

City of

Bainbridge Island

Shoreline Master Program Monitoring: Methods and Baseline Data

Project Report
Summer & Fall 2019



Sustainable
Communities
Partnership

March 2020



About SCP

Western's Sustainable Communities Partnership (SCP) program focuses the expertise, energy, and ideas of faculty and students upon the issues that communities face as our society transitions to a more sustainable future. SCP partners with communities each academic year, facilitating a program in which Western courses complete community-engaged learning projects that address challenges identified by the partner.



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SCP Partner for 2019-2020: City of Bainbridge Island, WA

SCP is proud to partner with City of Bainbridge Island, Washington, during the program's fourth year. One Western course and two interns will tackle projects identified in collaboration with city staff.



**CITY OF
BAINBRIDGE ISLAND**

Acknowledgement

The [Association of Washington Cities](#) (AWC) has provided invaluable assistance as SCP has grown and developed. AWC has provided advice on program development and has assisted in promoting the program.



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PREFACE

Through its Shoreline Master Program (SMP), the City of Bainbridge Island aims to protect shoreline functions and values through the net effect of shoreline regulations and restoration projects. Achievement of this goal will be tracked through an ongoing shoreline monitoring program. From summer to fall, 2019, Western Washington University (WWU) faculty member, Dr. Jenise Bauman, and students, worked with the City of Bainbridge Island to develop a shoreline monitoring methodology and to collect a baseline set of data. This report includes the recommended methods as well as statistics and visualizations of the baseline data set, as performed by a WWU biostatistics course (*BIOL 340, Biometrics*), taught by Dr. Robin Kodner. City employees and volunteers can use the recommended methods to collect more data and monitor changes in the shoreline over time. This information will offer insight into the effectiveness of the City's SMP.

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| | |
|--|---|
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EXECUTIVE SUMMARY

In Washington, shorelines are important at a local and state level as they protect natural resources, provide access to Washington's waters, and allow other water-dependent uses. Under the Shoreline Management Act of 1971, Washington cities and counties are required to have Shoreline Master Programs (SMP) that are consistent with state guidelines. In 2014, the City of Bainbridge Island updated its SMP with a goal of further protecting shoreline's functions and values through regulations and restoration strategies. By tracking and measuring the state of the shoreline through a local, long-term monitoring program, the City of Bainbridge Island can determine if the SMP is achieving no net loss of ecological function and whether changes are needed to current regulations or other city programs.

From summer to fall, 2019, Western Washington University (WWU) faculty and students worked with the City of Bainbridge Island to develop a shoreline monitoring methodology and to collect a baseline set of data that can be used by City employees and volunteers in the future. Under the guidance of WWU's Dr. Jenise Bauman; City of Bainbridge Island's Water Resources Technician, Christian Berg; and former Senior Planner, Christy Carr, incoming WWU student, Amanda Drago, and recent graduate, Skylar Wood, established a shoreline monitoring strategy and collected baseline data at a subset of pre-identified shoreline sites.

Chapter 1 describes a selection of shoreline monitoring sites used to collect the baseline data. A total of 16 sites were monitored in the period of summer to fall, 2019. A brief description of each of these sites, including information about access, is included in Chapter 1.

Chapter 2 describes the methods used for collecting data at each of the sites, including the recommended protocols and additional considerations for each protocol, if any. In the project scoping process, the City of Bainbridge Island had the following monitoring recommendations: 1) Eelgrass and Kelp (Monitoring Important Nearshore Subtidal Habitats), 2) Intertidal Beach Sediment Supply, Sediment distribution, and Shoreline Position, 3) Riparian Vegetation and Estuarine Emerging Vegetation (salt marsh), and 4) Water Quality Monitoring. Eelgrass and kelp monitoring were excluded from the data collection process due to time limitations and resource-intensive protocols. The methods are broken into the following three sections: beach parameters, vegetation, and water quality. The recommended methods are largely based on the protocols listed in the Shoreline Monitoring Toolbox (Toft et al., 2015). Detailed protocols and sample field data collection sheets can be found in Appendix 1.

Chapter 3 provides statistics and visualizations of the baseline data collected over the course of summer and fall, 2019. The protocols mentioned in Chapter 2 were carried out at each of the 16 selected monitoring sites, and an initial set of baseline data was recorded. The raw baseline data has been shared with the City of Bainbridge Island. The statistics were performed by a biostatistics class under the supervision of Dr. Robin Kodner, the Data Collection Research Assistant, Skylar Wood, and a WWU student from the biostatistics class, Molly Sutton.

The information in the report can be used by the City of Bainbridge Island for an ongoing shoreline monitoring program. City employees and volunteers can use the recommended protocols to monitor changes in the shoreline over time. Additionally, the data collected at the monitoring sites during the summer and fall of 2019 is a baseline set of data and can be used to compare changes over time. This information will offer insight into the effectiveness of the City's SMP.

CHAPTER 1: INTRODUCTION

Of the 50 shoreline sites that the City of Bainbridge Island has identified as potential monitoring sites, former City of Bainbridge Island Senior Planner, Christy Carr, identified a total of 19 monitoring sites as a representative subsample of Bainbridge Island's shoreline for the purposes of this project. These sites were labeled with letters, beginning at Agate Passage (Site A) and following the shoreline counterclockwise to West Port Madison (Site Z) (see Figure 1.1). The study sites were chosen based on factors including accessibility (e.g. slope to access sites), public access, and relative location to other sites. An evaluation of the 19 sites revealed that only 16 sites met these criteria. The sites that did not meet all the criteria include sites J, T, and X. These sites were excluded from the baseline data collection. However, a description of these sites is included below, as well as descriptions of all other sites that were included in the study.

The following site descriptions include information about parking, access, and additional relevant information for each site. See Figure 1.1 for site locations.

Site A (Agate Passage)

Limited parking for this site (2-3 vehicles) is located under the Agate Passage Bridge. The parking can be accessed by car by taking the first left off Agate Passage Bridge onto Reitan Road NE. The parking is at the end of this road. To access the site, one can either take a nature trail from the parking lot directly to the shoreline and walk south towards the site (about a 5-minute walk), or walk down the roadway to a land trust site and take a staircase directly to Site A. The GPS coordinates for this site are 47°42.471'N,-122°33.816'W.

Site B (Manzanita Bay)

The limited parking for this site (1-2 vehicles) is at the top of a hillside along Bay View Boulevard NE. The shoreline site is a short, but steep, walk from the parking location. The GPS coordinates for this site are 47°40.436'N,-122°33.665'W.

Site C (Battle Point)

The parking for this site is at the north end of Battle Point Park, at the Battle Point Park Auxiliary Parking Lot. The site is located along Arrow Point Loop NE, 3-blocks away from the parking. There is limited access to the shoreline during high tide. The GPS coordinates for this site are 47°40.368'N,-122°34.531'W.

Site D (Fletcher Bay)

This site has limited parking (2-3 vehicles) at the end of NE Fletcher Landing. There is limited access to the shoreline during high tide. The GPS coordinates for this site are 47°38.542'N,-122°34.715'W.

Site E (Gazzam Trail)

The parking for Site E is located at Gazzam Lake Trailhead. The site location is an approximately 30-minute walk down the trail from the trailhead to reach the northwest beach access. The trail to access the site is steep, winding and uneven, with an approximately 2-foot vertical drop off at the end. The GPS coordinates for this site are 47°37.694'N, -122°34.648'W.

Site F (Point White Dock)

The parking is located across Crystal Springs Drive NE from the dock. The site is adjacent to the south side of the dock. The GPS coordinates for this site are 47°35.980'N,-122°34.593'W.

Site G (Lynwood Center)

There is ample parking for this site. The site is located less than a 5-minute walk along the roadside from the parking lot. The GPS coordinates for this site are 47°36.218'N,-122°33.139'W.

Site H (Fort Ward)

There is parking in a gravel lot by American Gold Seafoods or along NE South Beach Drive. A short trail leads down to the shoreline and the site. The GPS coordinates for this site are 47°34.860'N,-122°31.594'W.

Site J (Excluded)

A small unstable cliff between NE Country Club Road and the shoreline, and private property, make this site inaccessible from the roadway. This site was excluded from the final site locations because of these barriers. The GPS coordinates for this site are 47°35.279'N,-122°30.053'W.

Site K (Blakely Harbor)

There is ample parking along NE 3-T Road. The site is a short walk to the shoreline from the parking location. This is the site of an old sawmill and has many wooden pillars along the shoreline. The GPS coordinates for this site are 47°35.807'N,-122°30.925'W.

Site L (Pritchard Park)

There is parking either along Rockaway Beach Road NE, at the top of the hill, or at the end of Creosote Place NE, closer to the shoreline. The site is about a minute walk south from the Creosote Park Bench. The GPS coordinates for this site are 47°36.856'N,-122°29.969'W.

Site M (Adams Park)

There is parking along Eagle Harbor Drive NE, or at Adams Park, with a longer walk southward to the site. However, access to the site from the roadway can be dangerous as there is a steep cliff between the roadway and the shoreline. This site is incredibly muddy, and caution should be taken when visiting. The GPS coordinates for this site are 47°37.379'N,-122°32.241'W.

Site N (Eagle Harbor)

There is parking at the public park. This site is incredibly muddy, and caution should be used when visiting. This site is at a well frequented public park. The GPS coordinates for this site are 47°37.335'N,-122°31.039'W.

Site P (Hawley Cove)

Parking for this site is located along Wing Point Way NE. There is a short trail to the shoreline site. The GPS coordinates for this site are 47°37.569'N,-122°30.266'W.

Site S (Manitou Beach)

There is limited parking (3+1 handicap vehicles) off Manitou Beach Drive NE. The site is directly across the road from the parking area. The GPS coordinates for this site are 47°39.348'N,-122°30.685'W.

Site T (Excluded)

This site is not accessible from the roadway. The only access point to the site is through private property, so this site was excluded from the final site locations. The GPS coordinates for this site are 47°40'59.2'N,-122°30'23.5'W.

Site U (Fay Bainbridge Park)

There is parking at Fay Bainbridge Park, a well frequented public park. There are some logs that need to be traversed to access the shoreline site. The GPS coordinates for this site are 47°42.238'N,-122°30.410'W.

Site X (Excluded)

This site is located at the Port Madison Park, which itself is accessible, but the shoreline is blocked off with fences at the edge of a cliff. This site is in close proximity to site Z (West Port Madison). This site was excluded from the project. The GPS coordinates for this site are 47°41'45.0'N,-122°32'01.8'W.

Site Z (West Port Madison)

There is limited parking along Broom Street NE (2-3 vehicles). The site is a short walk away from the parking area. The GPS coordinates for this site are 47°42.106'N,-122°31.796'W.

Bainbridge Island Shoreline Monitoring Sites

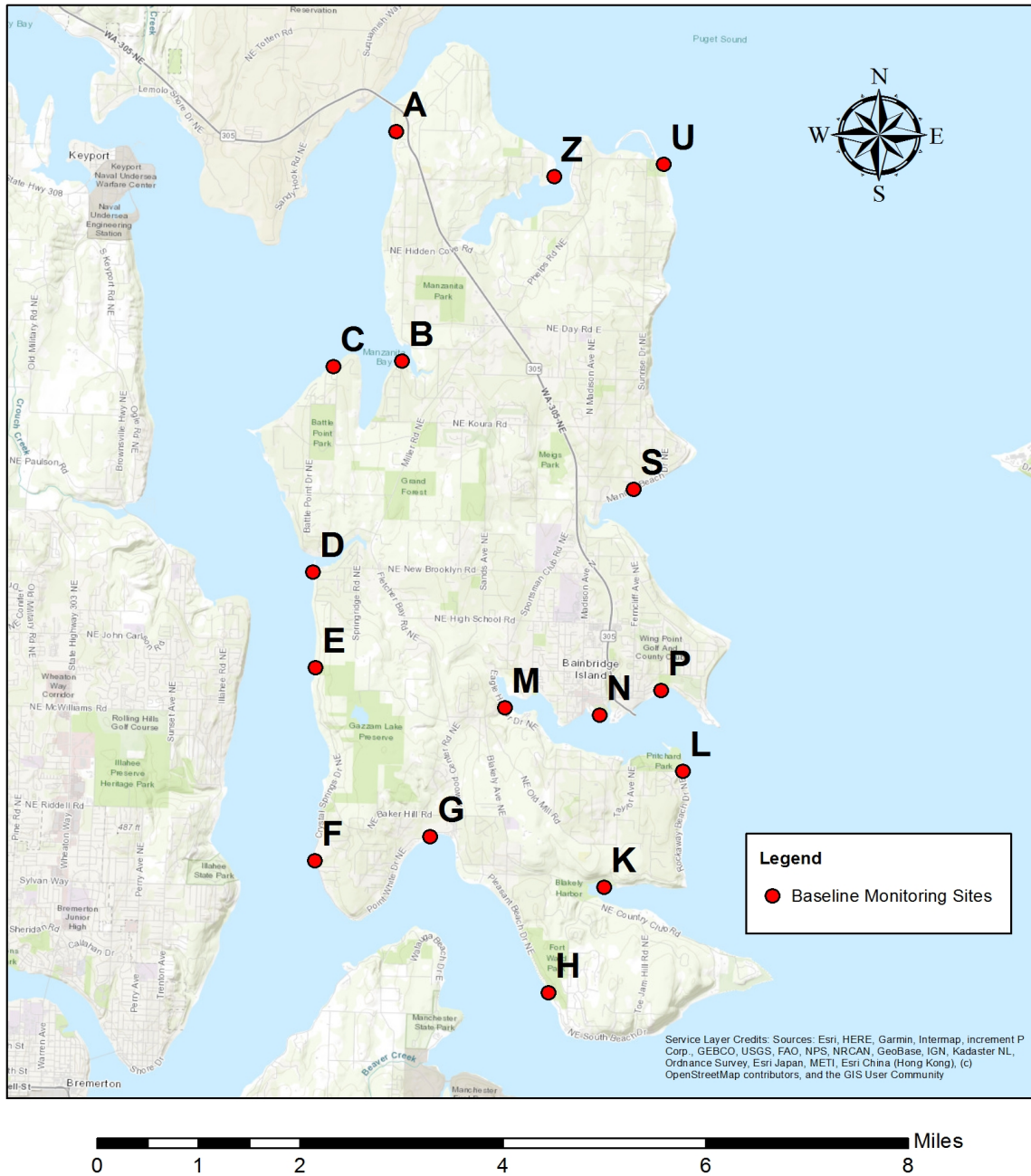


Figure 1.1. Each of the sample shoreline monitoring sites (A-Z) is labeled on this map of Bainbridge Island, WA.

CHAPTER 2: METHODS

This section describes protocols and additional considerations, when relevant, for the recommended shoreline monitoring methods. The methods are split into the following three sections: beach parameters, vegetation, and water quality. In the project scoping phase, the City of Bainbridge Island had the following monitoring recommendations: 1) Eelgrass and Kelp, 2) Intertidal Beach Sediment Supply, Sediment distribution, and Shoreline Position, 3) Riparian Vegetation and Estuarine Emerging Vegetation (salt marsh), and 4) Water Quality Monitoring. However, the complete eelgrass and kelp monitoring protocols proved to be both time and resource intensive and were beyond the capacity of the field team. Thus, they were excluded from the methods and are not recommended for the monitoring project. However, eelgrass presence/absence was recorded in the sessile biology survey. At the time the baseline raw data was collected, the Department of Natural Resources (DNR) and the Puget Sound Restoration Fund (PSRF) monitored both eelgrass and kelp. If the City of Bainbridge Island wants to include eelgrass and kelp monitoring in this project, they might reach out to DNR or PSRF for support.

Several of the recommended protocols included in this report were taken from the Shoreline Monitoring Toolbox (Toft et al., 2015), which provides standardized approaches for monitoring shorelines in Puget Sound, WA. The Toolbox was developed by Jason Toft, a research scientist at the University of Washington's School of Aquatic and Fishery Sciences. For this project, several additional methods for monitoring the shoreline were added, including vegetation presence or absence, sessile biology along the beach profile, and water chemistry. The beach profile protocols were adjusted due to equipment availability.

To ensure that quality data was collected and recorded in the field, standardized protocols and field data sheets were used across sites. Detailed protocol sheets from the Shoreline Monitoring Toolbox (Toft et al., 2015) and sample field data sheets can be found in Appendix 1. A random number generator was used for any protocol that required identifying random points along a transect.

A clear plan for collecting raw data in the field and entering it into the Bainbridge Island Shoreline Data 2019 spreadsheet (provided to the City) was established early on in the process. Having a consistent plan for organizing and tracking data allows for efficient analysis and reporting, and promotes effective collaboration across groups, including monitoring volunteers.

Physical Parameters

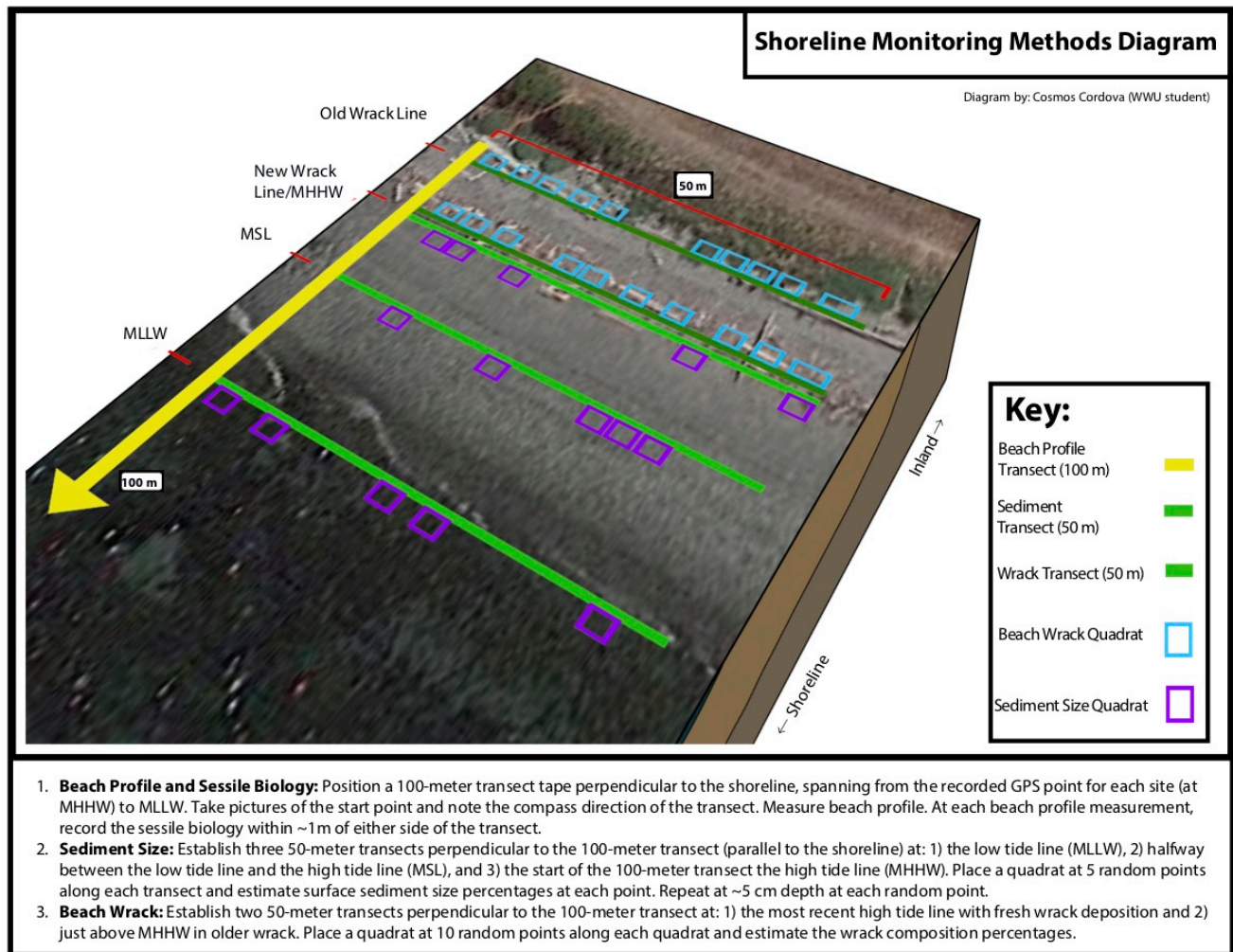


Figure 2.1. Shoreline monitoring transect set-up for beach profile, sessile biology, beach wrack, and sediment size protocols.

Beach Profile

Measure the beach profile, or the topography and slope of the beach, from the Mean Higher High Water (MHHW) to the Mean Lower Low Water (MLLW). The 'string method' for measuring beach profile requires three people, a 100-meter transect tape, two measuring sticks, two levels and a 3.5-meter, or longer, string.

The steps include:

1. Set the transect tape perpendicular to the shoreline, spanning from the MHHW to the MLLW (see Figure 2.1). This may not require all 100 meters of the transect tape. Take four photos of the starting location from various perspectives, as seen in Figure 2.2.



Figure 2.2. The starting location of beach profile transect for Site Z, as seen from four perspectives.

2. Person one places a measuring stick vertically at the starting location, marked by a GPS coordinate and compass direction. The GPS coordinates used for the preliminary dataset are noted in the site descriptions in Chapter 1. The GPS location and compass direction of the starting location were taken using the phone application, "GPS & Maps: Track Coordinates, Compass + Waypoints" by 2kit Consulting (<https://apps.apple.com/us/app/gps-maps-track-coordinates-compass-waypoints/id477998011>).
3. Hold a string at a specific measurement along the first measuring stick. The field team used 80 cm as the specific measurement. Record this measurement.
4. Person two places a second measuring stick vertically three feet down the transect tape and holds the other end of the string (held by person

Tidal Datums: standard elevation defined by a phase of the tide and used as a reference to measure water levels.

Mean Higher High Water (MHHW): The average height of the highest tide recorded each day.

Mean Sea Level (MSL): the sea level halfway between the mean levels of high and low water.

Mean Lower Low Water (MLLW): the average height of the lowest tide recorded each day.

(Tidal Datums, n.d.)

one) perpendicular to the second measuring stick (see Figure 2.3). Levels are used to ensure that the measuring sticks are vertical and that the string is horizontal.

5. Person three measures and records the height where the string intersects the second measuring stick.
6. Person one moves the initial measuring stick three feet down the transect from person two and repeats the above measurements. Repeat this process until crossing the low tide line.
7. Note the time and the low-tide line location along the transect. Later, consult the nearest tide station for the tidal elevation.



Figure 2.3. Field team measuring the beach profile using the 'string method'

When processing the field data, enter the data into the Excel spreadsheet. Calculate the beach slope from MHHW to MLLW by finding the difference between the string heights at each point along the transect. The resulting slope line can then be translated to elevation points by consulting the local tide station for tidal elevation at the time recorded in step 7.

This protocol is resource intensive as it requires three people to properly measure beach profile. Several sites are excessively muddy, which introduced a physical challenge to taking precise measurements while moving through the mud. Additionally, to collect the greatest amount of the beach profile data requires being at a site at the lowest tide so that the transect line passes MLLW. This timing does not always align with adequate sunlight, so working around the timing of low tides introduced another challenge for the baseline data collection. In the baseline data collection, the beach profile was often measured at only one site per day because of this.

The Shoreline Monitoring Toolbox recommends measuring the beach profile using a laser level instead of the string method (Toft et al., 2015). The string method was used for the baseline data collection as a laser level was not available. See the full laser level protocol sheet in Appendix 1.

Sessile Biology

Record the categories of sessile organisms present within 1-meter of either side of the transect points measured for the beach profile (see Figure 2.1). The categories include green algae, brown algae, red algae, barnacles, tube worms, dwarf eelgrass (*Z. japonica*), common eelgrass (*Z. marina*), mussels, and anemones. On the field data sheet (see Appendix 1), each category of organisms is recorded as present at each measured transect point when at least one individual of that category is present. It is critical that an identification tool, like a dichotomous key, or an expert, is available when identifying sessile biology to ensure proper identification.

Sessile organism: an organism that is not mobile and is fixed in one place

Once out of the field, enter the field data into the Excel spreadsheet. Record '1' when at least one individual of that category was present at a transect point and '0' when no individuals of that category were present.

Future studies should include presence or absence of sea stars (any species), in addition to green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Z. japonica*), pacific eelgrass (*Z. marina*), anemone, and mussels. Sea stars are a keystone species in the Pacific Northwest. Their presence/absence affects intertidal ecology to a high degree and therefore should be recorded. Sea stars generally can be observed at low tide in rocky areas. Tides may be too high when observers collect data, or tides may not be low enough to note presence, however it is important to note when they are seen.

Sediment Size

Materials needed to measure sediment size include a 50-meter transect tape, a quadrat, and a hand trowel. Establish three 50-meter transects at: MHHW, MSL, and MLLW. The transects should be set perpendicular to the beach profile transect, generally to the left of the beach profile transect line when the researcher is facing the water. In several cases, the 50-meter transect was set to the right of the beach profile transect because property lines or natural boundaries prevented the 50-meter transect from being set to the left side. Table 2.1 identifies the direction that the 50-meter transect was set for each site during the baseline data collection.

Table 2.1. Location of 50-meter transects for baseline data collection (2019) in relation to the beach profile transect at each site. Location is determined from the researcher's perspective while facing the water. For example, at Site A, the 50-meter transect was set perpendicular to, and on the right side of (when researcher is facing the water), the beach profile transect.

| Site | Direction of 50-meter Transect in Relation to Beach Profile Transect While Facing the Water |
|------|---|
| A | Right |
| B | Left |
| C | Left |
| D | Left |
| E | Left |
| F | Left |

| | |
|---|-------|
| G | Left |
| H | Left |
| K | Left |
| L | Left |
| M | Right |
| N | Left |
| P | Left |
| S | Left |
| U | Right |
| Z | Right |

The MHHW transect should start from the same starting point as the beach profile measurements (the recorded GPS points included in Chapter 1 for the baseline data collection), or just below the new wrack line. The MLLW transect should be set at the low tide line, and the MSL transect should be exactly halfway between the MHHW and MLLW transects (see Figure 2.1).

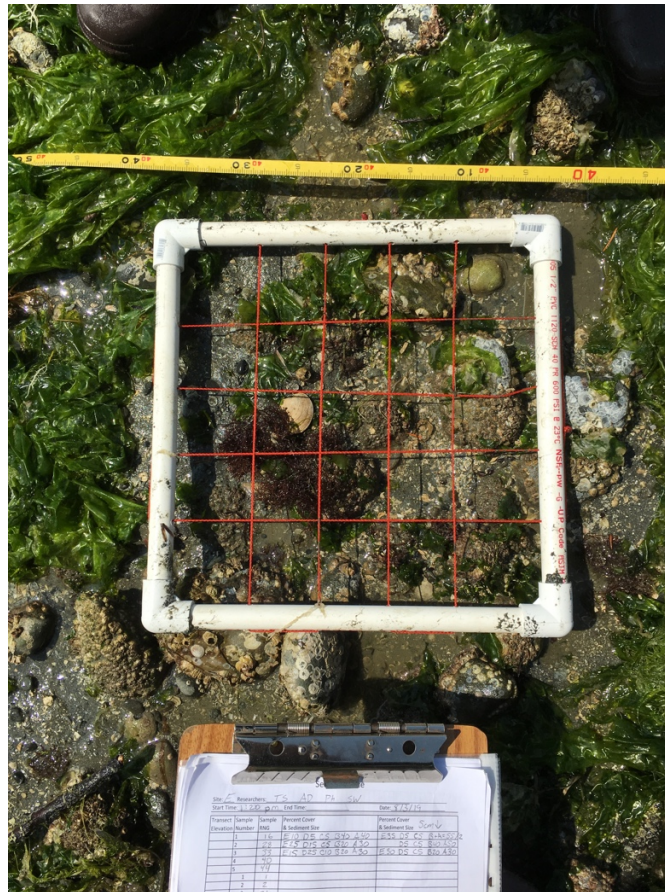


Figure 2.4. Quadrat set-up for estimating surface sediment size percentages (Site Z).

Place a quadrat at five random points along each transect. Within the quadrat at each point, make a visual estimate of the percent cover of surface and subsurface (five cm depth) sediment of each of the five sediment size classes: cobble, pebble, granule, sand, silt/clay. Use the 25 smaller squares within the quadrat to make this estimate. Each small square equals 4% of the quadrat. Some quadrats contain wooden logs or pillars, which were considered negative space in the quadrat during the baseline data collection. For example, if a pillar took up 25% of a quadrat, then the total percentage for the quadrat was noted as 75% instead of 100%. See Appendix 1 for the full protocols for measuring sediment size, as described by the Shoreline Monitoring Toolbox (Toft et al., 2015).

Five sediment size classes:

- Cobble (>6 cm)
- Pebble (4 mm to 6 cm)
- Granule (2-4 mm)
- Sand (“gritty” up to 2 mm)
- Silt/clay (smooth between your fingers)

Enter surface and subsurface percentages for each size category within each quadrat at MHHW, MSL, and MLLW, into the Excel spreadsheet.

A challenge in the low-tide sediment size classifications is that there is a limited window to take these measurements. Once the recorder starts taking the measurements, the tide almost immediately comes back up, making the low tide sediment quadrat samples increasingly more difficult to sample. This can be remedied by collecting the sediment in a bag and sifting later or higher on the beach to avoid the incoming tide.

Beach Wrack

Materials needed to measure beach wrack include a 50-meter transect tape and a 32x32 quadrat, divided with string into 25 6x6 squares (see Figure 2.4). Measure both the newer wrack line (closest to the water) and the older wrack line (furthest from the water) at each site. The MHHW transect used in the sediment size measurements can be used, again, for the newer wrack line transect. This transect should be at the most recent high tide line that has fresh wrack deposition. Another 50-meter transect should be set up parallel to and inland from the newer wrack line transect at the old wrack line (see Figure 2.1). See Table 2.1 for information about the 50-meter transect location used during the baseline data collection.



Figure 2.5. Quadrat placed for beach wrack compositions estimate.

At ten randomly determined points along each transect, place a quadrat on the beach surface and make a visual estimate of the percent composition of green algae, brown algae, red algae, dead algae, eelgrass, terrestrial plants, and trash. Use the 25 smaller squares within the quadrat to make this estimate. Each small square equals 4% of the quadrat.

When processing the field data, enter the percentages of each wrack type present within each quadrat into the Excel spreadsheet.

During the preliminary field collection, there was not an obvious old wrack line at some sites. When this was the case, old beach wrack data was not collected. At sites where a rock wall was present (i.e. in the case of shoreline armoring) and the old wrack line was within the rock wall, a quadrat was estimated (a quadrat could not be placed over the entire sample area). In future surveys, it is recommended that the observer note these areas as negative space in place of estimations. Additionally, in cases where the old and new wrack lines overlapped due to the shoreline's dynamic shape, the random quadrat sample for either the old or new wrack line was observed normally.

Log Line



Figure 2.6. The log line is the distance between the log furthest from and closest to the water along a transect.

Set up a 50-meter transect tape along the upper shoreline, perpendicular to the beach profile transect, or use the MHHW transect from the sediment size measurements. See Table 2.1 for information about the 50-meter transect location used during the baseline data collection. Mark five randomly determined points along the 50-meter transect. At each point along a line perpendicular to the transect, measure and record the distance between the log furthest from and closest to the water. This is the width of the log line. Next, count and record the abundance of small logs (smaller than 2 meters) and large logs (larger than 2 meters) that intersect the measuring tape. Record if these are natural or human altered. Make note of any other characteristics of these logs, such as moss, lichen, barnacles, or plants present on the logs. See Appendix 1 for the full methods for measuring the log line, as included in the Shoreline Monitoring Toolbox (Toft et al., 2015).

Once out of the field, enter the field data into the Excel spreadsheet. Calculate the averages of the width of the log line and the number of logs at each transect point.

A physical challenge with the log line method includes the need for the recorder to walk through vegetation, the mud or on uneven ground at certain sites. This can make it difficult to accurately measure the log line.

Vegetation

The vegetation monitoring protocols are detailed in the vegetation protocol sheet from the Shoreline Monitoring Toolbox (Toft et al., 2015). Materials needed to measure vegetation include two 50-meter transect tapes, a 0.25m² quadrat, and a plant identification tool, such as a dichotomous key.

Set up a 50-meter transect tape along the upper shoreline, in an area where some vegetation is present. See Table 2.1 for information about the 50-meter transect placement during the baseline data collection. Record the GPS location and compass direction of the starting point of the transect. At three locations that are representative of the vegetation along the transect, delineate a 5-meter x 5-meter plot. The plot does not need to intersect the transect. Within each quadrat:

1. **Generate a plant species list:** identify and record species present within the plot, noting native and introduced species.
2. **Measure the percent cover of overstory and understory vegetation:** make a visual estimate of the percent cover of each understory and overstory species within each plot.
3. **Characterize the health ratings of vegetation:** give each understory and overstory species within each plot an average health rating between 1 (dead) and 5 (vigorous growth).
4. **Measure the canopy diameter of trees:** use a transect tape to estimate the percent cover of each overstory species within each plot.
5. **Record dunegrass presence, dunegrass bed width, percent cover, and density:** establish a transect parallel to shore along the length of any dunegrass patches present, or for 50 m for large patches. Record dunegrass presence/absence at five random points along the transect line. Where dunegrass is present, use a 0.25m² quadrat to estimate shoot density and percent cover.

The Shoreline Monitoring Toolbox (Toft et al., 2015) contains protocols for estimating the supratidal (the area above the high tide line that is often splashed with water but not submerged) and backshore (the area between the coastline and the extreme inland limit of the beach that is only exposed to waves during extreme tides or storm surges) vegetation. However, the field team determined that the terrain was not hospitable to safely execute this method. In response, for the baseline data collection, presence/absence of understory and overstory cover was recorded instead.

6. **Understory and overstory vegetation presence/absence:** at each meter interval from zero to fifty along the transect line, measure and record the presence/absence of understory and overstory vegetation. Vegetation is recorded as present at each measured transect point when any vegetation is present.

When processing the field data, enter the data into the Excel spreadsheet. Record '1' when at least one understory/overstory plant was present at a transect point and '0' when no plants were present.

Shoreline Vegetation Monitoring Methods

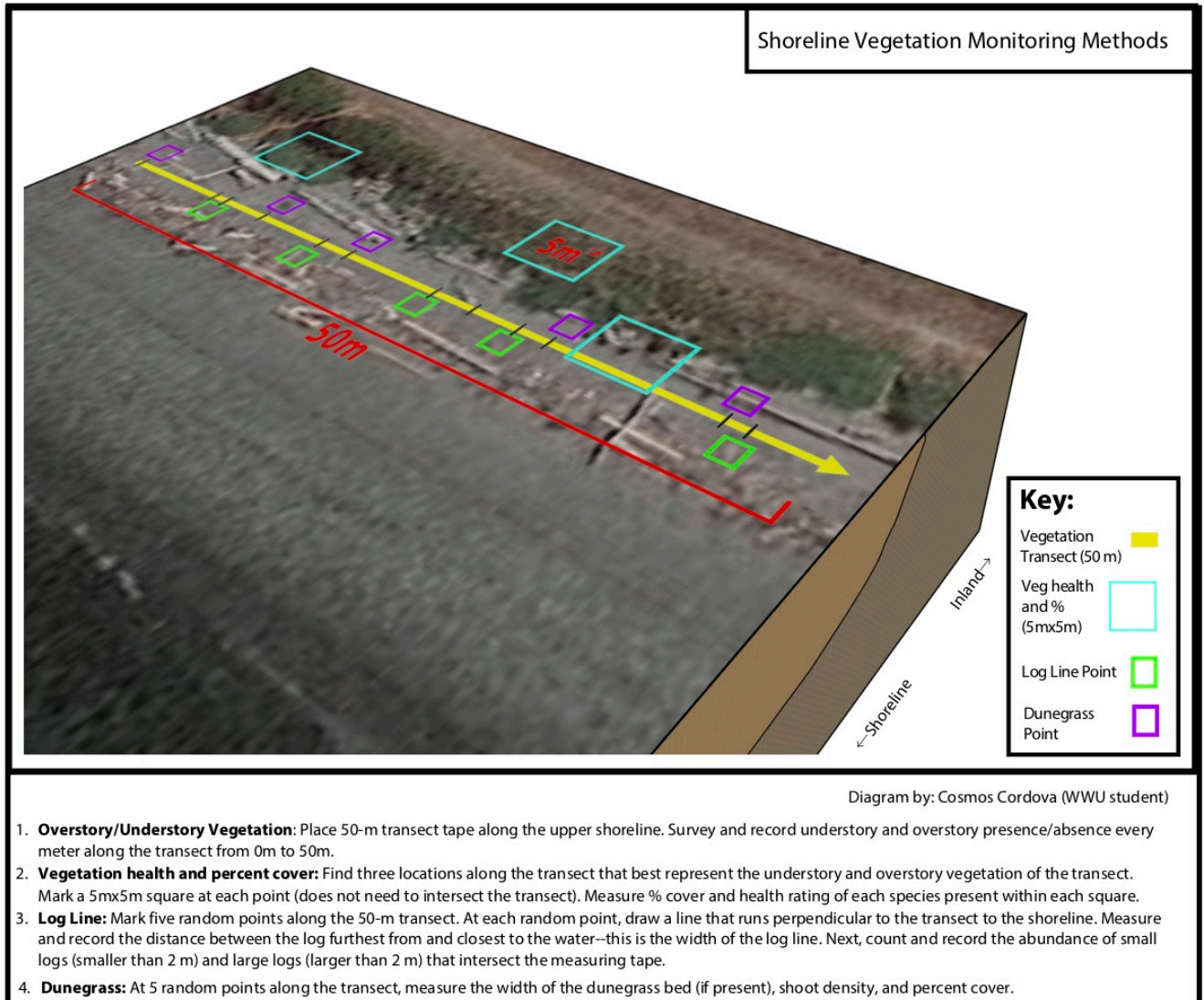


Figure 2.7. Shoreline vegetation monitoring transect set-up for understory/ overstory presence/absence, health, percent cover, log line, and dunegrass.

Water Chemistry

Materials needed to measure water chemistry include a 50-meter transect line, a Hydrolab MS5 sonde, and Hanna nitrate and phosphate kits. To measure water chemistry, establish a 50-meter transect line parallel to the water's edge. At three random locations along the line, walk perpendicular from the line and into the water to a depth of about one meter, lay the Hydrolab MS5 sonde down, and record the stabilized readings.

The tides posed a challenge in measuring water chemistry. At some sites, higher water impacted the transect line. The field team did not collect water quality data when this happened. However, in future monitoring efforts, water chemistry measurements can still be taken at each site, although the protocols will have to be adjusted.

Photo points

Photos were taken of the starting location for each beach profile. Additional photos were taken of the types of organisms found at each site. These photos are available for use by the City of Bainbridge Island in a shared folder.

Suggestions for Future Monitoring Frequency

Table 2.2 includes a list of recommended monitoring frequencies for data collection for each protocol. These recommendations are ideal, with the understanding that data collection at these frequencies may not be feasible with volunteer collection, time, and budget constraints. Not all variables need constant, monthly, or annual observation. Data collection frequency recommendations are based on many variables, such as season, growth ability, and nutrient availability.

Table 2.2 Suggested Collection Frequency

| Category | Variable | Frequency | Reason |
|--|---------------------------------------|------------|--|
| Beach Profile | Slope | annually | The slope can change annually depending on weathering/erosion. It is important to monitor because slope affects intertidal ecology by determining what organisms occupy what space on the shoreline. Organisms require different amounts of light and protection to survive. |
| Sessile Biology Presence | Green Algae | seasonally | Green algae need the most light of any algae and tend to be found near the surface. If beach slope, tide, or water clarity changes, the presence of this algae may change. Important to monitor seasonally. |
| | Brown Algae | seasonally | Brown algae need less light than green and more light than red algae and tend to be found in the middle intertidal zone. If beach slope, tide, or water clarity changes, the presence of this algae may change. Important to monitor seasonally. |
| | Red Algae | seasonally | Red algae need the least light of any algae and tend to be found furthest from the water surface. If beach slope, tide, or water clarity changes, the presence of this algae may change. Important to monitor seasonally. |
| | Barnacles | annually | Barnacles are important to monitor as their presence helps determine intertidal ecology, but as slow growing organisms, their presence is not likely to change frequently. |
| | Tube Worms | annually | Tube worms are not likely to change abundance frequently. |
| | Dwarf Eelgrass (<i>Z. japonica</i>) | 6 months | Eelgrass grows the most in spring/summer, however an entire bed can die within 30 days if water clarity is poor (i.e. from large and long-lasting algal blooms or suspended sediment from turbid waters). Eelgrass is an important habitat for many creatures and should be monitored more frequently than other vegetation. |
| | Pacific Eelgrass (<i>Z. marina</i>) | 6 months | Eelgrass grows the most in spring/summer, however an entire bed can die within 30 days if water clarity is poor (i.e. from large and long-lasting algal blooms or suspended sediment from turbid waters). Eelgrass is an important habitat for many creatures and should be monitored more frequently than other vegetation. |
| | Anemone | annually | Anemones are not likely to change abundance frequently. |
| | Mussels | annually | Mussels are important to monitor as their presence helps determine intertidal ecology. |
| Vegetation Presence, Cover, and Health | Sea Stars | annually | Sea Stars are a keystone species. Their presence prevents bivalves from overtaking rocky intertidal zones. |
| | Understory | annually | Understory can greatly affect coastal ecology as its presence may prevent coastal erosion, affect freshwater input, trash collection, and other factors. |
| | Overstory | annually | Overstory does not grow as quickly as understory but should be recorded yearly to monitor change over time. It can also prevent erosion and should be monitored over time for coastal protection. |

| | | | |
|-----------------|---|------------|---|
| Dune grass | Density, percent cover, width | annually | It is important to monitor dune grass annually as it provides coastal protection. |
| Beach Wrack | Composition (Green Algae, Brown Algae, Red Algae, Dead Algae, Eelgrass, Terrestrial Plants, Trash, Other) | weekly | Beach wrack composition indicates beach health. If lots of algae is found, this may indicate a harmful algal bloom. Loss of eelgrass may indicate critical loss of eelgrass habitat, and trash indicates anthropogenic impact. |
| Sediment | Size and Location | annually | Sediment can change because of weathering and erosion from greater wind exposure or changed freshwater input. Sediment determines intertidal ecology, as it determines what vegetation grows, and what organisms inhabit the coast. |
| Log Line | Width, Size, Type, Abundance | annually | Logs provide shelter for invertebrates and foraging habitat for birds. The log line might change in the case of high water or a storm. |
| Water Chemistry | Temperature (°C) | daily | Temperature fluctuates daily. Ideally would record daily and average for season or year. |
| | SpC (µS/cm) | daily | SpC fluctuates daily. Ideally would record daily and average for season or year. |
| | Salinity (ppt) | daily | Salinity can fluctuate daily. Ideally would record daily and average for season or year. |
| | pH | daily | pH can fluctuate daily. Ideally would record daily and average for season or year. |
| | LDO (mg/L) | daily | LDO (%) can fluctuate daily. Ideally would record daily and average for season or year. |
| | LDO (%) | daily | LDO (%) can fluctuate daily. Ideally would record daily and average for season or year. |
| | Phosphate | daily | Phosphate levels can fluctuate daily. Ideally would record daily and average for season or year. |
| | Nitrate | seasonally | No nitrate was present at all the sites. Monitor yearly to ensure this does not change as it may lead to algal blooms. |

CHAPTER 3: STATISTICAL ANALYSIS

Introduction

This section includes figures created by project Data Collection Research Assistant, Skylar Wood, and statistics performed by an upper division WWU biostatistics class, *Biometrics* (BIOL 340), supervised by Dr. Robin Kodner. The statistics in this section were performed using the baseline shoreline monitoring data collected for the City of Bainbridge Island during the summer and fall of 2019. Tests include Chi-Squared tests for independence, ANOVA tests, two sample t tests, Spearman Rank tests for correlation, and Wilcoxon Rank Sum tests.

Statistic Methods Explanation

This section contains 1) a brief overview of the statistical tests performed on the baseline data and 2) helpful vocabulary.

(n=): n indicates sample size. For example, in sediment plots, n=5 means there were 5 samples taken at each tidal elevation and then averaged to produce the stacked bar plots.

P-value: The p-value indicates probability of a statistical model's result. It means that when the null hypothesis is true, the statistical summary will be greater than or equal to the observed results. If $p < 0.05$ (the predetermined alpha value to avoid bias), then the results are considered significant.

Benjamini-Hochberg method of adjustment: a test to correct the error that sometimes small p-values happen by chance, which could lead an observer to reject a null hypothesis by mistake.

Shapiro-Wilk test for normality: a test to determine if data is normally distributed. The test rejects the hypothesis of normality when the p-value is less than or equal to your alpha (usually set at 0.05).

Levene's test for variance: a test to determine if variance of two populations is equal (or not) for two or more groups and is often used before comparing means among populations.

Pearson's Chi-Squared Test for Independence (χ^2): "Pearson's chi-squared test is used to determine whether there is a statistically significant difference (i.e., a magnitude of difference that is unlikely to be due to chance alone) between the expected frequencies and the observed frequencies in one or more categories of a so-called contingency table," (Wikipedia).

Two-Sample T Test: a test to determine if the means of two factors are statistically equal. Assumptions of this test are that the data is randomly sampled and normally distributed (data points fall along a bell curve).

ANOVA: an ANOVA is used to determine if the means of two or more factors are statistically equal. Assumptions of this test are that factors are independent of one another (one factor does not affect the other—this can be found using a Spearman Rank test for correlation), the data is normally distributed, and equal variance of means. The results of an ANOVA and a two-sample t test will be equal when analyzing two factors, but an ANOVA is useful to analyze many more factors at a time. The result of this test will tell if any factors' means differ significantly, but does not determine which ones differ.

Tukey's Honest Significant Difference (HSD) post hoc Test: After running an ANOVA, running Tukey's HSD will reveal what specific factors' means differ significantly (compared to each other).

Kruskal-Wallis Rank Sum Test: This is a non-parametric (data is not normally distributed) test used to determine if means are statistically different. Assumptions of this test are that the data has one ordinal or continuous variable, and two or more categorical variables. Also, observations are independent of one another. Similar to a one-way ANOVA, the result of this test will tell if any factors' means differ significantly, but not which ones differ.

Dunn Test post hoc: After running a Kruskal-Wallis Rank Sum Test, running a Dunn Test will reveal what specific factors' means differ significantly (compared to each other).

Spearman Rank Test for Correlation: a non-parametric test measures the strength of association between two ranked variables. Variables must be ordinal to run this test.

Mann-Whitney U Test/Wilcoxon Rank Sum Test: a non-parametric test of the null hypothesis that yields the probability of a randomly selected value from one population being selected over a randomly selected value from a second population. Assumptions of this test are that the samples are random and independent of each other, responses are ordinal, and distributions are equal.

Comparisons

Comparisons mainly analyze hypothesized interesting relationships between monitored parameters. These statistics do not necessarily need to be repeated annually but provide interesting data for long term coastal health.

Shoreline

This section includes the physical parameters of the shoreline observed at each site and the statistical significance related to each site.

Beach Profile & Biological Mapping

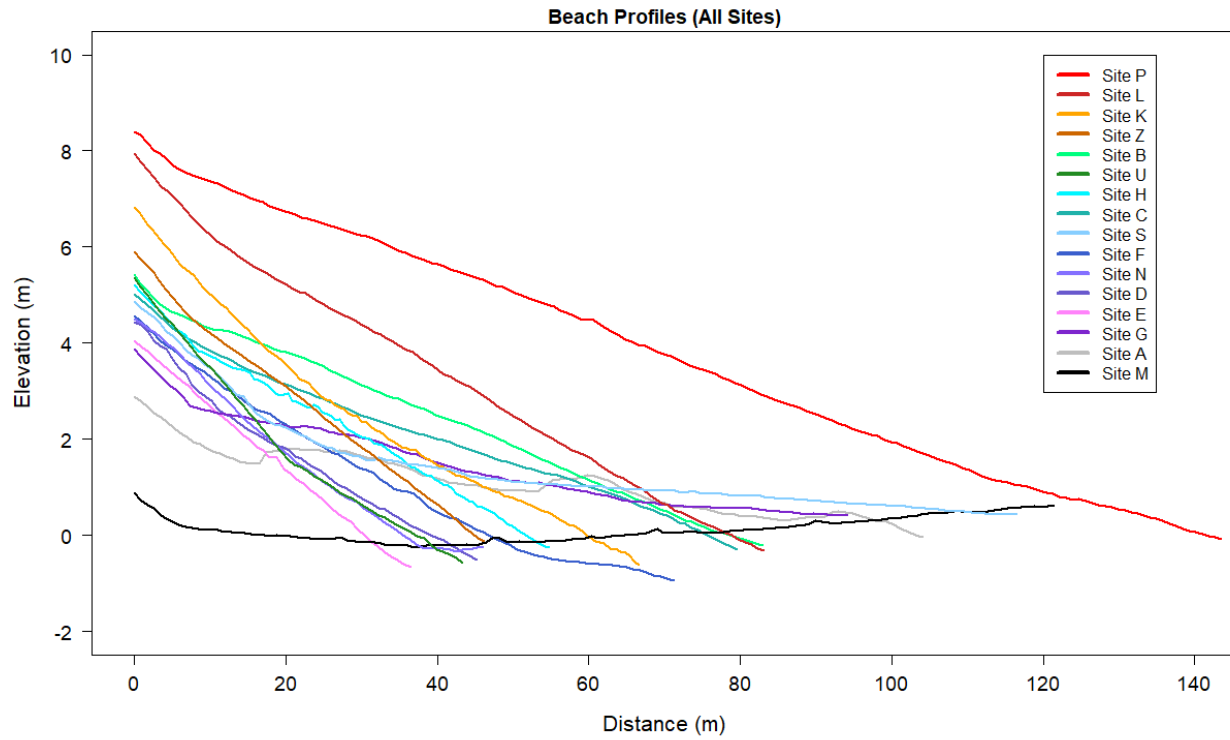


Figure 3.1. Comparison of beach profiles for all sites. Profiles were measured from MHHW to MLLW using the ‘string method’ (see Chapter 2 for additional details on methodology). Slope lines are corrected to tidal elevation to create a baseline for comparison among sites. Of note, site M, seen in black above, was particularly muddy, which might have affected the accuracy of this measurement and, therefore, might explain the discrepancy in its beach slope.

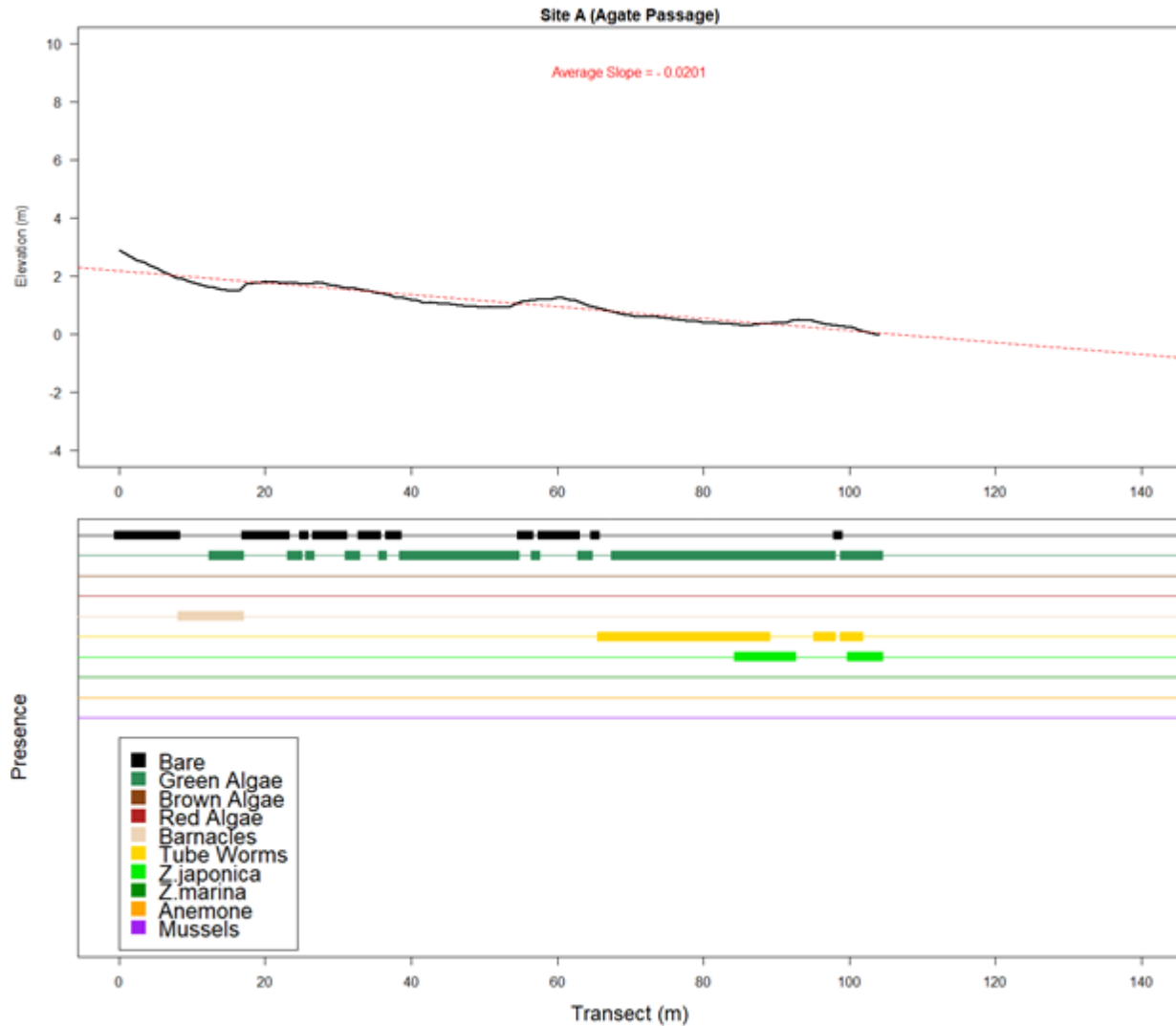


Figure 3.2. Beach profile (upper) and biological map (lower) of site A. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Brown algae, red algae, pacific eelgrass, anemone, and mussels were not observed along the beach profile of site A.

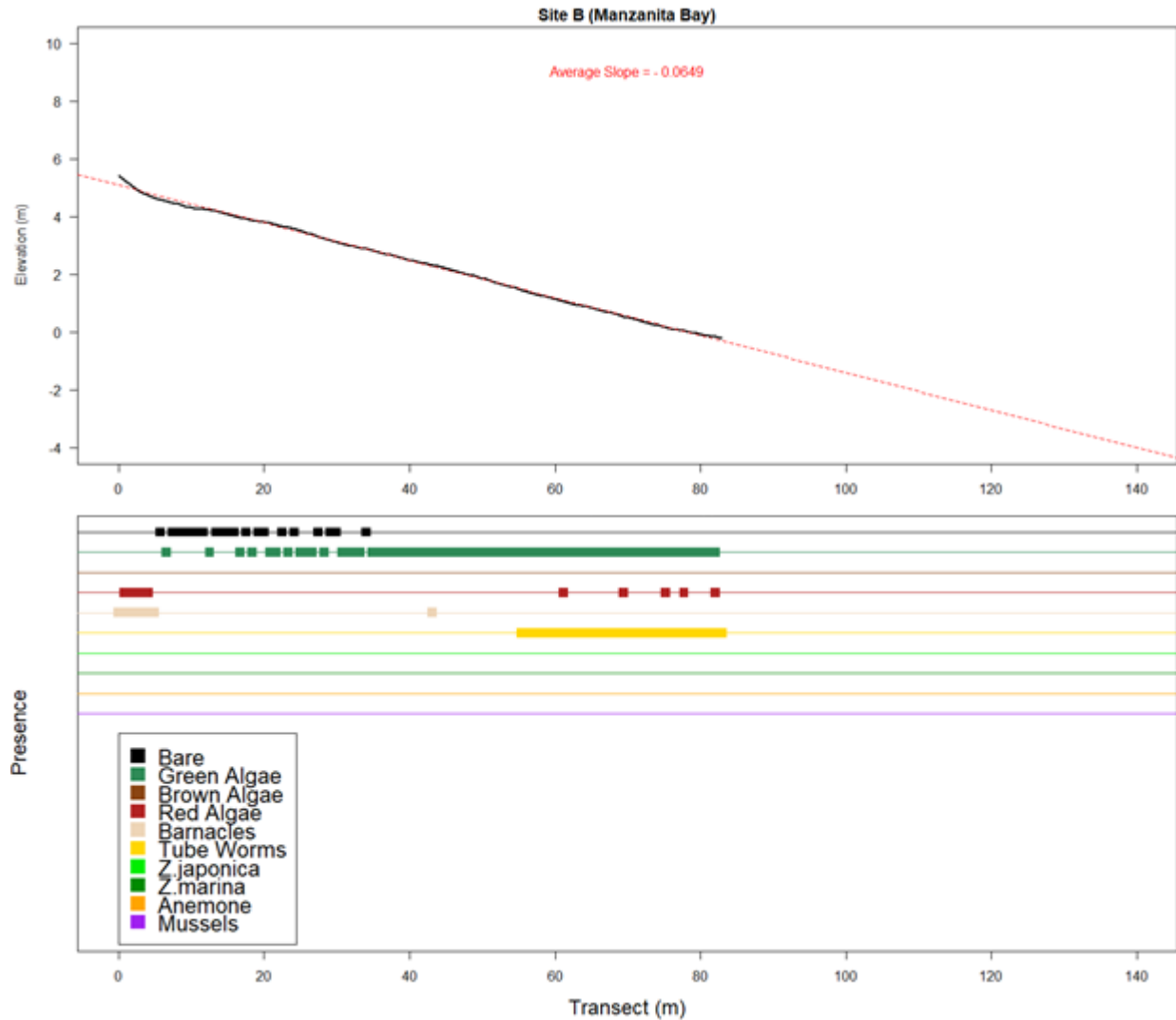


Figure 3.3. Beach profile (upper) and biological map (lower) of site B. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Brown algae, dwarf eelgrass, pacific eelgrass, anemone, and mussels were not observed along the beach profile of site B.

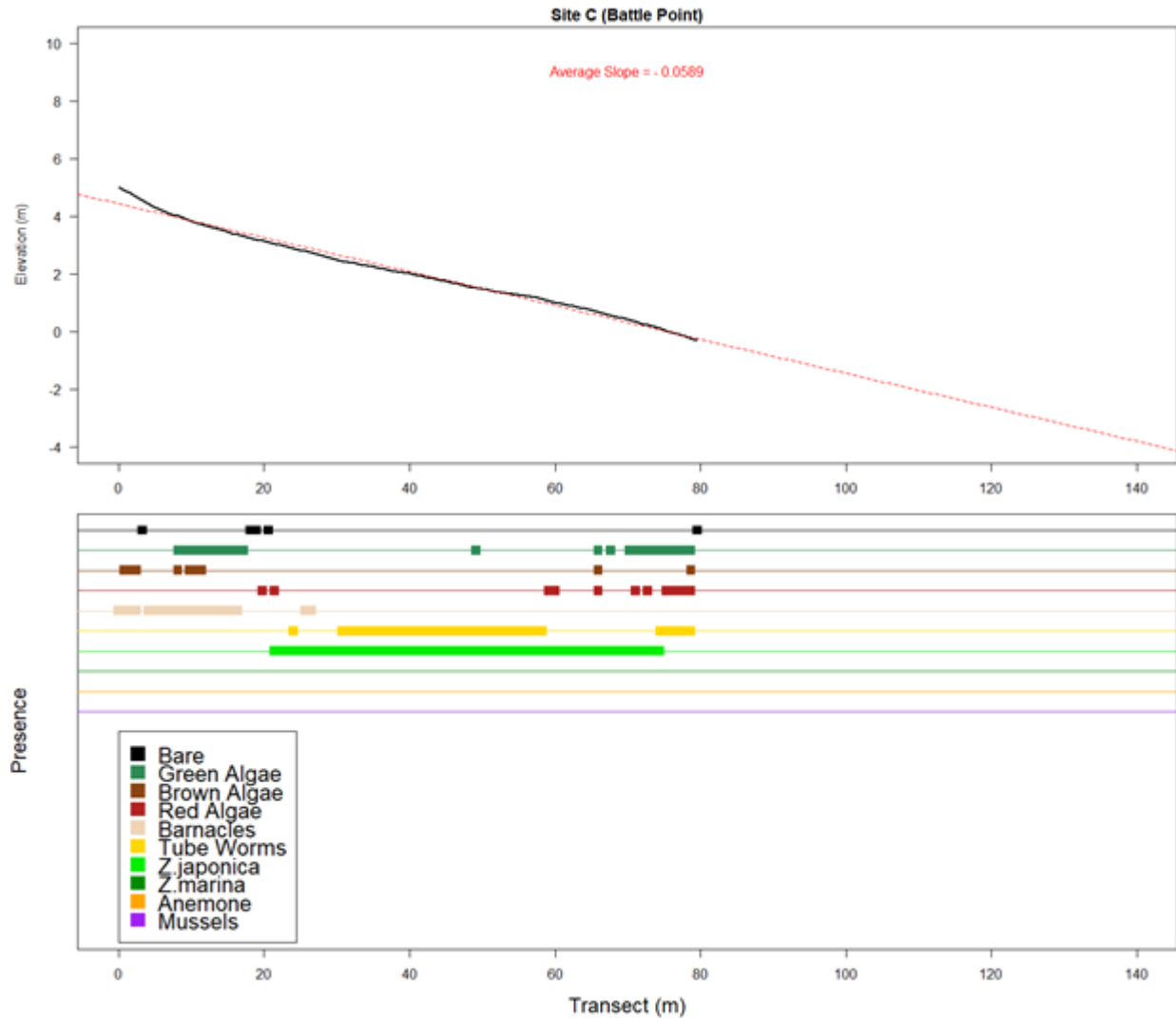


Figure 3.4. Beach profile (upper) and biological map (lower) of site C. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Pacific eelgrass, anemone, and mussels were not observed along the beach profile of site C.

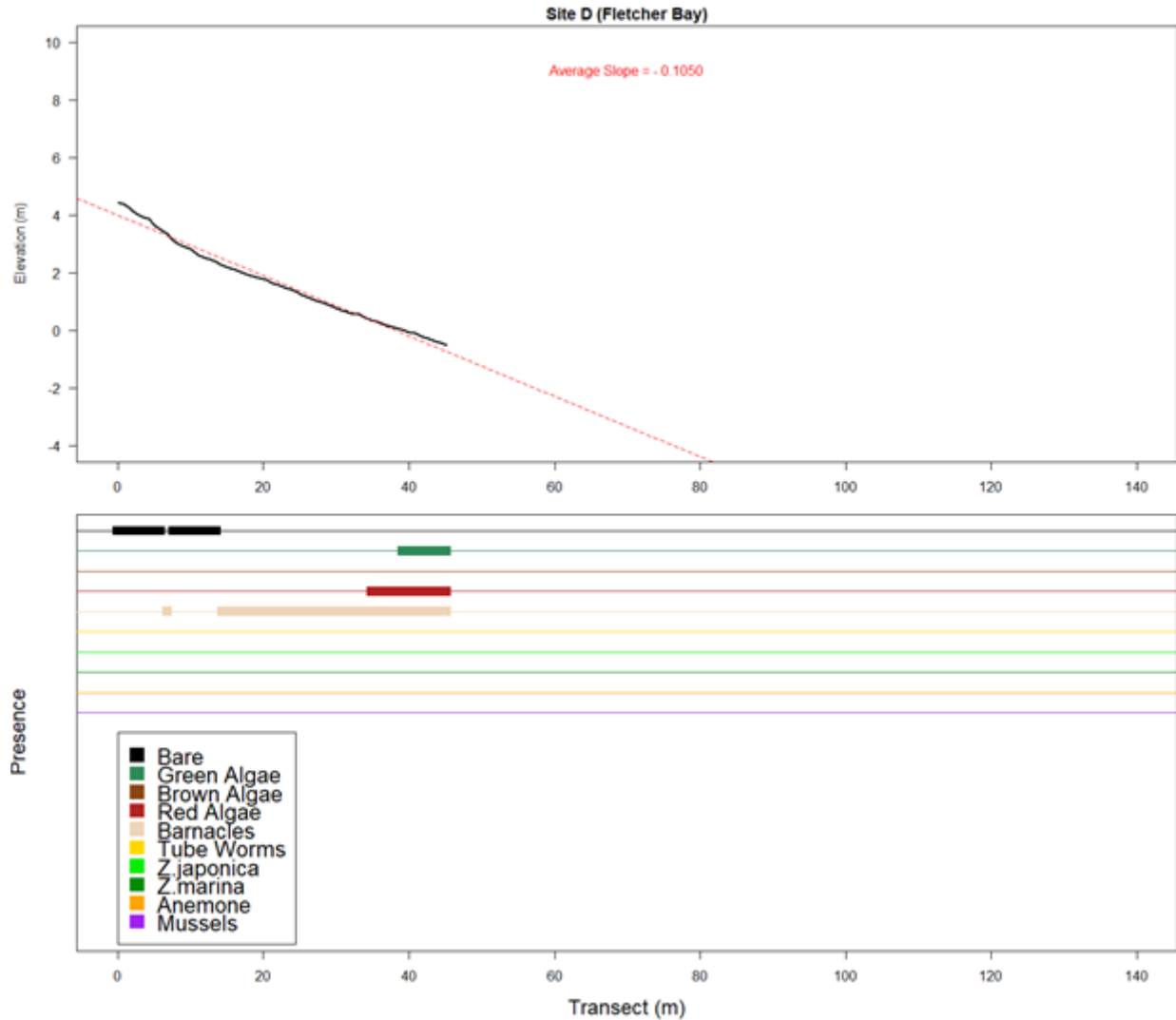


Figure 3.5. Beach profile (upper) and biological map (lower) of site D. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Brown algae, tubeworms, dwarf eelgrass, pacific eelgrass, anemone, and mussels were not observed along the beach profile of site D.

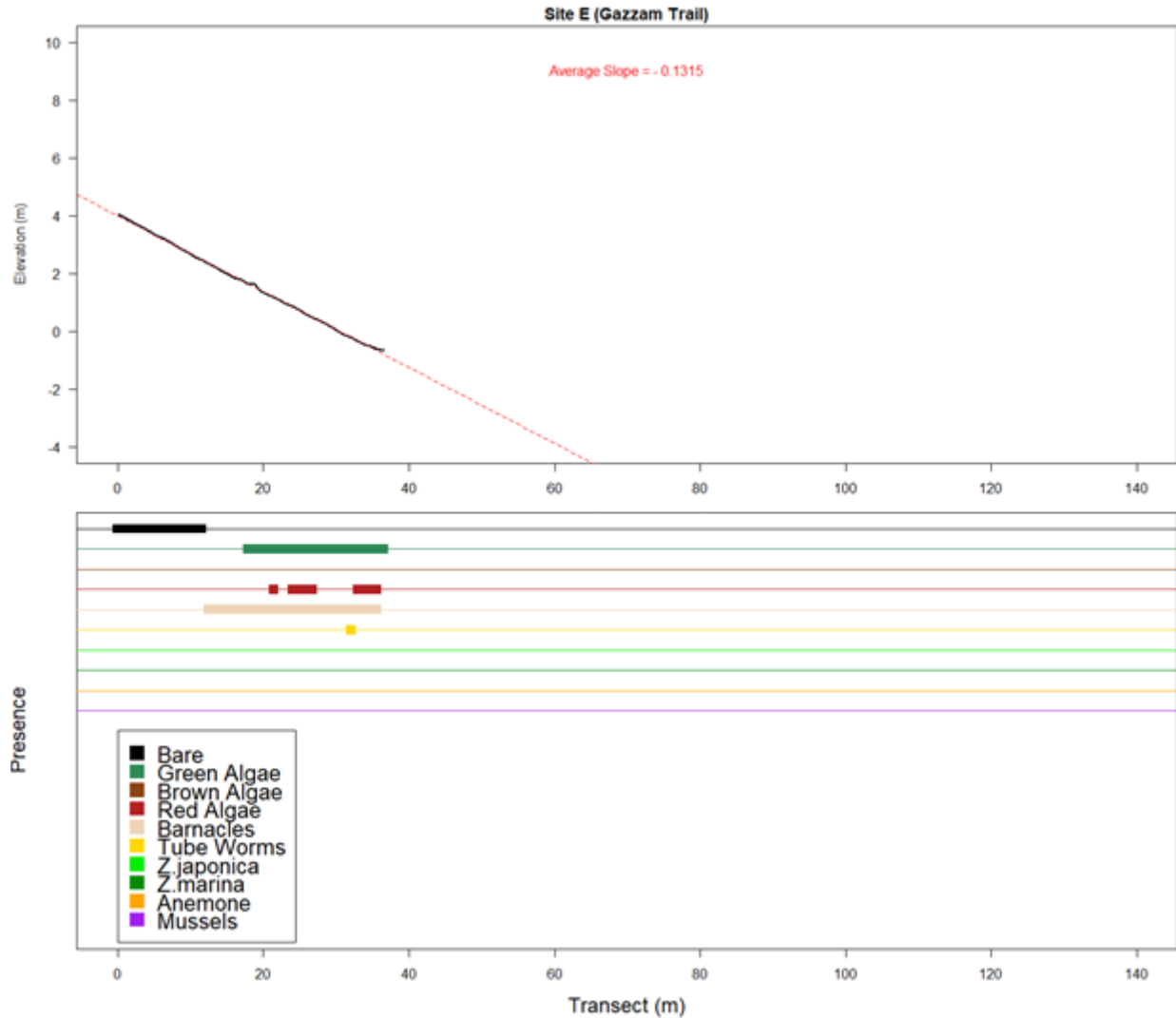


Figure 3.6. Beach profile (upper) and biological map (lower) of site E. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Brown algae, dwarf eelgrass, pacific eelgrass, anemone, and mussels were not observed along the beach profile of site E.

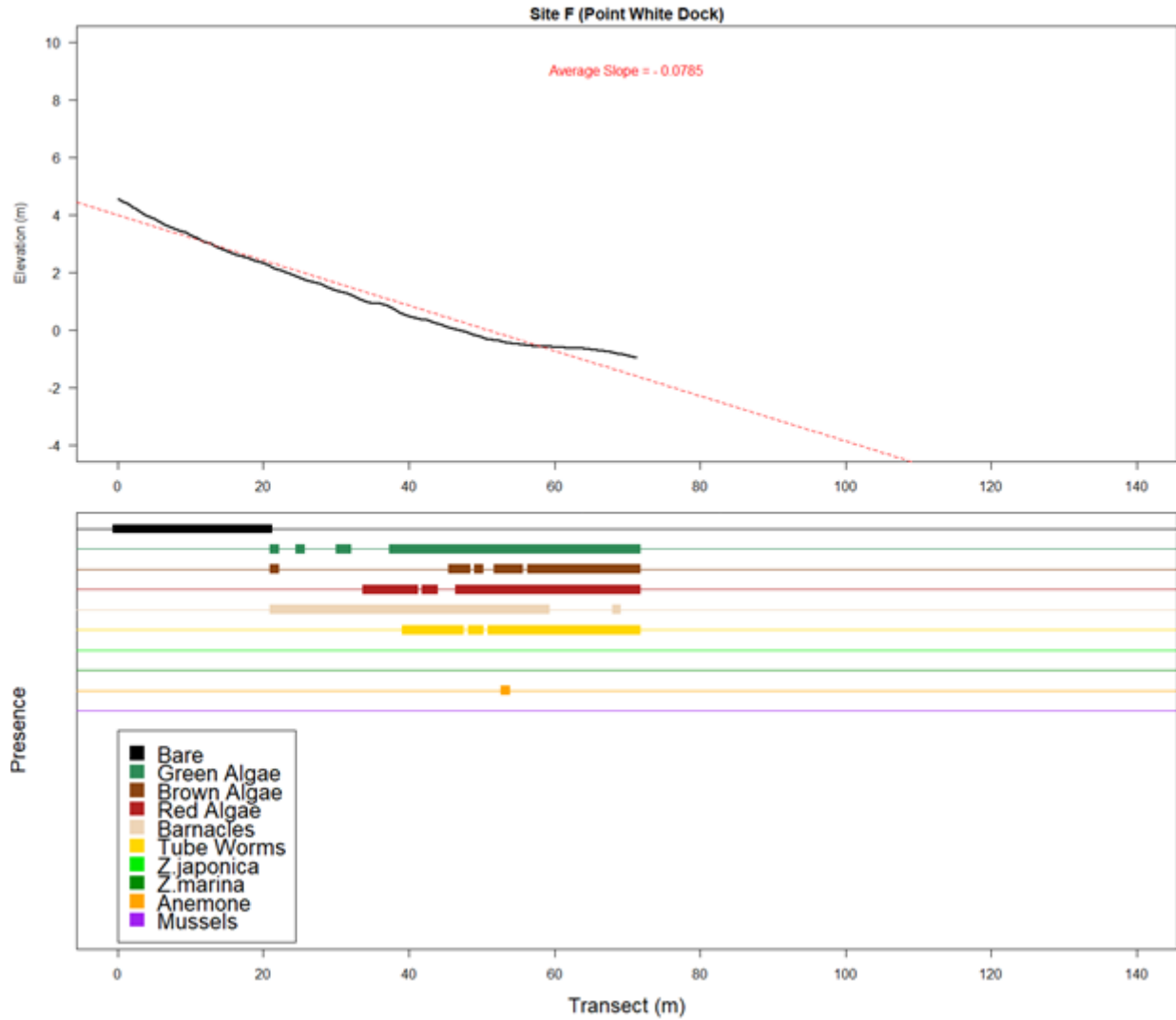


Figure 3.7. Beach profile (upper) and biological map (lower) of site F. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Dwarf eelgrass, pacific, and mussels were not observed along the beach profile of site F.

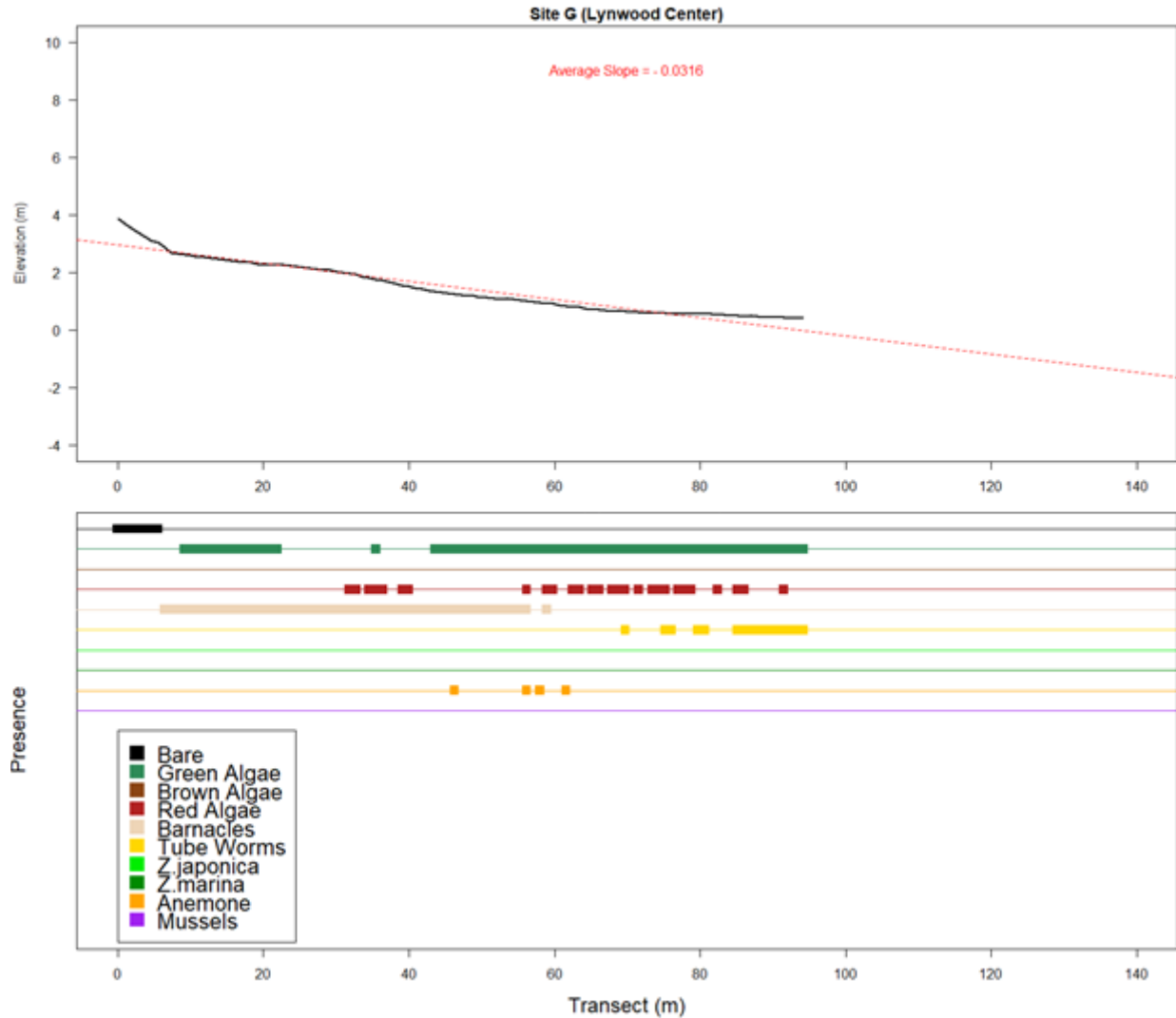


Figure 3.8. Beach profile (upper) and biological map (lower) of site G. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Brown algae, dwarf, pacific eelgrass, and mussels were not observed along the beach profile of site G.

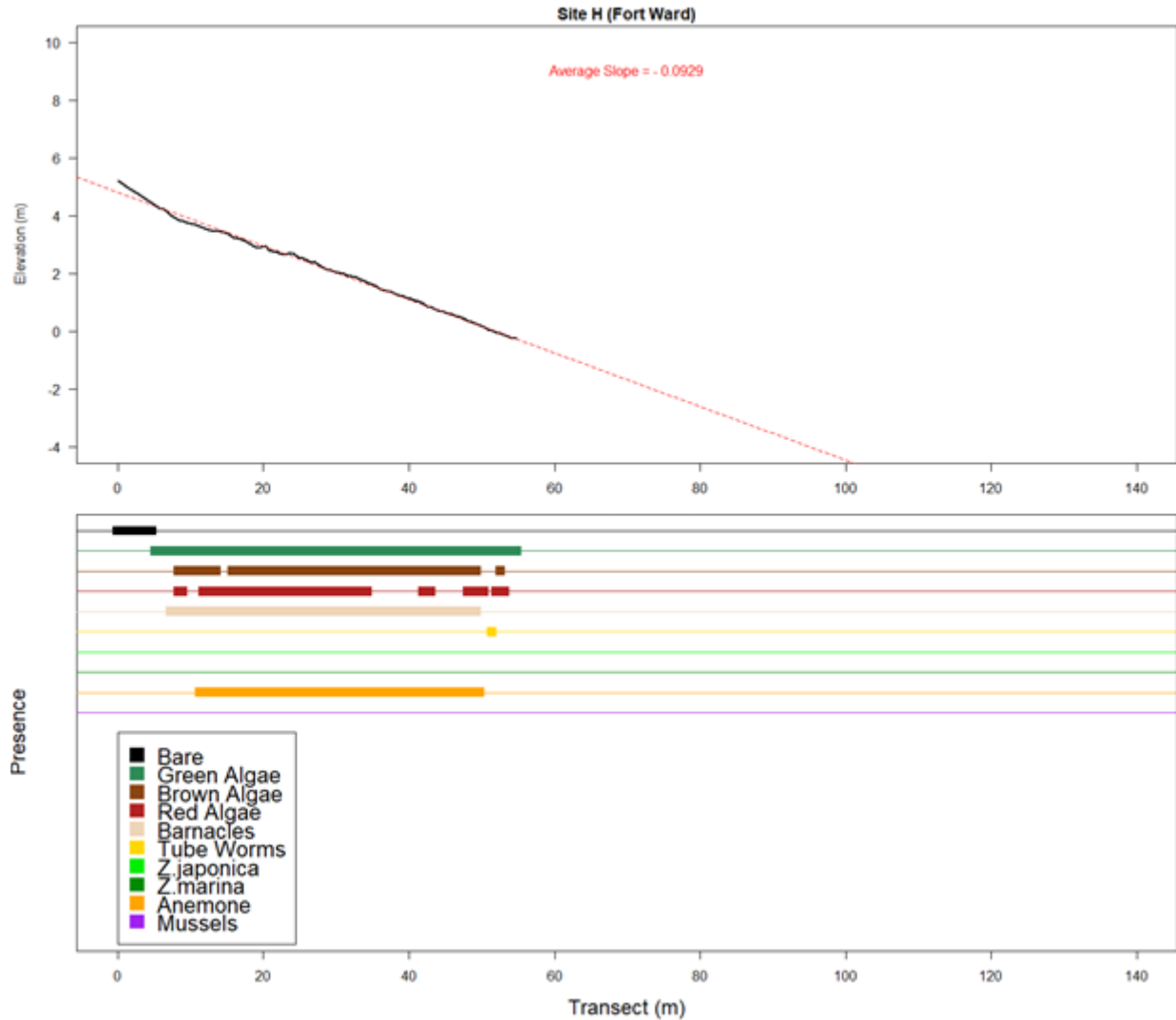


Figure 3.9. Beach profile (upper) and biological map (lower) of site H. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Dwarf eelgrass, pacific, and mussels were not observed along the beach profile of site H.

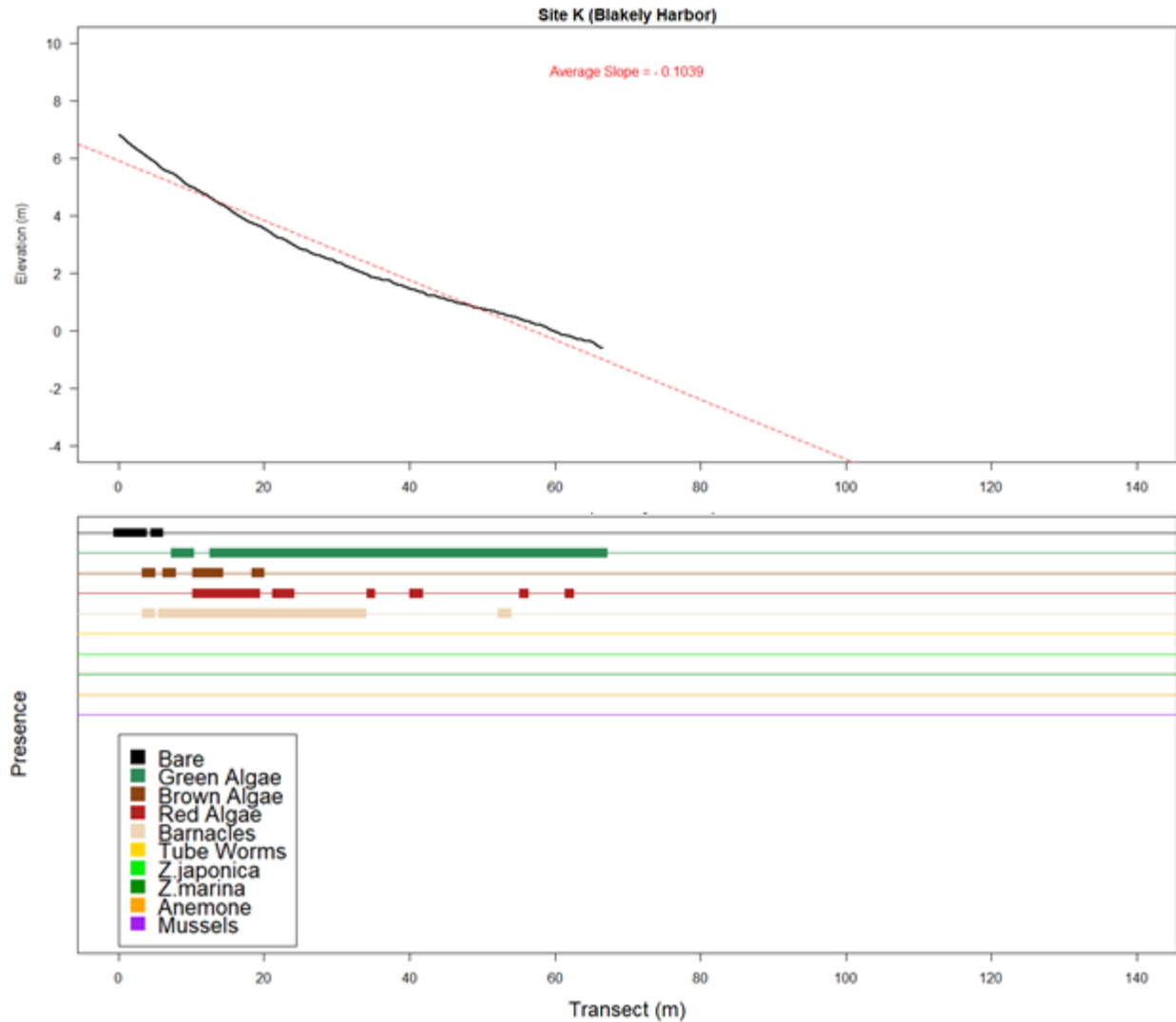


Figure 3.10. Beach profile (upper) and biological map (lower) of site K. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Tubeworms, dwarf eelgrass, pacific eelgrass, anemone, and mussels were not observed along the beach profile of site K.

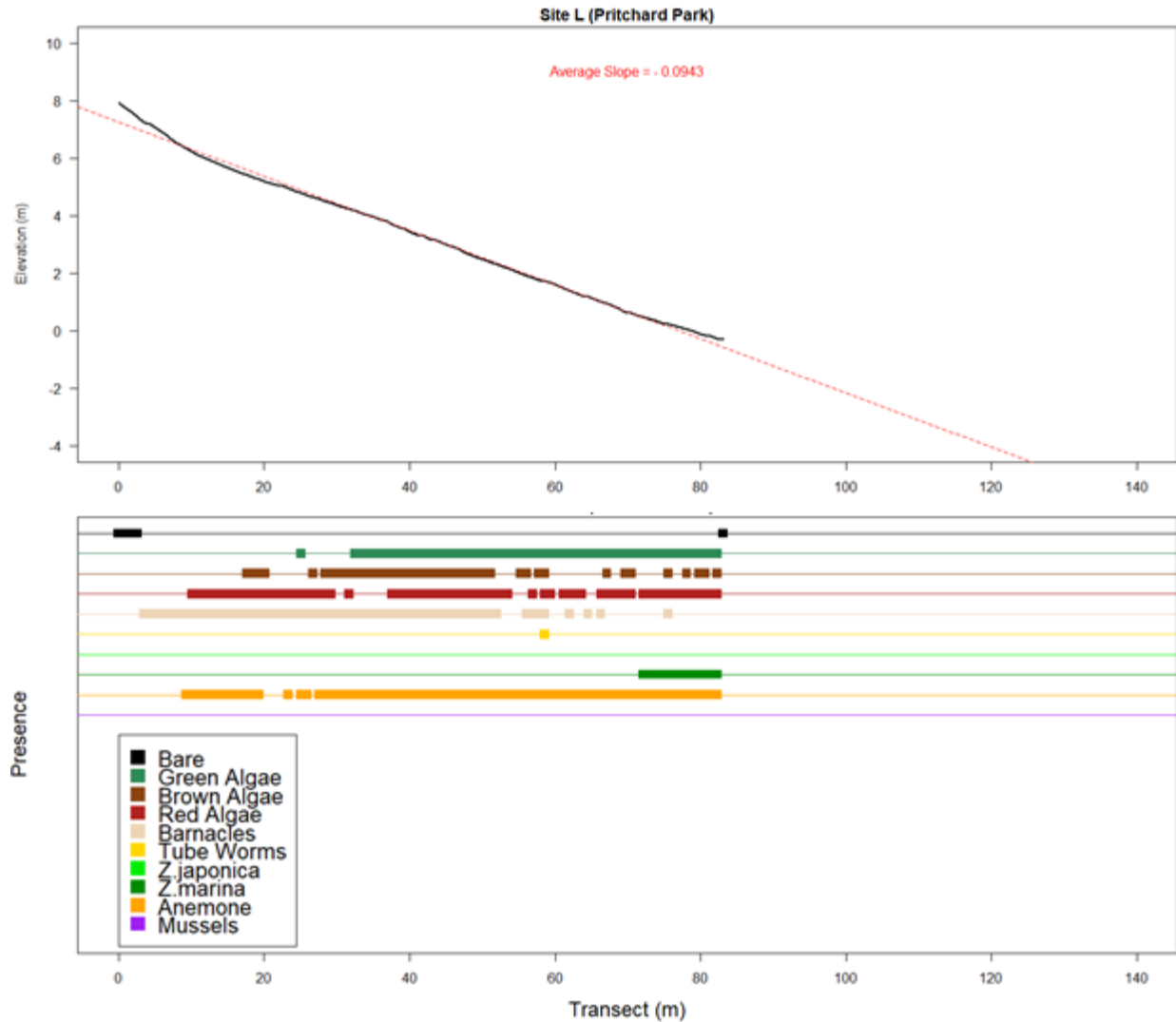


Figure 3.11. Beach profile (upper) and biological map (lower) of site L. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Dwarf eelgrass and mussels were not observed along the beach profile of site L.

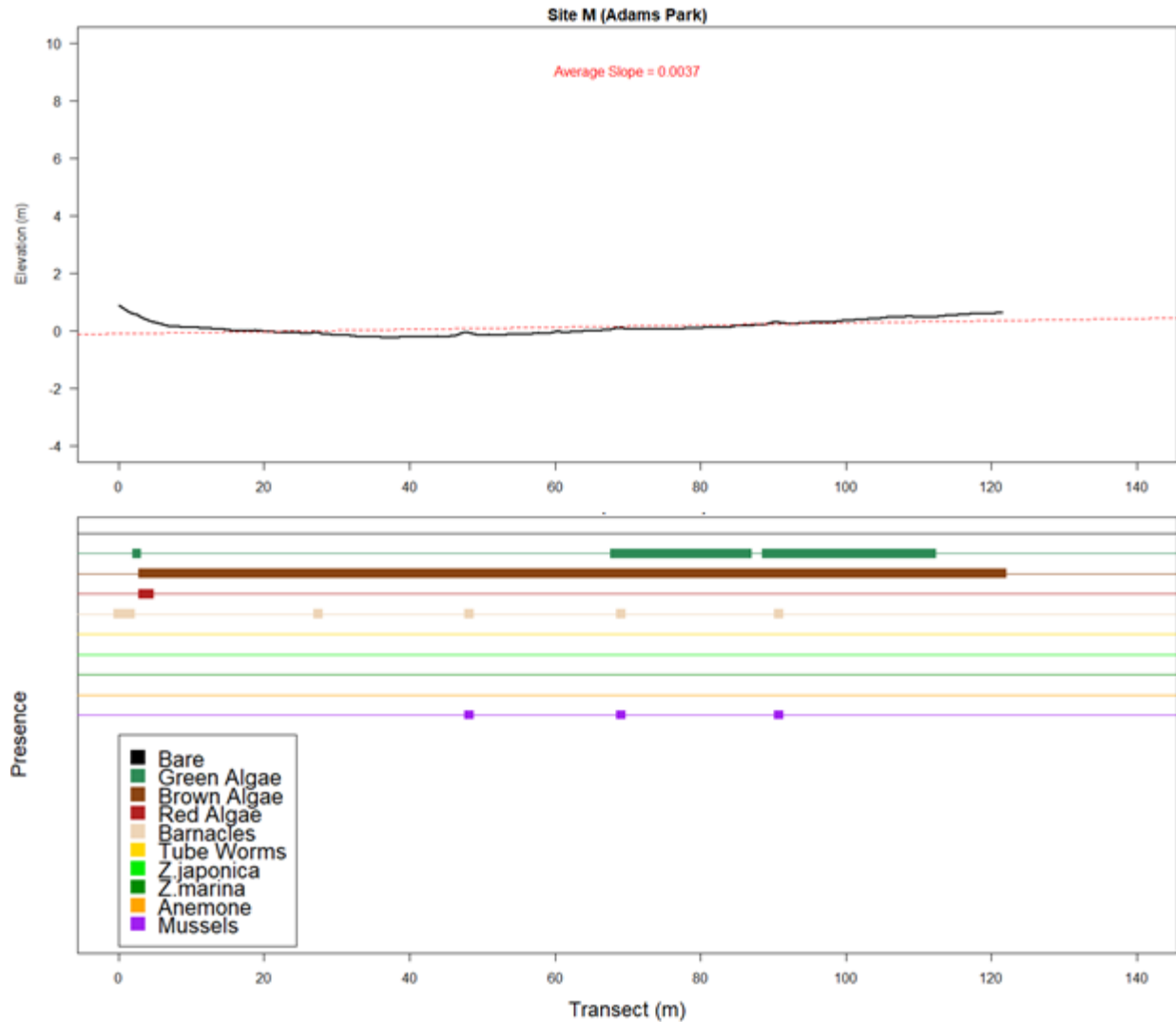


Figure 3.12. Beach profile (upper) and biological map (lower) of site M. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Bare ground, tubeworms, dwarf eelgrass, pacific eelgrass, and anemone were not observed along the beach profile of site M. Site M was particularly muddy, which could have affected the accuracy of the beach profile measurement.

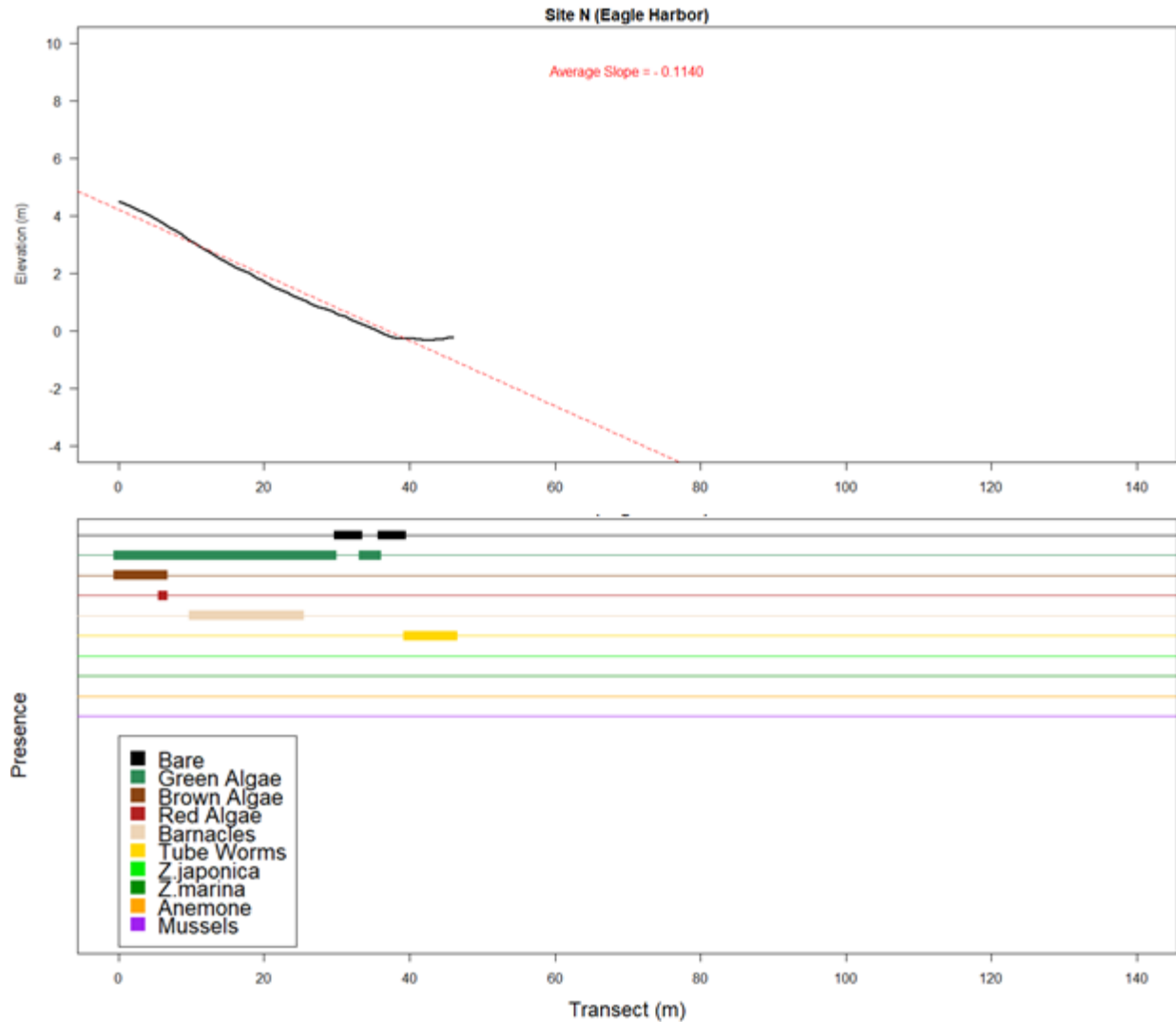


Figure 3.13. Beach profile (upper) and biological map (lower) of site N. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Dwarf eelgrass, pacific eelgrass, anemone, and mussels were not observed along the beach profile of site N.

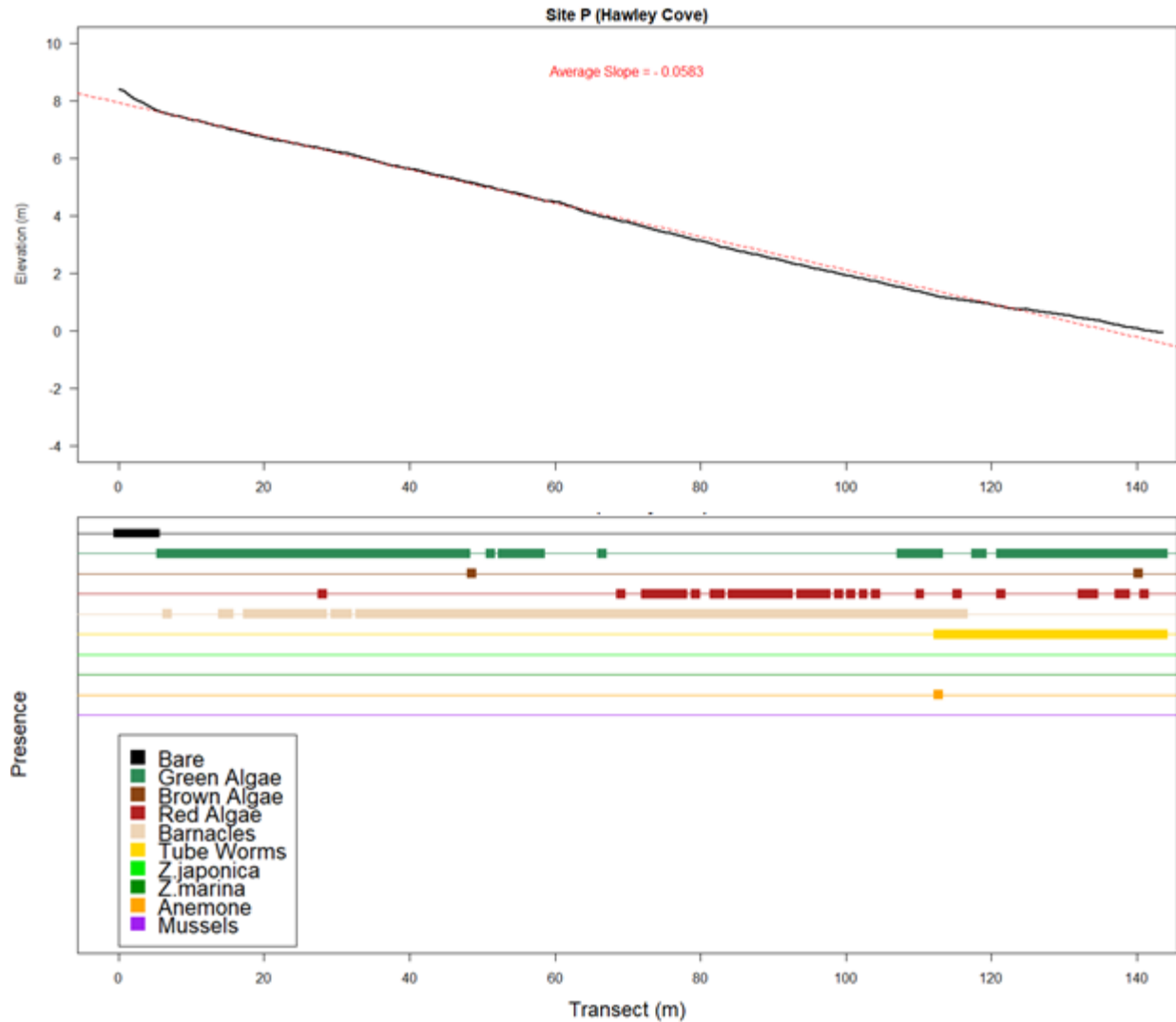


Figure 3.14. Beach profile (upper) and biological map (lower) of site P. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Dwarf eelgrass, pacific eelgrass, and mussels were not observed along the beach profile of site P.

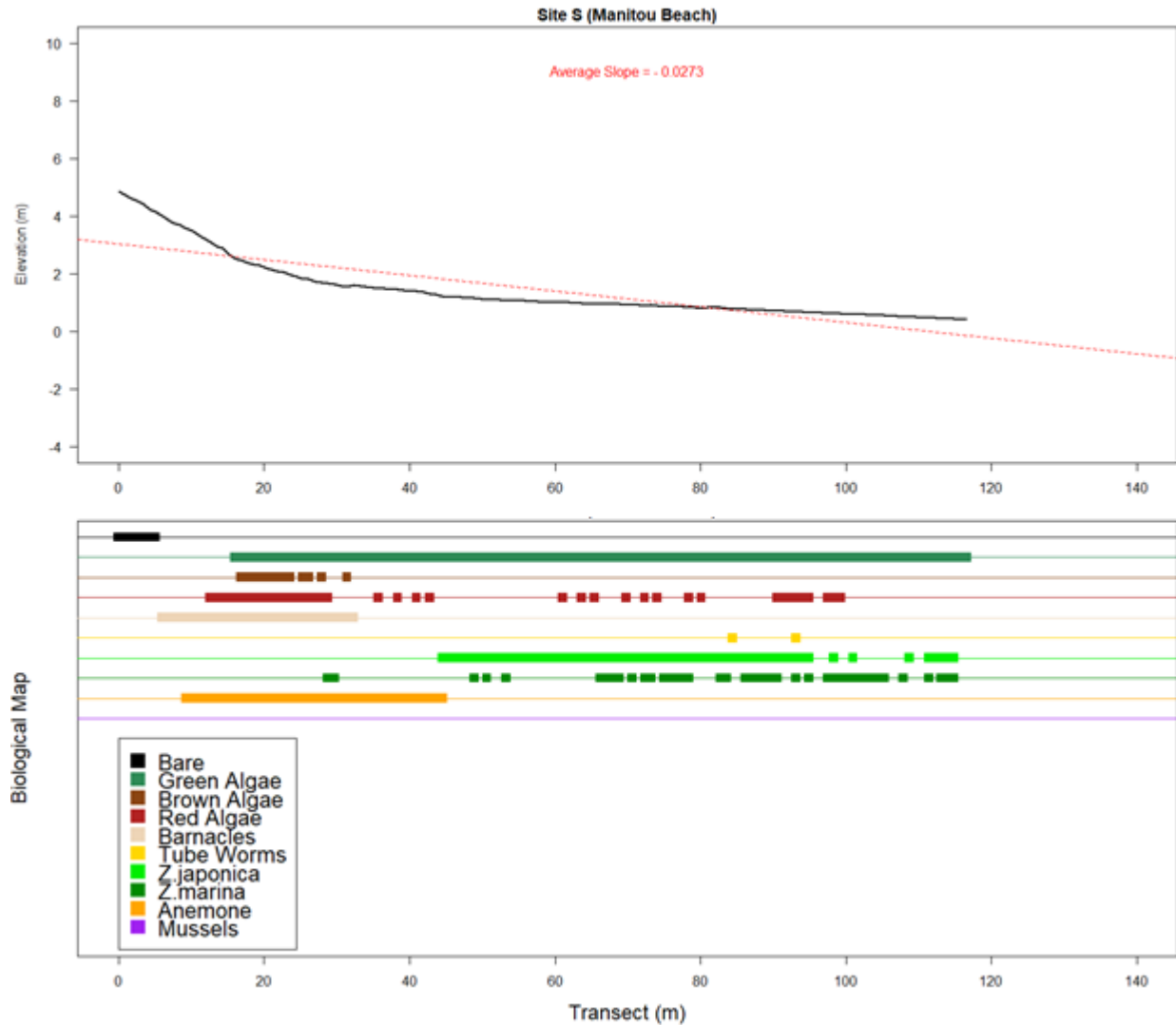


Figure 3.15. Beach profile (upper) and biological map (lower) of site S. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Mussels were not observed along the beach profile of site S.

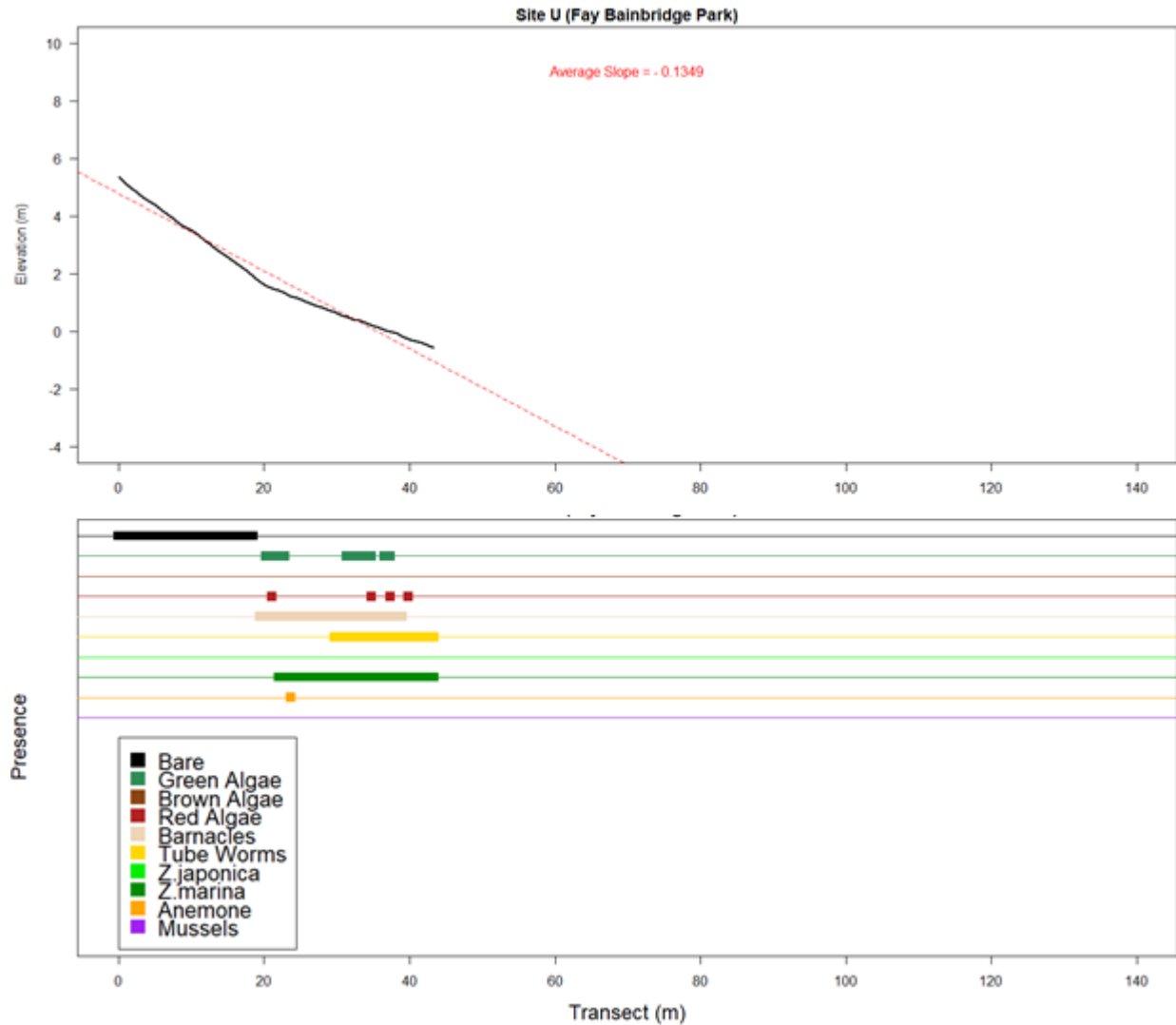


Figure 3.16. Beach profile (upper) and biological map (lower) of site U. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Brown algae, dwarf eelgrass, and mussels were not observed along the beach profile of site U.

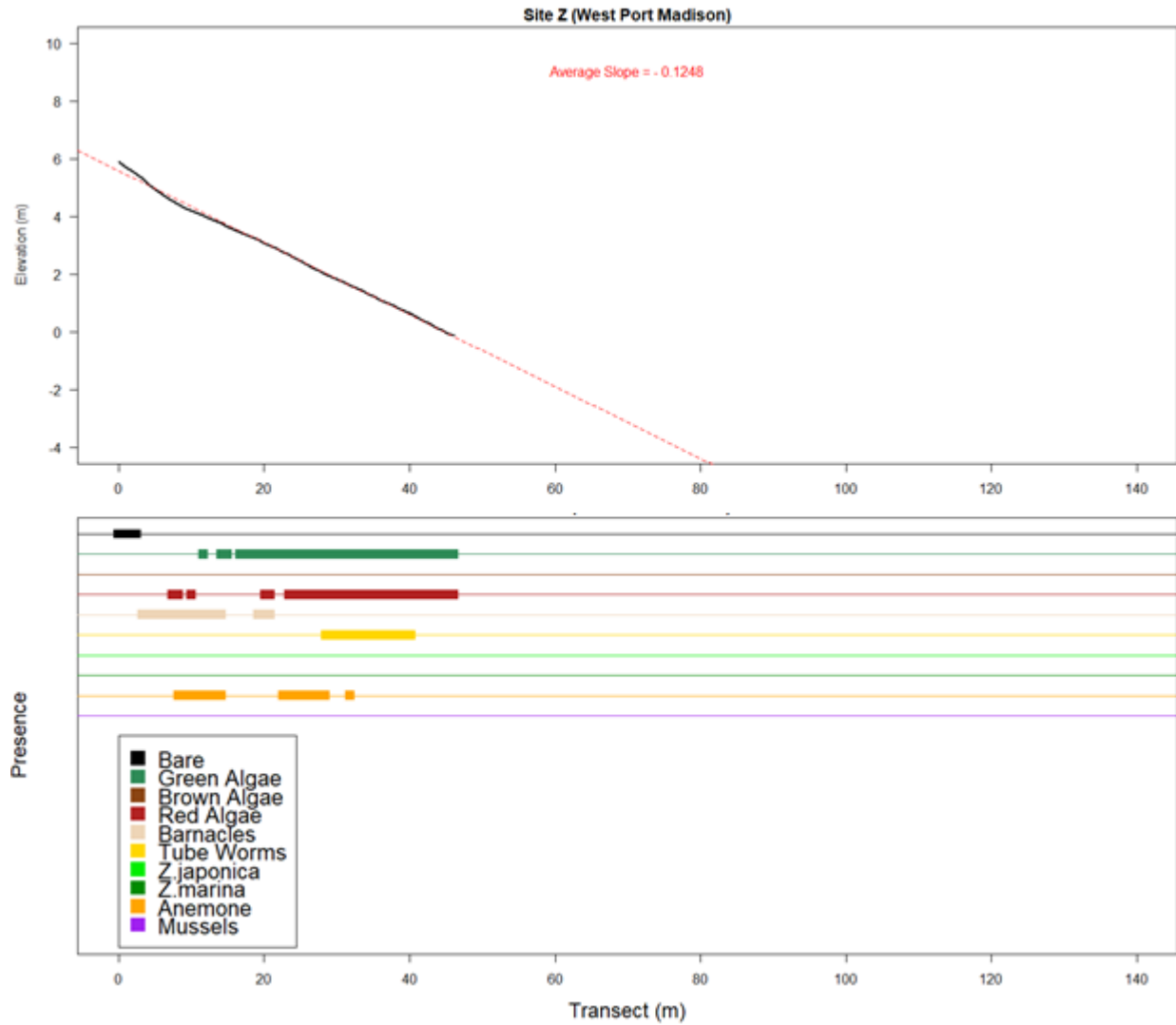


Figure 3.17. Beach profile (upper) and biological map (lower) of site Z. Slope line is corrected to tidal elevation to create a baseline for comparison among sites. The biological map includes bare ground and sessile organisms such as: green algae, brown algae, red algae, barnacles, tubeworms, dwarf eelgrass (*Zostera japonica*), pacific eelgrass (*Zostera marina*), anemone, and mussels. Dwarf eelgrass, pacific eelgrass, and mussels were not observed along the beach profile of site Z.

Dune Density and Dune Width

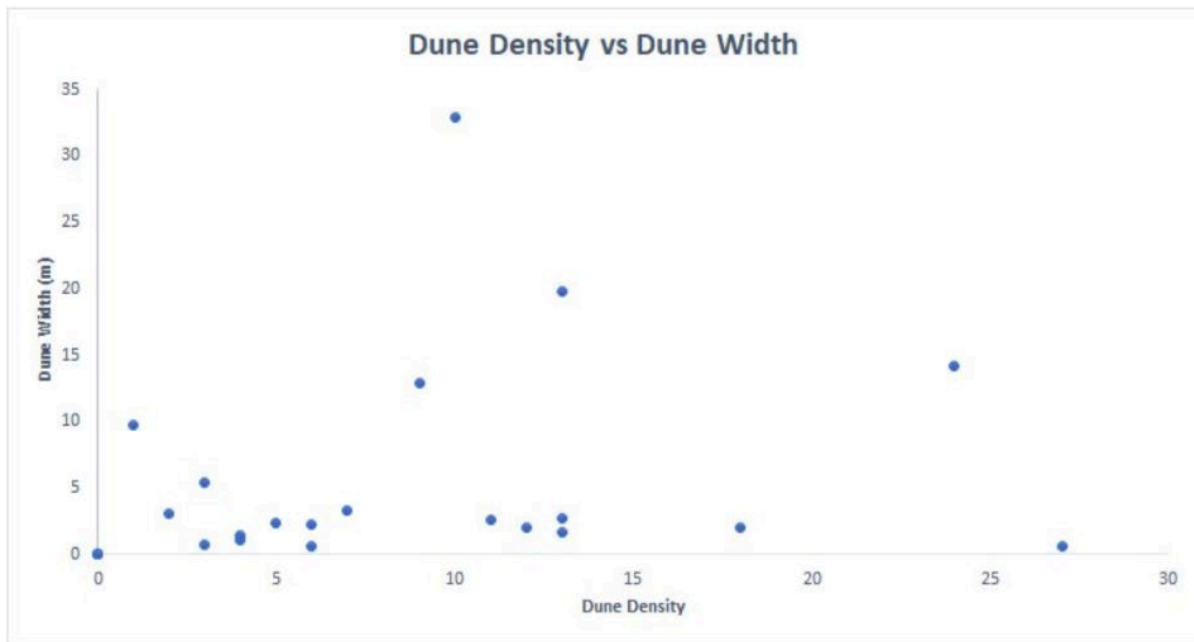


Figure 3.18. Comparison of dune density and dune width. A Spearman's Rank Correlation test was performed to determine if there was a correlation between dune density and width. There was a weak, positive correlation between dune density and width ($p = 0.003437$, $Rho = .55232$, $n=26$), indicating that one variable affects the other. This is important to monitor over time as dune density or dune width may change and affect the other variable, which may affect the protection provided to the beach.

Sediment Size

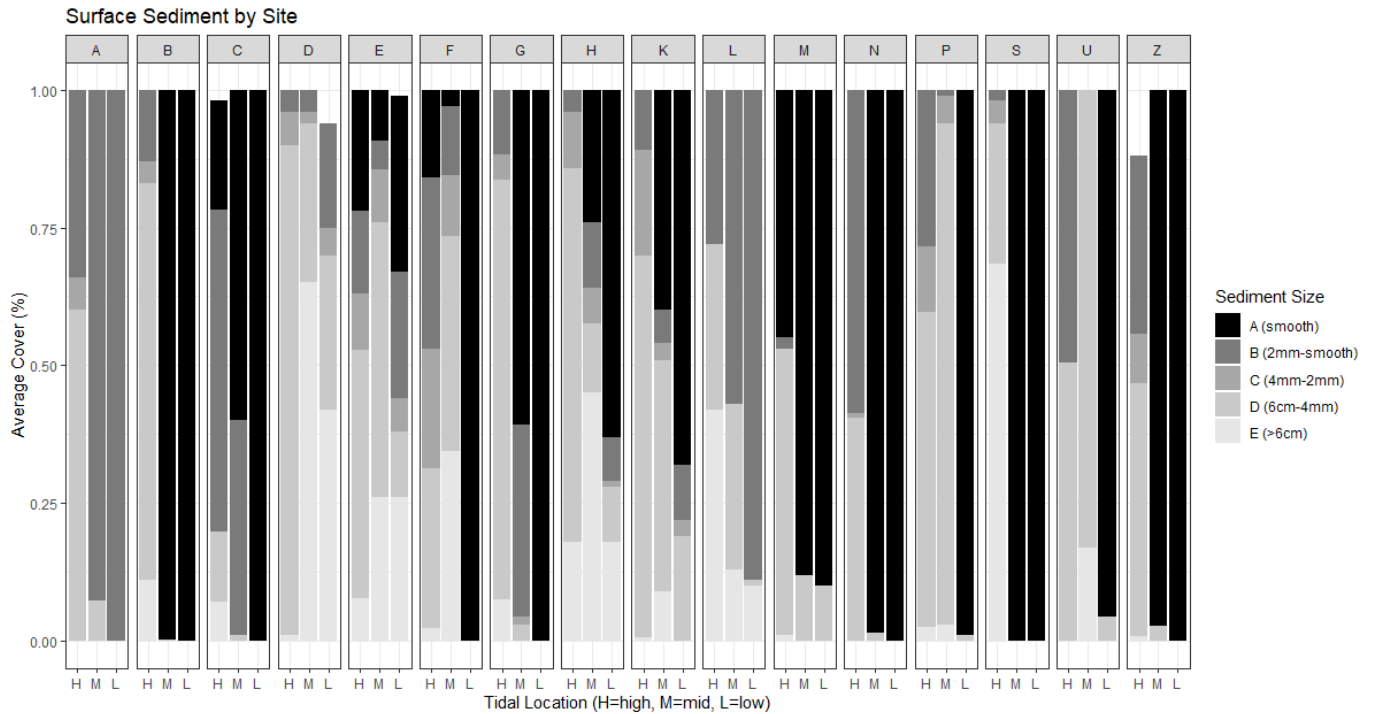


Figure 3.19. Stacked bar plot of the average percent of categorized surface sediment size covers observed at each site around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). Average site sediments adding up to less than 1, or 100-percent, were filled with material that was not sediment, such as wooden pilings. Sediment size tended to decrease from the high tidal elevation towards the low tidal elevation.

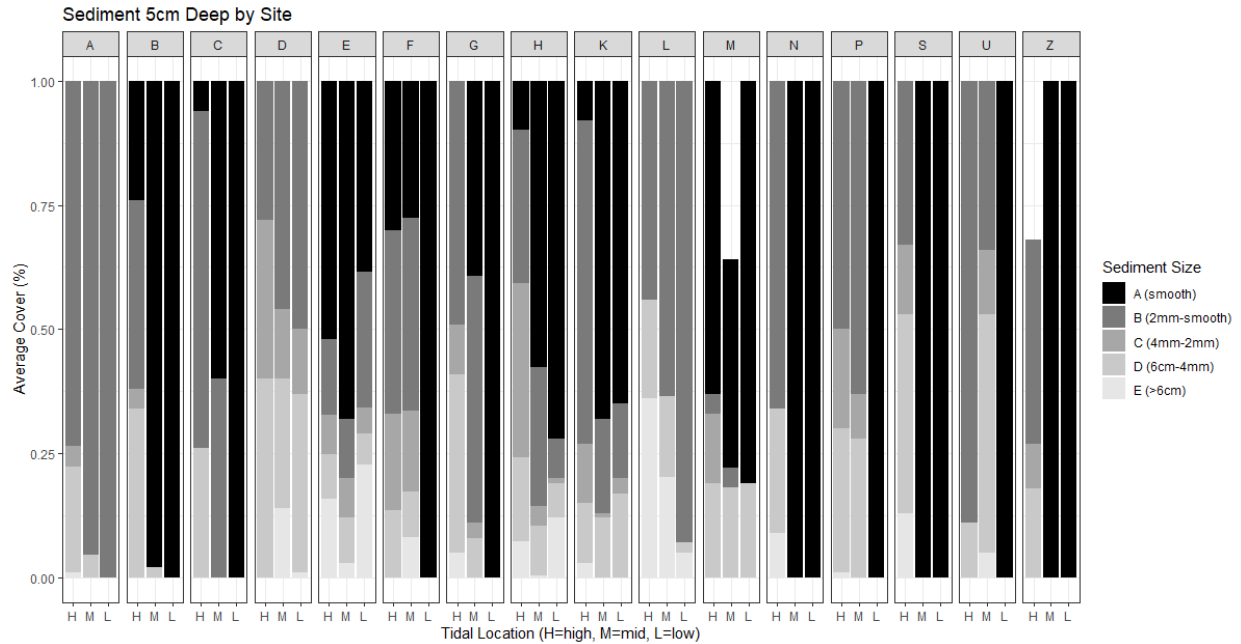


Figure 3.20. Stacked bar plot of the average percent of categorized sediment size covers observed 5-cm under the surface at each site around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). Average site sediments adding up to less than 1, or 100-percent, were filled with material that was not sediment, such as wooden pilings (Sites M and Z). Sediment size tended to decrease from the high tidal elevation towards the low tidal elevation.

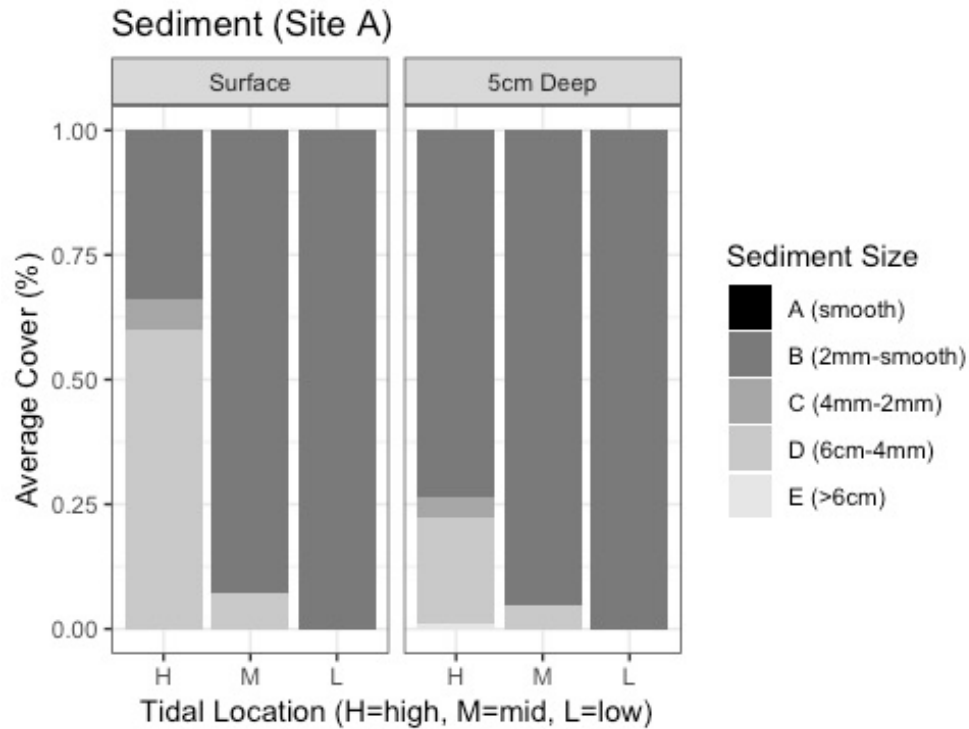


Figure 3.21. Stacked bar plot of the average percent of categorized sediment size covers observed at Site A at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). A majority of the beach was size B, but was larger around high tidal location both at the surface and below the surface.

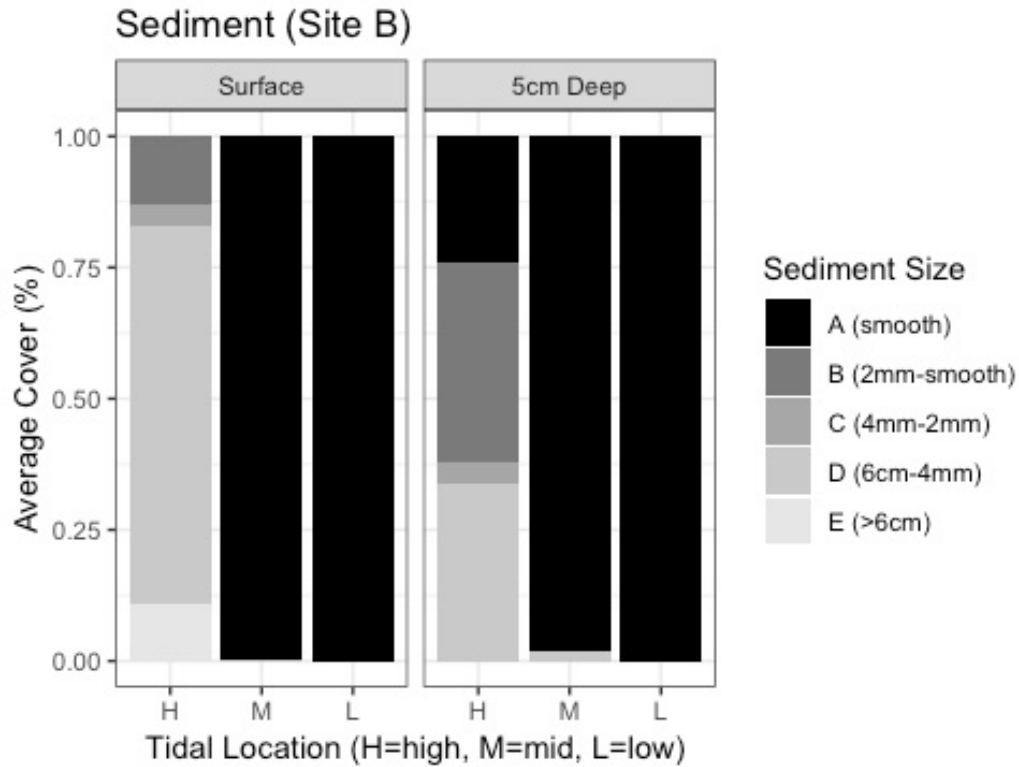


Figure 3.22. Stacked bar plot of the average percent of categorized sediment size covers observed at Site B at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). A majority of the beach was size A but was rocky around high tidal location both at the surface and below the surface.

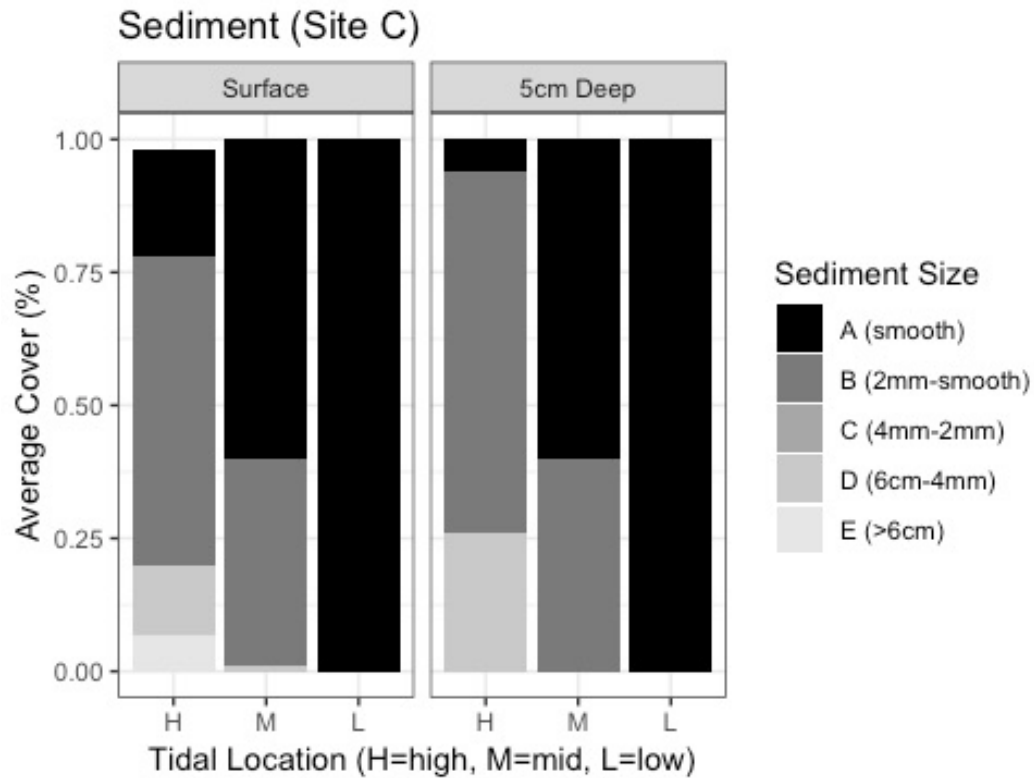


Figure 3.23. Stacked bar plot of the average percent of categorized sediment size covers observed at Site C at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The high tidal region was rocky (E) but became smaller lower down the beach.

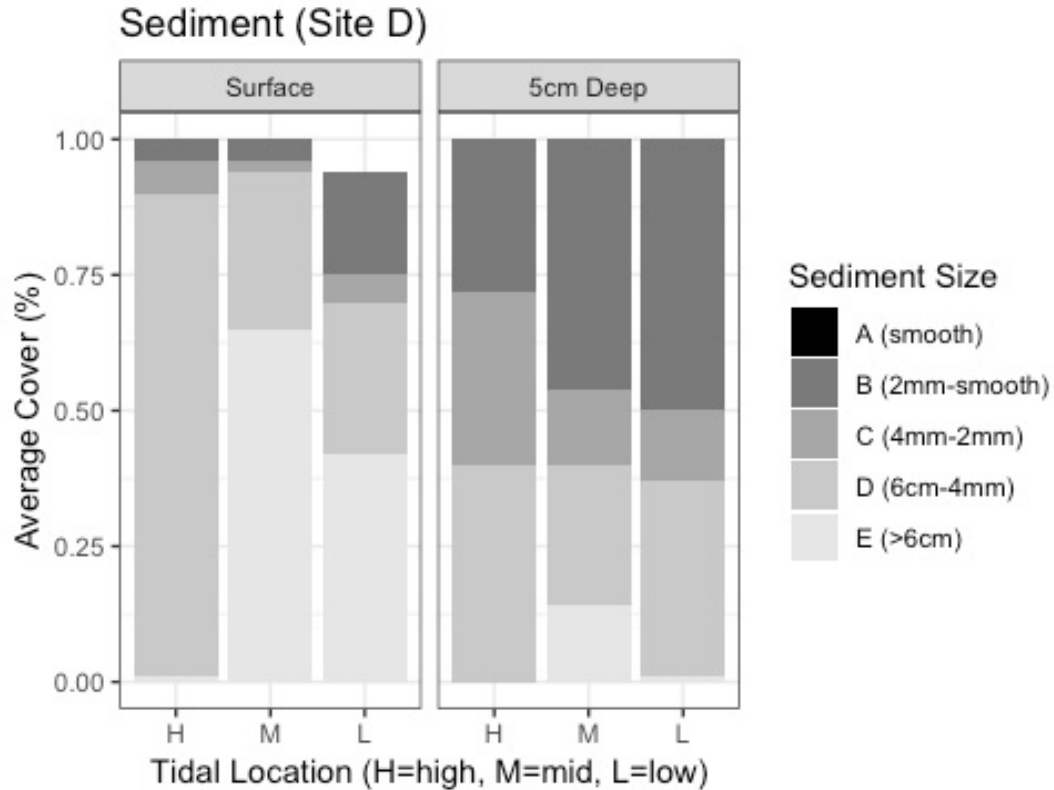


Figure 3.24. Stacked bar plot of the average percent of categorized sediment size covers observed at Site D at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). A majority of the beach was rocky (E or D) but became smaller lower down the beach.

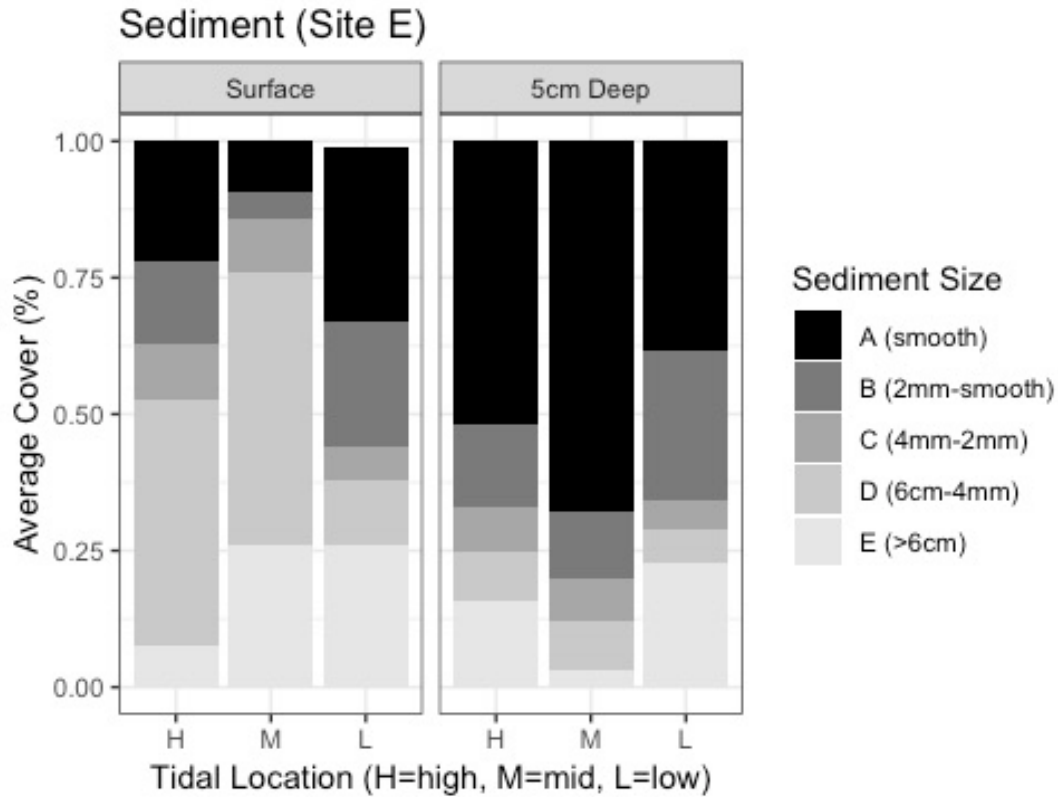


Figure 3.25. Stacked bar plot of the average percent of categorized sediment size covers observed at Site E at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The beach had a wide range of sediment sizes.

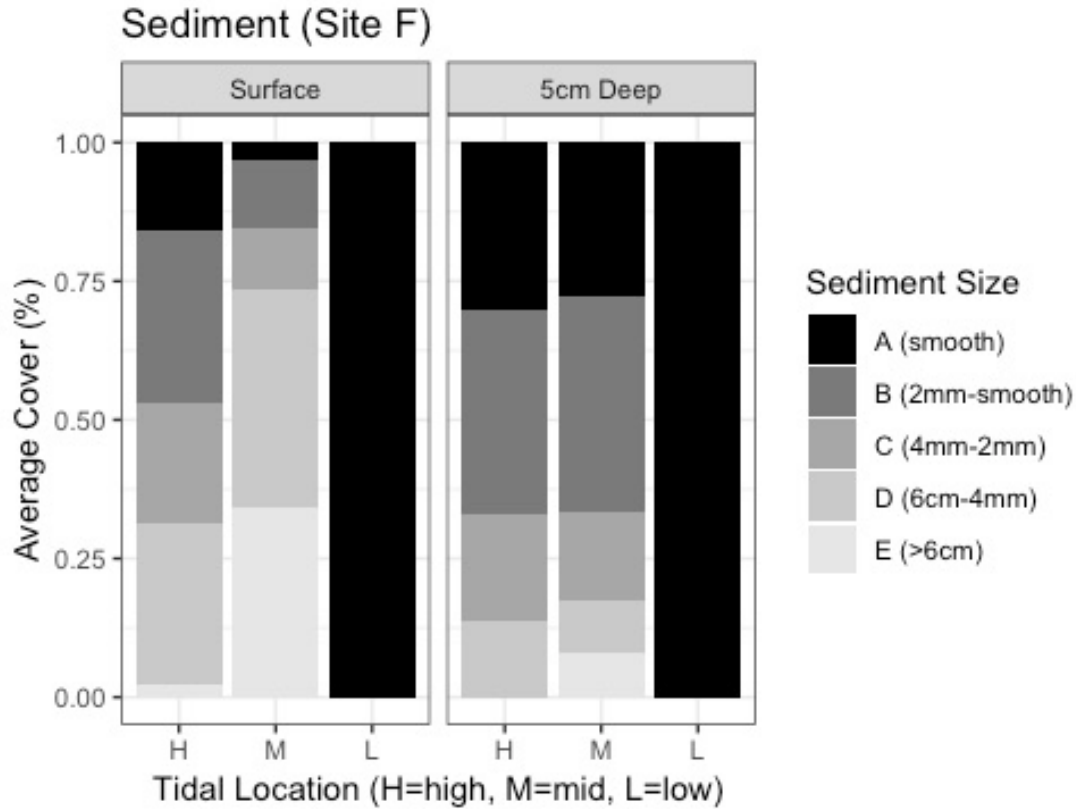


Figure 3.26. Stacked bar plot of the average percent of categorized sediment size covers observed at Site F at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment became smaller along the slope of the beach.

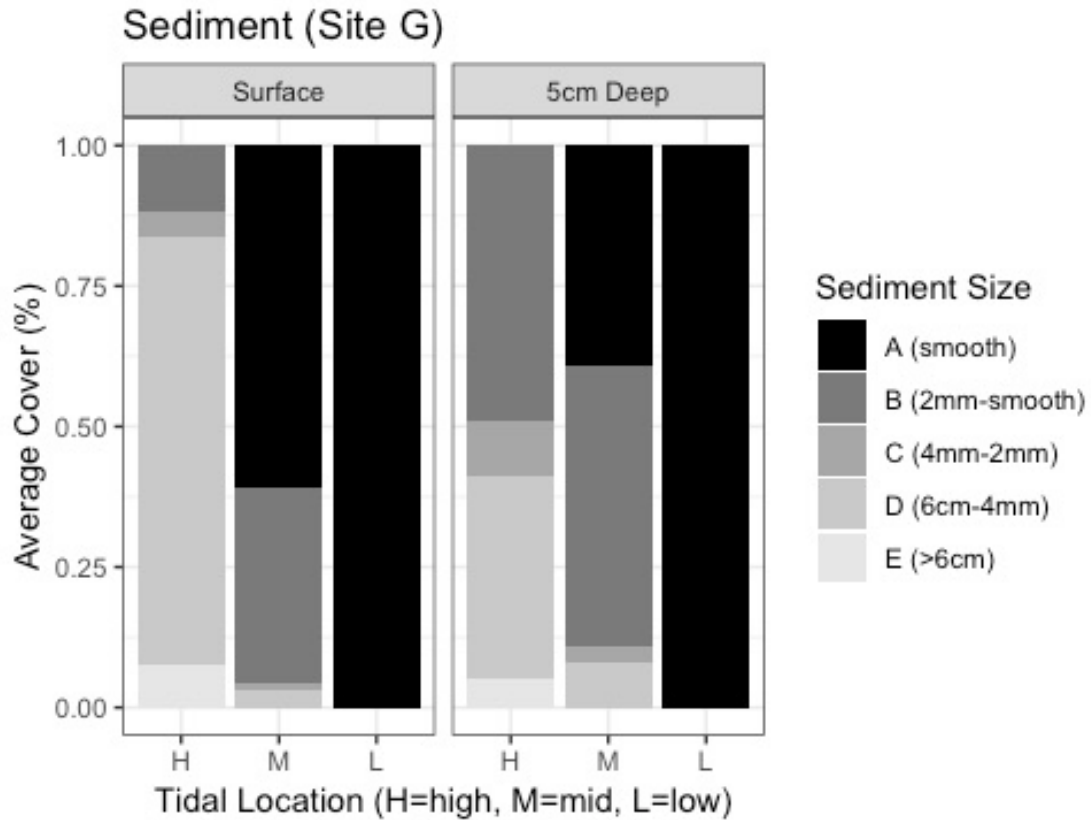


Figure 3.27. Stacked bar plot of the average percent of categorized sediment size covers observed at Site G at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment became smaller along the slope of the beach.

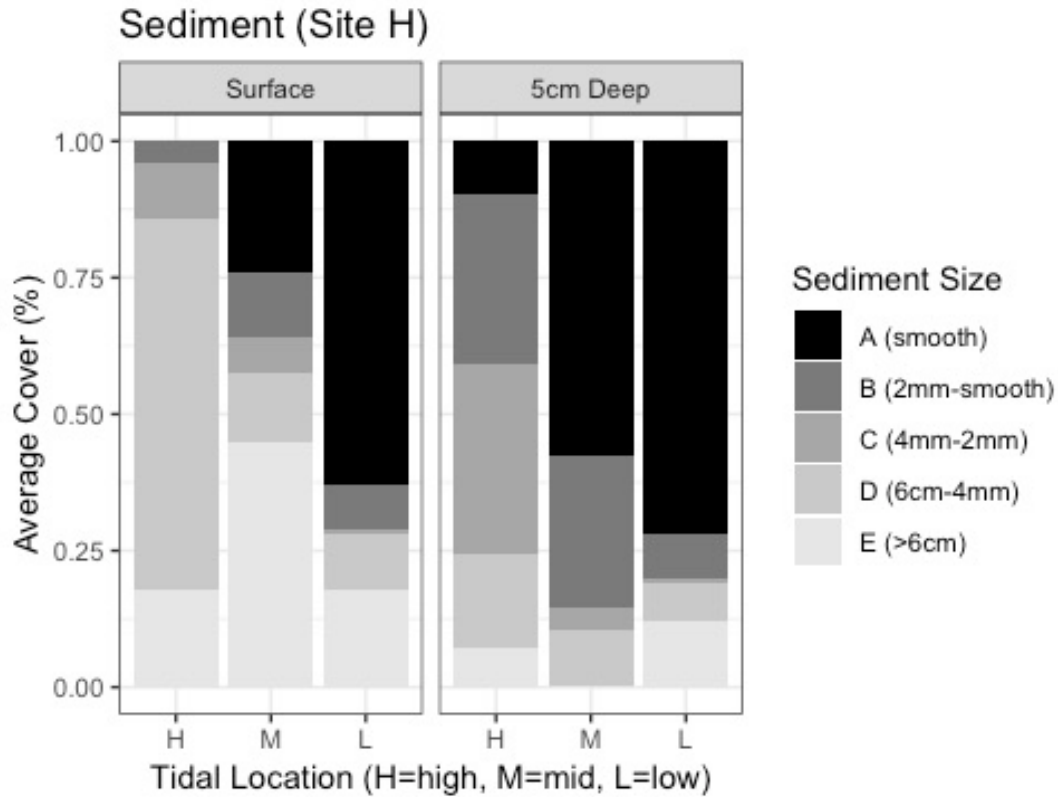


Figure 3.28. Stacked bar plot of the average percent of categorized sediment size covers observed at Site H at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment became smaller along the slope of the beach.

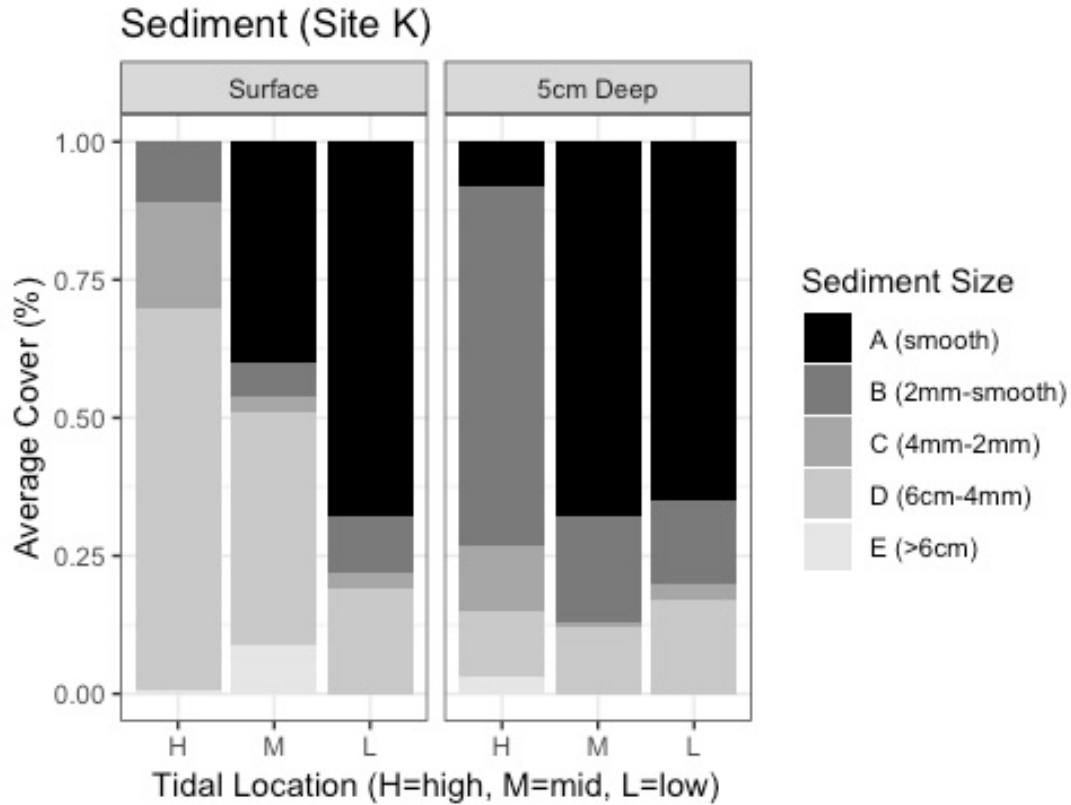


Figure 3.29. Stacked bar plot of the average percent of categorized sediment size covers observed at Site K at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment became smaller along the slope of the beach.

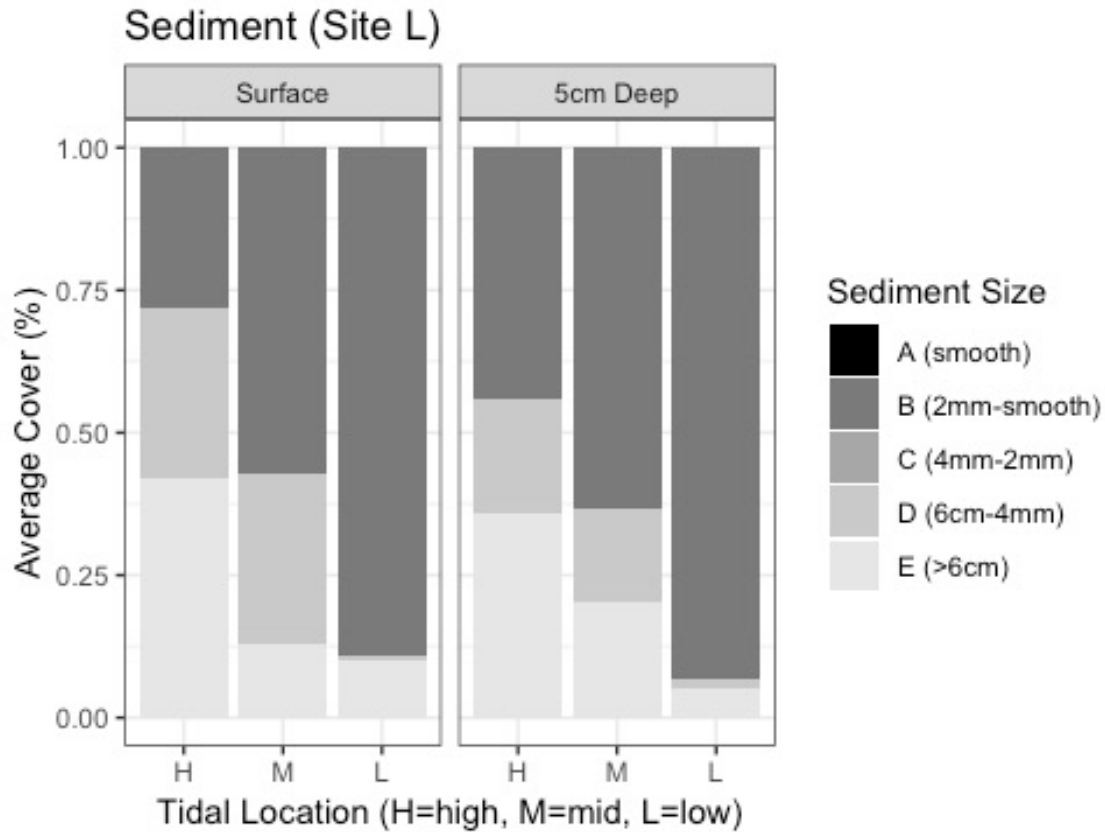


Figure 3.30. Stacked bar plot of the average percent of categorized sediment size covers observed at Site L at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment was rocky near the high tide region but became smaller along the slope of the beach.

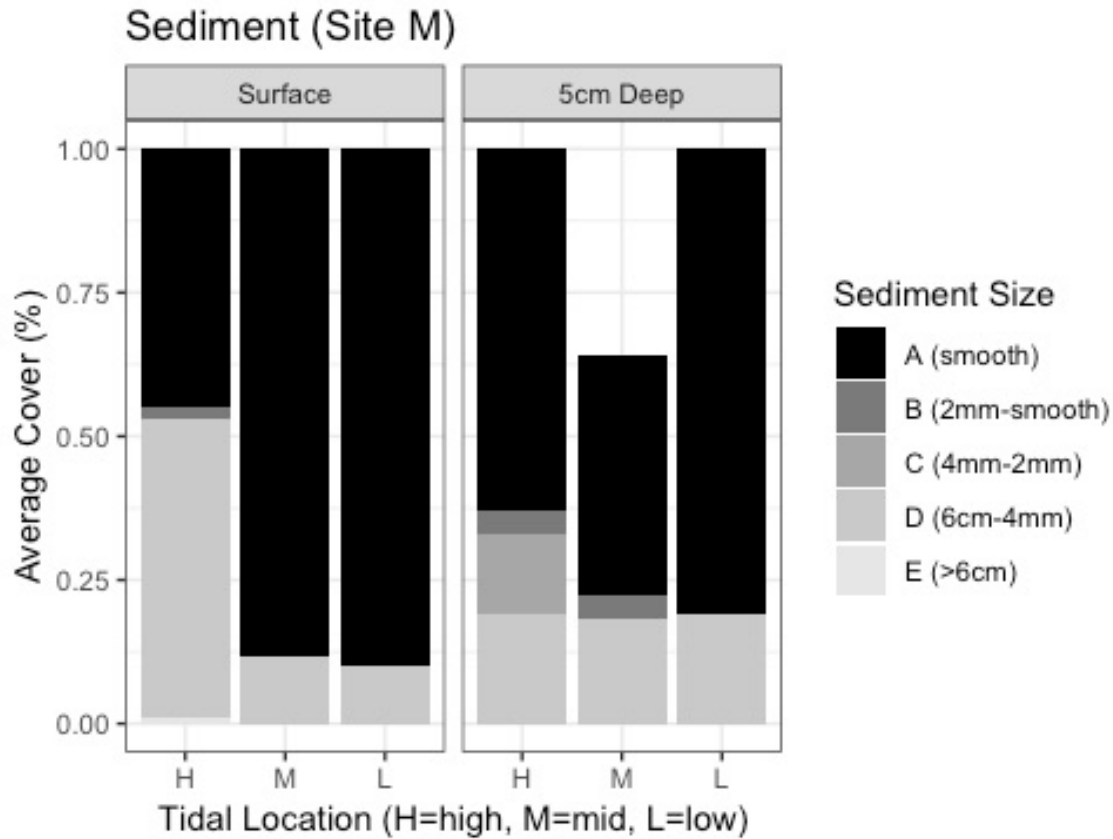


Figure 3.31. Stacked bar plot of the average percent of categorized sediment size covers observed at Site M at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment became smaller along the slope of the beach. The 5-cm deep samples at tidal location M does not equal 100% since it was partially filled with material that was not sediment, such as wooden pilings.

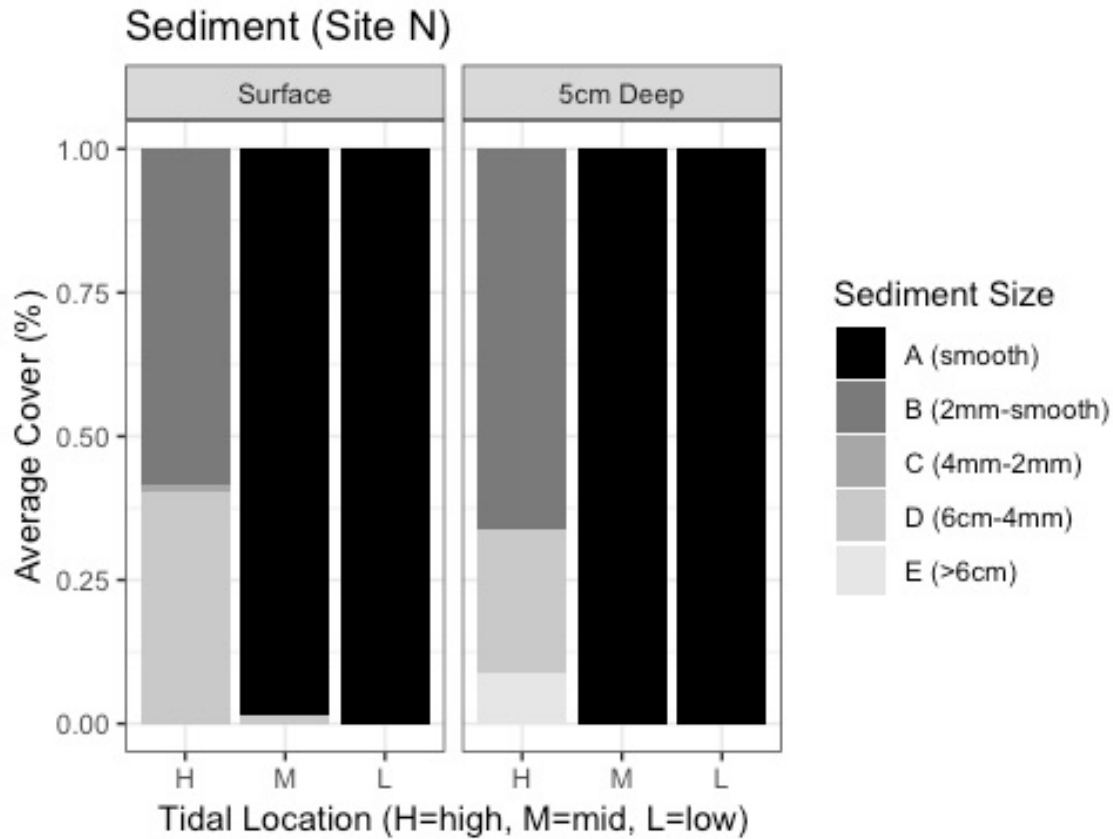


Figure 3.32. Stacked bar plot of the average percent of categorized sediment size covers observed at Site N at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment was larger at the high tidal region and smaller (size A) at the mid and low tidal regions.

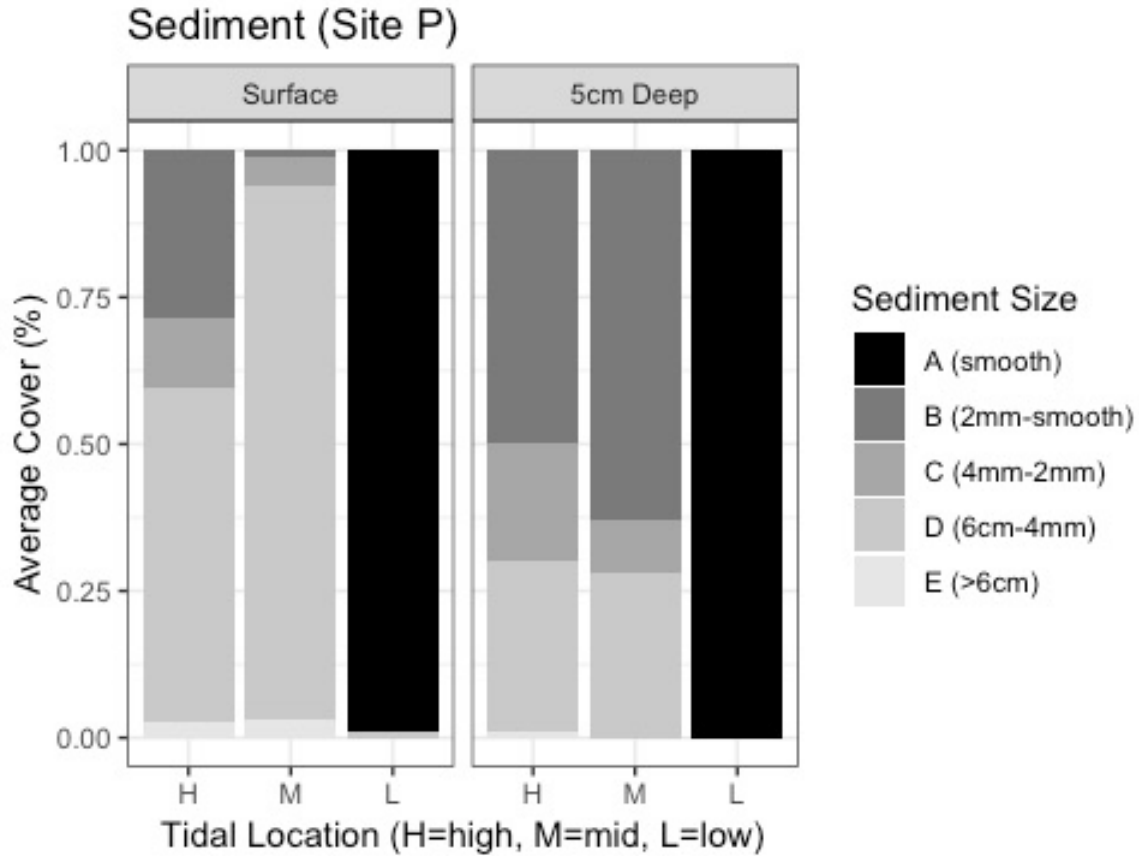


Figure 3.33. Stacked bar plot of the average percent of categorized sediment size covers observed at Site P at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment was larger at the high tidal region and smaller at the mid and low tidal regions.

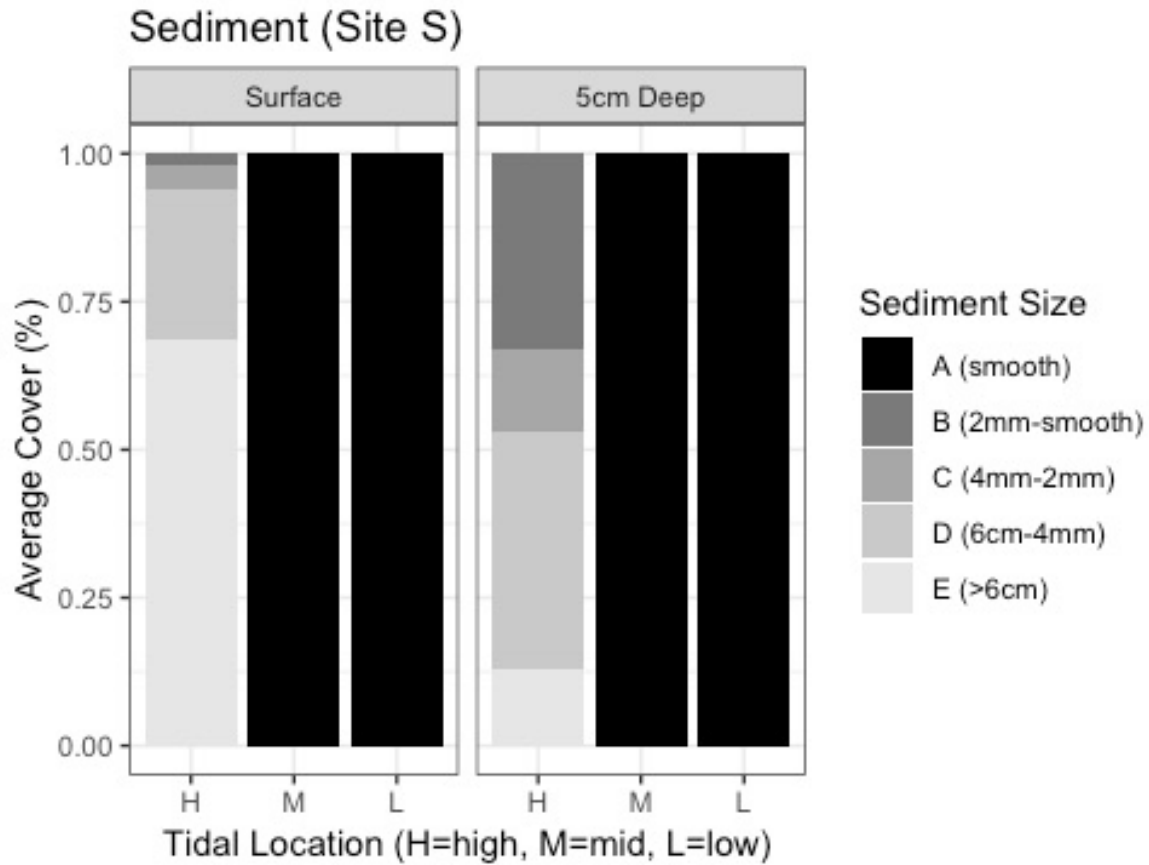


Figure 3.34. Stacked bar plot of the average percent of categorized sediment size covers observed at Site S at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment was larger at the high tidal region and smaller (size A) at the mid and low tidal regions.

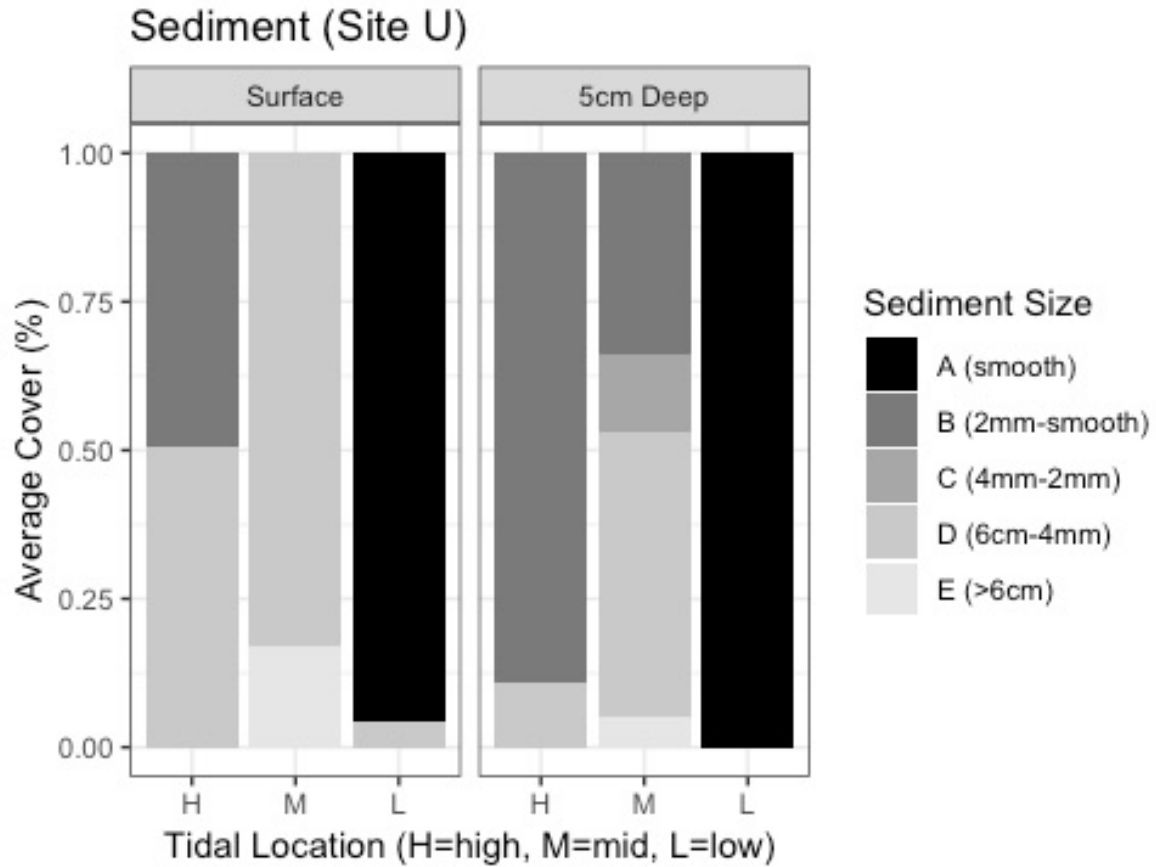


Figure 3.35. Stacked bar plot of the average percent of categorized sediment size covers observed at Site U at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment was larger at the high tidal region and smaller at the mid and low tidal regions.

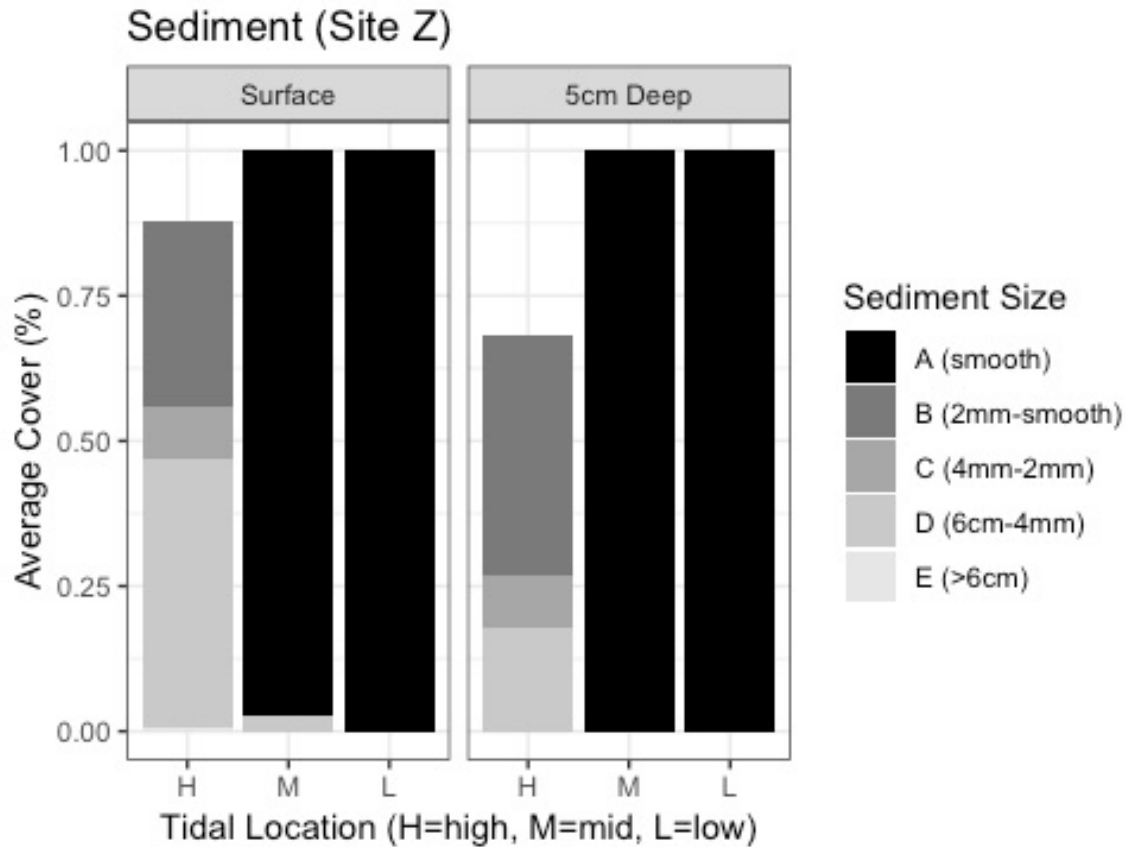


Figure 3.36. Stacked bar plot of the average percent of categorized sediment size covers observed at Site N at the surface around the tide lines (n=5) and 5-cm under the surface around the tide lines (n=5). The tidal locations were high (high tide), low (low tide), and mid (around MSL between high and low tide). The sediment size categories are A) Silt/Clay (smooth), B) Sand (smooth-2mm), C) Granule (2mm-4mm), D) Pebble (4mm-6cm), and E) Cobble (>6cm). The sediment was larger at the high tidal region and smaller (size A) at the mid and low tidal regions. The samples that do not add up to 100% were partially filled with material that was not sediment, such as wooden pilings.

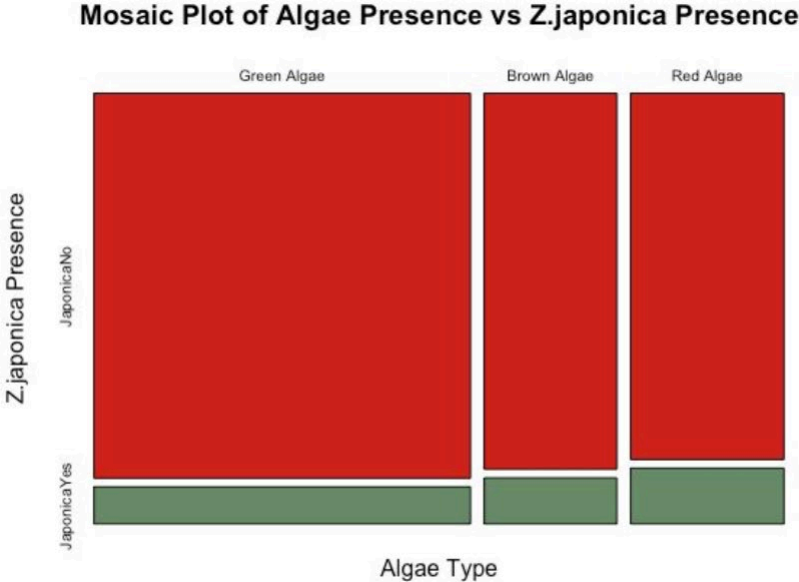


Figure 3.37. Mosaic plot of algae presence vs. dwarf eelgrass (*Z. japonica*) presence. Horizontal length shows relative frequency of algae type (n=1520) and vertical length shows relative frequency of *Z. japonica* presence. This figures shows green algae to be most prevalent on average, and highest abundance of *Z. japonica* in the presence of red algae. Pearson Chi-Squared test for independence revealed presence of algae type is independent of *Z. japonica* presence ($p=0.0545$). In other words, the presence of algae has no effect upon whether or not *Z. japonica* grows in that area or not.

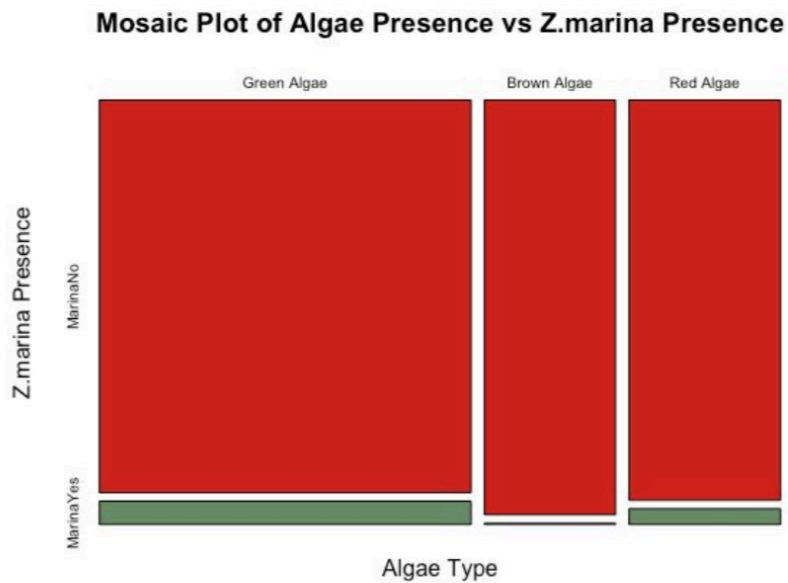


Figure 3.38. Mosaic plot of algae presence vs. pacific eelgrass (*Z. marina*) presence. Horizontal length shows relative frequency of algae type (n=1520) and vertical length shows relative frequency of *Z. marina* presence. Pearson Chi-Squared test for independence revealed presence of algae type is not independent of *Z. marina* presence ($p=0.000209$). In other words, the presence of algae does have an effect on whether or not *Z. marina* will grow in one area or not. More likely though, this is due to sunlight and sediment type. *Z. marina* requires a sandy, muddy floor and must be covered by water a majority of the day, whereas algae prefers more rocky surfaces so it can attach and grow. Generally, *Z. marina* grows deeper in the intertidal zone than algae (around 20-30ft) and *Z. japonica*, therefore when algae is present, generally that means *Z. marina* will not grow because the water is too shallow.

Nativity

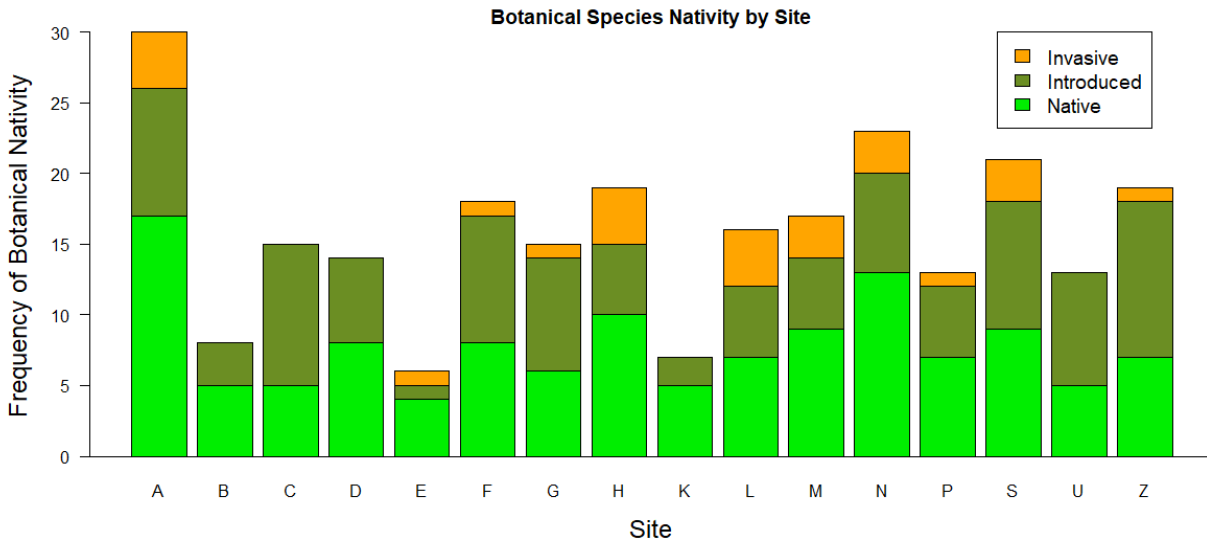


Figure 3.39. Stacked bar graph of terrestrial vegetative species' nativity identified for each site. Nativity was categorized as either invasive, introduced, or native species as shown in Table 1.

Botanical Species Functional Group

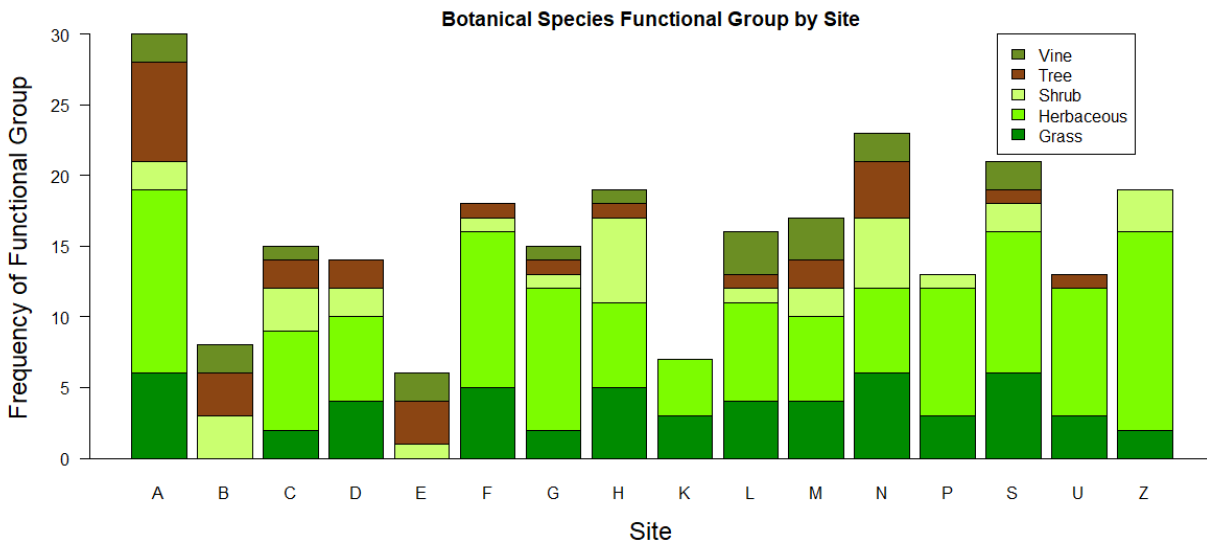


Figure 3.40. Stacked bar graph of terrestrial vegetative species' functional group for each site. Functional group was categorized as either vine, tree, shrub, herbaceous, or grass species.

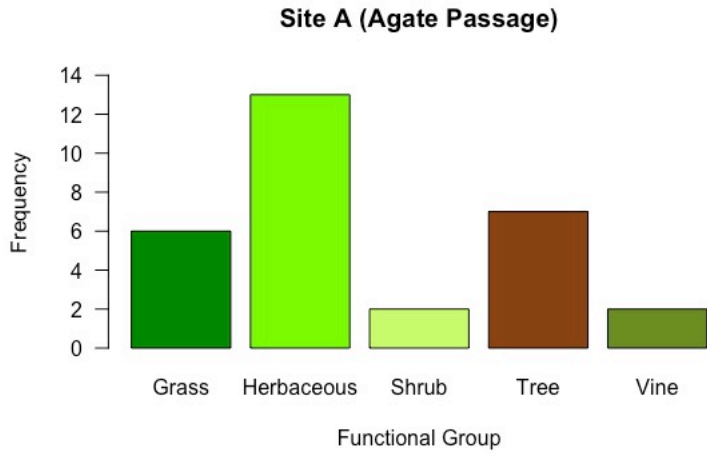


Figure 3.41. Bar graph of terrestrial vegetative species' functional group for Site A.

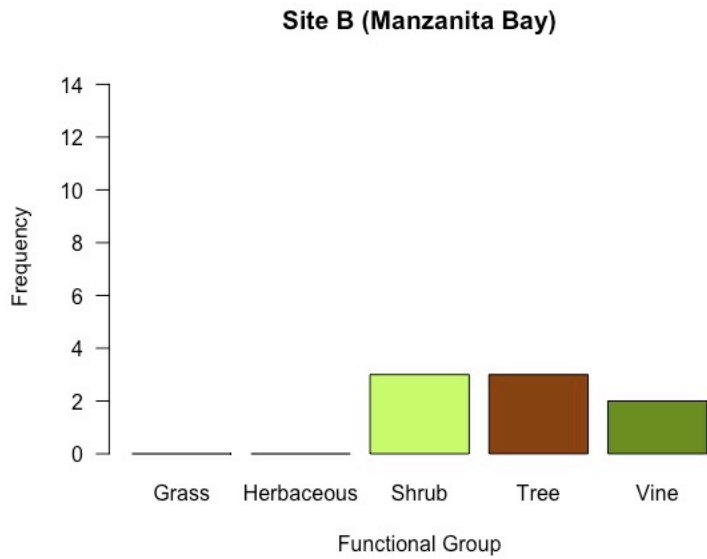


Figure 3.42. Bar graph of terrestrial vegetative species' functional group for Site B. Site B lacked grass and herbaceous plants.

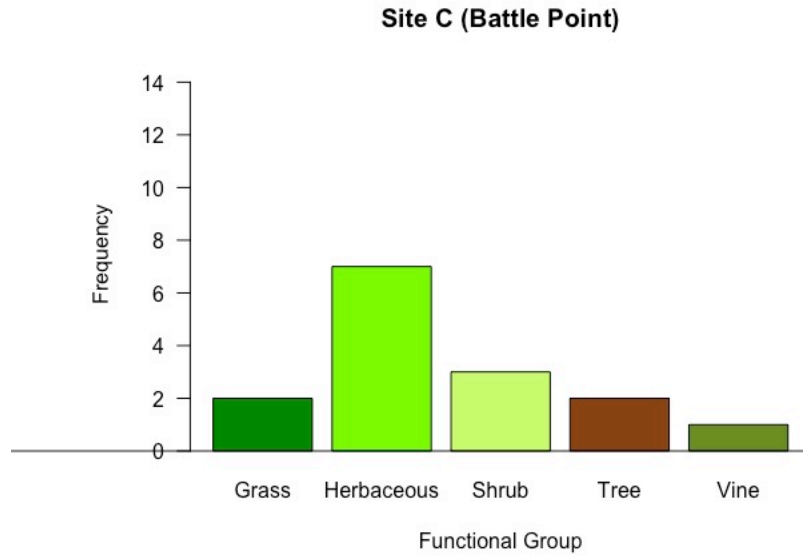


Figure 3.43. Bar graph of terrestrial vegetative species' functional group for Site C.

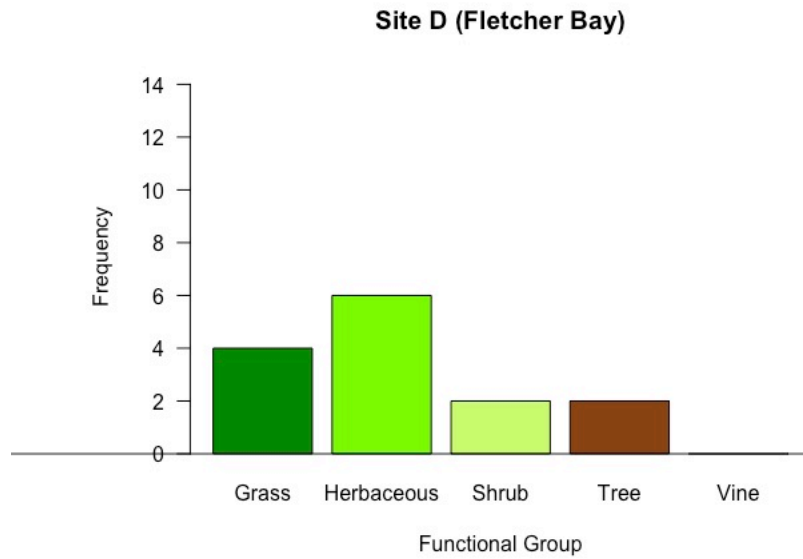


Figure 3.44. Bar graph of terrestrial vegetative species' functional group for Site D. Site D lacked vines.

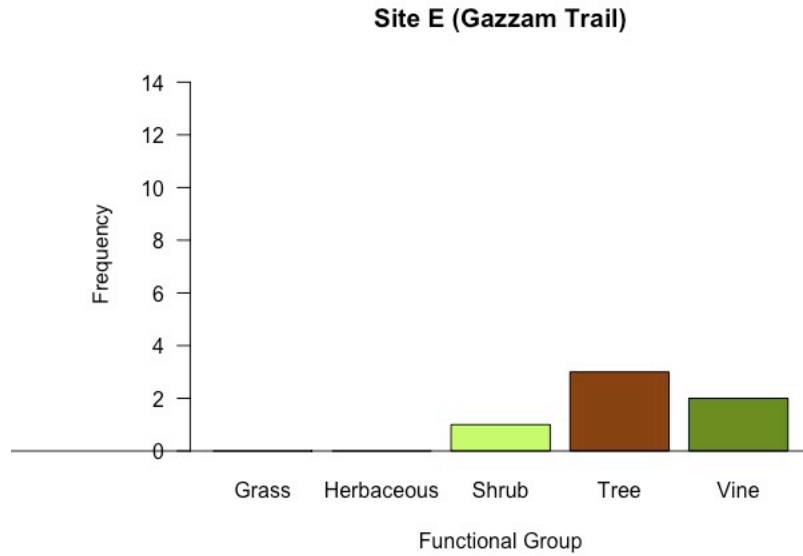


Figure 3.45. Bar graph of terrestrial vegetative species' functional group for Site E. Site E lacked grass and herbaceous plants.

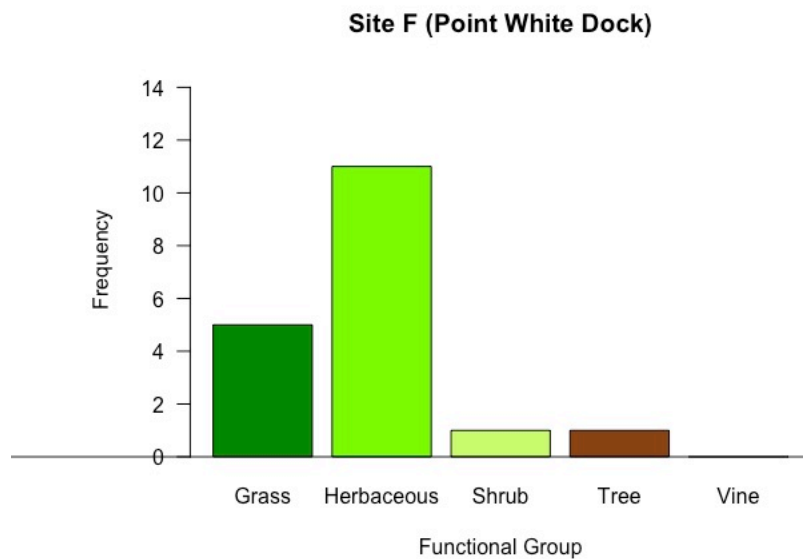


Figure 3.46. Bar graph of terrestrial vegetative species' functional group for Site F. Site F lacked vines.

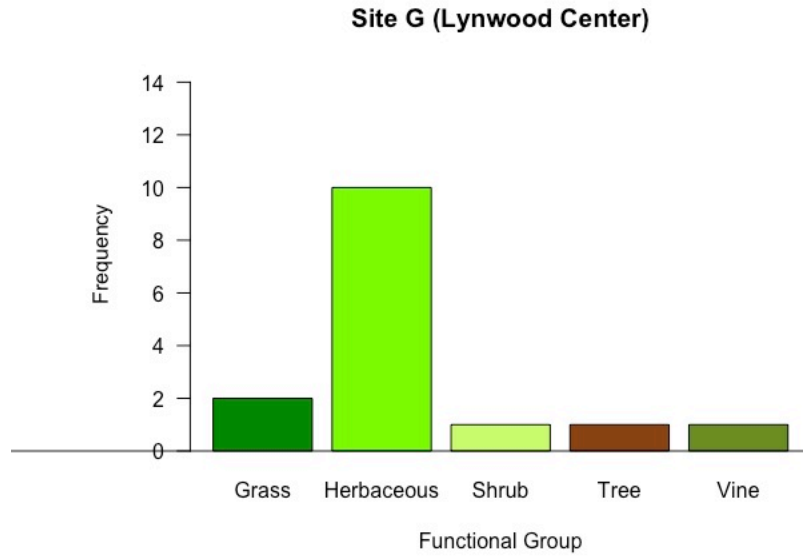


Figure 3.47. Bar graph of terrestrial vegetative species' functional group for Site B. Site B lacked grass and herbaceous plants.

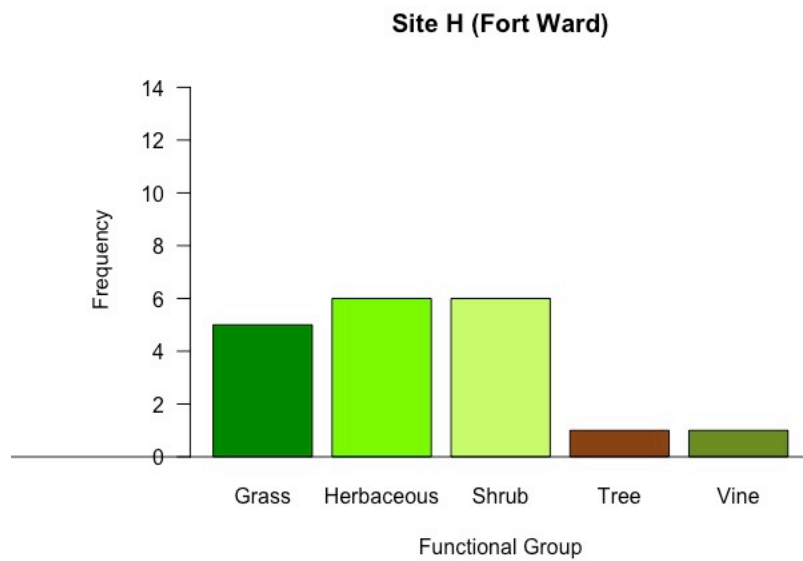


Figure 3.48. Bar graph of terrestrial vegetative species' functional group for Site H.

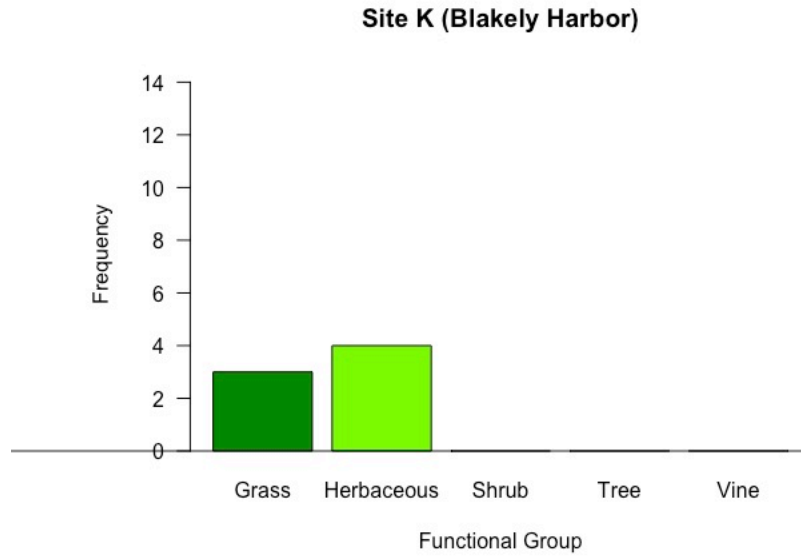


Figure 3.49. Bar graph of terrestrial vegetative species' functional group for Site K. Site K lacked shrubs, trees, and vines.

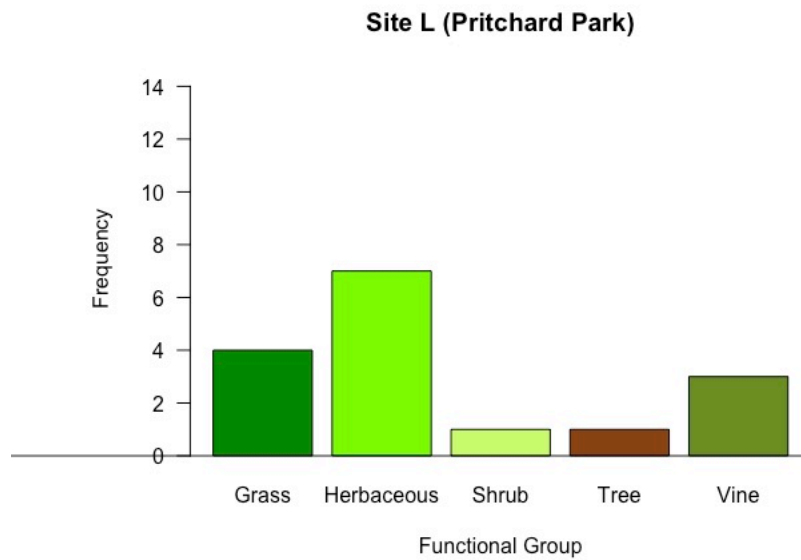


Figure 3.50. Bar graph of terrestrial vegetative species' functional group for Site L..

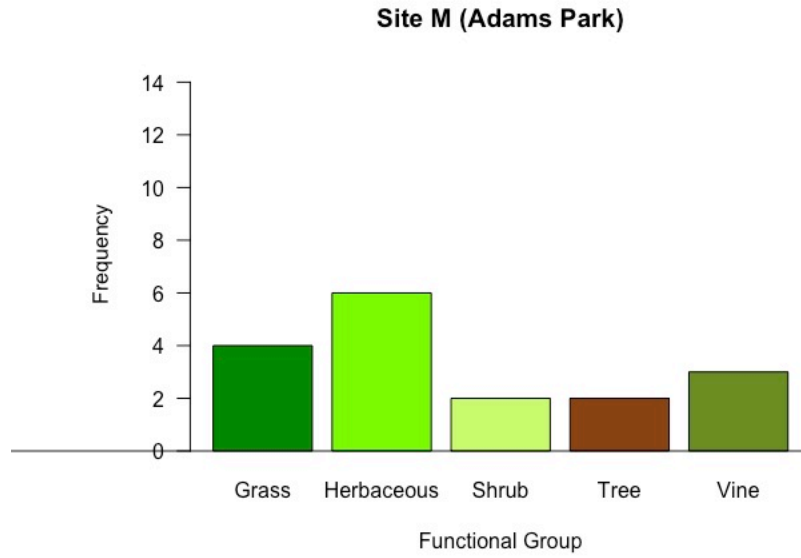


Figure 3.51. Bar graph of terrestrial vegetative species' functional group for Site M.

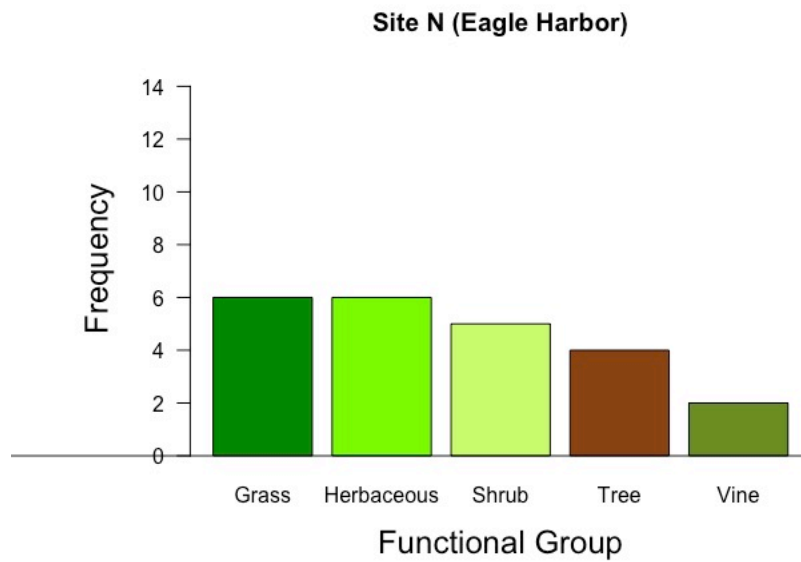


Figure 3.52. Bar graph of terrestrial vegetative species' functional group for Site N.

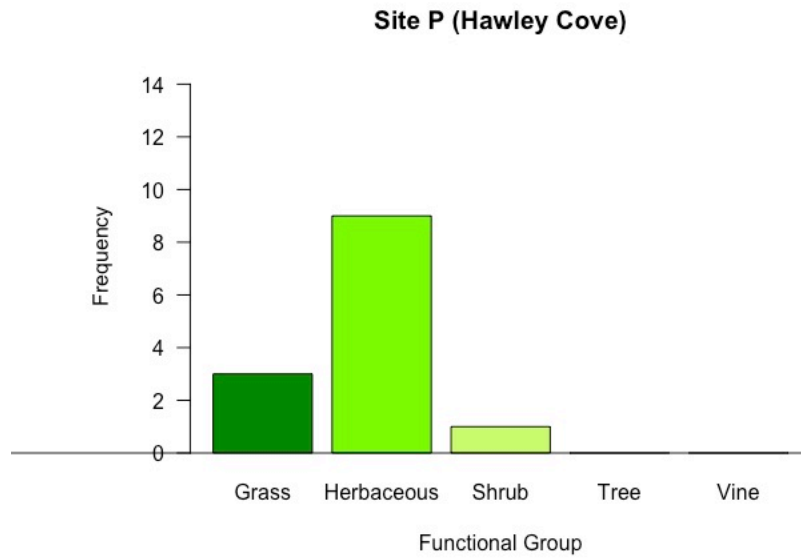


Figure 3.53. Bar graph of terrestrial vegetative species' functional group for Site P. Site P lacked trees and vines.

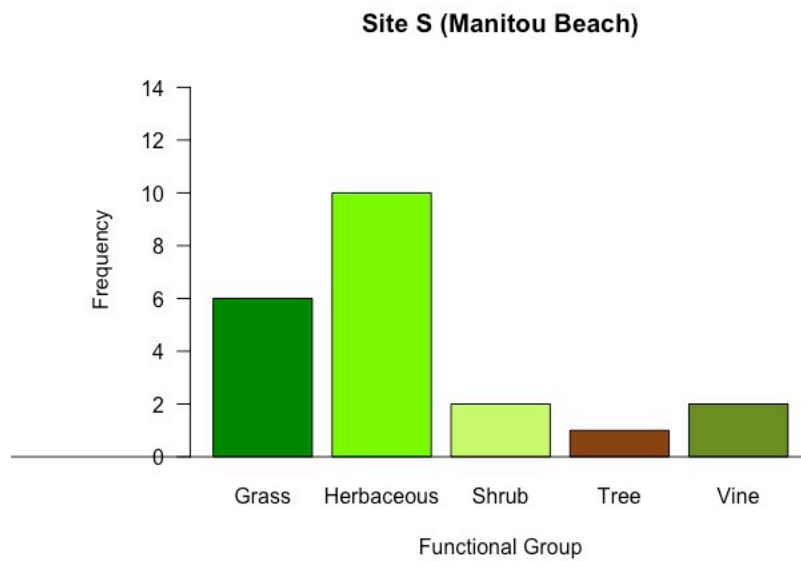


Figure 3.54. Bar graph of terrestrial vegetative species' functional group for Site S.

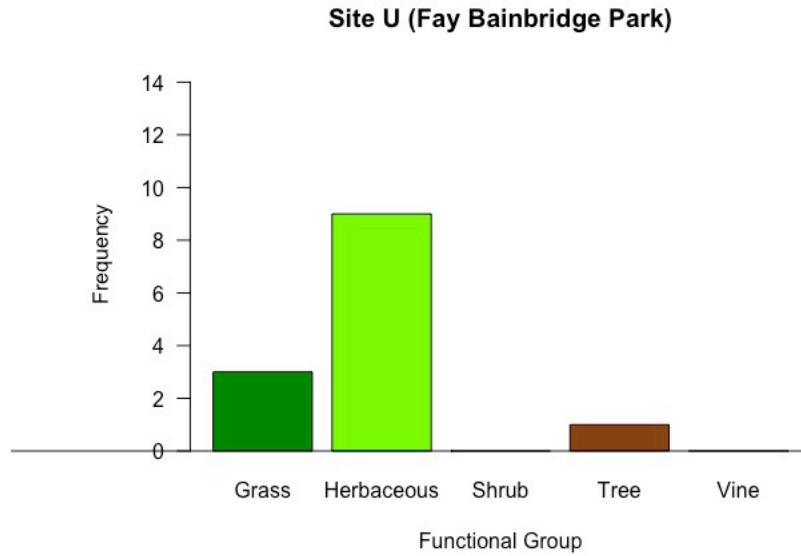


Figure 3.55. Bar graph of terrestrial vegetative species' functional group for Site U. Site U lacked shrubs and vines.

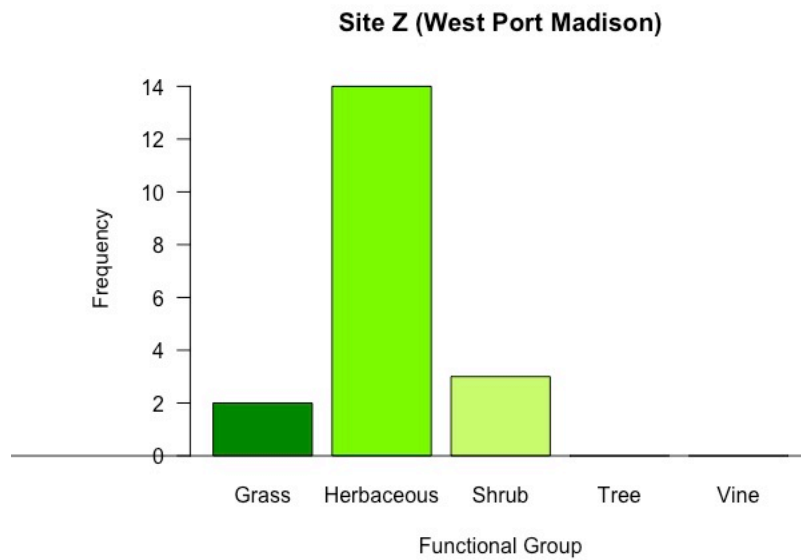


Figure 3.56. Bar graph of terrestrial vegetative species' functional group for Site Z. Site Z lacked trees and vines.

Beach Wrack

Wrack Line Composition

This section includes beach wrack line composition for all sites. Data is displayed as a bar graph for easier understanding of this year's data, but the best method for long-term monitoring would be a scatter plot of average percent cover for each factor (green algae, brown algae, red algae, dead algae, eelgrass, terrestrial plants, and trash). More data points are needed before this plot can be generated. Wrack line composition is important to monitor over time as it indicates beach and water health.

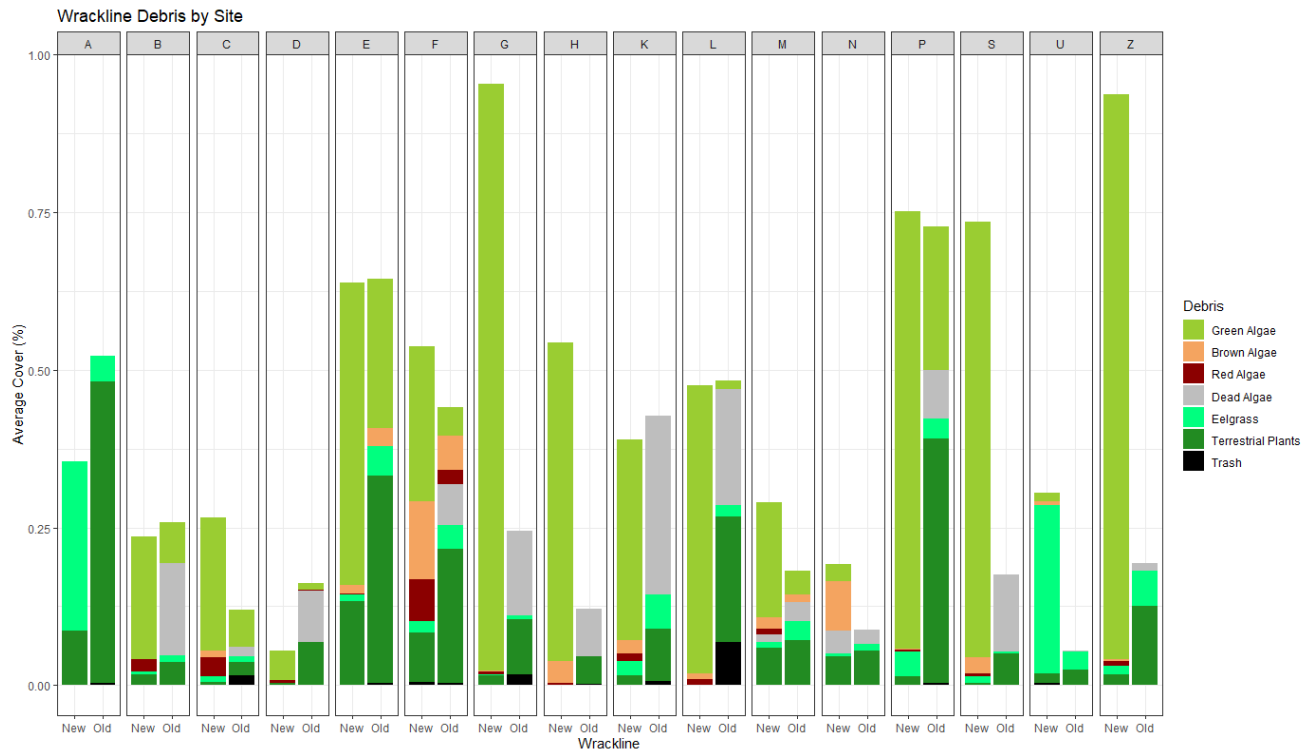


Figure 3.57. Stacked bar plot of the wrack lines average debris observed at each site (n=10). Site L had the most trash found, followed by sites G and C. Green, red and brown algae were more commonly found in the new wrack lines; while terrestrial plants, dead algae, and trash were more commonly found in old wrack lines.

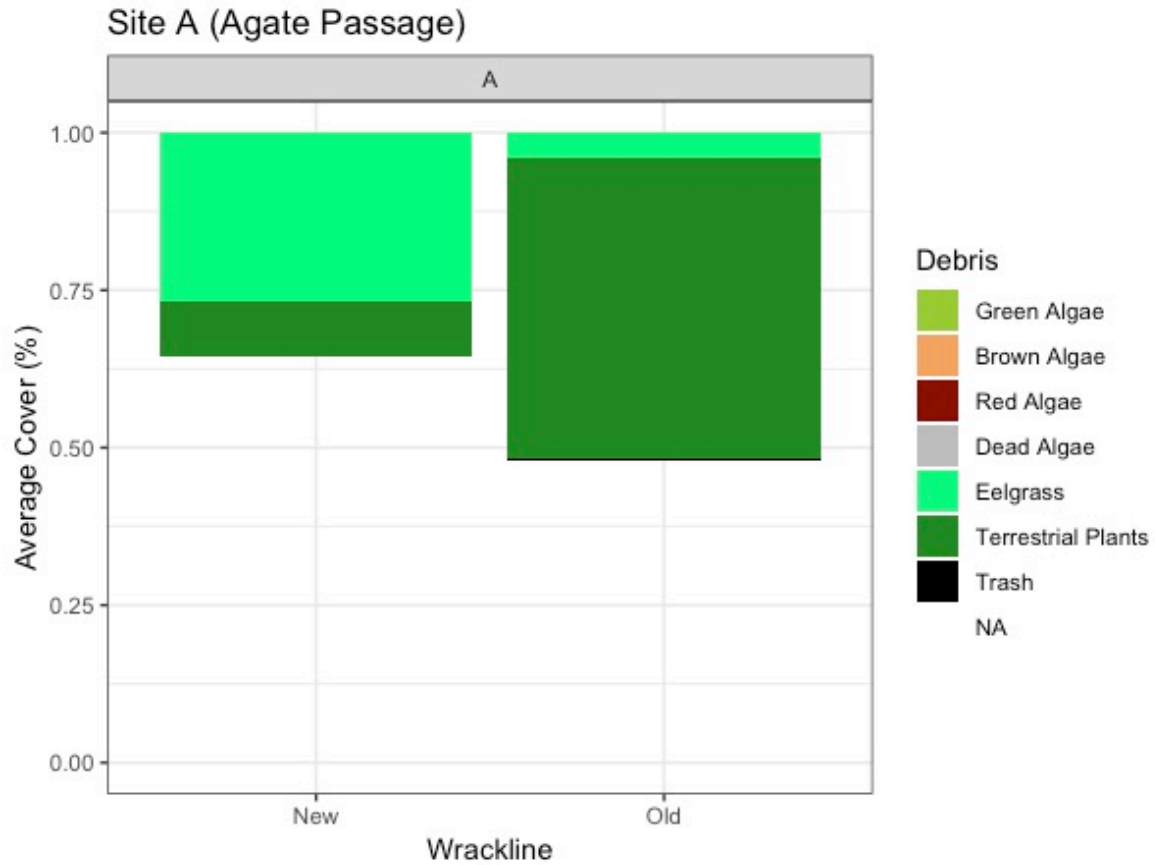


Figure 3.58. Stacked bar plot of the wrack lines average debris observed at Site A (n=10). A majority of the new wrack consisted of eelgrass. The old wrack consisted mainly of terrestrial plants. The high percentage of eelgrass is concerning as it may indicate a larger loss of eelgrass habitat.

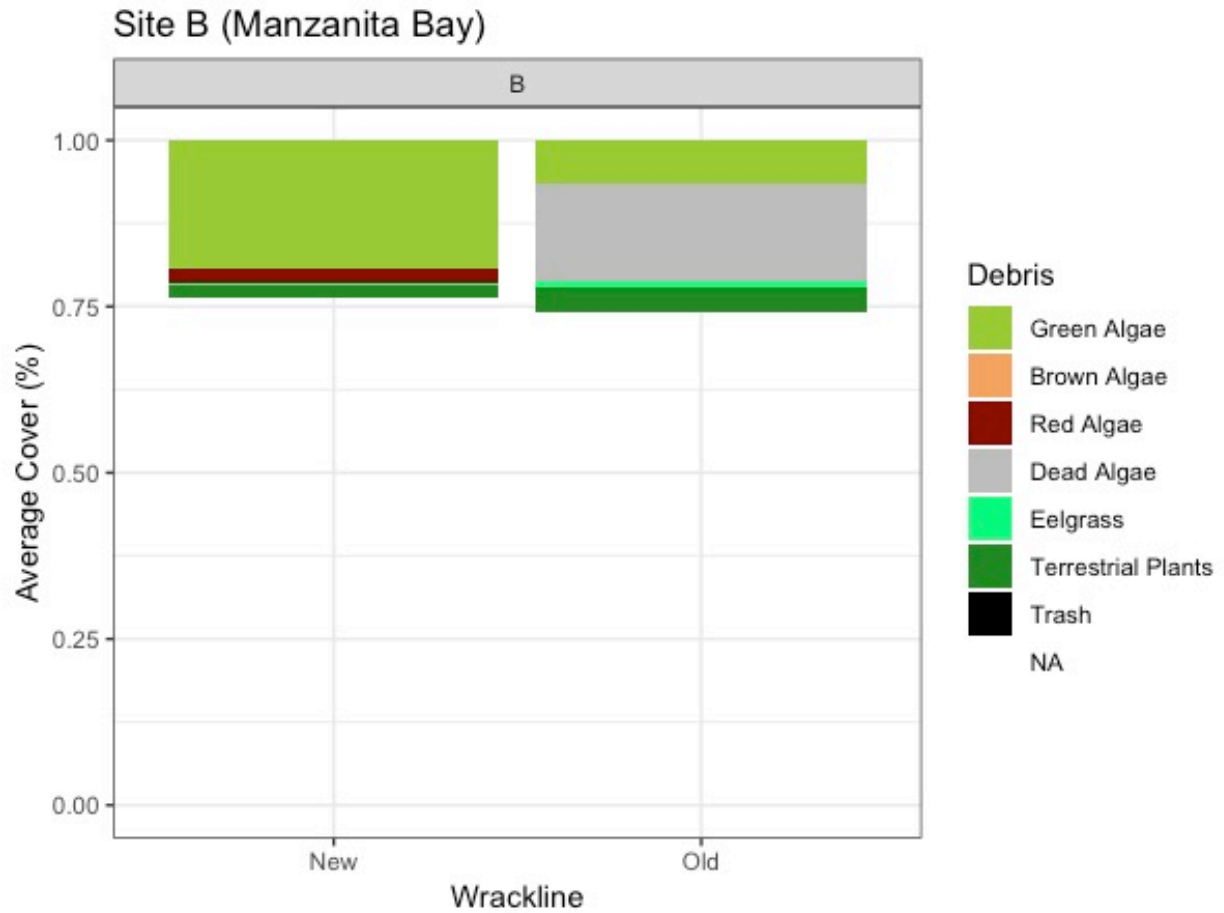


Figure 3.59. Stacked bar plot of the wrack lines average debris observed at Site B (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of dead algae and green algae.

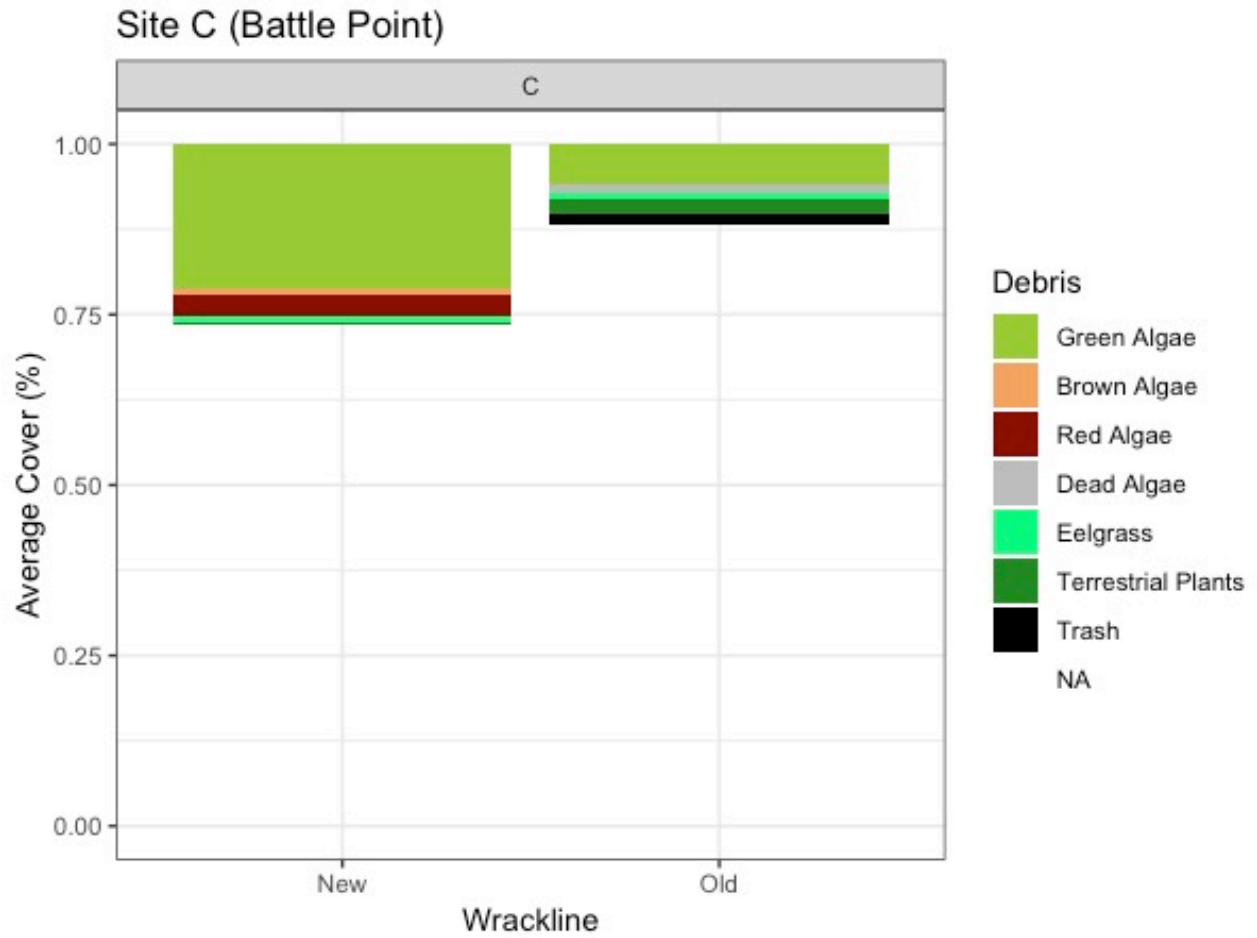


Figure 3.60. Stacked bar plot of the wrack lines average debris observed at Site C (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly green algae as well.

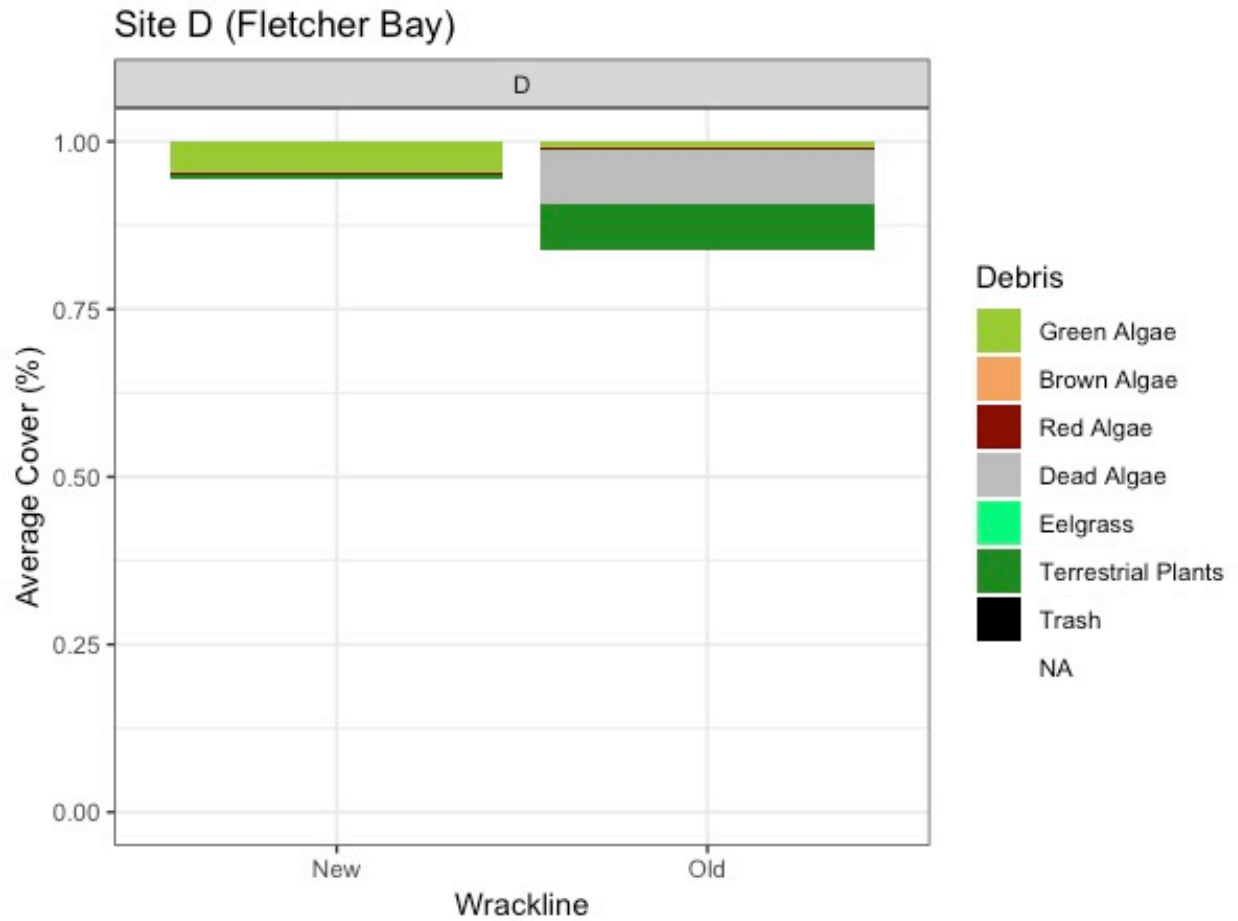


Figure 3.61. Stacked bar plot of the wrack lines average debris observed at Site D (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of dead algae and terrestrial plants.

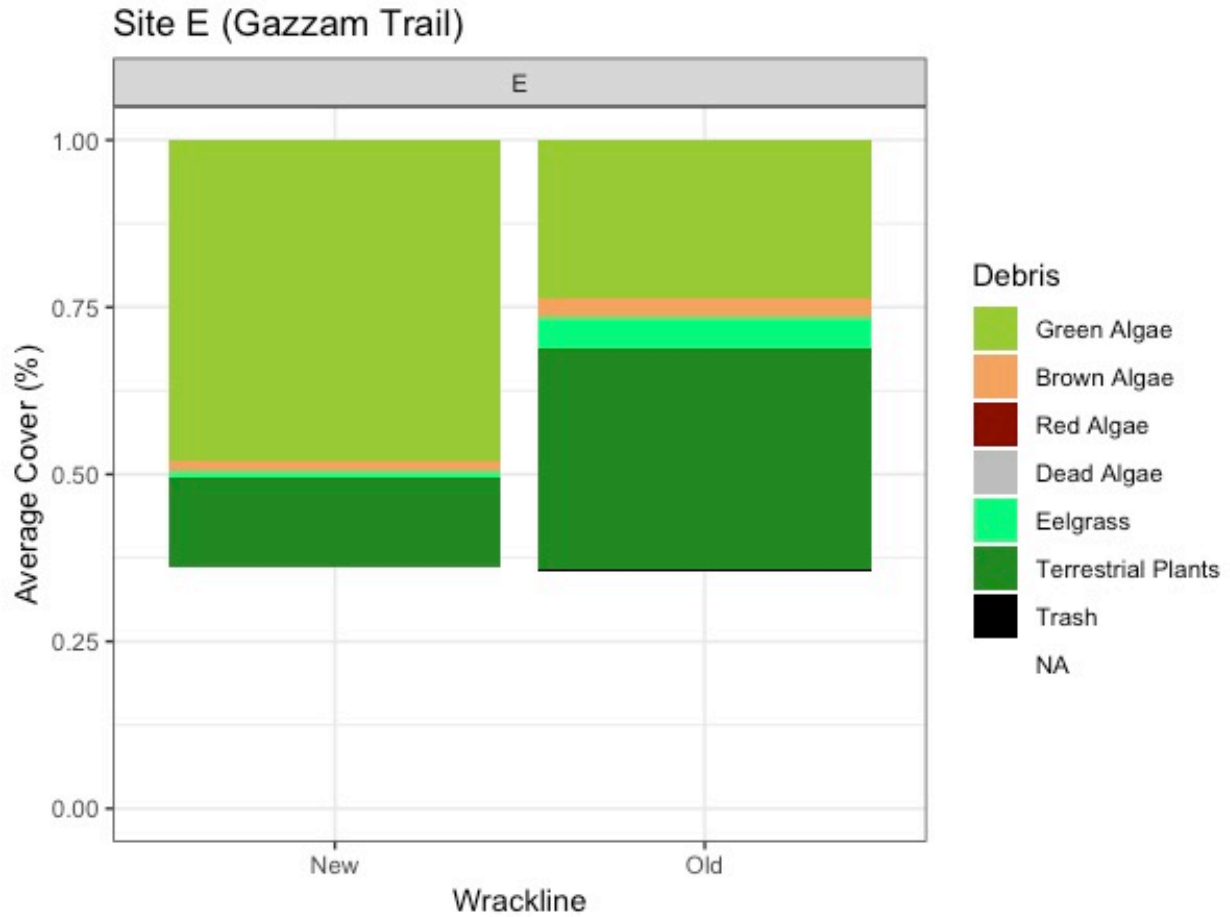


Figure 3.62. Stacked bar plot of the wrack lines average debris observed at Site E (n=10). A majority of the new wrack consisted of green algae and terrestrial plants. The old wrack consisted mainly of green algae and terrestrial plants as well.

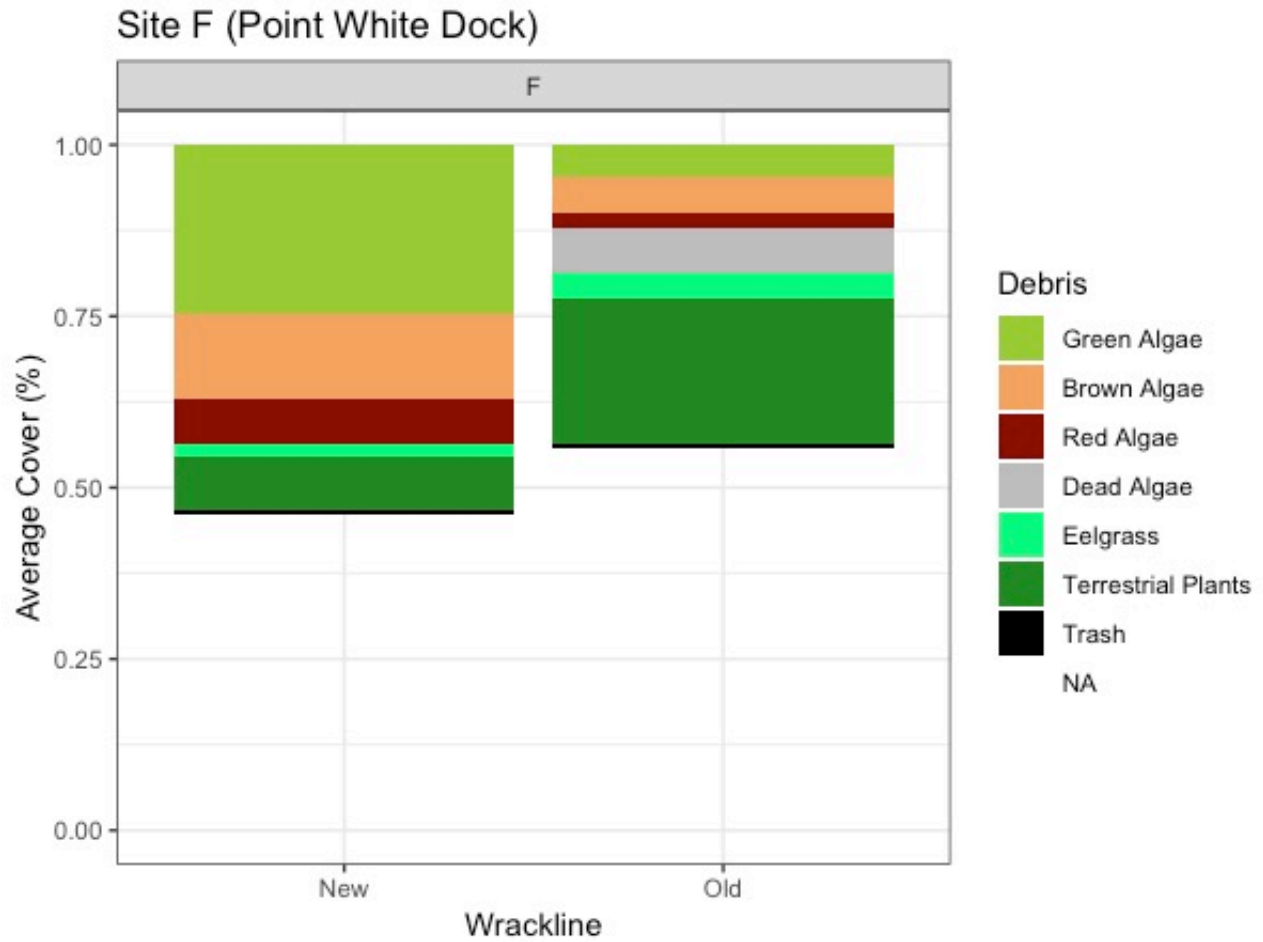


Figure 3.63. Stacked bar plot of the wrack lines average debris observed at Site F (n=10). A majority of the new wrack consisted of green algae, brown algae, red algae and terrestrial plants. The old wrack consisted mainly of terrestrial plants.

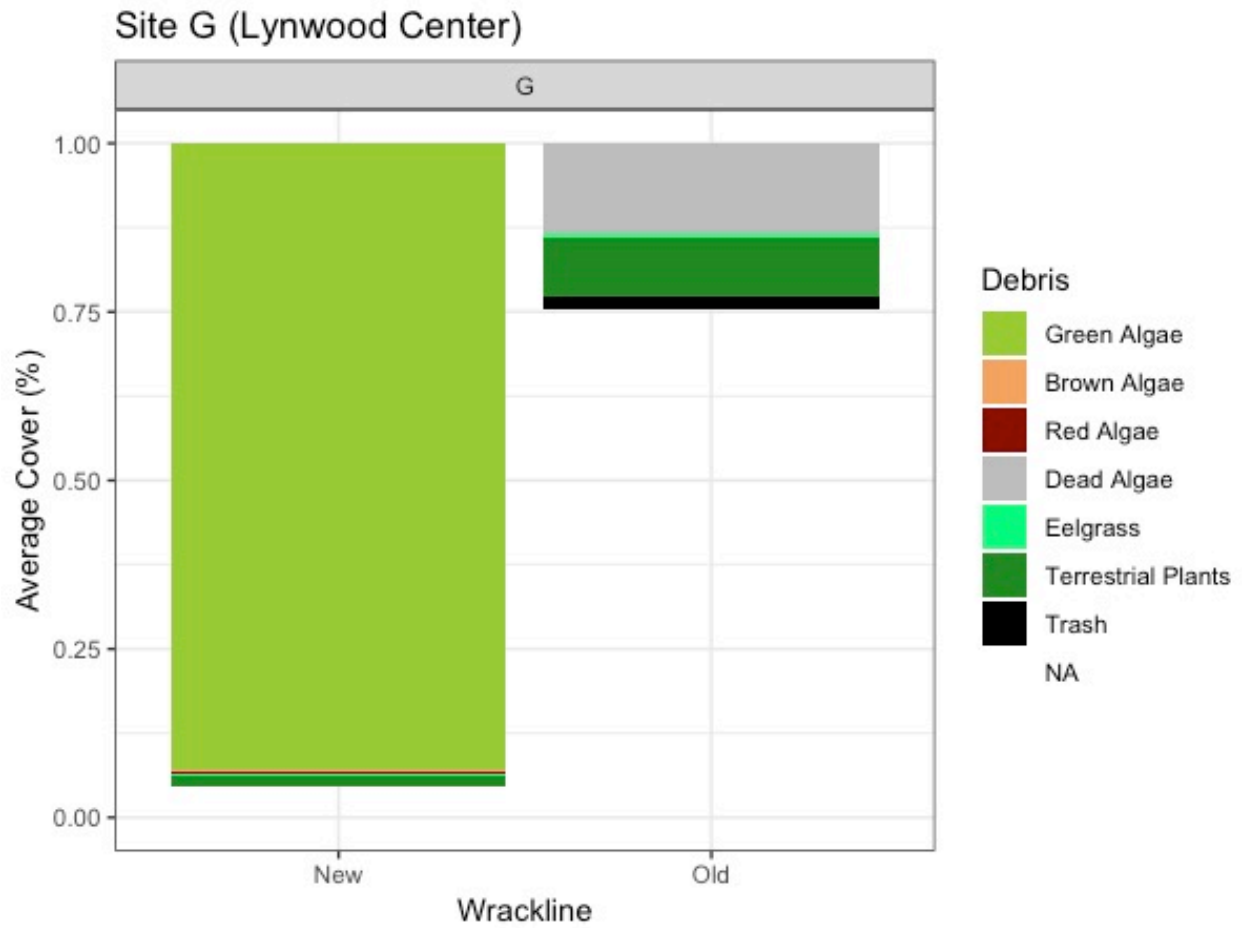


Figure 3.64. Stacked bar plot of the wrack lines average debris observed at Site G (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of dead algae and terrestrial plants.

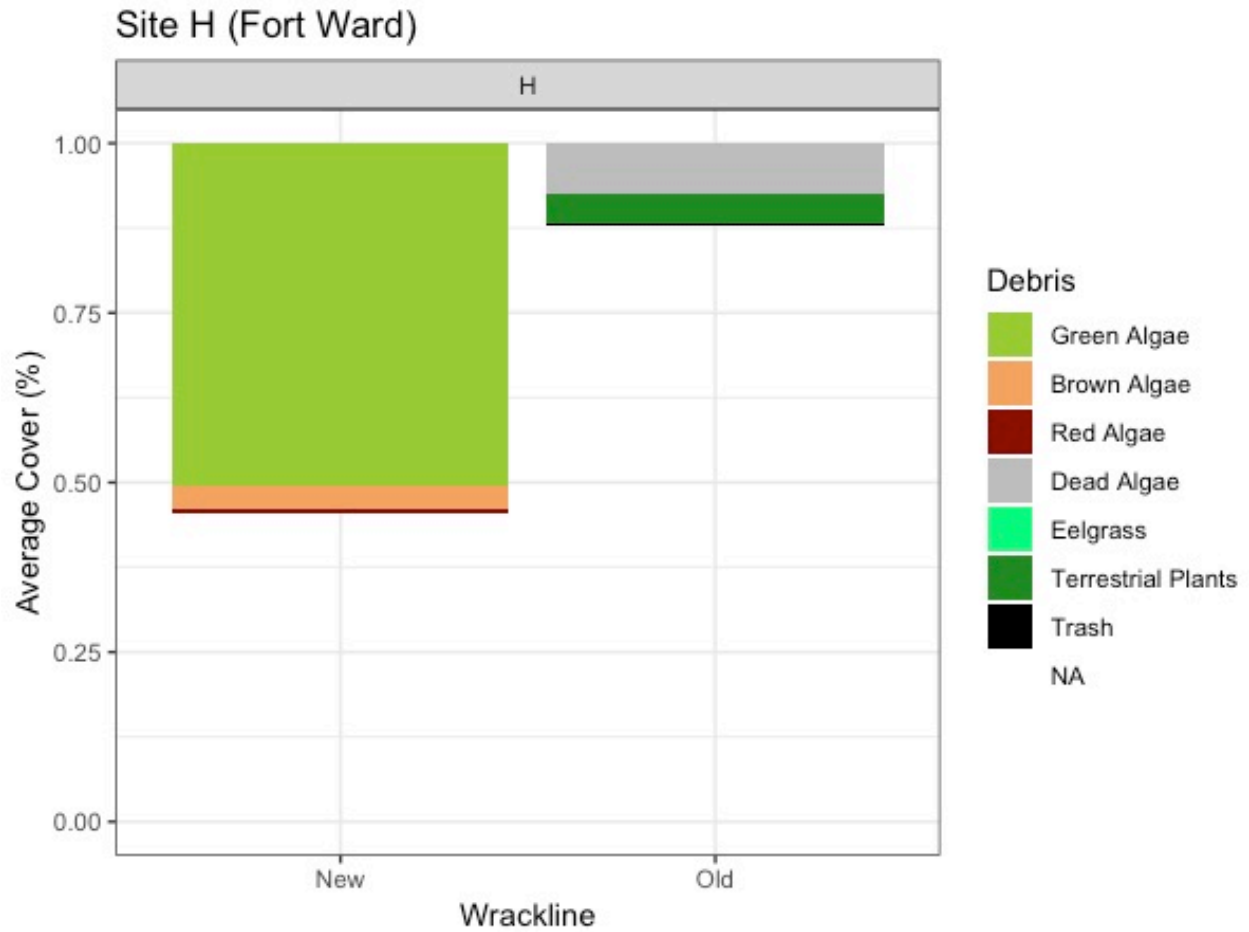


Figure 3.65. Stacked bar plot of the wrack lines average debris observed at Site H (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of dead algae and terrestrial plants.

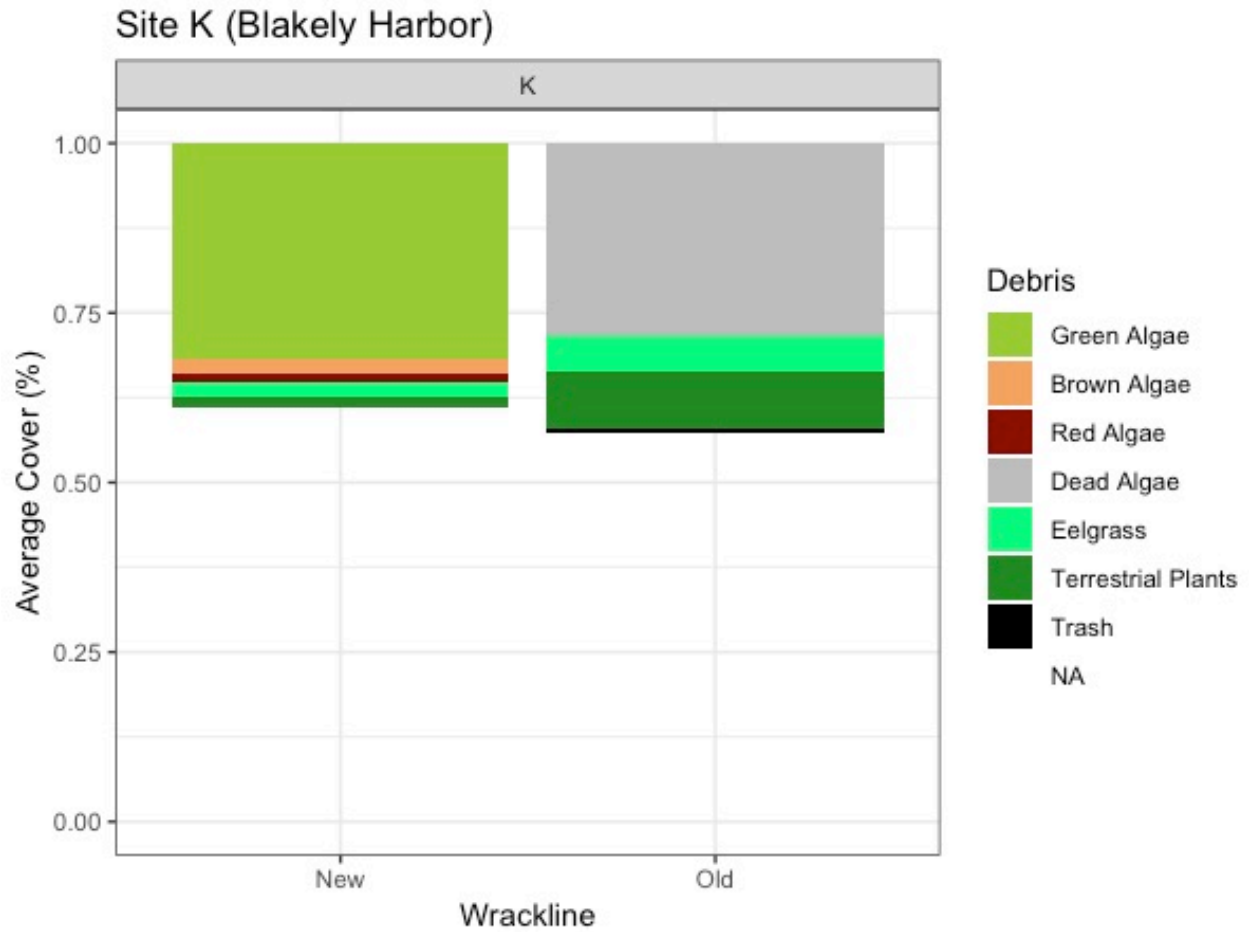


Figure 3.66. Stacked bar plot of the wrack lines average debris observed at Site K (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of dead algae, eelgrass and terrestrial plants.

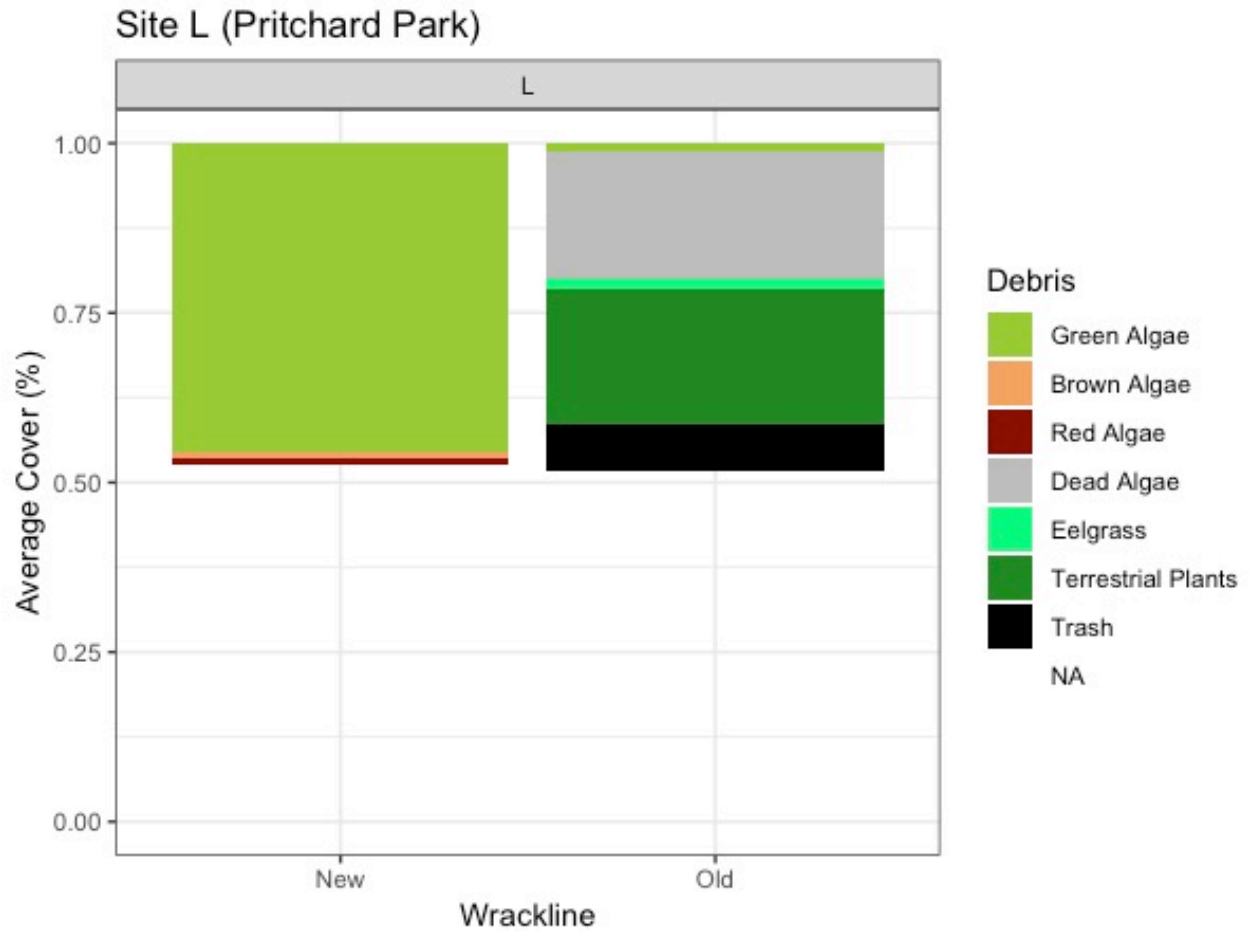


Figure 3.67. Stacked bar plot of the wrack lines average debris observed at Site L (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of dead algae and terrestrial plants.

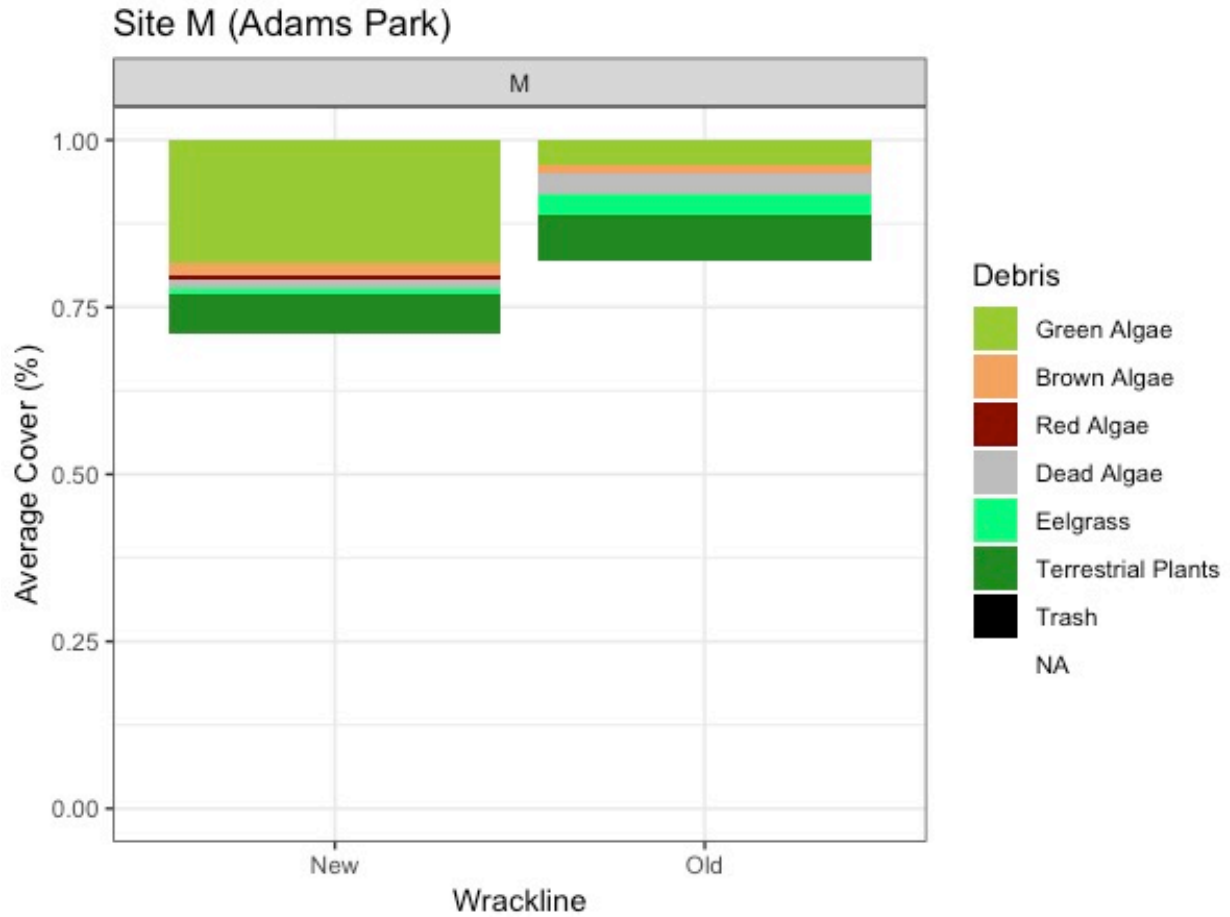


Figure 3.68. Stacked bar plot of the wrack lines average debris observed at Site M (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted a mix of green algae, brown algae, dead algae, eelgrass, and terrestrial plants.

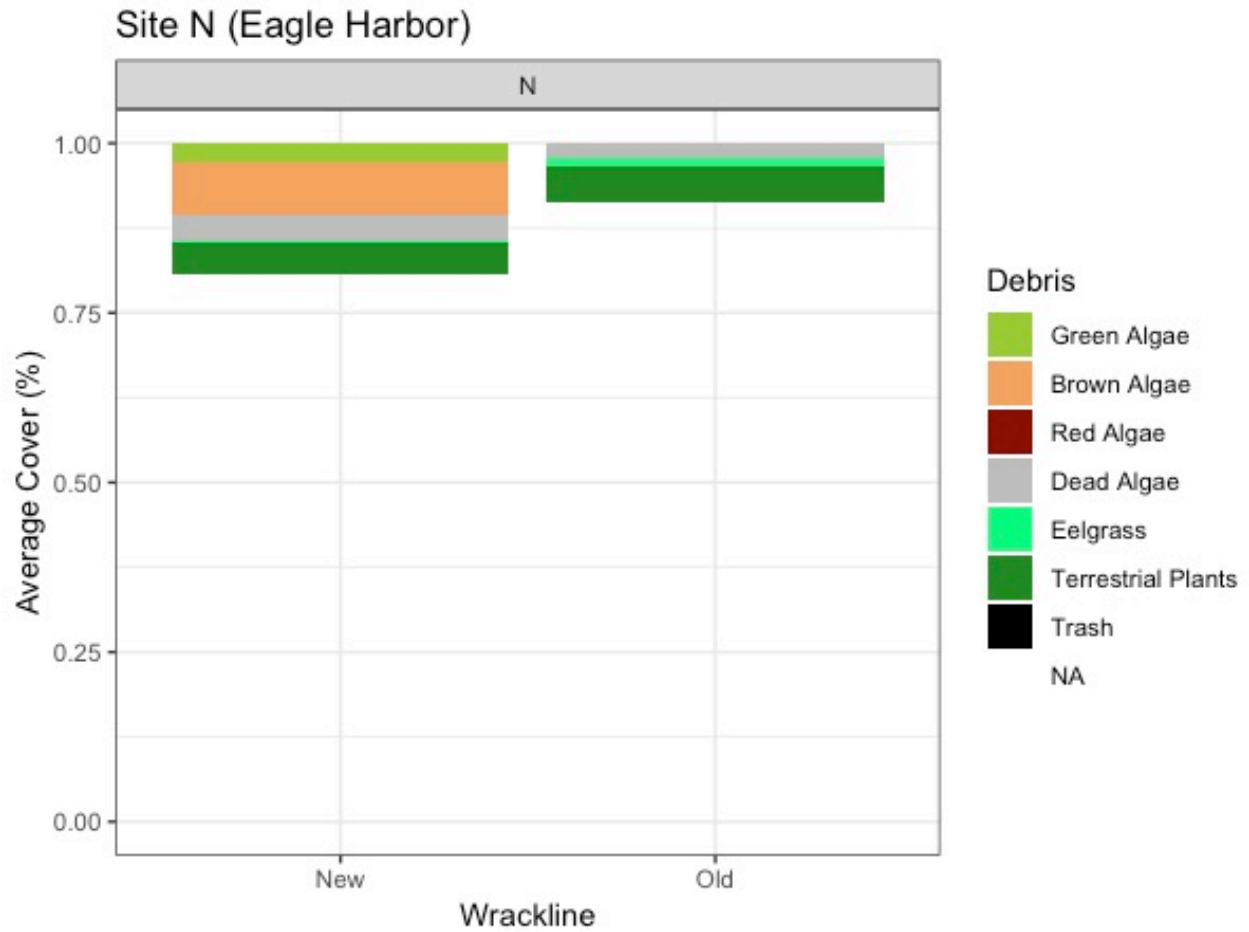


Figure 3.69. Stacked bar plot of the wrack lines average debris observed at Site N (n=10). A majority of the new wrack consisted of a mix of green algae, brown algae, dead algae and terrestrial plants. The old wrack consisted mainly of terrestrial plants.

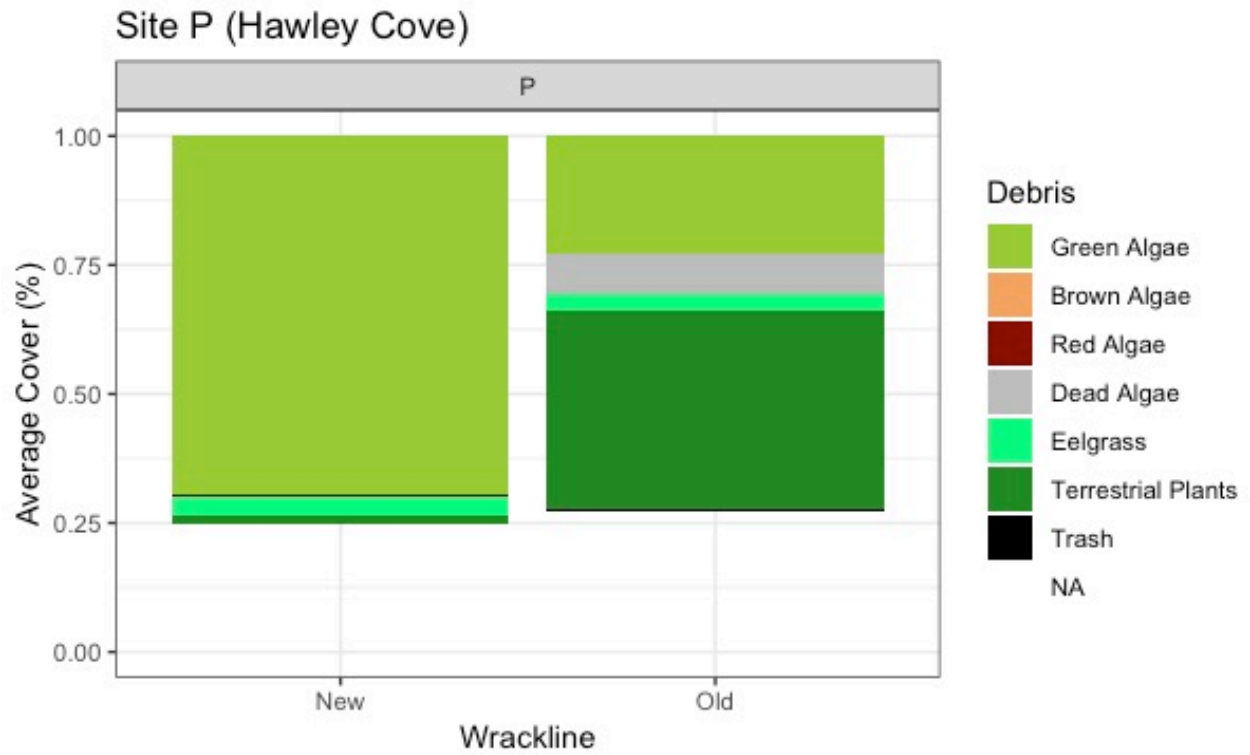


Figure 3.70. Stacked bar plot of the wrack lines average debris observed at Site P (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of green algae and terrestrial plants.

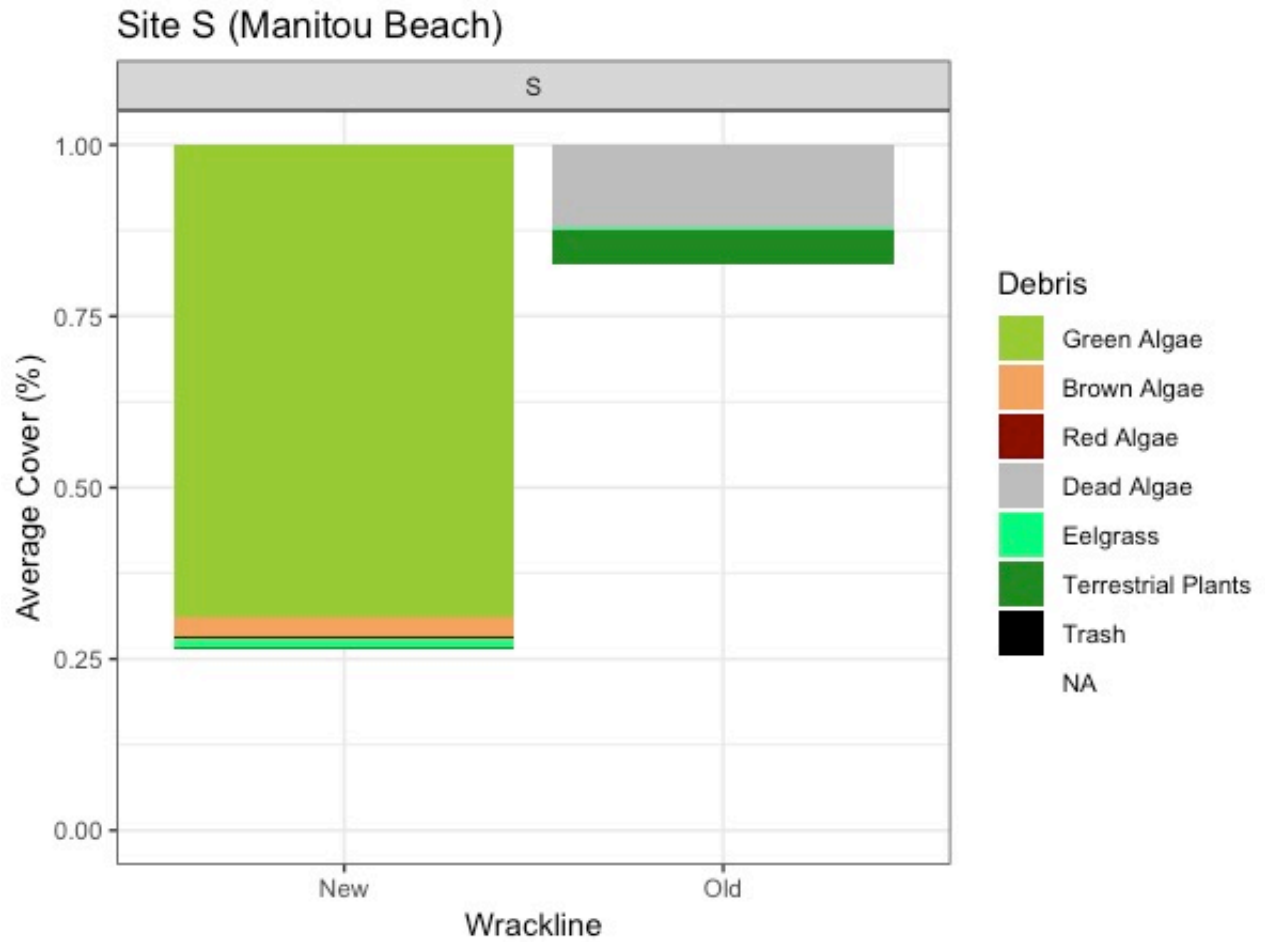


Figure 3.71. Stacked bar plot of the wrack lines average debris observed at Site A (n=10). A majority of the new wrack consisted of eelgrass. The old wrack consisted mainly of terrestrial plants.

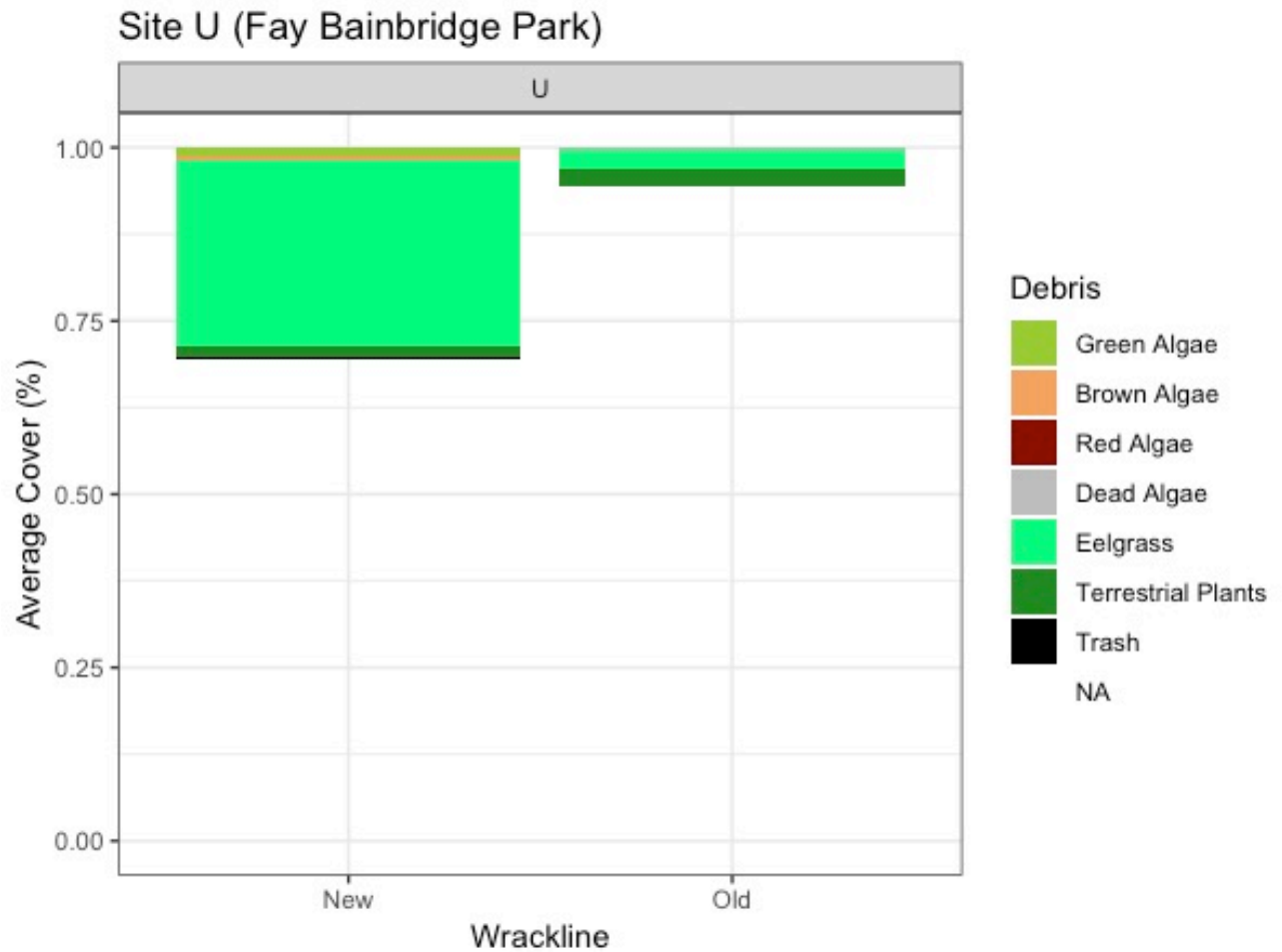


Figure 3.72. Stacked bar plot of the wrack lines average debris observed at Site U (n=10). A majority of the new wrack consisted of eelgrass. The old wrack consisted mainly of eelgrass and terrestrial plants. The high percentage of eelgrass is concerning as it may indicate a larger loss of eelgrass habitat.

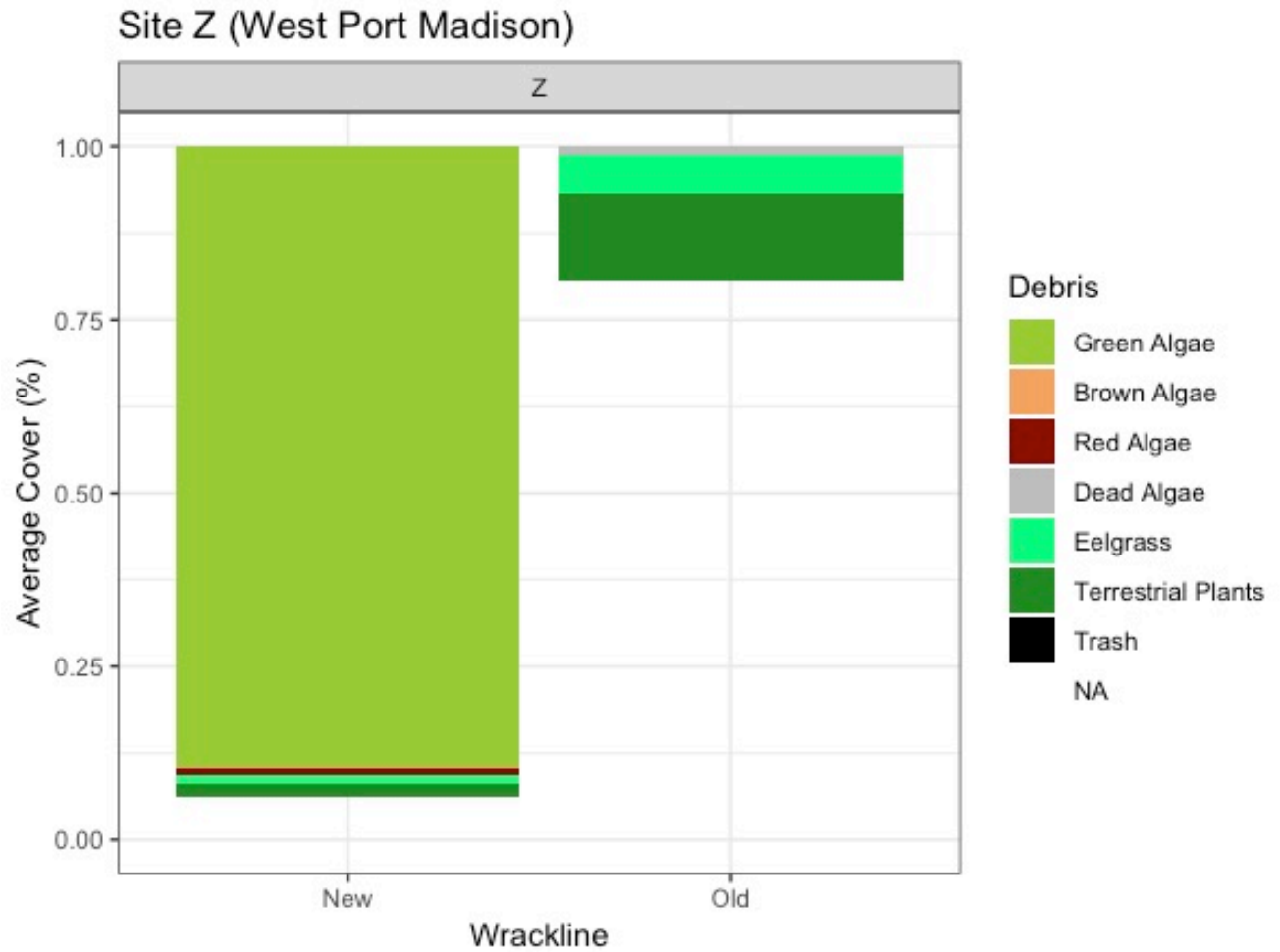


Figure 3.73. Stacked bar plot of the wrack lines average debris observed at Site Z (n=10). A majority of the new wrack consisted of green algae. The old wrack consisted mainly of terrestrial plants.

Algal Density Between Wrack Lines

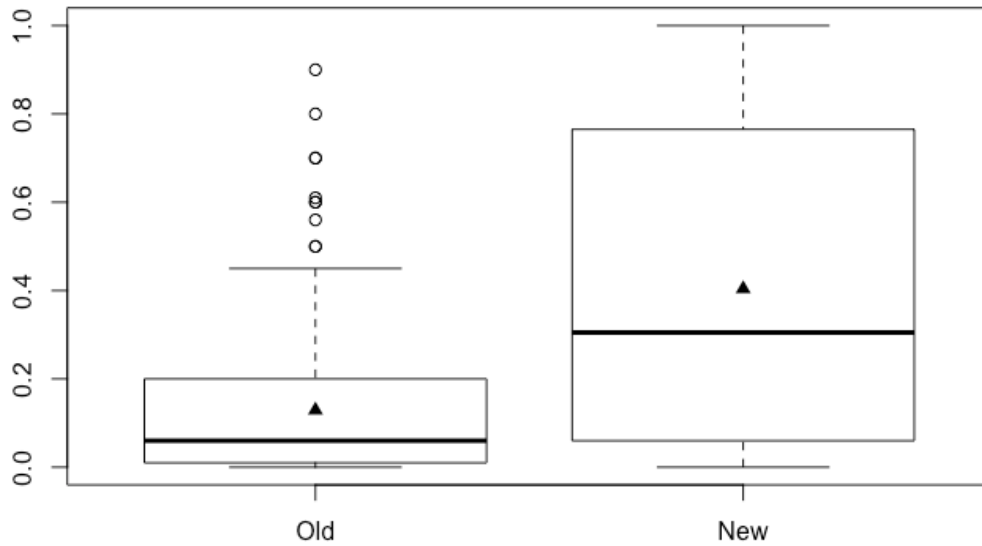


Figure 3.74. Comparison of total algal density in old and new wrack lines. We performed a Wilcoxon Rank Sum test in R. Results showed that mean, living algal density is greater in the new wrack lines than in the old wrack lines ($p=2.95e-12$). Algal density is important to monitor in wrack lines as it can indicate harmful algal blooms in the water.

Water Chemistry

This section includes the results of water chemistry parameters for sites B, D, G, K, M, S, and Z. Each parameter was tested with a Shapiro-Wilk test for normality, Levene's test for variance, and then either an ANOVA followed by a Tukey's Honest Significant Difference post hoc or a Kruskal-Wallis rank sum test followed by a Dunn test post hoc with the p-values adjusted with the Benjamini-Hochberg method.

Temperature

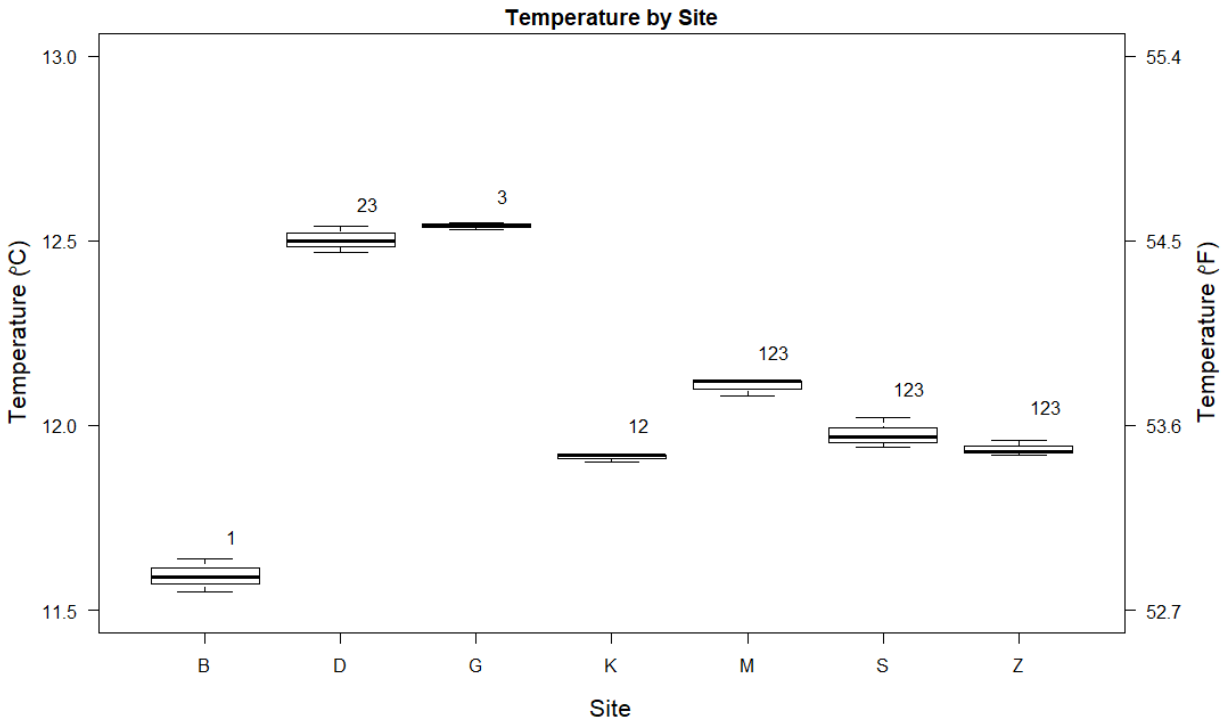


Figure 3.75. Box plot of the temperature found at each site ($n=3$). The axes are in Celsius from 11.5 to 13.0 degrees (left y-axis) and in Fahrenheit from 52.7 to 55.4 degrees (right y-axis). The numbers within the plot represent the significance between sites, where if two sites do not share a number with each other than they are significantly different from one another ($X^2=19.222$, $df=6$, $p=0.0038$). For example, site B is significantly different from D and G; and site G is significantly different than sites B and K.

Phosphate

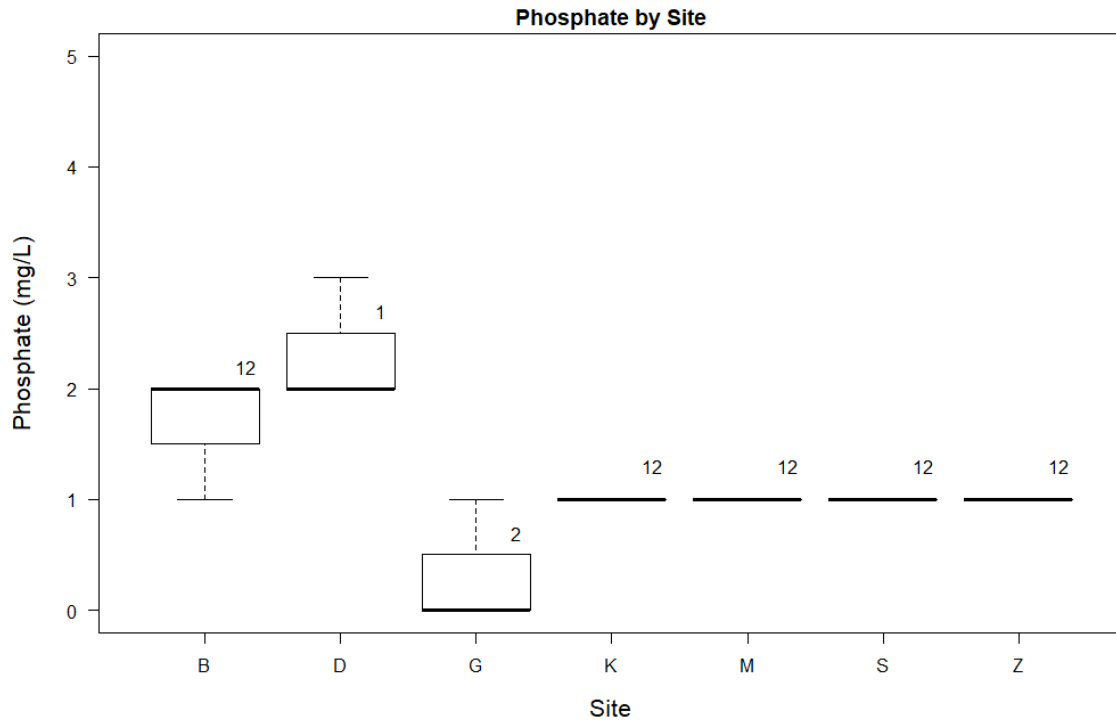


Figure 3.76. Box plot of the phosphate found at each site ($n=3$). The numbers within the plot represent the significance between sites, where if two sites do not share a number with each other then they are significantly different from one another ($X^2=16.245$, $df=6$, $p=0.0125$). Thus, site D and G are significantly different than each other, and are also significantly different than the other sites.

Nitrate

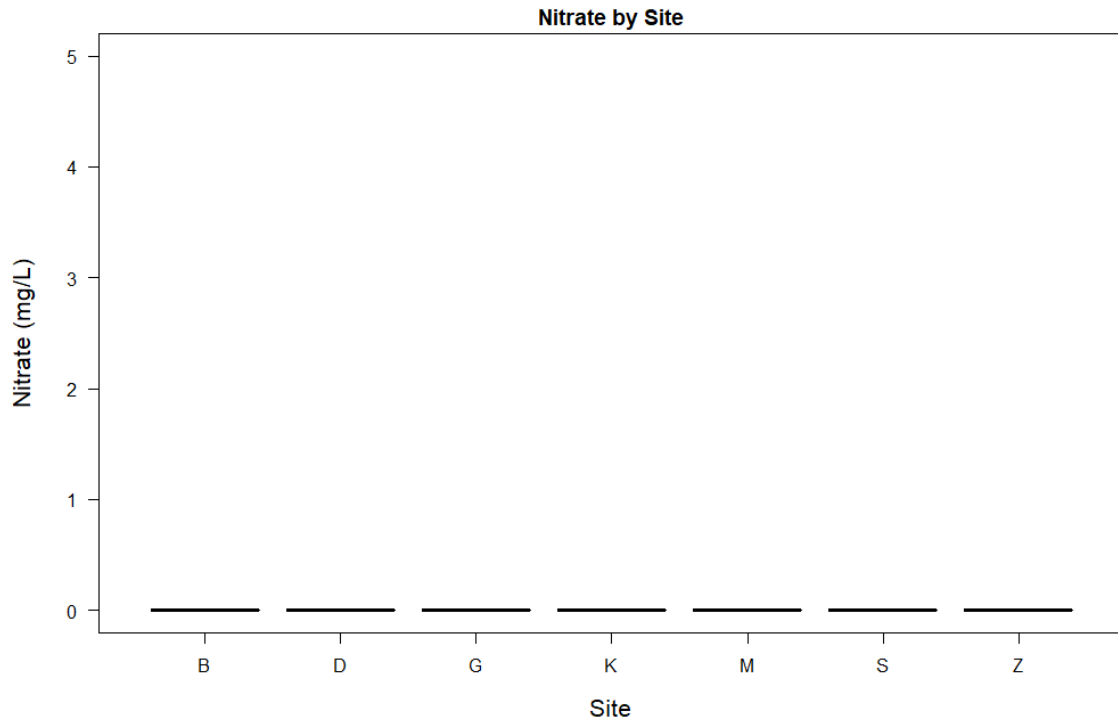


Figure 3.77. Box plot of the nitrate found at each site (n=3). Nitrate levels were 0mg/L at each site. This would be useful to monitor seasonally with stormwater runoff changes, as nitrate is a major factor for harmful algal blooms.

CHAPTER 4: CONCLUSION

The City of Bainbridge Island's SMP aims to protect the City's shoreline functions and values through regulations and restoration strategies. From summer to fall, 2019, WWU faculty and students worked with the City of Bainbridge Island to develop a shoreline monitoring methodology that can be used to track changes in the shoreline over time and, thus, offer insight into the effectiveness of the SMP. Additionally, the WWU field team collected a baseline set of data using the recommended methods.

The recommended protocols for monitoring are largely based off of the Shoreline Monitoring Toolbox (Toft et al., 2015), and these protocols can be found in Appendix 1. The protocols for water chemistry and beach profile can be found in Chapter 2, along with additional considerations for each recommended protocol.

The field team collected a set of baseline data at 16 Bainbridge Island sites. The raw data can be found in the 'Bainbridge Island Shoreline Data 2019 Spreadsheet' (provided to the City). Beach profile, sessile biology, vegetation, log line, sediment size, wrack line, water chemistry, and photo points are all recommended for continued monitoring.

In the future, the most informative figures will show changes over time at each site and comparisons between parameters at different sites.

The information in this report can be used by City of Bainbridge Island employees and volunteers to monitor changes in the shoreline over time. The data collected at 16 sites during the summer and fall of 2019 can be used as a baseline dataset to compare with future data and track changes over time. As more monitoring data is collected, this information will offer insight into the effectiveness of the City's SMP.

BIBLIOGRAPHY

1. Tidal Datums. (n.d.) NOAA. Retrieved from: https://tidesandcurrents.noaa.gov/datum_options.html.
2. Toft, J., Litle, K., and Adams, J. 2015. Shoreline Monitoring Toolbox. Washington Sea Grant. Website: wsg.washington.edu/toolbox

APPENDIX 1

Protocol Sheets

The following shoreline monitoring protocol one-pagers are from the Shoreline Monitoring Toolbox (Toft et al., 2015) and can be used by City of Bainbridge Island employees and volunteers.

Beach Profile Protocols

Beach profile

Characterizing the beach profile provides valuable information on the physical structure of the beach. This may change depending on winter storms, restoration activities, and shoreline armoring. The variability in beach topography and slope is indicative of physical forces acting on the beach and can affect associated algae and invertebrates.

Materials

- 100 m transect tape and wired flags
- Laser level
- 14' Stadia rod

Sampling Summary

- 100 m transect perpendicular to shore, from top of the berm or toe of bluff/armoring down to MLLW
- Take an elevation measurement every 2 meters and at key features
- Record elevation at the water line and note the time, adjust profile elevations based on the nearest [NOAA station measurements](#), or alternatively adjust elevations to that of a [benchmark](#)

Scale of Effort

\$\$ Cost – medium, supply costs are moderate, data are all field-based

\$ People – low, 2-3 people can establish transects and record profile data

\$ Fieldwork time – low, 1 day, once or twice a year (summer daytime low tides allow sampling to MLLW)

\$ Processing time – low, entering field data into computer format

\$\$ Technical expertise – medium, knowledge of laser level techniques

Additional Resources

Reports that have used this method: [Heerhartz et al. 2014](#), and [Toft et al. 2013](#)

Other methods that require more technical expertise: [RTK-DGPS](#)

See the [Beach Watchers procedures](#) for methods that are less costly and technical (profile poles and line)

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant. Website: wsq.washington.edu/toolbox



Methods

Establish a transect perpendicular to shore, starting from above MHHW at the top of the berm or toe of the bluff at natural beaches, or at the base of armoring if there is bulkhead or riprap. Extend the transect down to MLLW. Mark any key elevation or transition areas with wired flags such as at the wrack line, an obvious change in beach profile or sediment grain size, or where you may be collecting other data. Take elevation measurements using the laser level and stadia rod at all flagged areas and every 2 meters along the transect, more frequently if the topography greatly varies, and less frequently if there is an extensive low tide terrace with not much change in gradient. A 100 m transect should be long enough; some beaches may require moving the transect tape if they extend far from shore. The 'head' of the laser level must be higher than the highest point to be surveyed (e.g., the base of the bluff). For most sites you will need a 14 foot stadia rod, or will need to survey high and low sections separately. Record the elevation at the water line and note the time so that data can be corrected to actual elevations measured at NOAA stations (Note: uncertainty increases with distance from the tide station). It may also be possible to measure the vertical distance from the start of the transect to a benchmark with a known elevation. Laser levels are commonly used in surveying work – search for detailed instructions online if you are unfamiliar with their use. Summer daytime low tides allow sampling down to MLLW.

Data to record in the field

Date, time, site name, transect measurement, elevation data. It is advisable to take a digital photo of the transect for documentation.

Processing

Enter field data into computer spreadsheets. Correct the data based on the actual elevation at the water line or a benchmark. Calculate the beach width (distance from MHHW to MLLW) and the beach slope. Plot the elevations along the transect length to note any key features in the topography, which will allow visualization of changes over time.

Vegetation Protocols

Vegetation

Characterizing shoreline vegetation such as dune grass and willows can give valuable information on the habitat of the upper beach and marine-terrestrial connectivity. This may change depending on shoreline armoring, development in the uplands, and new plantings of vegetation at restoration sites. Vegetation stabilizes the shoreline and provides habitat for terrestrial insects that are prey resources for juvenile salmon.

Materials

- Two 50 m measuring tapes, one for the transect and one for vegetation measurements
- 0.25 m² pvc quadrat (0.5 x 0.5 m)

Sampling Summary

- Generate a plant species list
- Percent cover of over and understory vegetation
- Canopy diameter of trees
- Health ratings of vegetation
- Dune grass: 50 m transect parallel to shore. N=5 measurements for patch width and 0.25 m² quadrats for shoot density and percent cover

Scale of Effort

- \$ Cost – low, simple materials and data are all field-based
- \$ People – low, 2-3 people can establish transects and record vegetation data
- \$ Fieldwork time – low, 1 day, once a year in July when vegetation is lush
- \$ Processing time – low, entering field data into computer format
- \$ Technical expertise – medium, identification of plant species

Additional Resources

Reports that have used this method:
[Toft et al. 2012](#)

Also see [Chappell 2006](#) for species information of vegetation in the Puget Sound region

*Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsq.washington.edu/toolbox*



Methods

Start by generating a plant species list for the site, noting native and introduced species. Estimate the percent cover of over (trees) and understory (e.g., dune grass, salal) vegetation in increments of 5% at different areas; this is best done in ~5 x 5 m patches, choose a subset depending on the size of the site and location of key vegetation features. Measure the canopy diameter of trees at their widest point by using a transect tape. Give each vegetation area a health rating between 1 (dead) and 5 (vigorous growth), noting specific plants/trees that are characteristic of the rating. At patches of dune grass establish a transect parallel to shore along its length, or for 50 m if the patch is very long. At five random points along the transect measure the width of the dune grass patch, and use a 0.25 m² quadrat to estimate shoot density and percent cover in increments of 1%. Sample in a summer month such as July when vegetation is lush.

Data to record in the field

Date, time, site name, sample numbers, vegetation data. It is advisable to take a digital photo of the transect and specific vegetation types for documentation.

Processing

Enter the field data into computer spreadsheets. Monitoring over time can generate growth parameters for different vegetation types and detail any changes in over and understory structure. Vegetation data can be used as causal factors for other data types such as insects and shorebirds.

Logs and Riparian Vegetation Protocols

Logs and riparian vegetation

Characterizing logs and riparian vegetation provides valuable information on the habitat of the upper beach and marine-terrestrial connectivity. Logs provide shelter for many invertebrates such as beach-hopper amphipods, and foraging habitat for shorebirds. Riparian vegetation provides habitat for terrestrial insects that are prey resources for juvenile salmon.

Materials

- Two 50 m measuring tapes, one for the transect and one for width of the log line

Sampling Summary

- 50 m transect parallel to shore
- N=5 random samples per transect
- Width of log line, and number of large and small logs (< 2 m length)
- Total percent and type of riparian vegetation along the transect
- Total count of fallen trees along the transect

Scale of Effort

§ Cost – low, simple materials and data are all field-based

§ People – low, 2-3 people can establish transects and record quadrat data

§ Fieldwork time – low, 1 day, once a year in September when driftwood is exposed

§ Processing time – low, entering field data into computer format

§ Technical expertise – low, identification of major vegetation types

Additional Resources

Reports that have used this method:
[Dethier et al. 2016](#)
[Heerhartz et al. 2014](#)

Also see [Brennan 2007](#) for further information on riparian vegetation in Puget Sound

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant. Website: wsq.washington.edu/toolbox



Methods

At five random points along a 50 m transect parallel to shore, measure the width of the log line perpendicular to the transect as the distance from the seaward-most edge of logs to the landward-most edge of logs. Count the number of large and small logs (longer or shorter than 2 m) intersecting the perpendicular line, and categorize as “natural” log recruits or human-altered (e.g., cut poles, dock material). Note any other defining characteristics of the logs, such as if they have marine or terrestrial growth (e.g., barnacles, moss). Estimate total percent cover along the 50 m transect of vegetation overhanging the upper beach. Also estimate the percent of supratidal vegetation categories (e.g., dune grass, blackberries) and backshore vegetation categories (e.g., trees, shrubs, lawn). Make a total count of fallen trees along the 50 m transect. Sample in September at the end of the vegetation growing season, on an ebbing tide when the upper beach +6' MLLW and above is exposed.

Data to record in the field

Date, time, site name, sample number, log and vegetation data. It is advisable to take a digital photo of the transect for documentation.

Processing

Enter the field data into computer spreadsheets. Calculate averages of width of the log line and number of logs. Log and vegetation data can be used as causal factors for other data types such as insects, beach wrack, and shorebirds.

Sediment Size Protocols

Sediment Size

The physical structure of the beach may change depending on such actions as winter storms, restoration activities, and shoreline armoring. Sediment size can affect the type of invertebrates that live within and on top of the substrate. [Beach spawning forage fish](#) (surf smelt, sand lance) also target specific sediment sizes.

Materials

- 50 m transect tape
- 32 x 32 cm pvc quadrat, subdivided with string into 25 6 x 6 cm small squares
- Hand trowel marked with 5 cm depth

Sampling Summary

- 50 m transect parallel to shore
- 0.1 m² quadrat (32 x 32 cm)
- N=5 random quadrats per transect
- Transects at MHHW, MSL, and MLLW, others as appropriate
- Measure % cover of surface and subsurface (5 cm depth) sediment in 5 size classes

Scale of Effort

- § Cost – low, simple materials and data are all field-based
- § People – low, 2-3 people can establish transects and record quadrat data
- § Fieldwork time – low, 1 day, once or twice a year (summer daytime low tides allow sampling at MLLW)
- § Processing time – low, entering field data into computer format
- \$\$ Technical expertise – medium, knowledge on sediment size classes and analytical techniques is useful

Additional Resources

Reports that have used this method:
[Heerhartz et al. 2014](#)

Other methods that require a larger scale of effort and more technical expertise:

[Digital photographs/cobble cam](#)
[Ro-Tap shaker/sieve analysis](#)

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant. Website: wsq.washington.edu/toolbox



Methods

At five random points along a 50 m transect parallel to shore at MHHW, MSL, and MLLW, a 0.1 m² quadrat is placed on the surface sediment and a visual estimate made of the percent that is in five size classes: cobble (>6 cm), pebble (4 mm to 6 cm), granule (2-4 mm), sand (“gritty” up to 2 mm), and silt/clay (smooth between your fingers). Add other transect elevations based on the topography of the site, such as top of the most seaward berm. The quadrat is divided with string into 25 6 x 6 cm small squares (maximum pebble-size) to facilitate these estimates, and the frame has size-indicators for the other categories drawn on it. Once the surface has been categorized, the top 5 cm is scraped away and a visual estimate made for the subsurface sediment categories – these are often different than the surface because of the sorting action of waves. Summer daytime low tides allow sampling at MLLW.

Data to record in the field

Date, time, site name, transect elevation, sample number, sediment size data. It is advisable to take a digital photo looking straight down on top of the quadrat for documentation.

Processing

Enter the field data into computer spreadsheets. For each quadrat, the surface and subsurface percentages for each size category can be analyzed separately or averaged for characterization of the top 5 cm sediment layer. The median grain size (D_{50}) can be estimated from the grain-size distribution, and sorting estimated from the width of the grain-size distribution (span of size classes). Sorting indicates the distribution of grain size of sediments. Poorly sorted indicates that the sediment sizes are mixed (large variance), well sorted indicates that the sediment sizes are similar (low variance).

Beach Wrack Protocols

Beach Wrack

Characterizing beach wrack provides valuable information on the habitat of the upper beach and marine-terrestrial connectivity. This may change depending on shoreline armoring, source material alterations, and winter storms. Beach wrack provides food and shelter for many invertebrates, and foraging habitat for shorebirds.

Materials

- 50 m transect tape
- 32 x 32 cm pvc quadrat, subdivided with string into 25 6 x 6 cm small squares

Sampling Summary

- 50 m transect parallel to shore
- 0.1 m² quadrat (32 x 32 cm)
- N=10 random quadrats per transect
- Transects at most recent wrack line and higher elevation older wrack line
- Measure % cover of algae, eelgrass, terrestrial plants, and trash

Scale of Effort

§ Cost – low, simple materials and data are all field-based

§ People – low, 2-3 people can establish transects and record quadrat data

§ Fieldwork time – low, 1 day, once a year in September when wrack lines are exposed

§ Processing time – low, entering field data into computer format

§ Technical expertise – low, identification of major wrack types

Additional Resources

Reports that have used this method:

- [Dethier et al. 2016](#)
- [Heerhartz et al. 2014](#)
- [Sobocinski et al. 2010](#)

Other methods that require a larger scale of effort and more technical expertise: methods in [Heerhartz et al. 2014](#) that measure biomass of wrack

Suggested citation: *Shoreline Monitoring Toolbox. Washington Sea Grant.*

Website: wsq.washington.edu/toolbox



Methods

At ten random points along a 50 m transect parallel to shore, place a 0.1 m² quadrat on the beach surface and conduct a visual estimate of the percent composition of algae, eelgrass, terrestrial plant material, and trash. Divide the quadrat with string into 25 6 x 6 cm small squares to facilitate these estimates – each square equals 4%. If possible, specify the algae type (e.g., red, green, brown, or species). Establish two transects: (1) at the most recent high tide line that has fresh wrack deposition, and (2) just above MHHW in older wrack. The most recent high tide line will target mobile wrack, whereas the higher elevation sample will target the more stable wrack layer. If there is a bluff or shoreline armoring, sample the elevation at the base. Sample in September as it is typically a period of high wrack accumulation, and on an ebbing tide when the upper beach +6' MLLW and above is exposed.

Data to record in the field

Date, time, site name, transect elevation, sample number, beach wrack data. It is advisable to take a digital photo of the transect and of some example quadrats for documentation.

Processing

Enter the field data into computer spreadsheets. The percentages for each wrack type can be analyzed separately, or combined for a percentage of total wrack cover. The different wrack types give information on the source material available (e.g., riparian vegetation for terrestrial sources), and the amounts that deposit on the beach.

Table 6.3. Vegetation Presence/Absence Field Data Sheet

| Transect (m) | Understory | Overstory | Transect (m) | Understory | Overstory |
|--------------|------------|-----------|--------------|------------|-----------|
| 0 | | | | | |
| 1 | | | 26 | | |
| 2 | | | 27 | | |
| 3 | | | 28 | | |
| 4 | | | 29 | | |
| 5 | | | 30 | | |
| 6 | | | 31 | | |
| 7 | | | 32 | | |
| 8 | | | 33 | | |
| 9 | | | 34 | | |
| 10 | | | 35 | | |
| 11 | | | 36 | | |
| 12 | | | 37 | | |
| 13 | | | 38 | | |
| 14 | | | 39 | | |
| 15 | | | 40 | | |
| 16 | | | 41 | | |
| 17 | | | 42 | | |
| 18 | | | 43 | | |
| 19 | | | 44 | | |
| 20 | | | 45 | | |
| 21 | | | 46 | | |
| 22 | | | 47 | | |
| 23 | | | 48 | | |
| 24 | | | 49 | | |
| 25 | | | 50 | | |

Table 6.4. Dunegrass and Log Line Field Data Sheet

| Site: _____ | Researchers: _____ | | | | Date: _____ | | Start Time: _____ | | | End Time: _____ |
|-------------|--------------------|-------------------|-----------------|---------------------------|-------------|--------------------|-------------------|------------|----------------------|--------------------------|
| Sample # | Sample RNG | Dunegrass Density | Dunegrass Cover | Dunegrass Patch Width (m) | Sample RNG | Log Line Width (m) | Large Logs | Small Logs | Natural and/or Human | Defining Characteristics |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |

Table 6.5. Sediment Size Field Data Sheet

| Site: _____ | Researchers: _____ | | Date: _____ | Start Time: _____ | | End Time: _____ | | | | | | |
|---------------------------|--------------------|--------------|-------------|-------------------|----------------|-------------------|---------------|--|--|--|--|--|
| Transect Elevatio n | Sample RNG | Sample | E (>6cm) | D (4mm-6cm) | C (2mm-4mm) | B (Smooth-2mm) | A (Smooth) | | | | | |
| MLW | | Surf. 5cm | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | Surf. 5cm | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | Surf. 5cm | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | Surf. 5cm | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | Surf. 5cm | | | | | | | | | | |
| | | | | | | | | | | | | |

Table 6.6. Beach Wrack

| Site:___ | Researchers:_____ | | | | | Start Time:_____ | | End Time:_____ | |
|------------|-------------------|-----------|-------------|-------------|-----------|------------------|----------|--------------------|-----------------------|
| Sample RNG | Sample | Wrackline | Green Algae | Brown Algae | Red Algae | Dead Algae | Eelgrass | Terrestrial Plants | Trash (type of trash) |
| | 1 | Old | | | | | | | |
| | 2 | Old | | | | | | | |
| | 3 | Old | | | | | | | |
| | 4 | Old | | | | | | | |
| | 5 | Old | | | | | | | |
| | 6 | Old | | | | | | | |
| | 7 | Old | | | | | | | |
| | 8 | Old | | | | | | | |
| | 9 | Old | | | | | | | |
| | 10 | Old | | | | | | | |

Table 6.7 Water Chemistry (Nutrients) Field Data Sheet

| | | | | | | | | | | | |
|----------------|--|--|--|--------------|--|--|--|-------|--|--|--|
| Site: | | | | Researchers: | | | | Date: | | | |
| Transect (RNG) | | | | | | | | | | | |
| Nitrogen | | | | | | | | | | | |
| Phosphorous | | | | | | | | | | | |
| Notes: | | | | | | | | | | | |

Table 6.8 Water Chemistry (Sensor) Field Data Sheet

| | | | | | | | | | | | |
|--------------|--|--|--|--------------|--|--|--|-------|--|--|--|
| Site: | | | | Researchers: | | | | Date: | | | |
| GPS (Start): | | | | | | | | | | | |
| GPS (End): | | | | | | | | | | | |
| Transect | | | | | | | | | | | |
| Temp (°C) | | | | | | | | | | | |
| SpC (µS/cm) | | | | | | | | | | | |
| Sal (ppt) | | | | | | | | | | | |
| pH | | | | | | | | | | | |
| Tur (NTU) | | | | | | | | | | | |
| LDO (mg/L) | | | | | | | | | | | |
| LDO (%) | | | | | | | | | | | |
| IBV | | | | | | | | | | | |
| BP | | | | | | | | | | | |
| Iba | | | | | | | | | | | |
| Notes: | | | | | | | | | | | |

APPENDIX 2

Supplementary Material

The following analysis was completed as part of the project, but was deemed less relevant than the other analysis in the body of the text.

Slope and Barnacle Presence

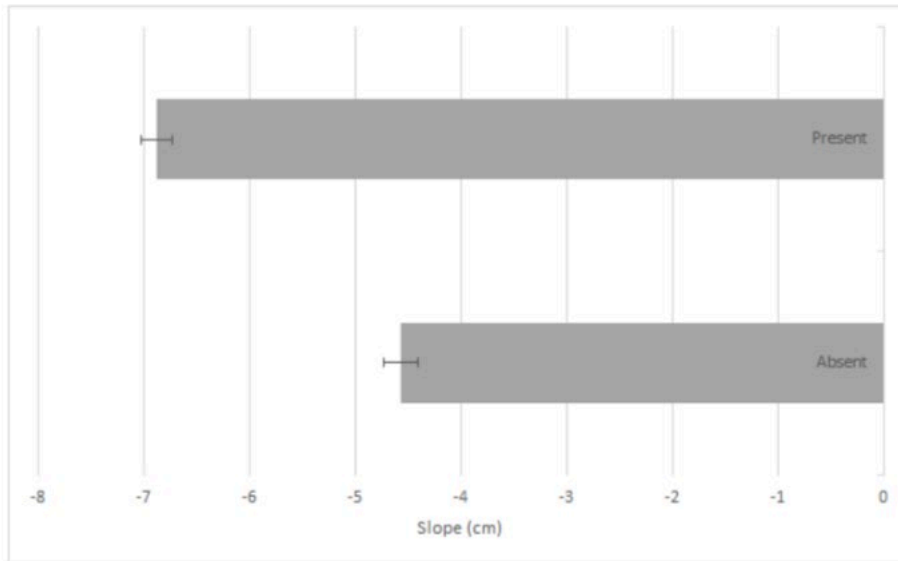


Figure 7.1. Comparison of slope and barnacle presence. We performed a two-sample t test in R and confirmed means of the slope in the presence and absence of barnacles were statistically different ($p=2.2e-16$). We found that Barnacles were present when the slope was greater on average than sites where the slope was not as pronounced.

Green Algae and Sediment Location



Figure 7.2. Comparison of green algae presence or absence and sediment type. Green algae were more prevalent lower on the beach. A Pearson Chi-Squared test of independence was run to find if there was a correlation between sediment location and green algae presence. The test showed green algae presence is not independent of sediment location ($p=2.573e-05$). In other words, green algae presence is dependent on which region of the intertidal zone it is in (low—toward deeper water, medium, or high—towards the beach). This is most likely because algae type is dependent upon light availability. Additional stats could be done to compare other types of algae with the sediment type, such as red algae and brown algae, however it is likely the test will yield the same results as it has long been known that algae is dependent upon light availability at these three different zones.

Overstory and Understory Presence

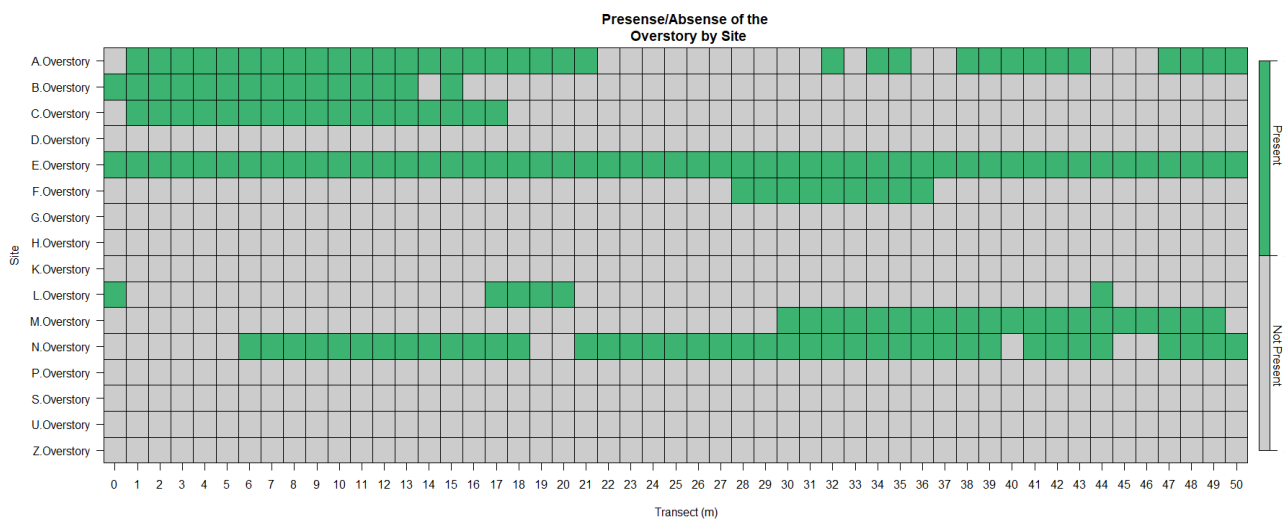


Figure 7.3. Presence/absence heatmap of overstory terrestrial vegetation observed at each site intersecting at each meter marker along a 50-meter transect. It is useful to monitor overstory coverage over time to track shoreline stability.

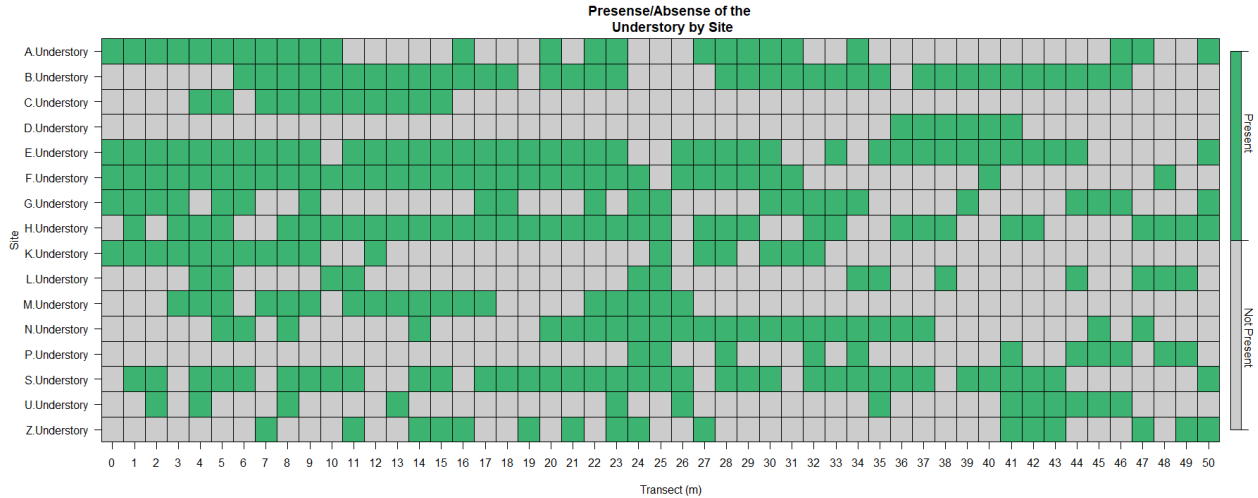


Figure 7.4. Presence/absence heatmap of understory terrestrial vegetation observed at each site intersecting at each meter marker along a 50-meter transect. It is useful to monitor understory coverage over time to track shoreline stability.

Table 3.1 shows a collective list of the terrestrial vegetation observed at the sites. The table includes each plant’s common name, scientific name and categories of nativity and functional group.

| Terrestrial Vegetation Present at Study Sites | | | |
|---|--------------------------------|------------|------------------|
| Common Name | Scientific Name | Nativity | Functional Group |
| Aarons Beard | <i>Hypericum calycinum</i> | Introduced | Shrub |
| Alumroot | <i>Heuchera sp.</i> | Native | Herbaceous |
| Annual Ragweed | <i>Ambrosia artemisiifolia</i> | Introduced | Herbaceous |
| Beach Pea | <i>Lathyrus japonicus</i> | Native | Herbaceous |
| Bedstraw | <i>Galium sp.</i> | Native | Herbaceous |
| Bent Grass | <i>Agrostis sp.</i> | Native | Grass |
| Bigleaf Maple | <i>Acer macrophyllum</i> | Native | Tree |
| Bitter Cherry | <i>Prunus emarginata</i> | Native | Tree |
| Black Gum | <i>Nyssa sylvatica</i> | Introduced | Tree |
| Blue Wild Rye | <i>Elymus glaucus</i> | Native | Grass |
| Borage | <i>Borago officinalis</i> | Introduced | Herbaceous |
| Bracken Fern | <i>Pteridium aquilinum</i> | Native | Shrub |
| Brome | <i>Bromus sp.</i> | Native | Grass |
| Bull Thistle | <i>Cirsium vulgare</i> | Invasive | Grass |
| Bunchgrass | <i>Nassella viridula</i> | Native | Grass |
| Cattail | <i>Typha latifolia</i> | Native | Herbaceous |

| | | | |
|-----------------------|--------------------------------|------------|------------|
| Coastal Mugwort | <i>Artemisia suksdorfii</i> | Native | Herbaceous |
| Common Lilac | <i>Syringa vulgaris</i> | Introduced | Herbaceous |
| Cotonester | <i>Cotoneaster sp.</i> | Introduced | Shrub |
| Crabapple | <i>Malus sp.</i> | Introduced | Tree |
| Creeping Buttercup | <i>Ranunculus repens</i> | Introduced | Herbaceous |
| Dandelion | <i>Taraxacum officinale</i> | Introduced | Herbaceous |
| Dogwood | <i>Cornus sp.</i> | Native | Tree |
| Douglas Fir | <i>Pseudotsuga menziesii</i> | Native | Tree |
| Dovefoot Geranium | <i>Geranium molle</i> | Introduced | Herbaceous |
| Dunegrass | <i>Ammophila breviligulata</i> | Introduced | Grass |
| Dwarf Barley | <i>Hordeum depressum</i> | Native | Grass |
| English Daisy | <i>Bellis perennis</i> | Introduced | Herbaceous |
| English Holly | <i>Ilex aquifolium</i> | Introduced | Vine |
| English Ivy | <i>Hedera helix</i> | Introduced | Vine |
| English Plantain | <i>Plantago lanceolata</i> | Introduced | Herbaceous |
| Epilobium | <i>Epilobium sp.</i> | Native | Herbaceous |
| Evergreen Blackberry | <i>Rubus laciniatus</i> | Invasive | Vine |
| Foxglove | <i>Digitalis purpurea</i> | Introduced | Herbaceous |
| Geranium | <i>Geranium sp.</i> | Introduced | Herbaceous |
| Golden Clover | <i>Trifolium aureum</i> | Introduced | Herbaceous |
| Gumweed | <i>Grindelia hirsutula</i> | Native | Herbaceous |
| Hairgrass | <i>Deschampsia sp.</i> | Native | Grass |
| Hairy Cats Ear | <i>Hypochaeris radicata</i> | Introduced | Herbaceous |
| Halberdleaf Tearthumb | <i>Polygonum arifolium</i> | Native | Herbaceous |
| Hawkweed | <i>Hieracium lachenalii</i> | Invasive | Herbaceous |
| Hawthorn | <i>Crataegus monogyna</i> | Introduced | Shrub |
| Hazelnut | <i>Corylus cornuta</i> | Native | Tree |
| Himalayan Blackberry | <i>Rubus armeniacus</i> | Invasive | Vine |
| Hooker's Willow | <i>Salix hookeriana</i> | Native | Tree |
| Ice Plant | <i>Delosperma sp.</i> | Introduced | Herbaceous |
| Juniper | <i>Juniperus scopulorum</i> | Native | Shrub |
| Knotweed | <i>Reynoutria sp.</i> | Invasive | Herbaceous |
| Laurel | <i>Prunus laurocerasus</i> | Introduced | Shrub |
| Lawngrass | <i>Zoysia Willd</i> | Introduced | Grass |

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| Madrone | <i>Arbutus menziesii</i> | Native | Tree |
| Meadow Barley | <i>Hordeum brachyantherum</i> | Native | Grass |
| Morning Glory | <i>Convolvulus arvensis</i> | Invasive | Vine |
| Mustard | <i>Brassica sp.</i> | Introduced | Herbaceous |
| Nipplewort | <i>Lapsana communis</i> | Introduced | Herbaceous |
| Nootka Rose | <i>Rosa nutkana</i> | Native | Shrub |
| Oceanspray | <i>Holodiscus discolor</i> | Native | Shrub |
| Orache | <i>Atriplex prostrata</i> | Introduced | Herbaceous |
| Orchard Grass | <i>Dactylis glomerata</i> | Introduced | Grass |
| Oregon Grape | <i>Mabonia aquifolium</i> | Native | Shrub |
| Oregon Stonecrop | <i>Sedum oreganum</i> | Native | Herbaceous |
| Pacific Ninebark | <i>Physocarpus capitatus</i> | Native | Tree |
| Pacific Willow | <i>Salix lucida</i> | Native | Shrub |
| Pearly Everlasting | <i>Anaphalis margaritacea</i> | Native | Herbaceous |
| Pickleweed | <i>Salicornia perennis</i> | Native | Herbaceous |
| Poppy | <i>papaver rhoeas</i> | Introduced | Herbaceous |
| Privet | <i>Ligustrum vulgare</i> | Introduced | Shrub |
| Purple Loosestrife | <i>Lythrum salicaria</i> | Invasive | Herbaceous |
| Queen Anns Lace | <i>Daucus carota</i> | Introduced | Herbaceous |
| Red Alder | <i>Alnus rubra</i> | Native | Tree |
| Redstem Storksbill | <i>Erodium cicutarium</i> | Introduced | Herbaceous |
| Rush | <i>Juncus sp.</i> | Native | Grass |
| Salal | <i>Gaultheria sballon</i> | Native | Shrub |
| Saltgrass | <i>Distichlis spicata</i> | Native | Grass |
| Scotch Broom | <i>Cytisus scoparius</i> | Invasive | Shrub |
| Sea Rocket | <i>Cakile edentula</i> | Introduced | Herbaceous |
| Shore Pine | <i>Pinus contorta</i> | Native | Tree |
| Silverweed | <i>Argentina anserina</i> | Native | Herbaceous |
| Snowberry | <i>Symphoricarpos albus</i> | Native | Shrub |
| Soft Brome | <i>Bromus hordeaceus</i> | Introduced | Grass |
| Sow Thistle | <i>Sonchus oleraceus</i> | Introduced | Herbaceous |
| Sword Fern | <i>Polystichum munitum</i> | Native | Shrub |
| Thimble Berry | <i>Rubus nutkanus</i> | Native | Herbaceous |
| Travelers Joy | <i>Clematis vitalba</i> | Invasive | Shrub |

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| Trumpet Honeysuckle | <i>Lonicera sempervirens</i> | Introduced | Vine |
| Tufted Hair | <i>Deschampsia cespitosa</i> | Native | Grass |
| Velvet Grass | <i>Holcus lanatus</i> | Introduced | Grass |
| Vine Maple | <i>Acer circinatum</i> | Native | Tree |
| Western Dock | <i>Rumex occidentalis</i> | Native | Herbaceous |
| Western Red Cedar | <i>Thuja plicata</i> | Native | Tree |
| White Clover | <i>Trifolium repens</i> | Introduced | Herbaceous |
| White Sweet Clover | <i>Melilotus albus</i> | Introduced | Herbaceous |
| Yarrow | <i>Achillea millefolium</i> | Native | Herbaceous |
