantic Cod, Redfish, and Shrimp; significant benthic areas (sea pens, sponges); eelgrass habitat; Important Bird Areas IBAs: Grand Bay

West to Cheeseman Provincial Park IBA, Big Barasway IBA; fish functional groups (planktivores, piscivores, plank-piscivores); Black Dogfish and Smooth Skate areas; seabird functional groups (surface shallow-diving coastal piscivores, surface shallow-diving piscivores); and seals (Hooded Seals [*Cystophora cristata*], Grey Seals). These features are further described in Wells et al. 2019.

The South Coast EBSA is adjacent to the proposed Bay De Vieux management area. While no lease areas or benthic feed-PEZs overlap the EBSA, two benthic fecal-PEZs (Denny Island, Gnat Island) minimally overlap the EBSA (Table 5). The Shoal Cove benthic fecal-PEZ is adjacent to but does not overlap the EBSA. There is overlap of the pelagic-PEZ (both azamethiphos and hydrogen peroxide) for Bay De Vieux (Table 5). Additional figures show the location of the South Coast ESBA and overlaps of the benthic and pelagic-PEZs (Appendix D, Figures A4 and A5).

Table 5: Spatial overlap in square kilometres of benthic and pelagic-PEZs with the South Coast EBSA.

PEZ	Overlap (km^2)
Benthic fecal-PEZ – Denny Island	<0.1
Benthic fecal-PEZ – Gnat Island	0.3
Pelagic-PEZ (Azamethiphos) – Bay De Vieux	5.6
Pelagic-PEZ (Hydrogen Peroxide) – Bay De Vieux	18.5
South Coast EBSA = 6,870 km^2	

The South Coast EBSA was delineated as part of a 2017 CSAS process (Wells et al. 2019). This process used the best available information up to and including 2016; however, the limited scope and availability of coastal data limits the level of confidence for coastal EBSA boundaries (Wells et al. 2019). This gap is particularly true for the fjords of the South Coast EBSA. New information, including an additional eight years of DFO's multispecies surveys and benthic surveys related to aquaculture development, have led to the discovery of sea pens in the nearby fjords of Gnat Island, Little Bay, Bay d'Espoir (Goblin Bay, Butter Cove), and Wild Cove.

All six applications are within the South Coast Fjords Study Area (proposed National Marine Conservation Area, NMCA). This study area is approximately 9,112 km^2 and is representative of the Laurentian Channel marine region. As aquaculture facilities are not permitted in NMCA's, these areas would be excised from the final boundary.

PHYSICAL INTERACTIONS

Groundfish Species Interactions

The proposed sites are in areas that provide habitat for several groundfish species, including but not limited to Atlantic Cod, Witch Flounder, and Redfish. The annual DFO MSS does not extend spatially to fully sample the inshore, however the nearest available data to the proposed lease sites indicate that Atlantic Cod occur in moderate to high density in the inshore in this area (Wells et al. 2021). The Sentinel Survey of Atlantic Cod has been carried out by trained fish harvesters at various inshore sites along the south coast of Newfoundland. This survey has been active in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps since 1995 and provides indices of relative abundance (i.e., catch rates) for resource assessments. The nearest active sampling locations to the proposed sites included in the Sentinel Survey are Ramea and Francois (Figure 1) and further east in Harbour Breton. Catch rates from these sites remained consistently high throughout 1995–2021 in contrast to decreases further east; this pattern indicates that the proposed aquaculture sites are within a relatively productive area for 3Ps Cod (Mello et al. 2022). It should also be noted that overall productivity of 3Ps cod remains low, and currently assessed to be in the Critical Zone of DFO's Precautionary Approach (DFO 2024b).

Although juvenile cod clearly play a role in overall population dynamics of cod (e.g., Lunzmann-Cooke et al. 2021), there is currently no inshore survey for juvenile cod in NAFO Div. 3Ps. Evidence from the north coast of Newfoundland shows the importance of eelgrass habitat for juvenile cod (e.g., Laurel et al. 2003a, 2003b), but little spatial data exist on the distribution of eelgrass in NAFO Div 3Ps beyond Placentia Bay (Robichaud and Rose 2006). However, the current proposal identifies no eelgrass beds in the three fjords; and the shoreline configuration is not suited to eelgrass growth (R. Gregory, pers. comm.).

The inshore Witch Flounder fishery is focused within the Fortune and Hermitage Bay areas (Wheeland et al. 2019) and the nearest available MSS data to the proposed lease sites indicate high densities in the inshore in this area (Wells et al. 2021). Similarly, although commercial fisheries do not target Redfish in this area, the nearest available DFO MSS data indicate moderate to high densities in the area (Wells et al. 2021).

Pelagic Species Interactions

Limited data exist for pelagic species the south coast west of Fortune Bay with no biomass estimates for Herring, Capelin and Mackerel specific to this area. However, herring primarily occupy nearshore waters somewhat similar to those used for aquaculture (Bourne et al. 2023, Tibbo 1956). Capelin are seasonally abundant in bays from the spring through fall, initially as spawning adults and then later as eggs and larvae (Templeman 1948, Mowbray et al. 2023). An overwintering population of juvenile Capelin may occur in deep-nearshore waters. Mackerel also use Newfoundland waters seasonally during summer and fall (Ware and Lambert 1985).

Aquaculture activities could potentially promote the growth of phytoplankton and zooplankton (Suikkanen et al. 2013; Navarro et al. 2008) in the waters surrounding the sites through increased nutrient loads (Bonsdorff et al. 1997, Callier et al. 2018, Skogen et al. 2009, Kutti et al. 2007). Increasing nutrient loading rates to Newfoundland's coastal bays, in combination with climate change, could potentially lead to coastal eutrophication and the formation of coastal hypoxic zones (e.g., Justić et al. 1996, Fennel and Testa 2019). It may also exacerbate hypoxia caused by high water temperatures and/or stronger water column stratification, which may 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 (e.g., Breitburg et al. 2003, Adamack et al. 2012).

Increased nutrient loading from these aquaculture sites could aggravate episodic low oxygen events associated with high water temperatures by increasing water column and/or sediment BOD. Peak feeding times for farmed salmon from mid-summer to early fall in the second year of production roughly corresponds to the timing of peak water temperatures along the south coast of Newfoundland (DFO 2023d). Because biological activity tends to increase with temperature, BOD will likely peak when high water temperatures contribute to low oxygen levels in the water column. Fjords are prone to hypoxic events because their location in deep, narrow valleys results in a low surface area to volume ratio. Oxygen is replenished by vertical diffusion and, if BOD is high, biota may consume diffusing oxygen within the water column before it mixes to the bottom (Fennel and Testa 2019) which could prolong the length of hypoxic events in bottom waters beyond the end of a high temperature period. These effects are more likely to affect benthic organisms than pelagic fish which could move to areas with more favorable oxygen conditions, but low bottom oxygen concentrations could affect pelagic species with benthic eggs.

The presence of elevated phytoplankton and zooplankton concentrations may affect pelagic fish such as Herring in bays with salmon farms. Additionally, any aquaculture facility lighting (e.g., for navigation or security purposes) may concentrate zooplankton, larval fish, and adult Herring to the waters surrounding the facility (e.g., Stickney 1970). Use of lighting at night, particularly when larvae are abundant, may expose larval Herring and Capelin to increased predation rates, given that lights attract both species (e.g., Stickney 1970, Keenan et al. 2007) into these areas with significantly higher predator concentrations (both wild fish and farmed salmon). Consequently, the aggregation of both piscivorous fish and small pelagic forage species such as Mackerel, Herring and Capelin likely increases mortality rates relative to their spatial distribution when not aggregating near salmon farms. Effects are likely to be greatest on Herring given their often year-round presence in coastal waters (Bourne et al. 2018) whereas Capelin spend much of their lives in deeper offshore waters (Mowbray et al. 2019) and Mackerel migrate to Newfoundland waters seasonally (Parsons and Hodder 1970). However, significant numbers of early life-stage individuals of all three species could experience increased predation pressure if they pass by waters occupied by fish farms.

Salmonid Species Interactions

Three of the 55 Atlantic Salmon rivers along the southwest coast of Newfoundland (35 in Salmon Fishing Area [SFA] 11 and 20 in SFA 12), have been monitored in recent decades. Atlantic Salmon returns to Little River (SFA 11) averaged 235 salmon annually (range: 47–801) from 1987–2016 but did not exceed ten fish annually from 2017–20 (DFO 2022a). Over the previous three generations (2008–22), adult Atlantic Salmon returns to Little River have declined by 98%. Total returns to Conne River (SFA 11) ranged from 8,047–10,671 salmon from 1986–88 and have been on a declining trajectory ever since. Consecutive record low adult Atlantic Salmon returns to Conne River were recorded from 2017–20 (DFO 2022a) and did not exceed 710 salmon each year. In 2022, total returns to Conne River were 41% below the previous generation average (2017–22) and 81% below the previous three generation average (2006–22). Atlantic Salmon returns to Garnish River (Fortune Bay-SFA 11) have been monitored since 2015 and averaged 441 salmon annually from 2015–22 (range: 155–895) starkly contrasting harvest levels of 1,000-2,000 fish in the 1970s. Since 2015–16, all three populations have been consistently assessed in the Critical Zone.

Longstanding population declines of wild salmon in southern Newfoundland (SFA 11) counter other regions of the province. This trend occurs against a backdrop of south coast populations subjected to different environmental conditions and different anthropogenic developments than other coasts. Atlantic Salmon that migrate to and from the south coast experience substantially different ocean conditions than fish on the Labrador coast and Newfoundland’s northeast coast. Hydroelectric developments in the Bay d’ Espoir area encompass large spatial scales and have significantly altered local drainage basins. Along the south coast of Newfoundland, the largest input of freshwater into the ocean occurs near Bay d’ Espoir, with large contributions from the hydroelectric power facility (Ings 2006). The inner region of the bay supports steelhead trout production in waters north of Bois Island, and the Coast of Bays region hosts the largest number of Atlantic Salmon aquaculture operations in the province, occurring mainly in Harbour Breton Bay, Great Bay de l’Eau, Hermitage Bay and bays west of Bay Espoir. Historic and periodic escape events, documented hybridization with escapees, reported disease outbreaks, and increased need for sea lice control measures, have all resulted in negative impacts to wild salmon populations (Bradbury et al. 2020, Glover et al. 2017, Wringe et al. 2018, Shephard and Gargan 2017). Two of the rivers where smolts are counted and marine survival is estimated occur in SFA 11 (Conne River and Garnish River) and both show poor marine survival in recent years (<3% since 2018 and <1% in 2020) relative to the other three populations DFO monitors in a similar fashion (DFO 2022a). At Western Arm Brook, Campbellton River, and Rocky River (located on the north coast of Newfoundland), mean marine survival rates over most of the past 10 years range from ~4–11% across rivers; however, rivers in the proposed area on the south coast of Newfoundland experience significantly different ocean conditions than fish in rivers on the north coast related to Gulf Stream influences versus the Labrador Current (COSEWIC 2010). Additionally, indigenous and local knowledge indicates that habitat alteration and hydrodynamic changes resulting from the hydroelectric facility may also contribute to declines. However, more investigation is required.

Past commercial salmon catch data and tag returns both indicate that salmon from all populations in Atlantic Canada occur in this area of southern Newfoundland. In describing tag returns from the commercial fishery, Reddin and Lear (1990) report recapture across the south coast of salmon tagged in locations such as St. Lawrence (1973), Placentia Bay (1975), and throughout the east coast (e.g., Burgeo, Port aux Basques) and the Maritimes. Historical data on commercial and recreational catches in southern Newfoundland further substantiates this result (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 2020) indicates dominant contributions from Gulf and Gaspé Peninsula regions and a smaller contribution from the northeast coast of Newfoundland. Individuals from southern Newfoundland populations and elsewhere likely migrate regularly through this area, exposing them to cage sites both as migrating smolts and returning adults.

Pests and Pathogens

Aggregation of fish near aquaculture facilities may also promote the spread of disease and parasites to and from wild fish stocks. The development of new sites could potentially increase the spread of diseases between aquaculture sites because it shortens the travel distance/time between sites for wild fish that may move frequently between farm sites (e.g., Uglem et al. 2009). Since 2016, there have been two reports of viral haemorrhagic septicemia in Atlantic Herring in waters off Newfoundland and Labrador. Additionally, there have been 55 detections of infectious salmon anemia virus (ISAV) in Newfoundland waters since 2012; however, 20 of the detections involved strains not known to cause disease.

The positioning of the proposed cages in narrow fjords and adjacent to coastlines and the position of the water column occupied by pelagic forage fish and their high relative abundance in the ecosystem all add to the likelihood that they will move past or interact with salmon aquaculture cages during their production cycles. Some research indicates ISAV can propagate in Atlantic Herring, which may be an asymptomatic carrier of the ISAV (Nylund et al. 2002). Herring move between bays and offshore areas, traveling tens or hundreds of kilometres (e.g., Wheeler and Winters 1984).

Bouwmeester et al. (2021) recently 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, potentially infecting conspecifics and/or other wild species, possibly leading to emerging disease. Farmed fish may host parasites from wild host species, potentially amplifying parasite numbers and increasing the frequency of parasite infections in the wild hosts when parasite infections spill back to wild hosts. Finally, the presence of farmed fish could alter the transmission of parasites between wild host species, potentially altering wildlife disease dynamics. Collectively, these effects of farmed fish populations could potentially degrade fish health in an ecosystem through increased rates of disease and parasitism depending upon host susceptibility and prevalence.

Sea lice are small, naturally occurring ectoparasites that can pose a significant health risk to farmed and wild Atlantic Salmon when present at host density threshold levels (Krkošek 2010). Extensive research over the last decade in Norway, Scotland, and Ireland has demonstrated significant demographic impacts to wild Atlantic Salmon associated with amplification of sea lice with salmon aquaculture (e.g., Shephard and Gargan 2017; Thorstad et al. 2015; Dempster et al. 2021; Johnsen et al. 2021; Vollset et al. 2022). The magnitude of wild population decline in years of sea lice outbreaks in salmon farms has been reported between 12–50% (Shephard and Gargan 2017; Thorstad et al. 2015). Additionally, prophylactically treating out-migrating smolts for sea lice has improved survival by 50 times (Bøhn et al. 2020).

Long-term data on sea lice abundance in southern Newfoundland is lacking. However, as of January 2021, public reporting of monthly averages of sea lice per fish across all sites/company has become a requirement for periods when water temperatures exceed 5°C (Table 6). Drug and pesticide use reporting has been a requirement since 2016. As a result, drug and pesticide use reporting is the only information currently available for inferring sea lice infestation potential. This public reporting provides insight into the Proponent's performance in managing sea lice abundance on farms in recent years.

Table 6: MOWI Canada East publicly reported aggregated average sea lice per fish.

Month	2021	2022	2023	Average
May	1.02	0.55	1.75	**1.11**
June	0.39	0.08	0.23	**0.23**
July	1.73	1.81	0.16	**1.23**
August	2.6	0.67	0.14	**1.14**
September	4.65	0.89	1.06	**2.20**
October	7.09	0.85	1.26	**3.07**
November	14.2	1.42	1.06	**5.56**
December	7.9	1.45	0.82	**3.39**
Max	**14.20**	**1.81**	**1.75**	**-**

While some cage sites reported low or no chemical usage for controlling sea lice, sea lice treatments in Newfoundland over the period 2016–21 peaked in 2017 and have since declined (Hamoutene et al. 2022b). Treatments in 2017 coincided with warmer surface temperature in the fall, a higher freshwater input in spring, and stronger wind conditions (Hamoutene et al. 2022b). However, drug and pesticide reporting does not provide insight as to whether the decline from 2017–21 reflects decreased salmon aquaculture production over this period, increased use of innovations (i.e., non-chemical methods) using biological and mechanical treatment methods (e.g., use of cleaner fish, thermolicers), a change in how the numbers are reported (Hamoutene et al. 2022b), or a natural reduction in sea lice in the marine environment due to unfavorable environmental conditions. The applicant's Integrated Pest Management Plan (Proponent's supporting document Appendix 5: Environmental Management and Waste Management Plan) outlines the preventative actions and interventions available in all the aquaculture management areas it operates within. The Integrated Pest Management Plan outlines thresholds, environmental and operational prerequisites for each option. Historically, sea lice treatments have occurred from June to December with an apparent peak in July, and thus the timing of outbreaks can coincide with the periods when wild salmon are either migrating from or returning to local rivers.

Aquaculture Escapees

Genetic studies in southern Newfoundland and in the Maritimes over the past decade have documented widespread hybridization between wild salmon and aquaculture escapees (Bradbury et al. 2022, Holborn et al. 2022, Keyser et al. 2018, Sylvester et al. 2019, Wringe et al. 2018). Across the North Atlantic, the magnitude of genetic impacts from escaped farmed Atlantic Salmon on wild populations correlates with the biomass of farmed salmon in nearby cages and the size of wild populations. The risk posed to wild salmon population abundance and genetic character by direct genetic interaction with escapees in southern Newfoundland has recently been assessed using a combination of a likelihood and a consequence assessment (see DFO 2024c). Two Designatable Units (DUs) in southern Newfoundland were evaluated as part of that risk assessment – South Newfoundland East (DU 4a) and South Newfoundland West (DU 4b). European-origin sterile (triploid) fish are used in production in DU 4a, whereas diploid Saint John River strain salmon are used in DU 4b. For DU 4a, the risk assessment concluded that risk to both abundance and genetic character was low across all escape rates examined, an outcome largely attributed to mitigation of risk by using sterile salmon. By comparison, the assessment concluded that risk to wild salmon abundance in DU 4b ranged from low to high and was high for genetic character across the range of escape rates examined. For DU 4b, this significant risk exists against the backdrop of a declining wild population which is currently designated as threatened under COSEWIC (2010) and under re-evaluation after further declines (DFO 2022a, 2023a).

The potential genetic interactions resulting from the proposed finfish expansion involving six sites (1M individuals/site) in southern Newfoundland were considered using a combination of empirical data (North American and European), and dispersal modeling (DFO 2024c). The distribution of escapees in the wild under the current and proposed production regime were modelled using a published spatial model of dispersal and survival following DFO (2024b). 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 (DFO 2024c; Bradbury et al. 2020). Wild population sizes were estimated based on river (axial) length and corrected for recent population declines through comparison with recent Atlantic Salmon monitoring data. For the Bay d'Espoir region, an 80% decline was used following counting fence trends in the region. For the rest of DU 4b (west of Garnish) a 60% decline correction was applied based on angling statistics. The number of expected escapees per unit production was estimated using reported escape event and production data from Newfoundland as well as several other jurisdictions, recognizing that reported escape events were previously shown to underestimate exposure of wild populations to escapees (Skilbrei et al. 2015). To account for this variability, analyses were completed at both 0.2 and 0.4 escapees per tonne production. Production levels used in the analysis utilized maximum allowable production levels recognizing the maximum allowable production levels have not historically been achieved (DFO 2024c). The model accounts for periods of fallowing and production losses of 20% as stated by the Proponent and assumes a 5 kg harvest weight. Furthermore, wild population sizes were likely overestimated given direct comparison with census data and stock assessments and ongoing evidence of continued declines in the region. It is also noteworthy that of the rivers considered, Grey River and White

Bear River contain two of the largest salmon populations along the entire south coast and are adjacent to some of the proposed expansion sites.

For the South Newfoundland East DU (DU 4a) there was no significant increase in the number of escapees predicted in the region associated with the expansion and no rivers are predicted to exceed the 10% threshold for the proportion of escaped farmed salmon. For the South Newfoundland West DU (DU 4b), escapee dispersal simulations suggest an approximate 10% increase in the number of escapees present in the region under the proposed expansion (both 0.2 and 0.4 escapees per tonne production). At 0.2 escapees per tonne production, 31/53 or 58% of salmon rivers in the DU are predicted to exceed 10% escapees compared with 30 rivers exceeding 10% escapees pre-expansion. The maximum values for the proportion of escapees are predicted to occur within rivers in the head of Bay d'Espoir, including Conne River, where predictions suggest the percentage of escapees is 38% (assuming a conservative 0.2 escapees per tonne production, Figure 9). The majority of escapees from the proposed sites (i.e., 55%) are predicted to disperse into White Bear River and Grey River. At the Regional (i.e., DU) level, the predicted 16.3% proportion of escapees exceeds the threshold of 10%. Using 0.4 escapees per tonne 35/53 or 66% of salmon rivers in the Southern Newfoundland West DU are predicted to exceed 10% escapees compared with 31 rivers exceeding 10% escapees pre-expansion. Again, the maximum values for the proportion of escapees are predicted to occur within rivers in the head of Bay d'Espoir, including Conne River, where predictions suggest 55% escapees (Figure 10). The majority of escapees from the proposed sites (i.e., 55%) are predicted to disperse into White Bear River and Grey River. At the Regional (i.e., DU) level, the proportion of escapees (32.6%) exceeds the threshold of 10%. In summary, for both the 0.2 and 0.4 escapees per tonne production escapee scenarios, predictions in the region under the proposed expansion suggest increased impacts of escapees on both the abundance and genetic character of wild salmon.

The Proponent has indicated they will employ various mitigation measures to reduce the likelihood of escapes such as high density polyethylene (HDPE) netting with a steel core, remote operated vehicle net cleaners and video with increased monitoring, and third-party certification standards for cage design and engineering. Since public reporting for Atlantic Salmon escape events commenced, one event with one escaped salmon was reported in 2020, one event with four in 2021, and one event with one in 2022 (Public Reporting Industry Statements).

A review of the Management of Wild and Farmed Salmon Interactions document (submitted by the Proponent in Appendix 5: Environmental Management and Waste Management Plan) highlighted the omission of a plan for a thorough evaluation of the success of any attempts to limit escapees through an escapee monitoring and traceability program. Without this component, there are limited data to evaluate the efficacy of containment measures and actual escape rates. In the absence of this information, escape rates will continue to be estimated based on the best available information which includes reported escape events and information available on underreporting of escape events (e.g., Skilbrei et al., 2015).

Additionally, a traceability program to identify farmed fish using genetic markers from a tissue sample would be important, regardless of a comprehensive escape monitoring program. Farmed fish are captured at some DFO monitoring sites in the region and assignment back to a given producer would be a valuable tool to manage impacts. DFO has developed standard operating procedures for this sort of genetic analysis and for maintaining chain of custody. Finally, to determine if HDPE nets effectively eliminate escape events in Newfoundland waters, data specific to the Newfoundland region are required. However, no research has been conducted on this issue. Moreover, a recent overview of potential mitigation measures

(DFO 2024c) led to a conclusion that eliminating all human errors and equipment failures associated with Atlantic Salmon net pen escapes is not realistic (DFO 2024c).

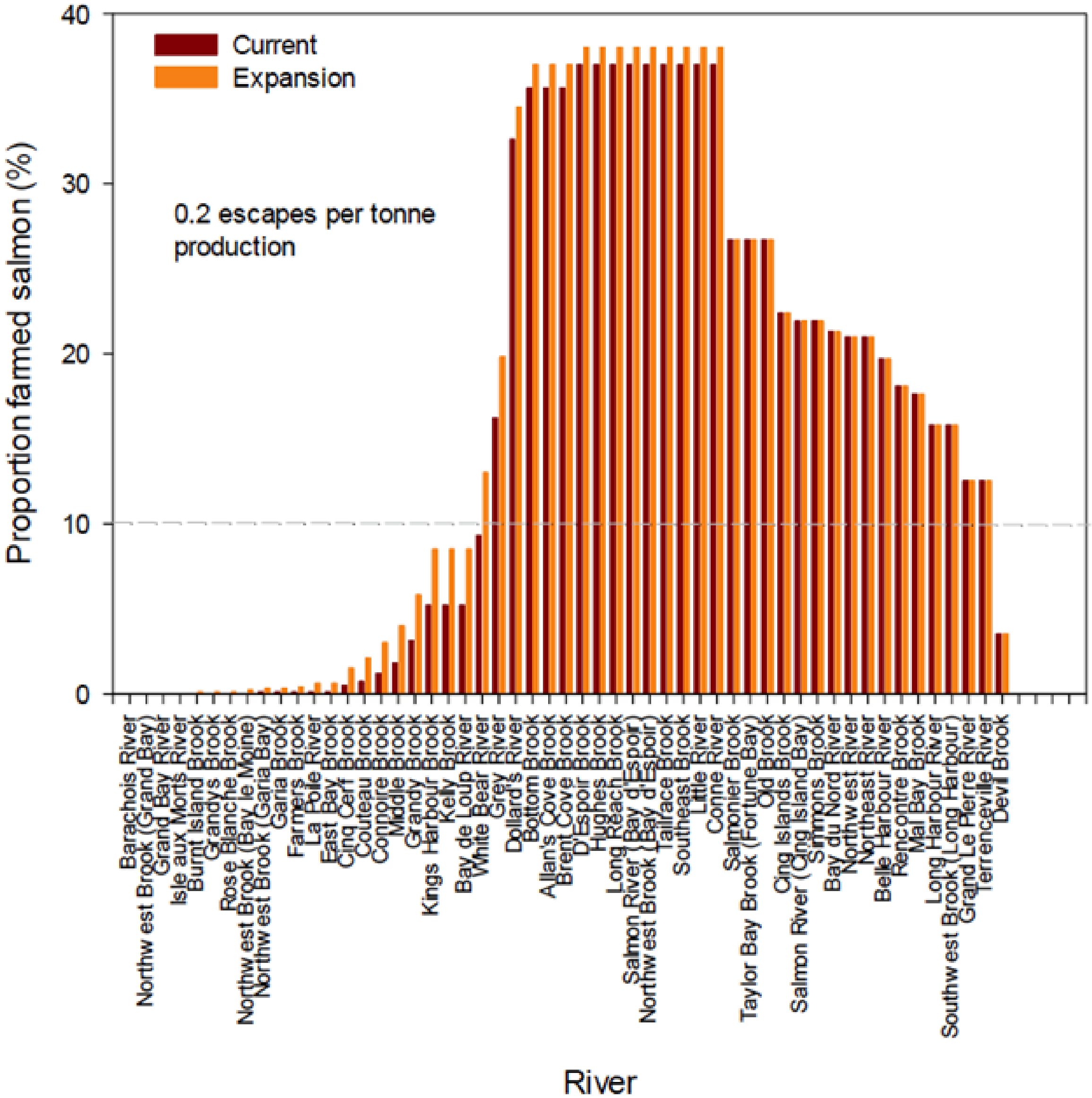

Figure 9: Simulated proportion of farmed to wild Atlantic Salmon in Southern Newfoundland West (DU 4b) rivers under both current and proposed expansion scenarios using 0.2 escapees per tonne aquaculture production following DFO (2024b). The 10% hatched line represents the threshold above which above which impacts to abundance and genetic character are predicted to occur.

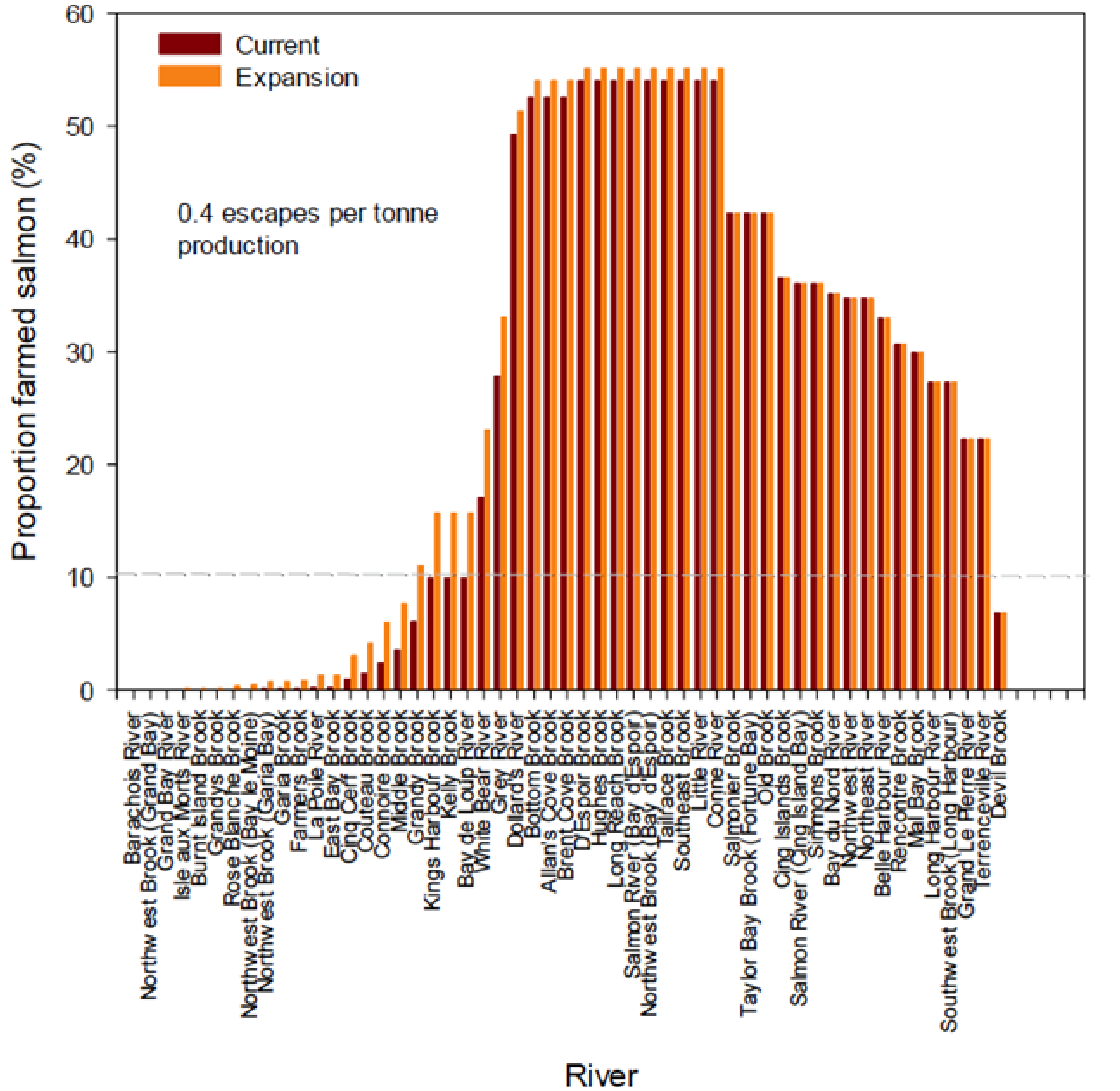

Figure 10: Simulated proportion of farmed to wild Atlantic Salmon currently in Southern Newfoundland West (DU 4b) rivers under both current and proposed expansion scenarios using 0.4 escapees per tonne aquaculture production following DFO (2024b). The 10% hatched line represents the threshold above which impacts to abundance and genetic character are predicted to occur.

European Ancestry

Recent analysis has used population genomics to explore the presence of European introgression into North American farmed and wild Atlantic Salmon (Bradbury et al. 2022). This study attributed a portion of the DNA of both contained and escaped farmed salmon sampled in Atlantic Canada to recent interbreeding with European origin domestic salmon. In addition, two escaped farmed salmon were detected with 100% European ancestry (Bradbury et al. 2022). In NL, European genes were detected in wild salmon sampled near aquaculture sites (e.g., Conne River), indicating aquaculture escapees with European genes that interbred with wild Atlantic

Salmon. These results demonstrate that, even though diploid European salmon have never been approved for use in Canada, individuals of full and partial European ancestry have been in use over the last decade, and that some of these individuals have escaped and bred in the wild (Bradbury et al. 2022). Recent analysis of samples of salmon that escaped from a net pen nursery site in southern Newfoundland (2021), and an escape event in the Bay of Fundy (2023), indicate continued presence of significant European ancestry in farmed salmon. In the 2021 escape, 21% of the 189 fish analyzed displayed more than 10% European ancestry and in the 2023 escape event, 33% of the escapees analyzed displayed more than 10% European ancestry. European salmon differ significantly from North American salmon across a variety of important genes and traits (Lehnert et al. 2019, 2020), thus this observation significantly elevates the risk to wild salmon populations if the documented escape and interbreeding of individuals continues (Bradbury et al. 2022). Pre-screening of fish for European ancestry prior to transfer to sea cages could help mitigate these impacts in southern Newfoundland. DFO has developed a new screening tool of genomic markers chosen to provide accurate identification of European ancestry (Nugent et al. 2023a).

Cleaner Fish Escapees

The aquaculture industry increasingly uses cleaner fishes such as Wrasse and Common Lumpfish 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 with future plans to use Cunner. As with Atlantic Salmon, research suggests genetic interactions between escaped cleaner fish and wild populations warrant consideration given likely negative impacts (Blanco Gonzalez et al. 2019, Faust et al. 2018, 2021). The DFO spring MSS in Subdivision 3Ps indicated declines in Lumpfish abundance of about 58% between 1996 and 2014 (Simpson et al. 2016). Accordingly, 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 suggests the presence of a distinct northern population that includes southern Newfoundland, and further structuring within that group around the island of Newfoundland (Langille et al. 2023). Similarly, although there are no assessment data on Cunner in Newfoundland waters, genomic analysis suggests significant structuring with west, northeast, and south coasts representing discrete and adaptively distinct populations (Nugent et al. 2023b). As such, considerable uncertainty remains with regards to the potential impact of the use of Cunner and Common Lumpfish in salmon aquaculture on local wild populations. Given evidence of negative genetic impacts of cleaner fish on wild populations elsewhere, the potential exists for negative interactions in southern Newfoundland.

Entanglements

Aquaculture sites could result in increased entanglements of wild species (e.g., wild fish, marine mammals, turtles and sharks) associated with the placement of infrastructure. Entanglement can cause drowning and direct injury from nets and ropes. Injuries from entanglement can reduce movement, impede feeding ability, cause internal injuries from struggling, constrict blood flow, sever appendages, cause infections, and lower reproductive success (Bath et al. 2023). Interactions that result in the death of megafauna have reduced dramatically over the past two decades through improved anti-predator netting, improved anchoring, and the prompt removal of attractants, such as dead fish (DFO 2023b).

Few scientific surveys have been completed in the coastal, sheltered areas of the south coast of Newfoundland, resulting in a lack of information regarding the distribution of marine mammals in the aquaculture lease areas under review. For these assessments, Local and Traditional

Ecological Knowledge collected from consultations would be valuable to assess the potential for entanglements. There is overlap of the proposed sites with the distribution of several species of whales (Blue Whale, Fin Whale, Sei Whale, Minke Whale, Humpback Whale, North Atlantic Right Whale, Sperm Whale), several species of dolphins, and Harbour Porpoise and seals (e.g., Grey Seals and Harbour seals). Based on opportunistic and systematic sightings data, these species can occur in Newfoundland waters year-round with seasonal peaks in abundance occurring typically in summer and fall. Some species, such as North Atlantic Right Whale and Grey Seal, are seasonal visitors typically absent in the winter.

Cetaceans

Globally, entanglement data associated with marine aquaculture infrastructure are relatively sparse and rarely quantitative (Bath et al. 2023). Marine mammal protection is not mandated in all countries and reporting of interactions with aquaculture farms may not be required (Bath et al. 2023), likely resulting in the underreporting of entangled animals and species. For species occurring in Canadian waters, Bath et al. (2023) reported global incidents of cetacean entanglement with marine finfish farms involving Humpback Whale, Sei Whale, Minke Whale, Common Dolphin (*Delphinus delphis*), Bottlenose Dolphin (*Tursiops truncates*), and Harbour Porpoise. Data on cetacean entanglement associated with aquaculture infrastructure are largely not available in Canada. In Newfoundland, no cetacean entanglements with finfish aquaculture net pens have been reported to date; however, in 2018 a Humpback Whale entangled in a gillnet deployed to capture escaped farmed salmon in Hermitage Bay was freed later the same day. British Columbia (BC) provides data on marine mammal fatalities at marine finish aquaculture sites, starting in 1990 to July 2023 (DFO 2023b). From 1990 to 2015, there were reports of cetacean fatalities that included five Harbour Porpoise (four in 2007; one in 2008) and one Humpback Whale (2013), which was found dead at an aquaculture site, but cause of death was unknown. Between 2016 and 2023, there were five reported Humpback Whale entanglements at aquaculture sites in BC, and two of those entanglements were fatal. Humpbacks are baleen whales (Mysticetes) that, unlike toothed whales (Odontocetes), do not use echolocation for navigation, which may make them more prone to entanglement (DFO 2023b, Bath et al. 2023). Storlund et al. (2024) examined reports of Humpback Whales interacting with Atlantic Salmon farms in BC from 2008 to 2021 to evaluate the conditions that may have contributed to their entanglements. Of the eight entangled humpbacks reported to the BC Marine Mammal Response Network, three individuals died and five were successfully disentangled and released. All were young animals (one calf, seven subadults). Multiple factors, including facility design, environmental features, seasonality, humpback whale age, and feeding behavior, were associated with two or more of the reported incidents. Humpback whales were trapped most frequently in the predator nets of the aquaculture facilities (6/8 incidents) and were less often entangled in anchor support lines (2/8). The presence of salmon smolts did not appear to attract humpback whales given that half of the reported entanglements (4/8) occurred at fallowed salmon farms. The authors noted that overall, the number of humpback whales impacted by fish farms was small compared to the numbers that return to BC waters (>7,000) and accounted for <6% of all types of reported entanglements in BC.

Seals

Seal species such as Harbour Seals and Grey Seals occur along the Newfoundland south coast regularly and may haul-out in the lease areas, particularly near islands and rocks. Harbour Seals occur year-round while Grey Seals are seasonal visitors that arrive in late spring and depart in late fall. 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 (DFO 2022c).

As with cetaceans, little data exist for pinniped entanglements associated with aquaculture infrastructure in Canada. In BC from 1990–2023, the most common marine mammal fatalities at aquaculture sites were Harbour Seal and California Sea Lion (*Zalophus californianus*); however, the vast majority of these fatalities were authorized (lethal removal due to imminent danger to aquaculture facilities or to human life) that were permitted prior to March 2020 (DFO 2023b). Publicly released data on marine mammal fatalities (authorized and accidental) for 2011–23 indicate 78 authorized fatalities and 50 accidental drownings for Harbour Seal (DFO 2023b). The accidental drownings were largely attributed to animal entanglement underwater in cage netting or other farm gear (Bath et al. 2023). In Newfoundland, no pinniped entanglements with finfish aquaculture infrastructure have been reported to date.

Turtles

Leatherback Sea Turtles and Loggerhead Sea Turtles frequent Newfoundland waters during summer and fall to forage, but they do not nest in Canada. Leatherback Sea Turtles frequent inshore waters, with nearby Placentia Bay as a particularly important habitat for the species (DFO 2011, 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 2020b) and are not expected to occur in the proposed aquaculture lease areas.

Bath et al. (2023) noted that relatively little is known about how marine cage farms impact sea turtles after finding no published reports of harmful interactions despite an exhaustive literature search. Extrapolating from reports on interactions with commercial fishery gear, sea turtles are vulnerable to entanglement in both vertical and horizontal lines with slack lines posing the greatest threat when the lines wrap tightly around flippers multiple times during escape attempts (Hamelin et al. 2017, Bath et al. 2023). There are three known incidents involving Leatherbacks entangled in shellfish aquaculture infrastructure in Notre Dame Bay, Newfoundland (Bath et al. 2023). One turtle was found dead in 2009, rolled up in mussel farm lines. The two other entanglements involved mussel spat collection lines with one resulting in death at depth in 2010 while the other was recovered alive in 2013 at the surface and released after disentangling its head and flippers. In Newfoundland no turtle entanglements with finfish aquaculture net pens have been reported to date. Acknowledging some concern about entanglement and subsequent injury and drowning, evidence to date suggests low risk of entanglement at the proposed sites.

Previous research documents the potential attraction and entanglement of large pelagic fish to the sea cages, notably tunas and sharks. Increased presence of White Sharks has been observed along the south coast in recent years. As opportunistic predators, White Sharks feed on a variety of prey, including marine mammals and fish; hence the potential for entanglement of White Sharks in sea cages cannot be dismissed, considering their feeding behavior, and the overlap between the distributional range of the species and the proposed aquaculture sites. However, the presence of White Sharks in coastal Newfoundland waters is rare, and the species occupies an extensive range of pelagic habitat (i.e., Ocean Basin scale), suggesting a negligible impact from the proposed aquaculture activities at species or population levels, or on their habitat.

OTHER CONSIDERATIONS/SOURCES OF UNCERTAINTY

Cumulative Effects

This process did not consider cumulative effects despite the proximity of sites to each other. For example, the benthic-PEZ associated with feces in Bay de Vieux and Aviron Bay, significantly overlapped amongst sites, with potential for cumulative exposure to organic enrichment. For example, sea pen fields in the Gnat Island area (located in Bay de Vieux) might be affected by activities at the two other proposed sites in that bay. The unknowns regarding potential cumulative effects of chemical use and organic matter deposition on benthic species indicate a need for future studies.

ROV Surveys

The Proponent followed AAR requirements for video assessment, however, surveys conducted often had suboptimal video quality. Although most frames allowed determination of the dominant fauna, the low-quality hampered more specific identifications. The low quality of the videos will challenge future comparative analysis of before and after aquaculture activities, emphasizing a need for the Proponent to improve the quality of the seabed videos. Species specific probabilities of detection are unknown. Taxa absences and abundance counts must be considered with caution, given that counts do not reflect relative counts (i.e., in relation to the surveyed area) and camera distance from the seafloor might differ slightly between stations.

Drugs, Pesticides and Fish Health

Better understanding of the potential toxicity of anti-sea lice treatment on geographically relevant species will require more toxicity data sites and field studies. To address the potential effects of active ingredients, quantitative modelling of sea lice treatment dispersion and dilution processes is required. This will also require better knowledge of the oceanographic conditions and properties of chemicals in use. The integration of quantitative modelling with toxicity thresholds would require new data from the Proponent to comment on impact.

Aggregation of fish around the aquaculture sites could potentially increase the spread of disease between farmed and wild fish resulting from increased density of fish in the vicinity of aquaculture sites. An increase in monitoring of disease and parasites in bait fisheries such as herring can provide a better understanding of potential disease and parasite spread between farmed and wild fish.

Escapees

The estimated number of farmed escapees relative to the annual production used to assess the potential magnitude and distribution of escapees entering scheduled salmon rivers does not correspond to the magnitude of those publicly reported in recent years. The extent to which this difference reflects underreporting, changes in regulatory oversight, or improved containment infrastructure and operational procedures remains an unknown. Expanded and more comprehensive monitoring could help refine model assumptions. Improvements in industry practices and containment infrastructure may prevent or minimize the possibility of future escapes. The current projection of the magnitude and distribution of farm escapees does not accurately account for the development and utilization of farms under the aquaculture management area framework, potentially skewing the projections of invasion in certain rivers. Applying the model to an aquaculture management area scenario would enable more precise forecasting of site production information, which would better support planning and assessment. However, to apply the model in this way, more specific and detailed production information than what is currently provided would be needed.

Oceanographic Data and Model Output Submitted by the Proponent

The expansion of aquaculture on the south coast of Newfoundland in remote areas with limited scientific knowledge requires that the DFO Science Review process relies on data provided by the Proponent. The review depends on the quality and quantity of these data. The Proponent has collected ocean current data at all proposed sites and at various depths. The analysis of the current speed at each depth shows variability in currents within the water column, which is consistent with variability observed in other bays in the same region (Ratsimandresy et al. 2019, Donnet et al. 2022).

Considering the seasonal variability observed in the region and stronger ocean currents in Fall, these proposed sites presumably experience similar variability. Ocean currents were measured for only 33 to 38 days (May-June and/or June-July), and such a short period of data collection cannot capture seasonal variability. In addition, the AAR stipulate that deposition be computed during the period of maximum farmed salmon feeding, which is planned for August, limiting the utility of the collected current data in assessing waste deposition around aquaculture sites and indicating a need for care in interpretation. To improve accuracy of the PEZ, DFO Science recommends collection of ocean current data during planned maximum feeding season and for a longer period to include seasons with higher current velocity.

The analysis of ocean currents from various locations indicated spatial variability. Currents in the offshore region also presumably differ from those measured within the bays. This difference will result in variability in the transport distance depending on the location, thereby potentially altering the associated PEZ.

In terms of climate variability, the Proponent's Appendix 6: Water Quality provides some information about temperature of the water at 3 m depth at the head of Bay de Vieux (including winter 1994 and winter 1995) and a table showing ocean temperature from 1–30 m depth measured in March 2018. Water temperature could be negative in winter (1994, 1995, 2018) and as low as -1.1°C at 30 m depth at two sites in March 2018. The Proponent also provided average seasonal temperature for Friar Cove and Chaleur Bay from 0.5 to 30 m depth without specifying the period of data collection. Seasonal temperatures at both Chaleur Bay and Friar Cove in winter were above 3.2°C at 5 m depth, suggesting higher temperature in winter season. These sites were only active in recent years (site licence request reviewed in August 2020), and the difference in temperature may reflect differences in conditions among bays, but it might also reflect warming of coastal ocean temperature through climate change.

The calculation of PEZ requires access to timeseries of ocean current data at various depths within the water column. Besides the data collected by the aquaculture industry, no other data are generally available for the south coast of the island of Newfoundland.

Potential Exposure Zones

Physical Environment

Salmon aquaculture activity in Newfoundland takes place in fjord-like bays/arms with complex shoreline and bathymetry. Shoreline distance from net-pen edges can range from 50 m to 600 m (Page et al. 2023a); in the present review, the shoreline to cage array edge distance varies from 120–240 m. The depths under the cage array could range from ~40 m to as deep as 300 m (DFO 2022b, 2022c, Page et al. 2023a, the present review). Within the lease area, depths range from very shallow (less than few meters near shoreline) to very deep (~380 m); with such depth, ocean currents presumably vary in the vertical.

The analysis of the ocean currents from the proposed sites shows spatial variability (in the vertical as well as in the horizontal) with current direction following the direction of the channel where data collection occurred. This pattern is consistent with Page et al. (2023a) who reported that the predominant current tends to follow the channel in which the proposed aquaculture site is located. Ratsimandresy et al. (2019) and Donnet et al. (2022) analyzed the currents in the region and confirmed vertical structure. The different regime in the upper layers than at depth suggests the possibility of high maximum current speeds at sub-surface depths (e.g., 20–60 m depths at some locations: DFO 2022b, Donnet et al. 2022). Although tides can strongly contribute to sea level (Ratsimandresy et al. 2020), they typically contribute minimally to variability in currents (Ratsimandresy et al. 2019).

In terms of seasonal variability, the ocean regime in bays and arms in the south coast of Newfoundland is more dynamic in fall compared to other seasons (Ratsimandresy et al. 2019, Donnet et al. 2022), both for mean currents as well as maximum currents. As such, calculation of dispersion and deposition of particles released from aquaculture activity may only reflect the period in which ocean currents data were collected.

Model Calculation

The PEZ calculation uses only a few inputs, namely a horizontal current speed representative of the whole water column, a particle sinking rate, and one depth data representative of the area of interest. The latter two variables are used to compute sinking time and the dilution period when looking at non-sinking particles. PEZ is a first-order displacement calculated by multiplying the horizontal current speed with the time taken by a particle to fall from the aquaculture cage and reach the seafloor (for benthic PEZ) or with the time necessary for a treatment patch to reach concentrations below the environmental quality standards, EQS (for the pelagic PEZ) and then added to half the size of the cage array. Selection of a current speed representative of the period of analysis is critical. The PEZs for various treatments provide a possible maximum spatial extent of exposure but not an accurate measurement of concentration, measure of duration, or frequency of exposure.

In the calculation of PEZ for aquaculture sites in Newfoundland, given the complexity of the currents and its variability, we propose a more advanced method that retains simplicity, consisting of first computing the maximum PVD for the period of sinking or dilution of particles for each depth, then using those values to estimate the average maximum current speed/distance for the whole depth of interest. This method provides a current speed more representative of the site and that minimizes overestimation. The analysis makes use of timeseries of current speed collected at various depths within the water column. Note that some refinement may still be necessary in the process of selection of the current speed that best represents the whole water column or the layer where non-sinking particles disperse; such refinement can be performed as more oceanographic data, and understanding of the process, become available for analysis.

PEZ provides an order of magnitude estimate of the spatial scale of potential exposure (Appendix C, Table A2-3). Combined with information on the presence of species, habitats, or other human activities in the area, any overlap with PEZ leading to a potential concern may necessitate a more detailed and precise estimate of the exposure to evaluate impact and/or mitigation measures. That analysis will require more advanced model(s), requiring more computer resources and time. These models should include data on temporal and spatial variation (in the vertical and in the horizontal) in ocean currents, as well as more realistic sinking rates of particles and temporally varying feeding information. For example, many advanced models calculate dispersion and deposition considering various physical processes, e.g., the ocean circulation model, such as FVCOM: Finite Volume Community Ocean Model (Chen et al. 2003, 2006) coupled with particle tracking model (Page et al. 2015) or the particle-tracking commercial software DEPOMOD (Cromey et al. 2002) and its more recent advanced version

NewDEPOMOD (Black et al. 2016) designed to predict dispersion of fish farm wastes in the benthic environment.

CONCLUSIONS

Question 1

Based on the available data for the sites and scientific information, what are the PEZs from the use of approved fish health treatment products in the marine environment, and the potential consequences to susceptible species?

- The benthic-PEZ associated with the use of in-feed fish health treatment products resulting in the greatest intensity of impacts occurs within a radius of 1 km from the site location which is generally of the same order of magnitude as the lease area. No overlap is expected among the feed-based benthic-PEZs.
- The PEZ associated with in-feed drug present in feces occurs within a radius of 3–6 km (depending on the site) from the site location. Overlap can be expected for treatments carried out at the same time in the same bay.
- The pelagic-PEZ associated with the use of approved pesticides occurs within a radius of ~5–7 km for azamethiphos and ~7–9 km for hydrogen peroxide from the site location.
- The pelagic-PEZ related to the usage of bath pesticides indicates significant overlap within the same bay. These pelagic-PEZs extend to water masses beyond the bays and could reach shorelines and impact the shallow areas adjacent to each site. This review recommends consideration of the cumulative impacts of these pesticides in relation to the timing of their usage to mitigate impacts on sensitive species.
- Anti-sea lice treatment could affect crustaceans through both exposure of adults in the benthos (benthic-PEZ), and through pelagic exposure of larval stages to bath pesticides (pelagic-PEZ). For krill species that mostly occupy the pelagic zone, exposure to bath pesticides might represent a risk for all sites. The highest concentrations of these species occur at Foots Cove, near cage areas, potentially representing the highest risk.

Question 2

Based on available information, what are the EBSAs, species listed under Schedule 1 of SARA, fishery species, ESS, and their associated habitats that are within the benthic-PEZ and vulnerable to exposure from the deposition of organic matter? How does this distribution 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?

- Sessile or sedentary benthic taxa, including soft corals, sponges and other sessile organisms present at the proposed sites, are expected to be more vulnerable to aquaculture wastes because they cannot relocate to another environment when under stress.
- Sea pen communities identified in the area are of particular concern, because of their status as VME indicators.
- There is currently limited to no data on recovery rates of sensitive species identified in this region, as well as on the connectivity with populations within and outside of these areas. All of these factors might limit their recovery and habitats.

Question 3

To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic species listed under Schedule 1 of SARA make use of the area, for what duration, and when?

- Leatherback Sea Turtles and large pelagic fish species (sharks and tunas) occur in the area, particularly from spring to autumn. An increasing presence of large pelagic species in recent years suggests the potential for entanglements of sharks and tuna.
- The general area overlaps the distribution of several species of whales, including SARA-listed species (Blue Whale, Fin Whale and, North Atlantic Right Whale). Seasonally, the distribution of marine mammals is highest in nearshore Newfoundland waters from spring to autumn. While entanglement and subsequent drowning are major concerns for marine mammal species, such as baleen whales (which do not echolocate and thus may not detect aquaculture infrastructure), the risk of entanglement is considered low at the proposed sites.
- Pinniped species such as Harbour Seals and Grey Seals may be at risk for entanglement because potential prey may attract them to the cage netting (DFO 2022c). Along the south coast of Newfoundland, Harbour Seals occur year round whereas Grey Seals are seasonal visitors that arrive in late spring and depart in late fall.

Question 4

What populations of conspecifics occur within a geographic range where escaped farmed fish are likely to migrate? What are the size and status trends of those populations in the escape exposure zone for proposed sites? Are any of these populations listed under Schedule 1 of SARA? What are the potential impacts and/or risks to these wild populations from direct genetic interactions associated with any escaped farmed fish from the proposed aquaculture activity?

- Local populations of Atlantic Salmon migrate through this area on a regular basis and will be exposed to cage sites both as migrating smolts and returning adults.
- A recent assessment of the risk posed to wild salmon by direct genetic interaction with escaped farmed salmon in southern Newfoundland indicated the risk to population abundance ranged from low to high and risk to genetic character was high across the range of escape rates examined. This risk exists against the backdrop of a declining wild population currently designated as threatened under COSEWIC (2010) and currently being re-evaluated after further declines (DFO 2022a, 2023a).
- COSEWIC (2017) designated Common Lumpfish as Threatened in Canadian waters. Given the status of this species in the NL Region, and evidence of negative genetic impacts of cleaner fish on wild populations elsewhere, the potential for increased negative interactions from the proposed expansion in southern Newfoundland is possible.

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APPENDIX A

Table A1: Summary of sensitive, commercial species, and SAR listed in Baseline reports. Y = present (highlighted), N = not reported

Site	Bacterial mats	Sensitive	Eelgrass	Sea Pen	Species at Risk	Commercial species						Other
						Acadian Redfish	American Lobster	Atlantic Cod	Pollock	Sea Scallop	Snow Crab	
Aviron North	N	N	N	Y[1]	N	Y	Y	N	N	N	Y	Multiple beds of kelp. broom algae and anemones. single bed of sea urchins observed (outside of cage structure).
Aviron South	Y	N	N	N	N	Y	Y	N	N	Y	N	Multiple beds of brown algae, green sea urchins, anemones and sand dollars, single bed of brittle stars observed (outside of cage structure).
Denny Island	N	N	N	N	N	Y	N	N	N	Y	Y	Kelp, brown algae, sea urchin, mussel, and feather star beds observed (outside of cage structure).
Foots Cove	N	N	N	N	N	Y	N	N	N	Y	Y	Moon snail sand collars, or egg masses were observed, which may imply moon snail nursery or juvenile habitat. Kelp, brown algae, red algae, green sea urchin and sand dollar beds observed (outside of cage structure).

Site	Bacterial mats	Sensitive	Eelgrass	Sea Pen	Species at Risk	Commercial species						Other
						Acadian Redfish	American Lobster	Atlantic Cod	Pollock	Sea Scallop	Snow Crab	
Gnat Island	N	N	N	Y[2]	Y[3]	Y	N	Y	N	Y	Y	Multiple beds of brown algae, red algae and anemones, as well as single beds of sea urchins and feather stars were observed (outside of cage structure).
Shoal Cove	N	N	N	N	N	Y[4]	N	Y	Y	Y	Y	Kelp, brown algae, sea anemone, feather star and brittle star beds observed (outside of cage structure).

[1]One sea pen reported, [2]several sea pens reported, [3]Atlantic Wolfish (*Anarhichas lupus*), [4]Schools.

APPENDIX B

Progressive Vector Diagram (PVD)

PVD provides information on "pseudo" displacement of a parcel of water from its origin over a defined period. It assumes that the water current field is uniform in the domain of interest. PVD is computed as the sum of the individual displacements of a particle associated with each current measurement over a specific time period (Page et al. 2023, Thomson and Emery 2014):

$$D = \sum (u_i, v_i)\, \Delta t_i$$

where D is the total displacement, (u_i, v_i) the x and y-component of the current velocity at each time interval of measurement, and Δt_i the time interval between two measurements.

The current speed associated with the displacement is

$$Spd = \frac{D}{t}$$

with Spd being the current speed and t is the duration (sinking period for benthic calculation and dilution period for pelagic calculation).

An example of PVD for ocean currents at Shoal Cove, at a depth of 29 m for a period of 21.7 h on 26 June 2018, is illustrated below:

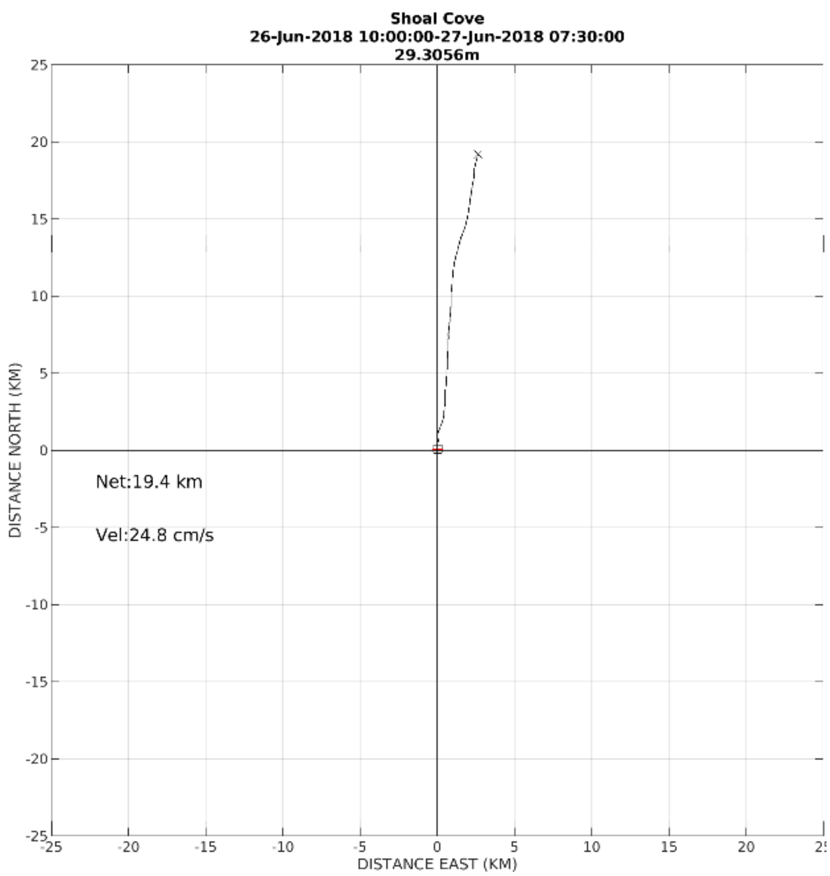

Figure A1: Displacement of a particle at 29 m depth for a period of 21.7 h on 26 June 2018 computed with progressive vector diagram.

Acoustic Doppler Current Profilers were used to measure currents at various depths. Timeseries of currents at these depths were analyzed. For each of these depths, various PVD are computed to cover the whole period of measurement.

For the benthic-PEZ, the maximum displacement is computed for each depth comprised between the bottom of the cage net and the maximum depth in the lease area, the average of these maximum displacements is then considered as benthic-PEZ.

For the pelagic-PEZ, since the treatment patch can be present within the water column from the surface layer down to the maximum patch depth, similar analysis and calculation are performed up to the maximum patch depth.

APPENDIX C

Order of magnitude of PEZ

Table A2: Settling time of particles (as function of depth and settling velocity)

Settling velocity [cm/s]	Settling time [h]		
	100 m depth	200 m depth	300 m depth
10	0.27	0.55	0.83
5	0.55	1.11	1.67
1	2.77	5.55	8.33
0.5	5.55	11.11	16.67
0.1	27.78	55.55	83.33

Table A3: Order of magnitude of displacement of particles as a function of settling/dilution time and ocean current speed. PEZ is computed as displacement + 1/2 cage array. Note: the further away, the less the assumption of constant depth and constant current speed and direction holds

Time [h]	Current speed [cm/s]		
	5	10	20
0.2–1	< ~200 m	< ~400 m	< ~700 m
1–5	~0.2–1 km	~0.5–2 km	~ 1–4 km
10–20	~2–4 km	~4–7 km	~ 7–14 km
20–30	~4–5 km	~7–10 km	~14–22 km

APPENDIX D

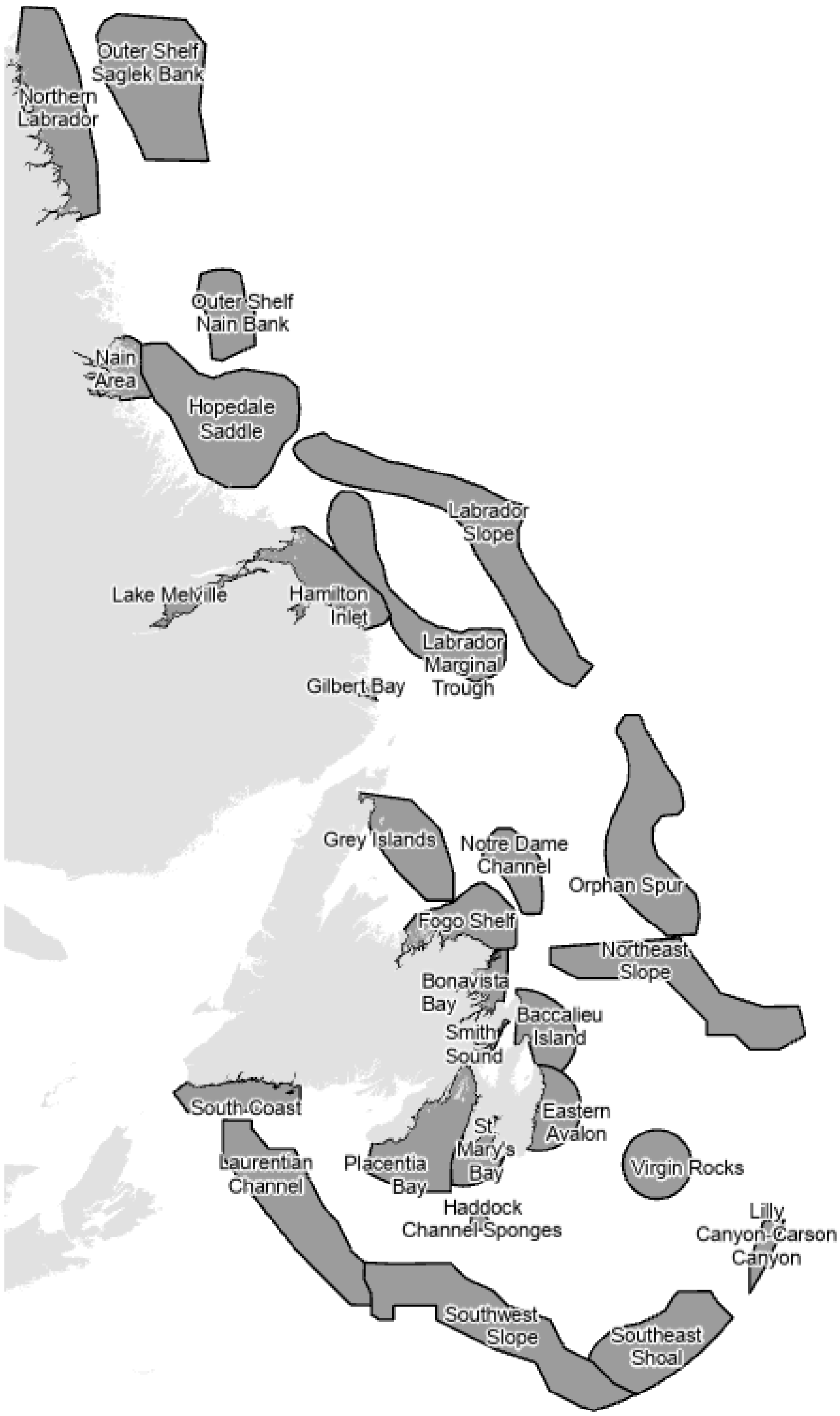

Figure A2: NL Region EBSAs further described in Wells et al. 2017, 2019. Not shown is a transitory EBSA that follows the southern extent of pack ice (Southern Pack Ice EBSA).

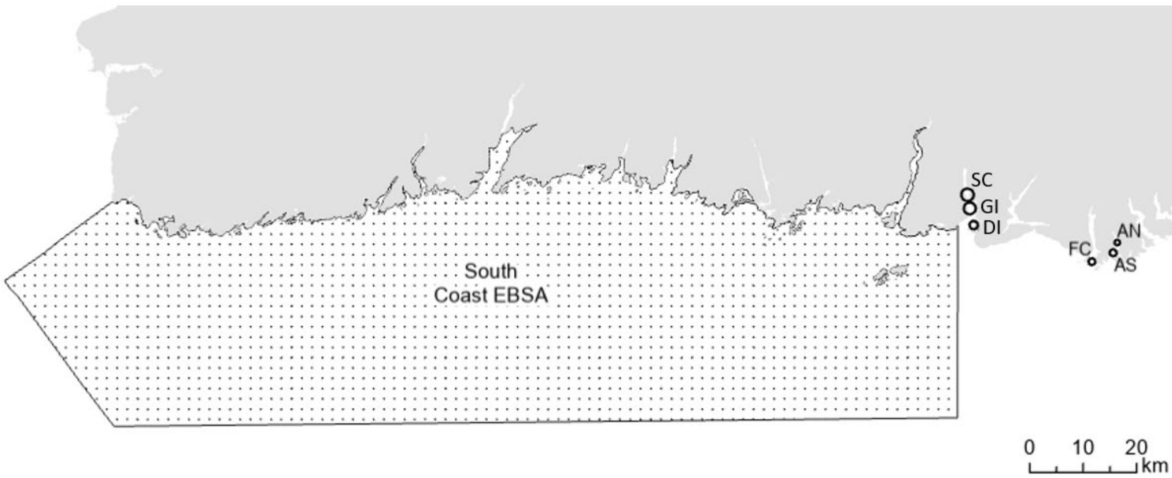

Figure A3: The South Coast EBSA in relation to the benthic waste feed-PEZs of the proposed aquaculture sites (Bay de Vieux: SC = Shoal Cove; GI = Gnat Island; DI = Denny Island; La Hune Bay: FC = Foots Cove; Aviron Bay: AN = Aviron Bay North; AS = Aviron Bay South).

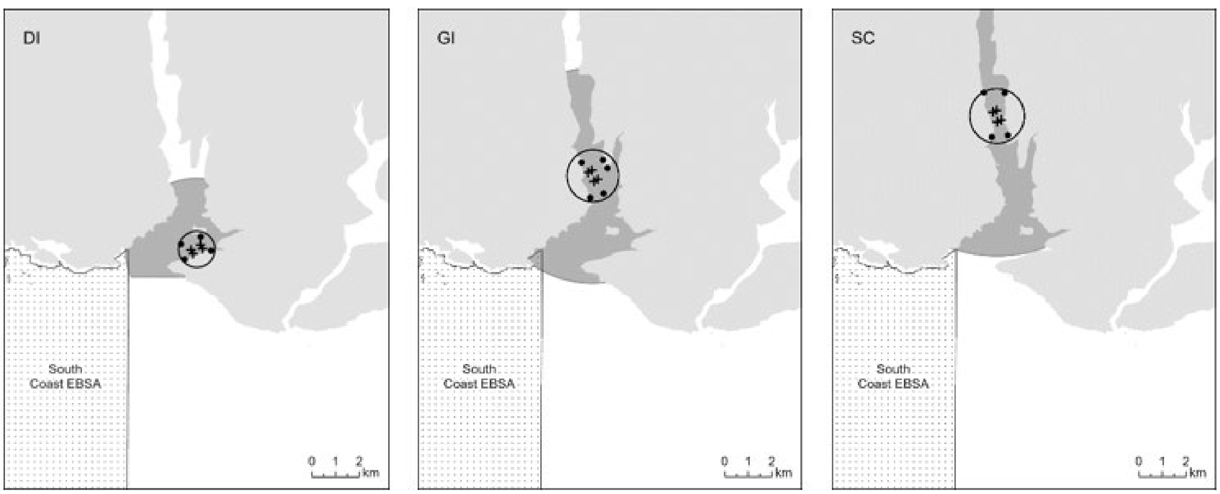

Figure A4: Overlap of benthic-PEZs for Denny Island (left), Gnat Island (centre), and Shoal Cove (right) with the South Coast EBSA. Black crosses symbolize cage boundaries, black dots symbolize lease areas, black circles represent benthic waste feed-PEZs, and dark grey shaded circles represent benthic fecal-PEZs.

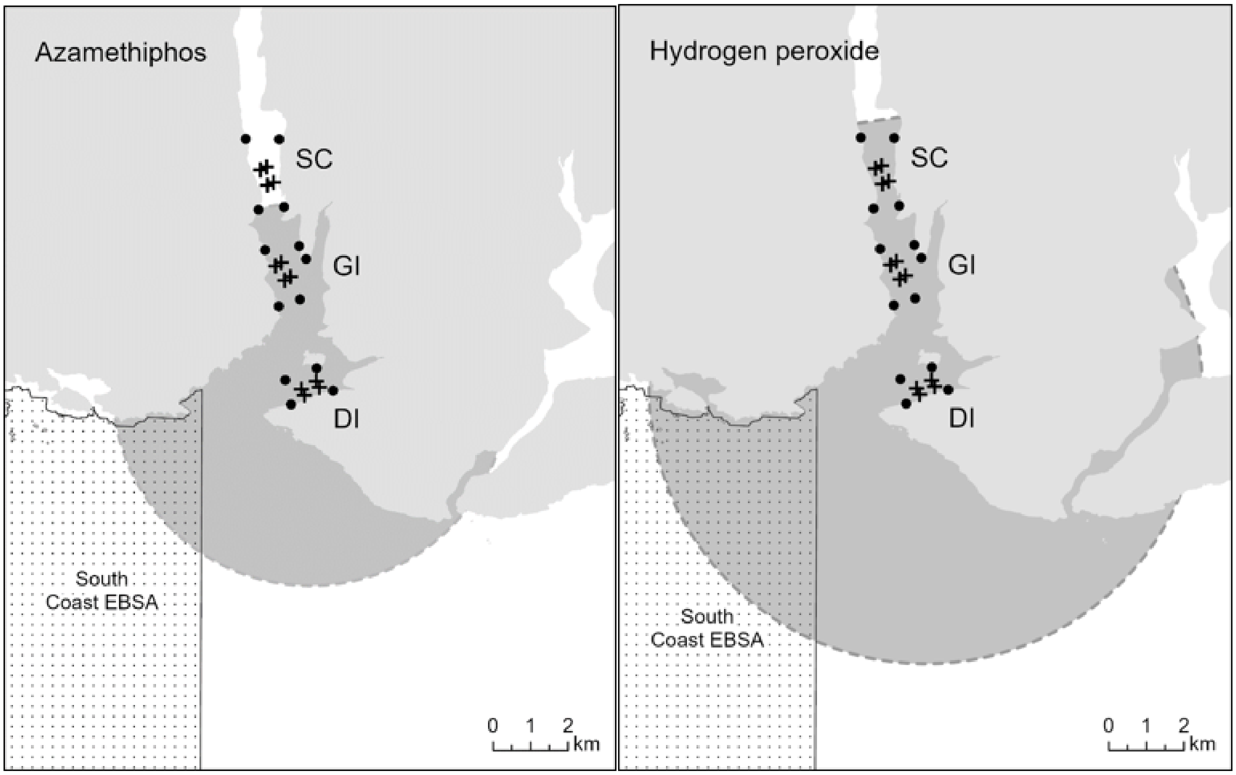

Figure A5: Overlap of azamethiphos (grey shaded circle, left) and hydrogen peroxide (grey shaded circle, right) pelagic-PEZs for Bay de Vieux. Black crosses symbolize cage boundaries and black dots symbolize lease areas for Denny Island (DI), Gnat Island (GI), and Shoal Cove (SC).

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