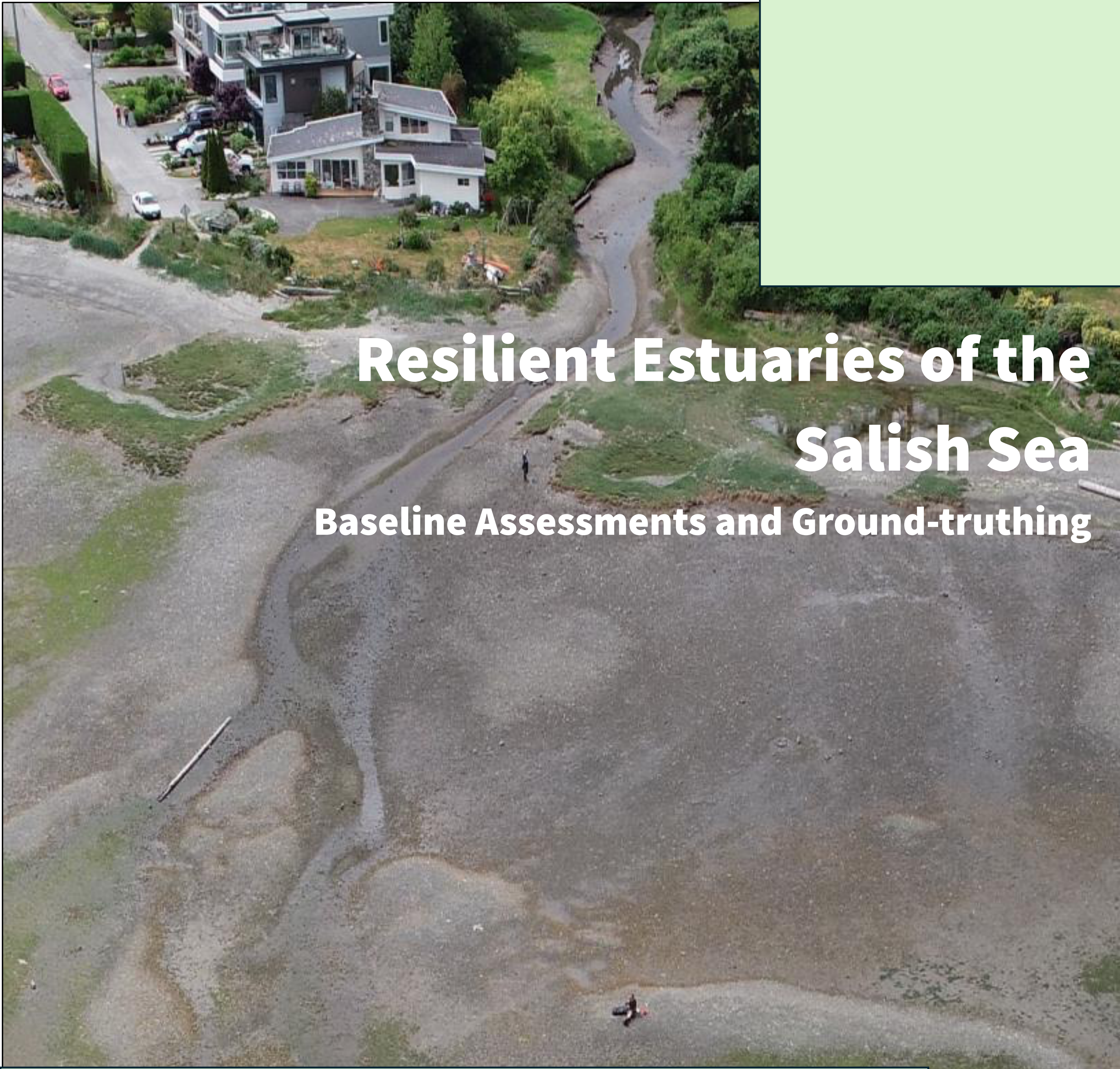

Resilient Estuaries of the Salish Sea

Baseline Assessments and Ground-truthing

Preliminary Year 1 Summary Report

2023-2024

SeaChange Marine Conservation Society

BC Salmon Restoration and Innovation Fund

The citations for this report should be:

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Contents

Executive Summary

Estuaries are essential aquatic habitats whose resilience is necessary to maintain with the increased impacts of human activities, especially climate change. The initial part of The Resilient Estuaries of the Salish Sea project is focused on studying the small and medium sized estuary ecosystems of the Salish Sea to understand features that lead to resilience and suggest ways in which humans can help maintain that resilience. For this project, we have defined estuaries as: a coastal region with freshwater input at some part of the year where there is sediment deposit (alluvial fan). Resilience was more challenging to define but through resistance, recovery, or adaptation, resilience for a functional estuarine has been correlated with diversity, which can be measured as habitat diversity, biodiversity, genetic diversity or other attributes. The main questions we focused on were: What estuary variables correlate with habitat and species diversity? Do habitat and species-diverse estuaries correlate with observations of resiliency in these local estuaries? Moreover, what ecosystem features differentiate resilient estuaries from non-resilient ones?

The result of our literature search and discussions with experts led us to focus on measuring water quality (pollutants, nutrient loads), physical water features and proxies for mixing (salinity, temperature, oxygen), biodiversity (underwater surveys, plankton ID, and eDNA), and habitat diversity (mapping via tow camera with GPS overlay). We also incorporated historical data, human impacts and shoreline modification, the proximity of estuaries to other features, sea level rise predictions, and personal experience and understanding of local water sites from communities. Traditional Knowledge was not part of this year's work; however, we have worked closely with First Nations conservation and fisheries teams. Our final ranking system is still being developed but will likely focus on a combination of low water contamination from bacteria, moderate nutrient concentrations, and high bio- and habitat-diversity.

In Area 1 (Victoria and the Saanich Peninsula) we identified 6 estuarine systems to focus on: Oak Bay, Cadboro Bay, Saanichton Bay, Roberts Bay, Tod Inlet and Portage Inlet. These estuaries were partly chosen for practical reasons including existing relationships with First Nations and other partners, accessibility, and existing historic information. We conducted field surveys in each of these systems and measured all the attributes being studied as proxies for resilience above. After preliminary analysis of the water quality data, the similarities and differences among the sites were evident. First, time of year has a large impact on the salinity and temperature values, and any future estuary visits should be planned with this in mind. Also, the size and shape of the estuaries plays a large role in water mixing and oceanic exchange. There were also a wide range of anthropogenic impacts to each of the estuaries noted. Action plans were created for each of these estuaries that identified conservation, restoration and educational activities that could be used to enhance and maintain estuary function and resilience. The final phase of the RESS project (funded through AERF) acted on those recommendations. Those activities are reported on under that funding umbrella.

The Resilient Estuaries Team

Project Manager/Researcher: Dr. Susan Anthony
Outreach Coordinator: Kendra Nelson
Operations Manager: Justin Lisaingo
Mapping Supervisor: Seanie Malcolm
Mapping Technician: Thomas Armitage
Executive Director: Sarah Cook, R.P.Bio.
Mentor: Nikki Wright
Dive Team: Jamie Smith (Boat Captain); Justin Bland (Diver); Viki Kolatkova (Diver)

Acknowledgements

SeaChange and the RESS Team would like to acknowledge the partners, collaborators, and contributors who put so much time, effort, and heart into the work outlined in this report:

Kyle Armstrong (Peninsula Streams Society)
Isobel Pearsall, Ben Skinner, Kyla Sheehan (Pacific Salmon Foundation)
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Pauline Finn (Shaw Centre for the Salish Sea)
Chris Hyde-lay (Parks, Recreation, and Culture, District of Oak Bay)
Dr. Amanda Bates and Dr. Caren Helbing (University of Victoria)
Ethan Edson (Ocean Diagnostics Inc.)
Dr. Hugh MacIntosh (Royal BC Museum)

1. Introduction

Estuaries are essential aquatic habitats for numerous fish and invertebrate species, including commercially important species such as Pacific salmon. Each Pacific salmon species relies on estuaries for one or more activities, such as shelter, food, and reproduction. Not only do salmon depend on the estuary at the mouth of their natal stream, but they also depend on a series of estuaries (Moore *et al.* 2016) along which they stop to feed and avoid predators. The estuaries that provide these stopover points along the 'salmon highway' are essential but difficult to identify as they may not have large or even small salmon bearing streams associated with them. The importance of the small to medium sized estuaries of the Salish Sea have not been well-studied, which is a significant gap in knowledge in terms of conservation of essential fish habitat for Pacific salmon and many other species. Preserving the connectivity between the natal river mouth of the large and small Pacific salmon populations and the open ocean through estuary restoration and conservation is therefore crucial to protect salmon.

The first stage of the Resilient Estuaries of the Salish Sea (RESS) project is focused on studying the small and medium sized estuary ecosystems of the Salish Sea to understand attributes that lead to resilience and suggest ways in which humans can help maintain that resilience. This portion is being funded through the BC Salmon Innovation and Restoration Fund (BCSRIF), which is supported by Fisheries and Oceans Canada (DFO) and the Province of BC. The second stage of the RESS project will be to take action to conserve and restore resilience in those estuaries as well as educate the public about the importance of estuarine systems and the actions they can take in their everyday lives to protect them. That stage is being funded by the Aquatic Ecosystem Restoration Fund (AERF) which is also through DFO. This report outlines the goals of the first stage of the RESS project, Baseline Assessment and Ground-truthing, and the preliminary work completed in Year 1 of the project, which focused on the Saanich Peninsula/CRD area. After looking at historic data and discussions with local experts, we chose 6 estuaries in Area 1 that met our criteria. They are: Tod Inlet/SNIDCEL, Roberts Bay, Saanichton Bay, Cadboro Bay, Oak Bay and Portage Inlet (Figure 1).

Given the importance of estuaries to ecologically, economically, and culturally important species, as well as to First Nations communities and settler communities, the goal of this first stage of the RESS project is to establish what attributes could make an estuary resilient to the effects of climate change. With this knowledge, we can suggest actions that SeaChange, or that First Nations or other community partners, can implement in the second phase of the project to help small- to medium-sized estuaries maintain resilience and support ecosystem healing. Our methods will be through the lens of reconciliation, acknowledging the role we play in the damage to these ecosystems and the rights of First Nations to lead within their traditional territory. We will receive Traditional Ecological Knowledge (TEK) openly and with reverence, allowing it to take priority. We will listen to the wants and needs of the First Nations communities and their representative organizations and we will not interfere with their planning or governance. We will also acknowledge that research and primary literature have historically and currently undervalued TEK, and with our work, we wish to share our knowledge and findings with all communities. We will also acquire data from areas using non-invasive sampling methods, except our plankton tows, which destructively sample planktonic organisms. Our divers are trained to observe marine life with little disturbance to the ecosystem, and the towed camera is manually operated to prevent dragging along the seafloor.

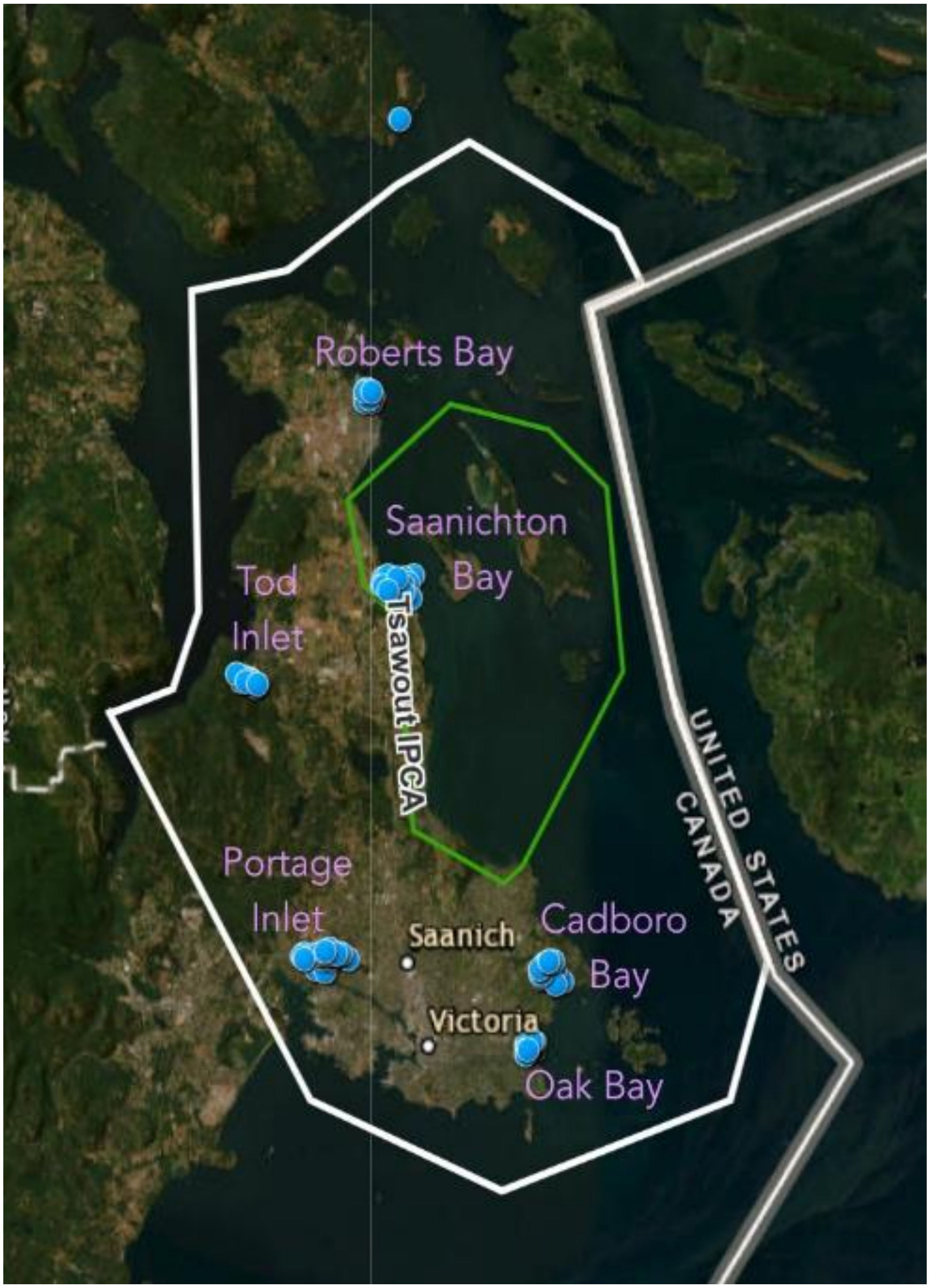


Figure 1: Resilient Estuaries of the Salish Sea Area 1. The six studied estuaries, Area 1 Boundary, and the Tsawout Indigenous Protected and Conserve Area are labelled.

Understanding Estuaries and Resilience

Estuaries are where freshwater from land meets seawater at the coast, they are the interface between land and sea. As straightforward as that seems, the actual definition of an estuary can get blurry: To what extent does an estuary extend from the mouth of the river into the sea? How far inland does an estuary extend *vs* where the river ends? Does the salinity of the region matter? Do the species and habitats in the area matter? What about the substrate composition? These questions and more have been hotly debated for decades. Every time a definition is declared, some regions are unacceptably identified as *not* being estuaries. The reality is that there is no "true" definition of an estuary (Elliott and McLusky 2002). Therefore, we began this project by creating our working definition of an estuary:

> For the Resilient Estuaries of the Salish Sea Project, an estuary is defined as: a coastal region with freshwater input for the majority of the year, and where there is sediment being deposited (delta or alluvial fan).

Based on this definition and our focus on small- to medium-sized estuaries, we expect most of our estuaries will be found within bays and inlets. We then also expect to see many similar characteristics, such as eelgrass beds, evidence of infaunal species, maximum salinity of approximately 31 ppm, and have shallower depth profiles.The next definition needed for this project was: What is coastal resilience and how does it relate to estuaries? This question was more complex. Resilience has been a popular word when we speak of ecosystems. No longer is there the debate that climate change will affect every part of our planet and cause shoreline erosion, sea level rise, impacts to harvesting and fisheries, and habitat destruction, amongst other things. The ability to completely prevent these effects is no longer possible. However, resilience, if we think of it as the ability to withstand these effects, is our hope for the coastline. Just as individual organisms can be resilient, so can ecosystems. The mechanisms can differ between species, populations, ecosystems, and even within an organism: the ability to resist change, recover from change, or adapt to change (Oliver *et al*. 2015). With these resilience mechanisms, there is always a ripple effect from the genotype to the phenotype, the organism, the population, the species, the community, and the ecosystem. Our research will focus on the overall ecosystem function rather than the individuals within, which will be more challenging to study. Our decision to focus on estuaries local to the Victoria area means we were working on systems more heavily impacted by human disturbance, so we also decided to focus efforts where conservation and restoration already have been implemented, where there is interest, or where we already have support from local First Nations communities. This focus allowed our team to build upon collaborations established by our predecessors and update our methodologies. Also, it allowed us to discover the features that may or may not be associated with estuary resilience, which will provide us with a yardstick by which to compare estuaries for future years.

One common definition is that a resilient estuary is one "untouched" by humans (Bates *et al*. 2015); however, being "untouched" does not mean that those estuaries directly *un*affected by human impacts are inherently essential habitats. This is also not a great working definition of resilience as estuaries tend to be highly utilized parts of the coast and with human occupancy ever increasing and the future expansion of marine traffic in the Salish Sea (eg. The Deltaport Expansion, Province of BC) the pressure on even the small and medium sized estuaries of the Salish Sea will only increase. And culturally and economically important species, such as salmon, herring, and surf smelt, do not have the luxury of choosing where they live and which estuaries they utilize.

How does an estuary's ecosystem function relate to its resilience? Whether through resistance, recovery, or adaptation, resilience has been correlated with diversity (the "Portfolio Effect"; Schindler *et al.* 2015). Diversity, such as habitat diversity, biodiversity, genetic diversity, *etc.*, has inherent redundancy. Just as investors have a range of investments where changes in one part of the market are offset by another, regime changes from climate change will be offset by the redundancies in nature. Just as habitat diversity will likely allow an estuary to maintain ecosystem function through changes, this diversity is also essential for salmon survival as smolts (Chalifour *et al.* 2019). What diversity looks like, how it can be measured through non-destructive methods, and what other features can act as proxies for resilience are concepts we are pursuing in the baseline assessment portion of the RESS project. Our main questions are:

What estuary variables correlate with habitat and species diversity?

Do habitat and species-diverse estuaries correlate with observations of resiliency in these local estuaries?

What ecosystem features differentiate resilient estuaries from non-resilient ones?

The results of our primary literature search for attributes that are potential proxies for resilience in estuarine systems led us to focus on measuring water quality (pollutants, nutrient loads), physical water features and proxies for mixing (salinity, temperature, oxygen), biodiversity (underwater surveys, plankton ID, and eDNA), and habitat diversity (mapping via tow camera with GPS overlay). We also decided to incorporate historical data, human impacts and shoreline modification, the proximity of estuaries to other features, sea level rise predictions, and personal experience and understanding of local water sites from communities. Traditional Ecological Knowledge (TEK) was not part of this year’s work, however, we have worked closely with some First Nations conservation and fisheries teams. The site assessments were shared with the interested groups as they were being produced (First Nations and settler conservation groups invested in the region), and feedback was given unofficially during the process. We have shared our methods and data freely, which has led to information sharing and training opportunities.

2. Baseline Estuary Assessments (Area 1)

Background

The RESS project is interested in studying functional estuary ecosystems to understand the features that lead to resilience and suggest ways in which humans can help in the healing process. We have identified several parameters to measure the extent of water exchange in the estuary, including depth profiles of salinity and temperature, oxygen profiles to identify areas of hypo- or hyper-oxia, turbidity as a proxy for shading or light attenuation, bacterial and nutrient concentration to identify pollution from sewage and/or farming, which can lead to eutrophic conditions, zooplankton tows for the presence of food for salmon (Copepoda), biodiversity surveys, habitat mapping for habitat diversity, and side-scanning for the detection of debris that can damage the seafloor and pollute the water. This section presents the methods used to collect the data for each of these estuaries and then the general results from that data collection. The sampling dates in the Fall were early to mid-October, so late summer weather conditions were persisting; Portage Inlet was not sampled until mid-November when the weather was colder and there had already been significant precipitation in the watersheds.

The data analysis and rankings presented here are considered preliminary as some surveys were conducted close to the end of the fiscal year (March 31, 2024) and for some attributes data is still being analyzed, particularly the zooplankton diversity assessments, eDNA sample analysis and habitat mapping. In this section, only the depth profiles measuring salinity, temperature and dissolved oxygen is presented in detail. A summary of the work completed to date for other attributes is present in Appendices A-F. An updated, final report will be produced after those analyses are completed and amalgamated into the ranking system.

Methods

General Site Descriptions

- Conduct a shoreline observation by boat and shore, where appropriate.
- Record general shoreline characteristics, animals observed, and human use.
- Provide a general sketch of the area and photographs.
- Water sampling sites were chosen in a non-randomised way: we created three lines radiating from the mouth of the predominant freshwater input (the lines are named “A”, “B”, and “C”); the sites are selected at 250, 500, 750, 1000 m from the mouth. the distances were decided from pilot site visits and as a way to keep the estuaries’ sites consistent for comparison among locations; additional sites are on lines running perpendicular to transect B (labelled “pB”) at B250, and 250 or 500 m and the direction (N,S,E,W) of the site from line B; where additional sites are required, we added another perpendicular line running from B500 (“ppB”).
- The site coordinates were pre-determined via ArcGIS app and transferred to the Navionics’s app aboard the *Klanawa*’s navigational computer.

Abiotic Water Measurements

- Salinity, Temperature, Dissolved Oxygen, Percent Oxygen were measured with a YSI Pro 2030 probe and replicated three times; Turbidity was determined by Secchi Disk on the sunny side of the boat and was only recorded once.
- Units are: Salinity (parts per thousand: ppt); Temperature (degrees Celsius: °C); Dissolved Oxygen (milligrams of dissolved oxygen per millilitre of seawater: mg/mL); Percent O_2 (%); Depth (metres: m); Secchi Depth (metres: m)
- We did readings at the surface (0 m depth), and -1, -2, -3 m depth (or at the Bottom, if the water was shallower than -3 m)
- Depth, seafloor composition, and time were noted for each sampling location, where possible.
- The Salinity, Temperature, and Oxygen plots for each site were based upon a mean of the three replicate measurements. The error bars were omitted as they were negligibly small in all situations; however, where we conducted statistical analyses, the three replicates were input.

Side Scan Sonar for Debris Mapping

- We followed a route throughout the estuary in parallel lines (c.50 m apart) and scanned at 2 knots.
- When an object was detected, the location was marked in the Navionics computer program and notes were made about its general size and shape on datasheets, relating the location to the notes by marker number.

Bacterial Sampling

- We collected 200 mL of surface water by plastic graduate cylinder rinsed three times with seawater from the site before collecting.
- Bottles were provided by Bureau Veritas (BV) with Sodium Thiosulphate as a preservative already portioned out in each bottle.
- We held the bottles on deck in a cooler with ice packs to keep it below 10 °C; we delivered the cooler to BV by 3 pm on the sampling date for it to be shipped to their laboratories in Burnaby BC; BV processes Fecal Coliform and *Enterococcus* spp. by membrane filtration and provides results as number of colony forming units (CFUs).

Nutrient Concentration

- We collected surface water samples and kept them in 250 mL polyethylene containers and measured the nitrate and phosphate concentrations within 12 h.
- Nitrate sampling and analysis: 5mL of the water sample is mixed with an acid reagent (V-6278) and a reducing agent (V-6279) and then measured photometrically with a Lamotte Smart3 BLE colorimeter.

- Phosphate, low-range, sampling and analysis: 10 mL of the water sample is mixed with a phosphate acid reagent (V-6282) and a reducing agent (V-6283) and then measured photometrically with a Lamotte Smart3 BLE colorimeter.
- Procedures were followed according to the Lamotte Smart3 BLE Colorimetre instructions.
- Replicate numbers differed among locations; the number of repeated readings per sample also differed and were recorded in each report.
- There are no "proposed" maximum allowable nitrate concentrations in seawater according to the Ministry of Environment (2009). According to the Canadian Water Quality Guidelines for the Protection of Aquatic Life, nitrate ions should be lower than 200 mg/L or ppm (long-term exposure) and 1500 mg/L or ppm (short-term exposure).
- Phosphate alone does not make up most of the phosphorous that is seen in excessive amounts in eutrophic areas (Correll, 1998); the value of dissolved orthophosphate (phosphate ions) was nearly 20 times the total inorganic phosphorous in a eutrophic estuary. The eutrophic threshold for phosphorous (not phosphate) is >35 µg/L (or 0.035 g/L = ppm).

Zooplankton Tows

- The purpose was to sample for copepods known to be salmon food.
- We used a 1000 µm zooplankton net with a 1000 µm cod end.
- We dragged the zooplankton just below the water surface (unless otherwise indicated) for 50 m at 0.5 knots.
- Any large fish or shrimp were removed from the cod end by hand, knowing that that may cause plankton to be lost.
- We closed the water samples in plastic 500 mL bottles (provided by staff at the Royal BC Museum) and we added 5 mL Formalin (with 40% formaldehyde) making it ~0.4% formaldehyde.
- With the assistance of Dr. Hugh MacIntosh from the Royal BC Museum, the samples were sorted into arthropods and "other". They have since been sent off to Biologica Inc. for sorting, counting, and identification and the identification process is ongoing.

Biodiversity surveys (Quadrats and Transects)

- Divers conducted one transect and four quadrats at each site in the estuary.
- Transect lines ran 50 m from the water sampling site towards the mouth of the freshwater input; the start and end of the transect lines were marked with buoys. In the case of perpendicular lines, the direction of the transect line was decided so that more habitats would be covered.
- The locations of the four quadrats were a random distance (10m to either side) on either side of the site, along a line perpendicular to the transect line. The negative numbers are the location in meters from the transect line to the left; the positive numbers are to the right.
- The divers entered the water, and one diver went to the start and identified (or photographed for future identification) and counted (or estimated percent cover) all the

species and substrate composition within the 25 cm^2 quadrat (likely capturing the sessile organisms).
- The second diver swam along the 50 m transect and identified and counted the species (likely capturing the mobile species).
- We conducted our biodiversity analyses in the software program R (version 4.3.2) through R Studio (2023.12.1+402) using the vegan package (version 2.4-6) for Shannon, Simpson's, and Fisher-Alpha Indices.
- For the stacked barplots, we took the sum of all four quadrats, making the barplot reflect the proportional cover of a $1m^2$ quadrat. Where the total percent coverage written by the divers is <100%, we created the category "Bare Substrate" to make up the difference; where the values are >100%, we made a best guess about the percent overlap of the organisms based upon photographs and general knowledge of the Salish Sea ecosystem.

Tow Camera

- We towed a SeaViewer camera from the boat along a route running lines parallel and perpendicular to the shore, 50 m apart (with some deviations on the route due to obstacles such as rocks and boats).
- The video was overlaid with GPS coordinates.
- The video was reviewed by a technician and the general habitat characteristics were entered into a spreadsheet and converted into GIS layers.
- Further work will conform the data into polygon layers (resulting in an area map) and the habitat descriptions will be refined to identify algal species and habitat-forming animal species.

Environmental DNA (eDNA)

- We collected eDNA following protocols outlined in Ocean Diagnostic Inc's (ODI) Ascension Deployment Apparatus instructions. Briefly, we suspended Ascension from the vessel and collected up to 2L of sample water, filtering it *in situ* through a 45 micron MCE filter.
- We collected six samples and one blank "Control" per location; the sampling depth and amount of seawater we filtered differed between sites in order to cover as many mesohabitats within the estuary and in response to the turbidity of the water (higher turbidity, the more difficult it was to filter the water, leading to lower volume).
- The filters were removed from their casings on shore in a somewhat sterile environment (countertop sterilized with DNase and/or diluted bleach solution), with proper PPE.
- We preserved the filters in 10mL Eppendorf tubes pre-filled with preservative, supplied by the eDNA analysis lab eDNATec (SOPs were asked not to be shared).

Water Sampling Results

This section presents a summary of the preliminary results of the baseline water sampling surveys from the Area 1 estuaries of the RESS project. For more detailed preliminary results from each estuary, please see Appendices A-F.

Salinity

Salinity plays a crucial role in determining the quality of water in estuaries. In estuaries, freshwater and saltwater mix, and the extent of mixing may determine the health of the ecosystem. The exchange of water with the open ocean helps in the removal of waste products, oxygenation of the water, and the supply of food and nutrients to immobile organisms. Salinity values in estuaries vary depending on several factors, such as freshwater input and exchange with the open ocean.

The salinity range in five of the six Area 1 estuaries was between 30 ppt and 33 ppt, with Portage Inlet being an exception (see Figure 2). Portage Inlet, which is at the end of the 8.5 km Gorge Waterway, has a lower salinity range of 22-30 ppt, indicating that there is very little exchange with the open ocean. This could lead to higher concentrations of waste, nutrients, and contaminants, potentially leading to hypoxic conditions in the area. The high salinity values in Tod Inlet may be due to the closed nature of the inlet, however the reason for the high salinity in Roberts Bay is unclear and may indicate less freshwater input than the other estuaries. It must be noted that the Portage Inlet dataset was collected in mid-November 2023 (unlike the other locations which were mid-October), after the fall rainy weather had begun (over 250 mm of rain between sampling times) so this likely affected the comparison with the other estuaries.

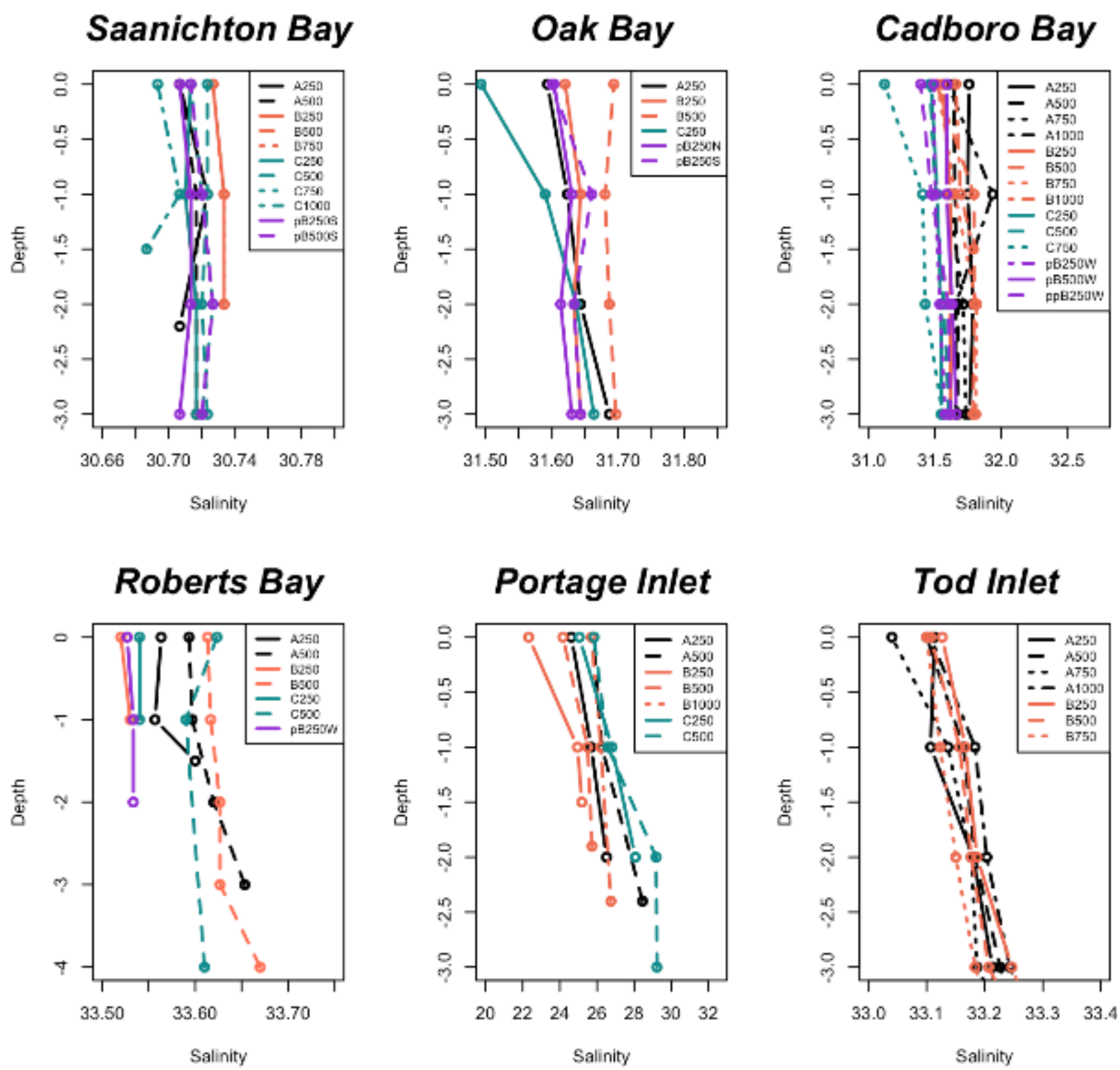
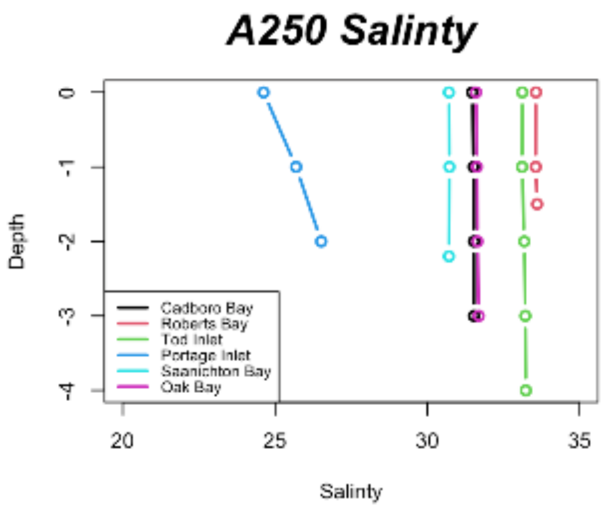


Figure 2. Salinity (ppt) profiles of the Area 1 estuaries, depth is in metres. The x-axis ranges differ between plots and the datapoints are the mean of three replicate measurements (error bars omitted as they are negligible).

The salinity profiles at equivalent sites in each estuary can also be plotted together so we can compare the estuaries site-to-site (Figure 3). Although the similarly named sites are not necessarily equivalent (they were named in a similar way, but not for the primary purpose of comparison), they can provide comparisons between sites equidistant from the freshwater input. As expected, Portage Inlet's salinity values are very low. Most surprisingly, salinity does not significantly diminish with distance from the freshwater input (see Activity 3 for analysis).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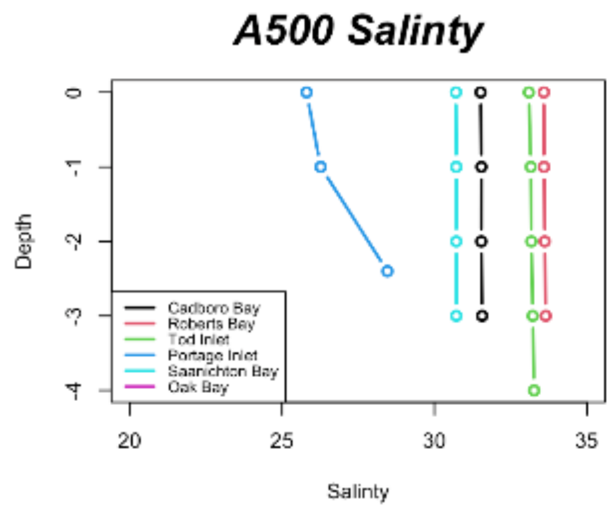
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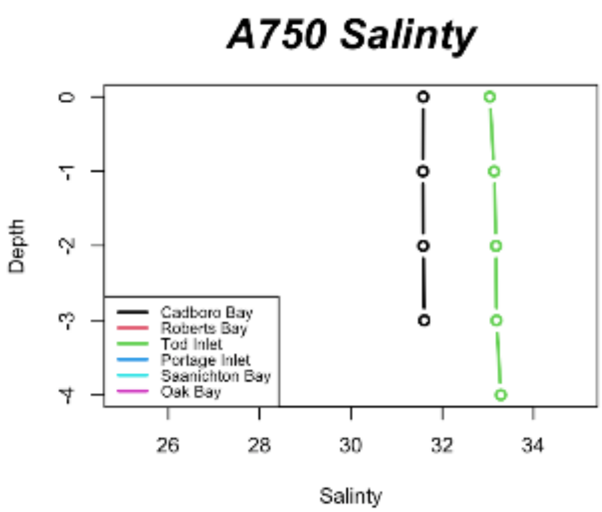
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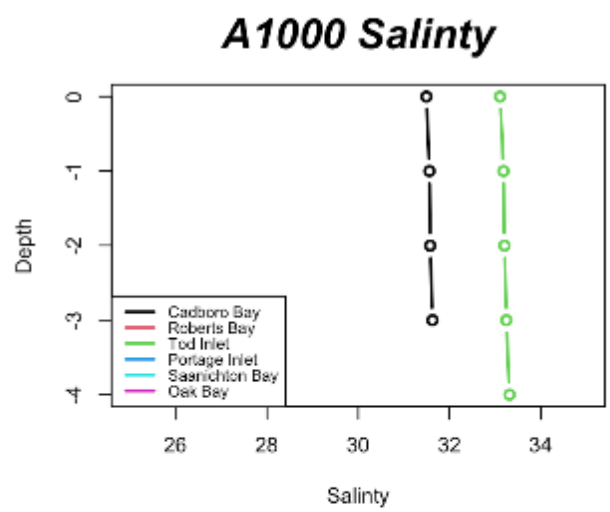
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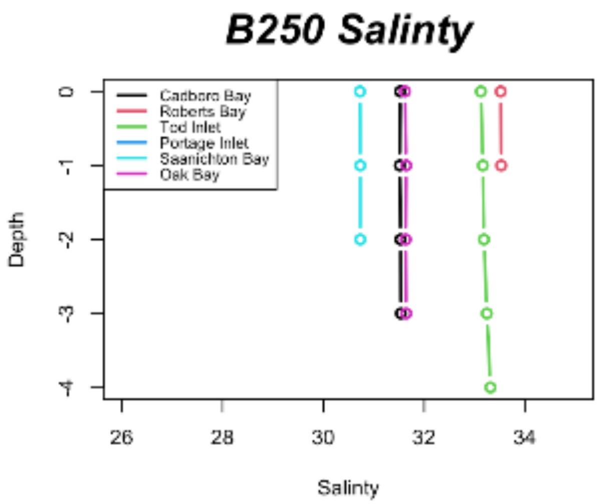
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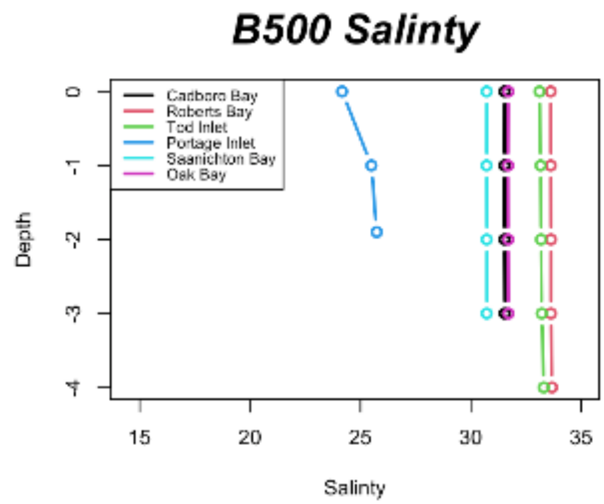
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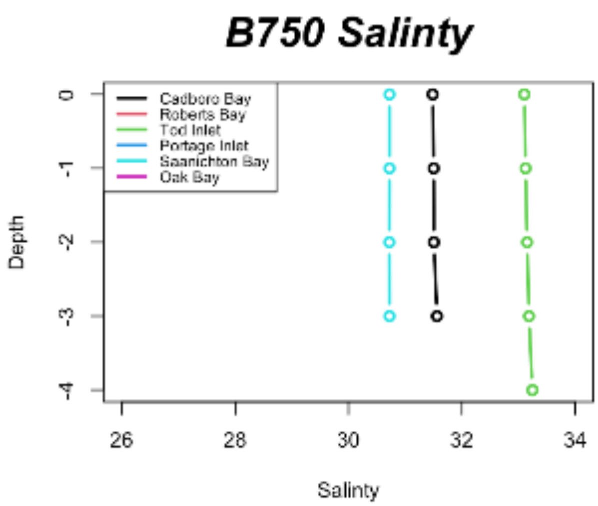
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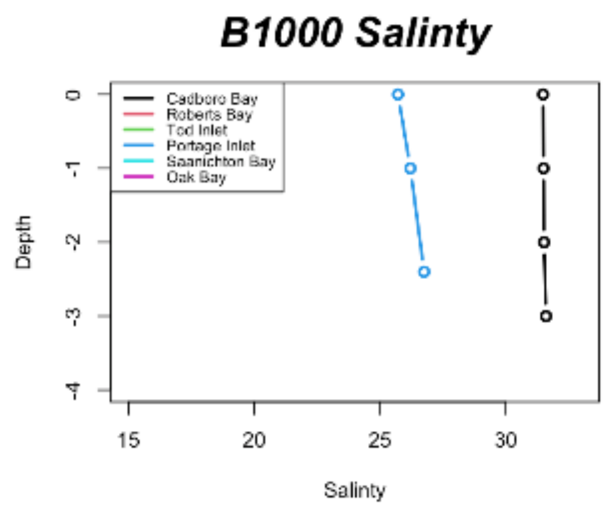
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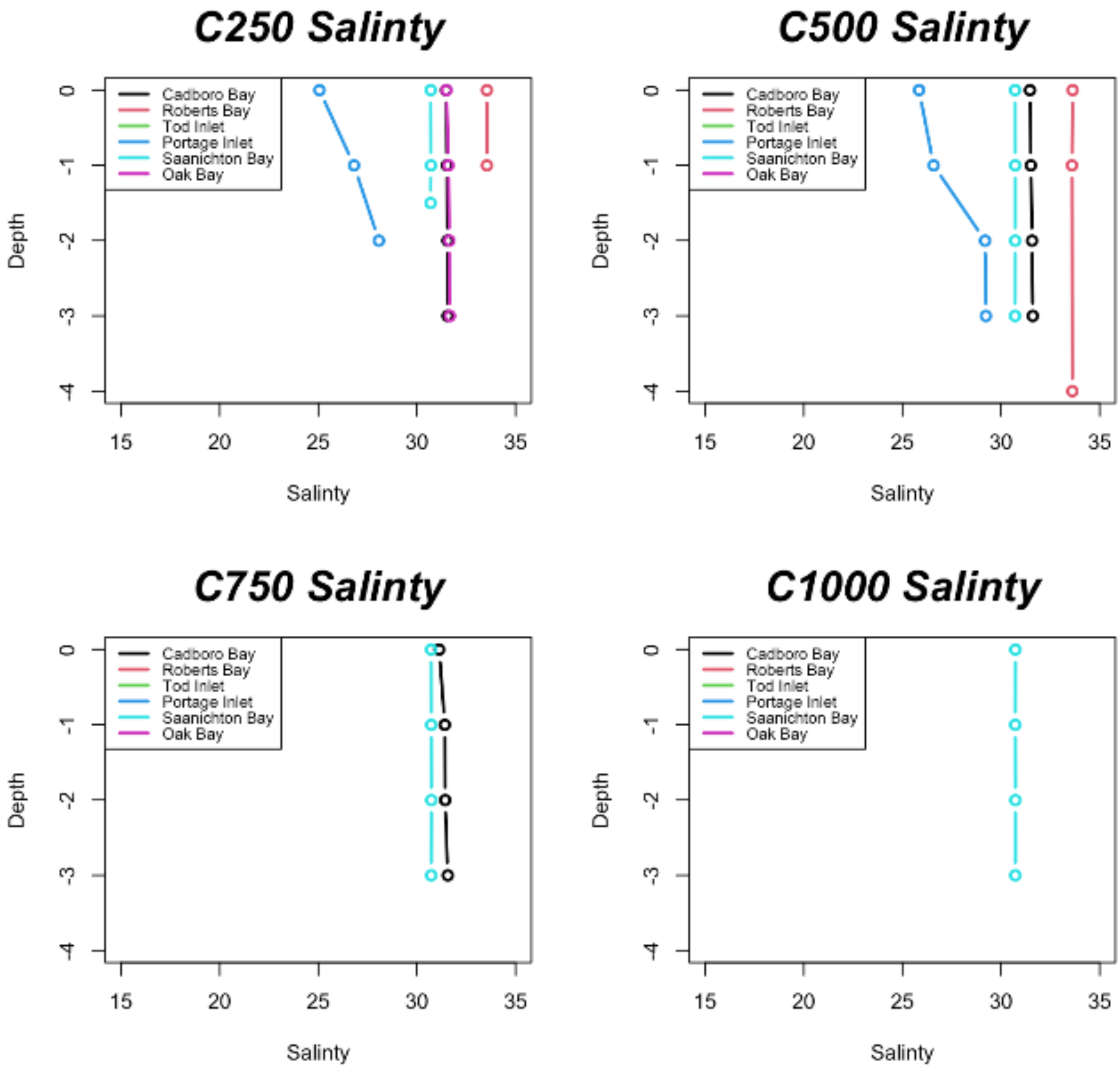
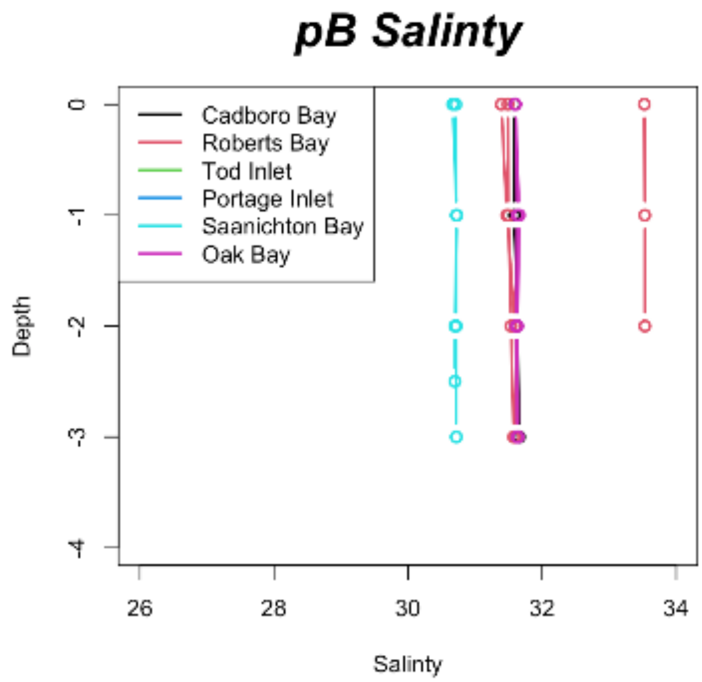
Roberts Bay
Tod Inlet
Portage Inlet
Saanichton Bay
Oak Bay
Depth
0
-1
-2
-3
-4
15
20
25
30
Salinty


C250 Salinty
Cadboro Bay
Roberts Bay
Tod Inlet
Portage Inlet
Saanichton Bay
Oak Bay
Depth
Salinty
C500 Salinty
Cadboro Bay
Roberts Bay
Tod Inlet
Portage Inlet
Saanichton Bay
Oak Bay
Depth
Salinty
C750 Salinty
Cadboro Bay
Roberts Bay
Tod Inlet
Portage Inlet
Saanichton Bay
Oak Bay
Depth
Salinty
C1000 Salinty
Cadboro Bay
Roberts Bay
Tod Inlet
Portage Inlet
Saanichton Bay
Oak Bay
Depth
Salinty



Figures 3: Salinity- depth profiles (ppt, metres) at similar sites among Area 1 estuaries. Salinity (x-axis) ranges differ between plots and the datapoints are the mean of three replicate measurements (error bars omitted as they are negligible). Not all locations are represented in all plots.

Temperature

Temperature is also an indication of the level of mixing and exchange with the open ocean. The general Salish Sea temperature is around 10°C, but it can vary depending on the season, depth, and shoreline composition.

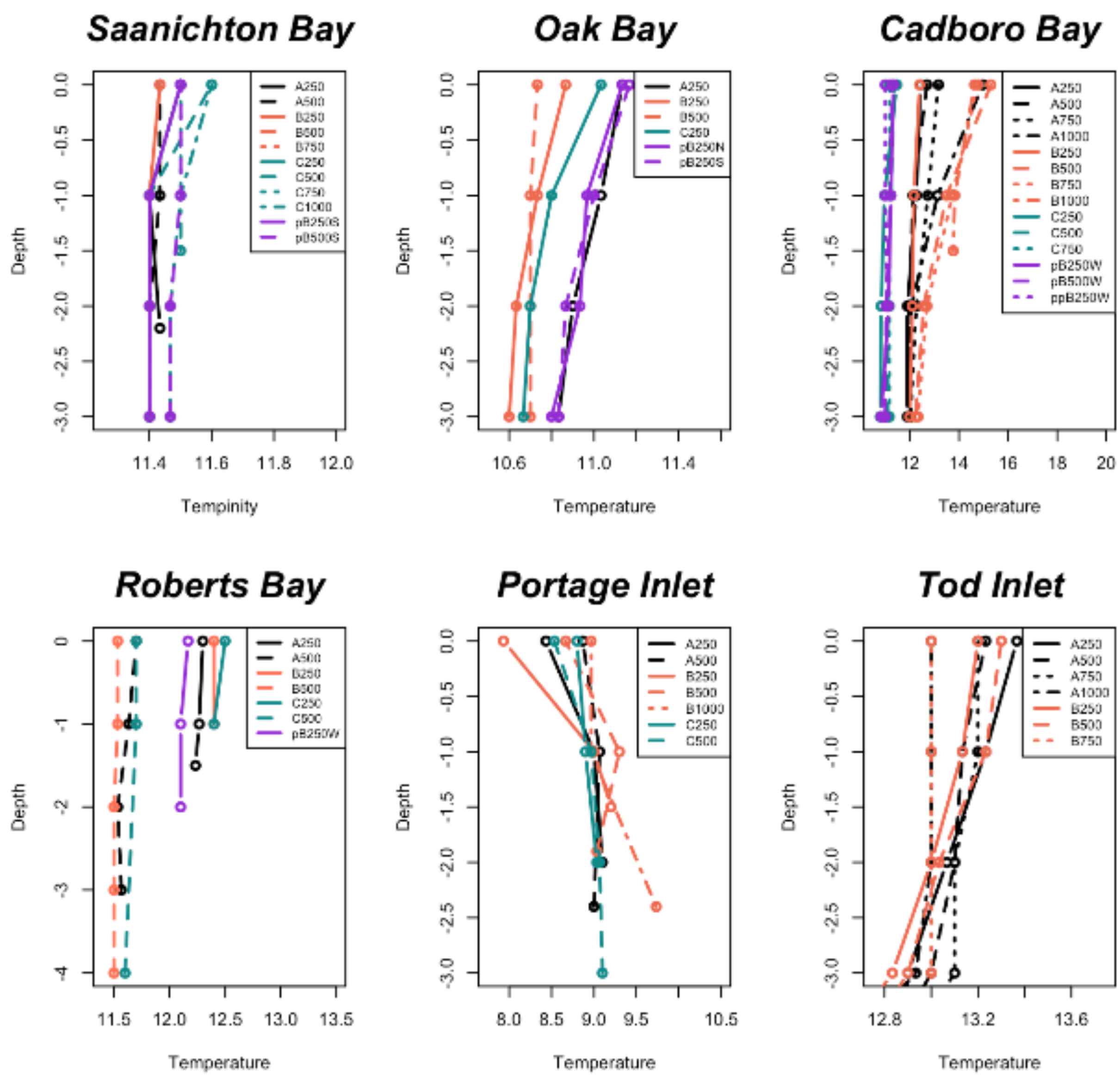


Figure 4: Temperature (in degrees Celsius) profiles of Area 1 estuaries, depth in metres. Temperature (x-axis) ranges differ between plots and the datapoints are the mean of three replicate measurements (error bars omitted as they are negligible).

The temperatures in Tod Inlet and Cadboro Bay were higher than this average, while they were lower in Portage Inlet (Figure 4). Leading up to the sampling days, the weather had been dry and warm, and therefore the temperature of the surface water will be warmer if there is little exchange with the open ocean. The higher temperature in Cadboro Bay could be due to its long and shallow beach/seafloor profile, which makes it an enjoyable place to swim, but also doesn't allow much shading from shoreline plants. Tod Inlet has surprisingly warm water, which could be due to low exchange with cooler water from the open ocean, and the water within Saanich Inlet being cut off from much cold ocean water input due to the sill at its opening that shrinks the water depth to less than 100 m. On the other hand, the low temperature water in Portage Inlet is surprising, especially since it gets warmer with depth. The source of the cooler water is unclear, but it could be from a recent input of cold, fresh water. The recent rains in the CRD between mid-October and mid-November 2023, which were over 250 mm, could be the cause of the low temperature and salinity.

The temperature range in Oak Bay and Saanichton Bay is similar to the general Salish Sea surface temperatures, which suggests good oceanic water exchange in these estuaries. This could be due to the shoreline geography (not closed off) and the currents between the shore and the closer islands in Oak Bay (Mary Tod Island) and Saanichton Bay (James Island). Oak Bay and Saanichton Bays also have low salinity stratification (consistent salinity values with depth), with the exception of a sheltered site in Oak Bay, which confirms oceanic water exchange.

In Roberts Bay, there is a significant temperature jump between the near-shore and far-shore sites, which is not observed in the other locations. This could be because Roberts Bay is smaller than the other locations, and the outer sampling sites are outside the general estuary area. The salinity values are also grouped into high and low values, based on their distance from Mermaid Creek. However, the difference in salinity between the close and near sites is less pronounced.

Dissolved Oxygen

The oxygen levels in the Salish Sea can indicate the high primary productivity from different types of plants and algae, including phytoplankton. Low oxygen levels can be caused by low rates of photosynthesis; or high nutrient concentrations which leads to the proliferation of bacteria and other respiratory organisms that consume oxygen. This can result in hypoxia or approaching hypoxia, where the oxygen concentration becomes insufficient. The oxygen concentration in the Salish Sea generally falls between 4 and 9 mL/L, according to the US Government's EPA website (https://www.epa.gov/salish-sea/marine-water-quality#what-happening).

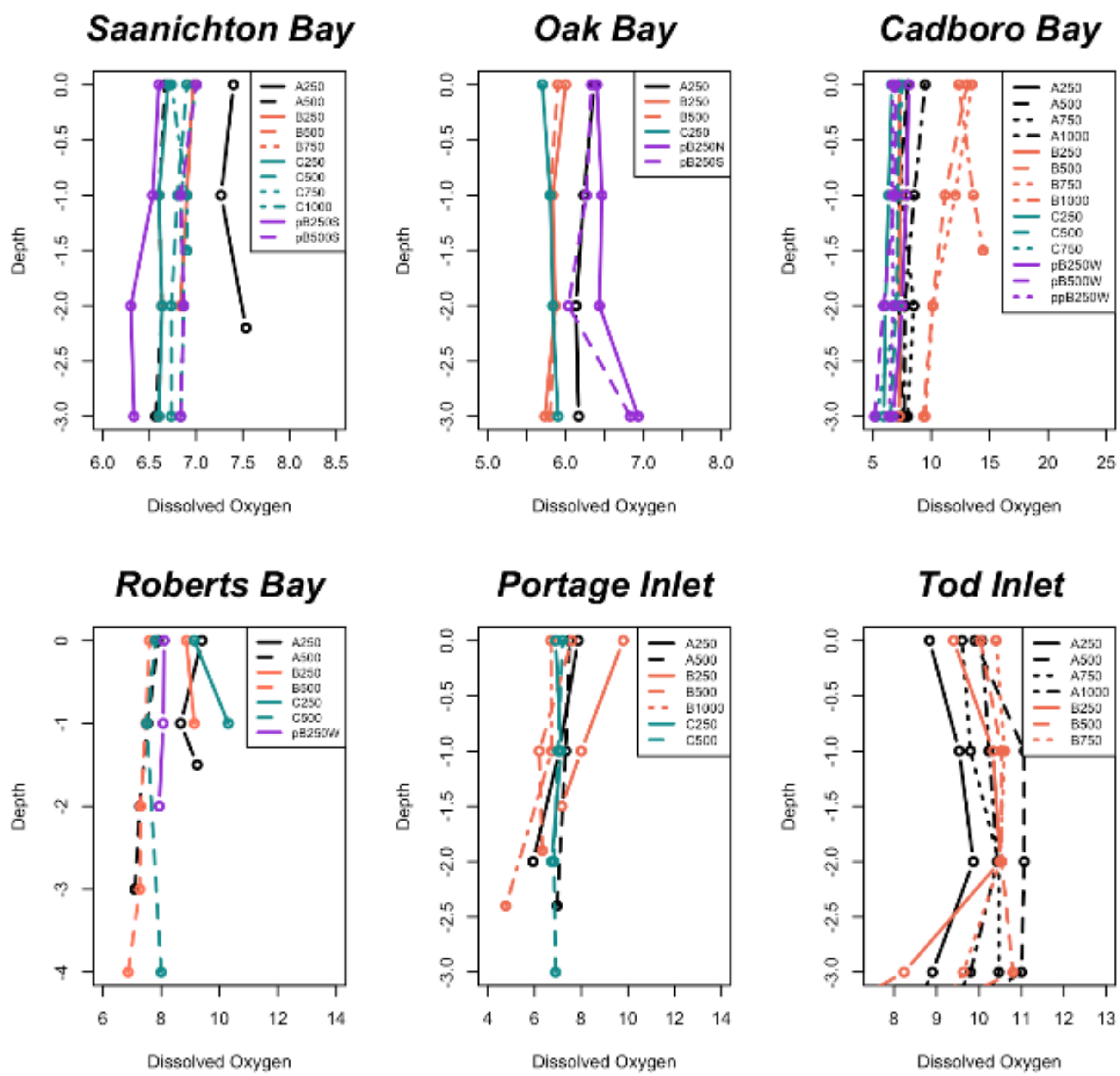


Figure 5: Dissolved oxygen (in mg/mL) profiles of Area 1 estuaries, depth in metres. Dissolved oxygen (x-axis) ranges differ between plots and the datapoints are the mean of three replicate measurements (error bars omitted as they are negligible).

Cadboro Bay has a larger range of oxygen levels than other locations, with one of the lowest and one of the highest values (Figure 5). The low oxygen content in this bay is likely due to low oceanic exchange due to the long and sheltered nature of the bay and a lack of photosynthetic organisms (*Ulva*, *Gracilaria*, and an unknown brown kelp): a higher oxygen concentration near the mouth of the bay, where there is more ocean water exchange, gives evidence that the low oxygen levels do not come from the ocean water. On the other hand, the low oxygen concentration in Portage Inlet is likely a result of eutrophic conditions, which the eelgrass beds cannot replenish with oxygen.

The cause of the sharp decrease in oxygen concentration at depth in Tod Inlet is unclear, but it is the only place that it is seen. The sharp increase in oxygen with depth in Oak Bay pB250N is likely due to the eelgrass bed at that location; the cause for the increase in pB250S is unclear, however there is algal presence in the area (*Ulva* mostly), and with the sheltering at that site, the oxygen could be retained at the bottom.

The similarities and differences among the sites are evident. It is also apparent that time of year when sampling has a large impact on the salinity and temperature values, and any future estuary visits should be planned with this in mind: comparisons between Portage Inlet and the rest of the estuaries are questionable. Although this comes as no surprise, the size and shape of the estuaries plays a large role in water mixing and oceanic exchange. Less-sheltered estuaries like Oak and Saanichton Bays are better mixed, with moderate and consistent Salinity, Temperature, and Dissolved Oxygen values with depth.

Biodiversity Assessments

After conducting extensive literature searches, consulting with researchers and other conservation organizations (including Fisheries and Oceans Canada), and learning from First Nations marine and fisheries conservation teams about their communities' cultural and economic needs, we identified priority and target species. The species of concern are: salmon (five indigenous species: *Oncorhynchus gorbuscha*, *Oncorhynchus nerka*, *Oncorhynchus kisutch*, *Oncorhynchus keta*, *Oncorhynchus tshawytscha*), clams (various bivalves), Olympia oysters (*Ostrea lurida*), surf smelt (*Hypomesus pretiosus*), herring (*Clupea pallasii*), and eelgrass (*Zostera marina*).

Invasive or non-native species of concern are: European green crab (*Carcinus maenas*), Sargassum (*Sargassum muticum*), and Atlantic salmon (*Salmo salar*: escapees from open-net farming).

Salmon are essential cultural, ecological, and economic species whose decline is linked to overfishing, habitat loss, climate change, and pollution. The species and population of our concern are those that enter the Salish Sea from inland freshwater habitats and spend months to years in the estuaries along the coasts. Although they begin at their natal stream estuaries, they feed and seek protection in other estuaries as they smoltify and grow. Salmon move to the open ocean when they are at the appropriate size and are physiologically able to survive in seawater. From personal observations, we saw young Chinook salmon smolts in the eelgrass by Fernie Island in August 2023, which is not close to any identified salmon-bearing stream; the closest salmon "habitat" stream according to (https://maps.gov.bc.ca/ess/hm/habwiz/) is 5.5 km south in Banzan Bay).

Aside from the importance of salmon, local First Nations representatives have stated that the ability to harvest clams has been a goal of local FN Fisheries and Marine Departments. The Tsawout Fisheries, who had signed an IPCA in June of 2023, have been monitoring bacterial contamination from the water treatment facility and spills into the Tetayut Creek, as well as the effects of excess nutrients from farmland in the Tetayut watershed leading to harmful algal blooms. Together, we have worked to identify the sources of contamination that would mean that harvesting clams from Saanichton Bay would be unadvised. Our results from Saanichton Bay have been continuously shared with the Tsawout Fisheries Department. We look forward to addressing the cultural and ecological needs of the region through restoration and conservation activities.

Of interest to many conservation groups, as well as Fisheries and Oceans Canada, is the Olympia oyster, which has returned in Tod Inlet/SṈIDȻEŁ. Many partners' previous restoration activities in Tod Inlet, including SeaChange (see Z. Colliers report for more information), have increased the number of oysters in the region, mainly the Pacific oyster (*Magallana gigas*). When the endangered Olympia oyster was spotted, the area was under heavier observation by the World Fisheries Trust and DFO. SeaChange, through either RESS or other projects, and with the support of PEPAKEṈ HÁUTW, will continue the restoration in this area.

Surf smelt and herring are culturally significant species of edible fish that use near-shore environments to spawn. The First Nations have harvested the adults and their eggs for food since time immemorial, and harvesting herring and their spawn still brings First Nations community members together. Aside from their importance ecologically and culturally, they are a fisheries resource in the Salish Sea, and their stocks concern many.

Eelgrass is a species of special concern, as it is a habitat engineer of near-shore environments. The soft sediment in which the plants take root is found in areas of slow water movement, such as bays, and their presence will act as a buffer to shoreline erosion by further slowing water currents and wave action. Eelgrass has a large range of salinity and temperature tolerance, allowing it to survive in brackish estuaries with low water circulation. In turn, it provides habitat and food for other important species, and it stabilizes the sediment for infaunal species. However, human actions damage the plants, whether with shading from structures, high sediment loads from inland urbanization and high phytoplankton concentrations from eutrophication, stress from shoreline modifications such as seawalls, habitat loss from sea level rise, increased thermal stress leading to low immunity from disease, and damage to the plants themselves from anchors, detritus, and mooring chains. SeaChange has worked to replant areas of eelgrass damage and continue to plant, however many places, the cause of eelgrass loss persists. RESS has collaborated with organizations that are working at a governmental level to enforce boating bylaws in busy mooring bays (such as the Royal Victoria Yacht Club and the Cadboro Bay Dead Boats Society along with the Mayor of Oak Bay), advise against anchoring in eelgrass beds (the No-anchor zone social marketing workgroup), and provide education about the sensitive eelgrass bed ecosystem (the Ocean Education Collaborative).

The invasive species of concern (the European green crab, Sargassum, and Atlantic salmon) damage the ecosystem to varying degrees. Much research has been conducted on the damage of escaped Atlantic salmon, such as their hybridization with indigenous salmon species and the long-term ecological effects and the possibility of out-competing wild Pacific salmon species. The use of salmon habitat by Atlantic salmon is still contentious. However, we would like to note any presence of escapees in our research.

Sargassum is an algal species that grows in dense bushes along the coast. Its presence is ubiquitous around the Salish Sea, including unperturbed areas with little human activity. The alga grows attached to rocks and in mixed-substrate environments and can shade the sun-loving eelgrasses.

The species of most concern is the European green crab. The devastation to local animal and algal species cannot be understated, as the damage caused by this crustacean has already been witnessed on the Atlantic Coast of North America. Early detection, trapping, removal, and destruction of the crabs is a combined transboundary effort (Canada and the US).

In order to properly assess these priority habitats and target species, we performed both biodiversity assessments with divers and habitat mapping surveys using a towed underwater camera system and are currently processing that data into habitat maps to assess area and connectivity within each estuarine system, as well as the presence of invasive or problematic species. We also collected eDNA samples from the estuaries in Area 1 of the RESS project, except for Portage Inlet due to difficulties with accessing the site. The targeted species for the eDNA analysis are: Pacific Salmon, Atlantic Salmon, Herring, Surf smelt, and European green crab. The purpose of focusing on these species, aside from their importance mentioned above, is the cryptic nature of the salmonids and the need for early detection of the EGC.

The results from the biodiversity assessments have not yet been fully analyzed from all the Area 1 estuaries and the eDNA samples are still being processed as of the writing of this report. This preliminary report will be updated after that data analysis is completed and the rankings will be updated.

3. Geospatial Layers and Online ArcGIS App

Background

The RESS team has designed an online ArcGIS App with historic data layers and the data collected during this first year of the RESS Project with data, images and documents. This interactive online app is accessible via this link.

List of ArcGIS App Layers

- Estuary Reports (Source: RESS)
- Site Data (Source: RESS)
- Transect Lines (Source: RESS)
- Saanichton Bay Anthropogenic Items (34.883 MB; Source: RESS)
- Saanichton Bay Estuary Habitat Map (34.883 MB; Source: RESS)
- Portage Inlet Anthropogenic Items (17.344MB; Source: RESS)
- Portage Inlet Estuary Habitat Map (17.344MB; Source: RESS)
- Roberts Bay Anthropogenic Items (14.766MB; Source: RESS)
- Roberts Bay Estuary Habitat Map (14.766MB; Source: RESS)
- Oak Bay Anthropogenic Items (9.305MB; Source: RESS)
- Oak Bay Estuary Habitat Map (9.305MB; Source: RESS)
- Cadboro Bay Anthropogenic Items (8.727MB; Source: RESS)
- Cadboro Bay Estuary Habitat Map (8.727MB; Source: RESS)
- Tod Inlet Anthropogenic Items (27.172MB; Source: RESS)
- Tod Inlet Estuary Habitat Map (27.172MB; Source: RESS)
- Eelgrass (ShoreZone) (18.102MB; Source: ShoreZone)
- Salt Marsh (ShoreZone) (18.102MB; Source: ShoreZone)
- Deltas (ShoreZone) (18.102MB; Source: ShoreZone)
- Tidal Flats (ShoreZone) (18.102MB; Source: ShoreZone)
- Estuaries (ShoreZone) (18.102MB; Source: ShoreZone)
- Slope (ShoreZone) (18.102MB; Source: ShoreZone)
- Rivers and Streams (ShoreZone 2017-2023) (80KB; Source: ShoreZone)
- Rivers and Streams (ShoreZone 2004) (1.953MB; Source: ShoreZone)
- Freshwater Inputs – Freshwater Atlas Data (Source: Government of BC)
- BC_ShoreZone_New_Imagery (2017-2023) (130.43MB; Soucre: ShoreZone)
- BC_ShoreZone_Old_Imagery (2004) (6.758MB; Soucre: ShoreZone)

Detailed Descriptions of Layers by Group

Estuary Reports

Within the boundaries of the estuaries from Year 1 (Area 1), there is a link to the full summary report of the estuary stored online.

Site Data

Similarly to the Estuary Report layer, these points on the map are at the sampling locations within the estuaries at each location. The user can see the data collection site in relation to the other sites within the estuary, and the point links to the site information, stored online.

Transect Lines

The lines directed outwards from the mouth of the freshwater input along which the data collection sites were chosen. The transect line directions were designed to cover the most habitats within the estuary.

Estuary Anthropogenic Items and Habitat Maps

These layers represent the result of the work we did filming the benthos with an underwater tow camera followed by video analysis. The information was split into two layers: “Anthropogenic Items” (points) and “Habitat Map” (points along the tow camera’s pathway. The locations are determined by the video being overlayed with GPS coordinates and through categorisating the substrate. The user can click on a point and there will be a link to an online video or image from that point.

The “Anthropogenic Items” layer was designed to help with any restoration activities under RESS Phase 2. The layer identifies the location of human detritus or debris and is separated into “Removable by dive team” and “Not removeable by hand”.

The “Habitat Map” layer was colour-coded according to the substrate composition and/or benthic algal or plant species. The habitat categories are: “Sandy”, “Sandy with algae present”, “Boulder/cobble/pebble mixture”, “Bedrock/large boulders”, “Eelgrass bed”, “N/A” (no data), and “Detritus field”.

ShoreZone Layers

These layers indicate the shoreline where the ecosystem/habitat/species were present at the time of filming. When the user clicks on a line in these layers, the specific year the area was filmed is shown. There are two layers for “Rivers and Streams”: 2017-2023 and 2004. The regions these area cover overlap and having the early survey (2004) separated from the more recent survey (2017-2023) allows the user to avoid confusing the points on the map. The 2017-2023 survey was of the Salish Sea, not including Vancouver Island from Victoria to Nanaimo; and the 2004 survey was of Vancouver Island from Victoria to Nanaimo. The qualities used to categorise the are into ecosystem/habitat/species by the mappers are available at www.shorezone.org. Source: ShoreZone.

Freshwater Inputs – Freshwater Atlas Data

This layer was retrieved from the Government of British Columbia's data portal and collected as part of the Integrated Land Management Bureau in the Ministry of Agriculture and Lands:

https://www2.gov.bc.ca/gov/content/data/geographic-data-services/topographic-data/freshwater.

ShoreZone Imagery

ShoreZone imagery layers are displayed as dots along the flightplan. When the user clicks on the red dots, the App will give a link to the online video at the point the user has chosen. The blue dots link to the image of that area at an online location. The Old Imagery is for the Vancouver Island Shoreline from Campbell River to Gonzales Point.

4. Resilient Estuary Ranking System

The ecologically resilient ranking system of Salish Sea small- to medium-sized estuaries aims to focus efforts and resources on regions where our actions will have the most impact. All estuaries are worthy of action towards protection or increasing resilience; however, there are estuaries that have yet to receive attention, and which have the possibility to better weather the effects of climate change and increased coastal human populations than the rest, given efforts to conserve and restore those areas. We will listen to the needs of the local communities, and we will make notes on where we believe that our data may not reflect the wants and needs of all. Our overall objective is to do the best for the estuaries of the Salish Sea and the species that depend on them. For this reason, we plan to stick to non-invasive sampling methods, seek permission, and share results immediately with the First Nations on whose territory we will be working, and be open and transparent about our goals, funding sources, and collaborators.

This section presents our preliminary methodology to rank the small to medium sized estuaries of the Salish Sea in terms of their resilience to climate change. These rankings will help to inform where we direct resources for this project in future years as well as the actions plans developed for each site. This ranking methodology will continue to evolve as we analyze more of the data from Area 1 and as the project progresses to other parts of the Salish Sea. The rankings of the estuaries for Year 1 will hold significant value as these sites are heavily utilized by humans and affected by urbanization, so were expected to exhibit a range of ecologically functional areas, albeit on the lower end of the scale. We were interested to see if any estuaries demonstrated functionality despite their proximity to human development. The estuaries we sampled were all heavily impacted by anthropogenic activities but also displayed more resilience than anticipated in different ways.

For our preliminary ranking of the estuaries of Area 1, we relied on expert opinion, which included the Technical Committee, representatives of local First Nations, as well as scientists and conservation and restoration practitioners, as well as a literature review. The data and observations we have gathered and are continuing to analyze will add to that ranking as the project progresses.

We were introduced to local communities' personal and cultural needs throughout the year. Although it would be simpler to "write off" the estuaries already impacted by human activity and focus any work on more remote and "pristine" environments, the Year 1 estuaries are important to settler and First Nations communities and local conservation groups. For example, Tod Inlet/SN̲IDȻEȽ is a wintering area for the W̱JOȽEȽP, and its restoration and continued conservation is not only vital to them but is part of the reparations that colonists/settlers need to take part in the damage to the area is our responsibility to heal. The estuary at the mouth of Bowker Creek (called Oak Bay by this team and Bowker Creek Estuary) is by the municipality of Oak Bay, adjacent to the City of Victoria. Oak Bay municipality has a population of 20,000, and Victoria's population is 92,000, with the Capital Regional District of close to 400,000 people. Bowker Creek's watershed covers over 1000 hectares (10 km2) under malls, schools, apartment complexes, and roads. However, the Friends of Bowker Creek, the nearby Marine Provincial Park, support the municipality and the marina; Bowker Creek supports salmon, surf smelt, migratory birds, and crabs. Now, the Songhees FN has a Marine conservation team. Adding to these examples is the recently declared W̱JOȽEȽP IPCA that includes Saanichton Bay, restoration activity at the Roberts Bay/Mermaid Creek salt marsh. The value First Nations and locals give their natural environment, should be prioritized especially in urbanized areas.

At the Pacific Estuarine Research Society's 2024 Conference in Nanaimo, the RESS team spoke to other researchers seeking simple measurements indicating resilience to sea level rise. Steven Henstra from Nature Trust had measured this attribute and when pressed, he said that the most likely indicator of resilience to sea level rise is shoreline slope. We did not measure the slope, but we can get this information for Areas 2, 3, and 4 from ShoreZone data (Area 1 was not surveyed for slope). We will incorporate slope in Year 2 data analysis.

The **preliminary** ranking for the Area 1 estuaries from this expert assessment, from most to least resilient was: Oak Bay, Saanichton Bay, Roberts Bay, Portage Inlet, Cadboro Bay, Tod Inlet/ SṈIDȻEȽ.

This ranking will be updated as we incorporate more data and analysis and will likely change.

Development of Statistical Ranking Methodology

The preliminary ranking from expert opinion is an excellent start but we intend to take the ranking methodology further once the full datasets from each estuary in Area 1 is analyzed. The intention is to use the statistical software R (version 4.3.2) through R Studio (2023.12.1+402) and conduct a regression analyses using a generalized linear model (lm, or glm, package "dplyr"), and ANOVA (base R) for comparing multiple sites or locations. Principal Component Analyses will be calculated using the "Hmisc" package and running the function princomp(). The literature and expert knowledge agree that diversity leads to resilience overall, so we assume biodiversity surveys and indices and results of the habitat mapping will be the best indicators of resilience. This project has the time and resources to commit to collection of this data; however, these metrics are costly and/or time-consuming. This is why we also collected extensive physical data so we can search for a proxy of estuary diversity using variables we can easily monitor, such as abiotic features or water quality metrics. Our very preliminary statistical analyses from a few of the sites have not found a good approximation for biodiversity with the methods we used in Year 1. We did find bacterial contamination and nutrient concentration correlate with the Simpsons Biodiversity Index but have concluded that this index does not appropriately describe our data. These preliminary statistical analyses are presented in Appendix G but are not summarized here as we feel there is as yet insufficient analysis completed to make any firm conclusions. There may also be missing metrics that would be useful in our analyses. These include shoreline composition, slope, watershed metrics, prevailing currents and winds, tidal heights, *etc.* We hope to add these and other metrics to our analyses and rankings in Year 2.

5. Restoration and Conservation Action Plans

A major goal of the RESS project is to create actions plans that outline restoration and conservation activities that could maintain or boost the resilience of the estuaries we assess. These could also help to inform such activities in other estuaries of the Salish Sea by providing a list of activities that provide these benefits to estuaries in general. These activities may be carried out under the RESS project (that work would be funded under the Aquatic Ecosystem Restoration Fund and is reported separately) or by outside organizations or agencies. Each estuary will have individual needs, such as marine debris removal, derelict vessel removal, eelgrass transplants, Voluntary No Anchor Zone buoy deployment, enforcement of boating bylaws, education into shoreline protection with indigenous plants, identifying sewage sources, and/or reducing the impacts of Canada goose herbivory. SeaChange has a long history of effective coastal zone restoration, along with collaborators in streamside and terrestrial restoration (ex. Tod Inlet), eelgrass transplanting, debris removal, and education.

Cadboro Bay

Preliminary results show that the water is contaminated, there is a lot of debris scattered through the mooring area, and the habitat looks like eelgrass could grow. There is also a large amount of crab and trap fishing in the bay, which also means a large amount of ghost gear. We recommend first removing the marine debris and/or ghost gear and then work to eliminate or moderate sources of new debris input. The Cadboro Bay Dead Boats Society and the Royal Victoria Yacht Club, with the support of Songhees Marine, are looking to require proof of adherence to boating by-laws by boaters moored in Cadboro Bay which includes proof of insurance and registration. With general observations of the eelgrass present in Oak Bay in areas prohibited from mooring/anchoring, and the contaminated, although eelgrass-plentiful Portage Inlet, it is reasonable that the increased boating pressure in the bay could be the cause of the lack of eelgrass. A test planting could be done, with boat and fishing exclusion zones, to test this hypothesis. We believe that the biggest impact in the area will be from implementing an education program, with events and signage, to encourage better practices in regard to garbage, effluent release, and seafloor scouring in the bay.

Oak Bay

Side scan sonar maps showed marine debris is prevalent in Oaks Bay, and removal is recommended. Following habitat mapping, we recommend implementation of eelgrass exclusion zones with on-site signage that are also added to navigation applications (if possible) along with educational events for boaters in the area. Mapping may also identify whether there is need for improved mooring systems for the liveaboards or other non-transient anchoring near the marina. Midline mooring buoys for those already moored close to eelgrass bed could mitigate the issue in the short-term.

We also identified a number of sunken vessels. A dive team could remove any smaller pieces from the boats (dismantling); however, much of the boat removal is beyond the ability of divers so a larger effort may be needed with outside contractors. One vessel was sunken in the eelgrass bed and has likely caused considerable damage so an eelgrass transplant could help to repair the eelgrass bed once the sunken vessel has been removed. A long-term system for garbage disposal and effluent pumping for those living aboard their boats in the bay is recommended, as well as proof of compliance with boating by-laws such as Cadboro Bay is hoping to implement.

Saanichton Bay

Saanichton Bay is a place of shellfish and crab harvesting, and it could be restored to safe harvesting if measures are taken. Debris removal and potentially eelgrass replanting could increase eelgrass beds to previous size which could provide better shoreline protection and habitat. To further protect the eelgrass beds following mapping, we could install sensitive ecosystem signage to prevent anchoring and replace mooring buoys to those with mid-line floats will protect the soft sediment seafloor. Further research into eelgrass bed depletion is warranted, to see if factors such as goose presence, land-based pollution, and the effect of the shoreline modification are impacting distribution in the bay.

At a community level, the underwater tow footage is available online, and we propose having a Q & A with representatives of the Tsawout Fisheries Department and SeaChange's RESS team. This event will seek to be educational and informative for adults and children, with games and activities. We will also seek input from the First Nations residents along Saanichton Bay to continue monitoring and conservation activities to work toward the goal of sustainable food harvesting.

Roberts Bay

Conservation is essential to the area, with shoreline restoration of the salt marsh habitat recommended. The large eelgrass bed in the bay should be provided with protection, so installation of a voluntary no anchor zone would be valuable if the area becomes more popular with boaters. If Canada geese become a problem, waddle fencing of the marsh and other shoreline areas will help with protecting the subtidal habitats. There is also a concern around the heavy *Ulva* blooms in the summer as well as diatom/bacterial films which should be investigated further so management techniques could be recommended.

Tod Inlet/SN̲IDȻEȽ

SN̲IDȻEȽ has already been the focus of restoration efforts due to its importance to the local First Nations community as well as the long history of impacts and contamination of the inlet due to the concrete factory sited there in the past. At this point, we would recommend updated signage about the restoration efforts in progress by the PEPAKEN̲ HÁUTW̲ organization as well as signage for boaters to treat the waters with respect and educate visitors in the cultural and ecological importance of the area. We also recommend continuing to work with PEPAKEṈ HÁUTW̱ toward land and sea connected restoration and education. Restoration of the impacted shoreline will continue to be a priority and contaminant mapping in the subtidal is recommended. There is a population of Olympia Oyster in the Inlet that also should be monitored and additional habitat should be provided to maintain that population. SeaChange has previously conducted eelgrass transplanting in a small area in SṈIDȻEȽ, and that transplant continues to be successful today. This indicates further transplants may be worth trying although sites would have to be chosen carefully to ensure contaminated sediments do not cause issues. There are also creosote pilings that could be removed, although many currently have swallow nesting boxes attached to them which are highly valued by the community so that would have to be done carefully to avoid disrupting the swallows.

Portage Inlet

There are a number of important salt marshes in Portage Inlet that have been impacted by grazing by Canada geese. Efforts are being made by Peninsula Streams and Shorelines to restore some of those areas so we recommend continuing control methods for non-migratory Canada geese in the area. The shoreline is already seeing improvement within replanted, fenced areas. This will not only reduce shoreline erosion and increase habitat diversity but will potentially help in water filtration, given that watershed pollution is inevitable. With the low amount of mixing with open ocean water, the best bet is to reduce the contaminants from the freshwater inputs through riparian planting and community education regarding what is put into the storm water system.

Long-Term Monitoring For Area 1 Estuaries

The baseline data collected in the project provides a snapshot in time while the true story of resilience in estuaries is told over a time series. One of the main recommendations from this project is to implement long-term monitoring activities in the estuaries chose for Area 1. These activities rely on access to the location or monitoring area (subtidal, intertidal), support of local groups, and restoration activities completed in the past, through the RESS project, or by other organizations.

The activities we believe would provide the best data over a long time period are biodiversity surveys, which could potentially be done using eDNA sampling with Ocean Diagnostics Inc's portable eDNA pump system (in development), and could be done in the field without extensive training. These samples would be best collected throughout the year to capture the transient nature of salmonids and other forage fish. We would also like to see water samples that test for bacterial and nutrient contents: water samples can be collected and kept cool before being transferred to a laboratory for processing, also easily doable by citizen scientists and volunteers. Along with the samples, general shoreline observations are always important, including counts of Canada geese, shoreline erosion, condition of current shoreline modifications and increase in number of modifications, and boater use.

6. Communications Report

Communicating the work the RESS Team is doing as part of the Baseline Assessment and Ground-truthing phase of the project has led to new collaborators and connections. It is also important to provide education around these activities so community members have a better understanding of the ecosystems at their doorstep and the steps that can be taken to protect them. At the beginning of the project, the RESS Team was made mostly of people new to SeaChange so the team took every opportunity to meet with people working in fields related to estuary and aquatic conservation and those that rely upon them for jobs, food, or enjoyment. An Outreach Coordinator was brought on to share our work and with her excellent communication skills, we have been able to work effectively with local First Nations, community conservation groups, and governmental organizations.

This section summarizes the communications that were undertaken as part of this phase of the project.

Outreach Events

The Salish Sea Symposium
Location: Vancouver Convention Centre, Vancouver BC
Date: January 23 –24th, 2024
Duration: 9am –5 pm
Organizers: Transport Canada
# of people engaged: 15 personally (250 in attendance)

At the Salish Sea Symposium in January, RESS team members had the opportunity to discuss the project with other professionals in the field at various workshops and presentations. This was a great opportunity to make connections for the project with other environmental nonprofit organizations, First Nations, and government workers.
Photos: IMG_0120.png, IMG_0147.png

Pacific Estuarine Research Society Conference
Location: Vancouver Island University, Nanaimo BC
Date: April 18 -20, 2024
Duration: 8am – 9pm , 8am – 12:30 pm
Organizers: Pacific Estuarine Research Society
# of people engaged: 80
Photos: IMG_3320.png

From April 18th – 20th, members of the RESS team was able to attend the annual Pacific Estuarine Research Society conference in Nanaimo. Thomas Armitage presented a poster about RESS entitled, "Mapping the habitat mosaics of Saanich Peninsula estuaries helps determine their resilience". There were over 80 people in attendance, all of which attended the poster presentation with the opportunity to discuss RESS and read the poster.

Songhees Nation Herring Event
Location: Gorge Nature House, Esquimalt BC
Date: March 23, 2024
Duration: 11am – 3pm
Organizers: Songhees Nation Marine Team/ Carmen Pavlov
# of people engaged: 20
Photo: Songhees Herring Event Thomas.png , Songhees Herring Event Table.png
Contact: carmen.pavlov@songheesnation.com

On March 23rd, RESS team members were invited to a Songhees Nation herring event to share about RESS. About 20 Songhees FN community members attended this event, it was not open to the public. We were able to share our RESS handouts with attendees and discuss more about our research associated with the project and restoration activities.

Bufflehead Day
Location: Roberts Bay, Sidney BC
Date: October 14, 2023
Duration: 10 am – 2pm
Organizers: Friends of Shoal Harbour Society
# of people engaged: 30
Photos: IMG_7353.HEIC
Contact with: bobpeart@shaw.ca

On October 14th, we were present at Bufflehead Day, put on by Friends of Shoal Harbour Society. Roughly 30 people attended this event and we were able to share more about RESS project with them, and the importance of estuaries for species like buffleheads.

SeaChange's Annual General Meeting
Location: Shaw Centre for the Salish Sea, Sidney BC
Date: November 20, 2023
Duration: 10 am – 2pm
Organizers: SeaChange
# of people engaged: 16
Photos: IMG_1873.JPG
Contact with: Shaw Centre – oceaneer1@salishseacentre.org and pauline.finn@oceandiscovery.ca

SeaChange held our AGM on November 20th, at the Shaw Centre for the Salish Sea. Executive Director, Sarah, shared about RESS with the 16 people in attendance. This was a great opportunity for us to introduce RESS SeaChange members and discuss the project more with the board of directors.

World Eelgrass Day
Location: Shaw Centre for the Salish Sea, Sidney BC
Date: March 2, 2024
Duration: 10 am – 4:30 pm
Organizers: SeaChange
# of people engaged: 358
Photos: IMG_1650.png IMG_1639.png IMG_1638.png
Contact: oceaneer1@salishseacentre.org

On March 2nd, in collaboration with the Shaw Centre for the Salish Sea, we organized an event to celebrate World Seagrass Day. RESS team members shared a presentation to families about the importance of estuaries and eelgrass, as well as the marine debris removal efforts of the RESS project. We were also able to distribute RESS informational handouts and educational colouring sheets to the 358 people in attendance at the Shaw Centre that day. Following this event, the Shaw Centre for the Salish Sea uploaded our educational colouring pages to their website (funded by RESS Phase 2), allowing for more people to access the information and learn about RESS.

Social Media Postings
Total reach via social media: 14,813
Instagram: 2,952
Facebook: 7,846
LinkedIn: 4,015

We have posted about RESS nine times on our social media platforms (9 posts on four different platforms). These posts are meant to inform the community of our work, goals, and accomplishments. They have also been a great tool in gauging volunteer interest and making connections with other groups. We have been able to reach a total of 14,813 people through our social media channels.

Newsletters
RESS project and work was shared across 5 newsletters. We shared details about the project, research/biodiversity surveys, debris cleanup work, and events that people can attend to discuss the project with us. These newsletters were sent to 374 people, with a 50% opening average for these newsletters.
Link to newsletter:
https://us15.campaignarchive.com/?u=72484b5f2a0dab1f75967ad96&id=a911a1828b

Handouts
With the help of an artist, we created informational handouts about RESS to give away at events or activities. Our goal is to use these materials to further inform the community and encourage stewardship for estuaries, as well as support for RESS. We plan to give these handouts to facilities and other organizations to also hand out when we are not there, to continue our impact.
RESS_HandoutV2[31].pdf

Metrics

Public communication products developed (e.g. reports, websites, videos, newsletters, brochures, information packages, training materials, social media posts)

- 5 newsletters
- 9 social media posts on 4 different sites
- 2 magazine articles
- 1 rack card

Workshops or other events attended with First Nations, stakeholders, or other public for engagement:

- Bufflehead Day – 30 people
- Annual General Meeting – 16 people
- Salish Sea Symposium – 250 people
- World Seagrass Day – 358 people
- Songhees Nation Herring Event – 20 people
- Pacific Estuary Research Society Conference – 80 people

7. References

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Amanda E. Bates, Robert S.C. Cooke, Murray I. Duncan, Graham J. Edgar, John F. Bruno, Lisandro Benedetti-Cecchi, Isabelle M. Côté, Jonathan S. Lefcheck, Mark John Costello, Neville Barrett, Tomas J. Bird, Phillip B. Fenberg, Rick D. Stuart-Smith. 2019. *Climate resilience in marine protected areas and the 'Protection Paradox'*. Biological Conservation 236: 305-314.

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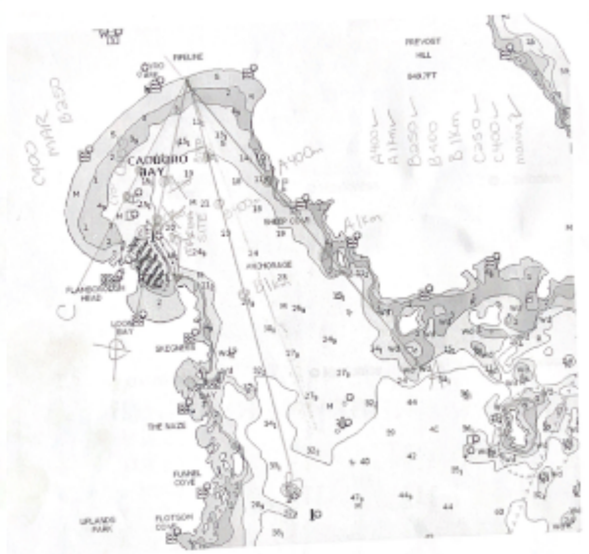
Appendix A: Cadboro Bay Site Report (October)

Site Survey: August 15, 2023

Boat: Klanawa **Crew:** Captain: Jamie Smith; Science Officer: Susan Anthony **Weather:** Clear and hot **Measurements:** Shoreline assessments, Zooplankton tows, Salinity, Temperature, Dissolved Oxygen, Preliminary debris scanning

Shoreline Observations

- Housing, park, rocky sides of the bay, soft sediment/cobble; on the N side, houses are on rocks; S side, more trees, and houses are back from the rock edge; steep N side, about 1/3 of shoreline is seawalls with houses (on the lower, soft sed part of the bay); some plantings and houses on soft sediment area; water input from pipeline; marina and lots of anchored/permanently moored sailboats; breakwater of rip rap sheltering the marina
- Geese, gulls, Herons, lots of people, all shoreline is modified in some way; sunken ships, and likely lots of trash from the liveaboards.
- Lots of people visiting the beach; “No swimming/water activities” because of high bacterial levels (Island Health testing https://inspections.myhealthdepartment.com/island-health/program-water-sample).

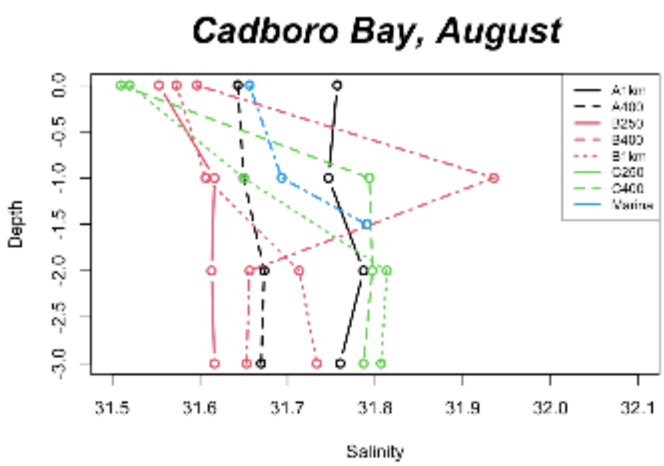


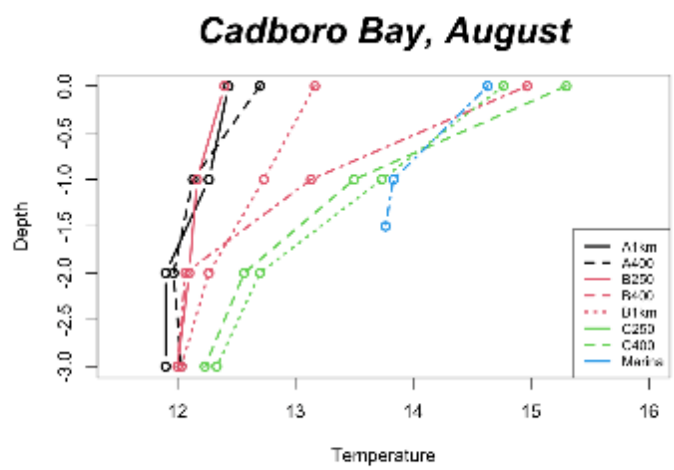
Zooplankton Tows

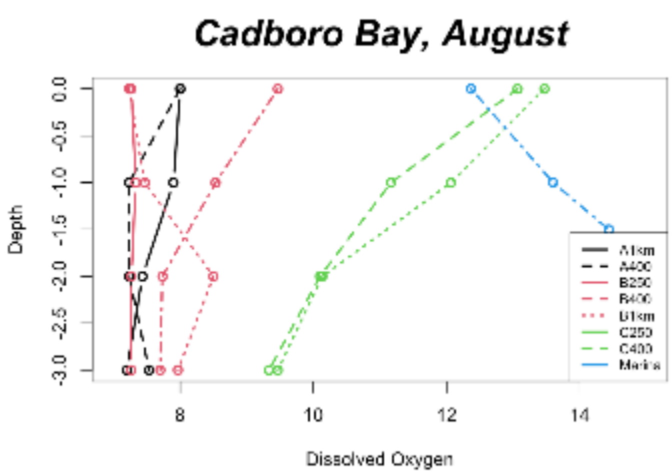
Tow #	Length of tow (m)	Tow speed (knots)	Depth of net bottom (-m)	Time	Water Depth (-m)	Bottle ID	Preserved with Formalin (Y/N)	Notes
1	50	1.5	Mid-column	13:45	2.4	MARINA	Y	Along the bull kelp (coordinates are start: 48.45477; 123.29789)
2	50	1.5	Mid-column	13:55	3.05	C400	Y	
3	50	1.5	Mid-column	14:07	6.1	B250	Y	

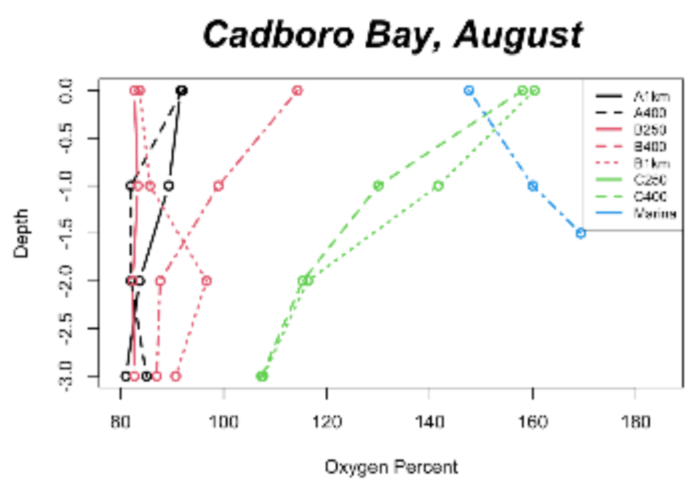
Interpretation: Zooplankton samples at Biologica Inc for identification.

Abiotic Water Features









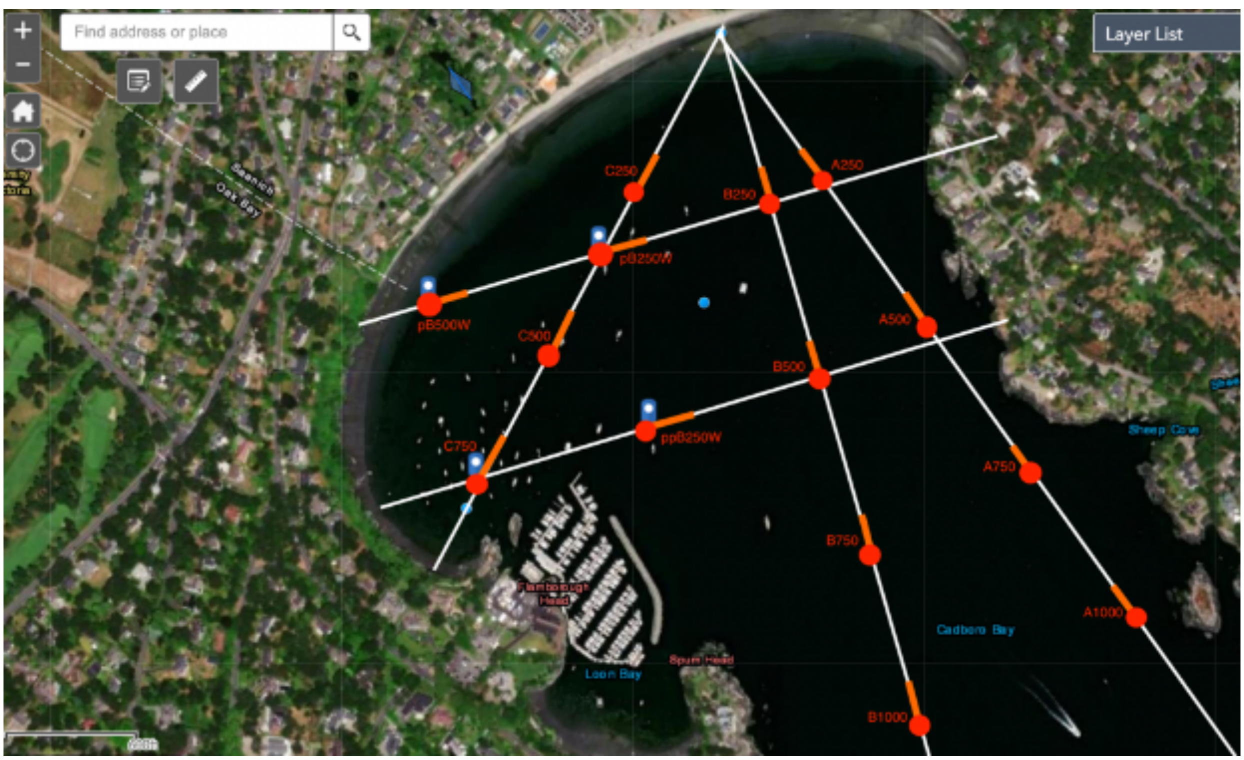
Preliminary Interpretation of abiotic water attributes:

- Water sampling for human wastes/bacteria such as faecal coliform and *Enterococcus* spp.
- Signage for waste dumping.
- Not likely a replanting site for eelgrass unless water quality and heavy use are improved.
- Potential riparian planting (as seen in some residents' yards).
- Likely lots of debris for removal.

Site Survey: October 4, 2023

Boat: Klanawa **Crew:** Captain: Jamie Smith; Science Officer: Susan Anthony; Diver (Quadrats): Viki Kolatkova; **Diver (Transect):** Justin Bland **Data Collected:** Salinity, Temperature, Dissolved Oxygen, Biodiversity surveys, side scanning, bacterial sampling.

Sampling Locations



Red dots= site locations
Orange lines= Biodiversity transects

Site Number	Latitude	Longitude	Bacterial Sample?	Abiotic Water Sample?
A250	48.4572	123.2905	Yes	Yes
A500	48.4553	123.2885		Yes
A750	48.4535	123.2866		Yes
A1000	48.4517	123.2846		Yes
B250	48.4568	123.2915	Yes	Yes
B500	48.4547	123.2906		Yes
B750	48.4525	123.2896		Yes
B1000	48.4503	123.2887		Yes
C250	48.457	123.294	Yes	Yes
C500	48.455	123.2956	Yes	Yes
C750	48.453	123.2972	Yes	Yes
pB250W	48.4562	123.2947		Yes
pB500W	48.4555	123.2979		Yes
ppB250W	48.454	123.2938		Yes

Bacterial Sampling Results

Site Number	Faecal coliforms (CFU/100mL)*	*Enterococcus* spp. (CFU/100mL)
A250	2	NA
B250	<1	NA
C250	2	NA
C500	4	NA
C750	61	NA

*CFU = Colony Forming Unit

NB: Reportable Detection Limit (RDL) = 1 CFU/100mL

NB: Health Canada limit for safe water for activity is 35 CFU/100mL *Enterococcus* spp.

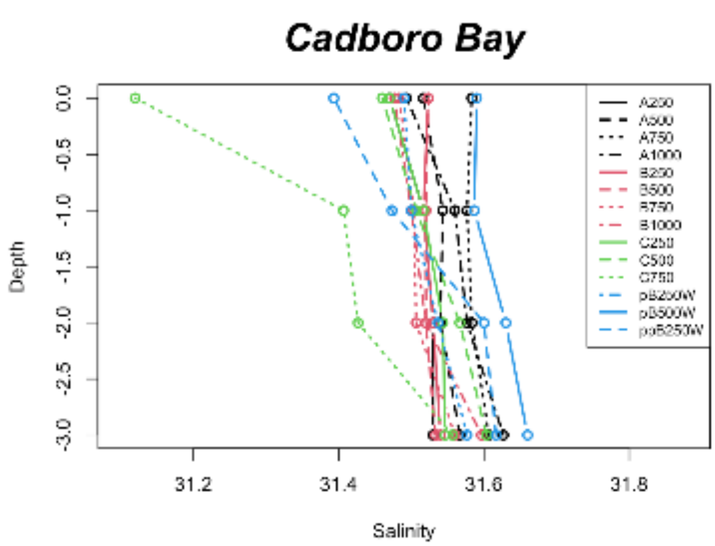
Interpretation: Very poor water quality even in October, especially near the liveaboards. Resampling to clarify the source of the bacteria is essential as a backup to allow for policy change.

Turbidity

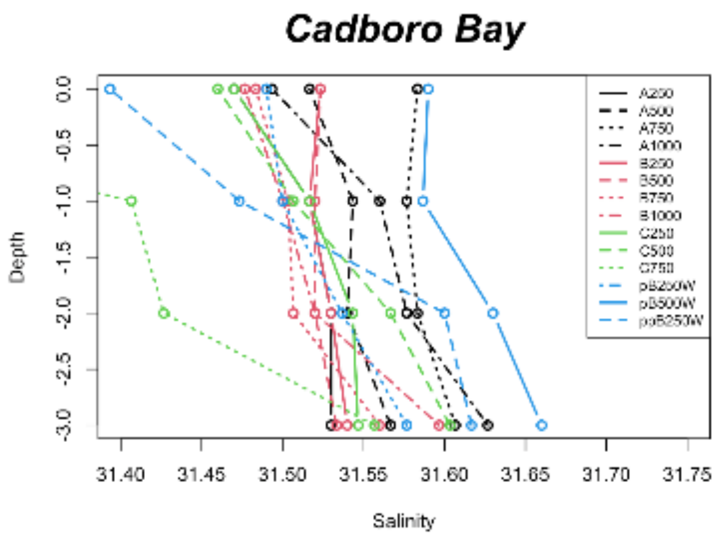
Site Number	Site Depth (m)	Secchi Depth (m)
A250	6.4	Bottom
A500	7.3	6.0
A750	7.6	6.5
A1000	9.1	7.0
B250	7.3	Bottom
B500	8.8	Bottom
B750	9.9	7.0
B1000	11.6	6.0
C250	6.1	Bottom
C500	7.0	Bottom
C750	3.4	Bottom
pB250W	6.4	Bottom
pB500W	3.0	Bottom
ppB250W	8.5	Bottom

Interpretation: Clarity is good, which is surprising for the likely heavy nutrient load. This may be because the low rainfall and sheltered nature of the bay has not allowed for much mixing. Or that the lower photoperiod in October would reduce the algal bloom. Seasonal changes in turbidity would improve the baseline info.

Salinity

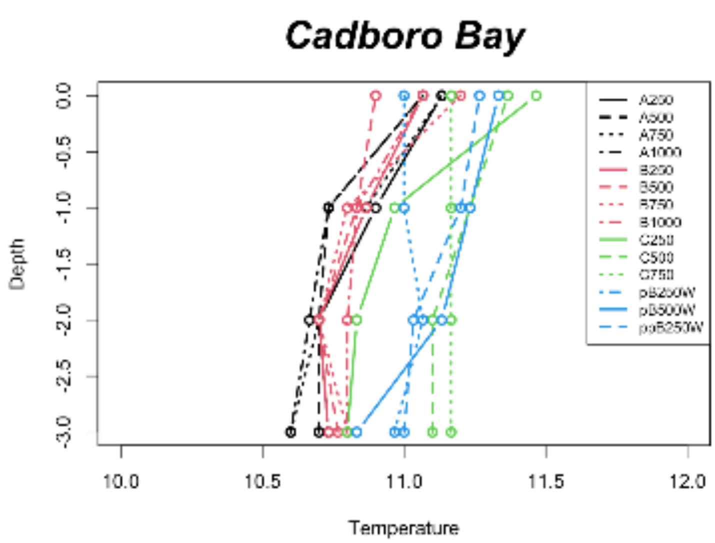


Interpretation: Surface salinity does not differ with depth and therefore stratification is low. The exception is C750 (right in the liveaboards, but not close to shore in the same area (pB500W; solid blue line above). This would mean that the source of the less saline water is not likely the shore. This is further evidenced by the fact that there was little rain up to this point (watershed map states that the freshwater input in that area is directly from the shore; see map below). Below is the same plot, zoomed in on the cluster of lines that are harder to differentiate in the above plot.



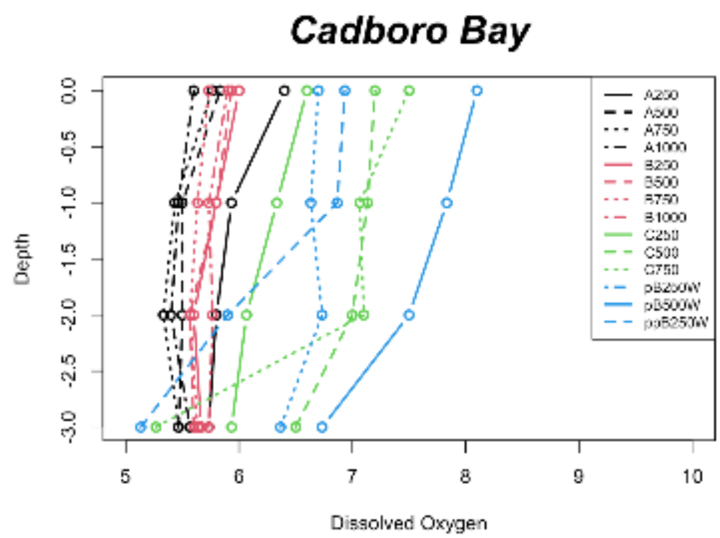
We still see that the pB500W (close to shore) does not have any surface low-saline water layer. We do see a very minor surface low-saline water at ppB250W, which is not too far to the liveaboards, but quite far from the shore and outflow pipe, the most common sources of freshwater. The other point within the liveaboard area has a very minute decrease in salinity towards the surface, but not much in the way of stratification (C500, dashed green line). The locations closest to the stormwater outflow pipe (A250, B250, and C250; black, red, and green solid lines) show no evidence of surface low-saline water or stratification. Therefore, what we see in C750, and to a lesser extent ppB250W, will be from other sources.

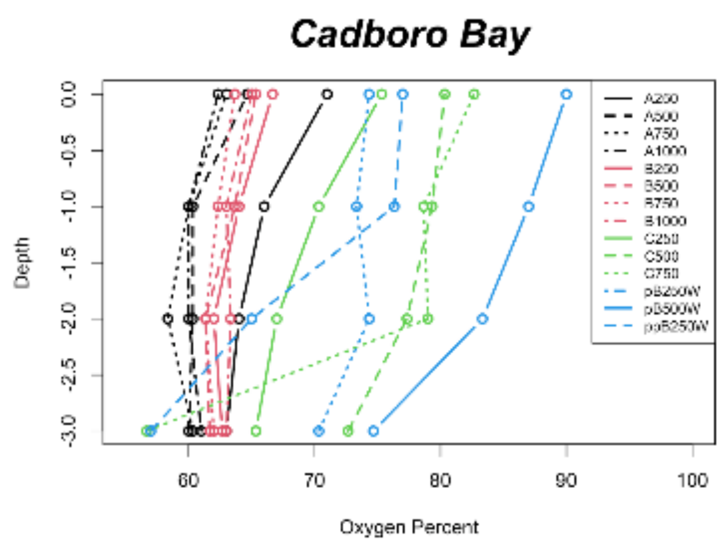
Temperature



Interpretation: Lots of overlap it is hard to see the individual depth contours. This means that there either is high mixing or no mixing at all. The slightly higher surface temperatures (which decrease with depth) are evidence of low mixing, but not significant. The weather has been warmer and the bay is long and somewhat shallow, so it is expected to see higher temperatures than other regions.

Oxygen

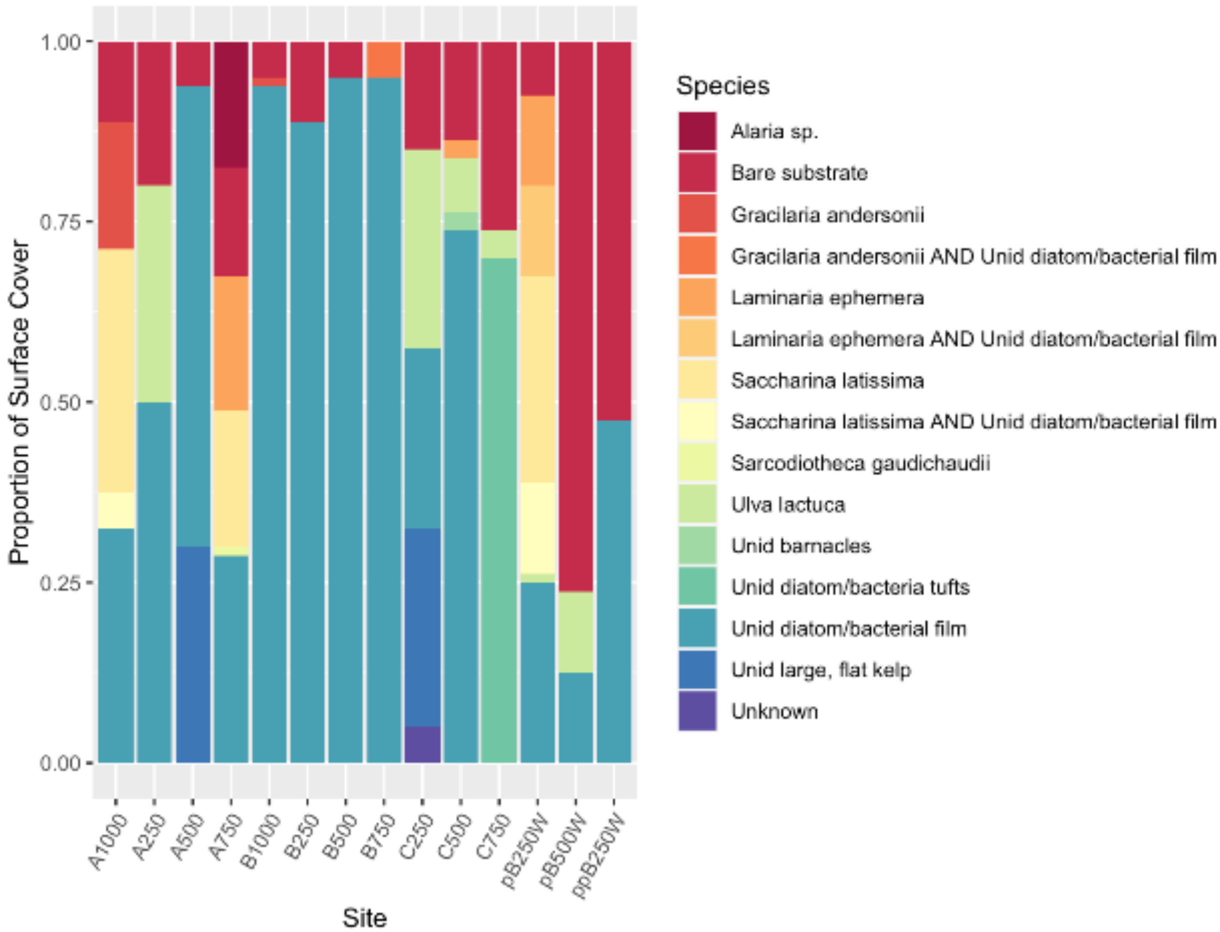




Interpretation: Oxygen levels are rather uniform in the top 3m of water. The sources of it are potentially larger algae (mentioned in the biodiversity section of the report), or photosynthetic plankton. Anecdotally, there were high levels of phytoplankton at this location, however not enough to truly affect the turbidity within the top c. 8 m. The truly interesting part will be comparing these values to other locations and correlating to biodiversity.

Biodiversity: Ground Cover by Site

The stacked barplots are a sum of the four 25 cm^2 quadrats.

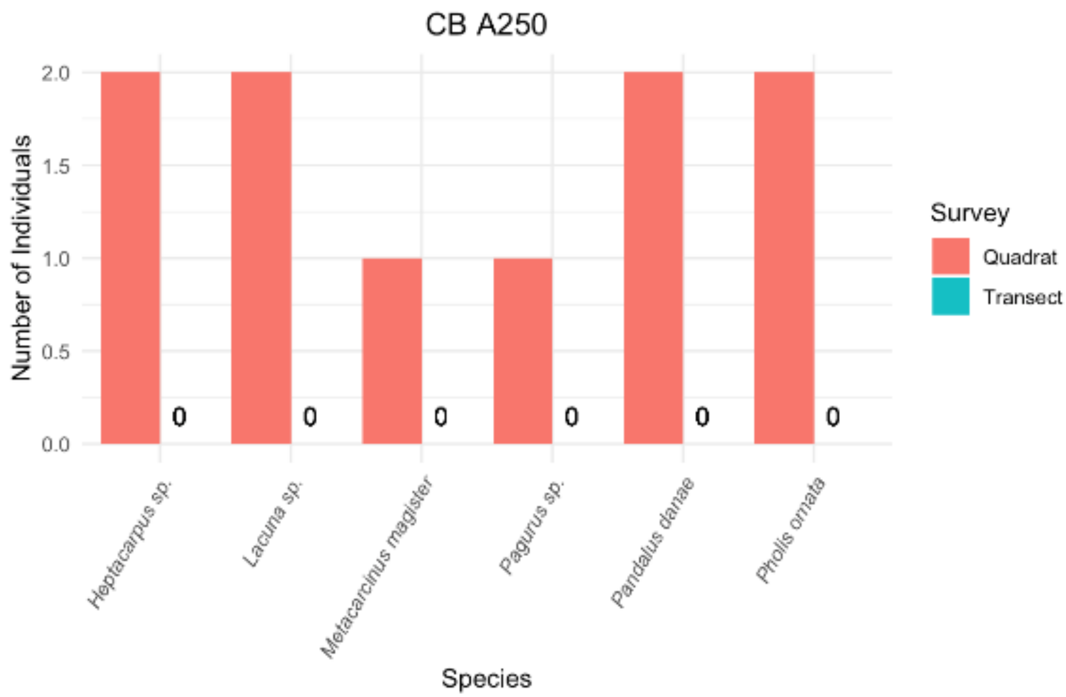


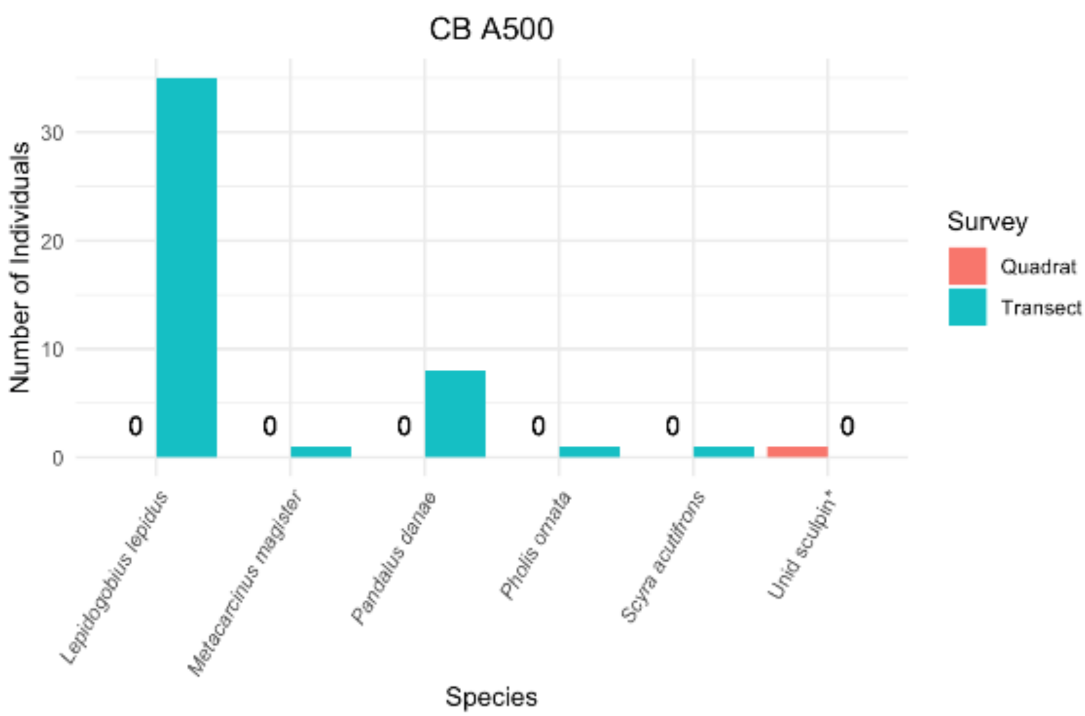
Interpretation: The high proportion of "Unid diatom/bacterial film" (aka brown gunk) and "Bare substrate" at each site leads us to think that there is space enough for eelgrass or algal growth, but with something preventing its sustained settlement. Other species of note are *Ulva lactuca* (sea lettuce), commonly found in areas of high nutrients and claims have been made that they displace other photosynthetic species by smothering or shading (they are more effective and less stressed in the high nutrient areas and outcompete eelgrass etc.). *Gracilaria andersonii* (sea spaghetti, Rhodophyta) are in minor quantities in A1000, B750, and B1000 and in c. 30% of the ground cover at A250, all sites that are closer to the rocky shore and more likely have higher tidal exchange. Laminaria and Saccharina are present along with other algal species in pB250W and A750, two largely differing sites. Laminaria is found (in minute quantities) at C500 and Saccharina at A1000, which again are two sites with highly different influences. The explanation for the algal differences among the sites is not evident, except for the Ulva presence in the most sheltered regions near the shore and the liveaboard boats (also the site of the high bacterial count, indicating high nutrient concentration): C250, C500, C750, pB250W, pB500W.

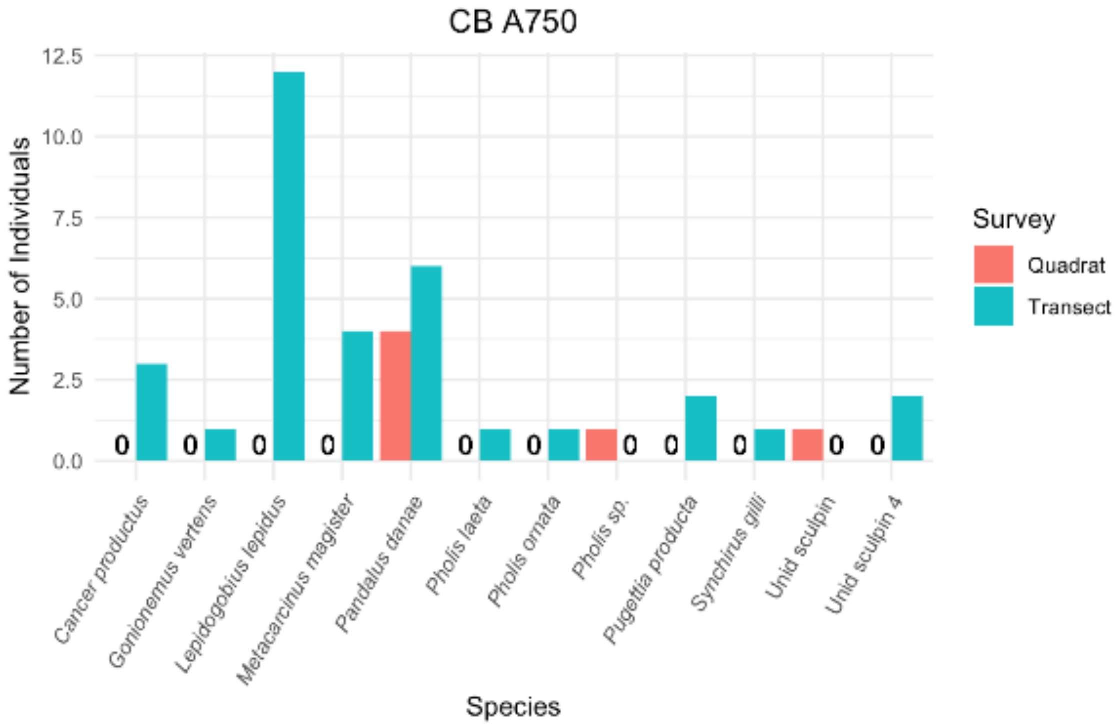
All species, common names, and brief information are in the attached document RESS Species List.

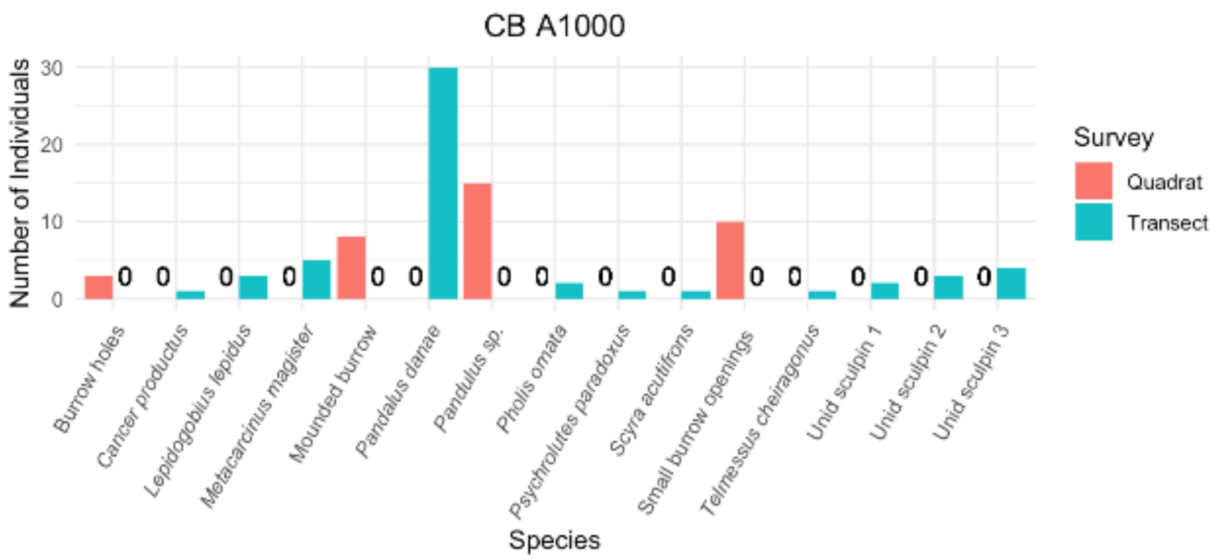
Biodiversity: Animal and Algae (by quantity)

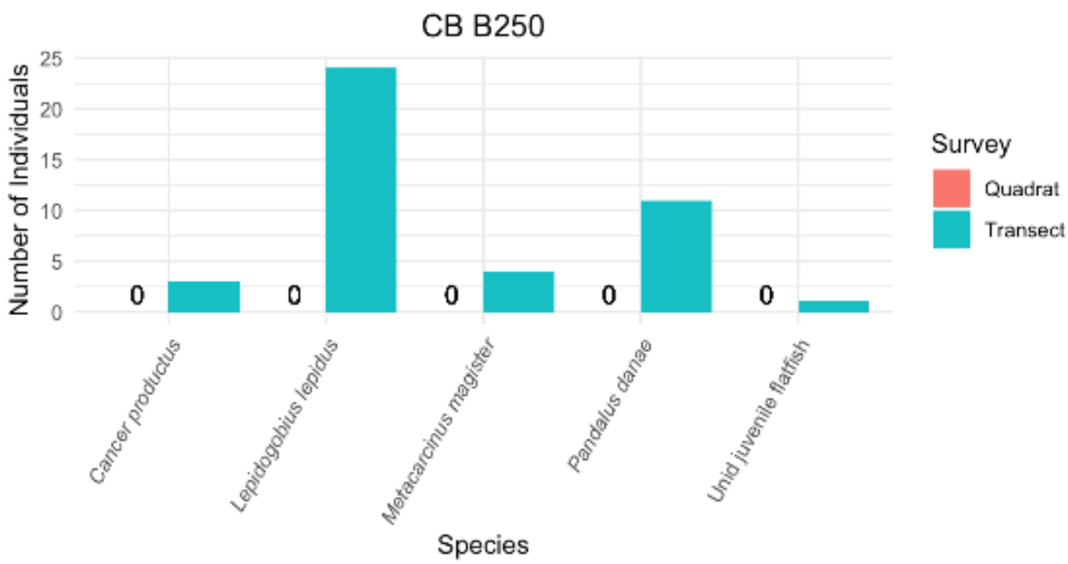
Please note that the vertical axes differ between the charts and for values greater than 10, the number is most likely estimated.

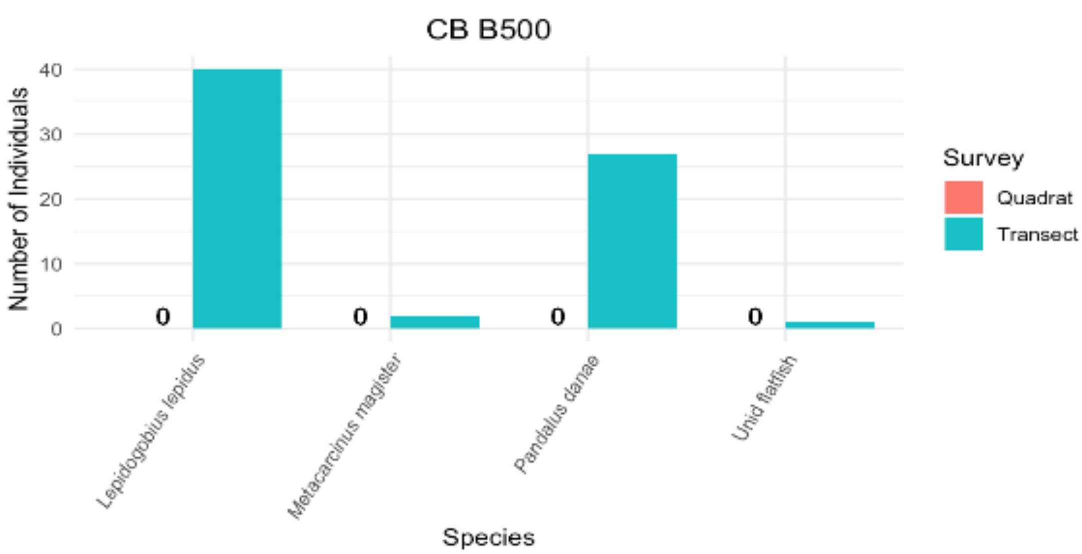


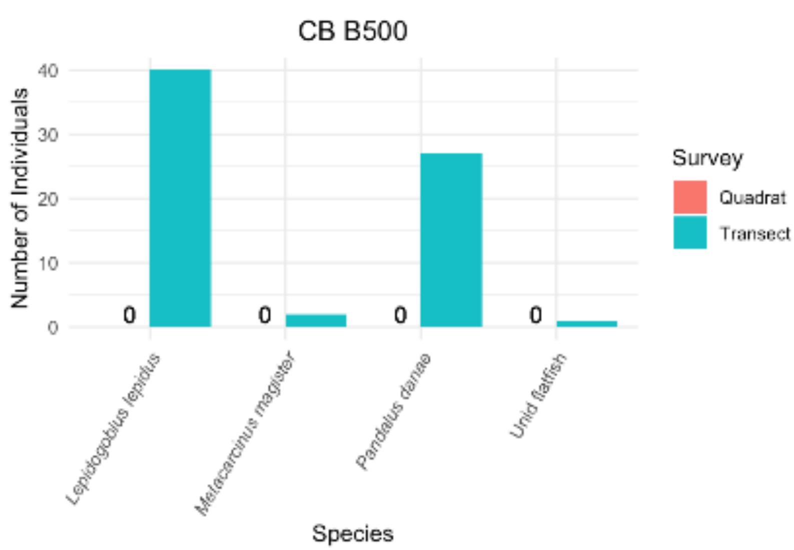


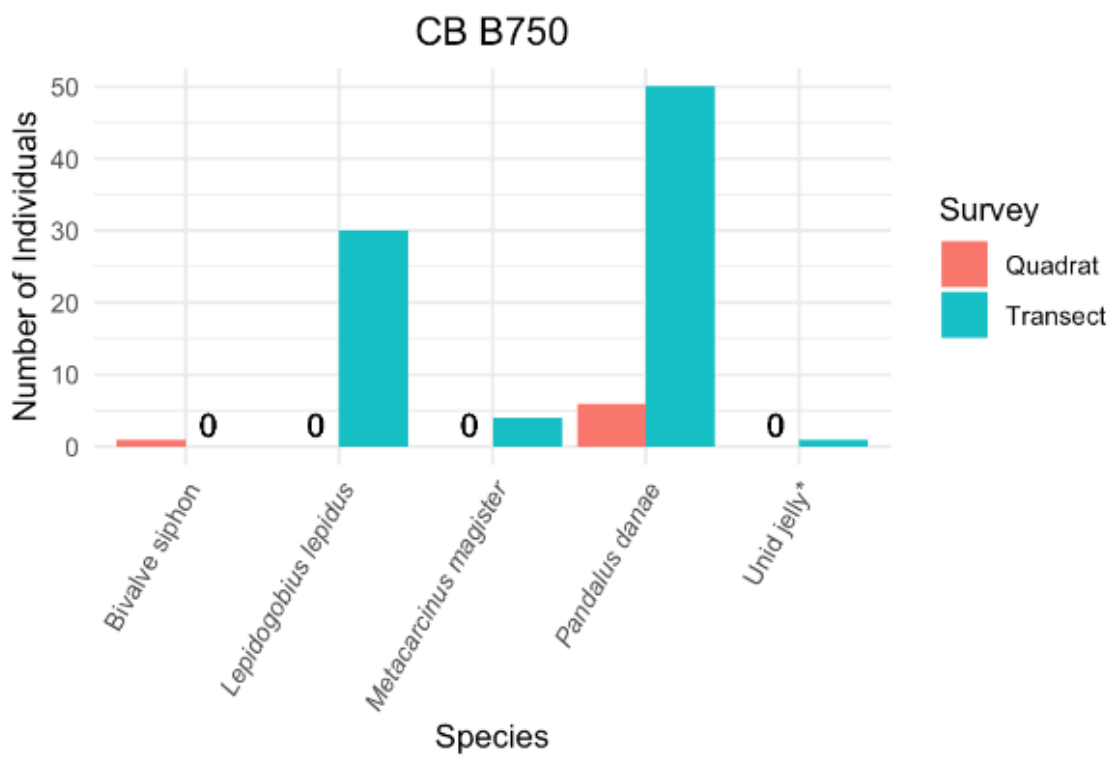

CB A750
Number of Individuals
Survey
Quadrat
Transect
Cancer productus
Gonionemus vertens
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Pholis laeta
Pholis ornata
Pholis sp.
Pugettia producta
Synchirus gilli
Unid sculpin
Unid sculpin 4
Species


CB A1000
Number of Individuals
Survey
Quadrat
Transect
Burrow holes
Cancer productus
Lepidogobius lepidus
Metacarcinus magister
Mounded burrow
Pandalus danae
Pandulus sp.
Pholis ornata
Psychrolutes paradoxus
Scyra acutifrons
Small burrow openings
Telmessus cheiragonus
Unid sculpin 1
Unid sculpin 2
Unid sculpin 3
Species

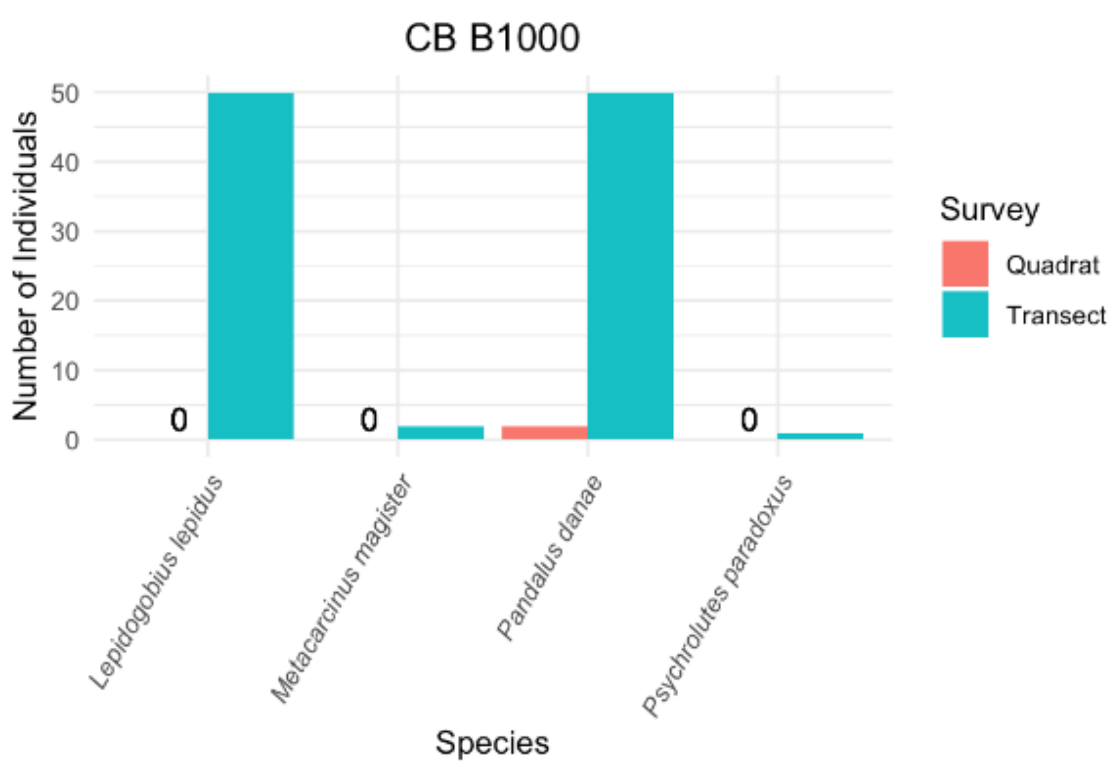

CB B250
Number of Individuals
Species
Cancer productus
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Unid juvenile flatfish
Survey
Quadrat
Transect


CB B500
Number of Individuals
Species
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Unid flatfish
Survey
Quadrat
Transect

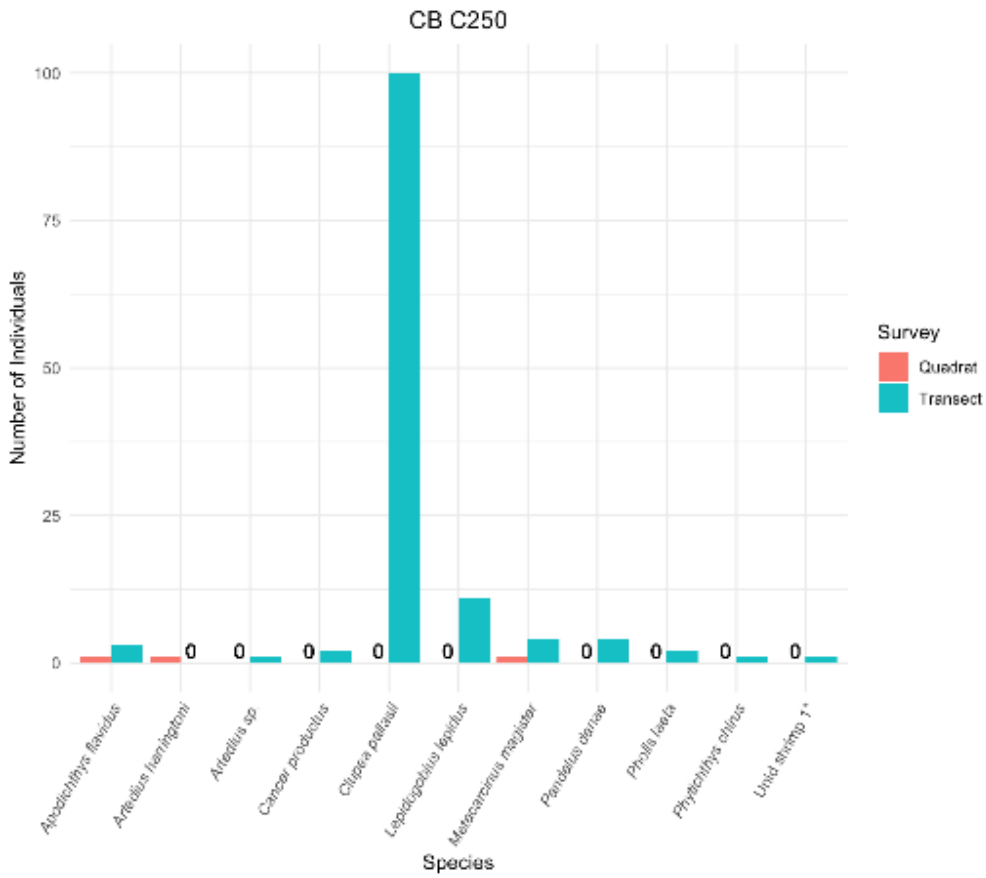

CB B500
Number of Individuals
Species
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Unid flatfish
Survey
Quadrat
Transect

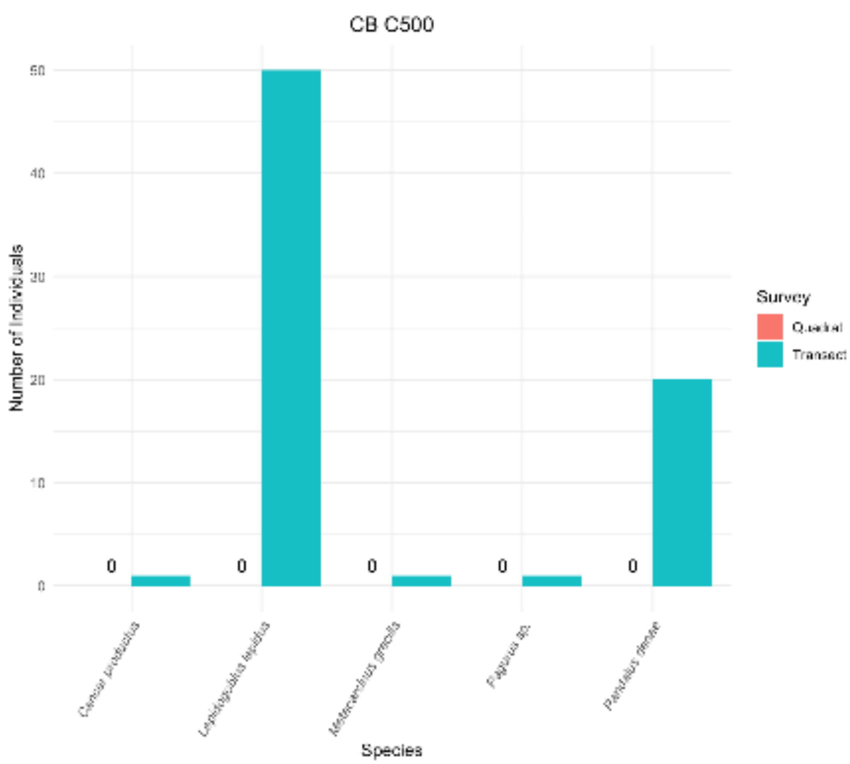


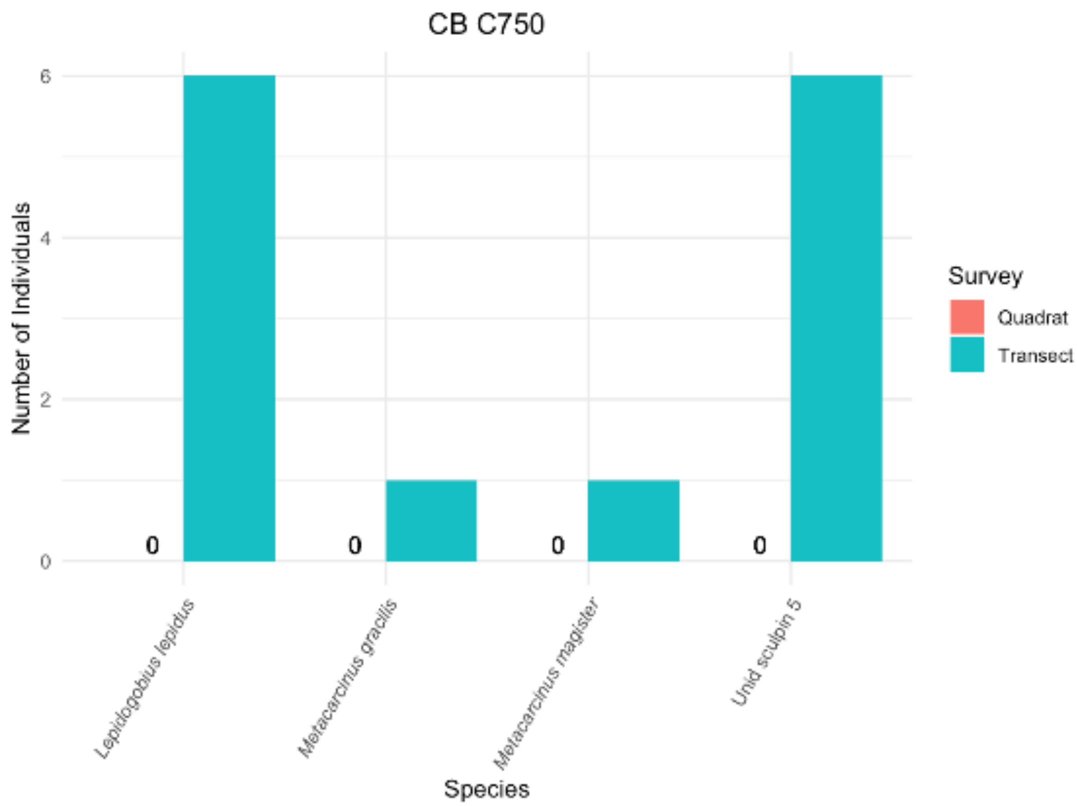
CB B750
Number of Individuals
50
40
30
20
10
0
0
0
0
0
Survey
Quadrat
Transect
Bivalve siphon
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Unid jelly*
Species

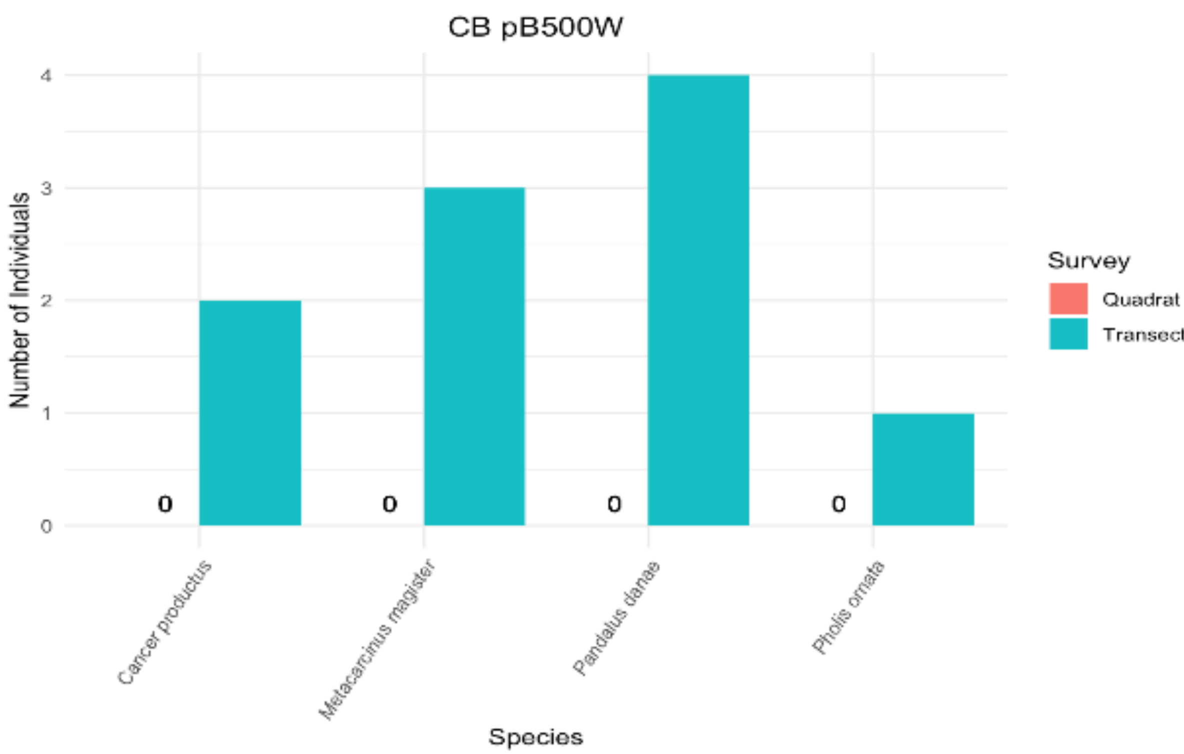


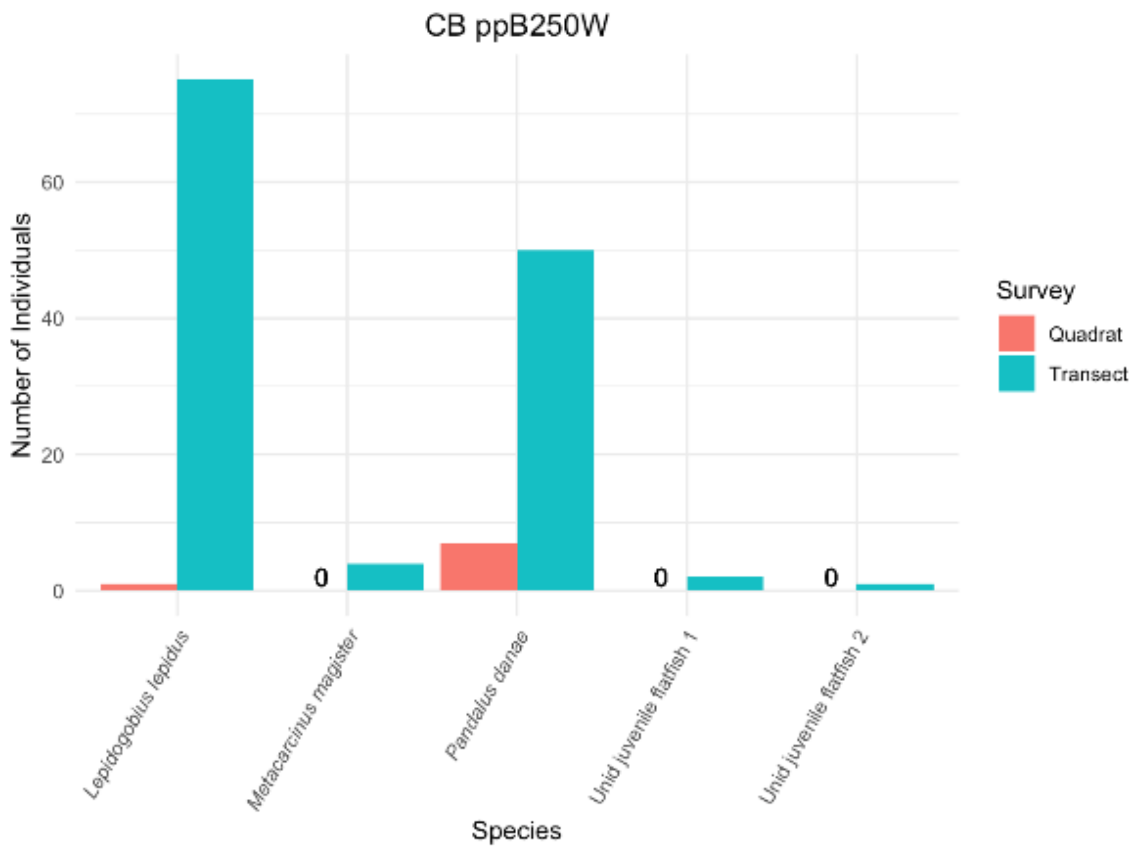
CB B1000
Number of Individuals
50
40
30
20
10
0
0
0
0
Survey
Quadrat
Transect
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Psychrolutes paradoxus
Species


CB C250
Number of Individuals
100
75
50
25
0
0
0
0
0
0
0
0
0
0
Apodichthys flavidus
Artedius harringtoni
Artedius sp
Cancer productus
Clupea pallasii
Lepidogobius lepidus
Metacarcinus magister
Pandalus danae
Pholis laeta
Phytichthys chirus
Unid shrimp 1*
Species
Survey
Quadrat
Transect


CB C500
Number of Individuals
50
40
30
20
10
0
0
0
0
0
0
Species
Survey
Quadrat
Transect


CB C750
Number of Individuals
6
4
2
0
0
0
0
0
Lepidogobius lepidus
Metacarcinus gracilis
Metacarcinus magister
Unid sculpin 5
Species
Survey
Quadrat
Transect


CB pB500W
Number of Individuals
4
3
2
1
0
0
0
0
0
Cancer productus
Metacarcinus magister
Pandalus danae
Pholis ornata
Species
Survey
Quadrat
Transect



Interpretation: Each site has the presence of *Lepidogobius lepidus* (bay goby) and *Pandalus danae* (coonstripe or bay shrimp) and they were in high abundance (in most cases, the number of individuals was approximated). *Clupea pallasii* (Pacific herring) is very exciting to see, the number is approximated. The herring (and a small amount of *Metacarcinus magister* (Dungeness crab)) show how this area is desired by local fisheries. The Dungeness especially does well with the alga cover.

All species, common names, and brief information are in Appendix H.

Biodiversity Calculations

*Richness***:** Number of species from abundance survey and not percent cover.

*Simpson's Biodiversity Index***:** Calculated based on the number of species and their relative abundances. Values range from 0 – 1, where higher values mean lower biodiversity. Simpson's Index is from abundance surveys and not percent cover.

*Fisher's Alpha***:** A logarithmic calculation because of the inherent differences between the abundances of each species: some species are found in groups *vs* rarer or individual. A higher Fisher's alpha results from higher biodiversity.

Site	**Richness (Q)**	**Richness (T)**	**Richness (Q & T)**	**Simpson's Index (Q)**	**Simpson's Index (T)**	**Simpson's Index (Q & T)**	**Fisher's Alpha (Q)**	**Fisher's Alpha (T)**	**Fisher's Alpha (Q & T)**
A250	8	5	8	0.9111	**NA**	0.9111	6.3331	0	6.3331
A500	3	10	8	0*	0.3981	0.4237	1342**	1.4271	1.8258
A750	8	4	18	0.6	0.8258	0.8677	2.3877	4.8796	5.9225
A1000	5	11	16	0.5	0.6669	0.8023	0.4566	4.2189	4.1913
B250	1	4	6	**NA**	0.6235	0.6235	0	1.4651	1.4651
B500	1	4	5	**NA**	0.5313	0.5313	0	0.9208	0.9208
B750	4	10	8	0.2857	0.5333	0.5984	0.9354	0.8714	1.1569
B1000	3	5	7	0*	0.5334	0.5509	0.7959	0.8279	0.8279
C250	6	5	16	1	0.3917	0.4192	5369**	2.5313	2.8528
C500	4	4	9	**NA**	0.4616	0.4616	0	1.2162	1.2162
C750	3	5	7	**NA**	0.6703	0.6703	0	1.8708	1.8708
pB250W	6	4	11	0.4762	0.4327	0.5291	0.9354	1.2382	1.5280
pB500W	2	5	6	**NA**	0.7778	0.7778	0	2.4710	2.4710
ppB250W	8	8	8	0.25	0.5365	0.5860	0.8559	1.0282	1.0282
All	23	29	44	0.8820	0.9497	0.7196	10.0212	20.1128	7.1976

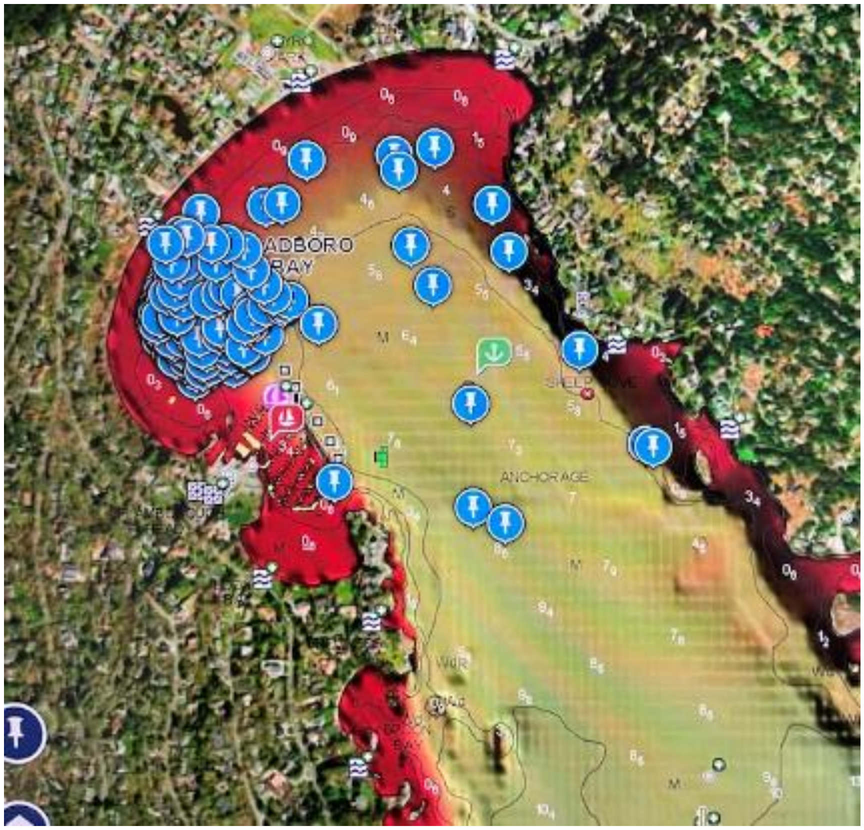
Q = from quadrat surveys, T = from transect surveys, Q & T = from a combination of both quadrat and transect surveys

*too few species to calculate Simpson's Biodiversity Index

**too few species that the Fisher's Alpha; value is arbitrarily high or unable to calculate

NA: not enough species in the abundance surveys (Richness may include species from percent cover survey)

Side Scan Marine Debris Mapping

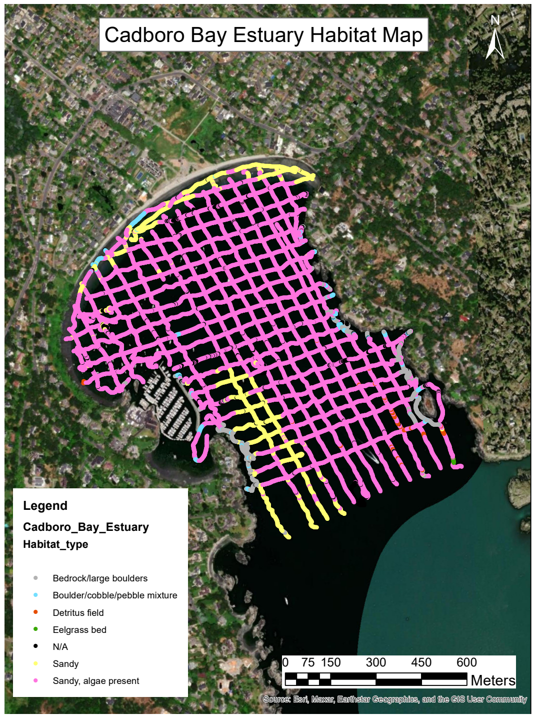


Interpretation: Lots of debris, especially in the region of the liveaboards. The area away from the liveaboards has ghost gear that is endangering the wildlife that is present (confirmed by tow camera video).

Site Survey: January/February 2024

Boat: Klanawa	
Crew: Captain: Jamie Smith; Science Officer: Thomas Armitage	
Weather: Cloudy and cold	
Measurements: Tow camera recording	

Habitat Diversity



Interpretation: There is a lack of eelgrass where there is lots of sandy substrate. The "alga" within the pink sections is a mix of kelp and unid diatom/bacterial film. Further refinement can determine if the large pink area is a suitable habitat for any animals, such a kelp as shelter. We could suppose that the sites with high species number and abundance (C250, A750, A1000) may be a subcategory of "alga present", which allows for species richness.

Future Work

Resampling the water to narrow down the source of bacterial and nutrient influx to help with conservation and education.

Resampling for bacterial sources would have to be along the shoreline, and away from the shoreline within the area of C750 (the high levels from the October sampling event). Red dots are the new sites: Mooring2024, Marina, ShoreSW, ShoreW, pB500W*, Hobbs, Mouth, ShoreE, B500* (*returned sites). We will take salinity, temperature, and oxygen measurements at the nine new sites and the original 14, plus nitrate, phosphate, and bacterial samples from the seven new and two old sites previously mentioned.

Permissions

We will not proceed without verbal or written consent from the Songhees First Nation and relevant residential and business committees. Operations of any kind will cease if we are not supported by relevant local organizations.

We have support from the Royal Vancouver Yacht Club and the Cadboro Bay Dead Boats Society.

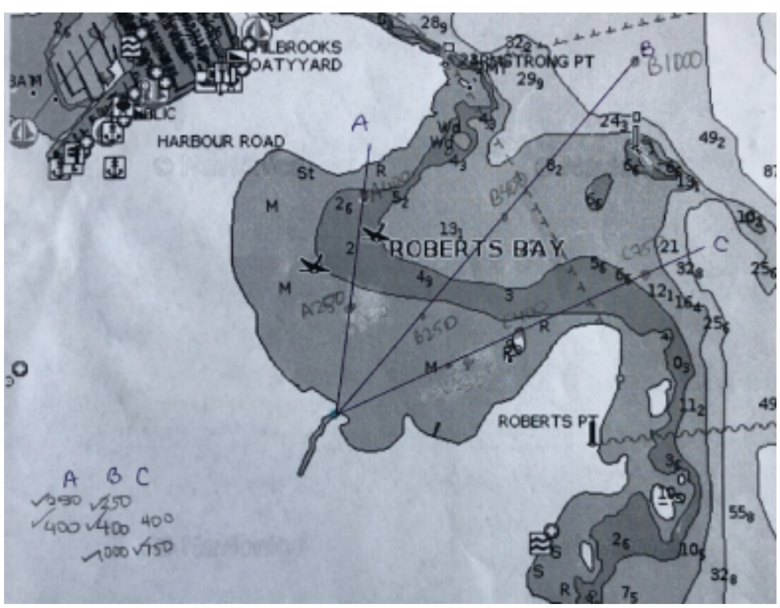
Appendix B: Roberts Bay Site Report (October)

Site Survey: August 16, 2023

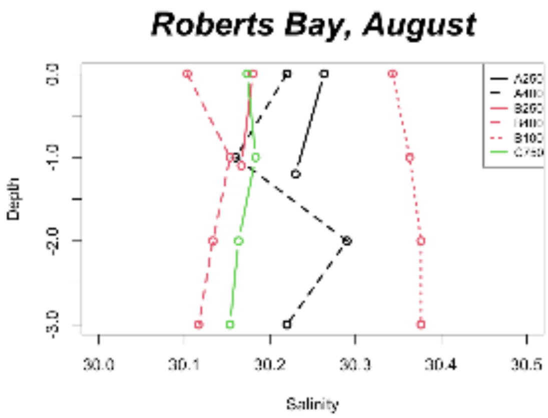
Boat: Klanawa
Crew: Captain: Jamie Smith; Science Officer: Susan Anthony, 2nd Science Officer: Justin Lisaingo
Weather: Sunny and warm (30°C), low wind (<5 km), no rain for a long time before
Measurements: Shoreline observations, Salinity, Temperature, Oxygen, Brief Sidescanning

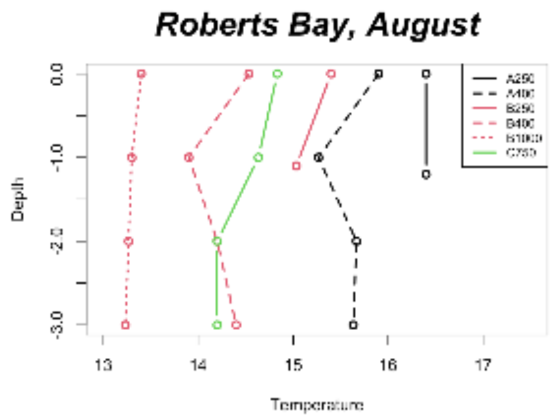
Shoreline Observations

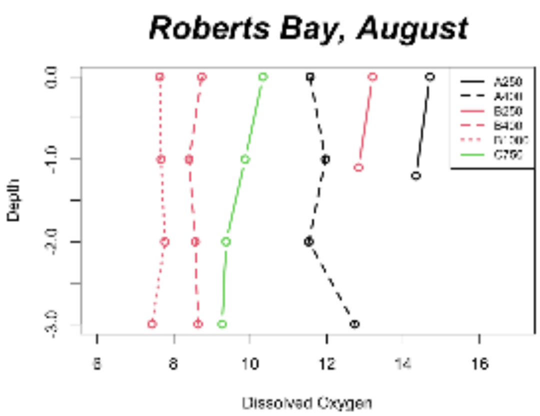
- Composition: Bedrock with *Fucus*; transitioning to cobble/gravel mixed with bedrock/boulder; mainly boulder on bedrock at the North end; beach is mainly gravel/soft sediment
- Houses surrounding whole bay; c. 25% seawalls
- along the inner bay, the houses are mostly built at a high beach line, whereas the outer bay, the houses are built further higher up; 3 houses on the south side of the bay have beach houses; most houses have manicured lawns
- Road runs along the whole bay
- Lots of *Ulva* visible
- Saltmarsh from Mermaid Creek
- Many gulls, 5 cormorants, 10 diving birds, 1 heron
- Dog walkers, several boathouses and docks/boat launches at the South end
- 1 large, anchored sailboat; 10 buoys
- Side scan noted 1 shipwreck; JB noted household trash on dive 1
- The phytoplankton concentration is high (pea soup-thick)

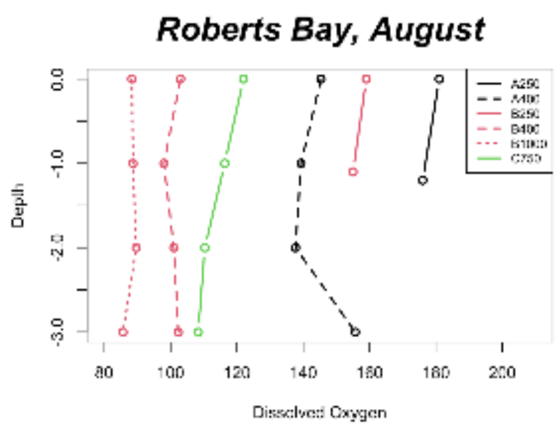


Water Sampling









Interpretation:

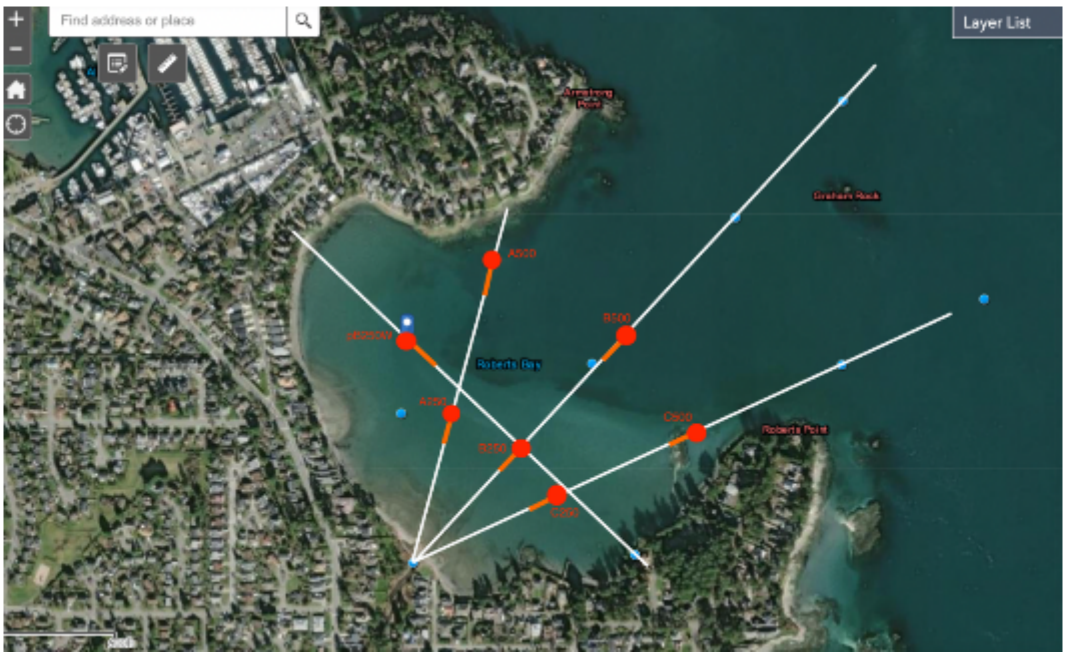
- lots of shoreline modification and lawns very close to where the water will intrude.
- Human recreational use may help keep geese away, but also other shorebirds (although herons were present)
- Summertime therefore no surface fresh water. However the lack of stratification for temperature may indicate either high or extremely low mixing (where the warm surface layer extends to depth); I would think the latter is most likely, considering the large range of temperatures among sites (compared to other oceanic areas) : c. 3°C
- Oxygen is consistent through the water column, with the exception of A400: the oxygen is high and therefore is evidence of the phytoplankton through the water column
- The shoreline use and already identified need for marsh restoration will mean that the estuary should be further sampled and restoration needs in the area should co-incide with shoreline restoration.
- Long-term, the likelihood of erosion along the shoreline indicates the need for shoreline planting to increase stability, and the hope is extensive eelgrass to reduce the intensity of storm forces.
- The proximity of roads and the low-lying residences will also mean increased pollutant input from shore, which there is previous record of in the estuary.

- We are not going to do a complete sidescan for debris, as it was not deemed necessary by Jamie Smith (personal knowledge of previous work in the area).

Site Survey: October 12, 2023

Boat: Klanawa **Crew:** Jamie Smith (Captain), Justin Bland (diver), Viki Kolatkova (diver), Justin Lisaingo (Science Officer) **Data Collected:** Salinity, Temperature, Dissolved Oxygen, Percent Oxygen, Turbidity, Biodiversity Surveys

Sampling Locations



Red dots= site locations
Orange lines= Biodiversity transect lines

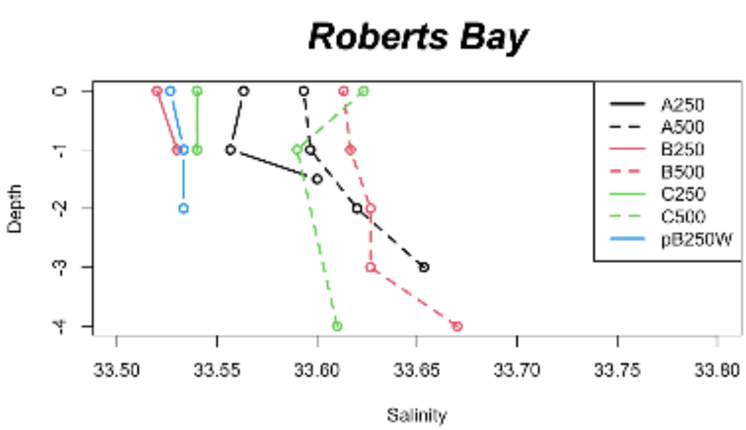
Site Number	Latitude	Longitude
A250	48.6628	123.4004
A500	48.6649	123.3995
B250	48.6622	123.3989
B500	48.6639	123.3966
C250	48.6615	123.3982
C500	48.6625	123.3952
pB250W	48.6638	123.4014

Turbidity

Site	Site Depth (m)	Secchi Depth (m)
A250	1.5	Bottom
A500	3.0	Bottom
B250	1.8	Bottom
B500	5.4	Bottom
C250	1.7	Bottom
C500	1.1	bottom
pB250W	2.7	Bottom

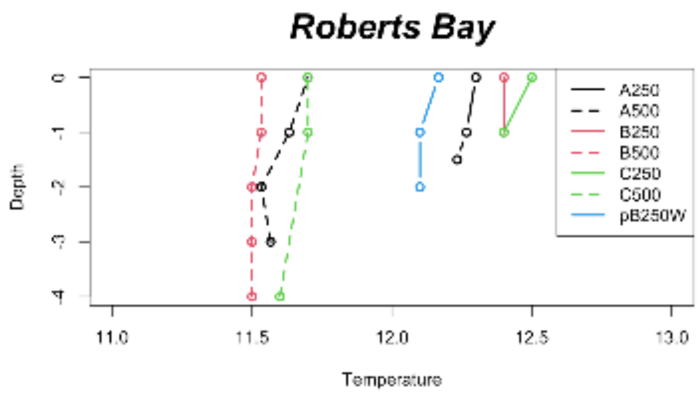
Interpretation: As has been common in other shallow estuaries, the turbidity was high, but it was not measurable with Secchi Disk. From my person knowledge, the water was very murky; high phytoplankton concentration.

Salinity



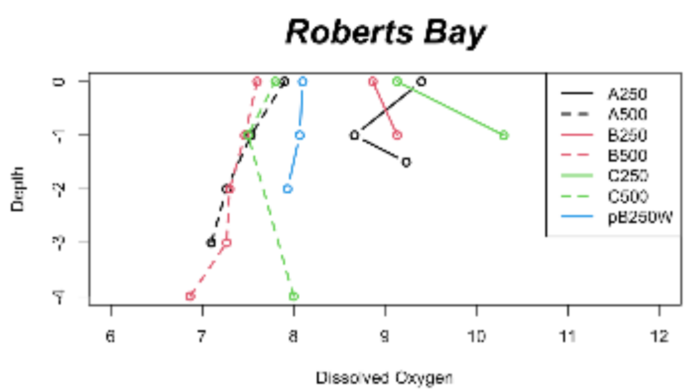
Interpretation: The salinity among sites and with depth at sites does not vary greatly (a change in 0.17 ppt is negligible). This means a very mixed region, with generally high salinity. Considering there had not been rain recently, the results are not surprising: no stratification (although with the shallow nature of the bay, it is difficult to determine changes with depth).

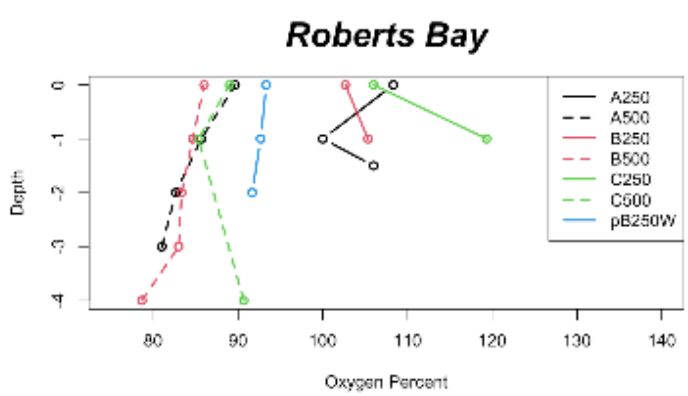
Temperature



Interpretation: Like salinity, there is very little variation among sites and with depth. This could be a result of low freshwater input or high seawater mixing (as the salinity measurements could be interpreted either way). Resampling after weather changes and freshwater input would tease this apart. The temperature for the surface is on the low side for such a long summer period and a shallow bay.

Oxygen

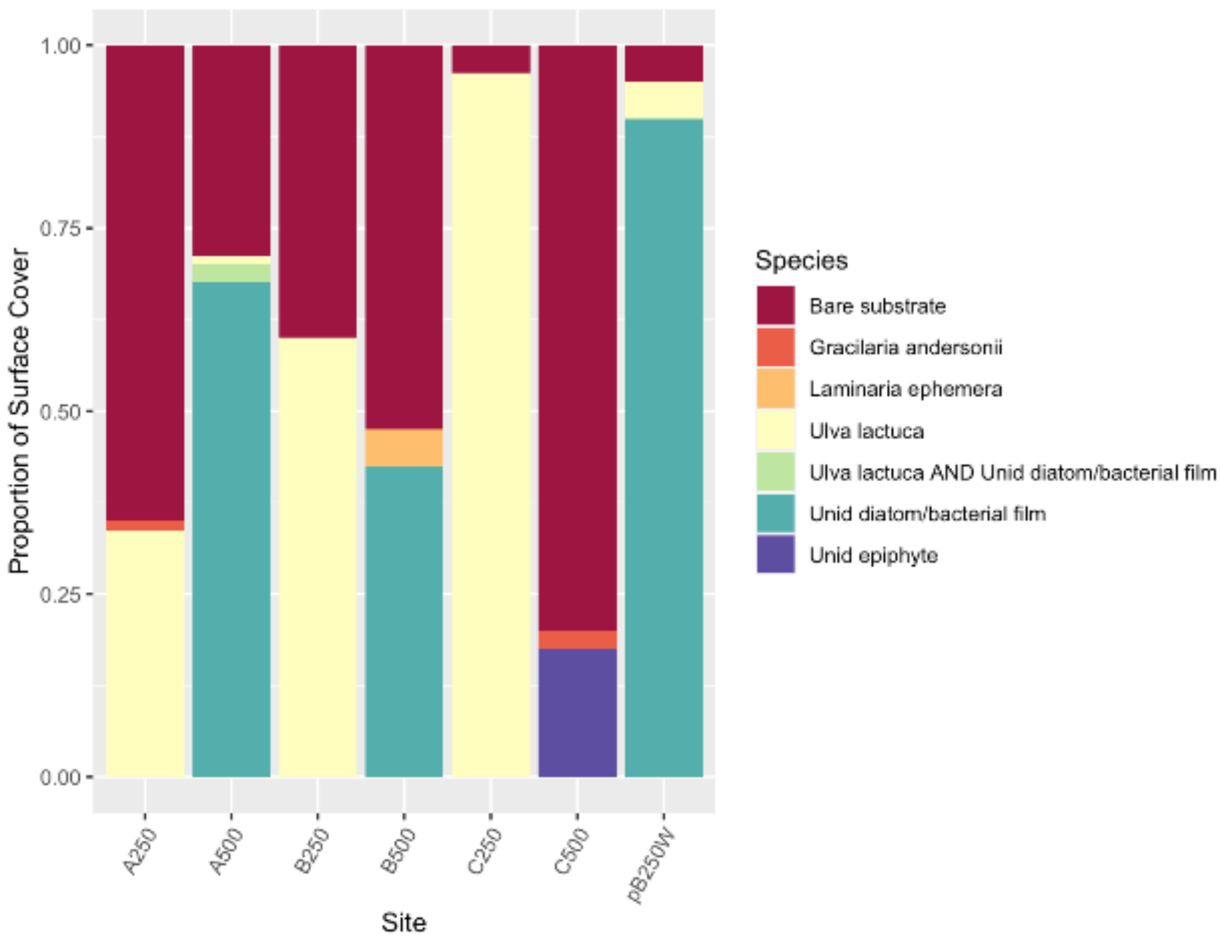




Interpretation: Some zig zags, and some large values (120%). The area is high in oxygen, particularly near the creek mouth and reducing as you move away. This could be oxygenated water coming from the creek, but at these levels, I suspect nutrient input resulting in blooms of algae (planktonic or sessile) with the sunlight. I would like to resample in winter to see if this has gone in an opposite direction, and the area around the creek has become low in oxygen. I will also look at it compared to sampling of nutrients (nitrate and phosphate) and the turbidity and algae presence. NB: Turbidity is low; however the shallow nature of the bay may mask any plankton blooms.

Biodiversity: Ground Cover by Site

The stacked barplots are a sum of the four 25 cm^2 quadrats.



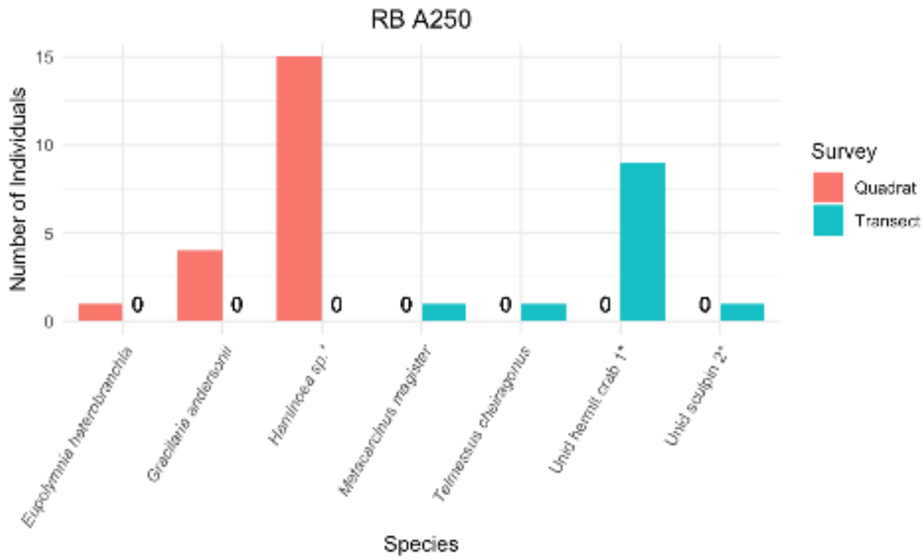
NB: It is not possible to create true proportions of the substrate-covering organisms. See general methods for details.

Interpretation: High areas of bare substrate, unid diatom/bacterial film, and *Ulva* shows that there is space for other habitat-forming species of alga (eelgrass, *Zostera marina* observed at C500, but in abundance plots below). Extensive *Ulva* indicates that there is excessive nutrient load concentration. All species, common names, and brief information are in the attached document RESS Species List.

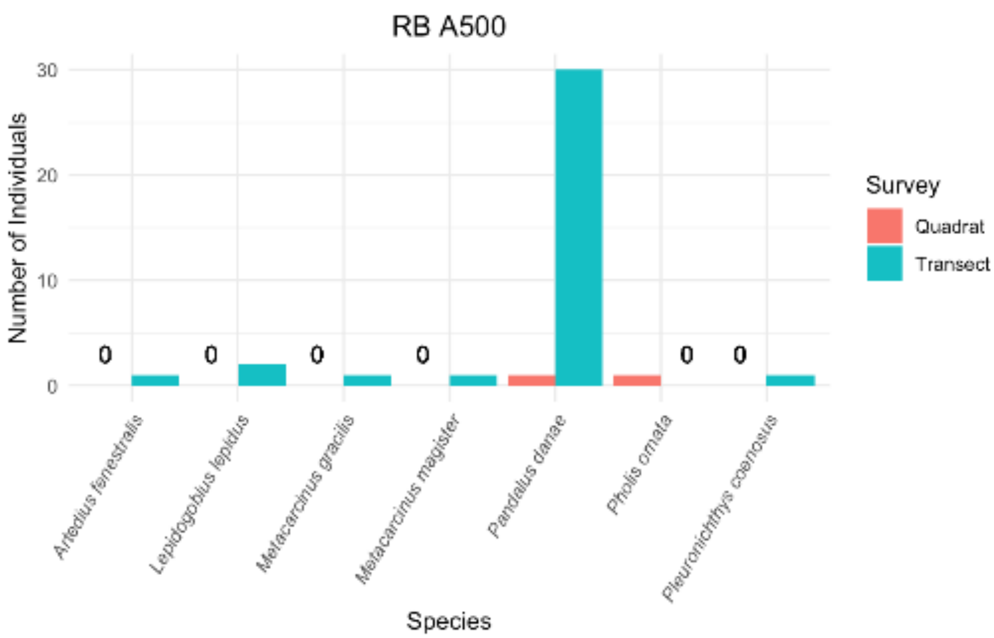
Biodiversity: Abundance by Site

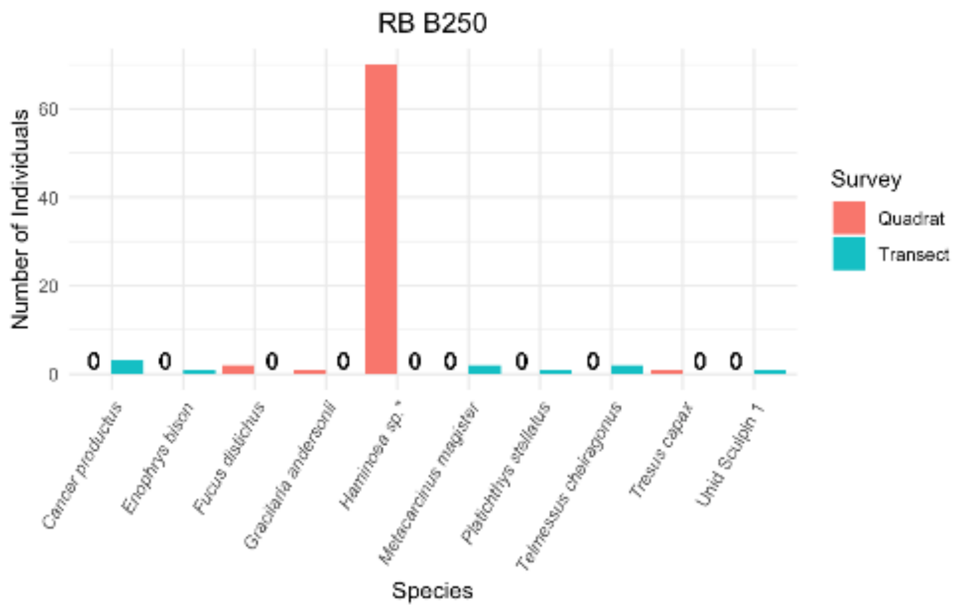
Animal and Algae (by quantity)

NB: Vertical axes differ among charts.

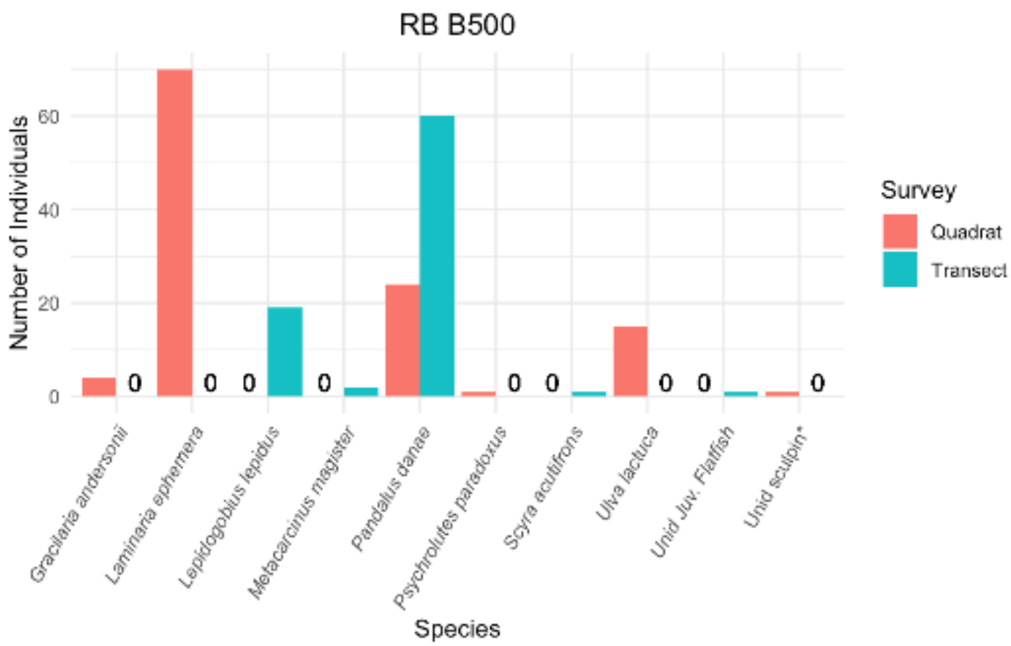


Haminoea sp.* likely *H. vesicular*, *virescens*, or *japonica*
Unid sculpin* likely *Artedius lateralis*

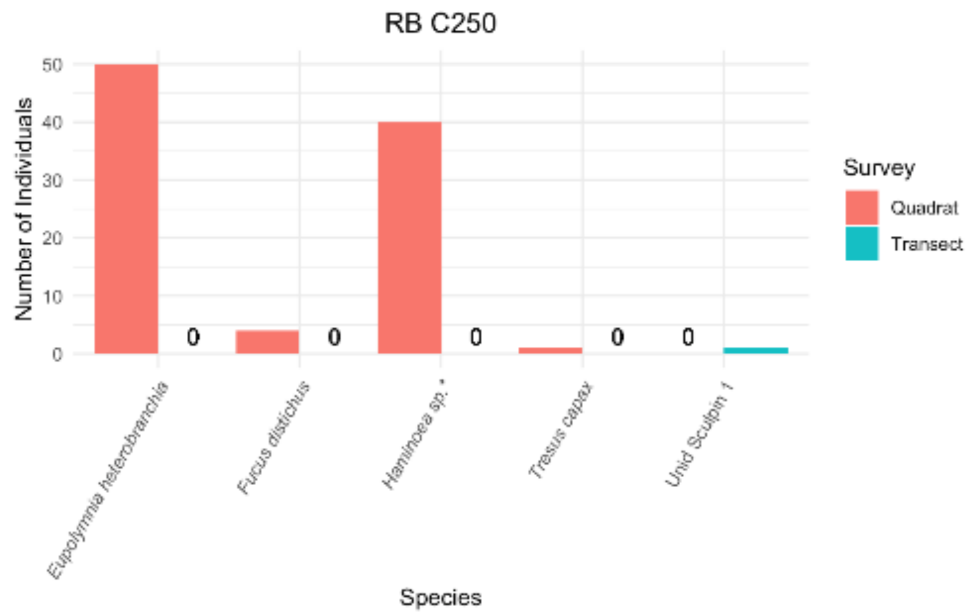




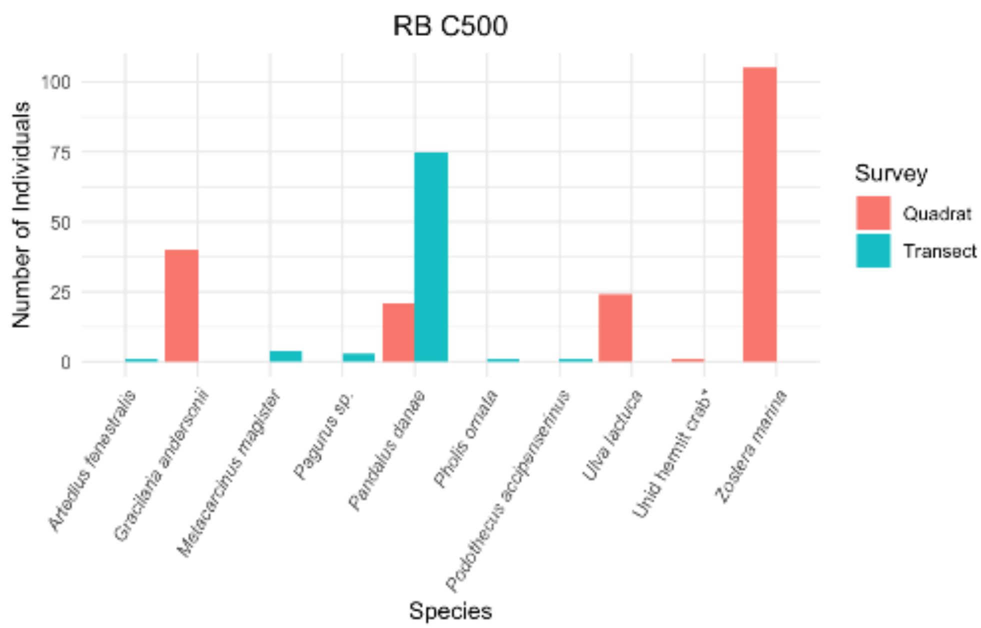
Haminoea sp.* likely *H. vesicular*, *virescens*, or *japonica*



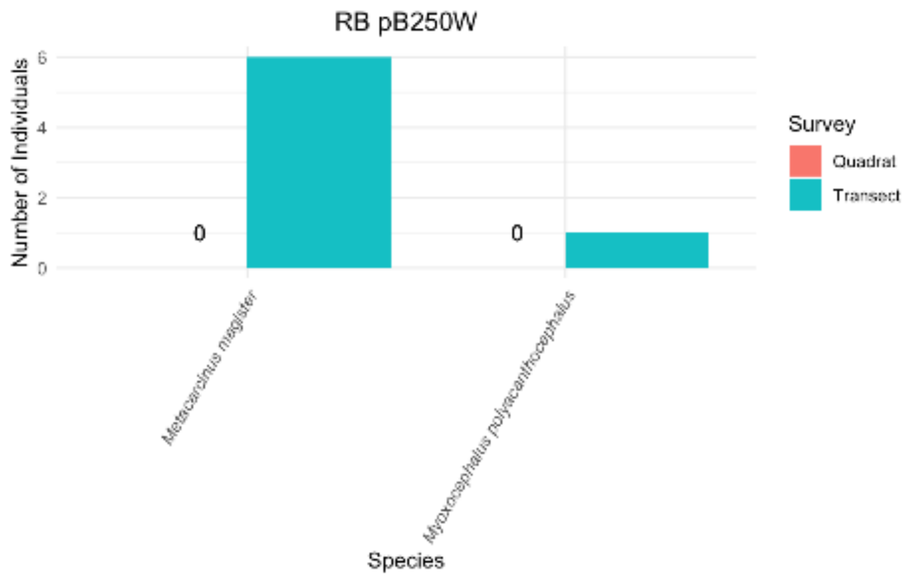
Unid sculpin* likely *Artedius harringtoni*



Haminoea sp.* likely *H. vesicular*, *virescens*, or *japonica*



Unid hermit crab* likely *Pagurus* sp.



NB: For values >10, the number is most likely estimated.

Interpretation: Sad situation at pB250W (which is likely the most sheltered location); the substrate was barren save for the “film” which provides no habitat and may smother other alga that may establish. Presence of *Zostera marina* shows the possibility of habitat for fish (eDNA and sampling at other times of year will provide more information on the eelgrass habitat’s use). Proper identification of *Haminoea* sp. is hard to determine; of the three cryptic species, two are indigenous and one introduced. Therefore, it is hard to determine if Roberts Bay is a site of high non-native species proliferation.

All species, common names, and brief information are in Appendix H.

Biodiversity Calculations

Richness: Number of species from abundance survey and not percent cover.

Simpson’s Biodiversity Index: Calculated based on the number of species and their relative abundances. Values range from 0 – 1, where higher values mean lower biodiversity. Simpson’s Index is from abundance surveys and not percent cover.

Fisher’s Alpha: A logarithmic calculation because of the inherent differences between the abundances of each species: some species are found in groups *vs* rarer or individual. A higher Fisher’s alpha results from higher biodiversity.

Site	Richness (Q)	Richness (T)	Richness (Q & T)	Simpson's Index (Q)	Simpson's Index (T)	Simpson's Index (Q & T)	Fisher's Alpha (Q)	Fisher's Alpha (T)	Fisher's Alpha (Q & T)
A250	5	4	9	0.4158	0.4545	0.7036	0.9788	2.1010	2.7652
A500	4	6	10	1	0.3079	0.3798	2.68E+08**	2.0560	3.0926
B250	5	6	11	0.1055	0.8889	0.3055	0.9060	6.3331	2.9577
B500	8	5	13	0.5725	0.4293	0.7568	1.3453	1.1692	2.5114
C250	5	1	6	0.5496	0*	0.5590	0.8456	1.34E+08**	1.1205
C500	7	6	13	0.6293	0.2202	0.7494	0.9400	1.4734	2.2920
pB250W	2	2	4	**NA**	0.2857	0.2857	0.0000	0.9354	0.9354
All	15	18	31	0.8859	0.8086	0.8488	5.2655	9.1451	6.0593

Q = from quadrat surveys, T = from transect surveys, Q & T = from a combination of both quadrat and transect surveys

*too few species to calculate Simpson's Biodiversity Index

**too few samples that the Fisher's Alpha value is arbitrarily high

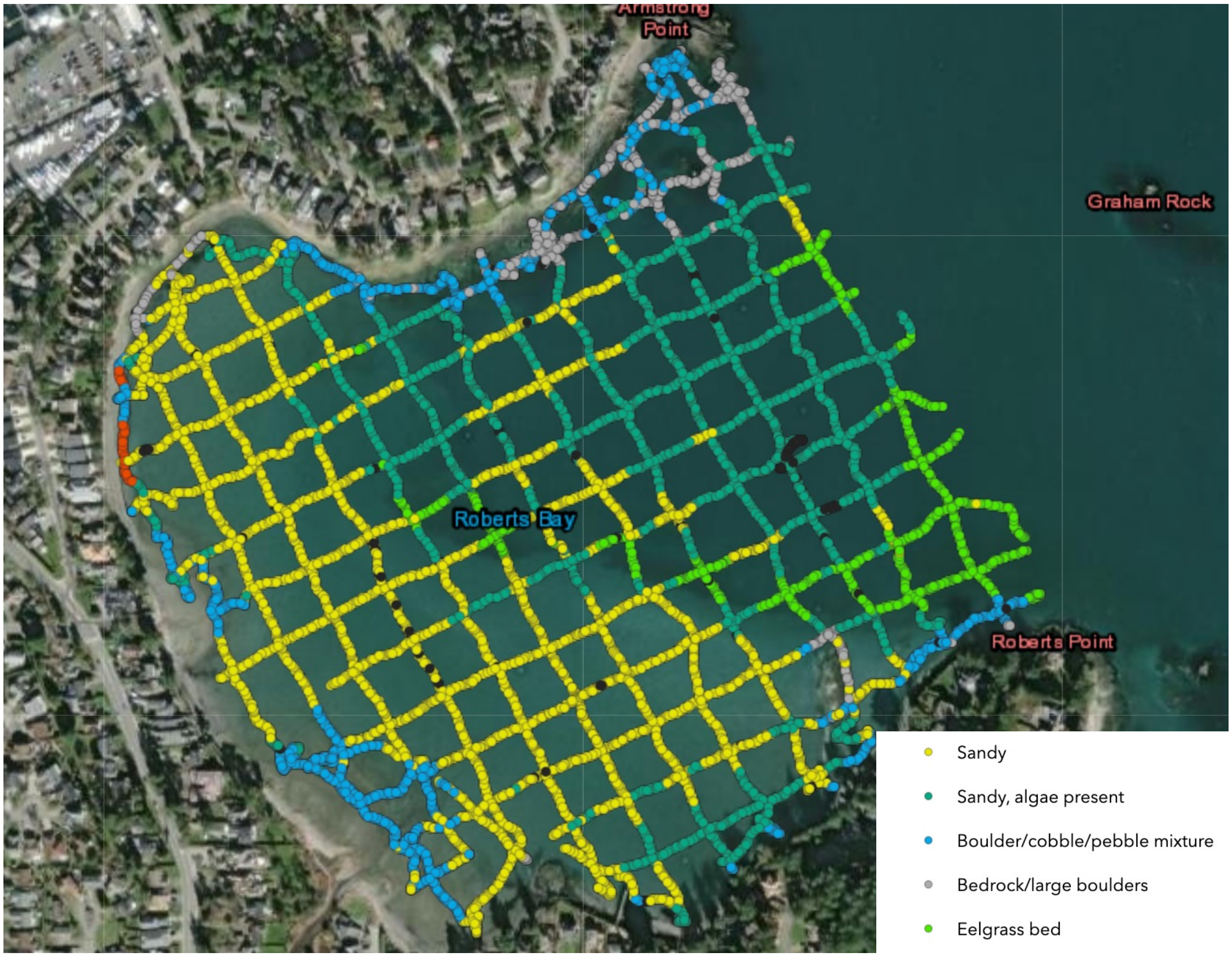
NA: no species in abundance survey (species are from percent cover)

Interpretation: With the exception of the arbitrarily high Fisher's alpha values (which occurs when the samples are low), there is low biodiversity at each location, when looking at each survey type independently. (NB: the calculations of Richness include species that were surveyed for abundance and percent cover; the Simpson's Index and Fisher's alpha were calculated using only species and their abundance data). What we see is that although all sites together show double the species between Q and Q & T, the biodiversity indices are only increased a small amount (Fisher's alpha) or decrease (Simpsons). When looking at Roberts Bay as a whole, one site does not show the extent of biodiversity, and therefore we could look at the bottom row for a more accurate representation of the overall biodiversity (from the many meso-ecosystems within the estuary). Judging by Simpson's Index alone, there is high species diversity (non-cryptic, this does not include plankton or infaunal species). If the *Haminoea* sp. is the introduced species, it will alter how we interpret the results (ie does biodiversity matter if they are introduced species that may lead to biodiversity loss). Looking at Fisher's alpha, the overall biodiversity (Q & T) is lower than that of T only (or B250 T). We could interpret this as the more the area is sampled, the less the biodiversity appears to be. However, judging by the rest of the sites having much lower Fisher's alpha, I would interpret it that some locations have higher biodiversity than others, and that Transect surveys yield higher estimates of biodiversity. As I have mentioned, compared to many urban estuaries, Roberts Bay has relatively high biodiversity, and has therefore a higher likelihood of resilience, according to the "portfolio effect".

Site Survey: February 20 & 21, 2024

Boat: Klanawa
Crew: Jamie Smith (Captain), Thomas Armitage (Mapper)
Data Collected: Tow camera video footage and GPS coordinates

Habitat Mapping



Interpretation: The eelgrass bed within the bay is in a band, which will help with shoreline erosion towards the creek area, especially with the thicker (but undetermined) eelgrass beds towards the outside of the bay. These eelgrass beds are essential not only for habitat but for shoreline protection from waves and tidal currents. The extensive areas free of alga may be due to the time of year (mapping was done in January) or other influences preventing the growth and expansion of eelgrass. The preservation and space for expansion of the eelgrass will be essential for protecting the marsh at Mermaid Creek, and if allowed to expand, may even help the area from the effects of sea level rise.

Site Survey: April 9, 2024

Boat: Klanawa
Crew: Jamie Smith (Captain), Susan Anthony (Science Officier), Thomas Armitage (Science Officer)

Data Collected: CTD cast (Conductivity, Temperature, and Depth), Nutrients, Bacteria, eDNA

Sampling Locations

Site	Lat	Long	Sampling
A250	48.6628	123.4004	eDNA
A500	48.6649	123.3995	eDNA, Bacteria, Nutrients
B250	48.6622	123.3989	eDNA, Bacteria, Nutrients
B500	48.6639	123.3966	eDNA, Bacteria, Nutrients
C500	48.6625	123.3952	eDNA, Bacteria, Nutrients
Eelgrass	48.66472	123.39344	eDNA, Bacteria, Nutrients

eDNA Analysis

Sampling completed, samples sent to eDNA Tech for processing.

Bacterial Sampling

Site	Faecal coliforms (CFU/100mL)*	*Enterococcus* spp. (CFU/100mL)
A500	<1	<1.0
B250	<1	<1.0
B500	1	<1.0
C500	1	<1.0
Eelgrass	<1	<1.0

*CFU = Colony Forming Unit

NB: Reportable Detection Limit (RDL) = 1 CFU/100mL

NB: Health Canada limit for safe water for activity is 35 CFU/100mL *Enterococcus* spp.

Interpretation: Negligible bacterial load in the bay. This means no input from land from septic systems/sewers and waterfowl.

Nutrient Sampling

Site	Nitrate (NO_3) ppm	Phosphate (PO_4) ppm	Nitrate (NO_3^-) µmol/L, µM	Phosphate (PO_4) µmol/L, µM
A500	0.31ppm	0.15ppm	5.0	1.6
B250	0.32ppm	0.13ppm	5.2	1.4
B500	0.28ppm	0.10ppm	4.5	1.1
C500	0.24ppm	0.09ppm	3.9	1.0
Eelgrass	0.27ppm	0.09ppm	4.4	1.0

Interpretation: The nitrate levels are well below toxic levels for aquatic life and below usual values for estuaries (half of the lowest yearly value of Saanich Inlet, for instance). Phosphate, not total phosphorous, is low enough that there is no concern, however total phosphorous may yield more answers. The eutrophication threshold of phosphorous is equivalent to 0.035 ppm, and the phosphate already exceeds this value, indicating high phosphorous levels and eutrophication, which is evident with the observed high levels of phytoplankton and presence of *Ulva*.

Future Work

Identifying the extent of nutrient load in the area, given the *Ulva* presence, is first. Following up with the other pollutants from urban run-off, of which the effects on the habitat are still unclear but will contaminate the food chain. We also should do measurements of suspended particulate matter (SPM, ie. Phytoplankton) and its effect on light attenuation (see Painting et al., 2007, appendix). A high level of SPM reduced light attenuation, which will mean essential eelgrass habitat will be much shallower than 10 m.

If the goal is protection of the marshland and estuary from sea level rise, the issue will be more about the encroachment onto "private" land: climate estimates expect that the area will experience relatively low sea level rise, however the shallow profile of the beach will mean that the shoreline will go far inland. Further modeling of the area along with detailed research on the accumulation of sediment and the shoreline profile changes over time will inform only, and the efforts needed will have to involve many partners. If the purpose of restoration in Roberts Bay is to allow seafood harvesting, the contamination levels will need to be monitored more than is already done and plans to provide remediation and removal of the source of input will have to be in place.

Subtidally, the eelgrass beds will need to be monitored for any decline or expansion, plus the extent of any impacts from humans and geese will inform future decisions on what actions can be done here. The large areas with Ulva and "film" may be preventing healthy habitats with diverse alga species, and nutrient analysis will tell us whether the waters have excessive nutrient concentrations.

Support

We will not proceed without verbal or written consent from the Tseycum Nation and relevant residential and business committees. Operations of any kind will cease if we are not supported by relevant local organizations.

Appendix C: Tod Inlet Site Report (October)

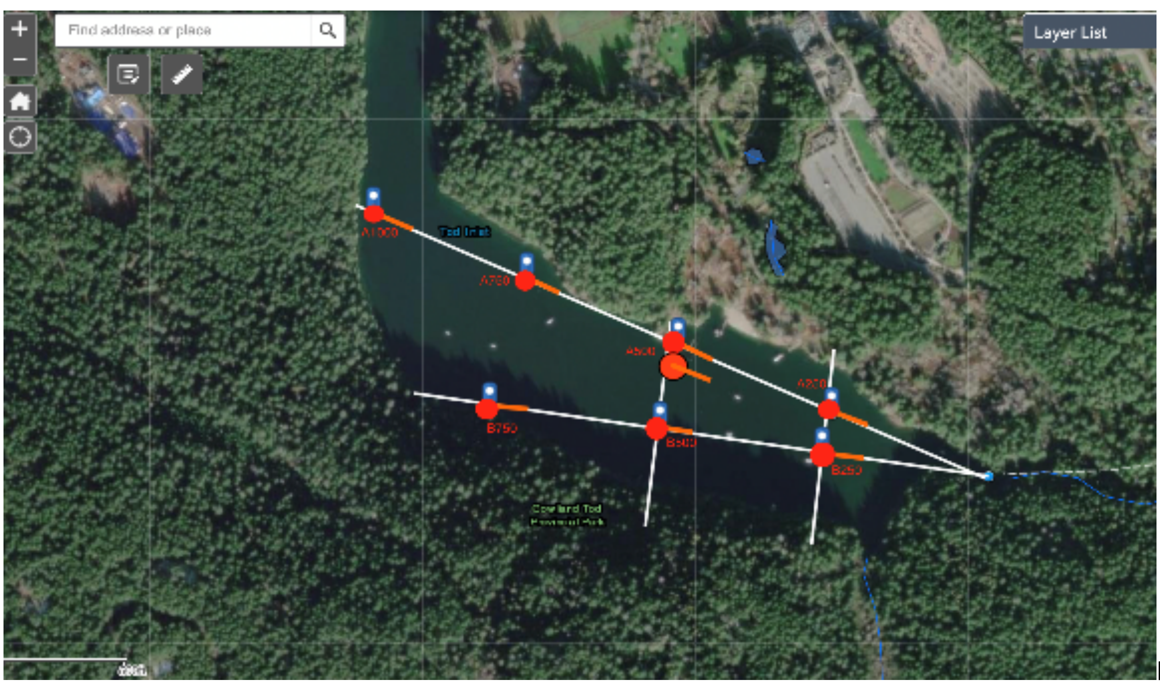
Site Survey: October 12 & 16, 2023

Boat: Klanawa **Crew:** Jamie Smith, Justin Lisaingo, Justin Bland, Viki Kolatkova **Weather:** Light rain, overcast, no wind; cleared mostly sunny; 15 °C **Measurements:** Salinity, Temperature, Dissolved Oxygen, Turbidity, Biodiversity survey, Bacteria sampling

Shoreline Observations

- Boulder, gravel, steep slope with dense treeline (mostly coniferous); small restored beach (gravel and shell hash); parts of shore mixed with concrete slag
- 1 seal, a few gulls, 1 kingfisher
- Boat launch, dog walkers, usually 2-3 ppl at any time
- Dock with the nature house, old pilings, small swim platform (moored), 3 anchored boats
- Nearby Butchart Gardens (fertilizer?) with weekly fireworks could impact the ecosystem
- Many moon jellies are visible
- Site A500 moved due to proximity to pilings
- (no sketch of site)

Sampling Locations



Red dots= site locations
Orange lines= Biodiversity transect lines

Site Number	Latitude	Longitude
A250	48.5598	123.4671
A500	48.56059	123.47036
A750	48.5617	123.4732
A1000	48.5626	123.4763
B250	48.5593	123.4673
B500	48.5596	123.4707
B750	48.5599	123.4740

Bacterial Sampling

Site	Faecal coliforms (CFU/100mL)*	*Enterococcus* spp. (CFU/100mL)
A250	1	1
A500	7	6
A750	5	4
A1000	8	10
B250	8	1
B500	2	2
B750	<1	6

*CFU = Colony Forming Unit

NB: Reportable Detection Limit (RDL) = 1 CFU/100mL

NB: Health Canada limit for safe water for activity is 35 CFU/100mL *Enterococcus* spp.

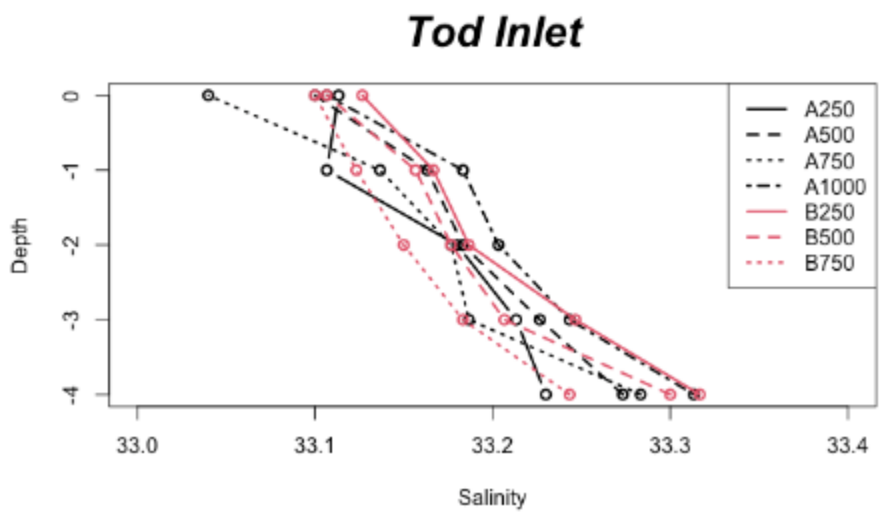
Interpretation: Despite the high boat use of Tod Inlet and its evidently low exchange with the ocean, the bacterial concentration is low. There is no evidence that the low bacterial contamination is due to recent rainfall, but there is not as much goose activity, which often adds to human waste contamination in these tests.

Turbidity

Site	Site Depth (m)	Secchi Depth (m)
A250	-4.1	3.6
A500	-8.3	4.6
A750	-6.7	5.5
A1000	-7.6	5.7
B250	-4.7	4.0
B500	-8.9	6.0
B750	-4.3	Bottom

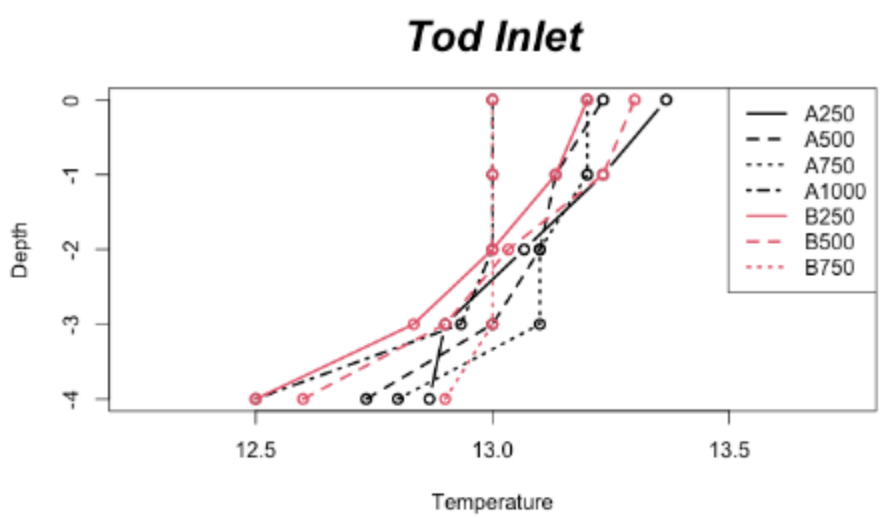
Interpretation: The turbidity is high for this time of year. The recent rainfall is not a cause for suspended sediment. This time of year, there is usually low phytoplankton bloom. However, the warm weather and sunshine have extended into autumn in recent years, which may cause plankton to continue to bloom later, regardless of the photoperiod.

Salinity



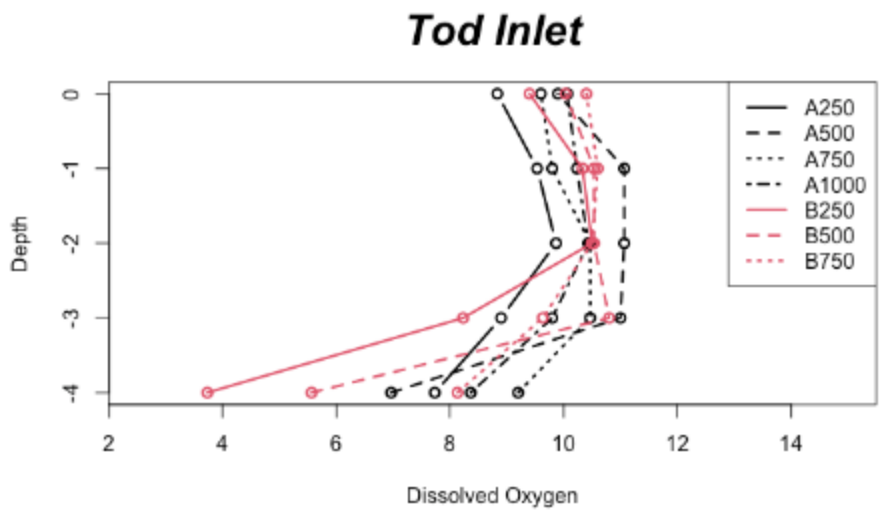
Interpretation: A low surface salinity means there is freshwater influx at this time of year, even without recent rains. The gradual increase of salinity with depth at all locations is indicative of low mixing and general diffusion. The similarity of each site within the inlet indicates also low mixing and stagnant water, even with tidal exchange, and that the lower salinity at the surface is from a large enough source to cover the inlet or comes from multiple sources along the shore.

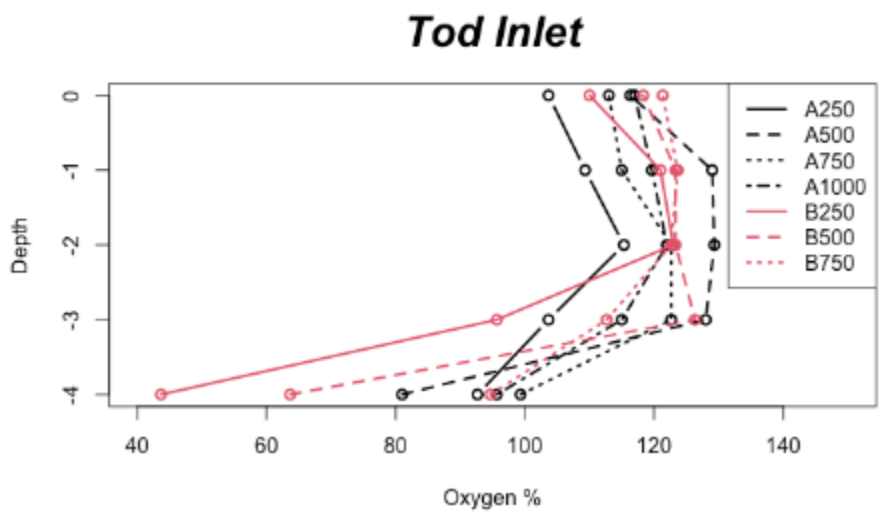
Temperature



Interpretation: Lots of overlap it is hard to see the individual depth contours, meaning again that each site within the inlet is similarly influenced by tides, freshwater, and mixing (the small amount that is evident).

Oxygen

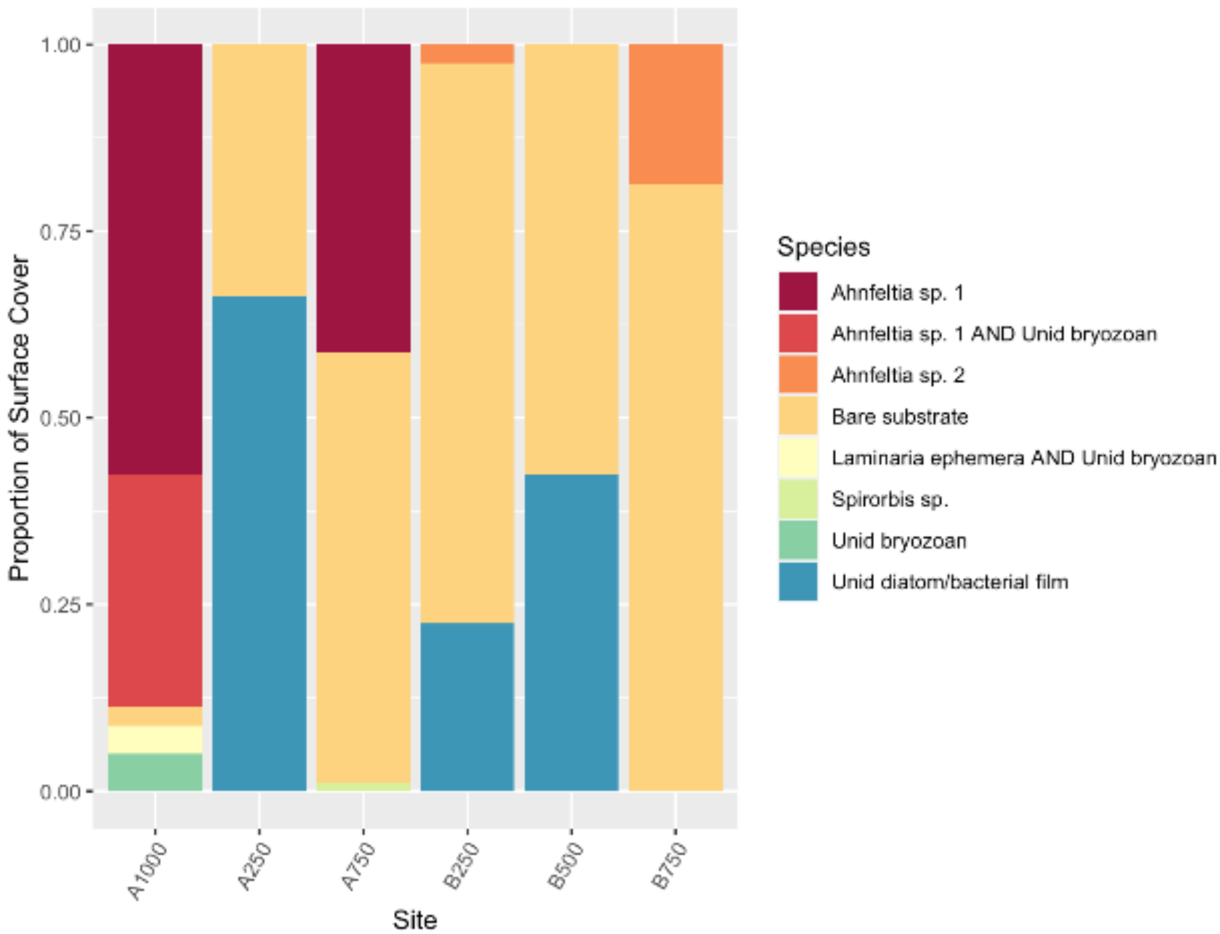




Interpretation: The two measurements of oxygen show the same trend towards high surface oxygen with decrease at depth. Comparing it to seafloor biotic composition will shed more light, but I would expect that the oxygen were from phytoplankton (which also decreases visibility through the water column; See **Turbidity**). The levels are extremely high and this could mean high nutrient levels (likely from run-off and not upwelling) and/or low filter-feeding residents. Further information from Biodiversity Surveys and Nutrient Concentrations as well as watershed size and land-use, should shed more light.

Biodiversity: Ground Cover by Site

The stacked barplots are a sum of the four 25 cm^2 quadrats.



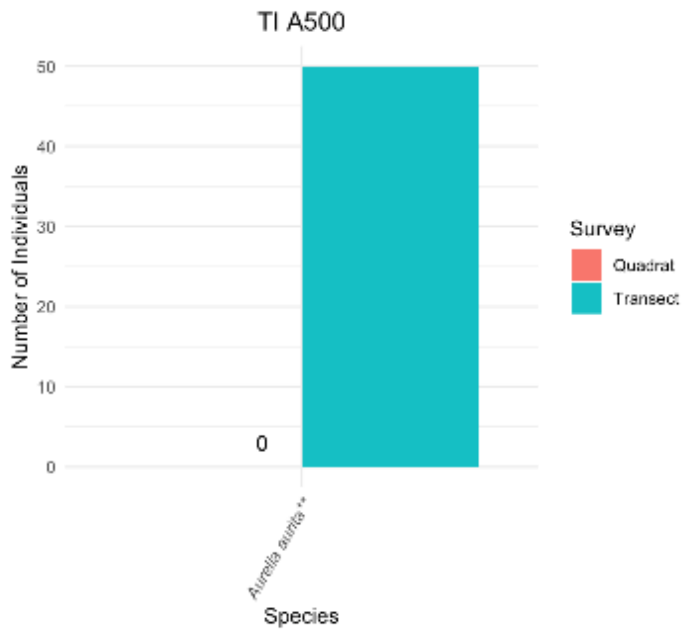
NB: It is not possible to create true plots of the substrate-covering organisms. See General Methods for more details.

Interpretation: The low species diversity, lack of eelgrass, and high coverage by unid diatom/bacterial film (possibly photosynthetic) leads to the interpretation of low habitat diversity. There is no evidence of other high-nutrient-loving algal species, such as *Ulva*.

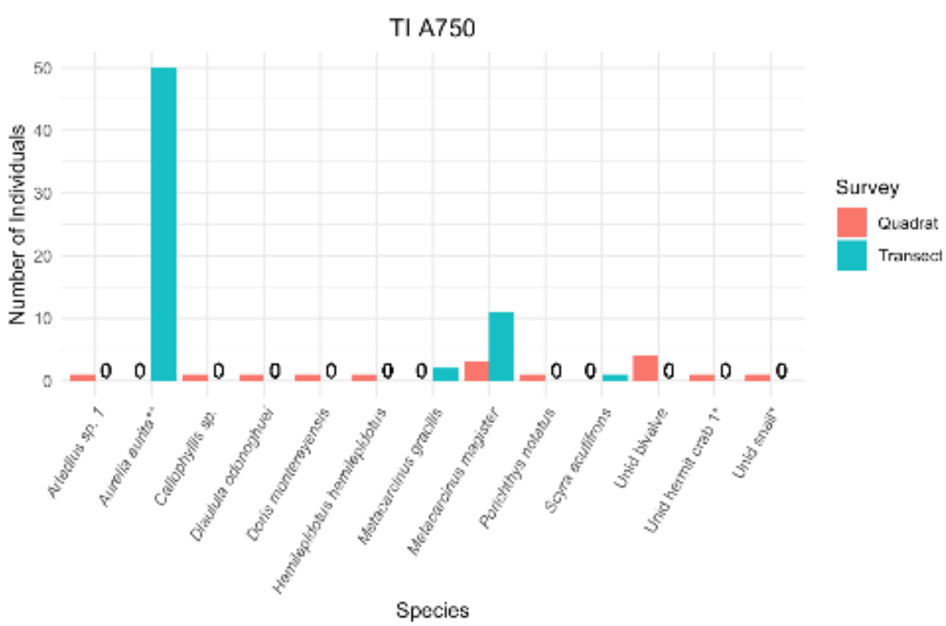
Biodiversity: Abundance by Site

Animal and Algae (by quantity)

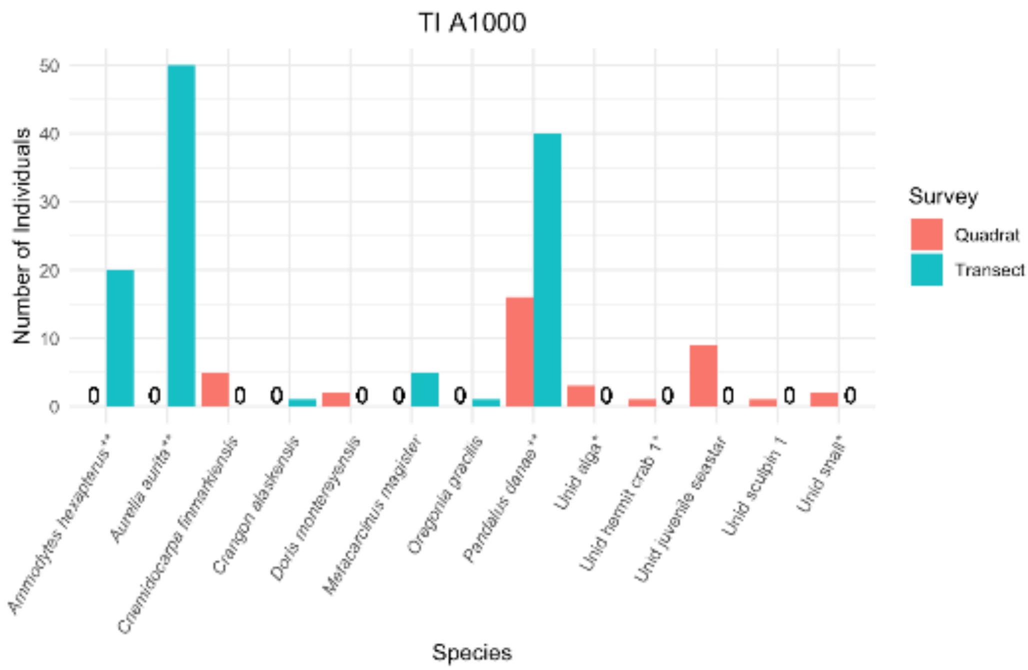
NB: Vertical axes differ among charts.



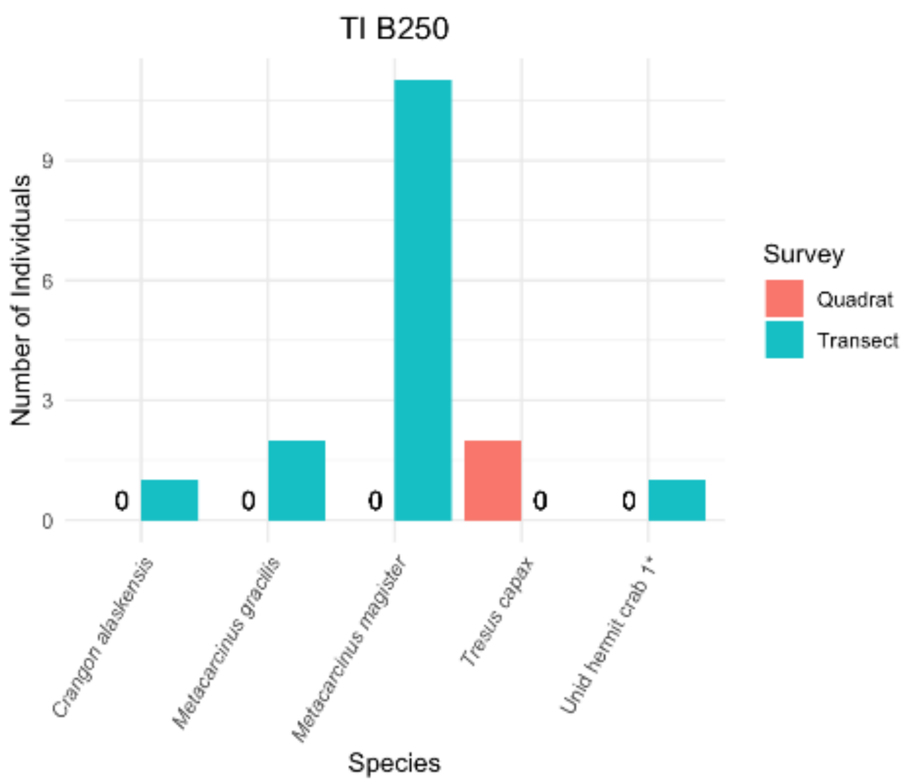
* the turbidity was too high to see and therefore there was no quadrat survey
**Estimated number



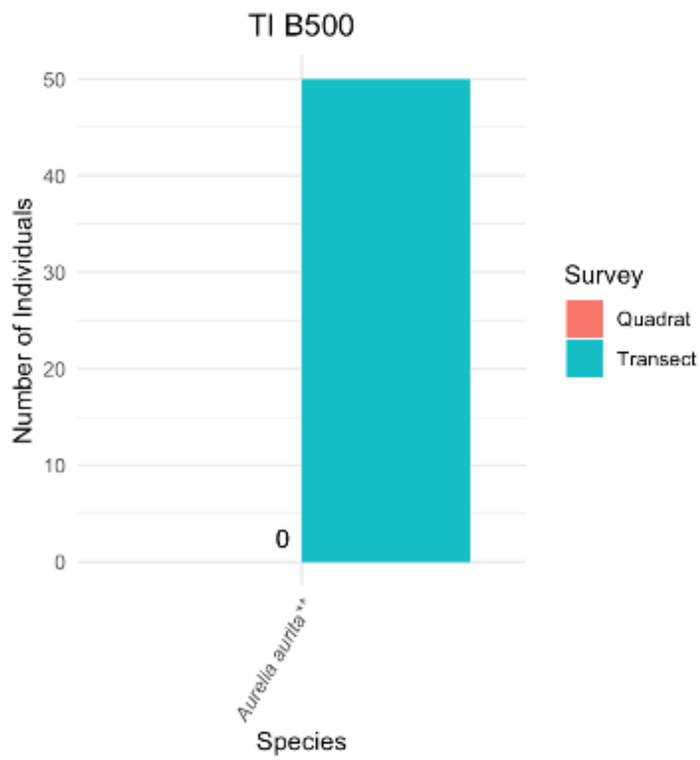
*Unid hermit crab 1 is likely *Pagurus* sp.
*Unid snail is likely *Nassarius* sp.
**Estimated number



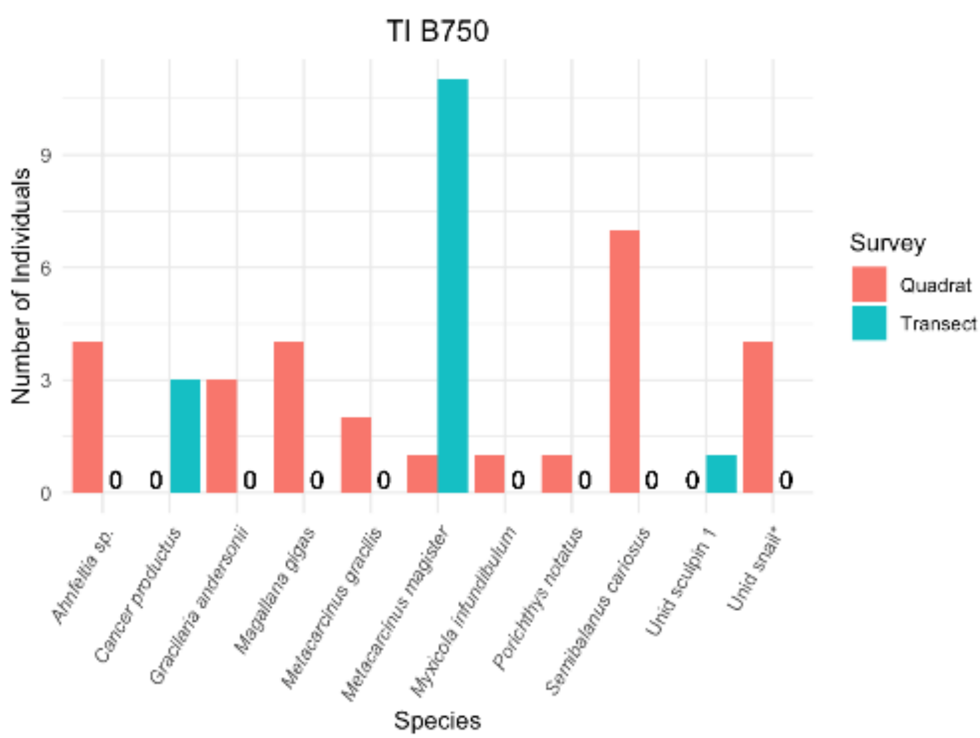
*Unid alga is likely *Fryeella gardeneri*
*Unid hermit crab 1 is likely *Pagurus* sp.
*Unid snail is likely *Nassarius* sp.
**Estimated number



*Unid hermit crab 1 is likely *Pagurus* sp.



**Estimated number



*Unid snail is likely *Nassarius* sp.
NB: for B750, *Ahnfeltia* sp. is counted (in Quadrat A) and measured as a percent cover (in Quadrat C)

Interpretation: There are several sites with very low species numbers and lots of jellies. There is a saying that when all the oceans are fished out and polluted, jellyfish will be all that remains. The presence of crabs indicates there are sheltered habitats for hiding, however there is no evidence of eelgrass. We observed *Magallana gigas* (Pacific oyster) and introduced oyster species from Japan, however, we know that the Olympia oyster (*Ostrea lurida*), a COSEWIC Species of Special Concern, is present in Tod Inlet. See Appendix H for a list of species and a brief description of each.

Biodiversity Calculations

Richness: Number of species from abundance survey and not percent cover.

Simpson's Biodiversity Index: Calculated based on the number of species and their relative abundances. Values range from 0 – 1, where higher values mean lower biodiversity. Simpson's Index is from abundance surveys and not percent cover.

Fisher's Alpha: A logarithmic calculation because of the inherent differences between the abundances of each species: some species are found in groups *vs* rarer or individual. A higher Fisher's alpha results from higher biodiversity.

Site	**Richness (Q)**	**Richness (T)**	**Richness (Q & T)**	**Simpson's Index (Q)**	**Simpson's Index (T)**	**Simpson's Index (Q & T)**	**Fisher's Alpha (Q)**	**Fisher's Alpha (T)**	**Fisher's Alpha (Q & T)**
A250	1	0	1	NA	**NA**	NA	0**	0**	0**
A500	0	1	1	NA	0	0	0**	NA	NA
A750	12	4	16	0.9143	0.3646	0.5813	13.1115	0.9458	4.4276
A1000	11	6	17	0.7692	0.6751	0.8035	3.0486	1.3387	3.0363
B250	3	4	7	0	0.4667	0.5809	0.7959	1.7848	2.3872
B500	1	1	2	**NA**	0	0	0**	NA	NA
B750	10	3	11	0.8775	0.4476	0.8827	4.7273	1.1277	4.8502
All	26	11	32	0.9341757	0.8745	0.7077	14.8512	4.4616	6.8961

Q = from quadrat surveys, T = from transect surveys, Q & T = from a combination of both quadrat and transect surveys

*too few species to calculate Simpson's Biodiversity Index

**too few species that the Fisher's Alpha; value is arbitrarily high or unable to calculate

NA: not enough species in the abundance surveys (Richness may include species from percent cover survey)

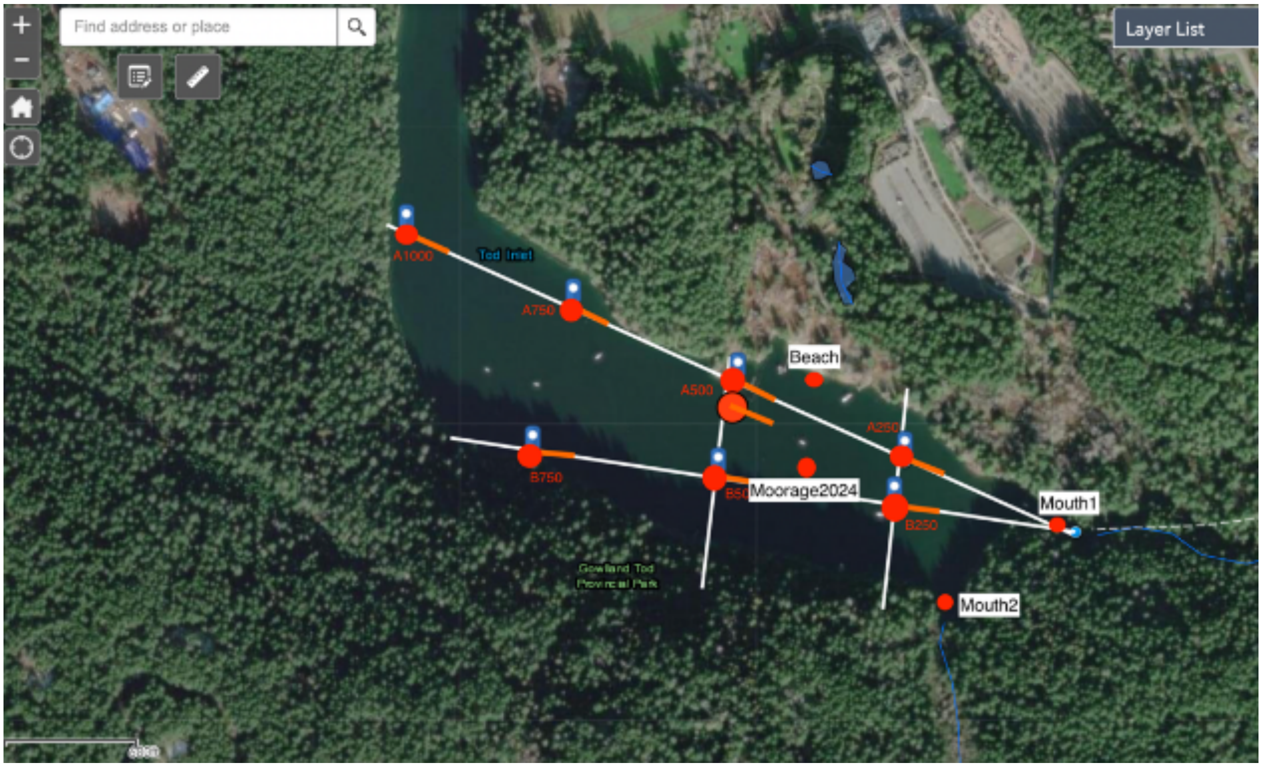
Marine Debris

No scanning in the area: debris collection conducted previous to this project.

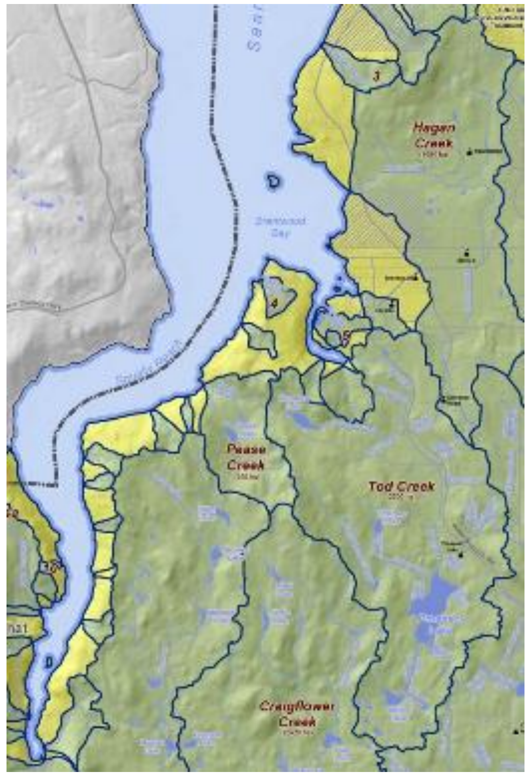
Habitat Diversity

In progress.

Future Work



- Identifying the source of any pollution and seasonal changes to the water column Resample in Spring of Salinity, Dissolved Oxygen/Percent Oxygen, Temperature, at the original seven sites
- Nutrients (nitrate and phosphate) and bacterial samples for analysis at Bureau Veritas at new sites: Beach, Moorage2024, Mouth1, Mouth2, A1000
- Potential zooplankton tow at original seven sites (for analysis by Biologica Inc.)
- Potential eDNA analysis
- To research: heavy metals testing



Yellow: direct drainage into the ocean
5 : Butchart Creek
(**4** : Rickinson Creek)

Support

We will not enter the area, collect data, or share information from SṈIDȻEȽ/Tod Inlet without a welcome from the Tsartlip FN, whose territory we speak of. Any plans for restoration or other action will be done collaboratively and with explicit permission (either via email or through talks) with representatives of the Tsartlip FN and with the land restoration group PEPAKEṈ HÁUTW.

Appendix D: Oak Bay Site Report (October)

Site Survey: August 14, 2023

Boat: Klanawa **Crew:** Jamie Smith (Captain); Susan Anthony (Science Officer) **Weather:** Clear and hot (23°C), no recent rain **Measurements:** Shoreline Observation, Salinity, Temperature, Dissolved Oxygen, Percent Oxygen, Turbidity, Zooplankton tows, Preliminary debris scanning

Shoreline Observations

- Made of bedrock, soft sediment and gravel
- Lots of seawalls
- A breakwater protecting the marina (bull kelp growing along the breakwater)
- Lots of seagulls at the mouth of Bowker Creek
- Along the shoreline is a school, mansions with pools
- People are kayaking and paddleboarding
- Sunken ships are obvious, have outboard motors still attached
- Water quality (bacterial contamination) spikes on occasion: https://inspections.myhealthdepartment.com/island-health/program-water-sample

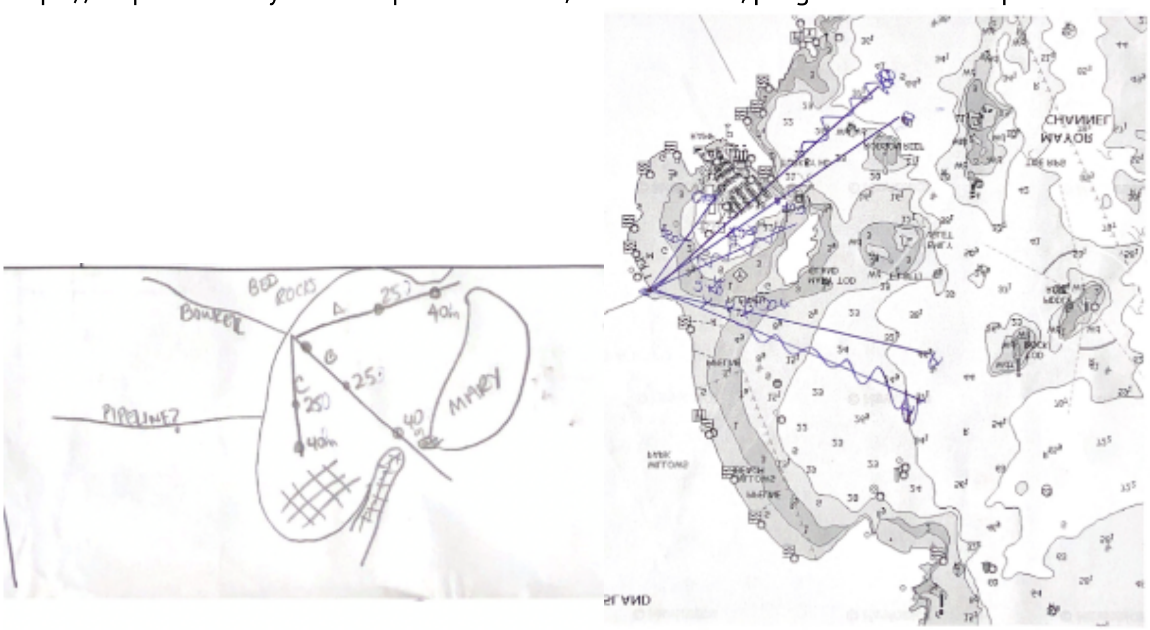


Figure: Sketch of Oak Bay with this day's data collection sites and location of landmarks and Navionics screenshot with Visit 1's transects drawn.

Preliminary Thoughts:

- Depending on the eelgrass extent: there were sunken ships within the eelgrass bed (replanting needed?)
- Eelgrass exclusionary zone signage

- Informational signage
- Waste testing; boat waste dumping signage

Site Survey: October 3 & 4, 2023

Boat: Klanawa **Crew:** Jamie Smith (Captain), Justin Lisaingo & Susan Anthony (Science Officers), Justin Bland and Viki NAME (Divers) **Data Collected:** Salinity, Temperature, Dissolved Oxygen, Percent O_2, Turbidity, Biodiversity Surveys, Bacterial Samples

Sampling Locations

Red dots= site locations
Orange lines= Biodiversity transect lines

Oak Bay	A250	48.4294	123.3028
	B250	48.4278	123.3034
	B500	48.4265	123.3007
	C250	48.4271	123.3045
	pB250S	48.4259	123.3052
	pB250N	48.4296	123.3015

Bacterial Sampling

Site (Oak Bay)	Faecal coliforms (CFU/100mL)*	*Enterococcus* spp. (CFU/100mL)
A250	<1	NA
B250	<1	NA
C250	<1	NA
C500**	1	NA

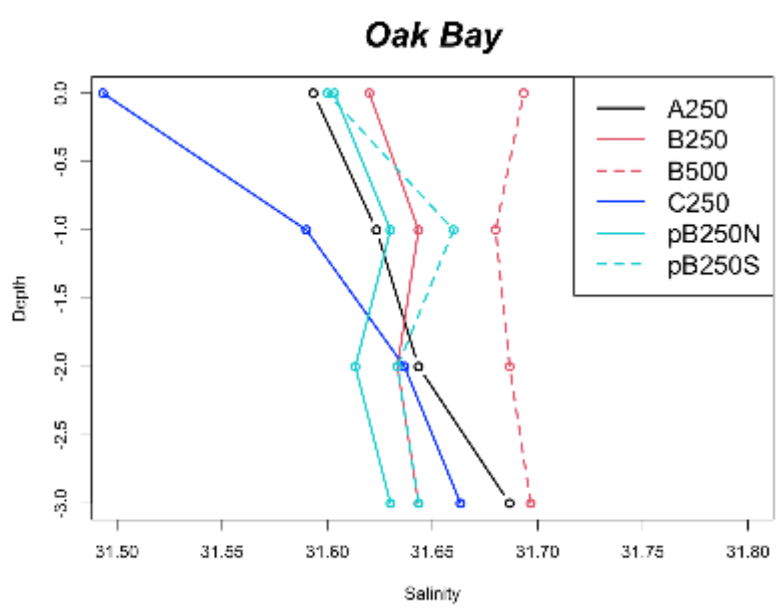
*CFU = Colony Forming Unit
**(Labelled as C500 but that is in the middle of the marina; Likely B500 like the abiotic measurements)
NB: Reportable Detection Limit (RDL) = 1 CFU/100mL
NB: Health Canada limit for safe water for activity is 35 CFU/100mL *Enterococcus* spp.

Turbidity

Site	Site Depth (m)	Secchi Depth (m)
A250	3.4	Bottom
B250	7.6	Bottom
B500	8.0	7.2
C250	6.1	Bottom
pB250N	3.4	Bottom
pB250S	3.7	Bottom

Interpretation: It is hard to determine turbidity in such shallow waters, but it is safe to say that a c. 7 m visibility is good for so close to shore with freshwater input. The currents that run between Mary Island and Vancouver Island would help flush the water.

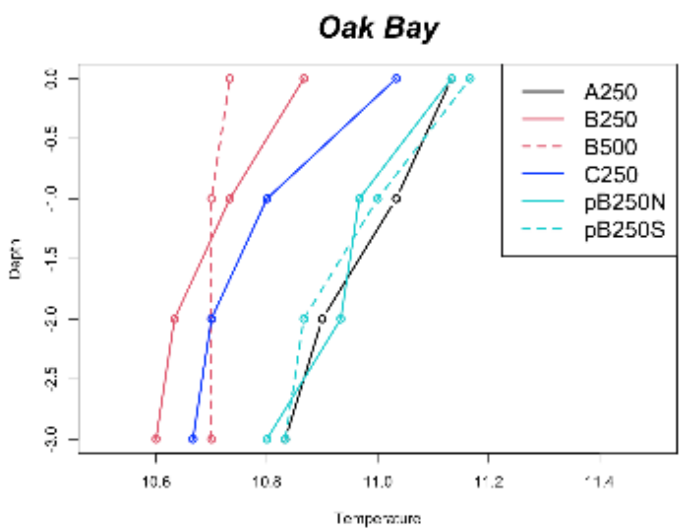
Salinity



Interpretation: Given the time of year, and how it hadn't rained for many months, there is no surface layer of freshwater, so salinity stratification is unlikely. Salinity is high through the water column. It could be interpreted as well-mixed, but I would say that at this time of year, this is most likely to be seen everywhere.

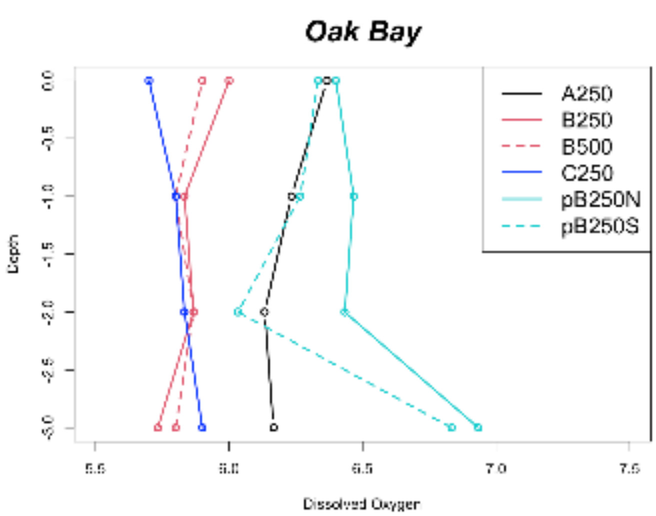
The surprise is that there is some evidence of stratification at C250 (fairly sheltered) but not at pB250S (more sheltered) or B250 (which is close by and still in the area with transient moorage). Unsurprisingly, A250 and pB250N, which are more exposed, are well-mixed.

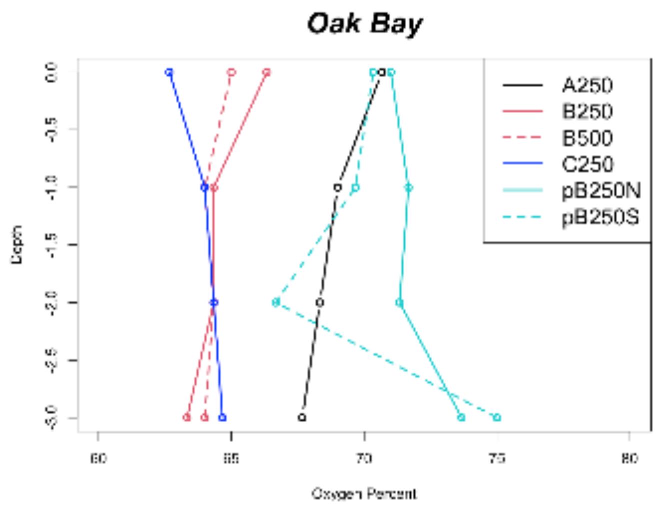
Temperature



Interpretation: Although there is little stratification, the gradual increase in temperature in the top 3m shows little mixing over the long term. No evidence of high mixing.

Oxygen



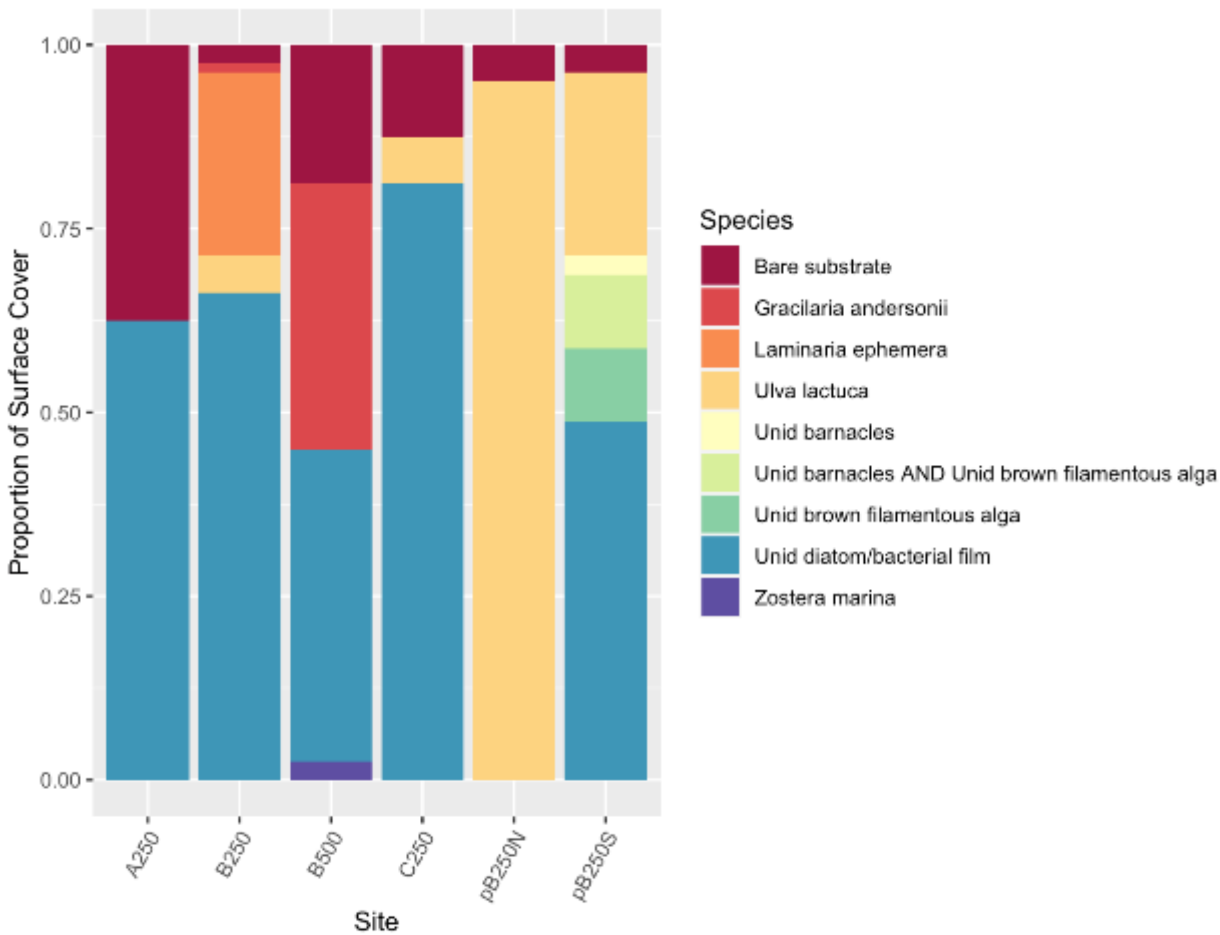


Interpretation: The sites can be grouped according to relative DO content: low (B250, B500, C250) and high (A250, pB250N, pB250S). Although the low-DO group sites are generally more sheltered, that doesn't account for pB250S. Biodiversity results will speak more to this.

The locations with high DO at the lower layers (especially pB250N&S) are indicative of photosynthetic organisms towards the bottom. Notes say that these locations are shallow, and the seafloor is less than a meter from the -3 m reading. pB250N is a sandy bottom with an eelgrass bed (also see biodiversity results); pB250S is also sandy, however, there is no evidence of eelgrass, but evidence of other photosynthetic organisms (red algae and *Ulva lactuca*, see biodiversity results).

Biodiversity: Ground Cover by Site

The stacked barplots are a sum of the four 25 cm^2 quadrats.



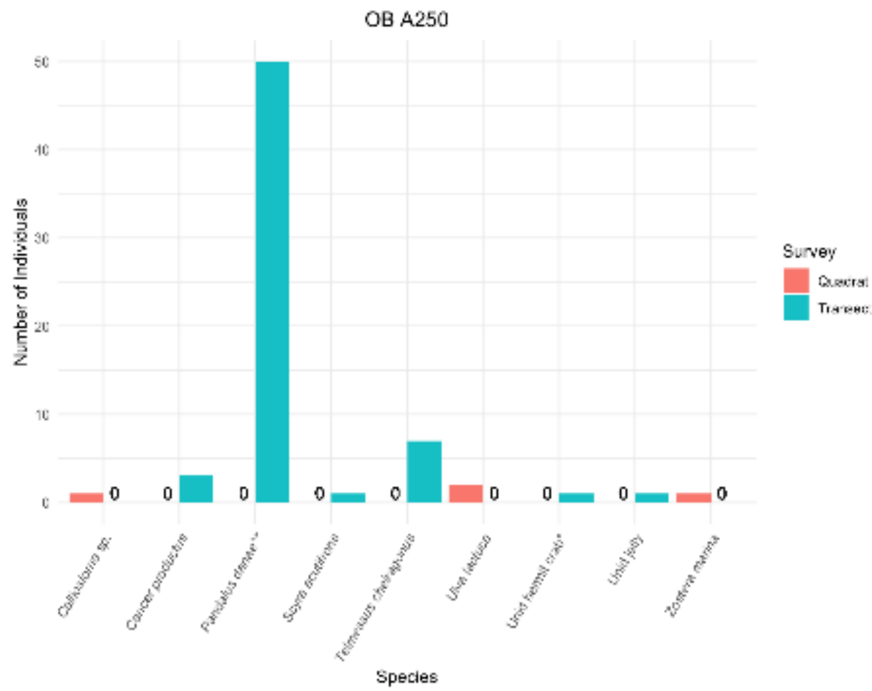
*NB *Zostera marina* was sometimes measured by percent cover, sometimes by individual plants.

Interpretation: The seabed cover is predominantly a film of photosynthetic diatoms. It looks barren and slimy, and the substrate may be better suited for eelgrass. Except pB250N, there is a low amount of *Ulva lactuca*, which can indicate excessive nutrients (surveys conducted at the end of the growing season). Very low biodiversity of alga species; most biodiversity is in B250 and B500, which is in the direction of the opening between Mary Island and the marina breakwater. All species, common names, and brief information are in the attached document RESS Species List.

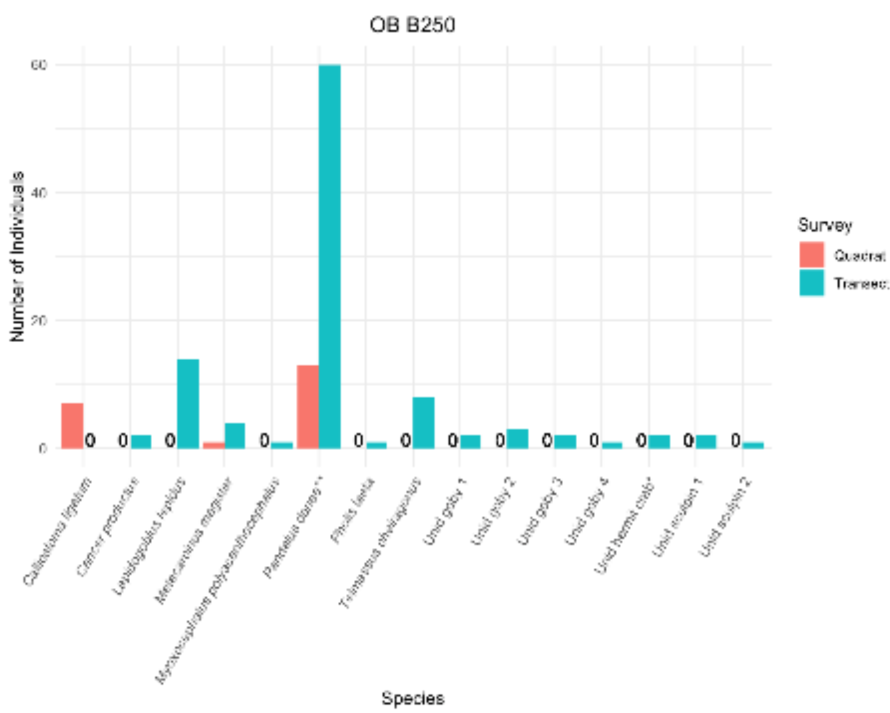
Biodiversity: Ground Cover by Site

Animal and Algae (by quantity)

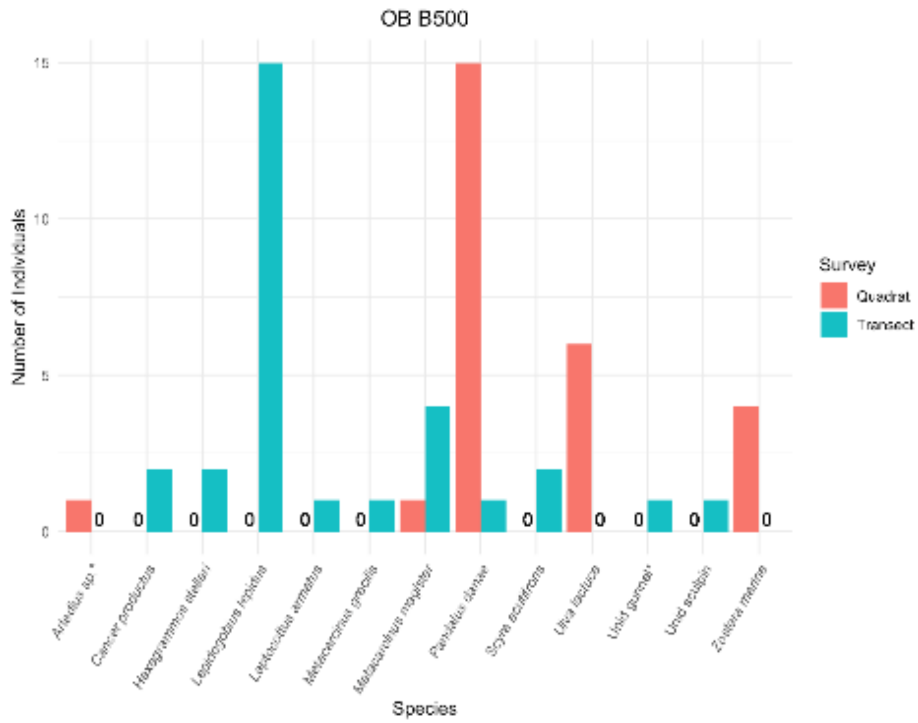
NB: Vertical axes differ among charts.



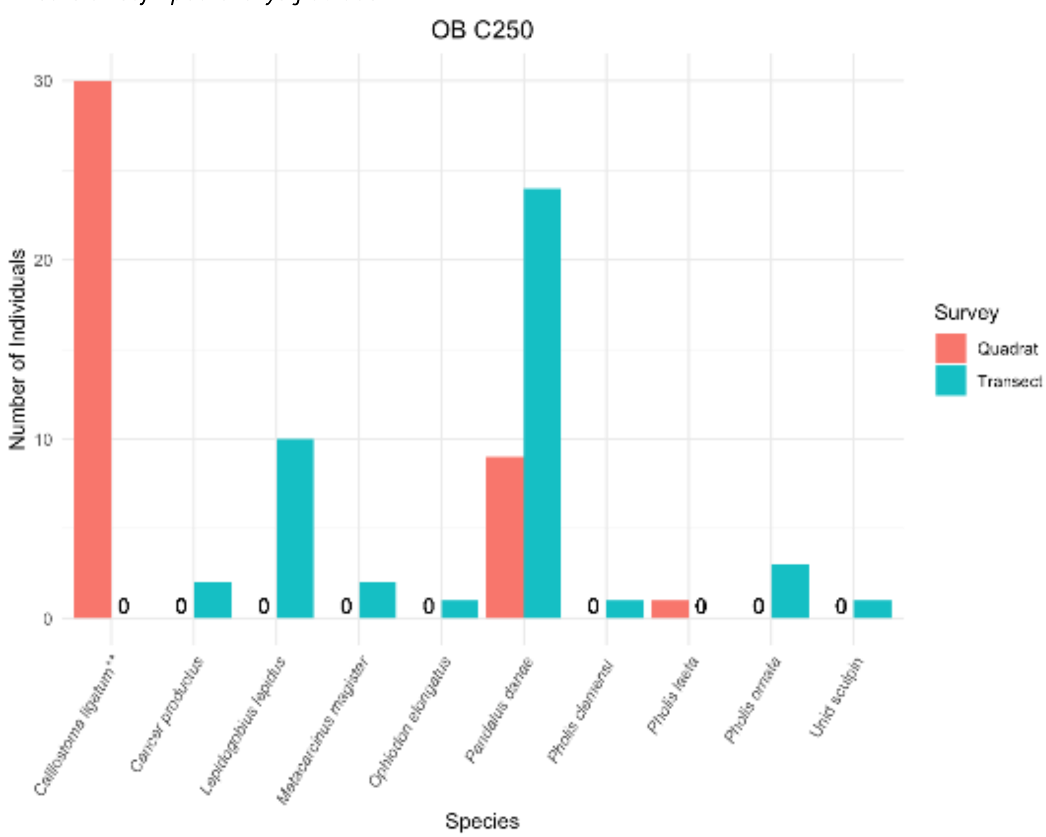
*Unid hermit crab is likely *Pagurus* sp.

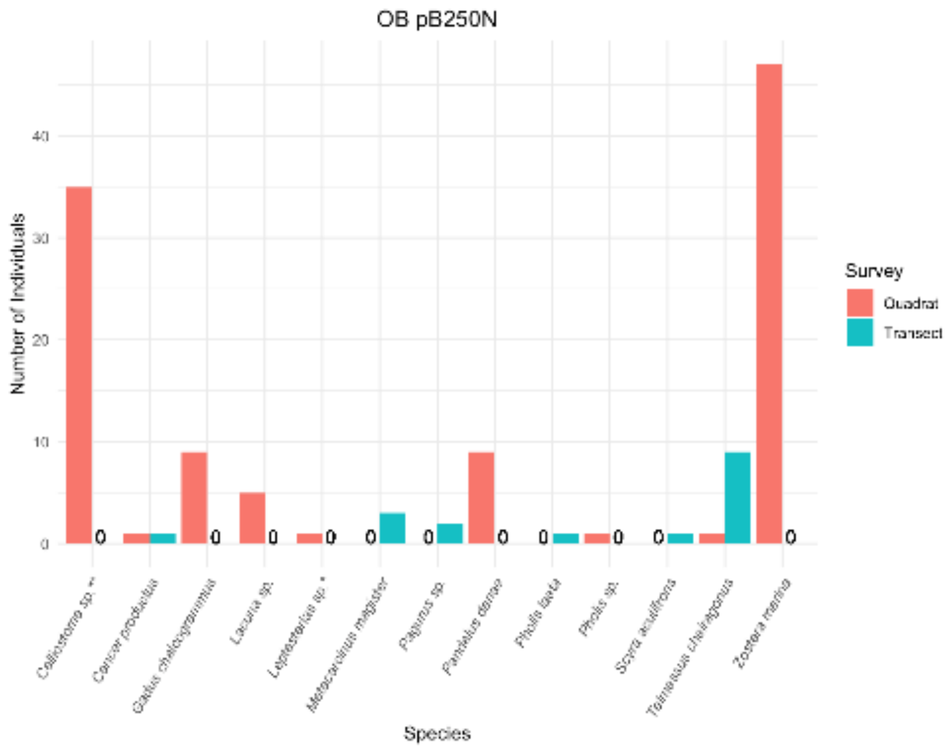


*Unid hermit crab is likely *Pagurus* sp.

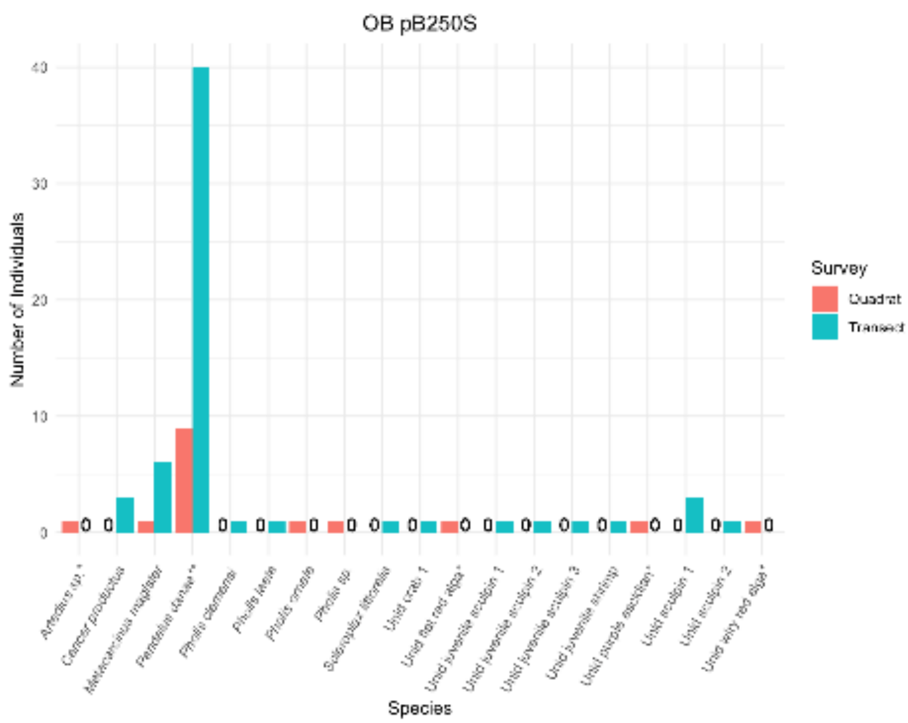


*_Artedius_ sp. is likely _A. lateralis_
*Unid gunnel is likely _Apodichthys flavidus_





Leptasterias sp. is likely *L. hexactis*



Artedius sp. is likely *A. fenestralis*
*Unid flat red alga is likely *Mazzaella splendens*
*Unid wiry red alga is likely *Gracilaria* sp.
**Estimated number (for all plots)

Interpretation: This provides evidence that many species may be missed if only using the quadrats or transects. Further, percent cover was only measured in the quadrats and density cannot be determined from transects. Although the total number of species at each site is rather the same (see Richness), it is more useful to see the abundance. Looking at the species involved, it is not fair to state that 50 *Pandalus danae* is equivalent to 50 *Pholis laeta*. Although one is more abundant, they are part of different functional groups in this ecosystem (*P. danae* are invertebrates and have less complex lifecycle whereas *P. laeta* is a vertebrate and carnivore and can live up to 6 years). Not all species are created equal. I would consider the number of species low, but estuaries are generally low in their biodiversity but high in biomass. This diversity is not unexpected for the area, but some species are a surprise: *Gadus chalcogrammus* (Alaska pollock) which is only seen at this time of year. No salmon evident, however it is not the season, and they are known to be shy (never do divers see them): eDNA would be in order to determine if it is a salmon-using estuary.

No evidence of non-indigenous species in the surveys, but *Sargassum* is present in shallow rocky area (observation).

All species, common names, and brief information are in Appendix H.

Biodiversity Calculations

Richness: Number of species from abundance survey and not percent cover.

Simpson's Biodiversity Index: Calculated based on the number of species and their relative abundances. Values range from 0 – 1, where higher values mean lower biodiversity. Simpson's Index is from abundance surveys and not percent cover.

Fisher's Alpha: A logarithmic calculation because of the inherent differences between the abundances of each species: some species are found in groups *vs* rarer or individual. A higher Fisher's alpha results from higher biodiversity.

Site	Richness (Q)	Richness (T)	Richness (Q & T)	Simpson's Index (Q)	Simpson's Index (T)	Simpson's Index (Q & T)	Fisher's Alpha (Q)	Fisher's Alpha (T)	Fisher's Alpha (Q & T)
A250	4	6	10	0.8333	0.3605	0.4346	5.4526	1.6305	2.7979
B250	7	14	21	0.5286	0.6377	0.7375	0.9578	4.3742	4.4366
B500	8	10	18	0.6410	0.7379	0.8496	1.8051	5.2526	5.3164
C250	5	8	13	0.3962	0.6554	0.7714	0.7512	2.8613	2.9577
pB250N	10	5	15	0.7013	0.5735	0.7694	2.3268	2.3872	3.2611
pB250S	12	13	25	0.7	0.5623	0.7139	6.3672	5.0599	8.0005
All	23	29	46	0.8937	0.9117	0.7843	9.8970	19.7114	10.6629

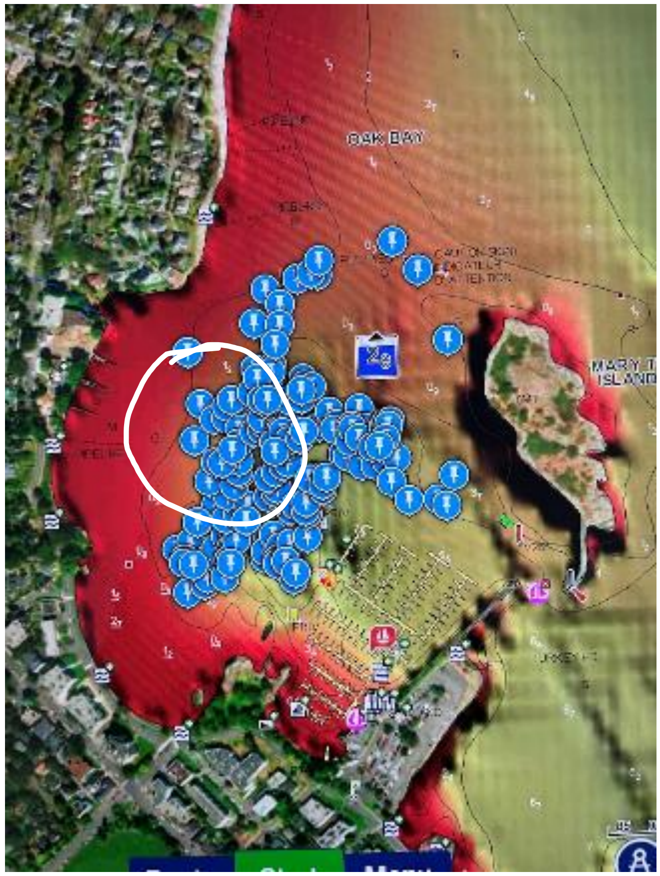
Q = from quadrat surveys, T = from transect surveys, Q & T = from a combination of both quadrat and transect surveys

*too few species to calculate Simpson's Biodiversity Index

**too few species that the Fisher's Alpha; value is arbitrarily high or unable to calculate

NA: not enough species in the abundance surveys (Richness may include species from percent cover survey)

Marine Debris



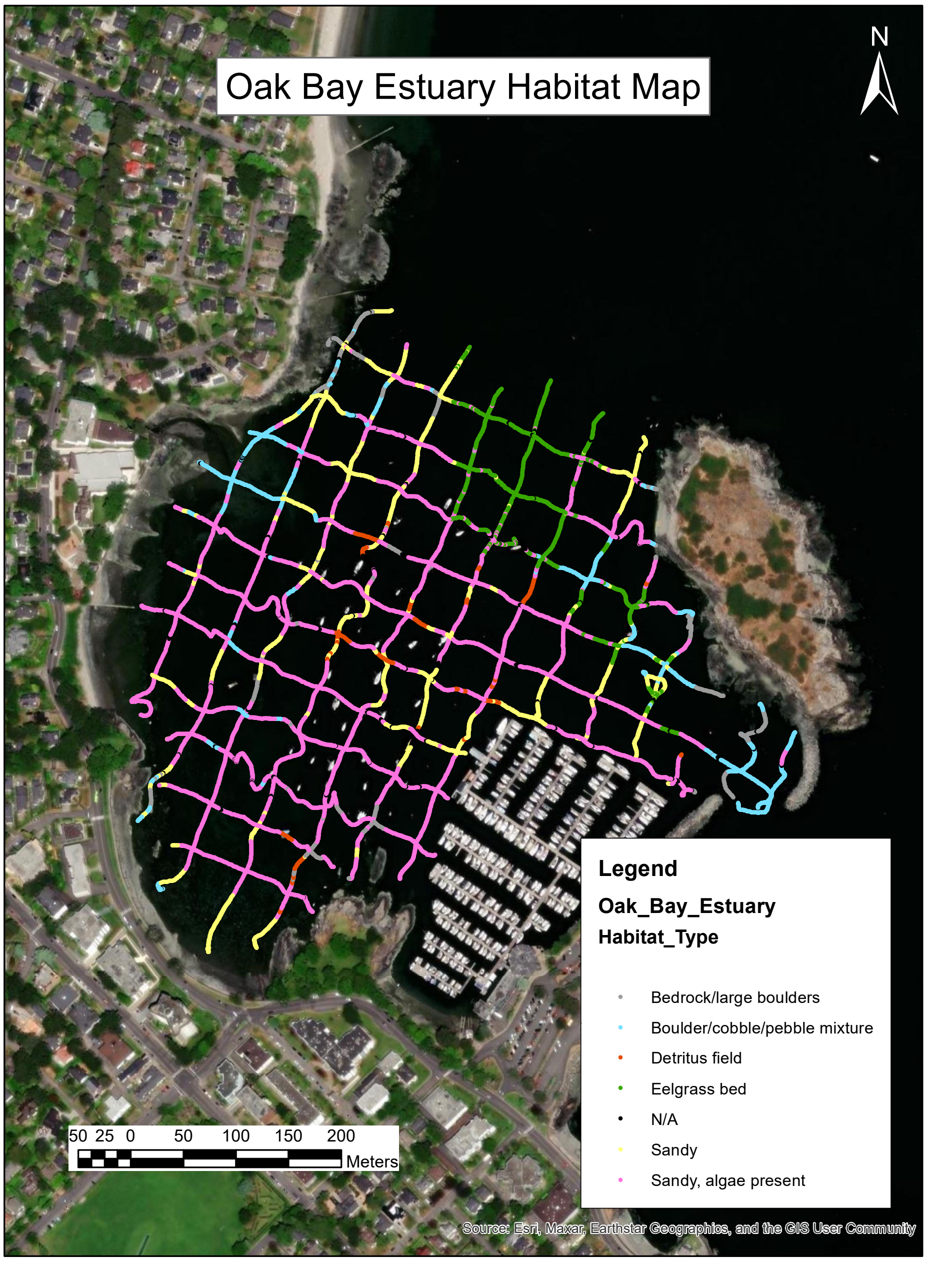
Debris points from sidescanning. One-hundred fifty-six items (some of them are clusters, some are large like boats). This does not include the boats that are sticking out from the water (two as of October 2023). There was no scanning in the marina.

Interpretation: There is good evidence that cleanup is necessary here. The debris is spread around the subtidal region with soft sediment: areas that do not show debris are in the “waterway” along Mary Tod Island, and near a rocky mound (with marker sign) where boats do not anchor. The raw data of the sizes and shapes of the objects tell us that on top of the two boats with masts poking out of the water, there are at least three others on the seafloor. There is also two what have been tentatively identified as mooring blocks which are not attached to buoys.

Site Survey: January/February 2024

Boat: Klanawa **Crew:** Captain: Jamie Smith; Science Officer: Thomas Armitage **Weather:** Cloudy and cold **Measurements:** Tow camera recording

Habitat Diversity



Interpretation: There is a bed of eelgrass along the west side Mary Island, specifically in the region that is the “throughfare” and boats are not allowed to anchor or moor. The remaining soft-sediment area is bare of eelgrass but with “algae present”. The mappers did not differentiate between different photosynthetic species and upon looking at the video, it is often the unidentified diatom or bacterial mat with occasional *Graciliaria* sp. or *Ulva* tufts. This leads me to think that the area is a potential site of eelgrass growth, but the long-term damage from boat anchors and mooring has caused sediment disturbance and/or uprooting of the eelgrass itself.

Overall Interpretation

There is a fair amount of water exchange in the bay that would make this area a good candidate for restoration and conservation actions. Debris removal is first and foremost, as well as education and outreach about trash removal and what to do with derelict boats. We observed anchoring and even a sunken vessel in the eelgrass beds, so, with debris removal, there may need to be a recovery in the form of eelgrass transplants in the bare sites. Further, to prevent future damage, buoys which alert anchoring vessels to the presence of eelgrass beds and biologically sensitive areas. For the long-term mooring vessels, outreach and education about anchoring and potentially offering mid-line buoys or requesting they anchor in less environmentally sensitive areas.

I do have two concerns: 1. I have a poor prognosis for the long-term effects of sea level rise on the eelgrass beds due to shoreline armouring, and 2. The urbanisation of the watershed and the artificial flow of the water along Bowker Creek. We are privileged that sea level rise from climate change will be moderate relative to other regions in the Pacific Ocean. However, this doesn’t account for storms surges and extreme weather events. There has been no statistical model done on predicted storm and sea level rise on Oak Bay, so the damages from these can only be speculated. The shoreline has extensive development, including old (potentially heritage) buildings, schools, and seawall. There is very little soft sediment beach before the road and buildings (paved surfaces). This is a perfect example of shoreline squeeze: the eelgrass cannot migrate towards land when sea levels rise. In my estimation, the likelihood of removing shoreline modifications is low. However, other modifications can be beneficial in the case of storm surges and wave action: the marina and breakwater may shelter the bay, but at the expense of losing area to modifications. The presence of Mary Tod Island also acts as a wave break.

Luckily, the breakwater, marina, and anchored vessels have not resulted in high levels of faecal bacteria. In August, the South End of Willows Beach (adjacent to Oak Bay) was closed for contamination issues: 4400 CFU/100mL, whereas at the end of July, it was 20 and one week after the August reading, it was less than 5 CFU/mL (NB 35 CFU/100mL is the maximum allowable reading before it is not recommended for seawater sporting activities).

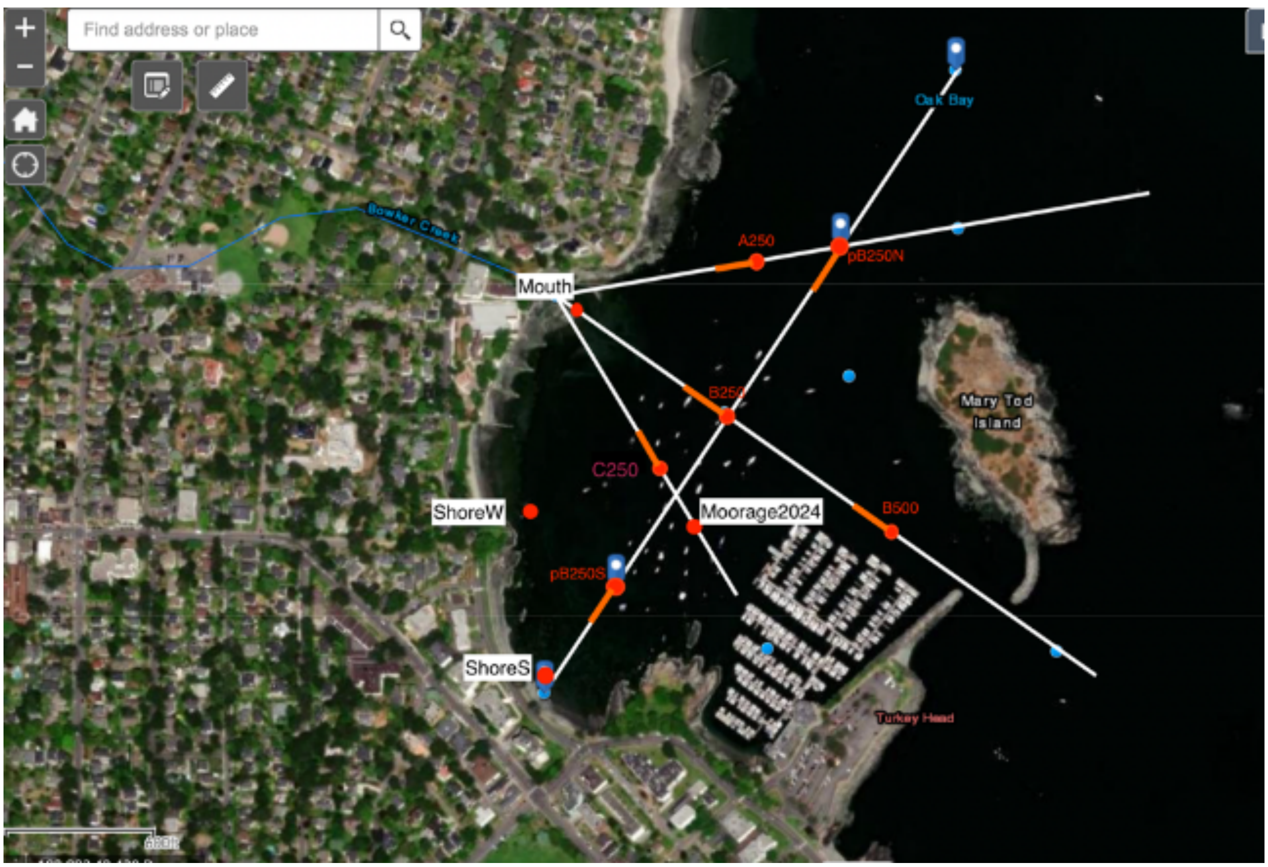
Considering the previously measured eelgrass bed and the eelgrass that is still present in this region, the mild water stratification, the interest in conservation from the local community, the number of fish and invertebrate species, the low levels of faecal bacteria, and the relatively low amount of *Ulva lactuca*, I recommend that we implement restoration and conservation actions in Oak Bay.

Future Work

With the previous closure of Willows Beach, adjacent to Oak Bay, due to high bacterial contamination, repeated testing during off-season (when the CRD is not testing regularly and targeted) may provide us with a source of bacterial contamination (live-aboard boats, land, etc.) and prevalence throughout the year. We would like to resample at the previous sampling locations at different times of year to see the seasonal changes, and targeted bacterial and nutrient sampling to address the sources of pollutants. Followed by testing of heavy metals at the regions of outflow, to identify any urban contamination to the bay.

As for the debris, education and awareness of the trash problem in Oak Bay is essential. Marina events with photos of the debris will highlight this immense issue. Also, providing resources for boaters who want to do the right thing.

Bacterial sampling: Mouth, ShoreW, ShoreS, Moorage2024, B250*, (pB250S*)



Support

We will not proceed without verbal or written consent from the Songhees First Nation and relevant residential and business committees. Operations of any kind will cease if we are not supported by relevant local organisations. We have support from the Oak Bay Marina (Oak Bay Marine Group) and the Friends of Bowker Creek. We had verbal support from the Songhees Marine Conservation Management and the Oak Bay Marina. We communicated our intent to remove debris to the Municipality and they have provided support in the form of permits for parking and holding the bin and excavator at Cattle Point.

Appendix E: Portage Inlet Site Report (October)

Brief Background Information

Portage Inlet is the traditional territory of the SENCOTEN/Machosen/Lekwungen/Semiahmoo/ T'Souke peoples. It was a traditional hunting and harvesting area and is currently stewarded by the Songhees and Esquimalt FNs and the W̱SÁNEĆ Marine Guardians. The area has been known to host herring spawns and salmon.

Portage Inlet is the furthest estuary region along the 8.5 km Gorge Waterway from the Juan de Fuca Strait. It is extremely enclosed, especially compared to other urban estuaries in the region with three main freshwater inputs, as described in the watershed map from the CRD: Craigflower Creek (Tansect B), Colquitz River (Transect C), and Hospital Creek (Transect A). The area surrounding the inlet also includes land that drains directly into the inlet. The overall watershed area for Portage Inlet is c. 76 km^2. The Craigflower Creek watershed is 2420 ha, Colquitz River is 4960 ha, and Hospital Creek is 242 ha. The large watersheds flow through rivers and lakes and forested areas, but also highly urbanised areas. This makes identifying point sources of pollution a challenge.

Industry is no longer the first source of pollution in the Gorge since the last sawmill closed in 1989. Now, the pollution sources are mostly surface run-off from the surrounding paved urban areas. Further, the high population of waterfowl, predominantly Canada Geese (non-migratory) will add to the pollution and the degradation of the plant life that provides filtration from land run-off.

Since the 1990s, the Gorge Waterway Initiative and the Veins of Life Watershed Society (along with the Peninsula Stream Society, PSS) have been working on clean-up in the gorge.

The waterway narrows and there are areas where boats cannot traverse because of low clearance. This limits the amount of boat traffic and will hopefully reduce any impact that liveaboards or transient boaters may cause. There is high goose traffic in the area, and the Peninsula Streams Society (PSS) and Guardians of Our Salish Estuaries (GoOSE) have worked in partnership to build Canada Goose exclusion areas and plant indigenous plants. More information on goose presence in Portage Inlet is available from the Capital Regional District: https://www.crd.bc.ca/education/concerns/regional-goose-management . Previous and ongoing water quality measurements are available online from the Vancouver Island Health Authority: https://inspections.myhealthdepartment.com/island-health/program-water-sample .

Site Survey: November 15, 2023

Boat: Klanawa
Crew: Jamie Smith (captain), Justin Lisaingo (science), Justin Bland (diver), Viki Kolatkova (diver)
Weather: Overcast, calm; 8°C (previous 2 weeks had 74.2 mm precipitation as measured at the Esquimalt Harbour station, according to Environment Canada)
Measurements: Bacteria content, Salinity, Temperature, Dissolved Oxygen, Percent O_2, Turbidity, Zooplankton tows, Biodiversity surveys.

Shoreline Observations

- Composition: mostly bedrock with riprap to the N; treeline mostly sparse
- Colqurtz Creek flows into PI is salmon-bearing; fish fence upstream
- ~200 seabirds: 50% gulls
- Many houses surround the shore, most with a dock or ramp into the water
- 3 Moored watercrafts
- Highway at N side, paved pedestrian walkway all around
- Some large, floating logs
- World Fisheries Trust and Peninsula Streams Society have been active here
- (Access to PI from Vic Harbour: 45 mins and the Klanawa had a 4-5 foot clearance at Admirals Bridge)
- Craigflower Creek saltmarsh at View Royal Park (Western influx of freshwater, transect B)
- Hospital Creek freshwater influx at Helmecken Park (Northern influx of freshwater, transect A)
- Colquitz Creek freshwater influx (Eastern influx of freshwater, transect C)
- A250 and B1000 are the closest sites to the smaller freshwater input from Hospital Creek

Sampling Locations

Red dots= site locations
Orange lines= Biodiversity transect lines

LOCATION			
	A250*	48.4617	123.4246
	A500*	48.4617	123.4213
	A750	48.4616	123.4178
	B250*	48.45726	123.42753
	B500*	48.459	123.426
	B750	48.461	123.424
	B1000*	48.463	123.422
	C250*	48.4603	123.4146
	C500*	48.4609	123.4178
	C1000	48.4624	123.4242
	**Zoop1	48.45977	123.41418
	**Zoop2	48.46141	123.42263
	A250*	48.4617	123.4246
	A500*	48.4617	123.4213

*Indicate sites where we did our sampling

**Zoop = Location of Zooplankton tows

Zooplankton Tows

Tow #	Length of tow (m)	Tow speed (knots)	Depth of net bottom (-m)	Time	Water Depth (-m)	Bottle ID	Preserved with Formalin (Y/N)	Notes
1	50	0.5	1.5	12:45	2.8	PI WSP 1	Y	Sampled in mud/ eelgrass; No pre-screening of samples before sending to Biologica
2	50	0.5	1.5	13:05	2.4	PI WSP 1	Y	Sampled in eelgrass; No pre-screening of samples before sending to Biologica

Interpretation: Samples at Biologica Inc for identification.

Bacterial Sampling

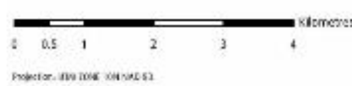
Site	Faecal coliforms (CFU/100mL)*	*Enterococcus* spp. (CFU/100mL)
A250	9	12
A500	14	10
B250	68	68
B500	29	46
B1000	8	22
C250	49	53
C500	16	11

*CFU = Colony Forming Unit

NB: Reportable Detection Limit (RDL) = 1 CFU/100mL

NB: Health Canada limit for safe water for activity is 35 CFU/100mL *Enterococcus* spp.

Interpretation: The high levels of faecal bacteria at the mouth of Craigflower Creek and Colquitz Creek requires follow-up to properly determine the source and whether it is seasonal. Both the Craigflower and Colquitz Creeks have large watersheds (and highly urban in the case of the Colquitz), compared to the smaller watershed for Hospital Creek. This may be the reason we see such different samples at the 3 creek mouths. Each creek has a park near its mouth, but a small one at Hospital Creek. Restoration of the parks at the creek mouths could provide filtration.



(estimated scale)

NB: The areas in yellow drain directly into the ocean

Nutrient Sampling

Site	Nitrate (NO_3) ppm	Phosphate (PO_4) ppm	Nitrate (NO_3) µmol/L, µM	Phosphate (PO_4) µmol/L, µM
A250	0.14	0.25	2.26	2.63
A500	0.14	0.33	2.26	3.47
B250	0.15	0.38	2.42	4.00
B500	0.11	0.30	1.77	3.16
B1000	0.03	0.36	0.48	3.79
C250	0.13	0.31	2.10	3.26
C500	0.17	0.38	2.74	4.00

Interpretation: Our results are surprisingly high (usually <0.7-1.5 μM, Portage Inlet is 2.6-4.0 μM), however when you consider that one of the top sources of phosphate pollution is "waterfowl waste" and plant decomposition (New Hampshire Environmental Agency), we may be seeing the effects of high goose population in and low water exchange.

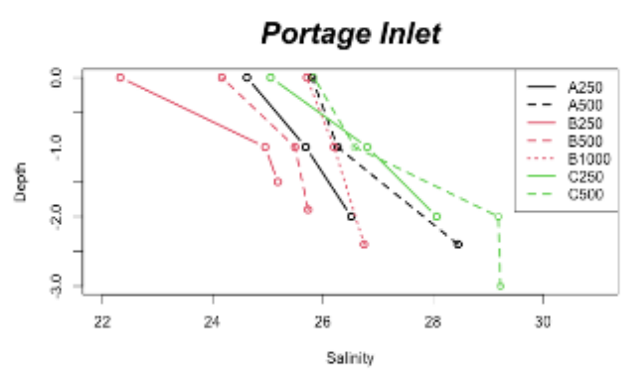
This would lead us to consider the sources of nitrate and phosphate and their seasonality and link it to the presence and abundance of waterfowl in the inlet.

Turbidity

Site	Site Depth (m)	Secchi Depth (m)
A250	-2	Bottom
A500	-2.4	-2.0
B250	-1.5	Bottom
B500	-1.9	Bottom
B1000	-2.4	Bottom
C250	-2.1	Bottom
C500	-3.0	Bottom

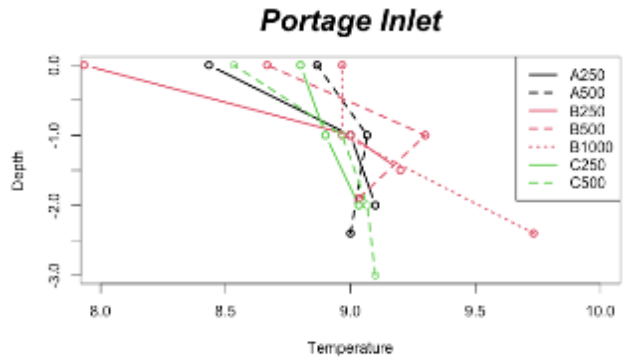
Interpretation: Very shallow inlet, therefore difficult to compare turbidity and to determine whether the turbidity is low or high. However, there is surprisingly low visibility at A500 (2.0 m) given the time of year. This coincides with the low nitrate (being used by phytoplankton).

Salinity



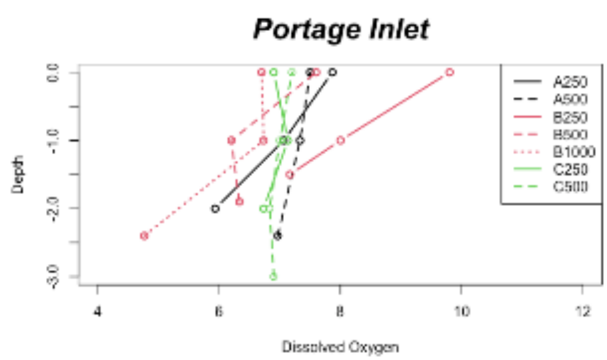
Interpretation: Clear evidence of previous days' rain. Salinity at depth is low for seawater, showing this to be a less saline inlet (low ocean/tidal influence) and likely low mixing (low "flushing").

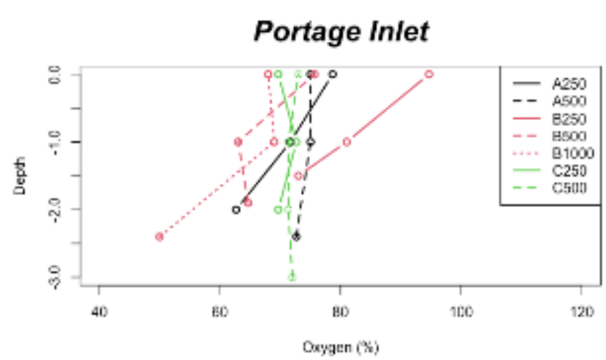
Temperature



Interpretation: Evidence of cooler surface water compared to water at depth; this is strongly seen in B250, B1000, and to a lesser extent A250. There is a huge amount of stratification in some locations, likely corresponding to the salinity differences (the cooler, fresher water brought into the inlet from the creeks). The stratification is not surprising considering the sheltered nature of the inlet and the density differences between fresh and salt water. However, the warmer water is likely to want to rise, so there are countering influences of temperature and salinity that may lead to mixing once the strength of the temperature gradient increases. We added an analysis comparing the salinity and temperature at the end of the report.

Oxygen

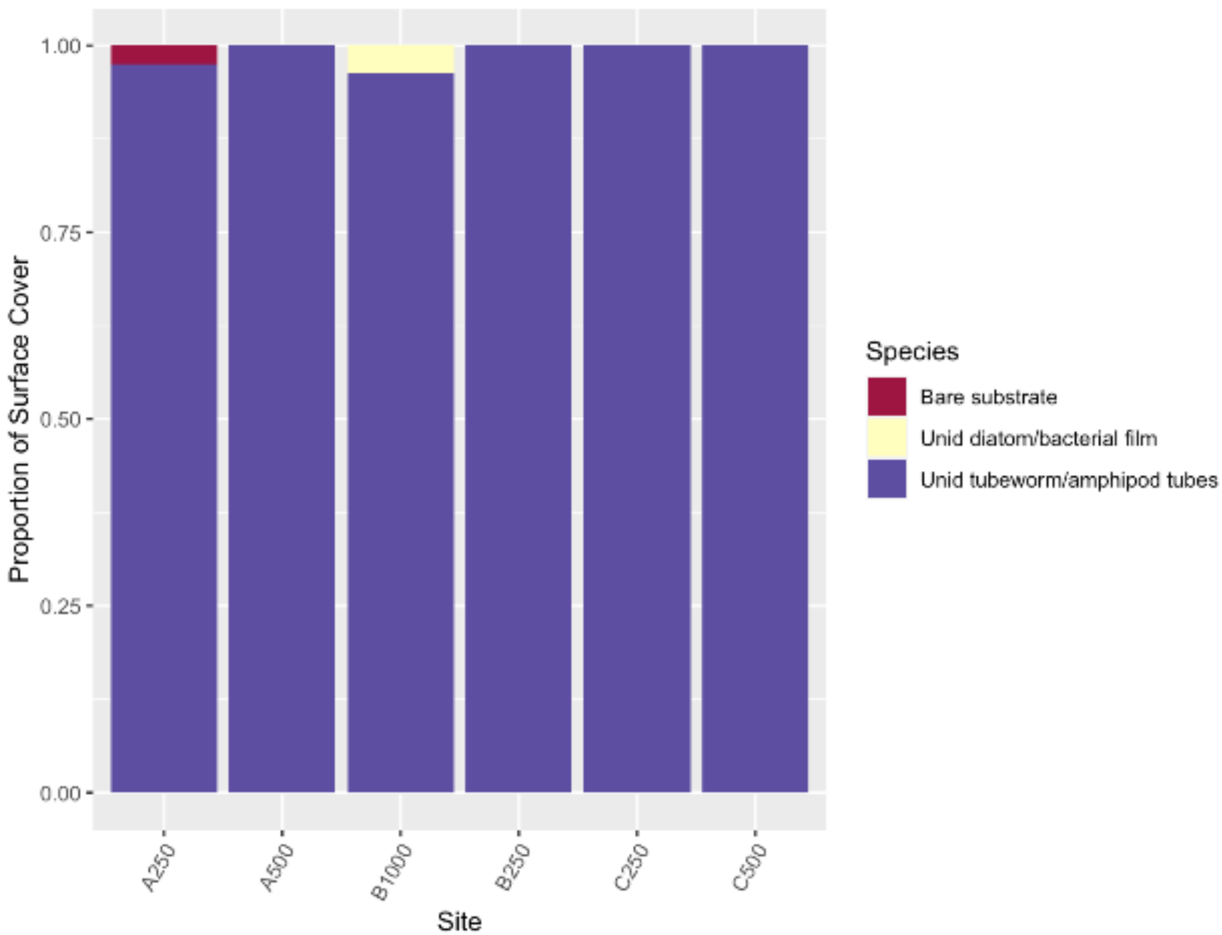




Interpretation: Generally, the normal dissolved oxygen levels for enclosed estuaries is 3-8 mg/L (see IUCN). Our values fit within those ranges, even at depth. There are some large decreases in dissolved O_2 with depth in A250, B1000, and B250 (however B250 started very high on the surface, and the decrease by depth could be from a recent input of highly oxygenated freshwater). The same could be said for A250, as it is a gradual decrease in DO with depth. However, B1000 has a sharp decrease between -1.0m and -2.0m, but it is stable between the surface and -1.0m. The biodiversity and tow camera work will investigate whether the region shows any evidence of low oxygen (not hypoxia, which is much lower at <1 mg/L DO).

Biodiversity: Ground Cover by Site

The stacked barplots are a sum of the four 25 cm^2 quadrats.



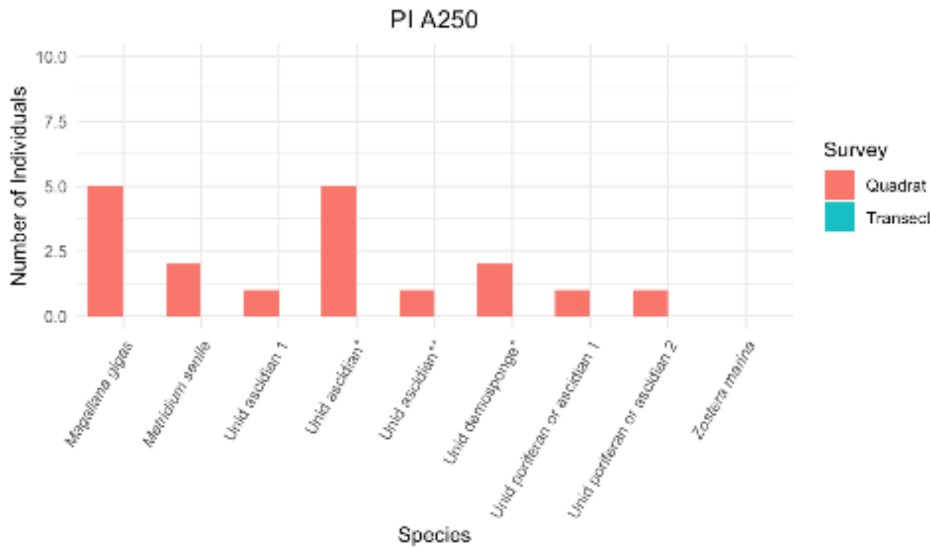
NB: *Zostera marina* was measured as individual shoots, not by percent cover.

Interpretation: The photosynthetic species in the inlet are only diatom or bacterial film and *Zostera marina*. Mapping will be able to tell us more about the extent of the eelgrass beds. The unidentified tube-building animals are abundant throughout the soft sediment. We have reached out to the Royal BC Museum for help with identification and will reach out to other underwater biodiversity experts. This species is so prevalent, it will be important to identify it and learn of its tolerances and ecology. All species, common names, and brief information are in Appendix H.

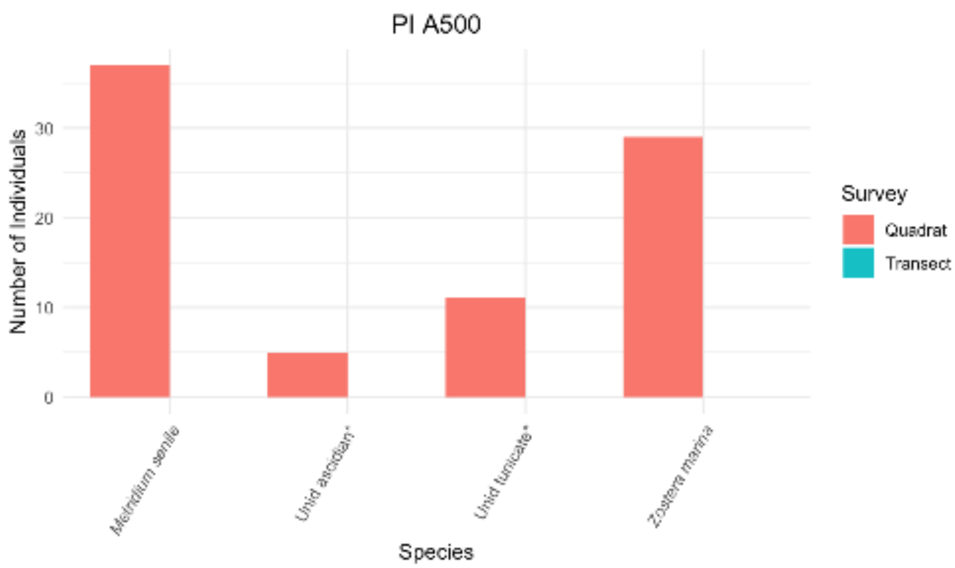
Biodiversity: Abundance by Site

***Anim*al and Algae (by quantity)**

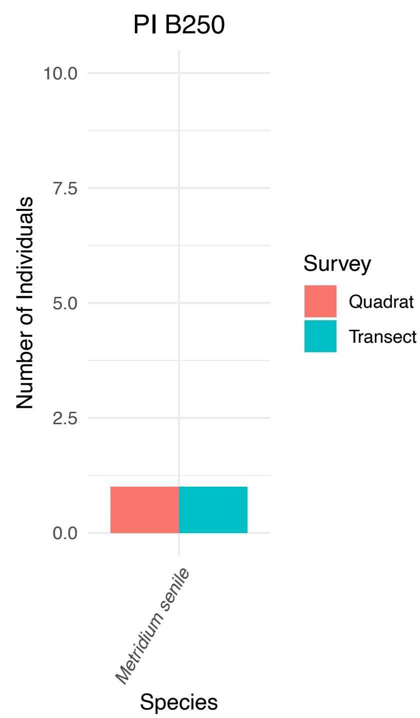
NB: Vertical axes differ among charts.

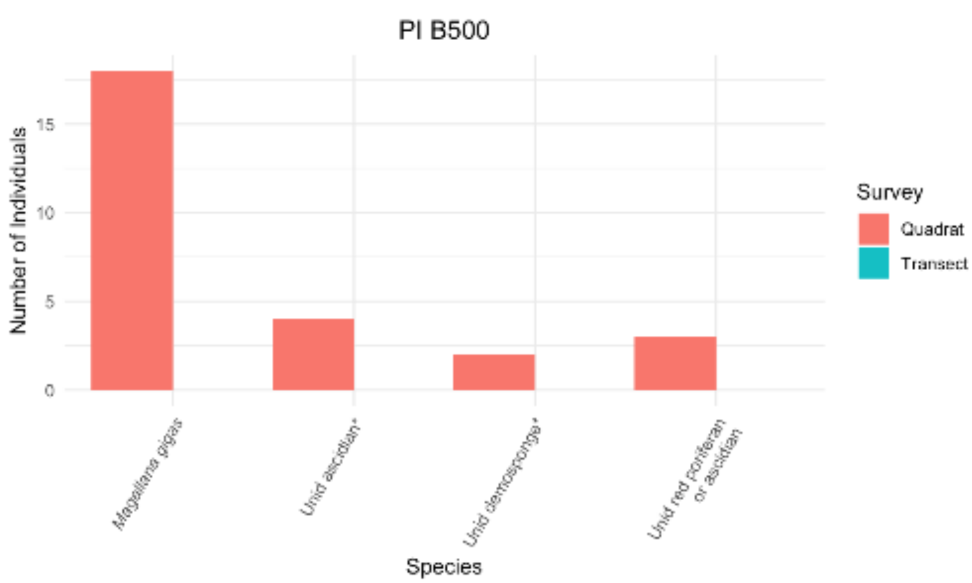


Unid ascidian* likely *Botrylloides violaceus*
Unid ascidian** likely *Botryllus schlosseri*
Unid demosponge* likely *Halichondria* sp.

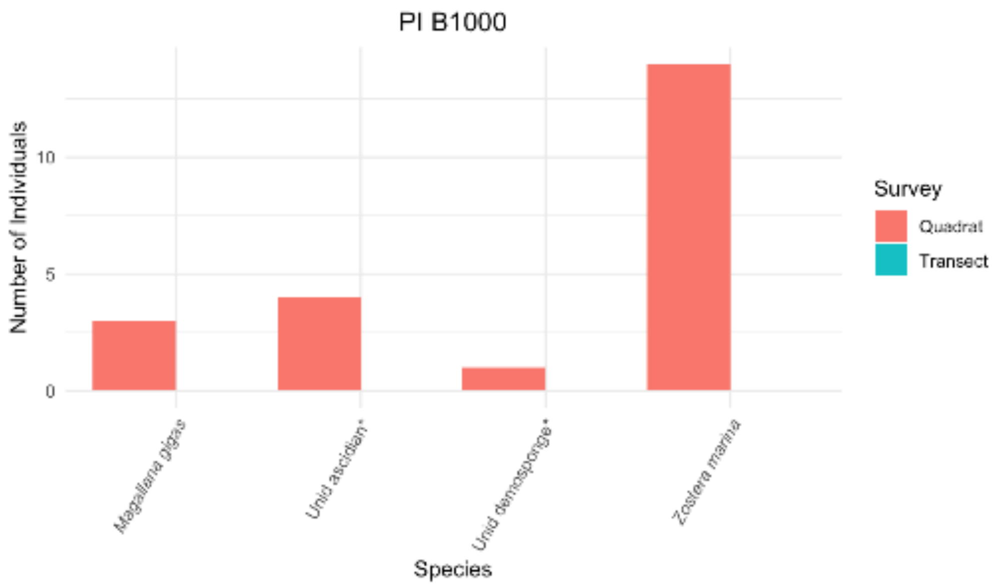


Unid ascidian* likely *Botrylloides violaceus*
Unid tunicate* likely *Molgula manhattensis* or *Ascidiella aspersa* (introduced)

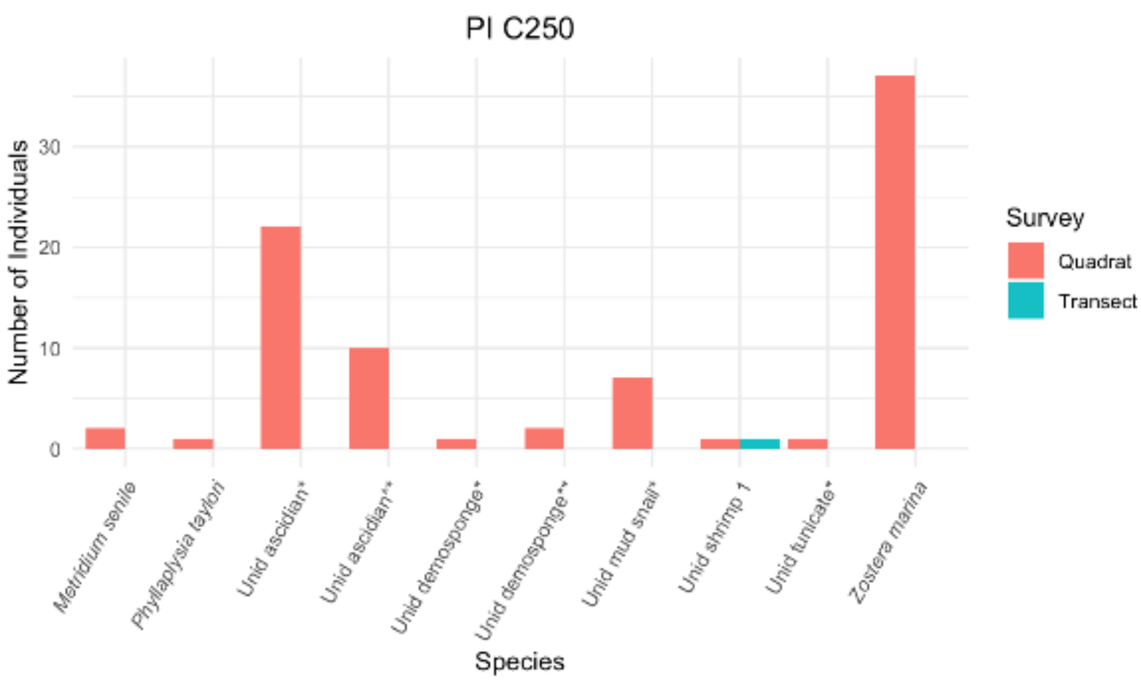




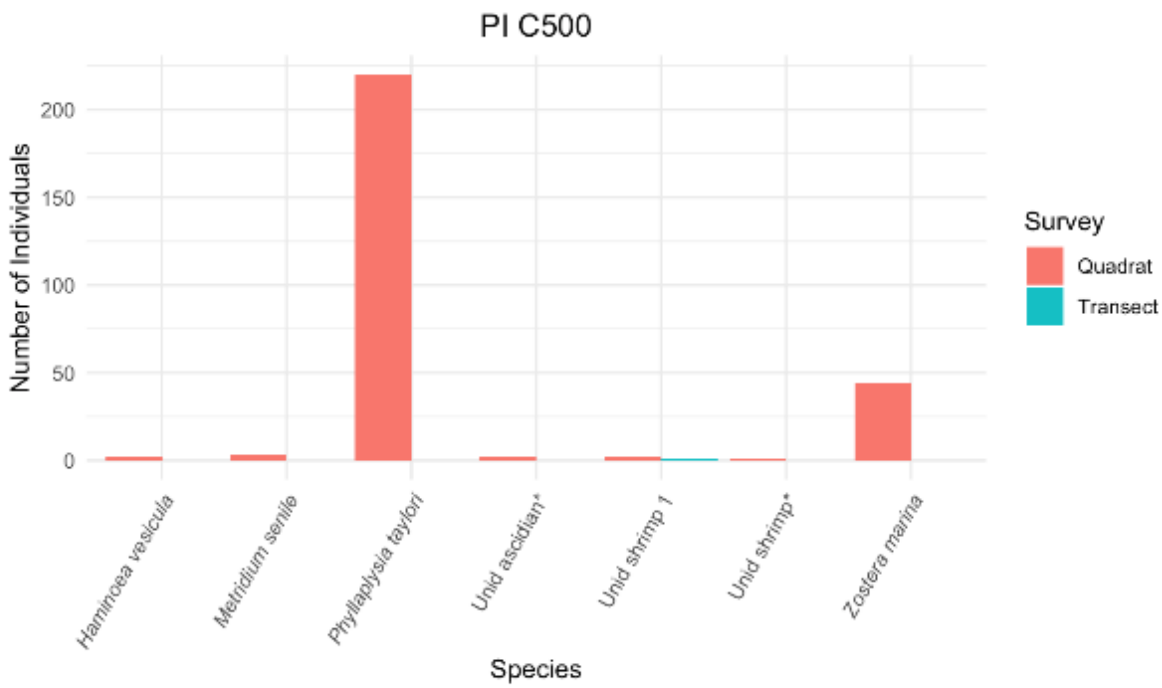
Unid ascidian* likely *Botrylloides violaceus*
Unid demosponge* likely *Halichondria* sp.



Unid ascidian* likely *Botryllus schlosseri*
Unid demosponge* likely *Halichondria* sp.



Unid ascidian* likely *Botrylloides violaceus*
Unid ascidian** likely *Botryllus schlosseri*
Unid demosponge* likely *Halichondria* sp.
Unid demosponge** likely *Suberites* sp.
Unid mud snail* likely *Batilaria cumingi* or *B. attramentaria*
Unid tunicate* likely *Molgula manhattensis* or *Ascidiella aspersa* (introduced)



Unid ascidian* likely *Botrylloides violaceus*
Unid shrimp* likely *Heptacarpus sitchensis*

NB: For values >10, the number is most likely estimated.

Interpretation: *Zostera marina* present throughout the inlet, with *many* eelgrass sea slugs (anecdotally, 100s). However, there were lots of invasive ascidian species and other tunicates. With the heavy abundance of invasive species, these is concern about the displacement of indigenous species not to mention the impact of ascidians on docks and boats. Since the area is not heavily used by people, the real concern may be that this area is a great source of ascidian (and mollusc) planktonic larvae/tadpoles. Here the low exchange of water from the ocean sea (or the strait) is a positive effect. Although it is not the season, the inlet has historically been the source of forage fish, which were not seen.

All species, common names, and brief information are in Appendix H.

Biodiversity Calculations

Richness: Number of species from abundance survey and not percent cover.

Simpson's Biodiversity Index: Calculated based on the number of species and their relative abundances. Values range from 0 – 1, where higher values mean lower biodiversity. Simpson's Index is from abundance surveys and not percent cover.

Fisher's Alpha: A logarithmic calculation because of the inherent differences between the abundances of each species: some species are found in groups *vs* rarer or individual. A higher Fisher's alpha results from higher biodiversity.

Site	Richness (Q)	Richness (T)	Richness (Q & T)	Simpson's Index (Q)	Simpson's Index (T)	Simpson's Index (Q & T)	Fisher's Alpha (Q)	Fisher's Alpha (T)	Fisher's Alpha (Q & T)
A250	10	0	10	0.8103	**NA**	0.8103	4.4706	0	4.470633
A500	6	0	6	0.6576	**NA**	0.6576	0.8801	0	0.8800582
B250	2	1	2	0.0000	0*	1	13421777**	134217777**	0.7959049
B500	5	0	5	0.5356	**NA**	0.5356	1.2978	0	1.297815
B1000	8	0	8	0.5671	**NA**	0.5671	1.4307	0	1.430653
C250	12	1	12	0.7232	0*	0.7297	2.9577	134217777**	2.943745
C500	8	1	8	0.3304	0*	0.3353	1.3087	134217777**	1.307599
All	22	2	22	0.7955	1	0.7385	9.7719	536870956**	3.366113

Q = from quadrat surveys, T = from transect surveys, Q & T = from a combination of both quadrat and transect surveys

*too few species to calculate Simpson's Biodiversity Index

**too few species that the Fisher's Alpha; value is arbitrarily high or unable to calculate

NA: not enough species in the abundance surveys (Richness may include species from percent cover survey)

Marine Debris

No scan conducted as this area is not a highly used boating area and our focus at this part of the Gorge Waterway will not involve debris removal.

Habitat Diversity

Processing in progress.

Overall Interpretation

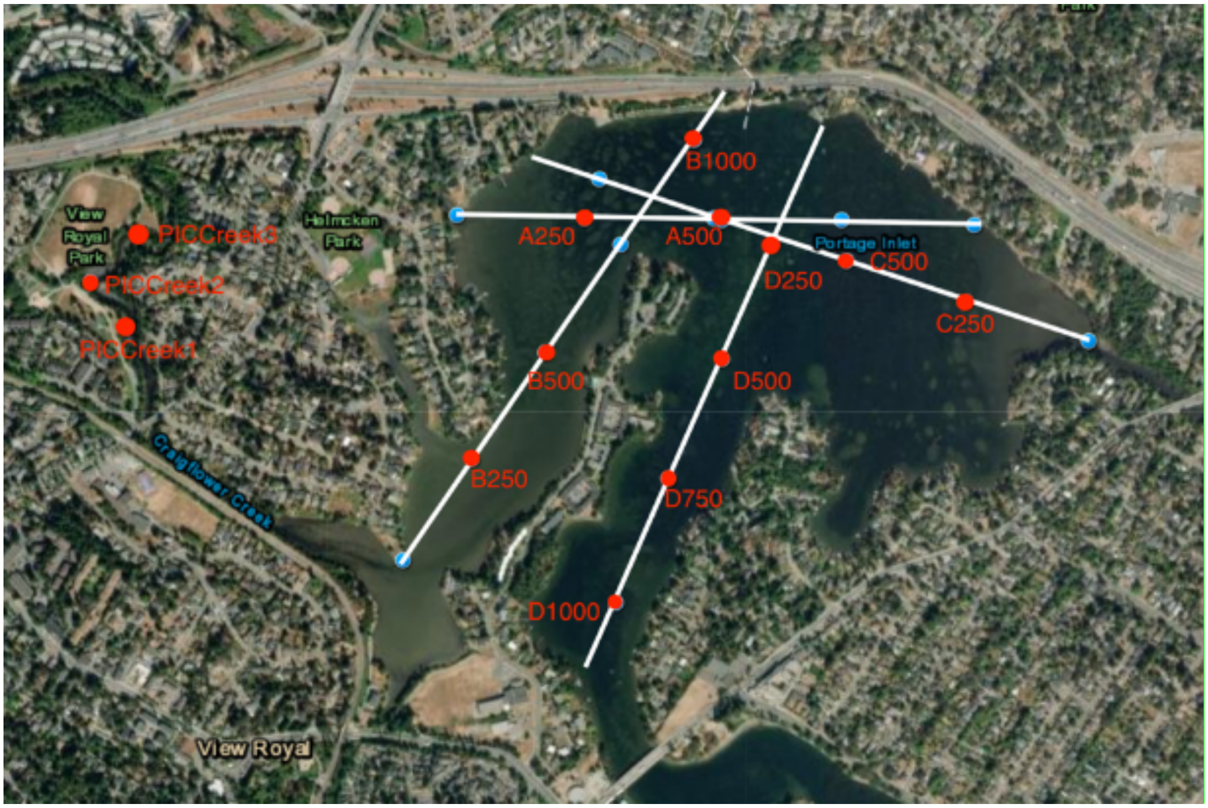
There is very little mixing and flushing in the inlet, along with high freshwater input influence. I would suspect that any issues with the inlet's water would be derived from land and with lack of filtration by adequate plant life (which continues to be decimated by the resident Canada geese), will continue to be a problem unless extreme measures are taken. The best we can do in the meantime is express what conditions Partage Inlet is relegated to under "business as usual".

Some help can occur with increased plant life and improved soil for percolation along the rivers and at their mouths. PSS has begun replanting the site with indigenous species and building waddling fences to exclude Canada geese herbivory. Further study on the type of soil deposition required to ensure the continuation of plant life will be required, along with expanding the exclusion zones and reducing impact from dogs and walkers in the sensitive replanting region. Ideally, an expanded planting area would be beneficial, as well as planting in the regions that have direct drainage from the shore.

Long-term help would include tracing the sources of the bacterial contamination. There is the possibility that the faecal contamination is not from the watersheds but from geese. This will have to be investigated. There is some idea of population control in other regions, however the idea may be unpopular. Tracing any contamination will also include identifying point-source pollution from local septic tanks.

Future Work

We will resample to locate the bacterial and nutrient sources up Craigflower Creek and Colquitz River, and further along to Gorge Waterway, where the water has greater exchange from the ocean. We will also follow up research with an eDNA approach and online research into current fish use in the area. Lastly, sediment salinity and grain composition will tell us whether the planting will require an input of new sediment. See future sampling sites in the figure below.



Future Sampling Sites:

Site	Salinity, Temperature, Oxygen	Nitrate and Phosphate	Bacterial Content	eDNA sampling+
A250**	Y		Y	
A500**	Y	Y		
B250**	Y	Y	Y	
B500**		Y		
B1000**	Y			
C250**	Y	Y	Y	
C500**	Y			
D250	Y			
D500	Y	Y	Y	
D750	Y			
D1000	Y	Y	Y	
PICCreek 1*	Y	Y	Y	
PICCreek 2*	Y	Y	Y	
PICCreek 3*	Y	Y	Y	

*Sampling from land

**Repeated sampling location

+If possible

Sediment sampling for Salinity and grain size:

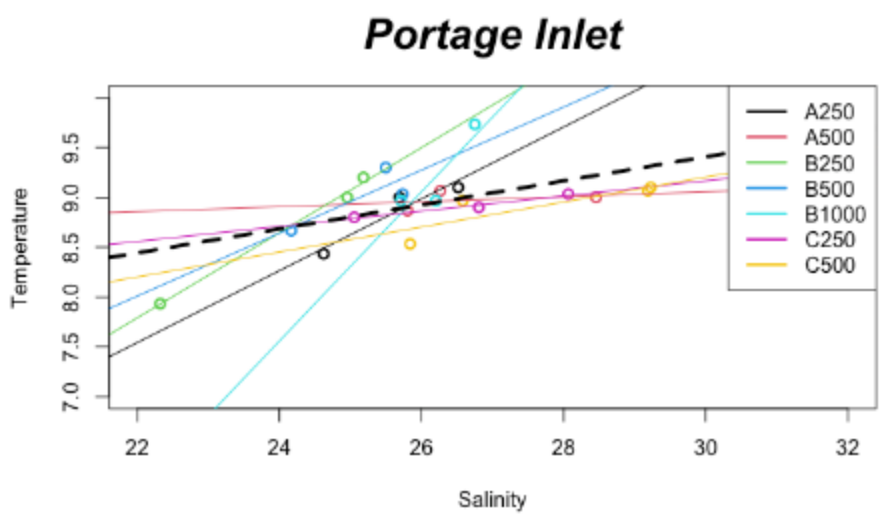
TBD

Other considerations: forage fish (herring especially) and salmon detection through observations and/or eDNA. (addition from 14 March 2024: herring do not appear to be returning. There is a Herring event hosted and for the Songhees on the 23rd of March).

Support

We will not proceed without verbal or written consent from the Songhees First Nation and relevant residential and business committees. Operations of any kind will cease if we are not supported by relevant local organisations.

Relationship between Temperature and Salinity



The mean salinity and temperature at the surface, at -1m and -2m (and -3m for C500 only). The csolid lines are the regression lines for each site; the black dashed line is the regression line for all the data points.

R-squared values (mean values):

	Multi R-sq	Adjust R-sq	F-stat	DFs	p
A250	0.9063**	0.8127	9.678	1,1	0.198
A500	0.1204	-0.7592	0.1369	1,1	0.7744
B250	0.9943**	0.9886	174.8	1,1	0.04806*
B500	0.7058**	0.4116	2.399	1,1	0.365
B1000	0.7752**	0.5504	3.448	1,1	0.3145
C250	0.9692**	0.9383	31.42	1,1	0.1124
C500	0.7072**	0.5608	4.831	1,1	0.159
Overall	0.3195	0.2855	9.389	1,20	0.006121*

*statistically significant with alpha = 0.05

**regression line highly represents the data

Interpretation: The regression lines show that even though there are very strong regression line fits for A250, B250, C250, and strong fits for B500, B1000, and C500, only site B250 has a significant relationship between the salinity and temperature.

There is a strong relationship resulting in the regression line “Overall”, the best-fit line poorly reflects the data.

R-squared values (not on the means, differs from the plot):

	Multi R-sq	Adjust R-sq	F-stat	DFs	p
A250	0.7147**	0.6739	17.53	1,7	0.0041*
A500	0.0739	-0.05833	0.5591	1,7	0.479
B250	0.8636**	0.8408	37.98	1,6	0.0008*
B500	0.5155	0.443	7.448	1,7	0.02938*
B1000	0.6324	0.5798	12.04	1,7	0.01041*
C250	0.5878	0.5289	9.983	1,7	0.01594*
C500	0.4098	0.3508	6.945	1,10	0.0249*
Overall	0.2848	0.2734	25.08	1,63	<0.0001*

*statistically significant with alpha = 0.05

**regression line highly represents the data

Interpretation: When all the data points within each site are considered, most sites have a regression line that is significantly different from zero (meaning that there is a relationship between temperature and salinity, as long as the data fit the regression line to an acceptable amount). The regression line for A500 does not differ from zero and therefore there is no relationship between salinity and temperature at that site.

Generally, the closer to 1 the R-squared value, the more the line represents the data. A250 and B250 are quite high, and B500, B1000, and C250 are acceptable amounts for many studies.

But considering we are dealing with abiotic and physical processes; we would expect the data to be represented by a high R-squared regression line (>0.7). We may be seeing low R-squared values because the data are for multiple depths at each site: the data may fit for the upper water layers vs the lower ones.

Overall, salinity and temperature are correlated in A250 and B250, the sites closest to the mouths of the rivers with larger watersheds.

Appendix F: Saanichton Bay Site Report (October)

Site Survey, August 23, 2023

Boat: Klanawa **Crew:** Jamie Smith; Laís Chaves, Neil Fowler, Susan Anthony **Weather:** Overcast, no wind; wind and chop picking up at 13:50; Air temperature cool and mild (approx. 20°C) **Measurements:** Zooplankton tows, (Phytoplankton water sampling and tows by Laís C and Neil F), Salinity, Temperature, Oxygen; Preliminary debris scanning to demonstrate

Shoreline Observations

- Soft sediment, salt marsh/tidal marsh, rock
- Houses with lots of trees
- Seals, seagulls, cormorants on the barge, lots of geese by marsh
- Large barge moored on industrial mooring buoy; other industrial mooring buoys made from oil or water tanks; small dock/barge attached to one
- Have been told by residents that there are sunken boats
- 5 mooring buoys in total; 2 boats currently moored
- On NW, public wharf (James Island Wharf)
- SE spit has the tidal marsh
- 2 freshwater inputs: one large on the W side (Tetayut), other with a flapgate to prevent salt water into the salt marsh; falpgate is under a road that runs over the river/tidal flat interface (gate is going to be replaced early Sept)
- lots of rip rap/potentially seawall; corrugated seawall.

Zooplankton Tows

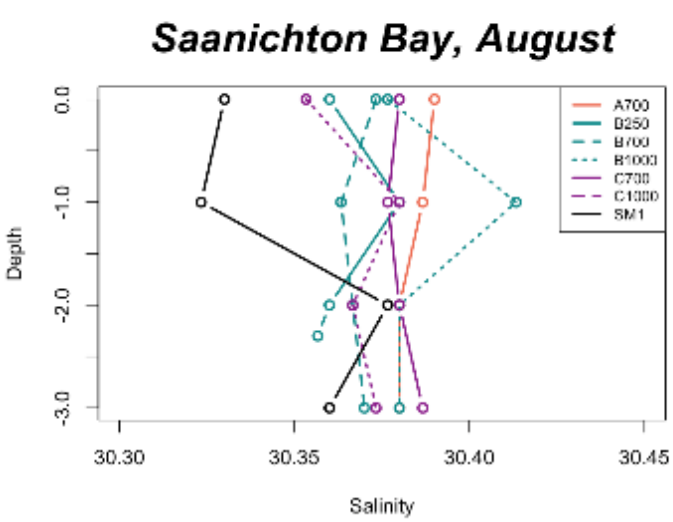
Tow #	Length of tow (m)	Depth of net bottom (-m)	Time	Water Depth (-m)	Bottle ID	Preserved with Formalin (Y/N)	Notes
1	50m	Surface	48.59338	123.37817	SM 1	Y	
2	50m	Surface	48.59700	123.38846	SB MOUTH 1	Y	

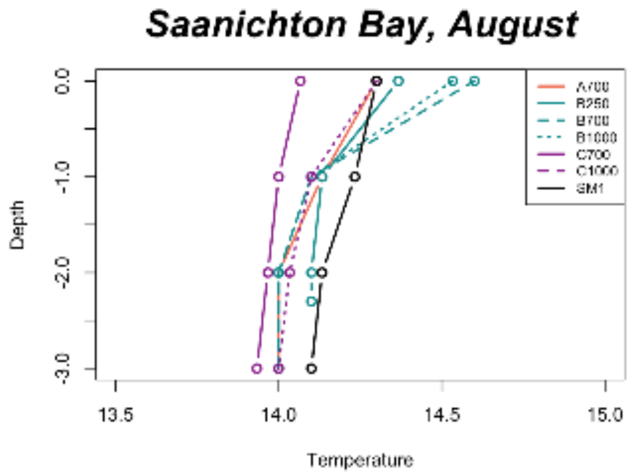
Interpretation: Samples at Biologica Inc for identification.

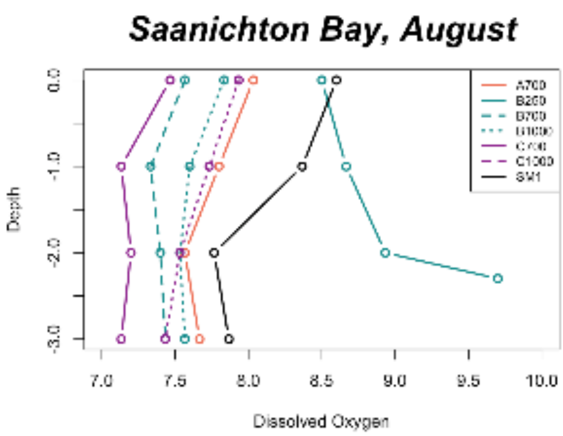
Preliminary Thoughts:

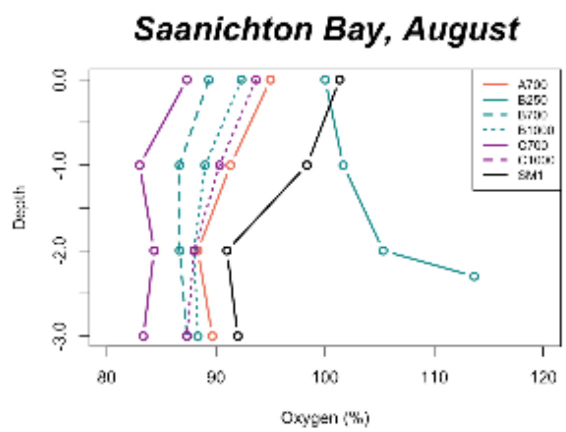
- The small amount of scanning shows the presence of some debris; therefore removal is warranted.
- The question arises about the use of large moorings and the occurrence of log booms and their effects on the estuary ecosystem; further knowledge of the harvesting and economic uses of the bay will better inform any other restoration and conservation actions.
- The presence of eelgrass and mooring buoys may allow for the possibility of eelgrass protection zones and installation of mid-line buoys.
- The use of the area by people (especially at James Island Wharf) gives an opportunity for educational signage.
- The future actions will be led by the Tsawout First Nation (Fisheries, IPCA) and we can support their efforts

Abiotic Water Features









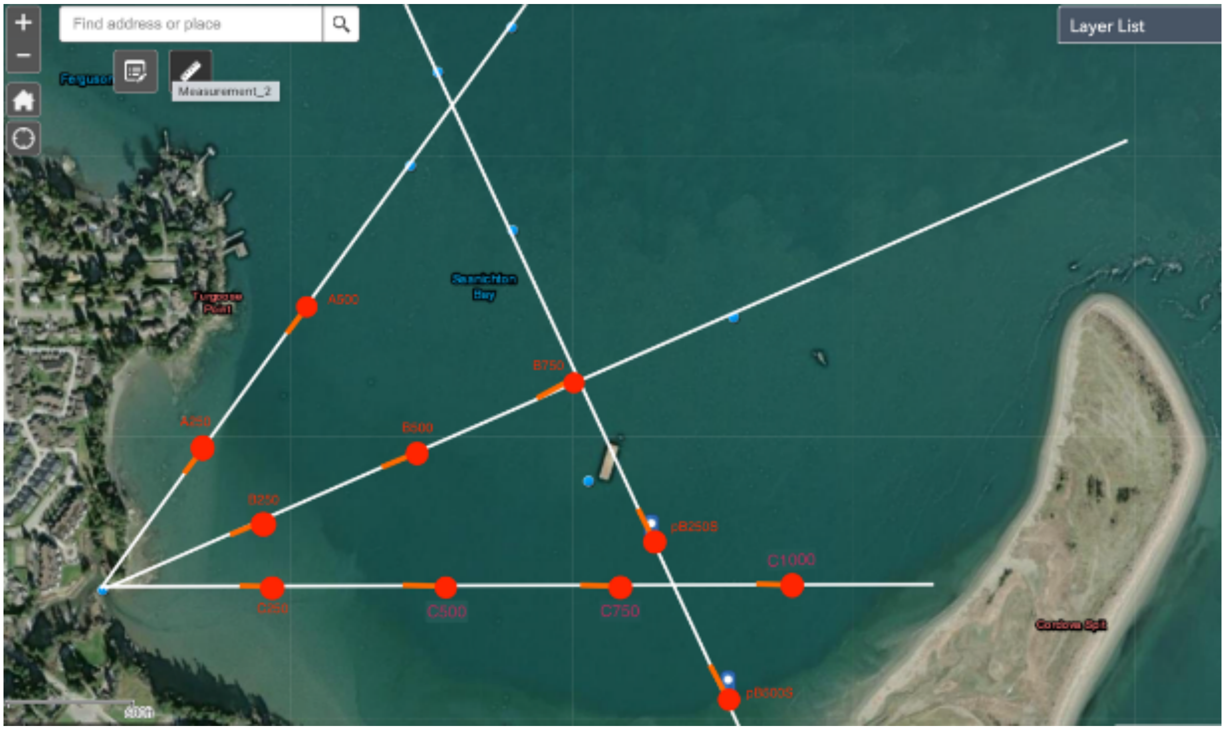
Preliminary Thoughts:

- Low stratification and deep water
- Site B250 has a different oxygen profile from the rest, potentially indicating higher photosynthetic organisms near the bottom of the water column; will do biodiversity surveys to see what is at the bottom.
- The non-linear salinity profiles are not substantive, as the variation is within 0.1 ppt, nearly in the realm of inherent equipment error.

Site Survey: October 06 & 11, 2023

Boat: Klanawa
Crew: Jamie Smith (captain), Susan Anthony (science), Justin Bland (diver), Leah (diver), Paul (diver)
Data Collected: Bacteria content, Salinity, Temperature, Dissolved Oxygen, Percent O_2, Turbidity, Sidescanning, Zooplankton tows, Biodiversity surveys

Sampling Locations



Red dots= site locations
Orange lines= Biodiversity transect lines

LOCATION	A250	48.5965	123.3893
	A500	48.5983	123.3871
	B250*	48.5956	123.388
	B500	48.5964	123.3849
	B750	48.5973	123.3818
	C250*	48.5946	123.3877
	C500	48.5946	123.3843
	C750	48.5947	123.3809
	C1000	48.59482	123.37771
	pB250S	48.5952	123.3804
	pB500S	48.5932	123.3789

Bacterial Sampling

Site	Faecal coliforms (CFU/100mL)*	*Enterococcus* spp. (CFU/100mL)
A250	<1	NA
A500	<1	NA
B250	<1	NA
B500	<1	NA
B750	<1	NA
C250	<1	NA
C500	1	NA
C750	<1	NA
C1000	<1	NA
pB500S	1	NA

*CFU = Colony Forming Unit

NB: Reportable Detection Limit (RDL) = 1 CFU/100mL

NB: Health Canada limit for safe water for activity is 35 CFU/100mL *Enterococcus* spp.

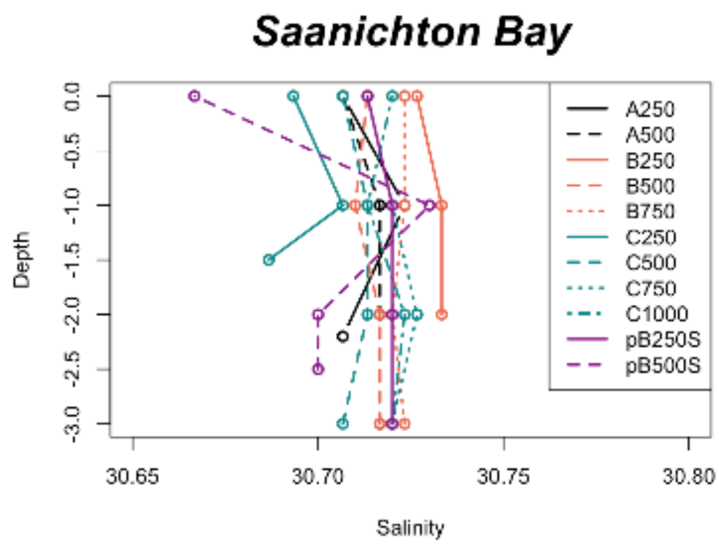
Interpretation: Very low bacterial content (negligible) at this sampling time. No concern about this sort of contamination year-round.

Turbidity

Site	Site Depth (m)	Secchi Depth (m)
A250	- 2.2	Bottom
A500	- 11.0	- 5.5
B250	- 2.4	Bottom
B500	- 4.6	Bottom
B750	- 16.0	- 5.5
C250	- 2.0	Bottom
C500	- 7.0	- 5.3
C750	- 11.8	- 6.2
C1000	- 12.0	- 5.7
pB250S	- 10.5	- 5.5
pB500S	- 3.0	Bottom

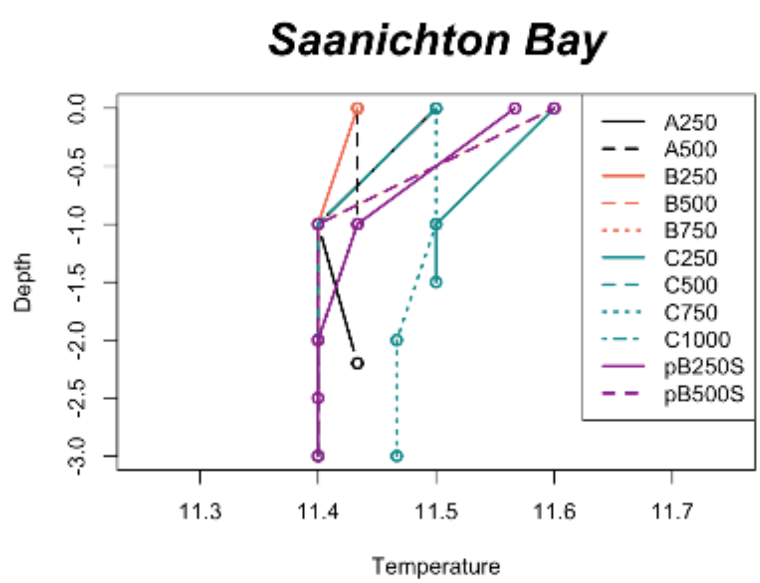
Interpretation: The turbidity is high, meaning there is high levels of mixing/sediment movement (suspended sediment clouding the water column) or high phytoplanktonic concentration. Although the measurement date was in early/mid-October, the warmer weather and low precipitation leading to this date may extend the summer algal growing season. Phytoplankton counts by the Tsawout Fisheries and water column features could help answer this question.

Salinity



Interpretation: The salinity is quite uniform among sites and with depth. The range between c. 30.67 ppt and c. 30.74 is negligible in the wild. There is either no freshwater input or high mixing throughout the bay. Considering the relatively high salinity and the low freshwater input due to lack of rainfall leading up to the sampling time, we would not conclude that the lack of stratification is due to mixing. Resampling after significant rainfall would aid in clarifying.

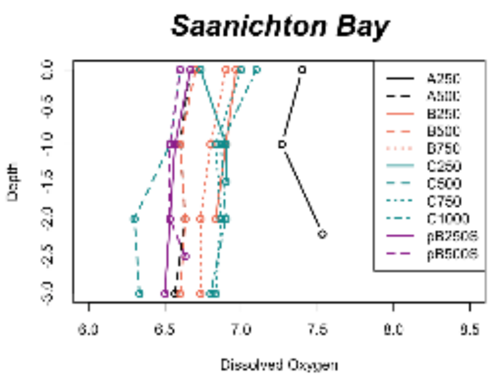
Temperature

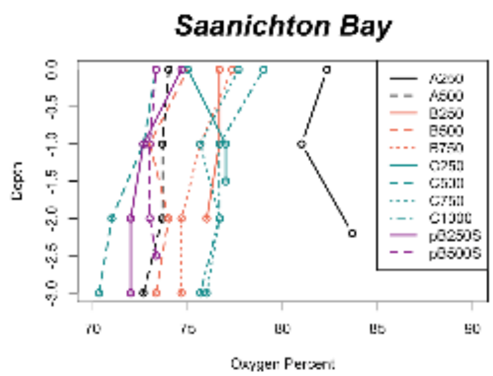


Interpretation: Lots of overlap it is hard to see the individual depth contours. But, this does indicate that there is highly similar water temperatures among sites. The surprisingly small range of 11.4 to 11.6 °C among sites and from the surface to depth is evidence that there is high mixing in the area.

Alternatively, it could be because of a large (>3m depth) water layer heated evenly, however this is unlikely to be seen at sites such as B750 (depth 16 m). Eleven and a half degrees Celsius is a low temperature for water that has been warmed by the sun throughout the summer, and more similar to general Salish Sea surface water temperature (see BC CDC and NOAA water temperature maps).

Oxygen

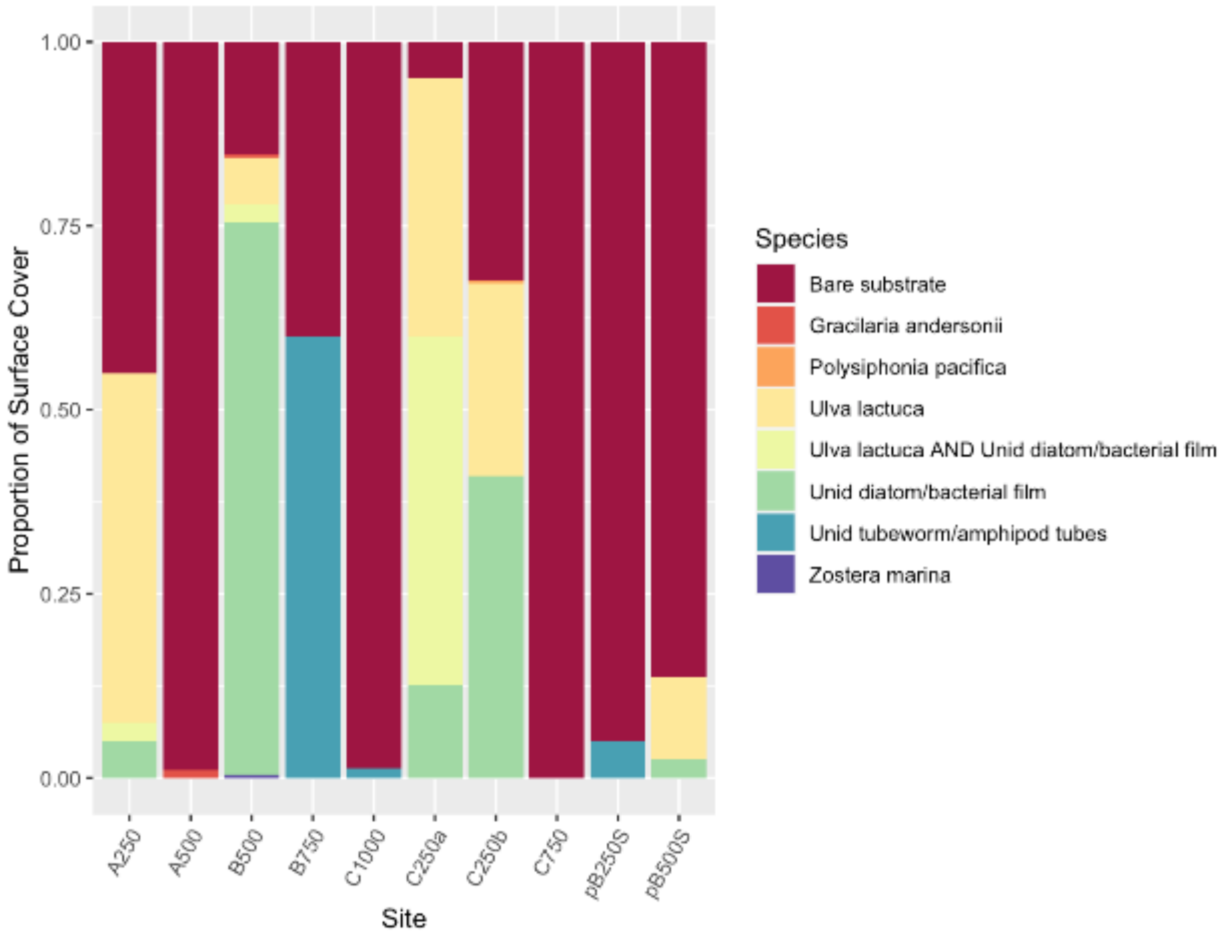




Interpretation**:** An unusual difference between A250 and the rest of the sites, especially as there is no obvious distinctions in salinity and temperature. At least, the range among the sites (excluding A250) is c. 6.3 – 7.1 mg/L (70 – 79%), which is more variable than the other physical properties of the water column previously measured on this visit. Oxygen content is generally even from the surface to – 3.0 m. The biota present at A250, especially compared to the other sites, may shed some light on these results.

Biodiversity: Ground Cover by Site

The stacked barplots are a sum of the four 25 cm^2 quadrats.



NB: It is not possible to create true plots of the substrate-covering organisms. See General Methods for more details.

Additional: The unidentified tubes were counted by the quadrat sampler at A250, A500, C250a and b, C500, C750, C1000 (in three of four quadrats); and measured as percent cover at B750, C1000 (only one of four quadrats), and pB250S.

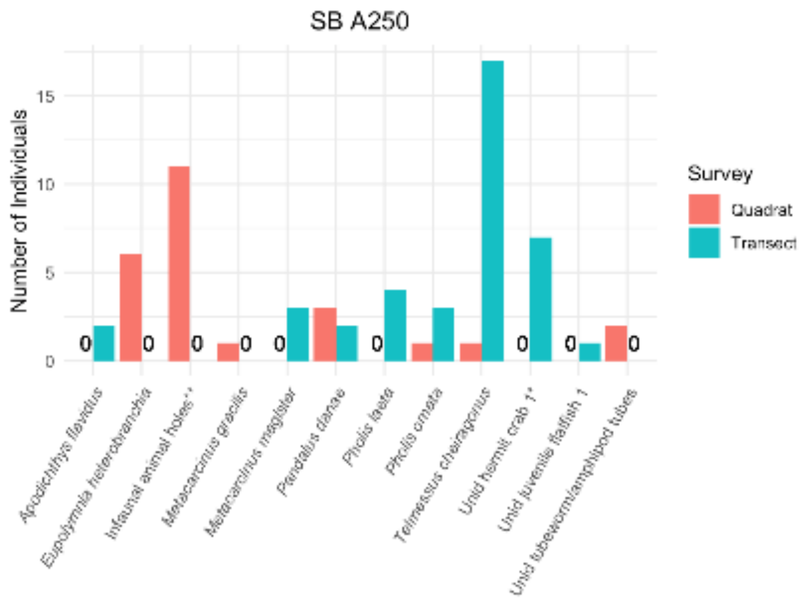
Interpretation: The pie charts do not represent the areas accurately, but it is a good way to have a view of the area. The data from the divers had overlapping percent cover from the photosynthetic organisms (most notably *Ulva lactuca* covered in diatoms or bacterial film). I made an approximation that allows a visual representation of the area. However, despite the inexactness of the charts, Saanichton Bay has a depauperate diversity of seabed photosynthetic organisms, but with a high coverage. The coverage is composed of visually barren areas with *Ulva lactuca*, diatom or bacterial film, and unidentified tubes (non-photosynthetic, but competition for space at these numbers). All these species are indicative of waters high in nutrients. There are a few additional photosynthetic organisms which were quantified by number rather than percent cover (below). Site

B250, which had higher oxygen content at depth than the other sites in the summer visit, could be either C250a or C250b, both of which have >50% photosynthetic organism cover.

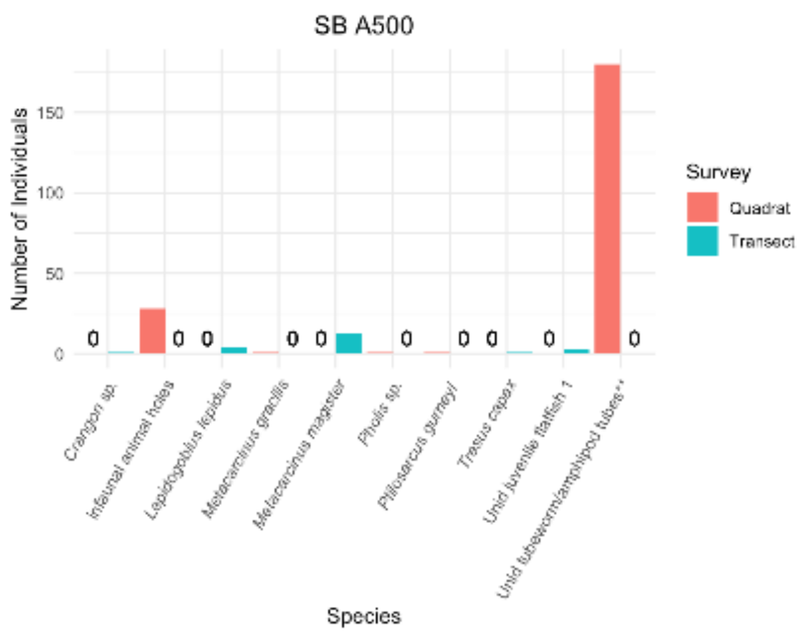
All species, common names, and brief information are in Appendix H.

Animal and Algae (by quantity)

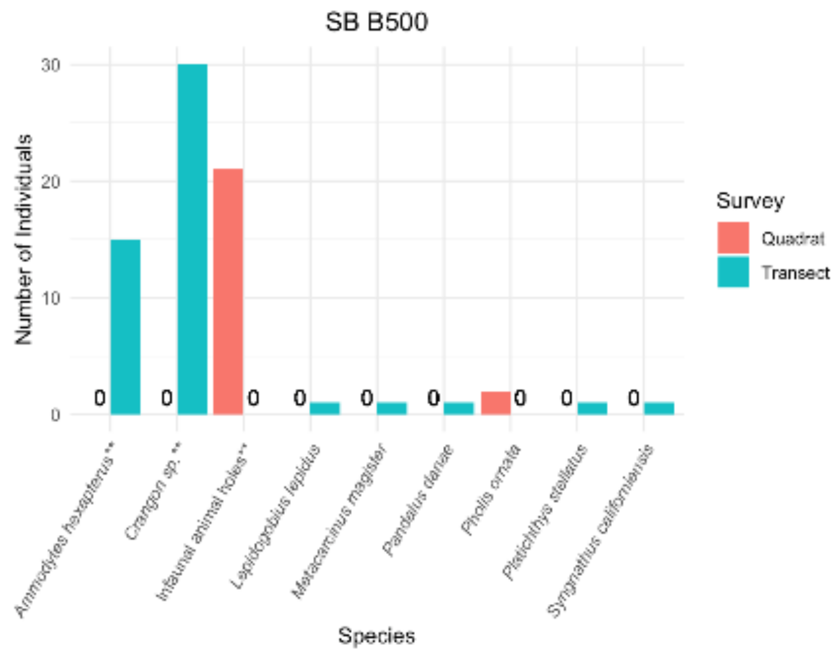
NB: Vertical axes differ among charts.



*Unid hermit crab likely *Pagurus* sp.
**Estimated quantity



**Estimated quantity



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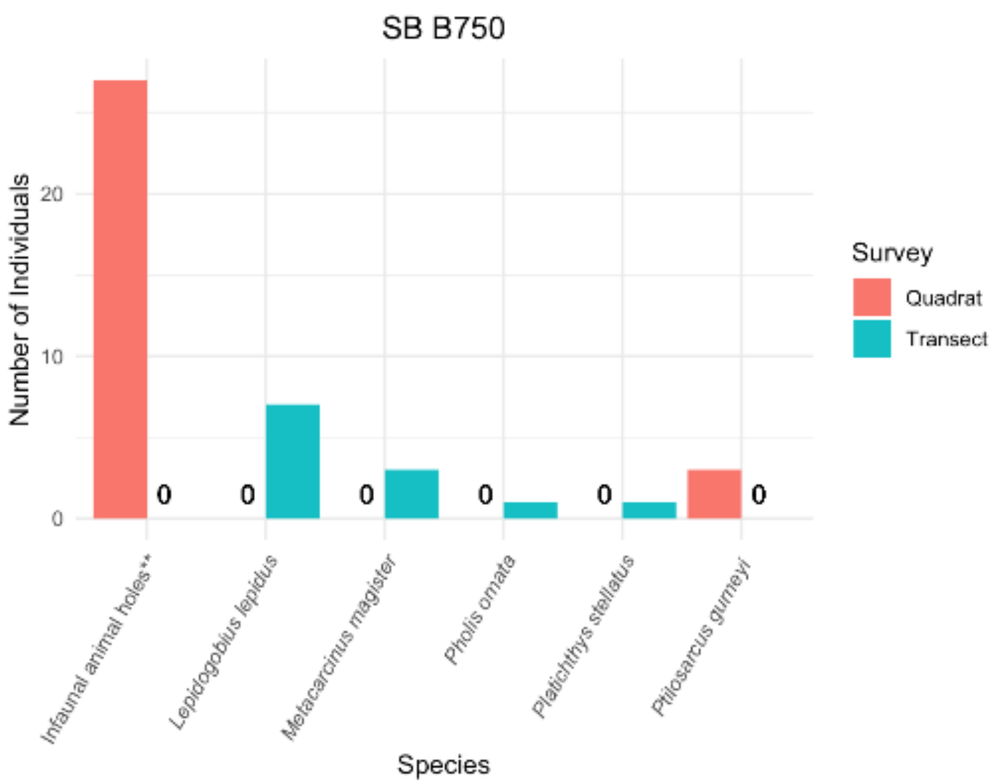

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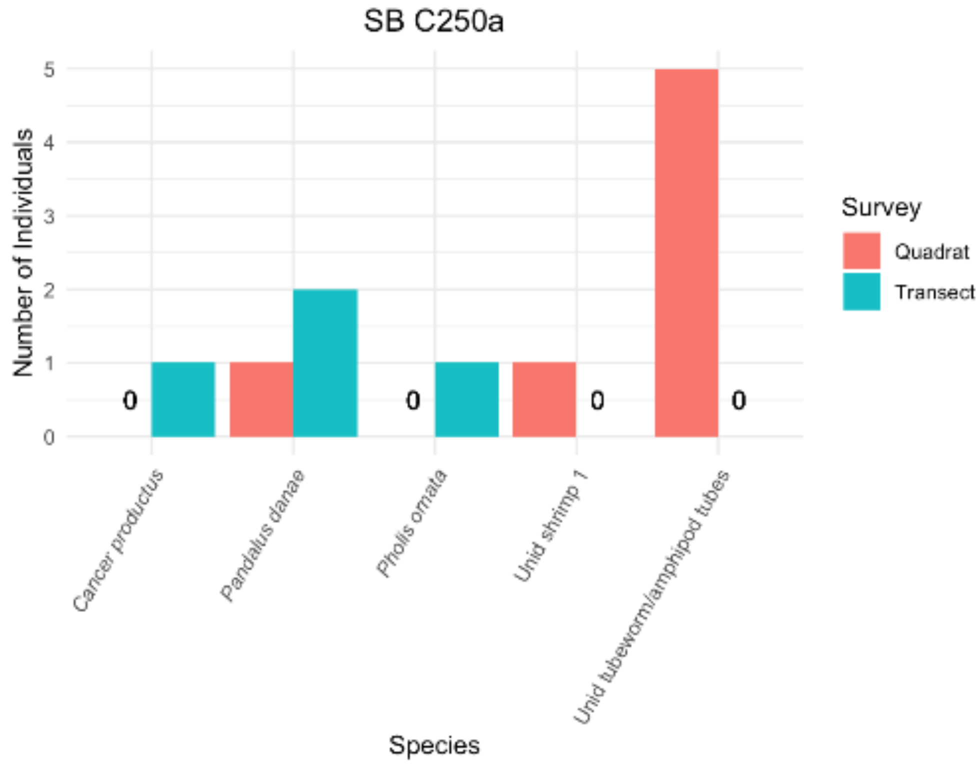
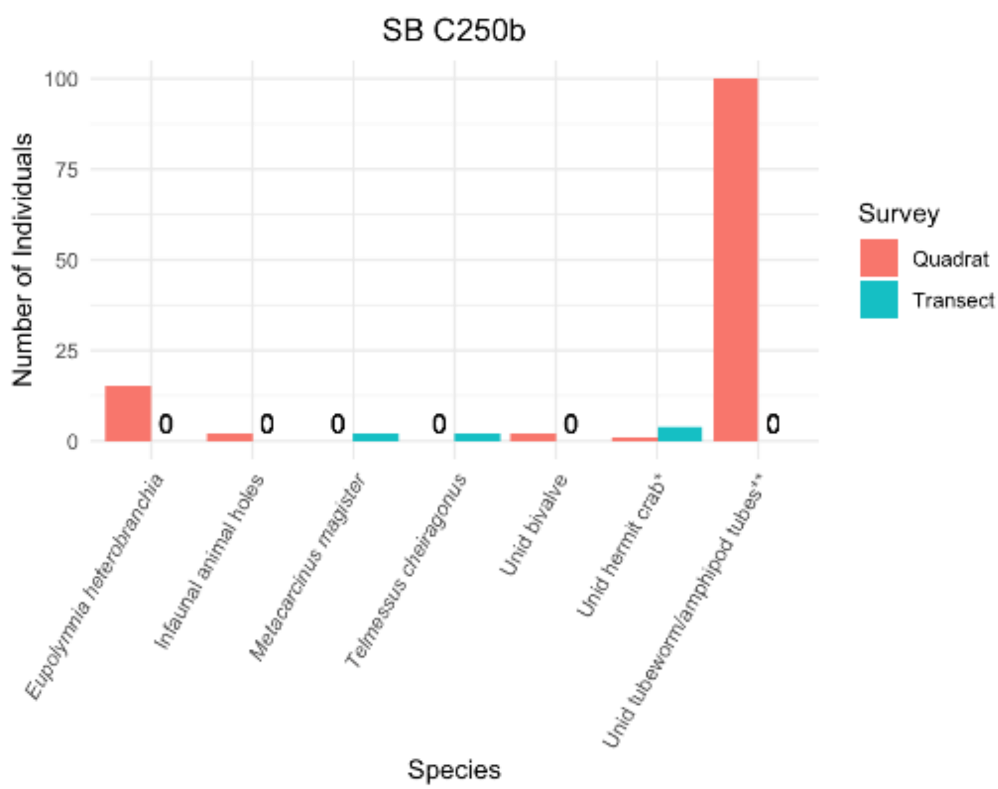
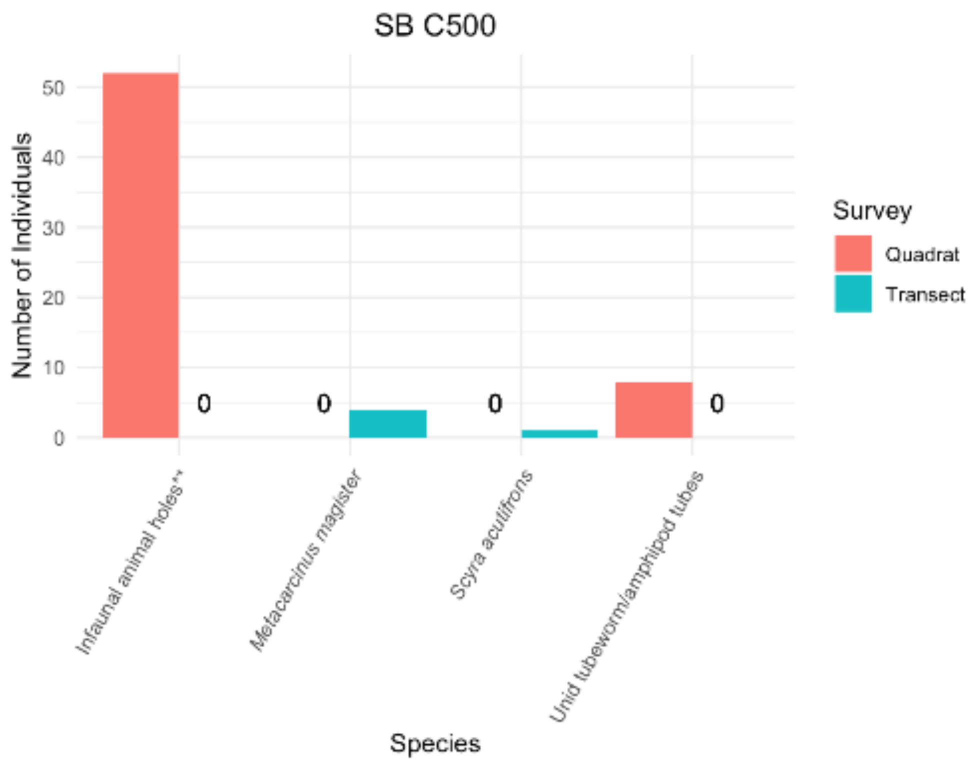




*Unid hermit crab is likely *Pagurus* sp.
**Estimated number



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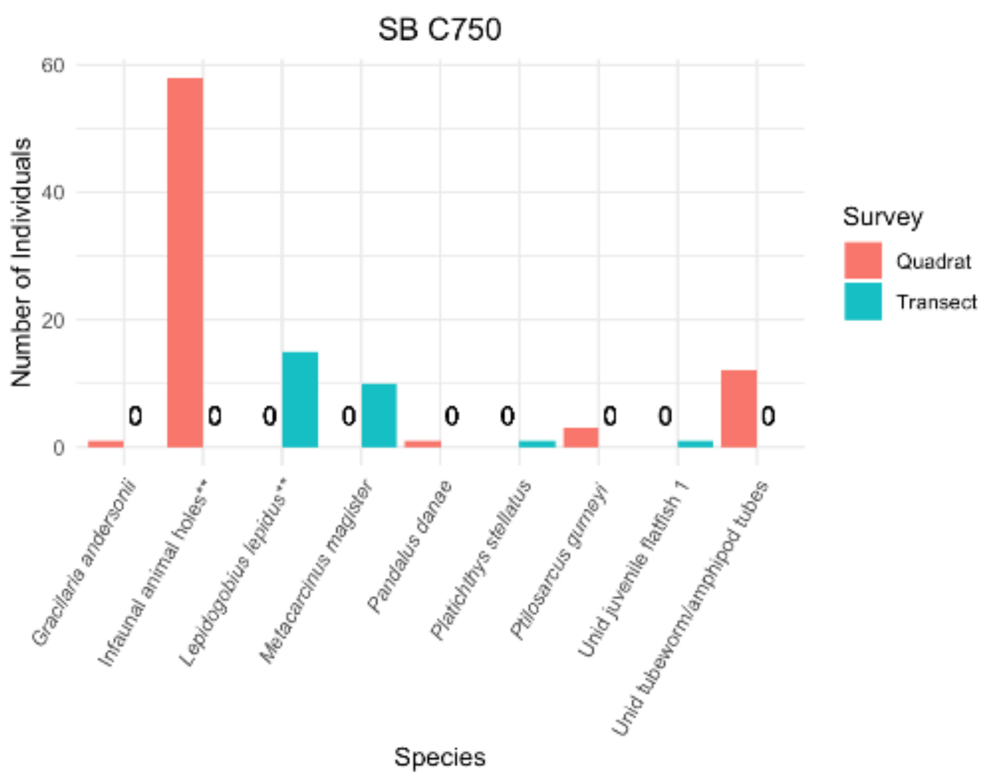
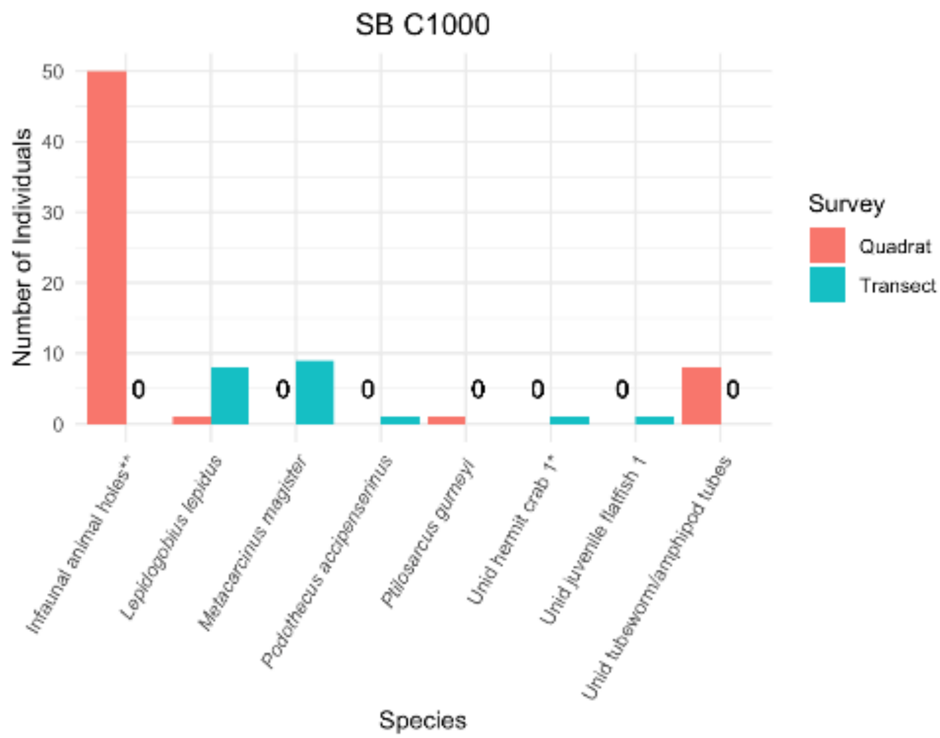
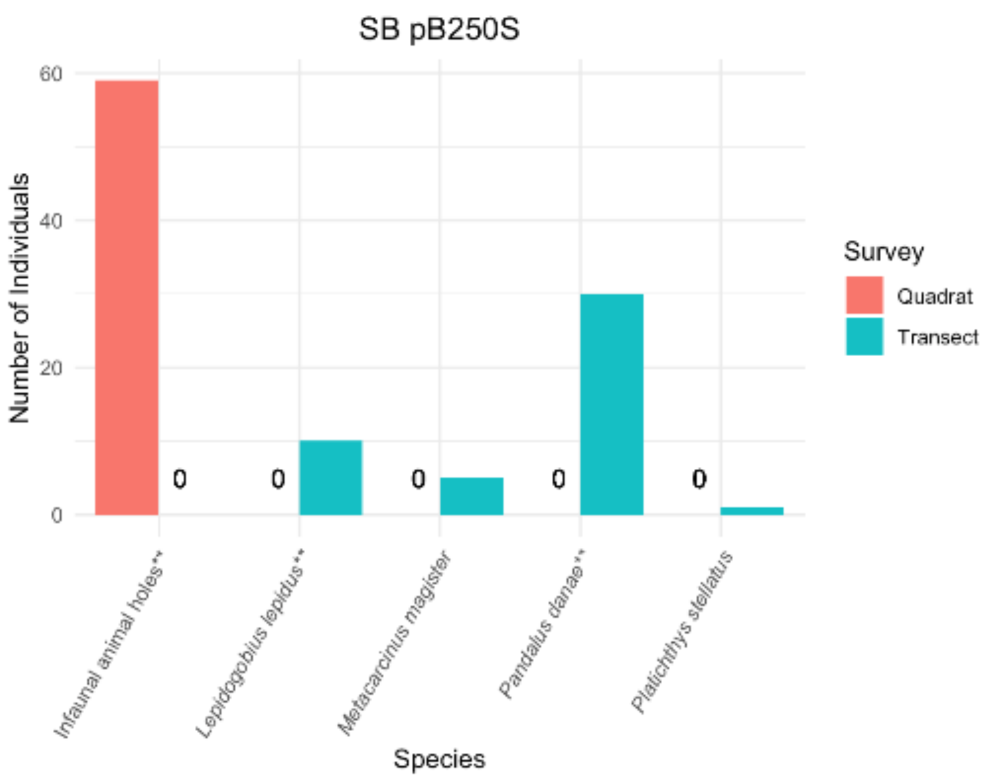


**Estimated number



*Unid hermit crab is likely *Pagurus* sp.
**Estimated number



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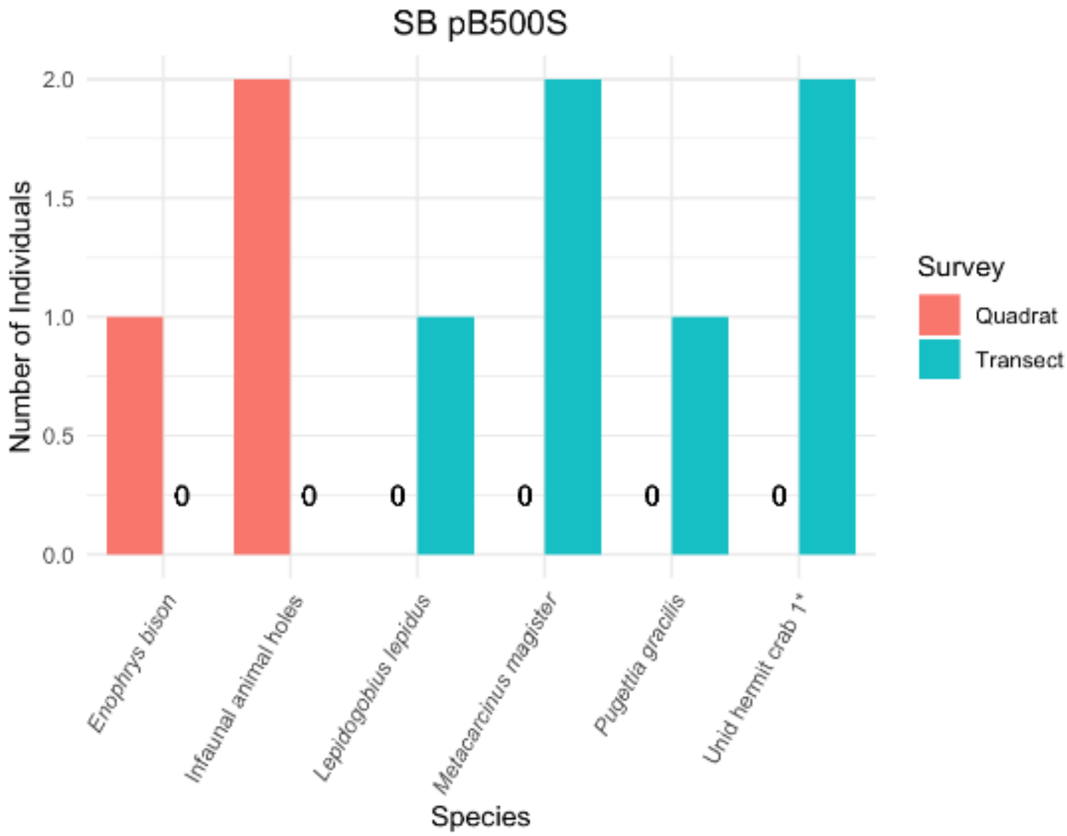


*Unid hermit crab is likely *Pagurus* sp.

Interpretation: Low species biodiversity, however, there is evidence of important species such as sand lance, crabs, and infaunal species. “Infaunal Animal Holes” could be bivalves, tubeworms, burrowing anemones, or arthropods such as the ghost shrimp (*Neotrypaea californiensis*); these holes are larger than the tubeworm/amphipod tubes that are also noted.

All species, common names, and brief information are in Appendix H.

Biodiversity Calculations

Richness: Number of species from abundance survey and not percent cover.

Simpson’s Biodiversity Index: Calculated based on the number of species and their relative abundances. Values range from 0 – 1, where higher values mean lower biodiversity. Simpson’s Index is from abundance surveys and not percent cover.

Fisher’s Alpha: A logarithmic calculation because of the inherent differences between the abundances of each species: some species are found in groups *vs* rarer or individual. A higher Fisher’s alpha results from higher biodiversity.

Site	Richness (Q)	Richness (T)	Richness (Q & T)	Simpson's Index (Q)	Simpson's Index (T)	Simpson's Index (Q & T)	Fisher's Alpha (Q)	Fisher's Alpha (T)	Fisher's Alpha (Q & T)
A250	9	8	17	0.7533	0.7692	0.8785	3.228186	3.048644	4.359971
A500	6	5	11	0.2558	0.6234	0.3867	0.9190137	2.019305	2.124739
B500	6	7	13	0.2350	0.5592	0.7142	0.5263209	2.215167	2.699808
B750	3	4	7	0.3795	0.6364	0.5610	0.4823704	2.101046	1.91552
C250a	6	3	9	0.1862	0.8333	0.8	1.988816	5.452556	1.743444
C250b	8	3	11	0.2921	0.8667	0.3768	1.054059	1.743444	2.265047
C500	3	2	5	0*	0.7143	0.3462	0.3982923	1.235493	0.9413532
C750	5	4	9	0.5238	0.4	0.6366	1.205926	1.297815	2.380497
C1000	5	5	10	0.1660	0.6632	0.5832	0.9647443	2.139826	2.244685
pB250S	2	4	6	0.6667	0.5726	0.5969	**	1.052656	1.092779
pB500S	4	4	8	0.2917	0.5266	0.9167	2.622302	5.244605	7.866907
All	20	18	33	0.8751	0.9457	0.7580	8.716898	18.66747	5.634346

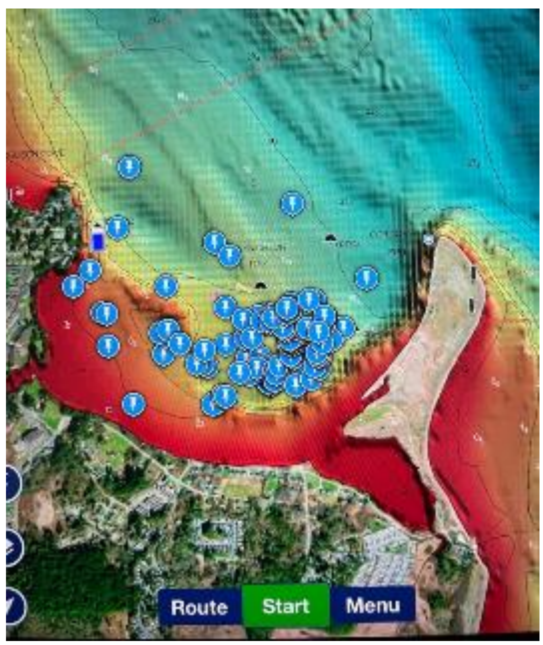
Q = from quadrat surveys, T = from transect surveys, Q & T = from a combination of both quadrat and transect surveys

*too few species to calculate Simpson's Biodiversity Index

**too few samples that the Fisher's Alpha value is arbitrarily high or unable to be calculated

NA: no species in abundance survey (species are from percent cover)

Marine Debris



Interpretation: The debris is concentrated near the area where water slows, and boats are anchored/moored. We have been told of lost crab traps, so we are eager to retrieve them to prevent ghost gear deaths. There is also the possibility that moored vessels are tossing things from the boats, but our observations of the area lead us to believe that this is not a heavily used anchoring area and the items may be accumulated over decades and the debris is likely a result of neglect rather than negligence. There are 45 points, most with one object, but a couple of them with a cluster of items. There is one potential boat (large) and one potential mooring block.

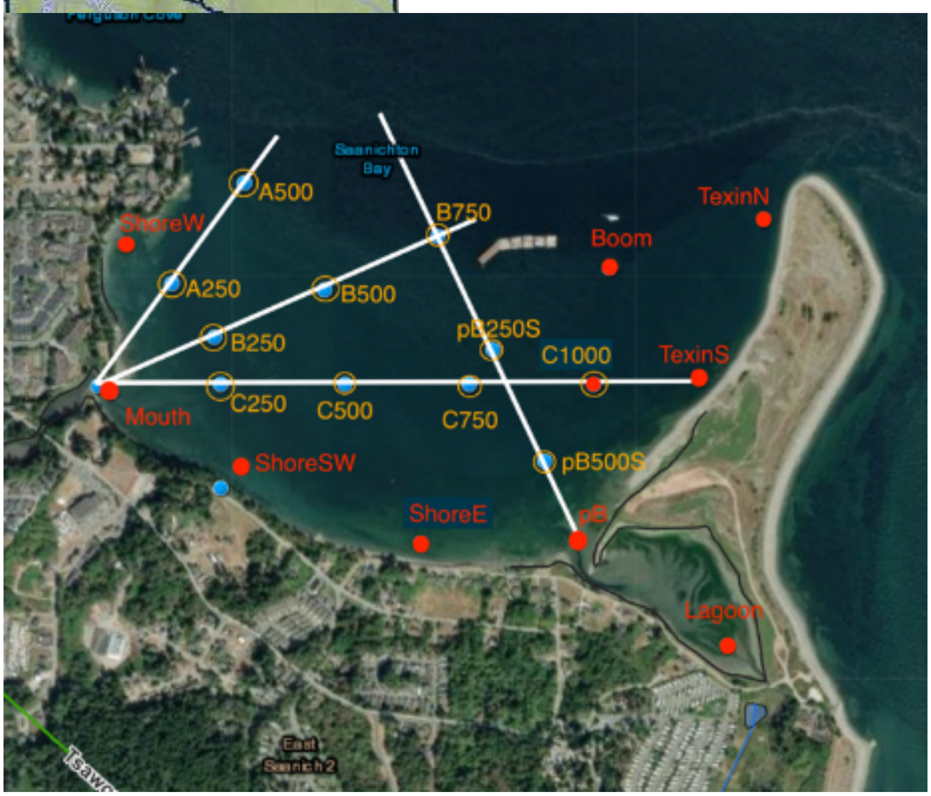
Habitat Diversity

Interpretation: Although incomplete, there are scattered eelgrass beds along the shore. From comments, I heard that eelgrass was commonly thick along the spit (TIX̱EN). This map is the winter extent of eelgrass, and further detailed eelgrass mapping would give a more fine-scale eelgrass bed area. However, the presence mostly in the Western side of the bay (near the mouth of Tetayut Creek) is a positive sign that pollution input from land may not have as large an impact on the beds as predicted. The question is what may be impacting the Eastern side of the bay, depleting the eelgrass below known levels.

Future Work

The large Tetayut Creek watershed, and the drainage from shore (where there is an unmarked water treatment facility near TIX̱EN), means there could have local and faraway sources of nutrient loads. Peninsula Streams Society may be interested in supporting any work in the marsh area and the tidal flats as they go up the creek from the bay. For identifying potential sites of excess nutrient or land-based pollution, we propose extra sites and resampling at original sites.


Cordova
Channel
Tetayut
Creek
Noble
Creek


Saanichton
Bay
A500
ShoreW
B750
Boom
TexinN
A250
B500
B250
pB250S
C1000
TexinS
Mouth
C250
C500
C750
ShoreSW
pB500S
ShoreE
pB
Lagoon
East
Saanich 2

Site name	Lat	Long
ShoreW	48.597331	123.390062
Mouth	48.594379	123.390534
ShoreSW	48.593215	123.387058
ShoreS	48.591909	123.381822
Lagoon	48.589922	123.373711
TexinS	48.595032	123.374097
TexinN	48.597614	123.372896
Boom	48.597132	123.377273
pB	48.591796	123.377917

We think these areas, along with some of the original sampling sites, should be (re)sampled at different times of year and before and after rainfall. These new sampling sites are designed to identify sources of nutrient loads if present. If there is a higher concentration of nutrients and bacteria at "Mouth" and "Lagoon" are higher than the "Shore" sites, we can deduce that the nutrient loads are from inland watersheds.

SeaChange's RESS team is in the process of making collaborations with eDNA researchers, which will enhance the knowledge of species richness of the bay and identify the area's usage by foraging fish and salmon.

Testing for heavy metals in shellfish. The Tsawout Fisheries Department is already tracking harmful algal blooms, which will temporarily stop filter and suspension-feeding shellfish harvesting for human consumption when toxic levels are found. Heavy metals persist in sediment and animal tissues, and their negative effects are not immediate.

Appendix G: Biodiversity Analyses for Resilience Ranking

Ranking by Biodiversity Indices

Richness overall (number of species)

1. OB: 46
2. CB: 44
3. SB: 33
4. TI: 32
5. RB: 31
6. PI: 22

*at OB site pB250S, the number was 25, which is more than all of RB

Simpson's (lower number is higher biodiversity)

1. TI: 0.7077
2. CB: 0.7196
3. PI: 0.7385
4. SB: 0.7580
5. OB: 0.7843
6. RB: 0.8488

Fisher's Alpha

(higher number is higher biodiversity, considers that some species are present in high numbers)

1. OB: 10.6629
2. CB: 7.1976
3. TI: 6.8961
4. RB: 6.0593
5. SB: 5.6343
6. PI: 3.3661

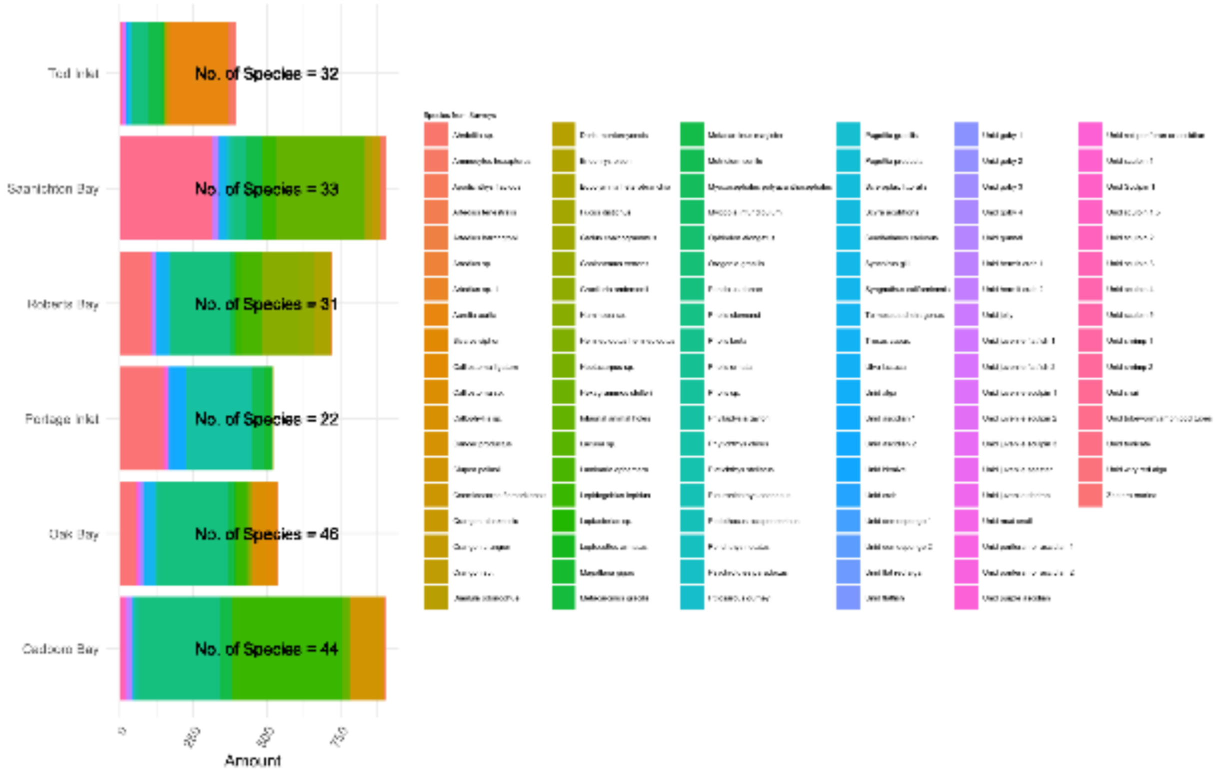


Figure 3-1: The number of individuals of each species by Estuary. This graphically represents the variability in species composition among sites: Oak Bay had the highest number of identified species, but on the lower side when it comes to the number of individual organisms.

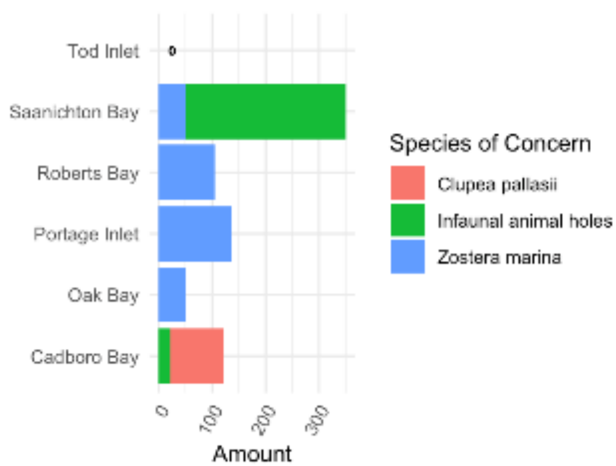


Figure 3-2: The number of species of concern in each estuary. Infaunal animal holes could be any number of infaunal species, including clams, but also ghost shrimp and tube-dwelling worms and cnidarians.

The relationship among three biodiversity indices: Richness, Simpsons, and Fishers Alpha

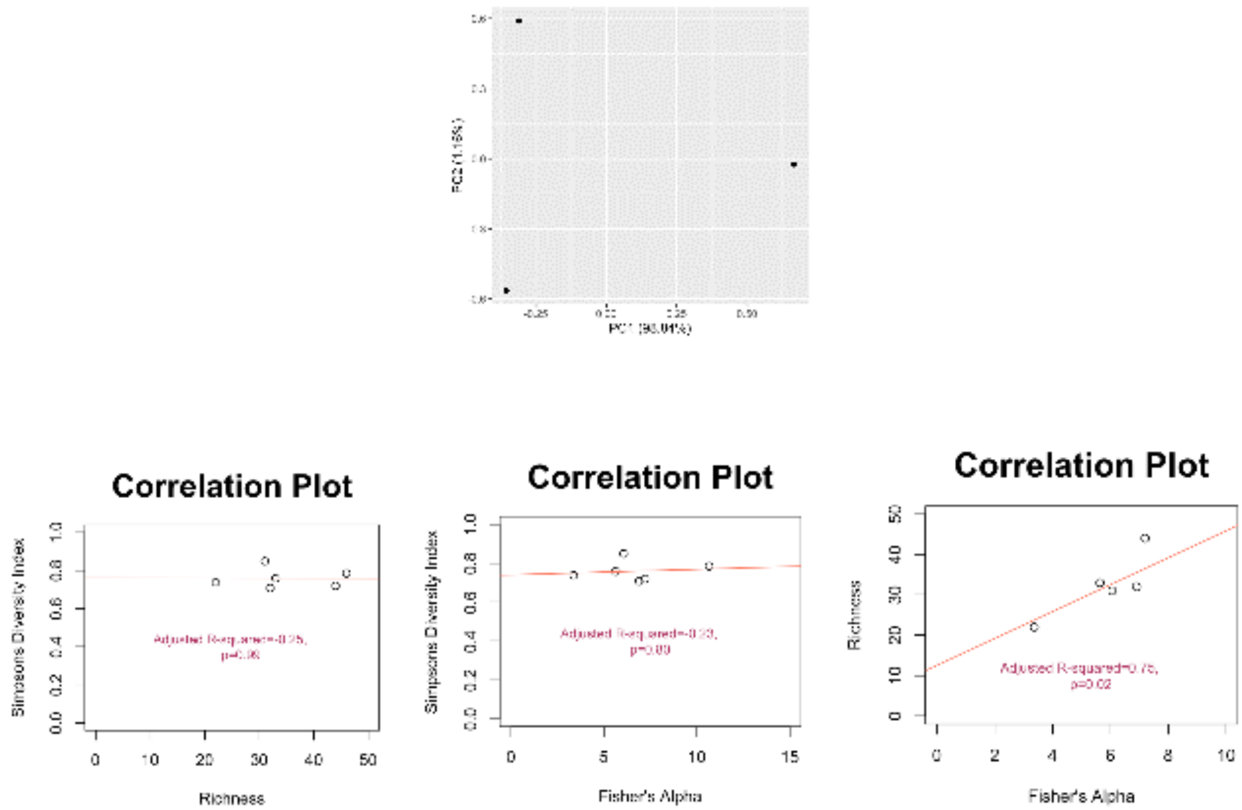


Figure 3-3: Comparing Biodiversity Indices with a Principal Component Analysis. Correlation Plots are to compare the Indices directly.

Conclusion

The biodiversity indices (Simpsons and Fisher's Alpha) do not correlate; however, Richness and Fisher's Alpha do. The Fisher's Alpha analysis uses the number of species and a log-transformed amount of each species. This method reduces the difference in the amount of each species, making the number of species (Richness) a critical factor in the result. However, the Simpsons Index looks at the evenness of the data: whether there is the same number of individuals within each species. Since many species are found in large quantities (even schooling), evenness is irrelevant to our ranking. In the future, Fisher's Alpha would be a better index for biodiversity.

Ranking by Habitat Composition

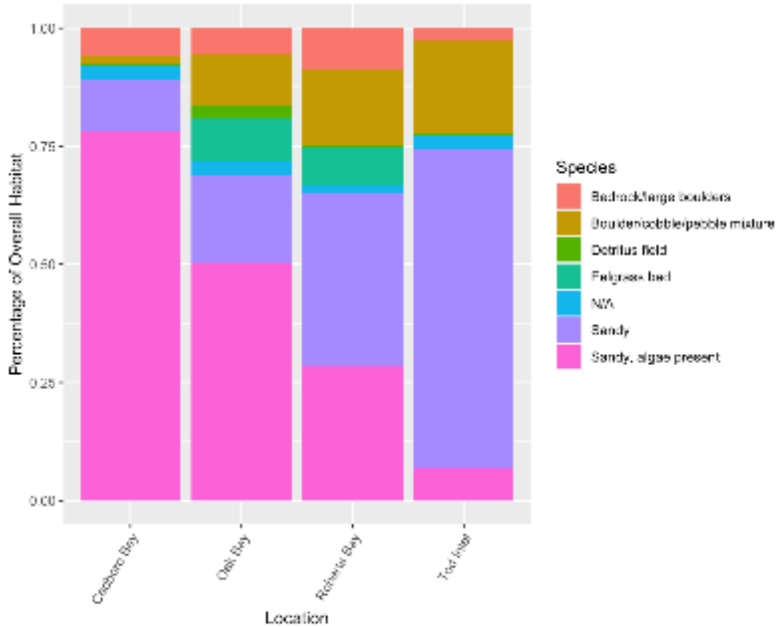


Figure 3-4: Habitat proportions at four Area 1 estuaries. The data comes from video analysis from tow camera footage. Algae can be film, *Ulva*, or kelp. Future work would be to separate this category further. Eelgrass is present in Oak Bay and Roberts Bay in measurable quantities, whereas Tod Inlet eelgrass is <0.1% of the area filmed and Cadboro Bay it is <0.06%. Saanichton Bay and Portage Inlet are still being analysed.

Ranking

1. Roberts Bay
2. Oak Bay
3. Tod Inlet
4. Cadboro Bay

Conclusion

We ranked the habitat mosaic visually, looking for evenness across categories. However, we acknowledge that Sandy and Sandy, algae present, could be considered one category if the algae in question were the diatom/bacterial mat. Therefore, large barren areas or algal mats would be considered one category. We would also like to add a category for animal presence, such as the evidence of infaunal animal holes and sea pen reefs.

Ranking by Salinity Depth Profiles (Slopes)

Table: The ranking of a) each individual Site within each Location (Estuary) and b) the slope averaged from each Site Slope, from closest to zero (uniform profile) to steepest (likely stratified and not well mixed). A negative slope indicates that it is less saline at the top of the water column than the bottom. A larger negative number means that the difference in salinity with depth is greater. A region with mixed water would have a nearly vertical regression line (slope approaching zero). Plots showing the regression lines are below the tables.

a)

Location	Site	Salinity/Depth Slope
PI	B250	-0.4138
PI	C250	-0.6437
PI	C500	-0.687
PI	A500	-0.8186
PI	B500	-0.952
PI	B1000	-1.988
CB	C750	-4.599
OB	C250	-11.33
CB	pB500W	-11.44
TI	A750	-16.37
CB	C500	-17.55
CB	B1000	-17.67
TI	A1000	-18.88
CB	A1000	-19.48
TI	B250	-20.61
TI	B500	-20.9
CB	ppB250W	-26.34
TI	B750	-26.67
CB	C250	-26.94

b)

Location	Sal.Slope
PI	-0.93
OB	-15.49
CB	-16.74
SB	-18.25
TI	-21.66
RB	-23.75

Table: The slopes of the salinity at depth regression lines from the six locations and the sites within those locations. The statistically significant slopes (those that are statistically different from zero) are “SIG” and those where the regression line most likely fits the data (adjusted R-squared > 0.5) are “YES”.

Location	Site	Salinity/Depth Slope	Is the regression line significant? (p<0.05	Does the data fit the regression line (R-squared > 0.5)	Conclusion
CB	A1000	-19.48	SIG	YES	Slope can be used for further comparisons
CB	A250	-19.91	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
CB	A500	-17.79	NO	NO	Slope is not representative of the data
CB	A750	-27.22	NO	NO	Slope is not representative of the data
CB	B1000	-17.67	SIG	YES	Slope can be used for further comparisons
CB	B250	-14.79	NO	NO	Slope is not representative of the data
CB	B500	-5.061	NO	NO	Slope is not representative of the data
CB	B750	-16.94	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
CB	C250	-26.94	SIG	YES	Slope can be used for further comparisons
CB	C500	-17.55	SIG	YES	Slope can be used for further comparisons
CB	C750	-4.599	SIG	YES	Slope can be used for further comparisons
CB	pB250W	-8.663	NO	NO	Slope is not representative of the data
CB	pB500W	-11.44	SIG	YES	Slope can be used for further comparisons
CB	ppB250W	-26.34	SIG	YES	Slope can be used for further comparisons
OB	A250	-20.21	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
OB	B250	-20.93	NO	NO	Slope is not representative of the data
OB	B500	-11.95	NO	NO	Slope is not representative of the data
OB	C250	-11.33	SIG	YES	Slope can be used for further comparisons
OB	pB250N	-12.41	NO	NO	Slope is not representative of the data
OB	pB250S	-16.12	NO	NO	Slope is not representative of the data
PI	A250	-1.029	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
PI	A500	-0.8186	SIG	YES	Slope can be used for further comparisons
PI	B1000	-1.988	SIG	YES	Slope can be used for further comparisons
PI	B250	-0.4138	SIG	YES	Slope can be used for further comparisons

PI	B500	-0.952	SIG	YES	Slope can be used for further comparisons
PI	C250	-0.6437	SIG	YES	Slope can be used for further comparisons
PI	C500	-0.687	SIG	YES	Slope can be used for further comparisons
RB	A250	-16.67	NO	NO	Slope is not representative of the data
RB	A500	-41.83	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
RB	B250	-42.86	NO	NO	Slope is not representative of the data
RB	B500	-39.81	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
RB	C250	NA	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
RB	C500	3.947	NO	NO	Slope is not representative of the data
RB	pB250W	-29.03	NO	NO	Slope is not representative of the data
SB	A250	0.8876	NO	NO	Slope is not representative of the data
SB	A500	-91.53	NO	NO	Slope is not representative of the data
SB	B250	-13.43	NO	NO	Slope is not representative of the data
SB	B500	-16.76	NO	NO	Slope is not representative of the data
SB	B750	6.061	NO	NO	Slope is not representative of the data
SB	C1000	-13.74	NO	NO	Slope is not representative of the data
SB	C250	5.455	NO	NO	Slope is not representative of the data
SB	C250a	NA	NO	YES	Regression line represents the data, but the slope cannot be used in further comparisons
SB	C250b	NA	NO	YES	Regression line represents the data, but the slope cannot be used in further comparisons
SB	C500	NA	NO	NO	Slope is not representative of the data
SB	C750	-12.5	NO	NO	Slope is not representative of the data
SB	pB250S	-52.94	NO	NO	Slope is not representative of the data
SB	pB500S	-12.22	NO	NO	Slope is not representative of the data
TI	A1000	-18.88	SIG	YES	Slope can be used for further comparisons
TI	A250	-25.26	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
TI	A500	-22.91	SIG	NO	The linear slope is not representative of the data, but the slope is significantly different from zero
TI	A750	-16.37	SIG	YES	Slope can be used for further comparisons
TI	B250	-20.61	SIG	YES	Slope can be used for further comparisons
TI	B500	-20.9	SIG	YES	Slope can be used for further comparisons
TI	B750	-26.67	SIG	YES	Slope can be used for further comparisons

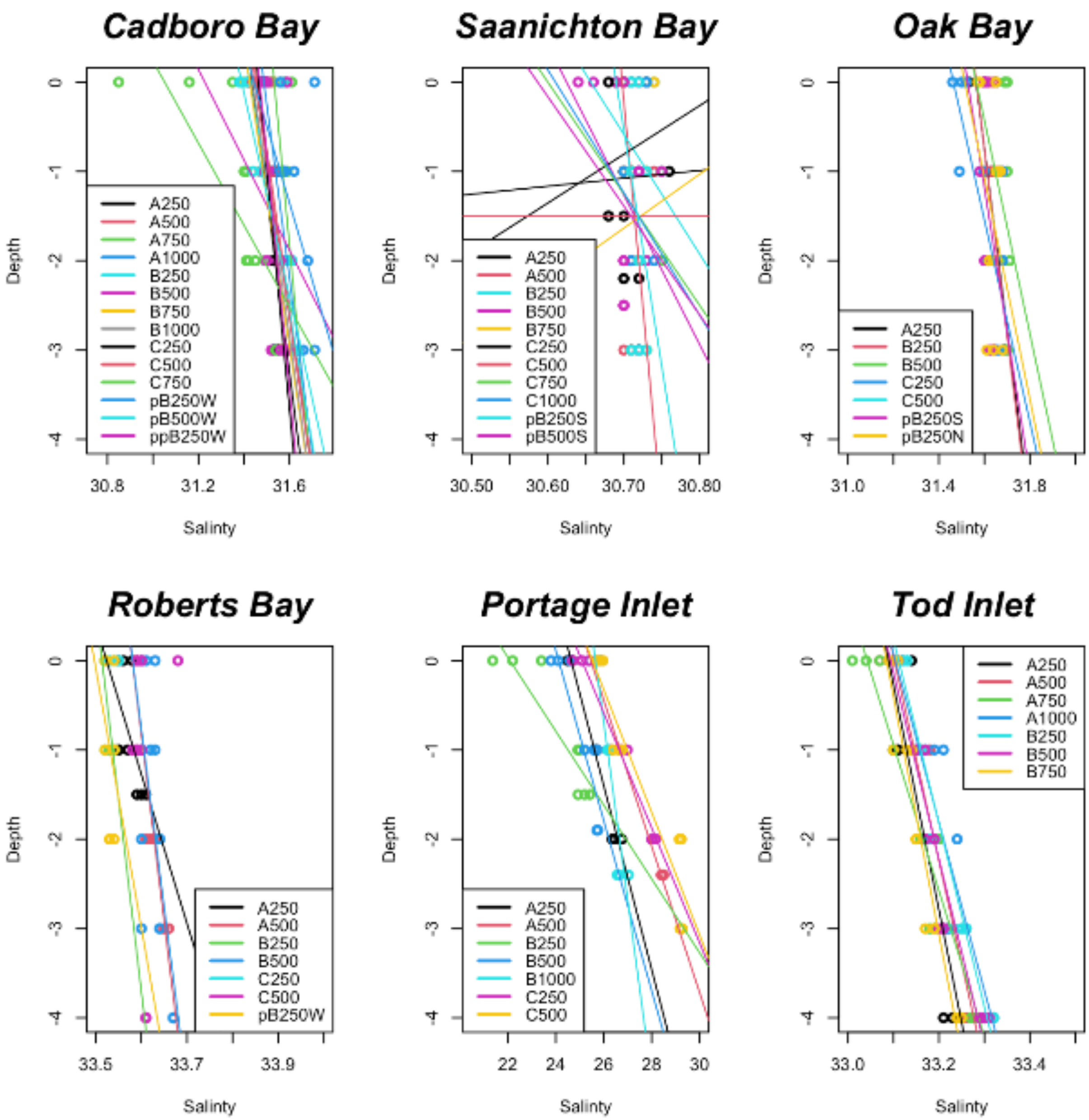


Figure 3-5: The regression lines for the salinity profiles of all sites with the Area 1 estuaries.

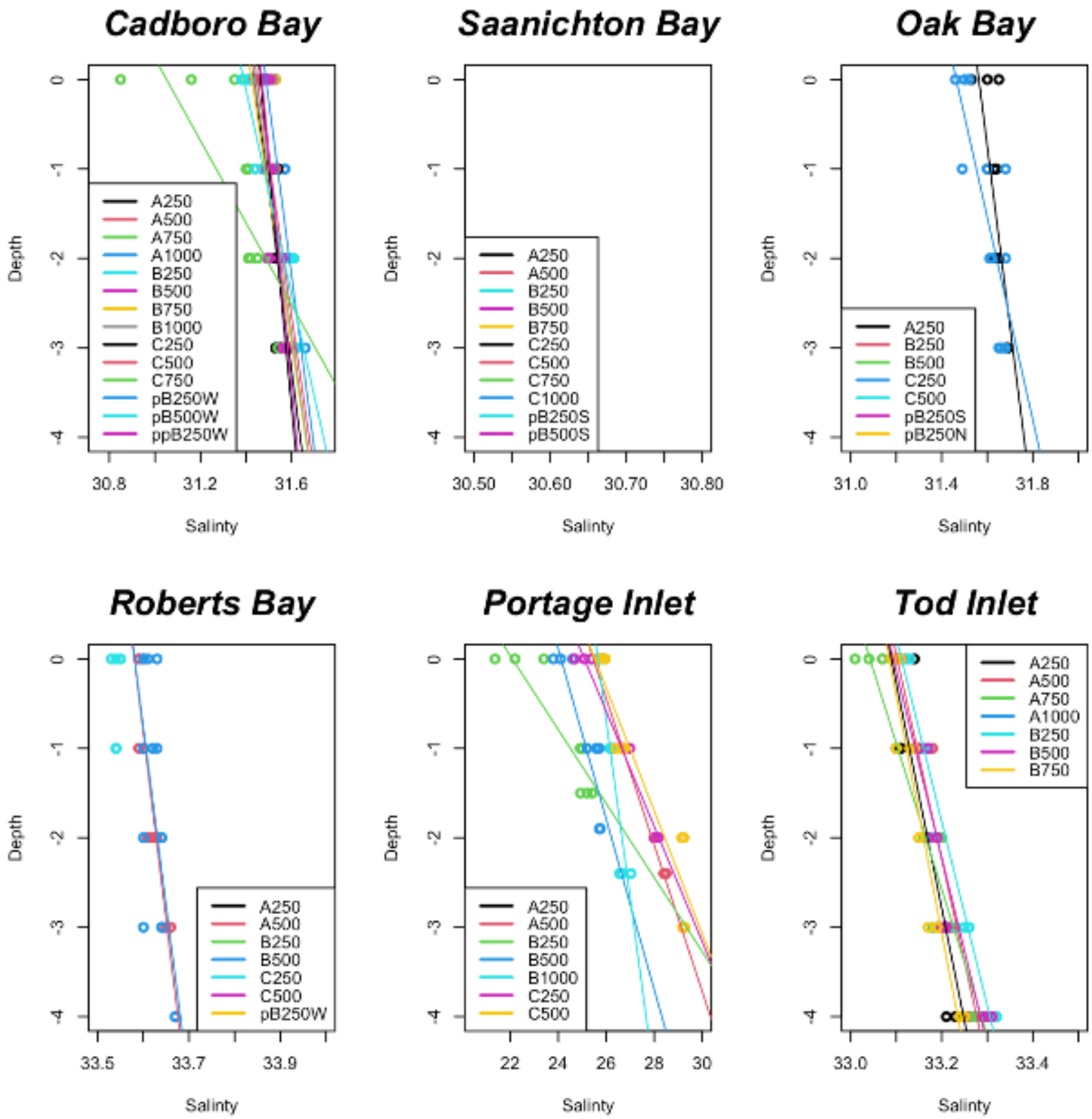


Figure 3-6: The regression lines for the salinity profiles of the sites with the Area 1 estuaries where the slope was significantly different from zero (horizontal).

FINDING CORRELATES OF BIODIVERSITY AMONG THE DATA

Correlating Salinity, Temperature, and Dissolved Oxygen

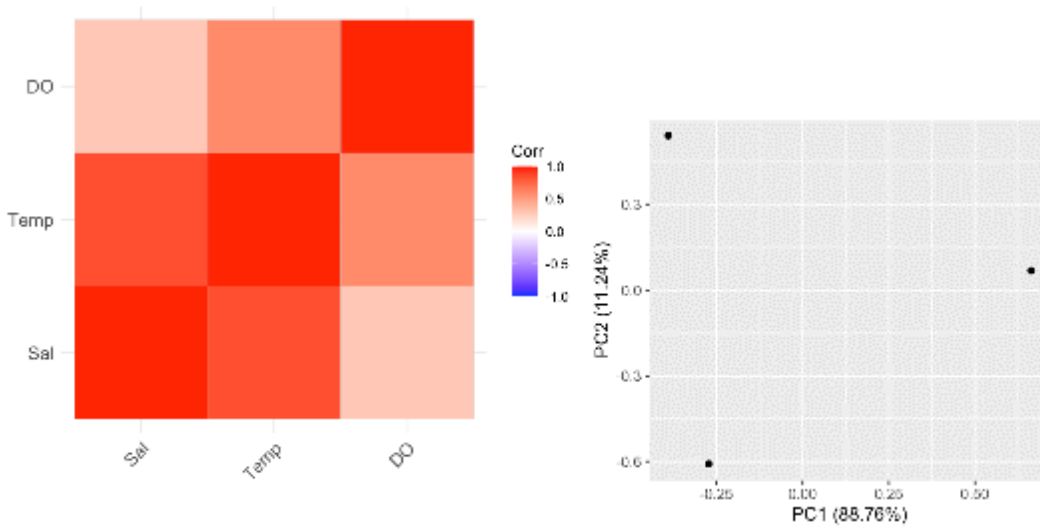
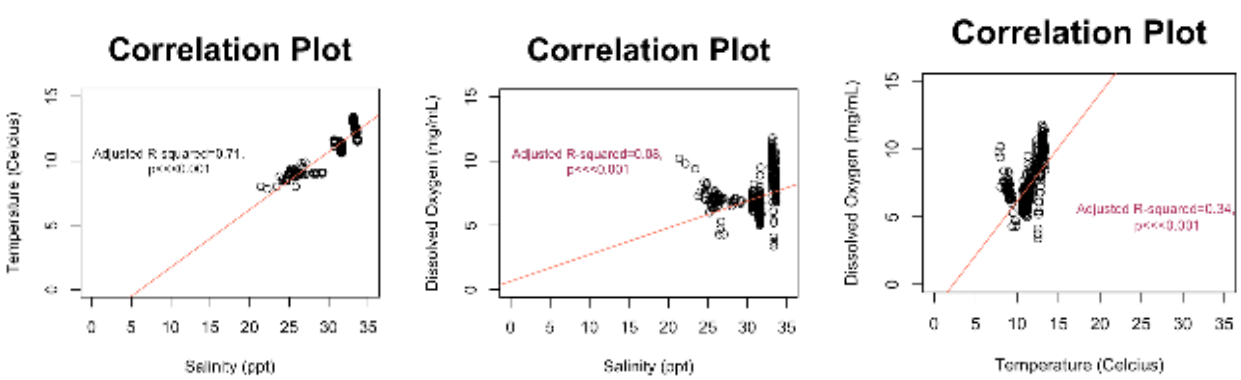


Figure 3-7: Correlation and resulting Principal Component Analysis of the Salinity, Temperature, and Dissolved Oxygen values at each location, site, and depth. There is a strong correlation between all values of Salinity, DO, and Temp (normalised, not averaged). With the greatest effect between Salinity and Temperature (plotted below for clarity).



Conclusion: Salinity and Temperature can be used as proxies for one another as they correlate. Both are probably due to the same effect of freshwater input from creeks and rivers. Dissolved Oxygen does not correlate with Salinity or Temperature, as different factors likely influence them.

Correlating Biodiversity with Mixing (Salinity Slope)

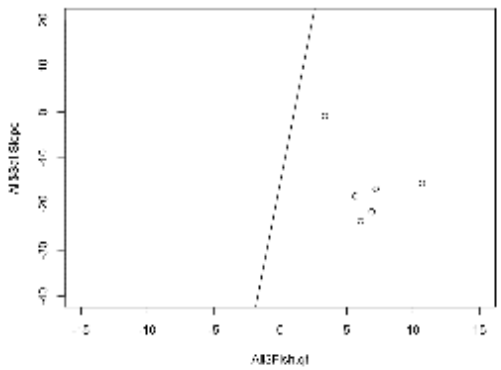


Figure 3-8: The relationship between Fisher's Alpha Index value and the slope of salinity. In this figure, the Fisher's alpha value (from quadrats and transects) shows not correlation to salinity slope for the average slope within sites.

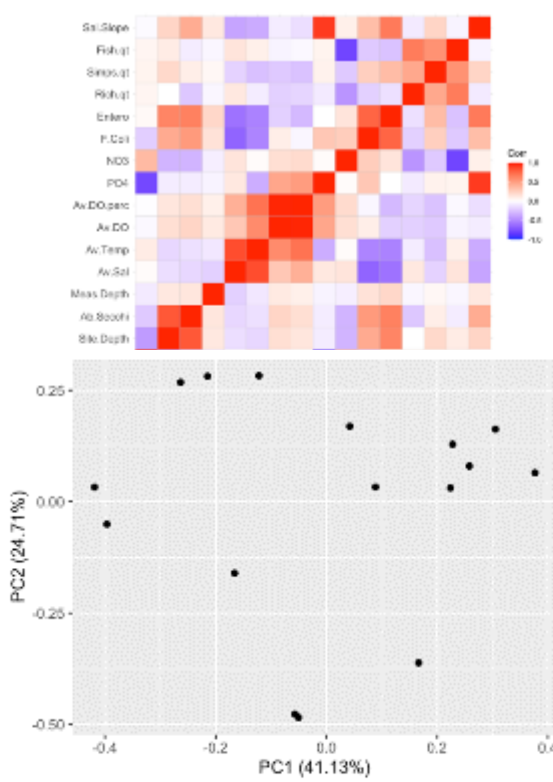
Conclusion:

Although mixing can help support life in estuaries, there is no relationship between the Salinity Slope and Fisher's Alpha. Therefore, at least for this mixing metric, we cannot assume that water mixing leads to greater biodiversity. However, the biodiversity indices do not consider the presence of rare species or species of concern.

Correlating All Metrics

Legend

Abbreviation	Definition
Sal.Slope	Salinity:Depth slope
Fish.qt*	Fisher's Alpha Index
Simps.qt	Simpsons Biodiversity Index
Rich.qt	Richness
Entero	*Enterococcus* spp. concentration
F.coli	Faecal coliform concentration
NO3	Nitrate concentration
PO4	Phosphate concentration
Av.DO.perc	Average dissolved oxygen percent
Av.DO	Average dissolved oxygen content (mg/mL)



Av.Temp	Average temperature (°C)
Av.Sal	Average salinity (ppt)
Meas.Depth	Depth of sample or measurement (m)
Ab.Secchi	Secchi Depth (m)
Site.Depth	Depth at the site (m)
Mouth.Dist	Distance from the freshwater input mouth

*qt = data from quadrat and transect survey

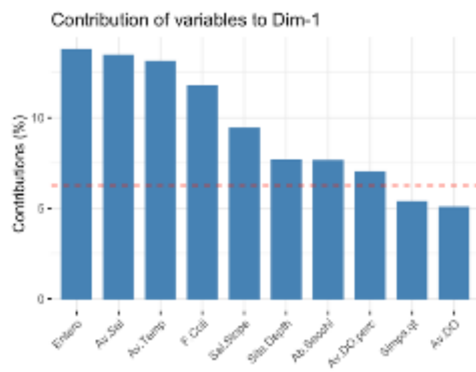


Figure 3-9: Principal Component Analysis (PCA) for multiple variables. This represents the relationship between all the metric we measured at each estuary site. We added in the variable of distance from the river mouth (Mouth.Dist), the depth (Site.Depth), measurement depth (Meas.Depth), and Secchi depth/turbidity (Ab.Secchi) for each site within all the Area 1 estuaries.

<u>Further analyses:</u>

We removed the nutrients and bacterial contamination values as they introduced low numbers and re-ran the PCA.

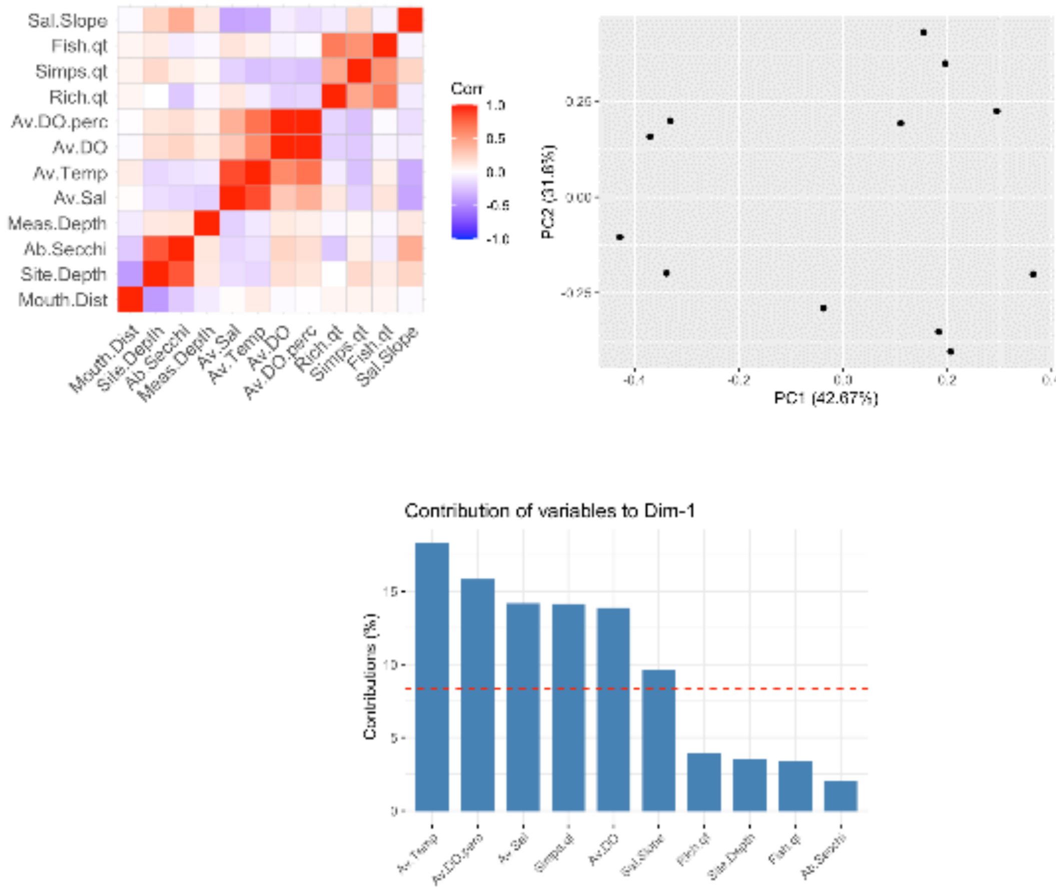


Figure 3-10: The PCA of multiple variables, omitting the data rows with Nitrate, Phosphate, *Enterococcus*, and Faecal coli values.

Conclusion:

There is little contribution towards PC1, with or without the omissions of bacterial and nutrient concentrations; however, the bacterial content and physical water features of salinity and temperature contribute the most to the analysis. Without the nutrients and bacterial concentration measurements, the physical water characteristics similarly correlate, but since they are responding to similar cues, this is to be expected. Surprisingly, the Simpsons Biodiversity Index is grouped within the physical characteristics of the estuary. Since Simpsons does not account for grouping or schooling animals compared to those that live solitary, we consider it an ecologically unreliable metric for biodiversity. Therefore, since they are grouped with Simpsons Index values, physical water quality measurements are not the right direction for finding a correlation for biodiversity in the Salish Sea estuaries.

Further analysis:

The PCA of an average of the biodiversity indices and salinity slope.

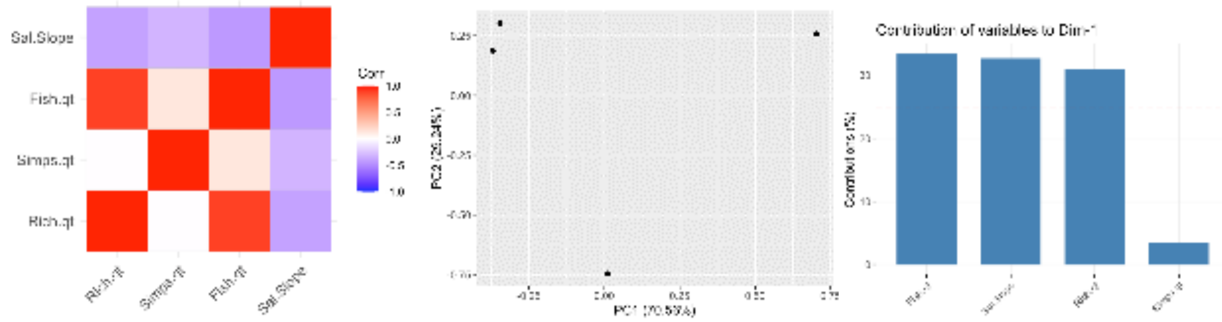


Figure 3-11: PCA results of the salinity slope and the biodiversity indices. The salinity slope is the mean of the slopes of each site in the estuaries, and the biodiversity indices were calculated by combining all the data from each site survey within an estuary.

Appendix H: Full Species List

Legend	
Arthropod	A
Cnidarian	C
Echinodermata	E
Fish	F
Mollusc	M
Photosynthetic	P
Sponge	S
Tunicate/Ascidian	T
Worm	W

Species	Common Name	Species Category		ID Guess	
Ahnfeltia sp.	Wiry red alga	P	indigenous		
Ammodytes hexapterus	Pacific sand lance	F	indigenous		
Apodichthys flavidus	Penpoint gunnel	F	indigenous		
Artedius fenestralis	Padded sculpin	F	indigenous		
Artedius harringtoni	Scalyhead sculpin	F	indigenous		
Artedius sp. 1	Sculpin	F	indigenous		
Artedius sp. 2*		F	indigenous	Smoothhead sculpin	*A. lateralis*
Artedius sp. 3*		F	indigenous	Padded sculpin	*A. fenestralis*
Aurelia aurita	Moon jelly	C	indigenous		
Calliostoma ligatum	Western ridged top snail	M	indigenous		
Calliostoma sp.	Top snail	M	indigenous		
Callophyllis sp.	Red alga	P	indigenous		
Cancer productus	Red rock crab	A	indigenous		
Clupea pallasii	Pacific herring	F	indigenous		
Cnemidocarpa finmarkiensis	Broad-based sea squirt	T	indigenous		
Crangon alaskensis	Northern crangon shrimp	A	indigenous		
Crangon sp.		A	indigenous		
Diaulula odonoghuei	Leopard dorid	M	indigenous		
Doris montereyensis	Monterey sea lemon	M	indigenous		
Enophrys bison	Buffalo sculpin	F	indigenous		
Eupolymnia heterobranchia	Brown intertidal spaghetti worm	W	indigenous		
Fucus distichus	Rock weed	P	indigenous		
Gadus chalcogrammus	Allaska pollock	F	indigenous		
Gonionemus vertens	Clinging jelly, cross jelly	C	indigenous		
Gracilaria andersonii	Sea spaghetti	P	indigenous		
Haminoea sp.	Bubble snails	M	indigenous/introduced	White or green bubble snail (or Japanese bubble snail)	*Haminoea vesicula or H. virescens (or H. japonica)*
Hemilepidotus hemilepidotus	Red irish lord	F	indigenous		
Heptacarpus sp.	shrimp	A	indigenous		
Hexagrammos stelleri	Whitespotted greenling	F	indigenous		
Lacuna sp.	Littorinid snail	M	indigenous		
Laminaria ephemera	Laminaria	P	indigenous		
Lepidogobius lepidus	Bay goby	F	indigenous		
Leptasterias sp.	sea star	E	indigenous		*L. hexactis*

Leptocottus armatus	Staghorn sculpin	F	indigenous		
Magallana gigas	Pacific oyster	M	introduced		
Metacarcinus gracilis	Graceful rock crab	A	indigenous		
Metacarcinus magister	Dungeness crab	A	indigenous		
Metridium senile	Plumose anemone	C	indigenous		
Myoxocephalus polyacanthocephalus	Great sculpin	F	indigenous		
Myxicola infundibulum	Slime tubeworm	W	indigenous		
Ophiodon elongatus	Lingcod	F	indigenous		
Oregonia gracilis	Graceful decorator crab	A	indigenous		
Pandalus danae	Coonstripe shrimp	A	indigenous		
Pholis clemensi	Longfin gunnel	F	indigenous		
Pholis laeta	Crescent gunnel	F	indigenous		
Pholis ornata	Saddleback gunnel	F	indigenous		
Pholis sp.	Gunnel	F	indigenous		
Phyllaplysia taylori	Taylor's sea hare	M	indigenous		
Phytichthys chirus	Ribbon prickleback	F	indigenous		
Platichthys stellatus	Starry flounder	F	indigenous		
Pleuronichthys coenosus	C-O sole	F	indigenous		
Podothecus accipenserinus	Sturgeon poacher	F	indigenous		
Porichthys notatus	Plainfin midshipmen	F	indigenous		
Psychrolutes paradoxus	Tadpole sculpin	F	indigenous		
Ptilosarcus gurneyi	Sea pen	C	indigenous		
Pugettia gracilis	Graceful kelp crab	A	indigenous		
Pugettia producta	Kelp crab	A	indigenous		
Scleroplax littoralis	Gaper pea crab	A	indigenous		
Scyra acutifrons	Sharp-nosed crab	A	indigenous		
Semibalanus cariosus	Thatched barnacle	A	indigenous		
Synchirus gilli	Manacled sculpin	F	indigenous		
Syngnathus californiensis	Kelp pipefish	F	indigenous		
Telmessus cheiragonus	Hairy helmet crab	A	indigenous		
Tresus capax	Fat gaper clam	M	indigenous		
Ulva lactuca	Sea lettuce	P	indigenous		
Unid alga*		P	indigenous	Arched red seaweed	*Fryeella gardeneri*
Unid ascidian 1*		C	Invasive	Violet tunicate/ascidian	*Botrylloides violaceus*
Unid ascidian 2*		C	Invasive	Golden star tunicate/ascidian	*Botryllus schlosseri*
Unid demosponge 1*		S	indigenous	Sponge	*Halichondria sp.*
Unid demosponge 2*		S	indigenous	Sponge	*Suberites sp.*
Unid flat red alga*		P	indigenous	Iridescent seaweed	*Mazzaella splendens*
Unid gunnel*		F	indigenous	Penpoint gunnel	*Apodichthys flavidus*
Unid hermit crab 1*		A	indigenous	Hermit crab	*Pagurus sp.*
Unid hermit crab 2*		A	indigenous	Grainyhand hermit crab	*Pagurus granosimanus*
Unid jelly*		C	indigenous	Moon jelly	*Aurelia labiata*
Unid mud snail*		M	Invasive	Asian hornsnail or Japanese false cerith snail	*Batillaria cumingii or B. attramentaria*
Unid purple ascidian*		F	indigenous	High cockscomb	*Anoplarchus purpurescens*
Unid sculpin 1*		F	indigenous	Tidepool sculpin	*Oligocottus maculosus*
Unid sculpin 2*		F	indigenous	Smoothhead sculpin	*Artedius lateralis*

Unid sculpin 3*		F	indigenous	Scalyhead sculpin	*Artedius harringtoni*
Unid shrimp 1*		A	indigenous	Kelp humpback shrimp	*Hippolyte clarki*
Unid shrimp 2*		A	indigenous	Red-banded transparent shrimp; Sitka coastal shrimp	*Heptacarpus sitchensis*
Unid snail*		M	indigenous	Nassarius snail	*Nassarius sp.*
Unid tunicate*		T	Invasive	Sea grape or Fluted sea squirt	*Molgula manhattensis or Ascidiella aspersa (introduced)*
Unid wiry red alga*		P	indigenous	Red spaghetti alga	*Gracilaria sp.*
Zostera marina	Eelgrass	P	indigenous		