Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Maritimes Region

Canadian Science Advisory Secretariat
Science Response 2020/015

DFO MARITIMES REGION REVIEW OF THE PROPOSED MARINE FINFISH AQUACULTURE BOUNDARY AMENDMENT, RATTLING BEACH, DIGBY COUNTY, NOVA SCOTIA

Context

Kelly Cove Salmon Ltd. has made an application to the Province of Nova Scotia to expand the boundaries at their existing site (#1039) near Rattling Beach, Digby County, Nova Scotia. As per the Canada-Nova Scotia Memorandum of Understanding on Aquaculture Development, the Nova Scotia Department of Fisheries and Aquaculture has forwarded this application to DFO for review and advice in relation to DFO's legislative mandate. DFO Science was asked to provide a review of the expected zone of influences of the expanded site, information on the species and habitat presence and use within the zone of influences, as well as possible benthic impacts to inform DFO's review. The location of the site is shown in Figure 1.

February 2020 (Erratum : January 2024)

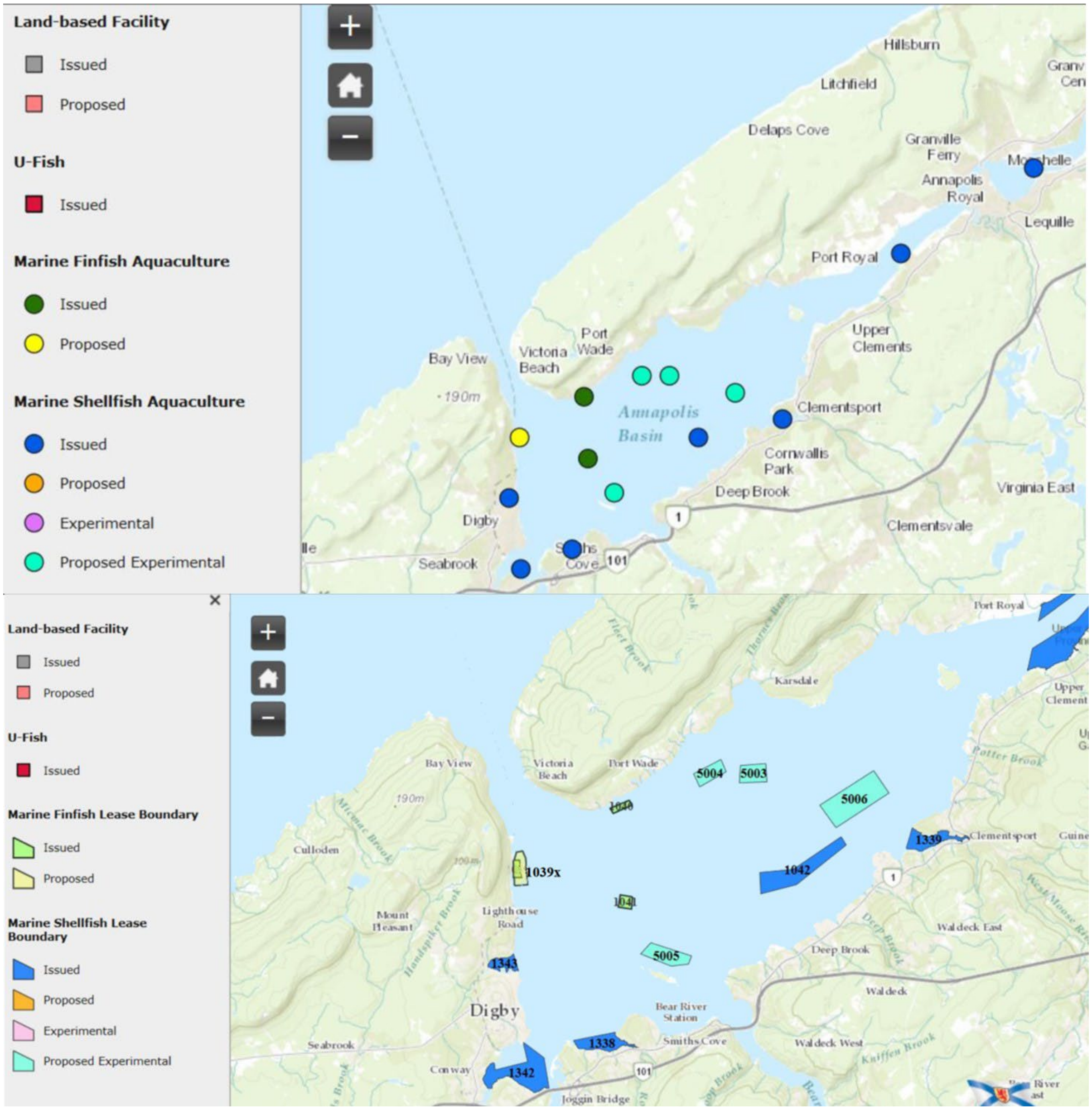

Figure 1[1]. Map of the whole Annapolis Basin area with the yellow dot as the location of the proposed site expansion (top panel), and the Rattling Beach site labeled as 1039x (bottom panel). Based on a snapshot of aquaculture activities in the Annapolis Basin from the [Nova Scotian Aquaculture Site Mapping Tool website](). Maps retrieved on April 16, 2019.

To help inform DFO's review of this application, the Maritimes Regional Aquaculture Coordination Office asked DFO Science three questions:

Question 1. Based on the biological, physical and geochemical information submitted by the proponent, and the accepted use of approved aquaculture products for fish health treatments in the marine environment, what is the expected zone of influence/exposure, from the use of these

[1] Erratum January 2024 – Figure updated

products, by species in and around the proposed aquaculture site? Does the expected zone of influence extend beyond the boundaries of the aquaculture facility?

Question 2. What species and habitats, focusing on species at risk, key Commercial Recreational and Aboriginal (CRA) species and species vulnerable to aquaculture impacts, exist within this zone of influence (and the broader Bay)? How do these species utilize (i.e., spawning, migrating, feeding, etc.) this area (e.g. the zone of influence)? Are there any habitats within the zone of influence considered critical or valuable for these species? Specifically,

a. What time of the year and for what duration of time do the species noted above utilize the habitat within the zone of influence?

b. How do the impacts on these species from the proposed aquaculture site compare to impacts from other anthropogenic sources? Does the zone of influence overlap with these activities and if so, what are the consequences?"

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 used by the proponent, consistent with the scientific knowledge of the potential impact of this operation?

Maritimes Science staff worked together to generate a science response to these questions, and the results were peer reviewed through a Canadian Science Advisory Secretariat (CSAS) Science Response Process. This Science Response Report results from the Science Response Process of February 8, 2019, on the DFO Maritimes Region Review of the Proposed Marine Finfish Aquaculture Boundary Amendment, Rattling Beach, Digby County, Nova Scotia.

Background

Kelly Cove Salmon Ltd. is requesting an amendment to the site boundaries at their existing site #1039 in Rattling Beach, Digby County, Nova Scotia, to change the configuration of the boundaries and increase the size. Kelly Cove Salmon is not requesting an increase in production nor additional cages on site.

Kelly Cove Salmon Ltd. Site #1039 is located on the western side of the Annapolis Basin, near the mouth of the Digby Gut channel in Digby County, Nova Scotia (Figure 1). The site is approximately 2.5 km north of Digby. Rattling Beach is located in the Annapolis Basin, along with seven marine shellfish and two other marine finfish aquaculture sites (Figure 1: right panel.

Supporting information was submitted to DFO for consideration in its review: 1) Nova Scotia Fisheries and Aquaculture Memorandum Regarding Aquaculture Amendment Application No. 1039 - Digby County Aquaculture Network Review, 2) Baseline Assessment Report for Site 1039 Rattling Beach, 3) Baseline Assessment Report Addendum for Site 1039 Rattling Beach, and 4) Kelly Cove Salmon Ltd. Baseline Assessment Videos.

DFO Maritimes is in the process of updating its aquaculture siting review process, as well as reviewing information concerning the use, fate and effects of aquaculture chemicals, models and approaches for predicting the exposure and influence of these chemicals and the approaches for assessing the distribution of coastal organisms and habitats of relevance to aquaculture siting. A review of the approach used by DFO to assess individual aquaculture site applications and site expansions in the Maritimes going forward, i.e., a framework review, is underway, but has not yet been completed. The review of this site application follows the draft framework.

Analysis and Response

Zones of Influence

Question 1. Based on the biological, physical and geochemical information submitted by the proponent, and the accepted use of approved aquaculture products for fish health treatments in the marine environment, what is the expected zone of influence/exposure, from the use of these products, by species in and around the proposed aquaculture site? Does the expected zone of influence extend beyond the boundaries of the aquaculture facility?

Estimations of the exposure of the seabed to organic releases from the finfish farm operation require information concerning the farm layout, feeding practices and the near and far-field oceanographic conditions. The estimates are often also sensitive to some of the input assumptions. The main oceanographic inputs are information on the bathymetry, water current, and wave field.

The response to these questions has been organized into two parts. Part A is a brief summary and review of the input information relevant to an estimation of an exposure and influence zone, and Part B is a rough estimate the expected zone of exposure and influence based on the inputs and a review of the proponent's exposure zone estimate.

Part A: Summary and Review of Input Information

For the purposes of this document, and specifically for the purpose of considering potential exposure and influence zones, the input information has been organized into several sub-categories including the location and layout of the site. Comments on the information provided to DFO Science for this review are included with the summary points.

Site Location

- The Rattling Beach site, site #1039, is located near the western shoreline of the Annapolis Basin at a location south of the Digby Ferry terminal and north of the town of Digby.
- The depth of water in the vicinity of the site varies from less than 4m near the western shoreline of the site to more than 20m in the eastern and northern portions of the proposed lease. Depths adjacent to the north and east of the proposed lease can be greater than 20 m and in the main channel to the north east of the site the depths exceed 30 m.
- Depending on the phase of the tides and the time of the year, the tidal range (difference between high tide and low tide) can be as small as 5.5 meters or as large as 8.4 meters.

Site Layout (Based on information contained in Winfield 2018)

- The individual net-pens are 100 m in circumference.
- The net-pens are contained in a mooring grid that consists of square grid cells with side lengths 49 m.
- The complete grid of net-pens is a 2 by 10 array so the outside dimensions of the net-pen array are approximately 98 m (2×49m) by 490 m (10×49m)
- The depth of the net associated with the net-pens is approximately 8 m (SIMCorp 2018)
- The net-pen array appears to be located over a sloping bottom in which the depth increases by about 10–20 m in a cross-slope horizontal distance of about 200 m, i.e., from about 10 m on the western side of the net-pen array to about 20–30 m on its eastern side.

- The grow out period for the fish is 20–22 months.
- The maximum number of fish on the site is expected to be 660,000.
- The average harvest weight of fish is expected to be 6 kg.
- The maximum stocking density of fish is to be 25 kg/m^3.
- The maximum biomass on this site is expected to be 3,504,000 kg.

Consistency Note: This maximum biomass is the number given in Table 2 of Winfield (2018). The number is comparable, i.e., within about 10%, to the following simple calculations based on numbers given in the memorandum.

a. The stated maximum biomass (3,504,000 kg) is within 10% of the biomass (3,960,000 kg) calculated as the product of the maximum number of fish expected on the site (660,000) times the expected maximum size of each fish (6 kg). This difference could be related to different assumptions about fish mortality; the simple calculation did not include fish mortality.
b. The volume of each net-pen implied by the maximum biomass is consistent with volume of a net-pen estimated by the dimensions of a net-pen. The volume of a net-pen based on the stated site maximum biomass and maximum stocking density is 7004 m^3 (3,504,000 kg/25 kg/m^3/20 net-pens). The estimated volume of a 100 m net-pen that has a net that hangs approximately 8 m below the sea surface is ca. 6350 m^3 ($V=\pi r^2 h$ and $r=100/2\pi$).

Bathymetry

In general, available bathymetry for the near-shore regions in the vicinity of the site is neither well resolved nor documented on charts (Figure 2). Given that the site is near shore and detailed estimates of bottom exposure will be sensitive to the details of the bottom bathymetry, a lack of detailed bathymetry can influence the estimates of the exposure zone. This is often the situation in the near shore, and it will require time and resources to resolve.

The proponent’s higher resolution data in the area of interest is, therefore, useful and confirms the general impression of a significant slope. Since the proponent’s data has not been adjusted to chart datum, caution must be used in the interpretation of the bathymetry. In order to incorporate this data into a hydrodynamic model, the data would need to be referenced to the chart datum for the area.

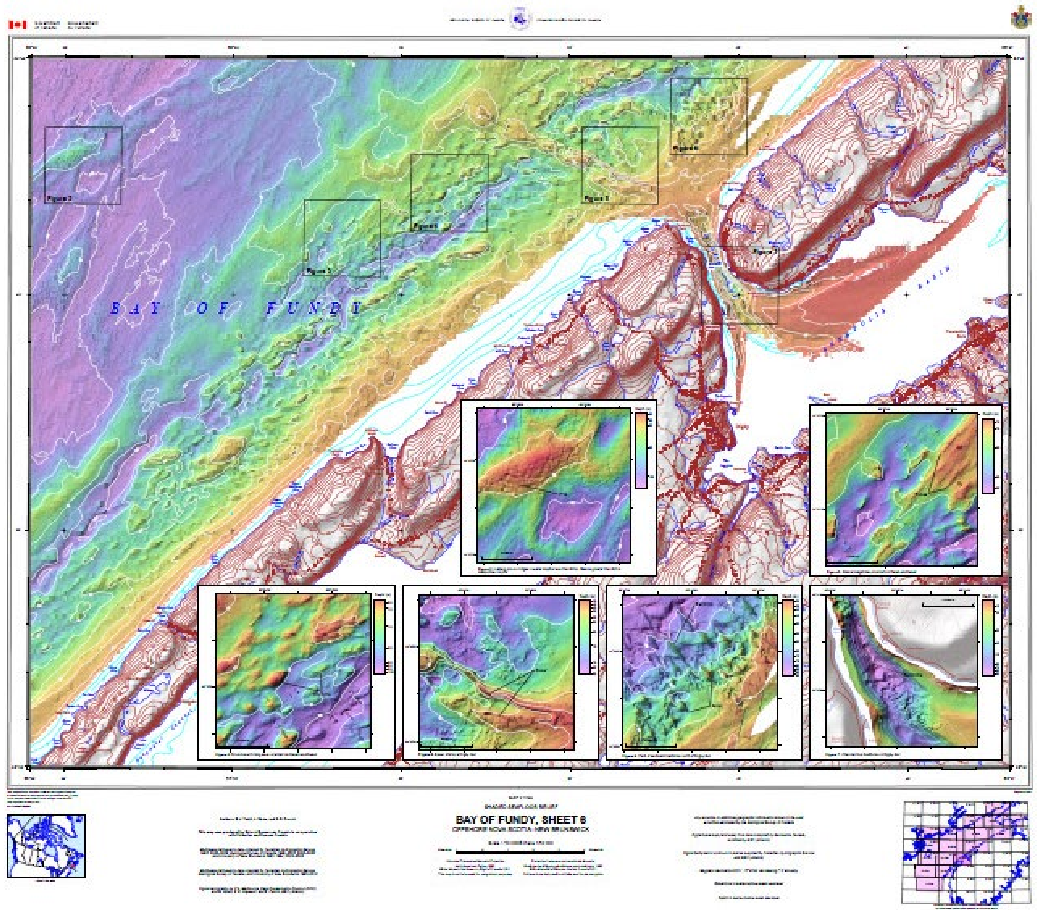

Figure 2. Shaded seafloor relief, Bay of Fundy, sheet 6 (2011). Geological Survey of Canada, "A" Series Map 2179A, 2011, 1 sheet, https://doi.org/10.4095/288683 (Open Access).

Water Currents

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

Information on water currents available at the time of preparing this document include:

- The statistics generated by the proponent from a single current meter, a 600 Khz acoustic doppler current profiler (ADCP) that had been moored in the southern portion of the proposed lease area between June 29 and August 4 of 2016. The ADCP was configured to record current velocity within 1 m thick vertical increments beginning a few meters above the seabed (Winfield 2018). Analysis of the current meter data was based on summary plots provided.

- A four dimensional (x,y,z,t) hydrodynamic model was used by DFO staff to produce a preliminary simulation of approximately 18 months of hydrodynamic conditions in the region under consideration. The model domain encompasses the Bay of Fundy, Gulf of Maine and eastern Scotian Shelf. The model included bathymetry at a resolution of approximately 10 to 50 m in the Annapolis Basin area. It was forced with spatially and temporally variable winds, heatflux, and offshore tidal and residual sea level. It also included river runoff from the major rivers flowing into the Bay of Fundy. A more detailed description of the model is included in Appendix 1. The model did not include freshwater inputs from rivers flowing into the Annapolis Basin (Bear, Annapolis and Moose Rivers). The model outputs have been compared to local observations within the model domain and include sea level time series, CTD profiles (i.e., temperature and salinity depth profiles), and SMART Buoy time. The model outputs compare favourably with the observations.

- The model output indicates spatial and seasonal (Figures 3 and 4) variation in the current within the geographic domain of the proposed lease and beyond.

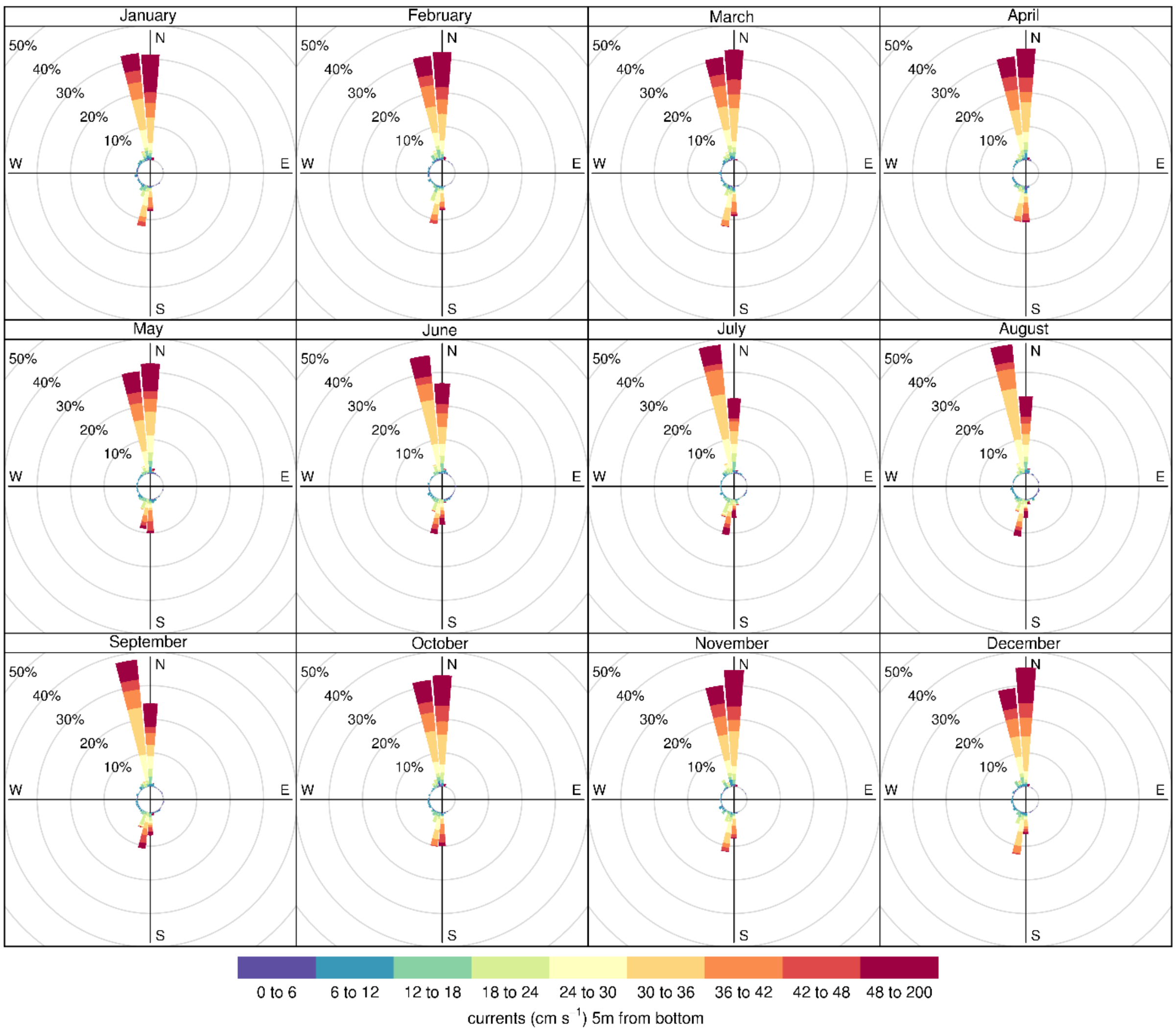

Figure 3. Rose diagrams showing the direction of the predicted water current at 5 m above the seabed at the location of the proponent's moored ADCP for each month from August 1, 2015 to August 1, 2016. The current predictions are from the DFO implementation of the FVCOM model in the Annapolis Basin and surrounding Bay of Fundy area. The proponent's current record was for June 29 through August 4, 2016.

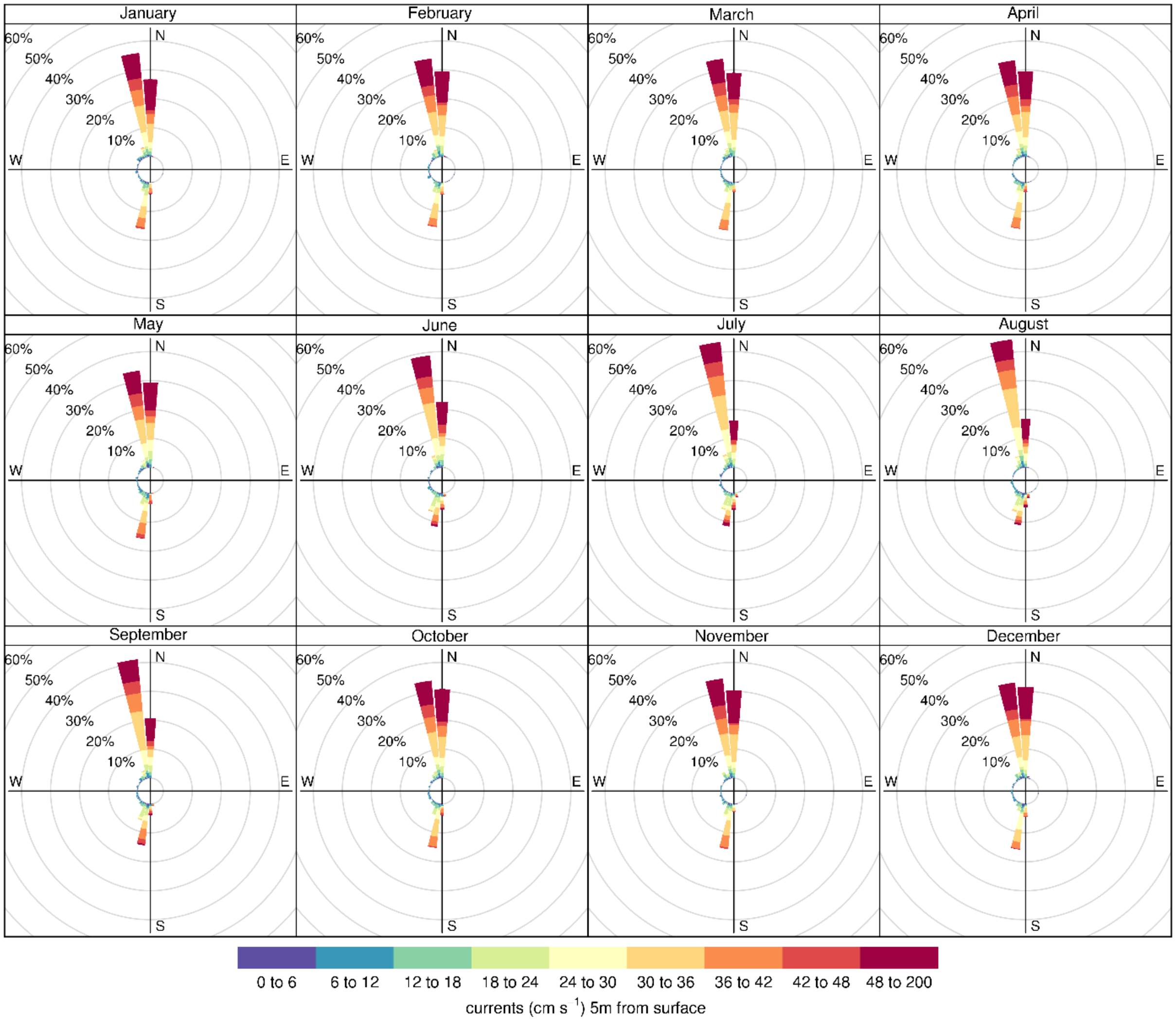

Figure 4. Rose diagrams showing the direction of the predicted water current at 5 m below the sea surface at the location of the proponent's moored ADCP for each month from August 1, 2015 to August 1, 2016. The current predictions are from the DFO implementation of the FVCOM model in the Annapolis Basin and surrounding Bay of Fundy area. The proponent's current record was for June 29 through August 4, 2016.

Based on the above information, the following has been concluded:

- The major axis of the water current in the vicinity of the proposed site is expected to be aligned with the local bathymetry and, hence, oriented primarily in a north-south direction. This expectation is consistent with the summaries of the current meter data provide by the proponent and with the outputs from the DFO model.
- There is significant vertical variation in the speed of the observed current with surface currents reaching greater speeds than mid-depth or bottom currents. This is consistent with the observations provided by the proponent and with the output generated by the DFO circulation model for the vicinity of the current meter.

- The currents are expected to exhibit significant spatial variation on the length scale of the farm, farm lease, and beyond given the spatial variation in the bathymetry. This is consistent with output from the DFO and other hydrodynamic models implemented for the area. A single current meter record, such as that provided by the proponent, as required by regulators, is insufficient to indicate whether there is significant spatial variation in the current. The location of the proponent's current meter record is in the relatively shallow and flat southern portion of the lease domain and, given the expectation of spatial variation in the current, this record may not be representative of the full exposure and influence domain. The DFO model results suggest that the current speeds in the northern area of the lease, and in the area of the net-pens, are greater than in the southern area of the lease.
- The currents in the vicinity of the Rattling Beach site are expected to undergo seasonal variation. A one-year portion of the simulation of the current in the area generated using the DFO hydrodynamic model is consistent with this and suggests the magnitude of the seasonal variation in the maximum current can be as much as plus or minus 15%.
- The magnitude of the current within the vicinity of the site is expected to be in the tens of centimeters per second.
  - The time averaged mean current speeds generated from the ADCP current record range from 19.8 to 32.7 cm/s (Winfield 2018).
  - The modal current speeds generated from the ADCP current record ranged from 11.7 cm/s at 6 m above the bottom to 40.7 cm/s at 9 m above the bottom (Winfield 2018).
  - The maximum current speed recorded by the ADCP was 81 cm/s and increased from 51.6 cm/s near the bottom to 81 cm/s at a height of 10 m above the bottom (Winfield 2018). These magnitudes are qualitatively consistent with outputs from the DFO circulation model.
  - The modelled time average mean current speed at the ADCP location over the same time period ranges from 29.9 cm/s to 44.9 cm/s. These values are higher than the observed values 19.8 and 32.7 cm/s, therefore suggesting the circulation model is over-estimating the magnitude of the mean current speed at this location by about 10–15 cm/s. This may not be the case for the rest of the model domain but sufficient information is not available to conduct more extensive comparisons between model and currents in the area of interest.

Waves

The wave information provided in the report (Winfield 2018) is not particularly representative of the site. The wave amplitudes presented (from Jonesport Maine) are likely overestimates of the wave heights expected to be experienced at the site. Wave height in the Bay of Fundy is typically less than that in the Gulf of Maine (Swail et al. 2006, Li et al. 2015).

The waves entering the vicinity of the site from the Bay of Fundy should generally be quite damped relative to those in the Bay due to the narrow opening through Digby Gut and the strong water currents in the Gut that may act to dampen incoming waves. Wind waves generated within the Annapolis Basin will not be represented in the Jonesport data, and they will be of relatively small amplitude because the wind fetch is limited by the dimensions of the Annapolis Basin.

Temperature, Salinity and Vertical Stratification

The water temperature and salinity at the Rattling Beach site are expected to vary on at least tidal and seasonal time scales and are expected to be within a few degrees and a few practical salinity units of the general Bay of Fundy conditions.

The graphics provided by the proponent (Winfield 2018) showing temperature data from the Prince 5 station give an indication of Bay of Fundy conditions. The Prince 5 station is not located within the Annapolis Basin; it is located across the Bay of Fundy to the east of Campobello Island, New Brunswick in about 90 m of open water. However, the Prince 5 data do illustrate the expectation for seasonal changes in the water temperature and salinity of order several degrees and several parts per thousand of salinity.

The specific temperature and salinity conditions within the Annapolis Basin and at the Rattling Beach site will differ somewhat from those at Prince 5. The temperatures recorded at the Rattling Beach farm site (Winfield 2018) indicate the farm site has a seasonal variation in temperatures as expected, with temperatures being colder in winter and warmer in summer and the seasonal range in temperature being of order 10°C. The Rattling Beach temperature record also indicates the water temperatures at Rattling Beach may be a few degrees colder that those at Prince 5 in the winter and a few degrees warmer in late summer-early fall. This is consistent with the site being in an enclosed basin with local temperature and salinity dynamics. The maximum low temperature shown for February – March 2015 in the Rattling Beach record is consistent with a potential for winter chill or winter kill at the site.

A site in the Annapolis basin (north and east of the town of Digby: 44.6362°N and 6S.7442°W) was sampled from 16 December 1988 to 26 March 1994 on 105 occasions (Keizer et al. 1996). Water temperatures were sampled in the surface, mid-depth, and bottom, and ranged seasonally from a minimum of -0.11°C and a maximum of 17.5°C (see Table 6 in Keizer et al. 1996). Salinity also varied seasonally, with a minimum of 31 psu in March through April, and 33 psu in September for the bottom (Keizer et al. 1996).

Vertical stratification of the water column has the potential to affect the transport and dispersal of effluents released from the farm site since it limits the vertical transfer of momentum and substances that have weakly negative sinking rates.

The stratification in the vicinity of the farm site is expected to be weak since the current speeds are relatively large and the water depth is relatively shallow. The data in Keizer et al. 996 support this expectation.

Chemical Use

Consideration of exposure to chemicals has become an important consideration for regulators. Hence, in order to respond to the request for advice on the potential zone of exposure associated with approved aquaculture products for fish health treatments, a first order estimate of the potential zones of exposure and influence for potential chemical use by the farm operator has been made.

The Canadian commercial finfish aquaculture industry as a whole has been required to report on its use of chemicals since 2015, with 2016 being the first full year of reporting. During the 2016 and 2017 calendar years, nine approved chemicals were reported as having been used within Canada. As of the preparation of this document, only data for the 2016 and 2017 calendar years were available. Data for the 2018 calendar year were not available. Publicly available summaries of this data are available from the government of Canada Open

Government Portal, specifically through the National Aquaculture Public Reporting Data website.

According to the above records, the Rattling Beach site has used only one of the chemicals included in the publicly available DFO summaries, and this was used in only one treatment, a treatment conducted in 2016. The chemical used was oxytetracycline. No bath or in-feed pesticides were used.

Pesticides

As noted above, the existing records indicate the Rattling Beach farm operation has not used pesticides and, hence, there has been no potential for the surrounding environment and ecosystem to be exposed to pesticides.

If the Rattling Beach were to use a bath pesticide in the future, there are, at present, only two pesticide active ingredients approved for use in bath treatments conducted in association with net-pens. These are hydrogen peroxide and azamethiphos. A brief description of these chemicals is given in Appendix E. Hydrogen peroxide and azamethiphos are unlikely to persist in the environment and, if used as per Health Canada's Pest Management regulatory guidelines, is unlikely to cause significant harm to non-target populations.

Drugs

As noted above, the existing records indicate the Rattling Beach farm operation has only used one drug, oxytetracycline, during the 2016 and 2017 calendar years. If the Rattling Beach farm operation were to use one or more drugs in the future, the drug may be one of the drugs that has already been reported as having been used in Canada in the 2016 and 2017 calendar years or listed by Fisheries and Oceans Canada on its web site referenced above. These potential drugs include the in-feed pesticides emamectin benzoate and ivermectin and the in-feed antibiotics oxytetracycline, florfenicol, erythromycin, ormetoprim and trimethoprim. Drugs such as lufeneron may be given to the fish while they are in the hatchery stage of production and residues may be released into the marine environment via excreted feces or exchange through the fish gills after the fish are transferred to the net-pens. A brief description of each pesticide and drug is given in Appendix E.

Part B: Estimation of Exposure Zones and Comments on the Proponents Estimates of Exposure Zones

Exposure to BOD

Spatial Extent of Exposure

Estimations of the exposure of the seabed to organic releases from the finfish farm operation require information concerning the farm layout, feeding practices and the near and far-field oceanographic conditions. The estimates are often also sensitive to some of the input assumptions. The main oceanographic inputs are information on the bathymetry, water current, and wave field.

Based on the limited available information and the considerations presented below, it is anticipated that the husbandry, bathymetry and water currents are the dominant factors affecting the exposure zones in the Rattling Beach area. Wave induced bottom resuspension is probably not a first order consideration in the estimation of benthic exposure zones in the vicinity of the Rattling Beach.

The proponent used AquaModel to estimate the zone of exposure associated with organic output from the proposed expansion. Their estimate is shown in Figure 4: top panel. As a consistency check for the proponent’s output, a first order estimate of the expected benthic exposure to organic effluent from the Rattling Beach site was also made (Figure 4: bottom panel). The two estimates are similar, although as expected the first order estimate over-estimates the dimension of the exposure zone in the cross-isobath direction, i.e., the direction perpendicular to the shore.

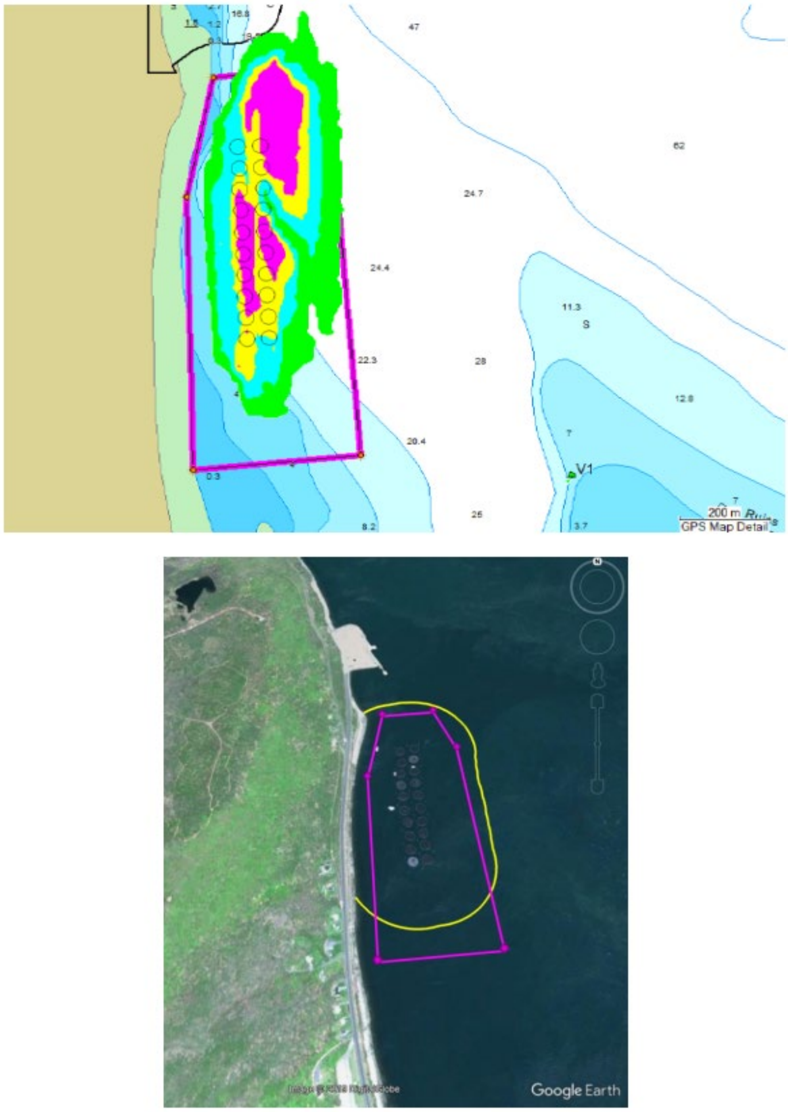

Figure 5. Estimates of the spatial distribution of organic loading released from the proposed finfish expansion. The top panel is the estimate provided by the proponent using AquaModel and is Figure 3 in SIMCorp (2018). The open circles in the top panel indicate the location of the net-pens. The estimate is associated with an estimate of peak feeding. The bottom panel is the first order estimate described here. The yellow line indicated the perimeter of the first order estimate of the BOD exposure zone. It was generated by placing a circle with a radius of approximately 215 m (15 radius net-pen plus a 200m exposure radius) over the center of each net-pens shown in the Google Earth image and outlining the perimeter of the cumulative set of circles.

The first order estimate of the expected benthic exposure to organic effluent was based on the following assumptions and simple calculations (Table 1). The estimates of the size of the potential zone of exposure are based on the information discussed above in Part A and additional information introduced below.

- 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 simple calculations, a fish feed sinking rate (w_s)of 0.1m/s and a fish faecal sinking rate of 0.01 m/s has been assumed.
- The water depth (*H*) has been assumed to be spatially and temporally constant and to be 15, 25, 30 or 60 m (Table 1).
- First order estimates of the sinking times have been estimated as H/w_s.
- First order estimates of the horizontal distances travelled by the sinking waste feed and faeces has been estimated as $(H/w_s)U$. The water depth, sinking rate and water current speed and direction have been assumed to be spatially and temporally constant.

The above calculations suggest that

- Waste fish feed pellets sink to the bottom within a few minutes (Table 1).
- Waste fish feed pellets could travel horizontal distances of 10s to a few hundred meters during their sinking time.
- Well-formed fish faeces sink to the bottom within a few tens of minutes to over an hour.
- Well-formed fish faeces could travel horizontal distances of 100s to a few thousands of meters, i.e., kilometers, during their sinking time. Faeces that are less well formed could take longer to sink to the bottom and could travel longer distances.
- Given that the exposure domain associated with feed waste and faeces is likely to be dominated by waste feed, and the feed sinks to the bottom before the deeper water is reached, the first order estimate of the potential benthic deposition exposure zone based on a maximum current of 81 cm/s and a depth of 25 m is conservatively a circle of radius about 200 m beyond the cage array (Figure 4) and more likely a curved ellipse with a major axis length scale of about 200 m (Table 1). As indicated in Figure 4, both the proponent and the first order estimates of exposure indicate a possibility of the exposure zone extending beyond the proposed site expansion boundary. The first order estimate likely over-estimates the eastward and westward extent of the exposure boundary.
- These length scales may be increased by benthic resuspension since the near bottom currents are reasonably strong at times.
- These 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.
- The current meter data provided by the proponent and the outputs from the DFO circulation model both suggest that the exposure zone will be oriented parallel to the bathymetry with the exposure axes longer in the northerly direction than in the southerly direction.
- The DFO circulation model suggests that the orientation of the major axis of the exposure zone may vary by ±25° or so depending on the details of the current.

Table 1. First order estimates of the potential horizontal distances travelled by sinking particles such as waste feed pellets, fish faeces, and in-feed drugs released from the fish farm.

Sinking Speed (m/s)	Water Depth (m)	Time to Sink to Bottom (min)	Duration of Horizontal Transport (min)	Horizontal Distance Travelled		
				Mean Depth Averaged Current 24 cm/s	Most Frequent Current 36 cm/s	Maximum Current 81 cm/s
Sinking Particles						
0.1 (feed)	15 (near-field low tide)	2.5	2.5	36	54	122
	25 (near-field high tide)	4.2	4.2	60	90	203
	30 (far-field low tide)	5.0	5.0	72	108	243
	60 (far-field high tide)	10.0	10.0	144	216	486
0.01 (faeces)	15 (near-field low tide)	25.0	25.0	360	540	1215
	25 (near-field high tide)	41.7	41.7	600	900	2025
	30 (far-field low tide)	50.0	50.0	720	1080	2430
	60 (far-field high tide)	100.0	100.0	1440	2160	4860

In the case of the Rattling Beach proposal, the proponent has provided some outputs from the AquaModel 2D simulations they have run (SIMCorp 2018). The model includes a salmon growth model and empirical specifications of the number and percentage of mortalities. Although a detailed examination and auditing of the proponent's model runs has not been conducted, the input parameters used to drive the proponents model runs are consistent with present scientific understanding of feed and faeces sinking rates, feed wastage rates, fish, and net pen size, background dissolved oxygen concentrations, etc. Although we did not find information in the provided documentation that specified the initial number of fish present in each cage, an estimate of the initial number of fish based on information provided in the proponent's documentation suggests the initial stocking numbers per cage are reasonable.

The first order estimate of the number of fish assumed to be initially placed into each net-pen is 33,000 (660,000 fish/20 net-pens) and is based on the proponent's specified expected maximum number of fish on the site and the assumption that these fish would be evenly distributed amongst the 20 net-pens on the site. Another consistency check is that the estimated stocking density based on the approximate weight of the fish at the time of stocking, is 0.78 kg/m^3 (4950 kg/6350 m^3) assuming a mean fish weight of 150 g, a total weight of fish in a net-pen of 4950 kg (150g/fish × 33,000 fish) and a net-pen volume of 6350 m^3 (estimated in Part A above). The mean weight of a fish at the time of stocking is based on the information provided by the proponent's Table 2 (SIMCorp 2018). This estimate of initial stocking density is consistent with the initial stocking densities reported by the proponent in their Table 2 (SIMCorp 2018).

The proponent's model runs, which include an estimate of benthic resuspension, suggest that the benthic exposure zone for the sinking organics extends about 200 m beyond the proposed net-pen array. This is consistent with the first order estimates described above.

Both the proponent's and the first order estimates of the exposure zone assume the current is spatially homogeneous and seasonally consistent.

As already indicated, the currents in the vicinity of the Rattling Beach site are likely to be spatially and seasonally variable. The current speeds in the area where the transport and dispersal of the organic matter will occur are likely to be higher than those recorded by the current meter and used in the exposure zone estimates. The DFO model suggests the currents are likely to be higher in the late summer, i.e., September, and fall than in the June through August mooring period encompassed by the current meter mooring. These factors may result in an increase in the current speed in the order of 10% to perhaps 20%. Although the influence of this variation on the outputs from the proponent's model are difficult to assess in detail without running the model with spatially varying current field, it can be expected that, since the current directions are predominantly toward the area of higher velocity, the exposure zone estimates will increase to perhaps an order of about 300 m.

Intensity of Exposure to Organic Loading

In an effort to make a first order estimate of the expected intensity of benthic exposure to organic effluent from the Rattling Beach site, the following assumptions and simple calculations result in a flux of carbon to seabed of 10–20 g·C/m^2/d.

- The horizontal surface area of the net-pens in use is 800 m^2
- The area of benthic impact assuming no transport and dispersal of the feed is the same as the surface area of the net-pen.
- Assuming the number of fish in a net-pen is 30,000 (less than the 33,000 mentioned earlier to account for some mortality) and the mean weight of the each fish is 5 kg (less than the proposed maximum weight of 6 kg per fish), the biomass of fish in a net-pen is 150,000 kg.
- The total amount of feed introduced into a net-pen per day of is approximately 1500 kg, assuming the feeding rate for the fish is 1% of the body weight per day.
- Assuming a feed wastage rate of 2%, the flux of feed to the bottom would be 30 kg.
- Further assuming a carbon content for the feed of 50%, this feed wastage converts to a flux rate of 15 kg·C/m^2/d.
- Assuming this carbon is spread over the area of the net-pen (800 m^2), the average flux of carbon to the bottom is approximately 0.2kg or 20 g·C/m^2/d.
- If the above calculations are repeated assuming the feed is spread over an area equivalent to a 120 m perimeter net cage (an estimate of some minimal spreading out of the waste feed), the flux of carbon to the bottom reduces to about 12 g·C/m^2/d.
- In reality, the intensity of the exposures is expected to decrease as distance from the net-pen increases, and there should be some overlap between the exposure zones generated by each net-pen. The highest exposure intensities are, therefore, likely to be near the net-

pen array, and the intensity of exposure should decrease with distance from the net pen to relatively low levels at a distance of a few hundred meters away from the cage array.

In the case of the Rattling Beach proposal, the proponent has provided some outputs from their running of the AquaModel. Unlike the above simple calculations, the model run includes the multiple daily releases that occur through the production cycle from multiple net-pens.

- The proponent's outputs seem to be consistent with the expectations based on the above simple calculations and do not seem to underestimate the deposition rate.
- The proponent's prediction of the benthic zone of exposure is based on the assumptions of a spatially and seasonally homogeneous current field. However, as acknowledged by the developers of AquaModel, the results are heavily impacted by the precision of the flow field incorporated into the model and that, for many farms, the use of a single current meter, i.e., a spatially homogeneous flow field, results in model outputs that are somewhat uncertain. As already indicated in Part A, the currents in the vicinity of the Rattling Beach site are likely to be spatially and seasonally variable. The influence of this variation on the outputs from the proponent's model are difficult to assess in detail without running a model that includes the spatial and seasonal variations. However, it is expected that the domain of the predicted exposure zones would be increased if this variability was incorporated.

Influence of Exposure to Organic Loading

Based on the above exposure considerations and the spatial distribution of natural resources in the area, it is not unreasonable to expect some of the lobsters, scallops and other organisms within the exposure zone will experience some degree of exposure to sinking organics. A 1 gC/m^2/d flux of carbon to the bottom sediment corresponds to a sediment free sulfide concentration of 750 and a flux of 5 gC/m^2/d corresponds to a sediment free sulfide concentration of 3,000 µM (Hargrave 2010). Sediments with carbon fluxes below 1 gC/m^2/d are considered to have a low effect on the sediment benthos, carbon fluxes above 5 gC/m^2/d are likely to cause adverse decreases in sediment infauna diversity and carbon fluxes above 10 gC/m^2/d correspond to sediment anoxia (Hargrave 2010, Table 2 below).

The proponent's model predictions (SIMCorp 2018), which are consistent with the simple calculations presented earlier, suggest the site expansion could result in carbon fluxes greater than 5 gC/m^2/d. The combination of our simple estimates and the proponent's model outputs provided by the proponent (SIMCorp 2018) suggest that sediment sulfide concentrations will at times be sufficiently elevated that benthic macro-infauna diversity will be reduced within a zone that extends 100 to 200 m beyond the net-pen array and a bit beyond the northeast boundary of the lease (Table 2 below).

Table 2. Levels of carbon flux to bottom soft sediment and their corresponding levels of sediment free sulfide and qualitative effects on marine sediment bio-diversity (based on Hargrave 2010). A description of the proponent's depositional model results (SIMCorp 2018) is also provided.

Flux of Grams Carbon ($gC/m^2/d$)	**Mean Sediment Sulfide** (µM)	**Sediment Classification in Terms of Sediment Oxygen**	**Effect on Marine Sediment Macro In-Faunal Bio-diversity**	**Proponent's AquaModel Prediction** ($gC/m^2/d$)	
				At time of peak feeding	**At time of mean feeding**
<1	<750	Oxic A	Low effects	<1 $gC/m^2/d$ occurs at more than 100 - 200m distance from the edge of cages	<1 $gC/m^2/d$ occurs at more than 100 - 200m distance from the edge of cages
1	750		Low effects		
	750–1499	Oxic B	Low effects	edge of 1 $gC/m^2/d$ contour within ~ 200, ~250 & ~150 m of western, eastern, northern & southern edges of cage array, respectively	edge of 1 $gC/m^2/d$ contour within ~ 200, ~250 & ~150 m of western, eastern, northern & southern edges of cage array, respectively
2.5	1500				
	1500–2999	Hypoxic A	May be causing adverse effects		
5	3,000				
>5	3000–4499	Hypoxic B	Likely causing adverse effects	>5 $gC/m^2/d$ under cages and in area to northeast of cage array to just beyond the lease boundary	>5 $gC/m^2/d$ under cages and in area to northeast of cage array to just beyond the lease boundary
	4500–5999	Hypoxic C	Causing adverse effects		
10	6000				
>10	>6 000	Anoxic	Causing severe damage	>10 $gC/m^2/d$ under cages and in area to northeast of cage array to just beyond the lease boundary	

Cumulative Exposure to Organic Loading

There are seven marine shellfish and two other marine finfish aquaculture sites within the Annapolis Basin area (Winfield 2018). The Rattling Beach site expansion does not increase the total number of marine finfish aquaculture sites in the Annapolis Basin area, since the pre-expansion site was already present (Figure 1). The distance between the sites is approximately 3 km based on estimates made from Google Earth imagery and Figure 1.

Estimates of cumulative exposures from multiple fish farms and other sources of organic loading have not been assessed in this report. However, given the location of the other two fish farms in the area and the water circulation within the Basin, an overlap between the benthic organic deposition zones associated with each of the farms is not expected, but an overlap of the pelagic exposure zones is more likely.

A waste water treatment plant is located 4.7 km to the south southeast of the boundary of the proposed site expansion. It is unlikely that the benthic exposure zone associated with the treatment plant overlaps the benthic zone associated with the site expansion.

Exposure to Chemicals

Pesticides

Scale of Exposure to Pesticides

Although pesticides have not been used at the Rattling Beach site in the recent past, an estimate of the scale of exposure if they were to be used is given in this section. The agency responsible for registering pesticides in Canada is the Health Canada Pest Management Regulatory Agency (PMRA). Before registering a pesticide, they try to anticipate the potential for a use pattern to expose sensitive organisms and prescribe in the use label associated with each pesticide the use restrictions that try to minimize potential impacts. The approach used here is based on that used by PMRA, DFO (2013), Page et al. (2014) and Page and Burridge (2014).

If hydrogen peroxide were to be used, the potential exposure zone associated with this chemical would have a length scale in the order of a few hundred meters from the edge of the site's net-pen array. This estimate is based on the following considerations. The half-life of hydrogen peroxide (Appendix E) is much longer than the time needed to dilute the peroxide to below toxic levels since the dilution time is in the order of minutes to hours depending upon the species being affected, the measure of effect and the method of treatment. The time to dilute to the 1-h LC50 (lethal concentration required to kill 50% of the population) for lobster adults is 28 minutes when the treatment method used is a tarp. Over this time scale, the hydrogen peroxide could travel a distance of 432, 648 or 1458 m if it was carried by the mean, most frequent or maximum current (Table 2). These current speeds are based on the current meter record provided by the proponent. The maximum distances are unlikely to be realized since tarp treatments cannot be conducted in high current speeds, and the maximum current speed is does not persist for the full duration of the transport period.

If azamethiphos were to be used, the estimated potential exposure zone associated with this chemical would be the horizontal geographic domain encompassed within the boundary defined by a distance in the order of a few hundred meters to a kilometer from the edge of the site's net-pen array. This estimate is based on the following considerations. Azamethiphos is highly soluble in water and, thus, is highly unlikely to bind to organics in suspension or in the sediment. The half-life of azamethiphos (Appendix E) is much longer than the time needed to dilute the azamethiphos to below toxic levels since the dilution time scale is of order minutes to hours depending upon the species being affected, the measure of effect and the treatment method. The time to dilute to the LC50 for lobster adults derived from 1-hour exposures to azamethiphos is about 30 minutes when the treatment method used is a tarp (Page et al. 2014). Over this time scale, the azamethiphos could travel a distance of 432, 648 or 1458 m if it was carried by the mean, most frequent or maximum current (Table 3). The time to dilute to the LC50 for stage I lobster larvae derived from 1-hour exposures to azamethiphos is about 5 hours when the treatment method used is a tarp (Page and Burridge 2014). Over this time scale, the azamethiphos could travel a distance of 4.3, 6.5 or 14.6 km if it was carried by the mean, most frequent or maximum current (Table 3). These current speeds are based on the current meter record provided by the proponent. The maximum distances are unlikely to be realized since tarp treatments cannot be conducted in high current speeds and the maximum current speed is does not persist for the full duration of the transport period.

The above exposure scales are consistent with the scale of near-surface drift estimated using the DFO circulation model of the area. Currents from the DFO circulation model were used with a particle tracking model to estimate the potential exposure zone. A total of 43,508 particles uniformly distributed among the cage array were release at a depth of 5 m for the surface.

Particles were neutrally buoyant and kept at a constant 5 m depth from the surface. Current fields from the DFO circulation model of the area were used to advect the particles. No dispersion was included. Particles were tracked for 5 hours, which is the time to dilute azamethiphos to the LC50 for stage I lobster larvae (Page and Burridge 2014). Results of the particle tracking model are shown in Figure 5.

The above distances for both hydrogen peroxide and azamethiphos are much less when the treatment is conducted within the well of a well-boat.

The scales of the estimated zones are such that the zones could extend beyond both the net-pen array and the lease boundary. The exposures are expected to occur mainly in the pelagic zone, although the seabed in the shallow water adjacent to the proposed site might be exposed under some circumstances.

Table 3. First order estimates of the potential horizontal distances travelled by non-sinking particles such as pesticides released from the fish farm after a tarp bath treatment. The dilution time scales correspond to the time to dilute to different concentrations (see above text for details).

Chemical	**Dilution Time Scale (h)**	**Horizontal Distance Travelled**		
		Mean Depth Averaged Current 24 cm/s	Most Frequent Current 36 cm/s	Maximum Current 81 cm/s
Hydrogen peroxide	0.5	432	648	1458
Azamethiphos	0.5	432	648	1458
	5	4320	6480	14580

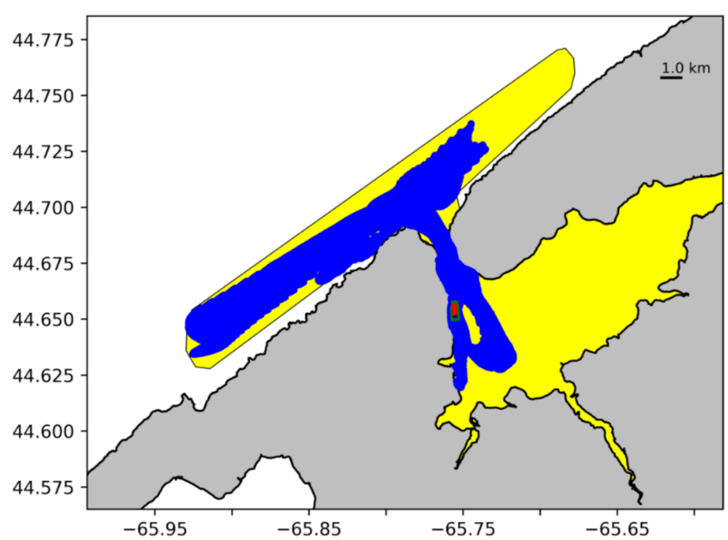

Figure 6. Estimate of the trajectories of particles (shown in blue), released from the proposed farm net-pen array (shown in red), at a depth of 5 m below the surface tracked for 5 hours. The trajectories were produced using the current fields from the DFO implementation of the FVCOM model for the Annapolis Basin and Bay of Fundy areas. The yellow area is the overall region of interest for consideration of potential cumulative effects.

Intensity of Exposure to Pesticides

The intensity of exposure to bath pesticides varies with the concentration of the pesticide at the time of treatment, decreases with time and distance from the treatment location due to dilution, decay and behaviour of the pesticide.

The exposure zones estimated in the above section take the decay, behavior and dilution of the pesticide into consideration. The domain between the treatment location and the edge of the exposure domain is exposed at a sufficient intensity to result in the potential for lethal consequences to the sensitive organisms. Low concentrations of pesticide still exist beyond the estimated exposure scales, but these are estimated to be below the lethal limits assumed in the estimation of the exposure scale.

Influence of Exposure to Pesticides

Sea lice pesticides are toxic to primarily crustaceans (Table 4). Based on the above considerations and the estimated distribution of natural resources in the area, it is not unreasonable to expect that the planktonic zooplankton and larval phases of crustaceans, such as lobster located within a few hundred to a few thousand meters of the proposed site, could be exposed and impacted by an exposure to the bath treatments and the azamethiphos treatments in particular. There is a lower degree of expectation that the benthic crustaceans (e.g., lobsters, mysids) present within the shallow water located within a few hundred meters of the proposed site could be exposed and impacted by the bath treatments.

Table 4. Summary of the bath pesticides that could potentially be used by the Canadian aquaculture, and the class of organisms that are sensitive to the pesticide.

Chemical	Organisms Sensitive to the Chemical
Bath Treatments	
Hydrogen peroxide	crustaceans including zooplankton
Azamethiphos	crustaceans and molluscs

Cumulative Exposures to Pesticides

There are seven marine shellfish and two other marine finfish aquaculture sites within the Annapolis Basin area (Winfield 2018). The Rattling Beach site expansion does not increase the number of marine finfish aquaculture sites in the Annapolis Basin (Figure 1). The shellfish sites are not expected to release pesticides.

The potential for cumulative exposures to pesticides has not been considered in this document in any detail. However, the estimates of the exposure zones are expected to be robust to multiple treatments conducted on the same 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, but the DFO model outputs in combination with the anticipated magnitude (approximately 1–15 km length scale depending upon the chemical) of exposure zones originating from the other fish farms sites suggest there could be overlap of the exposure zones associated with pesticide releases from any of the three fish farms in the area.

Drugs

Scale of Exposure to Drugs

Potential exposure and influence zones associated with the release of drugs by aquaculture operations in Canada are not well known and are the subject of active review and investigation both within Canada and internationally.

The exposure zone associated with drugs is expected to be smaller than that associated with pesticides. Drugs are administered as in-feed medications and, hence, environmental exposure to drugs occurs through wasted medicated feed, drug residues excreted in the faeces and perhaps through the gills.

The exposure zone associated with the release of drugs is assumed to be dominated by the waste of medicated feed and faeces. A reasonable first order estimate of the exposure zone of exposure may be the zone estimated for BOD. The exposure zone is, therefore, expected to be similar to that estimated for the release of organics. The estimated exposure zone for drugs is, therefore, within a few hundred meters of the net-pen array associated with the proposed site expansion. The initial deposition zones associated with the drugs may not be as extensive as those associated with regular feeding since BOD zones are estimated by assuming fish are usually fed one of more times per day throughout the production cycle whereas medicated feeds are applied much less frequently. Fish are fed medicated feed for only a few days at a time and for only a few treatment periods in the production cycle and, hence, the distribution of the medicated feed depends on the water velocities, drug quantities and feed wastage rates occurring during the treatment period(s).

Little empirical information exists concerning the spatial and temporal distribution of drugs released from marine aquaculture sites, although in-feed drugs have been found in sediments surrounding fish farms in some areas of the world. To our knowledge, no sediments from the Rattling Beach area have been sampled and analyzed for the presence of pesticides and/or drugs and sufficient information and consideration is not available whether the presence of the drugs, if used, would be expected in the marine sediments around the site.

Intensity of Exposure to Drugs

Work within the Federal government is being undertaken to develop approaches for estimating the intensity of exposure to drugs. This work is not yet complete and, hence, the intensity of a potential exposure to drugs has not been estimated. The proponent was not asked to make an estimate. However, as has been stated before, only one drug treatment has been reported for the Rattling Beach site for the years in which drug use has been reported, i.e., 2016 and 2017.

Influence of Exposure Drugs

Estimates of the influence of a potential exposure to drugs have not been estimated here or by the proponent; the proponent was not required to make this estimate. As outlined in Part A of this document and Table 5 below, the drugs available for use affect crustaceans, polychaetes, bacteria and parasitic worms. Antibiotics mentioned may induce anti-microbial resistance that may enter the food chain for some period of time depending upon the species (Armstrong et al. 2005). DFO Science is in the process of reviewing the potential for antibiotic impacts and is developing approaches to estimating the potential for an influence by these drugs.

Table 5. Summary of the in-feed drugs that are available for used by the Canadian finfish aquaculture sector and the class of organisms that are sensitive to the drug.

Chemical	Organisms Sensitive to the Chemical
In-Feed Pesticide	
Emamectin Benzoate	crustaceans, polychaetes
Ivermectin	crustaceans
Luefeneron	crustaceans
In-feed Antibiotic	
Erythromycin	bacteria
Florfenicol	bacteria
Oxytetracycline hydrochloride	bacteria
Praziquantel	parasitic worms
Sulfadimethoxine/Ormetoprim	bacteria
Trimethoprim/Sulfadiazine	bacteria

Cumulative Exposures to Drugs

There are seven marine shellfish and two other marine finfish aquaculture sites within the Annapolis Basin area (Winfield 2018). The Rattling Beach site does not increase the number of marine finfish aquaculture sites in the Annapolis Basin (Figure 1). The shellfish sites are not expected to release drugs.

The potential for cumulative exposures to drugs has not been considered in this document in any detail. However, the estimates of the exposure zones are expected to be robust to multiple treatments conducted on the same site. Estimates of cumulative exposures from the multiple fish farms and other potential sources of drug loading have not been assessed in this report. However, as in the case of organic deposition, it is expected that in absence of significant resuspension, there will be little overlap with potential exposure zones from the other farms. Other sources of pesticides and drugs have not been determined.

Species and Habitat Use

Question 2. What species and habitats, focusing on species at risk, key CRA species and species vulnerable to aquaculture impacts, exist within this zone of influence and the broader Bay? How do these species utilize (i.e., spawning, migrating, feeding, etc.) this area (e.g., the zone of influence)? Are there any habitats within the zone of influence considered critical or valuable for these species? Specifically,

a. What time of the year and for what duration of time do the species noted above utilize the habitat within the zone of influence?

b. How do the impacts on these species from the proposed aquaculture site compare to impacts from other anthropogenic sources? Does the zone of influence overlap with these activities and if so, what are the consequences?”

Methods

The proponent provided regional-scale information on a large number of species and habitats, including marine mammals, turtles, groundfish, pelagics, shellfish and other invertebrates, seaweeds, and birds. They also provided some recent information in the near vicinity of the site (SIMCorp 2016).

DFO Maritimes Science conducted a search of the literature and of Fisheries and Oceans regional databases to determine if other, more site-specific, information was available for this area as a complement to the information provided by the proponent, focusing on species at risk, key CRA species, and some limited information on species known to be vulnerable to impacts of aquaculture.

A polygon was created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 3. This polygon represents an estimate of the pelagic exposure zone associated with the release of a neutrally buoyant particle with a drift duration of five hours; a time scale consistent with the dilution or decay of the bath pesticide azamethiphos to its LC50. It is likely that this polygon is an estimate of the maximum zone of potential exposure and an over-estimate of the benthic exposure zone. The relative frequency of different species distributed within this polygon was obtained from the following databases:

- The Maritime Fishery Information System (MARFIS): MARFIS is a DFO database, managed by the Policy and Economics Branch, that houses information on the fisheries of the Maritimes Region. This fishery monitoring information represents a complete census of almost all commercial fishing activities.
- Industry Survey Database (ISDB): The at-sea monitoring information is maintained by DFO Maritimes Region. At-sea observers are also deployed on selected fishing activities to monitor and record events in greater detail than can be obtained from the submitted fishery monitoring documents.
- Sea scallop inshore survey: surveys are conducted annually and are used to provide advice on stock status to DFO Fisheries Management and industry stakeholders. For more information see Glass (2017).
- Whale sightings database: Most sightings are collected on an opportunistic basis and observations may come from individuals with a variety of expertise in marine mammal identification experiences. Most data have been gathered from platforms of opportunity that were vessel-based. The inherent problems with negative or positive reactions by cetaceans to the approach of such vessels have not yet been factored into the data. Sighting effort has not been quantified (i.e., the numbers cannot be used to estimate true species density or abundance for an area). Lack of sightings do not represent lack of species present in a particular area. Numbers sighted have not been verified (especially in light of the significant differences in detectability among species). For completeness, the data represent an amalgamation of sightings from a variety of years and seasons.

The database searches indicate that many species of interest have been and are likely present within the Annapolis Basin as a whole, within the proposed lease zone, and within the estimated zone of influence. Like much of the proponent’s information, the data generated by the database search indicates that, for the most part, available data is of low spatial and temporal resolution and is too sparse to give a robust indication of the seasonality and spatial distribution of the species and habitats in the area of interest.

Information considered to be of particular relevance to the DFO review of this application are summarized below.

Species at Risk

Species listed under the *Species at Risk Act* (SARA), or assessed by COSEWIC, as endangered, threatened or of special concern and of relevance to the Maritimes Region are listed in Appendix B. The likelihood of these species occurring within the pelagic zone of potential influence associated with the proposed aquaculture site expansion is also indicated. The sections below provide additional information on the species that have a possibility of occurrence within the zone of influence.

Atlantic Salmon

Information provided below on Atlantic Salmon (*Salmo salar*) is a synthesis of earlier science advice. For additional detail, readers are directed to the research documents published in support of the Recovery Potential Assessments for Southern Upland salmon (Bowlby et al. 2013, 2014) and Inner Bay of Fundy (IBOF) salmon (Amiro et al. 2008a,b, Gibson et al. 2008), the IBOF Recovery Strategy (DFO 2010), science responses on wild salmon populations in the vicinity of proposed finfish aquaculture development in St Mary's Bay (DFO 2011a) and Little Musquash Cove (DFO 2011b), science response on fish populations in the vicinity of three proposed finfish aquaculture sites in Shelbourne County (DFO 2012a), a research document on the pathway of effects of escaped aquaculture organisms or their reproductive material on natural ecosystems in Canada (Leggatt et al. 2010), and the most recent stock status update for salmon in the Maritimes Region (DFO 2017a).

Four Designatable Units (DUs) of Atlantic Salmon are identified in the Maritimes Region: Eastern Cape Breton (ECB), Nova Scotia Southern Upland, Outer Bay of Fundy (OBOF), and Inner Bay of Fundy (IBOF). The proposed aquaculture site expansion is located in the Southern Upland DU. Salmon from OBOF and IBOF populations move in and out of the Bay of Fundy and, therefore, have the potential to migrate in the vicinity of the proposed expansion site. The general Bay of Fundy area in the vicinity of the Annapolis Basin is considered to be used as a salmon migratory corridor and feeding ground in support of wild salmon growth, maturation, and post-spawning reconditioning.

IBOF salmon are listed as Endangered under Schedule 1 of SARA. IBOF salmon tend to migrate out along the New Brunswick side of the Bay of Fundy toward the outer Bay and Gulf of Maine (see Figure 1 of Lacroix 2012), but they are also detected on the Nova Scotia side of the outer Bay of Fundy. Some portion of individuals may leave the Bay of Fundy, over a period of approximately five months (June through October), but another portion may remain in the Bay of Fundy during this same period. Post-smolts that remain in the Bay of Fundy tend to move up into the Bay along the Nova Scotia side. They are also known to be present near the coastline and to move in and out of estuaries during this time period. Similarly, IBOF salmon kelts may be going near the mouth of Annapolis Bay (see Lacroix 2013 and Lacroix 2014). Returning adults from the IBOF, OBOF and Southern Upland DUs may pass near the proposed aquaculture site. Annapolis Basin is not part of the currently defined Critical Habitat for IBOF Salmon.

Outer Bay of Fundy and Southern Upland Atlantic Salmon have both been assessed as Endangered by COSEWIC, and are under consideration for listing under SARA by the Government of Canada. The Annapolis Basin contains two rivers that were previously known to be occupied by Southern Upland Salmon: the Annapolis River and Bear River. Historically, the population of Atlantic Salmon in the Annapolis River has been small, owing to a lack of suitable habitat, mostly available in tributaries such as the Nictaux River, covering a much smaller area than other Southern Upland Rivers (Bowlby et al. 2014). Atlantic Salmon were caught in the most recent (2008/2009) regional-wide electrofishing surveys of the Annapolis River in very low numbers, which corresponds to the general trend seen throughout the Southern Upland DU (Gibson et al. 2011). In this region-wide survey, salmon were detected on the Annapolis River (mean number per 100 m^2 =0.31 based on 7 sampling sites) but not on the Bear River (based on 1 sampling site) (Bowlby et al. 2013). In addition, the Clean Annapolis River Project did capture juvenile Atlantic salmon in an electrofishing survey of the Fales River subwatershed of the Annapolis system in the summer of 2018 (L. Cliche, pers comm).

Wild Atlantic salmon populations can be affected by salmon aquaculture either by interaction in the immediate vicinity of the site or by the interactions of escaped aquaculture salmon with salmon in the wild (Leggatt et al. 2010). Escaped aquaculture salmon have been found in rivers at distances greater than 200 km from the nearest aquaculture site (Morris et al. 2008). Salmon aquaculture sites can potentially impact wild populations through the transmission of parasites, pathogens and disease from cage-farmed salmon; potentially increased predation as a result of predator attraction to the cage sites; and through an additional range of pathways that arise from aquaculture escapees (Leggatt et al. 2010). Escapees can hybridize with wild salmon, which has the potential to reduce genetic fitness of wild populations (Leggatt et al. 2010). A number of mitigation measures have been identified to reduce impacts from aquaculture activities on wild salmon populations (DFO 1999, Amiro et al. 2008b, Lacroix and Flemming 1998; DFO 1999, 2008, 2010; Gibson and Bowlby 2013; Clarke et al. 2014; Gibson and Levy 2014; Jones et al. 2014).

For inner Bay of Fundy Atlantic Salmon, survival at sea is low enough that populations are not currently self-sustaining. Increases in mortality in the marine environment are not likely to jeopardize the live gene bank programs being used to sustain the populations but would make it more difficult to meet the longer-term objective of restoring wild, self-sustaining populations. For Southern Upland and Outer Bay of Fundy Atlantic salmon populations, maximum reproductive rates are very low placing populations at risk of becoming extirpated. Increases in mortality for these populations increases this risk.

Atlantic and Northern Wolffish

Atlantic Wolffish (*Anarhichas lupus*) are listed as Special Concern and Northern Wolffish (*Anarhichas denticulatus*) are listed as Threatened under SARA. There are two ISDB records of Atlantic Wolffish from within the pelagic zone of potential influence (1996 and 2018). Atlantic Wolffish are often caught in DFO's RV survey in the Bay of Fundy (several catches in the 2018 survey, for example). The exposure of near-bottom organisms for much of this zone is likely to be limited and unlikely to have a detectable impact on these fish.

There are no records of Northern Wolffish in the zone of influence, as their distribution does not include the Bay of Fundy. They are found in the waters off of Nova Scotia, in the Gulf of St. Lawrence, around the island of Newfoundland, up the Labrador coast to Baffin Island. The preferred depth range of Northern Wolffish is 500–1000 m. The proposed aquaculture site is, therefore, unlikely to have an impact on these fish.

Shortnose and Atlantic Sturgeon

Shortnose Sturgeon (*Acipenser brevirostrum*) are listed as Special Concern under SARA. The Saint John River population tends to reside mainly in the river and estuary and is rarely observed in the marine environment of the Bay of Fundy. It is considered unlikely to be present within the zone of influence and, therefore, unlikely to be impacted by the proposed site expansion.

Atlantic Sturgeon (*Acipenser oxyrinchus*) is assessed as Threatened by COSEWIC. A spawning population of Atlantic Sturgeon is known to occur in the Saint John River. Adults spend much of their non-breeding time at sea where they can migrate over extensive distances along the coast while feeding. Atlantic Sturgeon have been observed in the Annapolis River, and elsewhere in the Bay of Fundy. They are likely to pass by the proposed aquaculture site expansion and through the zone of influence. The site expansion is unlikely to increase any potential impact on these fish.

White Shark

White Shark (*Carcharodon carcharias*) are listed as Endangered under SARA. Sightings and bycatch records encompass a large geographic area in Atlantic Canada: from the coast off northern Newfoundland, along the edge of the continental shelf, and into the Bay of Fundy. There has been consistent records of White sharks in the Bay of Fundy for the past three summers, including the Annapolis Basina area. Prior to this, there were no monitoring efforts and there were fewer tagged individuals.

In an analysis of potential mortality in Canadian waters, the greatest potential for fishery interactions, in terms of gear type, was considered to be coastal gill nets and weirs (DFO 2017b). In relation to other threats, COSEWIC (2006) identified that bioaccumulation of pollutants may adversely affect populations of White Shark, including the one in the North West Atlantic (COSEWIC 2006). Shark species accumulate toxins readily due to their high trophic position, life history characteristics (slow growth and longevity), and large, lipid-rich livers (Schlenk et al. 2005). Due to the transient nature of white sharks, it is considered unlikely that this aquaculture site would lead to significant effects on the White Shark population.

Leatherback Sea Turtle

Leatherback Sea Turtle (*Dermochelys coriacea*) are listed as Endangered under Schedule 1 of SARA. Leatherback Sea Turtles feed in high densities in the North Atlantic during the summer. When in Canada, leatherbacks can be found in coastal, shelf and offshore waters. The Bay of Fundy is not considered to be important habitat for Leatherback Sea Turtles and it hosts relatively few foraging leatherbacks during the summer and fall.

The threat of highest concern to Leatherback Sea Turtles in Atlantic Canadian waters is entanglement in fishing gear, which can cause lethal or sub-lethal injuries to a turtle. There are records of Leatherback Sea Turtles entangled along the Nova Scotia side of the Bay of Fundy between 1998–2014: rock crab (n=1), inshore lobster gear (n=2), miscellaneous/unknown buoy line (n=2), boat mooring rope (n=1) (Hamelin et al. 2017). Entanglement can also compromise a turtle’s ability to swim, resulting in drowning. There are reports of Leatherback Sea Turtles becoming entangled in lines associated with coastal aquaculture operations in Atlantic Canada, e.g., scallop spat collector ropes, lines associated with mussel farm operations (Hamelin et al. 2017). The proposed site expansion is unlikely to increase the risk of impact on the leatherback turtles above that associated with the existing site.

North Atlantic Right Whale

North Atlantic Right Whale (*Eubalaena glacialis*) are listed as Endangered under SARA. North Atlantic Right Whale are a migratory species that frequents coastal waters. They come to Atlantic Canadian waters to feed and may be present in the Bay of Fundy in spring, summer and fall (Figure B4). Grand Manan Basin (Bay of Fundy) has been identified as critical habitat. A search of the whale sightings database resulted in 2 records from the entrance of the Annapolis Basin. A record in 2010 corresponds to a North Atlantic Right Whale that was entangled and reported as “dead on gear”, while the 2011 record was observed from shore and from passengers onboard the Princess of Acadia. The proposed site expansion is unlikely to increase the risk of impact on the North Atlantic Right Whale above that associated with the existing site.

Harbour Porpoise

Harbour Porpoise (*Phocoena phocoena*) are listed as of Special Concern under SARA. In Eastern Canada, Harbour Porpoise range from the Bay of Fundy to Baffin Island. They are often sighted close to shore, especially during the summer months. Figure 4 shows Harbour Porpoise sightings (from the marine mammal sightings database) recorded between 2001–2017 in the Bay of Fundy, close to the mouth of the Annapolis Basin. The proposed site expansion is unlikely to increase the risk of impact on the Harbour Porpoise above that associated with the existing site.

Blue Whale

Blue Whale (*Balaenoptera musculus*) are listed as Endangered under SARA. Northwest Atlantic Blue Whales are generally found in waters off eastern Canada: in the northern Gulf of St. Lawrence, off the coasts of Nova Scotia and Newfoundland, and in the Davis Strait (Figure B4). They are migratory and frequent the Gulf of St. Lawrence and eastern Scotian Shelf between January and November. They feed almost exclusively on euphasiids but can also consume copepods (*Calanus*). The proposed site expansion is unlikely to increase the risk of impact on the Blue Whale above the minimal risk associated with the existing site.

Fin Whale

Fin Whale (*Balaenoptera physalus*) are listed as Special Concern under SARA. Fin Whales generally travel alone or in small groups. They can be observed near the coast as well as far offshore. They feed on krill and small fish such as herring and capelin. During summer, they can be found in areas of krill concentration, including turbulent areas in the Bay of Fundy (Figure B4). Although bath pesticides, if released from the site, might negatively impact the crustaceans in the pelagic zone of exposure, the impact on the fin whales is expected to be minimal and the proposed site expansion is unlikely to increase the risk of impact on the Fin Whale above that associated with the existing site.

Other Marine Mammals

Figure 7 shows other marine mammal records from the study area, including Humpback Whale (*Megaptera novaeangliae*) and Harbour seal (*Phoca vitulina*). There was one record of a Humpback Whale inside the Annapolis Basin, which made an incursion into the Annapolis River in 2004. Humpback Whales have been sighted near aquaculture sites. Humpback Whale and Harbour Seal are listed as Not at Risk by COSEWIC and the proposed site expansion is unlikely to increase the risk of impact on these mammals above the minimal risk associated with the existing site.

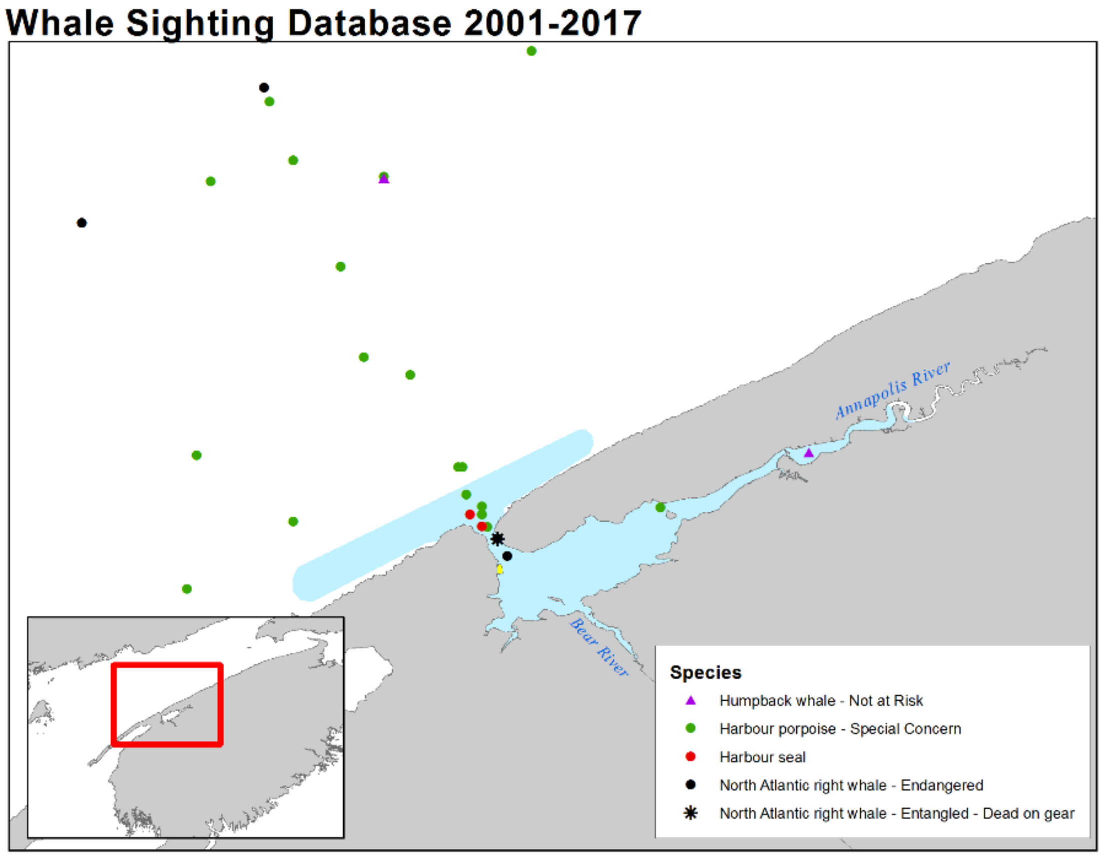

Figure 7. Map showing the location of marine mammal sightings that have been reported to and recorded in the Fisheries and Oceans whale sightings database. The blue polygon displays the region of interest for this review. The yellow polygon shows the distribution of the proposed aquaculture site expansion.

Commercial Fisheries Species of Interest

Based on a search of the MARFIS database, the commercial fisheries in the zone of influence include Scallop, Sea Urchin, Groundfish, and Lobster.

American Lobster

Based on the original surveys by Lawton et al. (1995), it can be expected that lobsters (*Homarus americanus*) will utilize the area within the zone of influence seasonally, including the potential for some overwintering habitat use. Based on tagging conducted in the early 1990s, it is expected that lobsters could either remain in the area of the zone of influence for a short period (e.g., as part of a seasonal migration through Annapolis Basin), or could remain in the vicinity for significant periods of time (e.g., for feeding and/or moulting).

In the early 1990s, diving surveys conducted between the Victoria Beach and Port Wade area did document the presence of newly-settled lobsters. Though there was no similar survey coverage in the Rattling Beach area, it may be expected that similar, shallow (e.g., <20 m) hard bottom (cobble/boulder) habitat within the aquaculture lease area could be considered as potential lobster settlement habitat. Following initial benthic settlement, lobsters are likely to occupy small home ranges within this type of habitat for at least one, potentially 2–3 years following settlement.

For Site 1039, given the documentation on depth profiles and benthic habitat as determined from the baseline video surveys, the primary juvenile habitat contained within the site is likely already within the existing site boundary, and within the existing zone of influence. Research on the interactions between lobster and aquaculture is underway. Much of the habitat in the lease expansion area is beyond 20 m depth and characterized by softer habitat types and so less likely to be significant settlement habitat. There may be potential for lobster in the near-vicinity of the existing and expanded site to be exposed to drugs (e.g., oxytetracycline used in 2016) and pesticides (not used in 2016–17) introduced into the environment via in-feed treatments.

Sea Scallop

The aquaculture site and zone of influence overlaps with Scallop Production Area (SPA) 5, and the nearshore portion of SPA 4 (Figure 7a; Nasmith et al. 2016). The area outlined in red in Figure 7a (referred to as the study area) includes highly productive habitat for the Sea Scallop (*Placopecten magellanicus*) (Shumway and Parsons 2006; Nasmith et al. 2016).

From 2014 to 2018 inclusive (5 years), 29 inshore scallop survey tows were conducted within the Annapolis area (Figure 7a,b). Sea scallops were present in all tows conducted (e.g., scallop found in 29 of 29 tows). Other bycatch recorded on the inshore scallop survey and found within the Annapolis boundary area, along with observed relative frequencies, are listed in Appendix C3. Bycatch recorded on the inshore scallop survey consists of recording lobster, commercial fish species, skates, octopus, and squid. Scallops remain in the area and on the bottom year-round and use the area for spawning and feeding. The scallop larvae are pelagic and are in the water column seasonally.

The effect of finfish farming on scallops is largely unknown. The proposed site expansion is unlikely to increase the risk of impact on scallop above the risk associated with the existing site.

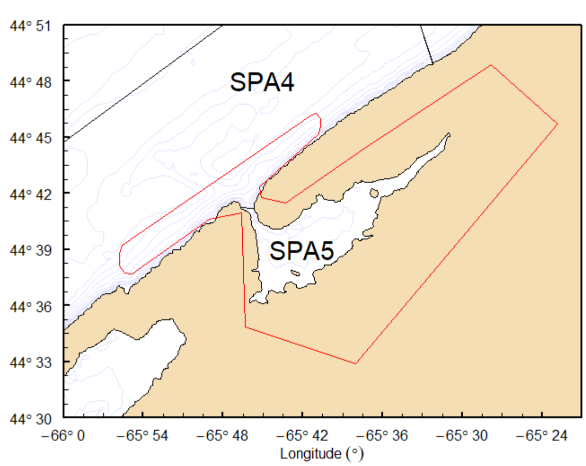

Figure 8a. Spatial overlap between the zone of influence (red boundary) and Scallop Production Areas (SPAs) 4 and 5 (black lines).

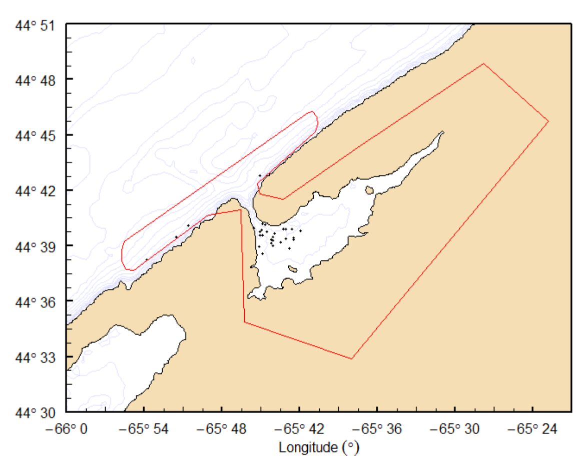

Figure 8b. Inshore scallop survey tow locations (black crosses) from 2014 to 2018 inclusive within the zone of influence.

Clams

The Maritimes Region is divided into seven Clam Harvesting Areas (CHA). Annapolis Basin falls within CHA 2, which includes both recreational and commercial harvest. Subject to any variation or prohibition orders, clam harvesting is open April 1 to Dec. 31, with no harvesting between sunset and sunrise. Clam harvesting may include bar clams, bay quahogs, razer clams and soft-shell clams. The recreational daily limit for Annapolis Basin is 100 clams/quahogs in total, with no limit for commercial harvesters. Only hand and handheld tools are permitted.

The Annapolis River is considered an important clam spawning area, supplying the rest of Annapolis Basin (Buzeta 2014). In 2007, a report by the Clean Annapolis River project reported that the intertidal zones of the Annapolis Basin had the potential for a very productive and lucrative soft-shell clam industry, but several factors have contributed to the decline of the clam populations and increasing closure of clam harvesting areas since the 1970s (Sullivan 2007).

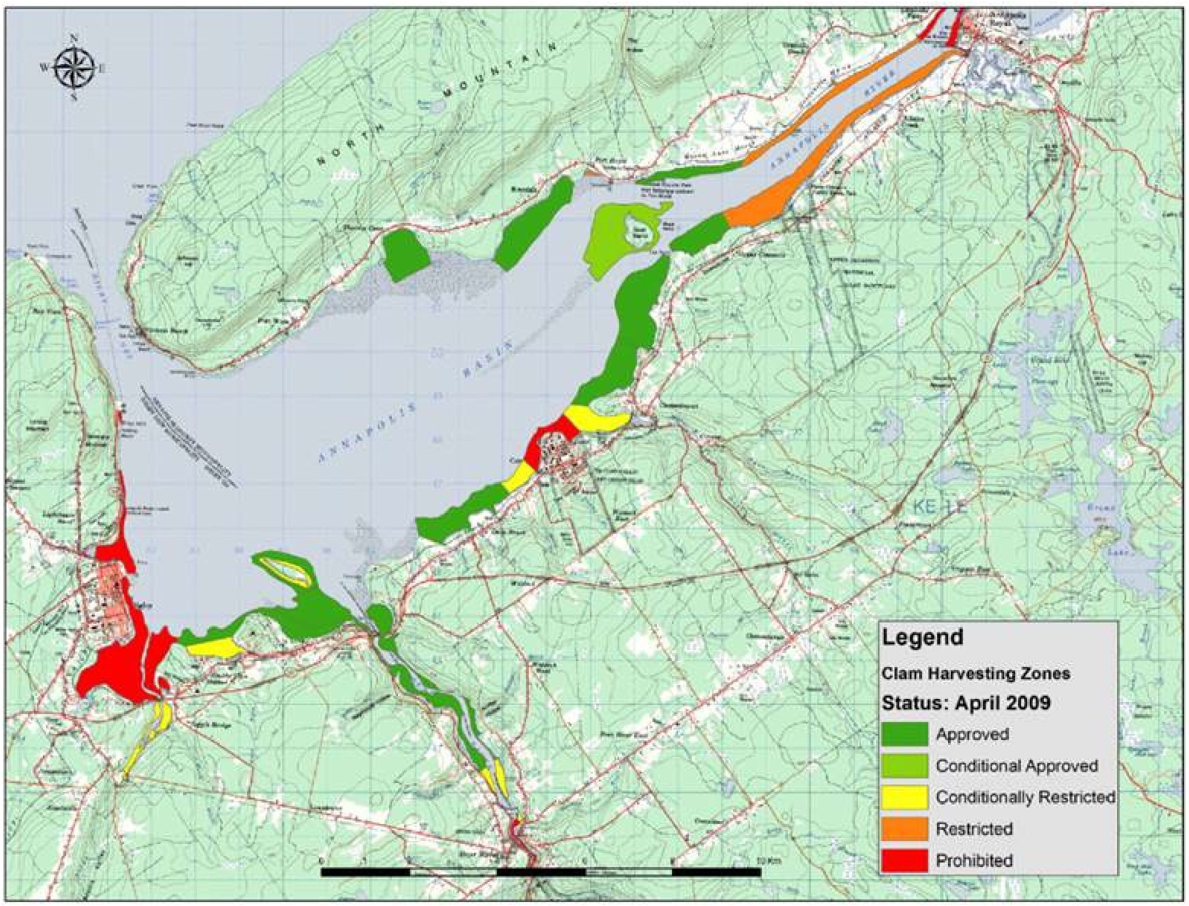

Figure 9. Clam harvesting zones within the Annapolis basin as of 2009 (data from Environment Canada).

Sea Urchin

There are 17 commercial dive-only licenses authorized to fish sea urchins in Southwest Nova Scotia by inshore vessels, including 1 license issued as a First National Commercial Communal License. Access is restricted to commercial harvesters only, on a limited entry basis. The Nova Scotia fishery has been limited in recent years. However, a search of the MARFIS database indicates that sea urchins are being landed from the zone of influence of the aquaculture site, as recently as 2017. There may be potential for sea urchins in the near-vicinity of the existing and expanded site to be exposed to drugs (e.g., oxytetracycline used in 2016) and pesticides (not used in 2016–17) introduced into the environment via in-feed treatments. The proposed site expansion is unlikely to increase the risk of impact above the risk associated with the existing site.

Groundfish

DFO's Research Vessel (RV) survey is typically used to describe the distribution of groundfish in the Maritimes Region, including the Bay of Fundy. Research Vessel survey catches and trends over time of key groundfish species are described in the annual Maritimes Research Vessel Survey Trends report for the Scotian Shelf and Bay of Fundy (DFO 2019). Since the RV survey does not conduct stations within the Annapolis Basin, other sources of information were used to confirm presence of groundfish species within the zone of influence of the aquaculture site: including the ISDB, MARFIS and the Scallop Survey. From these various sources, the groundfish species caught within the zone of influence between 2008–2018 include Cunner (*Tautogolabrus adspersus*), Sea Raven (*Hemitripterus americanus*), Longhorn Sculpin (*Myoxocephalus octodecemspinosus*), Thorny Skate (*Amblyraja radiata*), Winter Flounder (*Pseudopleuronectes americanus*), Winter Skate (*Leucoraja ocellata*), Atlantic Cod (*Gadus morhua*), Haddock (*Melanogrammus aeglefinus*), Monkfish (*Lophius americanus*), American Plaice (*Hippoglossoides platessoides*), Windowpane Flounder (*Scophthalmus aquosus*), Cusk (*Brosme brosme*), Halibut (*Hippoglossus hippoglossus*), Ocean Pout (*Zoarces americanus*), Pollock (*Pollachius virens*), Silver Hake (*Merluccius bilinearis*), Smooth Skate (*Malacoraja senta*), Little Skate (*Leucoraja erinacea*), Spiny Dogfish (*Squalus acanthias*), Summer Flounder (*Paralichthys dentatus*), White Hake (*Urophycis tenuis*), Red Hake (*Urophycis chuss*), Yellowtail Flounder (*Limanda ferruginea*) and Witch Flounder (*Glyptocephalus cynoglossus*) (Appendix C).

The most recent update of the RV Survey Trends Report (DFO 2019) includes the current status and trends for most of these species. There may be potential for the benthic feeding species within the near-field zone of influence of site to be exposed to drugs (e.g., oxytetracycline used in 2016) and pesticides (not used in 2016–17) introduced into the environment via in-feed treatments. The proposed site expansion is unlikely to increase the risk of impact above the risk associated with the existing site.

Recreational and Aboriginal Fisheries

There are a number of recreational and aboriginal, including FSC, fisheries of relevance to the study area. These include fisheries for diadromous species such as Striped Bass (*Morone saxatilis*), American Eel (*Anguilla rostrata*), Alewife (*Alosa pseudoharengus*), Blueback Herring (*Alosa aestivalis*), Rainbow Smelt (*Osmerus mordax*), and American Shad (*Alosa sapidissima*), as well as marine species such as Atlantic Tomcod (*Microgadus tomcod*), Mackerel (*Scomber scombrus*) and Tuna. Of these species, there is one ISDB record of Alewife and American Shad from the zone of influence from this aquaculture site expansion.

The **American Shad** (*Alosa sapidissima*) is an anadromous coastal migrant that naturally inhabits the Northwest Atlantic, ranging from Newfoundland and Labrador south to Florida (Scott and Scott 1988). Shad are an important species to commercial, recreational, and aboriginal fisheries. They are fished commercially in the Maritimes Provinces, including the Bay of Fundy, but are no longer fished commercially in the Annapolis River (Melvin et al. 1985, Chaput and Bradford 2003). They are also kept as bycatch in gaspereau fisheries in the Maritimes. They are fished recreationally in many rivers, including the Annapolis River. The Bay of Fundy population of American Shad includes the large Annapolis River spawning population (Hasselman et al. 2010). American Shad native to the Annapolis River are known to spawn in May–June; following spawning, adult fish will leave the estuary, and if in the Bay of Fundy, make their way counter-clockwise around the Bay, and head back out to sea in the fall (Melvin et al. 1985, Dadswell et al. 1987, Williams and Daborn 1984). The migrating fish may, therefore, pass by the aquaculture site.

Alewife and Blueback Herring are often grouped together under the broader term of gaspereau. They range coastally throughout the Northwest Atlantic. They live mostly at sea but enter freshwater habitats to spawn (Scott and Scott 1988). In the Annapolis River system, adult Blueback Herring and Alewife spawn in the river during spring or early summer and then move back to sea quickly following spawning. They migrate in and out of the Annapolis Basin and likely pass by the proposed lease area on their way to their spawning grounds.

Striped Bass had three spawning populations within the Bay of Fundy DU: Shubenacadie, Saint John, and Annapolis. The Annapolis population is considered extirpated (COSEWIC 2012a, DFO 2014, Bradford et al. 2015). These species are found in large numbers throughout the Bay of Fundy and likely transit in the vicinity of the proposed lease area.

American Eel spend most of their lives in fresh water, and all adults migrate to and spawn in the Sargasso Sea (Scott and Scott 1988, COSEWIC 2012b). Juveniles and adults are present in most freshwater water bodies with a connection to the Atlantic Ocean. Eels are fished commercially at a number of different life stages and are often caught recreationally as well. They are of significant value to aboriginal communities, who have fished them for thousands of years. They have been assessed as Threatened by COSEWIC. American Eel are present in the Annapolis River basin area (Gibson and Daborn 1995). Adults are expected to pass by the proposed lease area as they migrate out of the Annapolis Basin between February and August, with juveniles (glass eels and elvers) returning as they move into estuaries and towards fresh water.

Atlantic Tomcod is an inshore marine fish, seasonally abundant in the Bay of Fundy. In Canada, Atlantic Tomcod spawn in early to mid-winter, moving inshore, often into rivers and estuaries, in December, and moving back to sea in January swiftly following spawning (Scott and Scott 1988). Atlantic Tomcod have been captured in the Annapolis River area (Gibson and Daborn 1993, Gibson and Daborn 1995, Stokesbury 1985).

The interaction between the above species and the aquaculture site is expected to be of a transient nature, and the proposed site expansion is unlikely to increase the risk of impact above the risk associated with the existing site.

Other Species of Interest

Information on potentially vulnerable commercial species and species at risk has been provided above. Some additional information on plankton, other crustaceans, polychaete and potentially vulnerable species is provided below.

The relative abundance and frequency of 148 phytoplankton species was recorded in the Annapolis Basin from 1988–1994 (Keizer et al. 1996). The Annapolis Basin is a zone with high concentrations of biomass of *Ascophyllum nodosum* (Rockweed), an algal species that has commercial value in Atlantic Canada (Figure 3 in Ugarte et al. 2010). The nutrients released from the fish farm are likely diluted very quickly and impacts on the phytoplankton are likely to be minimal, especially if the phytoplankton production is light, rather than nutrient limited.

There are important concentrations of zooplankton and Atlantic Herring (*Clupea harengus*) feeding outside of the Annapolis Basin along Digby Neck and Long Island (Power et al. 2003). The Annapolis River is recognized as an important clam spawning area, supplying the rest of Annapolis (DFO 2013a). Juvenile lumpfish have been observed inside Annapolis Basin between July and October (Daborn and Gregory 1983 in DFO 2013a). Basking Sharks *(Cetorhinus maximus)* are listed as Special Concern by COSEWIC. Their distribution includes de Bay of Fundy. Sightings and tagging information does not include areas nearby the Annapolis Basin (Hoogenboom et al. 2015). The full list of species considered in this analysis is included in Appendix D.

The proponent reported Rock Crab. Green Crab and hermit crab, whelks, barnacles, kelp, rockweed, sea stars, *Flustra,* periwinkles, and quahogs from video footage and collected grab samples. ISDB records reported the presence of several invertebrate species including Jonah Crab, Atlantic Rock Crab, Brachyuran crabs, hermit crabs, Asteroidea (Sea stars) Phylum, and Green Sea Urchin (*Strongylocentrotus droebachiensis*) (Table B:1). Polychaetes such as *Nephtys neotella* under mussel lines and *Nereis diversicolor* under fish pens have been reported nearby aquaculture sites within the Inshore Scotian Shelf (Pocklington et al. 1994) and their presence is probable in the Annapolis Basin. Bloodworms are most abundant on estuarine soft muds rich in organic matter, whereas sandworms are on cleaner soil associated with clam flats (McCullough et al. 2005) and, thus, they may be distributed in the Annapolis Basin area.

Habitat Spatial Distribution and Usage

There is no identified marine Critical Habitat within the estimated zones of influence, but there is habitat suitable for a variety of species including lobster, scallop, and wild Atlantic Salmon.

Comparison of Potential Aquaculture Impacts to Habitat Impacts from Other Activities

No comparison to impacts from other anthropogenic sources have been made for this review. Earlier Science Responses on wild salmon populations in the vicinity of proposed finfish aquaculture provides information on how impacts to the wild salmon population from a proposed aquaculture development site compare to the impacts from other anthropogenic sources (DFO 2011a,b). In future, the application of a cumulative effects (CE) analysis during the advisory process would allow for a comparison of anthropogenic impacts on key marine habitats. As both human activities and marine habitats vary in their spatial (and temporal) distribution, the application of a CE impact analysis using GIS (e.g., Halpern et al. 2009; Clarke Murray et al. 2015) would allow patterns of overlap in human activities to be visualized, in order to identify intensely impacted areas and/or areas with a large human footprint. Partitioning cumulative impact scores among stressor categories or habitat types could identify the highest impact activities or particularly vulnerable habitats, respectively. Successive model scenarios could then be employed to evaluate the additive burden of additional human use activities in the area of interest. For the Annapolis Basin specifically, cumulative effects may stem from both land- and ocean-based human activities. For example, detrimental increases in BOD could result from the cumulative impact of the expansion of fin-fish aquaculture combined with excessive nutrient inputs from sewage treatment plant discharge and agricultural run-off from the Annapolis Valley, as well as the occurrence of seasonal algal blooms in the basin.

Co-occurring human activities create multiple impacts on marine ecosystems. The broader goal of cumulative effects research is to quantify the basic linkages along the human activity–

stressor–impact pathway and determine how such impacts accumulate and interact to produce cumulative effects (Clarke Murray et al. 2014). Towards this end, DFO has recently acquired capacity to help address cumulative effects through the creation of a National Ecosystem Stressors Program, with a central hub located in the Pacific Region (Ocean Sciences Division, Institute for Ocean Sciences, Sidney BC), whose work is focused on developing frameworks, conceptual models, and best-practice guidance for CE research. In the Maritimes Region, regional CE impact mapping exercises are currently underway, and results of this research will be available for 2019-2020 and beyond.

Although the Annapolis Basin receives nutrient inputs from a large agricultural area (Keizer et al 1996), there has been no attempt in this response to examine the potential for nutrient related effects.

Comments on Proponent's Deposition Model

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 used by the proponent, consistent with the scientific knowledge of the potential impact of this operation?

The proponent used the AquaModel to produce outputs concerning the flux of carbon to the seabed and the associated benthic effects. The proponent did not provide, and presumably was not asked to provide, estimates of pesticide or drug exposures or effects.

The predicted benthic effects, as demonstrated by the output of the depositional model used by the proponent, are consistent with the DFOs scientific considerations of the potential impact of the proposed operation. The details supporting this conclusion are given in Part B of the response to Question 1. Some of the uncertainties associated with the model are indicated in the Sources of Uncertainty Section of this Response.

Sources of Uncertainty

Model Estimates

The model results presented here suggest there could be a significant flux of carbon to the sea bed, that if the flux actually occurs there could be significant reduction in the bio-diversity of the benthic macro in-fauna and that the area of exposure and impact will be beyond the proposed site net-pen array, and beyond some portions of the lease boundary.

The model results are estimates of the potential scale and intensity of exposure and impact, especially for benthic impact. As with all models, outputs from the models have uncertainty associated with them. In the case of aquaculture models when predictions have been compared to observations the length scales of the exposure areas are more consistent with observations than the intensities of impact. For example, a comparison of output from the DEPOMOD benthic carbon flux model to observations in the Maritimes Region showed that predictions of low carbon flux corresponded with observations of low impact, but predictions of high carbon flux corresponded with observed impacts ranging from very little to very significant impacts i.e., high sediment sulfide concentrations (Chang et al. 2012, DFO 2012b).

The uncertainty is related to many factors including differences between assumed and actual feeding and feed wastage rates, actual currents throughout the production cycle, the duration of maximum and mean feeding periods, the assumptions of horizontal homogeneity in the current, errors in bathymetry, the accuracy and number of environmental impact indicators, and the time scale and history need for carbon flux to evolve into sulfide concentrations that result in changes to bio-diversity, among other factors. The deposition model results presented by the proponent are stated as being for the times of peak and mean feeding (SIMCorp 2018), but changes in the timing and duration of these may result in changes in the predictions as was the case in the DEPOMOD evaluation (Chang et al. 2012, DFO 2012b).

The proponent provided high resolution bathymetry data for the area of interest but did not correct the collected data for variation in tidal height at the time of the soundings (SIMCorp. 2016). Since the tidal range varies between 5 m and 8 m, if reduced to chart datum, the uncorrected bathymetry could differ from bathymetry adjusted to chart datum by as much as 8 m, depending on the time of year and phase of the tide the survey was conducted. This error is incorporated into the AquaModel results since it affects the estimated sinking times of the organic material released from the farm.

The current used to drive the proponent's AquaModel was from a single ADCP location. It is likely, however, that current patterns vary spatially as the bathymetry varies spatially. Using a single current meter record, especially in an area of spatially varying bathymetry, can result in either an over or under estimate of the spatial extent and shape of the exposure zone. The general magnitude of the zone is, however, likely to be robust to this uncertainty since the model results are consistent with the simple calculations.

It was determined that the DFO model estimates of the water current speeds at the location of the proponent's ADCP deployment were larger than the observed currents. However, since no other current data were available from the vicinity of the proposed site at the time of response, it was not possible to comprehensively determine the overall performance of the DFO hydrodynamic or particle tracking model in the region of interest. The fact that the model and simple calculations result in similar magnitudes of exposure zone length scales suggests the conclusions are robust to the differences between the model and observations.

Given the uncertainties the magnitude of the spatial scales of the predictions are thought to be reasonably robust but the intensity estimates, although reasonable, are thought to be less robust. Model sensitivity analyses and comparisons between model outputs and observations will be needed to reduce the uncertainty. Except for a comparison between model and observed current at one location, no comparisons between the present predictions and observations have been made, nor can they be made until data is available from the operations of the expanded site. The existing regulatory environmental monitoring program does not have sufficient spatial resolution or extent to thoroughly test the model predictions.

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, and hence information on these space and time scales is generally not contained within the various data sources available to DFO, including the surveys referred to in this document. Therefore, there is uncertainty as to the exact distribution of species in the area of the proposed expansion.

More specifically, the relative frequency of different species in the Annapolis Basin was obtained from MARFIS, ISDB, and the inshore scallop survey. These surveys do not fully sample the basin spatially or temporally and, therefore, additional information on presence and habitat use (i.e., spawning, migration, feeding) must be drawn from larger-scale studies, which were also generally utilized by the proponent.

Effects on Species and Habitats

Science has focused mainly on the effect of organic loading to the seabed and its correspondence with degrees of the bio-diversity of macro-infauna in the upper few centimeters if the bottom sediment. Relatively little effort has been directed to the relation between the benthic carbon fluxes and commercial, recreational, aboriginal and at risk species considered to be within the potential zones of exposure is not well explored in the scientific literature.

Conclusions

Question 1: Does the zone of influence extend beyond the boundaries of the aquaculture facility?

- The estimated zone of influence for BOD, potential pesticides and drugs appears to extend beyond the boundaries of the aquaculture net-pen array and the net-pen anchor system.
- The spatial extent of the predicted zones of benthic exposure and influence associated with both BOD and drugs extend beyond the northeast portion of the proposed site lease boundary by a distance of order 100 m.
- The pelagic zones associated with bath pesticides, if they were to be used, are estimated to extend a distance in the order of kilometers beyond the cage array and lease boundary.

Question 2: What species and habitats, with a focus on species at risk, commercial species and those sensitive to aquaculture, exist within this zone of influence (and the broader Bay)? How do these species utilize (i.e., spawning, migrating, feeding, etc.) this area (eg. the zone of influence)? Are there any habitats within the zone of influence considered critical or valuable for these species?

There are many aquatic marine species and habitats within the Annapolis Basin and within the proposed lease area.

- This response has focused on species of commercial, recreational, aboriginal (CRA) interest and species at risk (SAR).
- Several CRA and SAR species exist within the area of interest.
- The list includes:
    - lobsters, scallops, clams, Atlantic Salmon, Striped Bass, American Eel and perhaps North Atlantic Right Whales
    - Scallops are expected to be in the area year-round
    - Scallop and clam larvae are expected to be in the water seasonally.
    - Adult and juvenile Lobsters may be present year-round, with the majority of adult Lobsters migrating away from the area for the winter period.
- The area has been identified as being within or on the fringe of the migration pathways for several species including the endangered wild Atlantic Salmon, Striped Bass, and American Eel.
- No spawning grounds of important marine species have been identified within the Annapolis Basin and within the estimated zones of exposure and influence.
- No critical habitats for important marine species have been identified for the Annapolis Basin and within the estimated zones of exposure and influence.

- No comparison to impacts from other anthropogenic sources have been made.

Question 3: Are the predicted benthic effects, as demonstrated by the output of the depositional model used by the proponent, consistent with the scientific knowledge of the potential impact of this operation?

- The BOD benthic effects associated with organic loading of the sea bed and predicted by the proponent are consistent with existing scientific prediction capabilities.
- The proponent's predictions are limited to the flux of carbon to the seabed and are of most relevance to the bio-diversity of benthic infauna and to the spatial extent of in-feed drugs;
- The predictions suggest a potential for elevated sediment sulfide concentrations under the site net-pens and between the net-pens and 100–200 m distance from the net-pens.
- Previous science has indicated the existing prediction capabilities for BOD benthic impacts agree well with observations on the spatial length scales of the exposure and influence zones and with observations of low impact; predictions of high impact do not necessarily correspond to observations of high impact.
- The proponent was not required and did not provide information on the potential impact of pesticides or drugs.
- One drug, oxytetracycline, has been used at the site in the past. The exposure zone associated with this drug is assumed to be similar to that of exposure to BOD, since the drug is administered through feed.
- The impact of drugs on the benthic organisms and habitat is generally unknown, although the potential for inducing anti-microbial resistance in benthic microbes is a topic of growing interest.
- If the proposed site continues to operate without the use of pesticides there will be no influence or pesticide exposure zones to influence either the pelagic or benthic marine environment. If bath pesticides were to be used in the future, there may be some influence on pelagic zooplankton within a radius of a few hundred to a few kilometers of the site, depending upon the pesticide used. If in-feed drugs, including antibiotics and pesticides, were to be used in the future, there may be some influence on benthic fauna and bacteria within and near the site. The site has used oxytetracycline in the past.

Contributors

Name	Affiliation
Page, Fred (Lead)	DFO Science, Maritimes Region
Lawton, Peter	DFO Science, Maritimes Region
Haigh, Susan	DFO Science, Maritimes Region
O'Flaherty-Sproul, Mitchell	DFO Science, Maritimes Region
Wong, David	DFO Science, Maritimes Region
Paul, Stacey	DFO Science, Maritimes Region
Gomez, Catalina	DFO Science, Maritimes Region
Sameoto, Jessica	DFO Science, Maritimes Region
Taylor, Andrew	DFO Science, Maritimes Region
Lazin, Gordana	DFO Science, Maritimes Region
Bower, Brian	DFO Science, Maritimes Region
Rose-Quinn, Tammy	DFO Aquaculture Management, Maritimes Region
Laking, Erin	DFO Aquaculture Management, Maritimes Region
Coffen-Smout, Scott	DFO Oceans Management, Maritimes Region
Worcester, Tana	DFO Science, Maritimes Region
Fife, Jack	DFO Science, Maritimes Region
Wu, Youngsheng	DFO Science, Maritimes Region
Chang, Blythe	DFO Science, Maritimes Region (emeritus)
Burgetz, Ingrid	DFO Science, National Capital Region
Kelly, Noreen	DFO Science, Maritimes Region
Wingfield, Jessica	DFO Science, Maritimes Region
Wambolt, Mike	DFO Fisheries Protection Program, Maritimes Region
Hayman, Timothy	DFO Resource Management, Maritimes Region
Cooper-MacDonald, Kathryn	DFO Resource Management, Maritimes Region
MacIntosh, Robert	DFO Policy and Economics, Maritimes Region
Todd, Brian	Natural Resources Canada, GSC Atlantic

Approved by

Approved by
Alain Vézina
Regional Director of Science
DFO Maritimes Region
Dartmouth, Nova Scotia
Phone: 902-426-3490

Date: August 7, 2019

Sources of information

Amiro, P.G., J.C. Brazner, and J. Voutier, J. 2008a. An assessment of the potential for recovery of the Atlantic salmon designated unit for the inner Bay of Fundy: Habitat issues. DFO Can. Sci. Adv. Sec. Res. Doc. 2008/058.

Amiro, P.G., J.C. Brazner, and J. Voutier, J. 2008b. An assessment of the potential for recovery of the Atlantic salmon designated unit for the inner Bay of Fundy: Threats. DFO Can. Sci. Adv. Sec. Res. Doc. 2008/058.

Armstrong, S.M., B.T. Hargrave and K. Haya. 2005. Antibiotic use in Finfish Aquaculture: Modes of Action, Environmental Fate, and Microbial Resistance. Hdb Env. Chem. Vol 5 Part M (2005): 3541-357

Black, K.D., Fleming, S., Nickell, T.D., and P.M.F. Pereira. 1997. The Effects of Ivermectin, Used to Control Sea Lice on Caged Farmed Salmonids, on Benthic Infauna. ICES J. Marine Sci. 54: 276-279

Bowlby, H.D., Gibson, A.J.F., and Levy, A. 2013. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Status, Past and Present Abundance, Life History and Trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/005. v + 72 p.

Bowlby, H.D., Horsman, T., Mitchell, S.C., and Gibson, A.J.F. 2014. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Habitat Requirements and Availability, Threats to Populations, and Feasibility of Habitat Restoration. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/006. vi + 155 p.

Bradford, R.G., Halfyard, E.A., Hayman, T., and P. LeBlanc . 2015. Overview of 2013 Bay of Fundy Striped Bass Biology and General Status. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/024. iv+36 p.

Burridge, L. 2013. A Review of Potential Environmental Risks Associated with the use of Pesticides to Treat Atlantic Salmon Against Infestations of Sea Lice in southwest New Brunswick, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/050. iv + 25 p.

Burridge L.E., J.L. Van Geest. 2014. A Review of Potential Environmental Risks Associated with the use of Pesticides to Treat Atlantic Salmon Against Infestations of Sea Lice in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/002. vi + 39 p.

Buzeta, M-I. 2014. Identification and Review of Ecologically and Biologically Significant Areas in the Bay of Fundy. DFO. Can. Sci. Advis. Sec. Res. Doc. 2013/065. vi + 59 p.

Canty, M.N., J.A. Hagger, R.T.B. Moore, L. Cooper, T.S. Galloway. 2007. Sublethal Impact of Short Term Exposure to the Organophosphate Pesticide Azamethiphos in the Marine Mollusc *Mytilus edulis*. Mar. Pollut. Bull. 54: 396–402.

Capone, D.G., Weston, D.P., Miller, V., and C. Shoemaker. 1996. Antibacterial Residues in Marine Sediments and Invertebrates Following Chemotherapy in Aquaculture. Aquaculture, 145: 55–75.

Chang, B.D., Page, F.H., Losier, R.J., and McCurdy, E.P. 2012. Predicting Organic Enrichment Under Marine Finfish Farms in Southwestern New Brunswick, Bay of Fundy: Comparisons of Model Predictions with Results from Spatially-intensive Sediment Sulfide Sampling. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/078. iv + 146 p.

Chaput, G., and R.G. Bradford. 2003. American Shad (*Alosa sapidissima*) in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/009. iv + 71 p.

Clarke, C.N., S.M. Ratelle, and R.A. Jones. 2014. Assessment of the Recovery Potential for the Outer Bay of Fundy Population of Atlantic Salmon: Threats to Populations. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/006.

Clarke Murray, C., M. Mach, and R.G. Martone. 2014. Cumulative Effects in Marine Ecosystems: Scientific Perspectives on its Challenges and Solutions. WWF-Canada and Center For Ocean Solutions. 60 pp.

Clarke Murray, C., Agbayani, S., Alidina, H.M. and Ban, N.C., 2015. Advancing Marine Cumulative Effects Mapping: An Update in Canada's Pacific Waters. Mar. Policy, 58, pp.71–77.

COSEWIC. 2006. COSEWIC Assessment and Status Report on the White Shark *Carcharodon carcharias* (Atlantic and Pacific Populations) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. (Accessed September 2016).

COSEWIC. 2012a. COSEWIC Assessment and Status Report on the Striped Bass *Morone saxatilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Iv + 82 p.

COSEWIC. 2012b. COSEWIC Assessment and Status Report on the American Eel *Anguilla rostrata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii+109pp.

Coyne, R., Smith, P., and C. Moriarty. 2001. The Fate of Oxytetracycline in the Marine Environment of a Salmon Cage Farm. Mar. Environ. Health Series No. 3.

Coyne, R., Hiney, M., O'Connor, B., Kerry, J., Cazabon, D., and P. Smith. 1994. Concentration and Persistence of Oxytetracycline in Sediments Under a Marine Salmon Farm. Aquaculture. 123: 31–42.

Dadswell, M.J., Melvin, G.D, Williams, J.P. and D.E. Themelis. 1987. Influences of Origin, Life History, and Chance on the Atlantic Coast Migration of American Shad. Am. Fish. S. S. 1: 313 – 330.

Davies, P.A. Gillibrand, J.G. McHenery, G.H. Rae. 1998. Environmental Risk of Ivermectin to Sediment Dwelling Organisms. Aquaculture 163: 29–46.

DFO. 1999. Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces. DFO Mar. Reg. Hab. Status Rep. 99/1E.

DFO. 2006. Science Expert Opinion on Critical Habitat Designation for Inner Bay of Fundy Atlantic Salmon. Can. Sci. Adv. Sec. Sci. Res. 2006/004.

DFO. 2008. Recovery Potential Assessment for Inner Bay of Fundy Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/050.

DFO. 2010. Recovery Strategy for the Atlantic salmon (*Salmo salar*), Inner Bay of Fundy Populations [Final]. Species at Risk Act Recovery Strategy Series.

DFO. 2011a. Wild Salmon Populations in the Vicinity of a Proposed Finfish Aquaculture Development in St. Mary's Bay, Nova Scotia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2011/001.

DFO. 2011b. Wild Salmon Populations in the Vicinity of a Proposed Finfish Aquaculture Development at Little Musquash Cove, New Brunswick. DFO Can. Sci. Advis. Sec. Sci. Resp. 2011/004.

DFO. 2012a. Fish Populations in the Vicinity of Three Proposed Finfish Aquaculture Sites in Shelburne County, Nova Scotia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2011/017.

DFO. 2012b. Review of DEPOMOD Predictions Versus Observations of Sulfide Concentrations Around Five Salmon Aquaculture Sites in Southwest New Brunswick. DFO Can. Sci. Advis. Sec. Advis. Rep. 2012/042.

DFO 2013a. Identification and Review of Ecologically and Biologically Significant Areas in the Bay of Fundy. Can. Sci. Adv. Sec. Sci. Res. 2013/065.

DFO. 2013b. Potential Exposure and Associated Biological Effects from Aquaculture Pest and Pathogen Treatments: Anti-sea Lice Pesticides (part II). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/049.

DFO. 2014. Recovery Potential Assessment for the Bay of Fundy Striped Bass (*Morone saxatilis*) Designatable Units. DFO . Canadian Science Advisory Secretariat Science Advisory Report 2014/053.

DFO. 2017a. Stock Status Update of Atlantic Salmon in Salmon Fishing Areas (SFAs) 19–21 and 23. DFO Can. Sci. Advis. Sec. Sci. Resp. 2017/020.

DFO. 2017b. Evaluation of Scope for Harm for White Shark (*Carcharodon carcharias*) in Atlantic Canada. DFO Can. Sci. Advis. Sec. Sci. Resp. 2017/025.

DFO. 2019. 2018 Maritimes Research Vessel Survey Trends on the Scotian Shelf and Bay of Fundy. DFO Can. Sci. Advis. Sec. Sci. Resp. 2019/012.

EC. 2005. Use of Emamectin Benzoate in the Canadian Finfish Aquaculture Industry: A Review of Environmental Fate and Effects. Doug A. Bright, Ph.D., R.P.Bio. and Scott Dionne, M.Eng. UMA Engineering Ltd.

Elanco Animal Health. 2016. Lufenron for Salmonids. Environmental Assessment in Support of an Import Tolerance Request.

Fergusson, I., L.J.V. Compagno, and Marks, M. 2009. *Carcharodon carcharias*. The IUCN Red List of Threatened Species 2009: e.T3855A10133872.; (Accessed September 2016).

Glass, A. 2017. Maritimes Region Inshore Scallop Assessment Survey: Detailed Technical Description. Can. Tech. Rep. Fish. Aquat. Sci. 3231: v + 32 p

Gibson, A.J.F., and H.D. Bowlby. 2013. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Population Dynamics and Viability. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/142. iv + 129 p.

Gibson, A.J.F., H.D. Bowlby, D.C. Hardie, and P.T. O'Reilly. 2011. Populations on the brink: Low abundance of Southern Upland Atlantic salmon in Nova Scotia, Canada. North Amer. J. Fish. Manag. 31: 733–741.

Gibson, A.J.F., H.D. Bowlby, J.R. Bryan, and P.G. Amiro. 2008. Population Viability Analysis of inner Bay of Fundy Atlantic Salmon with and without Live Gene Banking. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/057. v + 71 p.

Gibson, A.J.F. and G.R. Daborn. 1993. Distribution and Downstream Movement of Juvenile Alosines in the Annapolis River Estuary, Final Report. Acadia Centre for Estuarine Research Publication No. 33, Wolfville, N.S.

Gibson, A.J.F. and G.R. Daborn. 1995. Population Size, Distribution and Fishway Utilization of Juvenile Alosines in the Annapolis River Estuary. Acadia Centre for Estuarine Research Publication No. 36, Wolfville, N.S.

Gibson, A.J.F., H.D. Bowlby, D.L. Sam, and P.G. Amiro. 2009. Review of DFO Science Information for Atlantic Salmon (Salmo salar) Populations in the Southern Upland Region of Nova Scotia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/081. vi + 83 p.

Gibson, A.J.F., and A.L. Levy. 2014. Recovery Potential Assessment for Eastern Cape Breton Atlantic Salmon (*Salmo salar*): Population Viability Analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/005. v + 43 p.

Halpern, B. S., C.V. Kappel, K.A. Selkoe, F. Micheli, C., Ebert, C. Kontgis, C.M. Crain, R. Martone, C. Shearer, and S.J. Teck. 2009. Mapping cumulative human impacts to California Current marine ecosystems. Conservation Letters 2:138–148.

Hargrave, B. T. 2010. Empirical relationships describing benthic impacts of salmon aquaculture. Aquacult Environ Interact. Vol. 1: 33–46

Haya, K., L.E. Burridge, I.M. Davies, and A. Ervik. 2005. A Review and Assessment of Environmental Risk of Chemicals Used for the Treatment of Sea Lice Infestations of Cultured Salmon. Env Chem, Vol. 5, Part M. Pp 305 – 340.

HC. 2016. Azamethiphos, Proposed Registration Decision, PRD2016–25. Pesticide Management Regulatory Agency, Health Canada.

Hasselman, D.J, R.G. Bradford, and P. Bentzen. 2010. Taking stock: defining populations of American shad (*Alosa sapidissima*) in Canada using neutral genetic markers. Canadian Journal of Fisheries and Aquatic Sciences. 67:1021–1039.

Hamelin, K.M, M.C. James, W. Ledwell, J. Huntington, and K. Martin. 2017. Incidental capture of leatherback sea turtles in fixed fishing gear off Atlantic Canada. Aquatic Conserv: Mar Freshw Ecosyst. 1-12. doi: 10.1002/aqc.2733.

Hektoen, H., Berge, J., Hormazabal, V., and M. Yndestad. 1995. Persistence of Antibacterial Agents in Marine Sediments. Aquaculture 133:175–184.

Hoogenboom, J. L., Wong, S. N., Ronconi, R. A., Koopman, H. N., Murison, L. D., and Westgate, A. J. 2015. Environmental predictors and temporal patterns of basking shark (*Cetorhinus maximus*) occurrence in the lower Bay of Fundy, Canada. J. Exp. Mar. Biol. Ecol. 465, 24–32. doi: 10.1016/j.jembe.2015.01.005

Huntsman, A.G. 1937. The cause of periodic scarcity in Atlantic salmon. Royal Soc. Can. 17–27.

Jones, R.A., L. Anderson, and C.N. Clarke. 2014. Assessment of the Recovery Potential for the Outer Bay of Fundy Population of Atlantic Salmon (*Salmo salar*): Status, Trends, Distribution, Life History Characteristics and Recovery Targets. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/008. vi + 94 p.

Keizer P, D. Milligan, D. Subba Rao, P. Strain, and G. Budgen. 1996 Phytoplankton monitoring program: Nova Scotia component—1989 to 1994. Canadian Technical Report of Fisheries and Aquatic Sciences 2136. Department of Fisheries and Oceans. Bedford Institute of Oceanography.

Kenneth D. Black, Stuart Fleming, Thomas D. Nickell and Paula M. F. Pereira. 1997. The effects of ivermectin, used to control sea lice on caged farmed salmonids, on infaunal polychaetes. ICES Journal of Marine Science, 54: 276–279.

Kwon, J.W. 2016. Environmental Impact Assessment of Veterinary Drug on Fish Aquaculture for Food Safety. Drug Test. Analysis. 8: 556–564.

Lacroix, G.L. 2012. Migratory strategies of Atlantic Salmon (*Salmo salar*) postsmolts and implications for marine survival fo endangered populations. Canadian Journal of Fisheries and Aquatic Sciences 70: 32–48.

Lacroix G. L. 2013. Population-specific ranges of oceanic migration for adult Atlantic salmon (*Salmo salar*) documented using pop-up satellite tags, Canadian Journal of Fisheries and Aquatic Sciences 70:1011–1030.

Lacroix G. L. 2014. Large predators could jeopardize the recovery of endangered Atlantic salmon, Canadian Journal of Fisheries and Aquatic Sciences 71: 343–350.

Lacroix, G.L. and I.A. Flemming. 1998. Ecological and behavioural interactions between farmed and wild Atlantic salmon: consequences for wild salmon. CSAS Research Document 98/162.

Lawton, P., D.A. Robichaud, and M. Moisan. 1995. Characteristics of the Annapolis Basin, Nova Scotia, lobster fishery in relation to proposed marine aquaculture development. Can. Tech. Rep. Fish. Aquat. Sci. 2035. iii + 26 p.

Leggatt, R.A., P.T. O'Reilly, P.J. Blanchfield, C.W. McKindsey, and R.H. Devlin. 2010. Pathway of effects of escaped aquaculture organisms or their reproductive material on natural ecosystems in Canada. Can. Sci. Adv. Sec. Res. Doc. 2010/019. vi + 70 p.

Levy, A.L., and A.J.F. Gibson. 2014. Recovery Potential Assessment for Eastern Cape Breton Atlantic Salmon (*Salmo salar*): Status, past and present abundance, life history, and trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/099. v + 72 p.

Li, M. Z., C. G. Hannah, W. A. Perrie, C. C.L. Tang, R. H. Prescott and D. A. Greenberg. 2015. Modelling seabed shear stress, sediment mobility, and sediment transport in the Bay of Fundy. Can. J. Earth Sci. 52: 757–775

Lyons, McKeigan, Wong and F.H. Page. 2014. Degradation of hydrogen peroxide in seawater using the anti-sea louse formulation Interox® Paramove™50. Canadian Technical Report of Fisheries and Aquatic Sciences 3080.

McCullough, D.M., P.A. Doherty, H.L. Schaefer, C. Deacoff, S.K. Johnston, D.R. Duggan, B.D. Petrie and V.V. Soukhovtsev. 2005. Significant Habitats: Atlantic Coast Initiative (SHACI): Halifax Regional Municipality, Units 4–6. Can. Manuscr. Rep. Fish. Aquat. Sci. 2724: xvii + 501 p.

MELP (British Columbia Ministry of Environment, Lands and Parks). 1996. *Angling Guide Report and Pollicy Review Implementation: Working towards Improvement*. Victoria: British Columbia Ministry of Environment, Lands and Parks, Fisheries Branch.

Melvin, G.D., Dadswell, M.J., and J.D. Martin. 1985. Impact of Lowhead Hydroelectric Tidal Power Development on Fisheries. Part 1: A Pre-Operation Study of the Spawning Population of American Shad, *Alosa sapidissima* (Pisces: Clupeidae), in the Annapolis River, Nova Scotia, Canada. Canadian Technical Report of Fisheries and Aquatic Sciences. 1340: iv+33p.

Morris, M.R.J., D.J. Fraser, A.J. Heggelin, F.G. Whoriskey, J.W. Carr, S.F. O'Neil, and J.A. Hutchings. 2008. Prevalence and recurrence of escaped farmed Atlantic salmon (Salmo salar) in eastern North American rivers. Can. J. Fish. Aquat. Sci. 65: 2807–2826.

Nasmith, L., Sameoto, J., and Glass, A. 2016. Scallop Production Areas in the Bay of Fundy: Stock Status for 2015 and Forecast for 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/021. vi + 140 p.

Page, F.H. and L. Burridge. 2014. Estimates of the effects of sea lice chemical therapeutants on non-target organisms associated with releases of therapeutants from tarped net-pens and well-boat bath treatments: a discussion. Canadian Science Advisory Secretariat (CSAS) Research Document 2014/103, v+36 p.

Page, F.H., B.D. Chang, M. Beattie, R. Losier, P. McCurdy, J. Bakker, K. Haughn, B. Thorpe, J. Fife, S. Scouten, G. Bartlett and B. Ernst. 2014. Transport and dispersal of sea lice bath therapeutants from salmon farm net-pens and well-boats operated in Southwest New Brunswick: a mid-project perspective and perspective for discussion. Canadian Science Advisory Secretariat (CSAS) Research Document 2014/102, 63 p.

Pocklington, P., D.B. Scott and C.T. Schaefer. 1994. Polychaete response to different aquaculture activities. Mem. Mus. Hist. Nat. 162: 511–520.

Power, M.J., G.D.Melvin and R. I. Stephenson. 2003. Stock status report of 4VWX herring. Dept. of Fish and Ocean Can. Mar. Reg. Stock Status Report 2003/027.

Samuelsen, O.B. 1989. Degradation of Oxytetracycline in Seawater at two Different Temperatures and Light Intensities, and the Persistence of Oxytetracycline in the Sediment from a Fish Farm. Aquaculture 83: 7–16.

Scott, W.B., and M.G. Scott. 1988. Atlantic fishes of Canada. Toronto, Canada: Toronto University Press.

Schlenk, D., Sapozhnikova, Y., and Cliff, G. 2005. Incidence of Organochlorine Pesticides in Muscle and Liver Tissues of South African Great White Sharks *Carcharodon carcharias*. Mar. Pollut. Bull. 42:703–704.

Schering-Plough Animal Health. 2005. Aquaflor® Florfenicol: Technical Monograph for Catfish Health Professionals.

Shumway, S.E., Parsons, G.J. (Eds). Scallops: Biology, Ecology and Aquaculture. Second Edition. Elsevier, B.V. Amsterdam, The Netherlands. pp. 765–868.

SIMCorp. 2016. Baseline Assessment Report Site #1039 Rattling Beach Annapolis Basin. Halifax, Nova Scotia, Canada: Sweeney International Marine Corporation.

SIMCorp. 2018. Baseline Assessment Report Addendum Site #1039 Rattling Beach Annapolis Basin. Halifax, Nova Scotia: Sweeney International Marine Corp.

Stokesbury, K. 1985. Downstream Movements of Juvenile Alosids and Preliminary Studies of Juvenile Fish Mortality associated with the Annapolis Tidal Power Turbine. Acadia Centre for Estuarine Research, Wolfville, N.S. Publication 2. 28p.

Sullivan, D. 2007. A Population Survey and Resource Valuation of Soft-shell Clams (*Mya arenaria*) in the Annapolis Basin, NS. Clean Annapolis River Project. 27 p.

Swail, V.R., V.J. Cardone, M. Ferguson, D.J. Gummer, E.L. Harris, E.A. Orelup and A.T. Cox. 2006. The Msc50 Wind and Wave Reanalysis. 9th International Workshop on Wave Hindcasting and Forecasting September 25–29, 2006 Victoria, B.C. Canada

Ugarte, R., J. Craigie and A. T. Critchley. 2010. Fucoid fauna of the rocky intertidal of the Canadian Maritimes: implications for the future with rapid climate change. In A. Israel, R. Einav and J. Seckbach (eds.) Seaweeds and their roles in globally changing environments. Springer, Heidelberg.

Wildsmith, B. 1981. Annapolis valley tidal project. Atl. Salmon J. Oct. 1981: 28–29.

Williams, R.R.G., and G.R. Daborn. 1984. Spawning of the American Shad (*Alosa sapidissima*) in the Annapolis River, Nova Scotia. Proceedings of the Nova Scotian Institute of Science. 34: 9 – 14.

Winfield, L. 2018. Memorandum to Aquaculture Network Agencies Re: Aquaculture Amendment Application No. 1039 - Digby County Aquaculture Network Review. Nova Scotia Department of Fisheries and Aquaculture.

Appendix A: Description of DFO Modelling

As part of several DFO aquaculture research programs, a FVCOM (Finite Volume Coastal Ocean Model) was developed for the coastal areas of southwest New Brunswick. A triangular unstructured grid was developed which encompasses the Bay of Fundy, the Gulf of Maine and extends to the Scotian Shelf Break. The model domain extends west to Narragansett, RI, USA and east to Louisbourg, NS. The model uses 21 geometrically spaced vertical sigma-levels resulting in layer thicknesses ranging from centimeters to hundreds of meters. The horizontal grid resolution ranges from ~30m to ~10km with the finest resolution occurring in areas of aquaculture activities. The horizontal grid contains 178291 nodes (triangle vertices) and 342191 cells (triangles). The model was run using a time step of 1.5 seconds (Table A:1).

Table A:1. Details of the FVCOM grids.

Grid	
Nodes	178291
Cells	*342191*
Horizontal Resolution	*~30m – ~10km*
Vertical Resolution	*21 geometrically spaced sigma-levels*
Time step	*1.5 seconds*

FVCOM version 4.1 (DFO repository) was used. The model was run in fully baroclinic mode. The vertical mixing scheme was the GOTM implementation of the Mellor-Yamada 2.5 turbulence model. The simulation started on February 1st 2015 and ran for ~18 months, ending on August 5th 2016. The model used wetting and drying and the same time step for both external (barotropic) and internal (baroclinic) solutions.

Model forcing included fresh water input from 9 rivers. The open boundary was forced with sea surface height, temperature and salinity. At the sea surface, winds and heat-flux fields were applied. The model was started from rest (i.e., flat sea surface and zero currents) and initialized with temperature and salinity from daily averaged RIOPS values. The model forcing was ramped up over 18 hours and spun-up over a two-month period.

The 9 rivers included in the model run were the St Croix, Dennis Stream (which discharges into the St Croix River), Magaquadavic, Lepreau, Black, Point Wolfe, Petitcodiac, Digdeguash, Saint John rivers. Discharge data were obtained from Environment and Climate Change Canada (ECCC) and NB Power. The rivers were forced as a discharge, by adding a volume of fresh water into an element.

At the open boundary, the model was forced with sea surface height which had both tidal and non-tidal components. The tidal components were acquired from the OSU East Coast of the USA regional model. Five tidal constituents were included in the model forcing: M2, N2, S2, K1 and O1. The model was preliminary tuned for tides by altering the minimum bottom friction parameter. The non-tidal component was obtained by de-tiding hourly sea-surface height data from RIOPS (Regional Ice Ocean Prediction System, an ECCC product). Temperature and salinity were specified at the open boundary using RIOPS daily averaged fields.

At the sea surface, atmospheric conditions were applied using data from the High Resolution Deterministic Prediction System (HRDPS), also an ECCC product, and included surface winds, air temperature, specific humidity, air pressure and long and short wave radiation. The heat-flux was calculated internally within FVCOM using the COARE 3.0 algorithm. Although evaporation and precipitation were not fully integrated in the model run, the COARE 3.0 algorithm computes the latent heat-flux thereby including the effects of evaporation on the total heat-flux.

Appendix B: Summary of SARA and COSEWIC species within the region of interest

Common name	Scientific name	Population	Range	COSEWIC status	Schedule 1 [2](Yes/No)?	SARA status	Expected Presence in Study Area?
Acadian Redfish	*Sebastes fasciatus*	Atlantic population	Atlantic Ocean	Threatened	No	No Status	Possible. This population is found along most of Canada's Atlantic coast, from Baffin Island to the Scotian Shelf, as well as in the Gulf of St. Lawrence.
American Plaice	*Hippoglossoides platessoides*	Maritime population	Atlantic Ocean	Threatened	No	No Status	Possible. Prefer depths of 50 to 200 meters.
Atlantic Bluefin Tuna	*Thunnus thynnus*		Atlantic Ocean	Endangered	No	No Status	Possible. Fisheries for Atlantic Bluefin Tuna include the Bay of Fundy.
Atlantic Cod	*Gadus morhua*	Laurentian South population	Atlantic Ocean	Endangered	No	No Status	No
Atlantic Cod	*Gadus morhua*	Southern population	Atlantic Ocean	Endangered	No	No Status	Likely. Distribution extends from southern Nova Scotia and the Bay of Fundy, to Eastern Georges Bank.
Atlantic Salmon	*Salmo salar*	Inner Bay of Fundy population	New Brunswick, Nova Scotia, Atlantic Ocean	Endangered	Yes	Endangered	Possible
Atlantic Salmon	*Salmo salar*	Eastern Cape Breton population	Nova Scotia, Atlantic Ocean	Endangered	No	No Status	No
Atlantic Salmon	*Salmo salar*	Nova Scotia Southern Upland population	Nova Scotia, Atlantic Ocean	Endangered	No	No Status	Likely. Annapolis and Bear River in the Annapolis Basin are part of the southern Bay of Fundy DU; migration routes would include the study area.
Atlantic Salmon	*Salmo salar*	Outer Bay of Fundy population	New Brunswick, Atlantic Ocean	Endangered	No	No Status	Possible

[2] Listing under Schedule 1 of the *Species at Risk Act (SARA)*. SARA establishes Schedule 1, as the official list of wildlife species at risk. It classifies those species as being either extirpated, endangered, threatened, or a special concern. Once listed, the measures to protect and recover a listed wildlife species are implemented.

Common name	Scientific name	Population	Range	COSEWIC status	Schedule 1 [2](Yes/No)?	SARA status	Expected Presence in Study Area?
Atlantic Wolffish	*Anarhichas lupus*		Arctic Ocean, Atlantic Ocean	Special Concern	Yes	Special Concern	Likely. There are 2 observer records from this location, but they are usually found at depths between 100-500m.
Basking Shark	*Cetorhinus maximus*	Atlantic population	Atlantic Ocean	Special Concern	No	No Status	Possible
Deepwater Redfish	*Sebastes mentella*	Gulf of St. Lawrence - Laurentian Channel population	Atlantic Ocean	Endangered	No	No Status	No. Distributed in the Gulf of St. Lawrence and on the Scotian Shelf, up to the continental slope.
Lumpfish	*Cyclopterus lumpus*		New Brunswick, Nova Scotia, Atlantic Ocean	Threatened	No	No Status	Likely. Lumpfish are widespread in both the pelagic and the demersal realm in waters off eastern Canada.
Northern Wolffish	*Anarhichas denticulatus*		Arctic Ocean, Atlantic Ocean	Threatened	Yes	Threatened	No. Found in the waters off of Nova Scotia, in the Gulf of St. Lawrence, around the island of Newfoundland, up the Labrador coast to Baffin Island.
Porbeagle	*Lamna nasus*		Atlantic Ocean	Endangered	No	No Status	Possible. Continuous distribution in Canadian waters ranging from northern Newfoundland and Labrador to the Gulf of St. Lawrence and around Newfoundland to the Scotian Shelf and the Bay of Fundy.
Roundnose Grenadier	*Coryphaenoides rupestris*		Arctic Ocean, Atlantic Ocean	Endangered	No	No Status	Unlikely. Species is most abundant from Davis Strait, on the continental slope off of Newfoundland and Labrador, and along the edge of the Grand Banks to Georges Bank. It is sometimes captured on the Scotian Shelf. Usually found at depths between 400-1200m.

Common name	Scientific name	Population	Range	COSEWIC status	Schedule 1 [2](Yes/No)?	SARA status	Expected Presence in Study Area?
Shortfin Mako	*Isurus oxyrinchus*	Atlantic population	Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador, Atlantic Ocean	Special Concern	No	No Status	Possible
Smooth Skate	*Malacoraja senta*	Laurentian-Scotian population	Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Atlantic Ocean	Special Concern	No	No Status	Likely
Thorny Skate	*Amblyraja radiata*		Nunavut, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador, Arctic Ocean, Atlantic Ocean	Special Concern	No	No Status	Possible
White Hake	*Urophycis tenuis*	Atlantic and Northern Gulf of St. Lawrence population	Atlantic Ocean	Threatened	No	No Status	Likely
White Shark	*Carcharodon carcharias*	Atlantic population	Atlantic Ocean	Endangered	Yes	Endangered	Yes
Winter Skate	*Leucoraja ocellata*	Eastern Scotian Shelf - Newfoundland population	Atlantic Ocean	Endangered	No	No Status	No. Designatable Unit is limited to 4VW (Eastern Scotian Shelf).

Common name	Scientific name	Population	Range	COSEWIC status	Schedule 1 [2](Yes/No)?	SARA status	Expected Presence in Study Area?
American Eel	*Anguilla rostrata*		Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador, Atlantic Ocean	Threatened	No	No Status	Possible
Atlantic Sturgeon	*Acipenser oxyrinchus*	Maritimes populations	New Brunswick, Nova Scotia, Atlantic Ocean	Threatened	No	No Status	Likely. A spawning population is known to occur in the Saint John River. Adults spend much of their non-breeding time at sea where they can migrate over extensive distances along the coast while feeding. Atlantic Sturgeon have been observed in the Annapolis River, and elsewhere in the Bay of Fundy.
Atlantic Whitefish	*Coregonus huntsmani*		Nova Scotia	Endangered	Yes	Endangered	No
Rainbow Smelt	*Osmerus mordax*	Lake Utopia small-bodied population	New Brunswick	Endangered	Yes	Threatened	No
Rainbow Smelt	*Osmerus mordax*	Lake Utopia large-bodied population	New Brunswick	Endangered	No	No Status	No
Shortnose Sturgeon	*Acipenser brevirostrum*		New Brunswick, Nova Scotia	Special Concern	Yes	Special Concern	Unlikely. The Saint John River population tends to reside mainly in the river and estuary, and is rarely observed in the marine environment of the Bay of Fundy.
Striped Bass	*Morone saxatilis*	Bay of Fundy population	New Brunswick, Nova Scotia, Atlantic Ocean	Endangered	No	No Status	Unlikely. Historically, three rivers draining into the Bay of Fundy supported striped bass spawning populations; however, the Annapolis River has shown no evidence of spawning or

Common name	Scientific name	Population	Range	COSEWIC status	Schedule 1 [2](Yes/No)?	SARA status	Expected Presence in Study Area?
							recruitment since 1976. A recreational fishery for striped bass is concentrated at the base of the dam in summer and fall.
Blue Whale	*Balaenoptera musculus*	Atlantic population	Atlantic Ocean	Endangered	Yes	Endangered	Unlikely. Observed in the entrance of Bay of Fundy.
Fin Whale	*Balaenoptera physalus*	Atlantic population	Atlantic Ocean	Special Concern	Yes	Special Concern	Possible. Observed near the coast, as well as far offshore. They feed on krill and small fish such as herring and capelin. During summer, they can be found in areas of krill concentration, such as turbulence areas in the Bay of Fundy.
Harbour Porpoise	*Phocoena phocoena*	Northwest Atlantic population	Atlantic Ocean	Special Concern	No	Threatened	Likely. Often sighted close to shore, especially during the summer months. In eastern Canada, harbour porpoises range from the Bay of Fundy to Baffin Island.
Killer Whale	*Orcinus orca*	Northwest Atlantic / Eastern Arctic population	Arctic Ocean, Atlantic Ocean	Special Concern	No	No Status	Unlikely. Distribution maps include the Bay of Fundy.
North Atlantic Right Whale	*Eubalaena glacialis*		Atlantic Ocean	Endangered	Yes	Endangered	Possible. A migratory species that frequents coastal waters. Come to Atlantic Canadian waters to feed and may be present in the Bay of Fundy in spring, summer and fall. Grand Manan Basin (Bay of Fundy) is critical habitat.
Northern Bottlenose Whale	*Hyperoodon ampullatus*	Scotian Shelf population	Atlantic Ocean	Endangered	Yes	Endangered	No. The Scotian Shelf population inhabits deep waters (>500 m) along the continental slope off of NS and southeastern NL. The majority of sightings to date have been

Common name	Scientific name	Population	Range	COSEWIC status	Schedule 1 [2](Yes/No)?	SARA status	Expected Presence in Study Area?
							in three adjacent submarine canyons on the Eastern Scotian Shelf: the Gully, Shortland Canyon, and Haldimand Canyon.
Sowerby's Beaked Whale	*Mesoplodon bidens*		Atlantic Ocean	Special Concern	Yes	Special Concern	No. Sowerby's Beaked Whale is thought to mostly inhabit deep waters (>500 metres) along the continental slope from Nova Scotia to the Davis Strait.
Leatherback Sea Turtle	*Dermochelys coriacea*	Atlantic population	Atlantic Ocean	Endangered	Yes	Endangered	Unlikely. Bay of Fundy hosts relatively few foraging leatherbacks during the summer and fall.

Appendix C: ISDB and MARFIS Species within the Region of Interest

The search of the Industry Survey Database (ISDB) resulted in 412 records within the zone of influence polygon (Figure B1; Table B1). These records indicated that multiple fish and invertebrate species are in the Annapolis Basin to the east and north of the proposed lease site.

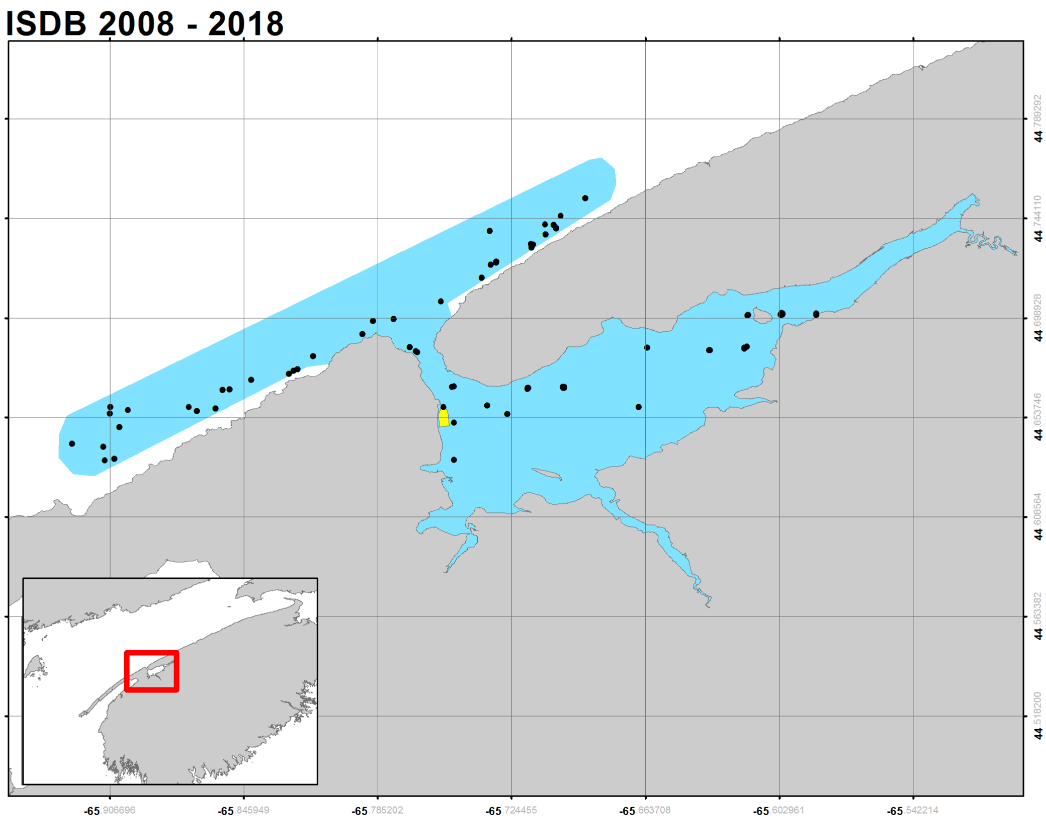

Figure B1. Maps showing the location of samples recorded in the ISDB database. Yellow polygon indicates location of the aquaculture site expansion. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 3.

Table B:1. ISDB records for the Annapolis Basin by species or species group from 2008 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 3.

Species	ISDB Records
SEA SCALLOP	58
AMERICAN LOBSTER	49
CUNNER	32
JONAH CRAB	19
SEA RAVEN	19
LONGHORN SCULPIN	18
ATLANTIC ROCK CRAB	16
ASTEROIDEA S.C.	15

Species	ISDB Records
SEA URCHINS	12
THORNY SKATE	10
SCALLOP SHELLS	7
WINTER FLOUNDER	7
STRONGYLOCENTROTUS DROEBACHIENSIS	6
BRACHIURAN CRABS	5
SEAWEED,(ALGAE),KELP	5
LEMONWEED	4
SEA CUCUMBERS	4
WINTER SKATE	4
SKATES (NS)	3
SPONGES	3
BRYOZOANS P.	2
COD(ATLANTIC)	2
HADDOCK	2
HERMIT CRABS	2
MONKFISH,GOOSEFISH,ANGLER	2
STRIPED ATLANTIC WOLFFISH	2
ALEWIFE (Gaspereau)	1
AMERICAN PLAICE	1
BRILL/WINDOWPANE	1
CRAB	1
CUSK	1
HALIBUT(ATLANTIC)	1
HERRING(ATLANTIC)	1
MUSSELS (NS)	1
NEW ENGLAND NEPTUNE	1
OCEAN POUT(COMMON)	1
POLLOCK	1
SCULPINS	1
SHAD AMERICAN	1
SILVER HAKE	1
SMOOTH SKATE	1
SPINY DOGFISH	1
SUMMER FLOUNDER	1
WHITE HAKE	1
YELLOWTAIL FLOUNDER	1

The search of the MARFIS database resulted in 1523 records particularly within the Digby Gut area but also within the proposed lease area. This data indicated that sea scallops, lobster and sea urchins were within the Annapolis Basin, that sea scallops and lobster were within the proposed lease area and that sea urchins were near the lease area (Figure B2; Table B2). The baseline surveys conducted by the proponent found scallop shells rather than live scallops and found evidence of the presence of live adult lobsters.

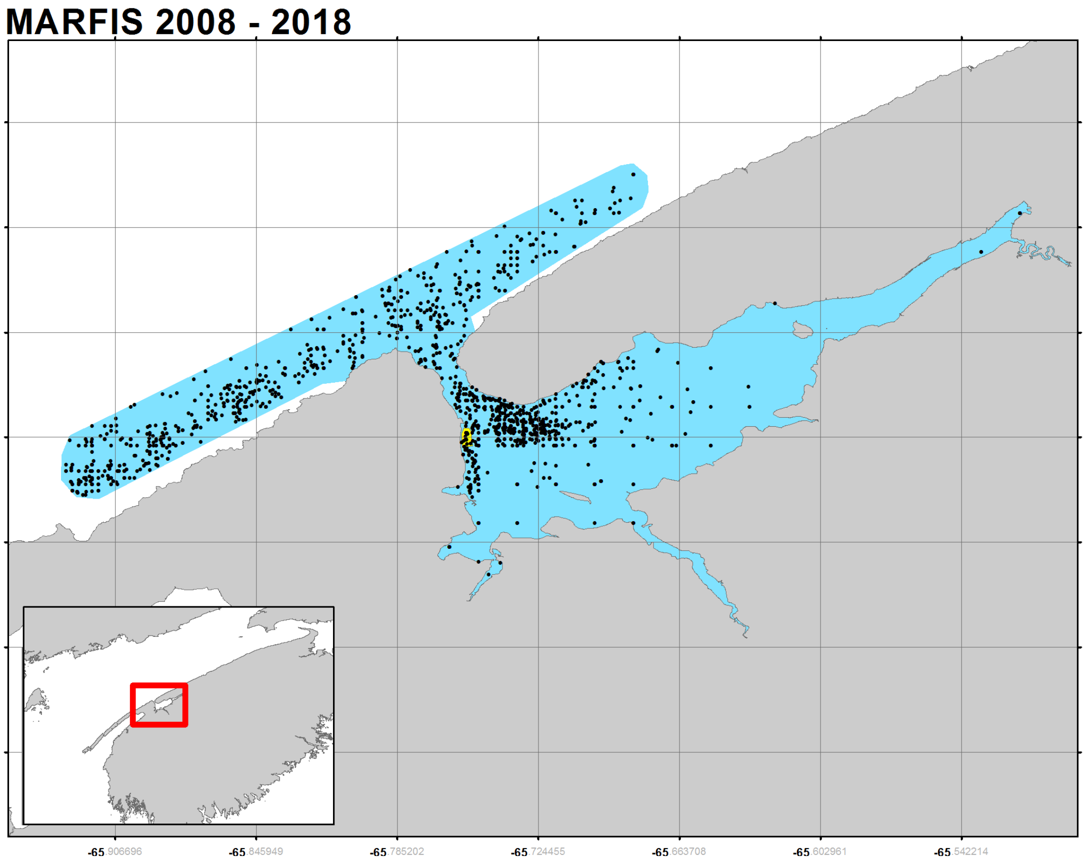

Figure B2. Maps showing the location of samples recorded in the MARFIS database. Yellow polygon indicates location of the aquaculture site expansion. Records were cropped to the polygon created based upon the estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 3.

Table B:2. MARFIS records for the Annapolis Basin by species or species group from 2008 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 3.

Species	MARFIS records
SCALLOP, SEA	1218
SEA URCHINS	178
HALIBUT	23
HADDOCK	22
ATLANTIC COD	18
WINTER FLOUNDER	16
SCULPIN	15
MONKFISH	12
CUSK	5

Species	MARFIS records
POLLOCK	5
WHITE HAKE	5
YELLOWTAIL	4
LOBSTER	2

Table B3. Bycatch recorded on the inshore scallop survey within the Annapolis zone of influence from 2014 to 2018. Note the field 'observed individuals' can be used to interpret relative frequency within catch but abundances are not standardized. Bycatch recorded on the inshore scallop survey consists of recording lobster, commercial fish species, skates, octopus, and squid.

OMMON	SCIENTIFIC	Observed Individuals	Total Tows
AMERICAN LOBSTER	HOMARUS AMERICANUS	252	29
WINTER FLOUNDER	PSEUDOPLEURONECTES AMERICANUS	121	29
SQUIRREL OR RED HAKE	UROPHYCIS CHUSS	16	29
MONKFISH,GOOSEFISH,ANGLER	LOPHIUS AMERICANUS	11	29
LITTLE SKATE	RAJA ERINACEA	8	29
WHITE HAKE	UROPHYCIS TENUIS	6	29
WINTER SKATE	RAJA OCELLATA	6	29
BRILL/WINDOWPANE	SCOPHTHALMUS AQUOSUS	4	29
AMERICAN PLAICE	HIPPOGLOSSOIDES PLATESSOIDES	2	29
COD(ATLANTIC)	GADUS MORHUA	2	29
LEUCORAJA <35cm	LEUCORAJA SP	2	29
HADDOCK	MELANOGRAMMUS AEGLEFINUS	1	29
SHORT-FIN SQUID	ILLEX ILLECEBROSUS	1	29
SMOOTH SKATE	RAJA SENTA	1	29
WITCH FLOUNDER	GLYPTOCEPHALUS CYNOGLOSSUS	1	29

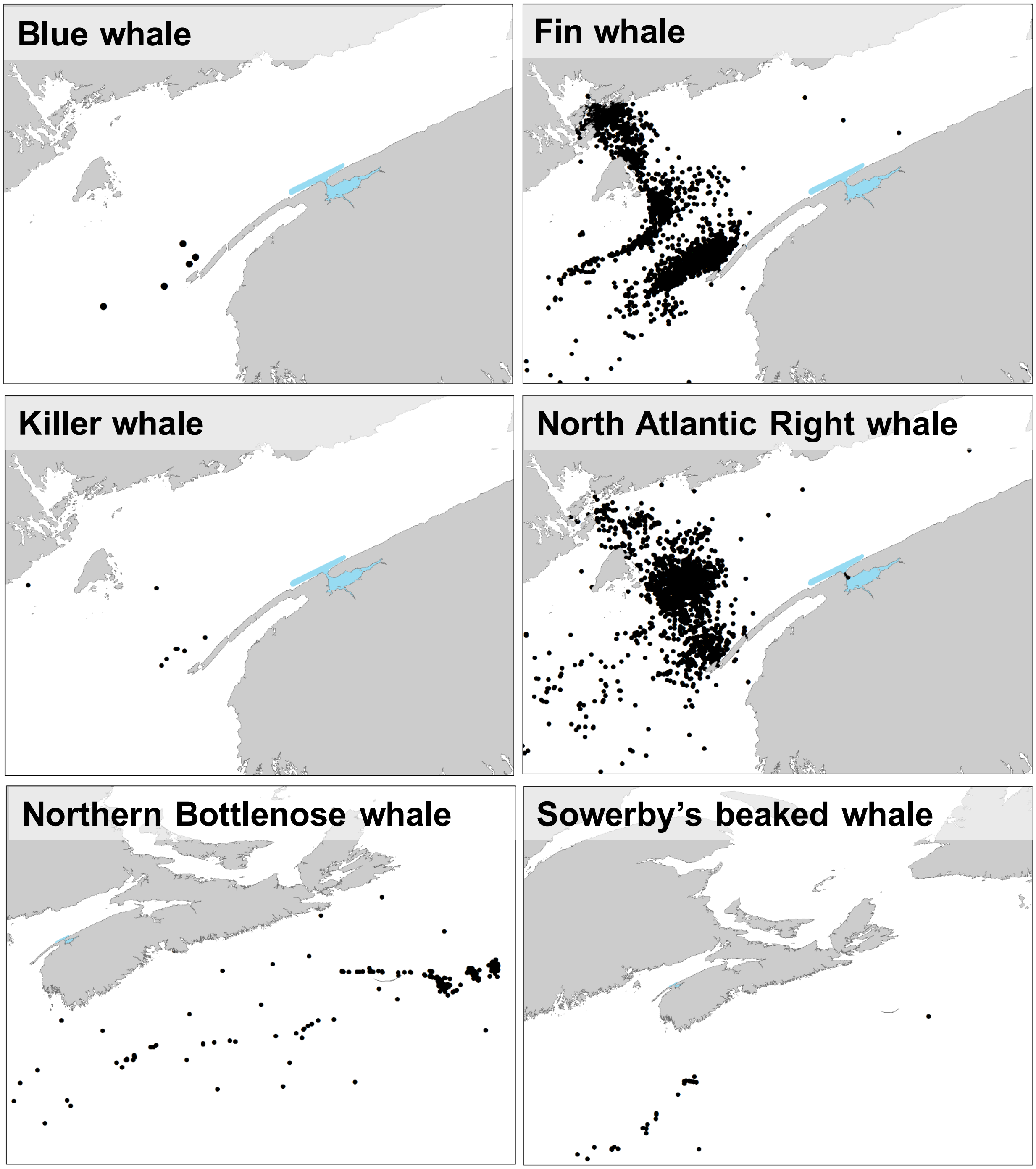

Figure B3. Map showing sightings that have been reported to and recorded in the Fisheries and Oceans whale sightings database of six SARA listed species. Records of this database are from 1963 to 2018. The blue polygon displays estimates of the trajectories of particles released from the proposed farm net-pen array illustrated in Figure 3.

Appendix D: List of Species considered in this report

Algae
Ascophyllum nodosum (rockweed)
Echinoderms
Sea urchin
Mollusks
Sea Scallop (*Placopecten magellanicus*)
Mussels
Clams, including soft-shell clam (*Mya arenaria*)
Crustaceans
American lobster (*Homarus americanus*)
Rock Crab
Jonah Crab
Diadramous
Atlantic Salmon (*Salmo salar*)
American Eel (*Anguilla rostrata*)
Alewife (*Alosa pseudoharengus*)
Shortnose Sturgeon (*Acipenser brevirostrum*)
Atlantic Sturgeon (*Acipenser oxyrinchus*)
Striped Bass (*Morone saxatilis*)
Rainbow Smelt (*Osmerus mordax*)
American Shad (*Alosa sapidissima*)
Pelagics
Atlantic herring (*Clupea harengus*)
Mackerel
Bluefin Tuna
Groundfish
Cunner (Tautogolabrus adspersus)
Sea Raven (*Hemitripterus americanus*)
Longhorn Sculpin (Myoxocephalus octodecemspinosus)
Thorny Skate (*Amblyraja radiata*)
Winter Flounder (*Pseudopleuronectes americanus*)
Winter Skate (*Leucoraja ocellata*)
Atlantic Cod (*Gadus morhua*)
Haddock (*Melanogrammus aeglefinus*)
Monkfish (*Lophius americanus*)
American Plaice (*Hippoglossoides platessoides*)
Windowpane Flounder (*Scophthalmus aquosus*)
Cusk (*Brosme brosme*)
Halibut (*Hippoglossus hippoglossus*)
Ocean Pout (*Zoarces americanus*)
Pollock (*Pollachius virens*)

Silver Hake (*Merluccius bilinearis*)
Smooth Skate (Malacoraja senta)
Little Skate (*Leucoraja erinacea*)
Spiny Dogfish (*Squalus acanthias*)
Summer Flounder (*Paralichthys dentatus*)
White Hake (*Urophycis tenuis*)
Red Hake (*Urophycis chuss*)
Yellowtail Flounder (*Limanda ferruginea*)
Witch Flounder (*Glyptocephalus cynoglossus*)
Atlantic Wolffish (*Anarhichas lupus*)
Northern Wolffish (*Anarhichas denticulatus*)
Atlantic Tomcod (*Microgadus tomcod*)
Lumpfish (*Cyclopterus lumpus*)
Sharks
White Shark (*Carcharodon carcharias*)
Basking Shark
Reptiles
Leatherback Sea Turtle (*Dermochelys coriacea*)
Marine Mammals
North Atlantic Right Whale (*Eubalaena glacialis*)
Harbour Porpoise (*Phocoena phocoena*)
Blue Whale (*Balaenoptera musculus*)
Fin Whale (*Balaenoptera physalus*)
Humpback Whale (*Megaptera novaeangliae*)
Harbour Seal (*Phoca vitulina*)
Killer Whale (*Orcinus orca*)
Northern Bottlenose Whale (*Hyperoodon ampullatus*)

Appendix E: 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 2013b) 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 a half-life of ca 14 to 28 days in unfiltered seawater at a concentration of 1.2 g·L-1 (Lyons et al. 2014). A half-life of 7 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 2019) and molluscs such as Blue Mussel (*Mytilus edulis*)(Canty et al. 2007). Due to its low 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 half-life of azamethiphos is ca 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 (HC 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, 2019) 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 (EC 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 faecal release and exchanges through the fish gills. The non-target organisms affected by ivermectin include crustaceans (DFO 2019). 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, 2019). 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 a half-life of ca 29 to 38 days in experiments conducted in artificial seawater and ca 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 (Shering-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 1988). Other studies determined oxytetracycline half-lives in marine sediment to be in the range of 16 to 419 days (MELP 1996). 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 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 2 days after use but not 3 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 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 1994).

This Report is Available from the:

Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
1 Challenger Drive, P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2

Telephone: 902-426-7070
E-Mail: XMARMRAP@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-3769

Correct Citation for this Publication:

DFO. 2020. DFO Maritimes Region Review of Proposed Marine Finfish Aquaculture Boundary Amendment, Rattling Beach, Digby County, Nova Scotia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/015. (Erratum : January 2024)

Aussi disponible en français :

MPO. 2020. Examen par la Région des Maritimes du MPO de la modification proposée des limites de la pisciculture marine, à Rattling Beach, comté de Digby (Nouvelle-Écosse). Secr. can. de consult. sci. du MPO, Rép. des Sci. 2020/015.