Investigating Concerns of Marine Finfish Aquaculture

Impacts at Bayswater Beach Provincial Park, NS

Nova Scotia Department of Fisheries and Aquaculture

Updated: February 2023

Acknowledgements

The Nova Scotia Department of Fisheries and Aquaculture would like to acknowledge the following individuals and organizations for their contributions toward this initiative: Dr. Ian Spooner (Acadia University); the Centre for Marine Applied Research; Queen's University facility for isotope research (QFIR) laboratory in Kingston, Ontario; Fisheries and Oceans Canada – Aquaculture Management; Fisheries and Oceans Canada – Aquaculture Science; Nova Scotia Department of Lands and Forestry, and Nova Scotia Department of Environment and Climate Change.

Executive Summary

In April 2021, the Bayswater Beach study report drafted by the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) was posted on the departmental website. The report detailed community concerns that a nearby Atlantic salmon aquaculture site AQ#1006 (Saddle Island) was the source of organics decomposing and impacting Bayswater Beach (Provincial Park). The report further outlined the actions taken by NSDFA and study collaborators to investigate these concerns and included the results of the study. The study findings indicated the organics detected from Bayswater Beach sediment were of different origin than organics detected from the sediment collected under aquaculture cages at lease AQ#1006.

NSDFA engaged the Aquaculture Science Advisory Committee ("the Committee") in August 2021 to undertake an independent review of the Bayswater Beach study. The Committee, comprised of experts within scientific disciplines relevant to aquaculture, delivers science-based recommendations to the Minister of Fisheries and Aquaculture to inform the development of the regulatory framework for aquaculture in Nova Scotia. NSDFA staff met with the Committee in October 2021, to present and discuss the study findings. The Aquaculture Science Advisory Committee concluded their independent review of the Bayswater Beach study report and provided scientific advice to NSDFA in May 2022. The Committee advised NSDFA to complete the following revisions to the study report: figure updates; inclusion of sampling area features (depths and ocean current dynamics); and acknowledgment of 'areas of uncertainty'. These recommendations have been addressed and information provided in this (February 2023) updated report. The Committee's conclusion of the study indicated "that the data presented in the report are valid and relevant, and the Committee is satisfied with the scientific work completed by the Department for this study".

The Committee's report and NSDFA's presentation are available on the departmental website: Aquaculture Research and Development Funding Program - Government of Nova Scotia, Canada. More information on the Committee can be found here: Laws & Regulations - Government of Nova Scotia, Canada.

Summary

The Nova Scotia Department of Fisheries and Aquaculture (NSDFA) set out to address concerns raised by residents of Bayswater, Nova Scotia that the nearby marine finfish aquaculture operation, (AQ#1006) was the source of organics decomposing on Bayswater Beach Provincial Park (Bayswater Beach), resulting in the

production of black sediment and sulphurous odours. A focused sediment composition study at Bayswater Beach, Nova Scotia was initiated in November 2020. This study was conducted to characterize the composition of sedimentary organic matter (SOM) on Bayswater Beach and compare with marine sediment samples collected from underneath nearby aquaculture pens. The suite of qualitative (visual indicators) and quantitative indicators (oxidation-reduction potential, free sulfide concentration, porosity, and organic matter) used to assess seafloor sediment conditions for Nova Scotia's Environmental Monitoring Program were measured at regular intervals along two (2) transects beginning at the southwestern edge of lease AQ#1006 and extending toward Bayswater Beach. Sediment samples collected from Bayswater Beach and the marine environment were analyzed for carbon and nitrogen isotopes (^{13}C, ^{15}N) at the Queen's University facility for isotope research (QFIR) laboratory in Kingston, Ontario. The beach area was also investigated from a geomorphological and limnological perspective to provide further insight into possible sources of SOM on Bayswater Beach.

Visual and geochemical analyses performed by NSDFA suggest that discernable environmental impact resulting from aquaculture related organic deposition was relatively low in the area adjacent to and immediately surrounding AQ#1006. Evidence of environmental impact, based on the parameters assessed, was seen to dissipate with increasing distance from the lease boundary, suggesting that the transport of organic materials resulting from finfish production is limited to a relatively small area around AQ#1006. Comparison of stable C-N isotope signals in SOM collected from the beach and near-lease benthos suggest that the organic materials found at these environments do not appear to share a common source. Historical, visual, and geomorphological assessments of the beach and its surrounding area offer the suggestion that SOM accumulation on the beachfront may be influenced by input from the connected Bayswater Pond and significant levels of macrophytic algae present locally.

Background

Bayswater Beach (44°30'12.7"N 64°03'57.9"W) is a relatively small beach-back beach lagoon complex located near Hubbards, on the Aspotogan Peninsula, in southwest Nova Scotia. The beach is a popular summer tourist destination and hosts a small provincial park with a picnic area with a view of the open ocean. Change rooms and toilets are available in the picnic area (Appendix A).

AQ#1006 is an aquaculture lease located in Aspotogan Harbour approx. 1 km from Bayswater Beach. This lease has cultured Atlantic salmon since its acquisition by Kelly Cove Salmon Ltd. in 1999. The site has had varying levels of production throughout its history. During the most recent production cycle, the maximum biomass (total kg of fish on site) reached a level approximately 75% as high as the historical peak production seen at AQ#1006. (Fig. 1).

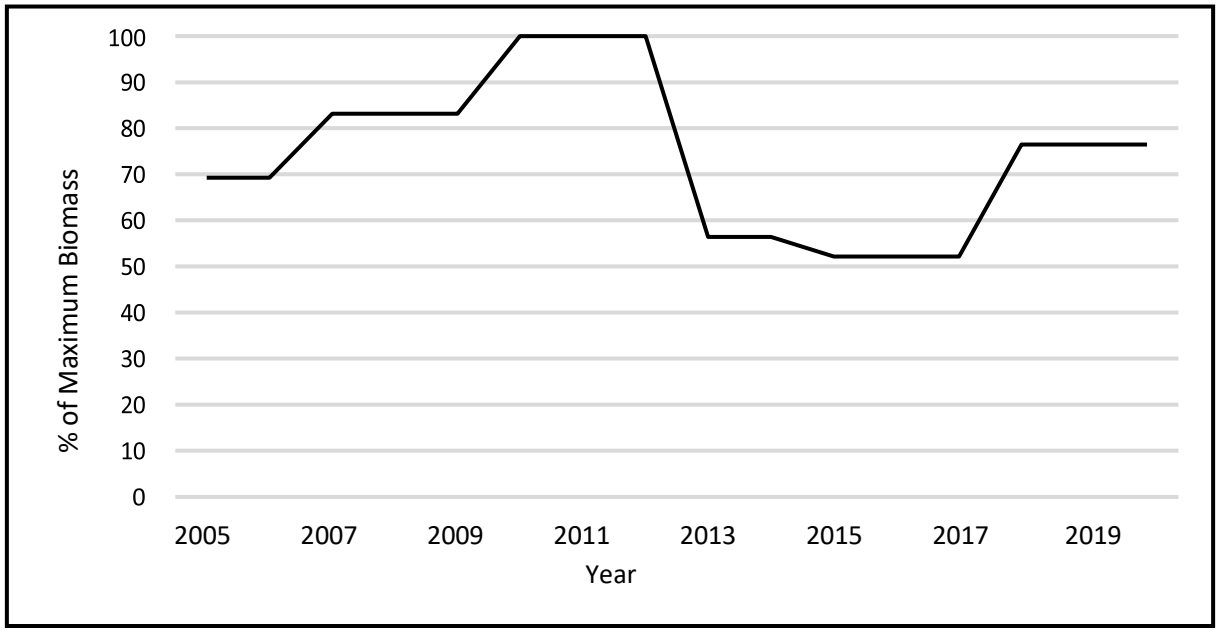

Figure 1. Relative historical biomass of Atlantic salmon grown at AQ#1006 between 2005 and 2020.

Concerns were raised by a member of the public close to Bayswater Beach starting in February 2020 that material from AQ#1006 *"…is mixing with the beach ecosystem and has been accumulating on Bayswater Beach over the last 25 years"*. The complainant reported that "*black sediment and odorous, hydrogen sulfide gas is present along Bayswater Beach*" and expressed concern that *"…these conditions could have been a result of the 25 years of Salmon farming directly off the beach and they could reoccur next summer*". Since the initial concerns were voiced by the complainant in early 2020 there has been regular correspondence regarding the topic both within the department, to outside agencies, and to the complainant. To our knowledge the Nova Scotia Department of Environment and Climate Change (NSECC) have conducted a minimum of three beach visits following complaints: two visits by an Environment Inspector and one by a Conservation Officer. An additional beach visit was conducted by Nova Scotia Lands and Forestry (NSL&F) to follow up on concerns. During these visits, no evidence was found directly associating the condition of the beach with the operation of aquaculture site AQ#1006. Following these inspections, the complainant continued to express concern regarding the condition of the beach through emails and phone calls to various departments. In response, a working group was established in 2020 consisting of representatives from NSDFA, NSL&F, NSECC, Fisheries and Oceans Canada (Aquaculture Management and Aquaculture Science), the Center for Marine Applied Research (CMAR), and Acadia University. The working group proceeded to share information and collaborate on an empirical approach to investigate the origins of sedimentary organic matter (SOM) on Bayswater Beach, with the intent to infer if any organics encountered were linked to the operation of AQ#1006.

Local Oceanographic Conditions

Measurements of current dynamics in the area around AQ#1006 have been conducted by the department through the deployment of two 600 kHz, RDI Workhorse Acoustic Doppler Current Profilers (ADCPs). Deployments of these instruments were conducted approximately 150-200 meters to the southwest and northeast of the existing lease boundary on October 7, 2015, and October 7, 2016, respectively (Fig. 2). The instruments recorded ocean current speed and direction at 15-minute intervals, in 1-meter bins throughout the water column, over the course of 41 and 48 days, respectively. The 2015 deployment, to the southwest of the lease area, recorded a depth-averaged current speed of approximately 4.2 cm/s, with over 75% of recorded currents falling below 6 cm/s. The primary direction of water movement was observed to be in the NE and SW directions, approximately parallel to Bayswater Beach shoreline (Fig. 3A, B). The 2016 deployment, to the northeast of the lease area, recorded a depth-averaged current speed of approximately 3.5 cm/s, with over 85% of recorded currents falling below 6 cm/s. Flow direction at this station was seen to more dispersed, though generally occurring in the WSW and ENE directions (Fig. 3C, D). Together, the two datasets indicate that ocean driven currents in the area are of relatively low energy and travel primarily parallel to the shorelines of the Aspotogan peninsula and Saddle Island.

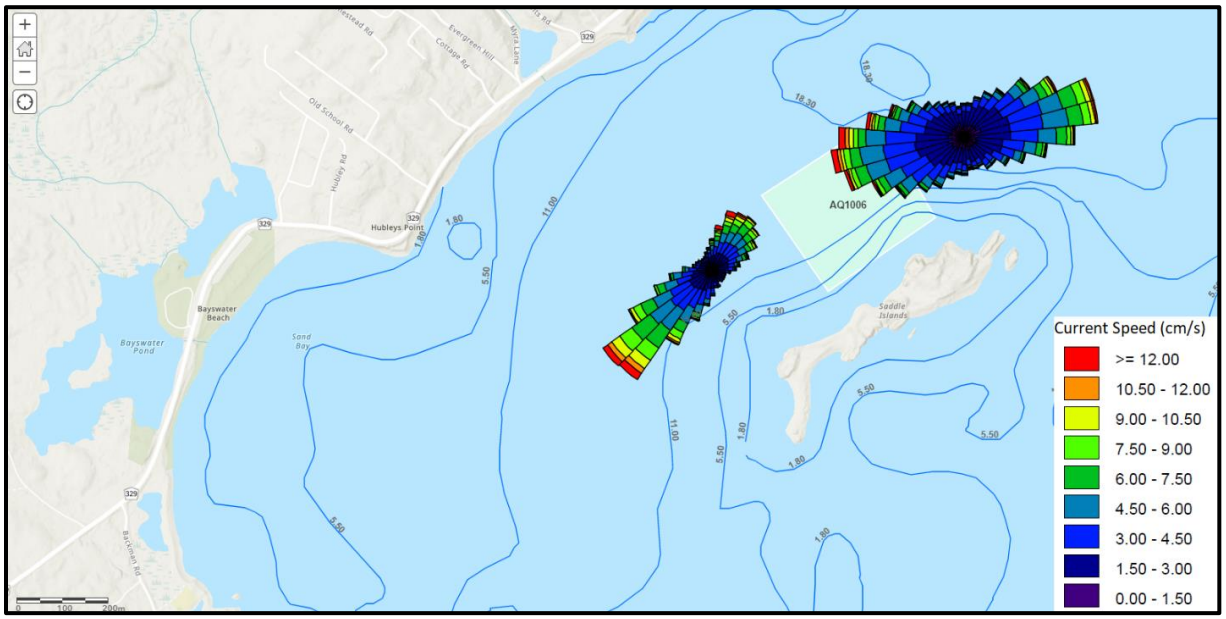

Figure 2. Installation locations and distribution of current speed and direction recorded via 600kHz ADCPs, deployed to the southwest and northeast of aquaculture site AQ#1006 on October 7, 2015 and October 7, 2016, respectively.

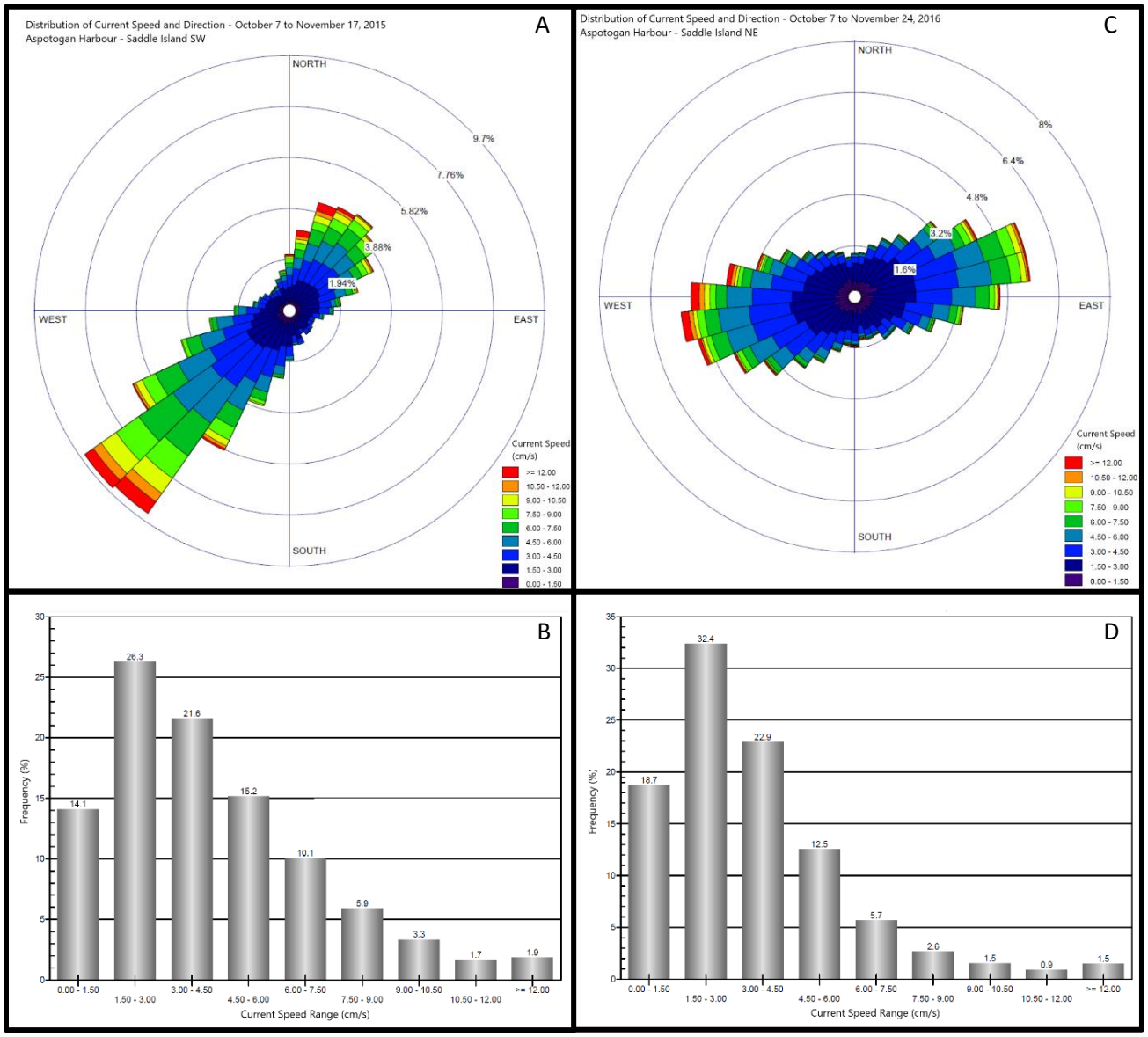

Figure 3. Depth averaged current rose diagrams and bar graphs demonstrating the distribution of current speeds and directions observed by ADCPs deployed to the southwest (A, B) and northeast (C, D) of aquaculture lease AQ#1006.

Sampling Events and Methodologies

Following the establishment of the working group, Dr. Ian Spooner, Environmental Geoscientist in the Earth and Environmental Science Department at Acadia University, was engaged to investigate the geomorphological and limnological environment surrounding Bayswater Beach. In November 2020 Dr. Spooner conducted an exploratory visit to Bayswater Beach to assess its morphology. From this visit, it was determined that "*Bayswater Beach is a relatively small and narrow, moderate to high energy, mesotidal barrier beach that has a fine siliceous sand veneer. Coarse cobbles underlie this veneer. A small, engineered outlet stream exits from Bayswater Pond, crosses underneath Route 329 and then, as of fall 2020, bisects the beach.*". It was further noted that "*No obvious deposits of sedimentary organic matter (SOM) other than beach wrack were observed on the surface of the beach…*" and that "*…some subtle sediment discolouration was noted in a cross section of the beach exposed by the outlet stream from Bayswater Pond*" (Appendix A).

On December 9, 2020, NSDFA staff conducted sediment sampling along two transects between AQ#1006 and Bayswater Beach (Fig. 4). The intent of this sampling event was to assess whether there was evidence of farm-derived organics being dispersed away from the farm in the direction of Bayswater Beach, as well as to collect marine sediments for comparative analysis with beach sediments.

Figure 4. Locations of beach sampling stations (BWB1 – BWB4) and marine transect sampling stations between AQ#1006 and Bayswater Beach (S1 – S14). Inset showing the location of an outlet stream flowing between Bayswater Pond and the SW end of Bayswater Beach.

Sediment samples were collected using a 9" Ponar dredge and were analyzed by NSDFA on December 10th, 2020 for various quantitative indicators of benthic health. Samples were collected from the top 2 cm of the collected sediment, and were analyzed for mean concentration of free sulfide, oxidation-reduction potential (redox), porosity and organic matter using the methodologies described in the Standard Operating Procedures for the Environmental Monitoring of Marine Aquaculture in Nova Scotia (PNS, 2020A). In addition to this geochemical analysis conducted on the sediment samples, a qualitative visual assessment was conducted at each station to identify indicators of non-oxic conditions, such as *Beggiatoa.* A total of 14 stations, along the two transects, were assessed for visual indicators of organic deposition and dispersion using an underwater video camera. Water depth at the sampling stations generally decreased with distance from the aquaculture site, as the transects moved towards the shoreline of the Aspotogan peninsula (Table 1). Thirteen (13) stations yielded useable sediment for quantitative analysis, in triplicate, along with additional samples for isotopic analysis (Fig.4). The top 2 cm of the sediment samples collected from stations closest to the lease boundaries (Fig. 5D) were analyzed for their carbon (C) and nitrogen (N) isotopic (13C, 15N) composition (called C-N analyses) to characterize the organic fraction in these sediments.

Table 1. Depth of marine transect sampling stations at time of sample collection

Station	Depth (m)
Station 1	14
Station 2	17.3
Station 3	16
Station 4	18
Station 5	17
Station 6	14.2
Station 7	7
Station 8	6.9
Station 9	5.6
Station 10	11
Station 11	12.8
Station 12	14
Station 13	18
Station 14	18

On January 16, 2021, 4 sediment samples were retrieved from Bayswater Beach, Nova Scotia for the purpose of better understanding the composition and potentially the source of SOM, if present, in the sediment. One sediment sample was obtained at 15 cm depth from surface from the stream cut in the beach. Three samples were obtained from test pits dug to 75 cm depth at three locations along the beach (Fig. 5A). Test pits encountered coarse SOM at approximately 50 cm depth that was underlain by a thin (5 cm) dark discolored layer that contrasted with the white sand (Fig.5 B, C). The samples taken for analyses from the test pits were from a 5 cm thick portion of this discolored sediment. No samples were taken from the overlying or underlying white sand. Four sediment samples obtained from this beach sampling (1 from the stream cut and 3 from test pits), along with the sediment samples obtained by NSDFA on December 9th, 2020, were prepared for C-N analyses. Samples were kept under 4°C and transported to Acadia University where they were freeze dried for 48 hours and lightly crushed with a mortar and pestle to reduce the size of any coarse SOM. The samples were then

transferred to analyses containers which were labelled and refrigerated until they were sent to Queens University QFIR lab for C-N isotope analyses on March 1st, 2021 (Fig. 5D) (Appendix A).

On March 16, 2021, Dr. Spooner produced an interim update, summarizing his efforts and observations to date. This document has been included as an Appendix and is referenced throughout this report.

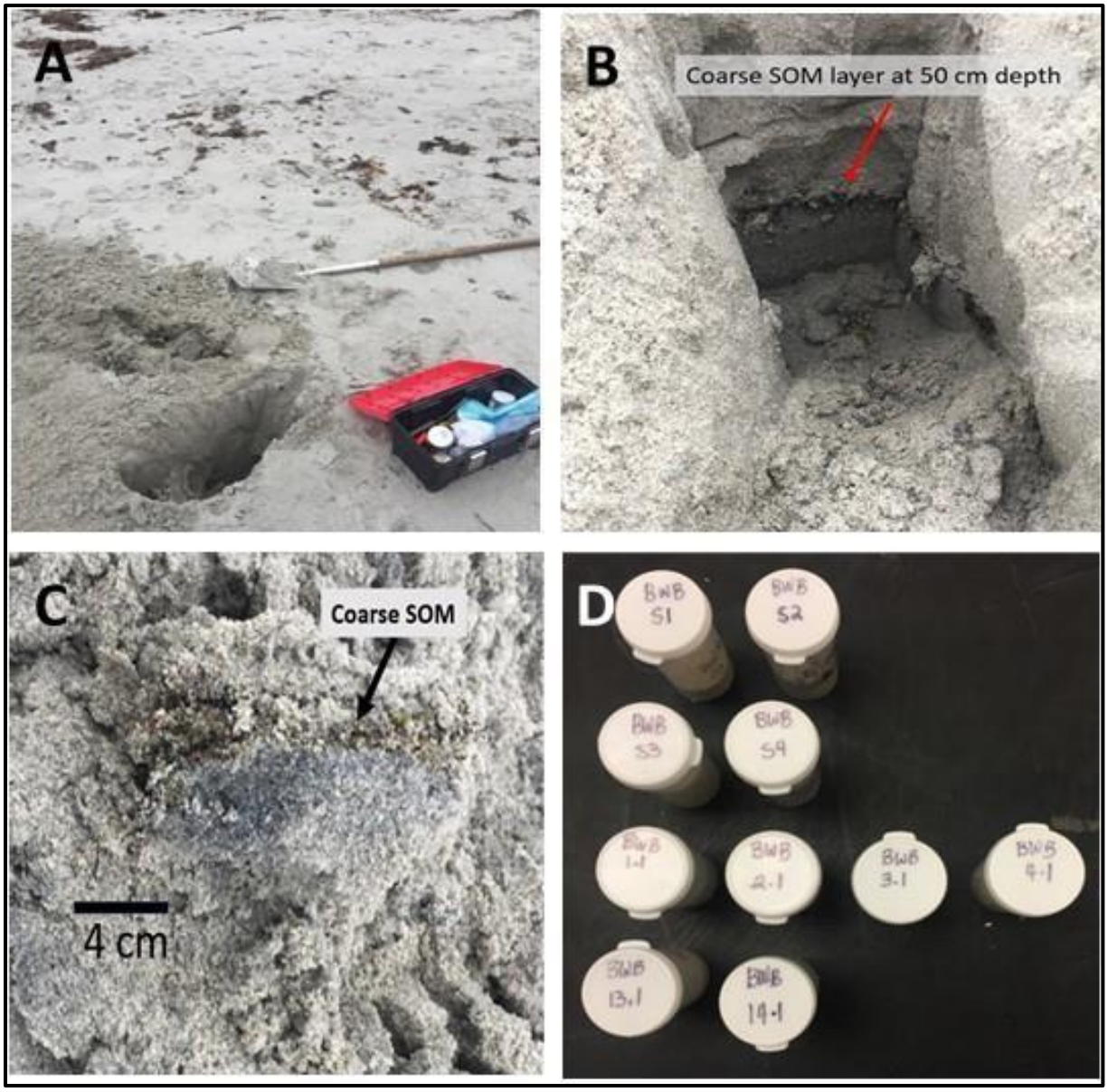

Figure 5. Sediment collection at Bayswater Beach. A) 75 cm deep sample pit from which samples BWB S1 and S2 were obtained. B) Close up picture of pit shown in A. Sample for analysis was at 50 cm depth. C) Close up image of sample BWB S2 showing dark staining below coarse SOM (All photos taken on 1/16/2021) D) Image of samples after drying prior to C N isotopic analyses. Samples BWB S1, S2, S3, S4 are from Bayswater Beach, samples BWB 1-1, 2-1, 3-1, 4-1 and BWB13-1, 14-1 were taken from marine sediment associated with the aquaculture site.

Results

Visual Assessment

All video footage collected during the December 9, 2020, sampling event was reviewed by NSDFA staff to classify general benthic conditions and to assess the seafloor for visual indicators of degraded benthic health associated with local aquaculture production (e.g., waste feed, excess feces, *Beggiatoa*, etc.). *Beggiatoa* is a sulfate reducing bacteria that thrives in low oxygen environments. As organic input (such as waste food or feces) is deposited in the marine environment near an aquaculture lease the microbial activity and biological oxygen demand (BOD) will likely increase, leading to a low oxygen environment that is conducive to increased levels of *Beggiatoa.* A variety of sediment conditions were observed over the length of the transects, with fine sand and silt found nearest to the lease, rocky, seaweed covered benthos at stations near the Hubley's Point outcropping, and coarser sand at stations nearest to the beach (Fig. 6). Trace evidence of *Beggiatoa* bacteria were observed at Station 1, directly adjacent to the southmost cage at AQ#1006; no other visual indicators of environmental impact were apparent at any of the remaining stations.

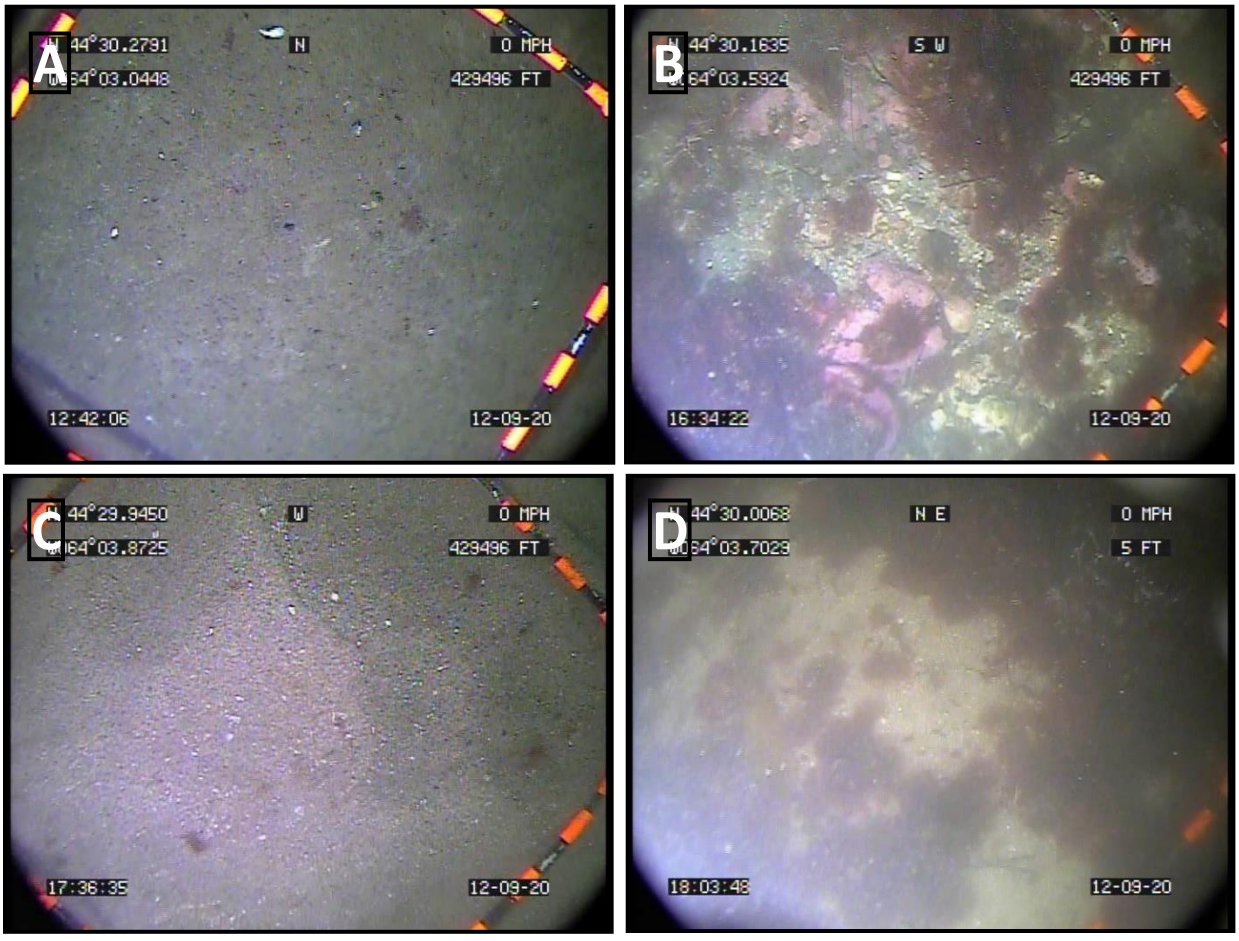

Figure 6. Still images captured from underwater video footage recorded at A) Station 1 B) Station 7, C) Station 9 and D) Station 10

Sulfide Concentration

NSDFA's Environmental Monitoring Program (EMP) dictates that the primary environmental indicator used to assess the benthic health at a soft bottom monitoring station is the mean concentration of free sulfide in the sediment. The use of mean sediment sulfide to classify the environmental quality of a soft bottom aquaculture station or lease is based on recommendations made in *Wildlish et al.* (1999). Elevated levels of sulfide can result from increased input of organic materials into a system as microbial activity and subsequent BOD increase. Sediment is generally considered to be hypoxic when sulfide concentrations reach 1500 micromoles per litre (µM). Analysis of the sediments collected during the December 9, 2020, sampling event revealed a negative correlation between distance from the aquaculture site and sediment sulfide concentration (Fig. 7). The highest average sulfide values were observed at the four stations nearest to AQ#1006, though readings at all stations were at a level that would be considered oxic according to the NSDFA EMP (PNS, 2020B).

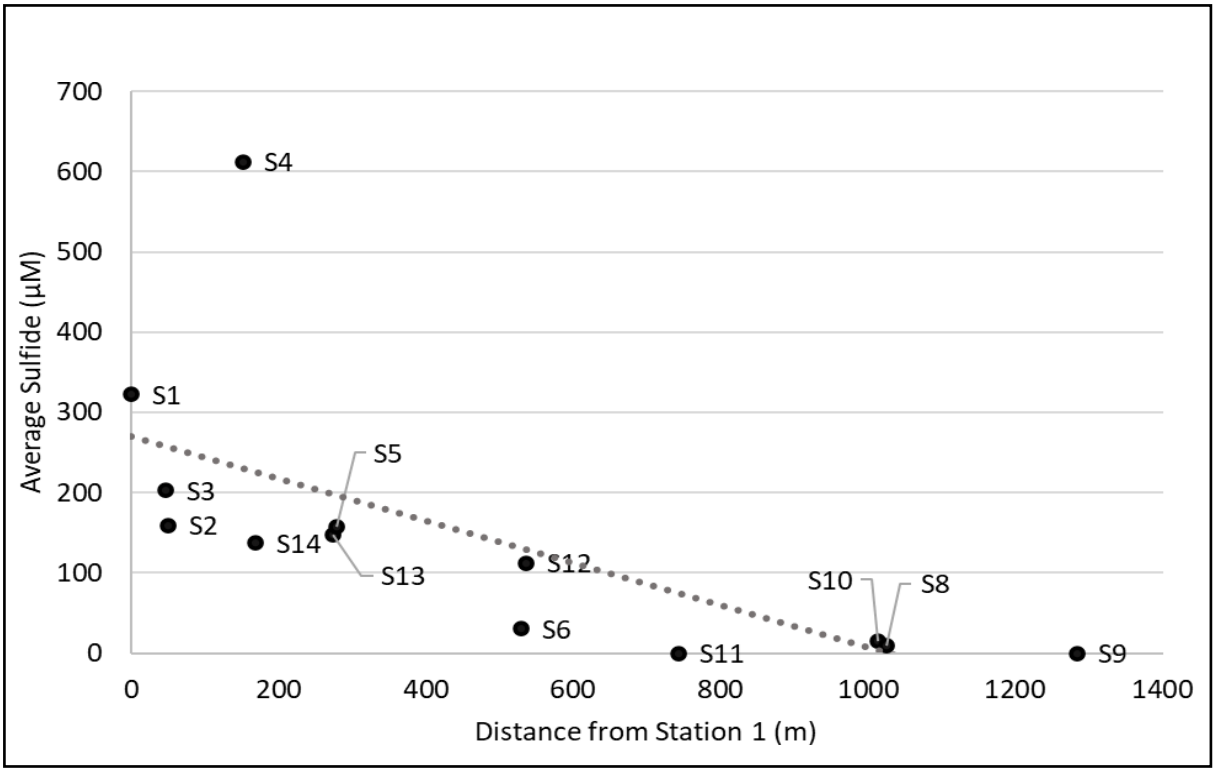

Figure 7. Average sulfide concentration (µM) (n=3) at marine transect sampling stations. Station distance is measured from Station 1 (m) which was within the lease boundaries of AQ#1006. Linear trendline is displayed.

Redox Potential

The redox potential of a system is indicative of its capacity for oxidation and is often used as a proxy measurement for the availability of oxygen with a sediment. Lower (or negative) values are associated with possible environmental impacts and are known to be correlated with elevated sediment sulfide concentrations. Within the NSDFA EMP (PNS, 2020B), sediment is considered to be showing signs of hypoxic conditions when redox measurements fall below -50 mV_{NHE}. The minimum average redox value observed from marine transect samples was 113.93 mV_{NHE} at Station 4, located approximately 150 meters from Station 1 (cage edge). Average redox values were seen to increase with relative distance from the aquaculture site (Fig. 8), with all stations further than 500 meters away exceeding 300 mV_{NHE}.

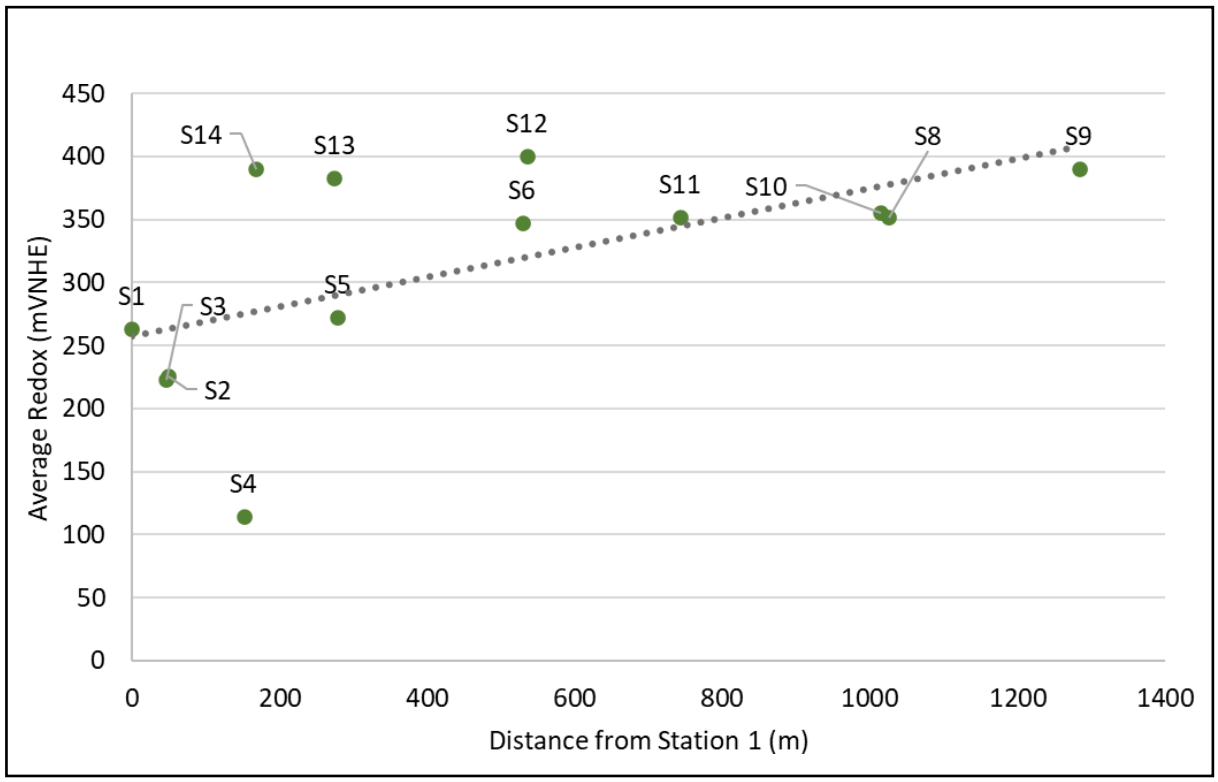

Figure 8. Average redox potential (mVNHE)(n=3) at marine transect sampling stations. Station distance is calculated from Station 1 (m) which was within the lease boundaries of lease #1006. Linear trendline is displayed.

Porosity and Organic Matter

Porosity is the percentage of void space within any material that can contain fluids and is an indirect measure of grain size. Additionally, it is used to detect changes in sediment consistency which may be influenced from organic deposition from aquaculture leases (PNS, 2020A). Sediments with high porosity typically have higher levels of organic content. The minimum average porosity observed from marine transect samples was 20.37% at Station 9, the station furthest from the lease boundaries. Average porosity values were seen to decrease with relative distance from the aquaculture site (Fig. 9).

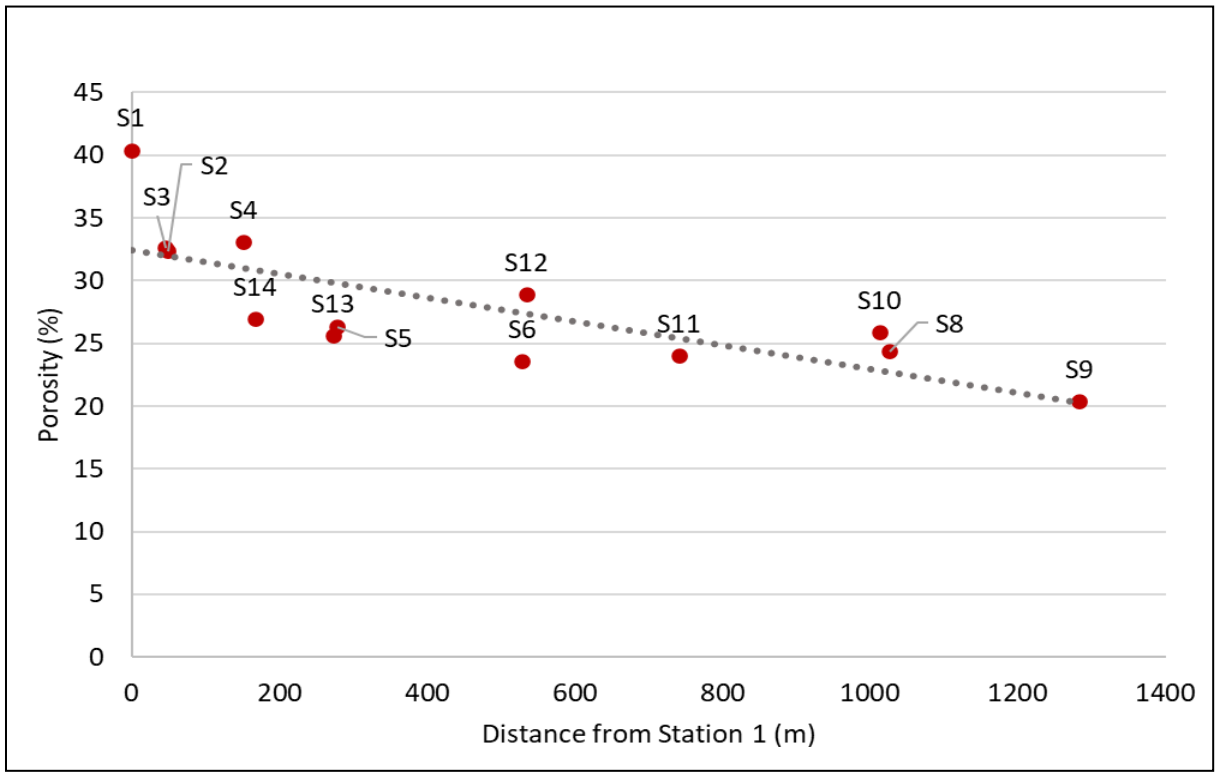

Figure 9. Porosity (%) (n=3) at marine transect sampling stations. Station distance is calculated from Station 1 (m) which was within the lease boundaries of lease #1006. Linear trendline is displayed.

Percent Organic Matter (%) is the portion of sediment that is of plant or animal origin and it acts as a measure of organic loading. POM decreases with relative distance from the aquaculture site (Fig.10). The minimum average POM % observed from marine transect samples at Station 9 (0.82%), the station furthest from the lease boundaries.

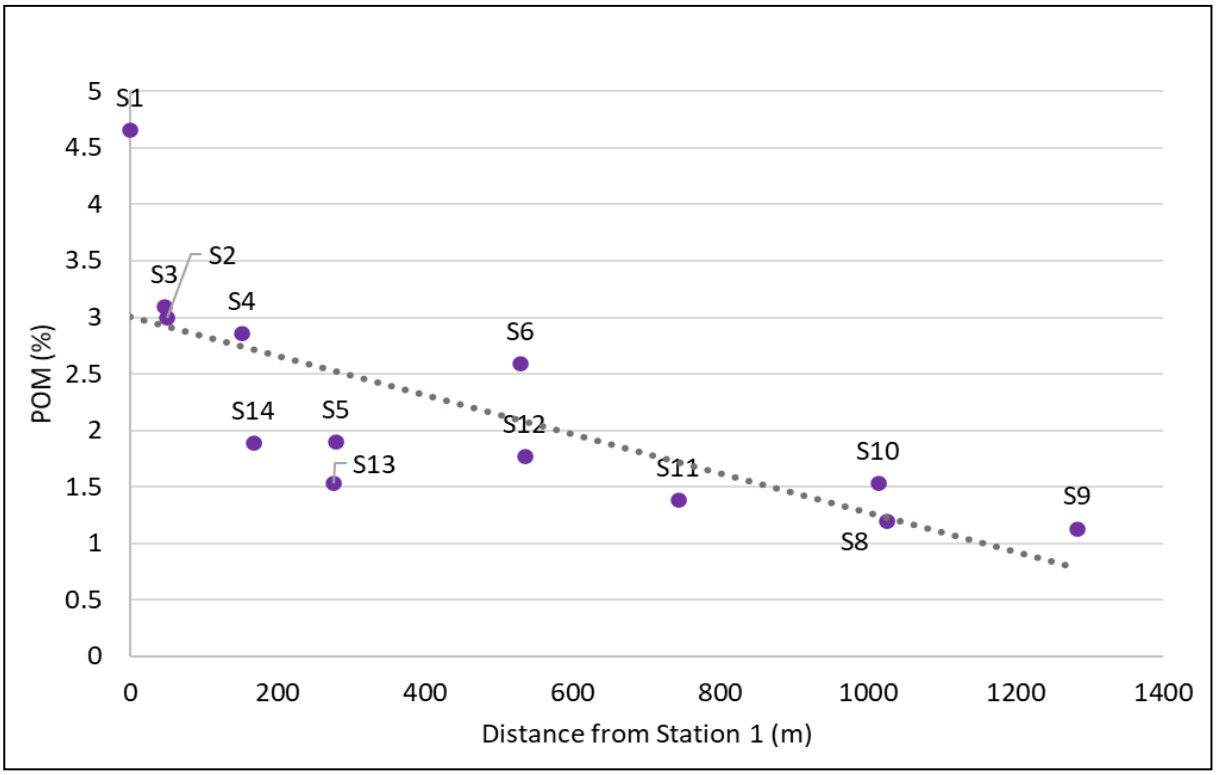

Figure 10. Percent Organic Matter (%) (n=3) at marine transect sampling stations. Station distance is calculated from Station 1 (m) which was within the lease boundaries of lease #1006. Linear trendline is displayed.

Stable Isotopes

Isotopic signals, resulting from the relative abundance of particular stable forms of carbon and nitrogen, can be used to identify complex ecological interactions and relationships. Such analyses have been used to investigate the dispersion area of waste material from aquaculture activities by comparing isotopic signals from fish feed and faeces to those found in surrounding sedimentary organic material (Sara et al., 2004). Similarly, in this investigation C-N ratios are compared between sediments collected at Bayswater Beach and near to AQ#1006. Stable isotope analysis was conducted on benthic samples from marine transect stations 1, 2, 3, 4, 13 and 14 as well as beach samples, BWB 1, BWB 2, BWB 3 and BWB 4 (Fig. 11). Beach sample BWB 3 had insufficient abundance of carbon and nitrogen for analysis. Stable isotope analysis results of individual locations are presented in Figure 11 and mean isotopic ratios for beach and benthic samples in Figure 12.

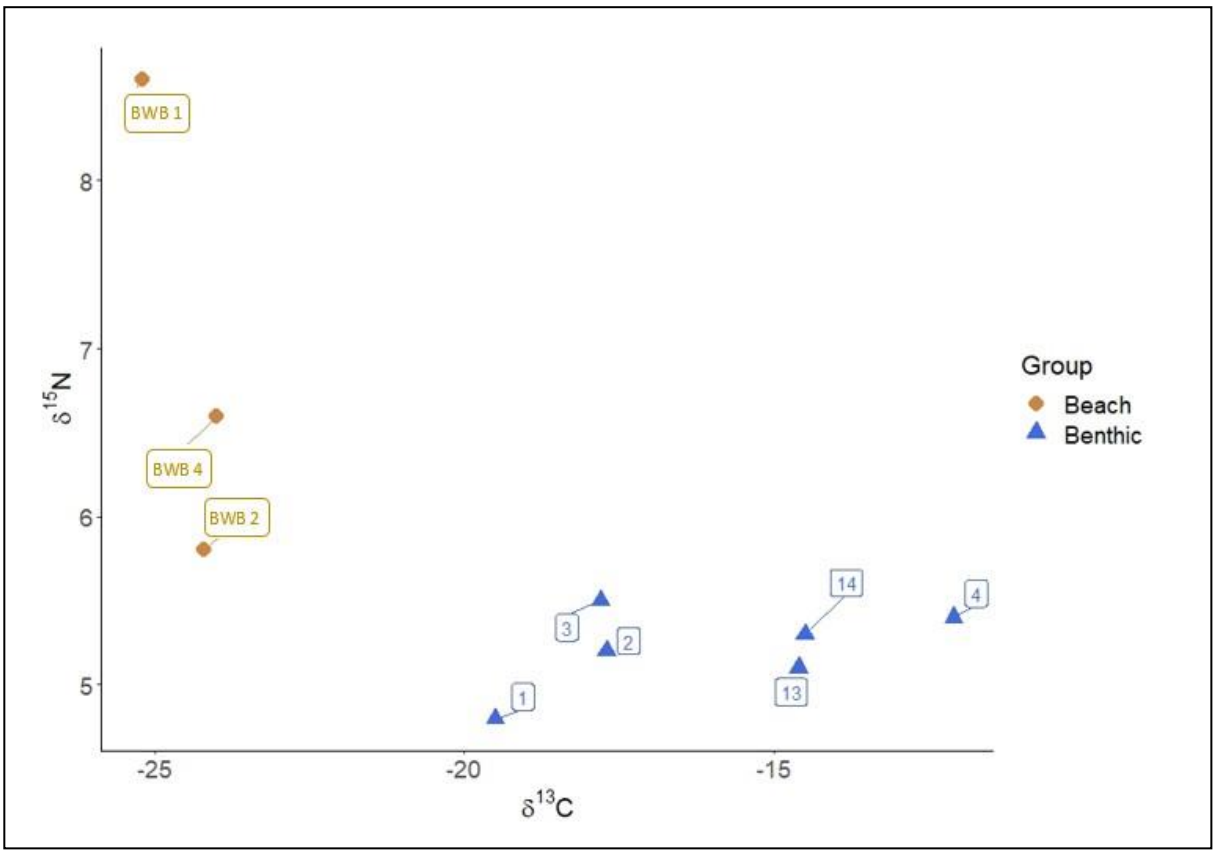

Figure 11. Nitrogen and carbon stable isotope ratios at individual locations.

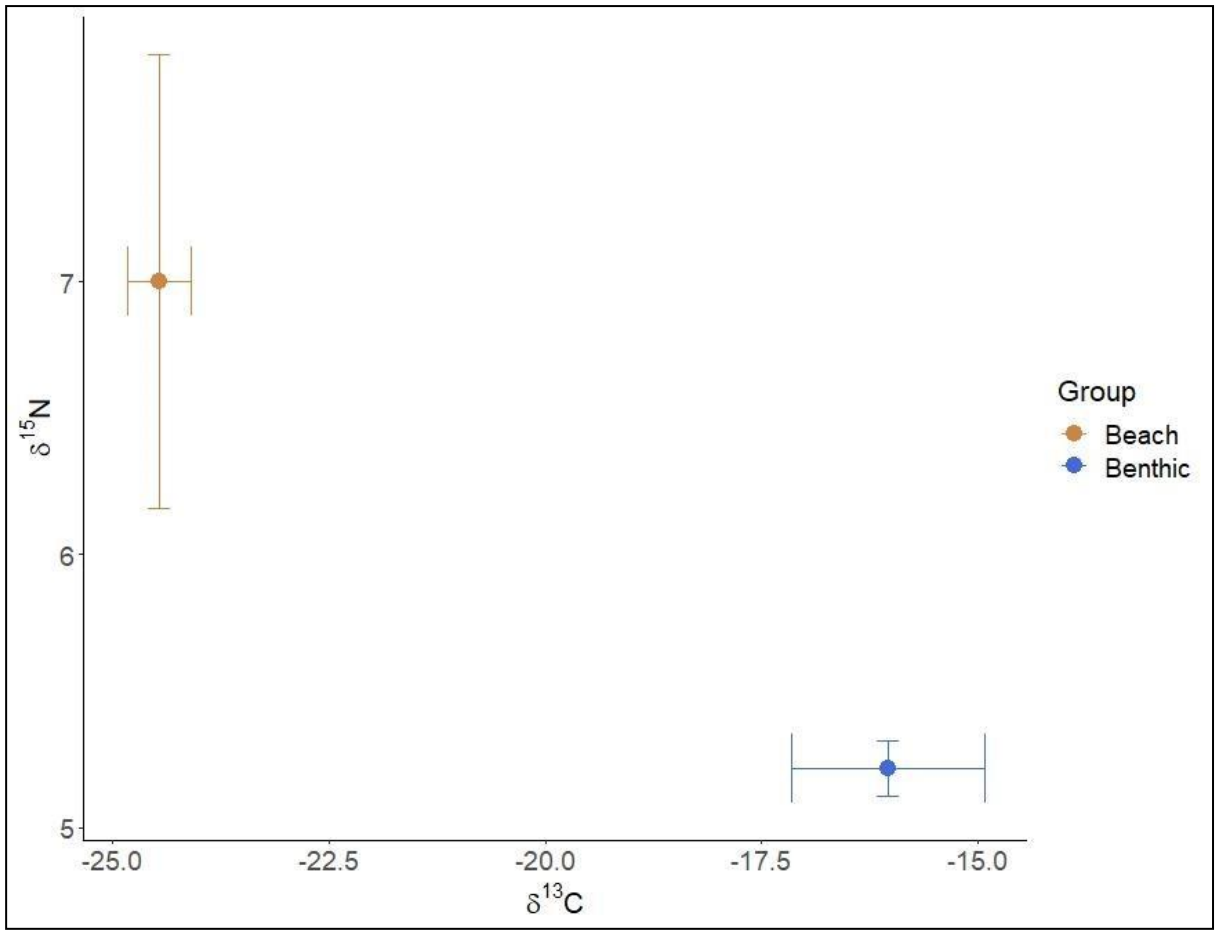

Figure 12. Mean beach and benthic stable isotope ratios of nitrogen and carbon. Error bars indicate +/- one standard error.

Conclusion

Results from geochemical and visual assessment of sediments at Bayswater Beach, aquaculture site AQ#1006 and from the adjoining bay area appear to consistently show similar trends. For all four quantitative analyses performed on collected marine sediments, sampling stations located at or immediately adjacent to the aquaculture site returned the values most indicative of environmental impact. Mean concentration of sulfide (Fig. 7), porosity (Fig. 9) and organic matter prevalence (Fig. 10) were all highest and redox potential (Fig. 8) was lowest at stations near the lease. Despite this, sediment at all stations, including those at and near the lease, would be considered relatively unimpacted and would be classified as oxic under the NSDFA's Environmental Monitoring Program criteria. Comparison of near-site stations to those further from the lease area reveals what relatively limited signs of impact are present at AQ#1006, quickly dissipate with distance from the lease boundary. Stations at distances greater than 300 meters exhibit virtually no signs of excess organic enrichment from any source. These results suggest that any environmental impacts related to organic deposition from AQ#1006 is limited to the immediate proximity of the lease area and that transport of sufficient amounts of organic material from the site to the larger surrounding area does not appear to be occurring. This conclusion is further supported by the results of direct observation of the seafloor along the study transects. Visual indicators that would typically be associated with excess deposition of sedimentary organic matter were not observed at any of the marine sampling stations beyond the lease boundary.

The comparison of the relative abundance of stable carbon and nitrogen isotopes between sediments from near-site and beach stations was intended to identify any potential similarity in the organic composition of SOM between the two locations. Analyses conducted by Queen's University Facility for Isotope Research (QFIR) laboratory demonstrated a relatively broad range of results across individual stations, though adjacent sampling locations did appear to show similar isotopic signatures. The grouping of individual stations (Fig. 11) as well as the beach and benthic group mean values (Fig. 12) appear to indicate no significant overlap in isotopic signals between the SOM present at Bayswater Beach and SOM present adjacent to AQ#1006. This result further suggests that any excess organic materials that appear to be resulting in hypoxic or anoxic conditions at Bayswater Beach are not the result of ongoing finfish production at aquaculture site AQ#1006.

In addition to collecting beach sediment samples, Dr. Spooner's examination of the beach and surrounding area from a geomorphological and limnological perspective has provided some insight into possible sources of SOM at Bayswater Beach. In his interim update (Appendix A) he notes a cursory investigation into the composition of the Bayswater Pond (an outflow of which bisects the beach) resulted in the collection of "*highly organic*" and "*likely…anoxic*" sediment. Dr. Spooner also cites a 2013 Nova Scotia Health and Wellness news release stating: "*Department of Environment inspectors believe that natural conditions in a nearby pond (Bayswater Pond) are contributing to elevated bacteria counts. Tidal action may also be playing a role in bringing bacteria from the pond to the beach through a shallow stream. Inspectors have not found any obvious signs of human activity contributing to the high bacteria counts. The bacteria of concern are not coming from fish. These bacteria only come from warm-blooded animals*".

Anecdotal observations from Dr. Spooner, NSDFA field staff and from available satellite imagery make note of significant accumulations of macrophytic wrack along Bayswater Beach at various times. Large macrophyte beds were also observed in several video recordings at near-shore stations along the sampled transects.

Transport, and decomposition of such organic material at the beach could contribute to significant organic loading and SOM accumulation (van Erk et al, 2020).

While observations and measurements made over the course of this study suggest that the accumulation of decomposing sedimentary organic matter at Bayswater Beach is likely not related to the ongoing operation of the nearby salmon farm, several areas of uncertainty remain regarding both the ultimate source of the observed organic enrichment, as well as the prevailing oceanographic conditions of the area which may influence continued deposition and decomposition. It has been proposed in this report that both the adjacent pond and the considerable accumulation of macrophytic wrack could serve as potential sources of organic loading, though neither the significance of their contribution nor the mechanisms by which these influences occur are well understood at this time. There is potential for further study in order to compare isotopic profiles of these potential loading sources with impacted beach sediment. In addition, a better understanding of localized onshore transport dynamics could be gained via the collection of additional current and wave data and the subsequent development of a bay-scale circulation model. Finally, it is notable that this study consisted of a single sampling event, taking place over a relatively short period of time. The effects of seasonal variables such as wind and wave direction and intensity, storm frequency, and the operational status of the salmon farm were not considered and remain as an area of uncertainty.

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Appendix A

Bayswater Beach, Nova Scotia sediment sampling program Interim Report

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March 16, 2021

Bayswater Beach Nova Scotia Sediment analyses

Prepared for:
Gregor Reid, PhD
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1.0 Summary

A focused sediment composition study at Bayswater Beach, Aspotogan Peninsula, Nova Scotia was initiated in November 2020 and is ongoing. This study is being conducted to characterise the composition of sedimentary organic matter (SOM) on Bayswater Beach and compare this to sediment samples taken from underneath nearby aquaculture pens that contain SOM. Both the Bayswater Beach and marine sediments are being analyzed for carbon and nitrogen isotopes (^{13}C, ^{15}N) at the Queen's University facility for isotope research (QFIR) laboratory in Kingston, Ontario. The site was also investigated from a geomorphological perspective to provide insight into possible sources of SOM on Bayswater Beach. This study is ongoing, and the sediment samples are presently being analyzed at QFIR with results expected soon.

2.0 Introduction

Bayswater Beach (44°30'12.7"N 64°03'57.9"W) is a relatively small beach-back beach lagoon complex located near Hubbards, on the Aspotogan Peninsula, southwest Nova Scotia. The beach is a popular summer tourist destination and hosts a small provincial park with a picnic area with a view of the open ocean. Change rooms and toilets are available in the picnic area.

Water quality at Bayswater Beach is typically sampled weekly from July 1st to September 1st. Of note are periodic closures of the beach due to high bacteria levels (https://www.theswimguide.org/beach/5553). The Lifesaving Society of Nova Scotia has noted that the small stream which bisects the beach "*can experience poor water quality and will be posted if it is unsafe*" (https://www.lifesavingsociety.ns.ca/index.php/bayswater). In August 21, 2013, The Province of Nova Scotia (Health and Wellness) reported that "*Department of Environment inspectors believe that natural conditions in a nearby pond (Bayswater Pond) are contributing to elevated bacteria counts. Tidal action may also be playing a role in bringing bacteria from the pond to the beach through a shallow stream. Inspectors have not found any obvious signs of human activity contributing to the high bacteria counts. The bacteria of concern are not coming from fish. These bacteria only come from warm-blooded animals*" (https://novascotia.ca/news/release/?id=20130821006)

On November 21, 2020, I. Spooner visited Bayswater beach to carry out an initial geomorphological examination of Bayswater Beach and Bayswater pond on the request of Dr. Gregor Reid, Director, of the Centre for Marine Applied Research, Perennia Food and Agriculture. This investigation was initiated to address citizen complaints about a sulfide smell at a beach. Photographs taken by concerned citizens indicated the presence of dark coloured sediment on the beach, the composition and source of which is unknown. No obvious deposits of sedimentary organic matter (SOM) other than beach wrack were observed on the surface of the beach, some subtle sediment discolouration was noted in a cross section of the beach exposed by the outlet stream from Bayswater Pond.

On January 16, 2021, 4 sediment samples were retrieved from Bayswater Beach, Nova Scotia for the purpose of better understanding the composition and potentially the source of SOM, if present, in the sediment. The sediment samples obtained on January 16, 2021 are being analysed for their C and N isotopic (^{13}C, ^{15}N) composition (called C-N analyses) to characterize the organic fraction in these sediments and possibly determine the source of any SOM in the

samples. Sediment samples were also collected from benthic transect surveys beginning immediately adjacent to the fish cages and heading towards the beach, by the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) on December 09, 2020. This was done to both characterise the isotopic composition of SOM at the site and for comparison to SOM composition of the samples collected from the beach sediments. Stable isotope C-N analyses can reveal complex interactions of food sources and are traditionally used for ecological and population biological studies (Peterson and Fry, 1987). For example, Sara et al. (2004) used carbon and nitrogen stable isotope analysis to investigate the dispersion area of waste material coming from fish farming activities in the western Mediterranean. Tests were conducted to see if isotopic signals in uneaten feed and faecal material, originating from fish farms, could be detected in particulate organic matter (POM) and sedimentary organic matter (SOM).

The purpose of the Bayswater Beach study is like that of Sara et al. (2004). It is an attempt to better understand whether SOM generated by the aquaculture process and that has accumulated underneath the aquaculture pens is being transferred to and sequestered at the beach environment.

3.0 Progress

Bayswater Beach was first visited by I. Spooner on November 21, 2020 to determine the morphology of the beach, to observe Baywater Pond and better understand relationships between shoreline processes and sediment dynamics. On January 16, 2021, 4 sediment samples were retrieved from Bayswater Beach, processed at Acadia university, and sent to the Queen's University QFIR Lab (Queen's Facility for Isotope Analyses). Benthic samples that were obtained immediately adjacent to the aquaculture pens near Saddle Island, were also delivered to
I. Spooner by Todd Mosher, of NSDFA. These samples were also processed in Spooner's lab at Acadia and sent to the QFIR lab for isotope analyses. Results from the QFIR Lab are pending.

4.0 Methods

Bayswater Beach and surrounding environs were investigated from a geomorphological and limnological perspective. Bayswater Beach is a relatively small and narrow, moderate to high energy, mesotidal barrier beach that has a fine siliceous sand veneer. Coarse cobbles underlie this veneer. A small, engineered outlet stream exits from Bayswater Pond, crosses underneath Route

329 and then, as of fall 2020, bisects the beach. Google Earth images as well as images of Bayswater Beach from internet sources indicate that, in the past, this creek has travelled parallel to the beach for over 300 m. The creek water is highly coloured (likely excess dissolved organic carbon), which is consistent with observations of water quality at Bayswater Pond. A sediment piston corer was used to obtain a sample of the sediment in Bayswater Pond which indicated that the sediment was highly organic; it is likely that conditions at the sediment water interface in Bayswater Pond are anoxic.

Bayswater Beach sediment samples were obtained from the stream cut in the beach as well as test pits dug to 75 cm depth at three locations along the beach. Test pits encountered coarse SOM at approximately 50 cm depth that was underlain by a thin (5 cm) dark discolored layer that contrasted with the white sand. 4 samples were obtained, transferred to 50 ml sterile glass analyses jars, and transported at 4°C to Acadia University. Sample processing consisted of freeze drying the samples for 48 hours then lightly crushing the samples with a mortar and pestle to reduce the size of any coarse SOM. The sample was then transferred to analyses containers which were labelled and kept refrigerated until they were sent to Queens University QFIR lab for C-N isotope analyses.

Sediment samples obtained from underneath the aquaculture pens near the Saddle Islands were kept cool until they were transferred to I. Spooner on February 5th, 2021. Processing was identical to the Bayswater Beach samples and both sample lots were sent to the QFIR lab on March 1, 2021.

5.0 Work plan

Upon completion of isotopic analyses, result comparisons of sediment samples from Bayswater Beach and marine sediment samples will be made with reference to available literature. At this time an assessment of the application of the data to the determination of the source of the SOM at both sites will be made as well as a determination of future research that might be required.

6.0 Disclaimer

This document is intended for the exclusive use of the Centre for Marine Applied Research, Perennia Food and Agriculture. I do not accept responsibility to any third-party use of the information presented in this document, and/or decisions/actions made based on the contents of the document.

The information, conclusions and recommendations presented in this report were based on historical, and site-specific information obtained during sediment sampling. Reasonable care, skill and diligence were taken to assess the information pertaining to the site. However, it should be noted that, when assessing the environmental status of a site, due to the nature of work and site-specific conditions, unknowns and limitations are inherent. This report is based upon the circumstances and conditions acknowledged herein, and on information made available by others at the time of preparing the report. Information provided by others it is believed to be accurate but cannot be guaranteed.

7.0 Figures

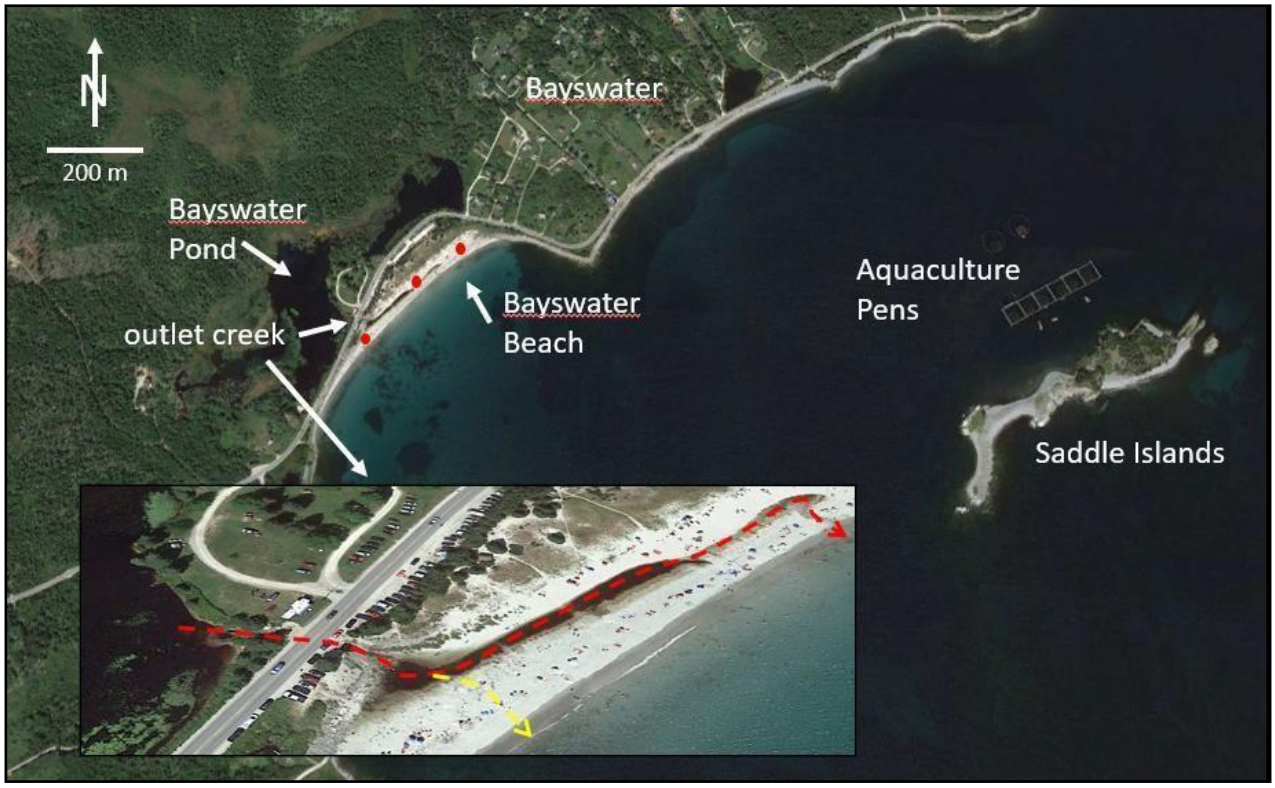

Figure 1. Google Earth© image of Bayswater Beach area with inset of the outlet creek location in 9/5/2015 (red dashes). The location of the outlet creek at present is shown by the yellow dashed line. Red dots indicate approximate sediment sampling locations. Image modified from Google Earth©. Location for samples is BWB S1 S2 415346.82 m E 4928322.61 m N, BWB S3 415276.05 m E, 4928242.39 m N, BWB S4 415195.99 m E 4928133.95 m N.

Figure 2. Sample pit from which sample BWB S1 and S2 was obtained. The pit was excavated to a depth of about 75 cm. A stainless-steel shovel was used to obtain all samples and was thoroughly cleaned between each sample site. Photo taken 1/16/2021

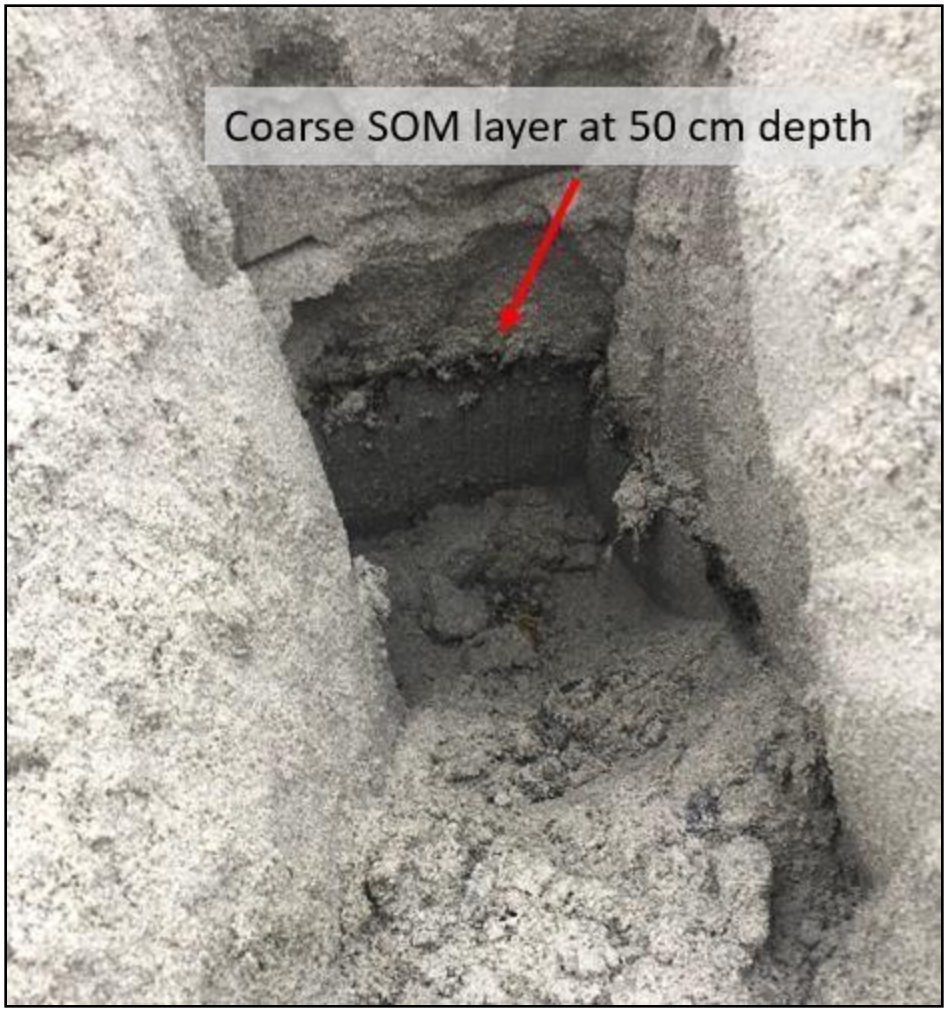

Figure 3: Image of sample collection pit from which sample BWB S1 and S2 was collected. The sample was obtained at 50 cm depth. Note the coarse sedimentary organic matter which is underlain by dark stained sediment. Photo taken 1/16/2021.

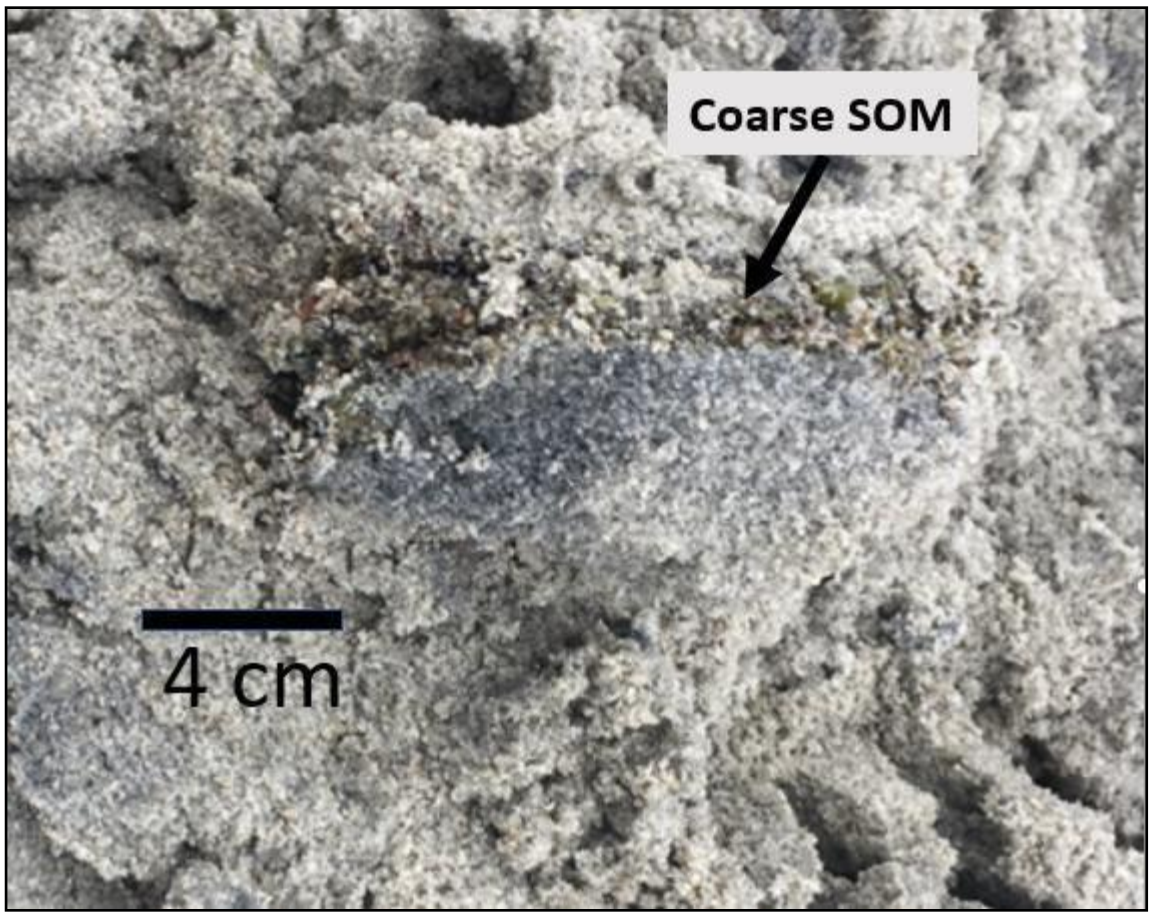

Figure 4: Close up image of sample BWB S2 showing dark staining below coarse SOM. Photo taken 1/16/2021.

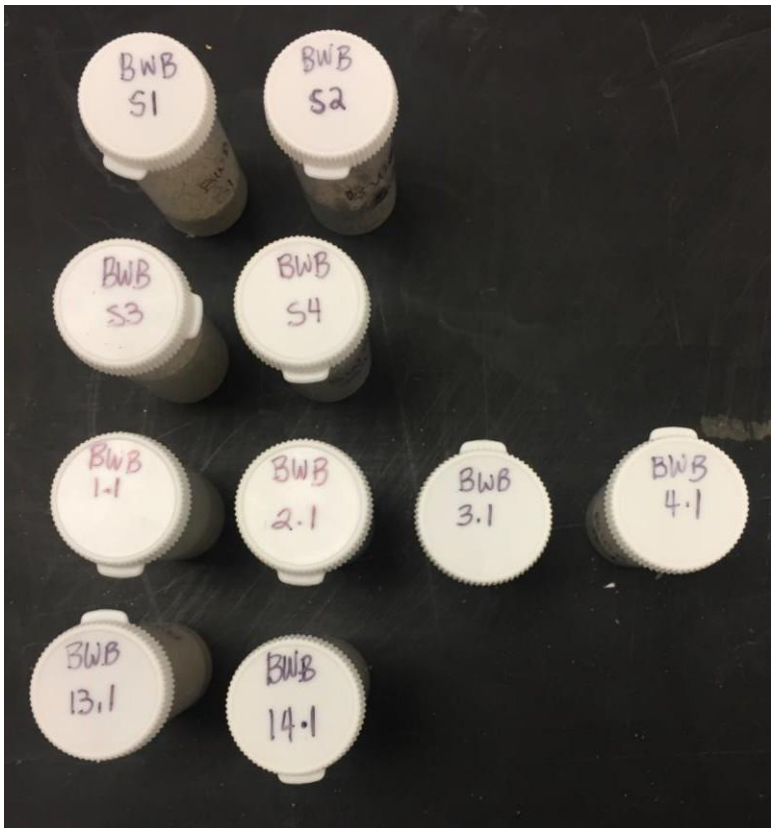

Figure 5. Image of samples after drying prior to being shipped to the QFIR Laboratory at Queen's University for C N isotopic analyses. Samples BWB S1, S2, S3, S4 are from Bayswater Beach, samples BWB 1-1, 2-1, 3-1, 4-1 and BWB13-1, 14-1 were taken from marine sediment associated with the aquaculture site.

8.0 References and internet sources

Peterson, B. J., and Fry, B. (1987). Stable isotopes in ecosystem studies. Annu. Rev. Ecol. Syst.18, 293–320. doi: 10.1146/annurev.es.18.110187.001453

Sara, G. Scilipoti, D., Mazzola, A., and Modica, A. 2004. Effects of fish farming waste to sedimentary and particulate organic matter in a southern Mediterranean area (Gulf of Castellammare, Sicily): a multiple stable isotope study (δ13C and δ15N). Aquaculture. 234, Pages199-213.

Internet sources

Beach water quality testing: https://www.theswimguide.org/beach/5553:

Beach closure: https://www.lifesavingsociety.ns.ca/index.php/bayswater

Contaminant source: https://novascotia.ca/news/release/?id=20130821006