DFO MARITIMES REGION SCIENCE REVIEW OF THE PROPOSED MARINE FINFISH AQUACULTURE NEW SITES, WHYCOCOMAGH BAY, BRAS D'OR LAKES, NOVA SCOTIA

Context

We'koqma'q First Nation has made an application to the Province of Nova Scotia for the addition of two new sites (#1430 and #1431) in Whycocomagh Bay, Bras d'Or Lakes, Nova Scotia. This is in addition to their existing sites (#0814, #0845, and #0600), for which boundary amendment proposals were previously reviewed (DFO 2021b).

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

To help inform DFO's review of this application, the Regional Aquaculture Management Office has asked for DFO Science advice on the Predicted Exposure Zones (PEZs) associated with the proposed range of aquaculture activities, and the predicted impacts on susceptible fish and fish habitat, including sensitive Species at Risk (SAR) listed species, susceptible fishery species and the habitats that support them.

Specifically, the following questions are addressed:

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

Question 2. Based on the available information for each site, 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?

Question 3. How do the impacts on these species from the proposed aquaculture sites compare to impacts from other anthropogenic sources (including existing finfish farms)? Do the zones of influence overlap with these activities and if so, what are the potential consequences?

Question 4. To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic Species at Risk make use of the area, and for what duration and when?

Question 5. What populations of Salmonids are within a geographic range that escapees are likely to migrate to? What are 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*?

This Science Response Report results from the regional Science Response Process on June 21–22, 2021, DFO Maritimes Region Review of the Proposed Marine Finfish Aquaculture Sites, Whycocomagh Bay, Bras d'Or Lakes, Nova Scotia.

Background

We'koqma'q First Nation is requesting the addition of two new Rainbow Trout (*Oncorhynchus mykiss*) sites, #1430 North Aberdeen and #1431 South Aberdeen. The proposed sites are located in Whycocomagh Bay, Bras d'Or Lakes, Nova Scotia, to the east of Indian Island and Aberdeen. The proponent's overall development plan for Whycocomagh Bay also includes the amalgamation of the existing #0814, #0845, and #0600 sites into an expanded #0814x site to the west of Indian Island, which has already been reviewed separately from sites #1430 and #1431. The existing sites have operated for over a decade in the area. The location of the proposed #1430 North and #1431 South Aberdeen sites, and proximity to the #0814x site, is shown in Figure 1.

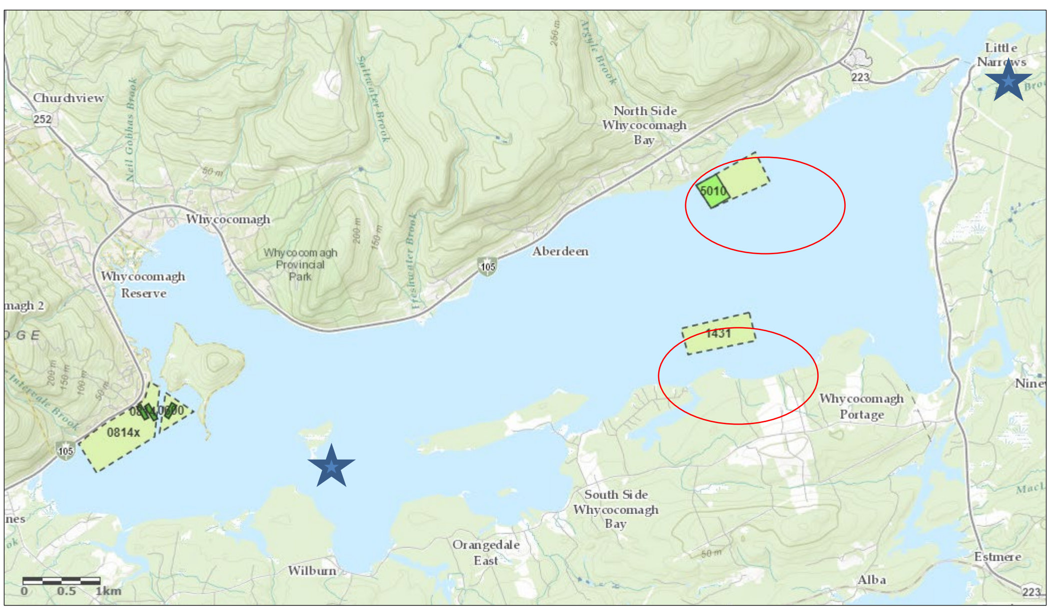

Figure 1. Map of finfish aquaculture site leases in Whycocomagh Bay, Bras d'Or Lakes, Nova Scotia. Light green polygons represent proposed finfish leases requested by We'koqma'q First Nation. Sites #1430 and #1431 are circled in red, and the others represent the proposed #0814x site. Experimental site #5010 is also shown as occupying a portion of the proposed #1430 site. Maps were retrieved from the Nova Scotia Department of Fisheries and Aquaculture Site Mapping Tool website on February 11, 2021. The stars denote an approximate location of shallow sills.

An experimental site (#5010) to evaluate the use of different sized polar circle cages has been operating in the location of the proposed #1430 North site since 2019, covering approximately 10 ha. The proposed #1430 and #1431 site additions would increase the total area under lease in the eastern end of the bay to approximately 68 ha. The lease infrastructure is currently proposed as one row of 10 cages at both #1430 and #1431; however, the cage array placement and configuration may not be static. The intent is for the stocked net-pen arrays to be variable in location within the lease boundaries to allow for fallowing of sections, based on results from environmental monitoring, while other sections within the leases are stocked. Figure 2 shows the site development plans with bathymetry.

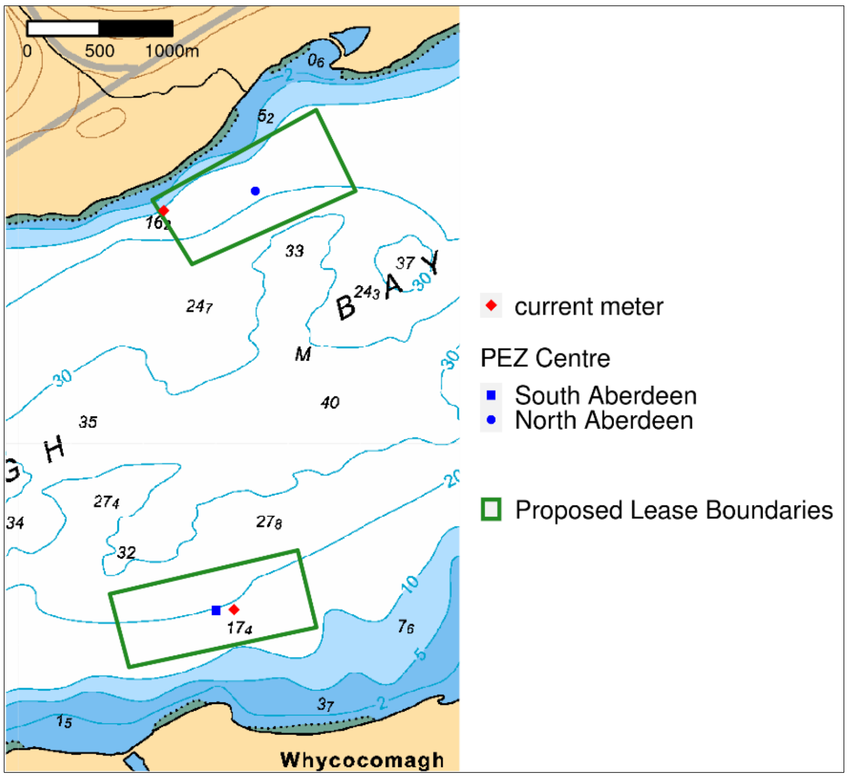

Figure 2. Proposed lease area (green) overlaid on CHS chart #4278 (depth is in metres). The centres of each lease for predicted exposure zone calculations and locations of proponent-deployed current metres are also shown in blue and red, respectively.

The sites are located in an area with a relatively homogenous bottom type. The proponent's baseline survey was conducted in October 2018. Sediment sampler log sheets of data describe the seabed as consisting predominantly of black to brown mud (n = 6 stations for North Aberdeen; n = 5 stations for South Aberdeen). Linkages between 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). Although described as consisting of black mud, sediment sulfide concentrations measured during the baseline survey ranged from 2–79 µM, indicating Oxic A levels based on Hargrave (2010) oxic categories.

The proposed maximum number of Rainbow Trout anticipated to be on each site at any one time is 550,000 based on the proposed maximum number of fish per net-pen, for a total of 1,100,000 fish between the two sites. This is in addition to the 720,000 Rainbow Trout at the proposed #0814x site, for a potential maximum of 1,820,000 farmed Rainbow Trout in Whycocomagh Bay. The staggered and complex nature of stocking throughout the year due to factors such as ice cover and grow-out periods of 5–10 months make it challenging to know how many fish will be on each site at any given time throughout the year.

All basins within the Bras d'Or Lakes, including Whycocomagh Bay, are part of the Bras d'Or Lakes Ecologically and Biologically Significant Area (EBSA). The Bras d'Or Lakes EBSA is a unique inland sea of special importance for Atlantic Herring, Atlantic Cod, sea urchin, and eelgrass (DFO 2006). Given the significant heterogeneity of ecosystems within the Bras d'Or Lakes, bays were evaluated separately. While Whycocomagh Bay is a unique area of the Lakes, it does not have the habitat diversity or qualities to support a diverse and productive biota, and the enclosed nature of Whycocomagh Bay further limits the impact that it has on the Bras d'Or Lakes ecosystem as a whole (DFO 2006). For these reasons, Whycocomagh Bay was ranked as the second least significant EBSA of the Lakes. Regardless, DFO (2004) states that EBSAs are intended as a tool for calling attention to an area that has particularly high ecological or biological significance to facilitate provision of a greater-than usual degree of risk aversion in management of activities in such areas.

Biological surveys conducted in the Bras d'Or Lakes of fish, algae, copepods, polychaetes, and foraminifera show Whycocomagh Bay as one of two areas with the least variety of species (Parker et al. 2007). Currently, Whycocomagh Bay also has limited fisheries. Lobster, Oyster, Scallop, and Rock Crab are the most significant commercial benthic invertebrate species in the Bras d'Or Lakes. Of these species, only wild Oyster production has been significant in Whycocomagh Bay (Parker et al. 2007), but they have been over fished in their native habitats within the Lakes and only small wild pockets still exist (Lambert 2002). The proposed sites are located in statistical reporting grid 363 of Lobster Fishing Area (LFA) 27, where the commercial season runs from May 15–July 15. Over the last five years, there have been up to five licenses that have reported fishing in grid 363, representing 0.1–0.4% of total annual landings in LFA 27. Within grid 363, Lobster is known to be caught as close to the proposed site as Little Narrows (Figure 1). Commercial groundfish and pelagic fisheries within the Bras d'Or Lakes have included Winter Flounder, Cod, and Herring. Of these species, trawl surveys conducted from 1952–2000 identified Cod and Winter Flounder in Whycocomagh Bay (Parker et al. 2007). The Winter Flounder fishery ended in 1992, and directed fisheries for 4VsW and 4Vn Cod were both closed in 1993 due to the depleted status of the stocks (Fanning et al. 2003, DFO 2002). The Skye River estuary in Whycocomagh Bay supports limited recreational fisheries for American Eel, Mackerel, and Smelt. The Unama'ki Institute of Natural Resources has identified that the area is important for American Eel, Atlantic Salmon, Herring, Mackerel, Cod, Smelt, Oyster, Painted and Snapping Turtle, and Otter trapping (S. Coffen-Smout, DFO, pers. comm.). A workshop sponsored by the Bras d'Or Collaborative Environmental Planning Initiative (CEPI) was held in 2006 to gather information about the environment of the Bras d'Or Lakes and watershed lands based on traditional ecological knowledge. Traditional ecological knowledge was considered the knowledge held about the environment of the Bras d'Or by local people who are familiar with it from their experiences living and working in the area over a number of years.

It was also anticipated that knowledge passed down from previous generations to the participants could be captured (CEPI 2006). During the workshop, it was noted that the majority of these populations have declined (CEPI 2006). Additionally, comments from DFO Resource Management note Food, Social, and Ceremonial (FSC) Lobster fishing efforts along the shoreline near the proposed sites.

American Eel is currently assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is under consideration for listing under the *Species at Risk Act* (*SARA*). Eastern Cape Breton (ECB) Atlantic Salmon occupy rivers in Eastern Cape Breton that drain into the Bras d'Or Lakes (DFO 2014a) and are located in Salmon Fishing Area (SFA) 21. Traditional ecological knowledge indicates that wild Atlantic Salmon in the area have declined in numbers and size (CEPI 2006, Parker et al. 2007). ECB Atlantic Salmon were assessed as Endangered by COSEWIC during the most recent Salmon assessment in 2010. In 2019, all rivers within SFA 19 were closed to Salmon fishing all year, with the exception of the Middle, Baddeck, and North rivers. These three rivers were open to catch-and-release angling during certain times of the year. Food, Social, and Ceremonial (FSC) allocations were available to First Nations on these three rivers; however, FSC harvest was discouraged where rivers are not expected to exceed their conservation egg requirement in a 2019–2020 Atlantic Salmon, Plamu, Conservation Harvesting Plan, and no harvest of returning Salmon was reported by Indigenous communities in ECB for 2019 (DFO 2020a).

Rainbow Trout are an introduced species to the Atlantic coast. Historically, escape events totaling over one million individuals from commercial Rainbow Trout aquaculture operations in the Bras d'Or Lakes have been recorded. These escapees were observed to have formed a feral, reproducing population in the late 1980s (Sabean. 1983 cited in Alexander et al. 1986), which still exists today. There have been escape events at the existing sites within Whycocomagh Bay. Available information on reported escapes in recent years indicates single escape events in 2017 and 2018, and multiple escapes in 2019, with numbers ranging from hundreds to tens of thousands.

The proponent's submission indicates that Grey Seal and Harbor Seal are the only marine mammals known to transit Whycocomagh Bay. Baseline data collected in 2018 at the proposed #1430 and #1431 sites denoted the common presence of Sea Stars. This is consistent with knowledge that echinoderms have been a dominant invertebrate biomass collected during surveys of the Bras d'Or Lakes (Tremblay 2004). Also commonly noted at baseline survey stations were bivalve shells and "strands of", "loose", "sparse" or "dead" eelgrass.

Whycocomagh Bay is noted for its high salt marsh concentration within the Bras d'Or Lakes (Hastings et al. 2014). These wetland habitats support a number of important ecological functions and host a diversity of species not typically found in other habitats (Parker et al. 2007). Little is known about the present abundance and distribution of eelgrass in Whycocomagh Bay, and in the broader Bras d'Or Lakes. Video surveys conducted in 2007, 2009, and 2010 indicated locations of eelgrass presence in parts of Whycocomagh Bay (Vandermeulen 2016). Eelgrass is known to have historically provided important spawning grounds for Herring (Denny et al. 1998) and may also have a significant contribution to the productivity of the Bras d'Or Lakes. Eelgrass is designated as an Ecologically Significant Species (ESS) because of the numerous ecological functions it provides, including habitat for fish and their prey.

Other human activities with potential impacts on habitats and species in the area include anthropogenic nutrient loading, coastal highway runoff, boating traffic, Lobster fishing, and additional aquaculture activities. Land-based inputs from the sub-watershed stem from forestry and agricultural activities, parks and trails (and other tourism), abandoned mines, transmission lines, suspected contaminated sites, and an increasing population and road density (Parker et al. 2007, Kelly et al. 2021).

Key oceanographic, farm infrastructure, and grow-out characteristics of the new sites considered in the following analyses are summarized in Table 1.

Table 1. Key oceanographic, farm infrastructure, and grow-out characteristics of the proposed sites (n/a = not applicable).

Characteristic	#1430 North Aberdeen	#1431 South Aberdeen	Additional Information	Source
Sea-level elevation range (m)	0.57	0.57	n/a	• Drozdowski et al. (2014)
Depth of tenure (m)	5.0–28.0 18.0 m (at centre)	11.0–28.0 20.0 m (at centre)	• Relative to vertical chart datum (lowest normal tide) • PEZ calculation depth = 37 m (North) and 32 m (South)	• CHS chart #4278 (2016) • Proponent submission
Current speed (cm/s) • **Surface**	0.1–42.0	0.0–22.6	• Surface currents measured at 13.7 m (North) and 15.7 (South) m above the bottom	• Proponent submissions (41-day records each) • July–August 2018 (South) • October–December 2018 (North)
• **Midwater**	0.1–40.8	0.0–10.2	• Midwater currents measured at 9.7 m above the bottom	
• **Bottom**	0.1–35.4	0.0–7.7	• Bottom currents measured at 2.7 m above the bottom • Dominant flow directionality to the SW (North), and E–W (South)	
Salinity (PSU)	8.8–23.2	8.8–23.2	• A lower salinity surface layer is present in spring (8.8–17 PSU) • Values in proponent submission were from Tremblay 2002 (not site-specific)	• Strain et al. (2001) • DFO data collected in 2014 and 2020 from < 10 km away (Appendix A)

Characteristic	#1430 North Aberdeen	#1431 South Aberdeen	Additional Information	Source
Temperature (°C)	-0.6–25.0	-0.6–25.0	• Ice cover experienced in winter months (maximum in early March) • Values in proponent submission were from data collected by NSDFA at site #1430	• Strain et al. (2001) • DFO data collected in 2014 and 2020 from < 10 km away (Appendix A) • Proponent submission
Dissolved oxygen (mg/L)	0–13.6	0–13.6	• Typically anoxic below 25 m	• Strain et al. (2001) • DFO data collected in 2014 and 2020 from < 10 km away (Appendix A)
Substrate type	Mud	Mud	n/a	• Proponent submission
Net-pen array configuration	1 x 10 array	1 x 10 array	• Arrays will not be static within lease boundaries	• Proponent submission
Individual net-pen circumference (m)	100	100	n/a	• Proponent submission
Net-pen depth (m)	8	8	n/a	• Proponent submission
Grow-out period (months)	5–10	5–10	n/a	• Proponent submission
Maximum number of fish on site	550,000	550,000	n/a	• Proponent submission

Characteristic	#1430 North Aberdeen	#1431 South Aberdeen	Additional Information	Source
Initial stocking number (fish/pen)	55,000	55,000	n/a	• Proponent submission
Average harvest weight (kg)	2.0	2.0	n/a	• Proponent submission
Expected maximum biomass (kg)	1,100,000	1,100,000	n/a	• Proponent submission
Individual net-pen volume (m^3)	6,350	6,350	n/a	• Proponent submission
Maximum stocking density (kg/m^3)	18.0	18.0	n/a	• Proponent submission

Sources of Data

Information to support this analysis includes data and information from the proponent, data holdings within DFO, publicly available literature, and registry information from the *SARA* database. Additionally, supporting information files submitted to DFO for consideration and used in its review are shown in Table 2.

Table 2. Summary table of information files submitted to DFO.

Description	Filename
Proposed development plan package	1) North Aberdeen Development Plan FINAL.pdf 2) AQ1431Application, Development Plan, Appendix A–E.pdf 3) Revisions to 1430 1431.pdf
Proponent-collected raw current meter data	1) North Aberdeen - Speed Direction and Waves.xlsx 2) South Aberdeen - Current Speed and Direction.xlsx
Baseline survey data submission	1) Waycobah new lease coords and maps with depths.xlsx 2) WBN A3_Video and sediment sampler log sheet.docx 3) WBS A4_Video and sediment sampler log sheet.docx 4) B2 Video Monitoring Summary of Observations for Baseline sample Site WBN.docx 5) B2 Video Monitoring Summary of Observations for Baseline sample Site WBS.docx 6) WBN A4 Video Monitoring Transect_Summary of Observations for Station.docx 7) WBS A4 Video Monitoring Transect_Summary of Observations for Station.docx 8) Data for Organix North Aberdeen.xlsx 9) Data for Organix South Aberdeen.xlsx 10) WBN_10_10_18.xlsx 11) WBN_10_23_18_2016_NSDFAAudit_Data_Check.xlsx 12) WBS_10_23_18_2016_NSDFAAudit_Data_Check.xlsx

The following DFO databases were searched for species records within the Predicted Exposure Zones (PEZs) of the proposed sites #1430 and #1431 and returned no records:

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

Site Description

Whycocomagh Bay is separated from the remainder of St. Patrick's Channel to the east by a shallow sill (approximately 12 m deep) at Little Narrows. A mid-bay sill (approximately 7 m deep) that further separates a pair of deep basins (40 and 48 m) also exists. The #1430 and #1431 sites are located in the eastern portion of the bay in an area that displays both shallow and deep characteristics. The sites are located to the north and south of the 40 m deep basin. The approximate location of these sills are shown in Figure 1.

The sills at Little Narrows and mid-bay effectively isolate the deep areas of the bay from the rest of the Bras d'Or Lakes and restrict flushing. This bathymetric isolation means there is no direct horizontal connection to other deepwater areas, and it has resulted in an environment of limited mixing and the longest flushing time (approximately two years) in the Lakes. This slow-water exchange facilitates the hypoxic and anoxic characteristics of these water bodies below the surface layer (Petrie and Bugden 2002, Gurbutt and Petrie 1995, Gurbutt et al. 1993). The deep basin of the western half of Whycocomagh Bay is typically anoxic below 25 m, a characteristic that is naturally-occurring and appears consistent over time. Data have also indicated that the deep portion of the eastern half has oxygen concentrations reduced by as much as 70% of their maximum potential value (Krauel 1975, Lambert 2002, Petrie and Bugden 2002, Strain and Yeats 2002). This deep hypoxic and anoxic water has periodically been known to be pushed into the shallower waters during phenomena, such as large storm events, although the exact mechanism is not well understood. The existing sites within the western end of Whycocomagh Bay have experienced oxygen issues in the past, including reported kills of on-site farmed fish.

Wave information provided by the proponent was collected at the proposed #1430 North Aberdeen site in the eastern end of Whycocomagh Bay. It is reasonable to assume waves experienced at the #1431 South Aberdeen site would be similar based on proximity within 2 km of each other. The maximum wave height measured at the site was 1.08 m during the late fall and early winter.

Current meters were deployed in 18 m of water over 41 days each at the #1430 North and #1431 South sites. Preliminary evaluation of the current data for #1430 identified some potential anomalous data in the upper three depth bins, so near-surface current data were taken from the bin 13.7 m from the seabed, approximately 4.5 m from the surface. Data were collected from July–August 2018 and October–December 2018 at the #1431 South and #1430 North sites, respectively. The difference in timing likely accounts for the differences in maximum observed current speeds, with measured current speeds at the #1430 North site being larger than those at the #1431 South site (Table 1). This presents a unique opportunity to consider seasonality influences in the potential spatial extent of exposure, and demonstrates that current speeds vary with complexities of seasonal, wind, and storm influences that may or may not be captured in the records. Based on proximity of the sites, it is not unreasonable to assume that, at any given time, current speeds at both sites would be similar.

At the #1431 South site, at all depths, 64–97% of observed current speeds were from 0–5 cm/s and less than 1% were greater than 15 cm/s. Although the current speeds recorded at #1430 North were faster than those measured at #1431 South, with a much smaller proportion (33–50%) of the observed current speeds in the 0–5 cm/s range, the majority of the observed current speeds (77–94%) were also less than 15 cm/s. At #1431 South, the mean current speeds were up to 4.6 cm/s in the near surface, with a trend of decreasing current speeds with increasing depths. At the #1430 North site, except for a slowing near the bottom, mean current speeds varied little with depth and were from 9.2–10.7 cm/s. The overall current dynamics at #1430 and #1431 are “low energy” with respect to marine finfish farming.

In general, supplemental information to proponent-submitted data on physical characteristics in the vicinity of the #1430 and #1431 sites is lacking in Departmental and public data holdings. Water temperature, salinity, and dissolved oxygen ranges reported in Table 1 are from data collected in the western half of Whycocomagh Bay (Appendix A**)**. The physical characteristics are reasonably expected to be similar given the close proximity of sites (i.e., < 10 km). The water temperature and salinity at the #1430 and #1431 sites are expected to have minimal variation on tidal time scales but larger variations on wind-driven and seasonal time scales. Review of satellite images and information submitted by the proponent indicates the presence of variable ice cover in the winter.

The amount of stratification varies seasonally, but all data indicate a less dense surface layer (Appendix A). Similar stratification patterns can be expected at the proposed sites based on similar bathymetry and the general circulation patterns in the region (Petrie and Bugden 2002); therefore, estimates of exposure zones at the proposed sites #1430 and #1431 should consider stratification influences with respect to water current speed selection.

Benthic Predicted Exposure Zones and Interactions

The benthic-PEZ is a first-order estimate of the size and location of benthic areas that may be exposed to the deposit of waste feed and feces released from a site, which can result in organic loading. Additionally, it is assumed that the PEZ associated with the release of in-feed drugs is also dominated by the deposition of medicated waste feed and feces. Both organic loading and the deposit of in-feed drugs can result in direct habitat and infaunal species impacts on the benthic community and seafloor. These predicted exposure zones are precautionary overestimates used as a tool for identifying, albeit at a larger spatial scale, areas of potential overlap with species and habitats that are sensitive to these exposures.

Benthic Predicted Exposure Zone

The dominant factors that will affect estimations of benthic exposure are farm layout, feeding practices, and oceanographic conditions, such as the bathymetry, water currents and stratification. The low flushing rate of Whycocomagh Bay makes it particularly sensitive to deleterious substance inputs as they cannot be quickly dispersed by water movement (Parker et al. 2007). Benthic exposure can also occur in relation to the use of bath pesticides, if used, particularly at sites over or near shallow depths such as the proposed sites. However, this will be considered in the Pelagic-PEZ and Interactions section of this review.

First-order estimates of the spatial extent of the benthic-PEZ related to organic effluent and in-feed drugs from the proposed #1430 North and #1431 South Aberdeen sites were calculated. Limited available data suggests that sinking rates of Rainbow Trout feed and feces are within similar ranges to that of Atlantic Salmon. Sinking rates of different particulate materials released from farmed fish (e.g., waste feed and feces) vary, and the distribution of sinking speeds amongst the released particles is poorly characterized. Therefore, the minimum sinking rate for each category of particle (Table 3), along with the maximum depth within 500 m of the proposed site, and maximum observed mid-water current speed in the proponent's record were used. The fish, and the release of waste feed and feces, are within the 8 m surface layer. Since these particles sink from the net-pens to the seabed, a mid-water current speed in the proponent's record was selected as representative.

Table 3. First order estimates of the potential horizontal distances travelled by sinking particles such as waste feed pellets, fish feces and in-feed drugs and pesticides released from the fish farm (settling rates obtained from literature; 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, Skøien et al. 2016). A. is site #1430 North Aberdeen and B. is site #1431 South Aberdeen.

A.	**#1430 NORTH ABERDEEN (max. depth within 500 m = 37 m)**			
Particle type	Min. sinking rate (cm/s)	Max. observed current (cm/s)	Horizontal distance travelled (m)	PEZ radius (m)
Feed	5.3	40.8	285	782
Feces	0.3	40.8	5,032	5,529
Fines and Flocs	0.1	40.8	15,096	15,593

B.	**#1431 SOUTH ABERDEEN (max. depth within 500 m = 32 m)**			
Particle type	Min. sinking rate (cm/s)	Max. observed current (cm/s)	Horizontal distance travelled (m)	PEZ radius (m)
Feed	5.3	10.2	62	580
Feces	0.3	10.2	1,088	1,606
Fines and Flocs	0.1	10.2	3,264	3,782

PEZs are a circular zone typically centered over the middle of the proposed net-pen array and represent the outer limit for potential exposure. In this instance, a precautionary approach was taken in estimating the PEZs by centering over the proposed lease given the proponent’s intent to move the net-pen array around within the lease boundaries. The maximum distance from the centre to the edge of the proposed lease boundaries was added to the displacement distance to obtain the PEZ radius. Although represented by a circle, the benthic footprint is more likely a curved ellipse with a shape that is dependent on local current flow.

The benthic-PEZ does not provide an estimate of the intensity of organic loading within the site, and the zones do not imply that everywhere within the zone has the same exposure risk. The intensity of exposure is expected to be highest near the net-pen arrays and decrease as distance from the net-pens increases, except for in areas of anticipated overlaps where cumulative exposures may occur. The feed-PEZ is anticipated to have the greatest intensity of impacts and is conservatively a circle centered on the lease as seen in Figure 3.

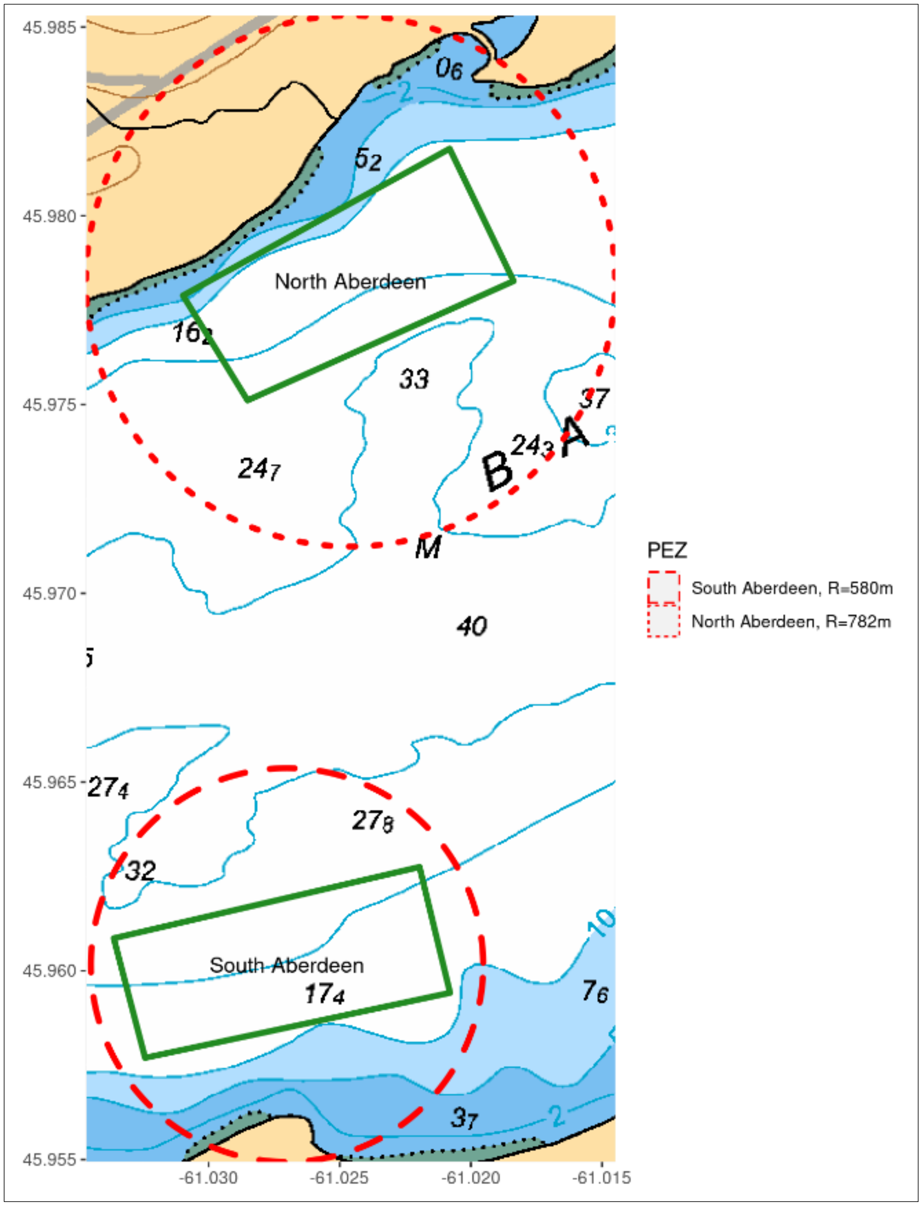

Figure 3. Benthic-PEZs for the #1430 North and #1431 South Aberdeen proposed sites using the waste feed minimum sinking rate are shown in red overlaid on CHS chart #4278 (depth is in meters). PEZs were estimated for fall-winter at the #1430 North Aberdeen site, and for summer at the #1431 South Aberdeen site.

Based on the feed-PEZs, there are no overlaps between the benthic deposition zones where smothering and oxic-state changes are anticipated to occur due to organic loading (Figure 3). However, the spatial extent of the PEZs based on feces provides a better indication of the full area that could be exposed to any in-feed drugs used. Potential overlaps in areas of feces deposition are predicted (Figure 4).

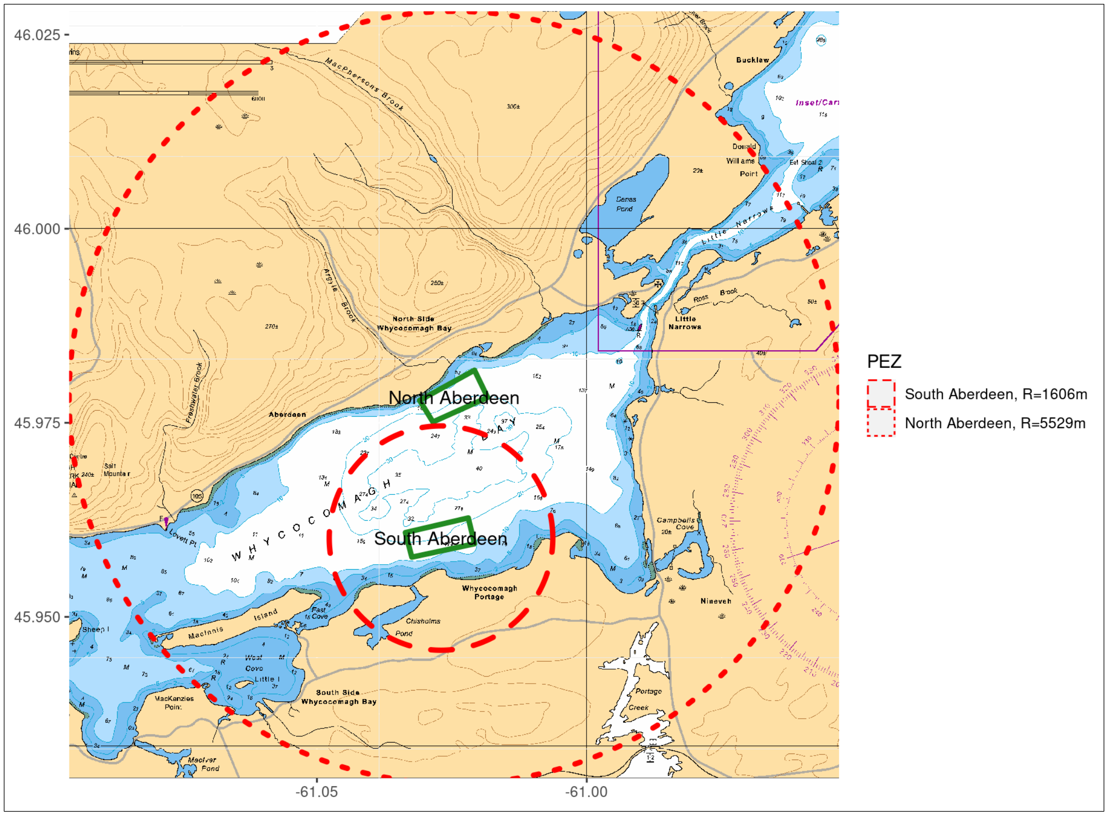

Figure 4. Benthic-PEZs for the #1430 North and #1431 South Aberdeen proposed sites using the feces minimum sinking rate are shown in red overlaid on CHS chart #4278 (depth is in meters). PEZs were estimated for fall-winter at the #1430 North Aberdeen site, and for summer at the #1431 South Aberdeen site.

The extent of the benthic-PEZs at the #1430 North site provide an indication of the full area that may be exposed to deposition of material during the fall-winter, as compared to the #1431 South site providing an indication of the area exposed during summer. However, applying the PEZ radius estimated during the summer months to both sites still predicts PEZ overlaps with respect to feces deposition. Conversely, using the maximum observed current speed during the fall-winter months to estimate PEZs for the #1431 South site would result in larger PEZs for that site and encompass some areas that are not covered in Figures 3 and 4. It should also be noted that there may be overlaps in the exposure zones for fines and flocs between the proposed Aberdeen sites and the sites located in the western end of Whycocomagh Bay.

Current- and wave-induced bottom resuspension is not explicitly considered for these first-order estimates of exposure. However, waste particles are unlikely to extend beyond the benthic-PEZ estimated for fines and flocs. The overall potential impacts of redistribution and flocculant deposition is unknown, but impacts are not anticipated to occur at levels where significant changes are predicted.

The total benthic area impacted within Whycocomagh Bay is expected to increase based on the proposed additions in lease area and production at the existing site in the western end (reviewed separately) and the addition of these two new sites. Areas of the benthic environment at the existing sites in the western end of Whycocomagh Bay have historically reported elevated levels of sulfides, reaching concentrations ≥ 3,000 and 6,000 µM. The location of the proposed #1430 and #1431 sites in the eastern end of Whycocomagh Bay demonstrate similarities with respect to bottom type, hypoxia and anoxia, and restricted flushing. It is therefore reasonable to suggest that similar challenges may be experienced at these locations with the addition of fish and consequent deposition of organic matter.

Since 2015, *AAR* reporting indicates that the existing sites in Whycocomagh Bay have not used in-feed drugs.

Susceptible Species Interactions

Species are considered to be susceptible within the benthic-PEZ if they are sessile at any life stage and are sensitive to either low oxygen levels, smothering, loss of access to the site, or exposure to in-feed drugs, if used. This includes species such as crustaceans and bivalves. Specific consideration was also given to the presence of certain sensitive sessile species, such as sponges, corals, and eelgrass, and critical habitat for *SARA*-listed species in the baseline survey data, scientific literature, and Departmental biological data holdings. When the available data were limited, consideration as to whether the benthic substrate type is suitable for the growth of these species was considered.

Departmental holdings of biological data from Whycocomagh Bay are sparse, and database searches of the PEZs returned no records. The ability to delineate present-day spatial overlaps between species distributions and the benthic-PEZs for sites #1430 and #1431 is limited; however, available information indicates that wild Oysters, Lobster, and eelgrass are present within the benthic-PEZ.

Oyster beds have been known to exist historically in Whycocomagh Bay, but present-day distributions within the bay are unknown. American Oyster leases that may have been established upon existing wild beds are present within Whycocomagh Bay but are located outside of the benthic-PEZs to the west of the proposed sites. These sites are also not currently in production due to a parasitic disease known as Multinucleate Sphere Unknown X (MSX). Given their sessile nature, Oysters are sensitive to increased siltation that could result in smothering due to excess deposition that exists within the benthic-PEZ. There is traditional ecological knowledge of increased silt deposition having contributed to the decline of Oysters in other areas of the Bras d’Or Lakes (CEPI 2006). Bivalves in the vicinity of net-pens elsewhere have also been shown to have measurable quantities of in-feed pesticides such as Emamectin Benzoate (EB). Currently, hazard information is primarily based on acute exposures; however, it does not indicate a high level of risk (Burridge et al. 2011). While the PEZ does encompass areas along the shoreline that meet the depth criteria for Oyster (i.e., mostly < 2 m, although some found up to 11 m; Mackenzie et al. 1997), and presence of bivalve shells were noted in the baseline survey, the majority of water depths within the benthic-PEZ are outside of the preferred habitat range for Oysters in the area. Additionally, the predominantly soft substrate type in the area is likely not suitable given that Oyster larvae typically require coarser-grained habitats for settlement. For these reasons, wild Oysters are not anticipated to be present in large aggregations within the benthic-PEZ.

It is known that Lobster fishing occurs along the shoreline near the proposed sites and in Little Narrows, indicating the likely presence of Lobster within the benthic-PEZ. In-feed anti-Sea Lice drugs, such as EB, have been shown in lab studies to have lethal toxic effects to crustaceans and can induce sub-lethal effects, including premature moulting (Burridge et al. 2000, Waddy et al. 2002, Burridge et al. 2008). Additionally, increased sedimentation associated with the proposed aquaculture activities may preclude the settlement of larval Lobster. However, the bottom habitat near the proposed sites where the greatest intensities of exposure are anticipated is not considered ideal habitat for Lobster settlement (or juvenile Lobster) given their preferential (but not exclusive) selection for hard-bottom substrates. Therefore, while Lobster may be present, they are not anticipated to be present in large aggregations within the benthic-PEZ.

Eelgrass is known to be present throughout the Bras d'Or Lakes and is not restricted to Whycocomagh Bay itself. Video surveys conducted in Whycocomagh Bay in 2009 and 2010 (Vandermeulen 2016) indicated potential spatial overlap between areas of patchy and continuous eelgrass coverage and the benthic-PEZs for all particle types (e.g., feed, feces, and fines and flocs; Figures 5a–c). Proponent-submitted baseline data collected in 2018 also describes “strands of”, “loose”, “sparse” or “dead” eelgrass at a number of stations sampled throughout the proposed leases (Figures 5a–c). Review of the baseline survey information shows the presence of eelgrass wrack at depths below which eelgrass can grow, confirming the presence of eelgrass in the vicinity and indicating that deposition of eelgrass detritus can occur here.

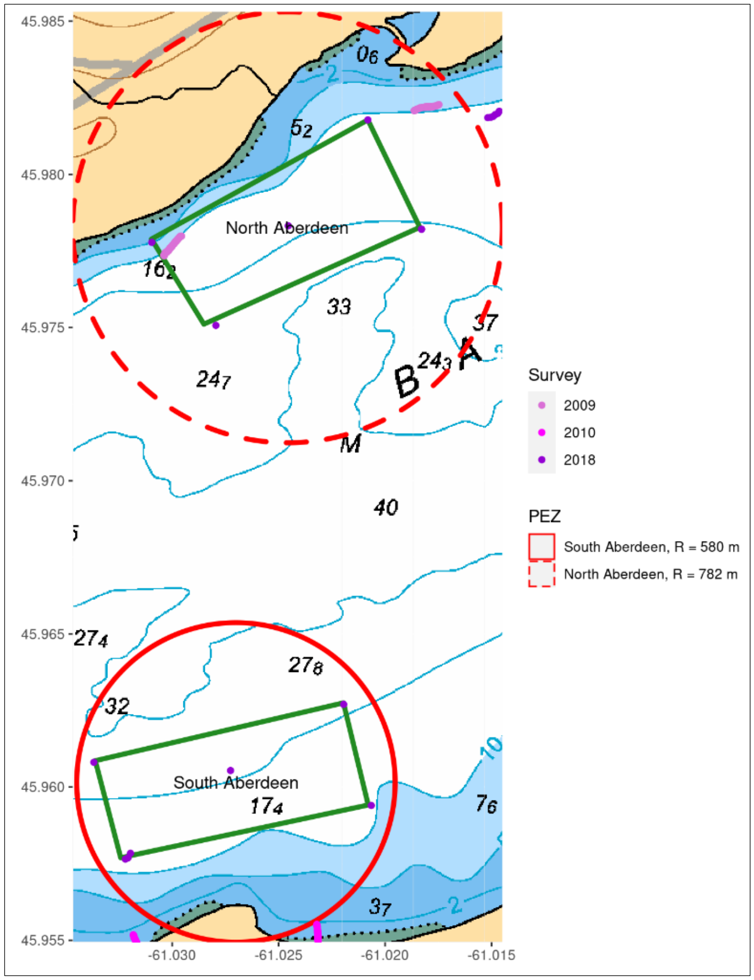

Figure 5a. Locations of identified eelgrass presence in Whycocomagh Bay from surveys conducted in 2009 and 2010 (Vandermeulen 2016), and 2018 (proponent-submitted baseline survey) overlaid on CHS chart #4278 (depth is in meters). The proposed leases are shown in green. The benthic-PEZs for feed are shown in dotted and solid red circles for the North and South Aberdeen sites, respectively.

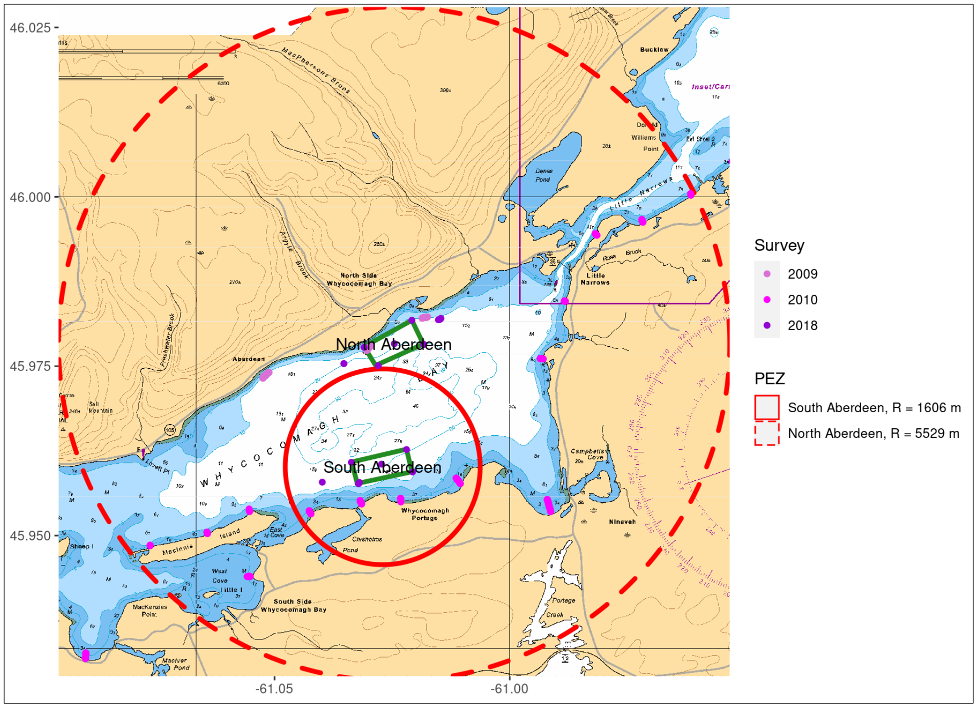

Figure 5b. Locations of identified eelgrass presence in Whycocomagh Bay from surveys conducted in 2009 and 2010 (Vandermeulen 2016), and 2018 (proponent-submitted baseline survey) overlaid on CHS chart #4278 (depth is in meters). The proposed leases are shown in green. The benthic-PEZs for feces are shown in dotted and solid red circles for the North and South Aberdeen sites, respectively.

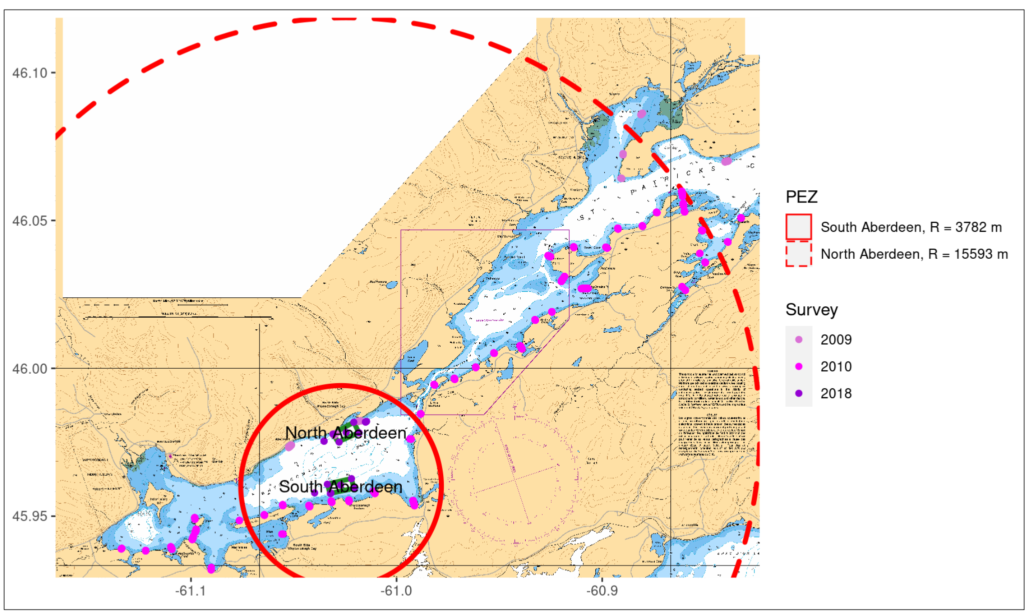

Figure 5c. Locations of identified eelgrass presence in Whycocomagh Bay from surveys conducted in 2009 and 2010 (Vandermeulen 2016), and 2018 (proponent-submitted baseline survey) overlaid on CHS chart #4278 (depth is in meters). The proposed leases are shown in green. The benthic-PEZs for fines and flocs are shown in dotted and solid red circles for the North and South Aberdeen sites, respectively.

Eelgrass beds along the coast of Atlantic Canada typically occur in shallow water depths up to 12 m (DFO 2009). However, Vandermeulen (2016) noted the presence of the majority of macrophytes in the Bras d'Or Lakes occurring in depths less than 3 m. This depth limitation means that eelgrass is unlikely to be present directly beneath the net-pens, and interactions within the benthic feed-PEZ will likely have few effects. Benthic feces, fines, and flocs will be transported further, potentially encompassing more locations of historically identified eelgrass habitat (Figures 5b and 5c); however, the organic deposition outside of the benthic feed-PEZ is not expected to occur at levels where oxic state or sediment biogeochemistry changes are predicted. Given the bathymetry of the area and the apparent 3 m depth limit for eelgrass occurrence in the Bras d'Or Lakes, potential eelgrass habitat within the PEZ is largely restricted to the shallow fringe immediately adjacent to land.

Benthic enrichment from organic matter deposition can have variable effects on eelgrass, ranging from stimulation of growth at low levels to mortality at high levels (Vinther and Holmer 2008). If present in sufficient quantity, suspended particulates can also impact the underwater light climate, reducing light availability for photosynthesis with implications for eelgrass growth, morphology, and persistence (Wong et al. 2020). The use of in-feed drugs may also affect associated communities such as grazers.

Even in the absence of anthropogenic activities, such as aquaculture, it is likely that eelgrass in this area is subject to multiple stressors and would be expected to exhibit high spatial and temporal variability when compared to areas with more suitable conditions. Optimal salinity for eelgrass growth ranges from 20–26 psu, although it can tolerate lower values for short periods (DFO 2009). While no site-specific salinity measurements are available from the site, salinity within the bay ranges from 8.8 to 23.2 psu with a lower range in surface waters in spring (8.8 to 17 psu) (Table 1). It is likely that the salinity regime would contribute to reduced growth rates and spatial fragmentation. Whycocomagh Bay experiences seasonal ice cover in the winter, which can further contribute to spatial fragmentation through scouring. Additionally, the natural light regime may also be affected by the presence of dissolved organic matter of terrestrial origin. Aside from these physical factors, the presence of the invasive European Green Crab, which is capable of causing stress to eelgrass habitat, has also been documented in the Bras d'Or Lakes (Vercaemer and Sephton 2016).

Eelgrass in the area may be particularly vulnerable to additional stressors and/or additional intensity of the same stressors given the observed poor conditions of eelgrass beds in the Bras d'Or Lakes (Vandermeulen 2016). However, given the documented suboptimal environmental conditions at the site, expanded aquaculture activities may not result in a measurable difference in eelgrass health and persistence.

Pelagic Predicted Exposure Zones and Interactions

The pelagic-PEZ is a first-order estimate of the size and location of pelagic areas that may be exposed to potentially toxic levels of registered pesticides, if used. Additionally, there may be shallow benthic areas with the potential for exposure. The release of pest control products from a site can result in direct impacts on susceptible species in both the water column and on the seafloor. These predicted exposure zones are precautionary overestimates used as a tool for identifying, albeit at a larger spatial scale, areas of potential overlap with species and habitats that are sensitive to these exposures.

Pelagic Predicted Exposure Zones for Pesticides

The two pesticides available for use in bath treatments (e.g., tarp bath and well-boat) are azamethiphos and hydrogen peroxide. The size of the PEZ depends on the decay and/or dilution rate of the pesticide, a chosen concentration threshold, and choice of horizontal water current depth. The PEZ is estimated using toxicity information of azamethiphos, the most toxic registered pesticide. Health Canada's Pest Management Regulatory Agency (PMRA) has assessed that the two registered pesticides (hydrogen peroxide and azamethiphos), and their breakdown products, are expected to remain in suspension since they do not bind with organics or sediments and do not accumulate in organisms tissues. Their half-lives are days to weeks, which influences their persistence in the environment at concentrations considered to be toxic (PMRA 2014, 2016a, 2016b, 2017).

Since the application of tarp bath treatments occurs in the surface waters, the maximum near-surface current speed is used in the calculation of the pelagic-PEZ for azamethiphos, and is assumed to persist throughout the duration of the dilution or decay scale (Figure 6). A three-hour duration was used to estimate the time required for the maximum azamethiphos target treatment concentration of 100 µg/L to dilute to the HCPMRA environmental effects threshold of 1 µg/L (DFO 2013).

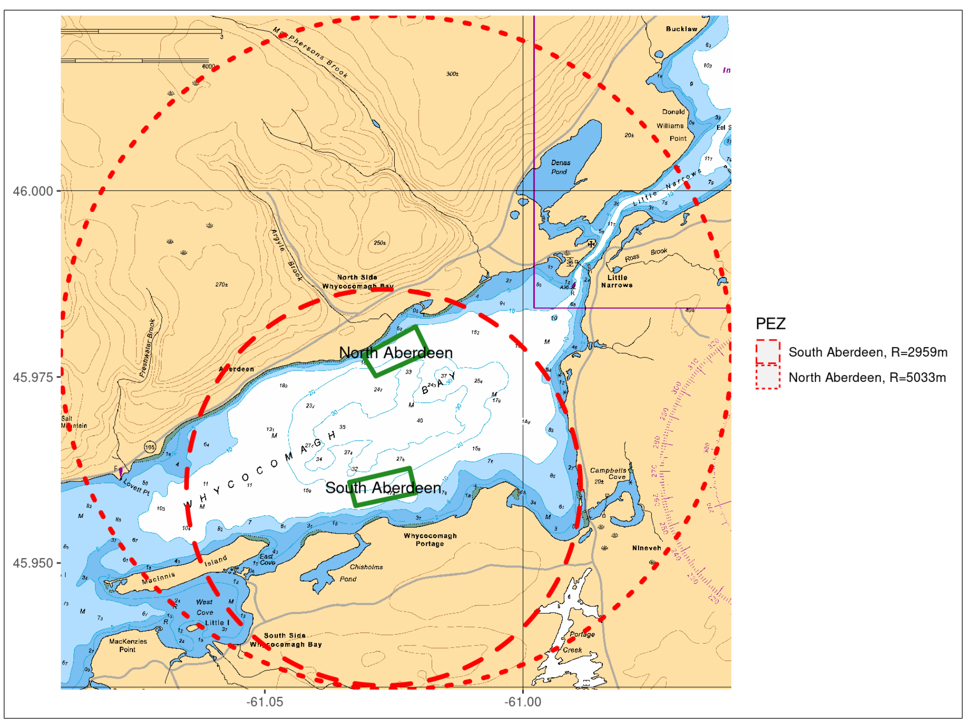

Figure 6. Pelagic-PEZs for the #1430 North and #1431 South Aberdeen proposed sites are shown in red overlaid on CHS chart #4278 (depth is in meters). PEZs were estimated for fall-winter at the #1430 North Aberdeen site, and for summer at the #1431 South Aberdeen site.

The pelagic-PEZ is calculated assuming use of tarp bath treatments, regardless of whether all net-pens would meet the PMRA treatment conditions for application, given the larger exposure zone anticipated to result from a tarp treatment versus a well boat.

The pelagic-PEZ is typically estimated by adding the horizontal transport distance to the longest length scale of the proposed net-pen array. Since the location of net-pens within the leases is unknown given the proponent's intent to move the arrays within the lease boundaries, a precautionary approach was taken in estimating the PEZ. The horizontal transport distance was added to the longest length scale of the proposed lease (i.e., the largest distance from the lease centre to the boundary), rather than the length scale of the net-pen arrays, and centering the PEZ on the lease.

The pelagic-PEZ does not quantify the intensity of duration of exposure, nor include a frequency of exposure. The zones do not imply that areas within the pelagic-PEZ have the same exposure risk. The intensity of exposure is expected to be highest near the net-pens and decrease as distance from the net-pens increases, except for in areas of anticipated overlaps where cumulative exposures may occur.

The exposure is expected to primarily occur in the pelagic zone; however, areas within the pelagic-PEZ where the bathymetry is less than 10 m may also be at risk of exposure to toxic pesticide concentrations. The PMRA restriction on the use of azamethiphos at shallow sites (i.e., no application to tarp net-pens in water depths ≤ 10 m) may be applicable to some net-pens. The low flushing rate of Whycocomagh Bay also makes it particularly sensitive to chemical inputs as they cannot be quickly dispersed by water movement (Parker et al. 2007), and chemical inputs may be more likely to interact with local bottom communities.

If treatment is used at both sites simultaneously, exposure overlaps associated with pesticide releases are predicted (Figure 6). The extent of the pelagic-PEZ at the #1430 North site provides an indication of the full area that may be exposed during the fall-winter, as compared to the #1431 South site providing an indication of the area exposed during summer. Applying the PEZ radius estimated during the summer months to both sites still predicts that overlaps between PEZs would occur. Conversely, using the maximum observed current speed during the fall-winter months to estimate the PEZ for the #1431 South site would result in a larger PEZ for that site and encompass some areas that are not covered in Figure 6. It should be noted, however, that seasonal ice cover in Whycocomagh Bay may render the use of bath pesticides during winter months not possible.

AAR reporting since 2015 regarding the application of pesticides indicates that the existing sites in Whycocomagh Bay have not required the use of pesticides such as azamethiphos.

Susceptible Species Interactions

Species were considered to be susceptible within the pelagic-PEZ if they are known to have sensitivities to pesticide exposures, should treatment be required. Specific consideration was given to the potential for interactions with crustaceans due to their higher relative susceptibility to the pesticides used in aquaculture.

Azamethiphos tarp bath treatments are reported to pose risk levels that are below the established level of concern (LOC) for marine fish (including larval fish), marine mammals, and algae, but they are above the LOC for pelagic and benthic invertebrates. While in the environment, azamethiphos is toxic to non-target crustaceans, including all life stages of Lobster (PMRA 2016b, PMRA 2017, Burridge 2013, DFO 2021a).

Departmental holdings of biological data from Whycocomagh Bay are sparse, and database searches of the PEZs returned no records. The ability to delineate spatial overlaps between species distributions and the pelagic-PEZs for sites #1430 and #1431 is limited. Lobster present in the Little Narrows area may be exposed to toxic levels of pesticides but are unlikely to be in large aggregations throughout the majority of the pelagic-PEZ. Surveys conducted in 2009, 2010, and 2018 identified both live eelgrass and wrack eelgrass within the pelagic-PEZ (Figure 7). There is no evidence for a direct effect of pelagic pesticides on eelgrass; however, indirect effects could occur through changes to its associated mesograzer communities.

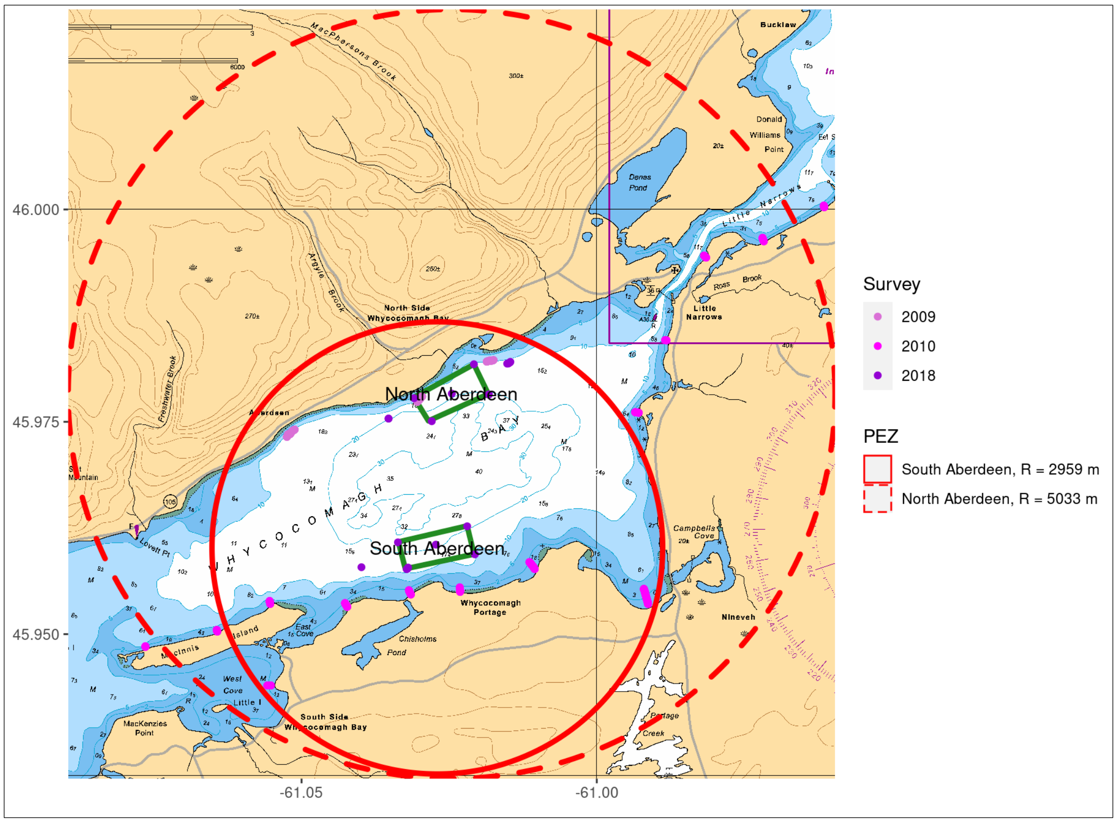

Figure 7. Locations of identified eelgrass presence in Whycocomagh Bay from surveys conducted in 2009 and 2010 (Vandermeulen 2016), and 2018 (proponent-submitted baseline survey) overlaid on CHS chart #4278 (depth is in meters). The proposed leases are shown in green. The pelagic-PEZs shown in dotted and solid red circles for the North and South Aberdeen sites, respectively.

There is limited literature describing the effects of aquaculture pesticides on seagrasses. Like most aquatic plants, seagrasses concentrate non-essential chemicals in their tissues (Lewis and Devereux 2009). The targeted nature of azamethiphos treatments on crustaceans suggests the diverse mesograzer communities associated with the eelgrass, such as amphipods and isopods, may be impacted (Wong 2018). A loss of grazers could result in higher plant fouling that shades plants and leads to reduced growth or increased mortality. Mesograzers are also an important food source for fish, and a loss of grazers could have cascading trophic effects for fish that use eelgrass beds as nurseries and feeding grounds. Crustacean-specific pesticides could also have an effect on the invasive Green Crab.

Given the potential for wide distribution of pesticides throughout the bay, eelgrass beds, and/or their trophic components, could possibly be impacted. Eelgrass is known to be present throughout the Bras d'Or Lakes and is not unique to Whycocomagh Bay itself.

Escapee Interactions

Interactions between farm escapees and wild populations can be both genetic and ecological. Genetic interactions result from exchange of genetic material (hybridization) and/or the alteration of selection pressures (indirect genetic effects) (Lacroix and Fleming 1998). Ecological interactions can involve the transfer of diseases, predation, or competition for space, food, or mates between wild and escaped farm fish (Lacroix and Fleming 1998). These ecological interactions can result in negative genetic impacts on wild populations (reviewed in Bradbury et al. 2020).

Crosses between Atlantic Salmon and Rainbow Trout have not produced any viable offspring (Refstie and Gjedrem 1975, Sutterlin et al. 1977, Blanc and Chevassus 1982). Therefore, direct genetic effects due to interbreeding between escaped Rainbow Trout and the native Atlantic Salmon population is not a concern. However, escaped Rainbow Trout could reproduce with and contribute to the feral populations of Rainbow Trout that exist in rivers leading into the Bras d'Or Lakes, potentially leading to increases in population size.

Ecological interactions can occur between escaped Rainbow Trout and native Atlantic Salmon, regardless of life stage. Ecological interactions and deleterious effects on wild Salmon from competition from introduced invasive Rainbow Trout are well documented, and they show that Rainbow Trout have stronger competitive abilities than Atlantic Salmon (Houde et al. 2017, Van Zwol et al. 2012a). There is a growing body of evidence linking low marine survival to delayed effects from the physical and biological interactions experienced by juvenile Salmon in rivers (Russel et al. 2012, Blanchet et al. 2007). At the individual level, behavioural strategies and dominance hierarchies of Salmon have been shown to be strongly disrupted by invasive Rainbow Trout, such that growth trajectories are affected (Blanchet et al. 2007, Van Zwol et al. 2012b). Some of these effects were linked to elevated stress hormones in Salmon when invasive trout were present (Van Zwol et al. 2012c). Rainbow Trout have also been shown to displace Atlantic Salmon out of preferred habitat and into increased competition with other native Salmonids, even at low trout densities (Hearn and Kynard 1986, Thibault and Dodson 2013).

These types of ecological interactions have been shown to change the selective landscape, resulting in changes to fitness-related allele frequencies (Bradbury et al. 2020). Ecological interactions can also lead to reduced Atlantic Salmon population size and consequently reduce their genetic diversity. Reduced population size and genetic diversity would in turn lead to increased susceptibility to genetic drift and impact of stochastic events. Given the known ecological interactions between Rainbow Trout and wild Atlantic Salmon, there is no reason to believe that the genetic outcome from interactions with escaped farmed Rainbow Trout would differ from that described in Bradbury et al. (2020).

While not native to Eastern Canada, Rainbow Trout have been stocked by the Province of Nova Scotia since the early 1900s, and there is now a successfully reproducing feral population in the Bras d'Or Lakes and the rivers and streams that flow into it (Madden and MacMillan 2010). Additionally, there have been multiple reported escape events at the existing aquaculture sites in Whycocomagh Bay. Madden and MacMillan (2010) noted that since Rainbow Trout aquaculture was introduced to the Bras d'Or Lakes in 1972, large escape events have been associated with an increased popularity of the Rainbow Trout fishery in the area. Data from Norway suggest that Rainbow Trout may escape at higher rates than Atlantic Salmon (Jensen et al. 2010, Skilbrei and Wennevik 2006).

In recent years, adult and juvenile Rainbow Trout have been observed in Middle, Baddeck, and Skye rivers during DFO assessment unit swim counts for ECB Salmon. In 2020, some observations of Rainbow Trout in both the Middle and Baddeck rivers were well upstream of the estuary (> 10 km river distance), and the presence of juvenile trout confirms that natural reproduction is occurring. Additionally, historic records have indicated the presence of Rainbow Trout in Indian, Gillis, and Breac rivers (Sabean 1983, Levy and Gibson 2014). This is consistent with the findings of Jonsson et al. (1993), who found reproductively mature escaped Rainbow Trout entered rivers in Norway, and heightens concerns about the continued use of diploid Rainbow Trout in both stocking and aquaculture.

The post-escape dispersal behaviour of Rainbow Trout is less well studied than Atlantic Salmon; however, a review of dispersal of escaped Salmonids suggests that Rainbow Trout may be slower to disperse than Atlantic Salmon (Dempster et al. 2018). The data shown by (Dempster et al. 2018) indicated that the majority of escaped Rainbow Trout were found to have dispersed by approximately 48 hours post escape, compared to < 24 hours for Salmon. That said, dispersal behavior of Rainbow Trout is also variable, with some fish remaining at the cage site for a period of time while others dispersed rapidly, and the number of fish that remained at the site decline over time (Blanchfield et al. 2009, Patterson and Blanchfield 2013). Rainbow Trout can disperse widely (Patterson and Blanchfield 2013, Veinott and Porter 2013), with individuals having been captured up to 1,760 km away from the site of escape (Jonsson et al. 1993). Their observed survival post-escape is mixed (Blanchfield et al. 2009, Bridger et al. 2001); however, escaped Rainbow Trout have been seen to survive for months to years (Jonsson et al. 1993, Patterson and Blanchfield 2013), successfully transition to wild feed (Nabaes Jodar et al. 2020, Rikardsen and Sandring 2006), and grow (Blanchfield et al. 2009, Jonsson et al. 1993, Patterson and Blanchfield 2013).

The above interactions and potential impacts are of particular concern to ECB Atlantic Salmon, which have been assessed as Endangered by COSEWIC since 2010. ECB Salmon support the last remaining recreational fishery and First Nations allocations in DFO Maritimes Region. There are ongoing monitoring efforts in Skye, Middle, and Baddeck rivers, which enter the Bras d'Or Lakes at approximately 6, 15, and 20 km, respectively, from the proposed #1430 and #1431 aquaculture sites. Both Middle and Baddeck rivers were below their conservation egg requirement in 2019 and have been for the previous 20 years (DFO 2020b), and the 2018 smolt estimate on Middle River was estimated among the lowest in recent years (albeit with large uncertainty) (DFO 2020b).

Gibson et al. (2014) identified commercial Salmonid aquaculture as a threat in both the marine and freshwater environment to the recovery potential for ECB Atlantic Salmon. While there are ongoing monitoring efforts and available information specific to the Middle, Baddeck and Skye rivers, all other known ECB Salmon rivers (Figure 8) are also within range of distances that farmed Rainbow Trout have been documented to travel following escape from aquaculture sites.

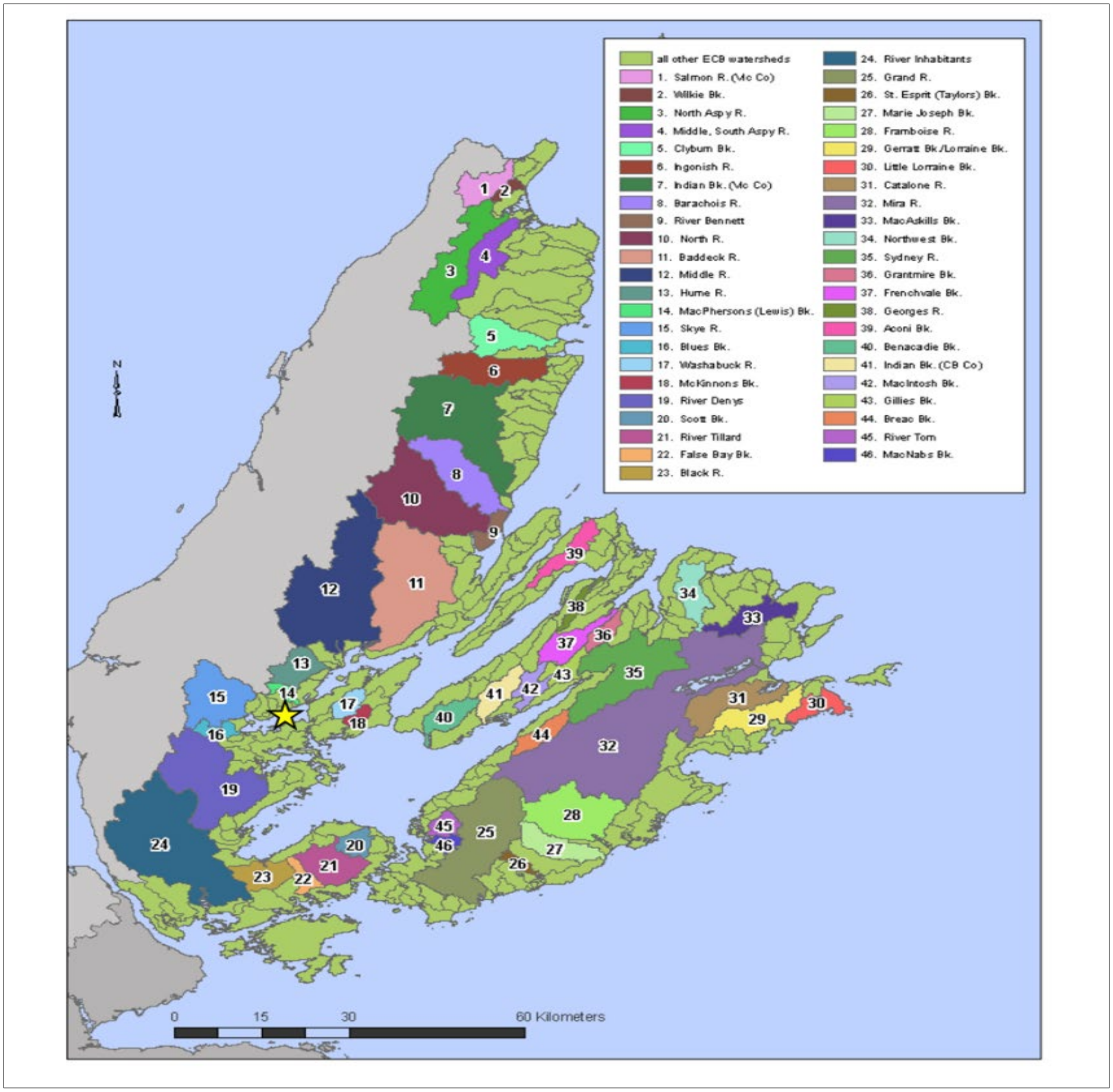

Figure 8. Location of known major watersheds associated with Eastern Cape Breton Atlantic Salmon rivers (Gibson et al. 2014). The yellow star represents the location of the proposed #1430 and #1431 aquaculture sites.

The use of sterile fish in marine cage aquaculture has been recommended in Newfoundland (DFO 2016). Additionally, the province of New Brunswick prescribes the use of sterile triploid

Rainbow Trout only in cage aquaculture as part of a process to mitigate risk to wild stocks as outlined in the New Brunswick Rainbow Trout Aquaculture Policy (NBDERD and NBDAAF 2016). Although not specific to Nova Scotia, these examples reinforce the use of sterile Salmonids in aquaculture to minimize adverse effects to wild Salmon from aquaculture. While sterile Rainbow Trout could still escape and interact with wild Salmon populations, they would not contribute to the feral reproducing population of Rainbow Trout in rivers leading into the Bras d'Or Lakes. Recapture efforts have had limited success elsewhere (Dempster et al. 2018). Moreover, efforts to determine escapee abundance in Norway resulted in the capture of both Rainbow Trout and Atlantic Salmon, and thus any recapture efforts for Rainbow Trout must take into consideration potential impacts on local Atlantic Salmon populations (Skilbrei and Wennevik 2006).

While the risks to ECB Salmon exist at the current leases in Whycocomagh Bay, they are expected to be at least proportional to the intensity of the farming activities in the area. Therefore, any increase in the total number of farmed trout in the area associated with the proposed #1430 and #1431 sites will also represent an increased risk to ECB Salmon. These concerns also need to be contextualized by other cumulative potential pressures, such as the presence of other introduced Salmonids (Brown Trout) and the additional continued stocking of diploid Rainbow Trout in the area for the purpose of sport-fishing.

Pest and Pathogen Interactions

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 2014b). Density-dependent transmission is observed in many host-pathogen systems, including Sea Lice on Salmonid farms (Kristoffersen et al. 2013, Frazer et al. 2012). This can pose a significant health risk 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).

The low flushing rate of Whycocomagh Bay may contribute to the occurrences of outbreaks, given that pests and pathogens cannot be quickly dispersed by water movement and therefore may persist longer, if present. However, the lower salinity brackish waters of Whycocomagh Bay are expected to keep Sea Lice levels low. Studies have demonstrated that low salinity may prevent Sea Lice from thriving as they actively avoid low salinities (< 27 ppt), and even short-term exposures to low salinity water significantly compromises survival and host infectivity (Bricknell et al. 2006).

Available *AAR* data since 2015 confirms that no pest control products have been used at the existing sites in Whycocomagh Bay. The exact level of Sea Lice abundance is unknown and linking back to historical use of approved drugs and pesticides may not be a predictor of future disease outbreaks as production within the bay increases or as other influencing factors change. The addition of farmed fish to an area is expected to amplify both endemic pathogens and pests in that area, due to the increase in the number of host fish. However, the impact on wild susceptible fish species will depend on the duration and extent of their exposure to the farm, the increased concentration of pathogens and parasites, and their relative susceptibility to infection and disease within the environmental conditions found in Whycocomagh Bay, all of which are currently unknown.

Physical Interactions

Bycatch or entanglement of wild species associated with the placement of infrastructure are also potential interactions associated with aquaculture sites. Potential displacement of fishing activities or species from habitat due to added infrastructure is also addressed here.

Available information indicates that Harbour and Grey Seals are present in Whycocomagh Bay and may be present around the #1430 and #1431 proposed sites. Seasonal ice cover in Whycocomagh Bay from mid-December through April may limit their presence in the bay around the site infrastructure during the winter months when they are known to be most abundant in the Bras d'Or Lakes for feeding (Parker et al. 2007).

Recreational and Aboriginal fisheries in the area that may experience displacement associated with the placement of infrastructure in the water include American Eel (assessed as Threatened by COSEWIC and under consideration for *SARA*-listing), Lobster, Herring, Mackerel, Cod, Winter Flounder, Smelt, and Atlantic Salmon.

Estuaries associated with rivers containing freshwater habitats are also considered to be important habitat for ECB Atlantic Salmon as successful migration through these areas is required to complete the life cycle. Traditional Ecological Knowledge also indicates that, in addition to serving as a migratory pathway, the Bras d'Or Lakes serve as a staging area for returning adults and as an over-wintering areas for kelts (DFO 2014a).

The exact magnitude of exposure and physical interactions between fish and infrastructure at the proposed #1430 and #1431 sites are unknown. To date, there have been no reports of entanglements of wild species at the existing sites in Whycocomagh Bay. However, the significant increase in total leased area and infrastructure from these proposed sites suggests a larger potential for interactions between these species and the infrastructure, should these species be present.

Potential Cumulative Interactions

The entire area of interest surrounding the two aquaculture sites (#1430 North and #1431 South) is influenced by human activity (Figure 9). The larger, widespread pelagic-PEZ of the proposed sites results in spatial overlap among the proposed lease areas, as well as with all other human activities occurring in the area of interest.

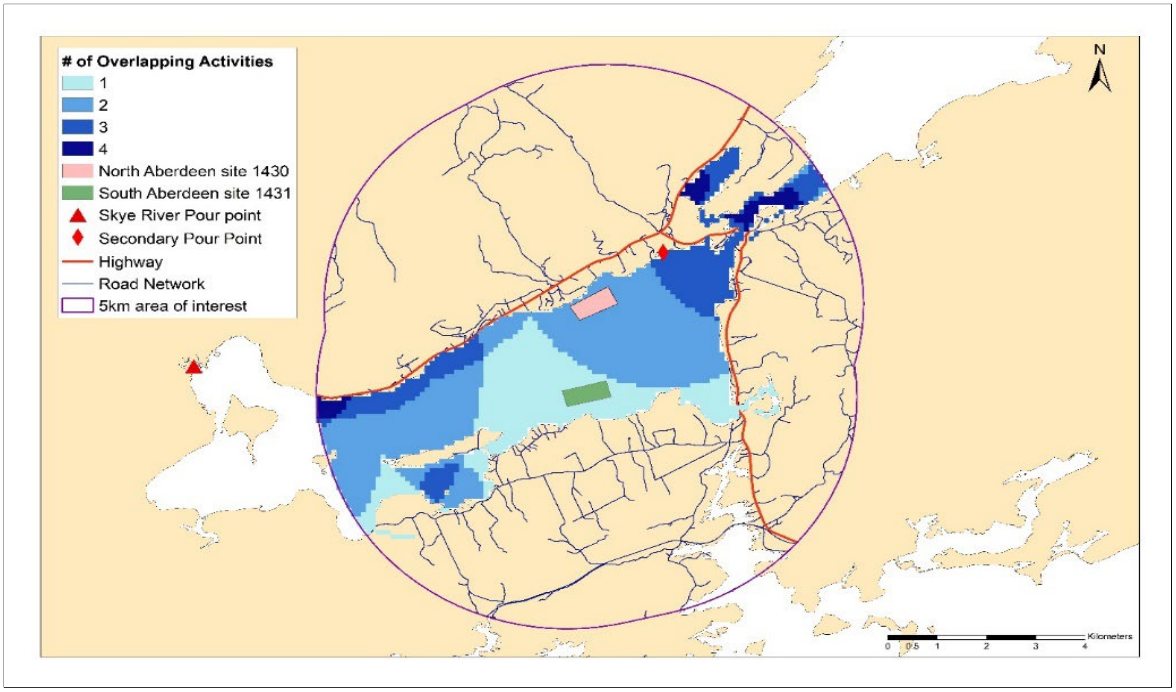

Figure 9. Number of overlapping human activities in each 0.01 km^2 grid cell (5 km radius from the centre of each site). The lease boundaries are represented by the green (#1431) and pink (#1430) rectangles. The red symbols (triangle and diamond) are the pour point locations (i.e., where the Skye River and secondary stream drains into the bay).

The number of overlapping activities is moderate, with approximately 50% of the area of interest being influenced by two co-occurring human activities in any given grid cell (Figure 10). Most human activities are concentrated in two locations: Little Narrows and the westernmost area towards Whycocomagh (Figure 9). Finfish aquaculture, then finfish aquaculture overlapping with nutrient loading, cover the largest spatial area along a central corridor within the area of interest (Figure 9). Appendix B provides methodology details of this analysis.

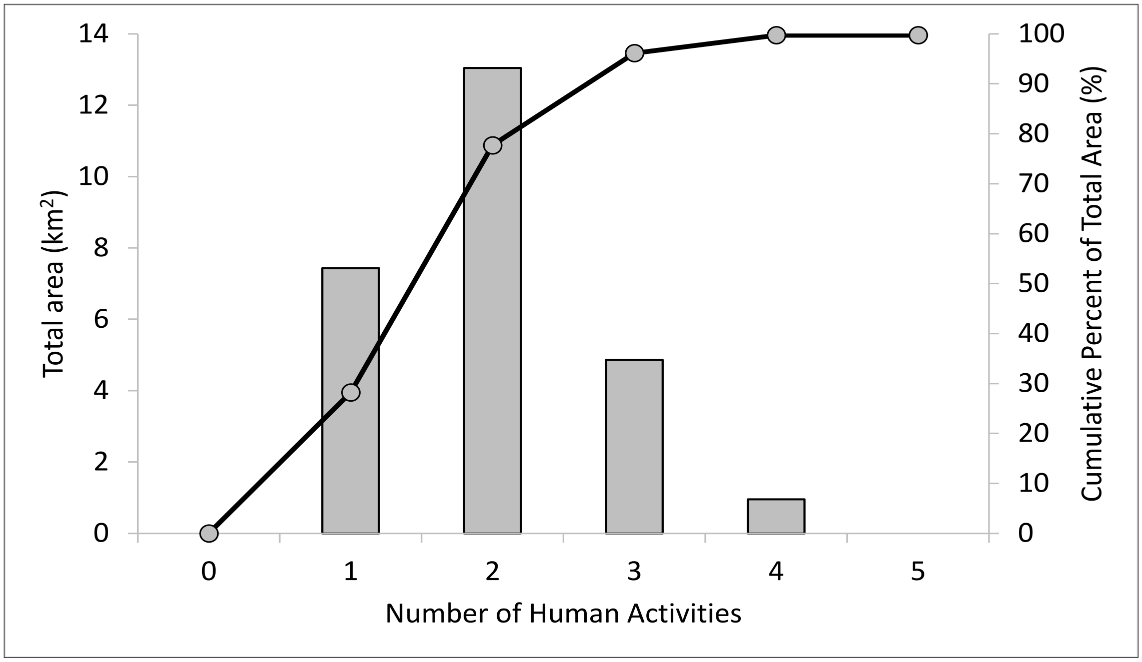

Figure 10. Total area (km^2; grey bars), and the cumulative percentage of the total area (%; black line, grey circles), in all grid cells with the corresponding number of human activities.

The stressors linked to human activities in the marine environment can be grouped into three main categories: physical (direct alteration to habitats), chemical (effects on water and sediment quality), and biological (changes to non-target species). All human activities considered within this analysis have been linked to > 1 stressor impact, and five of six of these activities have influences across all three categories (Table 4).

Table 4. Comparison of stressors associated with human activities identified in this analysis. Stressors linked to finfish aquaculture, shellfish aquaculture, recreational boating, and nutrient loading were summarized from Ban et al. (2010), while those linked to the Trans-Canada highway were summarized from Trombulak and Frissell (2000). Dash (-) = no stressor identified.

Category	Stressor	Activities					
		Finfish aquaculture	Shellfish aquaculture	Boating traffic†	Nutrient loading*	Coastal highway	Lobster fishing
Physical (direct alteration to habitats)	Benthic disturbance	X	X	X	X	-	X
	Collisions	-	-	X	-	-	X
	Freshwater input/decrease	-	-	-	-	X	-
	Change in currents/circulation	X	X	X	-	-	-
	Light	X	-	X	-	-	-
	Marine debris	X	X	X	-	X	X
	Noise	X	X	X	-	X	X
Chemical (water and sediment quality)	Bacteria	X	-	X	X	-	X
	Contaminants	X	-	X	-	X	X
	Nutrients	X	X	X	X	X	X
	Oil/waste	X	X	X	X	X	X
	Organic waste	X	X	X	X	X	X
	Sediment transport (turbidity)	X	X	X	X	X	X

Category	Stressor	Activities					
		Finfish aquaculture	Shellfish aquaculture	Boating traffic†	Nutrient loading*	Coastal highway	Lobster fishing
Biological (changes to non-target species)	Changes in behaviour (predator or prey)	X	X	X	-	-	-
	Biomass removal (incidental mortality)	X	X	X	-	X	X
	Diseases and parasites	X	-	-	-	-	-
	Genetic interactions	X	-	-	-	-	-
	Invasive species	X	X	X	-	-	-

† combined stressors from small docks, ramps, wharves, fishing vessel, and pleasure boating activity categories of Ban et al. (2010)

* stressors from agriculture category of Ban et al. (2010)

Existing finfish aquaculture, boating traffic, and Lobster fishing activities generate the greatest number of different types of chemical stressors that can affect water and sediment quality (Table 4). Boat traffic is also associated with causing the greatest number of different physical stressors, while finfish aquaculture activities are linked to the greatest proportion of different biological stressors (Table 4). Overall, finfish aquaculture activities and boat traffic may be responsible for the largest proportion of different stressor effects, while nutrient loading may generate the smallest proportion of different stresses on species and habitats (Table 4). The most common stressors linked to the six human activities are inputs of nutrients, oil/waste, organic waste, and sediment transport (chemical stressor; all six activities), benthic disturbance, debris, and noise (physical stressor; five of six activities), and biomass removal through incidental mortality (biological stressor; five of six activities) (Table 4).

At present, there is little scientific evidence to be able to weigh the relative magnitude of the effects of each stressor. However, weighing the relative impact of each human activity on a broad spatial scale (i.e., the whole area of interest) can be considered through an examination of the spatial distribution of the activity multiplied by a specific impact weight, which estimates the vulnerability to human activities of different habitats known to be present in Whycocomagh Bay (Kappel et al. 2012; see Appendix B for further explanation). The use of habitats also indirectly captures impacts on associated species. Individually, nutrient loading, followed by finfish aquaculture and then boat traffic, make the largest percentage contribution to the total relative impact score (Table 5; Figure 11).

Table 5. Mean (± SD [standard deviation]) relative impact score for six human activities occurring in Whycocomagh Bay. Relative impact score is calculated as the product of the mean impact weight (± SD) and the proportion of total area over which each activity occurs within the area of interest. Mean impact weights are calculated using individual stressor-habitat impact weights (from Kappel et al. 2012) for seven different habitat types in Whycocomagh Bay (beach, marine flat, salt marsh, eelgrass, algal habitat, nearshore soft benthic, nearshore hard benthic).

Human activity	Stressor category from Kappel et al. (2012)	Mean impact weight (± SD)	Proportion of total area	Mean relative impact score (± SD)
Finfish aquaculture	Aquaculture: finfish (predators)	0.90 (0.81)	0.97	0.87 (0.78)
Shellfish aquaculture	Aquaculture: shellfish	1.92 (0.41)	0.04	0.07 (0.01)
Lobster fishing	Fishing: demersal non-destructive, low bycatch	2.15 (0.07)	0.03	0.07 (0.002)
Nutrient loading	Nutrient input: into oligotrophic waters	1.95 (0.89)	0.69	1.35 (0.61)
Coastal highway	Pollution input: trash, etc. (urban runoff)	3.40 (0.99)	0.09	0.30 (0.09)

Human activity	Stressor category from Kappel et al. (2012)	Mean impact weight (± SD)	Proportion of total area	Mean relative impact score (± SD)
Boat traffic	Tourism: recreational boating	2.03 (0.44)	0.15	0.31 (0.07)

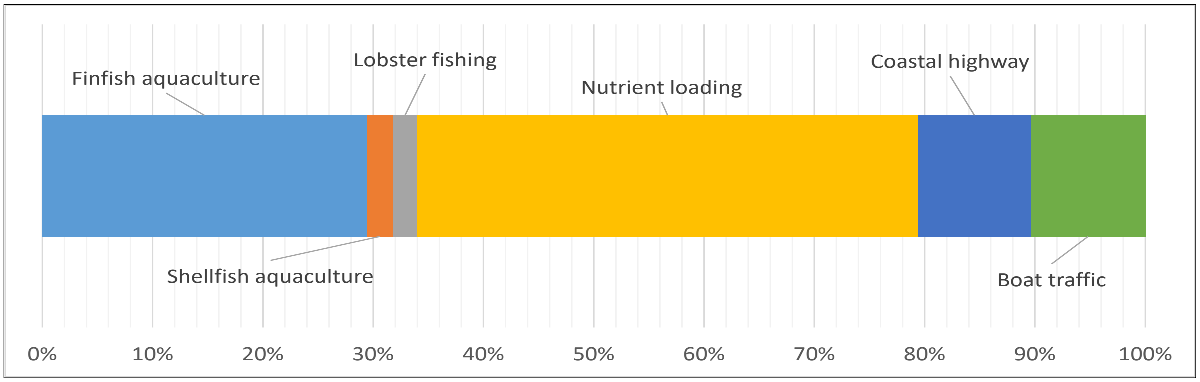

Figure 11. Percent contribution to relative impact of individual human activities. Impacts are averaged across seven different habitat types (beach, marine flat, salt marsh, eelgrass, algal habitat, nearshore soft benthic, nearshore hard benthic), and weighted by their spatial extent measured as proportion of total area of interest. Values of relative impact scores for each activity are listed in Table 5.

However, these activities overlap in space (Figure 9), and their impacts would not occur in isolation. Thus, when examined cumulatively, the large spatial overlap of finfish aquaculture and nutrient loading leads to the greatest cumulative impact score, followed by the cumulative impact of finfish aquaculture, nutrient loading, and boat traffic (Figure 12; Table B3). From the present analysis, the cumulative impact of finfish aquaculture and nutrient loading and boat traffic may have the most significant anthropogenic footprint on the Whycocomagh Bay ecosystem.

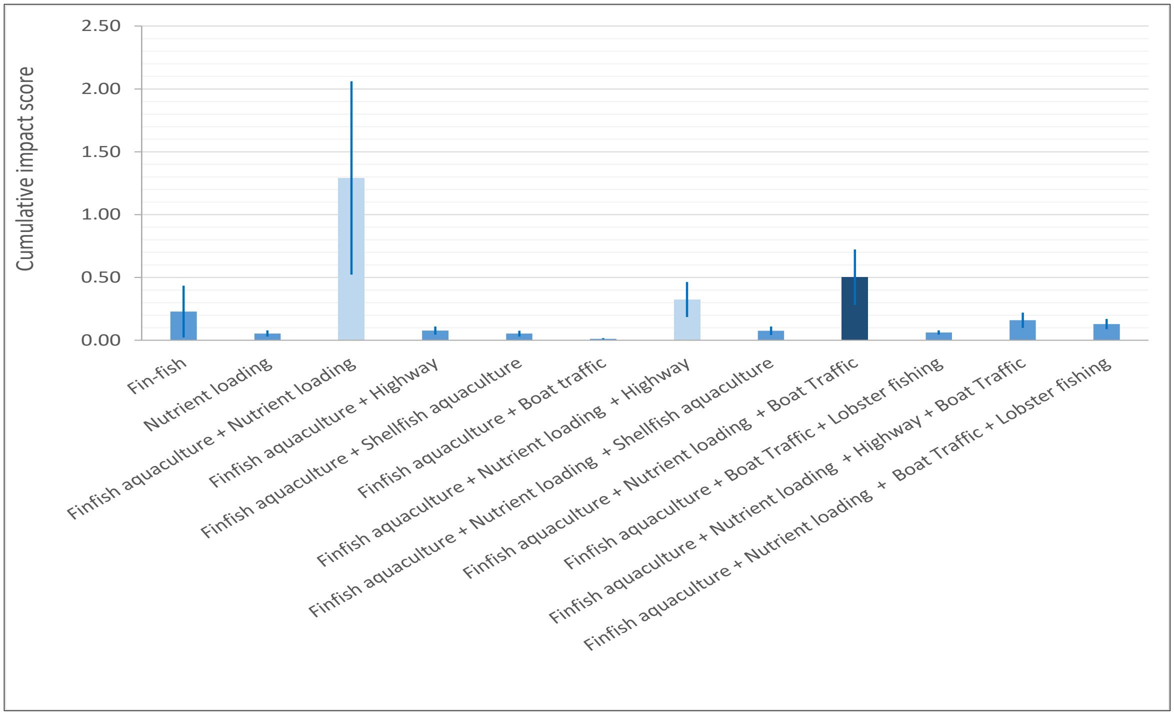

Figure 12. Relative cumulative impact scores for different combinations of overlapping human activities (as displayed in Figure 10). Light blue bars indicate combinations of human activities that could have significant impacts to water and sediment quality; the dark blue bar indicates a combination that could significantly impact both physical and chemical properties of habitats (as detailed in Table 4).

Whycocomagh Bay is characterized by minimal water circulation and low flushing rates, making it sensitive to various inputs (e.g., excess nutrients, water borne pollutants, organic contaminants, etc.) that cannot be quickly dispersed by water movement (Parker et al. 2007). As a result, coastal water and sediment quality in Whycocomagh Bay is most at risk from the cumulative effects of runoff (excess nutrients and sediment), pollution, and human waste generated from different land uses and boat traffic in combination with those generated by finfish aquaculture.

Excess nutrients from land runoff contribute sources of nitrogen (N) to Whycocomagh Bay. Runoff and sediment erosion impacting water quality due to human land use is already ranked as a high threat for the surrounding two watersheds that drain into Whycocomagh Bay (Sterling et al. 2014). Anthropogenic N loads from the surrounding watershed are estimated at 88,259 (± 29,205) kg N yr^{-1} (or a yield of 3.8 kg N ha watershed^{-1} yr^{-1}; Kelly et al. 2021). The addition of more finfish aquaculture to Whycocomagh Bay will also add to the existing anthropogenic total N loading in the bay, which may increase the risk of eutrophication problems occurring.

Sources of sewage pollution in Whycocomagh Bay include malfunctioning sewage or treatment systems, residential septic tanks and fields, and outhouses (EDM 2008). For Whycocomagh Bay, human wastewater sources are estimated to contribute 62% of the total annual N load (Kelly et al. 2021). Further, analysis of the mean fecal coliform counts from 2014–2018 (Canadian Shellfish Sanitation Program; ECCC 2019) suggest that despite mostly low values over this period, some years experienced higher average values, resulting in poorer water quality (Figure 13).

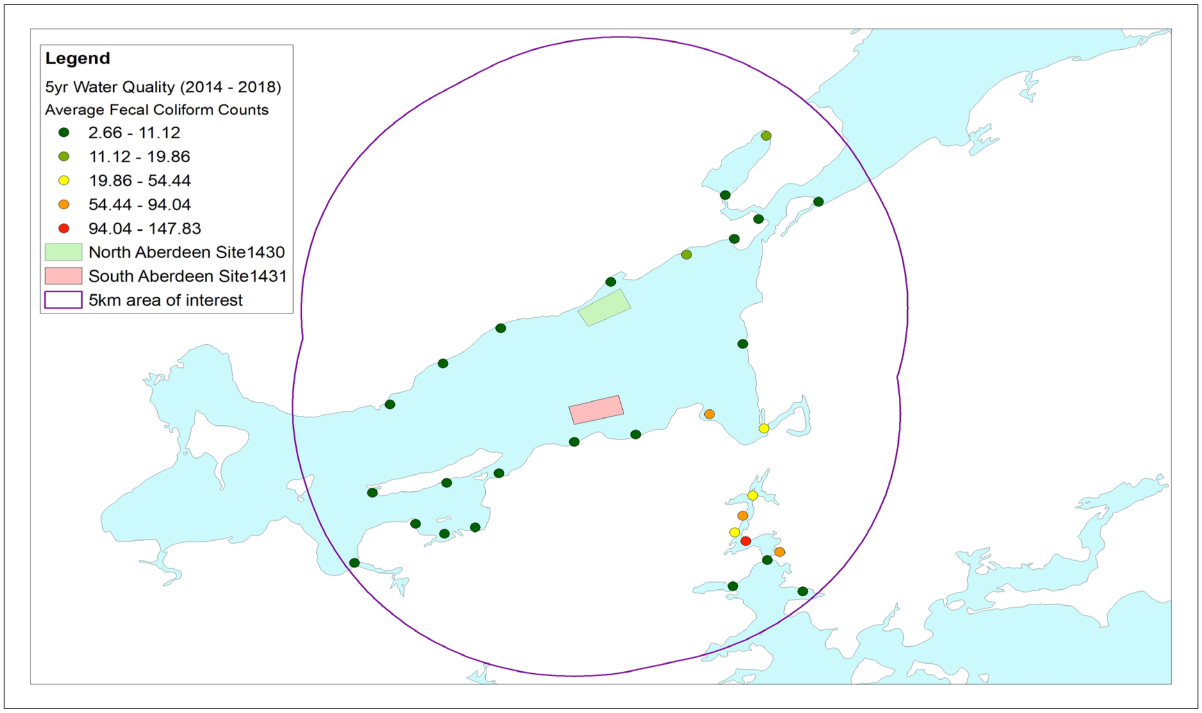

Figure 13. Mean fecal coliform counts (2014–2018) at Canadian Shellfish Sanitation Program sampling stations within the 5 km area of interest. Sites with values < 14 MPN (most probable number 100 mL^{-1}) are considered uncontaminated and of good quality.

These areas overlap with the pelagic-PEZs of the proposed leases and point to human sewage effluent being present in the area. In addition to contributing to bacterial contamination of the bay, such inputs, in combination with nutrient loading, may also exacerbate the reduced oxygen concentrations experienced in Whycocomagh Bay, for which finfish aquaculture is also a contributor.

Small vessels contribute to reduced water quality through pollution due to leakage of fuels and oils, antifouling paints (containing copper), and human waste (sewage effluents) (Leon and Warnken 2008). While the magnitude of recreational boating traffic is currently unknown, it is likely highly seasonal, following the typical tourist season for Nova Scotia (May–October, with peaks in June–August). While individually the impacts of boating are considered minor, often concentrated over short periods of time and in localized areas their cumulative impact may result in detrimental effects on species and/or habitats. The estimated impacts from boat traffic are likely an underestimate due to the lack of available information on the magnitude of recreational boating in the area.

Boating also contributes to the secondary spread of non-native species (Clarke Murray et al. 2011, Burgin and Hardiman, 2011). Aquaculture activity adds or removes physical structures (e.g., ropes, buoys, anchors) that can be colonized by diverse biological assemblages, which can affect the local ecosystem (DFO 2010). The invasive tunicate *Botryllus schlosseri* is already present in Whycocomagh Bay (Sephton et al. 2015); the combined effect of boating traffic and aquaculture structures may contribute to the spread and subsequent establishment of other non-native fouling species already present elsewhere in the Bras d'Or Lakes.

Conclusions

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

- The seabed up to approximately 5.5 km from the proposed sites may be exposed to in-feed drugs present in feces, if used.
- Pesticide levels that are toxic to susceptible species may travel up to approximately 5.0 km from the proposed sites, if used.
- Seasonal ice cover in Whycocomagh Bay may limit the use of bath pesticides during the winter months.
- The intensity of exposure is expected to be highest near the net-pen arrays and decrease as distance from the net-pens increases, except for in areas of anticipated overlaps where cumulative exposures may occur.
- Overlaps in the predicted exposure zones from fish health treatment products (both in-feed drugs and bath pesticides) are anticipated, if used at both sites.
- The low flushing rate of Whycocomagh Bay makes it particularly sensitive to the deposit of in-feed drugs that are passive and persistent, if used.
- Available information suggests that there is little evidence of species that are directly susceptible to fish health treatment products within the benthic-and pelagic-PEZ.
- Since 2015, AAR reporting indicate the existing sites have not used fish health treatment products. This may in part be related to the low occurrence of Sea Lice due to environmental conditions at the site.

Question 2: *Based on the available information for each site, 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?*

- The seabed up to approximately 780 m from the proposed sites may be exposed to deposition of organic matter due to waste feed. The intensity of exposure is expected to be highest near the net-pen arrays and decrease as distance from the net-pens increases.
- The total benthic footprint within Whycocomagh Bay is anticipated to increase, but overlaps in the areas of organic matter exposure due to waste feed are not predicted.

- The low flushing rate of Whycocomagh Bay makes it particularly sensitive to organic loading.
- Whycocomagh Bay is part of the Bras d'Or Lakes EBSA; however, it is ranked as the second least significant basin given its limited habitat diversity and ability to support a diverse and productive biota.
- Eelgrass has been identified within the benthic-PEZs related to all particle types. Significant spatial and temporal variability in eelgrass distribution and condition is expected due to natural factors within the region that are suboptimal for eelgrass.
- Interactions between eelgrass and deposition of waste feed are anticipated to result in limited impacts. Feces, fines, and flocs will be transported further and potentially encompass a significant portion of the eelgrass habitat; however, it is not possible to predict the likelihood or magnitude of effects or changes due to the lack of existing data on current eelgrass distribution and on sediment transport.
- Eelgrass habitat is not unique to Whycocomagh Bay within the Bras d'Or Lakes.

Question 3: *How do the impacts on these species from the proposed aquaculture sites 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?*

- The entire area of interest around the site is influenced by human activities with significant overlap.
- Overlaps in predicted exposure zones from the proposed aquaculture activities at sites #1430 and #1431 and site #0814x in the western end of the bay are not anticipated, with the exception of the transport of fines and flocs.
- Human activities include a combination of land- and marine-based sources: anthropogenic nutrient loading, coastal highway runoff, boating traffic, Lobster fishing, and marine aquaculture.
- From the present analysis, the cumulative impact of finfish aquaculture, nutrient loading, and boat traffic may have the most significant anthropogenic footprint on the Whycocomagh Bay ecosystem, with finfish aquaculture representing a major component of cumulative impact.

Question 4: *To support the analysis of risk of entanglement with the proposed aquaculture infrastructure, which pelagic aquatic Species at Risk make use of the area, and for what duration and when?*

- Species within Whycocomagh Bay include wild Atlantic Salmon, Harbour and Grey Seal, American Eel, Atlantic Herring, Mackerel, Atlantic Cod, and Smelt.
- Seasonal ice cover in the eastern end of Whycocomagh Bay may limit the presence of Harbour and Grey Seal around the site infrastructure during the winter months when they are known to be most abundant in the Bras d'Or Lakes for feeding.
- ECB Atlantic Salmon that use the area during various stages of their life cycle and/or as a migratory pathway may experience displacement due to the significant increase in total leased area and site infrastructure in the bay.

Question 5: *Which populations of Salmonids are within a geographic range that escapees are likely to migrate to? What are 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?*

- The proposed leases are within the ECB Designatable Unit of wild Atlantic Salmon, which is under consideration for *SARA* listing. ECB Atlantic Salmon populations are assessed as Endangered by COSEWIC and are the last remaining recreational fishery and First Nations allocations in the Maritimes Region. Other Salmonids are present but not assessed here.
- Both Middle and Baddeck rivers were below their conservation egg requirement for ECB Salmon in 2019 and have been for the previous 20 years, and the 2018 smolt estimate on Middle River was estimated among the lowest in recent years (albeit with large uncertainty).
- All ECB Salmon rivers are within potential dispersal distances of Rainbow Trout escapees from the proposed sites.
- There is no evidence of direct genetic interactions between Rainbow Trout and Atlantic Salmon.
- Ecological interactions and deleterious effects on wild Salmon from competition from introduced invasive Rainbow Trout are well documented. There is evidence that these types of ecological interactions can lead to indirect genetic effects that ultimately reduce Atlantic Salmon population size and consequently reduce their genetic diversity.
- There will be increased risks to wild Salmon with the proposed increases in the number of farmed Rainbow Trout within Whycocomagh Bay.

Sources of Uncertainty

Predicted Exposure Zones

Results of calculations based on the proponent's data are a subset of the full range of potential calculation outputs. The predicted exposure zones are based on current meter data provided by the proponent. The proponent-provided current record is from a single location over a 30-day time window. This means that the first-order estimates assume the current is spatially homogenous and seasonally consistent, and they are unlikely to be fully representative of the temporal and spatial variability that may be of relevance to estimating exposure and deposition zones. Available data are often insufficient for assessing the probability of sediment transport to specific areas within the predicted exposure zones. Additionally, it is not known whether sinking or floating feed will be used. If a floating feed is used, calculations of benthic exposure zones in this review may be underestimates.

The state of knowledge in relation to refining the assessment of the potential for in-feed drugs and pesticides impacts is evolving. Therefore, a more detailed assessment of potential pesticide and drug impacts was not conducted.

Species and Habitat Distributions

Coastal areas are generally not adequately sampled on spatial and temporal scales of most relevance to aquaculture (i.e., tens to hundreds of meters and hours to months). Information on these 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 those areas. Data based on surveys do not fully sample the area spatially or temporally and additional information on presence and habitat use (e.g., spawning, migration, feeding) must be drawn from larger-scale studies.

Currently, there is a lack of available data representing present-day eelgrass distribution within Whycocomagh Bay. Eelgrass habitat is subject to natural temporal and spatial variability, and it is unknown if distribution has changed since previous surveys were conducted. Additionally, there is a lack of data representing factors known to affect eelgrass health and distribution (i.e., existing light levels, turbidity, etc.). As a result of the above, the full scale of potential changes to eelgrass in the surrounding area specifically as a result of the proposed aquaculture activities cannot be predicted.

Farmed-Wild Interactions

Apart from Skye, Middle, and Baddeck Rivers, information is generally lacking on the size and distribution of wild Atlantic Salmon populations. Improved estimates of wild Atlantic Salmon population size and the presence of escapees in Salmon-bearing rivers within Maritimes Region would improve the assessment of genetic and demographic risk. Significant knowledge gaps also exist regarding disease and Sea Lice infestation levels in wild and farmed Salmonids, and monitoring and reporting of these levels would be informative.

Potential Cumulative Interactions

Many regional and global-scale human activities that may overlap with local-scale activities were excluded from this analysis, due to limits on data availability and/or spatial resolution. Historical activities that may have legacy effects (i.e., sedimentary contamination), impacts from natural disturbances (e.g., storms, marine heat wave), or episodic activities that can create infrequent but intense disturbances (e.g., oil spill), were not included in the current analysis. The geographic extent of human activities 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 impacts. Also, it is assumed that the influence of human activities diffuse equally in all directions, although it is more likely that alongshore currents and river plumes influence the diffusion of impacts, particularly close to the coastline. Overall, the human activity map should be considered a preliminary and conservative estimate of human uses 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.

Many of these impacts 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 the 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).

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Appendix A: Physical Data

The spatial and temporal sparsity of data available for an overall understanding of the area is important to note as it contributes to consequent uncertainties in variability.

Temperature and salinity data collected in the western end of Whycocomagh Bay (Figure A1) was used to supplement the minimal data collected in the area immediately surrounding sites #1430 and #1431. Vertical profiles of these physical characteristics were recorded from 1995–1997 in spring, summer, and fall (Strain et al. 2001), and also collected through DFO's Bras d'Or Lakes Monitoring Program (2014 and 2020).

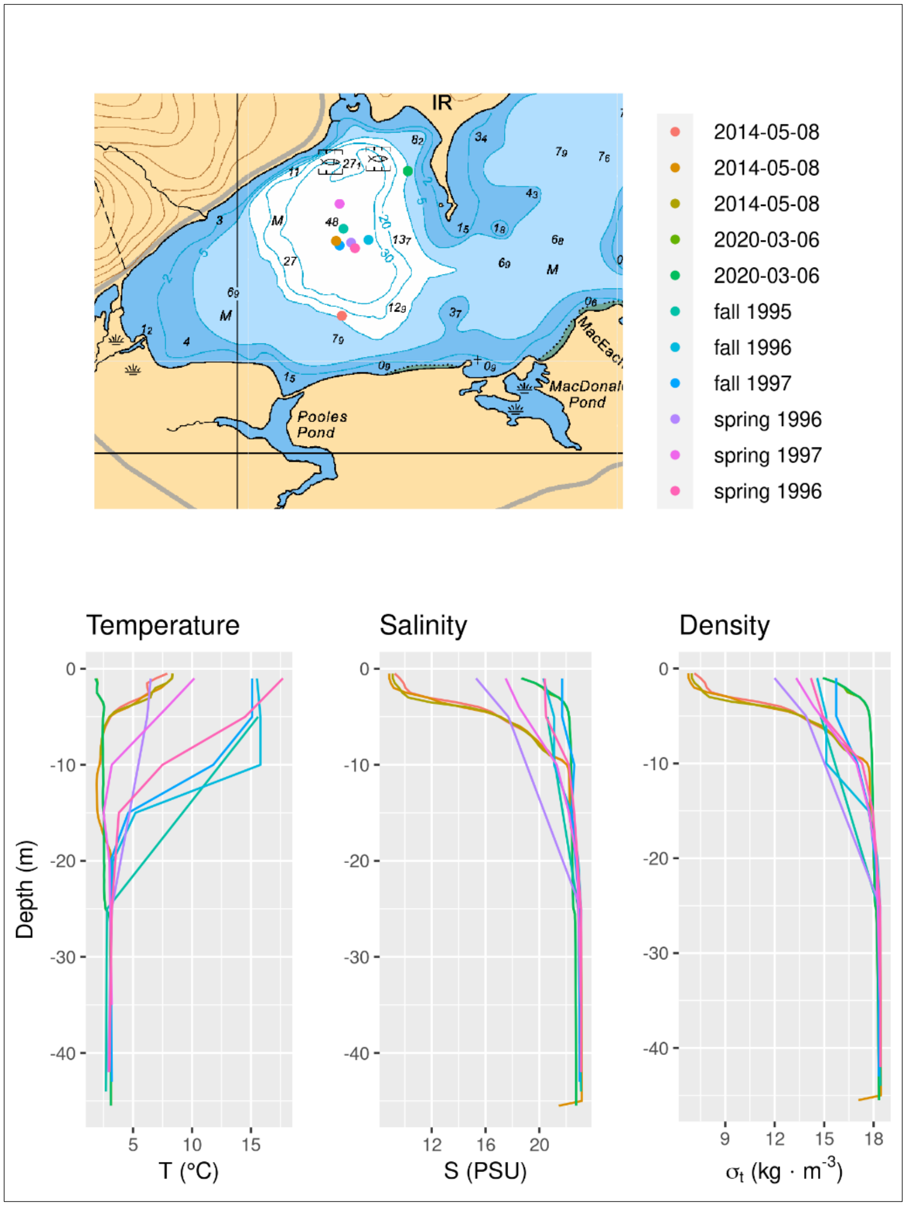

Figure A1. Vertical profiles of temperature, salinity, and density measured in the western end of Whycocomagh Bay.

Dissolved oxygen was measured as well during the vertical profiles described above, and two additional near-bottom time series were collected from November 2014–May 2015 to the north and south of the deep anoxic basin (Figure A2).

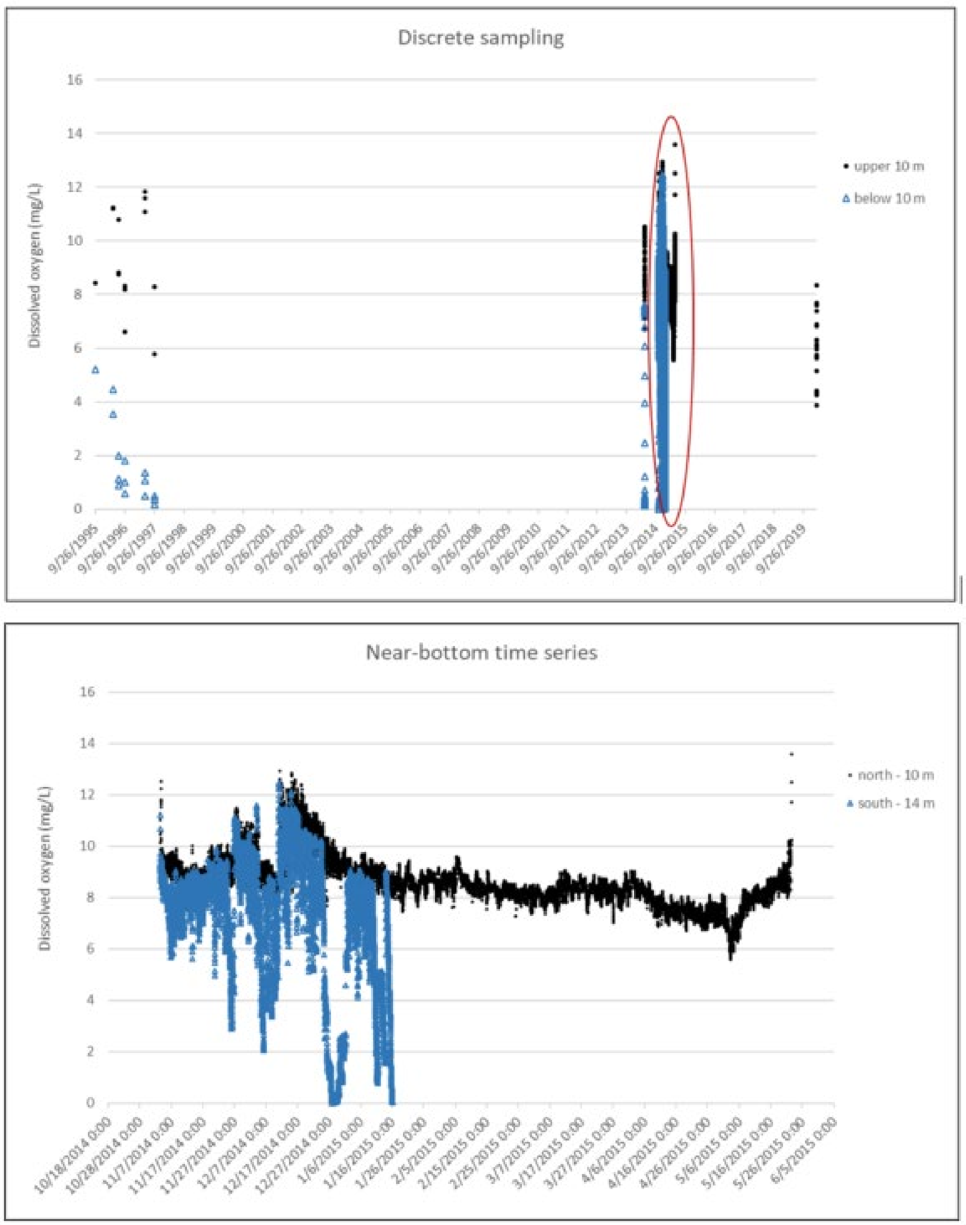

Figure A2. Dissolved oxygen (mg/L) data available at locations near the proposed #0814x site. Circled data in the top panel represents the time-series data collected near the site and shown in the bottom panel. The south side instrument died on January 16, 2015.

Appendix B: Cumulative Occurrence of Human Activities

Identification of anthropogenic sources

A visual representation of the pattern of human use can help illustrate the distribution of human activities in the ocean and identify overlaps among them. Spatial data for marine activities within a 5 km radius for the two sites (hereafter the "area of interest") were collated from a larger inventory of human activities developed for the Maritimes region (DFO unpublished data[1]). Human activities were selected that occurred on a "local" scale, defined as those operating over small spatial scales (i.e., < 10 km) or from point-sources that could produce a localized zone of impact, such as marine recreation, aquaculture, or benthic structures. The most recent years of data or up-to-date information were included when possible.

Overlapping occurrence of human activities

The impact of human activity in the marine environment often extends beyond its immediate occurrence. A "zone of influence" was used to estimate the actual footprint of the stressor(s) (assumed to be) caused by an activity. To estimate the geographical extent of each activity beyond its location of occurrence, a buffer was added that radiated from the point source of the activity. The furthest distance from the activity's origin was determined for the same or most similar activity based on either available data or extensive reviews presented in Ban and Alder (2008), Ban et al. (2010), and/or Clarke Murray et al. (2015) ("buffer radius"; see Table B1).

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

Table B1. Human activities occurring in the area of interest and buffer radii applied beyond location of activity occurrence. The buffer radius is the furthest extent an activity's impact extends from its origin.

Category	Human activity layer	Layer description	Buffer radius (m)
Marine	Finfish aquaculture	Leases #1430 and #1431. Pelagic PEZ model for 3-hr pesticides, based on maximum current speeds	North: 5,033
			South: 2,966
		Other leases within (#0193) or adjacent (#0814) to the area of interest whose buffers overlap	#0193: 2,000 #0814: 2,790
	Shellfish aquaculture	Location of lease #1295, currently stocked with a small number of Oysters for research purposes	500

[1] DFO. Data collected through the Ecosystem Stressors Program Cumulative Impact Mapping Project 2019–2022.

Category	Human activity layer	Layer description	Buffer radius (m)
	Boat traffic	Small craft harbours and boat launches (point sources) captures activity at three locations: Whycocomagh Marina, Little Narrows Ferry Terminal, and Little Narrows Gypsum Mine Marina	2,000
Fishing	Lobster fishing	Polygon (Serdynska and Coffen-Smout 2017)	0
Land-based	Coastal highway	Trans-Canada highway ≤ 30 m of shoreline, with rectangular buffer	500
	Nutrient loading	Captures activities within the watershed that input nitrogen into the bay, including agriculture, human settlements, wastewater inputs, runoff from roads, buildings, and other impervious surfaces. Layer contains two pour points draining into Whycocomagh Bay, with a buffer radius based on the stream order of the river (after Clarke Murray et al. 2015): one at the Skye River (outer buffer overlaps with area of interest) and a smaller second order stream on the north side of the bay near Little Narrows	Skye: 5,870 Secondary: 3,037

Estimating relative impact among human activities

Human activities in the ocean are presumed to cause stress on marine ecosystems. A literature review was conducted to examine the stressors linked to the six different human activities occurring in the area of interest. Stressor effects linked to finfish and shellfish aquaculture, lobster fishing, boat traffic, and nutrient loading were summarized from Ban et al. (2010; Table S4), while those linked to the Trans-Canada highway were summarized from Trombulak and Frissel (2000).

The relative impact of human activities on the marine environment depends on the spatial distribution of activities, the intensity of those activities in any particular place, and the vulnerability of the ecosystem component to a particular activity. To compare the relative impacts among human activities occurring in the area of interest (i.e., at the bay scale), stressor-habitat impact weights previously generated for the Cape Cod/Southern Gulf of Maine through an expert elicitation approach (Kappel et al. 2012) were matched to existing human activities and known habitat types occurring in Whycocomagh Bay. Habitat types in the area of interest included beach, salt marsh, marine flat, seagrass, algal zone, nearshore hard bottom, and nearshore soft bottom (Parker et al. 2007). Human activities in the area of interest were matched to the closest stressor category listed in Kappel et al. (2012), based on the predominant stressor linked to that activity (Table 4). Each stressor-habitat pair was assessed for their likelihood to overlap in space; if no overlap was deemed likely (e.g., beaches and lobster fishing, seagrass and coastal highway), this stressor-habitat pair was removed from further analysis. The stressor impact weight was then averaged across the habitats for each human activity (Table 5); an average across habitats was used since accurate spatial maps of the locations of all habitats in the area of interest was lacking. The intensity of each activity was considered to be uniform across the bay (i.e., given the value of 1) due to lack of prior information on the magnitude (or strength or intensity) of different stressors in the area. Spatial distribution of stressors was then considered in two different ways. First, to compare the relative impacts among human activity categories *individually*, the mean stressor impact weights were multiplied by the proportional area value to generate relative stressor impact scores (Table 5; Figure 11). Second, to examine the *cumulative* impacts of finfish aquaculture with other human activities, the spatial extent (expressed as a proportion of the total area) for all the different combinations of human activities that overlapped with finfish aquaculture was calculated (see Figure 9). For each 2-, 3-, and 4-way combinations of activities, the corresponding average stressor impact weights were summed and then multiplied by the respective proportional area (Figure 9; Table B2).

Table B2. Mean (± SD) relative cumulative impact score for combinations of six different human activities occurring in Whycocomagh Bay. Cumulative impact scores were calculated as the product of the cumulative impact weight and the proportion of total area over which each combination of activities occur within the area of interest. Cumulative impact weights are calculated by summing individual stressor impact weights (from Table B2) averaged across different habitat types in Whycocomagh Bay (beach, marine flat, salt marsh, eelgrass, algal habitat, nearshore soft benthic, nearshore hard benthic).

Activity combination	Proportion of total area	Cumulative impact weight (±SD)	Cumulative impact score (±SD)
Finfish	0.254	0.90 (0.81)	0.23 (0.21)
Nutrient loading	0.028	1.95 (0.89)	0.05 (0.02)
Finfish aquaculture + Nutrient loading	0.453	2.85 (1.70)	1.29 (0.77)
Finfish aquaculture + Highway	0.018	4.30 (1.80)	0.08 (0.03)
Finfish aquaculture + Shellfish aquaculture	0.019	2.82 (1.22)	0.05 (0.02)
Finfish aquaculture + Boat traffic	0.004	2.93 (1.25)	0.012 (0.005)
Finfish aquaculture + Nutrient loading + Highway	0.052	6.25 (2.69)	0.32 (0.14)
Finfish aquaculture + Nutrient loading + Shellfish aquaculture	0.016	4.77 (2.11)	0.08 (0.03)
Finfish aquaculture + Nutrient loading + Boat Traffic	0.103	4.88 (2.14)	0.50 (0.22)

Activity combination	Proportion of total area	Cumulative impact weight (±SD)	Cumulative impact score (±SD)
Finfish aquaculture + Boat Traffic + Lobster fishing	0.012	5.08 (1.32)	0.06 (0.02)
Finfish aquaculture + Nutrient loading + Highway + Boat Traffic	0.019	8.28 (3.13)	0.16 (0.06)
Finfish aquaculture + Nutrient loading + Boat Traffic + Lobster fishing	0.018	7.03 (2.21)	0.13 (0.04)

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