Fisheries and Oceans Canada | Pêches et Océans Canada
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Maritimes Region | Canadian Science Advisory Secretariat
Science Advisory Report 2025/004

# REVIEW OF FOUR PROPOSED NEW MARINE FINFISH AQUACULTURE SITES, ST. MARY'S BAY, DIGBY COUNTY, NOVA SCOTIA

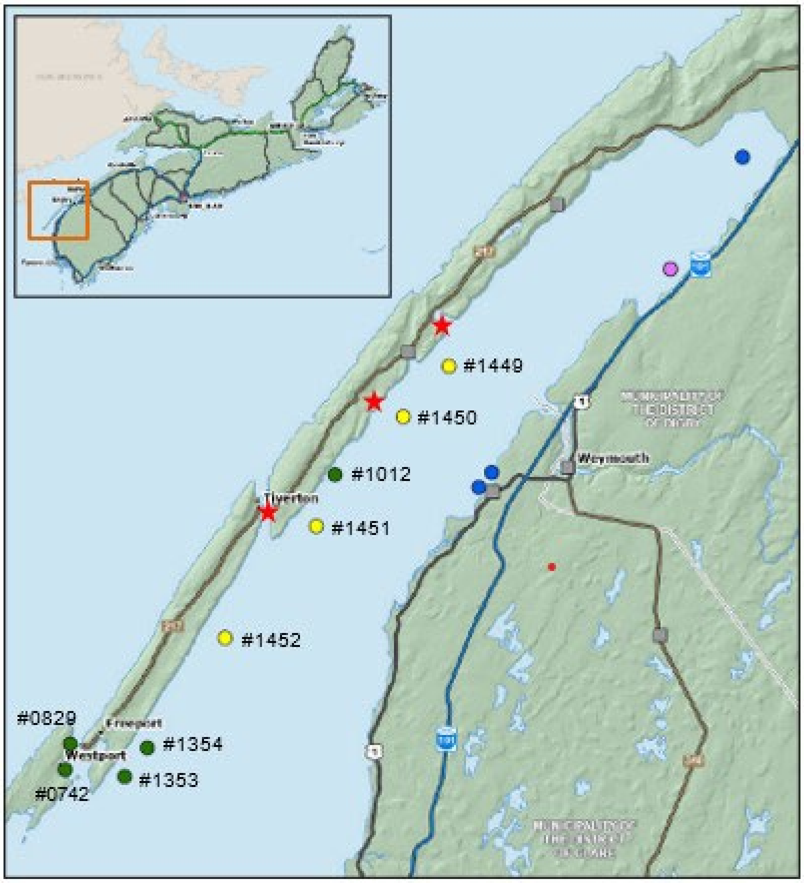


*Figure 1. Location of four proposed new marine finfish aquaculture sites in St. Mary's Bay, Nova Scotia, represented with yellow circles (●). Green circles (●) represent existing finfish aquaculture sites, blue (●) and purple circles (●) represent existing shellfish aquaculture sites, and grey squares (■) represent land-based aquaculture facilities. Red stars (★) represent approximate locations of seasonal lobster holding facilities in the vicinity. Base maps were retrieved from the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) [Site Mapping Tool] on November 22, 2022.*

## CONTEXT

Canadian Salmon Ltd. has applied to the Province of Nova Scotia to lease four new marine finfish aquaculture sites (#1449, #1450, #1451, #1452) in St. Mary's Bay, Digby County, Nova Scotia (Figure 1), as well as for associated licences for Atlantic Salmon (*Salmo salar*) and Rainbow Trout (*Oncorhynchus mykiss*) for a total production of up to 3 million fish. The proponent has indicated a primary intent to culture Atlantic Salmon. As per the Canada-Nova

Scotia Memorandum of Understanding on Aquaculture Development, the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) has forwarded these applications to Fisheries and Oceans Canada (DFO) for review and advice in relation to DFO's legislative mandate. These applications were supplemented by information collected by the proponent, as required by the Aquaculture Activities Regulations (AAR).

This Science Advisory Report is from the March 19–21, 2024, regional peer review for the DFO Maritimes Region Science Review of Four Proposed New Marine Finfish Aquaculture Sites, St. Mary's Bay, Digby County, Nova Scotia.

## SUMMARY


- Canadian Salmon Ltd. has applied to the Province of Nova Scotia to lease four new marine finfish aquaculture sites in St. Mary's Bay, Digby County, Nova Scotia, as well as for associated licences for Atlantic Salmon (*Salmo salar*) and Rainbow Trout (*Oncorhynchus mykiss)* for a total production of up to 3 million fish. The proponent has indicated a primary intent to culture Atlantic Salmon. St. Mary's Bay is an inlet of water measuring approximately 60 km in length and 15 km in width that has large tidal heights, medium to high current speeds, and exposure to offshore waves.
- To help inform DFO's review of this application, DFO Science identified Ecologically and Biologically Significant Areas (EBSA), Species at Risk, and a number of pertinent fish and benthic species within the area. Susceptibility of species to organic enrichment, exposure to in-feed drugs (emamectin benzoate) and/or pesticides (azamethiphos and hydrogen peroxide) used to control sea lice in farmed fish was considered. In addition, direct genetic interactions between wild and farmed salmon, species entanglement with infrastructure, and cumulative anthropogenic stressors were also considered. The advice primarily considered the culture of Atlantic Salmon with some consideration to Rainbow Trout.
- A Predicted Exposure Zone (PEZ) estimates a distance that a dissolved chemical or particulate material could travel from a proposed finfish aquaculture site. The PEZ approach is precautionary and used to characterize potential exposure of marine ecosystems and species to associated aquaculture activities. It does not provide a detailed analysis of impact, intensity, or risk associated with the potential exposure.
- A benthic-PEZ is an estimate of benthic (seabed) areas that may be exposed to deposited feed waste, feces, and bound substances (e.g., medications) released from a proposed aquaculture site. Two benthic-PEZ were estimated (one for feed waste and one for feces). There is no overlap between site-specific benthic-PEZs for potential feed waste, but there are overlaps in the benthic-PEZs for feces. When considering these PEZs, most of the seabed in St. Mary's Bay could be exposed to feces deposition. Adjacent coastal areas outside of St. Mary's Bay may also be exposed.
- A pelagic-PEZ is an estimate of the pelagic (water column) areas that may be exposed to registered bath pesticides from a proposed aquaculture site at levels above which adverse effects may occur, if used. The pelagic-PEZs demonstrate that most of the pelagic area and some shallower water benthos in St. Mary's Bay could be exposed. Adjacent coastal areas outside of St. Mary's Bay may also be exposed.
- An increase in aquaculture infrastructure may increase the potential for entanglement for some species at risk. These may include White Shark (*Carcharodon carcharias)* and North Atlantic Right Whale (*Eubalaena glacialis*), which have been detected within the vicinity of the proposed aquaculture sites. Reports of entanglement of marine mammals, sea turtles,

and sharks in marine finfish aquaculture gear in Atlantic Canada remain low or nil for these large-bodied species.

- The proposed aquaculture sites, and their associated PEZs, are within Lobster Fishing Area (LFA) 34 (LFA 34 represents greater than 20% of total Canadian landings). Within LFA 34, St. Mary's Bay consistently exhibits a higher presence and density of American Lobster (*Homarus americanus)* compared to the offshore area. A higher abundance of Lobster at all life stages, including berried females, is observed in the bay. Juvenile patterns of settlement also indicate that the overlying water column is important habitat for pelagic larval stages.
- The proposed aquaculture sites fall within Scallop Production Area (SPA) 3 which is an important area for wild Sea Scallop (*Placopecten magellanicus*); this area is important for scallop habitat at all life stages of the species. Scallop are relatively sedentary; three of the four proposed aquaculture site leases overlap areas of high abundances of young and adult scallop. Scallop in St. Mary's Bay have some of the highest physical quality attributes of scallop found in the Bay of Fundy and its approaches.
- Jonah Crab (*Cancer borealis)*, Rock Crab (C*ancer irroratus*), and Snow Crab (*Chionoecetes opilio*) have also been observed in St. Mary's Bay and within the PEZs. Shrimp and krill species identified within the benthic-PEZ and pelagic-PEZ include: Bristled Longbeak (*Dichelopandalus leptocerus)*; Sand Shrimp (*Crangon septemspinosa)*; Northern Shrimp *(Pandalus borealis*); Northern Krill (*Meganyctiphanes norvegica*); and krill (*Euphausiacea sp.*). St. Mary's Bay is also a productive area for Soft-shell Clam (*Mya arenaria*), Quahog (*Mercenaria mercenaria*), Bar Clam (*Spisula solidissima*), and Blue Mussel (*Mytilus edulis*). Some groundfish and small pelagic species are also found in the bay.
- Within the feed waste benthic-PEZs, shelter-restricted benthic juvenile lobsters and other crustaceans may be vulnerable to localized impacts such as hypoxia from increased organic deposition due to their restricted movement and preferential selection for shelter. The sedentary nature of scallops and other bivalves makes them vulnerable to excessive organic deposition.
- Within the benthic-PEZs, emamectin benzoate may have toxic effects on non-target organisms, especially crustaceans. Effects of emamectin benzoate on crustaceans include premature moulting, reduced growth rates, and mortality. Bivalves are currently considered less sensitive to emamectin benzoate, however data are limited.
- Within the pelagic-PEZs, azamethiphos and hydrogen peroxide may have toxic effects on non-target organisms, including all life stages of crustaceans (e.g., lobster, shrimp, krill, crab). Berried female (egg-bearing) lobsters specifically are more sensitive to azamethiphos during the summer months based on reproductive and moulting cycles. Impacts on bivalves are possible, however data are limited.
- Populations within the Nova Scotia Southern Upland – West (SU–W) and Outer Bay of Fundy (OBOF), as well as the Inner Bay of Fundy (IBOF) Designatable Units (DU) of Atlantic Salmon, are within the range that escapees from the four proposed finfish aquaculture farms could be expected to travel. The farms themselves are physically located within the Nova Scotia Southern Upland – West DU. Both the SU–W and OBOF DUs are assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the IBOF DU is listed as Endangered under the *Species at Risk Act* (*SARA*).
- Modelling of the demographics and genetics of populations predicts that impacts from interbreeding between fertile farmed Atlantic Salmon escapes and wild Atlantic Salmon

occur when the proportion of farmed salmon in a river exceeds 10% of the wild population. Dispersal modelling of escapees at two different escape rates predicts that a large number of rivers in the OBOF and SU–W DUs are already expected to be above the threshold of impacts.

- The same dispersal model predicts that with the addition of the four proposed aquaculture sites, there will be an increase in the proportion of escapees in most of the rivers within 200 km of the proposed St. Mary's Bay sites, both in the proposed SU–W and OBOF DUs, and to a lesser extent in the IBOF DU.
- Interbreeding between escaped Rainbow Trout and wild Atlantic Salmon would not be expected. However, interaction between them may still result in ecological or indirect genetic impacts on wild salmon populations.
- An analysis of the relative intensities of human activities and stressors, using cumulative impact mapping, on the St. Mary's Bay area, bounded by the pelagic-PEZ, estimated that the existing and proposed finfish aquaculture sites contributed 5.1% to the total cumulative impact score, which is lower relative to some other human stressors. This analysis also highlighted the current high complexity of human uses and relative effects of overlapping stressors on the benthic and pelagic habitats in the St. Mary's Bay area. After the addition of the proposed sites, the greatest change in cumulative impact score was within several kilometres of the proposed leases, where additional finfish aquaculture, warming waters, acidification, and bottom-contact fishing may interact to impact species found in pelagic, hard bottom and soft bottom habitats.
- Climate change was considered as a factor of anticipated changes in St. Mary's Bay that may alter the interactions between the ecosystem and the proposed aquaculture sites. Projected ocean warming due to climate change may increase the abundance of lobsters in St. Mary's Bay, including earlier and increased residence time for berried females, with potential for increased interactions of all life stages with farms (e.g., physical interactions and therapeutant use relating to timing of larval release). Sea scallops and bivalves are vulnerable to ocean acidification, which is predicted to increase. However, the potential for eutrophication and localized acidification from algal blooms related to fish farm nutrient inputs is considered low. Climate warming and freshwater availability in general may influence sea lice, disease, and the subsequent use of pesticides and drugs. Increased likelihood of storm incidence and severity, projections of increased wave height and sea level may all affect aquaculture infrastructure and increase the potential risk of escapees without additional mitigation.
- Various data sources and methodologies were incorporated into this report. Each of these components has uncertainties which should be considered when interpreting this information.

# BACKGROUND

Canadian Salmon Ltd. has applied to the Province of Nova Scotia to lease four new marine finfish aquaculture sites (#1449, #1450, #1451, #1452) in St. Mary's Bay, Digby County, Nova Scotia (Figure 1), as well as for associated licences for Atlantic Salmon (*Salmo salar*) and Rainbow Trout (*Oncorhynchus mykiss*) for a total production of up to 3 million fish. The proponent has indicated a primary intent to culture Atlantic Salmon.

As per the Canada-Nova Scotia Memorandum of Understanding on Aquaculture Development, the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) has forwarded the application package to Fisheries and Oceans Canada (DFO) for review and advice in relation to DFO's legislative mandate. The application package was supplemented by information collected by the proponent, as required by the *Aquaculture Activities Regulations* *(AAR)* and an associated Monitoring Standard.

To help inform DFO's review of these applications, the regional DFO Aquaculture Management Office has asked for regional DFO Science advice on predicted exposure zones of the proposed sites and associated susceptible fish and fish habitat potentially exposed to certain stressor categories, as identified in the Pathways of Effects for Finfish and Shellfish Aquaculture (DFO 2010a). Specifically, DFO Science has been asked the following questions:

1. Based on the available data for the sites and the scientific information, what are the predicted exposure zones from the use of approved fish health treatment products in the marine environment and the potential consequences to susceptible species?
2. Based on available information, what are the Ecologically and Biologically Significant Areas, species listed under Schedule 1 of the *Species at Risk Act,* fishery species, Ecologically Significant Species, and their associated habitats that are within the benthic predicted exposure zone and vulnerable to exposure from the deposition of organic matter? How does this compare to the extent of these species and habitats in the surrounding area (i.e., are they common or rare)? What are the anticipated impacts to these sensitive species and habitats from the proposed aquaculture activity(ies)?
3. How do the impacts on these species from the proposed aquaculture site compare to impacts from other anthropogenic sources (including existing finfish farms)? Do the zones of influence overlap with these activities and if so, what are the potential consequences?
4. To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic Species at Risk listed under Schedule 1 of the *Species at Risk Act* make use of the area and for what duration and when?
5. What populations of conspecifics are within a geographic range that escapees are likely to migrate to? What is the size and status trends of those populations in the escape exposure zone for the proposed sites? Are any of these populations listed under Schedule 1 of *the Species at Risk Act?* What are the potential impacts and/or risks to these wild populations from direct genetic interactions associated with any escaped farmed fish from the proposed aquaculture activity?

This Science Advisory Report adopts precautionary benthic- and pelagic-potential exposure zones to scope-out and identify marine features, habitats, and species that could be exposed to certain finfish aquaculture activities (i.e., deposition of organic matter and use of fish health treatment products) associated with the proposed four new marine finfish aquaculture sites in St. Mary's Bay, Nova Scotia. The report serves as a screening of marine features, habitats, and species that decision-makers should be aware of in their review of the applications.

Information contained in this report is used to identify potential effects of the proposed finfish aquaculture on the surrounding marine environment, which DFO considers in its review of the applications and the formulation of its advice to the Province of Nova Scotia. Any decision(s) on the proposed four new marine finfish aquaculture sites in St. Mary's Bay falls under the authority of the Nova Scotia Aquaculture Review Board, which is an independent decision-making body that has a mandate to make decisions regarding finfish aquaculture applications in the Province of Nova Scotia (see: Nova Scotia Aquaculture Review Board).

# ANALYSIS

## Data Sources

Information to support this analysis includes data and information from the proponent, data holdings within DFO, and publicly available literature and open-data. Information from the proponent included the application package and baseline survey data, which were available on the NSDFA webpage (see: Information for the Public | Aquaculture Applications in Progress | Adjudicative Applications in Progress). Supplementary to the proponent's application and baseline survey data, DFO were also provided raw current meter records from the proponent's current meter data files. In addition to data and information from the proponent, a data discovery tool developed by DFO was used to search for species observations within the PEZs of the proposed four new finfish aquaculture sites. Data sources included internal DFO databases, government and academic research labs, and open-source databases. More information on the data discovery tool can be found in Stoyel et al. (2022).

## Description of the Proposed New Finfish Aquaculture Sites

St. Mary's Bay, Nova Scotia is adjacent to the Gulf of Maine and Bay of Fundy located between Digby Neck and mainland southwestern Nova Scotia. It is a narrow ocean inlet approximately 60 km long and 15 km wide. The four proposed finfish aquaculture sites are located along the southeastern shore of Digby Neck and Long Island, and would occupy a lease area of approximately 80 hectares (ha) each, for a total addition of 320 ha leased area in St. Mary's Bay. Each lease area would consist of 12 net-pens in a 2 x 6 net-pen array configuration, for a total proposed addition of 48 finfish aquaculture net-pens to St. Mary's Bay.

The proposed production plan has a phased implementation, beginning with a stocking of 500,000 Atlantic Salmon during the first year at site #1451 only and eventual scale-up to 750,000 fish at all four sites within 3–4 years (for a total of 3 million farmed fish). The planned grow-out period is estimated to be 10–18 months from stocking, with a 1–3 month fallow period or as environmental monitoring dictates. Rainbow Trout (*Oncorhynchus mykiss*), an introduced species to the Atlantic coast, has also been identified by the proponent as a potential culture species at the proposed sites to allow for versatility and production assurance. It is noted by the proponent, however, that this will not impact total production numbers.

There are currently five finfish and four shellfish aquaculture leases in St. Mary's Bay and Grand Passage, as well as three land-based aquaculture facilities along the shoreline of St. Mary's Bay (Figure 1). Finfish aquaculture has been occurring within this area since the mid-1990s. Historical stocking numbers at existing sites have varied between production cycles and leases; however, the proposed production plan would represent an approximate doubling of farmed Atlantic Salmon in St. Mary's Bay and Grand Passage.

Within the proposed leases, the depth relative to Canadian Hydrographic Service (CHS) Chart #4118 datum ranges from approximately 11 to 47 m, with the shallowest depth at site #1449 and the deepest depth at site #1451 (Figure 2). The proposed lease sites are all within 1 km of the coastline where shallower water depths are observed.

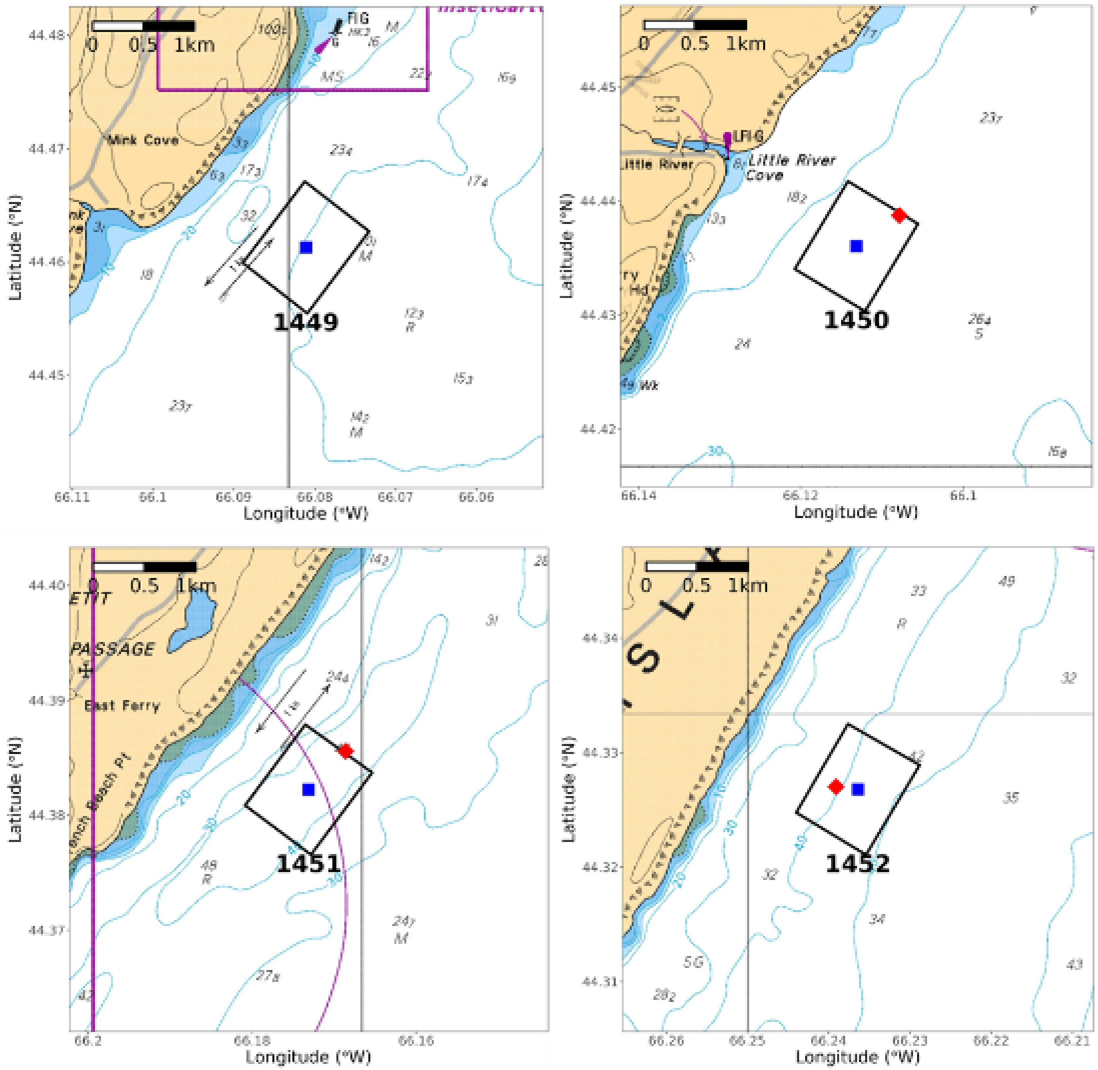


*Figure 2. Proposed lease boundaries for sites #1449, #1450, #1451, and #1452 overlaid on CHS chart #4118 (depth is in metres). Locations of proponent-deployed current meters and proposed cage array centres are shown in red and blue dots, respectively. No current meter was deployed at proposed site #1449.*

Baseline data collected by the proponent in 2022 within the proposed lease areas and immediate vicinity indicates that the sites are located in an area of variable bottom type and ecosystem characteristics (i.e., clay, silt, sand, pebble, cobble, boulder, and shell debris). The seabed beneath sites #1449, #1450, and #1451 is predominantly characterized as soft-bottom, with easily disturbed sediment, while proposed site #1452 is predominantly characterized as hard-bottom. However, all four sites were noted as having a mixture of sediment types. This characterization aligns with existing substrate classifications for St. Mary's Bay (Greenlaw and Harvey, 2022). Other observed seabed features during baseline data collection beneath the sites include substantial bioturbation features such as polychaete tubes, burrow structures, and fecal castings (particularly at sites #1450 and #1451), high concentrations of shell hash at site #1449 compared to the other sites, and macrophyte beds around groups of boulders at sites #1450 and #1452. Observations of fauna and flora during baseline data video surveys within the proposed sites noted the presence of arthropods, worms, scallops, jellyfish, barnacles, bivalves, crabs, sea stars, sea cucumbers, mussels, and various unidentified flatfish, as well as sparse, unattached macroflora.

The water characteristics at the four proposed sites are expected to be similar given their close proximity to each other in the bay, with variations on tidal, seasonal, and wind-drive time scales. Site #1452 will experience a different current regime during the ebb tide, as the wake of Petit Passage intersects the lease boundary. Salinity and temperature ranges from data collected in St. Mary's Bay and reported in the proponent's application are found in Table 1. Within those ranges, salinity is anticipated to be higher at the proposed sites closer to the opening of St. Mary's Bay. While the maximum water temperature observed at similar water depths to those within the proposed leases is 17 °C, some shallower areas of St. Mary's Bay outside of the proposed leases may reach up to 20 °C. Water mass characteristics in St. Mary's Bay are likely to change in time due to large scale climate change.

St. Mary's Bay is characterized as 'open-water', which is defined as being less than 10% surface ice cover. Canadian Ice Service maps from 2004 to 2019 demonstrate an inconsistent annual presence of sea ice in the bay. Near-shore analysis during four years of identified ice presence indicates that the extent of ice was limited to along the eastern shore of the bay (CMAR 2021), suggesting a low probability of sea ice during the winter at the four proposed sites located along the western shore (Figure 1).

Environment and Climate Change Canada wind data collected between 2001 and 2020 from Brier Island, which has a greater exposure to northerly winds than the proposed aquaculture sites, indicated prevailing winds from the northwest across the Bay of Fundy and Gulf of Maine, although the strongest winds are from the south. Winds from the west-northwest are predominant in the winter, while winds from the south are predominant in the summer. Strong north-westerly winds are expected at the sites throughout the winter months; however, the proposed sites are relatively protected by Digby Neck and Long Island from wind-generated waves coming from the north and west. In contrast, wind-generated waves coming from the northeast are anticipated to be significant due to the wind fetch from the inner towards the outer bay. The sites may also be particularly vulnerable to waves coming from the south and southwest, due to the larger south-southwest fetch and offshore swell that can travel directly into the bay (CMAR 2020). Waves and swell are anticipated to be highest at the southernmost sites and dissipate as they move further into the bay and into shallower waters.

Current meter data were collected by the proponent at three of the four proposed sites. Acoustic Doppler Current Profilers (ADCPs) were deployed on June 18, 2021, for 90-days at sites #1450 and #1451 and on August 4, 2021, for 50 days at proposed site #1452 (Figure 2). Based on proximity of the sites (i.e., less than 3 km boundary to boundary), it is reasonable to assume that current speeds at site #1449 are similar to site #1450. Current meter data from site #1450 indicated that the median current speeds decreased slightly with depth whereas the median measured current speeds at sites #1451 and #1452 varied little throughout the column, although larger current speeds were observed near the surface.

The St. Mary's Bay marine environment can be classified as having medium to high energy currents, with observed current speeds between 15 to 30 cm/s in 37%, 44%, and 32.6% of the ADCP records and greater than 30 cm/s in 37.4%, 31.2%, and 44.5% of the ADCP records from sites #1450, #1451, and #1452, respectively. At all sites, currents demonstrated little vertical variation in direction. Currents were predominantly moving to the north-northeast to northeast during the flood tide (i.e., into the bay), currents were predominantly moving to the south-southwest to southwest during the ebb tide (i.e., out of the bay). Current speeds vary due to coastline morphology and bathymetry, as well as seasonal, wind, and storm influences.

Preliminary hydrodynamic modeling results indicate that maximum current speeds in Petit Passage, and on the north coast of Brier Island and Digby Neck, can exceed maximum observed currents at the proposed lease sites by a factor of three to five (i.e., stronger). In St. Mary's Bay, maximum observed currents are within a factor of two of modelled maximum currents, except in the wake of Petit Passage where currents are observed to be stronger.

Stratification appears to be weak at the proposed sites based on water column data profiles of current speed, temperature, and salinity. As such, the exposure zones predicted below do not need to consider stratification with respect to current speed selection. Key oceanographic, farm infrastructure, and grow-out characteristics of the four proposed new finfish aquaculture sites are summarized in Table 1.

*Table 1. Key oceanographic, farm infrastructure and grow-out characteristics of the proposed sites. Information sources are from the proponent's application package unless otherwise stated. n/a means not applicable (i.e., no additional information necessary to report).*

| Characteristic | #1449 | #1450 | #1451 | #1452 | Additional notes |
|---|---|---|---|---|---|
| **Maximum tidal range (m)** | 6.4 | 6.4 | 6.3 | 6.8 | • Range does not include surges in sea level.<br>• Calculated from ADCP data (pressure sensor data). |
| **Depth within lease area (m)** | 11.0–28.0 | 20.0–26.0 | 31.0–47.0 | 37.0–43.0 | • Relative to vertical chart datum (lowest normal tide) on CHS chart. |
| **Current Speed (cm/s)** | | | | | • No data collected at #1449 (record used from #1450 based on proximity). |
| • **Near-Surface** | 0.4–70.4<br>(5 m) | 0.4–70.4<br>(5 m) | 0.0–88.7<br>(7 m) | 0.1–146.2<br>(6 m) | • Measured at specified depth from surface. |
| • **Midwater** | 0.2–68.8<br>(11.11–14.11 m) | 0.2–68.8<br>(11.11–14.11 m) | 0.3–63.1<br>(23.11–26.11 m) | 0.1–126.9<br>(20.23–22.23 m) | • Measured in specified depth range from bottom |
| • **Near-Bottom** | 0.4–50.3<br>(3.11 m) | 0.4–50.3<br>(3.11 m) | 0.0–51.5<br>(3.11 m) | 0.4–115.3<br>(5.23 m) | • Measured at specified depth from bottom. |
| **Current direction** | | | | | • No data collected at #1449 (record used from #1450 based on proximity). |
| • **Flood tide** | NE | NE | NE | NNE-NE | • n/a |
| • **Ebb tide** | SSW-SW | SSW-SW | SSW-SW | SSW-SW | • n/a |
| **Maximum 10-and 50-year significant wave height (m)** | 1.28 (ENE)<br>1.62 (ENE) | 1.4 (S)<br>1.73 (ENE) | 1.97 (S)<br>2.24 (S) | 1.92 (SSW)<br>2.25 (SSW) | • STWave results modelled in proponent application. Value in parenthesis is direction from. |
| **Salinity (PSU)** | 28.8–32.5 | 28.8–32.5 | 28.8–32.5 | 28.8–32.5 | • Salinity from shellfish lease #5008. |
| **Temperature within lease area (°C)** | 1.0–17.0 | 1.0–17.0 | 1.0–17.0 | 1.0–17.0 | • Based on short-term datasets from NS Open Data Portal, long-term historical data from ERA5 model, and long-term satellite data. |
| **Substrate type** | Clay, silt, sand, pebble cobble, shell debris | Clay, silt, sand, boulders, shell debris | Clay, silt, sand, pebbles, shell debris | Sand, pebble, cobble, shell debris | • Seabed video and grab samples from proponent baseline survey. |
| **Net-pen array configuration** | 2 x 6 | 2 x 6 | 2 x 6 | 2 x 6 | • Smolts initially introduced into 6 net-pens with eventual distribution to all 12 net-pens (density-dependent). |
| **Individual net-pen circumference (m)** | 120–160 | 120–160 | 120–160 | 120–160 | • Smaller polar circles used at first site (#1451). |
| **Net-pen depth (m)** | 15 | 15 | 15 | 15 | • Predator nets will be used — no depth reported. |

| Characteristic | #1449 | #1450 | #1451 | #1452 | Additional notes |
|---|---|---|---|---|---|
| **Grow-out period in marine cages (months)** | 10–18 months | 10–18 months | 10–18 months | 10–18 months | • Depends on smolt size and timing of stocking. |
| **Maximum number of fish on site** | 750,000 | 750,000 | 750,000 | 750,000 | • Plan to begin with 500,000 at first site (#1451) and scale up. |
| **Initial stocking number (fish/pen)** | 62,500–125,000 | 62,500–125,000 | 62,500–125,000 | 62,500–125,000 | • 125,000 fish x 6 net-pens upon initial stocking, and eventually 62,500 x 12 net-pens. |
| **Initial stocking size (g)** | 120–450 | 120–450 | 120–450 | 120–450 | • Depends on timing of stocking. |
| **Average harvest weight (kg)** | 4.8 | 4.8 | 4.8 | 4.8 | • n/a |
| **Maximum biomass (kg)** | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | • Maximum number of fish on site x average harvest weight.<br>• No mortality factored in. |
| **Maximum stocking density (kg/m$^3$)** | 25.0 | 25.0 | 25.0 | 25.0 | • 10–20 kg/m$^3$ during exploratory phase. |

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

During finfish aquaculture operations, organic material such as unconsumed feed (i.e., feed waste) and feces are released into the surrounding waters and can sink to the seafloor. This organic matter is, in turn, used by benthic organisms; however, if it accumulates, it can alter benthic habitat by depleting available dissolved oxygen, increasing 'free' sediment sulfide concentrations in soft-bottom habitats, and increasing the presence of *Beggiatoa* spp.-like bacterial mats, opportunistic polychaete complexes, and flocculent matter in hard-bottom habitats. For these reasons, organic matter is considered to be a deleterious substance. Under the federal *AAR* and provincial regulations, the aquaculture industry is required to conduct seafloor monitoring of finfish aquaculture sites with set regulatory thresholds that require management actions should they be exceeded.

Fish health treatment products may also be administered during finfish aquaculture operations to control pests and pathogens, as is the case in most forms of monoculture. In Canada, fish health management and regulatory control is the responsibility of both provincial and federal governments. Effective integrated pest management and health management of the marine finfish aquaculture industry relies on the use of both chemical (e.g., drugs, pesticides, antibiotics, disinfectants, etc.) and non-chemical strategies such as physical, biological, site management, and husbandry approaches. A summary table of the mode of action, treatment concentration and dosage, as well as recent degradation/metabolization information of the chemicals authorized for use in Canada can be found in Appendix I.

Prior to the administration of drugs and pesticides, the *AAR* require that industry first consider viable alternative, non-chemical measures. In Canada, only products that are registered under the *Pest Control Products Act* and the *Food and Drugs Act* and are regulated by Pest Management Regulatory Agency (PMRA) and the Veterinary Drugs Directorate in Health Canada are allowed to be used to preserve the best health and welfare of fish in aquaculture facilities. These products are only used under the authority and supervision of a registered veterinarian. The veterinarians consider a variety of site-specific information, including fish behaviour, environmental conditions, site records, and information from monthly site visits and from an ongoing dialogue with site managers, to determine the appropriate prescription for maintaining the health of farmed fish. Further information on prescription and administration procedures of drugs and pesticides in Canada can be found in Beattie and Bridger (2023).

The *AAR* require each marine finfish net-pen farm in Canada to report on its usage of drugs and pesticides on an annual basis. The information began to be collected by the Aquaculture Integrated Information System (AQUIIS) in 2015 and the first full year of data collection were 2016. In the Canadian marine finfish aquaculture context, the term "drug" generally applies to any in-feed product, including antibiotics and pest control drugs. The term "pesticide" applies to a pest control product that is applied as an in-bath treatment.

Predicted Exposure Zone (PEZ) estimations are part of a triage approach to help determine if there are issues of concern to coastal zone managers, users, and decision makers associated with discharges (feed waste, feces, drugs, and pesticides) from a proposed finfish aquaculture site (Page et al. 2023a). The PEZ-approach has been used in previous DFO finfish aquaculture site assessments (DFO 2020a, 2021a, 2022a, 2022b, 2023a) as a precautionary approach used to determine geographic scoping regions for screening of potential marine ecosystem and species exposure areas to open net-pen finfish aquaculture activities. The first use of PEZ was for the assessment of proposed finfish aquaculture sites in Newfoundland in 2019 (DFO 2022c, Page et al. 2023a). Since that first assessment, the PEZ calculations have evolved over time due to changes in calculation assumptions regarding toxic duration and the spatial variation of currents.

The PEZ is intended to be a simple model that predicts marine ecosystem and species potential zones of exposure to organic matter, drugs, and pesticides released from open net-pen finfish aquaculture for substances. In simple terms, a PEZ is a circle that defines a spatial area around a proposed aquaculture site whereby marine ecosystems and species may be exposed to various aquaculture activities. The radius of the PEZ, $R_{PEZ}$, is calculated according to:

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

where $L_{carray}$ is the maximum length scale of the cage array and $D$ is a calculated displacement distance. A PEZ is not used to predict the intensity of exposure, duration of exposure, or impact of exposure of marine ecosystems or species that fall within the area; rather, PEZ is used as a means to identify marine features and attributes that have the potential to be exposed to aquaculture activities. These estimations do not account for land features that may serve as natural barriers to exposure and, therefore, features such as coastal boundaries within the PEZ need to be factored in when considering potential exposure more broadly. Furthermore, although PEZ are used to estimate exposure, again this should not be interpreted as impact or even that all areas are exposed within a PEZ, given the simplified nature of these estimations. A more thorough description of the PEZ model can be found in Page et al. (2023a).

When PEZs are used in concert with information regarding the presence of species life stages, habitats, and other human activities, there may be a potential for aquaculture impacts on such sensitive entities exposed to various aquaculture activities. If from the initial triage analysis of exposure reported here there are concerns with some of the identified individual or cumulative overlaps, more detailed scientific analysis can be pursued that further explore the degree and nature of potential impacts, and/or mitigation measures that may need to be considered, as requested by managers, users, and decision makers.

The following sections on the PEZ are in the context of marine finfish aquaculture for Atlantic Salmon; no specific consideration was given to Rainbow Trout.

### Benthic Predicted Exposure Zones (Benthic-PEZ)

A benthic Predicted Exposure Zone (benthic-PEZ) is a first-order estimate of the size and location of benthic areas that may be exposed to deposited feed waste, feces, and other associated sinking particulates (i.e., medications) released within a proposed aquaculture site; fine particulate matter was not considered. For the benthic-PEZ, the displacement distance, $D$ , is given by:

$$D = \frac{uH}{W_s}$$

Where $u$ is the maximum water current speed, $W_s$ is the approximate minimum sinking rate of feed and feces particulate matter, and $H$ is the maximum depth of the water in the vicinity of the particulate matter release location (Page et al. 2023a). The timescale for released particulate matter to be deposited on the seabed is given by $H/W_s$. Since the PEZ is a theoretical circumference that surrounds the centroid of a proposed aquaculture site, the water flow direction is not used in the calculations. A benthic-PEZ indicates the area where organic loading on the seabed may occur and, if in-feed drugs are used as part of the aquaculture operations, a benthic-PEZ indicates the potential depositional domain of feed waste and feces, and the medications associated with them. It is recognized that the deposition of organic matter and in-feed drugs has the potential to result in direct impacts on the benthic habitat and benthos (DFO 2010a, Weitzman et al. 2019, Giles et al. 2021), although the degree of impact is not given particular focus in this report. Similarly, decay, resuspension, flocculation, and redistribution of depositional material from aquaculture operations is not considered.

A review of in-feed antibiotic use data from AQUIIS between 2018 and 2022 at Nova Scotia aquaculture sites shows that approximately 50% of sites have administered antibiotics, including three of the existing sites in St. Mary's Bay. Only one site in St. Mary's Bay reported more than one antibiotic treatment, and it was for two consecutive treatments within two days of each other. A review of in-feed pest control use data during the same time period indicated minimal use of in-feed pest control products for all Nova Scotia aquaculture sites. Of the existing sites in St. Mary's Bay, only one site reported a single use in August 2022. Although use of in-feed drugs to-date has been low, their use remains a possibility moving forward and therefore PEZs are considered as part of this review.

Benthic-PEZs associated with feed waste and feces for the four proposed sites were estimated using the common and site-specific input parameters summarized below (Tables 2 and 3). Particle sinking rates of different particulate matter types released from typical finfish aquaculture sites (i.e., feed waste and feces) vary, and the distribution of sinking rates amongst particle sizes that are released is poorly characterized. Minimum sinking rates for different particulate matter have been adopted from the literature for each category of particle type (Findlay and Watling 1994, Chen et al. 1999, Cromey et al. 2002, Chen et al. 2003, Sutherland et al. 2006, Law et al. 2014, Bannister et al. 2016, Law et al. 2016, Skoien et al. 2016). The maximum water depth within 500 m of each proposed site was used and a maximum observed midwater current speed for each site was adopted from the proponent's current data collected at each proposed site. Given the proposed net-pens and fish would occupy the upper 15 m surface layer, released feed waste and feces would sink throughout the entire water column. Hence, the mid-water current speeds were used to estimate the benthic-PEZs.

*Table 2. Summary of common input parameters used to calculate the benthic-PEZ estimates for the proposed sites.*

| Common Input Parameter Descriptions and Units | Input Values Used to Calculate Benthic PEZ Estimates |
|---|---|
| Individual net-pen circumference (m) | 130 |
| Radius of net-pen (m) | 21 |
| Number of net-pens in cage array (short by long) | 2 x 6 |
| Separation distance between cage centres (m) | 65 |
| Length of cage array (m) | 367 |
| Width of cage array (m) | 106 |
| Maximum length-scale of cage array, $L_{carray}$ , (m) | 191 |

*Table 3. Summary of site-specific input parameters used to calculate the benthic-PEZ estimates by particle type for the proposed sites.*

| Proposed site | Particle type | Data Inputs $W_s$(cm/s) | Data Inputs $H$ (m) | Data Inputs $u$ (cm/s) | Calculated Inputs Sink time (min) | Calculated Inputs $D$ (m) | Estimates $R_{PEZ}$(m) |
|---|---|---|---|---|---|---|---|
| #1449 | Feed | 5.3 | 49.4 | 68.8 | 16 | 641 | 832 |
| #1450 | Feed | 5.3 | 29.4 | 68.8 | 9 | 382 | 573 |

| Proposed site | Particle type | Data Inputs $W_S$(cm/s) | Data Inputs $H$ (m) | Data Inputs $u$ (cm/s) | Calculated Inputs Sink time (min) | Calculated Inputs $D$ (m) | Estimates $R_{PEZ}$(m) |
|---|---|---|---|---|---|---|---|
| #1451 | Feed | 5.3 | 27.3 | 63.1 | 9 | 325 | 516 |
| #1452 | Feed | 5.3 | 49.8 | 126.9 | 16 | 1,192 | 1,383 |
| #1449 | Feces | 0.3 | 49.4 | 68.8 | 274 | 11,329 | 11,520 |
| #1450 | Feces | 0.3 | 29.4 | 68.8 | 163 | 6,742 | 6,933 |
| #1451 | Feces | 0.3 | 27.3 | 63.1 | 152 | 5,742 | 5,933 |
| #1452 | Feces | 0.3 | 49.8 | 126.9 | 277 | 21,065 | 21,256 |

The benthic-PEZ is a circular zone centred over the middle of a proposed net-pen array, representing the outer limit of potential exposure to deposited particulate matter from aquaculture operations (i.e., feed and feces). A maximum distance of 191 m from the centre to the edge of the proposed net-pen array was added to an estimate of the maximum possible horizontal distance travelled by a particle to obtain the PEZ radius. The PEZ, a circle, typically encompasses the actual benthic footprint of finfish aquaculture sites, which is commonly an irregular ellipse whose shape depends on local current flow (e.g., tides). In reality, the intensity of exposure of benthic habitat to aquaculture deposition is expected to be highest near the net-pen arrays themselves, decreasing in intensity as distance away from the net-pens increases. However, in some instances where the benthic-PEZ of adjacent aquaculture sites overlap, a cumulative benthic exposure effect may be observed.

Based on a particle sinking rate for feed, there is no overlap in the estimated benthic-PEZs between all four sites (left-hand panel; Figure 3). In contrast, the lower particulate sinking rate for feces results in larger benthic-PEZs, which demonstrates overlap between the benthic-PEZs of the four proposed sites (right-hand panel; Figure 3).

Proposed site #1452 has the largest feces benthic-PEZ, attributed to the highest maximum current speed observed at this site (Table 1). The feces benthic-PEZ for #1452 fully consumes other adjacent sites, as each benthic-PEZ is estimated independent of the other using physical parameters unique to each individual site. Again, where benthic-PEZs overlap there is potential for cumulative effects on the benthos from adjacent sites (the same holds true where other aquaculture sites in St. Mary's Bay currently exist). In general, when considering the existing and proposed four new finfish aquaculture sites, most of the seabed in St. Mary's Bay could be exposed to feces deposition (Figure 3).

While the benthic-PEZs of the four proposed finfish sites extend beyond Digby Neck and into the Bay of Fundy, the coastal boundaries are such that the benthos within St. Mary's Bay is more susceptible to deposition compared to those areas outside of the bay. Some feces deposition north of Digby Neck and into the Bay of Fundy may occur via Petit Passage from sites #1451 and #1452, and via Grand Passage from site #1452, although any feces deposition is likely limited to within 20 km of the coastline along Digby Neck and Long Island. Some feces transport and deposition from site #1452 may also occur southward outside the mouth of the bay. Feces deposition from sites #1449 and #1450 is not expected to occur outside of St. Mary's Bay as the PEZs do not include Petit Passage and do not reach the mouth of the bay.

It is likely that areas where direct impacts from organic loading may occur are within the smaller benthic-PEZs calculated based on feed. Linkages between organic enrichment, sediment sulfide concentrations, and overall sediment conditions such as oxic state and macrofauna diversity at aquaculture sites are well documented (Pearson and Rosenberg 1978, Hansen et al. 2001, Wildish et al. 2001, Hargrave et al. 2008), and therefore sediment sulfide concentrations are used as an indicator of oxic state and biodiversity in soft sediments. Under the *AAR* and provincial regulations, aquaculture industry operators are required to conduct monitoring of marine sediment sulfide concentrations near finfish aquaculture sites to assess the potential impact of organic matter on the benthic environment. Should regulatory thresholds (i.e., concentration limits) be exceeded, management actions are required.

Average sediment sulfide concentrations measured during baseline surveys at the four proposed new aquaculture sites indicate Oxic A levels (i.e., less than or equal to 750 µM 'free' sulfides) based on Hargrave (2010) oxic categories. Environmental Monitoring Program (EMP) data available on the Nova Scotia Open Data Portal from 2009 to 2022 also demonstrate that the vast majority of sediments sampled beneath existing finfish aquaculture sites in St. Mary's Bay, and the surrounding vicinity, have remained at Oxic A or B levels (i.e., less than or equal to 1500 µM 'free' sulfides). Sampling conducted at the existing aquaculture site #1354 in St. Mary's Bay in 2017 reported a single station with Hypoxic B levels that were greater than or equal to 3000 µM 'free' sulfides, and subsequently reported recovery to Oxic A status by the following year. Similarly, sampling in 2022 also demonstrated that existing aquaculture sites #1354 and #1012 in St. Mary's Bay reported a single station with Hypoxic B levels, with follow-up sampling in 2023 yet to be completed and results reported for comparative purposes.

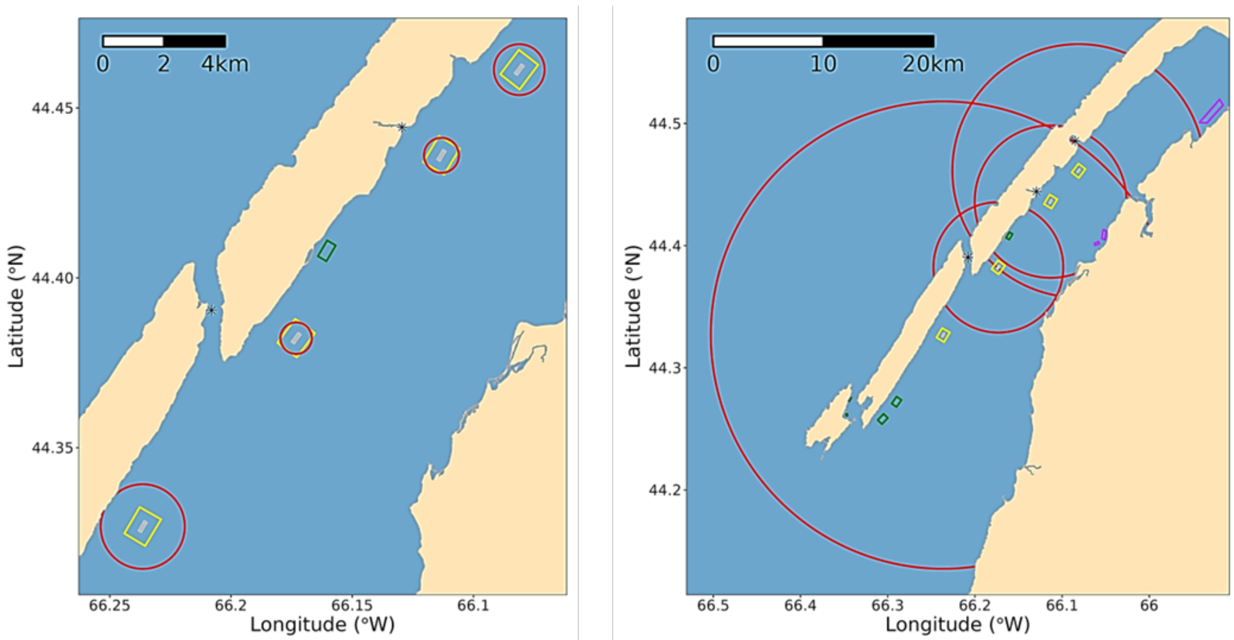


*Figure 3. Benthic-PEZs outlined in red circles for the four proposed new finfish aquaculture sites in St. Mary's Bay for feed waste (left-hand panel) and feces (right-hand panel). Proposed lease boundaries and net-pen array locations are shown as yellow and grey rectangles, respectively. Existing finfish and shellfish leases are shown in dark green and purple, respectively. Approximate locations of seasonal lobster holding facilities are denoted with black asterisks. Note the scale in the left- and right-hand panels differ.*

The sediment sulfide data and corresponding oxic state of existing sites in St. Mary's Bay indicated that, while there have been elevated sediment sulfide concentrations in certain locations, they have not historically exhibited adverse organic enrichment effects on marine sediments and infauna in the area. Given that the proposed sites are in similar oceanographic conditions and at comparable production levels to these existing sites, the same may be expected of the proposed sites.

**Pelagic Predicted Exposure Zones (Pelagic-PEZ)**

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

A review of pesticide use data in Nova Scotia from AQUIIS showed that between 2018 and 2022 no aquaculture sites in Nova Scotia, including St. Mary's Bay, used bath pesticides. However, their use remains a possibility moving forward and therefore PEZs are considered as part of this review.

Only registered pesticides are considered for the calculation of the pelagic-PEZs. The two registered pesticides available for use in bath treatments (e.g., tarp bath and well-boat) for the proposed aquaculture sites are azamethiphos and hydrogen peroxide. The pelagic-PEZs are calculated assuming use of tarp bath treatments, regardless of whether all net-pens would meet the Pest Management Regulatory Agency (PMRA) treatment conditions for such application type. Field studies (Page et al. 2015) and initial simple models (Page et al. 2023a) have indicated that pesticides released from a well-boat treatment dilute more quickly than those released from a tarp treatment. The size of the pelagic-PEZs depends on the decay and/or dilution rate of the pesticide used, the volume of treatment water, the target treatment concentration, an environmental effects concentration threshold, and an assumed horizontal water current speed. Hence, the pelagic-PEZs should be smaller for well-boat treatments relative to tarp treatments. The PMRA has determined that the two registered pesticides (i.e., azamethiphos and hydrogen peroxide), and their breakdown products, are expected to remain in suspension since they do not bind with organics or sediments and do not accumulate in organism tissues. The half-lives of the two pesticides are in the order of days-to-weeks, which influences their persistence in the marine environment at concentrations considered to be toxic (PMRA 2014, 2016a, b, 2017).

For both azamethiphos and hydrogen peroxide, the decay rate of the active ingredient is low compared to the dilution rate (see Appendix I for half-lives). Hence, a dilution time scale from a target treatment concentration to an Environmental Quality Standard (EQS) value (Hamoutene et al. 2023a) was used to calculate the pelagic-PEZ for both registered pesticides. The pelagic-PEZ was calculated using a conservative EQS value that ensures a level of protection of 95% of species (as per the data available) as inferred using HC5 values (i.e., the hazardous concentration for which 5% of species are affected or potentially affected) (TGD 2018). The EQS values for both pesticides include assessment factors of 2 and 5 for azamethiphos and hydrogen peroxide, respectively (Hamoutene et al. 2023a). Therefore, the pelagic-PEZ indicates the potential for sensitive species and habitats to be exposed to levels above the conservative EQS threshold.

The EQS values used in this report are lower than those used in prior DFO Science aquaculture site reviews and, therefore, the dilution times are much higher than the 3-h dilution time estimated previously for azamethiphos (DFO 2020a, 2021a, 2022a, 2022b, 2023a). Dilution times of 10.83-h and 26.87-h for azamethiphos and hydrogen peroxide, respectively, were estimated using a pesticide dilution model (Haigh et al. 2024) with the following input parameters (Tables 4 and 5) and assumptions:

- The size of the treatment cage is a cylinder with a perimeter of 130 m and a depth of 6 m, which is 60% of the cage depth based on net-pen treatment protocol in southwest New Brunswick (Page et al. 2015).
- The treatment concentration is $10^5$ ng/L and 1.5 x $10^9$ ng/L for azamethiphos and hydrogen peroxide, respectively.
- The EQS value is $10^2$ ng/L and 1.5 x $10^5$ ng/L for azamethiphos and hydrogen peroxide, respectively (Hamoutene et al. 2023a).
- The pesticide patch is assumed to be cylindrical in shape.
- The pesticide concentration is assumed to have a Gaussian distribution in the horizontal.
- The pesticide patch is assumed to grow according to the Okubo relationship in the horizontal.
- The pesticide concentration is assumed to be uniformly distributed in the vertical and the patch depth grows according to the relationship presented in Page et al. (2023b).
- The pesticide patch is assumed to contain concentrations above the EQS until the peak concentration (at the centre of the patch) is equal to the EQS. After this time, the patch is assumed to be non-toxic.

For calculations of the benthic-PEZs, maximum current speeds were used. In previous DFO aquaculture site assessments, maximum current speeds were also used for the calculation of the pelagic-PEZs. However, the longer dilution times yield PEZs that include regions that are highly unlikely to be exposed. In particular, St. Mary's Bay is a high tidal environment dominated by M2 tides that have a period of 12.42-h. The calculated dilution time for azamethiphos (10.83-h) approaches the tidal period and that of hydrogen peroxide (26.86-h) exceeds two tidal periods. Given the tidal nature of St. Mary's Bay, the pelagic-PEZs were calculated using a maximum progressive vector displacement (and not maximum current speeds), which takes into account the tidal nature of the currents.

*Table 4. Summary of common input parameters used to calculate the pelagic-PEZ estimates for the proposed sites. $\alpha$ and $\beta$ are used to characterize the empirical time dependent relationship of the equivalent radial variance determined by Okubo (1968, 1971). For more information on dispersion models of pesticides released from finfish aquaculture see Haigh et al. (2024).*

| Common Input Parameter and Units | Input Values Used to Calculate Pelagic-PEZs |
|---|---|
| **Cage Array** | **Dimensions** |
| Individual net-pen circumference (m) | 130 |
| Radius of net-pen (m) | 21 |
| Net-pen treatment depth (m) | 6 |
| Number of net-pens in cage array (short by long) | 2 x 6 |
| Separation distance between cage centres (m) | 65 |
| Length of cage array (m) | 367 |
| Width of cage array (m) | 106 |

| | |
|---|---|
| Maximum length-scale of cage array, $L_{carray}$ , (m) | 191 |
| **Pesticide Concentrations** | **Concentrations** |
| Azamethiphos treatment dose (ng/L) | $10^5$ |
| Azamethiphos EQS (ng/L) | $10^2$ |
| Hydrogen Peroxide treatment dose (ng/L) | $1.5 \times 10^9$ |
| Hydrogen Peroxide EQS (ng/L) | $1.5 \times 10^5$ |
| **Pesticide Diffusion Model Parameters** | **Input Values** |
| Okubo model for Horizontal dispersion parametrization | $\alpha = 5.6 \, x \, 10^{-6}; \beta = 2.22$ |
| Gaussian horizontal concentration distribution | $n = 1.5$ |
| Vertical growth model | $K_2 = 0.01 \, m^2 s^{-1}$ |

*Table 5. Calculated inputs used to estimate the pelagic-PEZs by pesticide for the proposed sites.*

| Proposed site | Pesticide | Calculated Inputs Dilution time (hours) | Calculated Inputs Max. patch depth (m) | $D$ (m) | Estimates $R_{PEZ}$ (m) |
|---|---|---|---|---|---|
| 1449 | Azamethiphos | 10.83 | 25.74 | 10,681 | 10,872 |
| 1450 | Azamethiphos | 10.83 | 25.74 | 10,681 | 10,872 |
| 1451 | Azamethiphos | 10.83 | 25.74 | 10,703 | 10,894 |
| 1452 | Azamethiphos | 10.83 | 25.74 | 13,317 | 13,507 |
| 1449 | Hydrogen Peroxide | 26.87 | 37.10 | 17,506 | 17,697 |
| 1450 | Hydrogen Peroxide | 26.87 | 37.10 | 17,506 | 17,697 |
| 1451 | Hydrogen Peroxide | 26.87 | 37.10 | 14,670 | 14,861 |
| 1452 | Hydrogen Peroxide | 26.87 | 37.10 | 23,850 | 24,041 |

For the pelagic-PEZ, the displacement distance, $D$ , is the maximum progressive vector displacement calculated using the current meter record and the dilution time. Comparison with particle tracking results using a Finite Volume Community Ocean Model (FVCOM; Ptrack, version 1.2.1) of the region indicates that, although the progressive-vector PEZ may underestimate the extent of the exposure zone for a single site, the PEZs for all sites considered together approximately encompass the potential exposure areas (Figure 4). Note that the use of progressive vectors for calculating the pelagic-PEZs should be evaluated on a case-by-case basis. For St. Mary's Bay, the progressive vector PEZs provides a reasonable approximation of the areas of potential exposure around the proposed aquaculture sites due to the locations of the proposed sites and local hydrographic conditions.

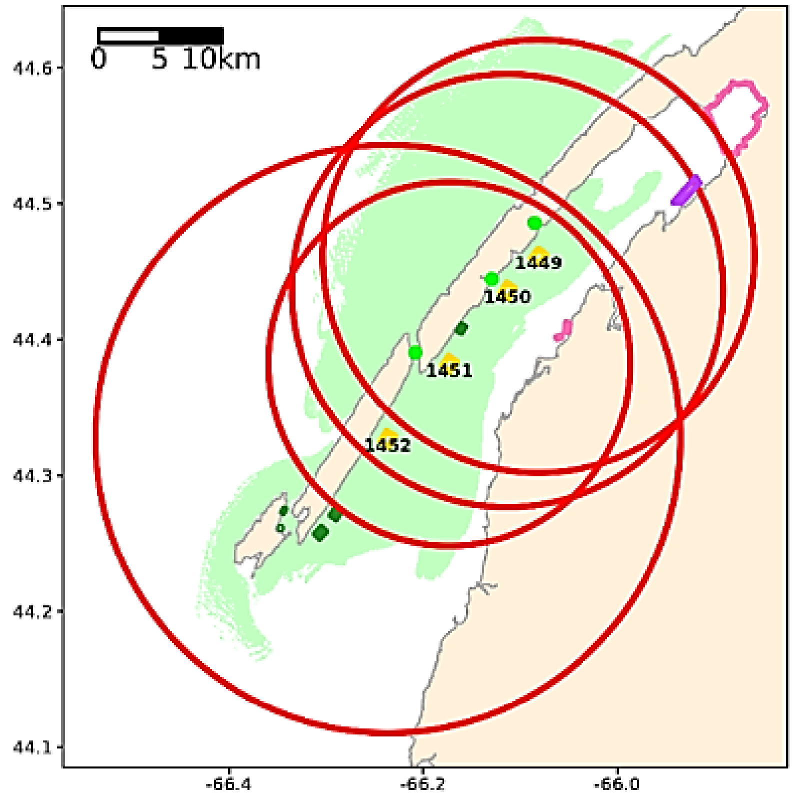


*Figure 4. Predicted pesticide patch locations (light green) for hydrogen peroxide treatments from all proposed sites based on particle tracking using FVCOM model output. The red circles represent PEZs calculated using the maximum progressive vector displacement for each site. Proposed sites are shown in yellow and existing finfish and shellfish sites are shown in dark green and pink/purple, respectively. Approximate locations of seasonal lobster holding facilities are also denoted as light green dots.*

Pelagic-PEZs are estimated assuming the release of pesticides into surface waters within the proposed sites. Based on current data provided by the proponent, there is little variation in the vertical profile of current speed with depth at each site. For the calculation of the pelagic-PEZs, currents at 10 m below the surface were used. The pelagic-PEZs are estimated by adding the maximum horizontal progressive vector distance travelled to the longest length scale of the proposed net-pen array. The pelagic-PEZs for the four proposed new aquaculture sites for azamethiphos (left-hand panel; Figure 5) and hydrogen peroxide (right-hand panel; Figure 5) are shown below.

The pelagic-PEZs demonstrate that almost any location in St. Mary's Bay has the potential to be exposed to a pesticide release, if used. It is also anticipated that some pesticides would be transported north of Digby Neck and into the Bay of Fundy via Petit Passage, Grand Passage, and the outer mouth of the bay. In addition to exposure in the pelagic zone, benthic exposures to pesticides are also likely. Since dilution times of pesticide patches are long, the patch can grow significantly in the vertical as well, reaching depths of 25.74 m and 37.1 m for azamethiphos and hydrogen peroxide, respectively. As a result, large areas of shallower water benthos in St. Mary's Bay may also be exposed to pesticides, including adjacent coastal areas outside of St. Mary's Bay (Figure 5).

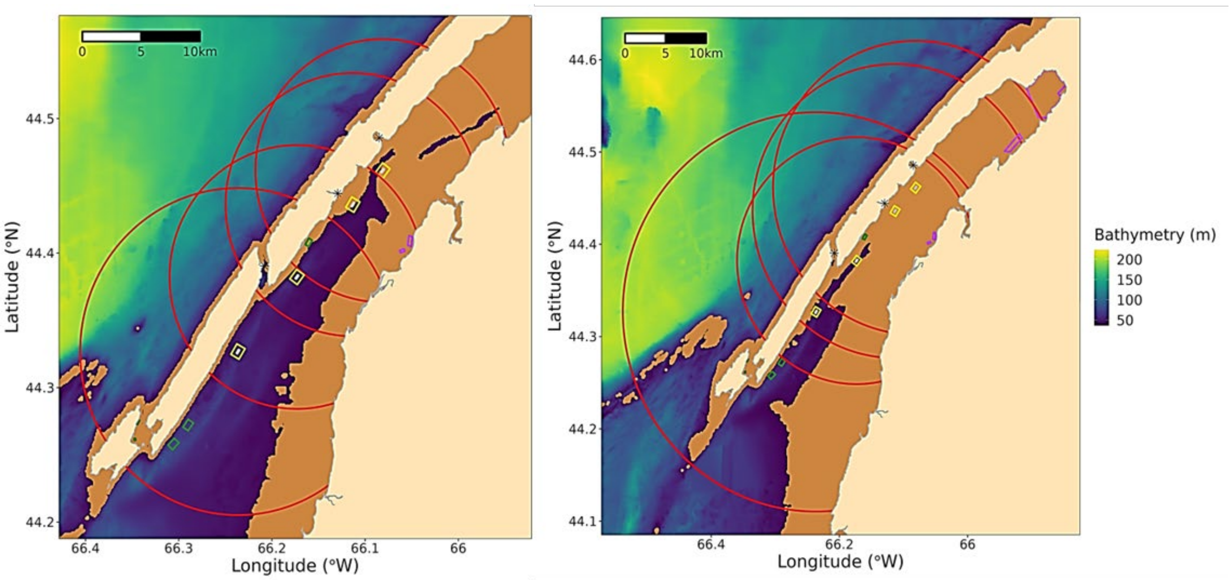


*Figure 5. Pelagic-PEZs of the four proposed sites for azamethiphos (left-hand panel) and hydrogen peroxide (right-hand panel) are shown in red overlaid on bathymetry (depth is in metres, referenced to mean water level). Brown denotes areas of the seabed that may be exposed to toxic pesticide concentrations (depths less than 25.74 m for azamethiphos and 37.1 m for hydrogen peroxide). Proposed lease boundaries and net-pen array locations are shown as yellow and grey rectangles, respectively. Existing finfish and shellfish leases are shown in dark green and purple, respectively. Approximate locations of seasonal lobster holding facilities are denoted with black asterisks. Note the scale in the left- and right-hand panels differ.*

Where multiple finfish aquaculture sites occupy areas of close proximity, and where pelagic-PEZ may overlap, the potential for chronic exposure of marine habitats and species will increase if multiple pesticide treatments occur, as well as from cumulative effects if net-pens are treated consecutively over short duration (Ernst et al. 2014) and due to longer exposure periods (Refseth et al. 2019). An overview of bath pesticide use data at New Brunswick aquaculture sites from AQUIIS between 2018 and 2022 showed that more sites report using azamethiphos only (26.5%) compared to hydrogen peroxide only (6.1%), but that more sites report use of both pesticides (32.6%) compared to either alone. However, approximately 75% of sites that use both have reported an interval of more than two weeks between use. Based on this, and given that estimated dilution times for azamethiphos (10.83 h) and hydrogen peroxide (26.87 h), it is unlikely that species and habitats within the pelagic-PEZs in St. Mary's Bay would be exposed to both pesticides at the same time from a single site, although proximity to other sites and overlapping pelagic-PEZs could still result in potential cumulative effects resultant of multi-chemical usage in the area (again noting that a review of pesticide use data in Nova Scotia from AQUIIS showed that between 2018 and 2022 no aquaculture sites in Nova Scotia, including St. Mary's Bay, have used bath pesticides).

## Susceptible Species and Habitats Observed in the PEZs for Organic Matter and Fish Health Treatment Products

Within the benthic-PEZ, species were considered susceptible if they are sessile or sedentary at any life stage and are sensitive to increased sedimentation, organic matter deposition and any associated changes in oxygen concentrations, and/or exposure to in-feed drugs, if used. This may include species such as bivalves and crustaceans during some life stages. Within the pelagic-PEZ, species were considered susceptible if they are known to have sensitivities to bath pesticide exposures of azamethiphos and hydrogen peroxide, should such treatment be used. Specific consideration was given to the potential for exposures to crustaceans due to their higher relative susceptibility to the pesticides used in aquaculture. For species within both the benthic- and pelagic-PEZs, specific consideration was also given to the presence of certain sensitive sessile species, such as sponges, corals, and eelgrass, as well as knowledge of critical habitat for *SARA*-listed species. Information on abundance and distribution of species and habitats within the PEZs and surrounding areas was considered where available to address how common or rare (i.e., uniqueness and/or importance) the identified species and habitats are within the PEZs.

In-feed pest control drugs are not used continuously, but are persistent in sediments following the end of a treatment period. This may lead to prolonged exposures for benthic species and a potential cumulative effect of multi-chemical usage (Strachan and Kennedy 2021, Hamoutene et al. 2023b). Among the in-feed pest control products authorized for use at marine finfish aquaculture sites in Canada, an in-depth review of the chemical use data from 2016 to 2018 indicates that emamectin benzoate (EMB) was the most used pest control drug (Chang et al. 2022). Measurements collected at 10 marine finfish aquaculture sites across Canada also reported that EMB was the most common pest control drug detected in sediment samples around the sites (Kingsbury et al. 2023). The main concern associated with the use of in-feed antibiotics is the potential development of antimicrobial resistance (AMR), a process whereby bacteria become insensitive to one or multiple antibiotics over time (Baquero et al. 2008). Many uncertainties still exist with respect to these indirect impacts of antibiotics on marine organisms; however, direct impacts to marine organisms have been deemed unlikely as per the amounts used. Given the lack of information on AMR in marine organisms the potential effects of antibiotic use are not considered further in this review.

Current knowledge on the exposure and potential biological effects (hazards) of drugs and pesticides used in the marine environment during finfish aquaculture activities on non-target organisms has been previously reviewed in Burridge and Holmes (2023). If in-feed drugs or bath pesticides were to be used at the proposed sites, it is possible that effects could be observed in susceptible species identified in the sections below. However, the degree of impact would depend on a number of factors, including the extent and timing of use and specifics of the treatment scenario. To more accurately determine impact, considerable scientific effort is required. Such effort would need to include improved modelling and field efforts to ground-truth model outputs, species-specific toxicology, sensitivity of population dynamics to potential increases in life stage mortalities, and additional observations. If fish health treatments are required, timing and method of treatment can be important considerations to reduce the potential for impacts on non-target species.

### Ecologically and Biologically Significant Areas (EBSA)

The Brier Island and Digby Neck Ecologically and Biologically Significant Area (EBSA) comprises part of St. Mary's Bay, which is also a proposed component of the long-term conservation network plan for the region given its high conservation value (Buzeta 2014) (left-hand panel; Figure 6). This EBSA is reported to have significant aggregations of marine mammals and birds due to its high concentration and diversity of copepods and other zooplankton (Buzeta 2014). It is also known for its benthic diversity, including potentially important aggregations of sensitive benthic species such as sponges and Horse Mussel *(Modiolus modiolus*). In particular, the area offshore of Brier Island has been identified as a Significant Benthic Area (SiBA) for sponges in Atlantic Canada (Kenchington et al. 2010, 2016). DFO (2004) stated that EBSAs are a tool for calling attention to an area that has particularly high ecological or biological significance to facilitate provision of a greater-than usual degree of risk aversion in management of activities in such areas. The southernmost proposed sites #1451 and #1452 are located within the EBSA boundaries, and the PEZs from all four proposed sites also overlap with the boundaries. There is also a small overlap with the largest PEZ for proposed site #1452 and the Southwest Scotian Shelf Coastal EBSA (right-hand panel; Figure 6), which is located to the south of St. Mary's Bay and supports numerous species and habitats within its many inlets, bays, and coastline (Hastings et al. 2014).

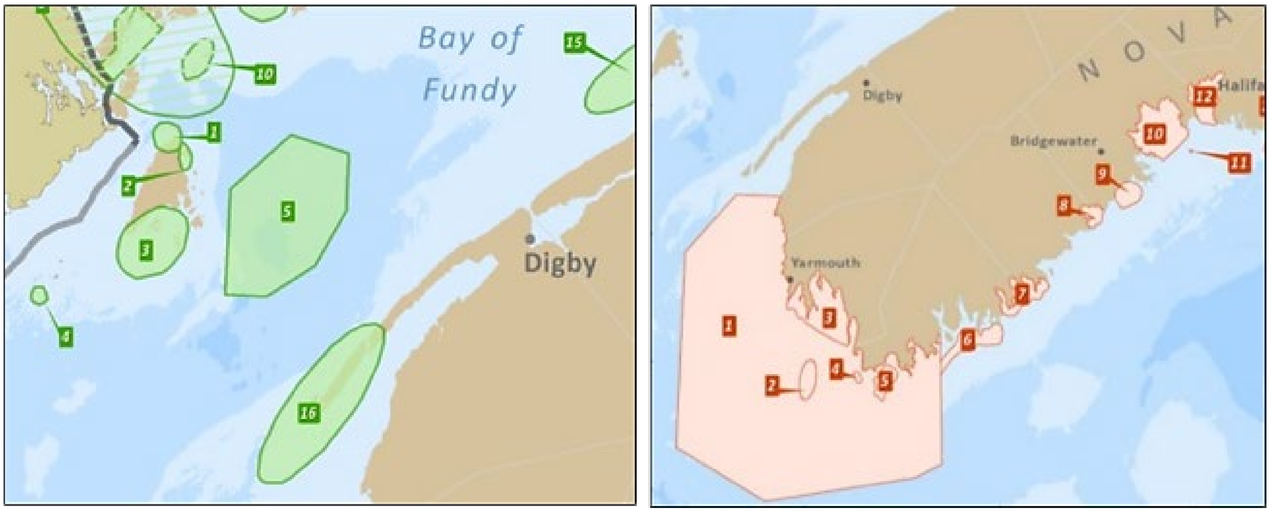


*Figure 6. Location of identified Ecologically and Biologically Significant Areas (EBSA) in the Bay of Fundy (Buzeta 2014) (left-hand panel) and for coastal Nova Scotia (Hastings et al. 2014) (right-hand panel) that overlap with proposed site locations and/or PEZs. Site 16 on the left-hand panel denotes the Brier Island and Digby Neck EBSA and Site 1 on the right-hand panel denotes the Southwest Scotian Shelf Coastal EBSA. Figures adopted from Buzeta (2014) and Hastings et al. (2014).*

Recent dive surveys in the Brier Island and Digby Neck EBSA identified a number of sponge taxa, a Horse Mussel reef, and an eelgrass bed in Grand Passage (Cooper et al. 2019), which is located within the benthic-feces PEZ and pelagic-PEZ of the southernmost proposed site (#1452). Sponges are considered "sensitive and susceptible to anthropogenic activities, including direct (e.g., removal or damage) and indirect (e.g., smothering by sedimentation) fishing impacts" (DFO 2010b). Horse Mussel provide an ecosystem engineering role in the formation of biogenic habitat conducive to occupation by a wide range of taxa. For this reason, Horse Mussel have been identified as an Ecologically Significant Species (ESS) that should be highlighted in Marine Protected Area planning due to their ecological importance (Buzeta 2014), and the protection of these biogenic habitats is a conservation priority within regional marine conservation network planning (DFO 2018). As a sedentary bivalve, Horse Mussel are also considered to be susceptible to increased sedimentation like sponges. Eelgrass is also designated as an ESS in Atlantic Canada providing numerous ecological functions, including habitat for fish and their prey. Potential impacts on eelgrass from finfish aquaculture activities have been summarized in previous DFO Science aquaculture site reviews (DFO 2021a, 2022b).

All of these species in Grand Passage are located in closer proximity to existing aquaculture sites as compared to the four proposed sites (Figure 1). While they may be exposed to increased sedimentation levels from the proposed sites, this is unlikely to occur at levels where changes to oxic-state and sediment geochemistry, or smothering, are predicted given their distance from the proposed sites and absence from any of the benthic-feed PEZs where the intensity of deposition is expected to be highest. Exposure of sponges and bivalves to increased sedimentation at low levels may even be of benefit since they capture food from the water column as filter feeders and have been advocated for use in integrated multi-trophic aquaculture (Soto 2009, Gökalp et al. 2021). With respect to the eelgrass bed, Cooper et al. (2019) noted that the location of this bed in a protected cove near Westport, Nova Scotia corresponded to a site reported by MacKay (1977) as having "lush eelgrass". The observation that this dense eelgrass bed still appears to be present in good condition may be an indication of the eelgrass health and persistence while coexisting with nearby aquaculture sites (some present as early as the mid-1990's) in Grand Passage. The eelgrass bed in Grand Passage is likely a known feature due to study of the EBSA. Given what is known about eelgrass biology, it is not expected in significant quantities elsewhere in St. Mary's Bay due to the substrate, hydrodynamics, and bathymetry of the area, though data are sparse (Bernier et al. 2023).

St. Mary's Bay was also discussed as a potential stand-alone EBSA at the time of EBSA assessment for the Bay of Fundy. Although not included in the final list of EBSAs, St. Mary's Bay was identified as having at least nineteen at-risk species observed within its waters (AECOM Canada Ltd. 2011, Buzeta 2014). St. Mary's Bay was also noted as an important area for Atlantic Herring (*Clupea harengus*) larvae that are believed to be transported by surface currents from the nearby spawning grounds on Trinity Ledge and Lurcher Shoals (Das 1968, Buzeta et al. 2003, Buzeta 2014). The Trinity Ledge-Lurcher Shoal was once one of the most extensive spawning and fishery grounds for purse seiners and gillnetters; it has been considered the smallest of three major spawning areas for the Bay of Fundy since its collapse in the late 1980's after a period of heavy fishing (Stephenson et al. 2015). It is thought that larval retention in St. Mary's Bay may aid in the recovery of the spawning ground. Whether aquaculture sites have any kind of impact (positive, negative, or negligible) on Herring larvae or on St. Mary's Bay as a retention area is not well understood.

#### Species Listed Under the Species at Risk Act (SARA) and Other At-risk Species

Several at-risk species have been observed in or in proximity of St. Mary's Bay, and within the PEZs. Observed species within the PEZs that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and/or are under consideration for listing on Schedule 1 of the *Species at Risk Act* (*SARA*) include: Sei Whale (*Balaenoptera borealis)*; Killer Whale (*Orcinus orca)*; Porbeagle Shark (*Lamna nasus)*; Shortfin Mako Shark (*Isurus oxyrinchus)*; Basking Shark (*Cetorhinus maximus)*; Striped Bass (*Morone saxatilis)*; Thorny Skate (*Amblyraja radiata)*; White Hake (*Urophycis tenuis)*; American Plaice (*Hippoglossoides platessoides)*; Atlantic Sturgeon (*Acipenser oxyrinchus)*; Atlantic Bluefin Tuna (*Thunnus thynnus)*; Cusk (*Brosme brosme)*; Spiny Dogfish (*Squalus acanthias)*; Lumpfish (*Cyclopterus lumpus)*; and Harbour Porpoise (*Phocoena phocoena)*.

Observations of *SARA Schedule 1*-listed species include: Shortnose Sturgeon (A*cipenser brevirostrum*, Special Concern); Spotted Wolffish (*Anarhichas minor*, Threatened); Northern Wolffish (*Anarhichas denticulatus*, Threatened); Atlantic Wolffish (*Anarhichas lupus,* Special Concern); Leatherback Sea Turtle (*Dermochelys coriacea,* Endangered); Fin Whale (*Balaenoptera physalus,* Special Concern); North Atlantic Right Whale (*Eubalaena glacialis,* Endangered); and White Shark (*Carcharodon carcharias,* Endangered). A search of the area using the DFO Aquatic Species at Risk Map tool indicates that *SARA Schedule 1*-listed Blue Whale (*Balaenoptera musculus,* Endangered*)* and Inner Bay of Fundy Atlantic Salmon (*Salmo salar*, Endangered) may also be present in the area based on their known geographic distribution. The high number of cetacean sightings within the PEZs, including North Atlantic Right Whale, suggests suitable and productive habitats for these species are found within St. Mary's Bay.

It is believed that any records of Shortnose Sturgeon in St. Mary's Bay are misidentifications (possibly of juvenile Atlantic Sturgeon), since the extent of occurrence for the Canadian population of Shortnose Sturgeon is thought to be largely isolated to the Saint John River (COSEWIC 2015). In contrast, summer surveys by DFO indicate that the Nova Scotia coast of the Bay of Fundy, southwest of Digby and near Brier Island, is one of the important habitats for Atlantic Wolffish (Horsman and Shackell 2009; Buzeta 2014). Areas near the proposed finfish aquaculture sites, however, are not thought to be particularly important wolffish habitat as their preferred habitat is typically in much deeper waters and trenches, though the full extent of presence and use of the area by Atlantic Wolffish is currently unknown. Atlantic Sturgeon has been assessed as *Threatened* by COSEWIC and is under consideration for *SARA*-listing. While habitat in St. Mary's Bay is not as important as the Saint John River and upper Minas Basin, there are known to be regularly occurring congregations of Atlantic Sturgeon in the bay and it may be overwintering habitat. Atlantic Sturgeon marked with acoustic tags have also been detected near Atlantic Salmon aquaculture sites in the Bay of Fundy, though their presence varies among different bays with aquaculture (M. Trudel, DFO, unpublished data).

Atlantic Salmon from the Inner Bay of Fundy (IBOF), as well as Outer Bay of Fundy (OBOF) and proposed Southern Upland – West (SU–W) Designatable Units (DUs), may also be in the area (Lacroix 2013a). Inner Bay of Fundy Atlantic Salmon are *SARA*-listed as Endangered, while the OBOF and proposed SU–W DUs are assessed by COSEWIC as Endangered and are under consideration for *SARA*-listing. A previous DFO Science response looked at habitat use of wild Atlantic Salmon life stages in St. Mary's Bay and reported that, based on limited available information, the area is thought to be used as an Atlantic Salmon migratory corridor and feeding ground in support of growth, maturation, and post-spawning reconditioning (DFO 2011b), as well as post-smolts returning from the Gulf of Maine (Lacroix 2013a).

The exposure of these at-risk species to increased deposition of organic matter from the proposed aquaculture sites is of minor concern given that all observed species are mobile (i.e., able to relocate) and that no critical habitat for these species has been identified within the benthic-PEZs. There is also currently no evidence to suggest impacts on fish or marine mammal species from the use of fish health treatment products. Potential interactions of greater concern for the at-risk large pelagic species observed in the area are those associated with the emplacement of site infrastructure (i.e., entanglement). These potential interactions are considered in the *Potential Entanglement of Wild Species at Risk in Aquaculture Infrastructure* section of this review (see below).

### Fishery Species

DFO database searches of the PEZs indicated overlap with numerous fish and benthic species. Observed invertebrates (as written in database records) include American Lobster; crab; shrimp; krill; Sea Scallop; Blue Mussel; Quahog; clam; whelk; squid; jellyfish; Sea Star; bryozoan; and sponges. Observations of groundfish and pelagic species (as written in database records) include Haddock; flounder; sculpin; halibut; Pollock; Atlantic Cod; Sea Raven; Ocean Pout; Monkfish; Rockling; Cunner; redfish; Atlantic Herring; Mackerel; Gaspereau; Butterfish; Shad; smelt; and tuna. St. Mary's Bay is an area that is also home to many important fish stocks and fisheries.

#### *Lobster*

The proposed aquaculture sites, and their associated PEZs, overlap with Lobster Fishing Area (LFA) 34, from which more than 20% of total Canadian landings are derived. The Lobster stock in LFA 34 is in the healthy zone (DFO 2023b). St. Mary's Bay supports Food, Social, and Ceremonial, Moderate Livelihood, communal commercial, and commercial Lobster harvesting.

St. Mary's Bay consists of Lobster reporting statistical grids 92 and 81, where the four proposed aquaculture sites are located, and grid 69 at the head of the bay. Accounting for these statistical grids, there is an estimated total 505.5 $km^2$ of Lobster fishing area in St. Mary's Bay with a combined mean seasonal Lobster landing of 662 t between 2020 and 2022 (which yields an estimated 1.3 t of Lobster landed per $km^2$). In addition, commercial Lobster holding facilities in St. Mary's Bay also fall within the PEZs of the proposed aquaculture sites, with those at Sandy Cove, Little River, and Tiverton/East Ferry being the closest in proximity to the four proposed aquaculture sites (Figures 3 and 5). The proximity of these facilities could mean that PMRA label conditions concerning the use of azamethiphos near active licensed lobster holding facilities may be applicable at certain times if these facilities are within 1 km of the proposed sites (PMRA 2017). These facilities operate during the season from the end of November through May each year and up to two weeks after the Lobster season closes.

Lobster survey efforts in St. Mary's Bay provide an indication of its importance as Lobster habitat. The fixed station inshore Lobster trawl survey (ILTS) was originally designed as a groundfish trawl survey but has recorded the presence of Lobster since its inception in 1996 (Denton 2020). In 2013, the survey officially transitioned into the ILTS, broadened its spatial scope, and increased its focus on Lobster. Survey stations have been in St. Mary's Bay since inception of the ILTS. Lobster densities observed in the trawl survey are consistently reported to be higher in the St. Mary's Bay region, and the adjacent inshore areas of southwestern Nova Scotia, compared to the offshore area. A higher abundance of all life stages of Lobster, including berried (egg-bearing) females, occurs in St. Mary's Bay than outside the area (Figure 7).

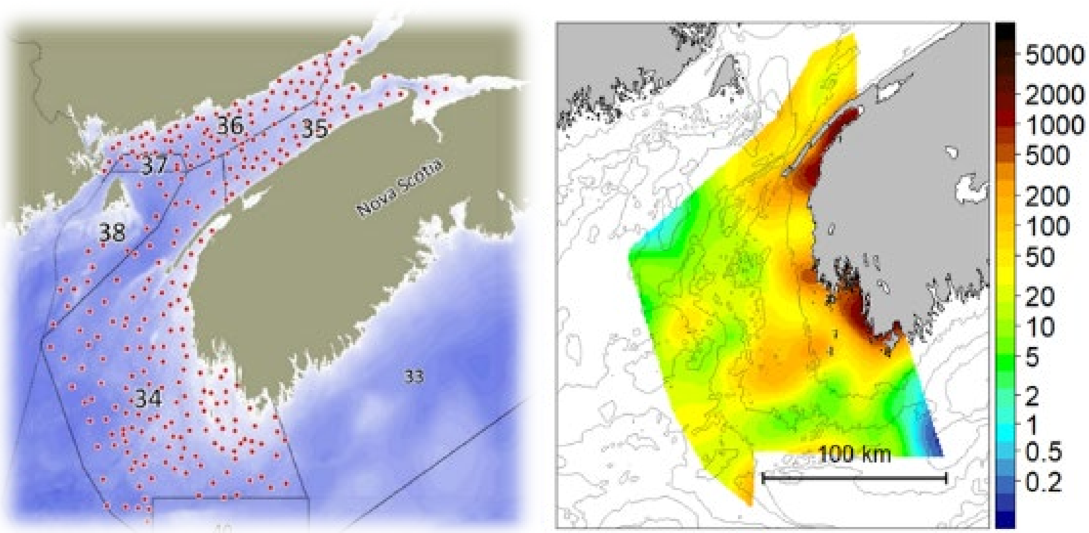


*Figure 7. Locations of fixed stations used for the Inshore Lobster Trawl Survey, ILTS (left-hand panel) and modeled density (kg/$km^2$) of commercial-sized Lobster during 2022 using data from the ILTS (right-hand panel). St. Mary's Bay exhibits high Lobster densities relative to adjacent and offshore areas.*

An annual scallop population dredge survey conducted in St. Mary's Bay has also provided a consistent time-series index of Lobster abundance. Overall, these surveys indicate a three-fold higher density of Lobster, both sub-legal (carapace length, CL, of 70–81 mm) and commercial-sized (CL greater than or equal to 82 mm), in St. Mary's Bay compared to outside St. Mary's Bay (Brier/Lurcher Shoals; J. Sameoto and B. Wilson, DFO, Dartmouth NS, unpublished data).

Cobble-filled passive collectors have also been deployed throughout Atlantic Canada and New England to sample post-larval American Lobster settlement, including in St. Mary's Bay (McManus et al. 2023). The published time-series throughout Atlantic Canada and New England spans from 1989 to 2021, with data still being collected in present day, and specifically in St. Mary's Bay since 2009. Data indicates that in the later years of the collector program St. Mary's Bay exhibited some of the highest indices of young-of-the-year Lobster found during the project (McManus et al. 2023). Figure 8 shows the size distribution of Lobster sampled in the St. Mary's Bay collectors.

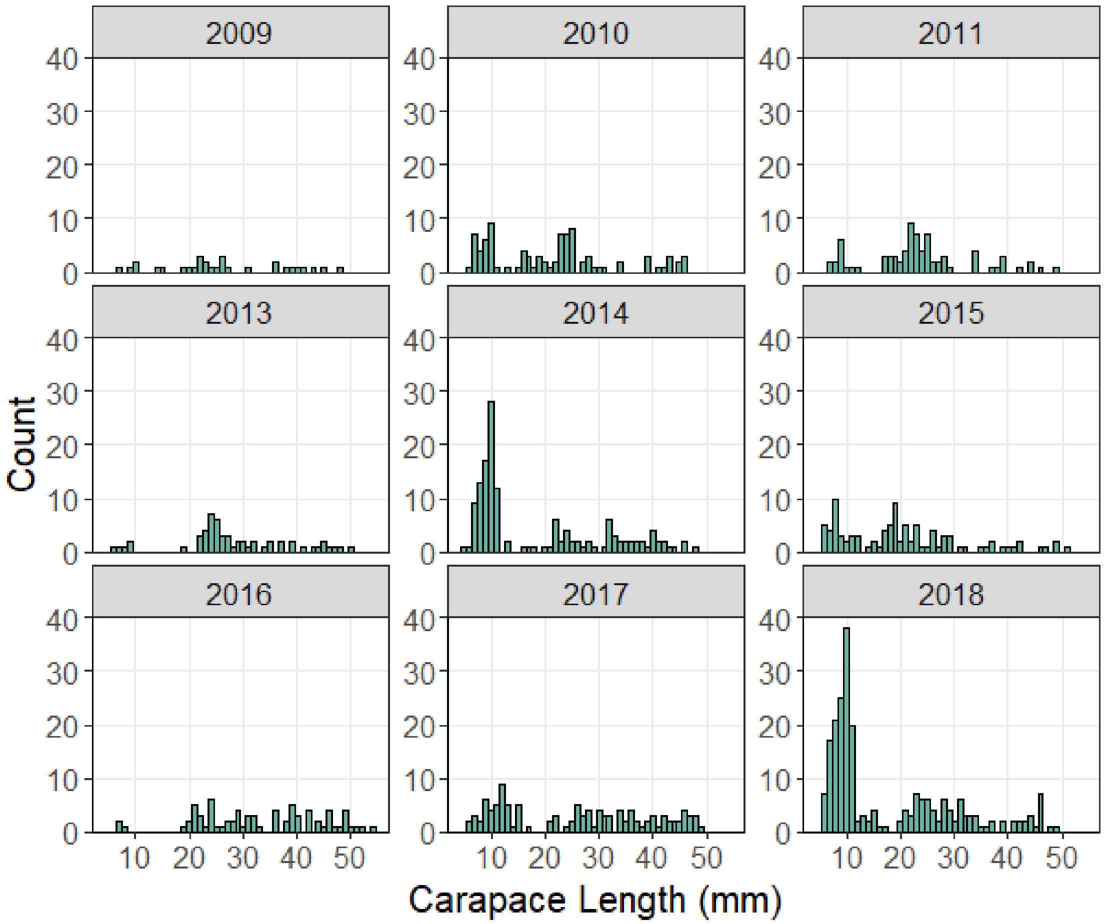


*Figure 8. Size frequency of all Lobster sampled from collectors in St. Mary's Bay from 2009 to 2018.*

A previous DFO Science response looked at habitat use of American Lobster life stages in St. Mary's Bay (DFO 2011a). All life stages of Lobster, including adults, are anticipated to be present during the summer months with a seasonal movement expected for adults as they move to the deeper offshore waters during the coldest months to maintain ideal temperatures. Preliminary observations have shown Lobster settlement to be five times higher on collectors set near the opening of Petit Passage than on collectors set further to the northeast on St. Mary's Bay Shoal (DFO 2011a). The finding of recently settled lobsters in a sampling location also suggests that pelagic larval stages have been present in the overlying water column in the preceding weeks to months, as lobsters do not move significantly over the seabed until at least the year following settlement, and potentially later (Lawton and Lavalli 1995). After settlement, young juvenile lobsters (up to approximately 15 mm CL) are present on the seabed in St. Mary's

Bay for some time given their limited mobility post-settlement (Lavalli and Lawton 1996). Larger juveniles (approximately 15–50 mm CL) emerge from their shelters more, but still behave as central-place foragers and do not move as far as adults do (Morse and Rochette 2016; Lawton and Lavalli 1995).

Juveniles 7–30 mm CL have been shown to remain in stressful conditions (e.g., high water temperatures greater than or equal to 20 °C; Nielsen and McGaw 2016) rather than leaving their shelter and may similarly choose shelter over avoiding hypoxia. Thus, changes in benthic oxygen conditions can potentially impact the early benthic recruit survival of lobsters. For adult lobsters, lethal oxygen limits observed in laboratory settings range from 0.2 and 1.72 mg/L, depending on temperature and salinity (McLeese 1956). The possibility that benthic-stage lobsters (at least adults) would move away from areas experiencing hypoxia, such as under organic-enriched aquaculture cages, has been raised (Horricks et al. 2022); however, it is unclear how alterations in benthic habitat from increased organic matter deposition may impact Lobster habitat conditions and overall abundance and distribution.

Observations of Lobster abundance and distribution in the vicinity of finfish aquaculture sites in Atlantic Canada have been varied. Lawton (2002) observed lower abundances of Lobster, particularly berried females, near finfish aquaculture farms near Grand Manan, New Brunswick when fish cages were stocked as compared to when fish were not stocked. Wiber et al. (2012) also reported that fishermen in Southwest New Brunswick believed that finfish aquaculture has influenced Lobster distribution and that berried females avoid these areas. In Nova Scotia, Loucks et al. (2014) and Milewski et al. (2018) suggested that long-term (i.e., 7 and 11 years, respectively) Lobster catches of commercial-size and berried females in Port Mouton were consistently lower during periods of finfish aquaculture production compared to fallow periods. In contrast, Grant et al. (2019) conducted a long-term study and observed no variation in commercial-size or berried female Lobster abundances between farm and reference sites at a finfish aquaculture site near Grand Manan over an 8-year period. Similarly, a recent study in Nova Scotia conducted at a finfish aquaculture site in Liverpool Bay from 2019 to 2021 observed that Lobster were less abundant in the farm area, as the fish production increased over the production cycle, although there was no indication of reduced Lobster movement in areas adjacent to the farm (see: Upcoming Hearings | Public Hearing on Applications by Kelly Cove Salmon Ltd. in Liverpool Bay, Queens County | Exhibit 056).

Exposure to finfish aquaculture in-feed drugs such as emamectin benzoate (EMB) may also have impacts on juvenile and adult lobsters that fall within the benthic-PEZs (Figure 3) (Daoud et al. 2018, Hamoutene et al. 2023c). EMB has been shown in laboratory studies to have toxic effects on juvenile lobsters, exhibiting impacts such as premature moulting, reduced growth rates, and mortality (Burridge et al. 2000, Waddy et al. 2002, Burridge et al. 2008, Daoud et al. 2018, Mill et al. 2021, Hamoutene et al. 2023c). Although more recent field studies have observed evidence of feed waste and/or feces consumption by lobsters near Atlantic Salmon fish cages (Sardenne et al. 2020, Baltadakis et al. 2020), previous laboratory feeding trials have demonstrated that adult lobsters had a preferential selection for their natural feed over medicated feed (Waddy et al. 2007). The exact mechanism of exposure (e.g., direct consumption, exoskeleton contact, low concentration water exposure, etc.) in the marine environment is not well understood.

Lobster larvae in the water column, and juvenile and adult lobsters in shallow water areas of pelagic-PEZs (Figure 5), may be exposed to toxic concentrations of pesticides. Azamethiphos is toxic to non-target crustaceans while in the environment, including all larval, juvenile, and adult life stages of lobster (Burridge 2013, PMRA 2016b, 2017). Acute toxicity tests indicate that lethality can occur at concentrations below the target treatment concentration for azamethiphos over a range of exposure times (Parsons et al. 2020, Hamoutene et al. 2023a, c). Specifically, berried female lobsters are more sensitive to azamethiphos during the summer months based on reproductive and moulting cycles (Burridge et al. 2005). A recent study of acute toxicity tests with hydrogen peroxide have also documented delayed lethal effects (24 h post exposure) on all stages of larval lobsters at concentrations much lower than recommended treatment concentrations for hydrogen peroxide after only 1 hour of exposure time (Escobar-Lux et al. 2020). Although dilution is a factor for the use of pelagic pesticides, active ingredients such as azamethiphos and hydrogen peroxide have proven to be more stable in the formulations used, which contain additives, and therefore may lead to prolonged exposures for non-target crustaceans (Strachan and Kennedy 2021).

*Scallop*

The four proposed aquaculture sites are located within Scallop Production Area (SPA) 3. The Scallop stock in SPA 3 is in the healthy zone (DFO 2023c). St. Mary's Bay supports Food, Social, and Ceremonial, communal commercial, commercial, and recreational Scallop harvesting. Since 2002, the proportion of SPA 3 commercial fishery removals from St. Mary's Bay has been increasing, from 20% pre-2010 to 37% post-2010; this reflects the increasing importance of St. Mary's Bay to the wild Scallop fisheries in the area. The benthic feces-PEZs overlap with SPAs 1A, 3, and 4, and there is direct overlap between fishing effort for the wild Scallop fishery in St. Mary's Bay and proposed leases #1449, #1451, and #1452 (Figure 9). Within the last six years, 44% of landings within SPA 3 alone have come from within the benthic feces-PEZs, and 9% and 7% of landings in SPA 1A and 4, respectively. As described above in the Predicted Exposure Zones (PEZ) section, PEZ calculations do not account for land features and, therefore, coastal boundaries within the PEZ need to be factored in when considering potential exposure. Given this, it is not anticipated that feces from the proposed sites would reach SPA 4 since the radius of the benthic feces-PEZ from proposed site #1449 does not reach Petit Passage where transport to the other side of Digby Neck would be possible.

St. Mary's Bay provides habitat of considerable importance for Scallop life stages. Scallop are relatively sedentary and not ubiquitous throughout the area. Three of the four proposed aquaculture leases (#1449, #1451 and, in particular, #1452) directly overlap areas of high abundance where young Scallop (10–65 mm shell height) and adult Scallop (greater than or equal to 65 mm shell height) are found (Figure 10). Important Scallop habitat within the benthic feces-PEZs has also been identified on the northern side of Digby Neck (Figure 10).

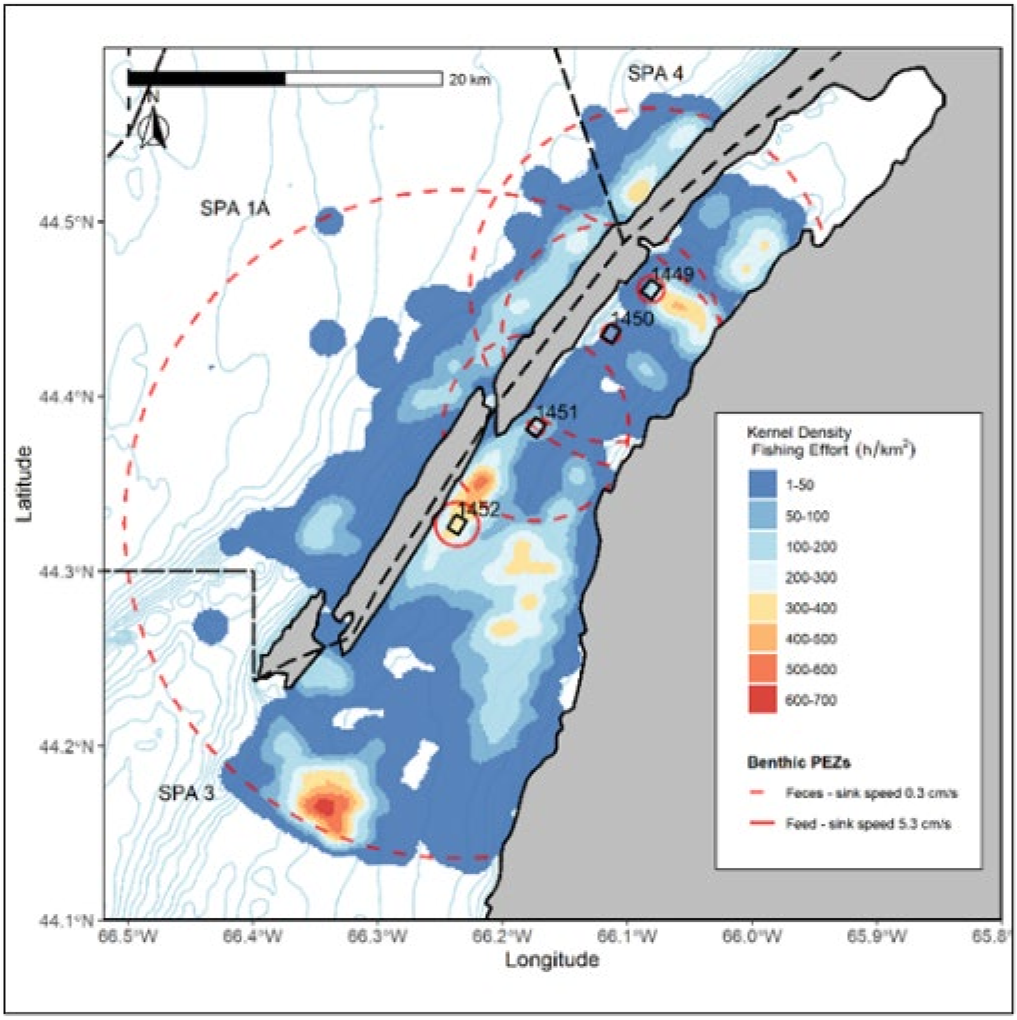


*Figure 9. Scallop fishing effort represented as Kernel Density of fishing effort (hours/km$^2$) from commercial logbook records from 2004 to 2022 in the benthic feces-PEZs (red dashed circles). Solid red circles are the benthic feed-PEZs. The productivity of scallops is tied closely to habitat suitability, and, in the absence of detailed habitat information, the spatial distribution of fishing effort is a good indicator of suitable habitat (Brown et al. 2012). Black polygons are the proposed lease locations. There is direct overlap between fishing effort for the wild Scallop fishery in St. Mary's Bay and proposed leases #1449, #1451, and #1452. Dashed black lines indicate the boundaries between management areas SPA 3, SPA 1A, and SPA 4. PEZ calculations do not account for land features; it is not anticipated that feces from the proposed sites would reach SPA 4.*

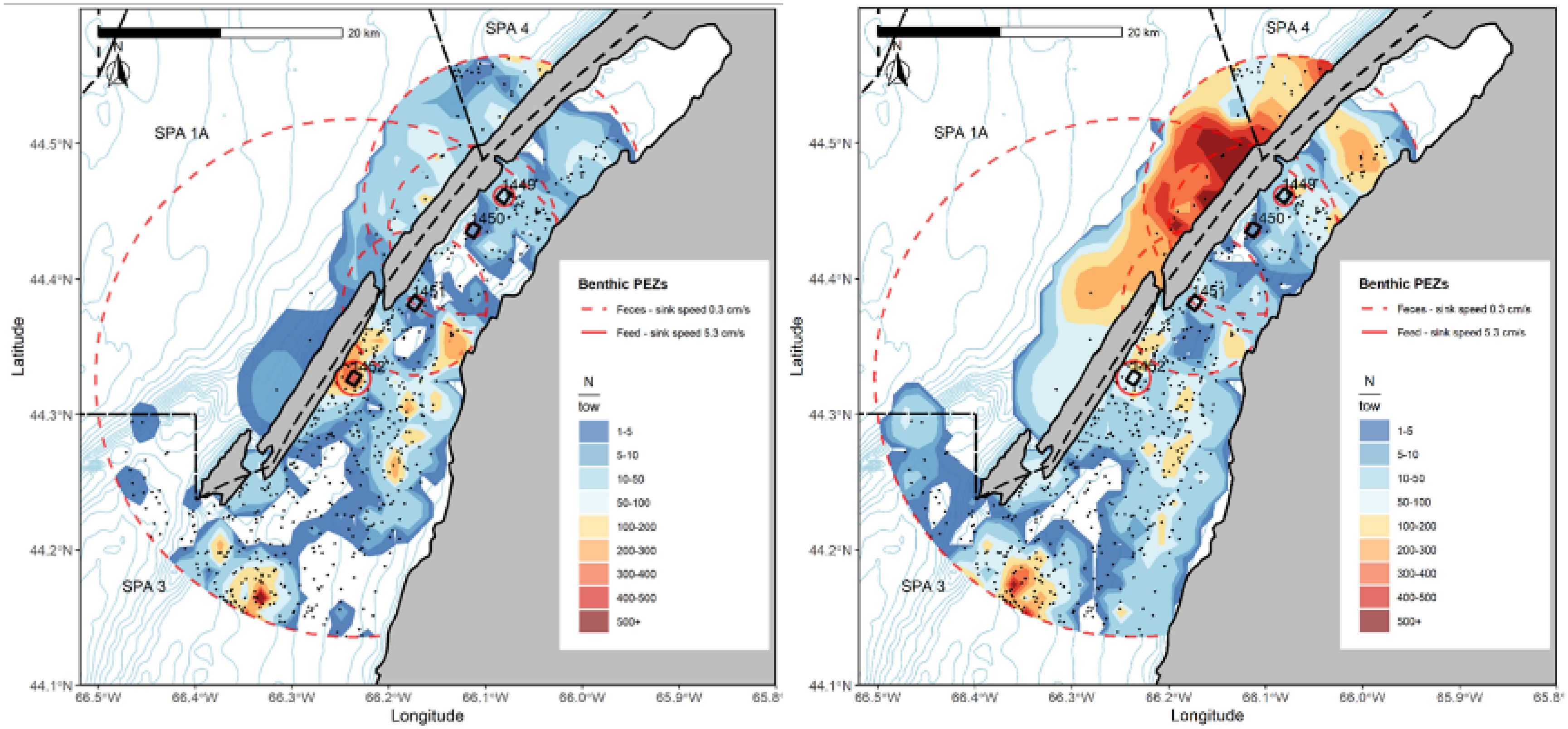


*Figure 10. Spatial density (numbers/tow) distribution of young Scallop (10–65 mm shell height; left-hand panel) and adult Scallop (greater than or equal to 65 mm shell height; right-hand panel) from 1991-2022 Scallop surveys in and proximal to St. Mary's Bay within the benthic feces-PEZs (red dashed circles). Solid red circles are the benthic feed-PEZs. Points represent tow locations. Black polygons are the proposed lease locations. There is direct overlap between areas of high abundance where young and adult Scallop are found in St. Mary's Bay and proposed sites #1449, #1451 and, in particular, #1452. Important Scallop habitat within the benthic feces-PEZs has also been identified on the northern side of Digby Neck. Dashed black lines indicate the boundaries between management areas SPA 3, SPA 1A, and SPA 4. PEZ calculations do not account for land features; it is not anticipated that feces from the proposed sites would reach SPA 4.*

These data come from Scallop population surveys conducted annually by DFO Science within SPA 3. Survey tow locations are in core Scallop habitat, some of which overlap with three of the four proposed lease locations (Figure 10). Although focused on Scallop, by-catch from these surveys have also been used to inform on other fishery species, including providing a consistent time-series index of Lobster abundance. Loss of access to survey this habitat in St. Mary's Bay will impact the current DFO Science framework approach used to provide stock status advice for Scallop within SPA 3.

Scallop in St. Mary's Bay have some of the highest physical quality attributes of all Scallop found in the Bay of Fundy and its approaches, likely due to favourable environmental conditions found in the bay. For the same size shell height of 100 mm, Scallop condition (quality) is significantly higher in St. Mary's Bay relative to other areas in the Bay of Fundy, exhibiting an average meat weight of 14 g compared to an average of 11 g (Nasmith et al. 2016). Gonad weight is also significantly higher in St. Mary's Bay, exhibiting an average of 7 g compared to 5 g in adjacent areas for a 100 mm shell height Scallop (Scallop Unit, DFO, Dartmouth NS, unpublished data). For the same size Scallop, egg production is significantly higher in Scallop from St. Mary's Bay compared to adjacent areas outside the bay; an individual female Scallop in St. Mary's Bay is estimated to produce great than 12 million more eggs than a Scallop of the same size outside St. Mary's Bay based on average egg weight calculations ($1.6 \times 10^{-7}$ g; Barber et al. 1988, Langton et al. 1987). The above metrics demonstrate the productivity and importance of St. Mary's Bay habitat for Scallop. In general, Scallop found in St. Mary's Bay represent an integral component of the brood stock for Scallop in and around SPA 3. Annual spawning typically occurs from late August to October, and larval settlement takes approximately 40 days (Hart and Chute 2004).

Scallop were also one of the most recorded species from the proponent's baseline survey within the proposed leases at sites #1449 and #1452. Scallop located within the lease areas and the benthic-PEZs (Figures 9 and 10) will be susceptible to increased sedimentation, organic matter deposition, and any associated changes in sediment oxygen concentrations given their sedentary nature; particularly, within the smaller benthic-PEZs calculated based on feed.

Scallops within the benthic-PEZs may also be exposed to in-feed drugs from the proposed aquaculture sites, if used. Bivalves in the vicinity of finfish net-pens have demonstrated measurable quantities of in-feed drugs such as EMB (Burridge et al. 2011). A study in adult Blue Mussel (*Mytilus edulis*) demonstrated a persistent bioaccumulation potential of EMB in tissue with no significant depletion in concentration after seven days (Brooks et al. 2019). Detection of EMB was also observed in Blue Mussel 100 m away from treated cages one-week post-treatment and 10 m away one-month post-treatment after uptake by these filter-feeders (Telfer et al. 2006). The long half-life of EMB proposed for marine sediments of 100 to greater than 400 days (Benskin et al. 2016, Strachan and Kennedy 2021, Hamoutene et al. 2023b), and half-life calculations in Blue Mussel tissue of over 14 days (Brooks et al. 2019), indicates an ability for EMB to persist in some organisms and in the broader marine environment. Tests conducted on larval Eastern Oyster (*Crassostrea virginica*; as cited in Bright and Dionne 2005), larval Mediterranean Mussel (*Mytilus galloprovincialis*; Strachan and Kennedy 2021), and adult Common Cockle (*Cerastoderma edule*; Cheng et al. 2020) have looked at acute water exposures, which is less of a concern given that the hydrophobic nature of EMB suggests that it is likely to bind with particulate matter that ultimately ends up in bottom sediments (Mushtaq et al. 1996, Roberts and Hutson 1999). Cheng et al. (2020) did also use sediment exposures during tests conducted on Common Cockle and observed no treatment-related effects in mortality and growth. However, the limited data available, which are primarily based on acute exposures, suggests that bivalves are not considered to be sensitive to EMB (Burridge et al. 2011, Strachan and Kennedy 2021).

Juvenile and adult Scallop located in shallow water areas of the pelagic-PEZs (Figure 5) may be exposed to toxic concentrations of pesticides that come into contact with the seabed. Scallop larvae in the water column may also be exposed. There are limited data on the effects of azamethiphos and hydrogen peroxide exposure on bivalves, and a different potential of exposure depending on the life stage tested (i.e. adults only in shallower areas and larvae throughout the water column). Varying sensitivities of different stages have been identified in other species that have a similar life cycle progression, from pelagic to benthic environments, such as shrimp and lobster (Mill et al. 2021).

For azamethiphos, only three bivalve species endpoints are available as per the latest data quality control completed in Hamoutene et al. (2023c): Blue Mussel; Mediterranean Mussel; and Pacific Oyster (*Crassostrea gigas*). These endpoints suggest that bivalves are considered as being moderate to not very sensitive to azamethiphos, as per species sensitivity distribution (SSD) curves (Hamoutene et al. 2023a,c). For hydrogen peroxide, both Mediterranean Mussel and Pacific Oyster can be considered as being sensitive based on SSD curves (Hamoutene et al., 2023a,c). Both species had toxicity endpoints very close or only three times higher than the threshold value, as determined in Hamoutene et al. (2023a,c).

In terms of potential repeated exposures, Montory et al. (2023) exposed Chilean Oyster (*Ostrea chilensis)* to azamethiphos over seven days, based on sea lice treatment protocols, and demonstrated that it can have a cumulative negative impact on bivalves; namely, respiratory performance, feeding and oxygen consumption rates, and a delayed mortality response (60 days post exposure). Given the general mode of action of these substances, the potential impact on bivalves is possible in both acute and chronic exposure scenarios.

*Crabs, shrimp, krill, and copepods*

Several decapod crustacean species have been identified in St. Mary's Bay. Jonah Crab, Rock Crab, and Snow Crab have also been observed in St. Mary's Bay and the PEZs. Shrimp and krill species identified within the benthic- and pelagic-PEZs include Bristled Longbeak; Sand Shrimp; Northern Shrimp; Northern Krill; and krill (*Euphausiacea* sp.). Distribution studies of krill in the Bay of Fundy demonstrate the highest concentrations in the Grand Manan Basin/Brier Island area, with the highest abundances in October and November (AECOM Canada Ltd. 2011, Buzeta 2014). In particular, large concentrations of Northern Krill, which are designated as an ESS based on being a food source for whales, fish, and seabirds (Buzeta 2014), are predicted for this area (AECOM Canada Ltd. 2011). The highest concentrations of copepods in the Bay of Fundy are found within the Grand Manan Basin and, as such, it has been identified as Critical Habitat for the *SARA*-listed Endangered North Atlantic Right Whale given its importance as a feeding ground. While there is no specific overlap, the proximity of the pelagic-PEZs from the proposed sites to this area (within 2–10 km) warrants consideration.

In general, there is a paucity of toxicity data on benthic exposures of shrimp, krill, copepods, and crabs to EMB (Hamoutene et al. 2023c), although recent studies demonstrate potential deleterious effects from EMB on Pacific Spot Prawn (Mill et al. 2021). Recent acute toxicity studies for both azamethiphos and hydrogen peroxide have documented morbidity and mortality effects on a variety of shrimp species, including Sand Shrimp, Northern Shrimp, and Spot Prawn (Bechmann et al. 2019, Escobar-Lux and Samuelsen 2020, Mill et al. 2021, Hamoutene et al. 2023c). In contrast, there are limited toxicity studies directly related to crabs; however, predicted impacts are similar to those for lobsters and shrimp given the targeted mode of action of these substances.

*Soft-shell Clam, Quahog, Bar Clam, Blue Mussel, and Periwinkle*

St. Mary's Bay is a highly productive area for Soft-shell Clam (Mya arenaria), Quahog (*Mercenaria mercenaria*), Bar Clam (Spisula solidissima), and Blue Mussel (Mytilus edulis). Various Food, Social, and Ceremonial, communal commercial, commercial and recreational harvesting activities occur in the bay for such species. Nearshore clam harvesting occurs throughout Clam Harvest Area 2, which covers Digby, Annapolis, and Kings Counties. There is no information specific to St. Mary's Bay; however, Clam Harvest Area 2 typically has some of the highest reported landings and represents more than 20% of the total landings across Clam Harvest Areas. A Quahog survey was last completed at the mouth of St. Mary's Bay by DFO in 2002 (Roddick et al. 2007). A Quahog bed of high biomass was identified within the feces benthic-PEZ of the southernmost proposed site (#1452) located less than 5 km to the south of the site. By-catch data from this same survey identified Bar Clam as being caught in only two tows (out of 43 sampled stations) and in low numbers (three individual clams).

Potential impacts of increased organic matter deposition and fish health treatment products to these bivalve species within the benthic- and pelagic-PEZs are anticipated to be similar to those described above in the Scallop section. An unmanaged Periwinkle (*Littorina littorea*) fishery also exists in the area, including Food, Social, and Ceremonial, commercial, and recreational harvesting activities. Periwinkle within the benthic-and pelagic-PEZs may be exposed and susceptible to the deposition of organic matter and fish health treatment products from the proposed sites given their sedentary nature, however the distribution and abundance of Periwinkle within St. Mary's Bay and the vicinity of the proposed sites is unknown.

*Groundfish (Sculpin, Flounder, Cod, Haddock, and Pollock) and small pelagics (Mackerel and Herring)*

Predominant groundfish commercial fisheries in St. Mary's Bay include Longhorn Sculpin (*Myoxocephalus octodemspinosus*) and Winter Flounder (*Pseudopleuronectes americanus*). Catch from the commercial Sculpin fishery is sold for Lobster bait, although the fishery closed in 2019 based on an assessment that the prognosis for the fishery was poor and exploitation needed to be reduced (Stone 2022). The fishery is currently closed. There has not been a stock status update on the directed commercial Flounder fishery in NAFO 4X since 1997 (Stobo et al. 1997); however, five-year total catch data from 2014 to 2018 indicate St. Mary's Bay as being actively fished. A rebuilding plan is currently being developed for the 4X5Y Atlantic Cod (*Gadus morhua*) stock, which overlaps with St. Mary's Bay, as the stock is in the critical zone (DFO 2019). There is no directed fishing due to the stock's population size, which was reassessed as *Endangered* by COSEWIC in 2010.

St. Mary's Bay is also within the Western Component (NAFO 4XOPQRS5) Atlantic Pollock (*Pollachius virens)* stock management unit. The last assessment for the stock indicated the stock was in the cautious zone (DFO 2021b). Reported bycatch landings of both Cod and Western Component Pollock in St. Mary's Bay are low, at less than 1% of total landings and less than 0.01% of the catch limit, respectively, for their NAFO divisions. The NAFO 4X5Y Haddock (*Melanogrammus aeglefinus)* stock, which overlaps with St. Mary's Bay, also exhibits low biomass and is in the cautious zone (DFO 2021c), although active fishing is still underway. Commercial catch data over the last seven years indicate that 4X5Y Haddock being caught in St. Mary's Bay accounts for approximately 8.6% and 1.7% of the Bay of Fundy and broader 4X5Y Haddock fishery, respectively. However, it cannot be determined whether this is bycatch or directed fishing. Food, Social, and Ceremonial, communal commercial, and recreational harvesting for these groundfish species also occurs in St. Mary's Bay.

Small pelagic fisheries in St. Mary's Bay include Atlantic Mackerel (S*comber scombrus*) and Atlantic Herring. Food, Social, and Ceremonial, communal commercial, and recreational harvesting for Mackerel and Herring also occur in St. Mary's Bay. The commercial Mackerel fishery is currently under moratorium due to low stock status but could re-open in the future. In contrast, landing reports for Herring demonstrate that some fishing occurs near Digby Neck, with the majority occurring on the north side of the bay. St. Mary's Bay is part of the Southwest Bay of Fundy/Southwest Nova Scotia Component of the 4VWX Herring stock, which is considered to be in the critical zone (DFO 2022d); therefore, a precautionary approach requires harvesting be kept to an absolute minimum to contribute to rebuilding of the Herring stock (DFO 2020b). As described above in the EBSA section of this review, St. Mary's Bay is considered to be an important area for Herring larvae retention (Das 1968, Buzeta et al. 2003, Buzeta 2014, Stephenson et al. 2015).

Exposure of groundfish and small pelagic species to increased organic matter deposition is likely of minor concern given that all observed species are mobile (i.e., able to relocate) and that no unique habitat for these species was identified within the benthic-PEZs. There is also currently no evidence to suggest impacts on fish species from the use of fish health treatment products. Whether aquaculture sites have any kind of impact (positive, negative, or negligible) on Herring larvae or on St. Mary's Bay as a retention area is not well understood.

## Potential Impacts to Wild Atlantic Salmon from Direct Genetic Interactions with Aquaculture Escapees

The four proposed new finfish aquaculture sites are physically located within range of the proposed Nova Scotia Southern Upland – West Designatable Unit (SU–W, DU–14B; Lehnert et al. 2023) of wild Atlantic Salmon and Salmon Fishing Area (SFA) 21 (Figure 11). A DFO review of anadromous Atlantic Salmon Designatable Units, prepared for COSEWIC, concluded that two discrete and evolutionarily significant groups were present within the Nova Scotia Southern Upland Designatable Unit. Following COSEWIC criteria, the DU was split into two: the Southern Upland – East and Southern Upland – West (Lehnert et al. 2023). The proposed sites are also within distances of rivers in the Outer Bay of Fundy (OBOF; DU–16) and Inner Bay of Fundy (IBOF; DU–15) Designatable Units that escaped farmed Atlantic Salmon could travel to (Keyser et al. 2018, Morris et al. 2008).

These wild Atlantic Salmon populations remain critically low. The Southern Upland (SU) and OBOF Atlantic Salmon populations were assessed in 2010 by COSEWIC g as Endangered and are under consideration for listing under *SARA*. The IBOF population has been listed as Endangered under *SARA* since 2003. For conservation, since 2010, all rivers within SFA 21 have been closed to recreational fishing for Atlantic Salmon and there have been no Food, Social, and Ceremonial (FSC) fishery allocations to Indigenous peoples. The SU, IBOF, and OBOF populations of Atlantic Salmon are each considered to be biologically unique and extirpation of any of these units would constitute an irreplaceable loss of Atlantic Salmon biodiversity (COSEWIC 2010, Gibson et al. 2011).

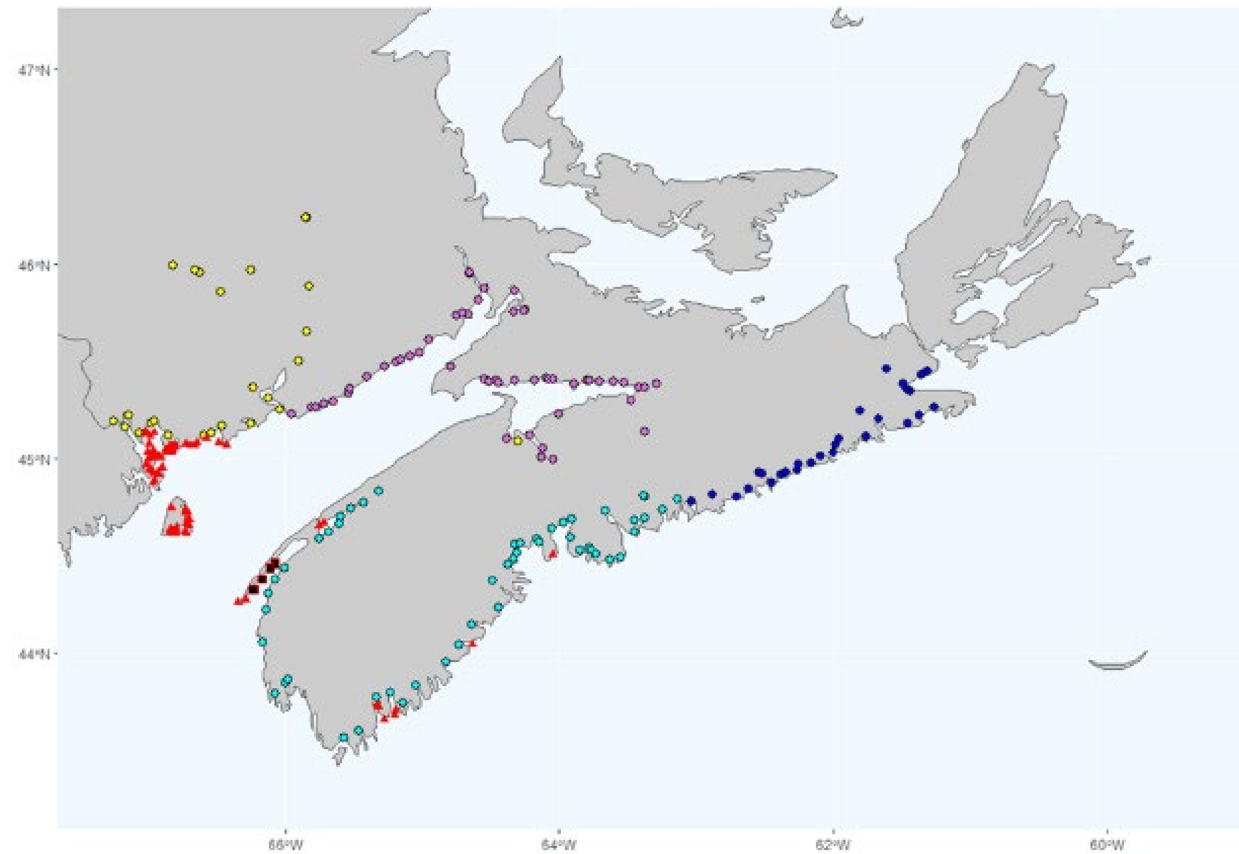


*Figure 11. Map of Atlantic Salmon farms and rivers included in the dispersal model. The four proposed finfish aquaculture sites in St. Mary's Bay are shown as black squares with red outlines. Finfish aquaculture sites currently in production are denoted by red triangles. Rivers included in the dispersal model are coloured, as per Lehnert et al. (2023) by proposed DU (DU–14A = dark blue (Southern Uplands – East); proposed DU–14B (Southern Uplands – West) = cyan; DU–15 (Inner Bay of Fundy) = purple; and DU–16 (Outer Bay of Fundy) = yellow).*

Atlantic Salmon escapees from aquaculture sites have been identified as an ongoing threat to the genetic integrity and persistence of wild Atlantic Salmon populations (Bradbury et al. 2020a, Forseth et al. 2017, Glover et al. 2020). Escapes of Atlantic Salmon from finfish aquaculture sites occur regularly, including in Atlantic Canada (Diserud et al. 2019, Glover et al. 2017, Keyser et al. 2018), and studies in Norway have estimated the actual number of escaped fish to be significantly higher than numbers reported (Føre and Thorvaldsen 2021, Mahlum et al. 2021, Skilbrei et al. 2015). A recent assessment of the risks posed to wild Atlantic Salmon populations due to direct genetic interactions with escaped aquaculture fish found that, within the area considered in this siting review, escape events have occurred each year between 2011 and 2021, which is the time period considered in the risk assessment (DFO 2024). Escaped Atlantic Salmon found in rivers are typically observed at distances of about 200-300 km from the nearest aquaculture site (Keyser et al. 2018, Morris et al. 2008), although much greater dispersal is possible (Hansen 2006, Jensen et al. 2013). Moreover, escapees may continue to pose a threat to wild Atlantic Salmon for several years after escape (Aronsen et al. 2020).

Genetic studies have documented widespread hybridization and introgression between wild Atlantic Salmon and aquaculture escapees across the natural range of wild Atlantic Salmon, notably in Norway (Karlsson et al. 2016) and Newfoundland (Sylvester et al. 2019, Wringe et al. 2018); signatures suggestive of direct genetic interaction have also been reported in the Maritimes Region (O'Reilly and Carr 2006, Bradbury et al. 2022). These interactions can occur over large areas and escapees can represent a significant portion of a population's annual production (Glover et al. 2013, Glover et al. 2017, Heino et al. 2015, Sylvester et al. 2018, Wringe et al. 2018). Across the North Atlantic, the magnitude of genetic impacts on wild populations due to escaped farmed Atlantic Salmon has been correlated with the biomass of farmed Salmon in net-pens and the distance between net-pens and rivers, as well as the size of wild populations (Keyser et al. 2018, Mahlum et al. 2021, Sylvester et al. 2018).

Direct genetic (i.e. reproductive) interaction between escapee and wild Atlantic Salmon can have negative impacts on the wild population (Glover et al. 2012), leading to changes in life history and phenology (Besnier et al. 2022), phenotype (Fraser et al. 2010, Perriman et al. 2022), genotype (Karlsson et al. 2016, Wringe et al. 2018), and ultimately fitness (Fleming et al. 2000, Sylvester et al. 2019) and population persistence (McGinnity et al. 2009, McGinnity et al. 2003). Both experimental and field studies have demonstrated decreased survival of hybrids in the wild (Fleming et al. 2000, McGinnity et al. 2003, Sylvester et al. 2019), with modeling indicating that population declines, and loss of genetic diversity are likely when the percentage of escapees in a river relative to wild population size exceeds 10% annually (Bradbury et al. 2020a, Castellani et al. 2015, Sylvester et al. 2019). An assessment of the risk posed to wild Atlantic Salmon population abundance and genetic character by direct genetic interaction with escapes from East Coast Atlantic Salmon aquaculture was also recently conducted by DFO (DFO 2024).

Several modelling approaches have been used to estimate the direct genetic impact of aquaculture production and escapees on wild Atlantic Salmon populations here, and in other siting reviews (DFO 2022a, 2023a). These models are as follows:

- Propagule pressure
- Individual-Based Salmon Eco-Genetic Model
- Spatial dispersal of escapees

In addition to model validation, the main sources of uncertainty in these models are outlined in DFO (2024).

**Propagule pressure**

Propagule pressure has been adapted from invasive species research where it represents the intensity of human-mediated species introductions. Propagule pressure has been used previously to quantify the intensity of aquaculture production on a river-by-river level assessment, where it was found to correlate with both numbers of escapees and levels of hybridization (Keyser et al. 2018). A similar result has also been found by Mahlum et al. (2021). Because of these relationships, propagule pressure has been used in the review of aquaculture siting proposals via the DFO Science advisory process through a comparison of propagule pressure with and without the proposed expansions in operation (DFO 2022a, 2022d, 2023a).

Propagule pressure is calculated separately for each river. It uses geographical coordinates of all farms and river mouths, farm-level production (i.e. number of fish stocked), and a distance function for each farm to each river (Keyser et al. 2018). The model makes no assumptions about salmon behaviour or mortality, so therefore represents a geographical relationship between all farms and rivers. Propagule pressure was calculated for both the current stocking levels as well as the proposed expansion scenario with the four proposed farm sites in St. Mary's Bay in operation (see DFO 2022a, DFO 2023a, Keyser et al. 2018 for description of methods).

With the four proposed new aquaculture sites in production, while those rivers in proximity of the proposed sites will see the greatest increase, the propagule pressure experienced by nearly all rivers in the DFO Maritimes Region will increase, albeit to a small amount in rivers beyond approximately 100 km (Figure 12).

Propagule pressure for rivers within 100 km of the proposed sites will increase by an average of approximately 24%, those within 50 km by an average of approximately 48%, and the largest increases will be approximately 67% for the Sissiboo River (Figure 12). It should be noted that no juvenile Atlantic Salmon were captured in the most recent electrofishing survey of the Sissiboo River (conducted in 2000); access to more than 90% of the available rearing habitat in this river is blocked by a dam (DFO 2013). However, the Salmon, Annapolis, and Tusket rivers at 43, 79, and 117 km distance would see propagule pressure increases of approximately 20%, 9%, and 12% respectively. Each of these rivers were found to have had juvenile Atlantic Salmon during the most recent electrofishing surveys (Bowlby et al. 2013). All rivers in the area would see increased propagule pressure with the proposed sites in operation and increases in escapees may hinder any future recovery efforts.

#### Individual-based salmon eco-genetic model (IBSEM)

To assess demographic and genetic impacts of aquaculture escapees on wild Atlantic Salmon populations, the Individual-Based Salmon Eco-Genetic Model (IBSEM, Castellani et al. 2015) used by Bradbury et al. (2020a) in Newfoundland was adapted for the current context. The model is summarized elsewhere in detail (Bradbury et al. 2020a, Castellani et al. 2015, DFO 2022a, DFO 2023a, Sylvester et al. 2019; see the supplementary materials of Sylvester et al. 2019 for detailed explanation of the model parameters), but briefly, it models changes in abundance, genotype, and individual size in response to the introduction of domesticated individuals. The model considers the duration of invasion by farm escapees, wild population size, number of invaders, environmental conditions, individual size, and genotypic, and phenotypic and fitness differences between individuals of farm and wild origin. Simulations show the impact on abundance and genetic change during the invasion period, as well as after the invasion has been "turned off" to assess the potential for recovery in these two measures. The IBSEM was re-parameterized to simulate the Tobique River for environmental and life-history data. The Tobique River was chosen because it is the river in the DFO Maritimes Region for which the most parameters for IBSEM were available. Other values to parameterize the model were taken from the best available data from the literature across the range of Atlantic Salmon. Invasions of 1-100% of the wild population per year were modelled and the results were compared to a zero-percent invasion baseline. Method details can be found in previous DFO aquaculture site assessments (DFO 2022a, 2022e, 2023a).

While impacts may occur at any level of farm escapees in a river, IBSEM simulations consistently predict that when farm escapees exceed roughly 10% of the total Atlantic Salmon in a given river, impacts to both abundance and genetic character are likely to occur (Castellani et al. 2015; Sylvester et al. 2019; Bradbury et al. 2020a). Therefore, consistent with the recent direct genetic interactions risk assessment (DFO 2024) and with previous DFO Science aquaculture siting reviews in the DFO Maritimes Region and DFO Newfoundland and Labrador Region (DFO 2022a, 2022e, 2023a), a threshold of 10% was chosen for the proportion of escapees relative to wild population size and carries forward as a benchmark for the dispersal model results presented below.

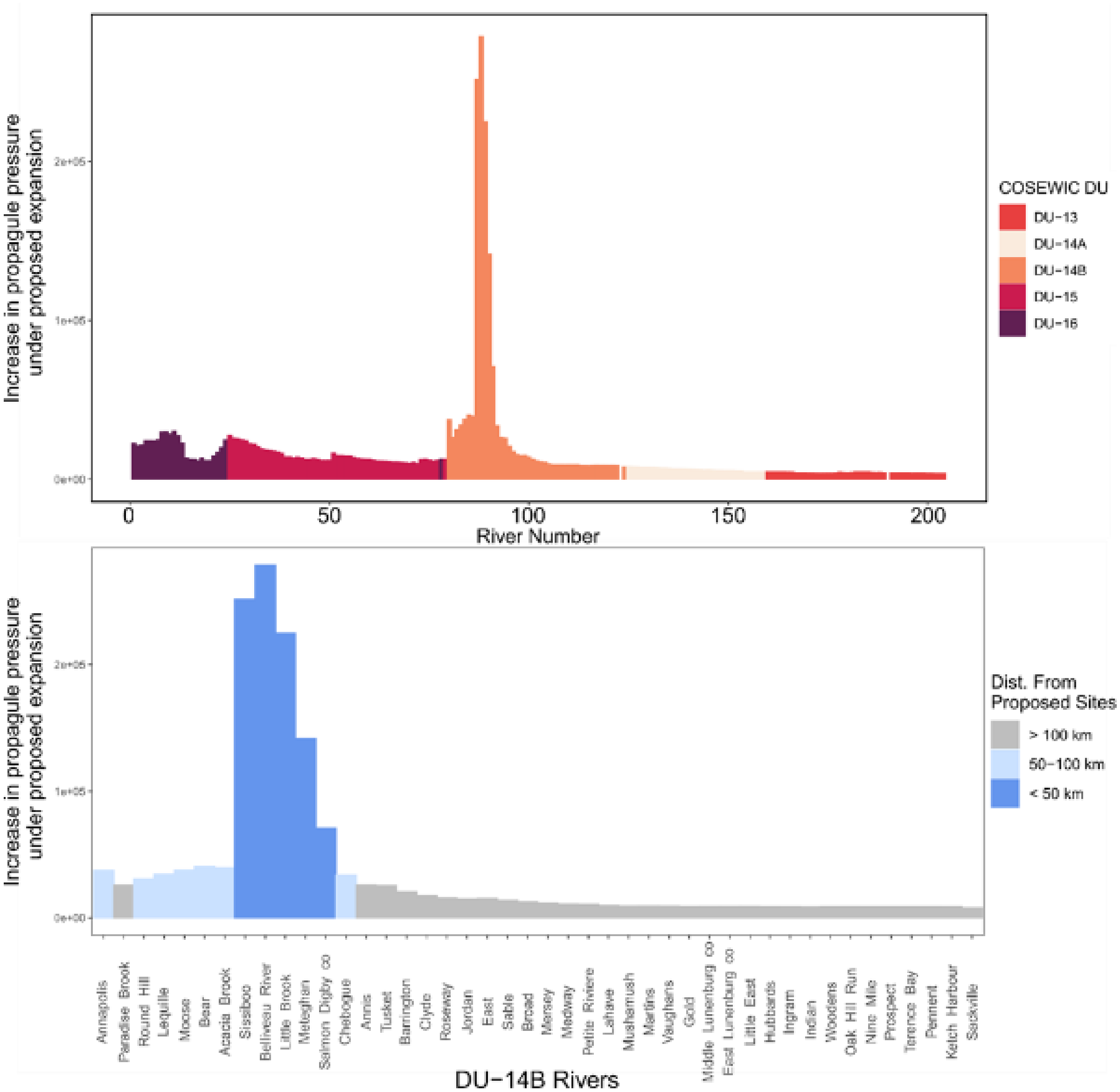


*Figure 12. Increase in propagule pressure for a subset of rivers included in the dispersal model in the DFO Maritimes Region (top panel). Propagule pressure was calculated as per Keyser et al. (2018). The four proposed farm sites are located within the proposed Nova Scotia Southern Uplands – West Designatable Unit (DU–14B) and their centroid is approximately 14 km from the mouth of the Sissiboo River, River Number 87. Rivers are plotted west to east around the coast, from the St. Croix River in Charlotte County (River 1), NB to the Salmon River in Victoria County in NS (River 204). Rivers in the top panel are coloured by current or proposed Designatable Unit. The bottom panel features the rivers in the proposed Nova Scotia Southern Uplands – West DU (DU–14B); river numbers 80 to 123. Colours reflect categorical distance from the centroid of the proposed sites. River numbers and associated names are in Appendix II; physical locations of rivers in DUs 14A, 14B, 15 and 16 are shown in Figure 11.*

### Spatial dispersal of escapees

Dispersal of escapees from aquaculture facilities was modelled using the method of Jóhannsson et al. (2017), as described in Bradbury et al. (2020a), and used in DFO (2022a, 2022e, 2023a). Briefly, this model incorporates the best available information on local levels of aquaculture production, rates of escape, survival, behaviour, environment, and size of wild populations. A maximum dispersal distance following escape of 200 km was assumed and was modelled using a Weibull distribution given that most escaped fish are likely to enter rivers close to the location of escape. While 200 km is less than has been observed elsewhere (e.g. Jensen 2013), including within the region studied (Morris et al. 2008, Keyser et al. 2018), it is consistent with tagging observations of simulated escapees from Newfoundland (Hamoutene et al. 2018). The model output is the proportion of escapees, as a function of wild population size estimates, within a given river. Previous estimates from this model have been consistent with observed levels of hybridization (Bradbury et al. 2020a). Salmon populations in all rivers are assumed to be at 5% of the conservation egg requirement (Gibson and Claytor 2012), a value that is consistent with the best available estimates (DFO 2020c), and percentages of escapees are calculated relative to these values. At current production levels, presumed escape rates of 0.2 and 0.4 Salmon per tonne of production per year (Bradbury et al. 2020a, Føre and Thorvaldsen 2021, Skilbrei et al. 2015) were tested with the dispersal model. This corresponds to the mid values in the direct genetic interaction risk assessment sensitivity analysis (DFO 2024), which were themselves a product of estimates calculated for Canada based on industry reports, as well as peer-reviewed assessments of underreporting of escapes (Skilbrei et al. 2015).

The dispersal model predicts that a large number of rivers in the DFO Maritimes Region are already expected to be above the 10% threshold at both escape rates with the current production levels (Figure 13). Within the proposed Nova Scotia Southern Upland – West DU (SU–W; COSEWIC DU–14B), all rivers to the west of the proposed sites are currently predicted to be above the upper 10% threshold, as are the majority of rivers to the east as far as Mersey River at both modelled escape rates (Figure 13). Similarly, most rivers in the OBOF, which are within the expected escaped Salmon dispersal distance of the proposed sites (Keyser et al. 2018, Morris et al. 2008), are also above the 10% threshold (Figure 13).

Compared to current production, the dispersal model predicts that the proposed expansion would result in an increase in the proportion of escapees in rivers for most of the rivers within 200 km of the proposed St. Mary's Bay cage sites, both in the proposed SU–W and the OBOF DUs (Figure 13). The dispersal model predicts that with the four proposed sites in St. Mary's Bay in operation and a modelled escape rate of 0.2 escapees per tonne of production, the number of rivers in the proposed SU–W above the 10% threshold will increase by one relative to the current state with the proposed sites not in production. At a modelled escape rate of 0.4 escapees per tonne, the number of rivers in the proposed SU–W above the 10% threshold is expected to increase by two with the proposed sites in production. Initiation of production at the four proposed sites is not expected to change the number of rivers above the 10% threshold in the OBOF DU at either modelled escape rate. For the *SARA*-listed Endangered IBOF population, the dispersal model predicts that there would be no change in the number of rivers above the 10% threshold with the four proposed sites in operation relative to without them in operation at the 0.2 escapee per tonne of production escape rate. However, at an escape rate of 0.4 escapees per tonne of production, the number of rivers above the 10% threshold in the IBOF is expected to increase by one with the four proposed sites in production. At the DU level, at an escape rate of 0.2 escapees per tonne of production, the dispersal model predicts that the number of escapees in rivers will increase by 62 for the proposed SU–W DU and 9 for the OBOF DU. An escape rate of 0.4 escapees per tonne increases the number of predicted escapees in rivers by 123 for the proposed SU–W DU, 10 for the OBOF, and 2 for the IBOF DUs.

The IBSEM model suggests that demographic and genetic impacts will increase with the proportion of escapees entering rivers. Therefore, for all rivers in which the dispersal model predicted increases in percentage escapees, the wild populations are likely to experience greater impacts. Moreover, even where the Atlantic Salmon populations are extirpated, increases in escapees may hinder any future recovery efforts. While examples including interaction with aquaculture escapees were not present, a recent review of Atlantic Salmon restoration efforts found that they were unsuccessful unless threats and the cause(s) of decline were mitigated (Lennox et al. 2021). Even in the absence of concerted recovery efforts such as stocking, re-establishment of populations through straying from other nearby populations would also be hampered in a similar manner.

#### Potential genetic impacts and local population conservation status

Keyser et al. (2018) found that the number of aquaculture escapees and their genetic impact was positively correlated with propagule pressure, while the IBSEM results shown in Bradbury et al. (2020a) and DFO (2022a, 2023a) indicate that both the genetic and demographic impact of aquaculture escapees increases with their proportion in rivers. Given that both propagule pressure and proportion of escapees in rivers will likely increase with the new St. Mary's Bay aquaculture sites in operation, it is likely that the genetic and demographic impact from escapees would also increase as a result of the proposed expansion. Additionally, it is important to note that even where the direct genetic impacts of hybridization or introgression between wild and escapee salmon does not occur, impacts on the wild population are still possible. Ecological interaction, for example competition or predation, can also result in negative outcomes for the wild population including genetic alteration (Bradbury et al. 2020b).

The closest rivers to the proposed new aquaculture sites for which electrofishing data are available are the Annapolis, Round Hill, Bear, Sissiboo, Belliveau, and Salmon rivers (Bowlby et al. 2013). These electrofishing surveys did not detect juvenile Atlantic Salmon in the Sissiboo, Bear, and Belliveau rivers. Juvenile Salmon were found in the Round Hill River in 2000, but not during surveys in 2008 and 2009. In both the Annapolis (79 km distance) and Salmon (44 km distance) Rivers, juvenile salmon were detected in the most recent electrofishing survey (Bowlby et al. 2013). Increases in escapees may hinder any future recovery efforts in these and other SU rivers.

For regional monitoring, the index population for SFA 21, which overlaps the SU–W DU is the LaHave River, which is located approximately 309 km from the proposed sites. The LaHave River watershed is one of the largest in SFA 21, and annual adult counts have occurred since 1970 at the Morgan Falls fishway (representing 51% of the total Salmon rearing habitat of LaHave River). In 2021, monitoring efforts indicated that adult Atlantic Salmon returns to Morgan Falls were at 7% of the conservation egg requirement (DFO 2023d). The total counts at the Morgan Falls fishway have been below 250 individuals since 2012, with fewer than 100 returning Atlantic Salmon in four of those years (DFO 2020c). In 2021, less than 200 adults were observed (DFO 2023d). For the LaHave River, the proposed aquaculture sites would be expected to increase the propagule pressure by about 7% and, because of its distance from the proposed sites, the dispersal model predicts the proportion of escapees would be unchanged.

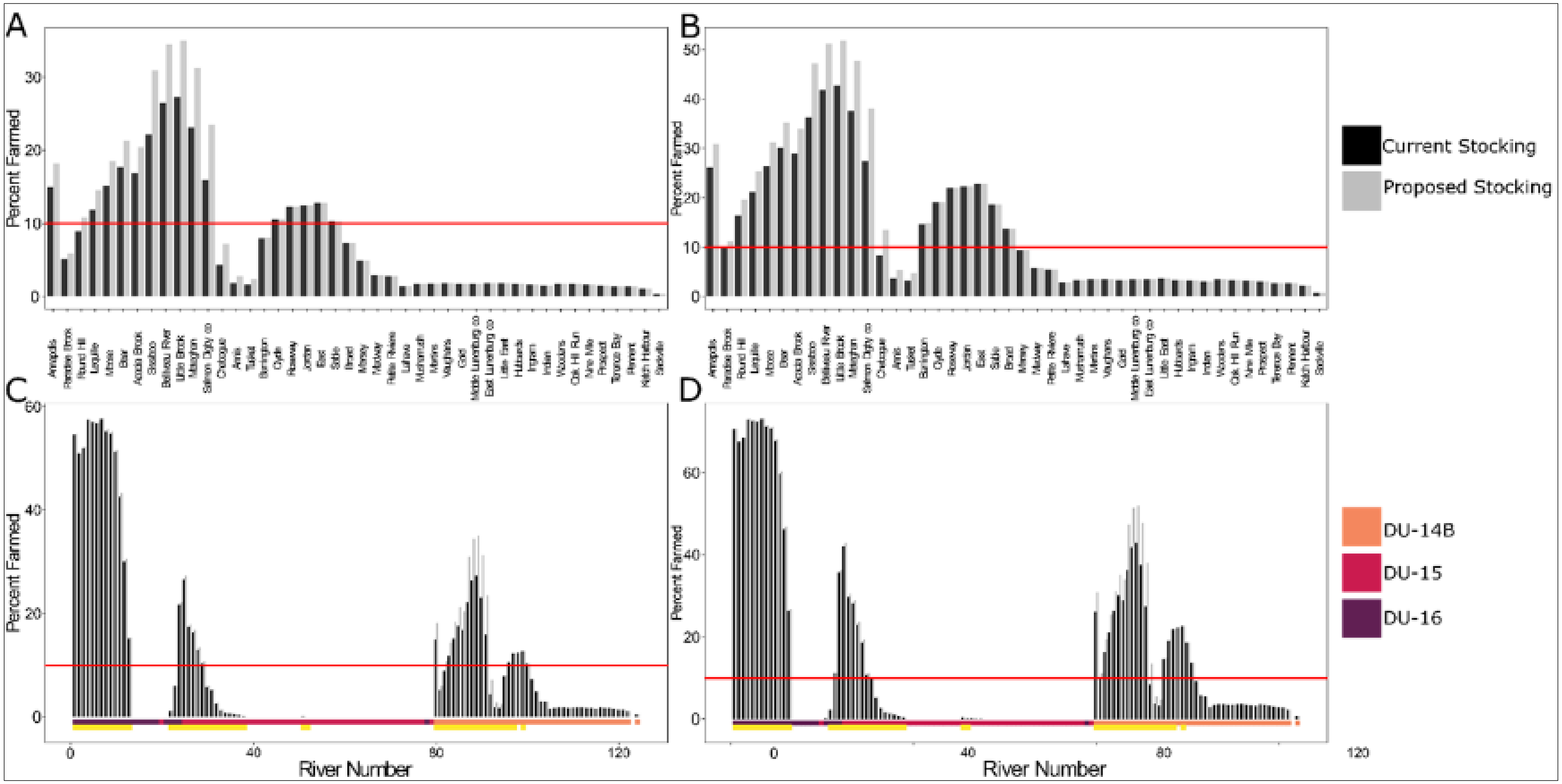


*Figure 13. Predicted percent farmed Atlantic Salmon in rivers included in the dispersal model, arranged west to east. Expected percentages under current stocking numbers are shown in black. Expected percentages with the four new proposed cage sites in St. Mary's Bay operational are shown in grey. The four proposed sites are located within the proposed Southern Uplands – West Designatable Unit (SU–W; DU–14B), and their centroid is approximately 14 km from the mouth of the Sissiboo River, River Number 87. Rivers within the proposed SU–W DU are shown for assumed escape rates of A) 0.2 fish per tonne of production and B) 0.4 fish per tonne of production. Rivers within the Outer Bay of Fundy (OBOF), Inner Bay of Fundy (IBOF) and the proposed SU–W DUs are shown with assumed escape rates of C) 0.2 fish per tonne of production and D) 0.4 fish per tonne of production. The horizontal red line denotes the 10% threshold. In panels C and D, DUs are indicated with colours under rivers. Also, rivers within the 200 km dispersal distance are underlined in yellow. Note the y-axis scales differ between panels.*

Recreational angling data from 1984 to 2008 indicate similar, if not more severe, declines in other SU rivers (Gibson et al. 2009) prior to the complete closure of Atlantic Salmon angling for all rivers in SFAs 20 and 21 in 2010. In their 2010 assessment COSEWIC, reported an overall decline in adult Salmon in this DU of 61% over three generations and assessed the Nova Scotia Southern Upland Designatable Unit as Endangered (COSEWIC 2010). In the same assessment, the overall decline of mature Salmon in the OBOF was reported as 64%, and they were also assessed as Endangered (COSEWIC 2010). And, as previously noted, the IBOF DU has been listed on Schedule 1 of SARA since 2001, and with data suggesting that fewer than 200 adults returned in 2008, their Endangered status was reconfirmed in 2010 (COSEWIC 2010). COSEWIC assessments consider population declines over the three generations prior to the assessment, and as such and as noted by COSEWIC, the true decline in these populations from historic levels exceeds those reported (COSEWIC 2010). Based on DU-specific fecundities and average number of spawners returning to the Scotia-Fundy reporting region (which includes the Eastern Cape Breton, SU and OBOF DUs, but not the IBOF), the International Council for the Exploration of the Sea Working Group on North Atlantic Salmon (ICES WGNAS) has determined that, between 2013 and 2022, the number of Salmon have declined to less than 5% of the spawning egg requirement (ICES 2003, Gibson and Claytor 2012). Thus, while COSEWIC have not assessed Atlantic Salmon since 2010, the available evidence, including the most recent data sent to COSEWIC in aid of their upcoming assessment (Raab et al. 2024; Reader et al. 2024a,b), is not indicative of an improvement in conservation status of the IBOF, OBOF or SU–W DUs.

Available DFO information from 2010 to 2017 on reported escapees show no evidence of significant escape events at existing sites in St. Mary's Bay, although there was reported net damage caused by a seal attack at the existing site #1354 in December 2017 (see: DFO Escape prevention for farmed fish). North Atlantic Salmon Conservation Organization (NASCO) annual reports from 2018-2021 also do not indicate any reported escape events from nearby finfish aquaculture sites. However, between 2011 and 2021, annual detections of escapees were reported at a facility on the Magaguadavic River in southwest New Brunswick. There were also less frequent detections on the Gaspereau River in the Inner Bay of Fundy, Nova Scotia. These findings suggest that Atlantic Salmon escape incidents have occurred during this time period from finfish aquaculture sites located in the southwestern regions of both New Brunswick and Nova Scotia (DFO 2024). In Nova Scotia, the Nova Scotia Department of Fisheries and Aquaculture's traceability program allows for the identification of the operator of origin for escapees from aquaculture facilities in the province.

The recently completed direct genetic interaction risk assessment from East Coast Atlantic Salmon aquaculture used IBSEM modelling and the results of the dispersal model to determine DU-level risks at current production levels (DFO 2024). This risk assessment followed the DFO Aquaculture Science Environmental Risk Assessment Framework with the level of risk estimation as the product of likelihood and consequence, conditioned by the conservation status of the DU (DFO 2024). The risks to abundance and genetic character were calculated separately and considered the overall proportion of escapees in the DU and proportion of rivers in which the proportion of escapees exceeded 10% respectively (DFO 2024). With the existing farms producing reproductively competent, diploid Salmon at modelled escape rates of 0.2 and 0.4 escapees per tonne of production, the risk assessment concluded that the risk to abundance for the proposed SU–W, OBOF, and IBOF DUs ranged from low to high, while the risk to genetic character ranged from medium to high (Table 6). These risks were calculated during the assessment without the four proposed St. Mary's Bay sites in operation, and therefore should be considered baseline levels of risk. It is acknowledged that triploids do exist in some farms in

Nova Scotia. If such culture becomes standard practice, this could be accounted for in future model runs (DFO 2024).

While direct genetic impacts to wild Atlantic Salmon already occur at current aquaculture production levels throughout the DFO Maritimes Region, the impacts are expected to be at least proportional to the intensity of the activities themselves (Bradbury et al. 2020a, DFO 2022a, DFO 2023a). Therefore, impacts to wild Atlantic Salmon from direct genetic interactions will be greater with the proposed increases in the number of farmed Salmon in St. Mary's Bay. Based on the critically low levels of Atlantic Salmon in the region and proximity of the proposed sites to Salmon rivers, it is crucial to minimize impacts to conserve wild Salmon populations. To minimize the impacts, mitigation measures that decrease the likelihood of direct genetic interaction, including physical containment and biocontainment measures such as sterility, could be considered (DFO 2024).

*Table 6. Risks to abundance and genetic character for the proposed Nova Scotia Southern Upland – West (DU–14B), Inner Bay of Fundy (DU–15) and OBOF (DU–16) Designatable Units reproduced from the CSAS Assessment of The Risk Posed to Wild Atlantic Salmon Population Abundance and Genetic Character by Direct Genetic Interaction with Escapes from East Coast Atlantic Salmon Aquaculture (DFO 2024). Note that these risks were calculated without the four proposed sites in St. Mary's Bay in operation and thus this level of risk exists for these DUs even in the absence of an expansion of the industry. Direct genetic interactions occur between reproductively competent, diploid, farmed Atlantic Salmon and wild Atlantic Salmon. COSEWIC statuses are based on the 2010 assessment (COSEWIC 2010).*

| DU | COSEWIC Status | Modelled Escape Rate | Risk to Abundance | Risk to Genetic Character |
|---|---|---|---|---|
| Nova Scotia Southern Upland (West) (DU–14B) | Endangered (as part of Nova Scotia Southern Upland Population COSEWIC 2010) | 0.2 | LOW | HIGH |
| Nova Scotia Southern Upland (West) (DU–14B) | Endangered (as part of Nova Scotia Southern Upland Population COSEWIC 2010) | 0.4 | MEDIUM | HIGH |
| Inner Bay of Fundy (DU–15) | Endangered (listed under SARA – 2003) | 0.2 | LOW | MEDIUM |
| Inner Bay of Fundy (DU–15) | Endangered (listed under SARA – 2003) | 0.4 | LOW | MEDIUM |
| Outer Bay of Fundy (DU–16) | Endangered | 0.2 | HIGH | HIGH |
| Outer Bay of Fundy (DU–16) | Endangered | 0.4 | HIGH | HIGH |

### Culture of Rainbow Trout

The impacts of Rainbow Trout escapes on wild populations of Atlantic Salmon, as well as feral populations of Rainbow Trout if they exist, have been discussed in previous aquaculture site reviews conducted by DFO (DFO 2021a, 2022b). Rainbow Trout escapes from aquaculture happen for the same reasons as Atlantic Salmon (Føre and Thorvaldsen, 2021), and Rainbow Trout escape events have occurred in Nova Scotia as reported on the NSDFA webpage (see: Information for the Public | Aquaculture and Marine Plant Notices).

The behaviour of Rainbow Trout after escape has not been studied as extensively as that of Atlantic Salmon. However, slower dispersal from the site of the escape is suggested in a review by Dempster et al. (2018). This review showed that while the majority of escaped Atlantic Salmon disperse in less than 24 hours, most Rainbow Trout remained in the vicinity of cages for approximately 48 hours. Even so, Rainbow Trout dispersal behaviour is varied: some disperse quickly and others slowly, but the number that remain at the escape location declines over time (Blanchfield et al. 2009, Patterson and Blanchfield 2013). Post-escape survival also varies; however, survival for months to years (Jonsson et al. 1993, Patterson and Blanchfield 2013), as well as successful transition to wild food (Nabaes Jodar et al. 2020, Rikardsen and Sandring 2006) and growth (Blanchfield et al. 2009, Jonsson et al. 1993, Patterson and Blanchfield 2013) have been observed. The potential for post-escape survival and observed dispersal distances within the range observed for Atlantic Salmon suggests that the area of concern for escapes of Rainbow Trout would be like that predicted for Atlantic Salmon.

Farm escapees can interact with wild populations genetically and ecologically. Genetic interactions can be direct (exchange of genetic material; hybridization) and/or indirect (altered selection pressure; Lacroix and Fleming 1998). While laboratory studies have produced adult hybrids between Atlantic Salmon and Rainbow Trout (Devlin et al. 2022), this type of direct genetic interaction would not be expected to occur in the wild since it's unlikely that spawning times would overlap. Therefore, the dispersal model was not run for Rainbow Trout escapees as a threshold for indirect genetic impacts has not been developed. As has been stated, the risk assessment conducted applies to direct genetic impact only between wild and escaped farmed Atlantic Salmon (DFO 2024). But non-sterile escaped Rainbow Trout could also reproduce with feral populations of trout if they exist.

Consequently, for wild Atlantic Salmon, the most likely types of interaction with escaped Rainbow Trout will be ecological through, for instance, competition for food and predation. The selective landscape can be altered by ecological interaction, and thus changes in fitness-related allele frequencies could occur in affected Salmon populations (indirect genetic interaction; Bradbury et al. 2020b).

## Pests and Pathogens Considerations

Cultured fish may acquire endemic diseases and/or parasites such as sea lice from wild fish or from other farmed fish in the area (DFO 2014). Density-dependent transmission is observed in many host-pathogen systems, including sea lice on salmonid farms (Frazer et al. 2012, Kristoffersen et al. 2013), as sea lice larvae can be dispersed over long distances (Myksvoll et al. 2018, 2020; Skarðhamar et al. 2018; Sandvik et al. 2021). This can pose a significant health concern to farmed and wild fish when pathogen or parasite loads exceed certain levels, which may be reached faster with more hosts in an area (Krkošek 2010). Potential impacts to wild susceptible fish species will depend on concentration and virulence of the pests and/or pathogens, the duration and extent of exposure of the wild fish to the proposed aquaculture sites, and their relative susceptibility to infection within the environmental conditions found in the area.

A review of chemical use data in Nova Scotia from AQUIIS between 2018 and 2022 showed minimal use of antibiotics and pest control products at the existing finfish aquaculture sites in St. Mary's Bay and Grand Passage, which indirectly suggests that pest and pathogen infestations have not been an issue at the existing sites in the area. However, the addition of up to 3 million fish at the proposed sites in St. Mary's Bay (i.e., an approximate doubling of farmed fish in St. Mary's Bay and Grand Passage) increases the potential for amplification of endemic pathogens and pests due to the increase in the number of host fish.

While pests and pathogens can be dispersed over great distances due to ocean currents (Foreman et al. 2015; Myksvoll et al. 2018, 2020; Skarðhamar et al. 2018; Sandvik et al. 2021), dispersal models that consider the dynamic of infection indicate that the concentration required to induce infections are expected to be within 2 km from aquaculture sites (Ding et al. 2024). For parasites such as sea lice, the infective zone is likely within 10–20 km from aquaculture sites (Gillibrand and Willis 2007; Salama et al. 2016, 2018). As such, exposure of wild Atlantic Salmon to pests and pathogens that could be released by farmed salmon reared in St. Mary's Bay is likely limited to those migrating in that bay (e.g., Sissiboo River, Beliveau River, Boudreau River, and Meteghan River) rather than to all Atlantic Salmon Designatable Units that are using the Bay of Fundy. This is supported by the lack of sea lice on Atlantic Salmon post-smolts in the Bay of Fundy (Lacroix and Knox 2005) despite that farmed Salmon were heavily infected with sea lice at that time in southwest New Brunswick (Carr and Whoriskey, 2004). Similarly, the infection profile of adult Atlantic Salmon returning to the Saint John River on the north side of the Bay of Fundy were distinct from those of farmed Salmon that were reared approximately 75 km southeast from that river (Teffer et al. 2020).

In St. Mary's Bay, Atlantic Salmon could be exposed to pests and pathogens originating from farm Salmon during their seaward migration as post-smolts or as kelts (i.e. repeat spawner), or as adults during their homeward migration to their natal rivers. Exact proportions and residence time of wild Atlantic Salmon near aquaculture sites or within areas of exposure to pests and pathogens generated and/or amplified by sites in St. Mary's Bay is unknown; however, Atlantic Salmon residency near the proposed sites is likely transient. Previous acoustic telemetry studies conducted throughout the world indicate that on average the travel speed of Atlantic Salmon post-smolts is around one body length per second (Thorstad et al. 2012) and, with a few exceptions such as the Conne River in Newfoundland (Dempson et al. 2011), leave the nearshore area rapidly (Lacroix 2008, 2013b; Halfyard et al. 2012). Hence, given the transient nature, it is anticipated that exposure time at the proposed sites would result in a low likelihood of infection, particularly in adult Salmon. Escaped farmed Salmon may also serve as a vector of pathogens to wild Salmon in the marine and freshwater ecosystems (e.g., spawning grounds) (Teffer et al. 2020; Madhun et al. 2024). However, any sea lice that may be transferred to adults returning to this area would drop off and die once the adults entered freshwater.

In other jurisdictions, such as Norway and Scotland, the large number of farmed Atlantic Salmon hosts and farming conditions have led to evolution of more virulent strains of sea lice (Mennerat et al. 2012, 2017; Ugelvik et al. 2017). Preliminary results from controlled laboratory experiments conducted by DFO Science suggest that sea lice are also becoming more virulent (i.e., inflict greater skin damage) in the Bay of Fundy (M. Trudel, DFO, St. Andrews NB, unpublished data). As a result, different practices may need to be considered to minimize the evolution of sea lice virulence and its impact on the welfare of Atlantic Salmon reared in open net-pens and in the wild, such as synchronizing fallowing over an area that is sufficiently large to prevent the reinfection of sea lice from other aquaculture sites or stocking larger smolts (Stige et al. 2024).

Aquaculture Management Areas are often set up in areas with multiple farm sites, such as in St. Mary's Bay, to allow for a coordinated approach to the management of fish health (Chang et al. 2022). Atlantic Salmon farms in Nova Scotia must be single-year class operations, with fallowing between successive year-classes. Additionally, provincially licensed veterinarians work closely with finfish farms in all aspects of fish health management. Fish health surveillance programs and regulatory requirements are in place under the guidance of the Provincial Fish Health Veterinarian and Aquatic Animal Health Program. These surveillance programs are aimed at early detection and control of pathogens of concern to the aquaculture industry, and regulatory requirements also involve monitoring of sea lice numbers on all marine finfish farms.

## Potential Entanglement of Wild Species at Risk in Aquaculture Infrastructure

An increase in aquaculture infrastructure may increase the potential for entanglement of some pelagic aquatic Species at Risk near the proposed sites. *SARA*-listed cetacean, sea turtle, and shark species potentially within the area include North Atlantic Right Whale, Fin Whale, Blue Whale, Leatherback Sea Turtle, and White Shark (Figure 14). Reports of entanglement of marine mammals, sea turtles, and sharks in marine finfish aquaculture gear in Atlantic Canada remain low or nil for these large-bodied species.

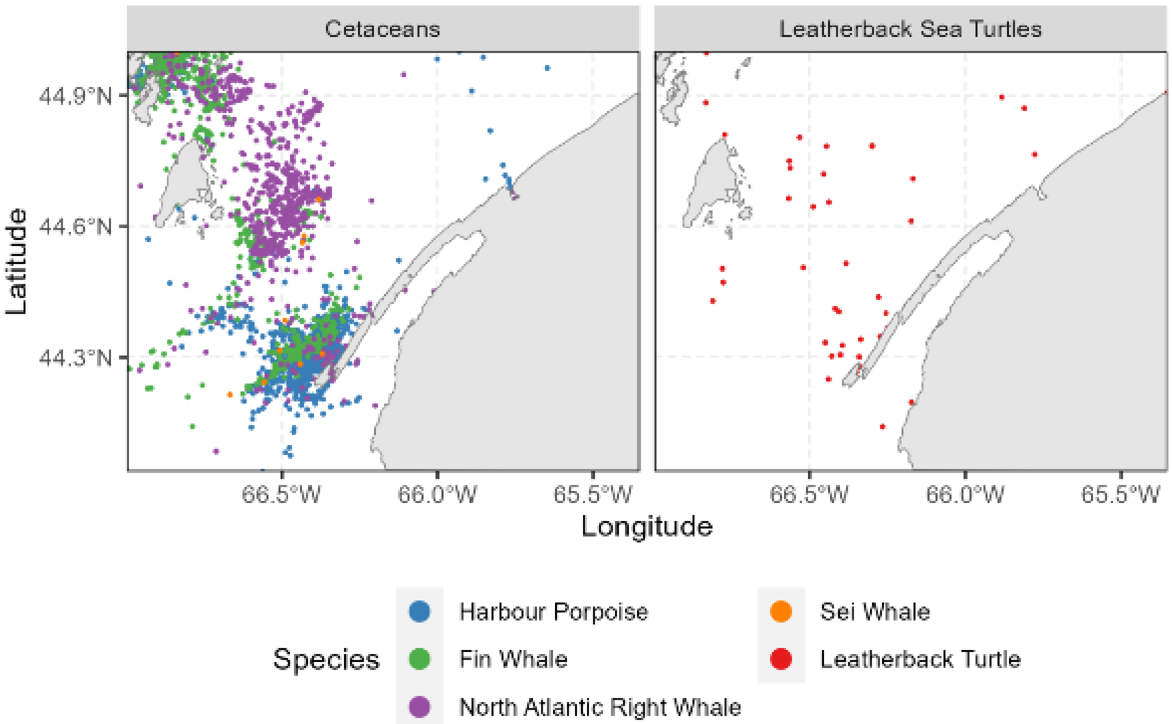


*Figure 14. Sightings of COSEWIC-assessed at-risk and SARA-listed cetacean species from 2010 to 2022 (left-hand panel; Whalesightings Database, Team Whale, Fisheries and Oceans Canada, Dartmouth NS, December 15 2023 — see Sources of Uncertainty section for important data caveats for the DFO Whalesightings Database). Leatherback Sea Turtle sightings from 1997-present (right-hand panel; Canadian Sea Turtle Network, National Oceanic and Atmospheric Administration – National Marine Fisheries Service, New England Aquarium).*

### Cetaceans

North Atlantic Right Whale, Fin Whale, and Blue Whale frequent both offshore and coastal waters, particularly to feed and mate, and may be present in the Bay of Fundy in spring, summer and fall. The high concentration and diversity of copepods and other zooplankton attract large aggregations of cetaceans to the Digby Neck/Brier Island area (Buzeta 2014). North Atlantic Right Whale are generally known to reside in water depths greater than approximately 36 metres (which would exclude much of St. Mary's' Bay), although they have been shown to frequent water depths of approximately 18 metres and less towards shore.

DFO's Whalesightings Database returned records of North Atlantic Right Whale observations from the area of interest every year from 2010 through 2022 (Figure 14; Whalesightings

Database, Team Whale, Fisheries and Oceans Canada, Dartmouth NS, December 15 2023). Specifically, within St. Mary's Bay, observations of North Atlantic Right Whale were reported in 2015, 2016, 2021, and 2022 (Figure 14; Whalesightings Database, Team Whale, Fisheries and Oceans Canada, Dartmouth NS, December 15 2023). The DFO Whalesightings Database is not a complete record of presence within St. Mary's Bay; the actual number and frequency of North Atlantic Right Whale in St. Mary's bay is anticipated to be greater than reported observations given that most sightings reported in the DFO Whalesightings Database are collected on an opportunistic basis without consistent effort (see Sources of Uncertainty section for important data caveats with respect to the DFO Whalesightings Database).

Harbour Porpoise, currently assessed as *Special Concern* by COSEWIC and under consideration for *SARA*-listing, is also in the area (Figure 14; Whalesightings Database, Team Whale, Fisheries and Oceans Canada, Dartmouth NS, December 15 2023). A study of Harbour Porpoise by-catch indicated that a large number are present off Brier Island (Trippel et al. 1996; Buzeta 2014). Most reported sightings are on the Bay of Fundy coast of Digby Neck, particularly to the south of Long Island and near Brier Island, however, there have been reported sightings in St. Mary's Bay. Species distribution modeling for Harbour Porpoise also indicates St. Mary's Bay as suitable habitat and a potential area for enhanced monitoring (Gomez et al. 2020).

#### Sea Turtles

Leatherback Sea Turtles have a wide geographic range within Canada and can be found in coastal, shelf, and offshore waters. Although Leatherback Sea Turtle is the most common sea turtle recorded in Nova Scotian coastal waters, the Bay of Fundy is not considered to be important habitat as it hosts relatively few foraging leatherbacks during the summer and fall. Leatherbacks have a median sighting water depth of over 100 m, and sightings in the vicinity of St. Mary's Bay have not been reported near the proposed site infrastructure (Figure 14).

#### Sharks

In the Atlantic Ocean, White Shark undertake seasonal north-south migration that brings them into Canadian waters from June to November where they feed on abundant prey including seal (Bastien et al. 2020; Franks et al. 2021; Bowlby et al. 2022). The North Atlantic population of White Shark has been listed as Endangered under *SARA* in Canada since 2011 because of significant declines that occurred in the 1970s and 1980s from which the population has failed to recover despite an apparent stability or slight increase since the 1990s (COSEWIC 2021). Hence, understanding the threats limiting their recruitment is required to develop effective mitigation strategies to support their recovery. While the risk of entanglement with aquaculture is currently considered low (COSEWIC 2021), White Shark have been observed in open net pens in the Mediterranean Sea (Galaz and De Maddalena 2004) and Australia (Cheshire 2006). As such, a better characterization of the interactions between White Shark and aquaculture is warranted in Canadian waters.

Heat maps produced from acoustic telemetry, Smart Position or Temperature Transmitting (SPOT) satellite tags, and pop-up satellite archival tags suggest that White Sharks may be present near St. Mary's Bay (Bastien et al. 2020; Franks et al. 2021). This is corroborated by the confidence interval of location estimates obtained from pop-up satellite archival tagging data from two individual White Sharks, that includes St. Mary's Bay (H. Bowlby, DFO, unpublished data).

To confirm the presence of White Shark in St. Mary's Bay, DFO deployed acoustic receivers at the four proposed aquaculture sites on May 3, 2023, and retrieved them on November 14, 2023 (M. Trudel, DFO unpublished data). The receiver detection data have been submitted to the

Ocean Tracking Network (OTN) and will be openly accessible via the OTN Data Portal (Quoddy Region Pelagics Tracking (QRPT)) and OBIS (see: Quoddy Region Pelagics Telemetry - Ocean Biodiversity Information System) once they are processed by OTN. A total of 19 unique White Shark were detected in the area from early June to late October (Figure 15; Table 7). The number of detections decreased from west (site #1452) to east (site #1449). Hence, sites that were more exposed to the Bay of Fundy had higher detections (i.e., the more western sites). A receiver deployed by the Centre for Marine Applied Research (CMAR) near the proposed site #1452 detected 14 unique White Shark between July 18, 2020, and October 21, 2020 (see: OTN CMAR Moorings). One of these individuals was also detected in 2023 (Shark #17). Thus, a total of 32 unique individual White Shark were detected in St. Mary's Bay over a period of two years, with at least one individual returning to the same area three years later. Taken together, these results indicate that there is a high potential that White Shark may interact with the proposed aquaculture sites in St. Mary's Bay.

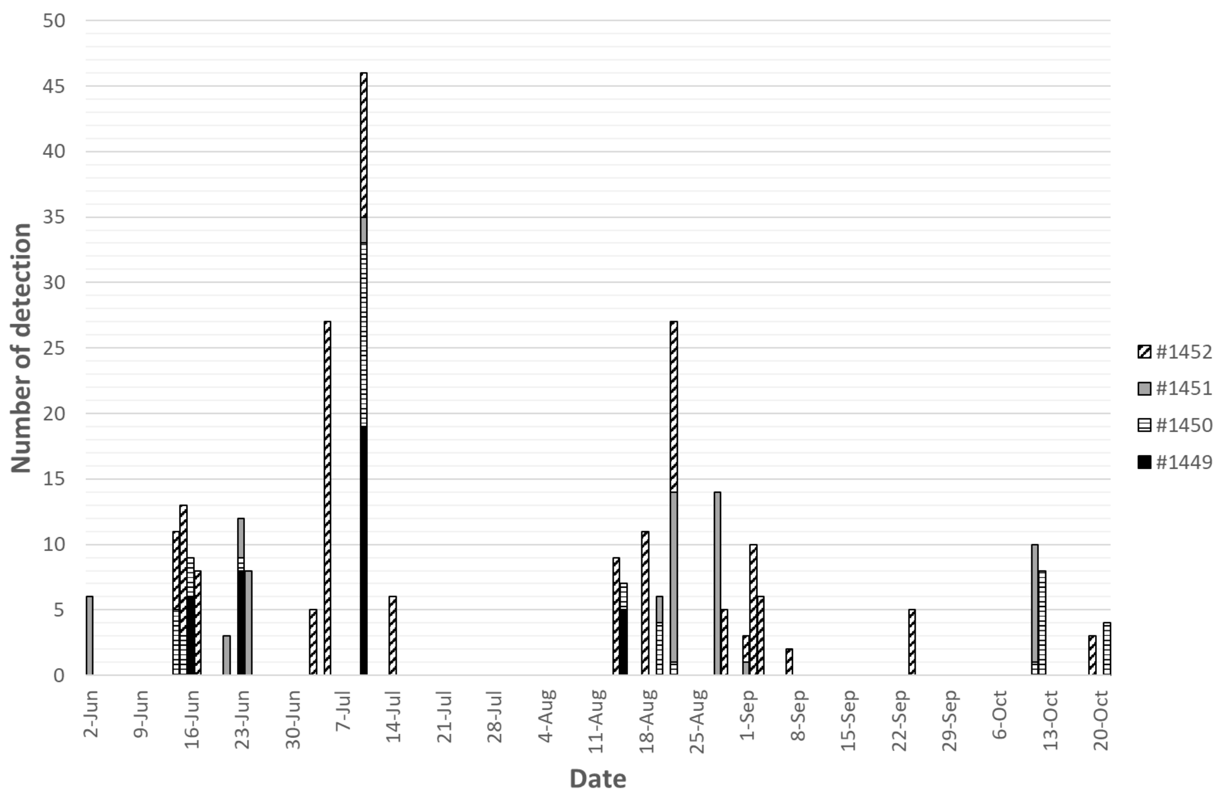


*Figure 15. Number of detections of white shark as a function of time at the acoustic receivers (VR2AR) deployed at four proposed salmon aquaculture sites in 2023. Tag codes provided by: M. Winton (Atlantic White Shark Conservancy, North Chatham, Massachusetts, USA), G. Skomal (Massachusetts Division of Marine Fisheries, New Bedford, Massachusetts, USA), and OCEARCH (Park City, Utah, USA).*

However, the relatively low number of detections for each White Shark suggests that the sharks were only briefly transiting through the area. Research conducted in Australia further suggests that White Shark are not attracted to finfish aquaculture, with no increase in the number of sharks detected nor in the length of time individual sharks were detected when aquaculture was present (Huveneers et al. 2022). Hence, due to the transient nature of White Shark, it is considered unlikely that infrastructure at the proposed sites would lead to significant effects on the White Shark population. Additionally, there have been no reports of White Shark entanglements in marine finfish aquaculture gear in Atlantic Canada to date.

*Table 7. Number of detections observed per white shark at the acoustic receivers (VR2AR) deployed at four proposed salmon aquaculture sites in 2023. Tag codes provided by: M. Winton (Atlantic White Shark Conservancy, North Chatham, Massachusetts, USA), G. Skomal (Massachusetts Division of Marine Fisheries, New Bedford, Massachusetts, USA), and OCEARCH (Park City, Utah, USA). A dash (—) = no detection*

| Animal | #1452 | #1451 | #1450 | #1449 |
|---|---|---|---|---|
| Shark 1 | 46 | 11 | 6 | 5 |
| Shark 2 | — | — | 11 | — |
| Shark 3 | 19 | — | 6 | 6 |
| Shark 4 | 6 | — | — | — |
| Shark 5 | 3 | — | — | — |
| Shark 6 | 3 | 4 | 1 | — |
| Shark 7 | 38 | 2 | 3 | 19 |
| Shark 8 | — | 11 | 1 | 8 |
| Shark 9 | 5 | — | — | — |
| Shark 10 | 5 | — | — | — |
| Shark 11 | 5 | — | — | — |
| Shark 12 | 2 | — | — | — |
| Shark 13 | — | — | 4 | — |
| Shark 14 | — | 3 | 5 | — |
| Shark 15 | — | 9 | 9 | — |
| Shark 16 | 2 | 1 | — | — |
| Shark 17 | 5 | — | — | — |
| Shark 18 | — | 6 | — | — |
| Shark 19 | — | 14 | — | — |
| Total | 139 | 61 | 46 | 38 |

## Cumulative Impact Mapping of Human Activities

To estimate the relative effect of human activities and stressors (hereafter "stressors") on the St. Mary's Bay area, an additive cumulative impact mapping (CIM) analysis was used, based on the analytical framework of Halpern et al. (2008) and following regional adaptations described in Clarke Murray et al. (2015). CIM analysis is a simple, additive model that identifies areas where stressors and habitats overlap in space, then applies a vulnerability weight to determine an impact score for each activity-habitat intersection. The use of habitats also indirectly captures effects on associated species. An Area of Interest was outlined by merging the pelagic-PEZ boundaries of the four potential leases and this area was then divided into 1 km x 1 km grid cells (no other values associated with the PEZs were used for the CIM analysis). Within this Area of Interest, spatial data and measures of intensity for 33 stressors and spatial locations of 15 habitats were sourced from Murphy et al. (2024).

Vulnerability weights for Atlantic Canadian ecosystems were sourced from Murray et al. (2024) which quantify the relative impact of each stressor on each habitat. The CIM model then sums all stressor-habitat combinations (weighted by their vulnerabilities) into a final cumulative impact score for each 1 $km^2$ grid cell. Results are displayed as a heat map of cumulative impact scores for the entire Area of Interest (e.g. cooler colours represent relatively lower impacts, warmer colours represent relatively higher impacts).

Thirty-three stressors were identified, representing a combination of terrestrial, coastal, and ocean-based sources that have the potential to influence the St. Mary's Bay marine ecosystem. Land-based stressors occur in watersheds that border St. Mary's Bay and include: agriculture; impervious surfaces; nutrient loading; and human population density. Coastal stressors occur directly along the coastline and include: coastal trash; diseases and pathogens; hardened shoreline; light pollution; marinas; and two measures of tourism (operators; trails and beaches and campgrounds). Marine stressors occur on or in the ocean and include: finfish aquaculture; shellfish aquaculture; contaminated sites; disposal at sea; invasive species; lost fishing gear; recreational boating; and marine shipping. Fishing stressors include 10 types of commercial fishing categorized by their potential effect on habitats, as well as the effect of fishing boats. Last, climate stressors include ocean acidification (aragonite saturation state), as well as sea-surface and bottom temperature anomalies. For each stressor layer, it was assumed that the influence of human activities diffuses equally in all directions. However, it is more likely that alongshore currents, river plumes, and land barriers influence the diffusion of impacts, particularly close to the coastline.

Fifteen habitat classes were defined for the Area of Interest that include both benthic and pelagic habitats. The intertidal (0–2 m depth) habitats include saltmarshes, beaches, tidal flats, and rocky intertidal areas. Subtidal (2–30 m depth) habitats include the algal zone (rockweed species), and hard, mixed and soft substrates. Shelf habitats (30–200 m depth) are comprised of hard, mixed, and soft bottom substrates. Pelagic habitats are defined based on bathymetry and are layered on top of benthic habitats, with shallow pelagic habitats ranging from 30 to 200 m and deep pelagic habitats covering all areas greater than 200 m deep. A deep biogenic habitat that represents significant biomass concentrations of cold-water corals, sponges, and sea pens is also included.

A second cumulative impact map was generated that included the addition of the four proposed aquaculture leases. The difference between the cumulative impact scores for these two maps were then calculated for each grid cell to quantify the relative change in cumulative impact to the marine habitats in St. Mary's Bay that would result from the addition of the four proposed leases. The largest change in cumulative impact score after the addition of proposed finfish aquaculture lease sites was 2.1 out of a possible value of 3 (i.e., if the highest intensity of finfish aquaculture overlapped with the most vulnerable habitat in any given grid cell). Grid cells whose difference in cumulative impact score was greater than or equal to 50% of this maximum observed change (i.e., 1.05) were used to define and outline an "Area of Potential Impact". The mean cumulative impact score was then re-calculated for the habitats present within this Area of Potential Impact, and the cumulative impact score decomposed to identify the stressors that made the largest contributions to cumulative impact scores by habitat.

A literature review was conducted to list the physical, chemical, and/or biological impacts linked to the different stressors occurring within the Area of Potential Impact, which were then used to determine the potential consequences to species and habitats in St. Mary's Bay. Stressors linked to fishing, finfish aquaculture, and coastal trash were summarized from Ban et al. (2010), with fishing effects being further refined from Fuller et al. (2008); climate change effects were summarized from Savard et al. (2016), Doney et al. (2012), and Guenette et al. (2014); invasive species from Therriault and Herborg (2007) and Gallardo et al. (2016); coastal trash from NOAA (2016).

#### Comparison of impacts among stressors

The current estimate of cumulative impact scores (i.e., excluding the proposed new aquaculture sites) in the Area of Interest ranges from minimally (less than 0.01) to highly affected (45.75).

The highest cumulative impact scores occur along Digby Neck and to the southwest of the Area of Interest, while the lowest cumulative impact scores occur in the north-eastern and south-eastern areas (Figure 16a). With the addition of the four proposed sites, the largest changes observed in the cumulative impact score occur primarily in the central zone of the Area of Interest, on both the east and west sides of Digby Neck, and particularly surrounding site #1451 (Figure 16b). This increase in cumulative impact scores results from increased intensity in finfish aquaculture activities (i.e. an increase in both the spatial overlap of leases and the strength of aquaculture activity in these grid cells) in the presence of some habitats with higher vulnerabilities to these activities. However, despite these increases in CI scores with the addition of the proposed leases, the absolute magnitude of CI scores in these locations remains lower than CI scores calculated elsewhere within of the Area of Interest (e.g., in the southwest; see Figure 16a).

After accounting for the proposed aquaculture leases, across all habitats, stressors from the fishing sector collectively made the largest contribution to the cumulative impact score (43%), followed by the climate (28.5%), marine (16%), coastal (8.2%), and land (4.4%) sectors, respectively. Again, finfish aquaculture is incorporated within the marine stressor. Fishing and climate change made the largest contributions to the cumulative impact score as a result of their broad spatial coverage and their overlaps with habitats with high vulnerabilities to these stressors. Stressors that contributed greater than or equal to 5% to the total cumulative impact score include three climate stressors (bottom temperature change (13.3%), surface temperature change (9.4%), acidification (5.7%)), four fishing stressors (bottom otter trawl (11.2%), pots and traps (9.6%), longline groundfish (7.8%), dredge (5.7%)), and two marine stressors (invasive species (5.8%), finfish aquaculture (5.1%)) (Figure 17a). Relative to other stressors within the entire Area of Interest, impacts from finfish aquaculture (existing plus the proposed sites) comprise 5.1% of the total cumulative impact score across all habitats (Figure 16a). In contrast, within the Area of Potential Impact, finfish aquaculture contributes 8.3% to the total cumulative impact score (Figure 17b), further suggesting anticipated higher impacts from this stressor within a localized area around the proposed leases.

Eleven different habitats occurred within the Area of Potential Impact (Figure 18a). Five of these habitats experienced the greatest change in mean cumulative impact score: soft bottom shallow; shallow pelagic; hard bottom shallow; mixed and hard bottom shelf, respectively (Figure 18a). The increase in mean cumulative impact score in these five habitats is due to a number of dominant (contributing greater than 10% to cumulative impact score within that habitat) climate, fishing, marine, and coastal stressors (Figure 18b). Common to all five habitats were higher mean impact scores of either surface (shallow pelagic, soft and hard bottom shallow) or bottom temperature change (mixed and hard bottom shelf). Soft shallow and mixed bottom shelf habitats also had higher impact scores for various types of bottom-contact fishing activities (dredge, bottom otter trawl, longline groundfish); soft and hard bottom shallow habitats also had higher impact scores for finfish aquaculture and invasive species; and hard bottom shallow habitat also had a higher impact score for coastal trash (Figure 18b).

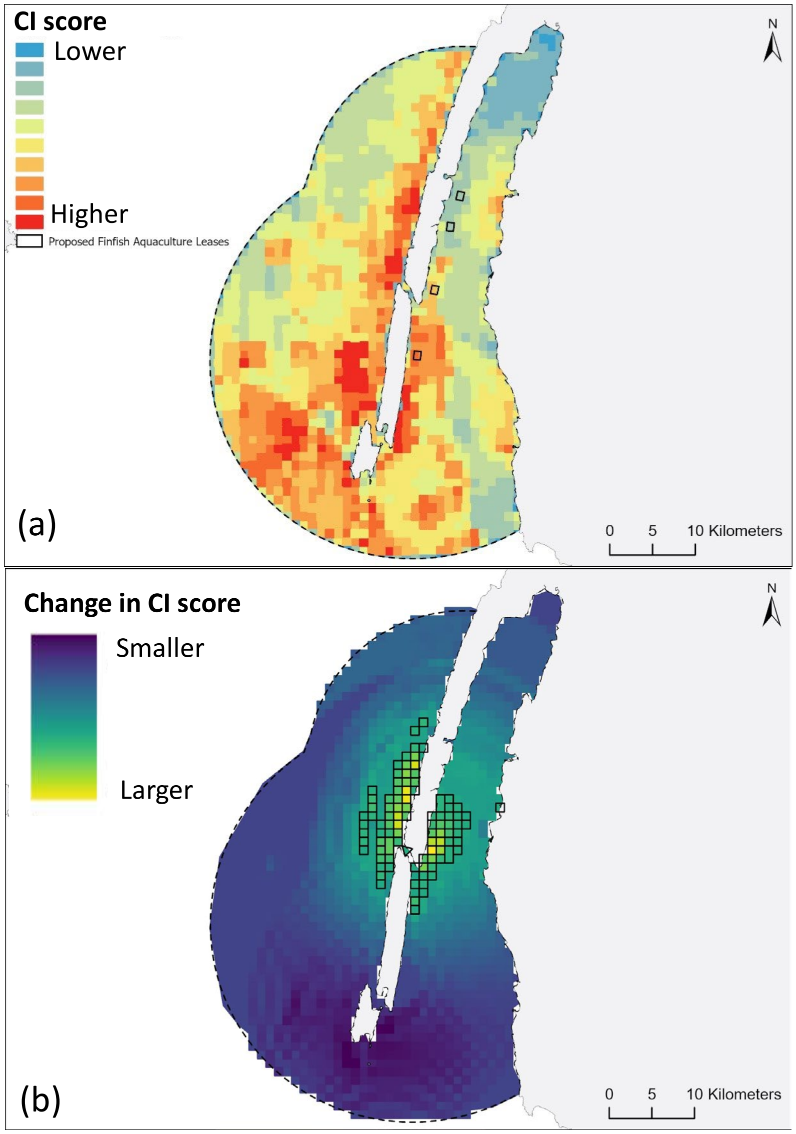


*Figure 16. (a) Current cumulative impact (CI) map for St. Mary's Bay, NS. Cooler colours are lower impact, warmer colours are higher impact. The locations of the proposed aquaculture leases are outlined in black, but are not included in the estimate of CI scores in Figure 16a. (b) Change in CI score with the addition of four proposed aquaculture leases. Cooler colours represent little to no change in CI score, warmer colours represent a greater change. An "Area of Potential Impact" is outlined in black, identifying grid squares where the differences in CI scores after the addition of the proposed aquaculture leases were greater than or equal to 50% of the maximum observed change.*

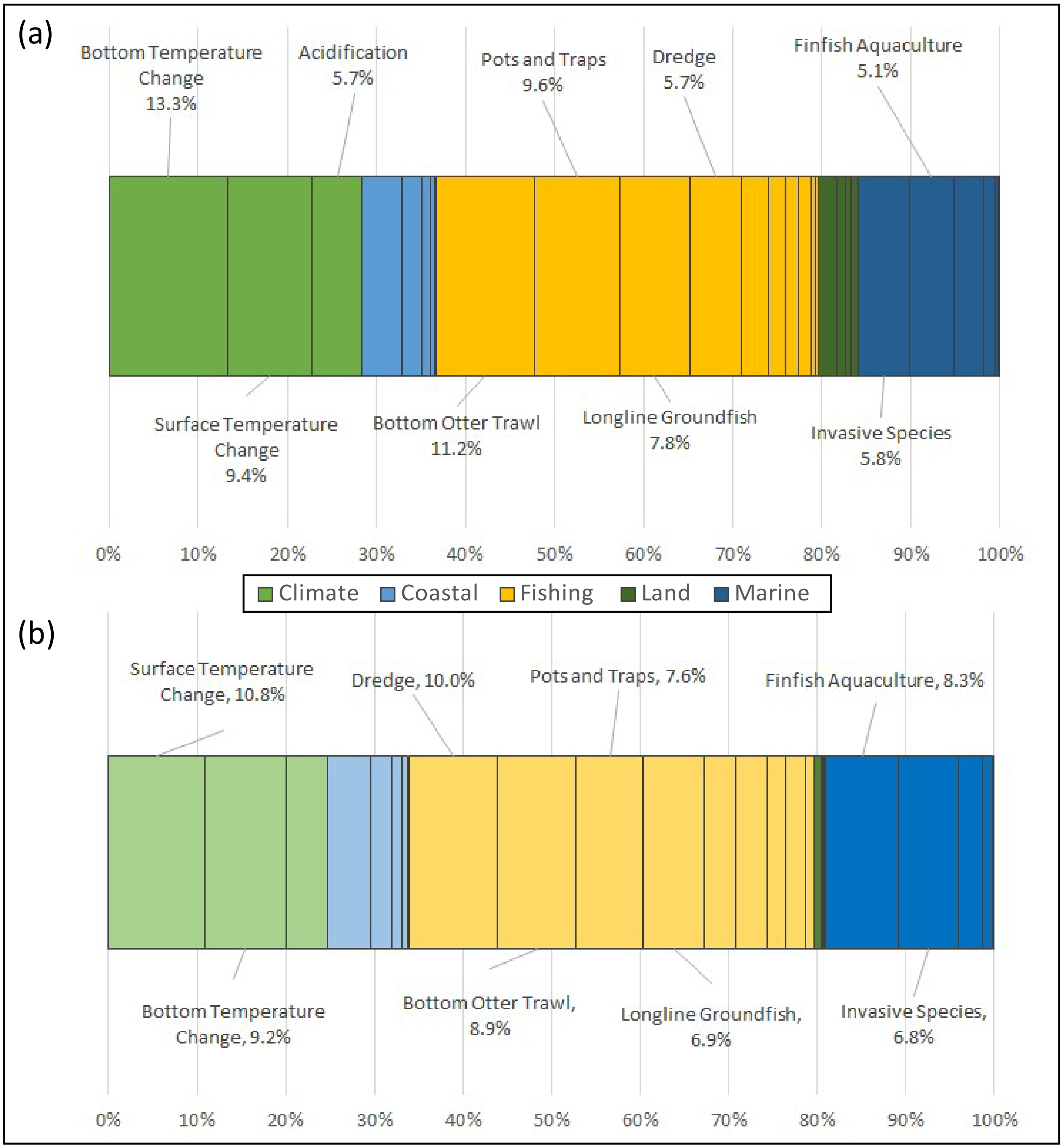


*Figure 17. Percent contribution of individual stressors to the total cumulative impact scores after the addition of the proposed aquaculture leases, (a) across all habitats in the Area of Interest; and (b) across all habitats present only within the Area of Potential Impact. Stressors are grouped by colour into one of five categories (Climate, Coastal, Fishing, Land, and Marine). Stressors that contributed greater than or equal to 5% to the total cumulative impact score are labelled.*

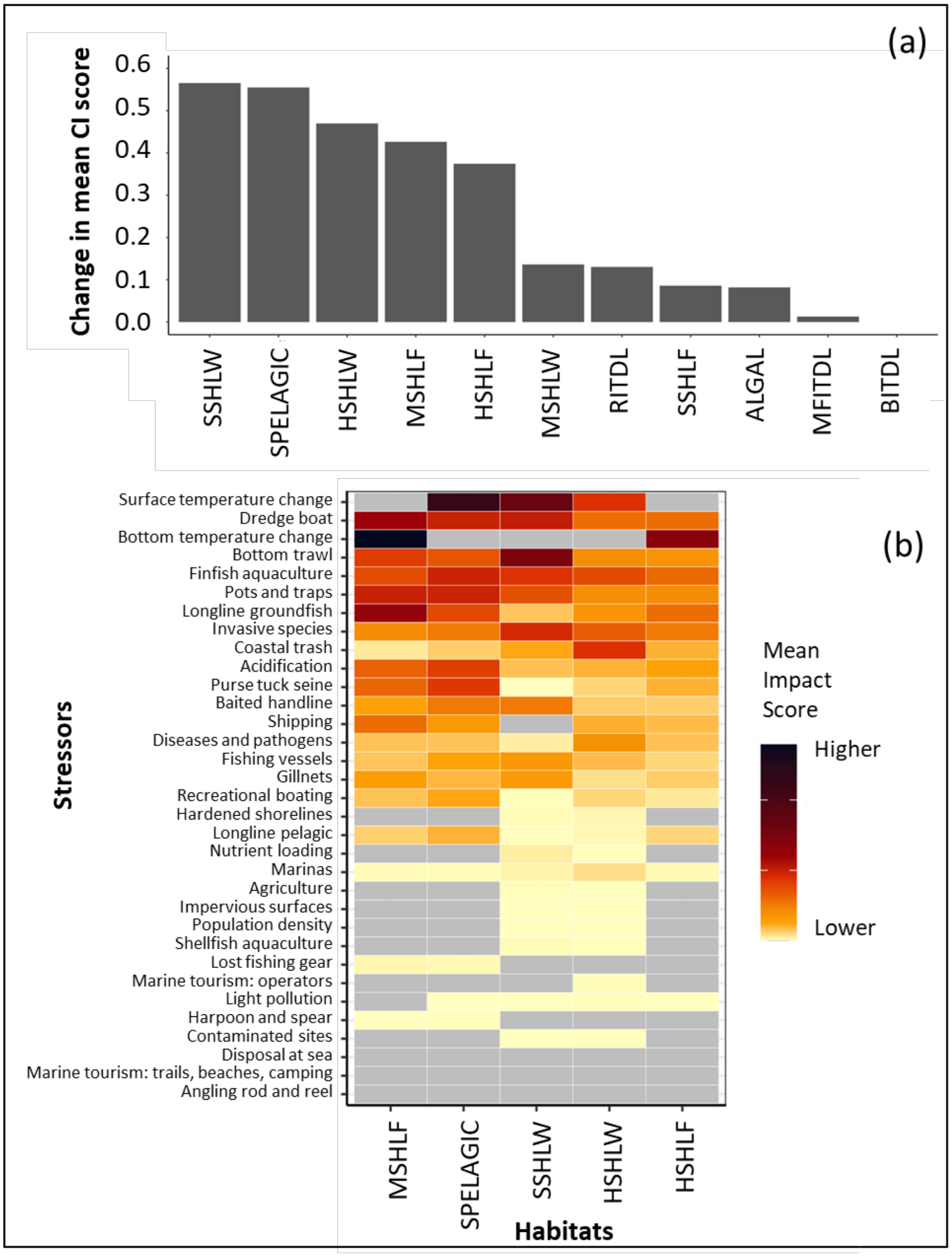


*Figure 18. (a) Change in mean cumulative impact score by habitats present within the Area of Potential Impact. (b) Mean cumulative impact scores by individual stressor-habitat combinations present within the Area of Potential Impact. Grey rectangles are null values, as the stressor and habitat do not overlap in this Area of Potential Impact. Five habitats, that experienced the greatest change in mean cumulative impact score after the addition of the new finfish aquaculture leases, are impacted by the cumulative effects of temperature change, bottom-contact fishing, finfish aquaculture, invasive species, and coastal trash stressors within the Area of Potential Impact. Habitat abbreviations: BITDL = Beach, MFITDL = Mudflat intertidal, ALGAL = Algal zone, SSHLF = Soft bottom shelf, RITDL = Rocky intertidal, MSHLW = Nearshore mixed bottom, HSHLF = Hard bottom shelf, MSHLF = Mixed bottom shelf, HSHLW = Nearshore hard bottom, SPELAGIC = Shallow pelagic, SSHLW = Nearshore soft bottom.*

### Potential impacts in a multi-stressor environment

Currently, the cumulative impact scores alone cannot determine at what level cumulative impacts cause harm. However, knowledge of the relative effects from the overlapping and dominant stressors identified through the CIM analysis can inform the potential impacts of human activities in the marine environment. The effects linked to stressors in the marine environment can be grouped into three main categories: physical (direct alteration to habitats); chemical (changes to water and sediment quality); and biological (changes to non-target species). Of the stressors identified in the Area of Potential Impact, all have been linked to more than one effect, and many stressors have effects across all three categories (Table 8). Overall, St. Mary's Bay presents a complex multi-stressor environment where climate variables, fishing, and marine stressors may compound or interact to reduce non-target species abundance, biomass, and/or diversity, in pelagic and hard, mixed, and soft bottom habitats within the Area of Potential Impact.

The overlap in the application of drugs and pesticides from finfish aquaculture and changes in sea surface temperatures suggest multiple stressor interactions on species behaviour, biomass removal through incidental mortality, and the promotion of invasive species in shallow pelagic habitats (Table 8). In St. Mary's Bay, shallow pelagic habitats are home to both holoplanktonic or meroplanktonic species, including Lobster, Scallop, Herring, Mackerel, shrimp, krill, and the larval stages of other benthic marine invertebrates. Predicted effects of increasing sea surface temperatures include physiological and life-history changes (Garzke et al. 2015, Pandori and Sorte 2019), but also shifts in phenology (the timing and production of planktonic communities); particularly, for the egg and larval stages of marine fish and invertebrates, with cascading effects for local populations and food webs (Poloczanska et al. 2016).

Few studies have considered the combined effects of climate-related variables and other anthropogenic stressors (O'Brien et al. 2023, He and Silliman 2019). However, current research suggests that the potential interactive effects of toxicants and climate variables may result from temperature-mediated increases in metabolic rates and food consumption leading to increased potential for exposure (through food) or increased susceptibility to toxic effects; alternately, chemical exposure may lead to a decreased resilience to thermal stress (Alava et al. 2017, Cabral et al. 2019). Larval stages of marine species are often more susceptible to the combined effects of multiple stressors than adult stages, suggesting combined effects of finfish aquaculture and changes in sea surface temperatures will be more detrimental to the development and survival of these life stages (Przeslawski et al. 2015, Pandori and Sorte 2019).

Hard, mixed, and soft bottom benthic habitats may be affected to varying degrees by a similar suite of stressors, including bottom temperature change, invasive species, fishing, finfish aquaculture and coastal trash, which suggests effects to the physical environment, water quality, and biomass removal in the Area of Potential Impact (Table 8). Species typically found in hard and/or mixed bottom habitats include Lobster, Scallop, Periwinkle, shrimp, Blue Mussel, Horse Mussel, and kelp, whereas eelgrass, Soft-shell Clam, and Quahog are found in soft bottom habitats. Bottom-contact fishing gears, such as trawling and dredging, have the most widespread direct human effect on marine benthic systems (Kaiser et al. 2006). Varying in severity by gear type, benthic damage occurs when trawls, longlines, and/or traps contact the bottom, and especially when they are dragged along the seafloor (Donaldson et al. 2010, Fuller et al. 2008). Bottom contact fishing gear impacts benthic habitat structure, can damage structural epibenthic species, reduces the biomass and diversity of benthic organisms, and causes loss of habitat for other benthic or demersal species (Watling and Norse 1998, Gordon et al. 2002, Henry et al. 2006, Kenchington et al. 2006, Sciberras et al. 2018).

Sediment plumes created from commercial fishing activities in soft sedimentary habitats can also smother benthic communities and increase organic enrichment and turbidity in the vicinity of trawl tracks (Palanques et al. 2001, O'Neill and Summerbell 2011). The addition of increased feed and waste products from the production of fish at the proposed sites and other nearby marine aquaculture facilities, in combination with these fishing stressors, may increase the potential for alterations to the composition, vegetative cover, biomass, and structure of benthic habitats in close proximity to the finfish net pens (Hargrave 2003, DFO 2010a, Cullain et al. 2018). Finfish aquaculture, through addition or removal of physical structures (ropes, buoys, anchors, etc.) and biological components (fish, fouling organisms), also has the potential to cause disturbance to the benthos (DFO 2010a). Thus, the proximity of finfish aquaculture and commercial fishing activities suggests increased benthic disturbance to habitats in the Area of Potential Impact. Increasing bottom water temperatures may also interact with fishing stressors; exploitation can alter the demographic, and spatial and temporal structure of harvested populations or alter species life-history traits; thereby, modifying their ability to respond to climate variability and change over interannual to interdecadal scales (reviewed by Planque et al. 2010, Perry et al. 2010).

In addition to contributing bycatch (Donaldson et al. 2010, Fuller et al. 2008), wild capture fisheries also contribute to abandoned, lost, and discarded fishing gear (ALDFG). St. Mary's Bay is known to be a 'hotspot' for ALDFG, and was the location of 'ghost gear' retrievals and shoreline cleanups under the federal Ghost Gear Fund. ALDFG poses entanglement threats to marine life and can smother or damage seafloor habitat through physical abrasion (Macfadyen et al. 2009). The benthic zone is a sink for marine debris (Galgani et al. 2015). In an assessment of ALDFG in LFA 34, Goodman et al. (2021) found that most (98%) debris items retrieved from the seafloor were connected to fishing activities (i.e., lobster traps, dragger cables, rope, buoys). While aquaculture-derived ghost gear has not been studied to the same extent as it has from wild capture fisheries, lost nets and ropes can result in entanglement of pelagic species or damage to benthic habitats through smothering or abrasion (GGGI 2021). However, the bulk of anthropogenic litter (e.g., cable ties and fastenings, plastic bottles, floats, pieces of rope) derived from aquaculture is likely smaller plastics (GGGI 2021), which can affect the aesthetics and recreational value of nearby beaches and shorelines (Brouwer et al. 2017). Additional sources of ghost gear and anthropogenic litter from new aquaculture activities may also increase disturbance to the benthos and incidental mortality of vulnerable or sensitive species.

Last, aquaculture adds or removes physical structures (e.g., ropes, buoys, anchors) that can be colonized by diverse biological assemblages, which can impact the local ecosystem (DFO 2010a). The invasive Violet Tunicate (*Botryllus violaceus),* Golden Star Tunicate *(Botryllus schlosseri)* and Vase Tunicate (*Ciona intestinalis)* are present in St. Mary's Bay (Sephton et al. 2017). These tunicates pose a moderate to high ecological risk to biodiversity, MPAs, and shellfish and finfish aquaculture in Atlantic coastal ecosystems (Therriault and Herborg 2007). Thus, aquaculture structures may contribute to the spread and subsequent establishment of other non-native species already present elsewhere in the Bay of Fundy or Southwest Nova Scotia. Further, increased exposure to drugs and pesticide applications from finfish aquaculture may limit the survival of less tolerant native species; thus, contaminants and infrastructure may interact to increase opportunities for non-indigenous species (O'Brien et al. 2023).

*Table 8. Comparison of effects associated with dominant stressors found within the Area of Potential Impact. Physical effects result in direct alteration to habitats; Chemical effects result in changes to water and sediment quality; Biological effects result in changes to non-target species. Unlike the CIM analysis, no quantitative weightings or scores are associated with the effects listed for each stressor below. A dash (—) = not applicable*

| Type of Effect | Effects | Marine Finfish aquaculture | Marine Invasive species | Fishing Bottom trawl | Fishing Dredge boat | Fishing Pots and traps | Fishing Longline groundfish | Climate Sea surface temperature change | Climate Bottom temperature change | Coastal Trash |
|---|---|---|---|---|---|---|---|---|---|---|
| Physical | Benthic disturbance | X | — | X | X | X | X | — | — | X |
| Physical | Changes in temperature | — | — | — | — | — | — | X | X | — |
| Physical | Change in currents/ circulation | X | — | — | — | — | — | X | X | — |
| Physical | Light | X | — | — | — | — | — | — | — | — |
| Physical | Marine debris | X | — | X | X | X | X | — | — | X |
| Physical | Noise | X | — | X | X | X | X | — | — | — |
| Chemical | Bacteria | X | — | X | X | X | X | — | — | — |
| Chemical | Contaminants | X | — | X | X | X | X | — | — | X |
| Chemical | Nutrients | X | X | X | X | X | X | — | — | — |
| Chemical | Oil waste | X | — | X | X | X | X | — | — | X |
| Chemical | Organic waste | X | — | X | X | X | X | — | — | X |
| Chemical | Sediment transport (turbidity) | X | X | X | X | X | X | — | — | X |
| Biological | Changes in behaviour (predator or prey) | X | X | — | — | — | — | X | X | — |
| Biological | Biomass removal (incidental mortality) | X | X | X | X | X | X | X | X | X |
| Biological | Diseases, pathogens, and/ or parasites | X | — | — | — | — | — | — | — | — |
| Biological | Genetic interactions | X | X | — | — | — | — | — | — | — |
| Biological | Invasive species | X | X | — | — | — | — | X | X | X |

## Climate Change Considerations

The cumulative impact mapping analysis identified climate stressors (bottom and surface seawater temperature change and ocean acidification) as the second largest contribution to the cumulative impact score for the St. Mary's Bay marine ecosystem. Climate change was considered below as a factor of anticipated changes in St. Mary's Bay that may alter the interactions between the ecosystem and the proposed finfish aquaculture sites.

### Climate modelling

To estimate future changes to water temperature and carbonate chemistry, the Gulf of St. Lawrence Biogeochemical Model (GSL-BGCM) developed by Lavoie et al. (2020) was used. This model combines downscaled outputs of three Earth System Models for 1970 to 2099 over a domain spanning from Cape Cod to Newfoundland. Coupled Model Intercomparison Project 5 (CMIP5) projections of future warming and carbon dioxide release under Representative Concentration Pathway 8.5 (RCP8.5) provided atmospheric forcing, which was then combined with coupled regional oceanographic circulation and chemical (driven by plankton dynamics and geochemical processes) sub-models. The model has a horizontal spatial resolution of 1/12°, up to 46 vertical layers depending on bathymetry, and an initial temporal resolution of two weeks, although it can be interpolated to smaller time steps.

Although the GSL-BGCM was originally developed for the Gulf of St. Lawrence and Scotian Shelf, it includes the Gulf of Maine-Bay of Fundy system, and was shown by Siedlecki et al. (2021) to perform well within this region. The model, however, has a relatively poor spatial resolution in coastal areas and does not fully resolve St. Mary's Bay because it does not represent areas of land enclosing the bay (Digby Neck, etc.) or shallow-water areas in the innermost portion of the bay. Notwithstanding, whilst the model is not at a spatial resolution for at-farm level decision-making, all projections considered herein represent general trends in regional future conditions including St. Mary's Bay (i.e. the southwestern Nova Scotian area of the Outer Bay of Fundy), rather than those exclusively of the Bay itself.

Ocean acidification is the reduction in ocean pH due to anthropogenic greenhouse gas emissions, and indicators of acidification include pH, partial pressure of carbon dioxide in seawater (pCO2) and calcium carbonate indices (aragonite and calcite saturation states; in general acidification reduces the amount of calcium carbonate ions in seawater and hence aragonite and calcite saturation states will decrease). Carbonate and ocean acidification-relevant variables predicted by the model include pH, pCO2, alkalinity, dissolved inorganic carbon, and aragonite and calcite saturation states. Surface and bottom water temperatures and aragonite and calcite saturation states were extracted for the St. Mary's Bay for this report, for 5-year periods around 2020 and 2050 from one of the Earth System Model outputs (CanESM2, which produces average rather than more extreme predictions) from the GSL-BGCM (see Appendix III). It should be noted that the aragonite and calcite saturations calculated by this model at depth require correction to compensate for the effects of pressure on dissolution, which is currently being completed, so bottom values for these variables are tentative; however, at 20–40 m depths in St. Mary's Bay the impact of this correction is expected to be minimal and would only decrease the saturation values estimated herein.

Commercial susceptible species in the PEZs that are most likely to be exposed to and impacted by the proposed aquaculture activities and are the most vulnerable to climate change effects are Lobster and Scallop. Therefore, the focus was on mean summer values of temperature and carbonate variables, as this is the season when all life stages of these and similar species should be present in the bay and when important life processes (development and spawning, mating) predominantly occur.

### Lobsters

Current (2020) average summer temperature ranges in St. Mary's Bay are 12–14 °C on the bottom (adult habitat) and 10–15 °C in the upper 1 m surface water (general larval habitat). Climate modelling referenced above was used to develop a biophysical model of the area, projecting increases in warming of approximately 2–4 °C by 2050, depending on location within the Bay, with the overall trend showing significant warming in the Bay region by 2050. By 2050, bottom and surface temperatures in St. Mary's Bay are predicted to increase to 15–16 °C and 15–17 °C, respectively.

The projected warming does not put either adults or larvae further into stressful temperature ranges but may impact adult (including berried female) movements and abundances into the Bay, as thermal habitat becomes more suitable for lobsters under warming. Berried (i.e. egg-bearing) females are known to move over short and even long distances, from inshore to offshore areas (Pezzack and Duggan 1986), to ensure they remain in waters at optimal temperatures for embryonic development (Campbell, 1986). While embryos seem able to develop successfully over a wide range of water temperatures (5–25 °C; Perkins 1972), berried females show preferences for coastal waters of approximately 16 °C during summer (Jury and Watson III 2013), avoid warmer waters (approximately 18 °C adult lobsters; Quinn 2017, Harrington et al. 2020), and will move into offshore areas during fall and winter. There are no published field studies on the distribution and abundance of planktonic lobster larvae in St. Mary's Bay; however, the finding of very recently-settled lobsters in cobble-filled passive collectors in St. Mary's Bay suggests that pelagic larval stages have been present in the overlying water column in the preceding weeks to months. Additionally, studies in adjacent areas (Tremblay and Sharp 1987, Annis et al. 2007) suggest that lobster larvae are likely in the water column from July through late-September, with the highest abundances expected from mid-July to mid-August; it should be noted that this timing may shift with climate-associated warming. Substrate habitat under the proposed finfish aquaculture sites includes cobble and pebble (Table 1), which are preferred settlement and shelter substrate for juvenile lobsters (Wahle and Steneck, 1992) and substrate preference is unlikely to change with warming (Nielsen and McGaw, 2016).

Climate warming is known to cause shifts in phenology for lobster, including earlier hatching times for lobster larvae (Haarr et al., 2020) and early or more frequent moulting in juvenile and adult lobsters (Groner et al., 2018, McMahan et al., 2016, Staples et al., 2019). Earlier hatching by lobster larvae may not keep pace with shifts in the timing of population peaks in their prey, such as copepods, resulting in food limitation in the plankton (Carloni et al., 2024). Combined warming temperatures and ocean acidification reduce lobster larval survival, decrease growth and moulting rates, alter gene expression and shell mineralization, and increase feeding and swimming rates (Waller et al. 2016, Niemisto et al. 2021, Noisette et al. 2021). Ocean acidification modelled conditions herein (aragonite and calcite saturation states) are projected to remain at or above those considered non-stressful for adult crustaceans for St. Mary's Bay during summer (approximately 3 for calcite, e.g., Waller et al. 2016, Dodd et al. 2021, Niemisto et al. 2021, Noisette et al. 2021).

### Scallops

Projected ocean warming and acidification is anticipated to decrease the larval availability of Sea Scallop and have negative impacts on juvenile and adult growth and survival, affecting Scallop productivity in the region. Increasing water temperatures due to climate change are potentially stressful for scallops, as it is a deeper-water species, and will decrease optimal habitat ranges in regions less than 60 m (Zang et al. 2023), such as St. Mary's Bay. Ocean acidification is known to have a negative impact on a range of bivalve larvae and is therefore highly likely to affect scallop abundances over time. Atlantic Sea Scallop, as bivalves, are considered highly vulnerable to ocean acidification through observations on other species and modelling efforts (Rheuban et al. 2018).

Model projections herein demonstrate that average surface aragonite saturation is anticipated to decrease from 2.1 in 2020 to 1.8 in 2050 in St. Mary's Bay, while bottom aragonite saturation is predicted to decrease from 2.0 to 1.6 on average, which cross the range considered stressful for bivalves (Barton et al. 2015). Combined temperature increases and greater acidification have been found to reduce growth and survivorship in adult (Cameron et al. 2022) and juvenile (Pousse et al. 2023) Atlantic Sea Scallop in experimental settings, indicating that combined warming and acidification in St. Mary's Bay may affect productivity. Field data on coastal ocean acidification and population effects are currently lacking for Atlantic Sea Scallop.

#### Eutrophication

There is scientific consensus that climate change will increase the occurrences and severity of harmful algal blooms (IPCC, 2022). While the exact triggers of bloom formation may be a combination of increased temperatures, freshwater availability and local hydrodynamics, increased nutrient loading from mariculture has been suggested as a contributing factor (Soto et al., 2021) and consideration of harmful algal bloom formation in aquaculture siting related to climate change has been recommended (Brown et al., 2020).

Harmful algal bloom formation has the potential to both affect local fisheries species abundances (e.g. through smothering), localized eutrophication leading to increased acidification (affecting sensitive life stages / species to ocean acidification) and food safety (with a potential to intensify under climate warming), but also has implications for finfish aquaculture species themselves. A 30-year review of harmful algal bloom events (McKenzie et al., 2021) shows an increase in bloom recurrence in St. Mary's Bay in the 2008–2017 period compared to 1998–2008, with blooms also occurring in other locations in the Bay of Fundy. For the sites in St. Mary's Bay, terrestrial nutrient loading models were developed which estimated low total nitrogen loads for St. Mary's Bay (Kelly et al., 2021), while the cumulative assessment in this report estimated low cumulative impacts from loading (Figure 17a). For aquaculture nitrogen loading, an approximate 494 tonnes would be produced by the existing and new proposed aquaculture sites, contributing an additional 38% of total nitrogen loading to the Bay (based on assumptions of similar waste from Atlantic Salmon as per Rainbow Trout from (McIver et al., 2018), a maximum stocking density of 6.5 million fish). However high flushing rates (68 hours) and the medium to high energy environment (see *Description of Proposed New Finfish Aquaculture Sites*) suggests that harmful algal bloom formation related to finfish aquaculture nutrient loading is considered unlikely.

#### Pests and pathogens

Historical use of approved drugs and pesticides may not be a predictor of future disease outbreaks as production in the Bay increases or as other influencing factors change, such as a warming of the ocean. Recent studies indicate that the Gulf of Maine and Scotian Shelf water temperatures have warmed very rapidly (Pershing et al. 2015). Warming waters in the future are expected to result in increased frequency and severity of sea lice outbreaks, related in part to shortened sea lice generation times in warmer waters (Ugelvik et al. 2022, Dalvin et al. 2020, Hamre et al. 2019). As a result, increased frequency and/or dosages of pest control treatments in general may be needed in future years for pest management to minimize impacts on the welfare of farmed Atlantic Salmon, with potential accrued impacts on wild susceptible species surrounding aquaculture sites over time (Dalvin et al., 2020, Godwin et al., 2020a, Godwin et al., 2020b, Sandvik et al., 2021).

Warmer waters have been associated with mass mortalities and liver damage to farmed salmon (Calado et al., 2021), and gill disease is likely to increase with warming (Boerlage et al., 2020). While simulations of Atlantic Canada's warmer summer months (up to 20 °C) were not found to impair immune responses to bacterial antigens (Zanuzzo et al., 2020), periods of prolonged high-water temperatures can affect fish immunity and cause mortalities (Islam et al., 2022). Climate warming may create new issues relating to diseases or parasites that were previously not problematic in colder waters (Falconer et al., 2020), and concurrent stressors associated with warming water (e.g. hypoxia, algal blooms) may further compound finfish disease issues. Whilst decadal level changes in seawater warming will have positive or negative effects on fish farming (dependent on proximity to upper thermal tolerances), marine heat waves will surpass interannual variability effects and have greater impacts on disease prevalence and fish physiology.

### Storms, sea level, and wave heights

Storms are projected to intensify in North America, occur more frequently, and increase in severity (Hicke et al., 2022), and sea level is projected to rise in the Halifax area (DFO, 2020d). Increasing storm occurrences and severity increases risks to infrastructure, and can result in an increase in aquaculture finfish escapees (Callaway et al., 2012). Storms have commonly been linked to large-scale finfish escapes, with examples including in Chile (650,000 salmon from a single net-pen farm) (Gomez-Uchida et al., 2018) and Canary Islands (1.5 million fish) (Toledo-Guedes et al., 2014). Projected increased storm event severity will also increase wave height with implications for aquaculture infrastructure.

St. Mary's Bay observations and projections showed reduced extreme wave heights compared to the Bay entrance, with wave height projections of 0.52–3.79 m in 10 years increasing to 0.65–3.98 m in 50 years (variation depending on wave direction and study location in St. Mary's Bay) (CMAR 2020). Corresponding projections of wind speeds were 18.8–23.39 m/s in 10 years compared to 21.88–27.33 m/s in 50 years (wind speed did not vary with location) (CMAR 2020). The Coastal Infrastructure Vulnerability Index (Greenan et al., 2018) has an exposure sub-index of sea level change, wind and wave climate, sea ice and coastal materials for the St. Mary's Bay harbours of Little River, Sandy Cove East and West, and Saulnierville. All had exposure sub-index values of 2.41 on a ranking of 1 (least exposed) to 5 (highest exposure), largely due to wave height and sea level change rankings; overall this indicates moderate exposure levels. In summary, it is therefore anticipated that projected climate change may pose infrastructure challenges, and the potential for an increase in associated finfish aquaculture escapes, if mitigation is not undertaken to withstand future environmental conditions.

## Sources of Uncertainty

### Predicted exposure zones

Predicted exposure zone (PEZ) estimates are based on current meter data provided by the proponent. Baseline current meter data were collected as required under the *Aquaculture Activities Regulations* and as outlined in the Monitoring Standard. Current meters were deployed for 90 days at a single location within the proposed leases, and records were provided for three of the four sites (no data were collected at site #1449). Current meter records of this length and from a single location are not fully representative of the temporal and spatial variability that may be of relevance to estimating exposure and deposition zones.

Time scales used in the calculation of the benthic-PEZs are based on minimum particle sinking rates of feed and feces. However, sinking speed distributions over a range of particle sizes are not well-characterized. It is also based on the maximum depth within a 500 m buffer of each proposed site, and therefore does not take into account the spatial variation of bathymetry. Fines and flocs were not accounted for in the estimation of the benthic-PEZs. Current- and wave-induced bottom resuspension, redistribution, and decay processes of deposited feed waste, feces, and other associated sinking particulates (i.e., medications) are not accounted for in the benthic-PEZ.

The time lengths used in the pelagic-PEZ calculations were determined from a simple dilution model. It is not fully understood how well this model represents true dilution times. The maximum depths of a released pesticide patch were determined from a simple vertical growth model. It is not fully understood how well this model represents true vertical growth.

The use of updated lower Environmental Quality Standard (EQS) values resulted in longer dilution times. Thus, the assumption that a pesticide patch could travel in a single direction during the dilution time is over-precautionary. As a mitigation measure, progressive vector distances were used to calculate the pelagic-PEZs. The progressive vector approach adds additional uncertainties. The use of a single 90-day current meter record in the calculation of the maximum progressive vector distance does not capture the spatial, seasonal, and inter-annual variations. A preliminary examination of four-dimensional hydrodynamic and particle tracking models suggests that the pelagic-PEZs based on progressive vector distances could underestimate the exposure associated with some releases (Figure 4).

The PEZs for this review were estimated with respect to Atlantic Salmon aquaculture; consideration was not given to Rainbow Trout. The radius of the benthic-PEZ may change if feed and feces sinking rates differ between Atlantic Salmon and Rainbow Trout finfish aquaculture. Similarly, the radii of the pelagic-PEZ may change if pesticide treatment concentrations for Atlantic Salmon and Rainbow Trout differ.

Predicted exposure zones do not represent any release scenario. They are intended to be a scoping tool to determine a precautionary estimate of the spatial scale of potential exposure (i.e., not intensity or impact) of anticipated finfish aquaculture activities with marine ecosystems and species. If the predicted exposure zones highlight areas of particular concern to decision makers, consideration should be given to more detailed analysis.

### Species and habitat distributions

Coastal areas are generally not adequately sampled on spatial and temporal scales of relevance to individual finfish aquaculture sites (i.e., tens to hundreds of meters and hours to months). Information on these space and time scales is typically not contained within the various data sources available to DFO to evaluate presence/use of species and habitats in these areas. Data based on surveys do not fully sample the area spatially or temporally, and additional information on presence and habitat use (i.e., spawning, migration, feeding) must often be drawn from larger-scale, historical, and/or opportunistic datasets.

The most comprehensive commercial Lobster fishing information for LFA 34 comes from mandatory logbook reporting. Locations of landings (kg) and effort (number of trap hauls) are given as reporting grids, which represent the finest spatial resolution available for the fishery in 10-minute grid squares. Estimated densities of removals represent an average over reporting grids and do not provide insight into the importance or variability of fishable and suitable habitat at spatial scales smaller than the reporting grids, which would be expected in St. Mary's Bay.

Databases such as the DFO Aquatic Species at Risk Map tool are typically based on common and/or historical knowledge of geographic range and habitat preferences and may not necessarily be based on the most current observations.

Most sightings reported in the DFO Whale Sightings Database are collected on an opportunistic basis and observations may come from individuals with varying expertise in marine mammal identification; reliability of the sightings records may vary. Observation effort has not been quantified and the sighting numbers cannot be used to estimate true species density or abundance for a given area or time-period; lack of sightings does not necessarily represent absence of species in a particular area or during a particular time of year. Most data have been gathered from vessel-based platforms of opportunity, and negative or positive reactions by cetaceans to the approach of such vessels have not been factored into the data. Similarly, aerial surveys often target specific areas for management purposes and are similarly limited by daylight, season, and sea-state/weather, as are additional limitations of vessel-based observations. These data are likely incomplete and additional sightings may be available from other sources. While quality control measures have been applied to reduce potential errors, the data may still contain errors or duplicates (multiple reports of the same sighting) and DFO does not guarantee the accuracy, completeness, or currency (i.e., real-time value or relevance) of the data.

Overall, the uncertainty regarding species and habitat distributions and abundance within coastal areas precludes a robust indication of seasonality and spatial distribution for several species and habitats in the vicinity of the proposed finfish aquaculture sites.

#### Impacts to susceptible species from exposures

Data gaps in relation to the full extent of species presence (in space and time) and habitat use in the area, as well as insufficient data to assess the probability of transport to specific areas within the PEZs, creates uncertainty as to the degree of exposure between wild fish and fish habitat and the proposed aquaculture activities. Additionally, the sensitivity of some species' life stages and habitats to the potential effects from the proposed aquaculture operations (i.e. organic loading, fish health treatment products, site infrastructure) is not well understood.

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

#### Farmed-wild Atlantic Salmon interactions

Apart from monitored index rivers, information is generally lacking on the size and distribution of wild Atlantic Salmon populations. While there has been evidence of escaped farmed Salmon in rivers in Nova Scotia and New Brunswick (Morris et al. 2008) and evidence that escapes from aquaculture sites have occurred within the DFO Maritimes Region between 2011 and 2021 (DFO 2024), the numbers reported in rivers are not from systematic or routine surveillance. Therefore, improved estimates of wild Atlantic Salmon population size and the presence of escapees in Salmon-bearing rivers in the DFO Maritimes Region would improve the assessment of genetic and demographic risk. Although Nova Scotia has an origin of operator escapee traceability program, determining the origin of escapees throughout the broader DFO Maritimes Region remains difficult without a coordinated region-wide program similar to what exists in Norway (e.g., Glover 2010).

Models used in this review only consider direct genetic interactions resulting from interbreeding with escapes. Uncertainty remains around the indirect genetic and/or ecological interactions and impacts on wild Salmon due to predation, competition, disease, or parasites. The potential stocking of Rainbow Trout as a secondary species at the proposed aquaculture sites may add to the potential for these indirect genetic effects and ecological interactions. Current knowledge of ecological interactions between escaped farmed Rainbow Trout and wild Atlantic Salmon that can result in negative genetic impacts has been summarized in previous DFO Science aquaculture site reviews (DFO 2021a, 2022b).

Exact proportions and residence time of wild Atlantic Salmon near aquaculture sites in the Bay of Fundy and St. Mary's Bay is unknown. Significant knowledge gaps also exist regarding disease and sea lice infestation levels in wild and farmed Atlantic Salmon. Monitoring and reporting of these levels would be informative; in particular, to improve knowledge of sea lice abundance and risk to wild populations.

#### Cumulative impact mapping

Historical stressors that may have legacy effects (e.g. sedimentary contamination), effects from natural disturbances (e.g. storms, marine heat waves), or episodic stressors that can create infrequent but intense disturbances (e.g. oil spills) were not included in the current analysis. The layer that includes Lobster fishing (Fishing: Pots (all types)) covers almost the entire Area of Interest (98%) around the proposed sites, which is an artefact of these data being mapped on a 10-minute square statistical grid (Serdynska and Coffen-Smout, 2017). Since it is unlikely that Lobster fishing actually occurs throughout the entire Area of Interest, the cumulative effect score for this activity is likely an overestimate. Effects from recreational boating, and vessel use in relation to aquaculture activities, are likely underestimated, as the spatial distribution, magnitude, and frequency of small vessels is currently unknown. Several layers remain under-developed and were estimated using binary values (1 vs. 0 for presence or absence) since the data required to calculate intensities were not available (i.e. contaminated sites, disposal at sea, shellfish aquaculture, hardened shorelines, marinas, tourism operators, tourism locations). Finally, the native resolution of some stressor layers was larger than the 1 $km^2$ grid cells used (e.g. most fishing layers are estimated at 10 $km^2$ and were downscaled for the CIM analysis), reducing the accuracy of the stressor layers at finer scales.

Many of these effects will vary spatially and temporally (e.g., increased boating traffic related to seasonal fishing or recreational activities, increased influx of nutrient loading or urban runoff in spring due to snow melt, etc.), so may only be of concern at particular times of year. Further, little information is available on the acute versus chronic effects of these stressors (e.g., noise, light, marine debris, changes in currents/circulation). The geographic extent of stressors is likely a minimum estimate. Buffer distances used in the analysis may be a conservative estimate, as the original studies on which the estimates were based were not designed to measure maximum detectable distances of human effects. Also, it was assumed that the influence of human activities diffuses equally in all directions, although it is more likely that alongshore currents and river plumes influence the diffusion of effects, particularly close to the coastline.

Overall, the cumulative impact map should be considered a conservative estimate of human use impacts within the Area of Interest. Despite the limitations outlined above, this mapping exercise can identify areas of particular concern where a high degree of cumulative impacts from multiple overlapping human activities are to be expected.

#### Climate change

Climate change models project future environmental conditions but are dependent upon global greenhouse gas (GHG) mitigations and intergovernmental decision-making related to mitigation targets and action. The climate model used here was under more extreme conditions (RCP 8.5), but if GHG mitigation targets are met, then more optimistic scenarios could be considered. In addition, a 'moderate' condition Earth System Model was used for predictions, whereas others predict greater oceanographic shifts (e.g., warm water inputs relating to Gulf Stream strength). The resolution on the biophysical model means that it is not possible to predict bay or at-farm level environmental changes, and it is noted that while it is unlikely to significantly change following pressure adjustments, bottom aragonite and calcite saturation states at depth require adjustment. Climate vulnerability assessments are ongoing, and more research across life stages and climate scenarios would be beneficial to determine the potential for adaptation.

## CONCLUSIONS

### Terms of Reference 1

*Based on the available data for the sites and scientific information, what are the predicted exposure zones from the use of approved fish health treatment products in the marine environment, and the potential consequences to susceptible species?*

First order calculations were used to provide an order of magnitude estimate of areas that may be exposed to registered fish health treatment products (i.e., deposited in-feed drugs and/or bath pesticides), if used. These areas do not estimate impact (i.e., likelihood, magnitude, or persistence).

Benthic predicted exposure zones (benthic-PEZ) were calculated for each proposed site to estimate the size and location of benthic areas that may be exposed to the deposition of in-feed drugs via medicated feed waste and feces released from a site. Based on these estimates, medicated feed waste and feces could travel up to 572 m to 1.38 km and 5.93 km to 21.25 km from the proposed sites, respectively. Pelagic predicted exposure zones (pelagic-PEZ) were calculated for each proposed site to estimate the size and location of pelagic areas that may be exposed to potentially toxic levels of bath pesticides via tarp bath treatments. Based on these estimates, azamethiphos and hydrogen peroxide could travel up to 10.87 km to 13.50 km and 14.86 km to 24.0 km from the proposed sites, respectively. These pelagic-PEZs include areas of the seabed less than 25.74 m and 37.1 m deep that may also be exposed to toxic levels of azamethiphos and hydrogen peroxide, respectively.

Proposed site #1452 has the largest PEZs, attributed to the highest maximum current speed observed at this site. When all sites are considered together, most of the seabed and water column in St. Mary's Bay has the potential to be exposed to fish health treatment products, if used. Transport may occur to the north side of Digby Neck and into the Bay of Fundy via Petit Passage and Grand Passage, as well as southward outside the mouth of St. Mary's Bay; however, exposure is likely limited to within 20 kilometers of the northern coastline along Digby Neck and Long Island. The intensity of exposure is expected to be highest near the proposed net-pen arrays and decrease as the distance from the net-pens increases, except for areas of anticipated overlap between PEZs from adjacent aquaculture sites. In those areas, the potential exists for chronic exposure from multiple treatments and for cumulative effects if net-pens are treated consecutively over a short period of time.

Non-target species such as crustaceans and bivalves within the PEZs may be exposed to in-feed drugs deposited on the seabed (juvenile and adult stages). They may also be exposed to pesticides in the water column (larval stages) and on the seabed in shallower areas (juvenile and adult stages). Lobster densities and abundances of all life stages, including berried females, are higher in the St. Mary's Bay region than the outside area. Preliminary observations have shown Lobster settlement to be five times higher on collectors set near the opening of Petit Passage than on collectors set further to the northeast on St. Mary's Bay Shoal, inferring that pelagic larval stages would also have been in the overlying water column. Planktonic Lobster larvae are likely in the water column from July through late-September, with the highest abundances from mid-July to mid-August. All life stages of Lobster are anticipated to be present during the summer months, with a seasonal movement likely for adult Lobster as they move to the deeper offshore waters during the coldest months. Projected increases in seawater temperature are anticipated to affect distribution of adult Lobster, including berried females, and further increase their likelihood of presence and duration in the bay. Seasonal licensed Lobster holding facilities are also located within the PEZs.

St. Mary's Bay provides significant habitat for all life stages of Scallop, with high abundances of young and adult Scallop; Scallop in this area have some of the highest physical quality attributes in all of the Bay of Fundy and approaches. St. Mary's Bay also represents an integral component of the broodstock for Scallop in and around SPA 3. Annual spawning typically occurs from late August to October, and larval settlement takes approximately 40 days.

Other crustaceans such as shrimp, krill and crabs within the PEZs could also be exposed. High concentrations of krill are observed in the Grand Manan Basin/Brier Island area, in particular Northern Krill. Similarly, other bivalves such as Soft-shell Clam, Quahog, Bar Clam, and Blue Mussel could also be exposed.

In-feed drugs such as emamectin benzoate (EMB) have documented toxic effects on non-target crustaceans, including premature moulting, reduced growth rates, and mortality. The limited data available suggests bivalves are not considered sensitive to EMB. Azamethiphos and hydrogen peroxide have documented morbidity and mortality effects on non-target crustaceans, including all life stages of lobster and a variety of shrimp species. Berried female lobsters specifically are more sensitive to azamethiphos during the summer months based on reproductive and moulting cycles. Limited data on the effects of azamethiphos and hydrogen peroxide exposure on bivalves also suggests impacts are possible in both acute (hydrogen peroxide) and chronic scenarios (azamethiphos and hydrogen peroxide).

A review of in-feed drug and pesticide use data in Nova Scotia between 2018 and 2022 shows that use has been minimal at the existing aquaculture sites in St. Mary's Bay. One site in St. Mary's Bay reported a single use of an in-feed pest control product, and no sites have used bath pesticides.

### Terms of Reference 2

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

Benthic-PEZs were calculated for each proposed site to estimate the size and location of benthic areas that may be exposed to the deposition of organic matter via feed waste and feces released from a site. These zones are the same as those for medicated feed waste and feces.

The Brier Island/Digby Neck EBSA is within the immediate vicinity of the proposed aquaculture sites, with proposed sites #1451 and #1452 located directly within the EBSA boundary. Significant benthic features observed within the EBSA that may be vulnerable to the deposition of organic matter include a Significant Benthic Area for sponges, a Horse Mussel reef, and an eelgrass bed. While these species and habitats are located within the broader benthic-PEZs based on feces and may be exposed to increased sedimentation levels, this is unlikely to occur at levels where changes to oxic-state and sediment geochemistry, or smothering are predicted given their distance from the proposed sites. Moreover, they have not been observed within any of the benthic-feed PEZs where the intensity of deposition is expected to be highest. The southern portion of the benthic-PEZ based on feces for proposed site #1452 also intersects with the northern tip of Southwest Scotian Shelf Coastal EBSA. While there may be some degree of exposure, impacts from organic matter deposition are unlikely.

All life stages of Lobster, including adults, are anticipated to be present in the vicinity of the proposed sites and within the feces and feed benthic-PEZs during the summer months. While Lobster are not unique to St. Mary's Bay, Lobster survey efforts consistently report higher Lobster densities in the St. Mary's Bay region when compared to both outside of St. Mary's Bay and the offshore area. Shelter-restricted benthic juvenile lobsters are more vulnerable to localized impacts such as hypoxia from increased organic loading due to their restricted movement and preferential selection for shelter. Therefore, changes in benthic oxygen conditions may have impacts on early benthic recruit survival. While adult lobsters are more likely to move to avoid suboptimal conditions, it is unclear how alterations in benthic habitat from increased organic matter deposition may impact Lobster habitat conditions and overall abundance and distribution.

Three of the four proposed sites, and consequently the benthic-PEZs, directly overlap areas with high abundances of young and adult Scallop; these sites also overlap areas important to the wild Scallop fisheries in the area. While Scallop are not unique to St. Mary's Bay, Scallop in St. Mary's Bay have significantly higher condition (quality) and egg production as compared to Scallop in areas outside of the bay, demonstrating the productivity and importance of St. Mary's Bay habitat for Scallop. The sedentary nature of Scallop makes them vulnerable to increased organic matter deposition and any associated changes in sediment oxygen concentrations, particularly within the smaller feed waste benthic-PEZs.

A review of Nova Scotia Environmental Monitoring Program data from 2009 to 2022 suggests that the existing sites in St. Mary's Bay have not historically exhibited adverse organic enrichment effects on marine sediments in the area.

## Terms of Reference 3

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

A cumulative impact mapping analysis combined the spatial intensity of 33 stressors across 15 pelagic and benthic habitats in St. Mary's Bay. A high degree of spatial overlap among all aquaculture sites, as well as with most other stressors occurring in the Area of Interest, was identified. With the addition of the four proposed new sites, the cumulative impact score increased primarily in the central zone of the Area of Interest, on both the east and west sides of Digby Neck, and particularly in the vicinity of proposed site #1451.

After accounting for the proposed aquaculture sites, across all habitats, stressors from the fishing sector collectively made the largest contribution to the cumulative impact score (43%), followed by the climate (28.5%), marine (16%), coastal (8.2%), and land (4.4%) sectors, respectively. In relation to other stressors, finfish aquaculture (which is incorporated within the marine stressor category) contributes 5.1% to the total cumulative impact score across all habitats within the Area of Interest. This increases to 8.3% of the total score within a localized Area of Potential Impact, further supporting anticipated increased impacts to benthic and pelagic habitats from finfish aquaculture activities within a localized area around the proposed leases.

St. Mary's Bay presents a complex multi-stressor environment where climate variables, fishing, and marine stressors may interact to reduce non-target species abundance, biomass, and/or diversity in pelagic and hard-, mixed-, and soft-bottom habitats.

Currently, the overlap of warming waters, acidification, and bottom-contact fishing in St. Mary's Bay has potential negative impacts (e.g., increased benthic disturbance, incidental mortality, changes to water quality, promotion of invasive species) on larval, juvenile, and adult life stages of benthic invertebrates, including Lobster and Scallop, that may affect productivity, recruitment, and abundance in the region. Aquaculture activities will likely add further pressure to both benthic and pelagic habitats in areas within close proximity to the proposed leases.

## Terms of Reference 4

*To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic Species at Risk listed under Schedule 1 of the* Species at Risk Act *make use of the area, and for what duration and when?*

Cetacean, sea turtle, and shark Species at Risk listed under Schedule 1 of the *Species at Risk Act*, and potentially within the vicinity of the proposed aquaculture sites, include North Atlantic Right Whale (Endangered), Fin Whale (Special Concern), Blue Whale (Endangered), Leatherback Sea Turtle (Endangered), and White Shark (Endangered).

North Atlantic Right Whale, Fin Whale, and Blue Whale frequent both offshore and coastal waters, particularly to feed and mate, and may be present in the Bay of Fundy in spring, summer and fall. The high concentration and diversity of copepods and other zooplankton attract large aggregations of cetaceans to the Digby Neck/Brier Island area. Preferential habitat for North Atlantic Right Whale is within waters generally deeper than approximately 36 m, although they frequent water depths of approximately 18 m and less towards shore. Sightings have been reported within St. Mary's Bay in the vicinity of the proposed sites, and it is anticipated that the actual number and frequency of North Atlantic Right Whale that utilize St. Mary's Bay in any given year are higher.

Leatherback Sea Turtle are the most common sea turtle recorded in Nova Scotian coastal waters. The Bay of Fundy, however, is not considered to be important habitat, and hosts relatively few foraging Leatherback turtles during the summer and fall. Leatherback turtles have a median sightings water depth of over 100 m, and reported sightings in the vicinity of St. Mary's Bay have not been near the proposed aquaculture sites.

White Shark undertake seasonal north-south migration that brings them into Canadian waters from June to November to feed on abundant prey. Acoustic receivers were deployed at the four proposed aquaculture sites to confirm the presence of White Shark in St. Mary's Bay. A total of 19 unique White Shark were detected in the area from early June to late October. The number of detections decreased from west (site #1452) to east (site #1449). Hence, sites that were more exposed to the Bay of Fundy had higher detections When also considering additional data from the Centre for Marine Applied Research near proposed site #1452, a total of 32 unique individual White Shark were detected in St. Mary's Bay over a period of two years, with at least one individual returning to the same area three years later. The relatively low number of detections for each White Shark suggests that they are only briefly transiting through the area.

Reports of entanglement of marine mammals, sea turtles, and sharks in marine finfish aquaculture gear in Atlantic Canada remain low or nil for these large-bodied species.

## Terms of Reference 5

*What populations of conspecifics are within a geographic range that escapes are likely to migrate to? What is the size and status trends of those populations in the escape exposure zone for the proposed sites? Are any of these populations listed under Schedule 1 of the* Species at Risk Act*? What are the potential impacts and/or risks to these wild populations from direct genetic interactions associated with any escaped farmed fish from the proposed aquaculture activity?*

The four proposed new finfish aquaculture sites are physically located within range of the proposed Nova Scotia SU–W DU (DU–14B) of wild Atlantic Salmon and Salmon Fishing Area (SFA) 21. The proposed sites are also within distances of rivers in the OBOF (DU–16) and IBOF (DU–15) DUs that escaped farmed Salmon could travel to. These wild Atlantic Salmon populations remain critically low. The Southern Upland (SU) and OBOF Atlantic Salmon populations were assessed in 2010 by COSEWIC as Endangered and are consideration for listing under *SARA*. The IBOF population has been listed as Endangered under *SARA* since 2003. Finfish aquaculture has been identified as a threat to the recovery of wild Atlantic Salmon populations.

Assuming the four proposed new aquaculture sites being in production, the propagule pressure experienced by nearly all rivers in the DFO Maritimes Region will increase, albeit to a small amount in rivers beyond about 100 km. Propagule pressure for rivers within 100 km of the proposed sites will increase by an average of approximately 24%, those within 50 km by an average of approximately 48%, and the largest increases will be approximately 67% for the Sissiboo River.

Predictions from the dispersal model suggest that at both escape rates tested (i.e. 0.2 and 0.4 escapees/tonne of production), all rivers within the proposed SU–W DU to the west of the planned locations are currently exceeding the 10% threshold, even without the four proposed sites in operation. This is also true of the majority of rivers extending eastward up to the Mersey River, and most of the rivers in the OBOF DU. Previous modelling has suggested exceeding the 10% threshold for proportion of escapes may lead to enduring demographic and genetic impacts.

The addition of the four proposed sites is predicted to result in an increase in the proportion of escapees in most of the rivers within 200 km of the St. Mary's Bay sites, both in the proposed SU–W and OBOF DUs. At the lower modelled escape rate of 0.2 escapees per tonne of production, the number of escapees in rivers is estimated to increase by 62 and 9 for the proposed SU–W and OBOF DUs, respectively. At the higher modelled escape rate of 0.4 escapees per tonne of production, the number of escapees in rivers is estimated to increase by 123, 10, and 2 for the proposed SU–W, OBOF, and IBOF DUs, respectively. For the proposed SU–W DU, this would increase the number of rivers above the 10% threshold by 1 at the lower escape rate and 2 at the higher escape rate. For OBOF, the number of rivers above the threshold is not expected to change. For IBOF, there would be no change to the number of rivers above the threshold at the lower escape rate, but an increase by 1 river at the higher escape rate.

A recent risk assessment concluded that at current production levels within DFO Maritimes Region, the risk to abundance for the proposed SU–W, the OBOF, and the IBOF DUs ranged from low to high, while the risk to genetic character ranged from medium to high (DFO 2024). Modelling suggests that demographic and genetic impacts will increase with the proportion of escapees entering rivers. Therefore, for all rivers in which the dispersal model predicts increases in percentage escapees, greater impacts on the wild populations are likely. Moreover, even where the Atlantic Salmon populations are extirpated, increases in escapees may hinder any future recovery efforts.

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# APPENDIX I: SUMMARY TABLES OF CHEMICAL COMPOUNDS AUTHORIZED FOR USE AT MARINE FINFISH AQUACULTURE SITES IN CANADA

| ANTIBIOTICS<br>Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| Erythromycin | Macrolide antibiotic from the bacterium *Streptomyces erythreus* used to treat gram-positive and non-enteric gram-negative bacteria.<br><br>It interferes with bacterial protein synthesis by binding to the 50S subunit of the bacterial ribosome (Armstrong et al. 2005).<br><br>Used for: Bacterial Kidney Disease (BKD). | Primarily used at land-based facilities, injectable only for brood fish and fish not destined for human consumption (DFO 2021).<br><br>50-100 mg/kg body weight per day for approximately 21 days (DFO 2021)<br><br>Delivered in feed. | More persistent in seawater than in freshwater: Half-life of 2.6 to 125.9 days in sea water and 6.8 to 37.9 days in freshwater because of its higher pH (pH 8–10 compared to pH 6.5–7.5) (Kwon 2016). |
| Florfenicol | Broad-spectrum antibiotic effective against both gram-positive and gram-negative bacteria, including some strains that are resistant to oxytetracycline (Lu et al. 2021).<br><br>It binds reversibly to the peptidyltransferase center at the 50S ribosomal subunit and thus inhibits bacterial protein biosynthesis (Zeng et al. 2019).<br><br>Used for: Furunculosis (*Aeromonas salmonicida)*, Vibrio sp. (e.g., *Vibrio* | 10 mg florfenicol per kg of body weight per day for 10 consecutive days.<br><br>Delivered in feed. | Half-life of 4.5 days in sediment (Armstrong et al. 2005) |

| ANTIBIOTICS Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| | *anguillarum*), salmonid piscirickettsiosis (*Piscirickettsia salmonis*), tenacibaculosis, and BKD (Armstrong et al. 2005, Lunestad and Samuelsen 2008, Mabrok et al. 2023, Rozas and Enríquez, 2014). | | |
| Oxytetracycline hydrochloride | Broad-spectrum antibiotic used against gram-positive and gram-negative bacteria, belonging to the tetracyclines class.<br><br>Tetracyclines interfere with protein synthesis by reversibly binding to the 30S ribosomal subunit, thereby blocking the binding of the aminoacyl tRNA to the mRNA/ribosome complex. Oxytetracycline is poorly metabolized or unmetabolized by fish. (Leal et al. 2019).<br><br>Used for: Furunculosis (*Aeromonas salmonicida*), Vibrio sp. (e.g., *Vibrio anguillarum*), salmonid piscirickettsiosis (*Piscirickettsia salmonis*), and BKD (DFO 2021). | 75 mg of oxytetracycline hydrochloride per kg of fish body weight per day for 10 consecutive days.<br><br>Typically delivered in feed, however can also be administered by bath and injection (Armstrong et al. 2005). | Half-life of 14 to 364 days and up to 419 days under anoxic conditions in sediment (Coyne et al. 2001).<br><br>Half-life of 30 to 319 hours in water (Schmidt et al. 2012). |
| Sulfadimethoxine (Ormetoprim) | Broad spectrum antibacterial agent effective against gram-negative bacteria. | 15 mg of active ingredients per kg of live body weight of fish per day for 10 | Sulfadimethoxine and ormetoprim stable at salinities of 0 and 30 ppt and at pHs of 2, 7, and 12 for a period of 1 year. |

| ANTIBIOTICS<br>Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| | It inhibits folic acid metabolism at two different levels (Guardabassi and Courvalin 2006, Todar 2020).<br><br>Used for: Furunculosis (*Aeromonas salmonicida*) strains susceptible to the sulfadimethoxine and ormetoprim combination, Vibrio sp. (e.g., *Vibrio anguillarum*), and other bacterial pathogens (Love et al. 2020). | consecutive days (Burridge and Holmes 2023).<br><br>Delivered in feed. | Sulfadimethoxine was stable at 25 °C and 37 °C, but showed a marked decrease in concentration at 4 °C. Warming of the 4 °C sample resulted in a return to original drug levels indicating that the drug had redistributed out of the aquatic phase at the lower temperature. Ormetoprim concentrations were stable at all temperatures evaluated.<br><br>No residue of drug (Romet 30) in sediments 21–62 days after treatment at 2 farm sites (Capone et al. 1996).<br><br>Potential environmental half-lives for these drugs must exceed 1 year and are likely to be several years (Bakal and Stoskopf 2001). |
| Sulfadiazine (Trimethoprim) | These antibiotics act by inhibiting folic acid metabolism at two different levels.<br><br>Used for: Furunculosis (*Aeromonas salmonicida*), enteric redmouth (*Yersinia ruckeri*), and Vibrosis (*Vibrio* spp., *Cytophaga* spp., *Flexibacter* spp.) (Armstrong et al. 2005). | Administered as sulfadiazine:trimethoprim in a 5:1 ratio.<br><br>The typical dose for Tribrissen (the formulation) is 30–75 mg per kg of body weight per day for 5 to 10 days (Armstrong et al. 2005).<br><br>Delivered in feed for finfish and as a bath treatment for molluscs in hatcheries (Armstrong et al. 2005). | Half-life in sediment of 50–75 days at 0–1 cm sediment depth and 100 days at 5–7 cm sediment depth (Hektoen et al. 1995). |

| IN-FEED PEST CONTROL DRUGS (ANTIPARASITICS) Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| Emamectin benzoate (EMB) | Emamectin benzoate belongs to the family of avermectins.<br><br>The general mode of action of these compounds is binding to glutamate-gated chloride ion channels in invertebrates altering nerve cells and interrupting nerve impulses (Burridge et al. 2010, Martin et al. 2002, Roberts and Hutson 1999), which can lead to paralysis and death of sea lice. They also have the potential to act as an endocrine disruptor.<br><br>Used for: Parasitic control of sea lice. | 50 µg per kg fish body weight per day for 7 consecutive days (Burridge and Holmes 2023). | Half-life in sediment from 188.6 days to 510.5 (up to greater than 6000 days in the presence of oxytetracycline in sediments) (Benskin et al. 2016, Hamoutene et al. 2023a, 2023b).<br><br>Half-life in water of up to 120 h (McCormick et al. 2023). |
| Ivermectin | Ivermectin belongs to the family of avermectins.<br><br>The general mode of action of these compounds is binding to glutamate-gated chloride ion channels in invertebrates altering nerve cells and interrupting nerve impulses (Burridge et al. 2010, Martin et al. 2002, Roberts and Hutson 1999), which can lead to paralysis and death of sea lice. They also have the potential to act as an endocrine disruptor. | 0.1 mg per kg fish body weight divided into two treatments of 0.05 mg per kg separated by 3 to 4 days (Haya et al. 2005). | Half-life in sediment of 100 days (Davies et al. 1998).<br><br>Half-life in sediment of 93 to 240 days in the dark at 22 °C (Halley et al. 1989). |

| IN-FEED PEST CONTROL DRUGS (ANTIPARASITICS) Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| | Used for: Parasitic control of sea lice. Effective against chalimus as well as adult stages of the parasite (Haya et al. 2005). | | |
| Teflubenzuron | Teflubenzuron acts by interfering with the synthesis of chitin in sea lice and are effective against all stages of the parasite that undergo moulting, including the larval and pre-adult stages (Samuelsen et al. 2015).<br><br>Used for: Parasitic control of sea lice. | 2 g per kg of feed. Recommended dosing regimen for Atlantic Salmon is 10 mg per kg of fish daily for 7 consecutive days (Samuelson et al. 2015). | Teflubenzuron has low water solubility, a strong affinity to organic substrates in water and sediments, and it, along with its degradation products, have been found to be more persistent in sediment than in water alone (SEPA 1999).<br><br>Persistence has been 6 months in an area less than 100 m from treated cage (SEPA 1999), but could last more than 4 years (Kingsbury et al. 2023). |
| Praziquantel | Praziquantel is a synthetic heterocyclic broad-spectrum anthelminthic agent. It is thought to disrupt calcium ion homeostasis in the worm and antagonises voltage-gated calcium channels leading to uncontrolled muscle contraction and paralysis (Thomas and Timson 2018).<br><br>Used for: Parasitic worm control (i.e., infestations of cestodes) (Norbury et al. 2022). | 75 mg per kg fish body weight for 6 consecutive days (in freshwater facilities and marine cages) (Burridge and Holmes 2023). | Praziquantel is rapidly metabolised by vertebrates and the parent compound rapidly degrades in seawater (Frohberg 1984).<br><br>Degradation in specific aquatic environments has not been thoroughly studied (Norbury et al. 2022) but seems to be dependent on the presence of microbial populations rather than an inherent instability in seawater; no drop in concentration after 15 days in a sterile system and little degradation at colder temperatures (Thomas et al. 2016). |

| BATH PESTICIDES (ANTIPARASITICS) Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| Hydrogen peroxide | The mode of action for hydrogen peroxide is mechanical by producing air bubbles in the organism and/or presents as oxidative stress in the exposed organism due to its reactive oxidizing ability (Burridge et al. 2014, Fedoseeva and Stom 2013, Gebauer et al. 2017). Most evidence supports the induction of mechanical paralysis when bubbles form in the gut and hemolymph, causing the sea lice to release and float to the surface (Haya et al. 2005).<br><br>Used for: Parasitic control of sea lice, though not effective on larval sea lice and is inconsistent against pre-adult and adult stages (Haya et al. 2005). It is also authorized for the treatment of fungal infections of fish and their eggs in hatcheries at different dosages than those reported here (Haya et al. 2005). | Registered dosage of 1200 to 1800 mg/L (Hamoutene et al. 2021).<br><br>Typically repeated at 3–4 week intervals (Haya et al. 2005). | Half-life in seawater of approximately seven days or greater, and degrades to oxygen and water (Haya et al. 2005, Lyons et al. 2014).<br><br>Not effective below 10°C. |
| Azamethiphos | Azamethiphos is an organophosphate pesticide affecting the nervous system of the pest, causing paralysis and death by | Application duration of 30 to 60 minutes at 0.2 ppm product (100 µg/L azamethiphos) in well boats and fully enclosed tarped | Breaks down by hydrolysis in water with a half-life of 8.9 days (PMRA 2016). |

| BATH PESTICIDES (ANTIPARASITICS) Active Ingredient | Mode of Action and Target | Dosage and Delivery System | Half-lives / Degradation / Metabolites |
|---|---|---|---|
| | inhibiting acetylcholinesterase and interfering with nerve function (PMRA 2016). It is mainly active through contact (PMRA 2016).<br><br>Used for: Parasitic control of sea lice. | net-pens, or at 0.3 ppm product (150 µg/L azamethiphos) in open-bottomed skirted net pens. | |

| DISINFECTANTS, ANTIFOULANTS, ANAESTHETICS Active Ingredient | Mode of Action and Usage | Dosage and delivery system | Half-lives/ Degradation/ Metabolites |
|---|---|---|---|
| Tricaine Methanesulfonate (TMS) | TMS (MS-222), [3-aminobenzoic acidethyl ester methanesulfonate] is the most widely used fish anesthetic, and it is extremely effective for rapid induction of deep anesthesia.<br><br>Used for: Anesthetic or sedation. | Between 25 to 100 mg/L for 3 minutes induction time (Ackerman 2017).<br><br>A typical lethal dose for salmonids (euthanasia) is 400 - 500 mg/L (Akerman 2017).<br><br>Bath applications. | No information available. |
| Metomidate Hydrochloride | Metomidate (dl-1-(1-phenylethyl)-5-(metoxycarbonyl) imidazole hydrochloride) is a fast-acting water-soluble non-barbiturate hypnotic (Mattson and Ripple 1989, Knoph 1995, Massee et al. 1995) that can block cortisol synthesis (Thomas and Robertson 1991, Olsen et al. | Sedation Concentrations: 0.25 to 1 mg/L (Akerman 2017).<br>Anesthesia Concentrations: 5 to 10 mg /L (Akerman 2017).<br><br>Bath applications. | No information available. |

| DISINFECTANTS, ANTIFOULANTS, ANAESTHETICS Active Ingredient | Mode of Action and Usage | Dosage and delivery system | Half-lives/ Degradation/ Metabolites |
|---|---|---|---|
| | 1995, Nilssen et al. 1996). It can also prevent handling related glucose increase (Thomas and Robertson 1991, Nilssen et al. 1996) but does not have proven analgesic properties (Horsberg and Samuelsen 1999).<br><br>Used for: Anesthetic or sedation. | | |
| Polyvinylpyrrolidone-Iodine | Ovadine™ (Active Ingredient: 10% Povidone-Iodine, 1% available iodine) is a polyvinylpyrrolidone-iodine complex intended for use in aquaculture as a fish-egg disinfectant for salmonids of the genera *Salmo* and *Oncorhynchus*.<br><br>Used for: Disinfectant for fish eggs against spread of several diseases and viruses such as *Aeromonas salmonicid* (Infectious Salmon Anemia Virus) associated with fish-egg surfaces. | Dilute 10 mL in 1 L water (for 100 ppm available iodine) and recommended usage is to rinse eggs in a diluted volume ratio of 4:1 ovadine solution to eggs.<br><br>Bath applications. | No information available. |
| Potassium Monopersulphate | Virkon is a multipurpose disinfectant containing potassium peroxymonosulfate (an oxidizing agent), sodium | A 1% Virkon® Aquatic solution for cleaning and disinfection of surfaces associated with aquaculture including: tanks, vehicles, | Virkon can be deactivated by organic matter and reduced to environmental salts after 4 to 24hrs (Stockton and Moffitt. 2013). |

| DISINFECTANTS, ANTIFOULANTS, ANAESTHETICS Active Ingredient | Mode of Action and Usage | Dosage and delivery system | Half-lives/ Degradation/ Metabolites |
|---|---|---|---|
| | dodecylbenzenesulfonate (a surfactant), sulfamic acid (a cleaning agent), malic acid, sodium chloride and inorganic buffers such as sodium hexameta phosphate.<br><br>The mix of chemicals works together as complex chemical pathway called the Haber-Will-Statter Reaction (acid-peroxygen system) which releases 6 biocides, cyclically, killing microorganisms. (Stockton-Fiti and Moffitt 2017).<br><br>Used for: Equipment disinfectant against viruses, bacteria, fungi and mold. | boats, nets, boots, waders, dive suits, & other equipment.<br><br>General surface disinfectant. | |
| Ethanol-Iodine (Buffodine (10%)) | Wescodyne is an iodophor compound that contains both iodine (contains 1.6% titratable iodine as its active ingredient) and a non-ionic surface-active agent (nonylphenoxypoly(ethylene oxy)ethanol-iodine). It works to increase the bactericidal activity of iodine by helping it penetrate lipids. They also reduce the vapour pressure of iodine which allows a slow release of free iodine over a | The prescribed concentrations range from 25 mg/L (as $I_2$) for several hours to 50 to 100 mg/L for 10 to 30 minutes (Denning 2008).<br><br>Only used in hatcheries (freshwater).<br><br>General surface disinfectant. | Wescodyne likely enters the marine environment via direct discharge in surface water; in concentrations that "may" cause risks to marine aquatic receptors in Atlantic Canada (Denning 2008).<br><br>$I_2$ is not persistent in soil or water (Government of Canada 2000 in Denning 2008). |

| DISINFECTANTS, ANTIFOULANTS, ANAESTHETICS Active Ingredient | Mode of Action and Usage | Dosage and delivery system | Half-lives/ Degradation/ Metabolites |
|---|---|---|---|
| | specific period. (Denning 2008).<br><br>Used for: Equipment disinfectant against viruses, bacteria, fungi and mold. | | |
| Sodium N-Chloro-P-Toluenesulfonamide | Chloramine-T, the sodium salt of N-chloro-p-toluenesulfonamide, is an antibacterial agent and disinfectant. When mixed with water, Chloramine-T dissolves forming hypochlorous acid which travels across cell walls ceasing enzyme activity and causing cellular death (Burridge et al. 2011).<br><br>Used for: Equipment disinfectant against viruses, bacteria, fungi and mold.<br><br>Also used to treat bacterial gill disease (*Flavobacterium columnare*) in freshwater fishes (Nayak et al. 2022). | Treatment concentrations for gill disease: 8.5 to 12 mg/L (Altinok 2004).<br><br>Only used in hatcheries (freshwater).<br><br>General surface disinfectant. | Chloramine-T may enter the aquatic environment via aquaculture effluent and has an estimated half-life of 1 to 2 days or less (Blok 1981). It also degrades rapidly in soils and shows poor adsorption and therefore is unlikely to be present in sediment (Schmidt et al. 2007).<br><br>The primary metabolite is p-TSA which has also has poor adsorption, but a lower toxicity and higher persistence (half-life between 132 days to 1 year) (Schmidt et al. 2007). |
| Bronopol | The mode of action of bronopol was considered to result from blocking thiol containing enzymes such as membrane bound dehydrogenase, causing alterations to the cell membrane, leading to cell | For eggs: Treat once daily at 50 mg bronopol per litre (1 ml product per 10 litres incubator water) for 30 minutes daily commencing 24 hours after fertilisation and until hatch. | Once diluted in a fixed volume of water, may be degraded by prolonged or repeated exposure to high intensity ultraviolet light (VMD 2023). |

| DISINFECTANTS, ANTIFOULANTS, ANAESTHETICS Active Ingredient | Mode of Action and Usage | Dosage and delivery system | Half-lives/ Degradation/ Metabolites |
|---|---|---|---|
| | leakage and destruction. The efficacy of bronopol against *Saprolegnia spp.* was dose-dependent. Resistance or a high level of tolerance in micro-organisms has not been reported with use of bronopol (VMD 2023).<br><br>Used for: Control of fungal infections (*Saprolegnia spp.*) for fish eggs. | For fish: Treat once daily at 20 mg bronopol per litre (1 ml product per 25 litres water) for 30 minutes daily, for up to 14 consecutive days. Do not use in smolting Atlantic salmon or rainbow trout alevins as studies have indicated increased toxicity at this stage.<br><br>Only used in hatcheries (freshwater).<br><br>Bath applications. | |
| Parasite-S<br><br>Formalin (Aqueous solution of formaldehyde) | PARASITE-S is the aqueous solution of formaldehyde gas and contains approximately 37% (by weight) of formaldehyde gas per weight of water and typically 6–14% methanol.<br><br>Used for: Treatment for parasites and fungal infections. | For fish: Concentration to apply to fish is between 170 to 250 µL/L for up to an hour.<br><br>For eggs: the concentration to apply is 100–2000 µL/L for up to 15 minutes.<br><br>Bath applications. | Half-life of formalin in natural environment is estimated to be 36 h (Masters 2004).<br><br>Formalin can reach the environment via effluent discharge; however biological degradation can occur in the aquatic environment via indirect photodegradation (Leal et al. 2018). |
| Supratect | There is no information presently on this product. It is described as a plant-based health product designed to improve the health of fish and their eggs in aquaculture facilities.<br><br>Tested at Huntsman. | Only used in hatcheries (freshwater).<br><br>Bath applications. | No information available. |

| DISINFECTANTS, ANTIFOULANTS, ANAESTHETICS Active Ingredient | Mode of Action and Usage | Dosage and delivery system | Half-lives/ Degradation/ Metabolites |
|---|---|---|---|
| | Used for: Treatment against "water mold" (*Saprolegniosis)*, fungus and Ich. | | |

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# APPENDIX II: SEQUENTIAL RIVER NUMBERS INCLUDED IN DISPERSAL MODEL FROM EASTERNMOST TO WESTERNMOST ALONG COASTS OF NEW BRUNSWICK AND NOVA SCOTIA

| River Name | River Number | Latitude | Longitude |
|---|---|---|---|
| St. Croix River (Charlotte Co.) | 1 | -67.17 | 45.16 |
| Dennis Stream | 2 | -67.26 | 45.19 |
| Waweig River | 3 | -67.14 | 45.22 |
| Chamcook Stream | 4 | -67.07 | 45.13 |
| Bocabec River | 5 | -66.99 | 45.18 |
| Digdeguash River | 6 | -66.96 | 45.19 |
| Magaguadavic River | 7 | -66.85 | 45.12 |
| Pocologan River | 8 | -66.59 | 45.12 |
| New River | 9 | -66.54 | 45.13 |
| Lepreau River | 10 | -66.46 | 45.17 |
| Musquash River | 11 | -66.25 | 45.18 |
| Saint John River | 12 | -66.04 | 45.25 |
| Nerepis River | 13 | -66.23 | 45.36 |
| Oromocto River | 14 | -66.48 | 45.86 |
| Nashwaak River | 15 | -66.63 | 45.95 |
| Nashwaaksis River | 16 | -66.66 | 45.97 |
| Keswick River | 17 | -66.82 | 45.99 |
| Little River (Sunbury Co) | 18 | -66.25 | 45.97 |
| Salmon River (Queens Co.) | 19 | -65.85 | 46.24 |
| Gaspereau River (Queens Co.) | 20 | -65.85 | 46.24 |
| Canaan River | 21 | -65.82 | 45.89 |
| Belleisle Creek | 22 | -65.85 | 45.65 |
| Hammond River | 23 | -65.90 | 45.50 |
| Kennebecasis River | 24 | -66.13 | 45.31 |
| Mispec River | 25 | -65.96 | 45.22 |
| Black River (Saint John Co.) | 26 | -65.81 | 45.26 |
| Emerson Creek | 27 | -65.78 | 45.26 |
| Gardner Creek | 28 | -65.72 | 45.28 |
| Tynemouth Creek | 29 | -65.65 | 45.29 |
| Mosher River (Saint John Co.) | 30 | -65.54 | 45.34 |
| Irish River | 31 | -65.53 | 45.36 |
| Big Salmon River | 32 | -65.40 | 45.42 |
| Little Salmon River | 33 | -65.28 | 45.47 |
| Quiddy River | 34 | -65.19 | 45.49 |
| Goose Creek | 35 | -65.16 | 45.51 |
| Goose River | 36 | -65.09 | 45.53 |
| Point Wolfe River | 37 | -65.02 | 45.55 |
| Upper Salmon River (Alma Par.) | 38 | -64.96 | 45.61 |
| West River (Albert Co.) | 39 | -64.85 | 45.65 |
| Shepody River | 40 | -64.67 | 45.74 |
| Crooked Creek | 41 | -64.75 | 45.73 |
| Sawmill Creek | 42 | -64.71 | 45.75 |
| Demoiselle Creek | 43 | -64.59 | 45.81 |
| Petitcodiac River | 45 | -64.66 | 45.96 |

| River Name | River Number | Latitude | Longitude |
|---|---|---|---|
| Memramcook River | 46 | -64.55 | 45.87 |
| Tantramar River | 47 | -64.33 | 45.86 |
| Nappan River | 48 | -64.25 | 45.76 |
| Maccan River | 49 | -64.26 | 45.76 |
| River Hebert | 50 | -64.33 | 45.75 |
| Apple River | 51 | -64.80 | 45.47 |
| Greville River | 52 | -64.55 | 45.40 |
| Fox River | 53 | -64.52 | 45.40 |
| Ramshead River (Ramsey) | 54 | -64.47 | 45.40 |
| Diligent River | 55 | -64.45 | 45.39 |
| Farrells River | 56 | -64.33 | 45.40 |
| Moose River (Cumberland Co.) | 57 | -64.19 | 45.40 |
| Harrington River | 58 | -64.10 | 45.41 |
| North River (Cumberland Co.) | 59 | -64.08 | 45.41 |
| East River (Colchester Co.) | 60 | -64.05 | 45.40 |
| Economy River | 61 | -63.90 | 45.38 |
| Little Bass River | 62 | -63.80 | 45.40 |
| Bass River | 63 | -63.78 | 45.40 |
| Portapique River | 64 | -63.71 | 45.39 |
| Great Village River | 65 | -63.61 | 45.39 |
| Debert River | 66 | -63.53 | 45.39 |
| Folly River | 67 | -63.53 | 45.39 |
| Chiganois River | 68 | -63.42 | 45.37 |
| Salmon River (Colchester Co.) | 69 | -63.37 | 45.36 |
| North River (Colchester Co.) | 70 | -63.29 | 45.38 |
| Shubenacadie River | 71 | -63.48 | 45.30 |
| Stewiacke River | 72 | -63.37 | 45.14 |
| Walton River | 73 | -64.01 | 45.23 |
| Avon River | 74 | -64.22 | 45.12 |
| Kennetcook River | 75 | -64.12 | 45.05 |
| St. Croix River (Hants Co.) | 77 | -64.13 | 45.00 |
| Gaspereau River (Kings Co.) | 78 | -65.85 | 46.24 |
| Cornwallis River | 79 | -64.39 | 45.10 |
| Annapolis River | 80 | -65.60 | 44.70 |
| Paradise Brook | 81 | -65.32 | 44.83 |
| Round Hill River | 82 | -65.43 | 44.77 |
| Lequille River | 83 | -65.52 | 44.74 |
| Moose River (Annapolis Co.) | 84 | -65.61 | 44.66 |
| Bear River | 85 | -65.68 | 44.62 |
| Acacia Brook | 86 | -65.75 | 44.59 |
| Sissiboo River | 87 | -66.01 | 44.44 |
| Belliveau River | 88 | -66.08 | 44.38 |
| Little Brook | 89 | -66.12 | 44.30 |
| Meteghan River | 90 | -66.14 | 44.22 |
| Salmon River (Digby Co.) | 91 | -66.17 | 44.05 |
| Chebogue River | 92 | -66.08 | 43.79 |
| Annis River | 93 | -66.00 | 43.85 |
| Tusket River | 94 | -65.98 | 43.86 |
| Barrington River | 95 | -65.58 | 43.56 |

| River Name | River Number | Latitude | Longitude |
|---|---|---|---|
| Clyde River | 96 | -65.47 | 43.60 |
| Roseway River | 97 | -65.34 | 43.77 |
| Jordan River | 98 | -65.24 | 43.80 |
| East River (Shelburne Co.) | 99 | -65.14 | 43.74 |
| Sable River | 100 | -65.05 | 43.83 |
| Broad River | 101 | -64.83 | 43.95 |
| Mersey River | 102 | -64.73 | 44.04 |
| Medway River | 103 | -64.64 | 44.14 |
| Petite Rivière | 104 | -64.45 | 44.23 |
| Lahave River | 105 | -64.49 | 44.37 |
| Mushamush River | 106 | -64.38 | 44.45 |
| Martins River | 107 | -64.33 | 44.49 |
| Vaughans River | 108 | -64.31 | 44.52 |
| Gold River | 109 | -64.33 | 44.55 |
| Middle River (Lunenburg Co.) | 110 | -64.29 | 44.56 |
| East River (Lunenburg Co.) | 111 | -64.17 | 44.59 |
| Little East River | 112 | -64.14 | 44.57 |
| Hubbards River | 113 | -64.06 | 44.64 |
| Ingram River | 114 | -63.97 | 44.67 |
| Indian River (Halifax Co.) | 115 | -63.91 | 44.69 |
| Woodens River | 116 | -63.92 | 44.59 |
| Oak Hill Run | 117 | -63.85 | 44.53 |
| Nine Mile River | 118 | -63.79 | 44.54 |
| Prospect River | 119 | -63.76 | 44.53 |
| Terence Bay River | 120 | -63.74 | 44.51 |
| Pennent River | 121 | -63.63 | 44.48 |
| Ketch Harbour River | 122 | -63.55 | 44.49 |
| Sackville River | 124 | -63.66 | 44.73 |
| Cow Bay River | 125 | -63.45 | 44.62 |
| Little Salmon River (Lake Major) | 126 | -63.45 | 44.68 |
| Lawrencetown Lake (Salmon River) | 127 | -63.38 | 44.69 |
| Porters Lake (East Brook) | 128 | -63.38 | 44.80 |
| Rocky Run (W. Brook Porters) | 129 | -63.38 | 44.81 |
| Chezzetcook River | 130 | -63.24 | 44.74 |
| Musquodoboit River | 131 | -63.14 | 44.79 |
| Salmon River (Halifax Co.) | 132 | -63.04 | 44.78 |
| Ship Hbr. River (L. Charlotte) | 133 | -62.88 | 44.81 |
| Tangier River | 134 | -62.71 | 44.80 |
| West Taylor Bay Brook | 135 | -62.62 | 44.85 |
| West River, Sheet Harbour | 136 | -62.54 | 44.92 |
| East River, Sheet Harbour | 137 | -62.52 | 44.92 |
| Halfway Brook | 138 | -62.45 | 44.87 |
| Salmon River (Port Dufferin) | 139 | -62.38 | 44.92 |
| Quoddy River | 140 | -62.35 | 44.93 |
| Necum Teuch (Smith Brook) | 141 | -62.27 | 44.94 |
| Moser River | 142 | -62.25 | 44.97 |
| Ecum Secum River | 143 | -62.17 | 44.98 |
| Liscomb River | 144 | -62.10 | 45.01 |
| Gaspereaux Brook | 145 | -65.85 | 46.24 |

| River Name | River Number | Latitude | Longitude |
|---|---|---|---|
| Gegogan Brook | 146 | -61.98 | 45.07 |
| Saint Marys River | 147 | -61.96 | 45.10 |
| Indian River (Guysborough Co.) | 148 | -61.77 | 45.11 |
| Country Harbour River | 149 | -61.80 | 45.24 |
| Isaacs Harbour River | 150 | -61.67 | 45.20 |
| New Harbour River | 151 | -61.46 | 45.18 |
| Larrys River | 152 | -61.37 | 45.22 |
| Cole Harbour River | 153 | -61.26 | 45.26 |
| Halfway Cove Brook | 154 | -61.44 | 45.35 |
| Salmon River (Guysborough Co.) | 155 | -61.47 | 45.36 |
| Guysborough | 156 | -61.49 | 45.38 |
| Roman Valley River | 157 | -61.61 | 45.46 |
| Clam Harbour River | 158 | -61.35 | 45.43 |
| Saint Francis River | 159 | -61.31 | 45.45 |
| Inhabitants River | 160 | -61.23 | 45.61 |
| False Bay Brook | 161 | -61.01 | 45.63 |
| River Tillard | 162 | -60.91 | 45.66 |
| Grand River | 163 | -60.63 | 45.61 |
| Saint Esprit | 164 | -60.49 | 45.66 |
| Marie Joseph Brook | 165 | -60.36 | 45.69 |
| Framboise River (Giant Lake) | 166 | -60.36 | 45.72 |
| Gerratt Brook | 167 | -59.98 | 45.92 |
| Lorraine Brook | 168 | -66.82 | 45.99 |
| Little Lorraine | 169 | -59.87 | 45.96 |
| Mira River | 171 | -59.97 | 46.03 |
| MacAskills Brook | 172 | -59.95 | 46.16 |
| Northwest Brook (River Ryan) | 173 | -60.08 | 46.22 |
| Sydney River | 174 | -60.23 | 46.11 |
| Grantmire Brook | 175 | -60.28 | 46.16 |
| Frenchvale Brook | 176 | -60.31 | 46.15 |
| Aconi Brook | 177 | -60.35 | 46.32 |
| MacIntosh Brook | 179 | -60.52 | 45.96 |
| Gillies Brook | 180 | -60.38 | 46.02 |
| Breac Brook | 181 | -60.53 | 45.92 |
| Toms Brook | 182 | -60.74 | 45.74 |
| MacNabs Brook | 183 | -60.72 | 45.73 |
| George | 184 | -60.83 | 45.73 |
| Scotts River | 185 | -60.87 | 45.75 |
| Black River (Richmond Co.) | 186 | -61.09 | 45.69 |
| River Denys | 187 | -61.09 | 45.86 |
| MacKinnons Brook | 188 | -60.90 | 45.94 |
| Washabuck River | 189 | -60.87 | 46.02 |
| Blues Brook | 191 | -61.14 | 45.94 |
| Skye River | 192 | -61.13 | 45.97 |
| Humes River | 193 | -60.94 | 46.05 |
| Middle River (Victoria Co.) | 194 | -60.90 | 46.08 |
| Baddeck River | 195 | -60.86 | 46.09 |
| North River (Victoria Co.) | 196 | -60.62 | 46.30 |
| River Bennett | 197 | -60.53 | 46.34 |

| River Name | River Number | Latitude | Longitude |
|---|---|---|---|
| Barachois River | 198 | -60.53 | 46.34 |
| Indian Brook | 199 | -60.53 | 46.37 |
| Ingonish River | 200 | -60.43 | 46.63 |
| Clyburn Brook | 201 | -60.40 | 46.66 |
| North Aspy River | 202 | -60.51 | 46.91 |
| Wilkie Brook | 203 | -60.46 | 46.94 |
| Salmon River (Victoria Co.) | 204 | -60.49 | 47.00 |

# APPENDIX III: COMPARISON OF PRESENT AND FUTURE BOTTOM AND SURFACE SEAWATER TEMPERATURE, ARAGONITE, AND CALCITE CALCIUM CARBONATE SATURATIONS IN ST. MARY'S BAY, NOVA SCOTIA

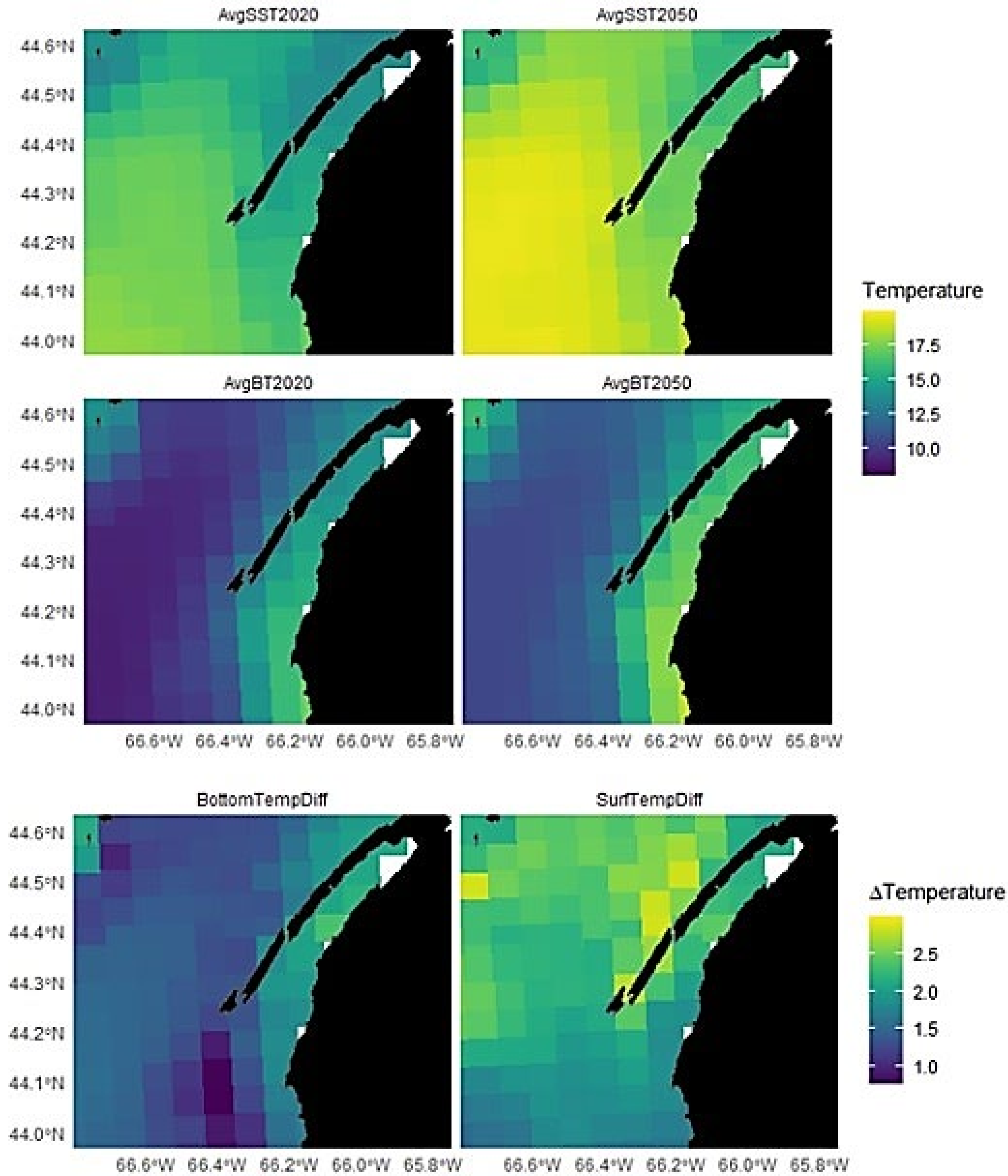


*Figure A3.1. Comparison of present (2020) and future (2050) surface seawater (top panel) and bottom seawater (middle panel) temperatures (°C), and projected temperature differences (°C) (bottom panel) at St. Mary's Bay from the GSL-BGCM. 2020 and 2050 conditions reflect summer averages from model using CanESM2 downscaling under RCP 8.5 scenarios. Values are plotted per 1/12° (approximately 54 km$^2$) cell.*

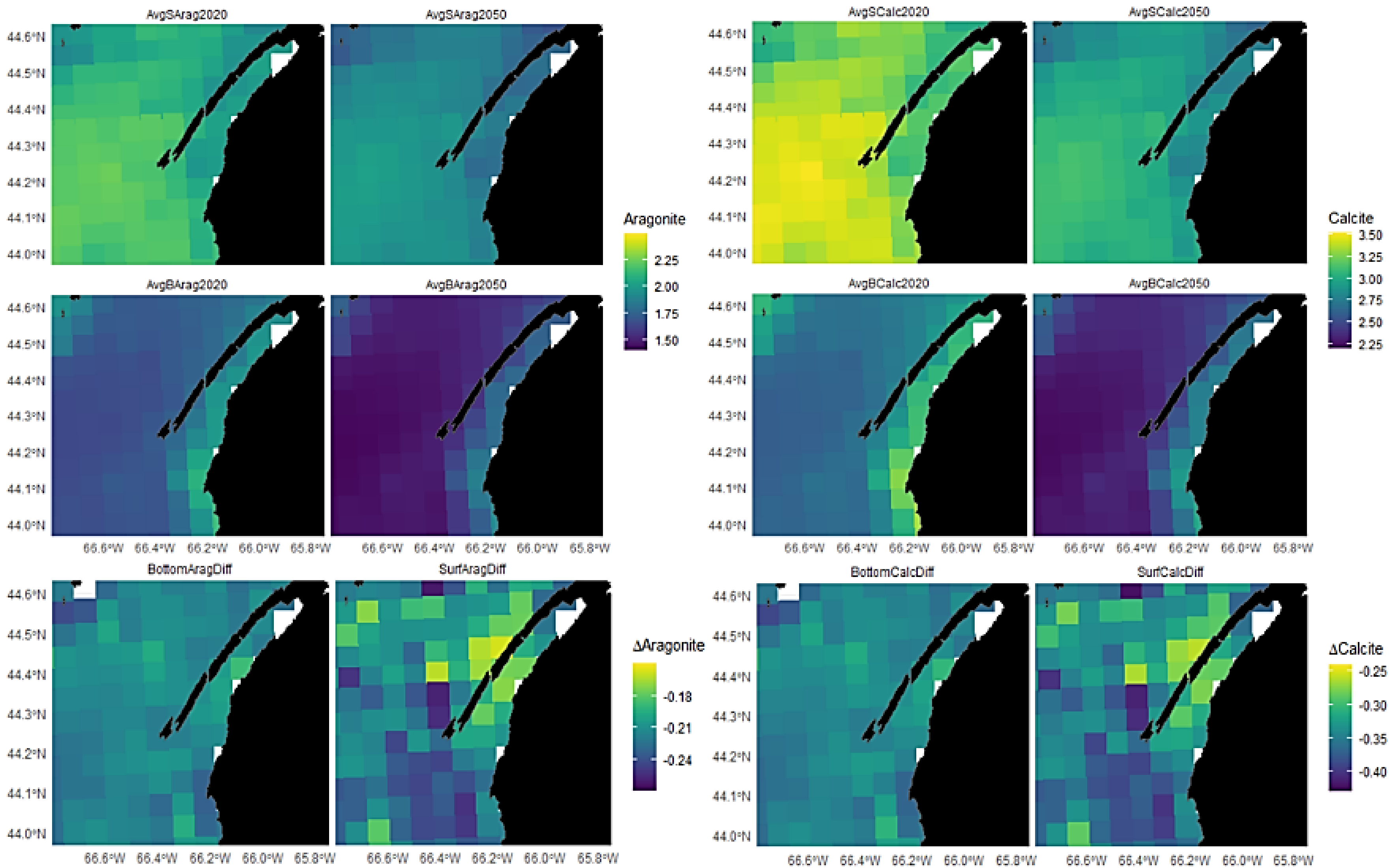


*Figure A3.2. Comparison of present (2020) and future (2050) bottom and surface seawater aragonite (left-hand panel) and calcite (right-hand panel) calcium carbonate saturations, and projected differences in St. Mary's Bay from the GSL-BGCM. 2020 and 2050 conditions reflect summer averages from model using CanESM2 downscaling under RCP 8.5 scenarios. Values are plotted per 1/12° (approximately 54 km²) cell.*

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