Fisheries and Oceans Canada / Pêches et Océans Canada

Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

SCIENCE REVIEW OF TWO PROPOSED TROUT AQUACULTURE SITES IN BAY D'ESPOIR ON THE SOUTH COAST OF NEWFOUNDLAND

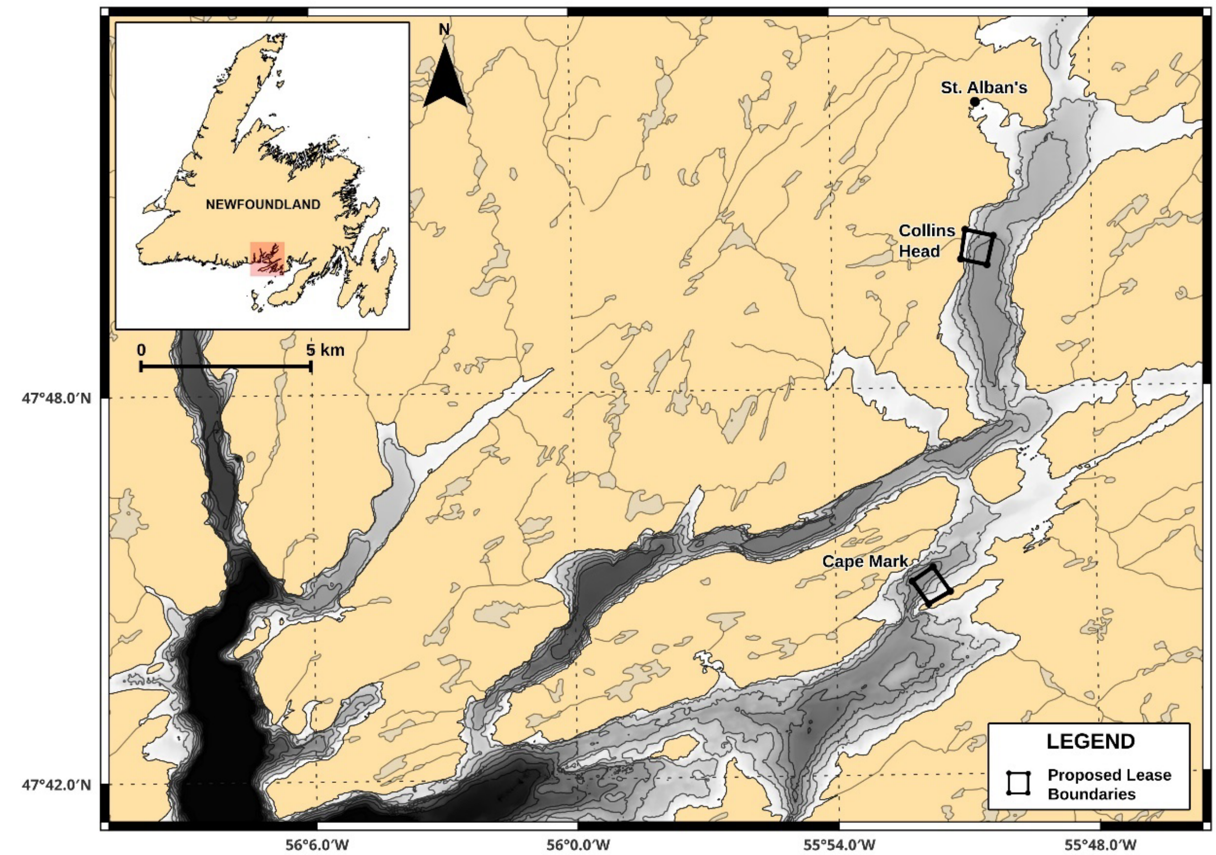

Figure 1: *Location of the proposed trout aquaculture site lease boundaries at Collins Head and Cape Mark in Bay d'Espoir, Newfoundland and Labrador (NL).*

CONTEXT

Nova Fish Farms Incorporated has submitted applications to the Province of Newfoundland and Labrador to develop and operate two new Rainbow Trout (*Oncorhynchus mykiss*) aquaculture sites at Cape Mark and Collins Head in Bay d'Espoir, located on the south coast of Newfoundland. As per the Canada-Newfoundland Memorandum of Understanding on Aquaculture Development, the Newfoundland and Labrador Department of Fisheries, Forestry and Agriculture has forwarded the applications to Fisheries and Oceans Canada (DFO) for review and advice in relation to DFO's legislative mandate.

The applications were supplemented by information collected by the Proponent, as required under the federal Aquaculture Activities Regulations (AAR). To help inform DFO's review of the applications, the regional DFO Aquaculture Management Office has sought DFO Science advice on the predicted exposure zones (PEZs) associated with certain aquaculture activities and the potential consequences on susceptible fish and fish habitat, including Species listed under Schedule 1 of the Species at Risk Act, susceptible fishery species, and the habitats that support them.

This Science Advisory Report is from the September 18–19, 2024, regional peer review for the Science Review of Two Proposed Trout Aquaculture Sites in Bay d'Espoir on the South Coast of Newfoundland. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Nova Fish Farms Incorporated has submitted applications to the Province of Newfoundland and Labrador to develop and operate two new Rainbow Trout (*Oncorhynchus mykiss*) aquaculture sites at Cape Mark and Collins Head in Bay d' Espoir, located on the south coast of Newfoundland.
- Estimates of benthic-Predicted Exposure Zone (PEZ) for both feed waste and feces at each site extend beyond the lease areas, although there is no predicted overlap expected between the two proposed sites. Feed waste and feces can potentially contain bound substances such as medications, if used.
- Geodiidae sponges and the Northern Cerianthid anemone, both vulnerable marine ecosystem (VME) indicators, were identified within the Collins Head lease area, but these taxonomic identifications are uncertain. No species listed under schedule 1 of *Species at Risk Act* (SARA) were reported at either of the sites. There are no Ecologically and Biologically Significant Areas (EBSA) that overlap with any portion of the benthic-PEZs or pelagic-PEZs or the lease area for either site.
- The pelagic-PEZ, predicting the spatial extent across which exposure to a registered pesticide may have an adverse effect, illustrated some overlap between the proposed sites and potential impact to the shoreline adjacent to each site.
- Shrimp and krill species were observed at both sites. For krill species occupying the pelagic zone, and some species of shrimp using it intermittently, the exposure to bath pesticides, although rarely used, could cause adverse effects.
- Although escapes from trout aquaculture farms remain possible, reported trout escape events in NL have been few and of low numbers since 2012. Escapees would primarily be expected to disperse to rivers within the proposed South NL-West Designatable Unit (DU) for wild Atlantic Salmon, where significant declines in abundance have occurred. Escapees may also disperse to a portion of rivers in the South NL-East DU.
- Interbreeding between escaped Rainbow Trout and wild Atlantic Salmon is not expected to occur. However, interactions between them may still result in ecological or indirect genetic impacts on wild Atlantic Salmon populations.
- While there have been no reports of entanglement of listed Species at Risk in finfish aquaculture gear in the DFO Newfoundland and Labrador Region, aquaculture infrastructure increases the potential for entanglement for some listed Species at Risk.

BACKGROUND

The Proponent, Nova Fish Farms Incorporated, has submitted applications to develop and operate two new Rainbow Trout (*Oncorhynchus mykiss*) aquaculture sites at Cape Mark and Collins Head in Bay d'Espoir, located on the south coast of Newfoundland (Figure 1).

The Newfoundland and Labrador (NL) Department of Fisheries, Forestry and Agriculture (NLFFA) is responsible for aquaculture licensing under the provincial *Aquaculture Act*. This licensing process includes a review focusing on the Proponent's ability to farm responsibly and comply with regulatory requirements. As per the Canada-Newfoundland Memorandum of Understanding on Aquaculture Development, NLFFA has forwarded the 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 regulations in place under the federal 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. These include measures to treat fish for disease and parasites, and regulatory thresholds for deposit of organic matter, under Sections 35 and 36 of the federal *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 encompass all stages of operation from siting to fallow. In accordance with the AAR, the Proponent submitted a baseline assessment report and Addenda for each site application.

Fisheries and Oceans Canada has developed a consistent approach for the review of marine finfish aquaculture site applications (DFO 2024a). This approach includes a first order analysis that estimates PEZs and the potential for physical and genetic interactions with wild species at the proposed sites. To guide DFO's review of the applications, the regional DFO Aquaculture Management Office (RAMO) requested DFO Science advice on the predicted exposure zones (PEZ) associated with the proposed aquaculture activities and the potential impacts on susceptible fish and fish habitat. Specifically, DFO Science was asked the following questions:

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

Information contained in this report is used to identify potential effects of the proposed trout aquaculture sites on the surrounding marine environment, which DFO assesses in its review of the applications and the formulation of its advice. However, decision(s) on the two proposed trout aquaculture sites remains under the authority of the NLFFA, which has a mandate to make decisions regarding finfish aquaculture applications in the Province of Newfoundland and Labrador (see: Fisheries and Aquaculture Licensing - Fisheries, Forestry and Agriculture (gov.nl.ca)). This Science Advisory Report provides information on the PEZs and physical and genetic interactions, but does not evaluate risk or impact to species and/or habitats within the PEZs associated with trout aquaculture interactions.

General Description of Sites

The two proposed trout aquaculture sites are located at Cape Mark and Collins Head in Bay d'Espoir on the south coast of Newfoundland (Figure 1). The proposed sites have a 2 x 8 cage array (total of 16 cages per site) with each net having a circumference of 90 m and a height of 30 m. The maximum number of fish per site is 750,000–800,000 with a maximum stocking density of 14 kg/m^3 at Cape Mark and 13 kg/m^3 at Collins Head. The stocking plan indicates that each of the two sites are fall-stocked sites whereby fish are stocked at the sites in October. In December, they are moved off-site to an overwintering site and then moved back to the same site as soon as the ice recedes the following spring. While a June start date for harvest is possible in a year with a warm fall and early spring, the majority of fish would be harvested beginning in August through November.

There are several licensed sites within the vicinity of the proposed aquaculture sites (Figure 2). While the majority of these are not stocked or used exclusively for overwintering (i.e., Roti Bay sites are licensed only for occupancy between November 1 and May 31) there are currently four active sites, three of which are licensed to the Proponent, that are located proximal to the two proposed sites.

The baseline assessment reports for the two 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. Video surveys were conducted to characterize flora, fauna, and substrate types along transects within the area of the proposed leases. The surveys covered the lease area for each site using transects spaced 100 m apart. Surveys were conducted for three days at each site in May or July, 2019. The video and still images were reviewed and analyzed for substrate type, flora, and fauna at stations and used to conduct fish habitat surveys. Video observations of substrate type, as well as flora and fauna abundances, are summarized in the Proponent's baseline assessment reports.

Site 1: Cape Mark, Bay d'Espoir, Newfoundland

The Cape Mark proposed lease area (0.587 km^2) is located approximately 13.4 km southwest of the town of St. Alban's by waterway. The bathymetric survey reports depth ranges from approximately 0–185 m. While this is the case for the entire lease area polygon, the depths directly beneath the planned cage array area range from 33–66 m.

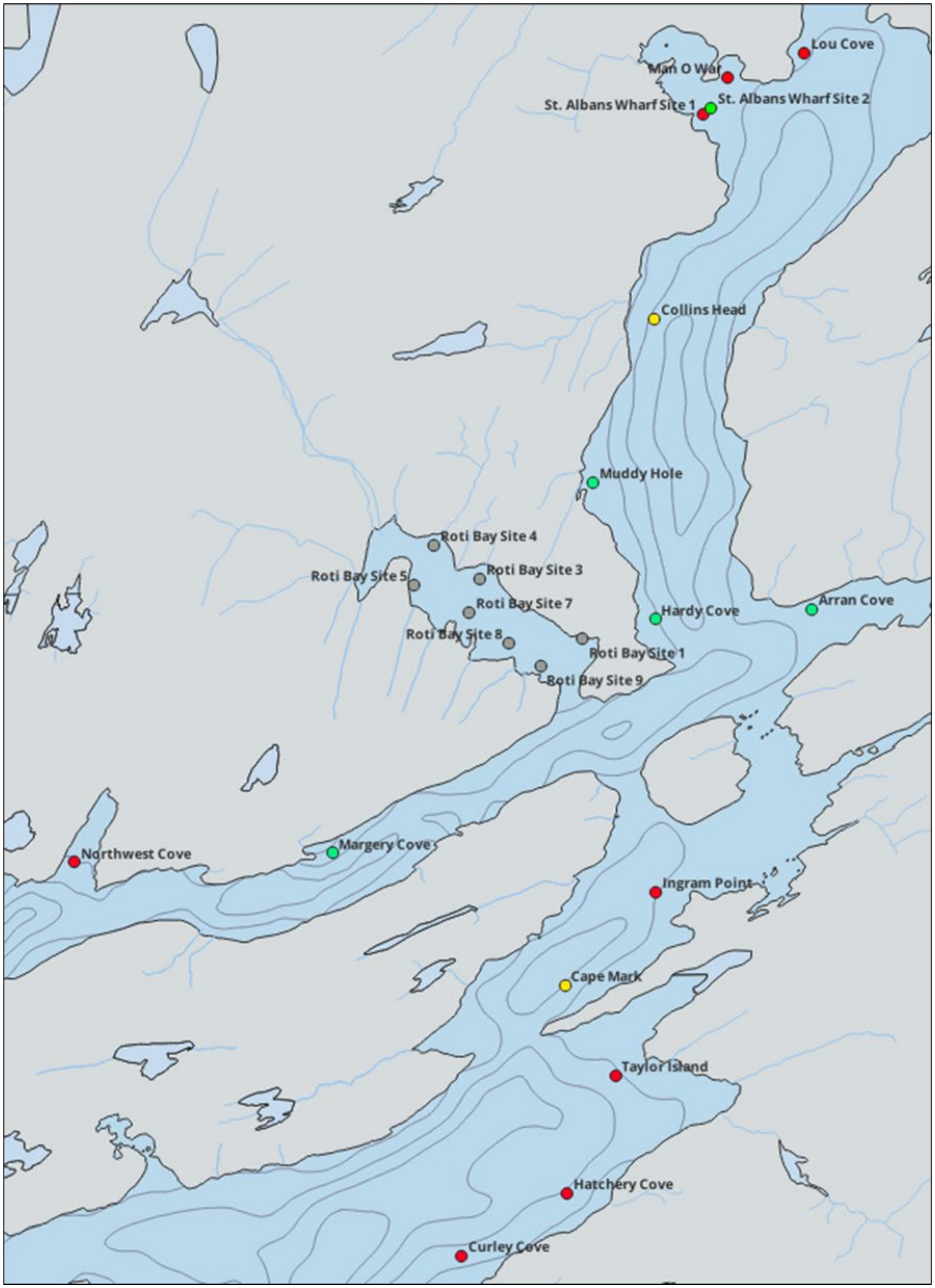

Figure 2: Licensed aquaculture sites located in the upper Bay d'Espoir, NL. Yellow dots denote the proposed trout aquaculture sites, green dots denote currently stocked sites, red dots denote sites not currently stocked, and grey dots denote trout overwintering sites.

The fish-habitat survey carried out in May 2019 at the Cape Mark site revealed that silt/mud was commonly observed; however, 51% of stations surveyed were characterized as having hard substrates. Stations classified as hard bottom were characterized by seafloor containing a mixture of larger grain sizes, such as cobble and gravel, often mixed with mud/silt.

As this site has not previously hosted aquaculture facilities, evidence of benthic indicators for aquaculture activity was not expected. Consistent with this, observations from the benthic survey did not show any indication of aquaculture disturbance, such as the presence of *Beggiatoa*-like bacteria, opportunistic polychaete complexes, and/or barrenness.

Crustose algae were recorded at 26 stations. The only other macroalgae noted were Irish moss (station 17 at 15 m depth) and *Agarum* (station 20 at 18 m depth). These two stations fall outside the anticipated footprint of deposition (i.e., 1 g C m^{-2} d^{-1}, as per the Proponent's depositional model). Krill and brittle stars were the most commonly observed fauna species. Other species noted within the survey area included more than 72 sea urchins, 126 individual shrimp, 58 scallops, two Acadian Redfish, and one flounder. No species listed under Schedule 1 of *SARA* were noted during the survey.

Site 2: Collins Head, Bay d'Espoir, Newfoundland

The Collins Head proposed lease area (0.674 km^2) is located approximately 4.2 km southwest of the town of St. Alban's by waterway. The water depth for the entire lease area ranges from approximately 0–220 m; however, the depths directly beneath the planned cage array area range from 30–80 m.

The fish-habitat survey carried out in May and July 2019 at the Collins Head site revealed that silt/mud was the most common substrate. Of the total of 90 stations analyzed, 34 stations (38%) were classified as hard substrate and 56 stations (62%) were soft, for an overall site classification of soft bottom. Annex 9 of the AAR prescribes the monitoring protocol specifically for finfish farms in NL, and under this protocol a site classification of soft bottom requires the Proponent to conduct benthic sediment sampling as part of the application package. In accordance with the AAR, sediment sampling was carried out in May 2023, with the results provided in the Proponent's baseline survey for new aquaculture sites.

As this site has not previously hosted aquaculture facilities, evidence of benthic indicators for aquaculture activity was not expected. Consistent with this, observations from the benthic survey did not show any indications of aquaculture disturbance such as the presence of *Beggiatoa*-like bacteria, opportunistic polychaete complexes, and/or barrenness.

Other than crustose algae, no macroalgae were recorded during the survey. Sponges were observed at several stations, most commonly along the northern boundary of the proposed lease and along the 30-m isobath. Soft corals were observed at stations 88, 91, and 92, near the northeastern corner of the proposed lease. Brittle stars and krill were the most commonly observed fauna. No commercially important species or species listed under Schedule 1 of *SARA* were noted during the survey.

Table 1: Key oceanographic, farm infrastructure, and grow-out information for the proposed sites. All information was extracted from reports provided by the Proponent in the site license applications. (*) = values computed from data provided by the Proponent; (—) = no value.

Characteristic	Cape Mark			Collins Head		
Dimension [m]	727 x 752			855 x 825		
Area [ha]	58.7			67.4		
Predominant substrate type	Bedrock/cobble			Mainly Mud/silt		
Net-pen array configuration	2 x 8			2 x 8		
Individual net-pen circumference/depth [m]	90 / 10			90 / 10		
Net-pen volume [m^3]	103,136			103,136		
Depth under the lease area [m]	0–185			0–220		
Depth under the cage array [m]	33–66*			30–80*		
Current measurement	17-Jul-2018 to 22-Aug-2018			10-Jul-2019 to 21-Aug-2019		
-	Depth [m]	Speed [cm/s]		Depth [m]	Speed [cm/s]	
		Mean	Max		Mean	Max
	5	7.8	33.1	5	4.7	22.4
	10	6.3	31.7	11	3.7	14.5
	15	4.4	21.4	21	2.0	33.8
	20	3.2	15.4	29	1.5	9.7
	27	2.7	11.1	39	1.5	5.0
Depth at ADCP location (m)	31			43		
Current measurement type	current profiler			current profiler		
Grow-out period [month]	—			13		
Maximum number of fish on site	800,000			750,000		
Total Initial stocking number 2024	500,000			500,000		
Total Initial stocking number 2025	800,000			—		
Total Initial stocking number 2026	—			500,000		
Total Initial stocking number 2028	—			750,000		
Initial stocking weight [kg]	0.150			0.150		
Average planned harvest weight [kg]	2.1			2.1		
Expected maximum biomass [kg]	1,428,000			1,338,750		
Maximum stocking density [kg/m^3]	14			13		

ANALYSIS

Sources of Data

Information to support these analyses includes documents from the Proponent, data holdings within DFO, registry information from the SARA database, and publicly available literature. The following supporting information was submitted to DFO for each of the proposed sites, which was used in this review:

Cape Mark site

- Nova Fish Farms Inc. Cape Mark Aquaculture Licence Application-Finfish Cage Culture;
- AAR Baseline Environmental Assessment Report, including Benthic Videos;

- Appendix 1: Depositional Model Report;
- Appendix 2: Site Restoration Plan;
- Appendix 3: Fishing and Recreational Activities;
- Appendix 4: Consultation Report;
- Appendix 5: Site Drawings;
- Schedule A: Finfish Cage Culture Operations

Collins Head site

- Nova Fish Farms Inc. Collins Head Aquaculture Licence Application-Finfish Cage Culture;
- AAR Baseline Environmental Assessment Report, including Benthic Videos and the Depositional Model Results;
- Appendix 1: Site Restoration Plan;
- Appendix 2: Baseline Survey for New Aquaculture Sites;
- Appendix 3: Consultation Report;
- Appendix 4: Site Drawings;
- Schedule A: Finfish Cage Culture Operations

Additionally, the Proponent provided their Site Stocking and Production Plans (2024–26), Fish Health Management Plan for Steelhead Trout, and Marine Farm Management Plan for Steelhead Trout.

Oceanographic Conditions

The waters on the south coast of Newfoundland are strongly and seasonally stratified and subject to a spatially uneven freshwater runoff (Donnet et al. 2018a,b). Data available from 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) and strongly influences the rate of vertical transport of dissolved oxygen (Breitburg et al. 2018). In this region, currents are complex, with large temporal and spatial (including vertical) variability, as well as 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 the long and narrow channel of Bay d'Espoir, NL (Figure 2). The channel is a fjord like bay with a maximum depth of 792 m, located near the mouth and with various sills; a shallow sill with a depth of 26 m is located northeast of Cape Mark and west of Riches Island (Figure 3). The sites are located in the upper part of the bay. The water depth ranges between 0–220 m below the proposed lease areas and between 30–80 m below the cage arrays, with bottom sediments consisting of mixed substrates.

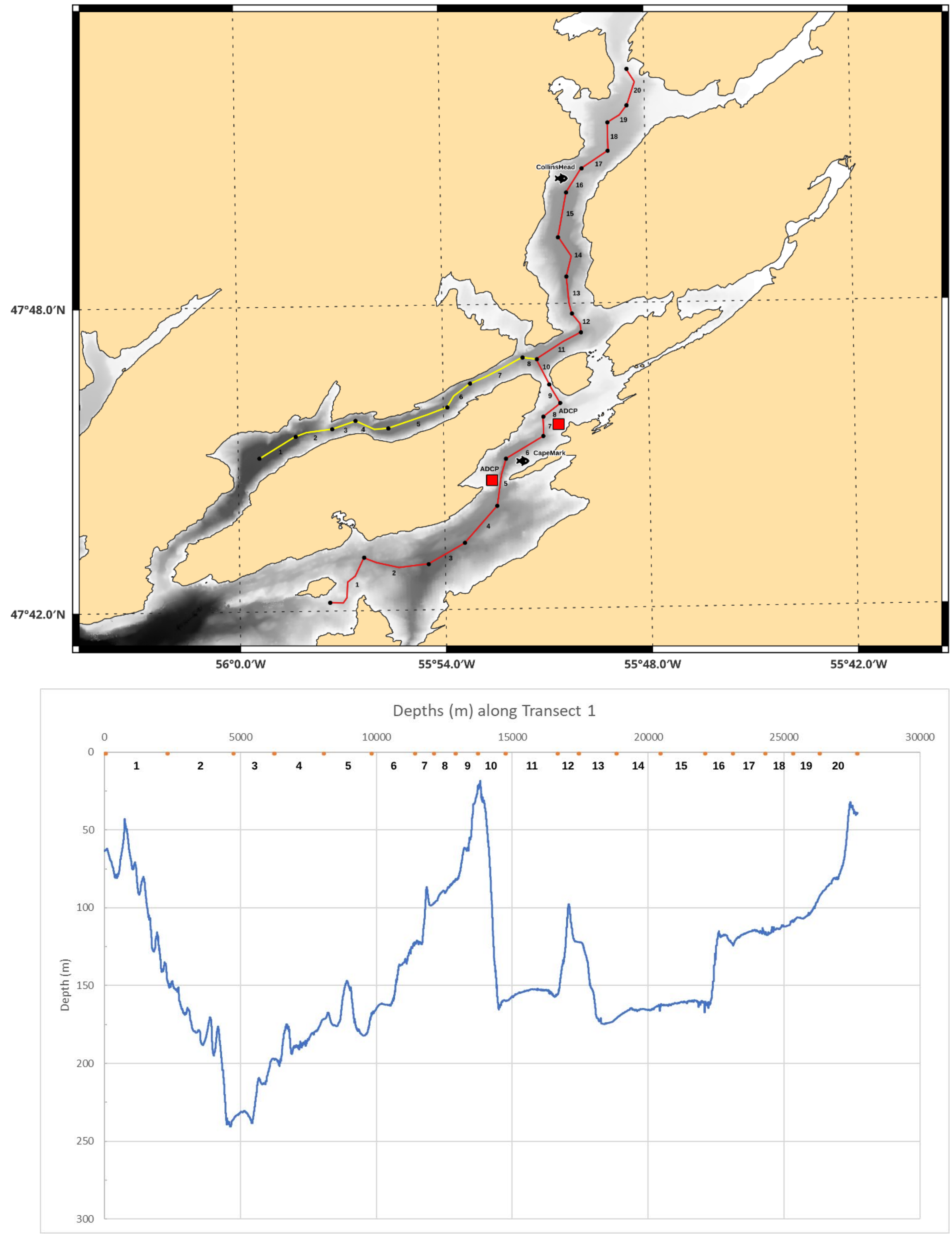

Figure 3: Bathymetry measurements in Upper Bay d'Espoir, NL. Location of the transects where depth values were extracted (Upper panel). Depth measurements along the transect (Lower panel).

Currents

Water currents are a critical input to estimations of the zone of exposure associated with the release of biochemical oxygen demanding (BOD) organic matter, pesticides, and drugs from any farm site. The Proponent provided water current data that were collected over a period of 35 to 42 days (July 2018 for Cape Mark and July 2019 for Collins Head), following the requirements of the AAR. The currents were measured using Acoustic Doppler Current Profilers (ADCPs) deployed at a single location, near the centre of the proposed cage arrays, and configured to measure ensemble average horizontal currents at 15-minute intervals (Table 1). The ADCP measured currents from the surface to 31 m and 43 m depth for Cape Mark and Collins Head, respectively.

The Proponent provided information about the current speed and direction at five depths from surface to the depth of the ADCP (Table 1). The water current speed presents high variability, with maximum speed approximately four to five times the mean speed at each depth and site. There is vertical variation in the maximum current speed, which is larger than the mean speeds. Current directions vary with depth; however, the main current directions are generally along the isobaths. This observation is consistent with results in Ratsimandresy et al. (2019), which highlighted the variability of the currents in the region. Despite meeting the AAR requirements, it is noted that given the depth where the ADCPs were moored and their configuration the sampling only measured currents in less than 20% of the entire water column within the lease areas.

Calculation of PEZ requires current data throughout the entire water column; thus, in order to have data that cover a larger part of the water column, previous measurements carried out close to the site locations were considered. Ratsimandresy et al. (2019) measured currents at two locations around Cape Mark (BDE25 is approximately 2 km southwest of the site with currents measured for the upper 80 m between 21 Sept. 2012 and 18 Nov. 2012; and BDE04 is approximately 1.4 km northeast, measuring currents in the upper 50 m depth between 17 June 2009 and 23 Sept. 2009). They also measured currents at a site north of Collins Head (BDE16 is approximately 2.3 km from the site with current profiles measured for the upper 69 m between 15 Oct. 2010 and 2 Mar. 2011). Figure 4 illustrates the locations of these measurements. A comparison of the mean and maximum current speeds at selected depths is presented in Figure 5. These data show stronger currents than the Proponent's data (2018/19) at all depths. This is likely because of the location of the ADCP mooring (e.g., BDE25 is located in a constricted area of the bay) and/or because the Proponent's current measurements were collected during a period when the circulation is less dynamic (generally during summer season: Donnet et al 2018b; Ratsimandresy et al. 2019).

Figure 4: Map showing the location of the current measurements reported in Ratsimandresy et al. (2019), which is used in the PEZ analysis herein. Map generated using Google Earth.

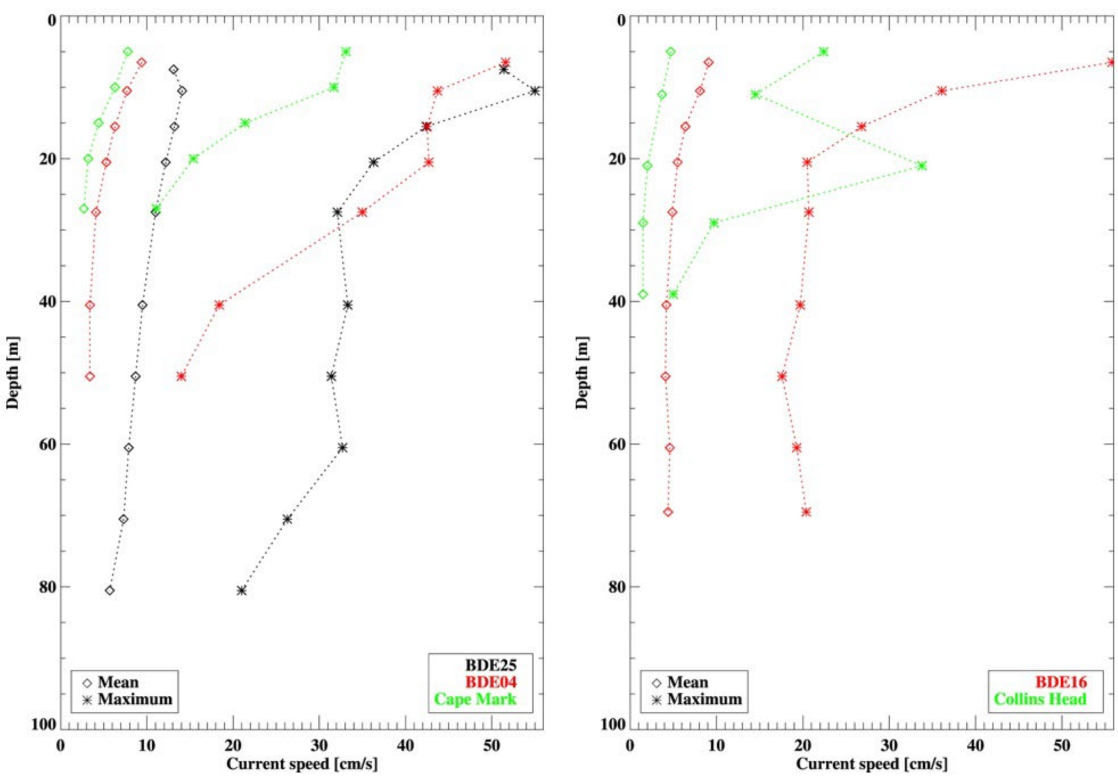

Figure 5: Mean and Maximum current speeds at selected depths at Cape Mark (Left panel) and Collins Head (Right panel) computed using measurements by the Proponent (green lines) and measured by DFO Science at nearby locations (red and black lines).

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 areas. 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 (*Gadus morhua)*, Witch Flounder (*Glyptocephalus cynoglossus*), and redfish (*Sebastes* spp.). Data on groundfish and pelagic species are limited in the proposed areas. The DFO multi-species survey (MSS) is typically used to describe the distribution and abundance of species in the NL Region, including the south coast, although this survey does not extend into the bay where the new sites are proposed. The Proponent's *Cape Mark Fishing Activity* document did note an aboriginal bait fishery for herring approximately 10 km from the proposed sites and that a recreational/aboriginal cod fishery occurs in the general area of the sites.

Commercial benthic invertebrate fish species in the general area of the proposed sites are American Lobster (*Homarus americanus*), Snow Crab (*Chionoecetes opilio*), and Sea Scallop (*Placopecten magellanicus).* The baseline video surveys did not record any observation of lobsters; however, lobsters are cryptic (especially during the day) and are not likely to be directly observed in the survey. Similarly, Snow Crab were not observed, although early life stages of Snow Crab are also cryptic. Both species could be susceptible to activities associated with aquaculture at all life stages. Scallop also were not observed in the Proponent's video surveys. The *Cape Mark Fishing Activity* document did note an aboriginal lobster fishery approximately 10 km from the site, as well as that scallops are harvested recreationally nearby.

Among non-commercial benthic invertebrate species, the taxa reported in the Proponent's surveys include brittle stars, shrimp, sea urchins, sea anemones, and sponges (unidentified). Brittle stars were the most abundant and found in high concentrations at both sites. Soft corals were observed with a total abundance of 36 colonies at Cape Mark and 45 at Collins Head. The only Vulnerable Marine Ecosystem (VME) indicator identified was Geodiidae sponges (Collins Head only: nine stations with greater than 20 individuals at some stations) and the Northern cerianthid anemone (Collins Head only: three stations had a maximum abundance of 3 individuals). It is unclear whether the individual Geodiidae were correctly identified.

Ecologically and Biologically Significant Areas (EBSA) are identified through formal scientific assessments as having biological or ecological significance when compared with the surrounding marine ecosystem. The EBSA are areas where regulators and marine users should practice risk aversion in an effort 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 DFO Newfoundland & Labrador Region has identified 29 EBSAs (Wells et al. 2017; 2019). The South Coast, Laurentian Channel, and Placentia Bay EBSAs are those located closest to the Bay d'Espoir, although they do not overlap with the lease areas for either Cape Mark or Collins Head (Figure 6).

At least 37 distinct taxa were identified by the Proponent at the proposed sites. In terms of Ecologically Significant Species (ESS), eelgrass has not been reported at any of the sites and, although criteria for the identification of other ESS exist (DFO 2006), there are few actual site assessments.

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. No SARA-listed species were observed during the Proponent's site surveys.

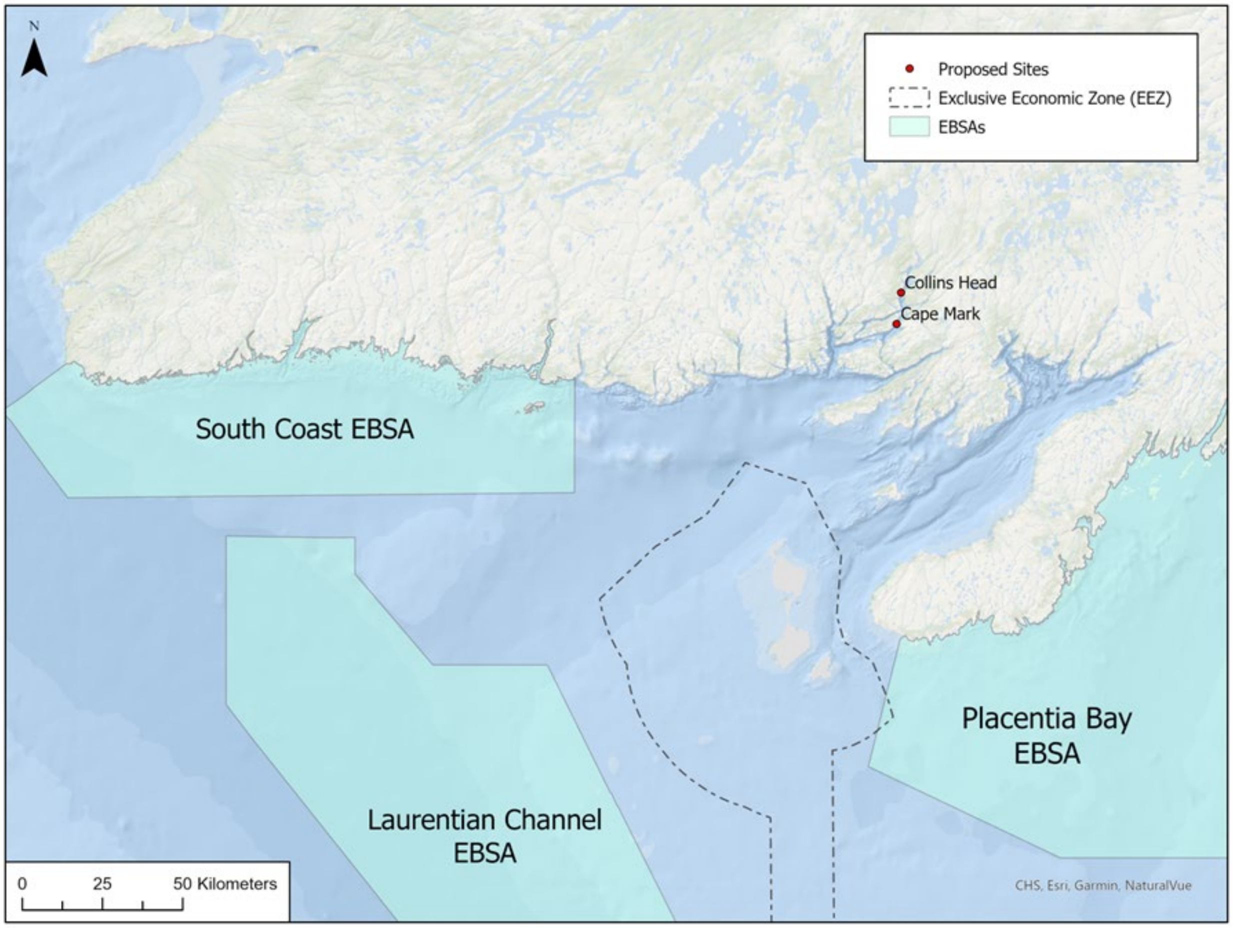

Figure 6: Map showing locations of Ecologically and Biologically Significant Areas (EBSA) in proximity of the proposed aquaculture sites at Cape Mark and Collins Head in Bay d'Espoir, NL.

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). However, COSEWIC's designation status of the species is being re-evaluated following further declines of salmon in waters of the DFO NL Region (DFO 2022a; DFO 2023a). 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).

The following cetaceans are potentially found at the proposed sites based on general species distribution, DFO survey data, and DFO marine mammal sightings/survey data: 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*), several species of dolphins (Killer Whale *Orcinus orca*, Atlantic White-sided Dolphin *Lagenorhynchus acutus*, White Beaked Dolphin *L. albirostris*, and Common Dolphin

Delphinus delphis), and Harbour Porpoise (*Phocoena phocoena*). Blue Whale (endangered), North Atlantic Right Whale (endangered), and Fin Whale (special concern) are listed on Schedule 1 of *SARA*.

Based on opportunistic and systematic sightings data, the cetaceans outlined above 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 NL south coast regularly and may have haul-outs in the lease areas, particularly near islands and rocks. Although Leatherback Sea Turtles (*Dermochelys coriacea*) and Loggerhead Sea Turtles (*Caretta caretta*), both listed on Schedule 1 of *SARA* as endangered, frequent Newfoundland waters during summer and fall to forage, they do not nest in Canada. Loggerhead Sea Turtles typically remain offshore, and although Leatherback Sea Turtles frequent inshore waters, they are not expected to commonly occur in the proposed areas.

Pesticide and Drug Use

The Proponent's Integrated Pest Management Plan (included in the Fish Health Management Plan for Steelhead Trout) indicates that chemical treatments will be prescribed in cases when a series of alternative treatments (mechanical or thermal treatments) fail to keep parasite infestation under control. The AAR require 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*, which are regulated by the Pest Management Regulatory Agency (PMRA) and Health Canada Veterinary Drugs Directorate, respectively. Any intervention therapy must be chosen by a licensed veterinarian, in consultation with the provincial Chief Aquaculture Veterinarian. As per the information provided by the provincial NL veterinary services and the Proponent, the potential therapeutants to be used would be based on the list of approved compounds (Inspection Canada 2024).

The following could be used in cases of sea lice infestation: Emamectin benzoate (EMB) (in-feed) and Azamethiphos (bath pesticide). Terramycin 800 (oxytetracycline as the active ingredient; in-feed) is the antibiotic that would likely be used in cases of bacterial infection. Under the AAR, the Proponent is required to report annually on the usage of drugs and pesticides at each marine finfish cage. Collection of this information by the Aquaculture Integrated Information System (AQUIIS) began in 2015 and the first full year of data collection was in 2016. In the Canadian marine finfish aquaculture context, the term "drug" generally applies to any in-feed product, including antibiotics and pest control drugs, while the term "pesticide" applies to a pest control product that is applied as an in-bath treatment.

Predicted Exposure Zones (PEZ) of Organic Matter and Fish Health Treatment Products

During finfish aquaculture operations, organic material such as unconsumed feed (i.e., feed waste) and feces are released into the surrounding waters and can sink to the seafloor. This biochemical oxygen demanding (BOD) matter is, in turn, used by benthic organisms. However, if large amounts accumulate, it can alter benthic habitat by depleting available dissolved oxygen, increasing 'free' sediment sulfide concentrations in soft-bottom habitats, and increasing the presence of bacterial mats and opportunistic polychaete complexes, as well as flocculent matter on hard-bottom substrates. Pursuant to the federal AAR, the aquaculture industry is required to conduct seabed monitoring of finfish aquaculture sites to determine the impact of BOD deposition through sediment sampling for soft-bottom or visual inspection for hard-bottom substrates. The AAR have set regulatory thresholds (e.g., at soft-bottom sites a maximum concentration of 3,000 µm of free sulfide and in hard-bottom sites a higher than 70% prevalence of the visual indicator species) that prohibit restocking of the site until further monitoring demonstrates a return to levels below compliance thresholds.

Fish health treatment products may also be administered during finfish aquaculture operations to control pests and pathogens, as is the case in most forms of monoculture. In Canada, fish health management and regulatory control is the responsibility of both provincial and federal governments. Effective integrated pest management and health management of the marine finfish aquaculture industry relies on the use of both chemical (e.g., drugs, pesticides, antibiotics, disinfectants, etc.) and non-chemical strategies (e.g., physical, biological, site management, and husbandry approaches).

Again, in Canada only products that are registered under the *Pest Control Products Act* and the *Food and Drugs Act* are allowed to be used to preserve the health and welfare of fish in aquaculture facilities. These products are only used under the authority and supervision of a registered veterinarian. To determine the appropriate prescription for maintaining the health of farmed fish, veterinarians consider a variety of site-specific information, including fish behaviour, environmental conditions, site records, information from monthly site visits, and from an ongoing dialogue with site managers. Additional information on prescription and administration procedures of drugs and pesticides in Canada can be found in Beattie and Bridger (2023).

The estimation of Predicted Exposure Zones (PEZ) is an approach used by coastal zone managers, users, and decision makers to determine the spatial extent of associated discharges (i.e., feed waste, feces, drugs, and pesticides) from proposed finfish aquaculture sites (Page et al. 2023). The PEZ-approach has been used in previous DFO finfish aquaculture site assessments in the NL Region as a screening tool (DFO 2022b,c,d). The first use of PEZ was for the assessment of proposed finfish aquaculture sites in Newfoundland in 2019 (DFO 2022b; Page et al. 2023). Since that first assessment, the PEZ calculations have evolved over time due to recent updates in threshold concentrations in the marine environment used to compute dilution times of pesticides and the necessity to consider spatial variation of currents.

The PEZ is intended to be a simple calculation that predicts potential zones of exposure to organic matter, drugs, and pesticides released from open net-pen finfish aquaculture. In basic terms, a PEZ is a circle that defines a spatial area around a proposed aquaculture site within which marine species and habitats may be exposed to various aquaculture activities. The radius of the circle represents the maximum distance that a particle released from a proposed site could disperse and eventually deposit on the seabed. The radius of the PEZ, R_{PEZ}, is calculated as the sum of the maximum length scale of the cage array (L_{array}) and a calculated displacement (D) (Page et al. 2023):

$$R_{PEZ} = L_{array} + D$$

In the above equation, the particle displacement is given by:

$$D = u * t_{sink/dilut}$$

where u is the current speed representative of the whole water column, $t_{sink/dilut}$ the sinking period or the dilution period. In the case of sinking particles the sinking period is given by:

$$t_{sink} = \frac{H}{w_{part}}$$

where H is the depth of the lease and w_{part} the particle sinking rate. The order of magnitude of the particle dispersion depending on the sinking/dilution period and the current velocity is outlined in Appendix A.

It is important to note that PEZ does not predict intensity of exposure, duration of exposure, or impact of exposure of marine habitats or species that fall within the area; rather it is an initial step in identifying areas of potential exposure that decision makers should be aware of. When PEZs are used in concert with information regarding the presence of species life stages, habitats, and other human activities, there may be a potential for aquaculture impacts on such sensitive entities exposed to various aquaculture activities. If the initial analysis of exposure reveals concerns with some of the identified individual or cumulative overlaps, more detailed scientific analysis could be pursued to further explore the degree and nature of potential impacts, and/or mitigation measures, that may need to be considered by managers, users, and decision makers.

Benthic Predicted Exposure Zones (Benthic-PEZ)

A benthic-PEZ is an estimate of the size and location of the benthic area potentially exposed to deposition of waste feed and feces released from a site that can result in organic loading. There are two kinds of benthic-PEZ:

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

The benthos may also be exposed to pesticides released into the water, particularly at shallow depth, although this is estimated using a pelagic-PEZ that is discussed in a subsequent section of this document below. Dominant factors that affect benthic-PEZ are farm layout, feeding practices, sinking rates of particles, and oceanographic conditions (i.e., bathymetry and water currents).

The benthic-PEZ is calculated by computing the transport distance during particle sinking (i.e., 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. Simplifying assumptions of the benthic-PEZ estimate are constant settling velocity of particles, constant ocean current speed during particle descent, constant depth (i.e., flat bathymetry), and no particle resuspension. To estimate the greatest-sized benthic-PEZ, which is a conservative strategy used to delineate a zone of potential effect, the model assumes slow particle sinking velocities (i.e., the minimum sinking rate obtained from the literature), the fastest water currents observed at the sites, and deep bottom topography (i.e., the maximum depth over the lease area).

The current speed is obtained by analyzing the maximum distance computed from a progressive vector diagram (PVD), based on the timeseries of current velocities at each depth over the period of sinking of particles and then averaged for the whole sinking depth. Further explanation of PVD and the calculation of PEZ is outlined in Appendix B below. The sinking rates for different particulate materials released from finfish aquaculture sites (i.e., waste feed and feces) vary, although the relationship between particle sinking rates and the size and properties of the sinking particles is not known. While information on sinking rates for feed and feces particles from farmed Rainbow Trout is limited, a recent review suggests these rates are within similar range to that of Atlantic Salmon (DFO 2022e). Sinking rates assumed in the analysis presented herein are based on reported values for salmon aquaculture (Findlay and Watling 1994; Chen et al. 1999; Cromey et al. 2002; Chen et al. 2003; Sutherland et al. 2006;

Law et al. 2014; Bannister et al. 2016; Skøien et al. 2016; DFO 2020a). The parameters used to compute the benthic-PEZ in this study are provided in Table 2.

Table 2: Parameters used to compute sinking period and PEZ (displacement + array length scale).

Characteristic	Cape Mark	Collins Head
Feed particle sinking rate [cm/s]	5.3	5.3
Feces particle sinking rate [cm/s]	0.3	0.3
Cage array length [m]	360	360
Maximum depth under the lease [m]	185	220

For the two locations, the conservative estimate approach is achieved by computing PEZs using the current data that had longer temporal coverage and larger vertical coverage. Table 3 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 for the proposed sites. For reference, a median PEZ was also computed using the median PVD displacement for each depth and averaging (see: Appendix B for explanation of the calculation) for the whole sinking depth (Table 4). This median PEZ illustrates the central tendency of the displacement of released particles. It is estimated that final dispersion of the feed and feces particles would fall somewhere within the median and maximum PEZ.

Table 3: 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), computed using maximum PVD at each depth.

Particle Type	Site	Minimum Sinking Rate [cm/s]	Sinking Period [h]	Current Speed During Sinking Period [cm/s]	PEZ Radius [km]
Feed	Cape Mark	5.3	1.0	28.4	1.2
Feces	Cape Mark	0.3	17.1	14.0	8.8
Feed	Collins Head	5.3	1.1	29.0	1.4
Feces	Collins Head	0.3	20.4	6.6	5.0

The benthic-PEZ is represented by a circular zone around the middle of the proposed cage array that is limited by the shoreline. It represents an inferred outer zone of potential exposure. The spatial extent of exposure of the benthic-PEZ associated with feed and feces particles at both proposed sites is illustrated in Figure 7. The benthic-PEZ associated with the feed (waste feed-PEZ) is almost twice the length scale of the lease area, which is on-order of one kilometre. The large dispersal extent associated with fine particles is not considered in this analysis, although they have been reported to be present around aquaculture sites (e.g., Law et al. 2014). Fine particles have very slow sinking rates (i.e., approximately 0.0001 m/s) and thus are able to disperse at very large distances from the centroid of aquaculture sites.

The benthic-PEZ approach does not provide an estimate of the intensity of organic loading around a proposed site nor assume uniform exposure throughout the zones. In reality, the intensity of exposure is expected to be highest near the net-pen arrays, decreasing with distance away from the centre of a proposed site. In particular, 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 a sinking velocity assumed 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. The benthic-PEZ associated with the fecal particles can also be seen in Figure 7. These benthic-PEZs cover a large part of the channel outside of the proposed sites. The size of the PEZ is of order of several kilometres. Overlap between sites is not expected for the benthic-PEZs associated with feed or feces particles. Additionally, the benthic-PEZ northeast of Cape Mark is expected to be limited by the shallow sills at Riches Island.

Table 4: Benthic PEZ computed using median progressive vector diagram (PVD) displacement.

Particle Type	Site	Minimum Sinking Rate [cm/s]	Sinking Period [h]	Current Speed During Sinking Period [cm/s]	PEZ Radius From Median PVD [km]
Feed	Cape Mark	5.3	1.0	8.1	0.4
Feces	Cape Mark	0.3	17.1	3.5	2.3
Feed	Collins Head	5.3	1.1	3.2	0.3
Feces	Collins Head	0.3	20.4	1.5	1.2

Important points to consider when interpreting benthic-PEZ results:

- PEZ analysis provides estimates only, which are sensitive to data input. It is a spatial scoping tool used to identify potentially sensitive marine features that may be exposed to aquaculture activities. The results should be interpreted as an order of magnitude of the distance that a particle released from an aquaculture site might disperse, acknowledging the complex flow field within the bay and that current measurement at a single location is often an insufficient representation of the full flow field in an area.
- The first-order estimates of extent of potential exposure do not consider current- and wave-induced bottom resuspension. It is assumed that the deepest ocean current speeds observed at various locations, though shallower than the deepest part within the proposed lease areas, also apply to near-bottom conditions. In this analysis, ocean currents with speeds greater than 9.5 cm/s, which is considered a critical value for resuspension within the depositional model DEPOMOD (i.e., Chamberlain and Stucchi 2007), were observed suggesting the potential for sediment resuspension. In contrast, overall impacts of redistribution and flocculant deposition remain unknown.

Spatial Extent of Drug Exposure

Drugs are administered as in-feed medications. The 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 proposed cages and lease sites within the bays may be subject to increased organic enrichment and feed chemical residues. This overlap suggests a potential interaction with the benthic species inhabiting these areas.

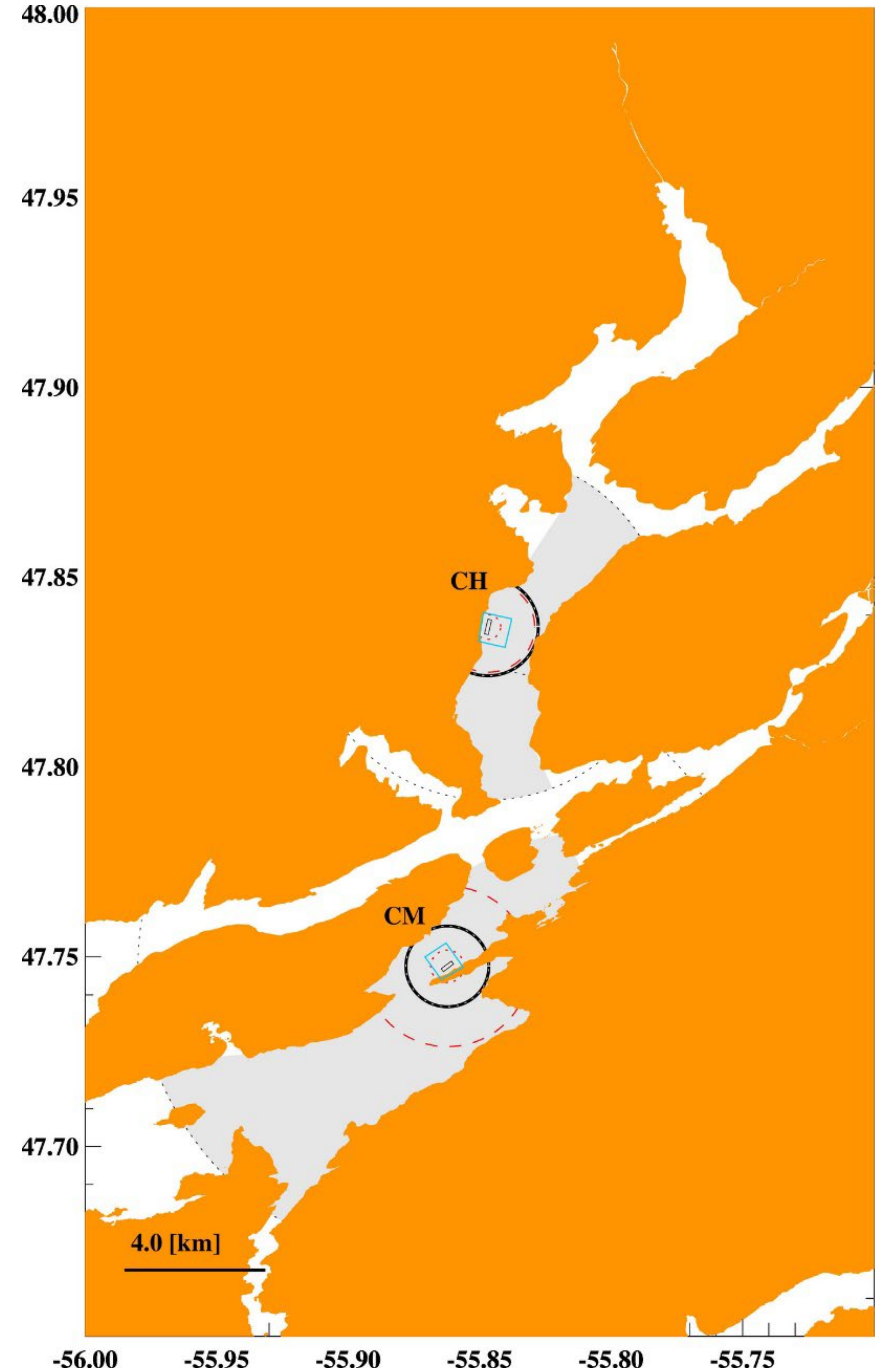

Figure 7: Benthic predicted exposure zone (benthic-PEZ) computed using the maximum progressive vector diagram (PVD) associated with feed particles (zones denoted by the black circles) and with feces particles (zones denoted by grey circles) for the proposed sites. Black rectangles denote the cage areas and blue polygons the lease area for each site (CM = Cape Mark, CH = Collins Head). The PEZs computed using median PVD for each depth are also included: small zones, mostly within the lease area, denoted by red dashed circles define the benthic-PEZ associated with feed particles and larger zones in red dashed circles define the benthic-PEZ associated with fecal particles.

In-feed therapeutants

The main concern associated with the use of in-feed antibiotics is the potential development of antimicrobial resistance (AMR), which is 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 have been deemed unlikely as per the amounts used. In addition, considering the lack of information on AMR in marine organisms, potential effects are not discussed in this document. It is important, however, to highlight the potential of AMR patterns if any to be influenced by the presence of other compounds through a co-selection/enhancement process (Jonah et al. 2024). Emamectin benzoate has very low water solubility (Mushtaq et al. 1996) and is predicted to remain in the water column for short durations and subsequently partition into solid environmental matrices (Jacova and Kennedy 2022; Strachan and Kennedy 2021). Thus, it should not be found in high concentrations in water and harmful effects on pelagic organisms through continuous aqueous exposures have been evaluated as unlikely (Mill et al. 2021).

Many of the potential concerns resulting from exposure are related to adverse effects on bottom-dwelling organisms especially in light of EMB persistence in sediment (Benskin et al. 2016; Strachan and Kennedy 2021; Hamoutene et al. 2023a). Avermectins act by disrupting electrical impulses via binding to invertebrate-specific chloride channels resulting in paralysis (e.g., Burridge et al. 2008). The combined effects of feces containing in-feed residues and medicated feed waste can result in deposits around sites, evidenced by measurements from Kingsbury et al. (2023). In addition, many 'unknowns' remain regarding the confounding effects of EMB and organic matter deposition on the benthos (Bloodworth et al. 2019).

Exposure to EMB is known to have impacts on crustaceans (e.g., Burridge et al. 2000; Waddy et al. 2002; Burridge et al. 2008; Daoud et al. 2018; Mill et al. 2021; Hamoutene et al. 2023b). The studies report deleterious effects on lobsters (adults and larvae) and shrimp species, although there is less data on the impacts to crabs (Hamoutene et al. 2023b; Kingsbury et al. 2023). At both sites, the use of EMB (if any) could have the potential to affect shrimp and krill species observed to be present, as per the mode of action of the compound. Other susceptible invertebrate taxa observed at the proposed sites include echinoderms, sponges, cnidarians, bryozoans, polychaetes, and tunicates.

The use of in-feed drugs in finfish aquaculture also 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 such as 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 benthic-PEZs.

Smothering and Hypoxia

Any sessile stages of species may be susceptible within the benthic-PEZ and likely vulnerable to low oxygen levels, smothering, or exposure to in-feed drugs, if and when used (DFO 2022c,d); particularly, those closest to the cage arrays. 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, eelgrass, and critical habitat for SARA-listed species identified in the baseline survey data, scientific literature, and DFO biological data holdings. When the available data are limited, science experts consider whether the benthic substrate type is suitable for the growth of these species. Finfish aquaculture at the proposed sites may increase the risk of anoxic or hypoxic conditions, which could potentially impact benthic species, including commercially-important species such as American Lobster, Snow Crab, and Sea Scallop.

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) impacts (DFO 2010). An elevated flux of particulate matter associated with salmon farms in Norway significantly affected epifaunal community composition, including an increase of the predator sea star *Asterias rubens* where fluxes were elevated, as well as a decrease in sponges (e.g., *Polymastia* spp. and *Phakellia* spp.) and soft coral *Duva florida* (Dunlop et al. 2021), which are also taxa observed in the southern coast of Newfoundland and some specifically found at the proposed sites. Because tolerance to different levels of particulate matter can be taxa-specific (Dunlop et al. 2021), these should be assessed in NL waters to allow for a better understanding of their effects within a regional context.

Pelagic Predicted Exposure Zones (Pelagic-PEZ)

The pelagic-PEZ is a first-order estimate of the size and location of pelagic areas that may be exposed to potentially harmful levels of registered bath pesticides if used at the proposed sites, with shallow benthic areas also having the potential to be exposed (for more information on the delineation of a pelagic-PEZ see: DFO 2024a). Like benthic-PEZs, pelagic-PEZs are estimated exposure zones that serve as a tool for decision makers to identify potential overlap with marine species and habitats that may be sensitive to aquaculture-related exposure. For instance, the release of bath pesticides from a finfish aquaculture site can result in direct impacts on susceptible species and habitats at various life stages in both the water column and on the seafloor.

The size of a pelagic-PEZ depends on various parameters, including the decay and/or dilution rate of the pesticide, a chosen concentration threshold, and choice of horizontal water currents that drive the dispersion of the pesticide. The 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 tissues of marine organisms. The half-lives of the pesticides range from days to weeks, suggesting that they can persist in the environment at toxic concentrations for long durations (PMRA 2014; 2016a,b; 2017). The pelagic-PEZ is calculated conservatively, assuming use of tarp bath treatment, given the larger exposure zone anticipated to result from the tarp treatment versus a well-boat. Tarp baths involve enclosing the net-pens with tarps and adding bath treatment medicine, while the well-boat method is a more contained environment in which fish are pumped into well-boats containing the pesticide (Shen et al. 2019). The release of pesticides presumably produces a patch containing the treatment pesticide, which expands and disperses with time. 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 using a tarp treatment (Page et al. 2015; 2023). It is noted that the Proponent has indicated that well-boats would be the method employed for any bath pesticide treatments.

Hydrogen peroxide and azamethiphos are the only approved pesticides currently available for use by the finfish aquaculture industry in Canada, with Health Canada providing regulatory guidelines for their use (PMRA 2014; 2016a,b; 2017). The Proponent has indicated that azamethiphos would be the only pesticide selected for this treatment. For azamethiphos, the decay rate of the active ingredient is low compared to the dilution rate. Hence, a dilution time scale from a target treatment concentration to an Environmental Quality Standard (EQS) value was used to calculate the pelagic-PEZ (Hamoutene et al. 2023b). The pelagic-PEZ was calculated using an EQS value that ensures a level of protection of 95% of 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; see: TGD 2018). Assessment factors are used to capture some of the uncertainties related to the quantity and relevance of the available toxicity data used to derive an EQS (TGD 2018); the EQS value for azamethiphos includes an assessment factor of two (Hamoutene et al. 2023b). Therefore, the pelagic-PEZ indicates the potential for sensitive species and habitats to be exposed to levels above the conservative EQS threshold. It should be noted, however, that EQS limits for aquaculture treatment products have not yet been established in Canada.

Hamoutene et al. (2023b) reported that the threshold for azamethiphos is lower than the previously used value of 1 µg/l, with an updated value of 0.1 µg/l. Assuming this new value, the treatment patch contains concentrations above EQS for a longer period than previously considered. Page et al. (2023) outlined a method to compute the time required for the pesticide concentration within the treatment patch to achieve dilution below the EQS (dilution time thereafter), as well as the potential maximum patch depth reached by the plume containing a toxic concentration of pesticide. It depends on various parameters, including the size of the cages, the depth of the tarp within which treatment is performed, the water depth and/or the pycnocline depth if present, and the initial treatment concentration of the therapeutants, as well as the EQS. The presence of a pycnocline prevents exchange of particles between the upper layer and lower layer of the water column; thus, restricting the movement of treatment particles only within the layer in which it is released. Applying the values provided in Table 5, the dilution time for azamethiphos is 7.2 h and the maximum patch depth is 20 m.

Table 5: Input parameters used to calculate the dilution time for the proposed sites.

Parameter	Value
Cage perimeter [m]	90
Treatment depth [m]	4
Pycnocline depth [m]	20
Initial treatment concentration [µg/l]	100

Given information on the potential maximum depth of the treatment patch, the ocean current information covering the maximum patch depth is used to evaluate the pelagic-PEZ. Current speed is assumed to be the average of all maximum PVD computed within the layer of the maximum patch depth. The speed is then multiplied by the period of dilution to give a 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 decreases as the distance from the net-pens increases, the pelagic-PEZ does not quantify the intensity or duration of exposure, nor does it include a frequency of exposure. In addition, although PEZ are used to estimate zone of exposure, this should not be interpreted as impact or even that all areas are exposed within a PEZ, given the simplified nature of the estimations.

Table 6 shows the distance reached by particles representing azamethiphos during the dilution period. The treatment particles can reach a distance of 4–7 km away from the center of the cage array during the 7.2 h dilution of azamethiphos, as computed using maximum PVD (see: Appendix B). The median pelagic-PEZ was also calculated using the methodology described previously, and using this calculation, the particles may reach a distance 1–2.2 km from the cage array. The pelagic-PEZs for the proposed sites are illustrated in Figure 8. The exposure is expected to primarily occur in the pelagic zone; however, since it reaches areas near the shoreline, shallow areas (less than 20 m depth) may also be at risk of exposure to toxic pesticide concentrations should ocean currents move plumes toward the shore. The figure shows that for the PEZs computed using maximum PVD, there is overlap of the two proposed sites, suggesting that the concentration of toxic pesticide could be additive should successive treatments occur in the same area within the period that a toxic pesticide is still present in the area. This would result in a longer dilution time from the first treatment, and thus a potentially larger exposed area. Note that this analysis does not consider exposure from other active finfish aquaculture sites that are present in the area. Similar to the benthic-PEZ, the interpretation of the above results should consider the fact that they provide only an order of magnitude of the distance a particle released from the aquaculture site might reach based on the available input data; in particular, the current information at one location near the respective site locations.

Table 6: Pelagic-PEZ estimates computed using maximum progressive vector diagram (PVD) at each depth, associated with the potential horizontal distances travelled by non-sinking particles (representing azamethiphos) for a dilution period of 7.2 h and a maximum patch depth of 20 m. Pelagic-PEZ computed using median PVD displacement is also included.

Parameter	Cape Mark	Collins Head
Current speed during dilution (from averaged max. PVD) [cm/s]	24.2	16.2
PEZ radius [km]	6.5	4.4
Current speed (from averaged median PVD) [cm/s]	7.7	3.3
PEZ radius (from median PVD) [km]	2.2	1.0

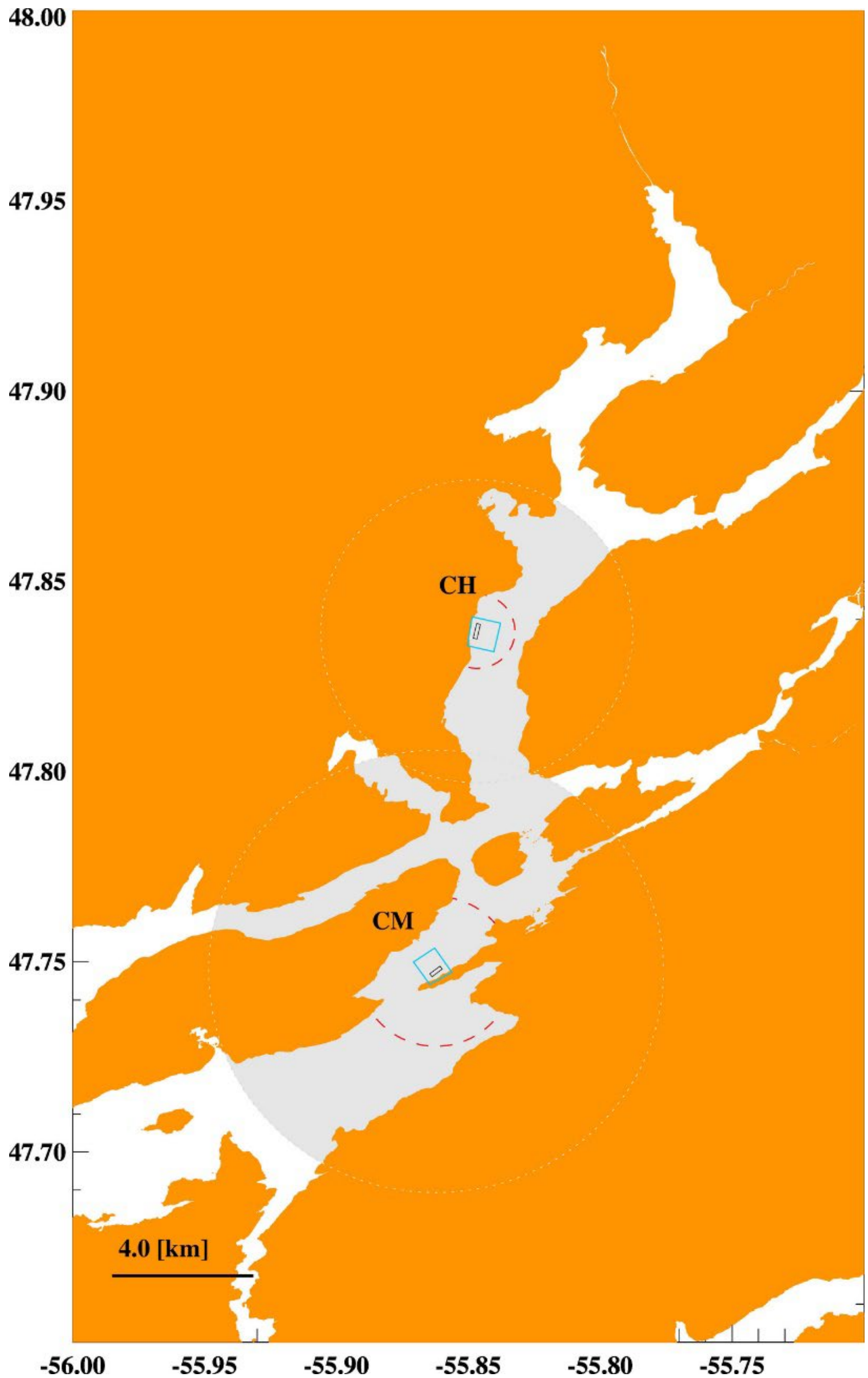

Figure 8: Pelagic predicted exposure zone (pelagic-PEZ) associated with treatment by azamethiphos (zones denoted by grey circles) for the proposed sites (CM = Cape Mark, CH = Collins Head). Note that the pelagic-PEZ covers much of the upper part of Bay d'Espoir, NL. Alongshore seabed shallower than 20 m may be exposed to toxic pesticide concentrations. The pelagic-PEZs computed using median progressive vector diagram are denoted by the red dashed circles.

Spatial Extent of Pesticide Exposure

Effects of Pesticides Exposure

Azamethiphos is an organophosphate insecticide (active ingredient in Salmosan®) applied in salmon aquaculture cages at 100 µg/L of the active ingredient for 30–60 minute pulses using tarps or well boats (PMRA 2016b). It acts by inhibiting cholinesterase enzymatic activity (Ernst et al. 2014) and exerts toxicity towards a wide range of non-target organisms, with crustaceans, including commercially important shellfish species such as lobster and shrimp, identified as being the most sensitive group (Burridge et al. 2014, Ernst et al. 2014). Azamethiphos is expected to remain mostly in the aqueous phase due to its hydrophilic nature and high solubility in seawater (Burridge et al. 2010) meaning that marine biota are mostly exposed in the water column as a route of exposure (e.g., PMRA 2016b).

Susceptible Species Interactions

Exposure to pesticides that target sea lice could threaten lobster at all life stages (Burridge 2013; PMRA 2016b;2017). 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). Behavioural changes, including reduced female reproductive success, have been reported after exposure to sub-lethal doses of sea lice pesticides (Burridge 2013). Another 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.

A review of all treatments administered at NL trout aquaculture sites from 2018 to 2023 (DFO 2023c) indicates that among the five sites active during this timeframe there were only three treatments: one was an anesthetic and the other two were oxytetracycline usage. In addition, as indicated by the Proponent, sea lice infestations in the area are unlikely due to the presence of brackish water and the fact that historically trout sites have not had to treat for sea lice infestations (pers comm.; Dr. Katrina MacNeill, Aquatic Animal Health Veterinarian, Ocean Trout Canada Inc.).

An overview of bath pesticide usage at NL finfish aquaculture sites between 2018 and 2022 (DFO 2023c) indicates that most sites used azamethiphos only. 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. 2023c). Therefore, any multi-chemical cumulative effect would mostly occur 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). The krill and species of shrimp that mostly and/or intermittently occupy the pelagic zone may be exposed to bath pesticides, if used (Figures 9 and 10).

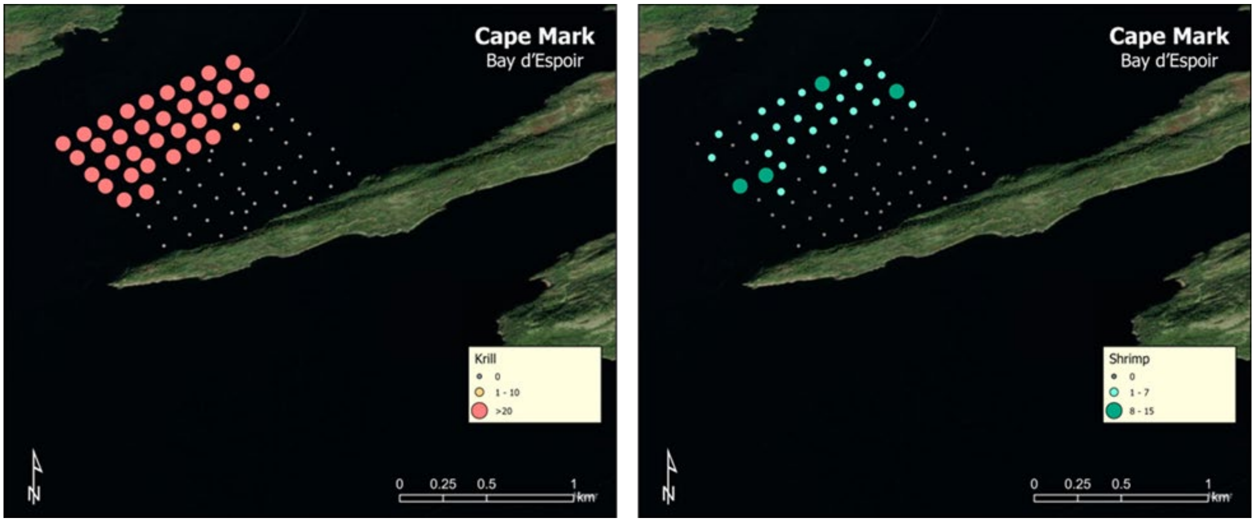

Figure 9: Representation of krill and shrimp presence at locations in the Cape Mark site. Dots are not to scale as per the limitations of video sampling; therefore, counts can be used only as partially-indicative of spatial density.

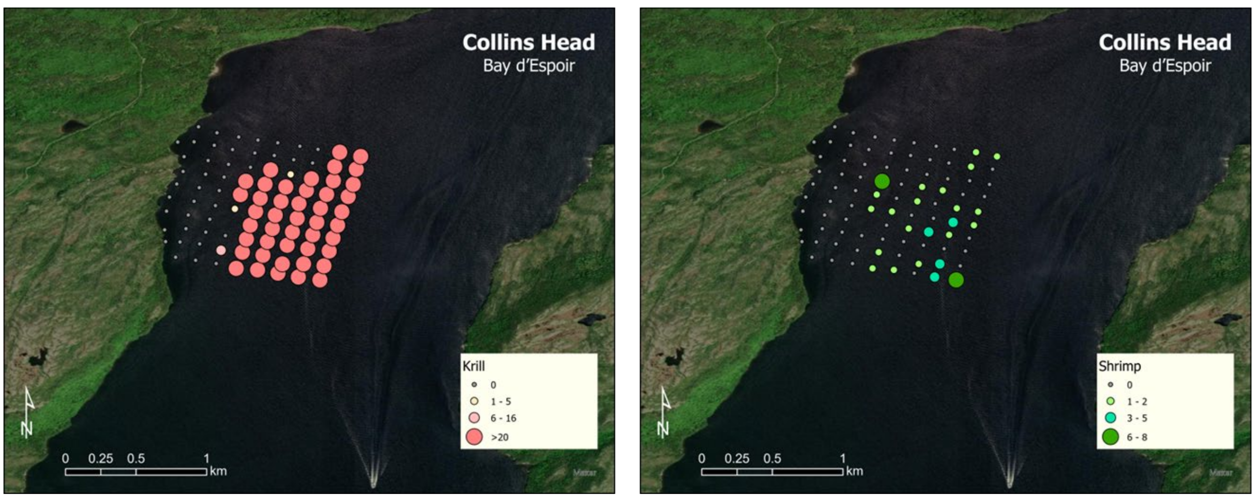

Figure 10: Representation of krill and shrimp presence at locations in the Collins Head site. Dots are not to scale as per the limitations of the video sampling; therefore, counts can be used only as partially-indicative of spatial density.

POTENTIAL INTERACTIONS

Commercial 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 NL. This survey has been active in Northwest Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps since 1995 and provides indices of relative abundance (i.e., catch rates) for resource assessments. Catch rates in this area 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 it is currently assessed to be in the Critical Zone of DFO's Precautionary Approach Framework (DFO 2024b).

Although juvenile cod 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 Subdiv. 3Ps. Evidence from the north coast of NL shows the importance of eelgrass habitat for juvenile cod (e.g., Laurel et al. 2003a,b), but little spatial data exist on the distribution of eelgrass in NAFO Subdiv. 3Ps beyond Placentia Bay (Robichaud and Rose 2006). However, the proposed sites did not identify eelgrass beds at either location.

Witch Flounder are fished commercially in the region but are typically found in waters between 100 and 500 m deep (Wheeland et al. 2019). Given the locations of the proposed aquaculture sites near the head of Bay d'Espoir and water depths in the area, Witch Flounder may not have access to the areas near the proposed sites. 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).

Limited data exist for pelagic species on 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 (Tibbo 1956; Wheeler and Winters 1984; Bourne et al. 2023). Capelin and Mackerel are seasonal visitors to the nearshore region, with adult Capelin spawning on beaches and in nearshore demersal areas during the summer (Templeman 1948) and Mackerel feeding across the region during summer (Ware and Lambert 1985). Early life stages of Capelin (e.g., eggs, larvae, and juveniles) may reside in coastal bays year round during their first year of life.

Aquaculture sites potentially have both positive and negative effects on local finfish species (Dempster et al. 2009; Uglem et al. 2014). Excess feed from aquaculture facilities can serve as a food subsidy for many species of fish (Dempster et al. 2009; Goodbrand et al. 2013) while the physical structure of the aquaculture facility itself can serve as a fish aggregation device (Callier et al. 2018). The attractive nature of both the excess feed from aquaculture operations and the structure itself could result in aquaculture facilities aggregating large numbers of fish and invertebrates. Aggregation of finfish around aquaculture sites may increase predation risk for early life stages (e.g., eggs, larvae and juveniles) of fish due to an increase in encounter frequencies with potential predators (e.g., more predators in the same volume of water with fish aggregating around aquaculture sites). 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 piscivorous fish and farmed salmonids).

Increased nutrient loading from aquaculture sites could aggravate episodic low oxygen events associated with high water temperatures by increasing water column and/or sediment BOD. Peak feeding times roughly correspond to the timing of peak water temperatures along the south coast of NL (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). This 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, although low bottom oxygen concentrations could affect pelagic species with benthic eggs.

During periods of elevated water temperatures, aeration systems are utilized to replenish dissolved oxygen and decrease temperature through mixing cooler water at depth with surface water. Additionally, feeding is monitored closely and modified as needed, including suspension of feeding when temperatures exceed 16ºC at 5m or dissolved oxygen levels drop below 6.5 mg/L. Under the AAR, aquaculture industry operators are required to conduct monitoring of marine sediment sulfide concentrations near finfish aquaculture sites to assess the potential impact of organic matter on the benthic environment. Should regulatory thresholds (i.e., concentration limits) be exceeded, management actions are required. Sediment sulfide concentrations are used as an indicator of oxic state and biodiversity in soft sediments; however, along the south coast of NL, most salmonid farms occur in deep bays or fjords (i.e., greater than 30 water depth) where substrates consist mainly of bedrock, rock, or cobble with patches of soft sediments (Anderson et al. 2005; Hamoutene 2014; Hamoutene et al. 2013, 2015).

Wild Salmonids Interactions with Trout Aquaculture Escapees

The impacts of escaped farmed Rainbow Trout on wild populations of Atlantic Salmon, as well as feral populations of Rainbow Trout if they exist, have been discussed (DFO 2021; 2022e). However, there are no established populations of Rainbow Trout on the south coast of NL. Rainbow Trout escapes from aquaculture happen for the same reasons as Atlantic Salmon (Føre and Thorvaldsen 2021). In NL, salmonid aquaculture site licenses have strict requirements for avoiding breaches of containment and escape reporting is managed under the Code of Containment. The Code of Containment requires the license holder to report escapees to the federal Department of Fisheries and Oceans and the provincial Department of Fisheries, Forestry and Aquaculture immediately. Compliance and inspection results report Rainbow Trout escape events in the NL region and can be found in the Annual Compliance Report; recent and archived. The reported number of Rainbow Trout escapees in NL has ranged from 0 to 93,000 fish per year since 1990. In recent years (2012–22), escapee events occurred in only two years (i.e., 2015 and 2022) and involved less than 1,000 fish per year.

The behaviour of Rainbow Trout after escape has not been studied as extensively as that of Atlantic Salmon. However, slower dispersal from the site of the escape is suggested in a review by Dempster et al. (2018). The review showed that while the majority of escaped Atlantic Salmon disperse in less than 24 hours, most Rainbow Trout remained in the vicinity of cages for approximately 48 hours. Even so, Rainbow Trout dispersal behaviour is variable, as some disperse quickly and others slowly, with some returning to the cage site; overall, the number that remain at the location of escape is shown to decline over time (Bridger et al. 2001; Blanchfield et al. 2009; Lindberg et al. 2009; Patterson and Blanchfield 2013). In Bay d'Espoir, a study carried out in 1998 found that 75% of experimentally released triploid Rainbow Trout remained in close proximity (less than 500 m) to cage sites for more than one month post-release (Bridger et al. 2001). While the majority of these Rainbow Trout eventually dispersed, many dispersed to other cage sites or showed directed movement to the hydroelectric spillway where the hatchery for the aquaculture industry was located (Bridger et al. 2001). In NL, Veinott and Porter (2013) identified Rainbow Trout escapees in rivers based on otolith chemistry and found that some escapees had travelled over 800 km. Post-escape survival also varies; however, survival for months to years (Jonsson et al. 1993; Patterson and Blanchfield 2013), as well as successful transition to wild food (Rikardsen and Sandring 2006; Nabaes Jodar et al. 2020) and growth (Jonsson et al. 1993; Blanchfield et al. 2009; Patterson and Blanchfield 2013) have been observed. The potential for post-escape survival and observed dispersal distances within the range observed for Atlantic Salmon (i.e., within 200–300 km; see: Morris et al. 2008; Keyser et al. 2018; Bradbury et al. 2020b) suggests that the area of concern for escapes of Rainbow Trout would likely be similar to that predicted for Atlantic Salmon.

In NL, occurrences of Rainbow Trout, including escapees, have been reported in rivers and at sea (Chadwick and Bruce 1981; Porter 2000; Veinott and Porter 2013). Initial reports of a small number of Rainbow Trout on the West Coast of NL coincided with the development of aquaculture in other regions of Atlantic Canada in the 1970s prior to development of Rainbow Trout aquaculture in Bay d'Espoir (Porter 2000). Therefore, evidence suggested these Rainbow Trout may have been escapees from other regions (e.g., Nova Scotia), supporting a view that long range dispersal of escapees is possible (Porter 2000). However, after the development of Rainbow Trout aquaculture in Bay d'Espoir, a larger number of Rainbow Trout escapees were reported in the Bay d'Espoir area. Specifically, data from Conne River, which is located near the proposed aquaculture sites (within 15 km of Collins Head and 25 km of Cape Mark), indicate the presence of Rainbow Trout escapees every year (except 2006) starting in 1990 to as recently as 2013. Rainbow Trout escapees have also been captured by fish harvesters in the upper Bay d'Espoir and surrounding areas (see: Dempson et al. 2000) and observed in other areas of the province, including rivers on the West Coast (Veinott and Porter 2013). This includes Western Arm Brook on the Northern Peninsula (Veinott and Porter 2013), where Rainbow Trout have been captured at DFO counting facility as recently as 2019, although their origin is unknown (i.e., escapee or wild).

As stated above, given that Rainbow Trout escapees will disperse similar distances to Atlantic Salmon, a conservative upper dispersal distance of 200 km can be assumed (DFO 2024c). The proposed aquaculture sites are located, within the proposed South NL-West Designatable Unit (DU-04B) for wild Atlantic Salmon (see: Figure 9 in Lehnert et al. 2023); thus, Rainbow Trout escapees would likely disperse to rivers located within it. Additionally, rivers within the adjacent South NL-East DU (DU-04A; Lehnert et al. 2023) are also within the conservative upper dispersal distance. These two DUs were previously considered to be a single DU (South NL) and assessed as 'Threatened' (COSEWIC 2010). The South NL-West DU is comprised of 52 Atlantic Salmon-bearing rivers and Atlantic Salmon populations in this DU continue to show concerning trends in abundance, with the total DU abundance estimated to have declined by 58% over the last three generations (COSEWIC In review[1]). Only Conne River in this DU is currently monitored by DFO (Figure 11). Since1986, Conne River has experienced a 92% decline in total adult returns of Atlantic Salmon, with aquaculture, climate change, and predation

[1] COSEWIC. In review. COSEWIC assessment and status report on the Atlantic Salmon *Salmo salar* (Nunavik population, Labrador North population, Labrador Lake Melville population, Labrador South population, Northeast Newfoundland population, South Newfoundland East population, South Newfoundland West population, Southwest Newfoundland population, Northwest Newfoundland population, Quebec Eastern North Shore population, Quebec Western North Shore population, Anticosti Island population, Inner St. Lawrence population, Gaspe Peninsula population, Southern Gulf of St. Lawrence and Cape Breton population, Nova Scotia Southern Upland East population, Nova Scotia Southern Upland West population, Inner Bay of Fundy population, Outer Bay of Fundy population) in Canada. Ottawa.

cited as threats to the population (Dempson et al. 2024). The adjacent South NL-East DU is comprised of 54 Atlantic Salmon-bearing rivers, with the total DU abundance estimated to have increased by 65% over the last three generations. Four rivers in the South NL-East DU are currently monitored by DFO, and one of these monitored rivers, the Garnish River, is within the distance that Rainbow Trout escapees could disperse; however, no Rainbow Trout escapees have been reported at this river to date. Total adult returns of Atlantic Salmon at Garnish River have been monitored since 2015, and in 2022, returns were similar to the previous generation average (i.e., plus 3%), suggesting little change in population abundance in recent years (Kelly et al. 2024).

When Rainbow Trout escape, they can interact with wild populations genetically and ecologically. Genetic interactions can be direct (e.g., exchange of genetic material and hybridization) and/or indirect (e.g., altered selection pressure) (Lacroix and Fleming 1998). While laboratory studies have produced adult hybrids between Atlantic Salmon and Rainbow Trout, no hybrids have survived to sexual maturation (Devlin et al. 2022). In addition, the two species do not spawn at the same time of year, as Rainbow Trout spawn in the spring and Atlantic Salmon in the fall. Thus, this type of direct genetic interaction between Atlantic Salmon and Rainbow Trout would not be expected to occur in nature. Non-sterile escaped Rainbow Trout could reproduce with feral populations of Rainbow Trout if they exist near the proposed sites (Consuegra et al. 2011). To date, however, no established populations of Rainbow Trout have been reported on the south coast of NL. The known established populations derived from stocking are limited to northern and eastern portions of NL, including on the Avalon Peninsula, Baie Verte Peninsula, and in the Clarenville area (Porter 2000; Mullins and Porter 2002); thus, would not be expected to interact with escapees.

Consequently, for wild Atlantic Salmon, the most likely types of interactions with escaped Rainbow Trout would be ecological through, for instance, competition for food, disease and pathogen transfer, and predation. Ecological interactions can occur between Rainbow Trout escapees and wild Atlantic Salmon, regardless of life stage. Rainbow Trout are considered a close 'ecological equivalent' to Atlantic Salmon, as both species are aggressive, have similar life histories, and have similar habitat and feeding preferences during the juvenile stage (Gibson 1981,1988; Hayes and Kocik 2014). While several studies have shown that Rainbow Trout have stronger competitive abilities than Atlantic Salmon (e.g., Van Zwol et al. 2012, Houde et al. 2017), they are based on wild populations of Rainbow Trout and not farmed Rainbow Trout escapees.

Ecological interactions have been shown to change the selective landscape, resulting in changes to fitness-related allele frequencies that can lead to a decrease in Atlantic Salmon population size and consequently reduced genetic diversity (Bradbury et al. 2020a). Reduced population size and loss of genetic diversity could in turn lead to increased susceptibility to genetic drift and impact of stochastic events (Whitlock 2000). This is of concern for wild Atlantic Salmon populations in the South NL-West DU, which continue to decline and already face increased risk due to interactions with farmed Atlantic Salmon escapees (DFO 2024c).

The Proponent is required to comply with the NL Code of Containment (NLFAA 2022), which is intended to minimize farmed fish escapees and to effectively deal with escapes if they do occur. This includes using materials (e.g., predator nets) that meet recognized industry best practices and standards, remotely-operated net cleaners with increased monitoring, and third-party certification standards for cage design and engineering.

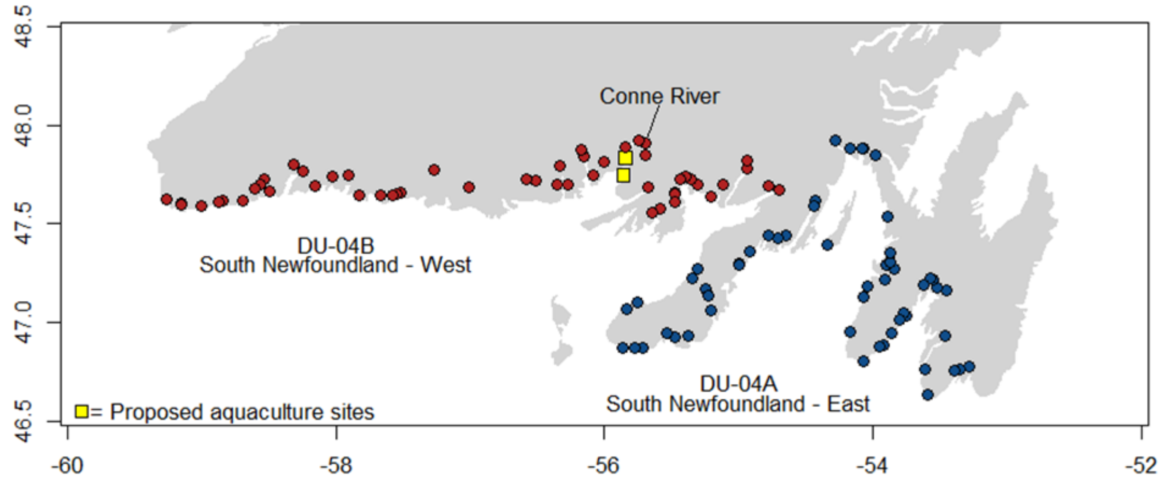

Figure 11: Map showing all Salmon-bearing rivers (points) located within proposed COSEWIC Designatable Units (DUs) for wild Atlantic Salmon. Red dots indicate the South Newfoundland-West DU and blue dots indicate the South Newfoundland- East DU. The two proposed aquaculture sites are denoted by the yellow squares.

Pests and Pathogens

Aggregations of fish near aquaculture facilities may promote the spread of disease and parasites to and from wild fish stocks. Development of new finfish aquaculture sites could potentially increase the spread of diseases because it shortens the travel distance/time between sites for wild fish that may move frequently between aquaculture sites (e.g., Uglem et al. 2009). The positioning of proposed cages in narrow fjords and adjacent to coastlines, and the position of the water column occupied by pelagic forage fish and their relative abundance in the ecosystem, all add to the likelihood that they will move past or interact with finfish aquaculture cages during their production cycles.

Bouwmeester et al. (2021) identified several potential means by which farmed fish populations may affect the disease dynamics of wild fish stocks. Specifically, farmed fish may co-introduce parasites to the environment, potentially infecting conspecifics and/or other wild species, possibly leading to emerging diseases. Farmed fish may also host parasites from wild host species, potentially amplifying parasite numbers and increasing the frequency of parasite infections in wild hosts when parasite infections spill back to them. 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 parasitic copepods that can pose a significant health risk to farmed and wild salmonid species when present above 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 an amplification of sea lice associated 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).

The sea lice species most commonly studied and reported to be of concern for salmonid aquaculture, including in NL, is *Lepeophtheirus salmonis*. However, ergasilids (i.e., belonging to the genus *Ergasilius*) are another group of parasitic copepods commonly referred to as "gill maggots", which have been described from a wide range of estuarine or freshwater fish species globally (Paperna and Zwerner 1976a,b; Kabata 1981; Tuuha et al. 1992; Tidesley 2008; Eaves et al. 2014; Murray et al. 2016; Murray and Ang 2018). This group has received considerable attention due to the extensive tissue damage caused by their attachment on the gill filaments of their hosts (Smit and Hadfield 2018). Observations of this parasite in association with cultured fish are becoming more frequent and have been reported from stocked trout reservoirs in central England and Wales (Tildesley 2008).

Recent observations of increasing prevalence of *Ergasilus labracis* on trout farms situated in Bay d'Espoir have raised some concern for the local industry (pers comm.; Melissa Burke, Senior Production Biologist, Ocean Trout Canada Inc.). Eaves et al. (2014) and Murray and Ang (2018) both reported enhanced prevalence of *E. labracis* within local populations of Three-spined Stickleback (*Gasterosteus aculeatus*) in the Bay. Murray and Ang (2018) also showed a link between seasonal environmental conditions (e.g., salinity and temperature) and the occurrence of the parasite in specific local environmental zones in the Bay and overlapping trout culture sites. This suggests conditions supporting a natural primary amplification source (i.e., sticklebacks) and a secondary cultured source (i.e., trout) creating the potential for significant impact on the industry. Mitigation strategies to control this parasite have primarily depended on environmental manipulation, based on the narrow tolerance ranges for this group (Paperna and Zwerner 1976a; Conroy and Conroy 1986; Barker and Cone 2000). While ergasilids generally should respond to commonly-used, commercially-available aquaculture therapeutants, few studies have reported their use or efficacy for this parasite.

Long-term data on sea lice abundance in southern Newfoundland is lacking. As of January 2021, however, public reporting of monthly averages of sea lice per fish across all sites/companies has become a requirement for periods in which water temperatures are above 5°C (Aquaculture Policy Procedures Manual). 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.

While some cage sites reported low or no chemical usage for controlling sea lice, sea lice treatments in NL over the period 2016–21 peaked in 2017 (Hamoutene et al. 2022) and declined thereafter. Treatments in 2017 coincided with warmer surface temperatures in the fall, a higher freshwater input in the spring, and stronger wind conditions (Hamoutene et al. 2022). However, drug and pesticide reporting does not provide insight as to whether the decline from 2017–21 reflects decreased salmonid 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. 2022), or a natural reduction in sea lice in the marine environment due to unfavorable environmental conditions. Nevertheless, sea lice treatments appear to peak in July, but have occurred from June to December, and thus, outbreaks can coincide with the period wild salmon are either migrating from or returning to local rivers. The Proponent's Integrated Pest Management Plan outlines preventative actions and interventions available to combat finfish pests.

Entanglements

The establishment of new 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 systems, and the prompt removal of attractants, such as dead fish (DFO 2023b). Entanglement mitigation measures, such as removal of unnecessary lines and ensuring all lines are taut, are employed to reduce the risk of entanglements. In general, reports of entanglement of marine mammals, sea turtles, and sharks in marine finfish aquaculture gear in Atlantic Canada remain low or nil for these species.

Cetaceans

Globally, entanglement data associated with marine aquaculture infrastructure are relatively sparse and rarely quantitative. 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 an under-reporting 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, Bottlenose Dolphin (*Tursiops truncates*), and Harbour Porpoise. Data on cetacean entanglement associated with aquaculture infrastructure are largely not available in Canada.

Few scientific surveys have been completed in the coastal, sheltered areas of the south coast of NL where finfish aquaculture sites occur, resulting in a lack of information regarding the distribution of marine mammals in proximity of the proposed aquaculture lease under review here. 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 (i.e., Blue Whale, Fin Whale, Sei Whale, Minke Whale, Humpback Whale, North Atlantic Right Whale, Sperm Whale), several species of dolphins, and Harbour Porpoise. Based on opportunistic and systematic sightings data, these species can occur in NL waters year-round with seasonal peaks in abundance occurring typically in summer and fall. In NL, 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.

Seals

Seal species such as Harbour Seals and Grey Seals occur along the south coast of NL regularly and may haul-out in the proposed 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. Publicly-released data on marine mammal fatalities for 2011–23 indicate 78 authorized fatalities (lethal removal due to imminent danger to aquaculture facilities or to human life) and 50 accidental drownings for Harbour Seal in British Columbia (DFO 2023b). The accidental drownings were largely attributed to animal entanglement underwater in cage netting or other farm gear (Bath et al. 2023). In NL, no pinniped entanglements with finfish aquaculture infrastructure have been reported to date.

Turtles

Leatherback Sea Turtles and Loggerhead Sea Turtles frequent NL waters during summer and fall to forage, but they do not nest in Canada. Leatherback Sea Turtles frequent inshore and offshore 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 lease areas. Leatherback Sea Turtles and Loggerhead Sea Turtles are listed as endangered under Schedule 1 of SARA.

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 fishing 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 Sea Turtles entangled in shellfish aquaculture infrastructure in Notre Dame Bay, NL (Bath et al. 2023). One turtle was found dead in 2009, rolled up in mussel farm lines. The two other turtle entanglements involved mussel spat collection lines, with one resulting in death at depth (in 2010) while the other (in 2013) was recovered alive at the surface and released after disentangling its head and flippers. In NL, 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 sea turtle entanglement at the proposed sites.

Large Pelagics and Sharks

Previous research has documented the potential attraction and entanglement of large pelagic fish to sea cages; notably, tunas and sharks (Fernandez-Jover et al. 2007; Dempster et al. 2009; Hamoutene et al. 2018). Increased presence of White Sharks has been observed along the south coast of NL 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 NL waters is rare, and the species occupies an extensive range of pelagic habitat (i.e., Ocean Basin scale), suggesting a negligible impact from proposed aquaculture activities at species or population levels, or on their habitat.

OTHER CONSIDERATIONS AND SOURCES OF UNCERTAINTY

Oceanographic Data and Model Output

The Proponent has collected ocean current data at the two proposed sites and at various depths consistent with regulatory requirements. However, these measurements only covered a period of 33–45 days, from July-August, and less than 20% of the depth of water found in the lease areas; such a short period of data collection cannot capture seasonal variability or vertical variability in deep areas. Previous reports on currents in the area of the proposed sites demonstrate seasonal variability, with stronger ocean currents observed in the fall (Ratsimandresy et al. 2019, Donnet et al. 2022). To improve accuracy of waste dispersion and deposition prediction, 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. These data need to be compared to existing measurements in the area to ensure predictions are conducted with the strongest observed ocean currents. Using the strongest current speed will ensure conservative predictions of waste transport distance and the associated PEZ diameter.

With respect to the current conditions measured at the proposed site locations, the Proponent provided ocean current data that were not corrected for the magnetic inclination. Such correction is necessary in order to have the current direction relative to true north. It is the understanding of DFO Science that the direction of the currents given in the baseline documents, and used in the model deposition output were not corrected, thereby inducing error in the reported depositional areas.

The model used by the Proponent to predict the area of deposition of wastes was *Aquamodel*. The modeled input used a 29.5-day period extracted from the Proponent's field measurements (July to August 2018 and July to August 2019) to run the model to predict deposition for a period of May 2024 to December 2024; however, the Proponent did not describe how they used this one-month current data to create a seven month simulation. The model was run in 2-D mode, but no explanation was given regarding the current information used to run the model. While the model output for Cape Mark shows deposition along the main direction of the currents, the output for Collins Head results in deposition occurring across the channel, suggesting that the main direction of the currents at that location is across the channel. This is not consistent with the current direction analysis that was reported. It is not clear whether this inconsistency is due to the model being run in 2-D mode, an issue with the selection of current time series used to feed the model, or some uncertainty in selecting the correct current direction.

The calculation of PEZ requires access to timeseries of ocean current data at various depths, from near surface to the maximum depth within a proposed lease area. Limited data (in this case information from only the upper portion of the water column was available) is expected to affect the PEZ estimate, as well as any prediction of deposition using a more complex model.

In order to improve the physical oceanographic information being collected/ provided by Proponents, and to obtain the necessary data for a depositional model to be run with reasonable confidence, revisions to the current guidance in the AAR should be considered. This would include collection of temperature and salinity profiles during the expected maximum feeding season, dissolved oxygen measurements in the upper layer, and the collection of ocean current observations at proposed sites during the expected maximum feeding season for at least three months.

Benthic Surveys

The diversity, distribution, and ecology of benthic communities in many areas of Bay d'Espoir, and along the south coast of NL in general, remains a knowledge gap. Seafloor video and imagery provided from industry surveys is frequently the first time these areas have been observed by DFO Science. While video quality is influenced by factors including, but not limited to, current speed, type of seafloor, presence of marine snow, and turbidity, as described in Proponent reports, sub-optimal camera quality also has an influence. In this instance, video was observed to zoom in and out during the deployment, although the reason for this is unclear (some screenshots clearly have different areas because of this). While the Proponent includes an area for each quadrat (i.e., 50 x 50 cm) it is unclear whether the area is the inner or outer area of the quadrat.

The low quality of the videos will challenge future comparative analysis of before and after aquaculture activities. Maximum video quality "4" (defined as "high-quality video with easy identification of animals and substrate conditions") was reported in 61–93% of the stations. This appears to be inaccurate, as in many instances it is very difficult to identify the fauna. Additionally, two of the screenshots provided in the report for Cape Mark (i.e., CM-26 and CM-29) are the same image and based on the timestamps and positions; that is, CM-29 may be missing.

In many previous DFO science peer-review processes, the Proponent video provided was from a remotely operated vehicle (ROV), while data submitted for this assessment process was collected using a drop camera system. The ROV has a forward-looking view, while the drop camera had a downward-looking view of the seafloor. In addition, altitude is different because the drop camera comes much closer to the seafloor compared to an ROV. The difference in camera angle and distance from the seafloor leads to two different spatial scales, meaning any before-after analyses or between-site comparisons may not be comparable. This should also be considered when revising the current protocols for seafloor imagery collection in the AAR.

The Proponent provided abundances of the benthic fauna observed during the seafloor surveys. Abundances represent the count of organisms per station. The Proponent indicates that *a* "minimum of one minute of bottom time was recorded at the accessible sampling location"; however, it is unclear whether distance covered was the same. If organisms were very abundant, the Proponent classified counts as greater than 20. In contrast, there is no clarification as to whether at a particular station greater than 20 means a much larger amount. Taxa absences and abundance counts need to be interpreted with caution, as these counts do not reflect relative counts (i.e., in relation to surveyed area), while camera distance from the seafloor may be slightly different between stations.

Analysis of video between stations indicates that sampling designs with discrete stations (drop camera) may mask presence of organisms, suggesting that reported absences or low abundances of species in these surveys should be evaluated with caution. Information regarding the ideal combination of sampling methods at a given spatial scale, habitat, or region to detect biodiversity patterns would help maximize the number and range of specimens collected, as well as the spatial coverage of the collection (Flannery and Przeslawski 2015).

Section 14.0 of the Cape Mark baseline report states that sediment within the lease area consisted mainly of mud/silt. However, 40 of the 79 stations (i.e., 51%) were characterized as having hard seafloor. Annex 9 of the AAR prescribes benthic sediment sampling at sites with a soft bottom classification (i.e., greater than 50% soft sediment). In consideration of typical hard bottom sites in the south coast area of NL, it is noteworthy that this site has a significant amount of soft sediment. This suggests that sediment sampling could be beneficial, especially given that only 0.0032% of the lease area was surveyed (based on a quadrat size of 0.25 m^2 at 79 stations over a lease area of approximately 0.6 km^2). The AAR requirement for benthic sampling only at sites that have predominantly soft sediments represents a missed opportunity for baseline sampling in this case.

Baseline survey requirements under the AAR Monitoring Standard currently lack specificity in a number of areas that affect the quality of the data available for analysis. As written, none of the specifications for operational visual monitoring under the AAR monitoring standard relate to image clarity, resolution, field of view, operation of diver-operated, towed, or remote-operated video cameras, as these apply to the collection of baseline survey information. Consistency in these requirements may have improved issues related to image clarity, field of view, and lack of adequate resolution. This should be considered when revising the current protocols for seafloor imagery collection in the AAR.

Impacts to susceptible species from exposures

The degree to which wild fish species and fish habitat may be exposed to the proposed aquaculture activities remains uncertain. There are data gaps regarding the full extent of species presence (in space and time) and habitat use in the area, as well as insufficient data to assess the probability of transport of wastes and chemotherapeutants to specific areas in the PEZs. Additionally, the sensitivity of some species life stages and habitats to the potential effects from the proposed aquaculture operations (i.e., organic loading, fish health treatment products, site infrastructure) is not well understood.

The state of knowledge on effects of in-feed drugs and pesticides on susceptible non-target species also continues to evolve (e.g., mechanism of exposure, acute versus chronic exposures, multi-chemical usage, sub-lethal and lethal impacts). Available toxicity data to date is largely derived from lab experiments, with the degree of exposure and impact of in-situ treatment conditions (ranging from a single treatment scenario to cumulative exposures) to wild susceptible species is uncertain. A lack of species-specific toxicity studies for important species in the area, such as Lobster and Sea Scallop, adds to the uncertainty of lethal and sublethal effects on various life stages, condition, health, and reproduction. These uncertainties limit the ability to predict a magnitude of impact and consequence of proposed aquaculture operations on species abundance and distribution.

Farmed Trout-wild Atlantic Salmon interactions

Uncertainty remains about the dispersal distance of Rainbow Trout escapees in the NL region. Limited studies in NL suggest localized dispersal of escapees (Bridger et al. 2001) with the potential of long range movement (Veinott and Porter 2013). However, the origin of escapees or occurrences (Chadwick and Bruce 1981) in areas outside of Bay d'Espoir (e.g., west coast of NL) remains unknown and may be non-NL origin. In addition, apart from monitored index rivers, information is generally lacking on the size and distribution of wild Atlantic Salmon populations. To assist with the assessment of risk, improved estimates of wild Atlantic Salmon population size, as well as the presence, number, and origin of Rainbow Trout escapees in salmon-bearing rivers in the DFO NL Region are needed.

Uncertainty remains around indirect genetic and/or ecological interactions and impacts on wild Atlantic Salmon due to predation, competition, disease, and/or parasites from finfish aquaculture. Current knowledge of ecological interactions between escaped farmed Rainbow Trout and wild Atlantic Salmon has been summarized in previous DFO Science aquaculture site reviews (DFO 2021).

Cumulative Effects

Cumulative effects are not being considered as part of this site assessment process despite proximity of the two proposed sites relative to each other (e.g., with overlap of the pelagic-PEZs from the two sites) or to other finfish aquaculture sites in Bay d'Espoir. Three of the currently-stocked sites (i.e., Arran Cove, Muddy Hole and Hardy Cove, which are owned by the Proponent) fall within the fecal benthic-PEZ for the Collins Head proposed site. All four currently-active sites fall within the pelagic-PEZ associated with the treatment by azamethiphos. The cumulative impacts of pesticide treatments in relation to the timing of their usage within the sites to mitigate impacts on sensitive species and their critical life-cycle stages should be considered.

Climate Change Considerations

Climate change due to anthropogenic release of greenhouses gases can have both direct and indirect consequences to ocean ecosystems, such as ocean warming, altered acid-base chemistry, rising sea levels, higher stratification resulting in limited mixing of euphotic waters, altered oceanic and coastal circulation, freshwater inputs, and reduction in subsurface concentration of dissolved oxygen (Doney et al. 2012). Changes in ocean climate conditions (e.g., ocean warming or the freshening of NL waters from increased ice melt) have potential to influence ecosystem productivity and alter the stratification of the water column (Cyr et al. 2024). This, in turn, may influence sea lice and diseases, including a subsequent need to use pesticides and drugs. Storms, in particular, are projected to intensify in North America, occur more frequently, and increase in severity (Hicke et al., 2022). Increased likelihood of storm incidence and severity, projections of increased wave height and rising sea levels may all affect aquaculture infrastructure and increase the potential risk of finfish escapees (Callaway et al., 2012).

CONCLUSIONS

Terms of Reference 1: *Based on the available data for the sites and the scientific information, what are the predicted exposure zones 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 occurs within a radius of 1.5 km from the sites, which is generally double the size of the proposed lease areas. No overlap is expected between the feed-based benthic-PEZs from both sites.
- The benthic-PEZ associated with in-feed drug present in feces occurs within a radius of 5–9 km (depending on the site) from the site location. No overlap between the benthic-PEZs is expected.
- The pelagic-PEZ associated with the use of azamethiphos bath treatments occurs within a radius of approximately 4–7 km from the site location.
- The pelagic-PEZ related to the usage of azamethiphos bath treatments yields some overlap and could reach the shorelines. The treatment product has a potential to impact the shallow areas (less than 20 m depth) adjacent to each site, should the ocean currents move plumes toward the shore.

Terms of Reference 2: *Based on available data, what are the Ecologically and Biologically Significant Areas; species listed under Schedule 1 of the Species at Risk Act (SARA); fishery species; and ecologically significant species, and their associated habitats that are within the predicted benthic exposure zone and vulnerable to exposure from the deposition of organic matter? How does this compare to the extent of these species and habitats in the surrounding area (i.e., are they common or rare)? What are the potential consequences to these sensitive species and habitats from the proposed aquaculture activity?*

- No species listed under SARA or ESS have been reported at either of the proposed sites. The South Coast EBSA, or another adjacent EBSA, do not overlap with any portion of the benthic or pelagic-PEZs or the lease areas for either site.

- Sessile or sedentary benthic taxa are expected to be vulnerable to aquaculture wastes, since they cannot relocate to another environment when under stress.
- Geodiidae sponges and the Northern Cerianthid anemone, both VME indicators, were identified in the proposed Collins Head lease area, although these taxonomic identifications are uncertain.
- There currently is limited to no data on recovery rates of sensitive species identified in the 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.

Terms of Reference 3: *To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic Species at Risk (SAR) listed under Schedule 1 of SARA make use of the area, and for what duration and when?*

- The general area overlaps the distribution of several species of whales, including SARA-listed species (Blue Whale, North Atlantic Right Whale, and Fin Whale). Seasonally, the distribution of marine mammals is highest in nearshore NL waters from spring to autumn. While entanglement and subsequent drowning are major concerns for marine mammal species, such as baleen whales, the risk of entanglement is considered low at the proposed sites.
- Pinniped species such as Harbour Seals and Grey Seals may be at risk of entanglement because potential prey may attract them to the cage netting. Along the south coast of NL, Harbour Seals occur year round whereas Grey Seals are seasonal visitors that arrive in late spring and depart in late fall. In NL, no pinniped entanglements with finfish aquaculture infrastructure have been reported to date.
- 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 presents the potential for entanglements of sharks and tuna.
- While there have been no reports of entanglement of listed SAR in finfish aquaculture gear in the DFO NL Region, aquaculture infrastructure increases the potential for entanglement for some listed SAR.

Terms of Reference 4: *Which populations of conspecifics are within a geographic range where escaped farmed fish are likely to migrate into? What are the size and status trends of those conspecific 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?*

- There are no established populations of Rainbow Trout on the South coast of NL.
- There is no evidence of direct genetic interactions between Rainbow Trout and Atlantic Salmon.
- Ecological interactions between introduced Rainbow Trout and wild Atlantic Salmon can lead to indirect genetic effects, which could reduce Atlantic Salmon population size; thereby, reducing their genetic diversity and making them more vulnerable under future change.
- Rainbow Trout escapees would primarily be expected to disperse to rivers within the proposed South NL-West DU and a portion of rivers in the South NL-East DU.

- There will be increased risks to wild Atlantic Salmon with the expansion of finfish aquaculture in Bay d'Espoir, which is especially a concern for populations in South NL-West DU, which continue to decline and already face increased risk due to interactions with Atlantic Salmon escapes.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Jon Carr	Atlantic Salmon Federation
Gregor Reid	Centre for Applied Marine Research (Reviewer)
Dounia Hamoutene	DFO-MAR – Science
Brent Law	DFO-MAR – Science (Reviewer)
Kristian Curran	DFO-NCR – Science
Emily Ryall	DFO-NCR – Science
Brittany Beauchamp	DFO-NCR – Science (Co-chair)
Chris Hendry	DFO-NL – Ecosystems Management
Terry Bungay	DFO-NL – Ecosystems Management
Jennifer Janes	DFO-NL – Ecosystems Management
Hilary Rockwood	DFO-NL – Science
James Meade	DFO-NL – Science
Kristin Loughlin	DFO-NL – Science
Andry Ratsimandresy	DFO-NL – Science
Zhaoshi Lu	DFO-NL – Science
Sarah Lehnert	DFO-NL – Science
Elizabeth Coughlan	DFO-NL – Science
Aaron Adamack	DFO-NL – Science
Lee Sheppard	DFO-NL – Science
Luiz Mello	DFO-NL – Science
Vonda Hayes	DFO-NL – Science
Barbara Neves	DFO-NL – Science
Harry Murray	DFO-NL – Science
Rachelle Dove	DFO-NL – Science
Kimberly Marshall	DFO-NL – Science
Ben Davis	DFO-NL – Science (Co-Chair)
Stephanie Synard-McInnis	NL Department of Fisheries, Forestry and Agriculture
Sheldon George	Nova Farms Incorporated
Melissa Burke	Nova Farms Incorporated

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APPENDIX A

Order of Magnitude of Particle Dispersion

For sinking particles, the time (t_{sink}) is time necessary for a particle to reach the bottom. It is given by

$$t_{sink} = \frac{H}{w_{part}}$$

where H is the maximum depth under the lease, and w_{part} is the sinking rate of the particles, which was assumed to be 5.3 cm/s for feed and 0.3 for feces particles. For non-sinking particles, time is defined as the dilution time to reach EQS. The order of magnitude of displacement of particles as a function of settling/dilution time and ocean current speed is given in Table A1.

Table A1: Order of magnitude of displacement of particles as a function of settling/dilution time and ocean current speed. The PEZ is computed as displacement plus 1/2 the cage array. (~) = approximately; (<) = less than; and (>) greater than.

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

APPENDIX B

Progressive Vector Diagram (PVD) and PEZ Calculation

A progressive vector diagram (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. A PVD is computed as the sum of the individual displacements of a particle associated with each current measurement over a specific time period (Thomson and Emery 2014; Page et al. 2023):

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

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

$$t = \sum \Delta t_i\,,$$

t is the duration of interest (sinking period for benthic calculation and dilution period for pelagic calculation). The current speed, Spd, associated with the displacement is:

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

Figure A1 is an example of PVD for ocean currents at Collins Head at a depth of approximately 36 m for a period of 20.4 h on 12 August 2019:

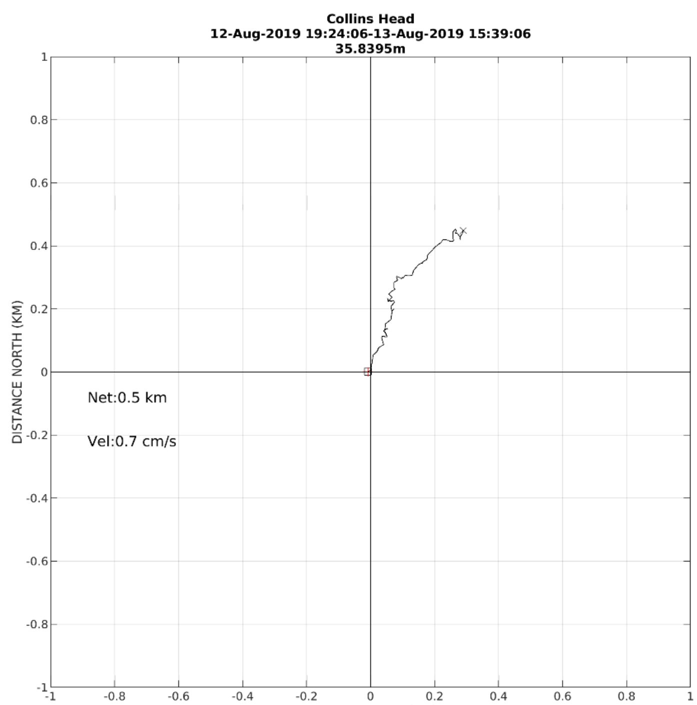

Figure A1: Displacement of a particle at approximately 36 m water depth for a period of 20.4 h on August 12–13, 2019, computed using a progressive vector diagram.

Using the timeseries of ocean currents at one depth, rolling subsets of the currents for the period of sinking or period of dilution are extracted for the whole measurement timeline and used to compute PVDs. Median and maximum distances can be computed and converted into associated current speed used in the PEZ calculation. The corresponding median and maximum PVD and associated current speeds are computed for each depth using the Acoustic Doppler Current Profilers (ADCP) measurements of currents at various depths.

For the benthic-PEZ, the maximum displacement and the associated current speed are computed for each depth measurement between the bottom of the net cage 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. The median PEZ illustrates the central tendency of the PEZ when examining all the displacements of the particles released from the site for the period of sinking or period of dilution.

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Center for Science Advice (CSA)
Newfoundland and Labrador Region
Fisheries and Oceans Canada
80 East White Hills Rd
P.O. Box 5667
St. John's NL A1C 5X1

E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
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