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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2022/002

REVIEW OF THE MARINE HARVEST ATLANTIC CANADA INC. AQUACULTURE SITING BASELINE ASSESSMENTS FOR THE SOUTH COAST OF NEWFOUNDLAND

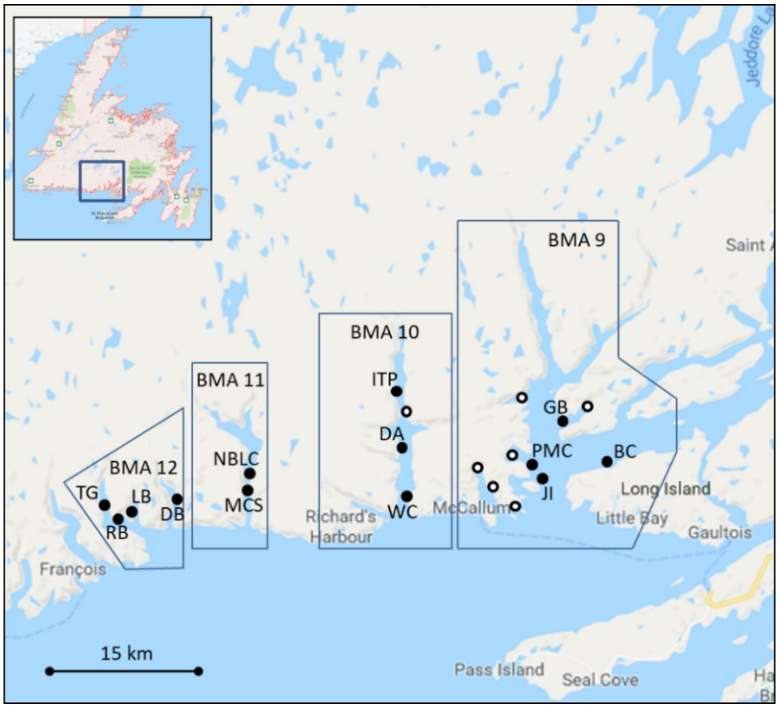

Figure 1. Location of the proposed aquaculture sites (solids circles) on the south coast of Newfoundland within the Bay Management Areas (BMA) 9-12. BC: Butter Cove, GB: Goblin Bay, PMC: Pass My Can, JI: Jervis Island, ITP: Indian Tea Point, DA: Dennis Arm, WC: Wild Cove, NBLC: North Bob Locke Cove, MCS: Mare Cove South, DB: Devil Bay, LB: Little Bay, TG: The Gorge, RB: Rencontre Bay. Open circles represent existing aquaculture sites.

Context:

Marine Harvest Atlantic Canada Inc. (MHAC) submitted applications to the Province of Newfoundland and Labrador (NL) for 13 finfish aquaculture site licenses at various locations on the south coast of Newfoundland. As per the Canada-Newfoundland and Labrador Memorandum of Understanding on Aquaculture Development, the Newfoundland and Labrador Department of Fisheries and Land Resources has forwarded these applications to Fisheries and Oceans Canada (DFO) for review and advice in relation to DFO's legislative mandate. In accordance with the Aquaculture Activities Regulations (AAR), the Proponent submitted a Baseline Assessment Report and Addendum for each site/license.

This Science Advisory Report is from the May 28-31, 2019 Regional Peer Review Process for the Review of the Marine Harvest Atlantic Canada Aquaculture Siting Baseline Assessments. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

September 2022

SUMMARY

- The review of the 13 site applications for Atlantic Salmon aquaculture farms was conducted using the baseline assessments provided by the Proponent as required by the Aquaculture Activities Regulations (AAR), and other relevant scientific data, to evaluate the potential habitat and species interactions.
- Fisheries and Oceans Canada (DFO) is currently developing a consistent approach for the scientific evaluation of marine siting applications for finfish aquaculture. This review is the first implementation of this approach in the Newfoundland and Labrador (NL) Region.
- The Proponent used a depositional model (DEPOMOD) to predict the benthic carbon footprint of the proposed aquaculture sites. DFO Science used potential exposure zone (PEZ) calculations to provide an estimate of the spatial scale of PEZs but these do not quantify intensity or duration of exposure nor include a frequency of exposure.
- The two models provided similar results. There was an overlap between the mean benthic PEZ and the DEPOMOD outputs.
- Discussions related to approved drug and pesticide usages were limited to spatial considerations.
- Cumulative effects of biochemical oxygen demand, drugs, and pesticides were not discussed.
- Each of the sites was assessed for the presence of sensitive species, species listed under the *Species at Risk Act*, and sensitive habitats. At six of the sites, cold-water corals (e.g. sea pens), which are indicators of vulnerable marine ecosystems, were identified. At the Little Bay site, sea pens, which are known nurseries for redfish, were detected under the proposed cage array. The population-level effect of potential impacts was not assessed due to a lack of information available on the density and distribution of these species throughout the region.
- Sea lice pose a threat to the wild Atlantic Salmon populations. It is anticipated that the addition of sites will increase the presence of sea lice and, therefore, sea lice treatments.
- Assessments of wild Atlantic Salmon population status in the area are limited; however, existing counting fences indicate significant and consistent ongoing declines (approximately 80% over three generations), the cause of which is not fully understood. These populations are in the Critical Zone (below 100% conservation egg requirement). Moreover, existing data has documented the presence of escaped farmed salmon and hybridization between wild and farmed Atlantic Salmon throughout Salmon Fishing Area (SFA) 11.
- The assessment of the potential genetic impacts on Atlantic Salmon populations along the south coast of Newfoundland was completed based on the best available scientific data (North American and European) and the size and location of the existing and proposed sites. The proposed scale of expansion is predicted to result in an increased number of escapees in southern Newfoundland rivers largely in the Bay d'Espoir area compared to present operations. These increases are predicted to be associated with demographic decline and genetic change, though there is uncertainty as to the magnitude of both.
- Mitigation measures proposed by the Proponent to reduce the frequency of escape events were not included in the empirical predictions. These mitigation measures have been shown to be effective in other jurisdictions.

BACKGROUND

Marine Harvest Atlantic Canada Inc. (MHAC) submitted applications to the Province of Newfoundland and Labrador for 13 aquaculture site licenses for Atlantic Salmon (*Salmo salar*). These sites are located within the provincial Bay Management Areas (BMAs) 9-12 on the south coast of Newfoundland within Hare Bay, Facheux Bay, Bay d'Espoir, and Rencontre Bay (Figure 1). Of the 13 sites, seven sites have no history of aquaculture activity, while six sites were previously licensed to Gray Aqua Group Ltd. Within BMA 9, there are currently seven licensed Atlantic Salmon aquaculture sites while BMA 10 has one licensed Atlantic Salmon site. In this report, a site is defined as the proposed lease area encompassing the cage array, all mooring lines, and anchors.

As per the Canada-Newfoundland and Labrador Memorandum of Understanding on Aquaculture Development, the NL Department of Fisheries and Land Resources has forwarded the applications to DFO for review in relation to DFO's legislative mandate. The applications are supplemented by information collected by the Proponent as required under the AAR. This information includes substrate characterization of the lease areas, fish and fish habitat surveys, and predictive modeling of Biochemical Oxygen Demanding (BOD) matter deposition at expected peak biomass.

To help inform DFO's review of these applications, the NL Regional Aquaculture Management Office asked DFO Science three questions:

1. Based on the available data for the site and scientific information, what is the expected exposure zone from the use of approved fish health treatment products in the marine environment, and the predicted consequences to susceptible species?
2. The Proponent has used a depositional model to predict the benthic effects (i.e., deposition of BOD matter) of the proposed aquaculture sites. Are the predicted benthic effects, as demonstrated by the output of the model used by the Proponent, consistent with the scientific knowledge of the potential impact of this operation?
3. 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, Commercial, Recreational, and Aboriginal (CRA) species and species vulnerable to aquaculture impacts? Are there predicted consequences to any critical or valuable habitats for species at risk, key CRA species?

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

1. Estimate the Potential Exposure Zones (PEZ) associated with:
   a. the deposit of the majority of uneaten food and faeces;
   b. use of regulated drugs;
   c. use of regulated pesticides; and
   d. pests and pathogens.
2. Identify the species and habitats within each PEZ that would be susceptible to interactions/impacts associated with each exposure/pathway type. For example:
   a. effect of smothering from the deposit of excess feed and faeces;
   b. toxicity of approved drugs used in aquaculture;
   c. toxicity of approved pesticides; and

   d. disease associated with pests and pathogens (farm-to-farm; farm-to-wild).

3. Assess the consequences of these exposures, including:
   a. spatial/temporal extent of site-specific impacts;
   b. importance of the exposure area to life processes of susceptible fish species (*Species at Risk Act* [SARA], CRA); and
   c. relative to population-level impacts, considering status (SARA status, relative to reference points) and management regime.
4. Beyond the PEZ, identify other possible interactions of interest to DFO, associated with the site, specifically:
   a. entanglement and displacement of wild species (e.g., marine mammals, turtles, sharks, tunas);
   b. smothering of habitat or species associated with placement of infrastructure;
   c. attraction of wild species to the site (e.g., sharks, marine mammals); and
   d. for conspecific species, genetic interactions of Atlantic Salmon.

Fisheries and Oceans Canada is currently developing a consistent approach for the scientific evaluation of marine site applications of finfish aquaculture. The approach includes a first order or triage analysis that estimates the benthic and pelagic exposure zones and the potential for physical and genetic interactions within the estimated exposure zones at the proposed sites. A review of the approach used by DFO to assess individual aquaculture site applications and site expansions going forward is underway, but has not yet been completed. The review of these siting applications is the first implementation of this approach in the NL Region.

ANALYSIS

Data Sources

Information to support this review includes data and information from the Proponent, data holdings within DFO, and publicly available literature.

The following information was submitted to DFO by the Proponent:

- Baseline Assessment Report and associated video for each site application;
- Baseline Assessment Report Addendum for each baseline report; and
- Mare Cove South Sediment Grab Trials report.

Site Description

General descriptions of the proposed sites are provided in Table 1.

Table 1. General site description of the 13 proposed sites within Bay Management Areas 9–12.

Site	BMA	Last Year of Production	Lease Depth Range (m)	Cage Array Depth Range (m)	Acoustic Doppler Current Profiler Deployment Dates	Nearest Salmon River	Lease Surface (ha)	% Cover by Cage Array (ha)	Benthic Survey
Goblin Bay	9	2013	2–312	60–160	09/10/2017 to 27/11/2017	d'Espoir Brook (16 km) Salmon River (20 km)	103.47	7.8	all lease
Butter Cove	9	2012	2–338	55–120	12/08/2017 to 12/09/2017	Little River (33 km) Conne River (38 km) d'Espoir Brook (26 km)	248.5	3.3	all lease
Pass my Can	9	2013	2–250	70–150	09/10/2017 to 27/11/2017	Salmon River (20 km) Allen Cove Brook (29 km) d'Espoir Brook (23 km)	144	5.6	all lease
Jervis Island	9	Unused but previously licensed	2–332	60–180	09/10/2017 to 27/11/2017	d'Espoir Brook (24 km) Salmon River (22 km)	241.52	3.3	stations <300 m
Indian Tea Point	10	2015	2–302	150–250	16/08/2017 to 15/09/2017	Allen Cove Brook (4.7 km) Bottom Brook (13 km)	161	5	all lease
Wild Cove	10	New site	4–302	140–250	09/10/2017 to 28/11/2017	Allen Cove Brook (5.5 km) Bottom Brook (6.3 km)	292.3	2.8	stations <300 m
Dennis Arm	10	New site	1–380	57–298	09/10/2017to 28/11/2017	Allen Cove Brook (8 km) Bottom Brook (16.3 km)	281.8	2.9	stations <300 m
Mare Cove South	11	2016	2–204	160–180	16/08/2017 to 15/09/2017	Dolland Brook (11 km) Morgan Brook (8.5 km)	91.29	8.9	all lease
North Bob Lock Cove	11	New site	1–188	150–188	13/08/2017 to 12/09/2017	Dolland Brook (9.5 km) Morgan Brook (6.7 km)	67.45	12	all lease
Devil Bay	12	New site	21–148	80–130	10/10/2017 to 28/11/2018	Dolland Brook (25 km)	95.46	8.5	all lease
Rencontre Bay	12	New site	7–194	130–190	10/10/2017 to 28/11/2018	Dolland Brook (28 km)	64.7	12.5	200 m around cage array
Little Bay	12	New site	1–250	215–240	10/10/2017 to 28/11/2018	Dolland Brook (29 km) Grey River (50 km)	89	9.1	200 m around cage array

Site	BMA	Last Year of Production	Lease Depth Range (m)	Cage Array Depth Range (m)	Acoustic Doppler Current Profiler Deployment Dates	Nearest Salmon River	Lease Surface (ha)	% Cover by Cage Array (ha)	Benthic Survey
The Gorge	12	New site	2–159	120–150	09/05/2018 to 14/06/2018	Dolland Brook (30 km)	86.8	10.3	200 m around cage array

Oceanographic Conditions

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

Bathymetry

The proposed sites are located within inlets at the mouth or middle of an inlet, in small coves, or along the coastline. The lengths of the inlets vary from 5-10 km while the widths vary from a few hundred meters to a few kilometers.

Many of the proposed sites are located on sloping bottom (i.e., water depths are highly variable within a site and not constant under the cage arrays or within the near-vicinity of the array; the depths can span more than 100 m [Figure 2, Table 1]).

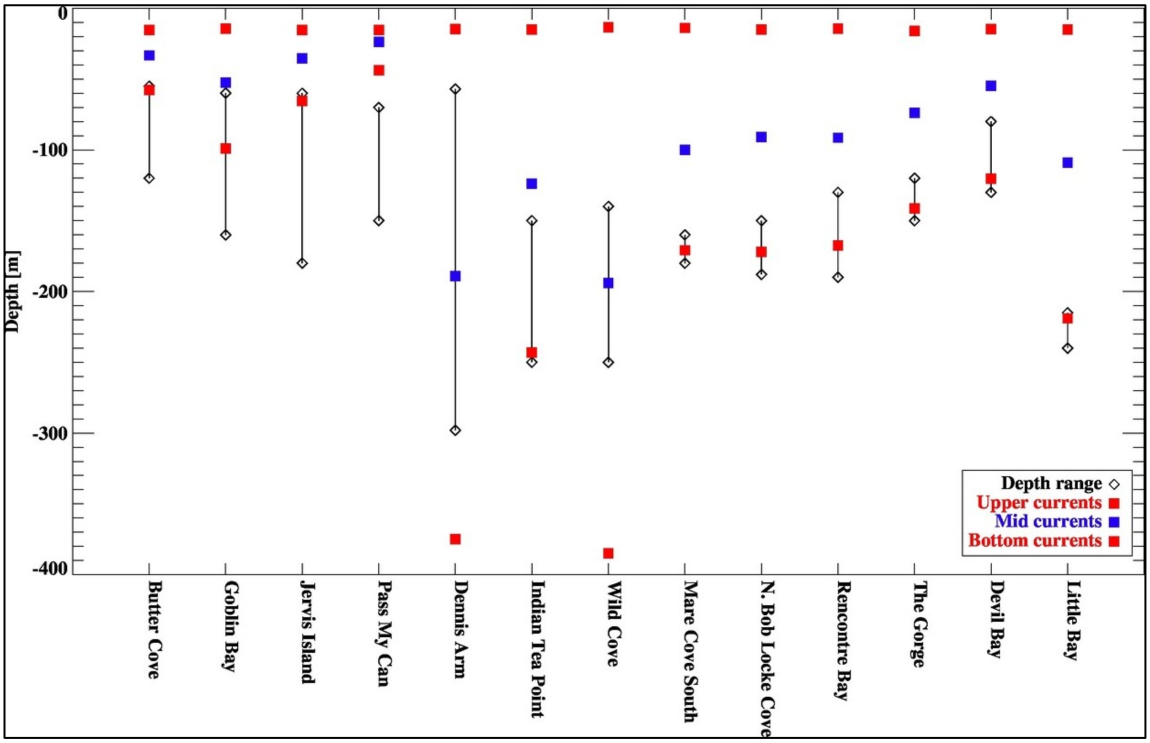

Figure 2. Depth range (m) under the cage arrays (black line with diamonds) and depths of current data series (squares) used as input for DEPOMOD and PEZ calculations at each of the proposed aquaculture sites.

Currents

Water currents are an essential and critical input to estimations of the zone of exposure associated with the release of BOD organic matter, pesticides and drugs from any farm site.

Water current data was collected over a period of 30 to 49 days and followed the requirements of the AAR. Information on the water currents in each of the proposed sites was provided by the Proponent. Acoustic Doppler Current Profiler (ADCPs) were deployed at a single location and configured to measure ensemble average horizontal currents at 15-minute intervals (Table 1). Most of the current meter moorings were within the boundary of the proposed cage array and near the center of the array. Water currents from a single location, particularly in areas where water depth varies, may not be representative of water velocity field throughout site or potential zones of exposure, especially near the bottom (Figure 2)

Currents were reported at near surface, upper, mid-water, and near bottom depths (Table 2). The maximum water current speed at each site and depth is approximately five times the mean speed. 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 is consistent with finding in Ratsimandresy et al. (2019), which highlighted the variability of the currents in the region.

Table 2. Mean and maximum (max) current speeds at analyzed depths at each of the proposed sites.

Site	Near surface (cm/s)			Upper (cm/s)			Mid-water (cm/s)			Near Bottom (cm/s)		
	Mean	Max	Depth (m)	Mean	Max	Depth (m)	Mean	Max	Depth (m)	Mean	Max	Depth (m)
Devil Bay	5.1	25.3	6.8	3.7	21.8	14.8	2.9	13.6	54.8	2.6	10.1	120.4
Rencontre Bay	4.2	26.2	10.3	4.0	23.5	14.3	3.1	16.3	91.4	1.8	15.5	167.4
Little Bay	6.1	36.5	7.	5.3	32.8	15.	4.9	22.2	109.	3.9	19.8	219.
The Gorge	7.0	38.7	4.7	4.5	20.2	15.9	2.4	9.5	73.8	3.0	8.9	141.4
Mare Cove South	13.6	61.7	9.9	14.1	48.9	13.9	4.0	33.0	100.	5.7	29.5	170.9
North Bob Locke Cove	9.6	36.8	5.	11.0	55.5	15.	6.7	30.1	91.	5.0	22.9	172.
Indian Tea Point	5.9	36.4	5.	4.5	42.1	15.1	3.7	15.4	124.	3.2	12.0	243.2
Wild Cove	ND	ND	ND	8.0	44.5	13.3	1.7	11.5	194.	2.0	5.6	385.
Dennis Arm	8.6	50.3	6.7	6.6	39.8	14.7	2.0	11.0	189.3	1.0	3.9	375.
Goblin Bay	6.7	27.9	4.5	5.6	28.8	14.5	3.4	16.4	52.6	1.5	7.8	99.
Butter Cove	9.6	58.4	5.3	7.6	28.3	15.3	5.0	23.7	33.3	3.1	18.7	57.8
Pass-My-Can	7.8	39.7	5.3	6.9	31.0	15.3	6.4	34.1	23.7	3.8	26.3	43.7
Jervis Island	14.0	48.3	5.5	12.5	49.6	15.5	10.2	51.0	35.5	4.8	21.3	65.4

ND = no data.

Pesticide and Drug Use

Consideration of exposure to chemicals has become an important consideration for regulators. The Canadian commercial finfish aquaculture industry as a whole has been required to report on its use of chemicals since 2015. During the 2016 and 2017 calendar years, nine approved chemicals were reported as having been used within Canada. Publicly available summaries of the approved chemicals are available from the government of Canada Open Government Portal, specifically through the National Aquaculture Public Reporting Data website.

A brief description of each pesticide and drug is provided in the Appendix.

In response to the request for advice associated with approved aquaculture products for fish health treatments, a first order estimate of the PEZs for potential chemical use was completed.

Pesticides

Hydrogen peroxide (PMRA 2017) and azamethiphos (PMRA 2017) are currently the only approved pesticides for use by the finfish aquaculture industry in Canada. These pesticides are unlikely to persist in the environment and, if used as per Health Canada’s Pest Management regulatory guidelines, are unlikely to cause significant harm to non-target populations (PMRA 2016, PMRA 2017).

Drugs

The use of the following drugs have been reported by the finfish aquaculture industry in Canada: emamectin benzoate, ivermectin (in-feed anti-parasitic drugs), oxytetracycline, florfenicol, erythromycin, ormetoprim and trimethoprim (in-feed antibiotics) and drugs made available through Health Canada emergency drug release program (e.g., lufeneron).

POTENTIAL EXPOSURE ZONES

Spatial Extent of Exposure

First order calculations for PEZs (using PEZ model) were used to provide an order of magnitude estimate of the size and locations of areas that may be exposed to a substance introduced into, or released from, each of the proposed sites. The PEZ is a circular zone centered over the middle of the proposed cage array and represents the outer limit for potential exposure. The circular zone of the PEZ may encompass terrestrial areas; however, PEZs are limited to the aquatic environment. The PEZs are not restricted to the spatial domain bounded by the fish cages, net-pens and other husbandry containment structures such as well-boats. These calculations provide an estimate of the spatial scale of the PEZ but do not quantify the intensity or duration of exposure, nor include a frequency of exposure and are not considered zones of impact. As a result, the PEZs are likely an overestimate of exposure. Additional information on the approach are provided in (Page et al. unpublished manuscript[1]).

Estimates of seabed exposure to organic releases from finfish farm operations require information concerning the farm layout, feeding practices and the near and far-field oceanographic conditions. The main inputs are information on the bathymetry, water current, and husbandry.

The PEZs are calculated using the site mean and maximum current speeds (Table 2), and typical settling rates.

The sinking particle estimates of the extent of the exposure zone are relevant to both the potential for exposure to organic loading, drugs, and antibiotics since the drugs and antibiotics are administered as in-feed additives. Since the near bottom currents are reasonably strong at times, the length scale of the PEZs may vary temporally and be increased by benthic resuspension. The length scale is an estimate of the major axis of the depositional zone.

The estimate of the expected benthic exposure to organic effluent (Table 3) was based on the following assumptions and calculations:

- Although the sinking rate of fish feed varies, it is designed to sink at a reasonably consistent rate, so the fish have an adequate time to feed. For the following calculations, a fish feed sinking rate (w_s) of 0.1 m/s and a fish fecal sinking rate of 0.02 m/s has been assumed.
- Mid-water depth (25 m) and surface (15 m) current estimates (*V*) are used to estimate exposure zones for sinking and non-sinking particles, respectively.
- First order estimates of the sinking times have been estimated as $\mathrm{H}/\mathrm{w_s}$, with *H* defined as the maximum water depths under the proposed cage arrays.
- The horizontal distances travelled by the sinking waste feed and faeces have been estimated as VH/Ws.

[1] Page, F., Haigh, S., and O'Flaherty-Sproul, M. In prep. Potential Exposure Zones for Proposed Newfoundland Marine Finfish Salmon Aquaculture Sites: Initial First Order Triage Scoping Calculations and Consistency Comparisons. DFO. Can. Sci. Advis. Sec. Res. Doc.

Table 3. Estimates of maximum potential exposure zones associated with waste fish feed and faeces for each proposed site.

Site	Maximum Water Depth (m)	Maximum Water Current (25 m) ($cm \cdot s^{-1}$)	Horizontal Displacement (km)		Radius of Circular Exposure Zone (km)	
			Feed	Faeces	Feed	Faeces
Goblin Bay	312	16.4	0.51	2.56	0.71	2.76
Butter Cove	338	23.7	0.79	4.01	0.99	4.21
Pass-My-Can	250	34.1	0.86	4.26	1.06	4.46
Jervis Island	332	51.0	1.68	8.48	1.89	8.68
Indian Tea Point	302	15.4	0.46	2.33	0.66	2.53
Wild Cove	320	11.5	0.35	1.73	0.55	1.93
Dennis Arm	298	11.0	0.33	1.64	0.53	1.84
Mare Cove South	204	33.0	0.67	3.37	0.88	3.57
North Bob Locke Cove	188	30.1	0.56	2.84	0.76	3.04
Devil Bay	148	13.6	0.20	1.00	0.41	1.21
Rencontre Bay	194	16.3	0.31	1.58	0.52	1.79
Little Bay	248	22.2	0.55	2.76	0.75	2.95
The Gorge	159	9.5	0.15	0.76	0.36	0.96

Estimates of cumulative exposures from multiple fish farms were not assessed in this peer review process.

Deposition Model – DEPOMOD

As per the AAR, proponents must submit BOD matter depositional contours for 1, 5, and 10 grams of carbon per square meter per day (g C/m^2/day) using a depositional model with maximum feeding rate at peak biomass (fall). The DEPOMOD model (V. 2.2) was used by the Proponent to determine benthic BOD concentrations, and in the absence of an available guideline in the Newfoundland Region, model inputs were based on a British Columbia (BC) guideline (Chamberlin et al. 2005). The DEPOMOD model is one among numerous tools for computing deposition.

The inputs into and outputs from the DEPOMOD simulations were provided to DFO. The feeding rates, feed and faeces sinking rates input parameters used in the model were consistent with present scientific knowledge.

Comparison of Potential Exposure Zones and DEPOMOD Results

A comparison of DEPOMOD and PEZ results indicated that the modeled depositional length scales from DEPOMOD were consistent with PEZ mean outputs (Figure 3). Benthic PEZs calculations using maximum site depths and currents may overestimate the dimensions of the exposure zone, as maximum conditions are not expected to occur for the full settling time.

The DEPOMOD predictions at maximum feeding rate at peak production suggest that the proposed sites could result in carbon fluxes greater than 5 g C m^{-2} d^{-1}, especially under the cage array.

Both DEPOMOD and PEZ models assume that the current is spatially homogenous and seasonally consistent. The currents in the vicinity of the sites are likely to be spatially and seasonally variable (Ratsimandresy et al. 2019); however, the influence of this variation on the outputs of the model cannot be assessed without running the model with a spatially varying current field and longer water current observations.

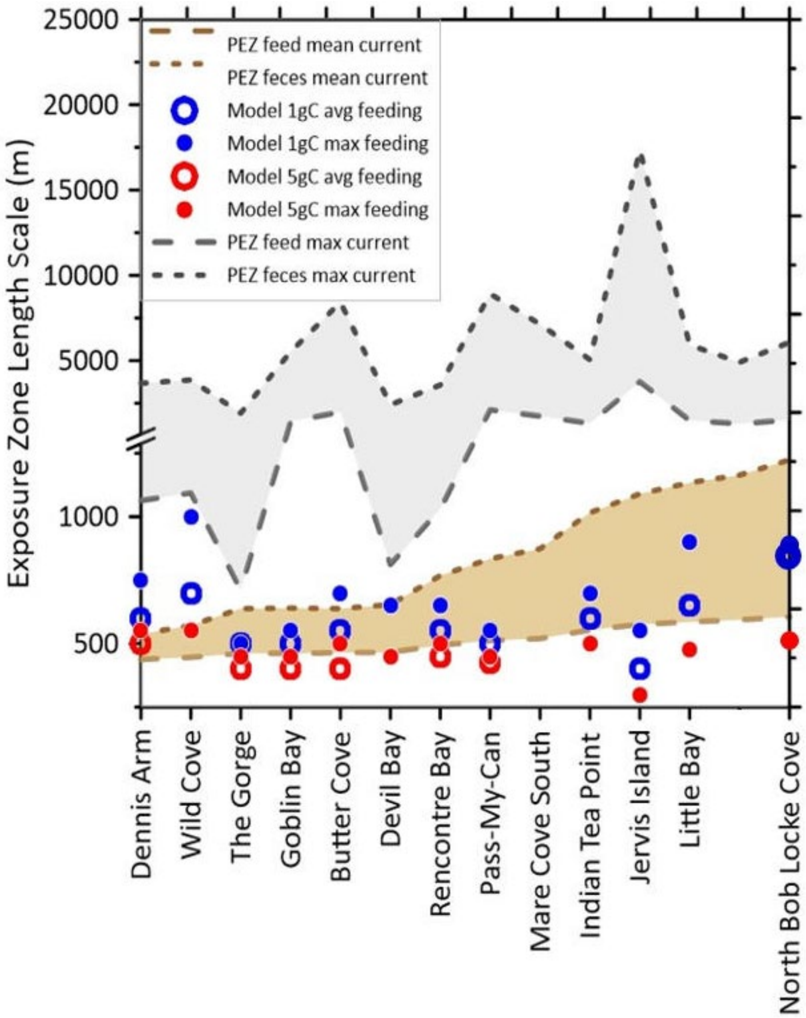

Figure 3. Composite of the length scales of PEZ for fish feed and fish faeces and the 1 g C·m^{-2}·d^{-1} and 5 g C·m^{-2}·d^{-1} deposition zones estimated by DEPOMOD. The sites have been ordered in relation to the length of the mean PEZ for fish feed.

EXPOSURE TO CHEMICALS

The Proponent was not asked to estimate exposure zones associated with pesticides or drugs and discussions related to approved drugs and pesticides were limited to spatial considerations provided by the PEZ.

Spatial Extent of Drug Exposure

Potential exposure zones associated with the release of drugs by aquaculture operations in Canada are not well known. Drugs are administered as in-feed medications, and exposure to drugs would therefore occur primarily through wasted medicated feed as well as drug residues excreted in the faeces. As a result, it is assumed that the maximum PEZ associated with the release of in-feed drugs are the same as the estimated benthic PEZs for BOD.

Spatial Extent of Pesticide Exposure

This review assumes that the potential use of any legal pesticide available to the license holder, is in compliance with any restrictions set by the regulatory authority. 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 calculated assuming the maximum current persists throughout the dilution or decay scale. The exposures are expected to occur primarily in the pelagic zone; however, the estimated zones extend beyond the net pen array and lease boundary area, with the maximum PEZs for tarp bath and well boats overlapping with portions of the coastline, suggesting a potential interaction with the intertidal and shallow subtidal areas adjacent to the proposed sites. The distances for both hydrogen peroxide and azamethiphos are less when the treatment is conducted using a well-boat. Given that tarp treatments cannot be conducted in high current speeds, and the maximum current speeds are unlikely to persist for the full duration of the transport period, the maximum distances presented in Tables 4 and 5 are considered overestimates and unlikely to be reached.

Azamethiphos

The PEZs from the use of azamethiphos in tarp bath and well boat treatments were calculated for each site (Table 4). The estimated PEZs for both treatments suggest the potential for coastline exposure of azamethiphos at each of the proposed sites.

The calculations assumed:

- The horizontal current to be the maximum current recorded at 15 m depth at each site;
- The dose concentration to be 100 µg/L, and the toxicity threshold to be 1 µg/L; and
- The dilution to be -2.303, based on the dye and chemical concentration dilution curve reported in DFO (2013a). The use of well-boat treatment results in a ten-fold reduction in pesticide concentration, which is expected to occur as a result of dilution during well flushing.

Table 4. Estimates of maximum potential exposure zones associated with azamethiphos tarp bath and well boat treatments for each proposed site.

Site	Maximum Water Current (15 m) (cm/s)	Horizontal Displacement During Dilution (km)		Radius of Circular Exposure Zone (km)	
		Tarp	Well-Boat	Tarp	Well-Boat
Goblin Bay	28.8	2.07	1.04	2.28	1.24
Butter Cove	28.3	2.04	1.02	2.24	1.22
Pass-My-Can	30.9	2.23	1.12	2.43	1.32
Jervis Island	49.6	3.57	1.79	3.77	1.99
Indian Tea Point	42.1	3.03	1.52	3.23	1.72
Wild Cove	44.5	3.20	1.60	3.41	1.80
Dennis Arm	39.8	2.87	1.43	3.07	1.64
Mare Cove South	48.9	3.52	1.76	3.72	1.96
North Bob Locke Cove	55.5	3.99	2.00	4.20	2.20
Devil Bay	21.8	1.57	0.79	1.77	0.99

Site	Maximum Water Current (15 m) (cm/s)	Horizontal Displacement During Dilution (km)		Radius of Circular Exposure Zone (km)	
		Tarp	Well-Boat	Tarp	Well-Boat
Rencontre Bay	23.5	1.69	0.85	1.89	1.05
Little Bay	32.8	2.36	1.18	2.56	1.38
The Gorge	20.2	1.45	0.73	1.66	0.93

Hydrogen Peroxide

The PEZs from the use of hydrogen peroxide in tarp bath treatments were calculated for each site (Table 5). The size of the PEZs suggest the potential for coastline exposure of hydrogen peroxide at each site.

The calculations assume:

- The horizontal current to be the maximum current recorded at 15 m depth at each site;
- The dose concentration to be 1800 µg/L, and the toxicity threshold to be 188 µg/L; and
- The dilution to be -2.303, based on the dye and chemical concentration dilution curve reported in DFO (2013a).the use of well boat treatments results in a dose concentration of 180 µg/L, which reduces the PEZ estimates to zero, since the dose concentration is less than the toxicity threshold (188 µg/L).

Table 5. Estimates of maximum potential exposure zones associated with hydrogen peroxide tarp bath treatments for each proposed site.

Site	Maximum Water Current (15 m) (cm/s)	Horizontal Displacement During Dilution (km)	Radius of Circular Exposure Zone (km)
Goblin Bay	28.8	1.02	1.22
Butter Cove	28.3	1.00	1.20
Pass-My-Can	30.9	1.10	1.30
Jervis Island	49.6	1.75	1.96
Indian Tea Point	42.1	1.49	1.69
Wild Cove	44.5	1.57	1.78
Dennis Arm	39.8	1.41	1.61
Mare Cove South	48.9	1.73	1.93
North Bob Locke Cove	55.5	1.96	2.17
Devil Bay	21.8	0.77	0.97
Rencontre Bay	23.5	0.83	1.03
Little Bay	32.8	1.16	1.36
The Gorge	20.2	0.71	0.92

SPECIES AND HABITAT USE

DFO Science conducted a search of the literature and DFO regional data on a large number of species and habitats, including marine mammals and turtles, groundfish, pelagics, shellfish and other invertebrates to determine if other, more site-specific, information was available to complement to the information provided by the Proponent. The regional data was of low spatial and temporal resolution and was too sparse to provide a robust indication of seasonality and spatial distribution of the species and habitats in the area.

There is no identified marine Critical Habitat within the PEZs, but there is habitat suitable for numerous species.

Pelagic Species

Atlantic Salmon

Information provided below on Atlantic Salmon is a synthesis of earlier science advice (DFO 2013b, DFO 2018a). The southern Newfoundland Designatable Unit (DU) has been classified as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) with record low numbers of abundance reported in recent years (COSEWIC 2011, DFO 2018ab, DFO 2019). The proposed expansion is within SFA 11, which contains 17 scheduled Atlantic Salmon rivers and 11 other rivers (28 total) known to have Atlantic Salmon. Regular monitoring of Atlantic Salmon occurs on three rivers, including the Conne River, Little River, and Garnish River (DFO 2018a). The general area of the south coast of Newfoundland in the vicinity of the proposed sites is considered to be used as an Atlantic Salmon migratory corridor and feeding ground in support of wild Atlantic Salmon maturation, and post-spawning recondition.

Marine Mammals

There is a lack of data regarding the distribution of cetaceans and pinnipeds within the BMAs, but there is overlap with the distribution of several species of whales (Blue Whale [*Balaenoptera musculus*], Humpback Whale [*Megaptera novaeangliae*], Minke Whale [*B. acutorostrata*], and North Atlantic Right Whale [*Eubalaena glacialis*]), dolphins, Harbour Porpoise (*Phocoena phocoena*), and seals (e.g., Grey Seals [*Halichoerus grypus*] - summer visitors; and Harbour Seals [*Phoca vitulina*]) in the region. Increased vessel traffic introduces elevated risk of both vessel strikes and sound pollution. The potential attraction to the proposed sites and the potential reduction of haul out space in the area are concerns for pinnipeds. While entanglement and subsequent drowning are the main concerns for marine mammal species, such as baleen whales, which do not echolocate, the risk of entanglement is considered low at the proposed sites.

Herring

Herring (*Clupea harengus*) is an important forage species in this region due to its broad inshore distribution. Spawning occurs mainly from mid-May to mid-June in shallow nearshore water on many parts of the coast, particularly at the heads of bays and inlets. Any loss of habitat or reductions in stock productivity due to the presence of the aquaculture sites is expected to be small.

Given the proposed positioning of the aquaculture pens, it is likely Herring will move past or through the cages. The potential transmission of disease between Atlantic Salmon and Herring is a concern. The Infectious Salmon Anemia Virus (ISAV) can be carried by Atlantic Herring (*C. harengus*, Nyund 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

Capelin *(Mallotus villosus)* make limited use of the region and there is limited commercial fishing on the south coast. In NAFO Division 3L, the spring acoustic surveys indicates that the peak depth for Capelin biomass is generally between 140-280 m (Mowbray 2014, Mowbray et al. 2019). Given the limited vertical overlap between the depth of the Atlantic Salmon cages and the depth of peak Capelin biomass, the limited portion of Capelin habitat involved, and limited Capelin spawning in the Bay d'Espoir, the potential risk from incidental predation associated with the proposed aquaculture sites is considered low.

Groundfish

The DFO spring multispecies survey is typically used to describe the distribution and abundance of groundfish in the Newfoundland region, including the south coast. This survey is completed in Hermitage Bay in three strata adjacent to the proposed aquaculture sites; however, the survey does not extend into the inshore bays where the proposed sites are located. From 2000-18, a variety of commercial species are encountered in these three adjacent strata, with up to 20% of Atlantic Cod (*Gadus morhua*), up to 16% of Witch Flounder (*Glyptocephalus cynoglossus*), up to 5% of Greenland Halibut (*Reinhardtius hippogloissoides*), and up to 2% of American Plaice (*Hippoglossoides platessoides*) survey biomass indices in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps coming from these three survey strata. There is no available information on the movement of these or other groundfish species within the BMAs. The interaction between groundfish and the proposed sites is unknown.

Invertebrates

American Lobster

Lobster fishing activity has been ongoing on the south coast of Newfoundland since the mid-1970s. Habitats and substrates identified in the baseline studies of the proposed BMAs (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. On average, cage arrays are located over water >100 m and DEPOMOD outputs show a deposition in deeper regions. The potential risk of deposition (i.e., faeces or feed) from the proposed sites affecting the intertidal zone (where lobster at various life stages could possibly be found) is considered low. It has been shown that there is a potential risk of pesticides affecting lobster at various life stages (Burridge et al. 1999, Pahl and Optiz 1999, Burridge et al. 2000ab, Burridge et al. 2004, Burridge et al. 2008, Burridge and Van Geest 2014, Burridge 2013).

Corals and Sponges

As per the AAR, seabed footage (i.e., by remotely operated vehicle [ROV]) was collected at depths less than 300 m, and within 200 m around the proposed cage array, up to the total surface of the site. Outputs for benthic assessments, including substrate type and identification of species and sensitive habitat (the latter only within the cage array) were provided for review.

Cold-water corals, including fields of pennatulacean (i.e., sea pens), soft, and gorgonian corals, as well as sponges were observed at numerous sites. Cold-water corals and sponges are considered vulnerable marine ecosystems.

Previous studies on the south coast of Newfoundland (Hamoutene et al. 2015, Hamoutene et al. 2016, Salvo et al. 2017, Verhoeven et al. 2018) indicate that visual indicators of organic enrichment from aquaculture activities were present after more than 15 months of fallow and were only occasionally accompanied by other taxa suggesting long recovery times (>5 years, Salvo et al. 2017, Verhoeven et al. 2018), which is a concern for a slow growing, long-lived species, such as corals. The limited information on the biology, density, and distribution of sponges, cold water corals within BMAs 9-12 and the south coast of Newfoundland limits our understanding of the potential impact and consequences of aquaculture activities on these organisms.

Sea pens

Sea pen ecology and distribution in this region (inshore) is unknown. Sea pens, which provide nursery habitat for juvenile fish (Baillon et al. 2012), were reported within the lease of six sites in three BMAs: Butter Cove, Goblin Bay, Pass My Can, and Jervis Island (BMA 9), Wild Cove (BMA 10), and Little Bay (BMA 12). At the Little Bay (BMA 12) site, sea pens were found inside of the proposed cage arrays where DEPOMOD modelling predicts a BOD deposition >5 g $C \cdot m^{-2} \cdot d^{-1}$ beneath and surrounding the cages.

Two sea pen taxa were reported in the baseline assessment reports: sea pens and sea whips (*Balticina* sp., recently taxonomically revised to *Halipteris* sp., Cordeiro et al. 2019). The DFO review of the ROV footage identified *Pennatula aculeata* as the main sea pen species in the footage. Specimens of *P. aculeata* had heights corresponding to both juveniles (<5 cm) and adults, with some colonies approximately 30 cm in height (above the sediment; excluding the buried peduncle). In the Laurentian Channel and Gulf of St. Lawrence, colonies of *P. aculeata* can reach heights of 31 cm including peduncle (estimated 21-year-old, Murillo et al. 2018), which indicates the presence of large (and potentially old) colonies at some of the proposed sites (e.g., Little Bay). Sea pens can live for decades (Neves et al. 2015; Murillo et al. 2018) and are ecosystem engineer species 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). Redfish larvae have also been found associated with the soft coral *Duva florida* (Baillon et al. 2012), which was also identified in the seabed surveys (identified as soft coral by the Proponent, B. Neves, DFO, personal observation).

Sea pens were abundant at several stations (e.g., >20 colonies/station, although the imagery field of view across stations was variable) and only observed in areas of soft bottom (typical of most sea pen species) and at depths greater than 200 m. Video survey limitations (e.g., variable field of view and ROV distance from the bottom and speed) preclude a definition of the spatial extent of the sea pen fields at the surveyed sites.

Sea pen distribution may be limited by oxygen availability (Chandler et al. 2017). Little information is available on tolerance of this species to BOD, their sensitivity to hypoxia and anoxia, and vulnerability to diseases, parasites and pathogens.

Gorgonians

The large gorgonian coral *Paragorgia arborea* (bubble gum coral) was observed in Jervis Island (BMA 9), where it was reported in five transects approximately 148-280 m depth. In transect 11, several colonies were observed along a bedrock wall. A colony measuring approximately 90 x 130 cm was observed during a review of the ROV footage, which leads to an estimated age of >80 years, based on growth rates of 1.6 $cm.yr^{-1}$ (Sherwood and Edinger 2009).

This region (south coast of Newfoundland) has not been studied to identify diversity, location and density of corals and their potential for species associations; there is also no data available on the connectivity between populations within defined BMAs and offshore populations.

Sponges

There is limited information on sponge diversity and distribution in coastal Newfoundland. Within the baseline assessment reports, sponge species identifications from ROV footage was restricted to high taxonomic levels (e.g., phylum and family). Sponge complexes with estimates of >20 individuals (e.g., Geodiidae) per single video frame were consistently reported at Jervis Island, Little Bay, North Bob Lock Cove, Recontre Bay, and the Gorge, including unidentified sponges, as well as Geodiidae, finger sponges, and branching sponges.

A DFO review of the ROV footage led to the identification of large (e.g., >30 cm tall, >50 cm wide) fan-shaped individuals at Jervis Island.

FARM AND WILD ATLANTIC SALMON INTERACTIONS

Wild Atlantic Salmon

Monitoring of adult Atlantic Salmon abundance over the last three generations (2003–17) indicates declines of 61%–97% in total numbers of spawners at Conne River and Little River, that all three rivers (Conne River, Little River, and Garnish River) are currently below 35% of the conservation limit, and all three populations are considered in the Critical Zone (DFO 2018a). The cause of the observed population decline on the south coast of Newfoundland is not presently known. Evidence exists regarding hybridization of wild salmon with escaped farmed salmon in each of these three systems (Wringe et al. 2018, Sylvester et al. 2018, 2019). Although the long-term impacts of continued farmed salmon escapes and subsequent interbreeding with wild Atlantic Salmon in the region remains uncertain, recent modelling suggests population decline and a loss of genetic diversity are likely outcomes. Based on population trends over the last three generations, the southern Newfoundland Designatable Unit (DU) now meets the criteria for endangered status under COSEWIC. A Recovery Potential Assessment, completed in 2012, indicated continued decline was likely (DFO 2013b). Recent genetic analysis suggests further subdivision of this DU is likely (Bradbury et al. 2015).

Tracking studies in the proposed expansion area (Dempson et al. 2011) have been used to examine migration route, residency time, and survival of smolts migrating through the Bay d'Espoir fjord and have been carried out at two locations (Conne River [n = 141]: 2006–08; Little River [n = 40]: 2007–08). Survival was moderately high (54–85%) to the outer fjord, with smolts from both rivers using the Lampidoes Passage, main channel, and Little (Gaultois) Passage to reach the outer areas. Some smolts also made periodic excursions into adjacent areas including Northern Arm. Smolts from both rivers were resident for periods of four to eight weeks moving back and forth in the outer part of the Bay d'Espoir fjord. Reasons for the extended residency are unknown. Studies in Norway have found that smolts taking longer to migrate through fjords are more likely to be negatively affected if this also coincides with periods of high sea lice infestation (Halttunen et al. 2018). Studies in Iceland have shown higher sea lice infestations in areas proximate to aquaculture production sites, concluding that as production increases or expands, there will be a greater risk of sea lice epidemics in proximate wild populations (Karbowski et al. 2019).

Genetic Interactions

Recent genetic studies have documented widespread hybridization between wild salmon and aquaculture escapees both in southern Newfoundland and in the Maritimes. 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 potential genetic interactions resulting from the proposed finfish expansion involving 13 sites (1M individuals/site) in southern Newfoundland was considered using a combination of empirical data (North American and European), and both individual-based and dispersal modeling. Estimates of exposure (i.e., propagule pressure, Keyser et al. 2018) of wild populations suggest that under the proposed expansion scenario, exposure pressure is expected to increase by at least 2x, particularly in Bay d'Espoir region. The modeling exercise utilized a recently developed Atlantic Salmon individual-based eco-genetic model and extended recent work completed both in Norway (Castellani et al. 2015, 2018) and Canada (Sylvester et al. 2019). The distribution of escapees in the wild under the current and proposed production regime were modelled using a spatial model of dispersal and survival recently implemented in Iceland (Jóhannsson et al. 2017). The eco-genetic individual-based Atlantic salmon model (IBSEM) was parameterized for southern Newfoundland populations, with regional environmental data and field-based estimates of aquaculture parr survival, to explore how the proportion of escapees relative to the size of wild populations influences genetic and demographic change in the wild. Simulations suggest that both demographic decline and genetic change would occur when the proportion of escapees relative to wild population size exceeds 10% annually (Bradbury et al. in press[2]).

The occurrence of escapees in southern Newfoundland rivers (estimated population size approximately 22,000 individuals), both at present and under the proposed expansion scenario were predicted using river and site locations, expected production numbers and schedule, simple models of dispersal for early and late escapees, and the best available validated and published data from Canada and Europe (Jóhannsson et al. 2017, Wringe et al. 2018, Hamoutene et al. 2018). Model predictions of escapee dispersal suggest that under the present regime, rivers characterized by the largest proportion of escapees relative to wild population size are located in the head of Fortune Bay and Bay d'Espoir (19 rivers total >10% escapees, max 14.9%) consistent with recent empirical evidence of escapees and hybridization in this region (Sylvester et al. 2018, Sylvester et al. 219, Wringe et al. 2018, Keyser et al. 2018). Under the proposed expansion, the number of escapees in southern Newfoundland rivers is predicted to increase by 49% and the rivers characterized by the greatest proportion of escapees relative to wild population size are predicted to occur in the Bay d'Espoir area (20 rivers total >10% escapees, max 23%). Sensitivity analysis of key parameters indicated that under most scenarios tested, the rivers in the Bay d'Espoir area were predicted to be characterized by greater than 10% escapees under the proposed expansion. Further details on these findings can be found in Bradbury et al. (in press[2]).

Mitigation measures proposed by the Proponent to reduce the frequency of escape events (e.g., steel-core containment nets, steel predator exclusion nets, regular net cleaning, and regular removal of mortalities) were not included in the empirical predictions. These mitigation measures have been shown to be effective in other jurisdictions.

Sea Lice

Sea lice (*Lepeophtherius salmonis*) are small ecto-parasites that pose a significant health risk to farmed and wild Atlantic Salmon.

The NL aquaculture industry has been treating for sea lice; however, there is no publicly available information on farm level sea lice levels or management in Newfoundland. Rather, data concerning the use of therapeutants was used a proxy for sea lice and treatment data. A review of publicly available data of therapeutants used by Newfoundland Atlantic Salmon farms

[2] Bradbury, I., Duffy, S., Lehnert, S. Johannsson, R., Fridriksson, J.H., Castellani, M., Burgetz, I., Sylvester, E., Messmer, A., Kelly, N., and Flemming, I. Model-based Evaluation of Potential Direct Genetic Effects of Proposed Marine Harvest Atlantic Salmon *Salmo salar*) Aquaculture Site Expansion in Southern Newfoundland. DFO. Can. Sci. Advis. Sec. Res. Doc. In press.

for 2016 and 2017 indicates in-feed and bath therapeutants were used on average of 7–9 treatments/farm annually.

In 2017, the number of farms on the Connaigre Peninsula increased approximately 12% (three farms) while the total number of sea lice treatments increased by 50% (additional 84 treatments). The characterization of treatments in the publicly available data is not consistent between years and the total amount of active ingredient may be more informative. However, the expansion of farming is still expected to result in an increase in sea lice levels. The low number of wild adult Atlantic Salmon returning to monitored rivers in the region in 2017 and the presence of sea lice may pose a risk to wild populations, given the high ratio of farmed to wild salmon in the region (DFO 2018a).

The interpretation of the therapeutant data is hindered by the lack of farm-level production and sea lice information, lack of knowledge of any changes in provincial sea lice management policy, limited environmental data, and limited therapeutant usage data.

It is anticipated that the addition of sites will increase the presence of sea lice and sea lice treatments. The use of hydrodynamic modelling, particle tracking, and sea lice population genetic analysis would determine the level of connectivity and the potential risk of sea lice transport between and within a BMA.

SOURCES OF UNCERTAINTY

Model Estimates

The currents used to estimate modelling outputs were determined from a single ADCP deployment. Using a single current meter record in an area of spatially varying bathymetry can result in an over or under estimate of the spatial extent and shape of the exposure zone. The PEZ and DEPOMOD estimates could be improved through the selection of current speed and depth values that incorporate regional oceanographic characteristics (e.g., stratification and seasonal variability).

The model estimates do not take into account the influence of storms on the re-distribution of particles.

The PEZ estimates could be refined using field studies conducted in conjunction with commercial operators to further characterize the dispersal area and the location and concentration of discharged substances.

Species and Habitat Distribution

Species and habitat distributions within 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. Thus, information on these space and time scales is generally not contained within the various data sources available to DFO to evaluate presence or usage of species and habitats in such areas.

There is uncertainty as to the population size and distribution of species, such as cold-water coral and sponges, in the vicinity of proposed aquaculture sites. Sensitivity to potential effects of aquaculture operations is also largely unknown. As per the AAR, benthic surveys are not required to be completed at depth >300 m or beyond the lease boundary. This limits the benthic habitat analysis, specifically on corals and sponges.

Monitoring is required to assess the sensitivity of identified species with the area and their ability to recover from the consequences of aquaculture activity.

The video footage, as per the AAR, was insufficient to identify all species at depths >100 m. The quality of the available video data limited scientific assessment (no abundance data available, species identification). The ROV video quality could be improved by maintaining a stable distance to seafloor and a constant field of view, by reducing the speed, and better lighting.

The 100 m grid survey design, as per the AAR, was found to be insufficient in terms of spatial coverage for determining species abundance and habitat associations.

Farmed-Wild Interactions

Escape events of Atlantic Salmon on the south coast of Newfoundland have previously been shown to result in genetic interactions with wild Atlantic Salmon in the region. Information is generally lacking on the size of wild Atlantic Salmon populations in the majority of these rivers and as such estimates of population size were derived using an established relationship between river size and wild population size for Newfoundland. This relationship is based on habitat; therefore, these estimates may not reflect declines in population size over recent decades and may overestimate the current population size and underestimate the proportion of escapees and risk to wild populations. Improved estimates of wild Atlantic Salmon population size and the presence of escapees in rivers on the south coast of Newfoundland would improve the assessment of genetic and demographic risk.

There are significant knowledge gaps regarding sea lice infestation levels in wild and farmed Atlantic Salmon. Monitoring and reporting of infestation levels and treatment frequency would improve knowledge of sea lice abundance and risk.

CONCLUSIONS AND ADVICE

Terms of Reference 1

Estimate the Potential Exposure Zones (PEZ) associated with: a) the deposit of the majority of uneaten food and faeces; b) use of regulated drugs; c) use of regulated pesticides, and; d) pests and pathogens.

First order calculations were used to provide an order of magnitude estimate of the size and location of the area that may be exposed to organic matter from waste feed and fish faeces and to regulated drugs and pesticides, if used. The PEZ for BOD and potential pesticides and drugs extend beyond the boundaries of the aquaculture cage array up to the coastline at all 13 of the proposed sites. The spatial extent of the benthic PEZ for BOD in the proposed sites range from 356 m to 1.89 km for waste feed and from 960 m to 8.7 km for fish faeces. The PEZs for drugs were assumed to be the same as those for BOD, while the PEZs for pesticides (bath treatment and well-boats) were larger than for feed waste and most faeces BOD.

Terms of Reference 2

The Proponent has used a depositional model to predict the benthic effects (i.e., deposition of biochemical oxygen demanding (BOD) matter) of the proposed aquaculture sites. Are the predicted benthic effects, as demonstrated by the output of the model used by the Proponent, consistent with the scientific knowledge of the potential impact of this operation?

A comparison of DEPOMOD and PEZ results indicated that the modeled depositional length scales from DEPOMOD were consistent with PEZ mean outputs. Results also indicated that dispersion estimates are consistent with present scientific understanding of feed and faeces sinking rates; however, both DEPOMOD and PEZ calculations assumed the current is spatially homogenous and seasonally consistent, while the currents in the vicinity of the sites are likely to be spatially and seasonally variable.

Terms of Reference 3

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, key commercial, recreational, and aboriginal (CRA) species and species vulnerable to aquaculture impacts? Are there predicted consequences to any critical or valuable habitats for species at risk, key CRA species?

The uncertainty regarding species and habitat distributions within coastal areas precluded a robust indication of seasonality and spatial distribution of the species and habitats in the vicinity of the proposed sites. Data provided for review indicated the presence of vulnerable species within the DEPOMOD predicted area of maximum deposition at Little Bay and high species diversity at Jervis Island.

The absence of sea lice infection level data precluded detailed conclusions on potential changes in on-farm sea lice abundances at both the site and adjacent areas, associated with the proposed development/expansion.

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

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This Science Advisory Report is from the May 28-31, 2019 Regional Peer Review Process for the Review of the Marine Harvest Atlantic Canada Aquaculture Siting Baseline Assessments. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX I: DESCRIPTION OF CHEMICALS THAT HAVE BEEN USED BY THE CANADIAN MARINE FINFISH INDUSTRY IN 2016 AND 2017.

Bath Pesticides

Hydrogen peroxide is a pesticide used to help control sea lice on cultured salmon while in the aquaculture facility net-pens. The pesticide is applied by using a bath treatment that involves either tarping of a net-pen or pumping of the fish from the net-pen into a well-boat well. In both cases, the untreated pesticide is released into the receiving environment after the treatment. The non-target organisms affected by hydrogen peroxide include crustaceans (DFO 2013a) and zooplankton. Hydrogen peroxide in its purest form is a short-lived compound and decomposes very quickly to form water and oxygen. Studies have shown that the anti-sea lice form of hydrogen peroxide has an estimated half-life of 14 to 28 days in unfiltered seawater at a concentration of 1.2 g·L-1 (Lyons et al. 2014). A half-life of seven days in seawater has also been documented (Haya 2005). Due to its decomposition and rapid dilution and dispersion effects after release from the net pen or when discharged from a well boat, it is thought that hydrogen peroxide would not persist significantly in the environment.

Azamethiphos is a pesticide used to help control sea lice on cultured salmon while in the aquaculture facility net-pens. The pesticide is applied by using a bath treatment that involves either tarping of a net-pen or pumping of the fish from the net-pen into a well-boat well. In both cases the untreated pesticide is released into the receiving environment after the treatment. The non-target organisms affected by azamethiphos include crustaceans (DFO 2020) and molluscs such as Blue Mussel (*Mytilus edulis*)(Canty et al. 2007). Due to its low octanol/water partition coefficient (log Kow) value, azamethiphos is highly soluble in water and, thus, is highly unlikely to bind to organics in suspension or in the sediment. The estimated half-life of azamethiphos is 8.9 days. These characteristics, coupled with physical dispersion and dilution after released into the aquatic environment, suggest that it would not be persistent in the aquatic or benthic environment (Health Canada 2016).

In-Feed Pesticides

Emamectin benzoate is a drug used to help control sea lice on the cultured salmon while contained within the aquaculture facility net-pens. The pesticide is delivered to the fish in the net-pen through the use of medicated fish feed. A portion of the pesticide is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the pesticide are released into the receiving environment as part of faecal release and exchanges through the fish gills. The non-target organisms affected by emamectin benzoate include crustaceans (DFO in press[4]) as well as polychaetes in sediment. The risk to other non-target organisms is documented (EC 2005) with LC50 toxicity data citing effects to a wide range of organisms ranging from sand fleas (*Corophium volutator*) to American lobster (*Homarus americanus*). Emamectin benzoate has been shown to be persistent in both water and sediment (Environment Canada 2005). In water, hydrolytic decomposition did not occur in a pH range of 5.2 to 8; however, at pH 9, the half-life of emamectin benzoate was reduced to 19.5 weeks. These values changed when photolysis was taken into consideration (0.7 to 35.4 days, summer/winter respectively). Due to the high log Kow value of emamectin benzoate it has a propensity to bind to organics. This is confirmed by an increase in half-life values in the region of 79 days and 349 days in aerobic and anaerobic soils respectively. Therefore, if the site were to be treated with this in-feed drug, it can be expected that it would persist in the benthic environment.

Ivermectin is a drug used to help control sea lice on the cultured salmon while in the aquaculture facility net-pens. The pesticide is delivered to the fish contained with a net-pen through the use of medicated fish feed. A portion of the pesticide is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the pesticide are released into the receiving environment as part of fecal release and exchanges through the fish gills. The non-target organisms affected by ivermectin include crustaceans (DFO unpublished manuscript[4]). Ivermectin has a high log Kow value which means that it readily partitions into sediment. A half-life value of 100 days in sediment was determined by Davies et al. (1998). This study determined that ivermectin was also toxic to starfish (*Asterias rubens*) and sand fleas (*Corophium volutator*). Polychaetes were also found to be affected by the presence of ivermectin in sediment at concentrations greater than would be expected from a single treatment. Such effects are possible due to the nature of the treatment application and the accumulative nature of the compound in sediment (Black et al. 1997).

Lufeneron is a drug used to help control sea lice on the cultured salmon. The pesticide is delivered to the fish through the use of medicated fish feed. A portion of the pesticide is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the pesticide are released into the receiving environment as part of faecal release and gill transfer. The non-target organisms affected by lufenuron include crustaceans (DFO unpublished manuscript[4]). Lufenuron has a high log Kow value which suggests that it partitions readily into sediment with a half-life range of 13 to 23.7 days (Elanco Animal Health 2016).

In-feed antibiotics

Erythromycin is an antibiotic drug used in the control of bacterial pathogens in cultured salmon while they are in the aquaculture facility net-pens. The drug is delivered to the fish through medicated fish feed. A portion of the antibiotic is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the pesticide are released into the receiving environment as part of faecal release and gill transfer. Though not directly toxic to marine organisms, the presence of antibiotics in the marine environment raises the possibility of the development of anti-microbial resistant bacteria. Erythromycin partitions readily into sediment due to its relatively high log Kow with an estimated half-life of 29 to 38 days in experiments conducted in artificial seawater and an estimated 11 days in an artificial seawater/sediment mix (Kwon 2016).

Florfenicol is an antibiotic drug used in the control of bacterial pathogens in cultured salmon while they are in the aquaculture facility net-pens. The drug is delivered to the fish through medicated fish feed. A portion of the antibiotic is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the drug are released into the receiving environment as part of faecal release and gill transfer. Though not directly toxic to marine organisms, the presence of antibiotics in the marine environment raises the possibility of the development of anti-microbial resistant bacteria. The half-life of florfenicol in marine sediment (loam) containing 3.2% organic carbon was determined to be 8.4 days (Schering-Plough Animal Health Corp. 2006).

Oxytetracycline hydrochloride is an antibiotic drug used in the control of bacterial pathogens in cultured salmon while they are in the aquaculture facility net-pens. The drug is delivered to the fish through medicated fish feed. A portion of the antibiotic is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the drug are released into the receiving environment as part of faecal release and gill transfer. Though not directly toxic to marine organisms, the presence of antibiotics in the marine environment raises the possibility of the development of anti-microbial resistant bacteria. The half-life of oxytetracycline in marine sediment has been shown to range from 12 days (Coyne et al. 2001) to 32 ± 3 days (Samuelsen 1989). Coyne et al. (1994) analysed sediments (top 2 cm) for oxytetracycline collected on day 10 of a 12 day treatment regime from under and around a cage block. Results showed concentrations were highest directly under the cage block with a lower concentration detected 25 m to the west; oxytetracycline was not detected in any other samples collected. Seventy-one days post end of treatment showed oxytetracycline to be below the limit of detection in all samples. Therefore, it may be assumed that the zone of exposure for oxytetracycline is directly under the cage site, although this may change in highly dynamic sites which experience strong tides and currents.

Praziquantel is a drug used in the control of internal parasitic worm infections in cultured salmon while they are in the aquaculture facility net-pens. The drug is delivered to the fish through medicated fish feed. A portion of the drug is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the pesticide are released into the receiving environment as part of faecal release and gill transfer. No data could be found regarding this drug's persistence in the environment.

Sulfadimethoxine/Ormetoprim is an antibiotic drug combination used in the control of bacterial pathogen infections in cultured salmon while they are in the aquaculture facility net-pens. The drug is delivered to the fish through medicated fish feed. A portion of the drug is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the drug are released into the receiving environment as part of faecal release and gill transfer. Though not directly toxic to marine organisms, the presence of antibiotics in the marine environment raises the possibility of the development of anti-microbial resistant bacteria. Investigations have shown that sulfadimethoxine/ormetoprim can be detected two days after use but not three weeks after treatment of salmon net cages (Capone et al. 1996). This suggests that these compounds are relatively non-persistent in sediment after standard treatment.

Trimethoprim/Sulfadiazine is an antibiotic drug combination used in the control of bacterial pathogen infections in cultured salmon while they are in the aquaculture facility net-pens. The drug is delivered to the fish through medicated fish feed. A portion of the drug is released into the receiving environment via uneaten fish feed and fish faeces and metabolites of the drug are released into the receiving environment as part of faecal release and gill transfer. Though not directly toxic to marine organisms, the presence of antibiotics in the marine environment raises the possibility of the development of anti-microbial resistant bacteria. Sulfadiazine and trimethoprim were found to have half-lives of 50 and 75 days respectively at 0 to 1 cm sediment depth. This increased to 100 days for both compounds when sampled at 5 to 7 cm sediment depth (Hektoen et al. 1995).

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