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Canadian Science Advisory Secretariat
Maritimes Region **Science Response 2020/051**

DFO MARITIMES REGION SCIENCE REVIEW OF THE PROPOSED MARINE FINFISH AQUACULTURE BOUNDARY AMENDMENT, FARMER'S LEDGE, GRAND MANAN, NEW BRUNSWICK

Context

Lambert Salmon Inc. and Kelly Cove Salmon Ltd. have made an application to the Province of New Brunswick to amend their existing site (MF-0002) near Farmer's Ledge, Grand Manan, New Brunswick.

As per the Canada-New Brunswick Memorandum of Understanding on Aquaculture Development, the New Brunswick Department of Agriculture, Aquaculture and Fisheries (NBDAAF) has forwarded this application to Fisheries and Oceans Canada (DFO) for review and advice in relation to DFO's legislative mandate. The application was supplemented by information collected by the proponent as required by the *Aquaculture Activities Regulations* (AAR).

To help inform DFO's review of this application, the Maritimes Regional Aquaculture Management Office asked for DFO Science advice on the Predicted Exposure Zones (PEZs) associated with the proposed aquaculture activities, and the predicted impacts they might have on sensitive listed species at risk and sensitive Commercial, Recreational, and Aboriginal (CRA) fishery species and the habitats that support them.

Specifically, the following questions are addressed:

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

Question 2a. What are the consequences to the species and habitats that exist within the proposed site's predicted exposure zones, and where applicable, in the broader vicinity, focusing on species at risk, CRA species, and species vulnerable to aquaculture impacts? Are there potential consequences to any critical or valuable habitats for species at risk or CRA species?

Question 2b. How do the impacts on these species from the proposed aquaculture site compare to impacts from other anthropogenic sources (including existing finfish farms)? Do the zones of influence overlap with these activities and if so, what are the potential consequences?

Question 3. The proponent used a depositional model to predict the benthic effects of the proposed aquaculture site. Are the predicted benthic effects, as demonstrated by the output of the depositional model, consistent with the scientific knowledge of the potential impact of this operation?

This Science Response Report results from the Science Response Process of January 17, 2020, on DFO Maritimes Region Review of the Proposed Marine Finfish Aquaculture Boundary Amendment, Farmer's Ledge, Grand Manan, New Brunswick.

Background

Lambert Salmon Inc. and Kelly Cove Salmon Ltd. have requested an amendment to expand and shift the boundaries and increase the production level at their existing MF-0002 site near Farmer's Ledge, Grand Manan, New Brunswick. Lambert Salmon Inc. and Kelly Cove Salmon Ltd. MF-0002 is located in Long Island Bay on the northeastern side of Grand Manan Island, New Brunswick. The site is located in Bay Management Area (BMA) 2b, which also encompasses twelve other marine finfish aquaculture sites. The location of the site is shown in Figure 1.

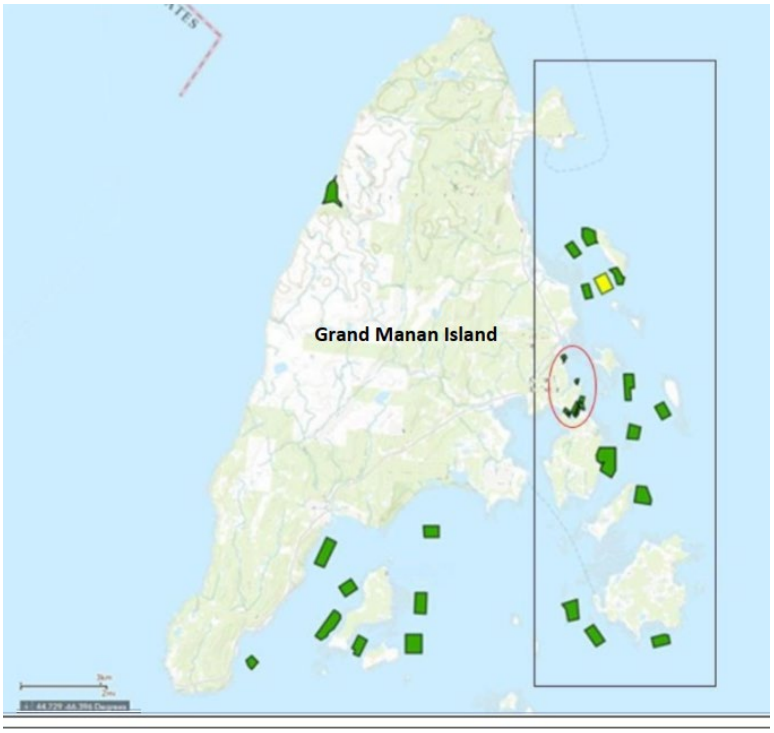

Figure 1. Map of aquaculture site leases in the Grand Manan Island, New Brunswick area. Sites within the black rectangle are encompassed within BMA 2b. The yellow polygon represents the location of the existing site and proposed amendment. The green polygons are other existing aquaculture sites, less the lobster pounds identified within the red circle. Maps were retrieved from the New Brunswick Marine Aquaculture Site Mapping Program (MASMP) website on October 2, 2019.

The existing site has been in operation since 1992. The current leased area is 9.78 ha and consists of a 3 × 3 cage grid configuration (as seen in Figure 3). The proposed boundary amendment would alter the cage configuration to a 2 × 7 grid on a north-south orientation, which would increase the site to 10.12 ha and allow for the addition of 5 cages. These changes represent an increase of 3.5% in leased area and 30% in the number of fish on site. Figure 2 shows the Proponents site development plan, bathymetry of the proposed lease area, and estimates of the intensity of organic loading for the proposed site as per the AAR.

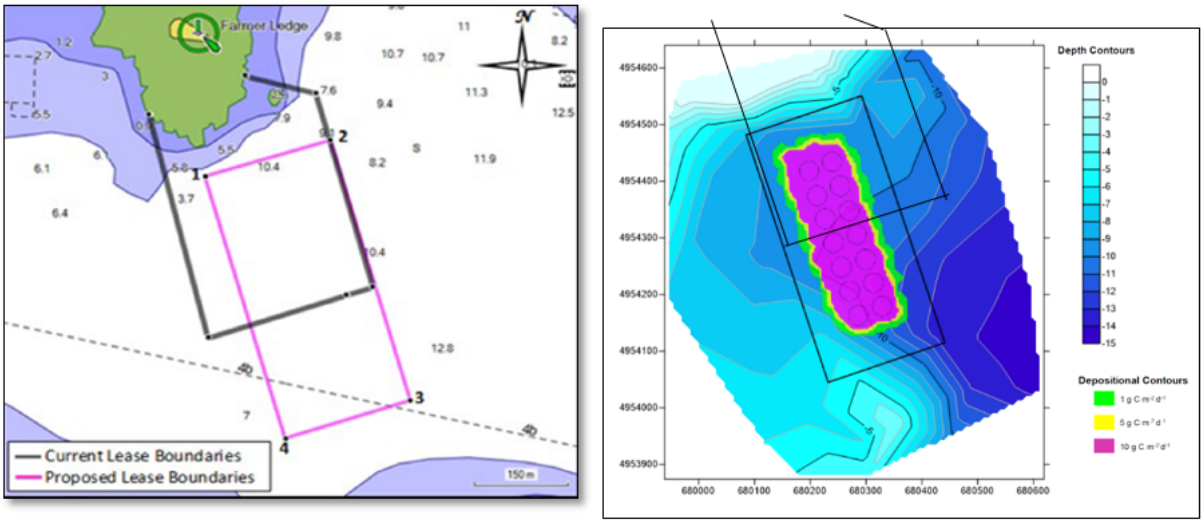

Figure 2. Left: Current and proposed lease boundaries (SIMCorp. Baseline Report 2019) of the Farmer's Ledge MF-0002 aquaculture site. Right: Estimate of the spatial distribution of organic loading released from the proposed finfish expansion provided by the proponent using AquaMod (SIMCorp. Baseline Report 2019). Visualization of current lease boundaries has been overlaid in black. Depositional contour levels refer to the outside edge of each colour polygon. The open circles indicate the location of the net-pens. The estimate is associated with an estimate of peak feeding.

The proponent's model shows that the 1 gC/m^2/d depositional contour for the time of peak feed use falls within lease boundaries, directly under and around the cage array with slightly more coverage to the northwest (Figure 2).

Historical stocking levels and associated provincial Environmental Monitoring Program (EMP) sulfide results are shown in Table 1. The site has demonstrated poor environmental performance in the past, with the exceedance of compliance thresholds during three of this site's previous production cycles. The existing site was last stocked in 2016 and has been fallowed since fall 2018. Compliance station locations throughout the last two production cycles can be seen in Figure 3.

Table 1. Historical stocking levels and associated provincial Environmental Monitoring Program (EMP) site mean sulfide results for site MF-0002 (Farmer's Ledge). Stocking levels were provided by DFO Regional Aquaculture Management on January 20, 2020, and EMP data was retrieved from the New Brunswick Department of Environment and Local Government (NBDELG) website on January 22, 2020. (--) indicates additional fish were not stocked in that year.

Year	# of fish	EMP site mean sulfide results	Classification
2002	328,019	14 µM	Oxic 1
2003	--	1819 µM	Oxic 2
2004	241,179	1244 µM	Oxic 2
2005	--	**5214 µM**	Hypoxic
2006	--	297 µM	Oxic A
2007	285,012	776 µM	Oxic B
2008	--	**3839 µM**	Hypoxic B
2009–2012	--	**site not stocked**	--
2013	236,744	11 µM	Oxic A

Year	# of fish	EMP site mean sulfide results	Classification
2014	--	**3833 µM** (Tier 1) **4099 µM** (Tier 2)	Hypoxic B (Tier 1) Hypoxic B (Tier 2)
2015	--	112 µM	Oxic A
2016	242,951	no survey	--
2017	--	22% of hard-bottom stations with indicators	Pass
2018	--	2713 µM + 100% of hard-bottom stations with indicators (Tier 1) 2518 µM (Tier 2)	Above Threshold A (Tier 1) Hypoxic A (Tier 2)
2019	**Approval request for 350,000*	203 µM	Oxic A

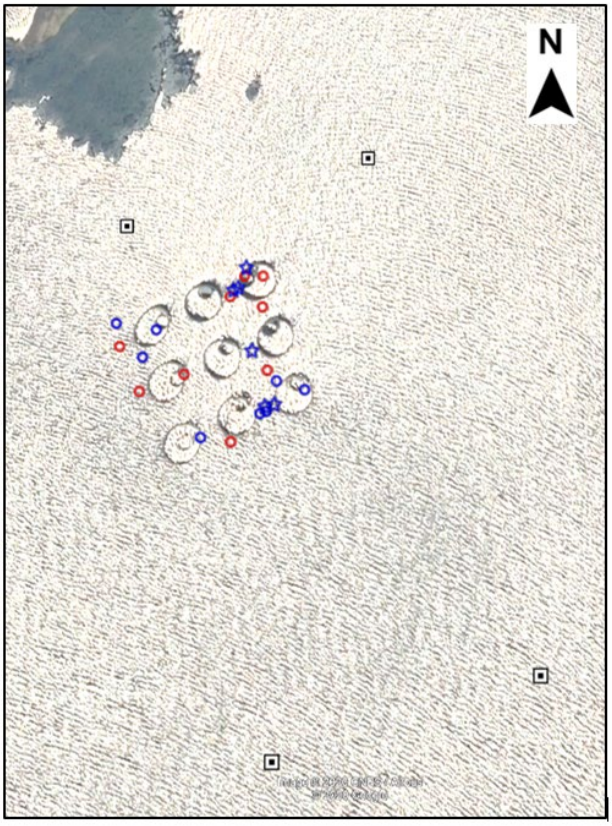

Figure 3. Environmental Monitoring Program compliance stations from MF-0002 measured in 2014 (circles; SIMCorp 2014) and 2018 (stars; SIMCorp 2018) overlaid on a Google Earth image of the existing cages. The blue and red circles depict stations where mean sediment sulfide concentrations exceeded 3000 µM and 6000 µM, respectively. The squares represent corners of the new proposed lease boundaries.

The site is located in an area with variable bottom type and ecosystem characteristics (i.e., mud, sand, gravel, cobble, shell debris, boulder). It is being proposed that this site alteration would

move the lease area away from the ledges (i.e., Farmer's Ledge), where organics accumulate, and into deeper water.

Available data from 2015–2018 indicate that no pest control products (i.e., azamethiphos, hydrogen peroxide) had been used at the existing site. Available information from the last two production cycles also show there have been no reports of escapes or entanglements of marine mammals, sea turtles, or other species of concern to this review at the existing site.

For the past 28 years, the site has operated in an area that has numerous active CRA fisheries. It is located within Lobster Fishing Area (LFA) 38 and, more specifically, within the reporting grid that has the second highest level of lobster landings of any grid cell within the LFA throughout the last several years. The site is also located within Scallop Production Area (SPA) 6. Analysis of Vessel Monitoring System (VMS) data from scallop dredges in 2010 and 2011 indicates fishing activity in the vicinity of both the existing and proposed lease area. Figure 4 depicts the spatial overlap between these active commercial fisheries and the area of interest. Indigenous harvesting in the immediate surrounding area also includes Lobster and scallop.

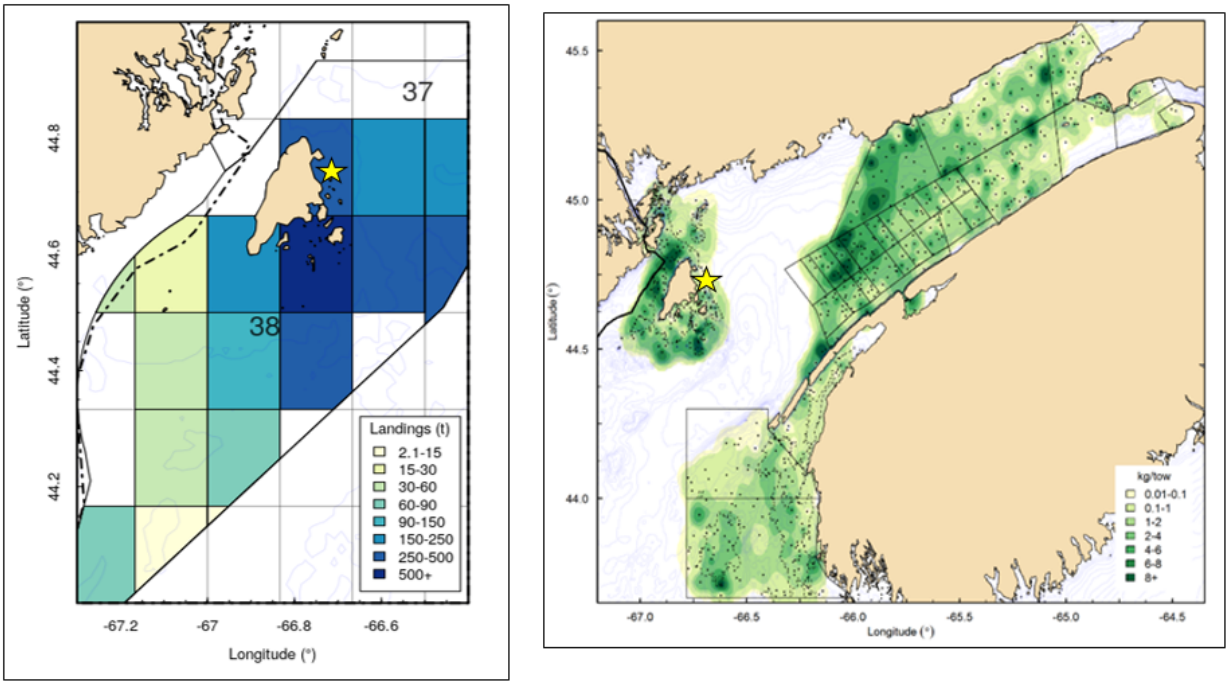

Figure 4. Left: Distribution of American Lobster landings (total weight of landings, tonnes) per reporting grid in Lobster Fishing Area 38 during the 2017–2018 fishing season. The appropriate grid is noted by the star. Right: Distribution of commercial scallop (≥80 mm shell height) biomass (kg/tow) in the Bay of Fundy and approaches in 2017. The site area is noted by the star.

Commercial database searches of the PEZ at the proposed site indicate that commercial groundfish species in the area include Atlantic Halibut (*Hippoglossus hippoglossus*), American Eel (*Anguilla rostrate*), Haddock (*Melanogrammus aeglefinus*), and Atlantic Cod (*Gadus morhua*), while the commercial pelagic fisheries include Atlantic Herring (*Clupea harengus*) and Alewife (*Alosa pseudoharengus*). A rebuilding plan is currently being developed for the 4X5Y Atlantic Cod stock. There is no directed fishing due to the stocks population size, which was re-assessed as Endangered by COSEWIC in 2010 and is pending a listing decision under the *Species at Risk Act* (SARA). Commercial Rockweed harvesting is highly abundant along the Grand Manan coastline (Ugarte et al. 2010; Ugarte and Sharp 2012). There are also a number

of Recreational and Aboriginal fisheries, including Food, Social, and Ceremonial (FSC) fisheries in the area that surrounds the site and the broader Bay of Fundy region. These fisheries include diadromous species such as Striped Bass (*Morone saxatilis*), American Eel, Alewife and Blueback Herring (*Alosa aestivalis*) (collectively referred to as Gaspereau), Rainbow Smelt (*Osmerus mordax*), and American Shad (*Alosa sapidissima*). The American Eel and Striped Bass are significant to Recreational and Aboriginal fishing activities, and they are assessed as Threatened and Endangered by COSEWIC, respectively. Searches of DFO databases indicate records of Atlantic Wolffish (*Anarhichas lupus*), which have been listed as Special Concern under SARA since 2003, within the PEZ of the proposed site.

Both the existing and proposed leases are within the migration pathways of wild Atlantic Salmon (S*almo salar*). The Bay of Fundy commercial fishery for Atlantic Salmon was closed in 1985 (Amiro 1998), and the recreational fishery for Atlantic Salmon has been prohibited for all rivers located around the Bay of Fundy since 1998 due to conservation concerns. Inner Bay of Fundy (iBoF) Atlantic Salmon have been listed as Endangered under SARA since 2003. Outer Bay of Fundy (oBoF) Atlantic Salmon have been listed as Endangered under COSEWIC since 2010, and are currently under consideration for SARA listing by the Minister.

Within a 5 km buffer zone from the existing and proposed expansion, there are other human activities with associated potential benthic and pelagic impacts on habitats and species in the area. These activities include additional finfish farm leases, lobster pen areas, small craft harbours, ferry terminals, boat tour companies, and land-based activities.

While the proposed site expansion does not overlap with any identified DFO Ecologically and Biologically Significant Areas (EBSA), the southern portion of the Flagg Cove EBSA (located to the north of MF-0002) is located within 5 km of the site. This EBSA (Buzeta 2014) has significant and unique aggregations of berried female Lobster, with these aggregations fulfilling the critical physiological requirements for Lobster egg development and extrusion. DFO (2004) states that EBSA are intended as a tool for calling attention to an area that has particularly high ecological or biological significance, to facilitate provision of a greater-than usual degree of risk aversion in management of activities in such areas. In addition, the entire Grand Manan Archipelago is considered an Important Bird Area (IBA).

Production-specific information have been checked against input data related to the number of fish on site, size at harvest, estimated grow-out mortality rate of 10%, net size, initial stocking density, and cage configuration. Key oceanographic and farm infrastructure and grow-out characteristics of the existing and proposed site expansion considered in the current review are summarized in Table 2.

Table 2. Oceanographic and farm infrastructure and grow-out characteristics of the existing and proposed site expansion. Information sources are from the proponent submission (i.e., development plan, production plan, baseline data report, current meter report), with the exception of DFO tide tables. (--) represents no additional information.

Characteristic	Existing site	Proposed site	Additional Information
Tidal range (m)	7.0	7.0	• Range does not include surges in sea level.
Depth of tenure (m)	0.9 – 10.0	6.0 – 13.0	• Relative to vertical chart datum (low tide).

			• Depth at site center of lease boundaries = 10 m for existing and proposed.
Current speed (m/s) • **Surface**	*Not available*	0.002–0.319	• Dominant flow directionality is to the north-northwest. • Surface currents measured at 11 m above the bottom. • Midwater currents measured at 8 m above the bottom. • Bottom currents measured at 4 m above the bottom.
• **Midwater**	*Not available*	0.0–0.319	
• **Bottom**	*Not available*	0.001–0.303	
Salinity (‰)	30–33	30–33	• Data from 2013–2018. • Salinity data from Prince 5 AZMP station located in the Bay of Fundy 25–30 km north-northwest of the proposed site.
Temperature (°C)	0.9–14.8	0.9–14.8	• Data from two previous production cycles, 2013 and 2016. • Water temperature data collected at MF-0002.
Dissolved oxygen (mg/L)	6.0–12.0	6.0–12.0	• Data from two previous production cycles, 2013 and 2016. • Dissolved oxygen data collected at MF-0002.
Substrate type	Mud, sand, gravel, cobble, shell debris, boulders	Mud, sand, gravel, cobble, shell debris, boulders	--
Net-pen array configuration	3 x 3	2 x 7	--
Individual net-pen circumference (m)	100	100	--
Net-pen depth (m)	6	6	--
Mooring grid cell side length (m)	48	45	--

Outside dimensions of net-pen array (m)	245 × 340	220 × 460	• Includes cages and lines out to anchorage blocks.
Grow-out period (months)	18–24	18–24	--
Maximum number of fish on site	242,951	350,000	• Existing site number from most recent production cycle (2016–2018).
Initial stocking number (fish/pen)	26,994	25,000	• Calculated based on proponent submitted maximum number of fish on site and number of pens.
Average harvest weight (kg)	5.9	5.9	--
Expected maximum biomass (kg)	1,137,645	1,858,500	• Existing site number from most recent production cycle (2016–2018). • Expected numbers assume 10% mortality.
Net-pen volume (m^3)	4777	4777	• Calculated based on proponent submitted net-pen size and depth.
Maximum stocking density (kg/m^3)	26.5	27.9	• Existing maximum stocking density estimated from expected maximum biomass, number of pens and net-pen volume.

Sources of Data

Information to support this analysis includes data and information from the proponent, data holdings within DFO, publically available literature, and registry information from the SARA database.

The following supporting information was submitted to DFO for consideration and was used in this review:

1. New Brunswick Department of Agriculture and Aquaculture Boundary Amendment Application MF-0002,
2. New Brunswick Department of Agriculture and Aquaculture Marine Aquaculture (Bay of Fundy) Application Form – Production Plan,
3. MF-0002 Site Development Plan,
4. Baseline Assessment Report for site MF-0002,
5. Current Profile Report for site MF-0002,

6. Farmer's Ledge Raw Direction & Speed Data.xlsx and Farmer's Ledge.xlsx,
7. Farmer's Ledge (MF-0002) PBS diagram May_19 (current lease), and
8. MF-0002 Environmental Monitoring Program Reports 2013–2019.

The following DFO databases were used and records are reported in Appendix A:

- Ecosystem Research Vessel (RV) Survey
- Industry Survey Database (ISDB)
- Maritime Fishery Information System (MARFIS)
- Whale Sightings database

Site Description

The water temperature and salinity at the MF-0002 site are expected to vary on at least tidal and seasonal time scales, and are expected to fall within the ranges indicated above (Table 2).

Near-shore bathymetry information in the vicinity of the MF-0002 site is lacking in Departmental and public data holdings. The proposed southward expansion of the site will shift the lease off of Farmer's Ledge (<4 m depth), and closer to the ledges off High Duck Island (<4 m depth). Low tide water depth relative to chart datum ranges from approximately 6 m at the northeastern corner to approximately 13 m at the southeastern corner of the proposed lease. Depths adjacent to the southeast of the proposed lease can be greater than 15 m.

The wave information provided in the proponent's report is from Jonesport, Maine, and is not considered representative of the MF-0002 site. The buoy is located in an open water at depths of 182 m. The wave amplitudes at the site are anticipated to be less due to the shallower water and sheltered location of the site from wind and waves coming from the west.

Over the 39-day period that current speeds were measured, approximately 60% of the mid-water current speeds were >10 cm/s and approximately 90% were >15 cm/s. The overall current dynamics at MF-0002 are described as "relatively low-energy" for marine fish farming with more than half of the measurements falling below 10 cm/s (SIMCorp. 2019b). Current speeds vary due to complexities of the coastline, bathymetry, and seasonal influences. Observations in the current speed data also demonstrate there is not significant vertical variation (Table 2).

Based on the depth profiles of current speed data, temperature, and salinity at the site, stratification is expected to be weak. Therefore, exposure and impact predictions do not consider stratification influences.

Analysis and Response

Benthic Predicted Exposure Zones and Interactions

Benthic Predicted Exposure Zone

The Benthic-PEZ provides an estimate of the size and location of areas that may be expoused to a substance introduced into or released from a site. It is used to assess the likely impacts on the benthic community and seafloor from the deposit of waste feed and feces, which can result in organic loading and direct habitat and infaunal species impacts. It is assumed that the PEZ associated with the release of in-feed drugs is dominated by medicated feed waste and feces.

Benthic exposure can also occur from the use of bath pesticides, particularly at shallow sites such as MF-0002; however, this is considered in the Pelagic-PEZ and Interactions section of this review.

The dominant factors that affect estimates of the benthic exposure zone are farm layout, feeding practices, and oceanographic conditions, such as the bathymetry and water currents.

A precautionary, first order estimate of the spatial extent of the benthic-PEZ related to organic effluent from the MF-0002 site was calculated as outlined in Appendix B. Sinking rates of particulate materials released from farmed finfish sites (i.e., waste feed and feces) vary, although the distribution of the sinking speeds is poorly characterized. The minimum sinking rate for each particle category (Table 3), along with the maximum site depth and maximum observed mid-water current speed in the proponent's record, were used to estimate the benthic-PEZ. A mid-water current speed was used since there is minimal vertical variation in current speeds and the majority of fish and consequent release of feces and waste feed occur in midwater.

Table 3. First-order estimates of the potential horizontal distances travelled by sinking particles released from the fish farm (i.e., waste feed pellets, fish feces and in-feed drugs, and fines and flocs). Settling rates were obtained from Findlay and Watling (1994), Chen et al. (1999), Chen et al. (2003), Cromey et al. (2002), Sutherland et al. (2006), Skoien et al. (2016), and Bannister et al. (2016).

Particle type	Benthic-PEZ			
	Min. Sinking rate (cm/s)	Max. Observed Current (cm/s)	Horizontal. Distance Travelled (m)	PEZ Radius (m)
Feed	**5.3**	**31.9**	**120**	**318**
Feces	0.3	31.9	2127	2324
Fines and Flocs	0.1	31.9	6380	6578

The benthic-PEZ does not quantify the intensity or duration of exposure, nor include a frequency of exposure, and are not considered zones of impact. Results of the proponent's modelling (Figure 2) indicate that the intensity of impacts will be greatest closer to the cages, with severe benthic impacts occurring under and near the cage array, since the predicted carbon flux is >10 $gC/m^2/d$ (Appendix C). Since the "feed" particle category has the fastest sinking rate, the highest intensity of impacts are anticipated in the feed-PEZ. Therefore, the first order estimate of the benthic-PEZ is based on the feed-PEZ (Figure 5).

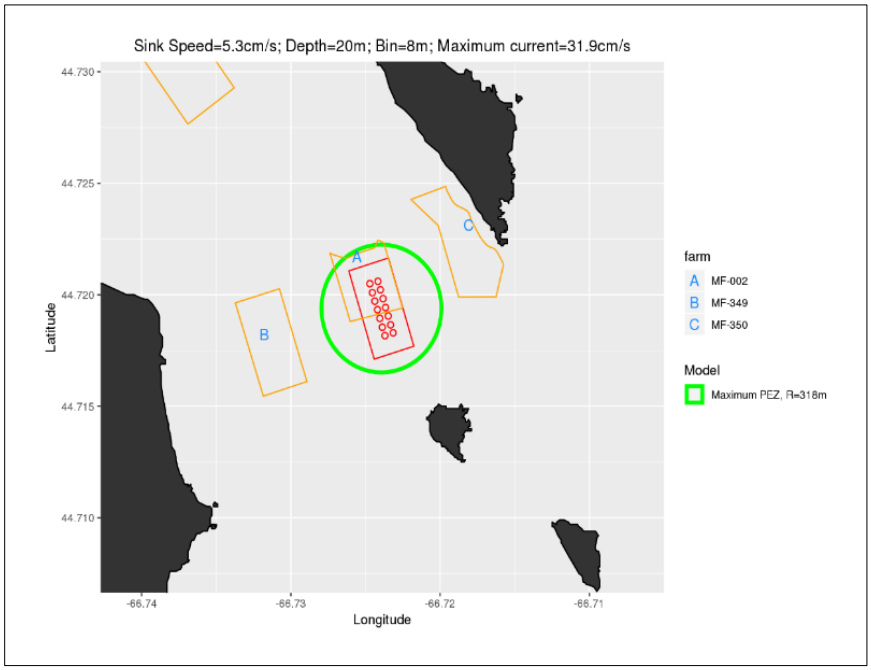

Figure 5. First-order estimation of the benthic-PEZ for MF-0002 using the waste feed minimum sinking rate (green circle with a radius of 318 m). The orange lines represent existing finfish sites in the area, including the existing MF-0002 site. The red lines represent the proposed site boundaries.

The PEZ is a circular zone centered over the middle of the proposed cage array and represents the outer limit for potential exposure; however, the benthic footprint is likely a curved ellipse with a major axis length scale of approximately 300 m due to current directionality. The zone was estimated by adding the horizontal transport distance to the length scale of the proposed net pen array.

Wave-induced bottom resuspension of waste particles is not considered in the PEZ, and flocculant materials will likely extend the benthic deposition beyond the benthic-PEZ. Given the nets are 6 m in depth, the distance between the bottom of the nets and the seafloor is only a few metres. This suggests that the nets may, at times, be very near or touching the sea floor, and the accuracy of depositional model estimates may be affected by the net-pen infrastructure. The potential impacts of sediment redistribution and flocculant deposition is unknown but are not anticipated to occur at levels where significant smothering or oxic-state changes are predicted.

Given the location of additional finfish farm leases in the near vicinity (Figure 5) and the water circulation within the region, an overlap between the benthic organic deposition zones associated with other finfarms is expected.

It is being proposed that the site alteration will shift the cage array, and consequent benthic footprint, away from Farmer's Ledge where organics accumulate. At the current location, production has resulted in an exceedance of the EMP regulatory thresholds (see Table 1 and Figure 3). Anoxic conditions have been recorded from compliance stations primarily to the north of the site closer to the shallower ledges. There are several compliance stations at the edge of the southern-most cages that have been classified as hypoxic B. The majority of the compliance stations that have previously exceeded regulatory thresholds are expected to remain beneath the proposed cage array. The PEZ has not been estimated for the current site; however, the

PEZs for the current and proposed site are expected to be similar since the water currents at the current site are only marginally stronger than the proposed site. The shift in lease boundaries and location of the cage array are not anticipated to mitigate the accumulation of organics on the shallower ledges, nor the intensity of organic loading throughout the site.

Susceptible Species Interactions

Species are considered to be susceptible within the benthic-PEZ if they are sessile at any life stage and are sensitive to low oxygen levels, smothering, loss of access to the site, or exposure to in-feed drugs such as crustaceans, bivalves, polychaetes, bacteria, and parasitic worms (see DFO 2019 for details).

Specific consideration was given to whether there are data in the baseline survey, scientific literature, or Departmental holdings for presence of sensitive sessile species, such as sponges, corals, and eelgrass, or critical habitat for SARA-listed species. When limited data are available, the presence of suitable benthic substrate for the growth of these species was considered when assessing species interactions.

Although industry and DFO RV surveys (Appendix A) are limited in their ability to observe all susceptible benthic species in the coastal zone, the available data indicate that American Lobster (*Homarus americanus*), scallops, and groundfish are present within the benthic-PEZ.

While Lobster and scallop distributions within the benthic-PEZ are unknown, the mixed substrate found beneath the site provides habitat for both species. The site (both existing and proposed amendment) is in an area considered to be important spawning and nursery grounds for Lobster and scallops by the Fundy North Fishermen's Association, among others (OCMD Coastal Fisheries Mapping Project). The eastern side of Grand Manan may provide important habitat for the extrusion and hatching of Lobster eggs, with its optimal temperatures and protection in its shallower waters (Cooper and Uzmann 1971; Campbell 1990; Tremblay et al. 2006). Lobsters migrate seasonally in May-July from deeper water on the eastern flank of Grand Manan into Long Island Bay and Whale Cove, aggregating in highest densities close inshore. These summer aggregations persist through October-November when the Lobsters migrate to deeper water. Prior studies and unpublished DFO survey data indicate that individual Lobsters (berried females in particular) may reside several weeks to over a month within these shallow waters. Local fisherman have also identified many of the fishing grounds surrounding Grand Manan as important for the reproductive cycle of Atlantic Cod and Haddock (Graham et al. 2002). Areas that fishermen have identified catching developing and spawning Atlantic Cod and Haddock spatially overlap with the PEZ.

In-feed drugs, such as Emamectin Benzoate (EB), have been shown in lab studies to have lethal toxic effects to lobsters and can induce sub-lethal effects, such as premature moulting (Burridge et al. 2000; Waddy et al. 2002; Burridge et al. 2010). Bivalves in the vicinity of net pens have also been shown to have measurable quantities of EB. Currently, hazard information is primarily based on acute exposures; however, it does not indicate a high level of risk (Burridge et al. 2011).

There is potential for smothering due to excess deposition within the benthic-PEZ, particularly for sessile species such as scallops. The exposure of other near-bottom organisms, such as groundfish, is expected to be less due to their increased mobility.

Given the lifespan of the site and anticipated similarity of the PEZ between the current and proposed sites, the proposed increases in leased area and productions are not expected to pose a greater risk to species interactions than exist under current conditions.

Pelagic Predicted Exposure Zones and Interactions

Pelagic-Predicted Exposure Zone for Pesticides

The pelagic-PEZ is used to predict the spatial scale of potential interactions between registered pesticides used in finfish aquaculture and susceptible species. The two pesticides available for use in bath treatments (e.g., tarp bath and well-boat) are azamethiphos and hydrogen peroxide. The size of the PEZ depends on the decay and/or dilution rate of the pesticide, a chosen concentration threshold and the choice of horizontal water current depth. The PEZ is estimated using toxicity information of the most toxic registered pesticide (azamethiphos). The Health Canada Pest Management Regulatory Agency (HCPMRA) has assessed that neither of the two registered pesticides (hydrogen peroxide and azamethiphos), nor 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. Their half-lives are days to weeks, suggesting they will not persist in the environment concentrations considered to be toxic (HCPMRA 2014; 2016a,b; 2017).

The method used to estimate the pelagic-PEZ is in Appendix B. The pelagic-PEZ for azamethiphos was calculated assuming the maximum near-surface current speed persists throughout the dilution or decay scale (Figure 6). The duration is an estimate of how long it takes for the maximum azamethiphos target treatment concentration (100 µg/L) to dilute to the HCPMRA environmental effects threshold (1 µg/L).

The near-surface current speed was used since vertical variation in the observed current speed is limited, and the application of tarp bath treatments occurs in the surface waters. The pelagic-PEZ is calculated assuming tarp bath treatments, regardless of whether all cages would meet the treatment label conditions for application given the larger exposure zone anticipated to result from a tarp treatment versus a well boat.

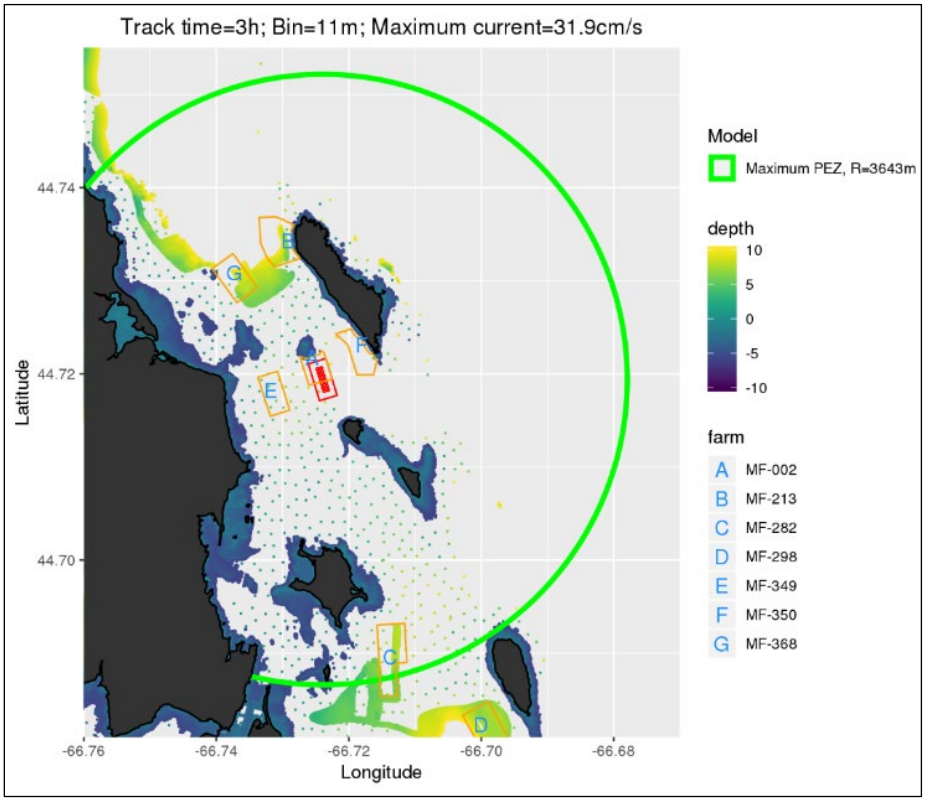

Figure 6. First-order estimation of the pelagic-PEZ for azamethiphos at MF-0002 using the maximum near-surface current speed tracked for 3 hours. The colour of dots indicates the observed depth of water (below chart datum) at the dot location. The orange lines represent existing finfish sites in the area, including the existing MF-0002 site. The red lines represent the proposed site boundaries.

The PEZ was estimated by adding the horizontal transport distance to the length scale of the proposed net pen array. The exposure is expected to primarily occur in the pelagic zone; however, the bathymetry and water currents at the proposed site suggest that the shallow water (<10 m) seabed within the pelagic-PEZ may also be at risk of exposure to toxic pesticide concentrations, during some phases of the tide. The pelagic-PEZ does not quantify intensity or duration of exposure.

A pelagic-PEZ has not been estimated for the existing site; however, the PEZ for the current and proposed sites are expected to be similar since the water currents are only marginally stronger at the current site. Estimates of cumulative exposures from the multiple fish farms and other potential sources of pesticide loading have not been fully assessed in this report. The location of other marine finfish sites in the area and the approximately 4 km pelagic-PEZ originating from the proposed site suggest that there may be exposure overlaps associated with pesticide releases from any of the 13 total finfish farms within the Bay Management Area (BMA).

Susceptible Species Interactions

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

Although industry and DFO RV surveys (Appendix A) are limited in their ability to observe all susceptible pelagic species in the coastal zone, the available data indicate that Lobster, shrimp, and crabs are present within the pelagic-PEZ for azamethiphos.

Azamethiphos bath and well treatments are reported to pose risk levels that are below the established Level Of Concern (LOC) for marine fish, marine mammals, and algae, but they are above the LOC for pelagic and benthic invertebrates. While in the environment, azamethiphos is toxic to non-target crustaceans, including all life stages of Lobster (HCPMRA 2016b, 2017; Burridge 2013).

The spatial extent of the pelagic-PEZ overlaps with the southern portion of the Flagg Cove EBSA. Berried female lobsters are known to inhabit the shallower waters within Long Island Bay during the summer months, when they are the most sensitive to azamethiphos (Burridge et al. 2005).

Water depth considerations at the proposed site indicate that some areas of the shallow water seabed within the pelagic-PEZ may be at risk of exposure to toxic concentrations released from the proposed site. The HCPMRA restriction concerning the use of pesticides at shallow sites (no application to tarped net-pens in water depths ≤10 m) will be applicable to some cages, particularly during low tide.

Although the size of the pelagic-PEZ at the current and proposed site are anticipated to be similar, the exposure time to azamethiphos within the pelagic-PEZ will increase with the addition of 5 net-pens at the proposed site. This is based on the number of tarped net-pens that can be treated simultaneously (no more than two) according to HCPMRA application restrictions.

Since 2015, there have been no report of azamethiphos use at the current site.

Pest and Pathogen Interactions

Many jurisdictions have limits on the proximity of finfish aquaculture sites to Atlantic Salmon bearing streams and use a zonation approach (e.g., Bay Management Areas (BMAs), fish health zones) to allow for the coordinated management of fish health. In the Bay of Fundy, NBDAAF established six aquaculture BMAs in 2006. The boundaries of each BMA serve to provide adequate water separation between BMAs, and these are based on numerous considerations including proximity between farms, pathogen spreading dynamics, and current speeds that will disperse and dilute pelagic particles released from these farm sites (Chang et al. 2007, DFO 2010).

The primary endemic diseases and pests that Atlantic Salmon farms in Atlantic Canada manage are Bacterial Kidney Disease (BKD), Infectious Salmon Anaemia (ISA), and sea lice.

Bacterial Kidney Disease is a slowly developing bacterial disease that typically results in chronic infection over months rather than mortality. It is treatable with antibiotics (see Rhodes and Mimeault 2019 for a recent review).

The virulent form of ISA does not commonly occur; however, it has been highly virulent in the past. In 1996, ISA spread between farms in the Bay of Fundy, New Brunswick (McGeachy and Moore 2003), prior to implementation of BMAs.

Sea lice are small ecto-parasites that can pose a significant health risk to farmed and wild Atlantic Salmon when present at certain host density threshold levels (Krkosek 2010). Sea lice has historically been a concern for finfish farms in New Brunswick. Annual Sea Lice Management Reports from BMA 2b's last stocked production cycle indicate sea lice issues during the fall of 2017 (ACFFA 2018, 2019).

Density-dependent transmission is observed in many pathogen-host systems, including sea lice on salmon farms (Kristoffersen et al. 2013). This applies to the density of fish within a given farm and the density of farms within a given area. While the proposed maximum stocking density is high relative to recommended densities for overall fish welfare, it is similar to the estimated maximum stocking density at the current site during its last production cycle (Table 2).

The existing site is positioned towards the northern part of the BMA but centered within the western and eastern boundaries (Figure 1). The proposed site remains within the boundaries of BMA 2b. The shift between the existing and proposed site is unlikely to result in a significant change in pest and pathogen dynamics and transmission.

Salmonid species that are resident around the proposed site are most vulnerable to contracting the above pathogens and diseases. The limited available data on salmon migration in this area suggest that wild iBoF and oBoF Atlantic Salmon may pass by the site and be exposed to pathogens released from the site while in the Bay of Fundy. The proportion and residence time of wild Atlantic Salmon near aquaculture sites surrounding Grand Manan Island, and specifically the MF-0002 site, is unknown; however, Atlantic Salmon residency near the site appears transient. It is not anticipated that the exposure time at the proposed site will result in infection.

Amplification of pest and pathogen risks is not expected at the proposed site.

Physical Interactions

Bycatch or entanglement of wild species (e.g., wild fish, marine mammals, turtles, sharks) associated with the placement of infrastructure are potential physical interactions associated with the site.

Database searches indicate sightings of North Atlantic Right Whales (*Eubalaena glacialis*), Fin Whales (*Balaenoptera physalus*), and Harbour Porpoises (*Phocoena phocoena*) within the area. The North Atlantic Right Whale and Fin Whale are both SARA-listed species. North Atlantic Right Whales are primarily found in coastal waters and occur in the Bay of Fundy during the summer and fall where they feed and mate. Fin Whales are typically found in deeper offshore waters. The majority of sightings have been offshore to the east of Long Island (Appendix A) and reflect what is known about where these species live and transit. It is unlikely these species would be in close enough proximity to the MF-0002 site infrastructure for entanglement to occur.

Other SARA-listed species within the Bay of Fundy that have the potential for entanglement are White Shark (*Carcharodon carcharias*) and Leatherback Sea Turtle (*Dermochelys coriacea*). White Sharks occur in water depths ranging from just below the surface to greater than 1,100 m and across a large geographic area within Atlantic Canadian waters. While there have recently been consistent records of White Sharks in the Bay of Fundy in the summer, the transient nature of this species makes it unlikely that infrastructure at the MF-0002 site will have a significant effect on the White Shark population. Leatherback Sea Turtles also have a wide geographic range within Canada and can be found in coastal, shelf, and offshore waters. The Bay of Fundy, however, is not considered to be important habitat for Leatherback Sea Turtles, and it hosts relatively few foraging Leatherback Sea Turtles during the summer and fall.

Herring and Gaspereau fisheries may experience disturbance (e.g., potential displacement) associated with the placement of infrastructure at the proposed site. While Herring are migratory, it is believed that juveniles stay inshore and use these coastal areas as habitat year round (Reid et al. 1999). Weir fishers have indicated that the presence of active aquaculture sites impact Herring migration along the coastal areas; however, studies in the Bay of Fundy

indicate that Herring have been seen schooling around aquaculture farms, rather than avoiding them (Robinson, pers. comm.). Gaspereau are present in the Bay of Fundy for most of the year and are expected to forage at the proposed site expansion; however, these interactions are expected to be transient in nature. The MF-0002 site is within Sustainable Fisheries Division (SFD) 50, which continues to have the largest Gaspereau commercial landings within DFOs Maritimes Region (Gibson et al. 2017). Striped Bass is a species of recreational and Aboriginal significance within the area. Striped Bass are found in large numbers throughout the Bay of Fundy and likely transit in the vicinity of the proposed lease area.

There were no entanglement reports during the last two production cycles at the current site. While the magnitude of exposure and physical interactions between fish and infrastructure at the MF-0002 site are unknown, the transient nature of these species combined with the history of the site suggest that the proposed increase in total leased area is unlikely to increase the risk of bycatch or entanglement above that already associated with the existing site. The proposed increase in total leased area may result in physical displacement of some traditional commercial fishing activities, such as Lobster fishing and scallop dredging.

Genetic Interactions

Direct genetic interactions (i.e., hybridization) between wild and domestic Atlantic Salmon have been detected across the natural range of wild Atlantic Salmon. These interactions can be spatially extensive and can represent a significant proportion of a population's annual production (Glover et al. 2013; Glover et al. 2017; Heino et al. 2015; Sylvester et al. 2018; Wringe et al. 2018). Genetic impacts have been shown to be greatest in small wild populations and in the lower stretches of rivers (Glover et al. 2017; Sylvester et al. 2018).

Escapes of Atlantic Salmon from finfish sites occur annually in Norway and Atlantic Canada (Diserud et al. 2019; Glover et al. 2017; Keyser et al. 2018). Escapees have been found in rivers at distances of up to 200 km from the nearest aquaculture site, and their numbers are estimated to significantly exceed those from reported escape events (Heino et al. 2014). Both experimental and field studies has demonstrated decreased survival of hybrids in the wild (Fleming et al. 2000; McGinnity et al. 2003; Sylvester et al. 2019), and recent modeling indicates that population declines are likely when the percentage of escapees in a river relative to wild population size exceeds 10% annually (Castellani et al. 2015, 2018; Sylvester et al. 2019; Bradbury et al. 2020).

Little is known on the dispersal of escaped farmed Atlantic Salmon in the Bay of Fundy. They have been reported in the Stewiacke River at the top end of the Bay of Fundy (Amiro and Jefferson 1996) despite the closest aquaculture site being 250 km away, which indicates escaped farmed Atlantic Salmon can disperse over long distances.

Given the critically low levels of oBoF and iBoF Atlantic Salmon populations throughout the Bay of Fundy and the proximity of the MF-0002 site to Critical Habitat for these species, escaped farmed salmon is a concern. The oBoF Atlantic Salmon are at higher risk of introgression with escapees from sites located around Grand Manan Island due to proximity; however, iBoF Atlantic Salmon are listed under Schedule 1 of SARA and several rivers are considered as Critical Habitat for this Designatable Unit (DU) within 250 km of the site (Figure 7).

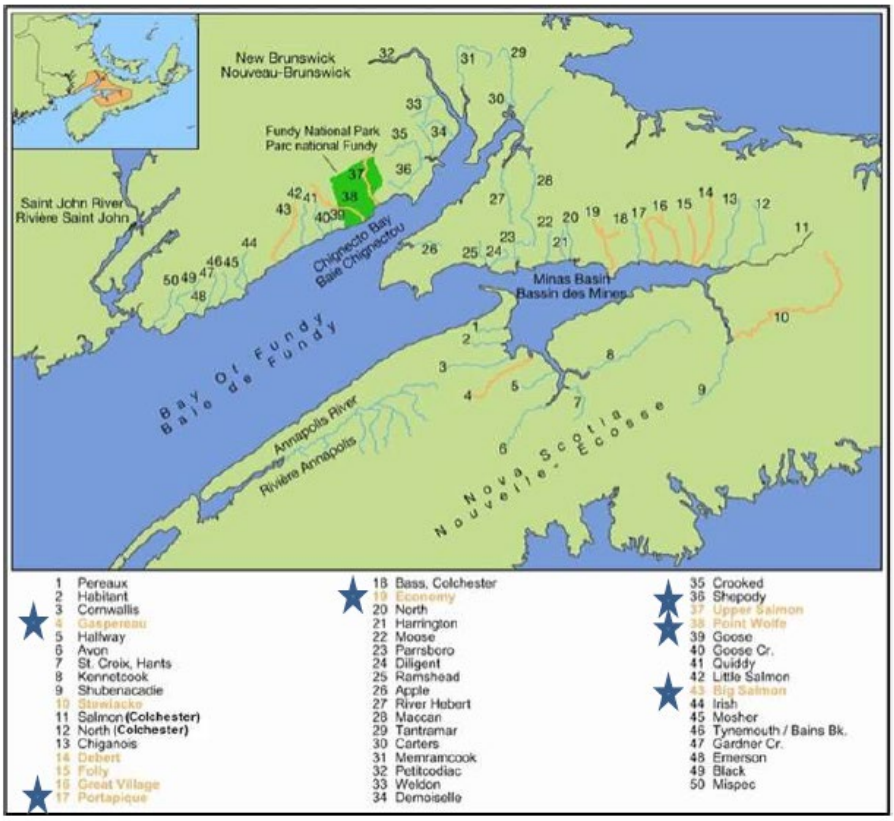

Figure 7. Location of the inner Bay of Fundy (iBoF) Atlantic Salmon DU and approximate location of the 50 rivers referred to in DFOs Action Plan for the Atlantic Salmon, iBoF population in Canada 2019 (DFO 2019). The orange lines denotes rivers containing critical habitat. The darkened green parcel represents the location of Fundy National Park. The stars reflect rivers containing critical iBoF habitat that are within 250 km of the MF-0002 site.

The current *New Brunswick Aquaculture Act* requires escape events of ≥100 fish to be reported. There have been no reported escapes at the existing MF-0002 site over the last two production cycles; however, this does not reflect escape events where the number of escapees were less than the reporting threshold. Given the population status of Atlantic Salmon in Bay of Fundy, efforts to reduce large and small escape events from finfish aquaculture sites are important.

The proposed production increase is small when scaled to the production level of all farms surrounding Grand Manan Island and the Bay of Fundy. Given the size of the wild Atlantic Salmon population, the proximity of the proposed site to iBoF Atlantic Salmon Critical Habitat, and the potential cumulative pressure from all finfish sites in the area, the potential risk of genetic interactions is a concern.

Potential Cumulative Interactions

The area of interest around the MF-0002 site (i.e., a 5 km^2 buffer zone) is used for a variety of human activities. Most activities are concentrated near the coastline, particularly in the northern and southwest sections of the area of interest. There are a large number of overlapping activities, with the majority of the buffer zone having four, and up to seven, co-occurring human activities (Figure 8). Appendix D provides the methodology details of this analysis.

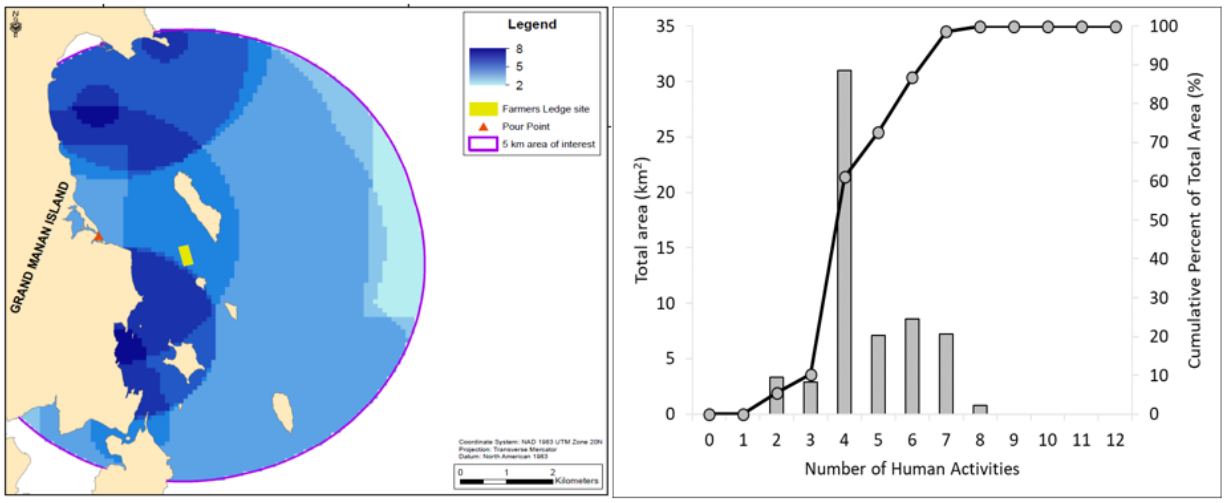

Figure 8. Left: Number of overlapping human activities in each 0.01 km² grid cell. The Farmer's Ledge lease boundary amendment is represented by the yellow polygon. The red triangle is the pour point location (i.e., the location where rivers drain into the coastal zone) for the confluence of two main rivers. Right: Total area (km²; grey bars), and the cumulative percentage of the total area (%; black line), in all grid cells with the corresponding number of human activities.

The pelagic-PEZ at the MF-0002 site overlaps with most human activities occurring in the area of interest, including other finfish sites in the PEZ and broader BMA. The risk of cumulative impacts associated with human activities in the area of interest stems primarily from the combination of potential impacts of finfish aquaculture with the potential physical, chemical, and biological impacts generated from vessel activities, commercial fishing, and land-based runoff (activities with the largest spatial overlaps with fin-fish aquaculture). Presently, the cumulative or interactive effects of these and other stressors, such as pollution and disturbance, on marine species and habitats is poorly understood. The spatial overlaps are not expected to significantly change with the proposed amendments to the MF-0002 site.

No comparison to impacts from other anthropogenic sources have been made for this review. A comparison of the impacts from a proposed aquaculture development and other anthropogenic sources on wild Atlantic Salmon population is provided in DFO (2011a, b).

Conclusions

Question 1: What is the predicted exposure zone (PEZ) of approved fish health treatment products in the marine environment, and the predicted consequences to susceptible species?

- The benthic-PEZ associated with the use of in-feed fish health treatment products is a radius of 318 m from the site location.
- The pelagic-PEZ associated with the use of approved pesticides is a radius of 3,643 m from the site location.
- The proposed site and cage locations are likely to result in the benthic environment in shallower areas around the site being exposed to pesticide concentrations that are toxic to sensitive benthic life stages and species; however, the effects are not expected to be different from those associated with the existing site.

Question 2a: What are the consequences to the species and habitats that exist within the proposed site's exposure zones, and where applicable, in the broader vicinity, focusing on species at risk, CRA species, and species vulnerable to aquaculture impacts? Are there predicted consequences to any critical or valuable habitats for species at risk or CRA species?

- Several CRA and species at risk exist within the area of interest including Lobster, scallop, Atlantic Salmon, Haddock, Cod, Herring, Gaspereau, Eel, Striped Bass, Atlantic Wolffish, Fin Whales, and North Atlantic Right Whale.
- Juvenile Lobster may be present year-round, with the majority of adult Lobsters migrating into deeper waters for the winter period. Scallops are expected to be in the area year-round.
- Spawning and nursery grounds for Lobster and scallop have been identified within the PEZ. Areas within the PEZ have also been identified as an important area for the reproductive cycle of Atlantic Cod and Haddock.
- The northern portion of the pelagic-PEZ overlaps with the southern part of the Flag Cove EBSA, which was identified due to significant and unique aggregations of berried female Lobster.
- The area has been identified as being within or on the fringe of migration pathways for several species such as Herring, Gaspereau, and iBoF Atlantic Salmon.
- The proposed boundary amendments does not impact the location of the site within the existing Bay Management Area. The shift is not expected to increase the risk of pests and pathogen transmission.
- Migrating iBoF Atlantic Salmon may be exposed to pathogens from the site; however, residency near the site is transient and the exposure time is not anticipated to result in infection.
- Physical interactions between the site infrastructure, species at risk (i.e., marine mammals, sharks), and other CRA species in the area are not anticipated due to water depth preferences and/or the transient nature of fish movement in the vicinity of the site.
- While oBoF Atlantic Salmon may be at higher risk of introgression with escapees from the site given its proximity to oBoF rivers, there are 6 rivers containing Critical Habitat for iBoF Atlantic Salmon within 250 km of the site.

Question 2b: How do the impacts on these species from the proposed site compare to impacts from other anthropogenic sources (including existing finfish farms)? Do the zones of influence overlap with these activities and if so, what are the consequences?

- There is spatial overlap between finfish aquaculture activities at the site and other human use activities in the surrounding area. The spatial overlap is not expected to change significantly between the current and proposed site.
- No comparison to impacts from other anthropogenic sources have been made. Presently, the cumulative or interactive consequences of pollution and disturbance on species and habitats are poorly understand.

Question 3: The proponent has used a depositional model to predict the benthic effects of the proposed aquaculture site. Are the predicted benthic effects, as demonstrated by the output of

the depositional model, consistent with the scientific knowledge of the potential impact of this operation?

- The proposed benthic organic footprint is consistent with the benthic-PEZ considerations and present levels of science understanding of the area.
- The accuracy of depositional model estimates for the site will be affected by the net-pen infrastructure, spatial and temporal current variation, and changes to husbandry practices.
- Historical EMP data, currents, and bathymetry of the site suggest that the southward shift of the lease may not mitigate the accumulation of organics on the shallower ledges and intensity of organic loading throughout the site.

Sources of Uncertainty

Model Estimates

The PEZs are based on the current meter data provided by the proponent, information available within DFO data archives, and model runs. The current meter data are from a single location over a 39-day period, and they are qualitatively consistent with independent data and hydrodynamic model predictions for the general area (Appendix B). Both the proponent and first-order estimates assume the current is spatially homogenous and seasonally consistent. The estimates do not consider the temporal and spatial variability in water currents, which may impact estimates of exposure, deposition zones, and intensities. Therefore, the estimates are only a subset of the potential outputs. Validation and sensitivity analyses for depositional models have not been completed in Maritimes Region.

The state of knowledge of in-feed drugs and pesticides released from finfish net pen operations in Canada, including models used to predict exposure zones and associated impacts to susceptible species, is under review by DFO, Health Canada (HC) and Environment and Climate Change Canada (ECCC). The potential risks identified with in-feed drug and pesticide use may change as environmental thresholds and predictive modelling capabilities evolve.

Species and Habitat Distributions

Coastal areas are generally not adequately sampled on spatial and temporal scales of most relevance to aquaculture (i.e., tens to hundreds of meters and hours to months). Information on these scales is generally not contained within the various data sources available to DFO and, additional information on presence and habitat use (i.e., spawning, migration, feeding) must be drawn from larger-scale studies.

Farmed-Wild Interactions

Information is generally lacking on the size and distribution of wild Atlantic Salmon populations. Improved estimates of wild Atlantic Salmon population size and the presence of escapees in rivers surrounding the Bay of Fundy would improve the assessment of genetic and demographic risk. Significant knowledge gaps also exist regarding disease and sea lice infestation levels in wild and farmed Atlantic Salmon, and monitoring and reporting of these levels would be informative. The sensitivity of many wild species to the potential effects of aquaculture operations remains largely unknown.

Potential Cumulative Interactions

Human activity maps should be considered a preliminary and conservative estimate of human uses within the area of interest. Many regional and global-scale human activities that may overlap with local-scale activities were excluded from this analysis, due to limits on data availability and/or spatial resolution. Historical activities that may have legacy effects (e.g., sedimentary contamination) or impacts from natural disturbances (e.g., storms), were not included in the current analysis. Human activities were chosen that occur regularly, constantly, frequently, and/or with some degree of predictability, and, therefore, episodic or infrequent activities that potentially create infrequent but intense disturbances or impacts are not included (e.g., cruise ship track, marine heat wave, hurricane/storm, coast guard rescue event, oil spill, etc.). The geographic extent of human activities is likely a minimum estimate. Assumptions that the influence of human activities diffuse equally in all directions was used, although it is likely that alongshore currents and river plumes influence the diffusion of impacts, particularly close to the coastline.

Additional research is required to determine the types and magnitude of interactions between key activities. Currently, information on the effects of human activities on the different components of the marine environment, or their appropriate decay of impacts in the area is lacking.

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Appendix A: Database Searches Of Species Within the Region of Interest

The search of the Ecosystem Research Vessel (RV) survey resulted in 55 records from 2002–2018 within the zone of influence polygon (Figure A1; Table A1). These records indicated that multiple fish and invertebrate species are in the area to the east and north of the proposed lease site.

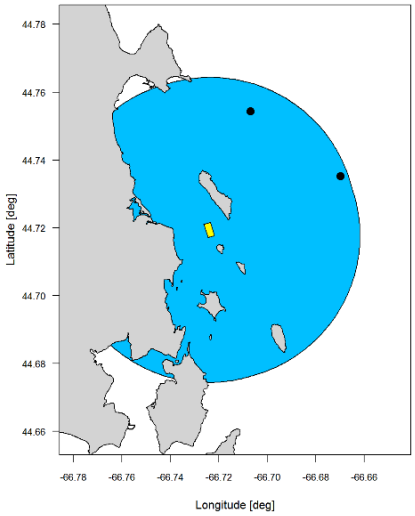

Figure A1. Map showing the location of samples recorded in the Research Vessel (RV) survey database. The yellow polygon indicates the location of the aquaculture site expansion. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 6.

Table A1. Fisheries and Oceans Research Vessel (RV) survey records by species or species group from 2002 to 2018. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 6.

Species	RV Survey Records
ALEWIFE	2
AMERICAN LOBSTER	2
AMERICAN PLAICE	2
ATLANTIC ROCK CRAB	2
BRITTLE STAR	2
HALIBUT (ATLANTIC)	2
HERRING (ATLANTIC)	2
HIPPASTERIA PHRYGIANA	2
LONGHORN SCULPIN	2
PANDALUS BOREALIS	2
PANDALUS MONTAGUI	2
SEA SCALLOP	2
SILVER HAKE	2
SPONGES	2
WHITE HAKE	2
WINTER FLOUNDER	2
ALLIGATORFISH	1

Species	RV Survey Records
BLOOD STAR (GENUS)	1
BUTTERFISH	1
COD (ATLANTIC)	1
DEAD MANS FINGERS	1
FOURBEARD ROCKLING	1
HADDOCK	1
JONAH CRAB	1
LONGFIN SQUID	1
LUMPFISH	1
MUD STAR	1
NORTHERN HAGFISH	1
OCTOPUS	1
PORANIA PULVILIS	1
PTERASTER MILITARIS	1
PURPLE SUNSTAR	1
SEA ANEMONE	1
SHAD AMERICAN	1
SNAKE BLENNY	1
SPINY SUNSTAR	1
SQUIRREL OR RED HAKE	1
TOAD CRAB	1
WITCH FLOUNDER	1

The searches of the Industry Survey Database (ISDB) and Maritime Fishery Information System (MARFIS) resulted in 921 and 2567 records, respectively, within the zone of influence polygon (Figure A2; Tables A2 and A3). These records indicated that multiple fish and invertebrate species are in the area both completely surrounding the lease and also within the proposed lease area. The baseline surveys conducted by the proponent found 6 of 18 stations with live scallops.

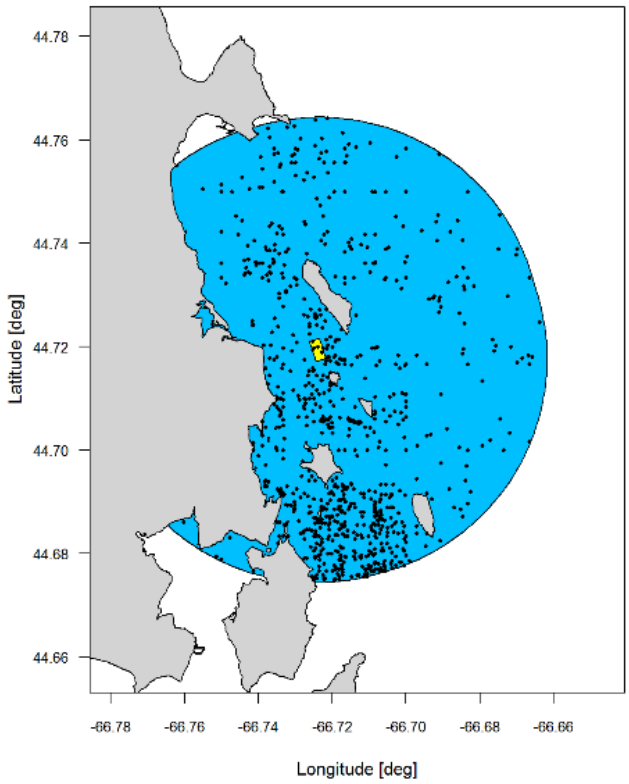

Figure A2. Maps showing the location of samples recorded in the ISDB and MARFIS databases. The yellow polygon indicates location of the aquaculture site expansion. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 6.

Table A2. Industry Survey Database (ISDB) records by species or species group from 2002 to 2018. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 6.

Species	ISDB Records
SEA URCHINS	135
SEAWEED, ALGAE, KELP	125
HERMIT CRABS	121
MUSSELS (NS)	104
SHRIMP	73
GREEN CRAB	46
ATLANTIC ROCK CRAB	45
SCULPINS	35
WINTER FLOUNDER	32
SEA SCALLOP	28
AMERICAN LOBSTER	18
HERRING (ATLANTIC)	18

Species	ISDB Records
STONES AND ROCKS	13
FOREIGN ARTICLES, GARBAGE	12
SEA RAVEN	12
LONGHORN SCULPIN	10
SILVER HAKE	10
PANDALUS BOREALIS	9
SCALLOP SHELLS	8
HALIBUT (ATLANTIC)	6
LUMPFISH	6
CRANGON SP.	5
AMERICAN PLAICE	4
LEMONWEED	4
OCEAN POUT (COMMON)	4
WITCH FLOUNDER	4
JONAH CRAB	3
SEA MOUSE	3
SQUIRREL OR RED HAKE	3
WHITE HAKE	3
ASTEROIDEA S.C.	2
HADDOCK	2
SCULPIN (NS)	2
SMOOTH SKATE	2
SPINY DOGFISH	2
TOOTHED WRACK	1
ALEWIFE	1
CANOE SHELLS	1
COD (ATLANTIC)	1
EELPOUTS (NS)	1
LITTLE SKATE	1
MUSCULUS NIGER	1
NORTHERN STONE CRAB	1
PANDALUS MONTAGUI	1
SAND	1
SAND DOLLARS	1
SAND LANCES (NS)	1
SKATES (NS)	1

Table A3. Maritime Fishery Information System (MARFIS) records by species or species group from 2002 to 2018. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 6.

Species	MARFIS Records
SEA URCHINS	995
SEA SCALLOPS	535
HERRING	373
HADDOCK	119
COD	109
POLLOCK	104
WHITE HAKE	94
SHRIMP, PANDALUS BOREALIS	63
REDFISH	28
JONAH CRAB	23
HALIBUT	23
HAGFISH	21
WINTER FLOUNDER	19
MONKFISH	13
AMERICAN PLAICE	7
GREYSOLE/WITCH	7
WOLFFISH, STRIPED	7
FLOUNDER, UNSPECIFIED	6
LOBSTER	6
SWORDFISH	4
SCULPIN	3
TUNA, BLUEFIN	3
CATFISH	2
YELLOWTAIL	2
DOGFISH	1

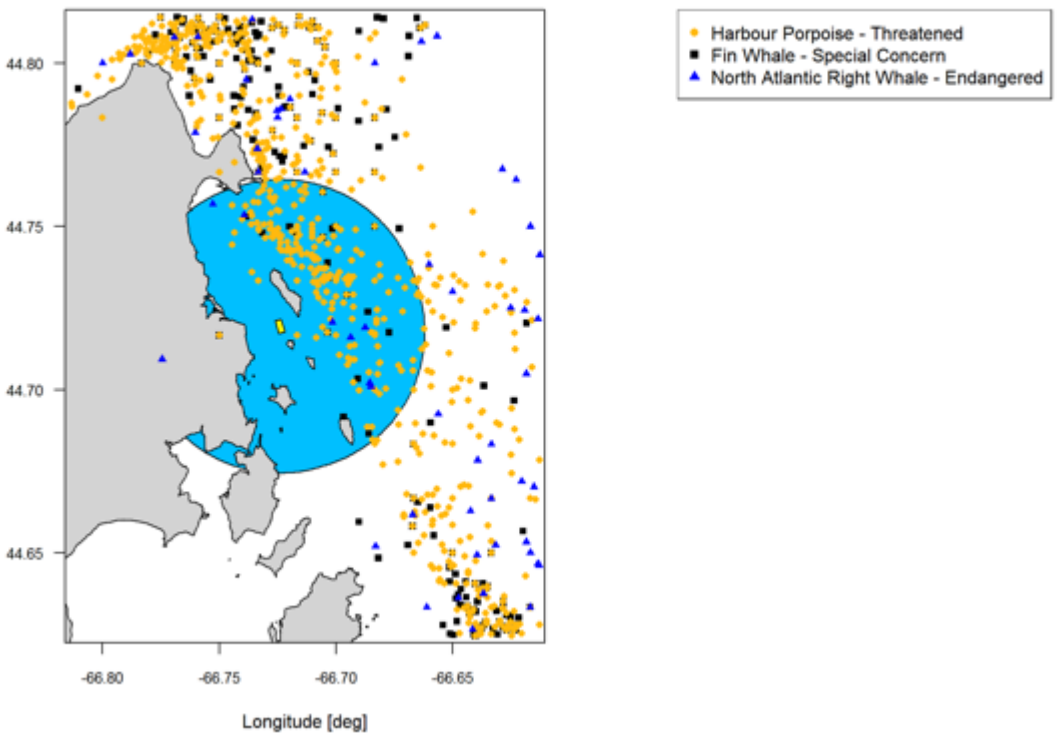

Figure A3. Map showing sightings that have been reported to and recorded in the Fisheries and Oceans whale sightings database of three COSEWIC and SARA*-listed species. Records of this database are from 1963 to 2018. The blue polygon displays estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 6.*

Appendix B: Description of DFO Modelling

Part A: Description Of Predicted Exposure Zone Calculations

The approach undertaken to providing an assessment of the likely impacts from a new or amended site is a triage-analysis based approach. An initial first order estimate of the benthic and pelagic exposure zones is calculated to determine broadly whether or not these zones overlap with critical habitats, and the likely impacts with CRA fisheries, SARA-listed species, or key species that are known to be sensitive or vulnerable to specific aquaculture inputs. These predicted exposure zones are intentionally conservative overestimates to determine whether or not there is anything within a larger area of concern that warrants further refinement of the spatial extent, intensity and/or duration of anticipated interactions. Otherwise, the triage analysis is considered sufficient for analyzing, albeit at a larger spatial scale, the likely impacts from the proposed activity.

Part B: Additional Hydrodynamic Modelling

A 3D baroclinic ocean circulation model, Finite Volume Coastal Ocean Model (FVCOM), was implemented for southwest New Brunswick to study regional oceanographic properties and issues originating from aquaculture activities. Preliminary comparisons of model results to observations in the region close to Farmer's Ledge show strong agreement.

There are three Acoustic Doppler Current Profiler (ADCP) records in close proximity to the proposed boundaries of the MF-0002 aquaculture site during the 2016-2018 period: two three-month deployments in 2016 by Fisheries and Oceans Canada (ADCP 594 and ADCP 595) and a one-month deployment in 2018 by the proponent. The locations of the ADCPs are displayed in Figure B1 overlaid with the model's horizontal resolution. The proponent's ADCP is located within the proposed lease boundaries. Relative to the location of the proponent's ADCP, ADCP 594 and ADCP 595 are 2766 m and 6452 m away, respectively.

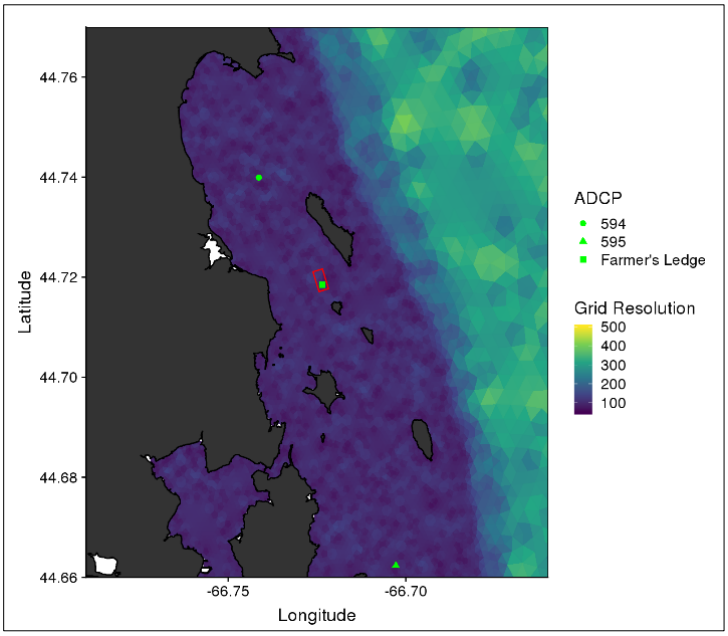

Figure B1. Model horizontal grid resolution in meters in the area around the proposed site. The proposed site is displayed as the red rectangle. Three Acoustic Doppler Current Profiler (ADCP) locations are denoted by the green icons. ADCP 594 (circle), ADCP 595 (triangle), Proponent ADCP (square).

The tidal currents from the model have been compared to the three ADCPs and, overall, agree well. The currents were compared at 2, 5, and 10 m below the surface; however, only the 5 m current plots and statistics are presented here (due to observational data gaps and 5 m below the surface approximately corresponding to depth of the fish nets. A five day subset of the time-series at 5 m below the surface are in Figure B2.

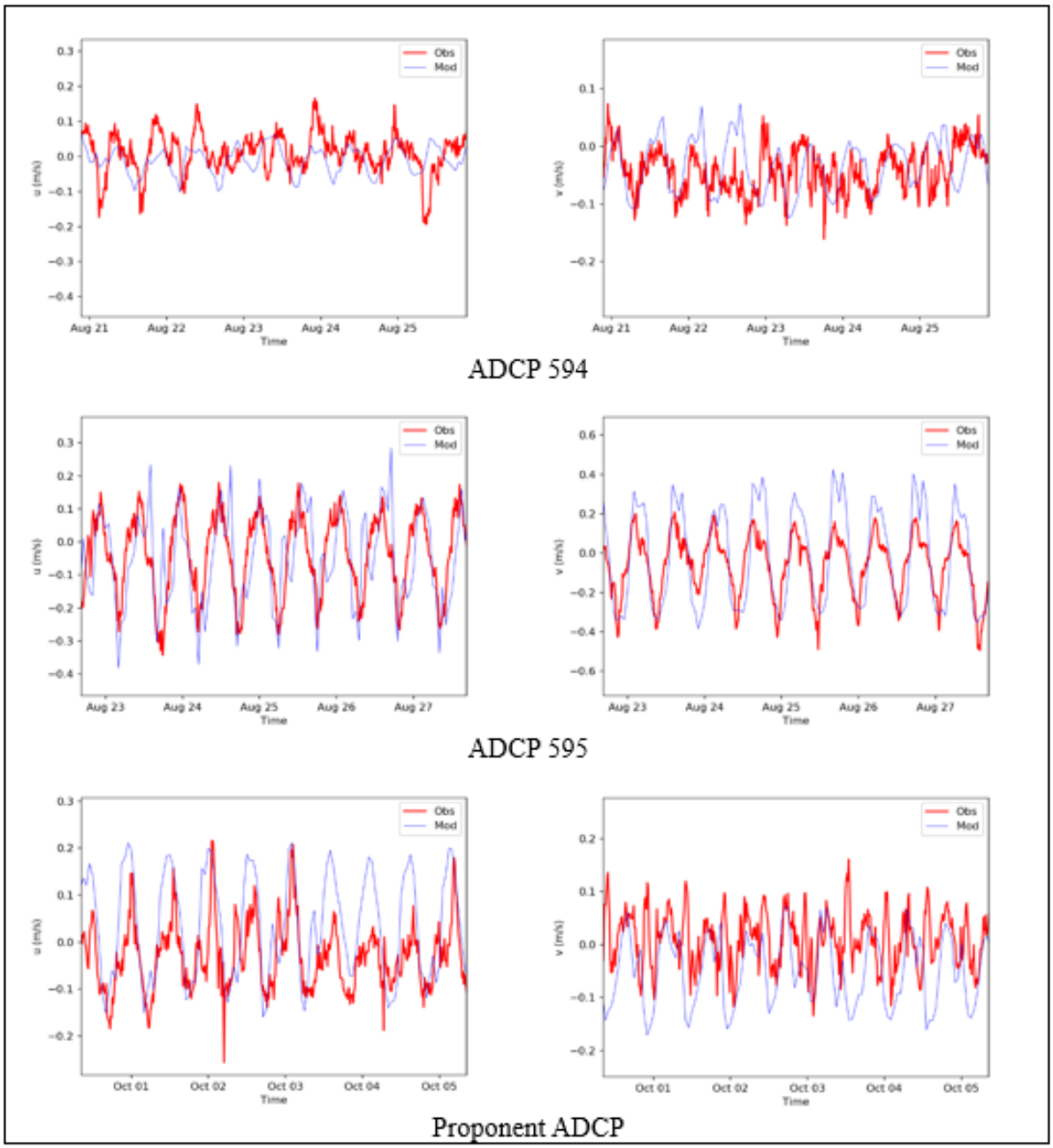

Figure B2. Five day time-series of the velocity for both the model and Acoustic Doppler Current Profilers (ADCP) at 5 m below the surface. The left column is the u-component (east-west), right column is the v-component (north-south). Observations (red) Model (blue).

The above hydrodynamic model was used as input into a particle tracking model to advect particles and simulate a specific release scenario from the proposed site to illustrate the usefulness of the PEZ approach. A horizontal diffusion of 0.1 m^2s^{-1} was used (Page et al. 2015). Particle movement in the vertical was a combination of the vertical water currents predicted by the FVCOM model and a specified sinking speed based on the type of particle being simulated (i.e., feed = 5.3 cm s^{-1} and azamethiphos = 0 cm s^{-1}).

Particles were released hourly for 13 hours starting 2 October 2019 12:00 UTC. The particles were tracked until the particle reached the bottom for feed or until the specified dilution time for azamethiphos. For sinking particles, only the final location (i.e., where the particle is on the bottom) is shown (Figure B3 top), whereas for non-sinking particles, all positions during the transect time are plotted (Figure B3 bottom).

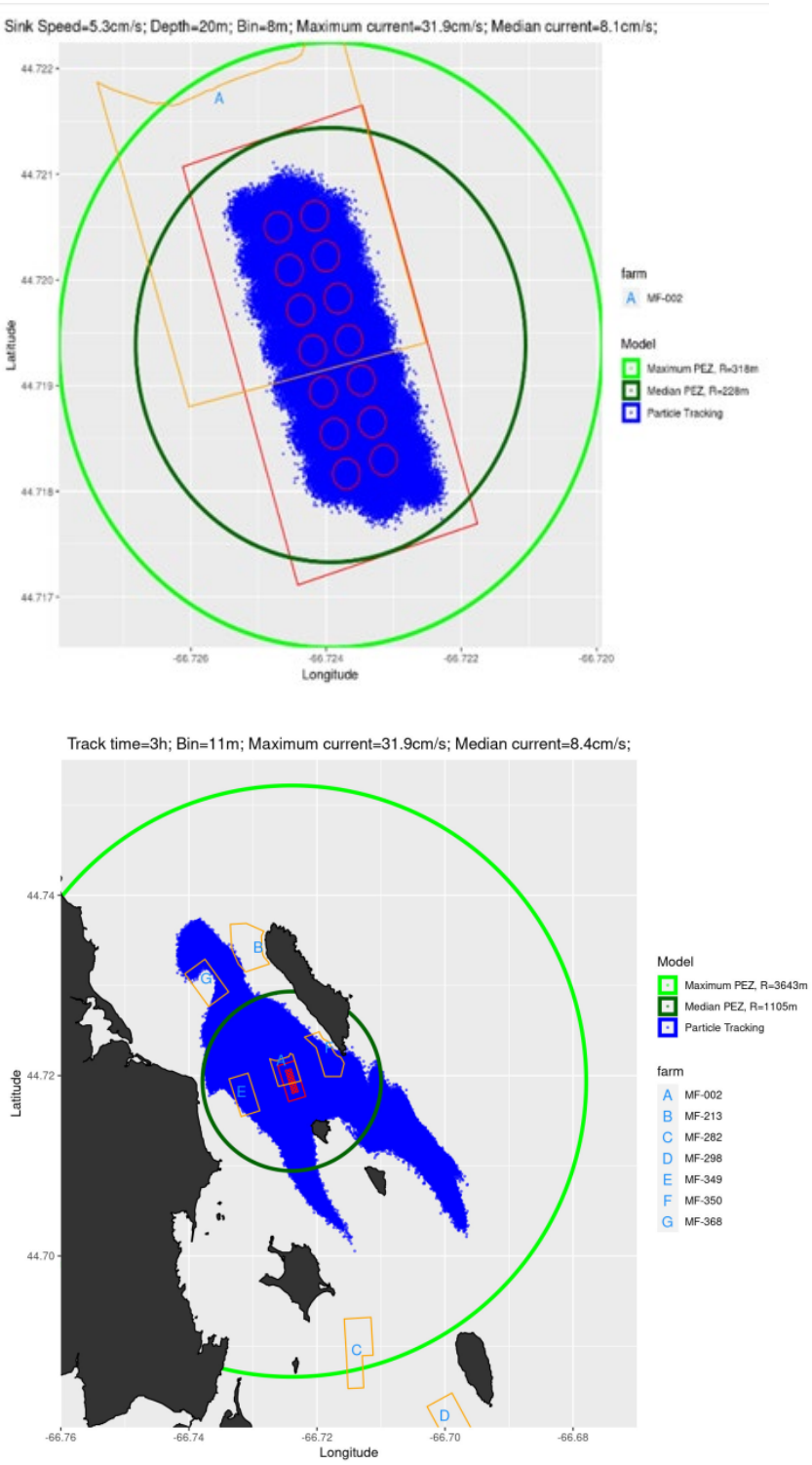

Figure B3. Results of the FVCOM particle tracking model are shown in blue. Benthic- (top) and pelagic- (bottom) Predicted Exposure Zones (PEZs) using the maximum (light green arc) and median (dark green arc) currents are overlaid. Existing lease boundaries of all aquaculture sites in the area, including MF-0002 are shown in orange and the proposed lease boundaries are shown in red.

Results of the particle tracking model illustrate two important points. Firstly, the maximum current is the appropriate metric to use for calculating both benthic and pelagic PEZs as the median current does not capture the maximum range of the displaced particles with small or zero sinking speeds. Secondly, the maximum PEZ encompasses the total footprint of impact but the footprint does not fill the entire PEZ. Care should be taken in interpreting this result. The preliminary illustrated results of the particle tracking model were for a single tidal cycle forced with a hydrodynamic model that has not yet been fully calibrated and validated for the area. Depending on the timing and frequency of release, specific details of the footprint will vary. Thus, the FVCOM modelled footprints should not be used to determine the potential zones that sensitive habitats and species may be exposed.

Appendix C: Organic Enrichment Interactions

Table C1. Levels of carbon flux to bottom soft sediment and corresponding levels of sediment free sulfide and qualitative effects on marine sediment biodiversity (based on Hargrave 2010).

Flux of Grams Carbon ($gC/m^2/d$)	Mean Sediment Sulfide (µM)	Sediment Classification in Terms of Sediment Oxygen	Effect on Marine Sediment Macro Infaunal Biodiversity
<1	<750	Oxic A	Low effects
1	750		Low effects
	750−1499	Oxic B	Low effects
2.5	1500		
	1500−2999	Hypoxic A	May be causing adverse effects
5	3000		
>5	3000−4499	Hypoxic B	Likely causing adverse effects
	4500−5999	Hypoxic C	Causing adverse effects
10	6000		
>10	>6000	Anoxic	Causing severe damage

Appendix D: Cumulative Occurrence of Human Activities

Spatial data for marine activities within a 5 km radius of the Farmer's Ledge location (hereafter the "area of interest") were collated from a larger inventory of human activities developed for the Maritimes region (Kelly, unpublished). Human activities were selected that occur on a "local" scale, defined as those operating over small spatial scales (i.e., <10 km) or from point-sources that could produce a localized zone of impact, such as marine recreation, aquaculture, or benthic structures. Episodic or ephemeral activities (e.g., coast guard activities, etc.) that may overlap with the area of interest were not included because these datasets were incomplete, had a lower spatial resolution, and/or were unavailable at the time. The most recent years of data or up-to-date information were included when possible.

The spatial distribution of commercial fishing activities in the area of interest was represented by commercial landings for scallop and lobster. While the spatial resolution of the lobster landings data is coarse (and thus spans the entire 5 km area of interest), it is included due to the consistently high level of fishing activity recorded over recent seasons (see Figure 4). Commercial benthic, pelagic, and recreational and Aboriginal fisheries occur throughout the area of interest, but either no spatial data were available to map the activity, or were not adequately sampled at the required spatial resolution to be included.

To estimate the geographical extent of each activity beyond its location of occurrence, a buffer was added that radiates from the point source of the activity. The furthest distance from the activity's origin was determined for the same or most similar activity based on extensive reviews presented in Ban and Alder (2008), Ban et al. (2010) and/or Clarke Murray et al. (2015) ("buffer radius"; see Table D1). The radius for all 5 finfish aquaculture sites in the area of interest were taken from the PEZ model for 3-hr pesticides, based on the maximum current speeds (Tables 2, D1). The pelagic-PEZ considers the potential exposure of species to pesticides and drugs used in finfish aquaculture operations, but also overlaps with the organic matter depositional zone for waste feed and feces. Thus, the pelagic-PEZ was used as a buffer distance to represent the maximum occurrence of both benthic and pelagic potential impacts.

The impact of land-based activities on coastal environments is more difficult to determine than for activities that occur directly in marine waters. A search through the human activity inventory (Kelly, unpublished) yielded information on the locations of roads and buildings on Grand Manan Island occurring within the area of interest, but no major industrial activities. To incorporate the potential impacts of runoff and pollution from these land-based sources, the location of pour points was used for the two largest watersheds draining into the coastal area within the area of interest (Kelly, unpublished data). As both pour points converge within a coastal lagoon, the drainage location of the lagoon into the coastal zone was used as a single pour point. The buffer radius of these land-based inputs were estimated from the stream orders of the rivers (after Clarke Murray et al. 2015).

A visual representation of the pattern of human use can help illustrate the distribution of human activities in the ocean. A GIS approach (ESRI ArcGIS version 10.6.1) was used to map each activity and its associated buffer. The map was then converted to a raster (100 m x 100 m grid). Where activities (and their buffers) overlapped, the values in the grid cell were added to estimate the total number of overlapping human activities per grid cell.

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