Phase Two: Creating a Living Laboratory for Deadmans Head Peninsula During the Age of Climate Change: Intertidal Zones within Deadmans Harbour and the Bay of Fundy

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Abstract

The owners of Deadmans Head Peninsula, Ernie and Judy Edwards, aim to create a living laboratory on their property to study the effects of climate change on the coastal ecosystem. Located within the Bay of Fundy the property is subject to many unique features including the natural wonder of the highest tides in the world that the Bay of Fundy is famous for. In Phase One of this project the forested landscape of the peninsula was assessed for floral and faunal assemblages and the possible impact of climate change on them. In Phase Two of this project we assess the coastal community structure that makes up the intertidal zone on both sides of the peninsula, sites are along Deadmans Harbour and the Bay of Fundy. From the field work and literature review done we present a comprehensive overview and baseline of the species that live within the site or those that could potentially interact with the site and what the possible impacts of climate change could mean for these species.

Using various methods of assessment including literature review, drone imagery, and literature review, we have created a baseline of data and have predicted some of the possible implications for the species within the area and have recommendations for the living laboratory going forward.

1.0 Introduction

1.1 Background

Deadmans Head Peninsula is located within the Bay of Fundy region, just east of the town of Blacks Harbour, in Southwestern New Brunswick. Deadmans Head is surrounded by Deadmans Harbour to the west and by the Bay of Fundy to the east.

The owners of Deadmans Head Peninsula, Ernie and Judy Edwards, have partnered with the University of New Brunswick to work with students to create a "living laboratory" on their property, which would be led by the Nature Trust of New Brunswick. Their primary goal is to identify and detail current species on and around the site using iNaturalist, track over time how these species respond to the change in climate, use remote tools to minimize human interaction with the site where possible, to share data with other like-minded organizations and encourage and work with expanding other research sites, and finally to preserve and protect their property so that future generations can enjoy it. The Edwards have also created a website, The Ecological Response Research Centre, where information is available about the property, the living lab and Phase One of the project.

1.1.1 Phase One

Phase One of the Living Lab Project occurred in 2022 and the forested peninsula of Deadmans Head was the area studied by four University of New Brunswick Master of Environmental Management students. Baseline data was collected to determine key characteristics of the forest located on the peninsula. A baseline data set for the forest was collected by taking field samples and capturing aerial images as well as observations about different tree species, wildlife, and other species in the forest (Evans *et al*, 2022). The fishnet tool on ArcGIS was used to create 57 random sampling points within the forest, and an 80-meter squared area was studied at each point. Some of the topics of study include determining canopy cover, tree circumference, tree age, tree height, different tree species found on the site, different insects, mammals and understory on site (Evans *et al*, 2022). Some of the areas of focus were on the impact climate change will have on these species and the study site as well as creating a Normalized Vegetation Index Map, which categorized the health of vegetation (Evans *et al*, 2022).

1.2 Project Scope

The scope of Phase Two for the Living Lab Project is to identify species throughout the intertidal area at three different locations around the peninsula. These sites are split up to analyze both Deadmans Harbour and the Bay of Fundy intertidal zones. Two sites are on the Harbour side of the peninsula at beaches located along the shore with the third site being a rocky cove on the Bay of Fundy coast. The project aims to assess the various organisms living within and interacting with the sites that could be impacted by climate change.

1.3 Project Team

The team for Phase Two consists of five Master of Environmental Management students with varying backgrounds and roles for this project. Allysia Murphy is the Project Manager and Subject Matter Expert; she possesses background knowledge in the field of marine biology and has taken courses in phycology and coastal ecology making her a prime candidate to lead the project. Sarah Dooley is the Report Editor for the group, she oversees editing the final report and final presentation. Allison Meister is the Data Analyst for the group and oversees raw data entry and analysis. Kianna Hughes-Clarke is the Spatial Analyst for the group with a background in geospatial analysis including experience flying drones. Finally, Dhiman Sen is the Surveying Assistant and helped record data while surveying the sites.

1.4 Study Site

1.4.1 General Site Information

The location of the site is within the boundaries of the Village of Blacks Harbour New Brunswick (Figure 1). Blacks Harbour is a small fishing village on the Bay of Fundy with a population of just under 1000 (Tourism New Brunswick, 2023). Blacks Harbour has been home to many leading seafood companies like Connors Bros., Clover Leaf Seafoods Company and Cooke Aquaculture due to the nutrient-rich waters of the Bay of Fundy (Tourism New Brunswick, 2023). Blacks Harbour is also home to Eastern Charlotte Waterways Inc., a non-profit environmental resource and research centre that aims to work with other like-minded groups to promote community well-being through environmental health (ECW, n.d). The Bay of Fundy is home to some of the highest tides in the world due to the natural seiche that occurs within it (Parks Canada, 2023). Due to these tidal movements high biodiversity is supported by different biophysical processes throughout areas of the Bay of Fundy (Daborn, 2018). The movement from the tides force deep, cold and nutrient-rich water to the surface provide an excellent foraging ground for fish, birds and other mammals (Daborn, 2018). The incredible tidal action that occurs within the Bay of Fundy also enable the rocky shore to support the growth of seaweeds and different fauna including diverse assemblages of invertebrates (Daborn, 2018).

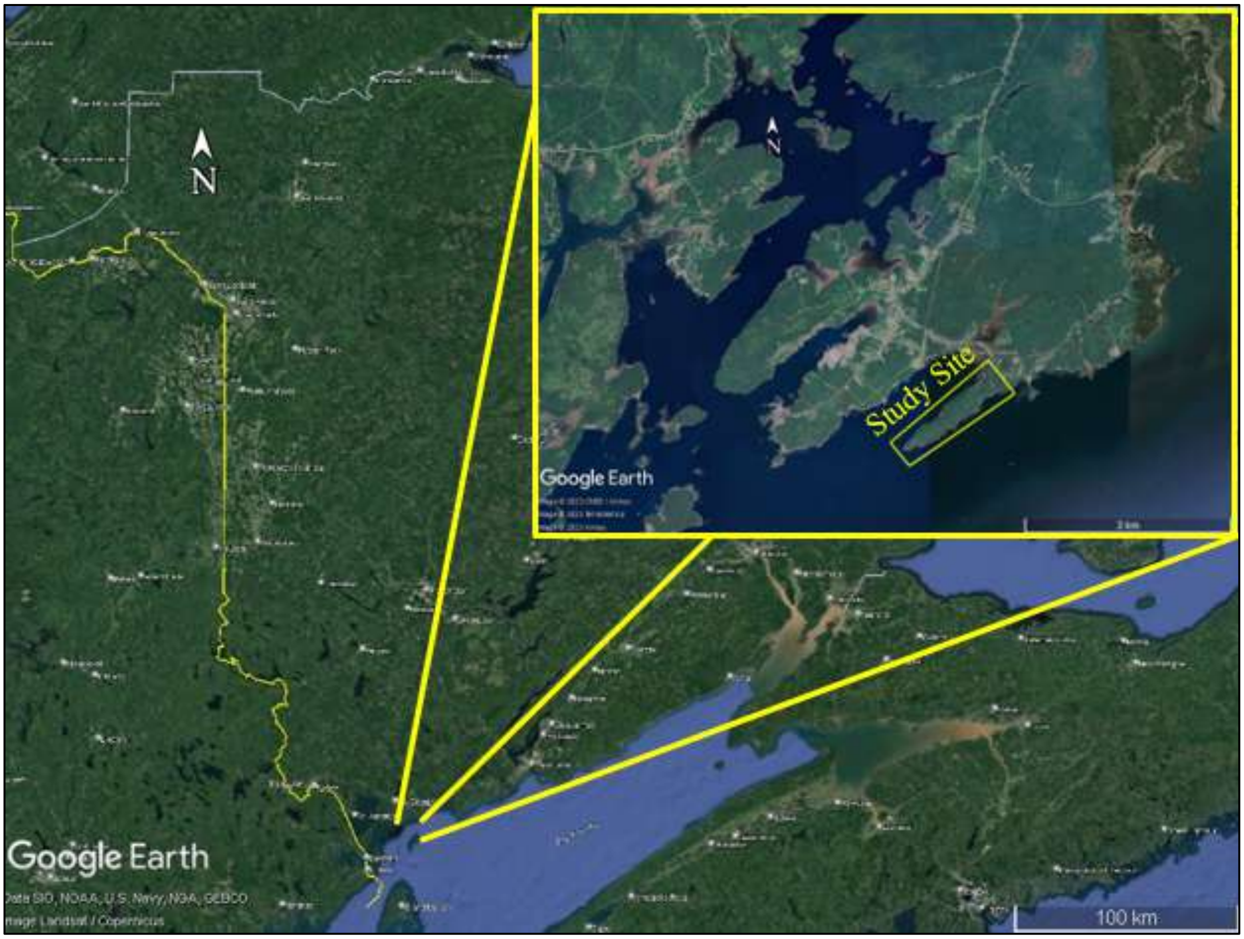

Figure 1. Google Earth imagery of the study site on a provincial scale and zoomed in view shown in upper right corner (Google Earth, 2023).

Climate change is predicted to have severe impacts on the Bay of Fundy and therefore could have impacts on the location of the study site. Impacts from climate change include rising sea levels and warming water temperatures. The rising sea level will increase the tidal range within the bay, which will increase the high-water level and will increase the risk of flooding, especially in low-lying areas along the Bay (Greenberg *et al*, 2011). Along with rising sea levels, the water temperatures are warming which is negatively impacting the organisms that live in the Bay. Warmer temperatures are impacting where the animals go within the Bay and what food is available to them (Greenberg *et al*, 2011). Warmer waters are also increasing the success of invasive species in the Bay, which is negatively impacting the native species (Greenberg *et al*.

2011). These impacts are also going to affect the local fishing industry in this area of the province, impacting the local economies and livelihoods of many people who rely on the industry.

1.4.2 Deadmans Harbour Beach Site One

Beach One is closer to the head of the harbour and is the first site analyzed (Figure 2). It is located close to the top of the harbour and is adjacent to a salt marsh, located at the head of the harbour. It is a relatively flat terrain lacking a true low tide zone, with non-distinct transition zones with a sheltered shore with relatively low wave action. The approximate length of the shoreline is 200m which backs onto a forested slope up to the rest of the property which is forested and described in Phase One of the project. There is easy access to the beach through a gravelled slope which can be used as a boat launch or to walk down to the beach and there are well-defined trails from the main property where the house is located down to the first beach from the main house. The beach is rocky with gravel and has some larger rocky outcrops, a smaller rocky outcrop closer to the right towards the salt marsh with a larger rocky outcrop to the left further down the site (Figure 3). When it is high tide, the entire beach is completely submerged. Further up the beach, closer to the mouth of the harbour some weirs that were once used in the fishing industry are visible and there is evidence along the beach of fishing gear, with ropes, nets and lobster claw bands.

Figure 2. Google Earth imagery of Deadmans Head Peninsula showing drone imagery captured of Beach One site (Google Earth, 2023).

Figure 3. Photos from Beach One site, on the left is a photo taken at mid tide during initial site visit on September 15th, 2023, on the right is a photo taken at low tide during Beach One survey visit on October 20th, 2023.

1.4.3 Deadmans Harbour Beach Site Two

The second site, known as Beach Two, is located further up the peninsula, closer to the mouth of the harbour (Figure 4). It has a very similar structural composition to Beach One, with relatively flat terrain, with no true low tide zone and non-distinct transition zones. It is also a sheltered shore with low wave action. The shoreline is approximately 175m in overall length. Similarly, to Beach One the beach is surrounded in part by dense forest and rocky cliffs. The trail to get to this location is not as well defined but marked, with easy access but some steep terrain. This location is adjacent to the weirs that were visible from Beach One. Like Beach One, Beach Two is a rocky beach with gravel and some larger rocky outcrops (Figure 5). There is also evidence along the shore of old fishing gear including rope, netting and lobster claw bands.

Figure 4. Google Earth imagery of Deadmans Head Peninsula showing Beach Two site (Google Earth, 2023).

Figure 5. Photos from Beach Two site, on the left is a photo taken at mid tide during initial site visit on September 15th, 2023, on the right is a photo taken at low tide during Beach Two survey visit on November 3rd, 2023.

1.4.4 Bay of Fundy Cove Site

The third site, also known as Canela's Cove or the Cove, is located on the eastern side of the peninsula facing the Bay of Fundy (Figure 6). There are trails from the house to the rocky shore where the survey was conducted that are well defined. The top of the cove site is forested but with a steep drop-off to the cove. The site is a classic rocky shore with steep cliff areas and faces the Bay of Fundy. There are very large rocky outcrops covered in in various algae species, with few feasible access points for the surveyors to get to (Figure 7). There are high elevation changes at this site with clearer evidence of zonation of species and a true low tidal zone. This site is more exposed and has a higher wave action. From the cove site you can occasionally see fishing vessels and other ships on the horizon. There was evidence on the site of washed-up fishing gear, like rope and lobster claw bands, as well as washed up plastic bottles and other waste.

Figure 6. Google Earth imagery of Deadmans Head Peninsula showing drone imagery captured of Cove site (Google Earth, 2023).

Figure 7. Photos from Beach Two site, on the left is a photo taken at mid tide during initial site visit on September 15th, 2023, on the right is a photo taken at low tide during Cove survey visit on October 27th, 2023.

2.0 Methods

2.1 Literature Review

To determine the effects of climate change on the Bay of Fundy and its constituent species, we performed a comprehensive literature review using scientific reports and government resources. This involved researching the effects of climate change and investigating environmental parameters including sea level rise, salinity changes, ocean acidification, and temperature changes. We focused on algal and invertebrate species commonly found in the region, as well as other marine animals found in the Bay of Fundy; research was not limited to species found within our transects but instead species known to occur within the area.

2.1.1 Species Literature Review

Twenty algal and 15 invertebrate species were researched regardless of if they were found within project transects (Table 1). While there is much data and research available for some species, others are not well documented in literature; this knowledge gap can cause issues with conservation plans and interpretations. It should be noted that some species are also found in other parts of the world and literature from these other regions was still used to help inform this report. Upon completion and finalization of our literature review and research, findings were summarized for all species to determine which could potentially be negatively affected by climate change. Although many species were analyzed through literature review only select few were analyzed further due to time constraints. We also researched 19 other animals (marine fishes and mammals and seabirds/shorebirds) that could potential interact with the site that are already monitored by government entities due to species concerns (Table 1).

Table 1. List of species that were researched during literature review.

Algal Species	Invertebrate Species	Marine Mammals	Marine Fishes	Migratory Birds
Agarum clathratum	*Acmaea testudinalis*	*Balaenoptera physalis*	*Sebastes fasciatus*	*Oceanodroma leucorhoa*
Alaria esculenta	*Asterias rubens*	*Phocoena phocoena*	*Anguilla rostrata*	*Charadrius melodus*
Ascophyllum nodosum	*Buccinum undatum*	*Eubalaena glacialis*	*Hippoglossoides platessoides*	*Phalaropus lobatus*
Chaetomorpha melagonium	*Cancer irroratus*		*Thunnus thynnus*	
Chaetomorpha brachygona	*Carcinus maenas*		*Gadus morhua*	
Chondrus crispus	*Crepidula plana*		*Salmo salar*	
Corallina officinalis	*Henricia sanguinolenta*		*Acipenser oxyrinchus*	
Fucus distichus	*Littorina littorea*		*Cyclopterus lumpus*	
Fucus spiralis	*Littorina saxatilis*		*Isurus oxyrinchus*	
Fucus vesiculosus	*Littorina obtusata*		*Amblyraja radiata*	
Hedophyllum nigripes	*Modiolus modiolus*		*Urophycis tenuis*	
Laminaria digitata	*Mytilis edulis*		*Carcharodon carcharias*	
Mastocarpus stellatus	*Nucella lapillus*		*Leucoraja ocellata*	
Palmaria palmata	*Semibalanus balanoides*			
Phycodrys fimbrata	*Strongylocentrotus droebachiensis*			
Plumaria plumosa				
Saccharina latissima				
Ulva fenestrata				
Ulva intestinalis				
Ulvaria obscura				

2.2 Field Research & Data Collection Methods

The project team travelled to Deadmans Head five times for this project (Table 2). These visits included an initial site visit, ID practice for the project team, flying drones for data collection, and three times to collect data at various sites. During the initial site visit, we were given a tour of the property trails leading to each of our sites: Beach One, Beach Two, and the Cove site which is affectionately called Canela's Cove after an old pet. During the second visit, we practiced species identification at Beach One and flew the drone over Beach One and the Cove at high, mid, and low tide. Beach Two could not be assessed with the drones as the launch site was too far away and terrain was not suitable to bring the drone closer. Species were identified using identification guides from various courses the University of New Brunswick offers while iNaturalist and Seek were used as secondary materials to verify species identifications if needed. The first surveying visit for data collection was October 20th, 2023, and was done at Beach One; this was done during a neap tide and took place around low tide which was 10:15am. The second surveying visit for data collection was October 27th, 2023, and was done at the Cove; this was done during a spring tide so that water levels would be the lowest possible and took place around low tide which was 5:24pm. The third surveying visit for data collection was November 3rd, 2023, and was done at Beach Two; this was done during a neap tide and took place around low tide which was 10:24am. The preference for this order was determined due to the geography of the cove site and the exposure to wave action; studying this site during a spring tide when the low tide is at its lowest point was ideal for reaching a truer low tidal zone within the site.

Table 2. Date of site visits and what activities took place during the visit.

Date	Activity
15-Sep	Initial site visit and property tour
27-Sep	Species ID practice and drone flights
20-Oct	Data collection at Beach One
27-Oct	Data collection at Cove
03-Nov	Data collection at Beach Two

2.2.1 Transects

Data was collected along transects, amount of transects at a site was dependent on-site size and feasibility of surveying area. As a result, Beach One had three completed transects each with six sampling points, Beach Two had two completed transects each with six sampling points, and the Cove had one completed transect with 12 sampling points. At each sampling point sampling quadrat were placed, placement was randomized along the length of the transect. At sites with multiple transects they were distributed relatively in the same positioning; quadrat placement was done with no pre-planning to ensure there were no biases in data collection. The algal percent cover quadrat was placed first with the invertebrate abundance quadrat being placed in an adjacent position (Figure 8). Transects were distributed strategically at each of the sites (Figure 9). For all transects, quadrat one was located at the high tide mark at the site, and the final quadrat was located near the low tide line, this final quadrat was taken at the low tide time as determined above. Distances between sampling points were measured using a 30m field tape measure. Collection methods were adapted from Dr. Myriam Barbeau's Coastal Marine Ecology class offered at the University of New Brunswick. Information recorded on data sheets for each transect included the site name, date, transect start and end times, the transect number, time of low tide, and the group members collecting data.

Figure 8. Quadrat set up during Cove survey visit on October 27th, 2023, showing both the algal cover 50-point random sampling quadrat (0.5m x 0.5m) and the invertebrate abundance quadrat to the upper left (10cm x 10cm).

Figure 9. Google Earth imagery of Deadmans Head Peninsula showing drone imagery captured of Beach One and Cove site with overlayed transects for all three survey sites (Google Earth, 2023).

2.2.1.1 Algal Cover

Percent algal cover was measured along transects using 0.5m x 0.5m quadrats. Quadrats were carefully placed along the transect at approximately equal distances to reduce sampling bias. Each quadrat has 50 flags indicating where to determine algal species present, this randomized the distribution of points at each sampling point along the transect to further reduce bias. At each flag on the quadrat, the species directly below were recorded on data sheets using predetermined species codes. A new data sheet was used for each transect. Any additional species not found in quadrats were also recorded, these were determined by doing visual scans of the site itself to ensure all species present could be accounted for.

For analysis of results, percent composition of each algal species in each quadrat was calculated by summing the count of each species within a quadrat, since there were 50 flags present on the quadrat the summation of species count could be multiplied by two to receive percent abundance. Data was then compared between transects, between beaches, and between the beach sites and cove. Data was also analyzed to determine patterns between species composition and elevation throughout tidal zones.

2.2.1.2 Invertebrate Assessment

Invertebrate species abundance was measured along transects using 10cm x 10 cm quadrats. Quadrats were placed haphazardly adjacent algal cover quadrats to reduce sampling bias. The number of invertebrate species in each quadrat were counted and recorded on data sheets. A new data sheet was used for each transect. Information recorded on data sheets for each quadrat denoted tidal zone or transition zone (H (high), H/M (high-mid), M (mid), M/L (mid-low), or L (low)), distance between quadrats in metres, total distance from the first quadrat, invertebrate species count, any additional species found in or around the quadrat, and a description of the immediate environment. Any additional species not found in quadrats were also recorded, these were determined by doing visual scans of the site itself to ensure all species present could be accounted for.

For analysis of results, abundance of invertebrate species in each quadrat were compared between transects, between beaches, and between the beach sites and cove. Data was also analyzed to determine patterns between species composition and elevation throughout tidal zones.

2.2.1.3 iNaturalist

Photos were taken of all species found and uploaded to iNaturalist. All photos uploaded to iNaturalist on the property are automatically added to Deadmans Head Forest, an iNaturalist Project. The property owners want to ensure this source is kept up to date as a repertoire for future studies on the site as photos are geographically referenced and time stamped.

2.2.2 Drone Imagery

Unmanned aerial vehicles (UAV's), also known as drones, have matured since their popularization in 2016 and are now a preferable method of conducting research (Turner *et al*., 2016). Under the legal restrictions that limit their application in Canada, UAVs offer a productive and economical survey instrument for topographic mapping and measuring in the seaside region (Turner *et al*., 2016). Coastal specialists now have easy access to commercially accessible UAV equipment, data processing, and analysis tools designed for surveying environments (Turner *et al*., 2016). Survey-grade UAVs with integrated RTK-GPS for precise positioning eliminates the need for on-site surveying of ground control points (GCPs), which was previously necessary for post-deployment data processing (Turner *et al*., 2016).

The biodiversity that inhabits coastal habitats has been disappearing at previously unheard-of rates, taking with it vital ecosystem services that are essential to human survival (Monteiro *et al*., 2021). Comprehending the many elements and processes that propel the operation of shoreline ecosystems is essential for determining how species, ecosystems, and eventually human populations will adapt to the ecological aftermath of both natural and man-made influences (Monteiro *et al*., 2021). To achieve this, data on the geographical distribution of habitat, the anthropogenic stress such as pollution and land use must be provided via coastal monitoring programs and studies (Monteiro *et al*., 2021).

With the aim of establishing a baseline of the existing species and their locations in the intertidal zone of Deadmans Harbour, an UAV was flown on site at two of the three research sites. Three flights were conducted at each location: one during high tide, one during mid tide, and one during low tide. This provided us with a set of aerial photos that would serve as a baseline for additional research and be used to assess the locations of the current species.

The industrial-grade mapping drone that was utilized was the DJI Matrice 300 RTK. Its real-time kinematic (RTK) positioning capabilities yield accuracy levels of 1.5cm+1ppm in the vertical and 1cm+1ppm in the horizontal directions (DJI, 2023a). The wind conditions on the day of flight (September 27^{th}) also have a significant impact on these accuracy levels; however, it was observed that the average wind speed that day was a very low at 3 km/h (Government of Canada, 2023). The DJI Zenmuse XT2 camera was utilized to retrieve the aerial data. With its attachment to the UAV via a gimbal, it can produce raster images and thermal imagery for further analysis (DJI, 2023b).

The Zenmuse XT2 can record thermal images because its TIR (thermal infrared) sensors detect radiation emitted from objects passively. The infrared data is transformed by the camera into an electronic image that displays the object's apparent surface temperature. The device primarily records data in the 8–15 micrometer (μm) Long Wavelength Infrared (LWIR) region of the electromagnetic spectrum for environmental studies. The bolometric effect, which is the change in a material's electrical resistance brought on by temperature increases brought on by absorbed radiation, is how this device produces TIR images. The primary constraint on TIR sensors is thermal drift, which arises from the device's exposure to heat. Utilizing tinfoil on the Zenmuse XT2 has been shown to minimize thermal drift, which was utilized during the flights (O'Sullivan *et al*., 2022).

3.0 Field Data Results

3.1 Species Identified

Several species were identified within the quadrats and the surrounding areas (Table 3; Table 4). After sampling each quadrat, the surrounding area was also looked over to identify if there were species close by that were not found within the quadrat, and these species were noted and added to iNaturalist. We did this for both seaweed and invertebrate species, for invertebrates this included presence of shells.

Table 3. Algal species found within the three survey sites and if they were found within the quadrats.

Algal Species	Found in Quadrat	Species Code
Fucus spiralis	Yes	FS
Fucus vesiculosus	Yes	FV
Fucus distichus	Yes	FD
Ascophyllum nodosum	Yes	AN
Elachista fucicola	Yes	EF
Vertebrata lanosa	Yes	VL
Chondrus crispus	Yes	CC
Corallina officinalis	Yes	CO
Saccharina latissima	Yes	SL
Ulva lactuca	Yes	UL
Ulva intestinalis	No	UI
Ahnfeltia plicata	No	AP
Agarum clathratum	No	AC
Porphyra umbilicalis	No	PU
Chaetomorpha brachygona	No	CB

Table 4. Invertebrate species found within the three survey sites and if they were found within the quadrats.

Invertebrate Species	Common Name	Found in Quadrat	Alive
Littorina littorea	Common Periwinkle	Yes	Yes
Littorina obtusata	Smooth Periwinkle	Yes	Yes
Semibalanus balanoides	Acron Barnacle	Yes	Yes
Cancer irroratus	Rock Crab	No	No
Cancer borealis	Jonah Crab	No	Yes
Carcinus maenas	European Green Crab	No	Yes
Nucella lapillus	Dog Whelk	No	No
Crepidula fornicata	Atlantic Slippershell	No	No
Mytilus edulis	Blue Mussel	No	No
Modiolus modiolus	Horse Mussel	No	No

3.2 Elevation Data

The elevation information for the Cove and Beach One was taken from the drone data. Digital Elevation Models (DEM) can be created with the Zenmuse XT2 data and post-processing, so elevation diagrams were made to display the precise low, mid, and high tide. The lowest recorded tide was chosen as the zero point, and the elevation change was plotted from there. With those numbers, we were able to illustrate all the tidal zones by dividing the areas into ranges including low intertidal zone (L), transition zone from mid to low intertidal zone (L/M), mid intertidal zone (M), transition zone from high to mid intertidal zone (M/H), and the high intertidal zone (H) (Figure 10; Figure 11).

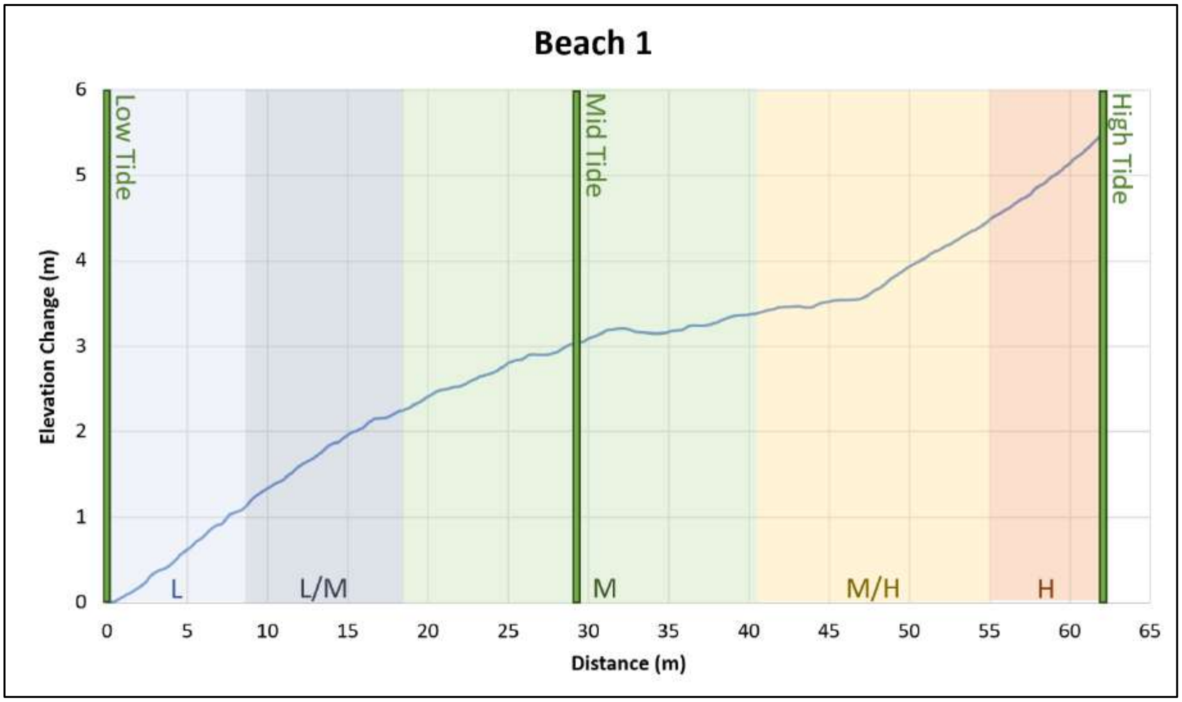

Figure 10. Elevation from Beach One site, elevation data was collected through the drone flight that took place on September 27th, 2023, through digital elevation models.

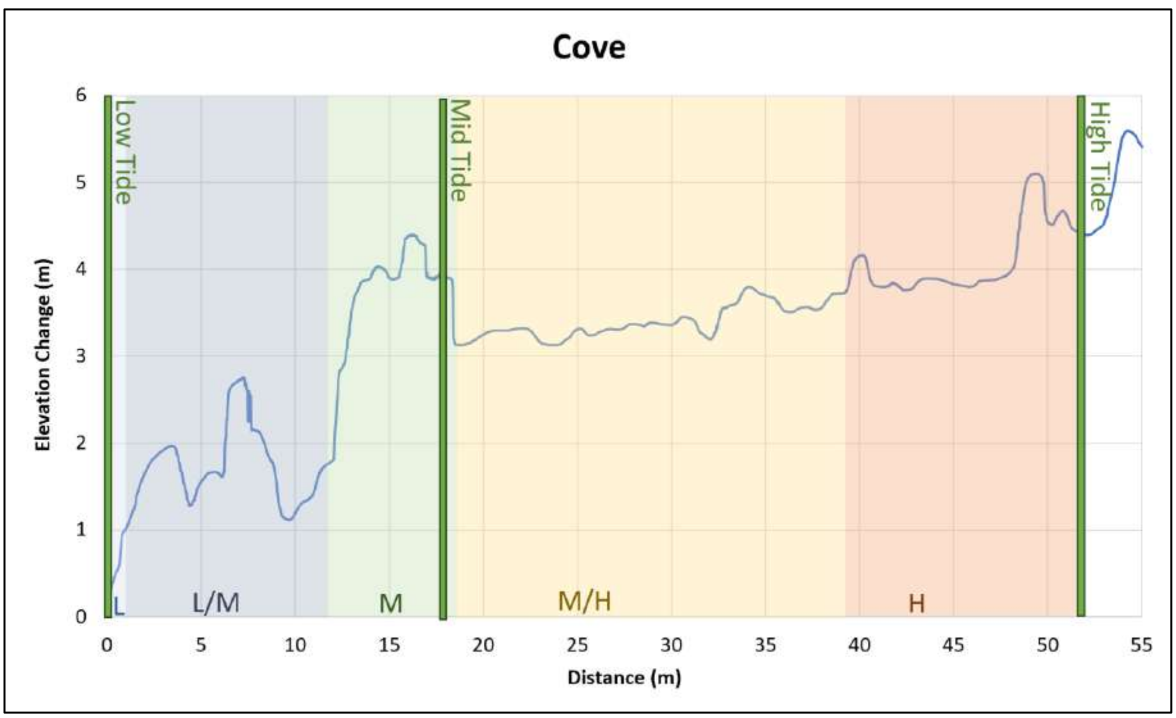

Figure 11. Elevation from Cove site, elevation data was collected through the drone flight that took place on September 27th, 2023, through digital elevation models.

3.3 Invertebrate Distribution

Three main species of invertebrates were identified: Smooth Periwinkle, Common Periwinkle, and Acorn Barnacle. The distribution graph for the transects at each of the three study sites, along with their placement within the tidal zones, were graphed to further demonstrate zonation of invertebrate species along an intertidal zone (Figure 12; Figure 13; Figure 14; Figure 16; Figure 17; Figure 20). Summary graphs of average invertebrate abundance per quadrat within each zone are also presented for each site (Figure 15; Figure 18; Figure 21), as well as for both beaches combined (Figure 19). Completed data sheets with the raw data are included in Appendix A.

3.3.1 Beach One

Beach One consisted of three transects each with six quadrats, at all three transects the following species were identified: Smooth Periwinkle, Common Periwinkle, and Acorn Barnacle. Acorn Barnacles were often the most abundant invertebrate throughout transects as they would be encrusted on rock faces. In Transect One the highest invertebrate abundance was in quadrat six (Figure 12), in Transect Two the highest invertebrate abundance was in quadrat five (Figure 13), and in Transect Three the highest invertebrate abundance was found in quadrat three (Figure 14). Common Periwinkles were more abundant than Smooth Periwinkles but neither species was overly abundant within this site; Acorn Barnacles were the dominant invertebrate at Beach One (Figure 15).

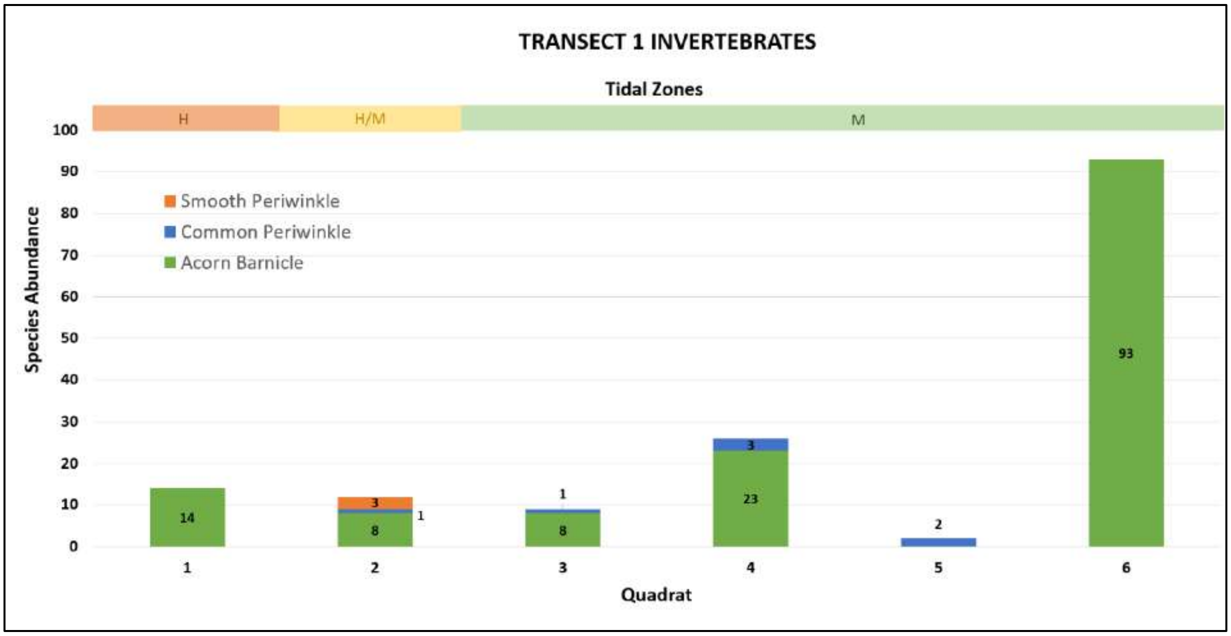

Figure 12. Beach One Transect One species abundance of invertebrates found within the six quadrats, data collected on October 20th, 2023.

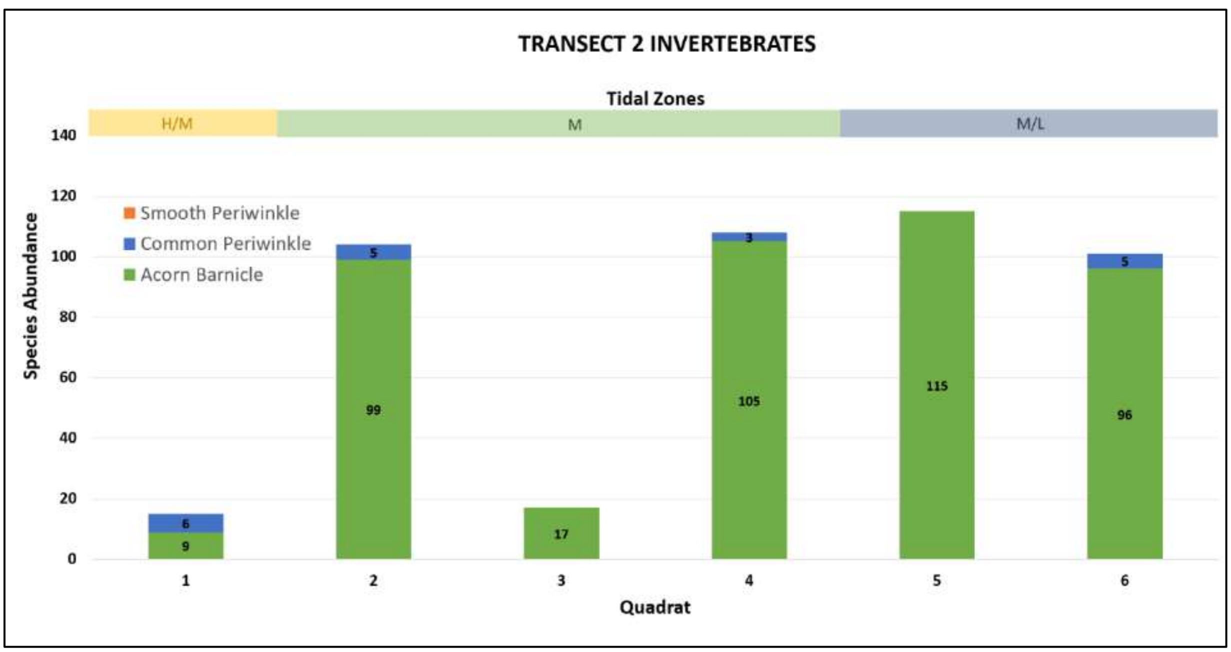

Figure 13. Beach One Transect Two species abundance of invertebrates found within the six quadrats, data collected on October 20th, 2023.

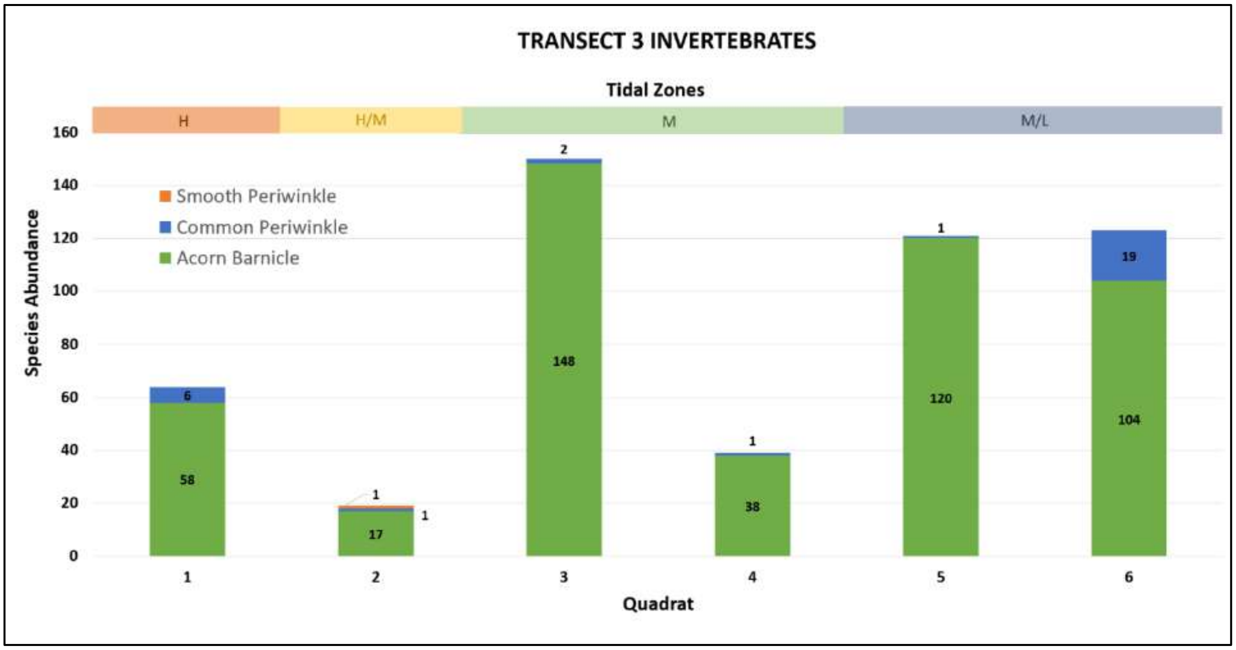

Figure 14. Beach One Transect Three species abundance of invertebrates found within the six quadrats, data collected on October 20th, 2023.

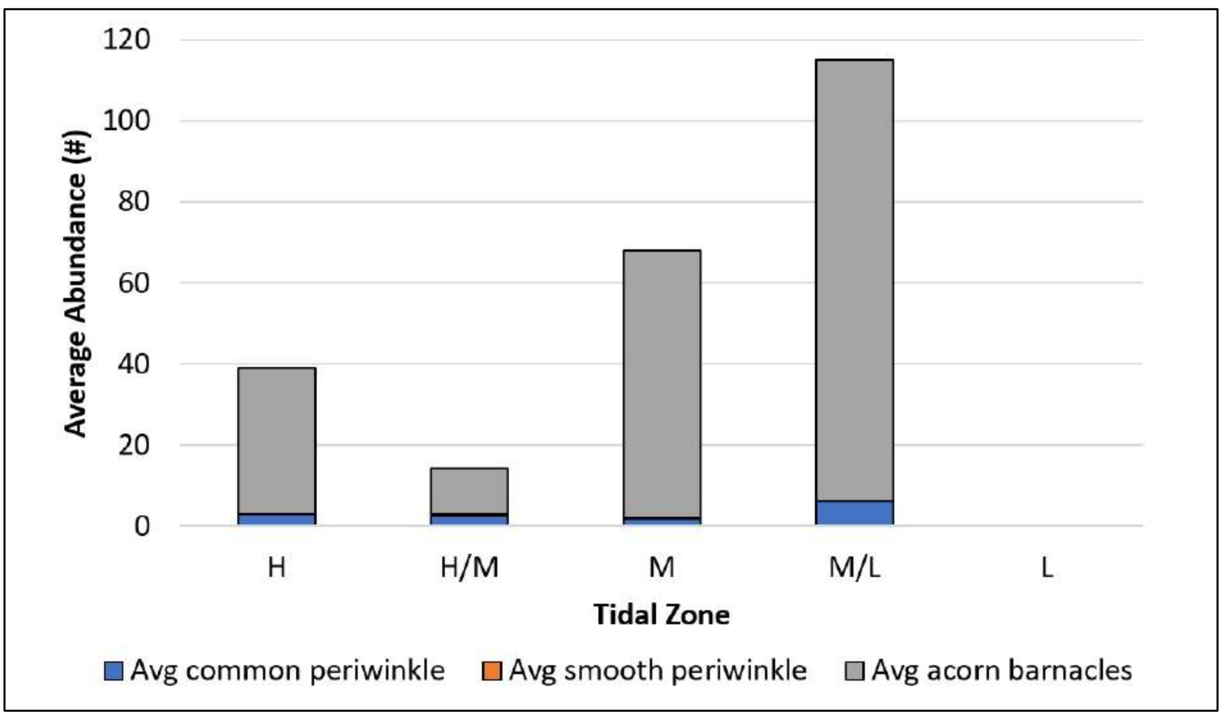

Figure 15. Beach One distribution of invertebrate average abundance based on three transects throughout the three tIt idal zones and their transition zones, data collected on October 20th, 2023.

3.3.2 Beach Two

Beach Two consisted of two transects each with six quadrats, at both transects the following species were identified: Smooth Periwinkle, Common Periwinkle, and Acorn Barnacle. Acorn Barnacles were often the most abundant invertebrate throughout transects as they would be encrusted on rock faces. In both Transect One and Transect Two the highest invertebrate abundance was in quadrat four (Figure 16; Figure 17). Common Periwinkles were more abundant than Smooth Periwinkles in Transect One while Smooth Periwinkles were more abundant than Common Periwinkles in Transect Two but neither species was overly abundant within this site; Acorn Barnacle was the dominant species at Beach Two (Figure 18).

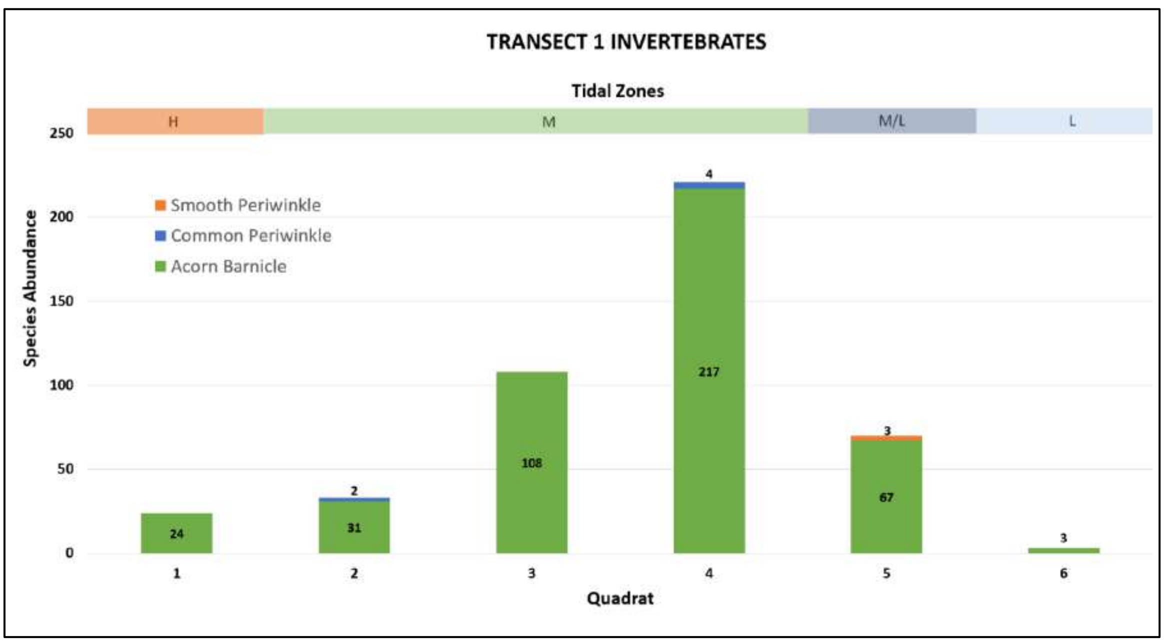

Figure 16. Beach Two Transect One species abundance of invertebrates found within the six quadrats, data collected on November 3rd, 2023.

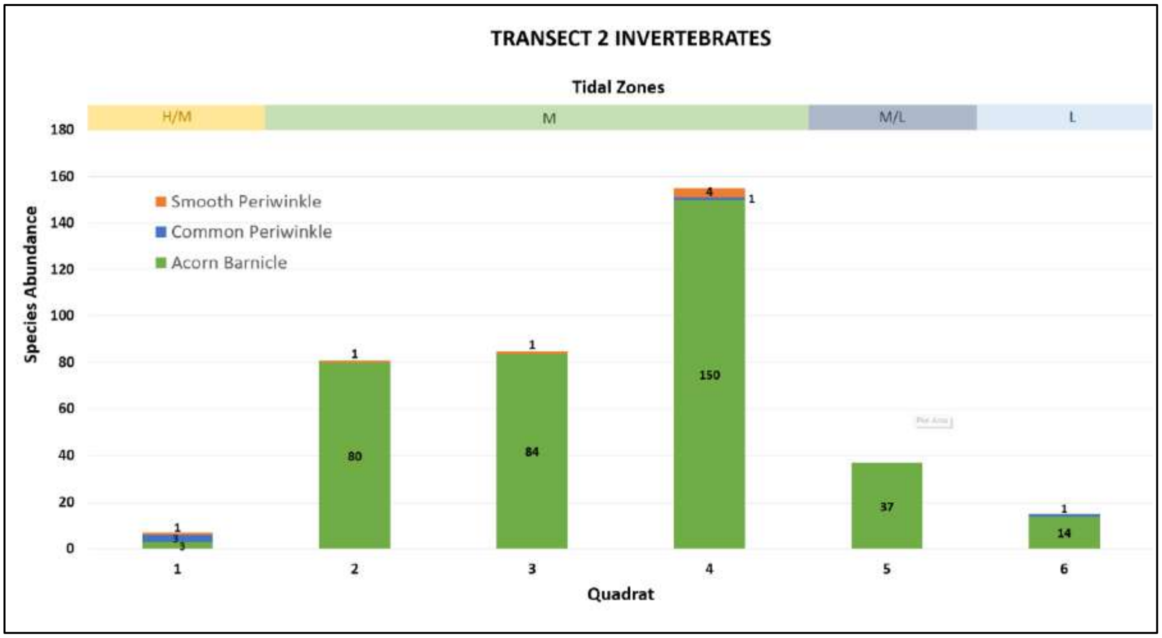

Figure 17. Beach Two Transect One species abundance of invertebrates found within the six quadrats, data collected on November 3rd, 2023.

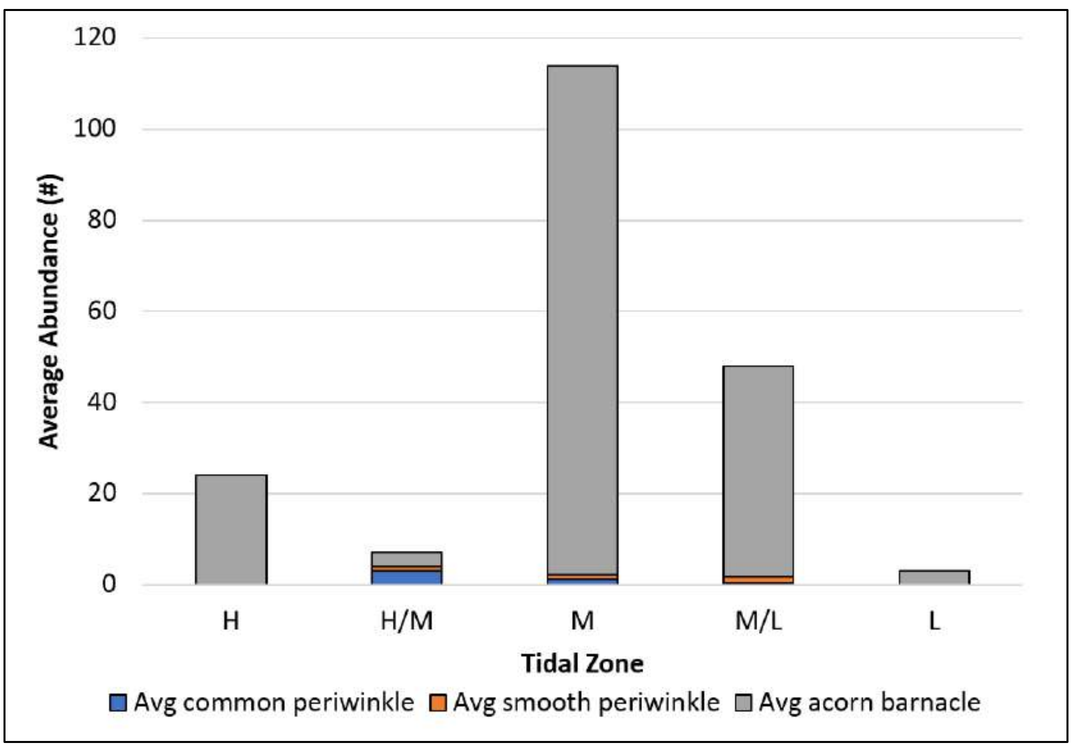

Figure 18. Beach Two distribution of invertebrate average abundance based on two transects throughout the three tidal zones and their transition zones, data collected on November 3rd, 2023.

3.3.3 Beach One and Beach Two Combined

Comparing the data from both beach sites shows that the highest abundance for Acorn Barnacles were found within the mid-tide zone and the transition zone between mid-tide and low-tide zone, while both periwinkle species were more evenly dispersed throughout the zones (Figure 19).

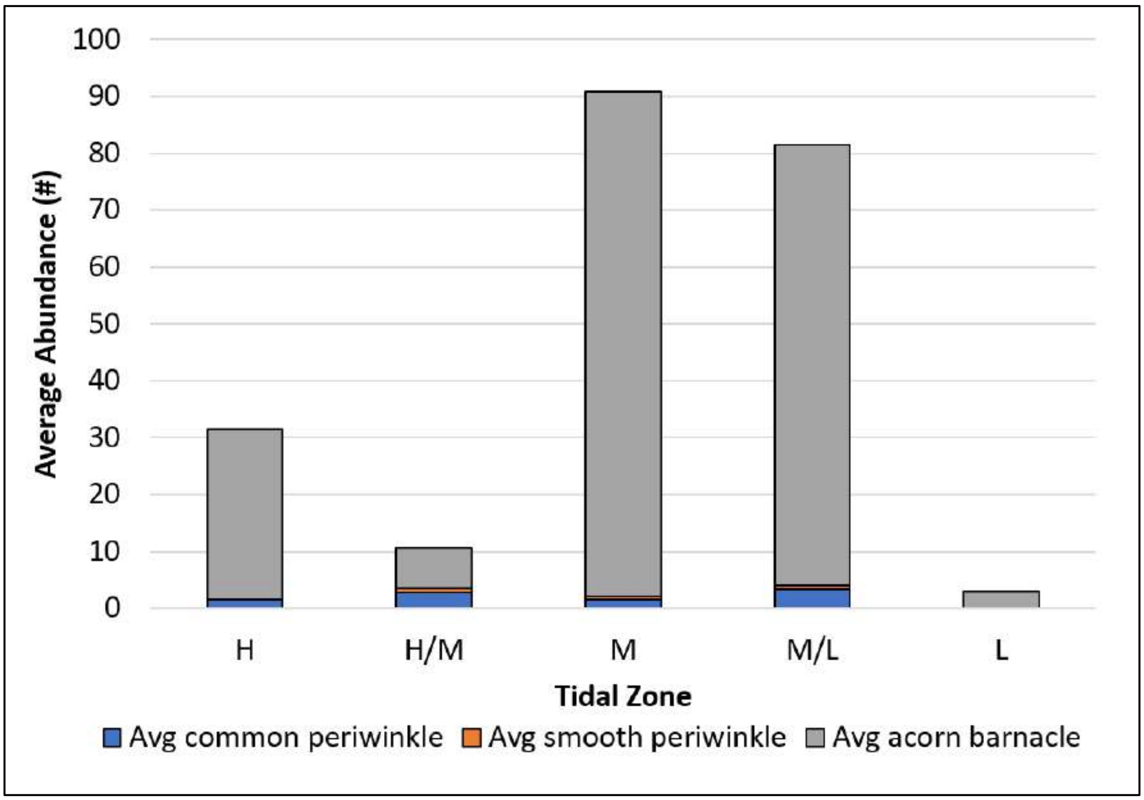

Figure 19. Beach One and Two combined distribution of invertebrate average abundance based on five transects throughout the three tidal zones and their transition zones, data collected on October 20th, 2023, and November 3rd, 2023.

3.3.4 Cove

The Cove site consisted of one transect with twelve quadrats, and the following three species were identified: Smooth Periwinkle, Common Periwinkle, and Acorn Barnacle. Acorn Barnacles were often the most abundant invertebrate throughout the transect as they would be encrusted on rock faces. The highest invertebrate abundance was in quadrat seven (Figure 20). Common Periwinkles were more abundant than Smooth Periwinkles but neither species was overly abundant within this site, Acorn Barnacles were the dominant invertebrate at the Cove site (Figure 21).

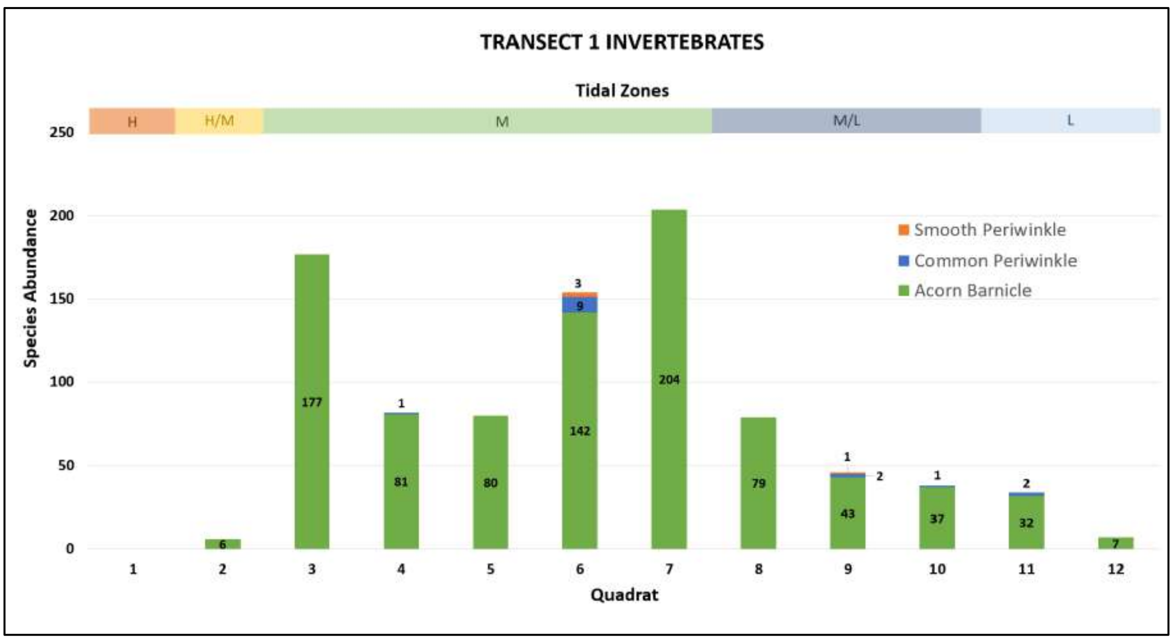

Figure 20. Cove Transect One species abundance of invertebrates found within the 12 quadrats, data collected on October 27th, 2023.

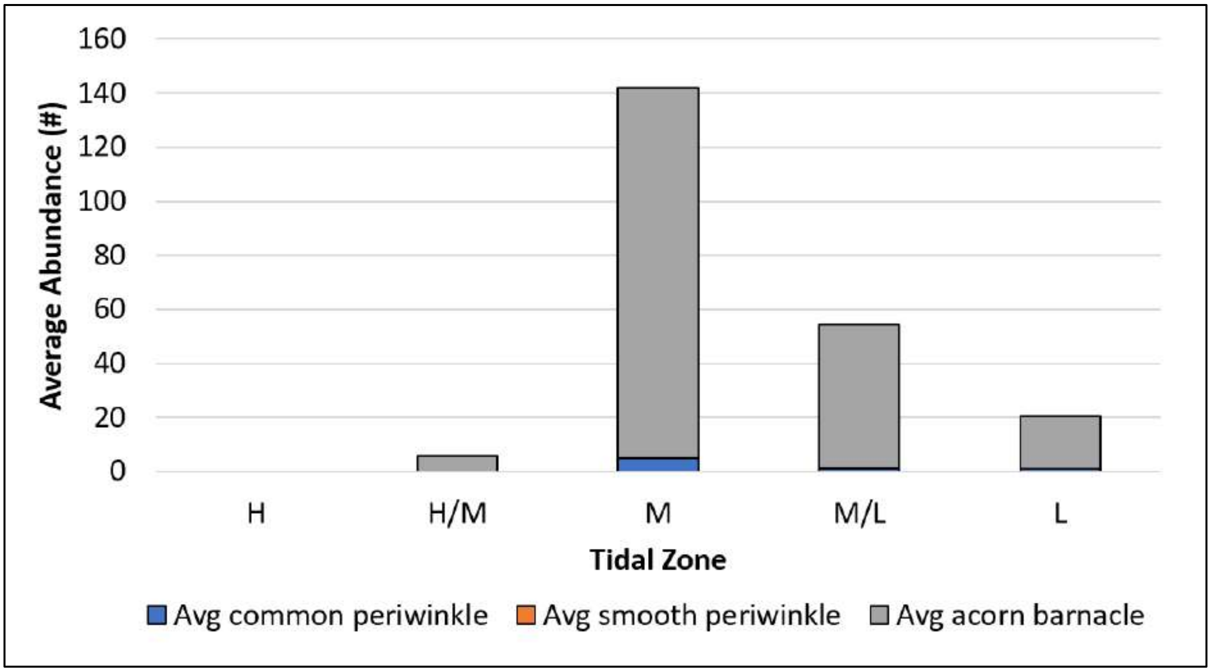

Figure 21. Cove distribution of invertebrate average abundance based on one transect throughout the three tidal zones and their transition zones, data collected on October 27th, 2023.

3.4 Algal Cover and Distribution

Ten species of seaweed were identified: *Fucus spiralis*, *Fucus vesiculosus*, *Fucus distichus*, *Ascophyllum nodosum*, *Saccharina latissima*, *Ulva lactuca*, *Elachista fucicola*, *Vertebrata lanosa*, *Corallina officinalis*, and *Chondrus crispus*. The distribution graph for the transects at each of the three study sites, along with their placement within the tidal zones, were graphed to further demonstrate zonation of invertebrate species along an intertidal zone (Figure 22; Figure 23; Figure 24; Figure 26; Figure 27; Figure 30). Summary graphs of average invertebrate abundance per quadrat within each zone are also presented for each site (Figure 25; Figure 28; Figure 31), as well as for both beaches combined (Figure 29). Completed data sheets with the raw data are included in Appendix A.

3.4.1 Beach One

Beach One consisted of three transects each with six quadrats, at all three transects the following species were identified: *Fucus distichus*, *Fucus vesiculosus*, *Fucus spiralis*, *Elachista fucicola*, *Vertebrata lanosa*, and *Ascophyllum nodosum*. In Transect One the highest algal species abundance was in quadrat six (Figure 22), in Transect Two the highest algal species abundance was in quadrat one (Figure 23), and in Transect Three the highest algal species abundance was found in quadrat four (Figure 24). *Fucus vesiculosus* was also abundant in the mid-tide zone while *Fucus spiralis* was abundant in the high-tide zone due to species zonation patterns, but the overall dominant species on Beach One was *Ascophyllum nodosum* as it is a main canopy forming algal species (Figure 25).

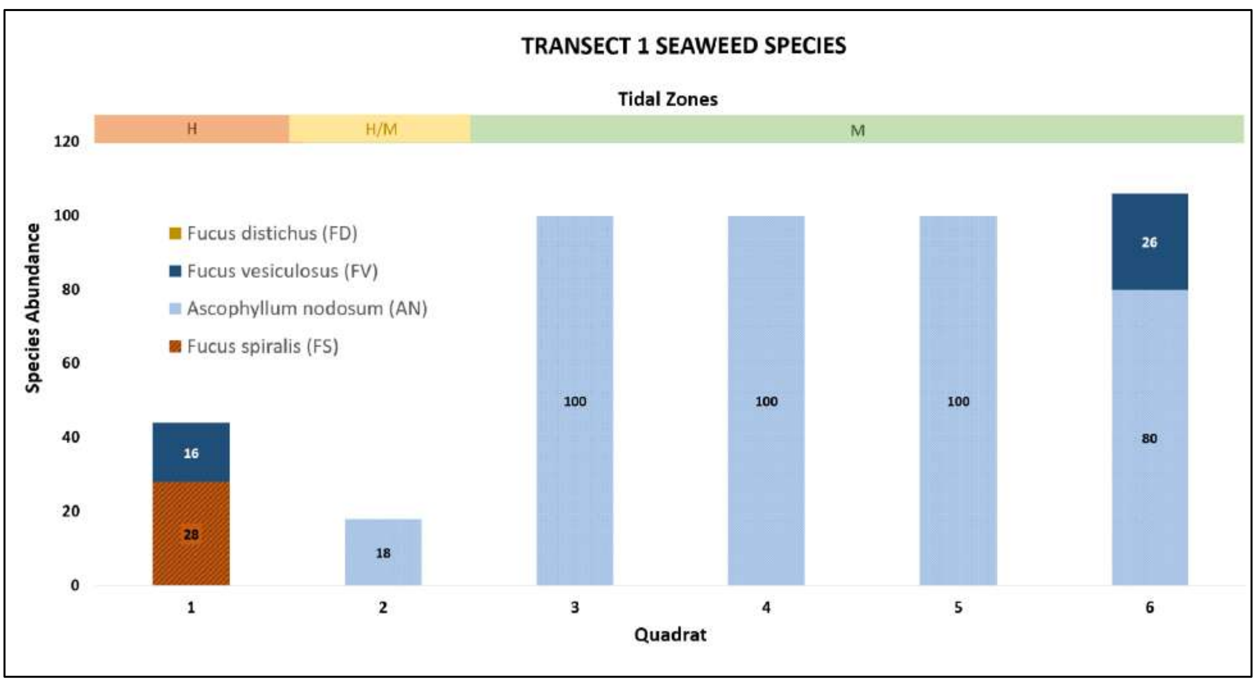

Figure 22. Beach One Transect One species abundance of seaweed found within the six quadrats, data collected on October 20th, 2023.

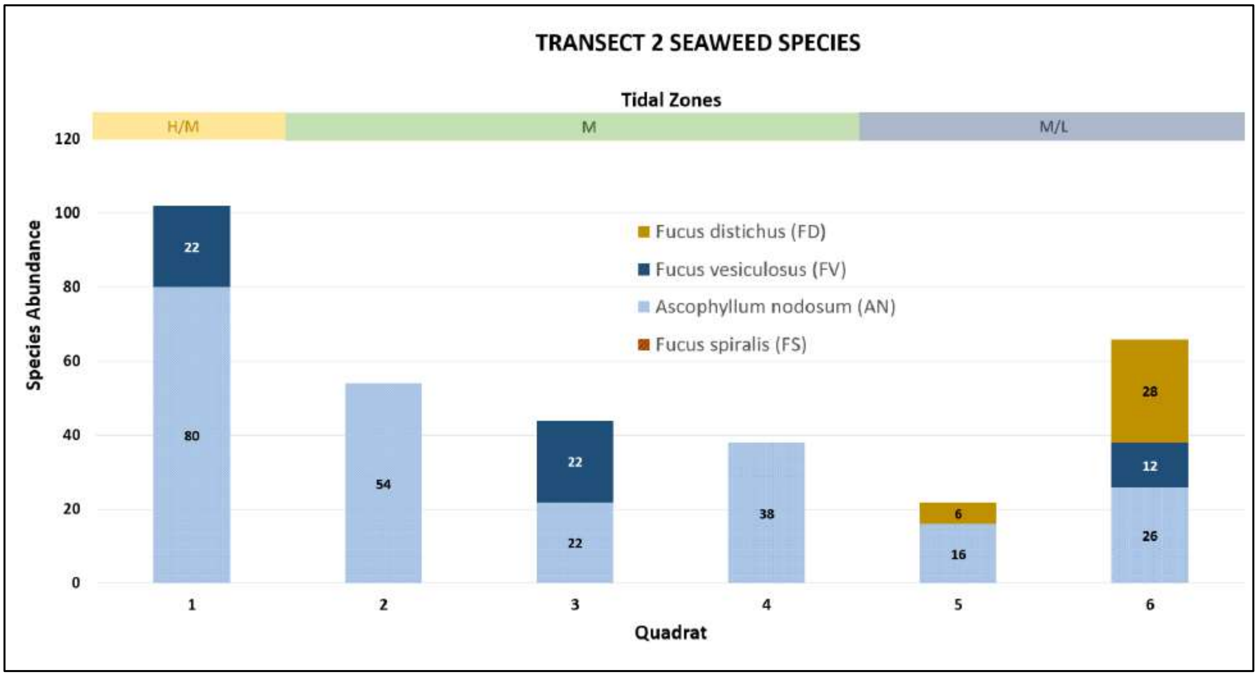

Figure 23. Beach One Transect Two species abundance of seaweed found within the six quadrats, data collected on October 20th, 2023.

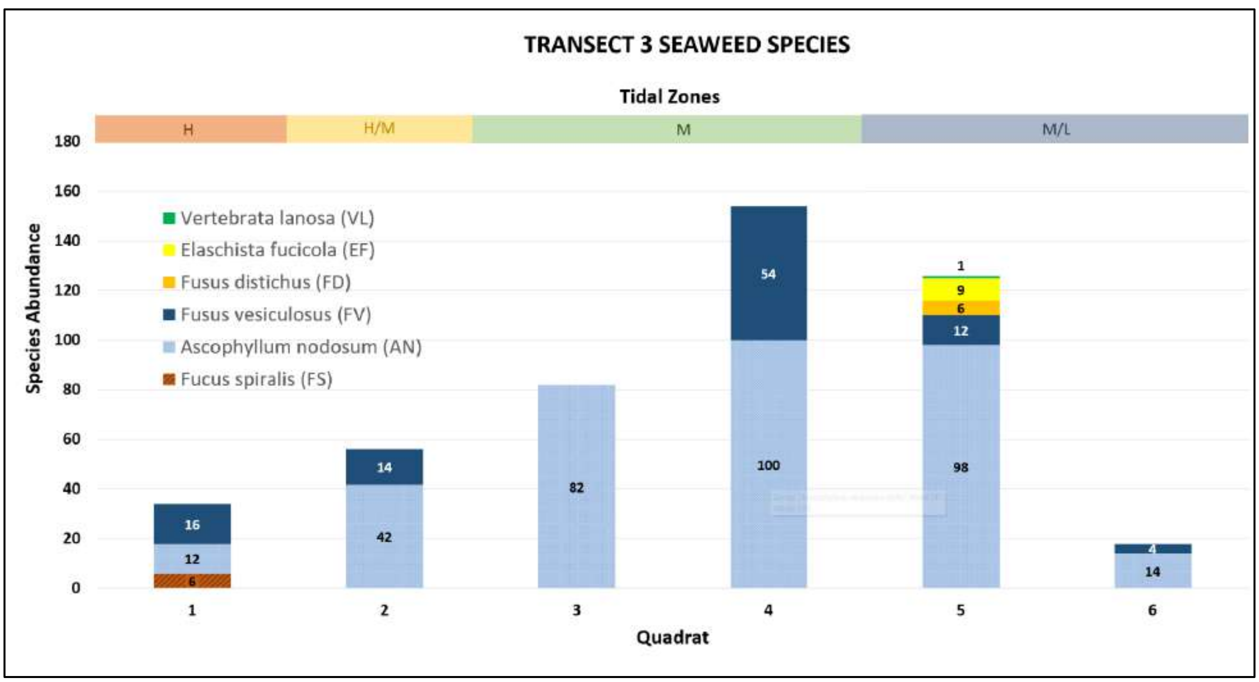

Figure 24. Beach One Transect Three species abundance of seaweed found within the six quadrats, data collected on October 20th, 2023.

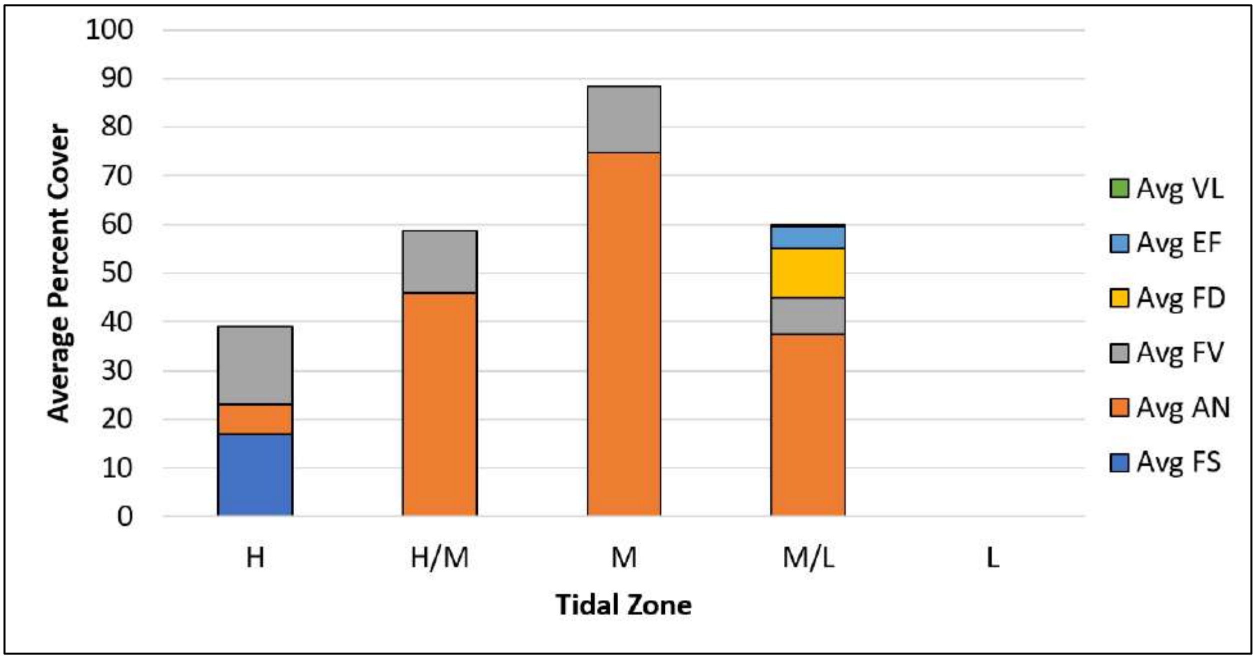

Figure 25. Beach One average percent cover based on three transects throughout the three tidal zones and their transition zones, data collected on October 20th, 2023.

3.4.2 Beach Two

Beach Two consisted of two transects each with six quadrats, at both transects the following species were identified *Fucus distichus*, *Fucus vesiculosus*, *Fucus spiralis*, *Elachista fucicola*, *Vertebrata lanosa*, and *Ascophyllum nodosum*. In Transect One the highest algal species abundance was in quadrat three (Figure 26), in Transect Two the highest algal species abundance was in quadrat two (Figure 27). *Elachista fucicola* and *Vertebrata lanosa* were also abundant in both transects with *Ascophyllum nodosum* explaining its abundance as it is an epiphytic species (Figure 28). The dominant species on Beach Two was *Ascophyllum nodosum* as it is the main canopy forming algal species (Figure 28).

Figure 26. Beach Two Transect One species abundance of seaweed found within the six quadrats, data collected on November 3rd, 2023.

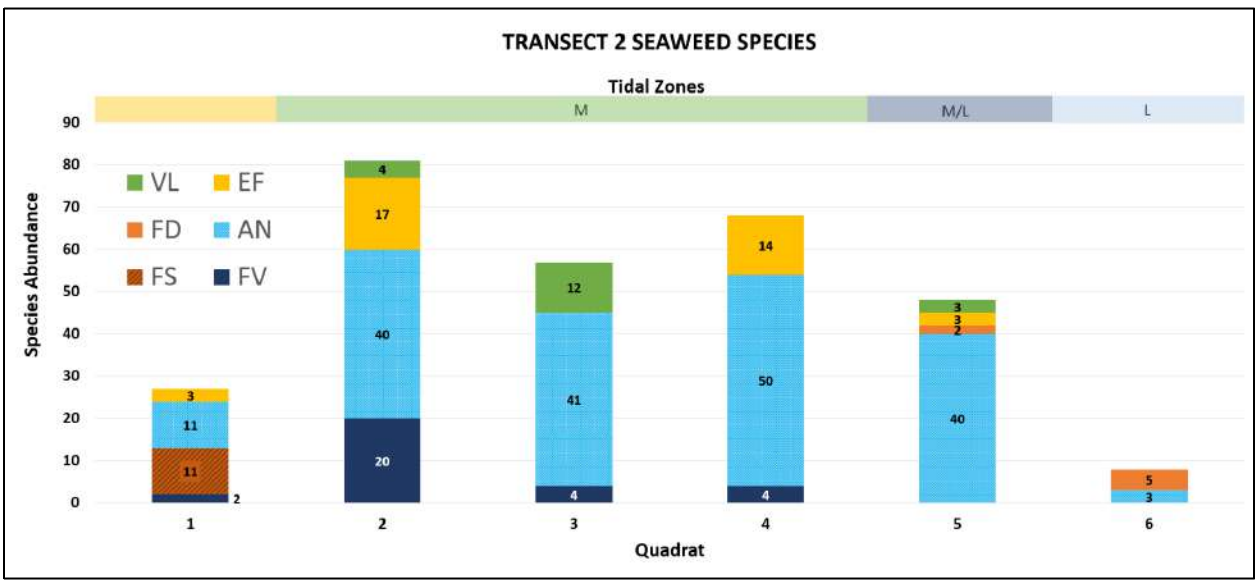

Figure 27. Beach Two Transect Two species abundance of seaweed found within the six quadrats, data collected on November 3rd, 2023.

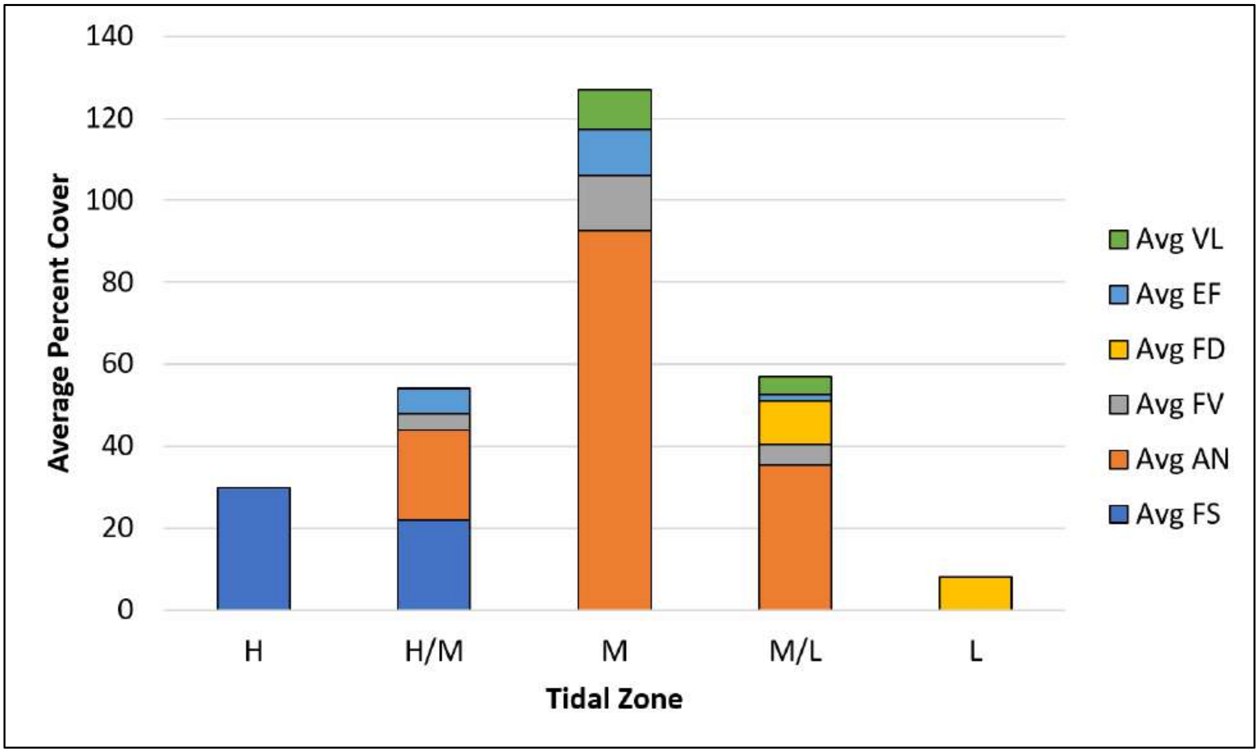

Figure 28. Beach Two average percent cover based on two transects throughout the three tidal zones and their transition zones, data collected on October 27^{th}, 2023.

3.4.3 Beach One and Beach Two Combined

A comparison of the data from both beach sites shows the abundance of algal species identified at both sites at each zone. The highest abundance of species was found within the mid-tide zone and both the transition (Figure 29).

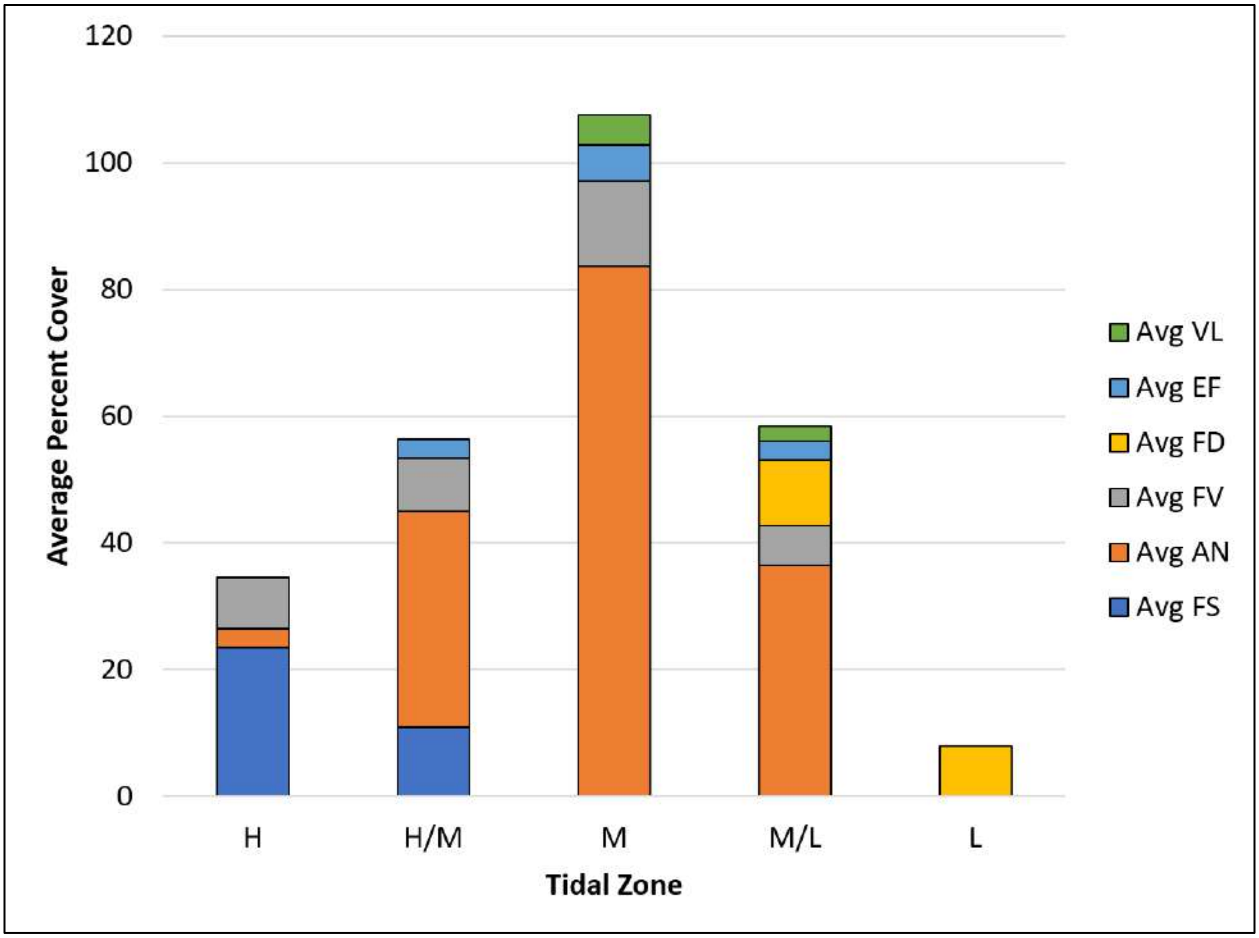

Figure 29. Beach One and Beach Two combined average percent cover based on five transects throughout the three tidal zones and their transition zones, data collected on October 20th, 2023, and October 27th, 2023.

3.4.4 Cove

The Cove site consisted of one transect with 12 quadrats, the species found within the 12 quadrats included *Fucus distichus*, *Fucus vesiculosus*, *Fucus spiralis*, *Vertebrata lanosa*, *Elachista fucicola*, *Ascophyllum nodosum*, *Ulva lactuca*, *Corallina officinalis*, *Saccharina latissima*, and *Chondrus crispus*. In the Transect the highest algal species abundance was in quadrat seven while the most diverse quadrat was quadrat 12 with five present species (Figure 30). For this site, each zone had different abundant species. *Fucus spiralis* was the most abundant in the high tide zone and its transition zone, *Ascophyllum nodosum* was the most abundant in the mid-tide zone as it is the main contributor to the canopy cover within this zone and *Chondrus crispus* was the most abundant in the low-tide zone (Figure 31).

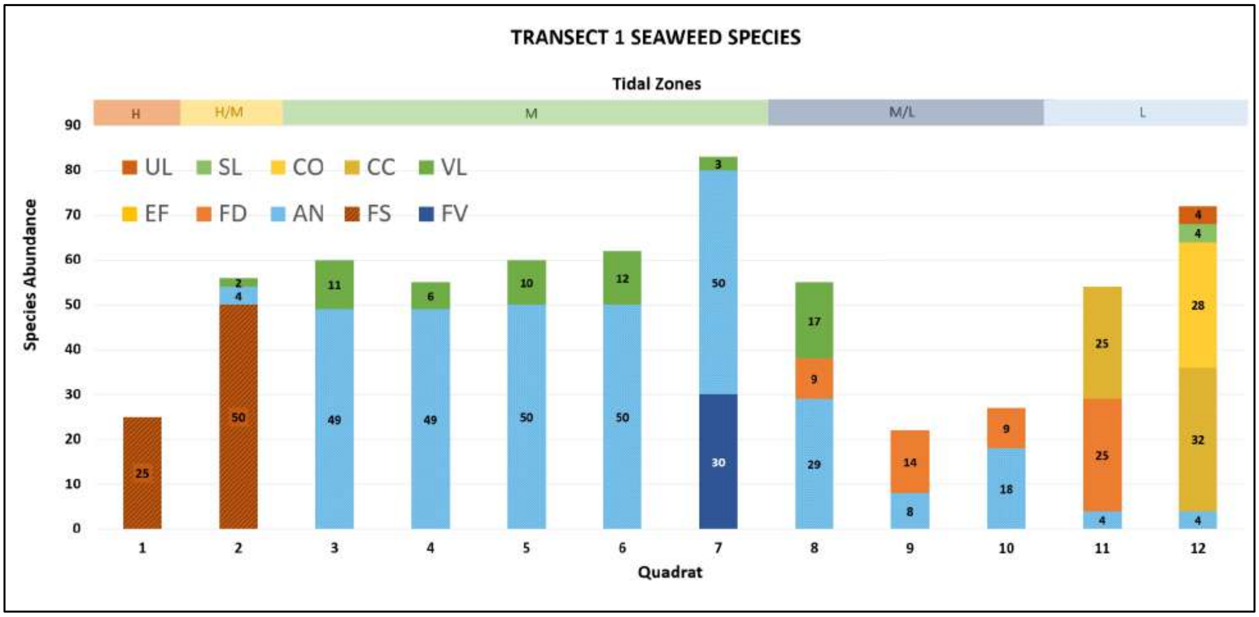

Figure 30. Cove site transect species abundance of seaweed found within the twelve quadrats, data collected on October 27th, 2023.

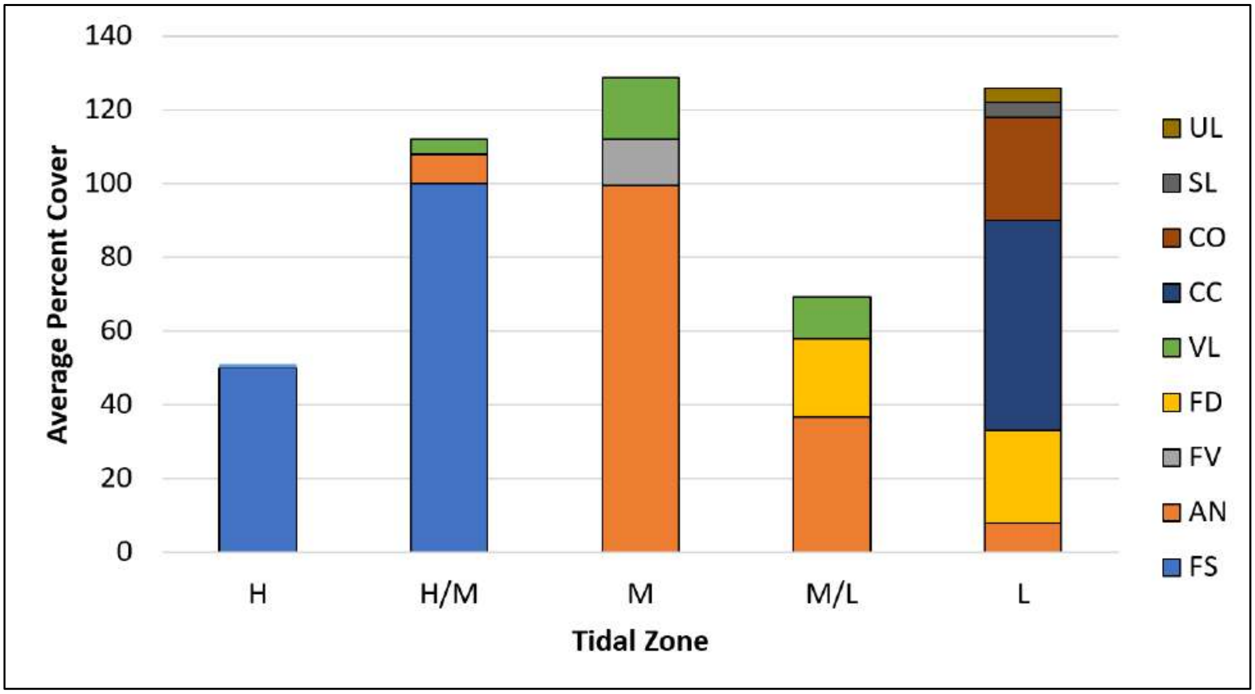

Figure 31. Cove site average percent cover based on twelve quadrats in a transect throughout the three tidal zones and their transition zones, data collected on November 3rd, 2023.

3.5 iNaturalist

Our group added 41 observations and 34 species to the iNaturalist Project for the site, named Deadmans Head Forest (Figure 32). All added observations are presented in Appendix B. Note that not all iNaturalist entries were of seaweed or invertebrate species found at one of the sites. Pictures were also taken along the near the sites and subsequently uploaded to the Project.

Figure 32. iNaturalist header for the Deadmans Head Forest Project, created in order to collect reference of all species within the designated area.

4.0 Field Data Analysis

4.1 Deadmans Harbour Beach Site One

Due to lack of elevation change and the sheltered nature of the harbour there was no zonation characteristic of a low-tide zone within this site.

4.1.1 Invertebrate Species

The greatest abundance of invertebrate species is observed in the mid-tide zone and the transition zone going towards the low-tide zone (Figure 15). Common Periwinkle abundance shows less of a trend but is greatest in the mid-tide to low-tide transition zone (Figure 15). Smooth periwinkles are the least abundant but within the transects are more commonly found in the transition zone from high-tide to mid-tide zones and the mid-tide zone itself (Figure 12; Figure 14). Overall, abundance at this site tends to increase with decreasing elevation (Figure 15). A possible explanation for this is that more species are found lower on the beach due to intolerance to desiccation or possibly due to food availability.

4.1.2 Seaweed Species

Seaweed percent cover is greatest in the mid-tide zone (Figure 25). Multiple quadrats had 100% cover of *Ascophyllum nodosum*, which was the most abundant overall. Further, *Elachista fucicola* and *Vertebrata lanosa* are only present in the mid-low transition zone where they are growing on *Ascophyllum nodosum* as epiphytic species (Figure 25). *Fucus vesiculosus* is present throughout the site occasionally encroaching on high-tide zones with *Fucus spiralis*. Therefore, it is likely tolerant to desiccation and able to grow in a diverse range of conditions. *Fucus spiralis* is only found within the high-tide zone while *Fucus distichus* is only found in the low-tide zone, these are characteristic of their species zonation patterns (Figure 25).

4.2 Deadmans Harbour Beach Site Two

Due to lack of elevation change and the sheltered nature of the harbour there was very little zonation characteristic of a low-tide zone within this site until surveyors were at the low-tide waterline.

4.2.1 Invertebrate Species

The greatest abundance of invertebrate species is observed in the mid-tide zone (Figure 18). Common Periwinkle abundance shows less of a trend but is greatest in the high-tide to mid-tide transition zone (Figure 18). Smooth periwinkles are more commonly found in the transition zone from the mid-tide zone and the transition zones on either side of it (Figure 18). Overall, abundance at this site peaked at the mid-tide zone (Figure 18). This differs from Beach One and this difference could be due to Beach Two being closer to the mouth of the harbour and a difference in habitat preference within the intertidal zone.

4.2.2 Seaweed Species

Seaweed percent cover is highest, again, in the mid-tide zone. At this site, *Ascophyllum nodosum* is only found in within the mid-tide zone and the transition zones on either side. *Elachista fucicola* is found in all three of these zones, and *Vertebrata lanosa* is found in the latter two. *Fucus spiralis* is only found in the high-tide zone, and *Fucus distichus* is only found in the low-tide zone, *Fucus vesiculosus* is found in the mid-tide zone with *Ascophyllum nodosum* which is characteristic of all four species zonation patterns (Figure 28).

4.3 Bay of Fundy Cove Site

Due to the drastic changes in elevation and the exposed nature of the site there are more habitat niches for the algal species to inhabit which allows for higher diversity and the description of a true low zone.

4.3.1 Invertebrate Species

No invertebrates are found in the high tide zone. Similarly to the beach sites, abundance is greatest in the mid tide zone, with acorn barnacles being the most abundant. Perhaps acorn barnacles are the most abundance because they are not dependent on seaweed presence; periwinkles browse on seaweed, so they can only occur where their food source is present. Common periwinkles are present in the mid, mid/low, and low zone, with decreasing abundance towards the lower zones. Smooth periwinkle is also present in lower numbers in the mid and mid/low zones (Figure 19).

4.3.2 Seaweed Species

Although the mid-tide zone has the highest percent cover, the low-tide zone has a similar percent cover (Figure 31). *Fucus spiralis* is only found in the high-tide zone, and *Fucus distichus* is only found in the mid-low transition zone and low-tide zone, *Fucus vesiculosus* is found in the mid-tide zone with *Ascophyllum nodosum* which is characteristic of all four species zonation patterns (Figure 31). *Elachista fucicola* and *Vertebrata lanosa* are only present in zones with higher Ascophyllum nodosum cover as they are epiphytic species (Figure 31). The most interesting differences at the cove site are the new species found in the low-tide zone which includes *Chondrus crispus*, *Corallina officinalis, Saccharina latissima,* and *Ulva lactuca,* which are all low-tide zone species that are highly intolerant to desiccation (Figure 30).

4.4 Beach One and Beach Two Combined

When combining the data collected from both beach sites new trends arise based on the average abundances of invertebrate species and their distribution throughout the intertidal zone.

4.4.1 Invertebrate Species

Acorn Barnacles are the most abundant invertebrate species throughout the beach sites, their abundance is also higher in the mid-tide zone and in the transition zone between that and the low-tide zone (Figure 19). Both periwinkle species were more evenly dispersed throughout all tidal zones (Figure 19). This trend of distribution makes sense when considered with the fact that during tidal cycles the periwinkle species may travel for grazing purposes or will remain where they were when the tide went down to avoid desiccation while barnacles are sessile encrusting invertebrates that have habitat requirements so certain zones are more beneficial to inhabit.

4.4.2 Seaweed Species

Both beach sites had the highest algal percent cover in the mid-tide zone (Figure 29). *Ascophyllum nodosum* for both sites was the main canopy forming algal species occasionally reaching 100% cover within quadrats. Where *Ascophyllum nodosum* was present *Elachista fucicola* and *Vertebrata lanosa* could be present as well due to the reliance on the species as an epiphyte (Figure 29). *Fucus spiralis* is only found within the high-tide zone while *Fucus distichus* is only found in the low-tide zone, these are characteristic of their species zonation patterns (Figure 29).

5.0 Species Review

5.1 Algal Species

5.1.1 Species Overview

Twenty algal species were analyzed through literature review based on species prevalence in the Bay of Fundy, these species were researched by the group to help determine their susceptibility to various climate change parameters like sea level rise, temperature rise, salinity decreases, and ocean acidification. Of the initial 20 species, five species were selected as being the most intolerant to climate change and its environmental effects which are described further below. From the literature review the most prominent effects on algal species and notably those that form protective canopies for other species are rising temperatures and increase in wave action due to increased storm severity.

5.1.2 Probable Intolerance to Climate Change

5.1.2.1 *Alaria esculenta*

Alaria esculenta could potentially be an intolerant species to climate change since it has a noted intolerance to low salinity and rising temperatures (Karsten, 2007). Due to the low intolerance to high wave action increased storm severity due to climate change could also impact this species (MarLIN, 2023). Due to these parameters the species is considered intolerant to climate change, however, due to a lack of reporting on the species in literature there is not a clear consensus on tolerance levels and projected range going forward. This species may need to be monitored through literature review in future years to determine the actual impacts as more research comes out.

5.1.2.2 *Ascophyllum nodosum*

Ascophyllum nodosum, a primary canopy forming alga, could be an intolerant species to climate change since it is intolerant rising temperatures (Khan *et al*. 2018). The species is noted to still be in range by the year 2100 but with an upper thermal tolerance of 20.1°C increased water temperatures during summer months could be detrimental to growth and maintenance (Khan *et al*., 2018). Due to the low intolerance to high wave action increased storm severity due to climate change could also impact this species (MarLIN, 2023). Due to the abundance of this species at our sites it is important to monitor for loss of canopy cover as this could potentially impact the abundance of epiphytic species like *Elachista fucicola* and *Vertebrata lanosa* which primarily grow on *Ascophyllum nodosum* and invertebrate species who use the canopy as protection from the elements.

5.1.2.3 *Fucus distichus*

Fucus distichus seems to be well researched within scientific literature but there are some conflicting remarks about the species tolerance to climate change and rising water temperatures. In literature this species is often grouped together with other fucoids for research purposes and is said to be benefitted by warming temperatures with little impact on species productivity (Wood, 2023; Jueterbock *et al*., 2016). However, some sources refute this by noting that they have a tolerance to cooling temperatures but that warming waters could become an issue if sustained long-term (MarLIN, 2023). Salinity decreases are not expected to impact this species as they are noted to tolerate a wide range of salinity levels (Karsten, 2007).

5.1.2.4 *Fucus spiralis*

Fucus spiralis is a species characteristic of the high intertidal zone and is tolerant of desiccation under current conditions but with an increase in air temperatures desiccation could become a more pervasive concern (Ferreira *et al.*, 2014). Since this species spends most of its time uncovered by the tides it is not often subjected to extreme wave action unless on a highly exposed site but due to the predicted increase in storm severity wave action could harm the species ability to proliferate in various sites (MarLIN, 2023).

5.1.2.5 *Saccharina latissima*

Saccharina latissima is beneficial to many invertebrate species that could potentially be impacted by ocean acidification as it is known to buffer acidic conditions (Young *et al*., 2022).

This service provided indicates that lowered abundance could have cascading effects on the surrounding environment. This species has an upper thermal limit of between 21.5°C and 22°C and has been shown in literature to have decreased survival in warmer waters (Khan *et al.*, 2018; Redmond, 2013; Niedzweidz *et al*., 2022). This low intertidal species is also characterized as being intolerant to increased wave action indicating that storm severity could be another compounding factor on future abundance declines (MarLIN, 2023).

5.2 Invertebrate Species

5.2.1 Species Overview

Fifteen invertebrate species were analyzed through literature review based on species prevalence in the Bay of Fundy, these species were researched by the group to help determine their susceptibility to various climate change parameters like sea level rise, temperature rise, salinity decreases, and ocean acidification. Of the initial 15 species, seven species were selected as being the most intolerant to climate change and its environmental effects. From the literature review the most prominent effects on shelled invertebrate species is ocean acidification, with the effect impacting other being rising temperatures. We also investigate a prevalent invasive species that could benefit from climate changes impacts.

5.2.2 Probable Intolerance to Climate Change

5.2.2.1 *Modiolus modiolus*

Modiolus modiolus, or Horse Mussel, in research is a species that can tolerate vast environmental parameters but when subject to severe changes the species could see decline sin growth rate and survival (Lesser and Kruse, 2004; Ning *et al*., 2015). This species is expected to be challenged by lowered salinity and higher temperatures as the species thermal optimum is around 15°C (Zhan *et al.*, 2018; MarLIN, 2023). This bivalve could also face potential impacts from ocean acidification due to calcium requirements for shell maintenance which could also cause issues for growth and survival if conditions are not mediated (Gormley *et al.*, 2013). This species is a subtidal species and as such was not found within our transect surveys, but shells were found along the harbour beach sites.

5.2.2.2 *Asterias rubens*

Asterias rubens, the Common Sea Star, (also referred to as *Asterias vulgaris*) is one of the more common sea stars found within the Bay of Fundy. This species is intolerant to temperature increases as noted in literature by sea star wasting events that coincide with drastic changes in temperature conditions in localized regions (Wahltinez, 2023; MarLIN, 2023). Temperature increases are the main factor impacting the species as salinity decreases are tolerated well but due to extreme die-off events even short-term increases in temperature can have a drastic effect on population size (Binyon, 1961; Wahltinez, 2023). Although their species was not found within our three study sites its prevalence within the Bay of Fundy should be monitored for changes and further searches of the sites could be done to look for the species.

5.2.2.3 *Littorina saxatillis*

Littorina saxatillis, the Rough Periwinkle, is one of the main littorinid species found within the Bay of Fundy and have been noted in literature to be susceptible to increasing temperatures under the influence of climate change (Sokolova and Portner, 2001). Under elevated temperatures species growth and population survival precipitously decline due to stress associated with unfit environmental parameters (Sokolova and Portner, 2001). This species has a high tolerance to changes in salinity levels but lowered pH due to ocean acidification could impact the species due to calcium availability for shell maintenance, ocean acidification is noted in this report as the main impact for this species under climate change (Melatunan *et al*., 2013; Bibby *et al*., 2007). It should be noted that this species although not found within our study sites is present in nearby locations and should be included in future research.

5.2.2.4 *Littorina littorea*

Littorina littorea, the Common Periwinkle, is another one of the main littorinid species found within the Bay of Fundy and have been noted in literature to be susceptible to ocean acidification due to lowered ocean pH due to warming waters (Melatunan *et al*., 2013). Under ocean acidification shell thickness is anticipated to decline which can pose survivability issues (Bibby *et* al., 2007). This species has a notable tolerance to changes in salinity levels, but lowered pH could significantly impact the species and is noted in this report as the main threat for this littorinid (Melatunan *et al*., 2013; Bibby *et al*., 2007; Bommarito *et al.*, 2020).

5.2.2.5 *Littorina obtusata*

Littorina obtusata, the Smooth Periwinkle, is the third species of the main littorinid species found within the Bay of Fundy and have been noted in literature to be susceptible to ocean acidification due to lowered ocean pH due to warming waters (Melatunan *et al*., 2013). Under ocean acidification shell thickness is anticipated to decline which can pose survivability issues and development as a result will be lowered (Ellis *et al.*, 2009; Bibby *et al*., 2007). A pH of 7.6 is noted as the point where growth, development, maintenance, and survival begin to decline (Ellis *et al.*, 2009). Lowered pH could significantly impact the species and is noted in this report as the main threat for this littorinid (Melatunan *et al*., 2013; Bibby *et al*., 2007; Bommarito *et al*., 2020).

5.2.2.6 *Mytilus edulis*

Mytilus edulis, or Blue Mussel, is another bivalve species found within the Bay of Fundy and is another species that may be impacted negatively by climate change primarily by ocean acidification. Under warming oceanic conditions there is anticipated to be a decrease in pH leading to acidified water within systems, this ocean acidification could potentially impact *Mytilus edulis* like that of other shelled invertebrates talked about previously. For this species specifically, it is predicted to have a drastic decline in growth under ocean acidification as shell maintenance and growth rate will slow (Gazeau *et al*., 2010). This species is a subtidal species and as such was not found within our transect surveys, but shells were found along the harbour beach sites.

5.2.2.7 *Cancer irroratus*

Cancer irroratus, or Rock Crab, is a common crustacean found scavenging throughout the intertidal zone, although in our sites we never saw live animals we say many recently deceased or shelled remnants throughout all three sites. Due to their requirement to molt as they grow any disruptions to this cycle could cause issues for the species, under warming conditions it is predicted that their molt timings could be affected as the species uses environmental cues to determine molt timings (Johns, 1981). Since they also feed on other invertebrates found throughout the sites, like the littorinids, further impacts on their prey from climate change could affect the trophic ecology within the intertidal zone.

5.2.3 Invasive Species Prevalence

5.2.3.1 *Carcinus maenas*

Carcinus maenas, the European Green Crab, is a prevalent invasive species throughout the Bay of Fundy coastal zone and was first found in the region in the early 1950s (NB ISC, 2023). This species directly competes with *Cancer irroratus* and other native species and can disrupt the ecosystems natural processes impacting water quality, marine fish and vegetation (NB ISC, 2023). This species has been shown to be highly tolerant to rising temperatures and can thrive in a wide range of salinities indicating that under various models for climate change their range could spread and the conditions could favour the species compared to others (MarLIN, 2023). This invasive species should as a result be monitored within the sites as during the initial site visit two live green crabs were found at the harbour beach one site, this indicates that there is a presence there and it should be monitored in future research.

5.3 Marine Fishes

5.3.1 Species Overview

Thirteen marine fish species, including catadromous and anadromous species, that can be found within the outer Bay of Fundy were analyzed through literature review of COSEWIC Assessment Reports for susceptibility to climate change (Table 5). Of the initial 13 species five were found to be considered susceptible or intolerant to climate change. Due to various life stages of these fish species being in marine environments, some being fully marine, knowing the true impact of climate change can be difficult to understand. With commercial and recreational fisheries and other anthropogenic factors compounding the effects of climate change and with some of the most recent reports being over a decade old, predictions from them could be considered outdated so it is important going forward that researchers for the living laboratory continue to keep up to date with the most recent reports.

Table 5. Marine Fish Species

Common Name	Scientific Name	Designation	Date of Last Report	Citation
Atlantic Cod	*Gadus morhua*	Special Concern	2003	COSEWIC, 2003
Winter Skate	*Leucoraja ocellata*	Threatened	2005	COSEWIC, 2005a
American Plaice	*Hippoglossoides platessoides*	Threatened	2009	COSEWIC, 2009
Atlantic Salmon	*Salmo salar*	Endangered	2010	COSEWIC, 2010a
Acadian Redfish	*Sebastes fasciatus*	Threatened	2010	COSEWIC, 2010b
Atlantic Bluefin Tuna	*Thunnus thynnus*	Endangered	2011	COSEWIC, 2011a
Atlantic Sturgeon	*Acipenser oxyrinchus*	Threatened	2011	COSEWIC, 2011b
American Eel	*Anguilla rostrata*	Threatened	2012	COSEWIC, 2012a
Thorny Skate	*Amblyraja radiata*	Special Concern	2012	COSEWIC, 2012b
White Hake	*Urophycis tenuis*	Threatened	2013	COSEWIC, 2013a
Lumpfish	*Cyclopterus lumpus*	Threatened	2017	COSEWIC, 2017
Shortfin Mako	*Isurus oxyrinchus*	Endangered	2019	COSEWIC, 2019
White Shark	*Carcharodon carcharias*	Endangered	2021	COSEWIC, 2021

5.3.2 Probable Intolerance to Climate Change

5.3.2.1 *Acadian Redfish*

Acadian Redfish (*Sebastes fasciatus*) is a species that has faced declines in recent years due to direct and indirect effects from the fishing industry, as a result this species was listed at Threatened in 2010 (COSEWIC, 2010b). This species is is also anticipated to be affected by climate change due to the dependence of the larval life stage feeding at the surface of the water and showing high mortality rates at temperatures above 14ºC, this could cause declines in subsequent populations (COSEWIC, 2010b). Due to compounding of threats like the directed fisheries on ground fish species, bycatch, and natural predation from seals the additional threat of climate change could heavily impact the species (COSEWIC, 2010b).

5.3.2.2 *American Eel*

American Eel (*Anguilla rostrata*) was previously designated as Special Concern by COSEWIC in 2006 but was reassessed in 2012 and designated as Threatened, this is due to many different threats the species faces including climate change and the changes conditions in relation to temperature, pH, and productivity (COSEWIC, 2012a). This species is catadromous meaning that it is born in marine environments and returns to spawn, this means that shifting oceanic conditions may affect both young glass eels and mature silver eels life stages (COSEWIC, 2012a). Other threats to the species include a swim bladder parasite (Anguillicola crassus) which impacts their migration back to sea to spawn, fisheries on various life stages, habitat degradation, and hydro developments, all of these with the looming danger of climate change could drastically impact this economic and cultural significant species (COSEWIC, 2012a).

5.3.2.3 *American Plaice*

American Plaice (*Hippoglossoides platessoides*) is another ground fish species that is impacted greatly by direct and indirect impacts of fisheries and as a result is listed as Threatened by COSEWIC in 2009 (COSEWIC, 2009). This species in adult life stages in a benthic dwelling species and as a result is a cold-water species, however, eggs are hatched at the surface and similar to Acadian Redfish are susceptible to high mortality rates at temperatures above 14ºC (COSEWIC, 2009). From 1970 to 2005 adult populations have declined by 67%, this is due to overfishing, bycatch, and abnormal water conditions in the late 20th century but with the implications of climate change on this species recuperation of population numbers seems challenging to achieve (COSEWIC, 2009).

5.3.2.4 *Atlantic Salmon*

Atlantic Salmon (*Salmo salar*) is an anadromous species that spawns and is born in freshwater environments but lives out its adult life in marine systems, over the past three-generations the outer Bay of Fundy grouping of the species has faced a 64% decline based on low return rates to their traditional spawning sites and as a result has been designated as Endangered in 2010 (COSEWIC, 2010a). The changes in marine ecosystems are poorly understood in relation to the coinciding survival decline and when also subjected to pressures from recreational fishing, habitat degradation and loss, and the influence of escaped farmed salmon on both genetic and ecological parameters the species is heavily affected by anthropogenic impacts (COSEWIC, 2010a). Salmon at sea prefer sea surface temperatures of 1-12.5ºC and over this could result in declines in survival rates while at sea (COSEWIC, 2010a). This species is traditionally used by 49 Indigenous groups and holds a high degree of cultural significance while also being a source of economic gain for some First Nations as well indicating that loss of this species would heavily affect many surrounding communities (COSEWIC, 2010a).

5.3.2.5 *Atlantic Cod*

Atlantic Cod (*Gadus morhua*) was first designation by COSEWIC as Special Concern in 1998 which subsequently led to the implementation of the fishing moratorium in Canadian waters, as of 2003 this species is still considered Special Concern (COSEWIC, 2003). This species is subject to multiple threats including small population sizes and biological changes within populations, derelict fishing gear, alteration of benthic environments, indirect effects from fishing and changes to natural ecosystem parameters including water temperature (COSEWIC 2003). Habitat requirements for this fish are poorly understood making conservation efforts and climate predictions difficult, an updated report for this species would be highly beneficial to understanding the current status and the future implications of climate change.

5.4 Marine Mammals

5.4.1 Species Overview

Three marine mammal species that can be found within the outer Bay of Fundy were analyzed through literature review of COSEWIC Assessment Reports for susceptibility to climate change (Table 6). Of the initial three species two were found to be considered susceptible or intolerant to climate change. All three species however are subject to anthropogenic forces that could result in negative species impacts like underwater noise and general pollution.

Table 6. Marine Mammal Species

Common Name	Scientific Name	Designation	Date of Last Report	Citation
Fin Whale	*Balaenoptera physalis*	Special Concern	2005	COSEWIC, 2005b
North Atlantic Right Whale	*Eubalaena glacialis*	Endangered	2013	COSEWIC, 2013b
Harbour Porpoise	*Phocoena phocoena*	Special Concern	2022	COSEWIC, 2022

5.4.2 Probable Intolerance to Climate Change

5.4.2.1 *Harbour Porpoise*

Harbour Porpoise (*Phocoena phocoena*) has been assessed five times, designated as Threatened in 1990 and 1991, and Special Concern in 2003, 2006, and most recently in 2022 (COSEWIC, 2022). This species rarely occurs in waters warmer than 16ºC and as a result could be heavily impacted by increased temperatures which could push them out of the region during summer months, other implications from climate change could also cause declines in prey abundance initiating further travels for feeding (COSEWIC, 2022). Other impacts the species is facing includes indirect mortality from fisheries, algal blooms, increase in disease prevalence, and habitat degradation and noise pollution (COSEWIC, 2022). Climate change as a result could drastically impact the status of this species going forward.

5.4.2.2 *North Atlantic Right Whale*

North Atlantic Right Whale (*Eubalaena glacialis*) has been designated as Endangered in five assessments in the years 1980, 1985, 1990, 2003, and most recently in 2013, primary threats include mortality from vessel strikes and entanglement from derelict fishing gear but in recent years climate change has shifted food availability which has impacted the location for feeding within the Atlantic Ocean (COSEWIC, 2013a). Shifts in food availability can also create fluctuations in reproductions rates and due to already low population levels this could result in drastic declines in adult populations going forward (WWF, 2023). In previous years it was estimated that around 60% of lactating females would migrate into the Bay of Fundy with their calves for their feeding migration, due to recent shifts in food availability though this number may be lower resulting in less frequent visits within the region (COSEWIC, 2013a).

5.5 Birds

5.5.1 Species Overview

Three species of birds who rely on marine environments within the outer Bay of Fundy for feeding and breeding were analyzed through literature review of COSEWIC Assessment Reports for susceptibility to climate change (Table 7). Of these three species all were characterized as being susceptible or intolerant to various forces connected to climate change. Due to the various life stages the birds spend within the Bay of Fundy the impact on the species is dependent on life stage, those who breed within the region could face lower reproduction rates because of changing climate while those who feed before or during migrations in the region could result in higher mortality in the migration season.

Table 7. Bird Species

Common Name	Scientific Name	Designation	Date of Last Report	Citation
Piping Plover	*Charadrius melodus*	Endangered	2013	COSEWIC, 2013c
Red-Necked Phalarope	*Phalaropus lobatus*	Special Concern	2014	COSEWIC, 2014
Leach's Storm Petrel	*Oceanodroma leucorhoa*	Threatened	2020	COSEWIC, 2020

5.5.2 Probable Intolerance to Climate Change

5.5.2.1 *Leach's Storm Petrel*

Leach's Storm Petrel (*Oceanodroma leucorhoa*) is a migratory seabird that was designated as Threatened in 2020 due to population declines of around 54% over three-generations (COSEWIC, 2020). This migratory species is subject to numerous threats including predation from gulls, encroachment from other species initiating habitat shifts, increased storm severity, and anthropogenic modifications within habitats (COSEWIC, 2020). Storm severity is anticipated to increase with climate change and could induce drastic flooding, high winds associated with storms can blow birds ashore interrupting migrations and feeding while flooding could flood nesting sites if burrows have low drainage (COSEWIC, 2020). For feeding their summer range is ideally between 10.6-23.3°C to ensure high rates of food availability and an increase in temperatures could cause a range shift for foraging (COSEWIC, 2022).

5.5.2.2 *Piping Plover*

Piping Plover (*Charadrius melodus*) is a migratory shorebird common along Bay of Fundy shorelines during feeding migrations, this species has faced a 23.3% decline over the past three generations and as a result has been listed as Endangered since 1985 when it was reassessed from its 1978 assessment of Threatened, the species has remained Endangered in subsequent assessments in 2001 and most recently in 2013 (COSEWIC, 2013c). Threats to this species include predation, anthropogenic disturbance, loss of suitable habitat, and increase of storm severity and sea level rise because of climate change (COSEWIC, 2013c). Similar to Leach's Storm Petrel high winds associated with increased storm severity can blow birds ashore, sea level rise and flooding can impact coastal feeding grounds for the species as well reducing food availability (COSEWIC, 2013c).

5.5.2.3 *Red-Necked Phalarope*

Red-Necked Phalarope (*Phalaropus lobatus*) is a migratory shorebird that was first assessed in 2014 and designated as Special Concern (COSEWIC, 2014). Some threats they face include food availability and distribution, ingestion of microplastics, and general impacts of climate change including sea level rise and temperature and how that will further affect prey availability (COSEWIC, 2014). Foraging for this species is sensitive to various environmental conditions and as a result changes to these could heavily impact the abundance of prey (COSEWIC, 2014).

5.6 Climate Change Impact on Species

This species review is not an exhaustive list of species that could be impacted by climate change within the region, the list is likely much longer. To assess algal and invertebrate species the focus was on those species that are known to already persist within the area, for marine mammals, fishes, and birds the use of COSEWIC Assessment Reports was utilized as these government reports are well-received by other agencies and governmental groups and with them being somewhat regularly updated, they can be a useful tool for the future of the living laboratory project. It would be beneficial for future studies on these species to include more academic journals but due to the scope of this project and time allotted government assessments were the primary source of information.

Based on our assessment alone of the species above it is important to keep note of any changes to the species COSEWIC status or any changes in distribution that could be connected to the impacts of climate change. Although some of the species listed above have not been directly found on the property or within proximity to the site it is still important to note that that does not mean they are not there or that they do not interact with the site. The assemblages of algal and invertebrate communities and their distributions along the sites studied could also be used as future indicators of the impact of climate change. These species can be easily studied following the methods above and assessing new literature and reports can help ensure that the possible impacts are being fully investigated.

Of the original 44 species investigated through our literature review and analysis, half of the species were denoted as being susceptible or intolerant to climate change. Within the species some are economically valuable like Atlantic Salmon and Atlantic Cod, but all species noted have an intrinsic value to the region. These species require protection from the elements of climate change and the implications of our own human influence on their environments to ensure their populations remain sustainable and viable for future generations to enjoy.

6.0 Drone Imagery

6.1 Drone Flight Paths

Both sites saw brief flights conducted at a height of 70m. On September 27th, 2023, the flights were conducted at low-tide, mid-tide, and high-tide all on the same day. Flight paths were created for both Beach One and the Cove site (Figure 33; Figure 34). The drone could not be flown at Beach Two due to the distance from launch site.

Figure 33. Google Earth imagery showing Beach One flight path for drone imagery (Google Earth, 2023).

Figure 34. Google Earth imagery showing Cove site flight path for drone imagery (Google Earth, 2023).

6.2 4K Imagery

The post-processed imagery of Beach O

ne includes images at low-tide, mid-tide, and high-tide shown with the surveyed transects (Figure 35). The Cove sites low-tide, mid-tide, and high-tide images are also shown with the transect surveyed (Figure 36). All transects are completely submerged at high tide.

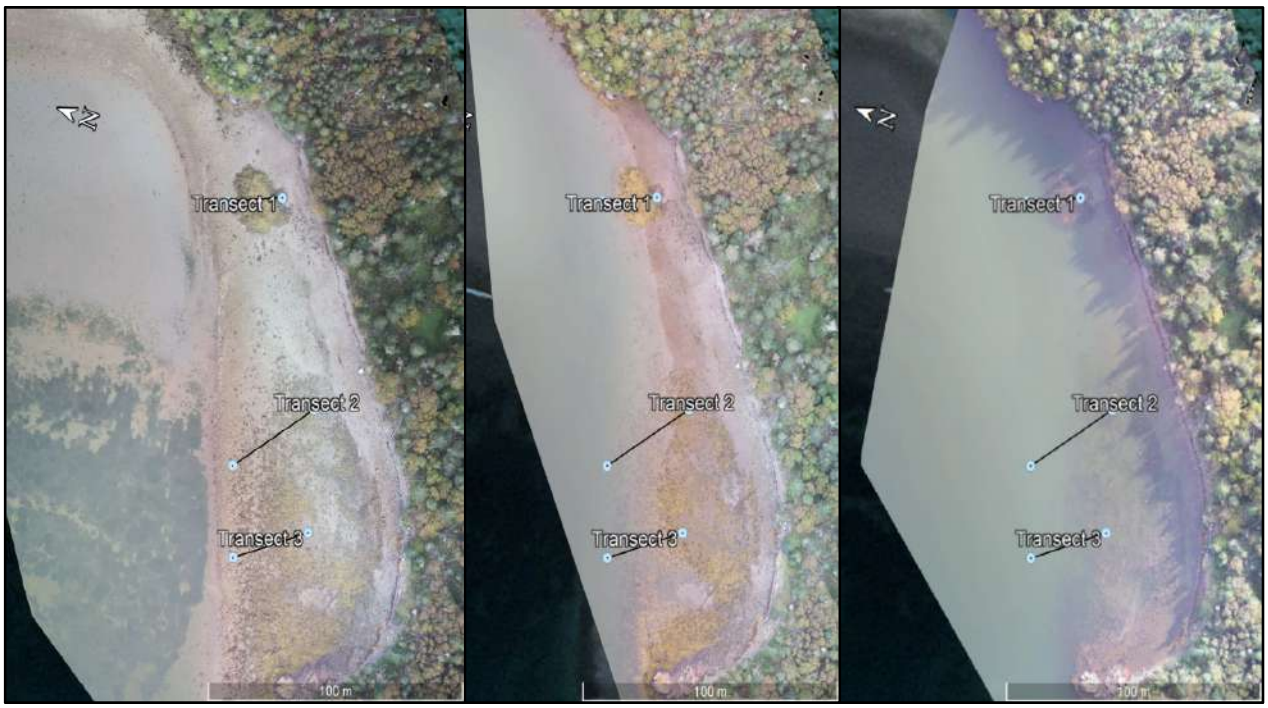

Figure 35. Aerial view of transects at Beach One site, left image shows the site at low tide, middle image shows site at mid tide, and the right image shows the site at high tide, all images collected from drone imagery on September 27th, 2023.

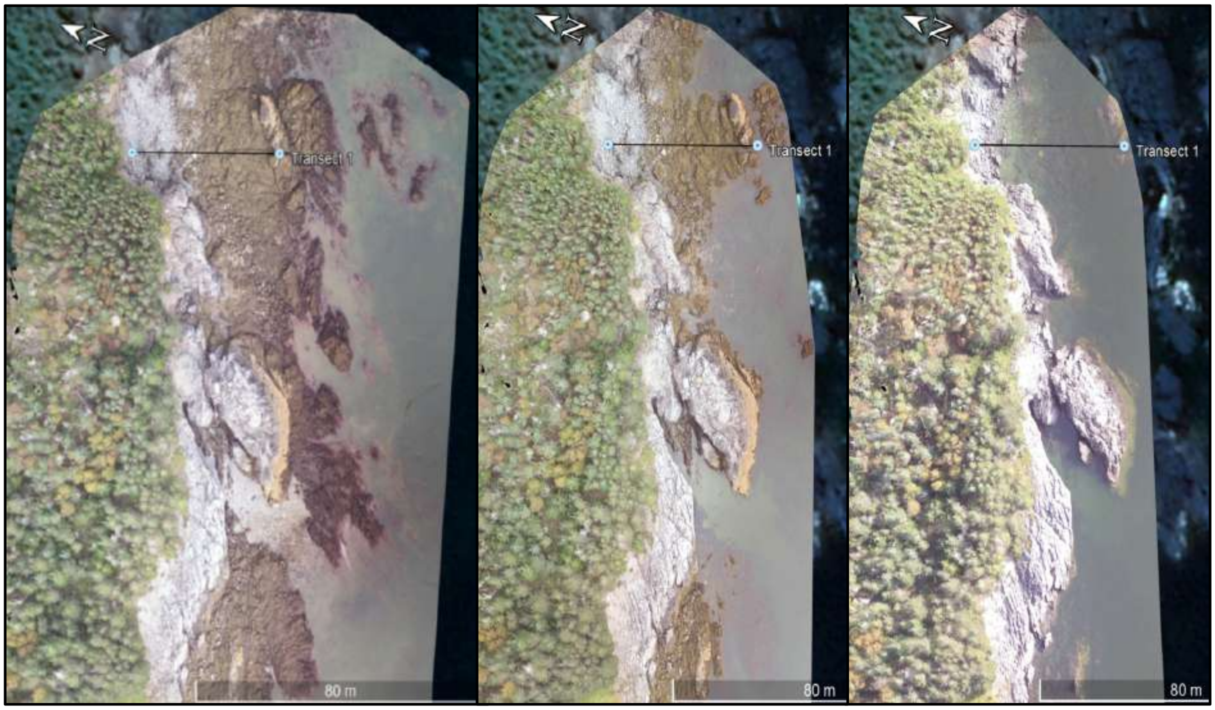

Figure 36. Aerial view of transect at Cove site, left image shows the site at low tide, middle image shows site at mid tide, and the right image shows the site at high tide, all aerial imagery was collected on September 27th, 2023.

6.3 Thermal Imagery

Post-processed thermal imagery for Beach One shows yellows and other lighter colors which exhibit a higher thermal reflectance due to the emission of heat and infrared radiation, whereas dark colors like dark pink or blue have a lower thermal reflectance (Figure 37). Any regions that are displayed in black have little to no infrared reflectance or heat emissions and may be the result of disparities in the data collected, shadows, or deep water. Since water tends to block many infrared wavelengths, regular thermal sensors can only penetrate it to a certain extent (GStiR, 2021). Areas showing dark blue, dark pink, and light pink are the sensor attempting to pick up the data under the water when it is shallow and clear. The thermal imagery and the colour differences show the possible location of the deeper areas within the intertidal zone and the extent of the elevation change (Figure 37). Dry algae and lighter rocks have a higher thermal reflectance while the water have a higher variance in thermal reflectance based on depth and heat signatures (Figures 35; Figure 37). Imagery from the Cove site shows that the rocks emit more heat and infrared light due to their constant exposure even during high tide cycles (Figure 36; Figure 38).

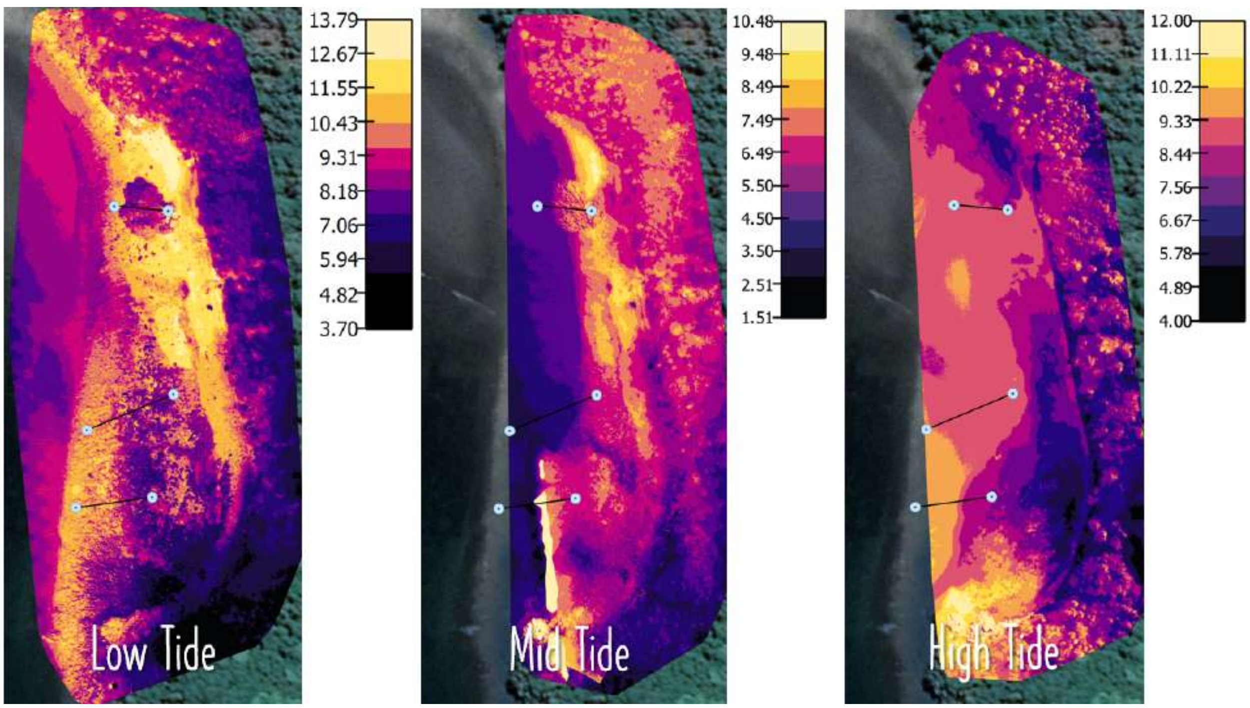

Figure 37. Thermal drone imagery of Beach One site, left image shows site at low tide, middle image shows site at mid tide, right image shows site at high tide, all thermal imagery was collected on September 27th, 2023.

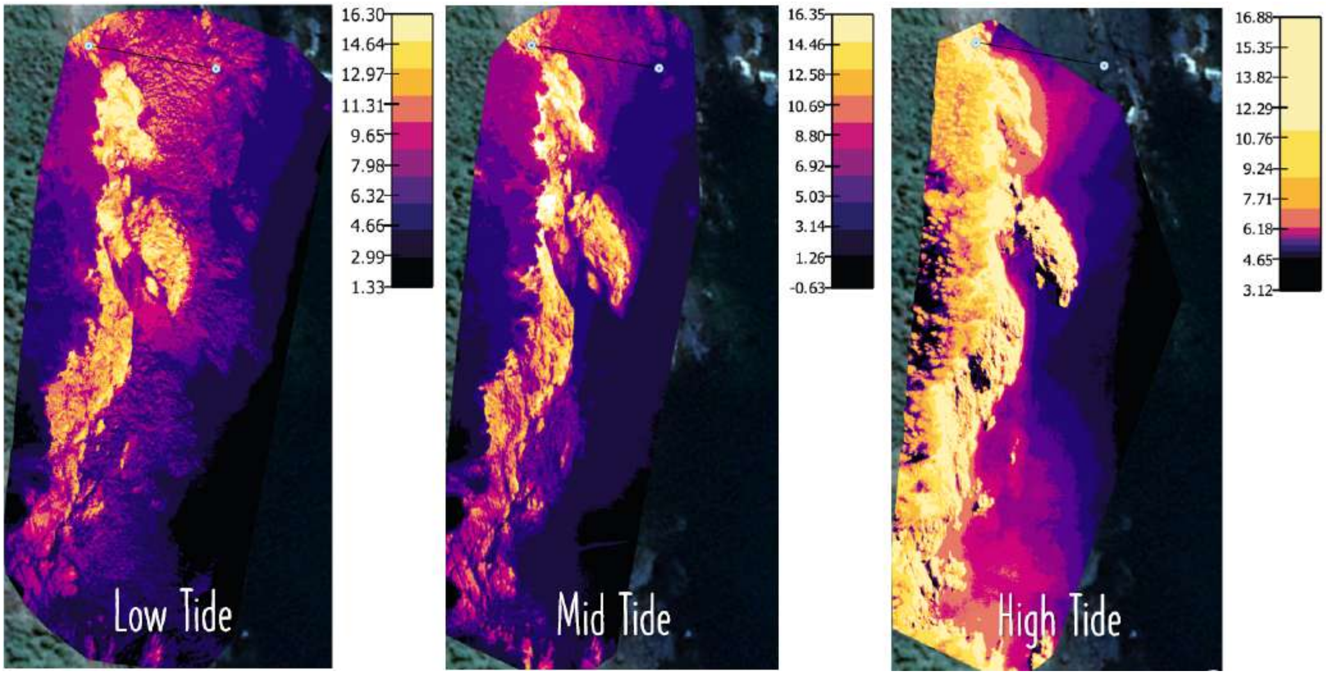

Figure 38. Thermal drone imagery of Beach One site, left image shows site at low tide, middle image shows site at mid tide, right image shows site at high tide, all thermal imagery was collected on September 27th, 2023.

7.0 Other Future Impacts on Deadmans Head Peninsula

7.1 Erosion

Climate change may affect coastal erosion at Deadmans Head Peninsula due to factors like increased frequency of severe storms as well as sea level rise. Storm severity is linked to climate change which may bring more powerful winds and heavier rainfall, leading to more intense wave action and erosion along coastlines (Dawson *et al*., 2009; Mentaschi *et al*., 2017; Laino and Iglesias, 2023). The severity of these storms can drastically impact coastline geography and accelerate erosion processes while changes in freeze-thaw cycles due to shorter winters or hotter summers may also have an affect on cliff stability along coastlines (Dawson *et al*., 2009). Environmental parameters influenced by climate change can include increased temperatures, altered rainfall patterns, and severe weather events can lead to the loss of vegetation cover along the coast, and which may weaken the natural defences against degradation that vegetation provides (root stabilization), making the coastline more susceptible to erosion (Crespi *et al*., 2020; Laino and Iglesias, 2023). However, due to the stable geological structure of Deadmans Head Peninsula, the effect of erosion may not be a major cause of concern under future climate change scenarios.

7.2 Flooding

Parts of Deadmans Head Peninsula that are low-lying areas, such as Beach One and Beach Two, may experience more frequent and severe flooding events during high tides, storm surges, and extreme weather conditions. As temperatures increase the glaciers and ice caps will melt, this contributes to rising sea levels and may increase the risk of coastal flooding

(Seneviratne *et al*., 2021). Climate change is anticipated to increase in the intensity and frequency of extreme weather events, within the Atlantic Ocean the most notable occurrence will include hurricanes which may bring more impactful storm surges that can flood the beach areas of the peninsula (Crespi *et al*., 2020; Peduzzi, 2005).

8.0 Future Plans and Considerations

Our current report has focused on a single season at each of the study sites, however, to see the full impact of climate change on species present within Deadmans Harbour, the Bay of Fundy, and its surrounding areas long-term studies spanning multiple seasons would be required. A longer study would enable a better understanding of trends and patterns in species abundance related to the changing climate. Long-term data holds the potential to unveil more precise trends and facilitate predictive models which could forecast potential implication of species abundance under climate change. The insights from this long-term study could inform strategies for the sustainable management within the Bay of Fundy which may involve adapting management plans, initiating habitat restoration initiatives, or implementing and updating conservation and mitigation measures.

Future study plans should implement the methodologies that have been followed during this study to ensure cohesive comparisons throughout time. We recommend that as this living laboratory continues other seasons are analyzed and that a comprehensive assessment is done every 10-20 years to ensure accurate reporting on the changes happening. The future study plan may include collaboration efforts with local groups, NGOs, and government agencies.

Collaboration efforts may enhance the project itself by initiating a holistic approach to the conservation efforts at Deadmans Head Peninsula.

9.0 Limitations

The Cove site of our current project location is primarily characterized by steep cliffs that remain unaffected by high tides. Consequently, sampling on such cliffs presents challenges due to accessibility concerns. During our study, we could only find one suitable “rocky shore” that was accessible but sites along the Bay of Fundy coastline may be feasible for surveying if accessible by boat. Additionally, wave action may contribute to erosion in intertidal zones, potentially influencing species abundance notably of algal species since they require stable rock formations to secure themselves to. The study period was limited to a particular season, repetition of the study during other seasons could provide better understanding of our above findings and provide more accurate results.

10.0 Conclusion

Ernie and Judy Edwards property was studied to create a baseline dataset to establish a possible living laboratory. Phase One of the project occurred in 2022 and focused on the forested area of the property, with this report being Phase Two and focusing on the intertidal zone of the property. Data was collected to identify the species that can be found in the various tidal zones, as well as drone images and thermal imagery of Beach One and the Cove site. A literature review was done to identify what species may be impacted by different parameters that can be caused by climate change.

Various species in the intertidal zone and surrounding area will be impacted by climate change, according to literature and what was identified on the site. Research of the sites analyzed in this report is important for ensuring the sustainability of the area for future generations, continuation of this project in the future can be used to get a clearer understanding of the impact a changing climate is having on the region.

Acknowledgements

Territorial Land Acknowledgement

Deadmans Head, where fieldwork for this project took place is situated on the unceded and unsurrendered territory of the Passamaquoddy Peoples. This territory is covered by the Treaties of Peace and Friendship which Wolastoqiyik (Maliseet), Mi'kmaq, and Passamaquoddy Peoples first signed with the British Crown in 1725. This research has taken plan on traditional land of Indigenous Peoples, and we reaffirm our commitment and responsibility in improving relationships between nations and to improving our own understanding of local Indigenous Peoples and their culture. We understand the cultural significance of many different species found within the Bay of Fundy region and that the impacts of climate change on them and the surrounding communities could result in great loss. We hope that this report and the continuation of the Deadmans Head Living Laboratory help to protect the traditional land and all its inhabitants.

Project Acknowledgements

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Appendix A: Collected Data

Transect Information

Date	Site	Transect	Low Tide Time	Start Time	End Time	Top of transect Coordinates	Bottom of transect Coordinates	Notes	Other species notes
20-Oct	Beach 1	1	10:15 AM	9:18 AM		N 45° 02.9290' W 066° 46.1954'	N 45° 02.9378' W 066° 46.2006'	No true low zone of distinct transition	FD found near Q6
20-Oct	Beach 1	2	10:15 AM	10:18 AM		N 45° 02.9086' W 0.66° 46.2565'	N 45° 02.9227' W 066° 46.2659'	No true low zone of distinct transition	AP and AC found outside of transect
20-Oct	Beach 1	3	10:15 AM	10:22 AM		N 45° 02.9036' W 066° 46.2748'	N 45° 02.9171' W 066° 46.2883'	No true low zone of distinct transition	FS near Q2; 2 VL outside Q3 points but within the quadrat
27-Oct	Cove	1				N 45° 2' 52.296" W 66° 46' 2.064"	N/A	Large rocky shore that relatively flattens out	Rock crab found outside of transect; green mossy stuff on rocks and UI just outside Q1; FV outside Q7
03-Nov	Beach 2	1	10:24 AM	9:32 AM	10:27 AM	N 45° 02.6741' W 066° 46.6438'	N 45° 02.6852' W 066° 46.6642'	No true low zone but more distinct transition than beach one	Rocky outcrop that transitions to the gravel beach
03-Nov	Beach 2	2	10:24 AM	9:30 AM	10:23 AM	N 45° 2' 43.332" W 66° 46' 37.092"	N/A	No true low zone but more distinct transition than beach one	

Beach 1 Invertebrates

Beach	Transect	Quadrat (#)	Zone (H,M,L)	Distance (m)	Total Distance (m)	Invertebrate Species and Number (per 10cm X 10 cm) (small quadrat)			Other Species and Number/Notes	Quadrat Description (sand, rock, etc.)
						LL	LO	SB		
1	1	1	H	0	0	0	0	14		Large Rock Outcrop
		2	H/M	2.8	2.8	1	0	8		Large Rock Outcrop
		3	M	3.25	6.05	1	3	8		Large Rock Outcrop
		4	M	3.2	9.25	3	0	23		Large Rock Outcrop
		5	M	4.6	13.85	2	0	0		Large Rock Outcrop
		6	M	7.45	21.3	0	0	93		Large Rock Outcrop
	2	1	H/M	0	0	6	0	9	FS near quadrat	Small Rocks
		2	M	5.35	5.35	5	0	99		Small Rocks
		3	M	4.5	9.85	0	0	17		Small Rocks
		4	M	4.85	14.7	3	0	105	Dead Rock Crab near quadrat	Small Rocks
		5	M/L	9.8	24.5	0	0	115		Small Rocks
		6	M/L	3.2	27.7	5	0	96	AP near quadrat	Medium Rocks
	3	1	H	0	0	6	0	58		Medium Rocks
		2	H/M	5.2	5.2	1	1	17		Medium Rocks
		3	M	4.95	10.15	2	0	148		Medium Rocks
		4	M	5.3	15.45	1	0	38		Medium Rocks
		5	M/L	5.55	21	1	0	120		Medium Rocks
		6	M/L	8.4	29.4	19	0	104		Medium Rocks

Common Name	Code 1	Code 2
common periwinkle	CP	LL
acorn barnacle	AB	SB
smooth periwinkle	SP	LO

Beach 1 Seaweed

Beach	Transect	Point (#)	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6
1	1	1	FS		AN Li	AN Li	AN Li	AN FV Li
		2	FS	H	AN Li	AN Li	AN Li	AN FV Li
		3	FS		AN Li	AN Li	AN Li	AN FV Li
		4	FS		AN Li	AN Li	AN Li	AN FV Li
		5	FS	H	AN Li	AN Li	AN Li	AN FV Li
		6	FS FV		AN Li	AN Li	AN Li	AN FV Li
		7	FV		AN Li	AN Li	AN Li	AN FV Li
		8	FV FS	H	AN Li	AN Li	AN Li	AN FV Li
		9	FV FS		AN Li	AN Li	AN Li	AN FV Li
		10	FS		AN Li	AN Li	AN Li	AN FV Li
		11	FS	H	AN Li	AN Li	AN Li	AN FV Li
		12	FS	H	AN Li	AN Li	AN Li	AN FV Li
		13	FS		AN Li	AN Li	AN Li	AN FV
		14	FS FV		AN Li	AN Li	AN Li	AN
		15	FV		AN Li	AN Li	AN Li	AN
		16	FV		AN Li	AN Li	AN Li	AN
		17	FV	H	AN Li	AN Li	AN Li	AN
		18	FS		AN Li	AN Li	AN Li	AN
		19			AN Li	AN Li	AN Li	AN
		20		H	AN Li	AN Li	AN Li	AN
		21		H	AN Li	AN Li	AN Li	AN
		22			AN Li	AN Li	AN Li	AN
		23			AN Li	AN Li	AN Li	AN
		24			AN Li	AN Li	AN Li	AN
		25			AN Li	AN Li	AN Li	AN
		26		AN	AN	AN Li	AN	AN
		27			AN	AN Li	AN	AN
		28			AN	AN Li	AN	AN
		29			AN	AN Li	AN	AN
		30			AN	AN Li	AN	AN
		31			AN	AN Li	AN	AN
		32		AN	AN	AN Li	AN	AN
		33			AN	AN Li	AN	AN
		34			AN	AN Li	AN	AN
		35			AN	AN Li	AN	AN
		36			AN	AN Li	AN	AN
		37			AN	AN Li	AN	AN
		38			AN	AN Li	AN	AN
		39			AN	AN Li	AN	AN
		40			AN	AN Li	AN	AN
		41		AN H	AN	AN	AN	
		42		AN	AN	AN	AN	
		43		AN	AN	AN	AN	
		44			AN	AN	AN	
		45			AN	AN	AN	
		46		AN	AN	AN	AN	
		47		AN	AN	AN	AN	
		48		AN	AN	AN	AN	
		49		AN	AN	AN	AN	
		50			AN	AN	AN	

Beach	Transect	Point (#)	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6
1	2	1	Li	AN Li				Li
		2	Li FV	AN Li				Li
		3	Li FV AN	AN Li	FV Li	AN	AN	Li
		4	Li FV AN	AN Li	FV		AN	Li FD
		5	Li FV AN	AN Li			AN	Li FD
		6	Li FV AN	AN Li			AN	Li FD
		7	Li	AN Li	FV		AN	Li FD
		8	Li FV		FV			Li
		9	Li FV	AN	FV			Li
		10	Li	AN	FV			
		11	Li FV		FV			
		12	FV	AN				FD
		13	AN					
		14	AN				AN	
		15	AN	AN			AN	
		16	AN	AN	FV		AN	FD
		17	AN	AN	FV			FD
		18	AN FV			AN		FD
		19				AN		FD
		20	FV			AN		FD
		21	AN			AN		FD
		22	AN					
		23	AN		FV			
		24	AN		AN			
		25	AN	AN				
		26	AN	AN				
		27	AN	AN				AN
		28	AN					
		29	AN		FV			FD
		30	AN			AN		FD
		31	AN					FD
		32	AN					
		33	AN		AN			
		34	AN	AN	AN	AN		
		35	AN	AN	AN			AN
		36	AN	AN	AN			AN
		37	AN	AN		AN		AN
		38	AN				FD	AN FV
		39	AN			AN		AN FV
		40	AN					AN FV
		41	AN			AN		
		42	AN			AN		
		43	AN			AN		AN FV
		44	AN	AN	AN	AN		AN
		45	AN	AN	AN	AN	FD	AN
		46	AN	AN	AN	AN		
		47	AN	AN	AN	AN		AN
		48	AN	AN	AN	AN		AN FV
		49	AN	AN	AN	AN		AN FV
		50	AN FV	AN		AN	FD	

Beach	Transect	Point (#)	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6
1	3	1		AN	AN	AN FV	AN Li	FV Li
		2		AN	AN Li	AN FV	AN Li	
		3		AN	AN	AN FV	AN Li FV	Li
		4	Li	AN	AN	AN	AN Li FV	
		5		FV	AN	AN	Li FV	
		6			AN	AN	FV	
		7	AN			AN	AN	
		8	FS		AN	AN	AN	
		9		AN FV	AN	AN FV	AN	
		10		AN	AN Li	AN FV	AN Li	Li
		11		AN	AN	AN FV	AN	Li
		12	FS	AN	AN	AN	AN	
		13		AN	Li	AN	AN	Li
		14		AN		AN	AN EF	
		15	AN	AN	AN	AN	AN	Li
		16		AN FV	AN Li	AN FV	AN	Li
		17			AN	AN FV	AN EF	
		18			Li	AN FV	AN Li	
		19				AN FV	AN	AN
		20	FV	FV	AN	AN FV	AN	
		21		AN	AN	AN FV	AN	Li
		22		Li	AN	AN FV	AN EF	Li
		23		AN		AN FV	AN	
		24		Li		AN FV	AN EF	
		25			AN	AN FV	AN	
		26		FV	AN	AN FV	AN EF	
		27		FV	AN	AN	AN	Li
		28	FV			AN	AN	
		29	FV		AN	AN Li	AN FV	Li
		30	FV		AN	AN	AN Li FD	
		31	Li	Li	AN	AN FV	AN FD	
		32		Li	AN	AN FV	AN Li	
		33		FV	AN	AN FV	AN EF Li	Li
		34		AN	AN	AN FV	AN	Li
		35		Li	AN	AN FV	AN FD	
		36	FS	Li		AN	AN VL	
		37			AN	AN	AN EF	AN
		38		AN	AN Li	AN	AN	AN
		39			AN	AN	AN	
		40	AN	Li	AN	AN	FV	
		41	FV		AN	AN FV	AN	AN FV
		42	FV	AN	AN Li	AN FV	AN EF FV	AN
		43	FV	AN	AN Li	AN FV	AN	Li
		44	FV Li		AN	AN FV	AN EF Li	
		45	AN	Li	AN	AN	AN Li	
		46	AN	Li	AN Li	AN	AN Li	
		47	AN	AN	AN	AN FV Li	AN	AN
		48		AN Li	AN	AN Li	AN Li	AN
		49		Li	AN	AN Li	AN	Li
		50			AN	AN	AN	

Common Name	Code
Fucus spiralis	FS
Ascophyllum nodosum	AN
Fusus vesiculosus	FV
Fusus distichus	FD
Vertebrata lanosa	VL
Elaschista fucicola	EF

Transect	Quadrat	Total Number						Total Distance	Zone
		FS	AN	FV	FD	EF	VL		
1	1	14	0	8	0	0	0	0	H
	2	0	9	0	0	0	0	2.8	H/M
	3	0	50	0	0	0	0	6.05	M
	4	0	50	0	0	0	0	9.25	M
	5	0	50	0	0	0	0	13.85	M
	6	0	40	13	0	0	0	21.3	M
2	1	0	40	12	0	0	0	0	H/M
	2	0	27	0	0	0	0	5.35	M
	3	0	11	11	0	0	0	9.85	M
	4	0	19	0	0	0	0	14.7	M
	5	0	8	0	3	0	0	24.5	M/L
	6	0	13	6	14	0	0	27.7	M/L
3	1	3	6	8	0	0	0	0	H
	2	0	20	7	0	0	0	5.2	H/M
	3	0	41	0	0	0	0	10.15	M
	4	0	50	27	0	0	0	15.45	M
	5	0	47	7	3	9	1	21	M/L
	6	0	7	2	0	0	0	29.4	M/L

Transect	Quadrat	% Cover						Total Distance	Zone
		FS	AN	FV	FD	EF	VL		
1	1	28	0	16	0	0	0	0	H
	2	0	18	0	0	0	0	2.8	H/M
	3	0	100	0	0	0	0	6.05	M
	4	0	100	0	0	0	0	9.25	M
	5	0	100	0	0	0	0	13.85	M
	6	0	80	26	0	0	0	21.3	M
2	1	0	80	24	0	0	0	0	H/M
	2	0	54	0	0	0	0	5.35	M
	3	0	22	22	0	0	0	9.85	M
	4	0	38	0	0	0	0	14.7	M
	5	0	16	0	6	0	0	24.5	M/L
	6	0	26	12	28	0	0	27.7	M/L
3	1	6	12	16	0	0	0	0	H
	2	0	40	14	0	0	0	5.2	H/M
	3	0	82	0	0	0	0	10.15	M
	4	0	100	54	0	0	0	15.45	M
	5	0	94	14	6	18	2	21	M/L
	6	0	14	4	0	0	0	29.4	M/L

**Li (lichen) and H left out of summaries because they are not seaweed

Beach 2 Invertebrates

Beach	Transect	Quadrat (#)	Zone (H,M,L)	Distance (m)	Total Distance (m)	Invertebrate Species and Number (per 10cm X 10 cm) (small quadrat)			Other Species and Number/Notes	Quadrat Description (sand, rock, etc.)
						LL	LO	SB		
2	1	1	H	0	0	0	0	24	N/A	Large rock outcrop
		2	M	4.35	4.35	2	0	31	N/A	Large rock outcrop
		3	M	3.2	7.55	0	0	108	N/A	Large rock outcrop
		4	M	2.9	10.45	4	0	217	N/A	Large rock outcrop
		5	M/L	6.15	16.6	0	3	67	N/A	Gravel beach
		6	L	8.4	25	0	0	3	N/A	Gravel beach
	2	1	H/M	0	0	3	1	3	N/A	Larger rocks
		2	M	6.55	6.55	0	1	80	N/A	Smaller rocks
		3	M	9.8	16.35	0	1	84	N/A	Smaller rocks
		4	M	7.85	24.2	1	4	150	N/A	Larger rocks
		5	M/L	4.4	28.6	0	0	37	N/A	Smaller rocks
		6	M/L	3.4	32	1	0	14	N/A	Smaller rocks

Beach 2 Seaweed

Beach	Transect	Point	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6
2	1	1	FS	AN FV	AN FV VL	AN FV VL EF	AN FV FD VL	FD
		2	FS	AN FV	AN FV VL	AN FV VL EF	AN FV FD VL	FD
		3	FS	AN FV	AN FV VL	AN FV VL EF	AN FV FD VL	FD
		4	FS	AN FV	AN VL	AN VL	AN FV FD	FD
		5	FS	AN FV	AN VL	AN	AN FV FD	
		6	FS	AN FV	AN VL	AN	AN FD	
		7	FS	AN	AN VL	AN	AN FD	
		8	FS	AN	AN VL	AN	AN	
		9	FS	AN	AN VL	AN	AN	
		10	FS	AN	AN VL	AN	AN	
		11	FS	AN	AN	AN	AN	
		12	FS	AN	AN	AN	AN	
		13	FS	AN	AN	AN	AN	
		14	FS	AN	AN	AN	AN	
		15	FS	AN	AN	AN		
		16		AN	AN	AN		
		17		AN	AN	AN		
		18		AN	AN	AN		
		19		AN	AN	AN		
		20		AN	AN	AN		
		21		AN	AN	AN		
		22		AN	AN	AN		
		23		AN	AN	AN		
		24		AN	AN	AN		
		25		AN	AN	AN		
		26		AN	AN	AN		
		27		AN	AN	AN		
		28		AN	AN	AN		
		29		AN	AN	AN		
		30		AN	AN	AN		
		31		AN	AN	AN		
		32		AN	AN	AN		
		33		AN	AN	AN		
		34		AN	AN	AN		
		35		AN	AN	AN		
		36		AN	AN	AN		
		37		AN	AN	AN		
		38		AN	AN	AN		
		39		AN	AN	AN		
		40		AN	AN	AN		
		41		AN	AN	AN		
		42		AN	AN	AN		
		43		AN	AN	AN		
		44		AN	AN	AN		
		45		AN	AN	AN		
		46		AN	AN	AN		
		47		AN	AN	AN		
		48		AN	AN	AN		
		49			AN	AN		
		50			AN	AN		

Beach	Transect	Point	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6
2	2	1	AN FS FV EF Li	AN EF FV VL	AN FV VL	AN FV EF Li	AN EF Li VL	AN FD
		2	AN FS FV EF	AN EF FV VL	AN FV VL	AN FV EF Li	AN EF Li VL	AN FD
		3	AN FS EF	AN EF FV VL	AN FV VL	AN FV EF Li	AN EF Li VL	AN FD
		4	AN FS	AN EF FV VL	AN FV VL	AN FV EF Li	AN Li FD	FD
		5	AN FS	AN EF FV	AN VL	AN EF VL Li	AN Li FD	FD
		6	AN FS	AN EF FV	AN VL	AN EF VL Li	AN Li	
		7	AN FS	AN EF FV	AN VL	AN EF VL Li	AN	
		8	AN FS	AN EF FV	AN VL	AN EF Li	AN	
		9	AN FS	AN EF FV	AN VL	AN EF Li	AN	
		10	AN FS	AN EF FV	AN VL	AN EF Li	AN	
		11	AN FS	AN EF FV	AN VL	AN EF Li	AN	
		12		AN EF FV	AN VL	AN EF Li	AN	
		13		AN EF FV	AN	AN EF Li	AN	
		14		AN EF FV	AN	AN EF Li	AN	
		15		AN EF FV	AN	AN	AN	
		16		AN EF FV	AN	AN	AN	
		17		AN EF FV	AN	AN	AN	
		18		AN FV	AN	AN	AN	
		19		AN FV	AN	AN	AN	
		20		AN FV	AN	AN	AN	
		21		AN	AN	AN	AN	
		22		AN	AN	AN	AN	
		23		AN	AN	AN	AN	
		24		AN	AN	AN	AN	
		25		AN	AN	AN	AN	
		26		AN	AN	AN	AN	
		27		AN	AN	AN	AN	
		28		AN	AN	AN	AN	
		29		AN	AN	AN	AN	
		30		AN	AN	AN	AN	
		31		AN	AN	AN	AN	
		32		AN	AN	AN	AN	
		33		AN	AN	AN	AN	
		34		AN	AN	AN	AN	
		35		AN	AN	AN	AN	
		36		AN	AN	AN	AN	
		37		AN	AN	AN	AN	
		38		AN	AN	AN	AN	
		39		AN	AN	AN	AN	
		40		AN	AN	AN	AN	
		41				AN		
		42				AN		
		43				AN		
		44				AN		
		45				AN		
		46				AN		
		47				AN		
		48				AN		
		49				AN		
		50				AN		

Common Name	Code
Fucus spiralis	FS
Ascophyllum nodosum	AN
Fusus vesiculosus	FV
Fusus distichus	FD
Vertebrata lanosa	VL
Elaschista fucicola	EF

Transect	Quadrat	Total Number						Zone	Distance
		FS	AN	FV	FD	EF	VL		
1	1	15	0	0	0	0	0	H	0
	2	0	48	6	0	0	0	M	4.35
	3	0	50	3	0	0	10	M	7.55
	4	0	50	3	0	3	4	M	10.45
	5	0	14	5	7	0	3	M/L	16.6
	6	0	0	0	4	0	0	L	25
2	1	11	11	2	0	3	0	H/M	0
	2	0	40	20	0	17	0	M	6.55
	3	0	40	4	0	0	12	M	16.35
	4	0	50	4	0	14	3	M	24.2
	5	0	40	0	2	3	3	M/L	28.6
	6	0	3	0	5	0	0	M/L	32

Transect	Quadrat	% Cover						Zone	Distance
		FS	AN	FV	FD	EF	VL		
1	1	30	0	0	0	0	0	H	0
	2	0	96	12	0	0	0	M	4.35
	3	0	100	6	0	0	20	M	7.55
	4	0	100	6	0	6	8	M	10.45
	5	0	28	10	14	0	6	M/L	16.6
	6	0	0	0	8	0	0	L	25
2	1	22	22	4	0	6	0	H/M	0
	2	0	80	40	0	34	0	M	6.55
	3	0	80	8	0	0	24	M	16.35
	4	0	100	8	0	28	6	M	24.2
	5	0	80	0	4	6	6	M/L	28.6
	6	0	6	0	10	0	0	M/L	32

Cove Invertebrates

Quadrat (#)	Zone (H,M,L)	Distance (m)	Total Distance (m)	Invertebrate Species and Number (per 10cm X 10 cm) (small quadrat)			Other Species and Number	Quadrat Description (sand, rock, etc.)
				LL	LO	SB		
1	H	0	0	0	0	0		Rocky
2	H/M	2.9	2.9	0	0	6		Rocky
3	M	3.1	6	0	0	177		Rocky
4	M	1.9	7.9	1	0	81		Rocky
5	M	4.15	12.05	0	0	80	2 dogwhelk outside Q5	Rocky
6	M	3.8	15.85	9	3	142		Rocky
7	M	5.5	21.35	13	0	204		Rocky
8	M/L	5.15	26.5	0	0	79		Rocky
9	M/L	4.1	30.6	2	1	43		Rocky
10	M/L	3.2	33.8	1	0	37		Rocky
11	L	3.9	37.7	2	0	32		Rocky
12	L	4.7	42.4	0	0	7		Rocky

Distribution by tidal zone				
Zone	LL	LO	SB	Total
H	0	0	0	0
H/M	0	0	6	6
M	5	1	137	142
M/L	1	0	53	54
L	1	0	20	21
Total	7	1	215	223

Cove Seaweed

Point	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6	Quad 7	Quad 8	Quad 9	Quad 10	Quad 11	Quad 12
1	FS	FS AN VL	AN VL	AN VL	AN VL	AN VL	AN FV VL	AN VL FD	AN FD	AN FD	AN FD CC	CC CO AN SL UL
2	FS	FS AN VL	AN VL	AN VL	AN VL	AN VL	AN FV VL	AN VL FD	AN FD	AN FD	AN FD CC	CC CO AN SL UL
3	FS	FS AN	AN VL	AN VL	AN VL	AN VL	AN FV VL	AN VL FD	AN FD	AN FD	AN FD CC	CC CO AN SL UL
4	FS	FS AN	AN VL	AN VL	AN VL	AN VL	AN FV	AN VL FD	AN FD	AN FD	AN FD CC	CC CO AN SL UL
5	FS	FS	AN VL	AN VL	AN VL	AN VL	AN FV	AN VL FD	AN FD	AN FD	FD CC	CC CO
6	FS	FS	AN VL	AN VL	AN VL	AN VL	AN FV	AN VL FD	AN FD	AN FD	FD CC	CC CO
7	FS	FS	AN VL	AN	AN VL	AN VL	AN FV	AN VL FD	AN FD	AN FD	FD CC	CC CO
8	FS	FS	AN VL	AN	AN VL	AN VL	AN FV	AN VL FD	AN FD	AN FD	FD CC	CC CO
9	FS	FS	AN VL	AN	AN VL	AN VL	AN FV	AN VL FD	FD	AN FD	FD CC	CC CO
10	FS	FS	AN VL	AN	AN VL	AN VL	AN FV	AN VL	FD	AN	FD CC	CC CO
11	FS	FS	AN VL	AN	AN	AN VL	AN FV	AN VL	FD	AN	FD CC	CC CO
12	FS	FS	AN	AN	AN	AN VL	AN FV	AN VL	FD	AN	FD CC	CC CO
13	FS	FS	AN	AN	AN	AN	AN FV	AN VL	FD	AN	FD CC	CC CO
14	FS	FS	AN	AN	AN	AN	AN FV	AN VL	FD	AN	FD CC	CC CO
15	FS	FS	AN	AN	AN	AN	AN FV	AN VL		AN	FD CC	CC CO
16	FS	FS	AN	AN	AN	AN	AN FV	AN VL		AN	FD CC	CC CO
17	FS	FS	AN	AN	AN	AN	AN FV	AN VL		AN	FD CC	CC CO
18	FS	FS	AN	AN	AN	AN	AN FV	AN		AN	FD CC	CC CO
19	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
20	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
21	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
22	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
23	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
24	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
25	FS	FS	AN	AN	AN	AN	AN FV	AN			FD CC	CC CO
26		FS	AN	AN	AN	AN	AN FV	AN				CC CO
27		FS	AN	AN	AN	AN	AN FV	AN				CC CO
28		FS	AN	AN	AN	AN	AN FV	AN				CC CO
29		FS	AN	AN	AN	AN	AN FV	AN				CC
30		FS	AN	AN	AN	AN	AN FV					CC
31		FS	AN	AN	AN	AN	AN					CC
32		FS	AN	AN	AN	AN	AN					CC
33		FS	AN	AN	AN	AN	AN					
34		FS	AN	AN	AN	AN	AN					
35		FS	AN	AN	AN	AN	AN					
36		FS	AN	AN	AN	AN	AN					
37		FS	AN	AN	AN	AN	AN					
38		FS	AN	AN	AN	AN	AN					
39		FS	AN	AN	AN	AN	AN					
40		FS	AN	AN	AN	AN	AN					
41		FS	AN	AN	AN	AN	AN					
42		FS	AN	AN	AN	AN	AN					
43		FS	AN	AN	AN	AN	AN					
44		FS	AN	AN	AN	AN	AN					
45		FS	AN	AN	AN	AN	AN					
46		FS	AN	AN	AN	AN	AN					
47		FS	AN	AN	AN	AN	AN					
48		FS	AN	AN	AN	AN	AN					
49		FS	AN	AN	AN	AN	AN					
50		FS		AN	AN	AN	AN					

Quadrat	Total Number										Zone	Distance
	FS	AN	FV	FD	EF	VL	CC	CO	SL	UL		
1	25	0	0	0	0	0	0	0	0	0	H	0
2	50	4	0	0	0	2	0	0	0	0	H/M	3
3	0	49	0	0	0	11	0	0	0	0	M	6
4	0	50	0	0	0	6	0	0	0	0	M	8
5	0	50	0	0	0	10	0	0	0	0	M	12
6	0	50	0	0	0	12	0	0	0	0	M	16
7	0	50	30	0	0	3	0	0	0	0	M	21
8	0	29	0	9	0	17	0	0	0	0	M/L	27
9	0	8	0	14	0	0	0	0	0	0	M/L	31
10	0	18	0	9	0	0	0	0	0	0	M/L	34
11	0	4	0	25	0	0	25	0	0	0	L	38
12	0	4	0	0	0	0	32	28	4	4	L	42

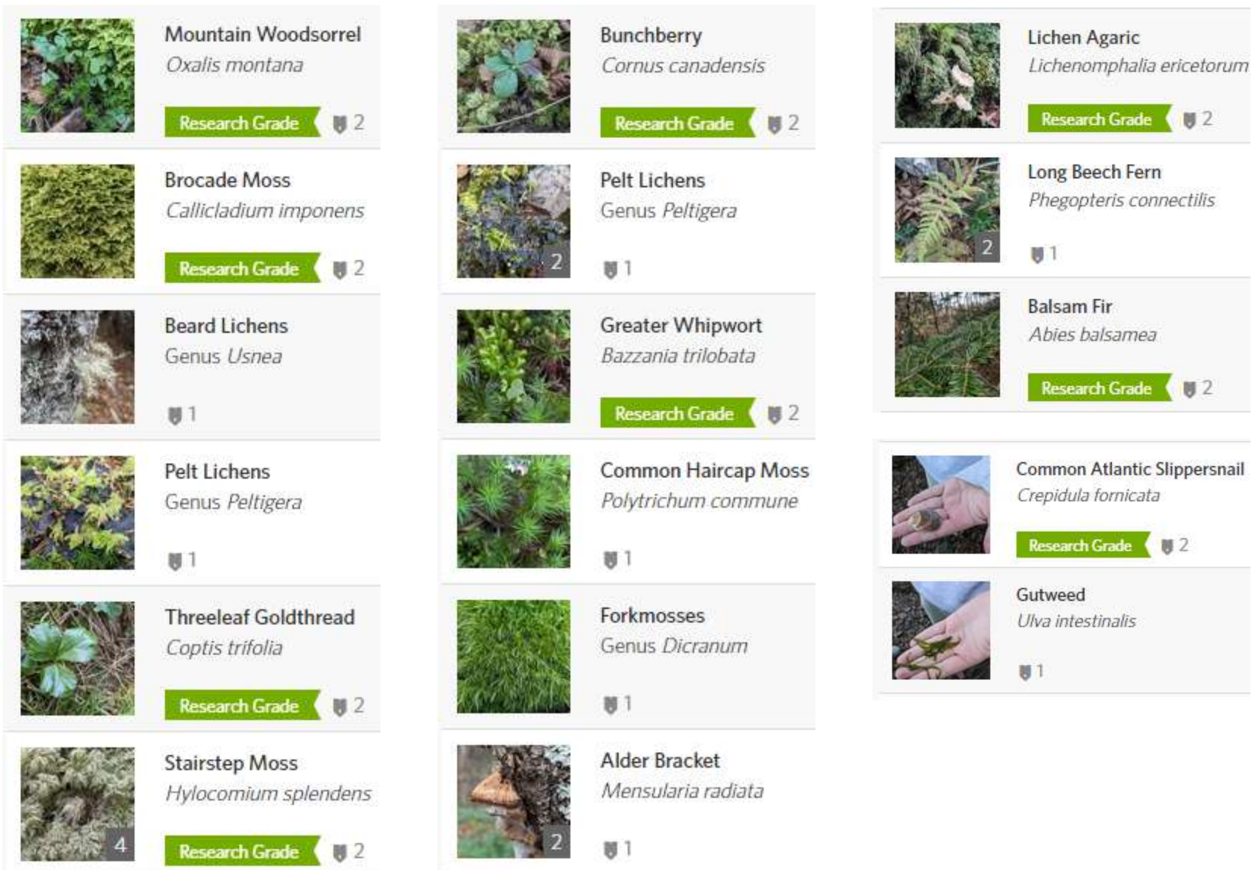
Quadrat	% Cover										Zone	Distance
	FS	AN	FV	FD	EF	VL	CC	CO	SL	UL		
1	50	0	0	0	0	0	0	0	0	0	H	0
2	100	8	0	0	0	4	0	0	0	0	H/M	3
3	0	98	0	0	0	22	0	0	0	0	M	6
4	0	100	0	0	0	12	0	0	0	0	M	8
5	0	100	0	0	0	20	0	0	0	0	M	12
6	0	100	0	0	0	24	0	0	0	0	M	16
7	0	100	60	0	0	6	0	0	0	0	M	21
8	0	58	0	18	0	34	0	0	0	0	M/L	27
9	0	16	0	28	0	0	0	0	0	0	M/L	31
10	0	36	0	18	0	0	0	0	0	0	M/L	34
11	0	8	0	50	0	0	50	0	0	0	L	38
12	0	8	0	0	0	0	64	56	8	8	L	42

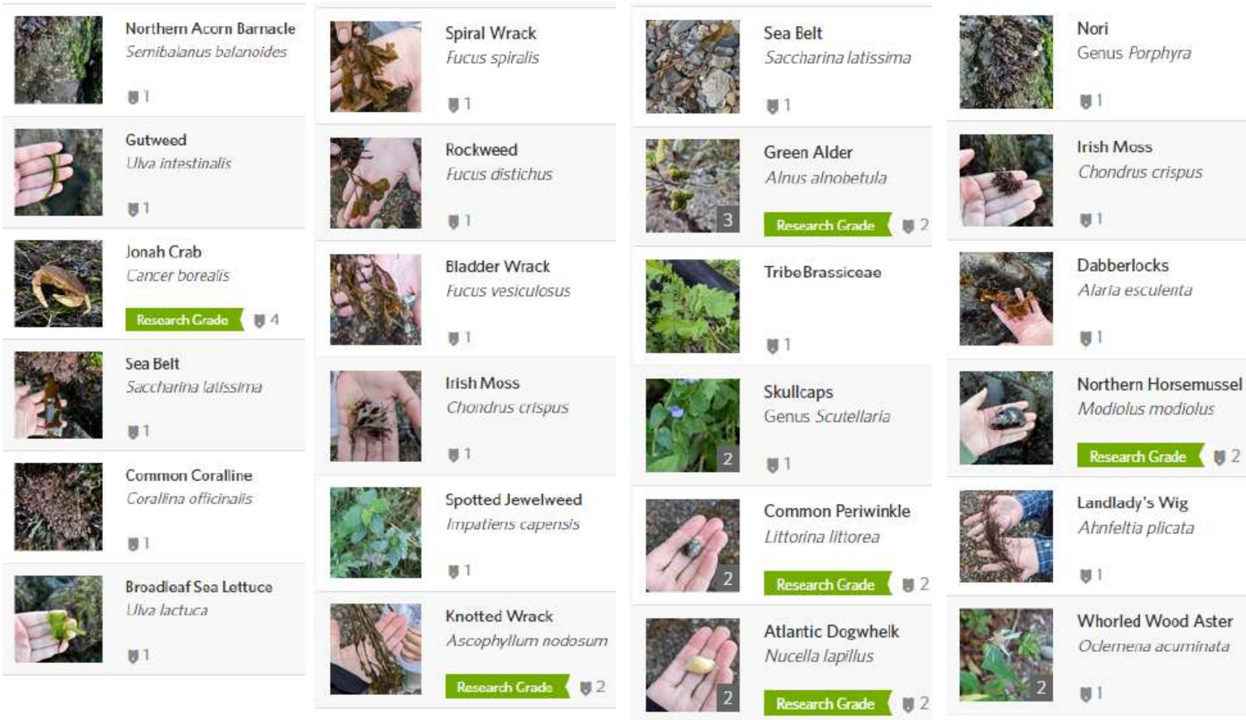
Distribution by tidal zone										
Zone	FS	AN	FV	FD	EF	VL	CC	CO	SL	UL
H	50	0	0	0	0	0	0	0	0	0
H/M	100	8	0	0	0	4	0	0	0	0
M	0	100	12	0	0	17	0	0	0	0
M/L	0	37	0	21	0	11	0	0	0	0
L	0	8	0	25	0	0	57	28	4	4

Common Name	Code
Fucus spiralis	FS
Ascophyllum nodosum	AN
Fusus vesiculosus	FV
Fusus distichus	FD
Vertebrata lanosa	VL
Elaschista fucicola	EF
Chrondrus crispus	CC
Coralinna officinalis	CO
Saccharina latissima	SL
Ulva lactuca	UL

Appendix B: Observed Species

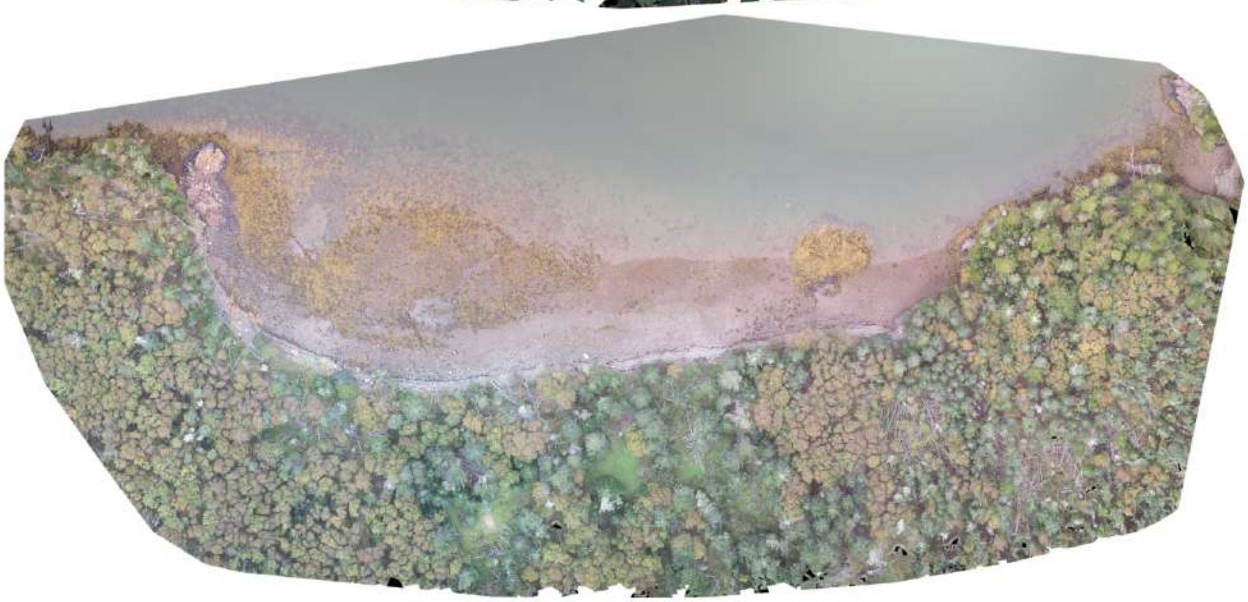
iNaturalist Project: *Deadmans Head Forest* entries

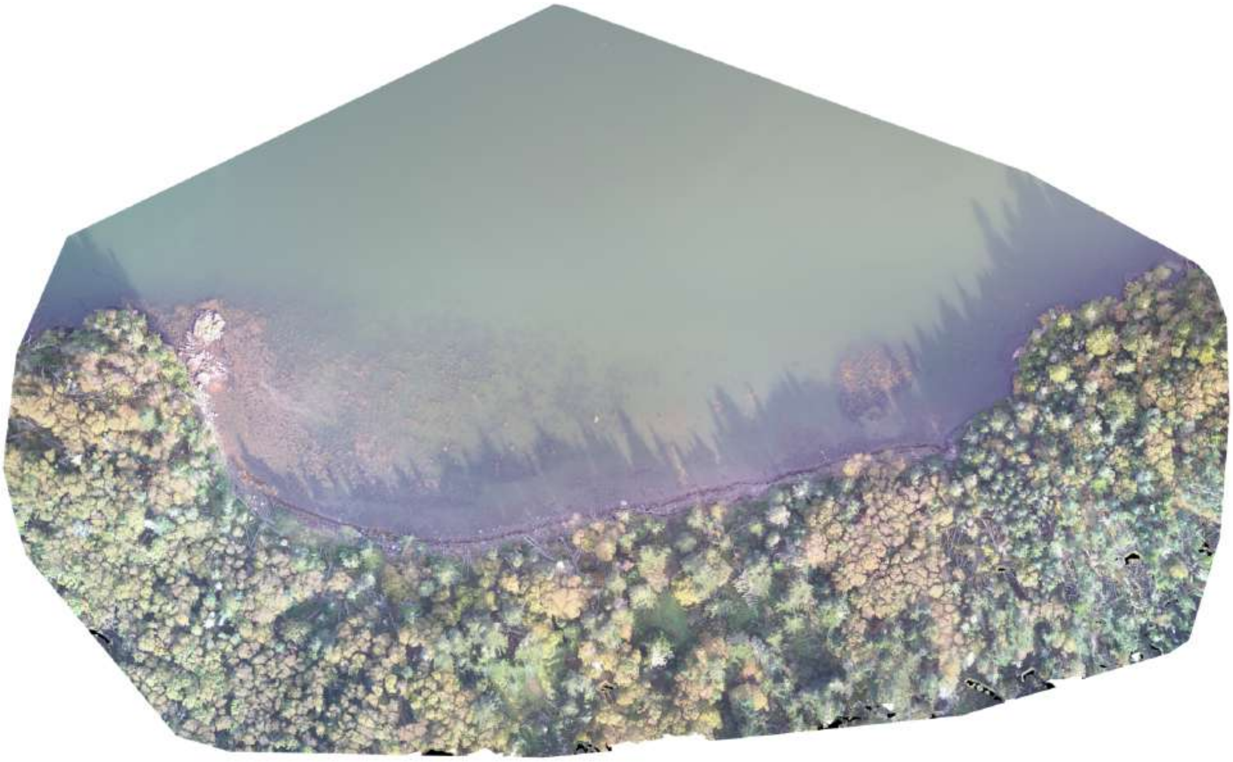




Northern Acorn Barnacle
Semibalanus balanoides
1
Gutweed
Ulva intestinalis
1
Jonah Crab
Cancer borealis
Research Grade
4
Sea Belt
Saccharina latissima
1
Common Coralline
Corallina officinalis
1
Broadleaf Sea Lettuce
Ulva lactuca
1
Spiral Wrack
Fucus spiralis
1
Rockweed
Fucus distichus
1
Bladder Wrack
Fucus vesiculosus
1
Irish Moss
Chondrus crispus
1
Spotted Jewelweed
Impatiens capensis
1
Knotted Wrack
Ascophyllum nodosum
Research Grade
2
Sea Belt
Saccharina latissima
1
Green Alder
Alnus alnobetula
3
Research Grade
2
Tribe Brassiceae
1
Skullcaps
Genus Scutellaria
2
1
Common Periwinkle
Littorina littorea
2
Research Grade
2
Atlantic Dogwhelk
Nucella lapillus
2
Research Grade
2
Nori
Genus Porphyra
1
Irish Moss
Chondrus crispus
1
Dabberlocks
Alaria esculenta
1
Northern Horsemussel
Modiolus modiolus
Research Grade
2
Landlady's Wig
Ahnfeltia plicata
1
Whorled Wood Aster
Oclemena acuminata
2
1

Appendix C: Aerial Drone Imagery





Appendix C: Thermal Drone Imagery