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Canadian Science Advisory Secretariat
Newfoundland and Labrador Region | Science Response 2025/028

SCIENCE REVIEW OF PROPOSED INCREASES IN BIOMASS AT MOWI CANADA EAST INC. EXISTING FINFISH AQUACULTURE SITES

CONTEXT

The Proponent, MOWI Canada East Incorporated, has submitted a request to the Province of Newfoundland and Labrador to increase stocking capacity from three million to six million fish at three previously licensed aquaculture sites in Facheux Bay (Wild Cove, Dennis Arm, and Wallace Cove) on the south coast of Newfoundland. This increase from one million to two million fish at each site will not require any modification to the lease boundaries. Fisheries and Oceans Canada (DFO) conducted reviews of site license applications for these sites in 2018 (Wallace Cove) and 2019 (Wild Cove and Dennis Arm) and therefore some science advice is already available and does not need to be re-evaluated. The scope of the current review will focus primarily on aspects specific to the increases in biomass being requested.

To help inform the DFO review of this request, the Regional Aquaculture Management Office (RAMO) has asked for DFO Science advice on the potential exposure zones (PEZs) associated with certain aquaculture activities and the potential impacts on susceptible fish and fish habitat.

Specifically, DFO Science has been asked the following questions in the context of increasing stocking capacity at three licensed sites:

- Based on the available data for Wallace Cove and the scientific information, what are the potential exposure zones from the use of approved fish health treatment products in the marine environment, and the potential consequences to susceptible species?
- Based on available information for Wallace Cove, what are the Sensitive Benthic Species, and their associated habitats that are within the potential benthic exposure zones and vulnerable to exposure from the deposition of organic matter? How does this distribution compare to the extent of these species and habitats in the surrounding area (i.e., are they common or rare)? What are the anticipated impacts to these sensitive species and habitats from the proposed aquaculture activity(ies)?
- What are the potential impacts and/or risks to Atlantic Salmon populations from direct genetic interactions associated with any escaped farmed fish from the proposed increase in biomass at all three sites?

This Science Response Report results from the regional peer review held January 15–16, 2025, on the Proposed Increase in Biomass at MOWI Canada East Inc. Existing Finfish Aquaculture Sites in Facheux Bay.

BACKGROUND

The Proponent has submitted a request to the Province of Newfoundland and Labrador (NL) to increase stocking capacity from three million to six million fish at three previously licensed aquaculture sites (Wild Cove, Dennis Arm, and Wallace Cove) on the south coast of

Newfoundland. All three sites are located in Facheux Bay (Figure 1). Another site within this bay (Indian Tea Point) is also licensed to the Proponent but will not be developed and there are no additional sites or operators within this Bay.

DFO 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 exposure zones, and the potential for physical and genetic interactions with wild species at the sites. In 2019, DFO conducted site license reviews of the Wild Cove and Dennis Arm sites using this guidance and consequently, the advice from that process will be used for this current request. The 2018 review conducted for the Wallace Cove site was completed prior to the development of this guidance and therefore a comprehensive review of this site is required.

General Description of the Sites

The Wild Cove site is located approximately 9.3 km north northwest of the town of McCallum, 33.3 km north northwest of the town of Hermitage, and 35.7 km northwest of the town of Gaultois (all distances by waterway). The site lease is located 1.5 km north of the mouth of Facheux Bay, and is approximately 2,400 m long by 2,300 m wide at the widest point. The proposed cage grid will consist of 160 m (circumference) circular cages in a 2x7 layout.

The Dennis Arm site is located approximately 12.8 km northwest of the town of McCallum, 36.8 km north northwest of the town of Hermitage, and 39.2 km northwest of the town of Gaultois (all distances by waterway). This site is located adjacent to Dennis Arm, approximately 1.7 km north of the Wild Cove aquaculture site and 2 km south of the Wallace Cove site. The lease is approximately 2,350 m long by 1,500 m wide at the widest point and the proposed cage grid will consist of 160 m circular cages in a 2x7 layout.

The Wallace Cove site is located approximately 24.4 km north northwest of the town of McCallum, 42.4 km north northwest of the town of Hermitage, and 43.6 km northwest of the town of Gaultois (all distances by waterway). The site lease is located 9.3 km north of the mouth of Facheux Bay, in Wallace Cove, and is approximately 1,200 m long by 1,100 m wide. The proposed cage grid will consist of 160 m circular cages in a 2x7 layout.

Previous Reviews of the Sites

The objective of the 2018 Science Response Process for the review of the Wallace Cove site was to determine whether the output of the depositional model (DEPOMOD) used by the Proponent was supported by the current relevant scientific knowledge of local oceanographic conditions and the nature of substances that could be released at the site (DFO 2019). This review concluded that the DEPOMOD simulation results appeared to be reasonable based on the input information used to run the model. However, it was stated that the report would benefit from additional explanation of the selection of the model inputs and assumptions.

In 2019, a review was conducted for 13 proposed aquaculture sites along the south coast of Newfoundland, including the Wild Cove and Dennis Arm sites in Facheux Bay (DFO 2022a). This review examined PEZs and potential effects on benthic and pelagic commercial fishery species. However, the calculation of PEZ for the 2019 process did not include the selection of a time series of current velocities throughout the water column, or the use of a toxicity threshold for pesticides, which is the method used currently, and described in detail below. Species listed under Schedule 1 of the Species at Risk Act (SARA), ecologically significant species (ESS), and Ecologically and Biologically Significant Areas (EBSA) were also examined as part of the 2019 review. It also assessed the potential for entanglements of large pelagic fish, marine mammals, and sea turtles in aquaculture infrastructure, and the potential impacts to wild salmon

populations from direct genetic interactions associated with any escaped farmed fish from the proposed aquaculture sites.

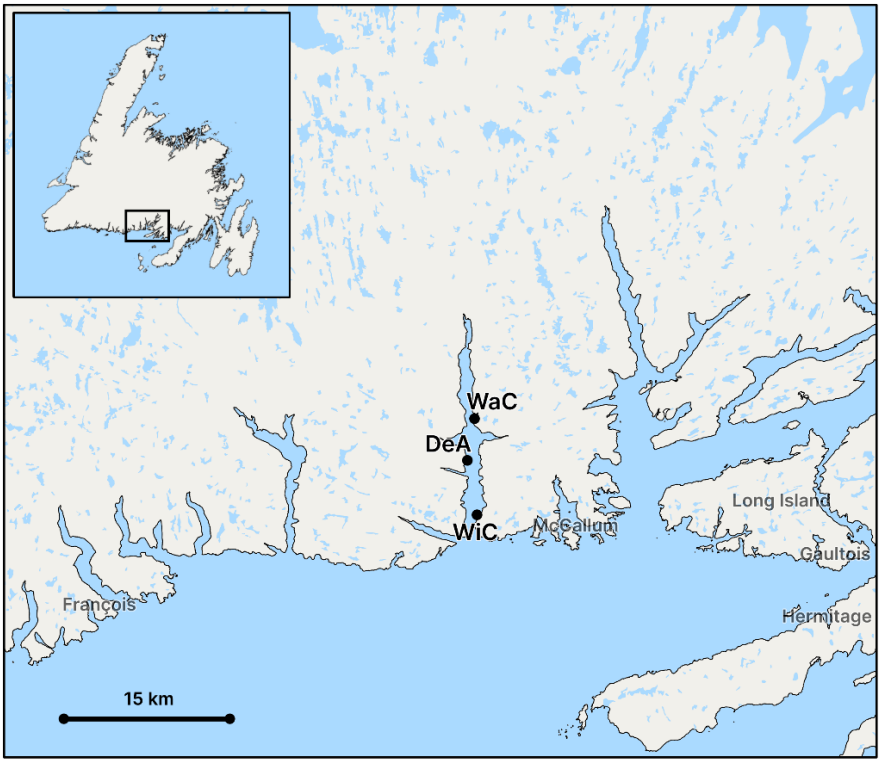

Figure 1: Location of the aquaculture sites in Facheux Bay, NL: Wild Cove (WiC); Dennis Arm (DeA); and Wallace Cove (WaC).

For the 2019 review (DFO 2022a), DFO Science conducted a search of the literature and DFO regional data on a large number of species and habitats, including marine mammals and sea turtles, groundfish, pelagic fish species, shellfish, and other invertebrates to determine if other, more site-specific information was available to complement the information provided by the Proponent. The regional data were of low spatial and temporal resolution and were too sparse to provide a robust indication of seasonality and spatial distribution of the species and habitats in the area. While there were no identified marine Critical Habitats within the PEZs, there is habitat suitable for numerous species.

The general area includes habitat for several groundfish species, including, but not limited to Atlantic Cod (*Gadus morhua)*, Witch Flounder (*Glyptocephalus cynoglossus*), Greenland Halibut (*Reinhardtius hippogloissoides*), and American Plaice (*Hippoglossoides platessoides*). The DFO spring multispecies survey is typically used to describe the distribution and abundance of groundfish in the Newfoundland region, including the south coast; however, the survey does not extend into the inshore bays, including Facheux Bay. There is no available information on the movement of groundfish species within the bay and thus the interaction between groundfish and the proposed sites is unknown.

Atlantic Herring (*Clupea harengus*) is an important forage species in this region due to its broad inshore distribution; however, it was noted that any loss of habitat or reductions in stock productivity due to the presence of the aquaculture sites was expected to be small. Given the proposed positioning of the aquaculture pens, it is likely herring will move past or interact with the cages. The potential transmission of disease between Atlantic Salmon (*Salmo salar*) and herring was identified as a concern. The Infectious Salmon Anemia Virus (ISAV) can be carried by Atlantic Herring (Nylund et al. 2002) and the presence of Viral Haemorrhagic Septicaemia Virus strain IVa (VHSV IVa) has been confirmed in wild herring harvested in Newfoundland waters (CFIA 2016). Capelin *(Mallotus villosus)* make limited use of the region and there is limited commercial fishing along the south coast. Given the limited vertical overlap between the depth of the aquaculture cages and the depth of peak Capelin biomass, the limited portion of Capelin habitat involved, and limited Capelin spawning in the area, the potential risk from incidental predation associated with the proposed aquaculture sites was considered low.

Atlantic Salmon populations on the south coast of Newfoundland (Salmon Fishing Areas [SFAs] 9–12) remain a concern for DFO Science; data indicate that salmon populations are declining and returns are at a historical low (DFO 2023a). Both modeling and the results from empirical studies were used to predict the impact on Atlantic Salmon populations from the development of the proposed sites. Genetic change and demographic decline were predicted as a result of the proposed expansion, as the number of escapees increases proportionally, with impacts predicted to be highest in the rivers of the Bay d'Espoir area.

Habitats and substrates identified in the general area (i.e., bedrock, boulder, kelp) are known as suitable habitat for American Lobster (*Homarus americanus*). In Newfoundland, lobster commonly frequent shallow depths (within 20 m) in the spring and summer months and move into deeper waters in the fall. The potential risk of deposition (i.e., feces or feed) from the proposed sites affecting the intertidal zone (where lobster at various life stages could possibly be found) is considered low. However, it was noted that there is a potential risk of pesticides affecting lobster at various life stages (Burridge 2013, Burridge et al. 1999, 2000a, b, 2004, Burridge et al. 2008, 2014, Pahl and Optiz 1999).

The general area overlaps the distribution of several species of whales, including SARA-listed species (Blue Whale [*Balaenoptera musculus*], Fin Whale [*Balaenoptera physalus*], and North Atlantic Right Whale [*Eubalaena glacialis*]). Seasonally, the distribution of marine mammals is highest in nearshore Newfoundland waters from spring to autumn. While entanglement and subsequent drowning are major concerns for marine mammal species, such as baleen whales (which do not echolocate and thus may not detect aquaculture infrastructure), the risk of entanglement was considered low at the proposed sites.

Pinniped species such as Harbour Seals (*Phoca vitulina*) and Grey Seals (*Halichoerus grypus*) may be at risk for entanglement because potential prey may attract them to the cage netting (DFO 2022a). Along the south coast of Newfoundland, Harbour Seals occur year round whereas Grey Seals are seasonal visitors that arrive in late spring and depart in late fall. Leatherback Sea Turtles (*Dermochelys coriacea*) and large pelagic fish species (sharks and tunas) occur in the area, particularly from spring to autumn. An increasing presence of large pelagic species in recent years suggests the potential for entanglements of sharks and tuna. To date, there have been no reports of entanglements of pinnipeds, sea turtles, or large pelagics with finfish aquaculture infrastructure in NL.

Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*Anarhichas minor*), Atlantic Wolffish (*Anarhichas lupus*), and White Shark (*Carcharodon carcharias*) 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 surveys.

The 2019 review (DFO 2022a) revealed that sea pens, which provide nursery habitat for juvenile fish (Baillon et al. 2012), were reported within the lease areas of six sites, including at Wild Cove in Facheux Bay. Sea pens can live for decades (Neves et al. 2015; Murillo et al. 2018) and are indicators of Vulnerable Marine Ecosystems (VME) and known to be nurseries for redfish (*Sebastes spp.)* larvae, and host eggs or larvae of lantern fish (*Benthosema glaciale*) and eelpout (*Lycodes esmarkii*) (Baillon et al. 2012). Little information is available on the tolerance of sea pens to biochemical oxygen demanding (BOD) organic matter, their sensitivity to hypoxia and anoxia, and vulnerability to diseases, parasites, and pathogens. In terms of ESS, eelgrass was not reported at either of the sites.

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. These are areas where regulators and marine users should practice risk aversion to maintain healthy and productive ecosystems (Government of Canada 2023). The NL Region has identified 29 EBSAs (Wells et al. 2017, 2019). The South Coast EBSA (Figure 2) is located to the west of Facheux Bay and does not overlap with the lease areas for either of the sites.

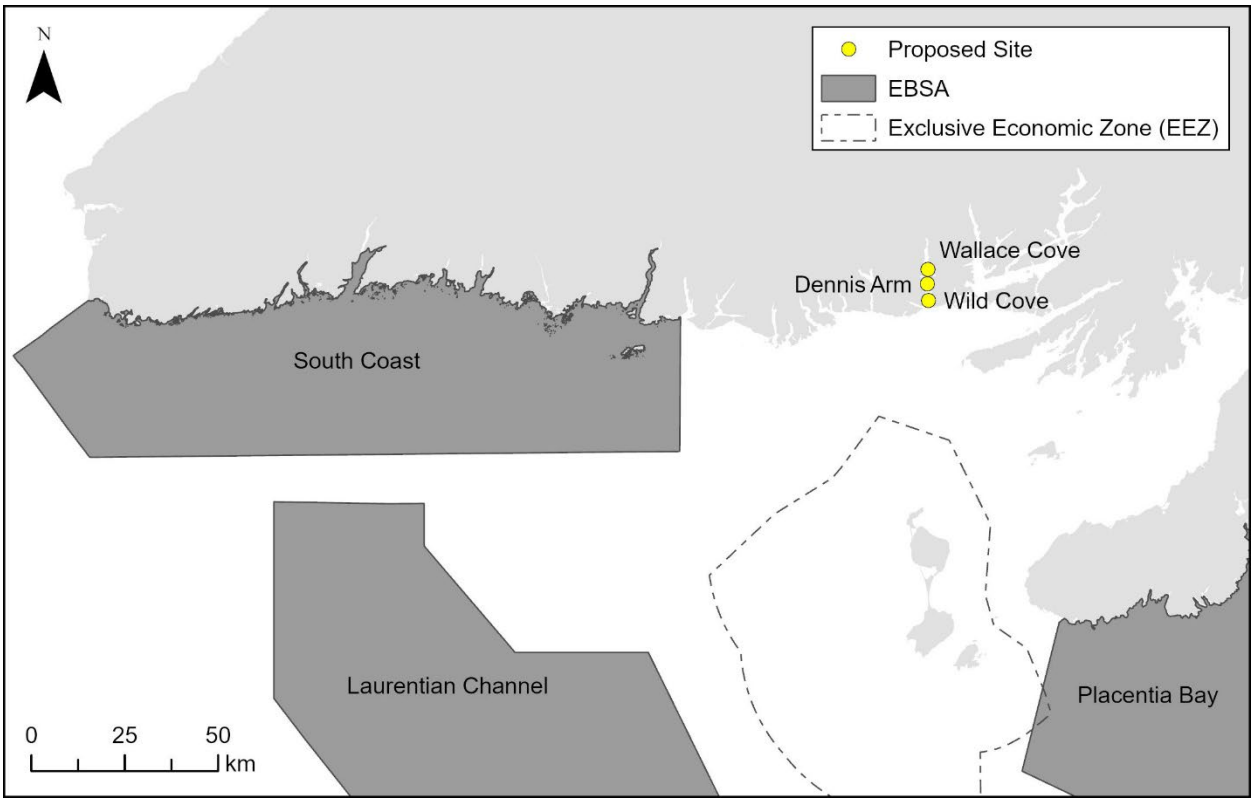

Figure 2: Map showing locations of the South Coast EBSA and the licensed aquaculture sites at Wild Cove, Dennis Arm and Wallace Cove in Facheux Bay, NL.

The Facheux Bay Proposed Ecological Reserve is an area identified by the NL government for protection under the *Wilderness Ecological Reserves Act*. The objective of protected areas is to conserve the biodiversity of the province and maintain cultural, spiritual, and recreational connections to the land, as well as to fulfil Canadian and global protected area targets.

ANALYSIS AND RESPONSE

Sources of Data

Information to support this analysis includes data and information provided by the Proponent, holdings within DFO, publicly available literature, and registry information from the SARA database. The DFO multispecies survey database was referenced to supplement commercial fisheries information provided in the Proponent's submissions.

Oceanographic Conditions

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

Bathymetry

The sites occupy the long, narrow, and deep fjord of Facheux Bay. The fjord has steep walls and several sills, and is open to the ocean in the south. The deep part of the mouth of the fjord is separated from the shelf by a ~100-m depth sill (Figure 3) as shown from the transect of bathymetry extracted from Canadian Hydrographic Service Non-Navigational (CHS NONNA) database (CHS NONNA 2024). The water depth below the site lease areas ranges from 1–390 m (Table 1) with bottom sediments consisting of mixed substrates. The differences between the bathymetry measured by the Proponent and the CHS data suggest the need for an update of CHS measurements for this fjord. The sites were classified as having mostly hard substrates with some mixed substrates.

Currents

Water currents are a critical input to estimations of the zone of exposure associated with the release of BOD organic matter, pesticides, and drugs from any farm site. The Proponent followed the requirements of the Aquaculture Activities Regulations (AAR) by providing a map of modelled footprint of deposition, and they also provided water current data over a period of 31 to 51 days for the 2017 data and 101 days for the near-surface 2022–23 data (Wild Cove). The water currents were measured by Acoustic Doppler Current Profilers (ADCPs) which were deployed at a single location and configured to measure ensemble average horizontal currents at 15-minute intervals (Table 1). Note that profiles of ocean currents below ~200 m were not available for all three sites and Dennis Arm did not have current data between ~41 and 120 m.

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

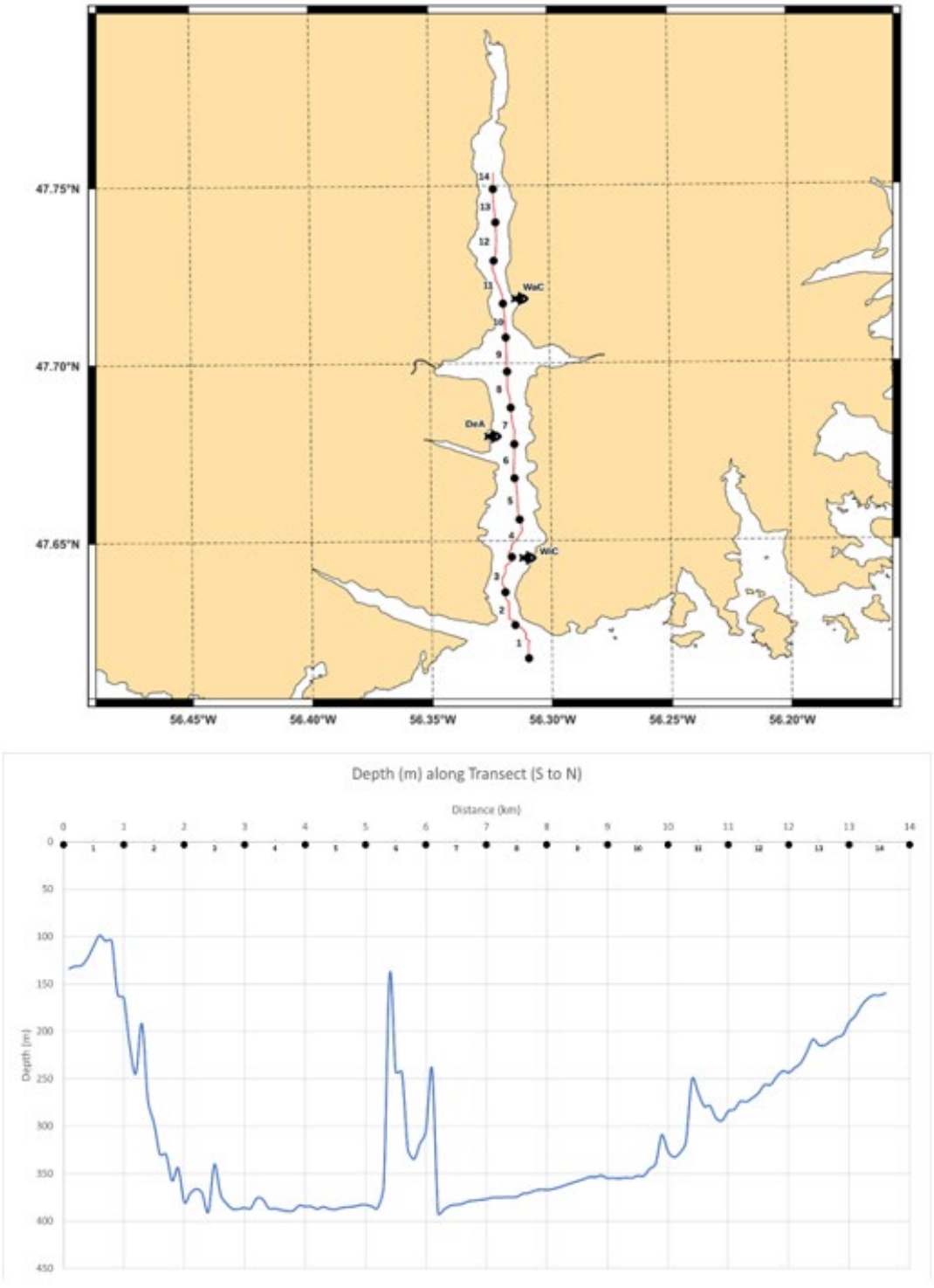

Figure 3: Bathymetry measurements within Facheux Bay. Top: location of the transects where depth values were extracted; bottom: depth measurements along the transect. Bathymetry information was extracted from Canadian Hydrographic Service Non-Navigational database (CHS NONNA 2024).

Table 1: Key oceanographic, farm infrastructure and grow-out information for the sites. All information was extracted from the reports provided by the Proponent for the site licence applications. (computed using the 2022 near surface data provided by the Proponent).*

Characteristic	Wallace Cove	Dennis Arm	Wild Cove
Dimension [m]	1,200 x 1,100	2,350 x 1,500	2,400 x 2,300
Area [ha]	84.64	281.78	292.3
Predominant substrate type	Hard bottom	Hard bottom	Hard bottom
Net-pen array configuration	2 x 7	2 x 7	2 x 7
Individual net-pen circumference/depth [m]	160 / 40	160 / 40	160 / 40
Net-pen volume [m^3]	1,141,400	1,141,400	1,141,400
Depth under the lease area [m]	1–370	1–380	1–390
Depth under the cage array [m]	310–350	57–380	150–250
Current measurement period	16-Aug-2017 to 15-Sep-2017	9-Oct-2017 to 28-Nov-2017	16-Nov-2022 to 24-Feb-2023 (near surface) 16-Aug-2017 to 15-Sep-2017
Depth coverage of current measurements	Near surface - ~185 m No data below 185 m	Near surface - ~37 m ~117–241 m	Near surface – 22 m ~10–242 m

Characteristic	Wallace Cove			Dennis Arm			Wild Cove		
	Near Bottom (7 m above bottom)			No data below 241 m 375 m (5 m above bottom)			No data below 242 m 385 m (5 m above bottom)		
	Depth [m]	*Speed [cm/s]*		*Depth [m]*	*Speed [cm/s]*		*Depth [m]*	*Speed [cm/s]*	
		Mean	*Max*		*Mean*	*Max*		*Mean*	*Max*
	5.7			*6.7*	*8.6*	*50.3*	*6*	*3*	*55.2*
	9.7	*9.6*	*44.6*	*10.7*	*7.1*	*37.8*	*10**	*1.4**	*47.1**
	15.7	*7.6*	*40.1*	*14.7*	*6.6*	*39.8*	*13.3**	*~8. **	*44.5**
	119	*3.3*	*13.8*	*189.3*	*2.0*	*11.0*	*194*	*1.7*	*11.5*
Current speed [cm/s]	*338*	*3.5*	*12.2*	*375*	*~1.*	*3.9*	*385*	*2.0*	*5.6*
Current measurement type	*current profiler*			*current profiler*			*current profiler*		
Grow-out period [month]	28			28			28		
Maximum number of fish on site	2,000,000			2,000,000			2,000,000		
Initial stocking number [fish/pen]	142,857			142,857			142,857		
Initial stocking weight [kg]	0.250			0.250			0.250		

Characteristic	Wallace Cove	Dennis Arm	Wild Cove
Average planned harvest weight [kg]	5.95	5.95	5.95
Expected maximum biomass [kg]	11,305,000	11,305,000	11,305,000
Maximum stocking density [kg/m^3]	15	15	15

Potential Exposure Zones (PEZs)

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 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 (OPC), as well as flocculent matter on hard-bottom habitats. Under the AAR, the aquaculture industry is required to conduct seabed monitoring of finfish aquaculture sites to determine the impact of the deposition of the BOD matter (sediments for soft-bottom or visual for hard-bottom). The AAR have set regulatory thresholds (e.g., in soft-bottom sites, a maximum concentration of 3,000 µm of free sulfide; or in hard-bottom sites, a higher than 70% prevalence of the visual indicator species) that prohibit restocking of the site until further monitoring shows a return to levels below the compliance threshold.

Fish health treatment products may 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) and non-chemical strategies such as physical, biological, site management, and husbandry approaches. 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*, and are regulated by the Pest Management Regulatory Agency (PMRA) and Health Canada Veterinary Drugs Directorate. These products are only used under the authority and supervision of a registered veterinarian. The veterinarians consider a variety of site-specific information, including fish behaviour, environmental conditions, site records, and information from monthly site visits and from an ongoing dialogue with site managers, to determine the appropriate prescription for maintaining the health of farmed fish. The potential therapeutants to be used will be based on the list of approved compounds (Inspection Canada 2024). Further information on prescription and administration procedures of drugs and pesticides in Canada can be found in Beattie and Bridger (2023).

Under the AAR, the Proponent is required to report on the usage of drugs and pesticides at each marine finfish cage on an annual basis. The collection of this information by the Aquaculture Integrated Information System (AQUIIS) commenced in 2015 and the first full year of data collection was 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.

The estimation of a 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 finfish aquaculture sites (Page et al. 2023a). The PEZ-approach has been used in previous DFO finfish aquaculture site assessments in the NL Region (DFO 2022a, b, c, DFO 2024c) as a screening tool to determine the areas within which marine species and habitats may be exposed to open net-pen finfish aquaculture activities. The first use of PEZ was for the assessment of proposed finfish aquaculture sites in Newfoundland in 2019 (DFO 2022a, Page et al. 2023a). Since that first assessment, the PEZ calculations have evolved due to changes in assumptions regarding dilution times of pesticides and the necessity to consider spatial variation of currents. Consequently, for the current process, the PEZs for Wallace Cove

were calculated using the most recent method, and to provide appropriate comparisons, the PEZs for the other sites were also re-calculated and updated using the same method.

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 one particle released from the site can 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) (DFO 2024c, Page et al. 2023a):

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

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 sinking rate. The order of magnitude of the particle dispersion depending on the sinking/dilution period and the current velocity is provided in Appendix B.

It is important to note that PEZ does not predict intensity of exposure, duration of exposure, nor impact of exposure of marine habitats or species that fall within the area; rather it is an initial step in identifying potential areas of 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 can be pursued to further explore the degree and nature of potential impacts, and/or mitigation measures that may need to be considered, as requested by managers, users, and decision makers.

Benthic Potential Exposure Zones (Benthic-PEZ)

The benthic-PEZ estimates the size and location of the benthic area potentially exposed to the deposition of waste feed and feces released from a site, which can result in organic loading. There are two kinds of benthic-PEZ. The zone potentially exposed to the deposition of medicated waste feed is known as the waste feed-PEZ, and the zone potentially exposed to the deposition of feces is the fecal-PEZ. The benthos may also be exposed to pesticides released into the water, particularly at shallow depths; however, this issue is addressed through the calculation of the pelagic potential exposure zone (pelagic-PEZ), detailed below. Dominant factors that affect benthic-PEZ are farm layout, feeding practices, sinking rates of the particles, and oceanographic conditions (i.e., bathymetry and water currents).

The benthic-PEZ calculation takes as conservative an approach as possible while retaining simplicity. It is calculated by first 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. This calculation gives an area where one can determine whether or not there are species or habitats of concern that warrant further refinement (i.e., more comprehensive study of the spatial extent, intensity and/or duration of anticipated interaction). The simplifying assumptions for the model include: constant settling velocity of the particles, constant ocean current speed during particle descent, constant depth (i.e., flat bathymetry), and no resuspension mechanism. To make the approach conservative, the parameters used are slow sinking velocities (the minimum sinking rate obtained from the literature), fast water currents, and deep bottom topography (the maximum depth over the lease area). Due to the presence of a 100-m depth sill near the mouth of the fjord (Figure 3), this depth is used for the calculation of benthic-PEZ for the site closest to the mouth. Current speed is obtained by analyzing the maximum distance computed from progressive vector diagram (PVD) based on the time series of current velocities at each depth over the period of sinking of particles and then averaged for the whole sinking depth (see Appendix A for an explanation of PVD and the calculation of PEZ). The sinking rates for different particulate materials released from farmed fish (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. The rates were obtained from previously reported values (Bannister et al. 2016, Chen et al. 1999, 2003, Cromey et al. 2002, Findlay and Watling 1994, Law et al. 2014, Skøien et al. 2016, Sutherland et al. 2006). The parameters used to compute the PEZ are provided in Table 2.

Table 2: Parameters used to compute sinking period and PEZ (displacement + array length scale). (Note: a ~100-m depth sill is present near the mouth of Facheux Bay and is used for the calculation of PEZ at Wild Cove).*

Feed particle sinking rate [cm/s]	**Feces particle sinking rate [cm/s]**	**Cage array length [m]**	**Maximum depth under the lease or used for the calculation [m]**		
5.3	0.3	450	Wallace Cove	Dennis Arm	Wild Cove
			370	380	390 (100*)

Table 3 provides the selected minimum sinking rate for each particle category and the corresponding maximum current speed as well as the first order estimates of the spatial extent of the benthic-PEZ related to organic effluent and in-feed drugs from the sites.

The benthic-PEZ is represented by a circular zone centered in the middle of the proposed cage array and limited by the shoreline. It represents the inferred outer limit for potential exposure. The spatial extent of exposure of the benthic-PEZ associated with feed and feces particles is illustrated in Figure 4. The benthic-PEZ associated with the feed (waste feed-PEZ) is of the same length scale as the lease area, of the order of one kilometer. Overlap between sites is not expected for the benthic-PEZ associated with feed particles at the sites.

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 fish farms (settling rates correspond to the slowest rate obtained from literature to ensure conservative result). PEZs were computed using current speeds above ~185 m for Wallace Cove, and above ~240 m for the other two sites.
**Note: PEZ for Wild Cove was computed considering the presence of a ~100 m depth sill near the mouth of the fjord.*

Particle type	Min. sinking rate [cm/s]	Sinking period [h]	Current speed during sinking period [cm/s]	PEZ radius [km]
Wallace Cove (370 m)				
Feed	5.3	1.9	11.7	1.0*
Feces	0.3	34.3	2.8	3.7*
Dennis Arm (380 m)				
Feed	5.3	2.0	8.1	0.8
Feces	0.3	35.2	2.5	3.3
Wild Cove (390 m with a 100 m sill near the mouth)				
Feed	5.3	2.0	11.5	1.1
Feces	0.3	7.4	11.7	4.1*

The benthic-PEZ does not provide an estimate of the intensity of organic loading within the site, and the zones do not imply the same potential exposure everywhere within the zone. The intensity of exposure is expected to be highest near the net-pen arrays, decreasing with distance away. The waste feed-PEZ is anticipated to have the greatest intensity of exposure at positions closer to the net-pens.

Calculation of the fecal-PEZ is carried out with the same method but using the period of sinking for fecal particles (Table 3). 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 4. These benthic-PEZs, when combined, cover most of the channel outside of the lease, where the sites are located, and into the shelf outside of the fjord. The size of the PEZ is of the order of several kilometers. Note that the benthic-PEZ south of Wild Cove is affected by the presence of a 100-m depth sill near the mouth of the fjord.

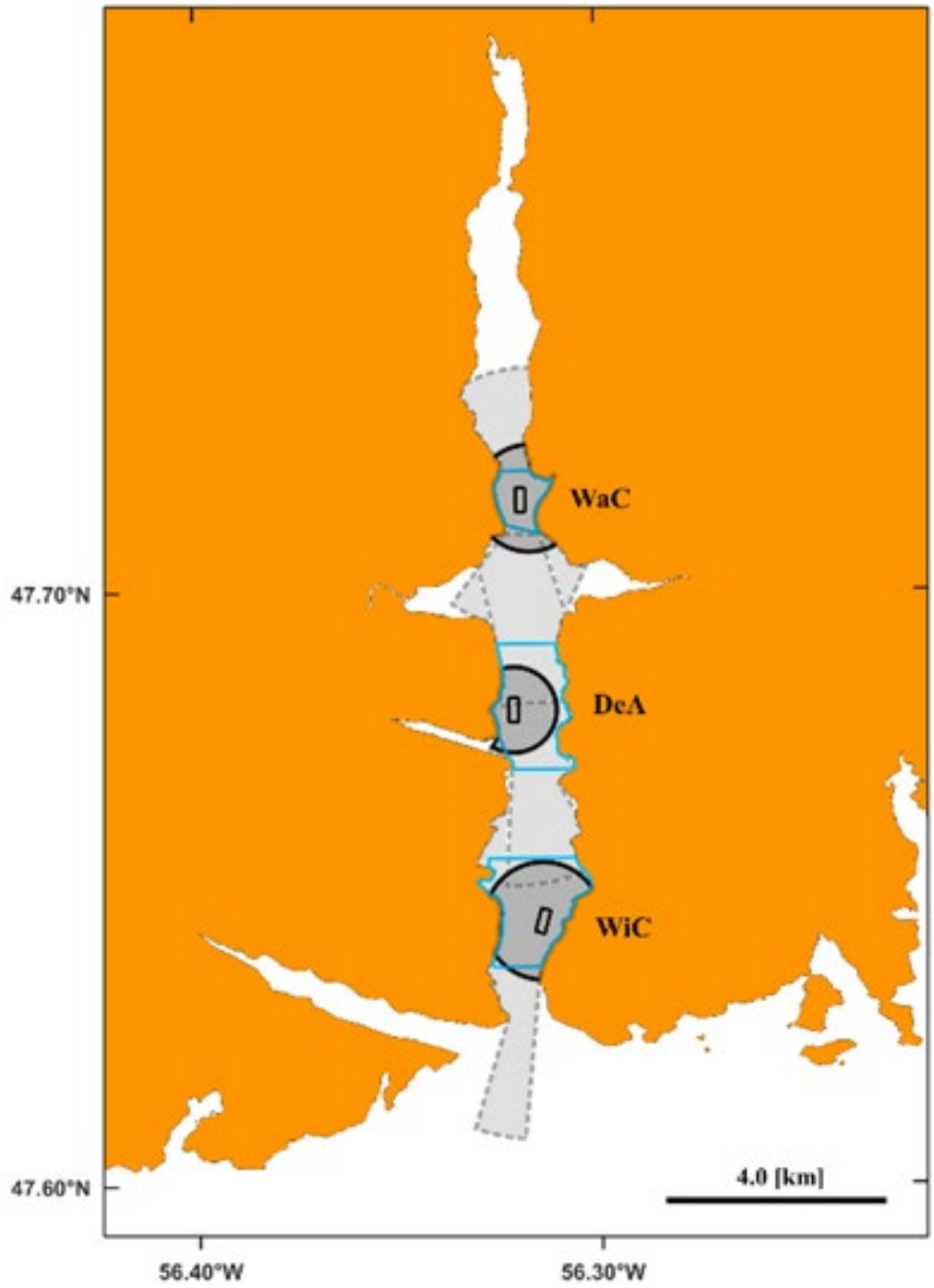

Figure 4: Benthic-PEZ associated with feed (dark grey area delimited by black circle) and with feces (light grey area) particles for the sites. Black rectangles represent the cage areas and blue polygons the lease area for each site (Wild Cove: WiC, Dennis Arm: DeA, and Wallace Cove: WaC).

Note that very fine particles are not considered in the analysis. These particles have been reported to be present around aquaculture sites (e.g., Law et al. 2014) and have very low sinking rates (~0.0001 m/s) thus are expected to disperse at larger distance from the aquaculture site.

Some important points to consider when interpreting PEZ results:

- PEZ analysis provides estimates only, which are sensitive to data input. It is a spatial scoping tool to identify potentially sensitive marine features. The results should be interpreted as an order of magnitude of the distance a particle released from the aquaculture farm might reach, acknowledging the complex flow field within the bay and offshore and that current measurement at a single location is an insufficient representation of the full flow field in the area.
- These first-order estimates of area of exposure do not consider current- and wave-induced bottom resuspension. However, assuming the deepest ocean current speeds, as provided by the Proponent, also apply to near-bottom conditions, ocean currents with speed over 9.5 cm/s (the critical value for resuspension for the deposition model DEPOMOD, Chamberlain and Stucchi 2007) were observed at Wallace Cove, suggesting potential for sediment resuspension. The overall impacts of redistribution and flocculant deposition are unknown.

Spatial Extent of Drug Exposure

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

In-feed therapeutants

The main concern associated with the use of in-feed antibiotics is the potential development of antimicrobial resistance (AMR), a process whereby bacteria become insensitive to one or multiple antibiotics over time (Baquero et al. 2008). Many uncertainties still exist with respect to these indirect impacts of antibiotics on marine organisms; however, direct toxicity to marine organisms 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. However, it is important 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 (EMB) 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). Most of the concerns resulting from exposure are related to adverse effects on bottom-dwelling organisms, particularly due to the persistence of the avermectin compound EMB in sediment (Benskin et al. 2016, Hamoutene et al. 2023b, Strachan and Kennedy 2021). Avermectins, a series of drugs and pesticides used to treat infections with ectoparasitic copepods, disrupt electrical impulses by binding to invertebrate-specific chloride channels, causing paralysis (e.g., Burridge et al. 2008). The combined effects of feces containing in-feed residues and medicated feed wastage can result in deposits around sites, as evidenced by measurements from Kingsbury et al. (2023). Additionally, unknowns remain regarding the confounding effects of EMB and organic matter deposition on the benthos (Bloodworth et al. 2019).

Exposure to EMB has been documented to have impacts in particular on crustaceans (e.g., Burridge et al. 2008, Daoud et al. 2018, Hamoutene et al. 2023a, Mill et al. 2021, Waddy et al. 2002). These studies report deleterious effects on lobsters (adults and larvae) as well as shrimp species with less data on crabs (Hamoutene et al. 2023a, Kingsbury et al. 2023). A review of the baseline video observations showed that crustaceans (mostly krill) were observed at 23 of 74 stations, and at 4 of these stations, krill was reported in numbers greater than 20 individuals. The use of EMB (if any) could have the potential of affecting the krill and crab species observed to be present at the Wallace Cove site, as per the mode of action of the compound.

Smothering and Hypoxia

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

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). Although corals were not identified in the Baseline Assessment Report, they were identified from the video (e.g., *Gersemia* sp.), between stations. Sea anemones were also very abundant on rocky substrate (often >20 individuals per station). Although it is stated that these are not located within the boundary of the cage array (Figures 5 and 6), there was no usable video data under the cage array to confirm. Crinoids (feather stars) were one of the most abundant taxa (sometimes >20 individuals per station) and brittle stars were also common at certain stations (Figures 5 and 6). Bryozoans were observed between stations, however they were not reported in the Baseline Assessment Report. Scallops were reported, but not in high abundance, and one bed of blue mussels (*Mytilus edulis*) was reported.

Elevated fluxes 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, and a decrease in sponges (e.g., *Polymastia* spp. and *Phakellia* spp.) and the soft coral *Duva florida* (Dunlop et al. 2021); all taxa observed in the southern coast of Newfoundland. Kutti et al. (2022) showed that corals (*Desmophyllum pertusum*, published as *Lophelia pertusa*) exhibited decreased metabolic rates, reduced growth and reduced energy reserves compared to those outside the main depositional footprint of salmon aquaculture farms in Norway. Because tolerance to different levels of particulate matter can be taxa-specific (Dunlop et al. 2021), these need to be assessed in Newfoundland waters to allow a better understanding of their effects in a regional context.

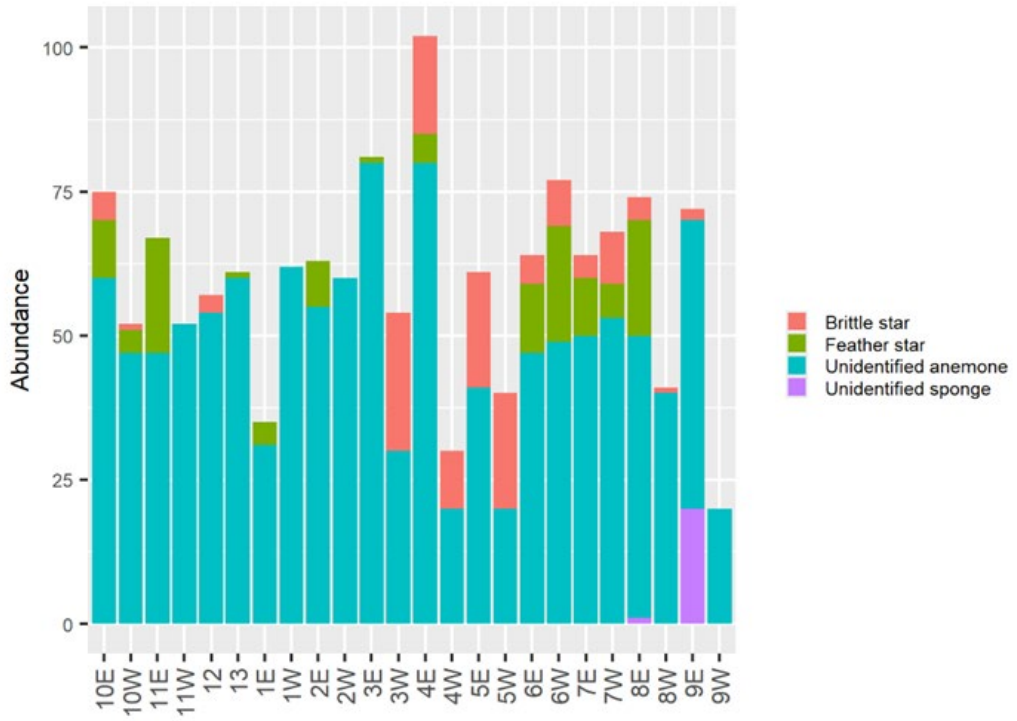

Figure 5: Summary of specimen counts for some taxa reported in the Baseline Assessment Report for Wallace Cove. (Note: these are raw counts and do not consider area).

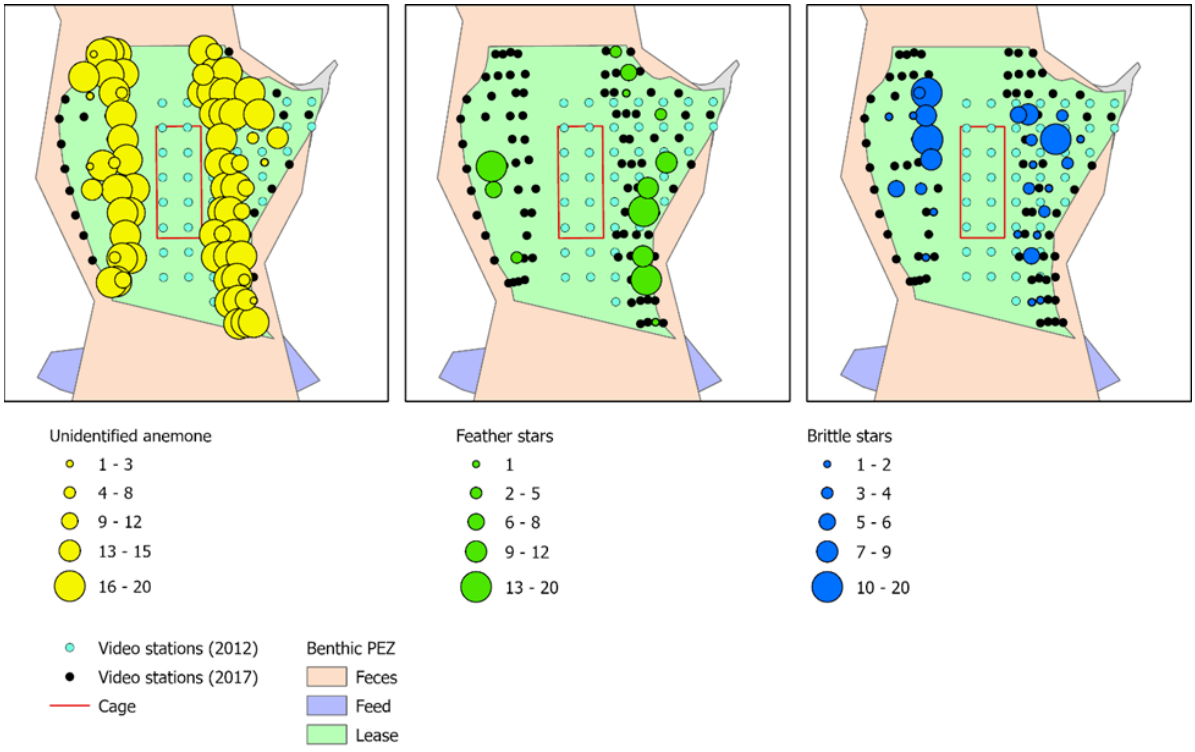

Figure 6: Distribution of three common benthic species based on the 2017 ROV video at Wallace Cove.

Pelagic Potential 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 aquaculture 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 are sensitive to such exposures. 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 the 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 organisms' tissues. The half-lives of the pesticides range from days to weeks, suggesting that they can persist in the environment at toxic concentrations for some time (PMRA 2014, 2016a, 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 moves 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 from a tarp treatment (Page et al. 2015, 2023b).

Hydrogen peroxide and azamethiphos are currently the only approved pesticides for use by the finfish aquaculture industry in Canada and Health Canada provides regulatory guidelines for their use (PMRA 2014, 2016a, b, 2017). Azamethiphos and hydrogen peroxide both yield a low decay rate of the active ingredient compared to the dilution rate. Hence a dilution time scale from a target treatment concentration to an Environmental Quality Standard (EQS) was used to calculate the pelagic-PEZ. The PEZ was calculated using a conservative EQS value that ensures a level of protection of 95% of the species (as per the data available) as inferred using HC5 values (i.e., the hazardous concentration for which 5% of species are affected or potentially affected, TGD 2018). 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 values for both pesticides include assessment factors of 2 and 5 for azamethiphos and hydrogen peroxide, respectively (Hamoutene et al. 2023a). 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. (2023a) inferred an EQS for azamethiphos lower than the previously used value of 1 µg/L, with an updated value of 0.1 µg/L. Furthermore, hydrogen peroxide is not as benign as initially assumed (Bechmann et al. 2019, Escobar-Lux and Samuelsen 2020, Escobar-Lux et al. 2020, Mill et al. 2021) and may remain above suggested threshold concentrations for longer than azamethiphos. The EQS for hydrogen peroxide is 150 µg/L (Hamoutene et al. 2023a). Table 4 gives the values of the main parameters used in the calculation of pelagic-PEZ. Page et al. (2023b) 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) for the above therapeutants, as well as the potential maximum patch depth reached by the plume containing a toxic concentration of pesticide. The time required depends on various parameters including the size of the cages, the depth of the tarp within which treatment is performed, the water depth, and the initial treatment concentration of the therapeutants, as well as the EQS. Considering a treatment depth of 24 m (assuming 60% of the height of the net), the dilution time for azamethiphos is 18.4 h, and that of the hydrogen peroxide is 47.3 h. The half-life in seawater of azamethiphos is 8.9 days and hydrogen peroxide ranges from 7 to 28 days, and depends on multiple chemical (formulation, stabilization) and environmental factors (Burridge and Holmes 2023). For both compounds these dilution times fall within the half-lives as evaluated, whether as active ingredients or formulations. Azamethiphos breaks down by hydrolysis (PMRA 2016b) and hydrogen peroxide degrades to oxygen and water (Haya et al. 2005; Lyons et al. 2014). The maximum patch depth is 49.8 m and 65.2 m, for azamethiphos and hydrogen peroxide, respectively.

Table 4: Values of the main parameters used in the calculation of pelagic-PEZ.

	Azamethiphos	**Hydrogen peroxide**
Treatment depth (~60% of net height) [m]	24	24
Cage circumference [m]	160	160
Treatment concentration [µg/L]	100	1.5×10^6
EQS [µg/L]	0.1	150

Given the 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 obtained as the average of all maximum PVDs (Appendix A) computed within this layer which multiplied by the period of dilution gives the total transport distance. The PEZ is then estimated as the distance plus half the length of the proposed net-pen array. While the intensity of exposure is expected to be highest near the net-pen arrays, and to decrease as the distance from the net-pens increases, the pelagic-PEZ does not quantify the intensity or duration of exposure, nor does it quantify frequency of exposure. The zones do not imply that areas within the pelagic-PEZ have the same exposure risk.

Given the large difference between the decay rate necessary to reach EQS for azamethiphos and hydrogen peroxide (1,000 fold for azamethiphos and 10,000 fold for hydrogen peroxide) and assuming a treatment concentration of 100 µg/L for the former and 1.5×10^6 µg/L (1.5 g/L) for the latter, two different pelagic-PEZs were computed. Table 5 shows the potential distance travelled by particles representing azamethiphos and similarly, Table 6 for hydrogen peroxide, during the respective dilution period. As shown in the tables, the treatment particles can reach a distance of 9–11 km and 10–16 km away from the center of the cage array during the 18.4 and 47.3 hour dilution times of azamethiphos and hydrogen peroxide, respectively. The pelagic-PEZ is illustrated in Figures 7 and 8 for the sites. Most exposure is expected in the pelagic zone; however, because the pelagic-PEZ reaches areas near the shoreline, shallow areas (less than 49.8 m and 65.2 m depth for azamethiphos and hydrogen peroxide, respectively) may also be exposed to toxic pesticide concentrations should the ocean currents move plumes toward the

shore. Note that in a channel with several sites where individual PEZs overlap, the PEZ defined by the most shoreward current data should be used to describe the potential exposure when assessing the offshore-PEZ, as particle movement is subject to ocean currents closest to its location. Because the pelagic-PEZ extends into offshore areas, the different current regime increases uncertainty in the calculation. Figures 7 and 8 show overlap of the PEZs from the different sites, illustrating the additive nature of potentially toxic pesticides should successive treatments occur in the same area within that period. This overlap would result in a longer dilution time from the first treatment, and thus a potentially wider exposure area. Similar to the benthic-PEZ, the interpretation of the pelagic-PEZ results should consider that they provide only an order of magnitude of distance based on the available data input, particularly the current information at one location near the respective site locations.

Table 5: First order pelagic-PEZ estimates associated with the potential horizontal distances travelled by non-sinking particles representing azamethiphos for a dilution period 18.4 h and a maximum patch depth of 49.8 m. PEZs were computed using current information above ~37 m. (outside of the bay, information from Wild Cove should delimit the overall PEZ in the offshore area).*

	Wallace Cove	**Dennis Arm**	**Wild Cove**
Max. current speed during dilution [cm/s]	13.9	16.7	12.2
PEZ radius [km]	9.4	11.3*	8.3*

Table 6: First order pelagic-PEZ estimates associated with the potential horizontal distances travelled by non-sinking particles representing hydrogen peroxide for a dilution period of 47.3 h and a maximum patch depth of 65.2 m. PEZs were computed using current information above ~41 m. (outside of the bay, information from Wild Cove should delimit the overall PEZ in the offshore area).*

	Wallace Cove	**Dennis Arm**	**Wild Cove**
Max. current speed during dilution [cm/s]	5.7	9.6	7.4
PEZ radius [km]	9.9	16.5	12.8*

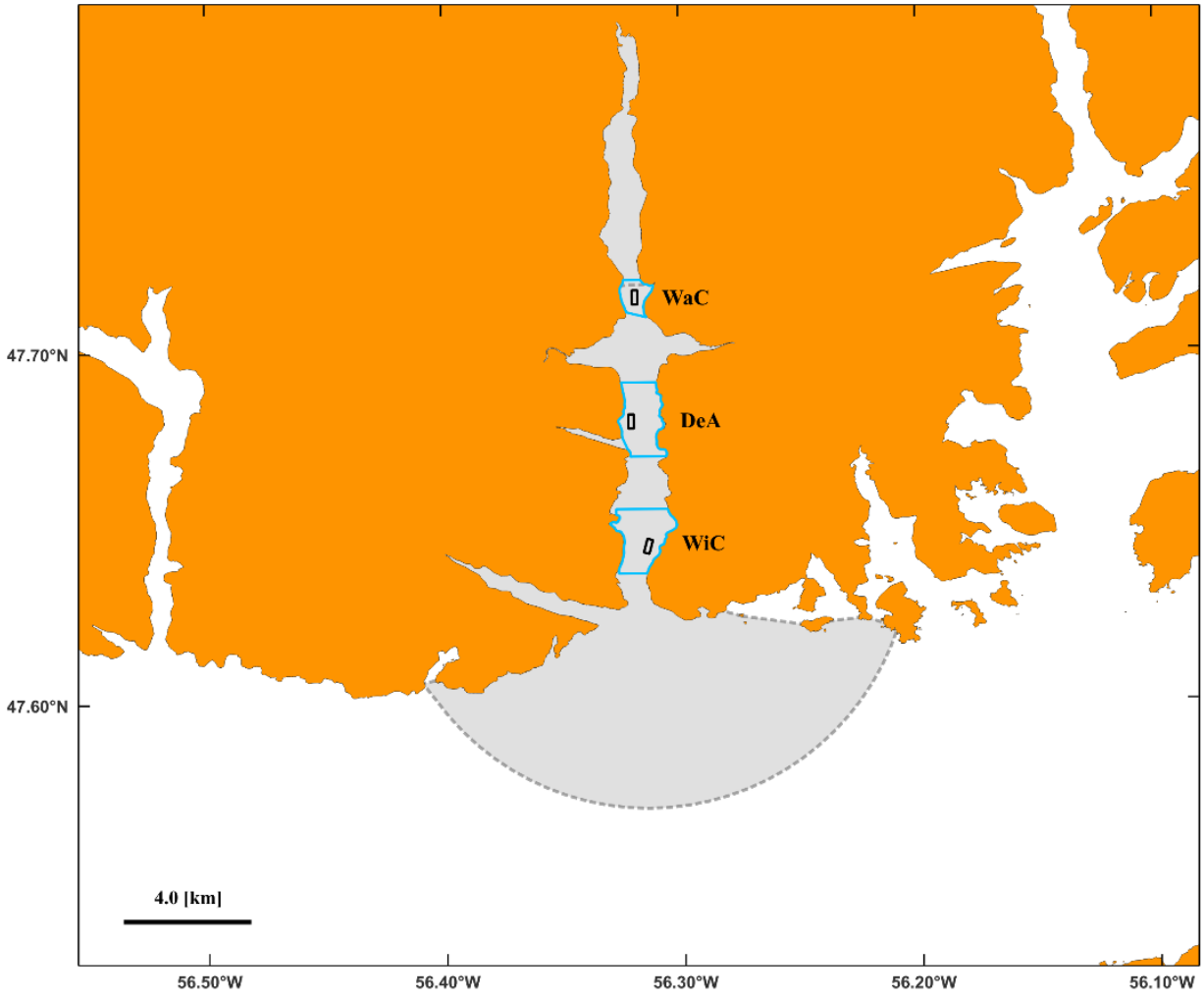

Figure 7: Combined pelagic-PEZ (shaded grey areas) for the sites associated with treatment by azamethiphos. Black rectangles represent the cage areas and blue polygons the lease area for each site (Wild Cove: WiC, Dennis Arm: DeA, and Wallace Cove: WaC). Note that the pelagic-PEZ covers the entire Facheux Bay and that the offshore-PEZ area has a greater uncertainty due to a different and unknown current regime. Alongshore seabed shallower than 49.8 m may be at risk of exposure to toxic concentrations. The delineation of PEZ outside of the channel is assessed using only the information from the current measurement closest to the mouth of the channel (WiC).

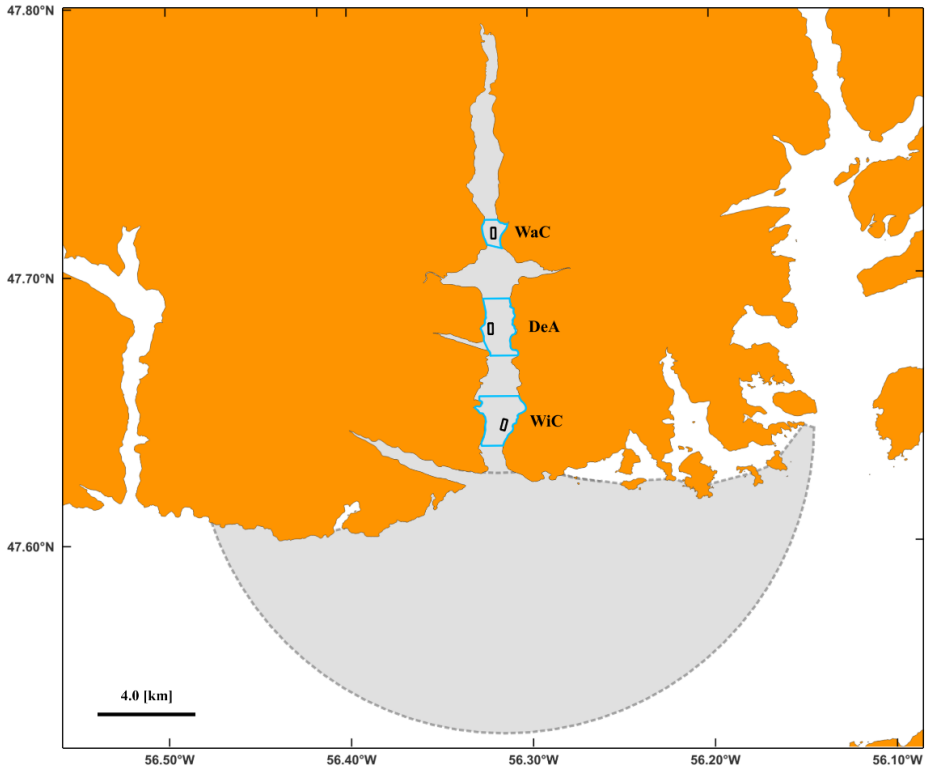

Figure 8: Combined pelagic-PEZ (shaded grey areas) for the sites associated with treatment by hydrogen peroxide. Black rectangles represent the cage areas and blue polygons the lease area for each site (Wild Cove: WiC, Dennis Arm: DeA, and Wallace Cove: WaC). Note that the pelagic-PEZ covers the entire Facheux Bay and that the offshore PEZ area has a greater uncertainty due to a different and unknown current regime. Alongshore seabed shallower than 65.2 m may be at risk of exposure to toxic concentrations. The delineation of PEZ outside of the channel is assessed using only the information from the current measurement closest to the mouth of the channel (WiC).

Susceptible Species Interactions

Crustaceans are the group with the most toxicity data available for both of the approved bath pesticides (Hamoutene et al. 2023b). With respect to azamethiphos, crustaceans are known to have high sensitivity (e.g., Burridge et al. 2014, Ernst et al. 2014). For hydrogen peroxide, recent toxicity data indicate that crustaceans have a lower tolerance for lethal concentrations compared to other species, placing them at the more sensitive end of a Species Sensitivity Distribution (SSD) curve. However, when considering sublethal effects, crustaceans are evenly distributed across the SSD curve (Hamoutene et al. 2023b). As stated previously, the baseline video observations showed that crustaceans (mostly krill) were observed at 23 of 74 stations, and at >20 individuals at four of these stations, indicating the potential exposure of these sensitive species to both benthic and pelagic use of anti-sea lice compounds.

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

azamethiphos can modulate the transcriptome signatures related to early development (Núñez-Acuña et al. 2022).

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).

The potential effects of pesticides on non-target species are unknown but will likely be limited to individuals and habitats present within the PEZ and surrounding areas. However, their use at aquaculture sites may also reduce the abundance of copepods and other invertebrates that are the prey of pelagic fish species and early life stage organisms.

Salmonid Species Interactions

Aquaculture Escapees

Genetic studies in southern Newfoundland and in the Maritimes over the past decade have documented widespread hybridization between wild salmon and aquaculture escapees (Bradbury et al. 2020a, 2022, Holborn et al. 2022, Keyser et al. 2018, Sylvester et al. 2019, Wringe et al. 2018). Across the North Atlantic, the magnitude of genetic impacts due to escaped farmed Atlantic Salmon on wild populations has been correlated with the biomass of farmed salmon in nearby cages and the size of wild populations. The risk posed to wild salmon in southern Newfoundland has recently been assessed using a combination of a likelihood and a consequence assessment (DFO 2024b). This process concluded that the risk to wild salmon abundance in this region (i.e., South NL - West Designatable Unit [DU] 04B) ranged from low to high and the risk to genetic character was high across the range of escape rates examined. This significant risk exists against the backdrop of a declining wild population which is currently designated as threatened under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010) and under re-evaluation after further declines (DFO 2025).

The potential genetic interactions resulting from the proposed finfish license increase (from 1M individuals/site to 2M individuals/site) at three sites in Facheux Bay in southern Newfoundland was considered here. The distribution of escapees in the wild under the proposed production regime (existing and proposed increase) was modelled using a spatial model of dispersal and survival (Bradbury et al. 2020b) and described in detail in DFO (2024b).

Model predictions for individual rivers were evaluated against a 10% threshold for the proportion of escapees relative to wild population size, above which demographic declines and genetic changes have been predicted in wild populations (Bradbury et al. 2020b, DFO 2024b). This threshold is also routinely used in Norway (e.g., Glover et al. 2020, Taranger et al. 2015) and Iceland (MFRI 2020). Wild population sizes were estimated based on axial length and corrected for recent population declines through comparison with recent Atlantic Salmon monitoring data. Within the DU 04B, which extends from Terrenceville Brook to Barachois River, a 60% decline correction was applied, based on angling statistics. However, for rivers located within Bay d'Espoir, an additional 20% decline correction (80% total) was applied, based on counting fence trends specific to that region (DFO In Press[1]). For rivers in the neighbouring DU 04A (South NL - East), the population size was used without any decline correction applied based on population abundance trends in the area. For assessed rivers in both DUs where actual abundance estimates were available (e.g., Conne River, Garnish River, Northeast Placentia), these values were used.

The number of expected escapees per unit production was estimated using reported escape event and production data from Newfoundland as well as several other jurisdictions

as ~0.2 escapees per tonne production, recognizing that reported escape events have been shown previously to underestimate exposure of wild populations to escapees (Skilbrei et al. 2015). Production levels used in the analysis utilized maximum allowable production levels recognizing that these levels have not historically been achieved following DFO (2024b). Furthermore, wild population sizes were likely overestimated given direct comparison with census data and stock assessments and ongoing evidence of continued declines in the region. The model accounts for periods of fallowing and production losses of 20% as stated by the Proponent and assumes a 5 kg harvest weight.

Wild Cove, Dennis Arm, and Wallace Cove are located in Facheux Bay, in DU 04B. Contained in Facheux Bay are three small salmon systems; Bottom Brook, Allan's Cove Brook (both scheduled), and Brent Cove Brook (unscheduled). Escapee dispersal simulations suggest that there would be a 2.75% total increase in the number of escapees present in the region associated with the proposed increases to these sites, all dispersing to rivers within DU 04B. Overall, 31/53 or 58% of salmon rivers in this DU are predicted to exceed 10% escapees, unchanged from the current licensing scenario. The majority of escapees from the sites are predicted to occur in the three river systems mentioned, Bottom Brook, Allan's Cove Brook, and Brent Cove Brook (increase from 37.8% to 39% escapees at each) and also at Dolland Brook in Hare Bay (increase from 35.2% to 36.5%), and dispersion impacts from this increase may be seen as far west as Middle Brook and as far east as Old Brook (Figure 9). This dispersion area encompasses rivers in the head of Bay d'Espoir, including Conne River, where predicted proportions of escapees were already highest and are predicted to increase further (from 38.9% to 40%). At the Regional (i.e., DU) level, the proportion of total escapees to total salmon exceeds the cautionary threshold of 10% and is predicted to be 17.2% (an increase from 16.8%). This is consistent with significant genetic impacts present in the region. Ultimately, although the proportion of predicted escapees has increased at some locations near the sites, the risk at the DU level to wild salmon abundance (low risk) and genetic character (high risk) remains unchanged from DFO (2024b). It is important to note that for risk to abundance from escapes, the assessment considered only the direct consequences of interbreeding between farmed and wild Atlantic Salmon; it did not consider ecological effects.

In the absence of an escapee monitoring program, there remains significant uncertainty as to the number and distribution of escapees in southern Newfoundland. Farmed fish are captured at some DFO monitoring sites in the region and assignment back to producer would be a valuable tool to manage impacts. The federal Department has developed standard operating procedures for this sort of genetic analysis and for maintaining chain of custody. Moreover, a recent overview of potential mitigation measures (DFO 2024b) led to a conclusion that eliminating all human errors and equipment failures associated with Atlantic Salmon net-pen escapes is not possible. The review concluded that no single measure would eliminate escapees with the exception of fully sterile populations or fully closed containment (DFO 2024b).

The Proponent is required to comply with the NL Code of Containment (NLFFA 2022) which is intended to minimize farmed fish escapes and to effectively deal with escapes if they do occur. This includes using materials (including netting and 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. The Code of Containment requires the license holder to report escapees to DFO and the provincial Department of Fisheries, Forestry and Agriculture immediately.

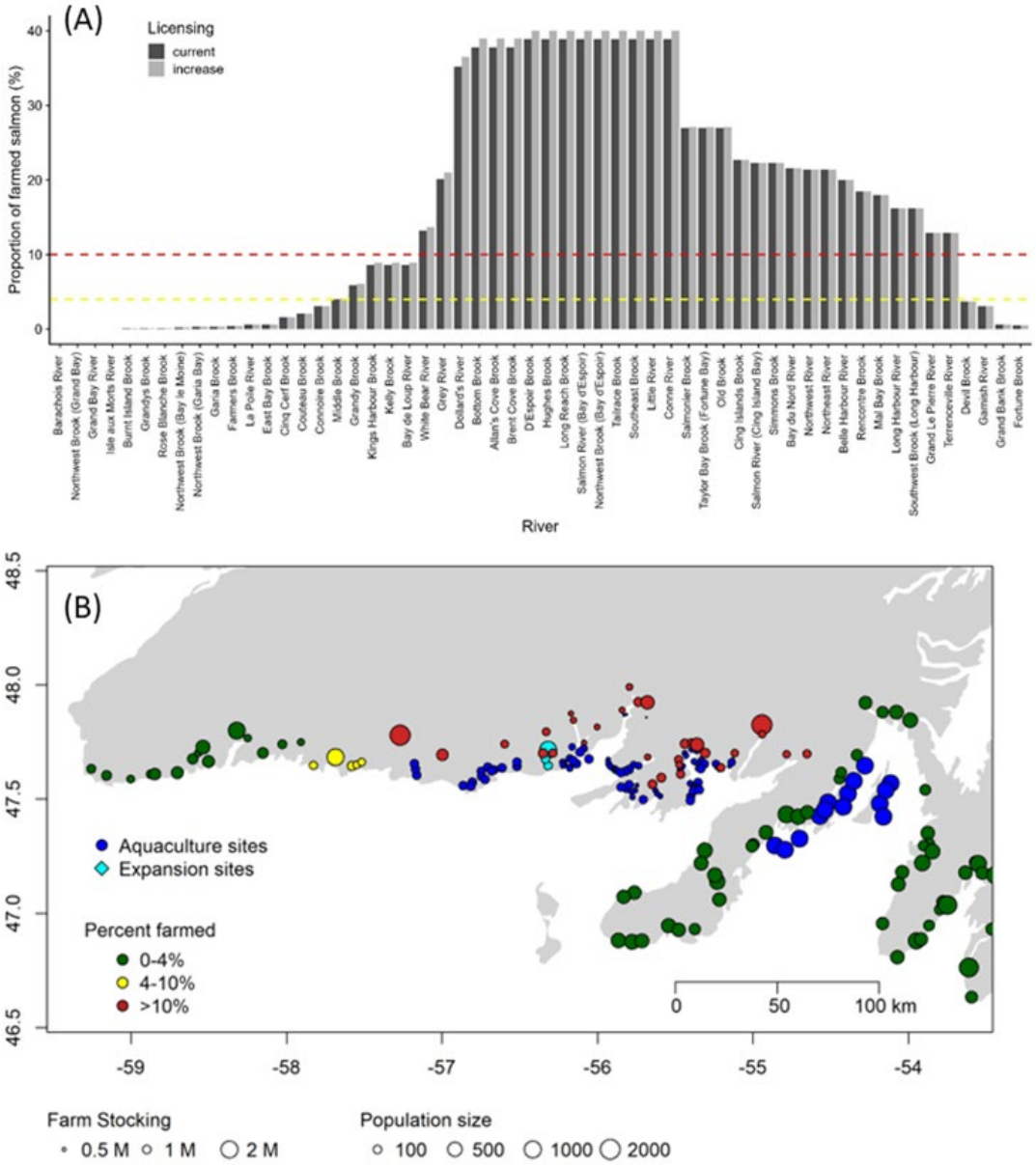

Figure 9: (A) The modeled proportion (%) of farmed salmon escapees relative to the wild population of Atlantic Salmon, based on 0.2 escapees per tonne, for 106 rivers on the south coast of Newfoundland (NL). Only 56 of 106 rivers (from SFA 11 and 12) are displayed, as the percent escapees from SFA 10 are negligible. Numbers are based on the current license maximum stocking for Wild Cove, Dennis Arm, and Wallace Cove at 1 million and the proposed increase of 2 million maximum stocking for each site. The yellow line indicates 4% proportion of escapees relative to wild population size while the red line indicates 10%, above which demographic declines and genetic changes have been predicted in wild populations. (B) Distribution of wild salmon rivers/streams and aquaculture sites throughout southern Newfoundland. Aquaculture sites are represented by blue circles and are scaled by maximum stocking size as set out in each license. Rivers are represented by red, yellow, and green circles, grouped by risk to change in genetic character determined by percent farmed in the river, and scaled to population size.

European ancestry

Recent analysis using population genomics to investigate the presence of European introgression into North American farmed and wild Atlantic Salmon (Bradbury et al. 2022) has demonstrated that both contained and escaped farmed salmon sampled in Atlantic Canada had a portion of their DNA attributable to recent interbreeding with European origin domestic salmon. In addition, two escaped farmed salmon were detected following an escape event in Fortune Bay in 2015 with 100% European ancestry (Bradbury et al. 2022). Throughout Atlantic Canada, European ancestry has been detected in wild salmon sampled in areas around aquaculture sites (e.g., Conne River), indicating the source to be aquaculture escapees with European genes that have interbred with wild Atlantic Salmon. These results demonstrate that individuals of full and partial European ancestry have been in use over the last decade, and that some of these individuals have escaped and hybridized in the wild (Bradbury et al. 2022). Recent analysis of samples of salmon which escaped from a Long Pond (net-pen nursery) site in southern Newfoundland (2021) and an escape event in the Bay of Fundy (2023) indicate presence of significant European ancestry in farmed salmon. In the 2021 escape, 21% of the 189 fish analyzed displayed more than 10% European ancestry and in the 2023 escape event, 33% of the escapees analyzed displayed more than 10% European ancestry. European salmon have been shown to differ significantly from North American salmon across a variety of important genes and traits (Islam et al. 2020, 2021, 2022a, b, Lehnert et al. 2019, 2020), thus this observation significantly elevates the risk to wild salmon populations if individuals escape and interbreed, as has been demonstrated (Bradbury et al. 2022). In other jurisdictions (e.g., Maine), pre-screening of fish for European ancestry prior to transfer to sea cages is required and such efforts could be used to mitigate these impacts in southern Newfoundland as well. Fisheries and Oceans Canada has developed a new screening tool of genomic markers chosen to provide accurate identification of European ancestry (Nugent et al. 2023).

OTHER CONSIDERATIONS AND SOURCES OF UNCERTAINTY

Eutrophication

Increased nutrient loading from the increases in biomass at the 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 Newfoundland (DFO 2023b). Because biological activity tends to increase with temperature, BOD will likely peak when high water temperatures contribute to low oxygen levels in the water column. Fjords are prone to hypoxic events because their location in deep, narrow valleys results in a low surface area to volume ratio. Oxygen is replenished by vertical diffusion and, if BOD is high, biota may consume diffusing oxygen within the water column before it mixes to the bottom (Fennel and Testa 2019) which could prolong the length of hypoxic events in bottom waters beyond the end of a high temperature period. These effects are more likely to affect benthic organisms than pelagic fish which could move to areas with more favorable oxygen conditions, but low bottom oxygen concentrations could affect pelagic species with benthic eggs.

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 5 m 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 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). The entire cage array at Wallace Cove is positioned over depths greater than 300 m, and therefore monitoring under the current AAR is not required. Consequently, the presence of visual indicators of organic enrichment (e.g., *Beggiatoa* spp. percent cover, OPC) or elevated levels of sulfide concentrations in sediments cannot be assessed to determine whether these indicators are within the compliance thresholds outlined in the AAR.

Cumulative Effects

Cumulative effects are not being considered as part of this process despite the proximity of the sites to each other (with overlap of the benthic-fecal PEZ and the pelagic-PEZs for both bath pesticides). 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.

Oceanographic Data and Model Output Submitted by the Proponent

The expansion of aquaculture on the south coast of Newfoundland in remote areas with limited scientific knowledge requires the DFO Science review process to rely on data provided by the Proponent. The review depends on the quality and quantity of these data. The Proponent has collected ocean current data at the sites and at various depths with limited information below ~200 m. The analysis of the current speed at each depth shows variability in currents within the water column, which is consistent with variability observed in other bays in the same region (Donnet et al. 2022, Ratsimandresy et al. 2019).

Considering the seasonal variability observed in the region and stronger ocean currents in fall, these sites presumably experience similar variability. Ocean currents were measured for only 31–51 days and such a short period of data collection cannot capture seasonal variability.

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

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

Potential Exposure Zones (PEZs)

Physical Environment

Salmon aquaculture activity in Newfoundland takes place in fjord-like bays/arms with complex shoreline and bathymetry. Shoreline distance from net-pen edges can range from 50–600 m (Page et al. 2023a); in the present review, the distance varies from 160–260 m. The depths under the cage array could range from ~40 m to as deep as 380 m (DFO 2022a, c, Page et al. 2023a, the present review). Within the lease area, depths range from very shallow (less than

a few meters near the shoreline) to very deep (~390 m); with such depths, ocean currents presumably vary vertically.

The analysis of the ocean currents from the sites shows spatial variability (vertically as well as horizontally) with current direction following the direction of the channel where data collection occurred. This pattern is consistent with Page et al. (2023a) who reported that the predominant current tends to follow the channel in which the aquaculture site is located, and with the analysis of ocean currents in the region by Donnet et al. (2022) and Ratsimandresy et al. (2019) showing the presence of vertical structure. There is also the possibility of higher maximum subsurface current speed found between 20–60 m (DFO 2022a, Donnet et al. 2022). Although tides can contribute to the variability in the sea level (Ratsimandresy et al. 2020), they typically contribute minimally to variability in currents (Ratsimandresy et al. 2019).

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

Model Calculation

The PEZ calculation uses only a few inputs, namely a horizontal current speed representative of the whole water column, a particle sinking rate, and one depth data point representative of the area of interest. The latter two variables are used to compute sinking time and the dilution period for non-sinking particles. Selection of a current speed representative of the period of analysis is critical. The PEZs for various treatments provide a possible maximum spatial extent of exposure but not an accurate measurement of concentration, duration, or frequency of exposure.

In the calculation of PEZ for aquaculture sites in Newfoundland, given the complexity and variability of the currents, PEZ is computed using a method that considers the maximum PVD. This method provides a current speed that is more representative of the site and that minimizes overestimation. The analysis makes use of a time series of current speeds collected at various depths within the water column. Note that some refinement may still be necessary in the process of selection of the current speed that best represents the whole water column or the layer where non-sinking particles disperse; such refinement can be performed as more oceanographic data, and understanding of the process, become available for analysis.

A PEZ provides an order of magnitude estimate of the spatial scale of potential exposure (Appendix B, Table A1-2). Combined with information on the presence of species, habitats, or other human activities in the area, any overlap with PEZ leading to a potential concern may necessitate a more detailed and precise estimate of the exposure to evaluate impact and/or mitigation measures. Such precise estimation would require more advanced model(s) involving more computer resources and time. These models should consider ocean current data with temporal and spatial variation (vertically and horizontally), as well as more realistic sinking rates of particles and temporally varying feeding information to compute the dispersion and eventually deposition of waste from aquaculture farms; for example, the 3-D ocean circulation model FVCOM (Finite Volume Community Ocean Model, Chen et al. 2003, 2006) coupled with particle tracking model (Page et al. 2015) or the 3-D circulation model ROMS (Regional Ocean Modeling System; Shchepetkin and McWilliams 2005) coupled with the farm waste dispersion/deposition commercial software NewDEPOMOD (Chary et al. 2021).

Benthic Surveys

The diversity, distribution, and ecology of benthic communities in many areas along the south coast of Newfoundland remains a knowledge gap. Seafloor video and imagery provided from industry surveys is frequently the first time these areas have been observed. For the current assessment, the video quality is too low to make a meaningful assessment regarding the presence of any benthic fauna and the baseline report only qualitatively describes the benthic fauna for stations ≤65 m depth. The absence of seafloor video data for the area directly beneath the cage array means the potential sensitive benthic species and associated habitat that could be vulnerable to exposure from organic matter deposition cannot be adequately assessed. The deepest sections of the bay could have a different faunal community compared to shallowest parts, but this could not be assessed.

Maximum video quality of 4 (defined as “high-quality video with easy identification of animals and substrate conditions”) was reported in 100% of the stations. These images are not high quality. 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 the report, camera quality also has a major influence.

Although it is possible to determine the main fauna groups at most frames, the low quality hampers more specific identifications and in many cases it is difficult to understand how animals could be identified at the low taxonomic levels at which they were identified. The low quality of the videos will challenge future comparative analysis of before and after aquaculture activities.

The Proponent provided abundances of the benthic fauna observed during the seafloor survey. If organisms were very abundant, the Proponent classified counts as >20. However, there is no mention of whether at a particular station >20 means a much larger amount, such as 25 or 50. Taxa absences and abundance counts need to be considered with caution, as counts do not reflect relative counts (i.e., in relation to surveyed area) and camera distance from the seafloor might be slightly different between stations.

Additionally, faunal abundances were only recorded at specified intervals along each transect. Analyzing only a small number of intervals / segments of the entire transect underestimates the fauna present. For example, redfish were abundant at transects 4E and 4W among the sea anemones and in rock crevices (based on the video), but these were not recorded in the Baseline Assessment Report. Further, soft corals, Atlantic Cod, flatfish, and sponges were observed in the video but were not counted because they did not fall at the selected distance value along the transect. Every effort should be made to adequately and accurately represent the fauna present in the lease area.

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 related to image clarity, resolution, field of view, or operation of diver-operated, towed, or remote-operated video cameras apply to the collection of baseline survey information. Consistency in these requirements might 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.

As part of their application package, the Proponent provided data from the AAR peak biomass monitoring of two previous production cycles at Wallace Cove; however, these were not provided for review by the meeting.

Impacts to susceptible species from exposures

The degree to which wild fish species and fish habitat will be exposed to aquaculture activities is 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 within the PEZs. Additionally, the sensitivity of some species' life stages and habitats to the potential effects from the 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 is evolving (e.g., mechanism of exposure, acute versus chronic exposures, multi-chemical usage, lethal and sub-lethal impacts). Available toxicity data to-date are largely derived from lab experiments, and the degree of exposure and impact of in-situ treatment conditions (ranging from a single treatment scenario to cumulative exposures) to wild susceptible species remains uncertain. A lack of species-specific toxicity studies for important species in the area, such as lobster and scallop, adds to the uncertainty of lethal and sub-lethal effects on various life stages, condition, health, and reproduction. These uncertainties limit the ability to predict the magnitude of impact and consequence on species and abundance and distribution.

Salmonid Species Interactions

The reliance on a dispersal model to predict impacts to wild salmon populations is largely due to a lack of or limited local data on the number of escapees, their dispersal, and survival to reproduction. The main sources of uncertainty around escapees include: the accuracy of reported escape events in reflecting actual escapes, the actual number of escapees per unit of production, escapee dispersal behaviour and dispersal distance, proportion of escapees that are sexually mature, and the time of year of the escape event. While values for these parameters used in the model may not apply equally to all areas, the limited data available for southern Newfoundland required the use of the best available estimates for these parameters from the literature. Compliance and inspection results report escape events in the NL Region and can be found in recent and archived Annual Compliance Reports. The reported number of Atlantic Salmon escapees in NL has ranged from 0 to 140,000 fish per year since 1990. From 2012–22, escapee events occurred in four years: 20,500 in 2013; 1,000 in 2015; 3,000 in 2018; and 10,000 in 2021.

A sensitivity analysis by Bradbury et al. (2020b) included several key dispersal model parameters and formed the basis for model parameter estimates in a previous risk assessment (DFO 2024b). Such sensitivity analyses allow for predictions of the degree of change in genetic interactions across a range of potential values, where empirical data are lacking or insufficient. For the risk assessment (DFO 2024b), these sensitivity analyses and a range of escape rates were used to assess impacts from genetic interactions across various scenarios. In addition, multiple lines of evidence for escapes (industry reported escapes, river monitoring, and genetic screening for introgression) were used given the uncertainty associated with these parameters.

Another source of uncertainty is the current implementation of production values for the industry. Production levels in the model used maximum allowable production per site. While efforts were made in the model to account for fallowing and a proportion of loss from stocking to harvest, it is recognized that maximum allowable production levels were not achieved and currently do not necessarily reflect the management area production cycle, as not all farms are in operation all at the same time.

From the wild Atlantic Salmon perspective, the main source of uncertainty are the estimates for river-specific population size. These estimates were based on habitat area and egg conservation requirements, adjusted for regional declines from stock surveys in wild Atlantic Salmon. Therefore, uncertainty remains both for the estimates of the population size as well as the vulnerability of individual wild salmon populations given that multiple characteristics of a population (e.g., female fecundity, male to female sex ratios) could affect the level of impact of direct genetic interactions from farm escapees.

There has been an overall decline in the reported number of escapees in recent years, despite a simultaneous increase in production (Strand et al. 2024). This decline has been linked to improvements in operational conditions (e.g., engineering, equipment, regulation). Model results are only as good as the data available/used for simulations; updating model simulations using recent and local escape data and using actual numbers of fish in the water, if recent data were available, would benefit both industry and government agencies.

CONCLUSIONS

Terms of Reference 1: *Based on the available data for Wallace Cove and the scientific information, what are the potential 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, resulting in the greatest intensity of impacts, occurs within a radius of 1 km from Wallace Cove site which is generally of the same order of magnitude as the lease area. No overlap with the other sites within the fjord is expected for the feed-based benthic-PEZs.
- The PEZ associated with in-feed drug present in feces occurs within a radius of ~3.7 km from the Wallace Cove site. Overlap with the other sites within the fjord can be expected for treatments in the same bay.
- The pelagic-PEZ associated with the use of approved pesticides occurs within a radius of ~9.4 km for azamethiphos and ~9.9 km for hydrogen peroxide from the Wallace Cove site.
- The pelagic-PEZ related to the usage of bath pesticides indicates significant overlap within the bay. These pelagic-PEZs extend to water masses beyond the bays and could reach shorelines and impact the shallow areas adjacent to each site. Consideration of the cumulative impacts of these pesticides on sensitive species is recommended.
- Anti-sea lice treatment could affect crustaceans through both exposure of adults in the benthos (benthic-PEZ), and through pelagic exposure of larval stages to bath pesticides (pelagic-PEZ). For krill species that mostly occupy the pelagic zone, exposure to bath pesticides might represent a risk for all sites.

Terms of Reference 2: *Based on available information for Wallace Cove, what are the Sensitive Benthic Species, and their associated habitats that are within the potential benthic exposure zones and vulnerable to exposure from the deposition of organic matter? How does this distribution compare to the extent of these species and habitats in the surrounding area (i.e., are they common or rare)? What are the anticipated impacts to these sensitive species and habitats from the proposed aquaculture activity(ies)?*

- Given the overlap of both the feed and feces PEZ, benthic communities directly underneath cages and in the lease are expected to be exposed to both organic enrichment and

chemical residues. Overlap with the PEZ of other sites in the Bay (Dennis Arm and Wild Cove) might occur as well.

- Based on their life history characteristics, sessile or sedentary benthic taxa are expected to be vulnerable to aquaculture wastes, as they cannot relocate to another environment when under stress. Due to the absence of data for depths greater than 300 m, the impact of the increase in biomass on sensitive benthic species and habitats at those depths could not be assessed.
- Although corals were not identified in the Baseline Assessment Report, they were identified from the video (e.g., *Gersemia* sp.), between stations, which is not a requirement under the AAR. Encrusting sponges and sea anemones were abundant. However, fauna could not be identified beyond higher-level taxonomic groups due to poor quality imagery data; physical samples are required for species-level identifications. The previous reviews of Dennis Arm and Wild Cove also identified abundant sea anemones (identified as *Stomphia* sp.), encrusting sponges, and soft corals. Feather stars were also identified at those sites, but not in the high abundances observed at Wallace Cove.

Terms of Reference 3: *What are the predicted impacts and/or risks to Atlantic Salmon populations from direct genetic interactions associated with any escaped farmed fish from the proposed increase in biomass at all three sites?*

- A recent assessment of the risk posed to wild salmon by direct genetic interaction with escaped farmed salmon in southern Newfoundland indicated the risk to population abundance (excluding ecological effects) ranged from low to high and risk to genetic character was high across the range of escape rates examined. This risk exists against the backdrop of a declining wild population currently designated as threatened under COSEWIC and currently being re-evaluated after further declines.
- Escapee dispersal simulations suggest that there would be a 2.75% total increase in the number of escapees present in the region associated with the proposed increases at the three sites, all dispersing to rivers within the South NL - West DU (04B).
- Despite this small increase overall, 31/53 (or 58%) of salmon rivers in this DU still exceed the 10% escapees threshold, above which demographic declines and genetic changes have been predicted in wild populations, with several rivers being 2–4 times this threshold. This is unchanged from the current licensing scenario.
- Furthermore, the simulations suggest an increase from 37.8% to 39% in the potential proportion of escapees to population size for the three populations within the bay, and dispersion impacts from this increase may be seen as far west as Middle Brook and as far east as Old Brook.

Additional conclusions of the meeting

- Predictions of genetic risk from escaped farmed salmon resulting from the proposed increases in production may be elevated by the presence of European ancestry within farmed Atlantic Salmon in Atlantic Canada repeatedly observed over the past two decades. In Newfoundland, Atlantic Salmon have been approved for transfer to marine aquaculture sites. Transfer applications and permitting for established sources (e.g., diploid, St. John River strain) is routine and decisions are primarily based on confirmation of the health status of the fish. The application process could consider the requirement for producers to demonstrate genetic testing to confirm the genetics (origin) of the fish.

- Baseline data and operational standards provide the majority of the data used in this review. Updates are needed to the required inputs to bring monitoring programs to current standards and decrease the uncertainty seen in many of the data streams.

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APPENDICES

Appendix A

Progressive Vector Diagram (PVD) and PEZ calculation

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

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

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

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

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

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

An example of PVD for ocean currents at Wild Cove is illustrated below:

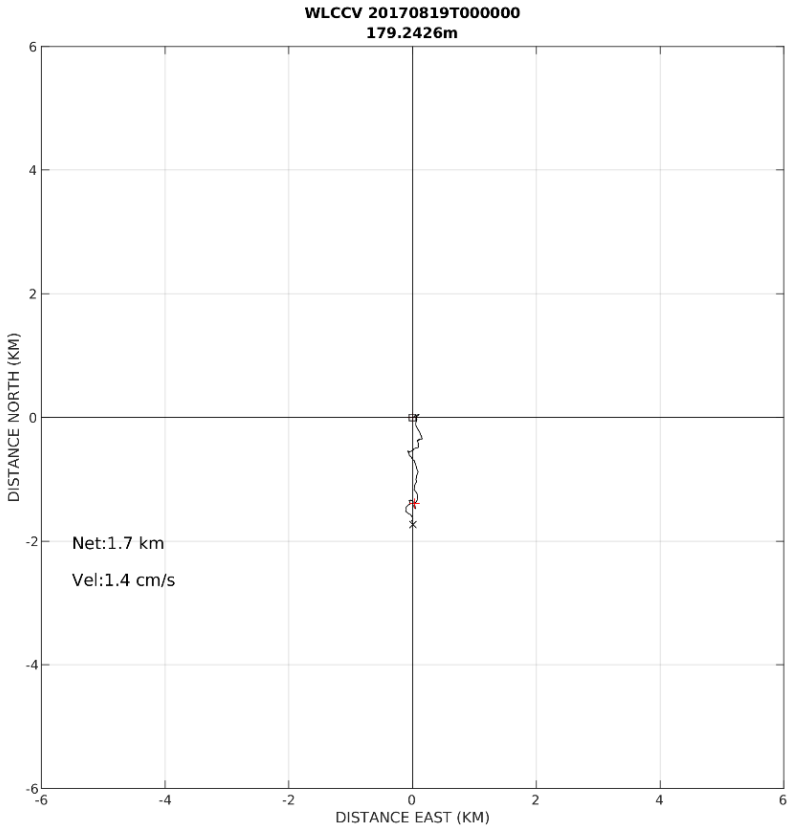

Figure A1: Displacement of a particle at ~179 m depth for a period of 31.5 h on 19 August 2017 computed with progressive vector diagram.

Using the time series 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 for the PEZ calculation.

With the Acoustic Doppler Current Profilers (ADCP) measuring currents at various depths. The corresponding median and maximum PVD/associated current speeds are computed for each depth.

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

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

Appendix B

Order of magnitude of PEZ

Table A1: Settling time of particles (as function of depth and settling velocity).

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

Table A2: Order of magnitude of displacement of particles as a function of settling/dilution time and ocean current speed. PEZ is computed as displacement + 1/2 cage array. Note: the further away, the less the assumption of constant depth and constant current speed and direction holds.

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

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