ShoreWatch App

Living Shoreline Monitoring Protocol Manual

VIMS | William & Mary
Virginia Institute of Marine Science
Center for Coastal Resources Management

TABLE OF CONTENTS

Suggested Citation: Center for Coastal Resources Management (CCRM). 2024. ShoreWatch App Living shoreline Monitoring Protocol Manual. Virginia Institute of Marine Science. Gloucester Point, Virginia. 74 p.

MONITORING PROTOCOL INTRODUCTION

Living shorelines are nature-based coastal protection strategies that provide erosion control and water quality benefits; protects, restores or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials, while preserving the natural continuity of the land-water interface. In the Chesapeake Bay, living shorelines often use tidal wetland vegetation and may incorporate nearshore-engineered structures, such as a rock sill or oyster reef structure to facilitate the establishment of a newly planted marsh or to protect the edge of an existing marsh. Living Shorelines have increased in use and acceptance in recent years with ever-broadening applications.

Monitoring provides information about how well a living shoreline technique works to achieve protection and ecosystem goals. Living shoreline benefits evolve over time by leveraging natural processes for less erosion, nitrogen load reduction, and other services. Key indicators of living shoreline performance are related to these physical and biological processes and reflect the level of shore protection and ecosystem function.

This manual details low-cost, accessible monitoring protocols for living shorelines. The collection of standardized monitoring data will strengthen our understanding of the effectiveness of these projects for shore protection and ecosystem benefits in different settings and for varied designs. This guidance can be used by the living shoreline community to ensure installed projects meet both ecological and protection goals. Applying the protocols through the use of the companion ShoreWatch App allows for the data to be easily and consistently collected and then viewed or exported via an online **Living Shoreline Monitoring Data Dashboard** in easy-to-understand performance metrics.

For additional guidance and a walkthrough of the ShoreWatch App, reference Appendix A of this manual. Website (coming soon).

PRE-MONITORING PLANNING

PLAN YOUR VISIT

Monitoring the same sites over time after construction allows for the impact of living shorelines to be more accurately evaluated. Routine monitoring will facilitate understanding whether the living shoreline is performing as planned and providing the expected benefits. To compare data from the same site, it is important to keep data collection consistent among data collectors and ensure that measurements and observations, both qualitative and quantitative, are made in the same way as past site visits.

Annual monitoring is encouraged at a minimum. The optimal time for plant and oyster measurements is between June and September (Fig 1). The marsh vegetation will be in peak production and newly settled oysters will be at the end of their growing season.

Figure 1. Visual of marsh plants at living shoreline sites in the summer versus the fall.

DETERMINE MONITORING GOALS

ShoreWatch provides the ability to collect data on numerous aspects of living shoreline projects. It would benefit users to consider what their goals for monitoring are before using ShoreWatch so they can focus on the metrics that are important to their outcomes.

Monitoring Living Shorelines with ShoreWatch can be categorized into two tiers:

Tier I - Rapid Monitoring: captures broad visual assessments of living shoreline components to track trends of living shoreline projects. These qualitative metrics include observations about percent cover of vegetation in the marsh to assess marsh establishment, and surveying the integrity of structures to determine whether maintenance may be required.

Tier II - Advanced Monitoring: provides the ability to capture more detailed quantitative data about living shoreline components such as the distribution of plant species in the marsh, and the density of oysters on structures.

Reviewing these protocols and determining which aspects of monitoring are most beneficial to your needs will allow you to use make the most efficient use of monitoring with ShoreWatch.

Reviewing the monitoring protocol manual and terminology, and determining which aspects of monitoring are most beneficial to your goals, prior to a site visit will help equip monitors to comprehend and implement the protocol in the field more effectively.

Figure 2 provides a snapshot of the elements of ShoreWatch and the information they provided.

Living Shoreline Component	Data Collected		Information Provided
	Tier I - Rapid	Tier II – Advanced	
Structures	Structural Integrity, Presence of oysters, Percent Oyster Cover	Areal extent of structure, Density of oysters	Possible maintenance needs, Bivalve establishment
Marsh	Areas of marsh plantings, Percent vegetation cover, Presence of key fauna	Vegetation species distribution	Marsh establishment, Ecosystem services
Bank Condition	General bank conditions, Height and slope ranges	Measured height and slope of bank, Tree/shrub counts	Potential for marsh migration, Ecosystem services
Overall	Fixed photos, Potential problem areas		Observable living shoreline changes, Possible maintenance needs

Figure 2: Monitoring Tiers and information provided in ShoreWatch.

KNOW THE TIDE

It is important to check the tides before going out in the field. Sites should be monitored at or within hours of **low tide** when shoreline features are exposed. The nearest tide station to a monitoring site can be located using CO-OPS Map - NOAA Tides & Currents. Predicted tide stages may vary slightly online compared to in the field.

MONITORING SAFETY

It is important to keep safety in mind while monitoring!

- Monitoring should be done in pairs or groups, never alone.
- Check the weather forecast for the planned site visit time before going out in the field.
    - When at the site, if the weather begins to take a turn for the worst, especially if you hear thunder, leave the site immediately.
- Please do not walk along the top of a living shoreline structure, as it may be slippery and lead to a fall or injury.
- While at the site, be aware of the terrain, whether it be rocky or muddy, as well as the presence of oyster shells. Oyster shells are sharp and carry bacteria. If cut by a shell, use a first aid kit to immediately clean and disinfect the wound. Seek medical attention immediately if any signs of infection develop.
- Pack more than enough drinking water.
- Bring sunscreen and bug spray or wear UPF and insect-repellent clothing.
- Always wear closed-toed shoes while monitoring.
- During warmer months, it is recommended to wear lightweight clothing and a hat for protection from the sun. During cooler months, dress in layers, as there is a higher wind chill by the water.
- Pack a bag with a dry change of clothing in case it is needed.

EQUIPMENT LISTS

Much of the necessary equipment **(Fig 3)** is affordable and can be purchased from most hardware stores.

Setting markers (bamboo poles, etc.) for monitoring purposes can help monitoring groups return to the correct locations each time. Check with the property owner before installing temporary or permanent markers for monitoring purposes.

Necessary Field Equipment	
Bamboo Poles[1], PVC Poles, or Tomato Stakes[2]	Rubber Mallet or Hammer
100 m Tape Measures (waterproof is ideal)	Marking of Flagging Tape
Meter Stick	Cruz Angle
Phone or Tablet (GPS enabled)	Sampling Plots[4]
GPS Survey Tool (e.g., Bad Elf from VIMS)[3]	

1. Bamboo is a natural material that can be hidden in the marsh but may need to be replaced periodically.
2. 5 stakes per transect (1 required every 30 m (~100 ft), with a max of 10 transects, per living shoreline treatment.
3. GPS Survey Tool and Phone/Tablet are connected via Bluetooth for increased GPS accuracy **(Fig 4)**. GPS Survey Tool should be turned on upon arrival at site to allow time for connection to satellites.
4. One sample plot may be used repetitively. More than one can speed up sampling plot data collection. The recommended size to use is a 0.25 m^2 plot. Other plot sizes may also be used.

Apps to Install on Phone or Tablet	
ArcGIS Field Maps App	ArcGIS Survey123 App
Inclinometer App (e.g., Bubble Level)	Plant ID App (e.g., Seek)

Additional Recommended Equipment	
Waterproof Boots &/or Waders	Binoculars
Sunscreen	First Aid Kit
Drinking Water	Calipers (for oyster measures)
Portable Charger and Charging Cord[1]	UPF/Insect Repellent Clothes, Hat, Sunglasses

1. It is highly recommended to bring a portable charger and charging cord. When using GPS, phone or tablet batteries may drain more rapidly than normal. A device may be charged in a vehicle, but it is most efficient to use a portable charger to continue fieldwork when the battery gets low. Battery may be saved by turning off the Bluetooth connection when not creating GPS-related features.

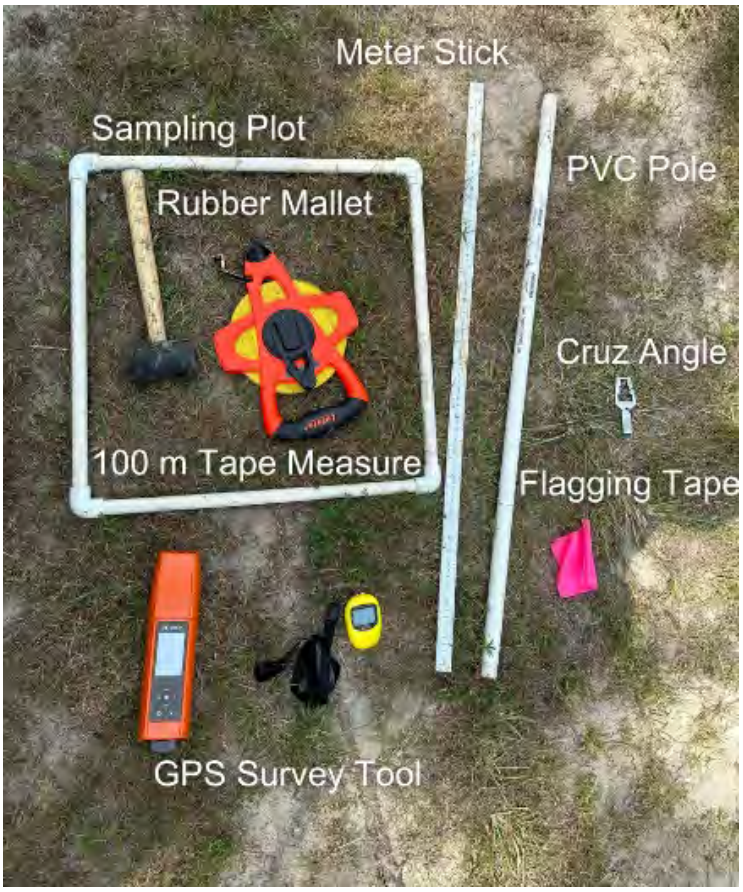


Fig 3. Necessary field equipment.

Fig 4. Use of a tablet and GPS survey tool connected via Bluetooth for increased accuracy.

SHOREWATCH APP FIRST STEPS

More detailed app set-up instructions can be found in Appendix A.

Any device used for monitoring through the ShoreWatch App needs to be GPS and Bluetooth enabled. A Bluetooth connection is used to link to an external GPS survey tool, such as Bad Elf, for enhanced accuracy.

ArcGIS Field Maps App & ArcGIS Survey123 App must be downloaded to use the ShoreWatch App **(Fig 5)**. Field Maps is used to delineate and geolocate elements of living shoreline projects for monitoring. Survey123 is integrated into Field Maps to provide forms for data collection.

Fig 5. ArcGIS Survey123 and ArcGIS Field Maps Apps.

ArcGIS Field Maps - Apps on Google Play

ArcGIS Survey123 - Apps on Google Play

These apps must then be signed into using the CCRM-provided username and password.

Once both apps are downloaded and signed in, follow the steps below to set up the device and app for monitoring:

- Set the measurement units in Field Maps to Metric
- Change the default GPS accuracy from 30 ft (9.144 m) to 3 m to ensure adequate location data
- Learn how to turn snapping on and off. Snapping automatically connects a point to another point or vertex of previously created features, which may cause a point to be created away from the desired location. However, there may be instances, such as low and high marsh zones that share a border, where snapping is useful.
- Open ArcGIS Field Maps and select the ShoreWatch Map. This is the map that will be used to download offline maps, create features, and collect data during monitoring
- Click the 3 dots to “Reload Map” before monitoring for the most up-to-date App version. When using the App for the first time, reload map will not appear, so select the current map.

Note: Instructions in this manual are based on the use of an Apple device and Bad Elf Unit. There may be minor differences if using a different brand (i.e., clicking a submit button or a checkmark).

INITIAL SITE SET-UP AND MONITORING

An initial site set-up must be conducted before routine monitoring data are collected. The purpose of the initial site set-up is to create a Monitoring Site where routine monitoring visits can be made. This includes one-time delineations of the site and living shoreline components (e.g., structures and marsh zones) and marking locations for routine data collection. Once a Monitoring Site has been set up and features have been delineated, data can be quickly collected from the same locations to track changes over time.

Setting up the site and creating features for monitoring only needs to be done once; however, there may be circumstances where this section needs to be referred to during a routine monitoring visit, such as when delineating newly (re)planted areas. For more detailed, step-by-step ShoreWatch App instructions for the initial set-up site visit, refer to Appendix A.

IMPORTANT TERMS

Living Shoreline Treatment: A type of nature-based shoreline protection. Multiple treatments may be applied along a long reach of shoreline. For example, Treatment 1: Marsh with Rock Sill; Treatment 2: Marsh with Oyster Structure.

Delineate: To outline or mark the boundary of a particular area or component.

Polygon: A feature created in the ShoreWatch App by delineating an area of interest.

Monitoring Site: The spatial extent within which monitoring will occur. Represented by a polygon in the ShoreWatch App delineated by a user.

Transect: A line that bisects the site from the water or nearshore structure through the riparian zone to capture the intertidal and different vegetation zones (e.g., the low marsh and high marsh). It is used as a guide for establishing plot locations.

Plot: A defined sample area to collect data. For this protocol, 0.25 m^2 quadrat plots are used for measuring marsh vegetation and oyster density and 12.5 m^2 circular plots are used to measure riparian vegetation.

RECOMMENDED INITIAL SET-UP AND MONITORING

Below is a recommended order for setting up the site and collecting monitoring data. This list may be followed in a different order based on a group's monitoring interests or tide levels, but it is suggested to follow this order as certain delineations must be done before others (i.e., Monitoring Site must be created to delineate any other feature). Detailed guidance for the initial site set-up follows this suggested order.

1) **Delineate Monitoring Site & Start a Monitoring Event**
2) **Establish Survey Reference Points**
3) **Establish Fixed Photo Stations** to take photos that capture the Monitoring Site throughout time.
4) **Delineate Living Shoreline Treatment(s)** within the Monitoring Site.
5) **Indicate Tide Stage** while monitoring each living shoreline treatment.
6) **Delineate Each Structure & Record Structure Observations** within each Living Shoreline Treatment.
7) **Advanced Monitoring - Establish Structure Plot Points & Record Structure and Oyster Measures** for each structure within a Living Shoreline Treatment to easily record structure and oyster plot measures at the same location during each monitoring event.
8) **Delineate Planted Areas & Record Planting Information** (associated with project installation or replanting) for each marsh vegetation zone within a Living Shoreline Treatment.
9) **Delineate Marsh Vegetation Zones & Record Marsh Zone Observations** for each Living Shoreline Treatment. Marsh vegetation zones include low marsh and high marsh.
10) **Advanced Monitoring - Establish Transects and Marsh/Riparian Plots & Record Plot Measurements** within each Living Shoreline Treatment to easily record marsh vegetation measures at the same location during each monitoring event.
11) **Record Upland Bank Conditions** either general conditions or through Specific Bank Points (Advance Monitoring)
12) **Establish Erosion and Other Problem Area Points & Record Potential Problem Information**
13) **Record Grazing Exclusion Status**
14) **Record Wildlife Observations**
15) **Delineate Length of Shoreline Protected by Living Shoreline Treatment(s)** for the Monitoring Site.

1. MONITORING SITE

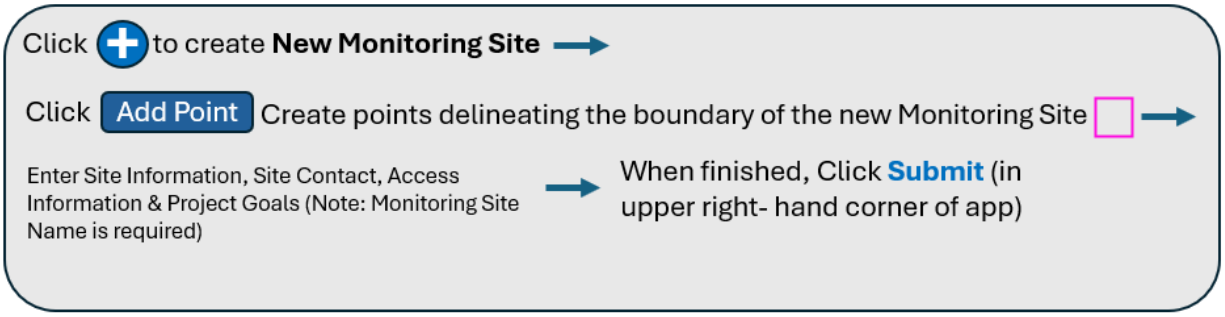
The first step of monitoring site characterization is to outline the area of the site to be monitored. All data collected during monitoring will be linked to the monitoring site. At the Monitoring Site level, users can also create a GPS point for any survey reference points used in project construction and establish fixed photo stations to document project changes over time.

Monitoring Site: The spatial extent within which monitoring will occur. Represented by a polygon in the ShoreWatch App delineated by a user.

Delineate: To outline or mark the boundary of a particular area.

Polygon: A feature created in the ShoreWatch App by delineating an area of interest.

SET-UP: DELINEATE MONITORING SITE



The outline of the Monitoring Site should be drawn generously to encompass the shoreline, upland, and shallows to ensure that all data collected is captured within the bounds of the site.

- In the ShoreWatch App, create a polygon by adding points that outline the Monitoring Site **(Fig 6)**
  - The Monitoring Site polygon should encompass the living shoreline structure, marsh area, and upland features, and some of the surrounding area to ensure the site is fully captured.
  - Parcel boundaries may provide guidance to outline the Monitoring Site

REMINDER

Turn on your GPS Survey Tool to allow enough time (~15 minutes) to connect to surrounding satellites

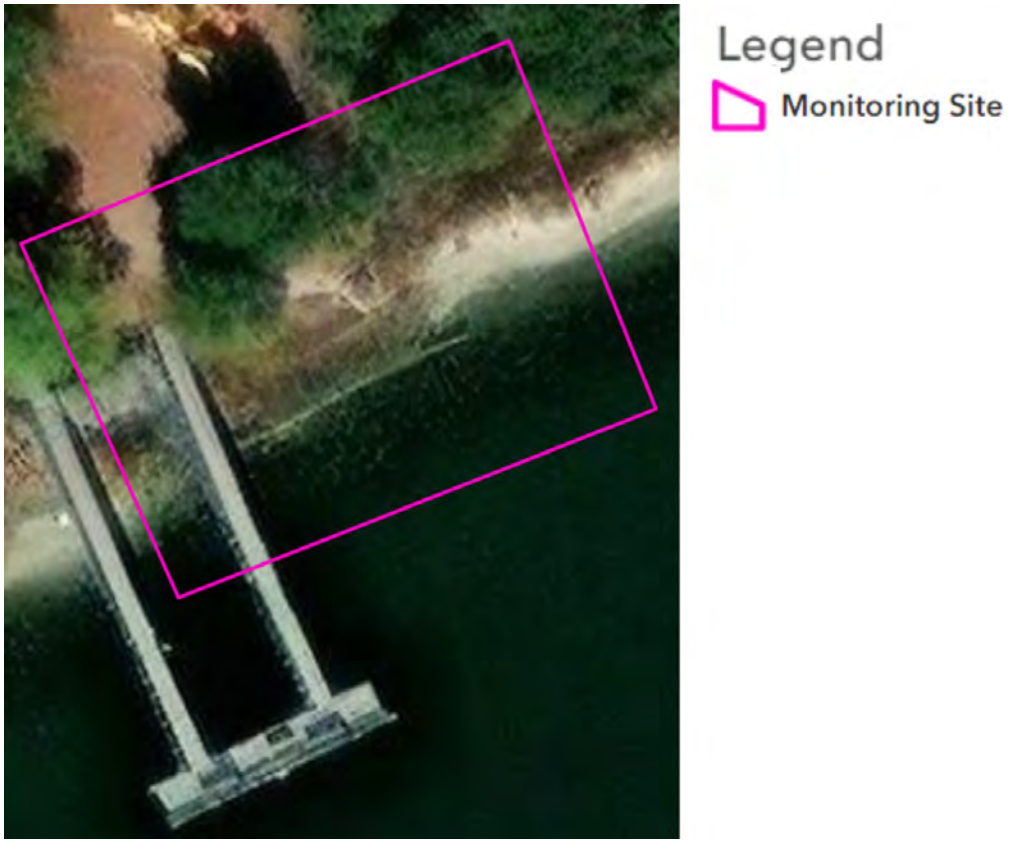


Figure 6. ShoreWatch App view of a delineated monitoring site.

- Fill out Site Information (e.g., Monitoring Site Name, Land Use, Owner Type)
    - Monitoring Site Name is required – The name is up to the user, but the ShoreWatch App will not allow for duplicate names
- Fill out Site Contact and Access Information
- Fill out Project Goals (e.g., Erosion Control, Flood Mitigation)

MONITORING: MONITORING EVENT

Monitoring Events link all of the data collected while monitoring by the date the data is collected, providing the ability to track changes over time. Information in Monitoring Event forms includes the Monitor's Name, Affiliation and Contact Information. This allows user groups to keep track of all of their sites monitored with ShoreWatch.

TYPES OF MONITORING EVENTS

As-Built Monitoring: The 1st or initial routine monitoring event, ideally within 1 year after the living shoreline project installation. A monitoring event to assess whether a living shoreline was installed as planned or permitted and is becoming established.

Rapid Monitoring - Long Term: Broad observational monitoring of a completed living shoreline project. This may be done once or multiple times a year. Optimal annual monitoring timeframes are between June and September.

Advanced Monitoring - Long Term: Detailed quantitative measurements of a completed living shoreline project. This may be done once or multiple times a year. Optimal annual monitoring timeframes are between June and September.

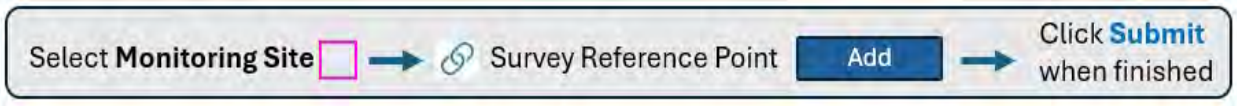
Post-Storm Monitoring: A monitoring event of a completed living shoreline project following a significant storm event during any time of the year.

- Select type of Monitoring Event
- Fill in the Monitoring Event Information
    - If a Post-Storm Monitoring Event, record information about the Storm, its impacts, and resulting Wrackline (**Fig 7)**.

Fig 7. Wrack lines. *A band of accumulated herbaceous dead plants, large woody debris, trash, or other material left behind after a high tide or flood recedes.*

Site Performance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Storm impacts	Need for further assessment/maintenance	Site: Y/N/Uncertain: Tidal flooding, Excessive rain, Strong winds, Debris damage
Position of the highest wrack line after storm	Extreme water levels	Site: In the low marsh, In the high marsh, In the riparian zone

2. SURVEY REFERENCE POINTS



Survey Reference Points, if available from the construction phase, can be recorded in the app for future reference.

- Add and name Survey Reference Points
  - Notes field to describe further

3. FIXED PHOTO STATIONS

Fixed photos document visual changes by comparing photos of the same area at different points in time. Photos should capture as much of the Living Shoreline Treatment(s) as possible to illustrate how a particular project site matures. The number and location of fixed photo stations are project-specific based on the project size, shape, and number of Living Shoreline Treatments. Small sites may only require one fixed photo point located, for example, on an existing pier looking back at the entire living shoreline project area. Larger, more complex sites may need multiple fixed photo points.

Photos at fixed photo stations/locations should be taken at least once a year during late summer when maximum vegetation growth is visible. It is also useful to have an additional photo taken during early spring prior to plant growth. Taking multiple photos throughout the year will help capture seasonal changes in vegetation. Photos taken during different tide stages or weather conditions may impact how well the photos can be compared. Take a photo at the appropriate photo station(s) before the vegetation is affected by monitoring access and foot traffic.

SET-UP: ESTABLISH FIXED PHOTO STATION(S)

- In the ShoreWatch App, create fixed photo stations by adding photo station points at locations where photos will be consistently taken during routine monitoring **(Fig 8)**
- Provide the Photo Station point(s) with a name and add any descriptions/notes that may help future users take similar photos

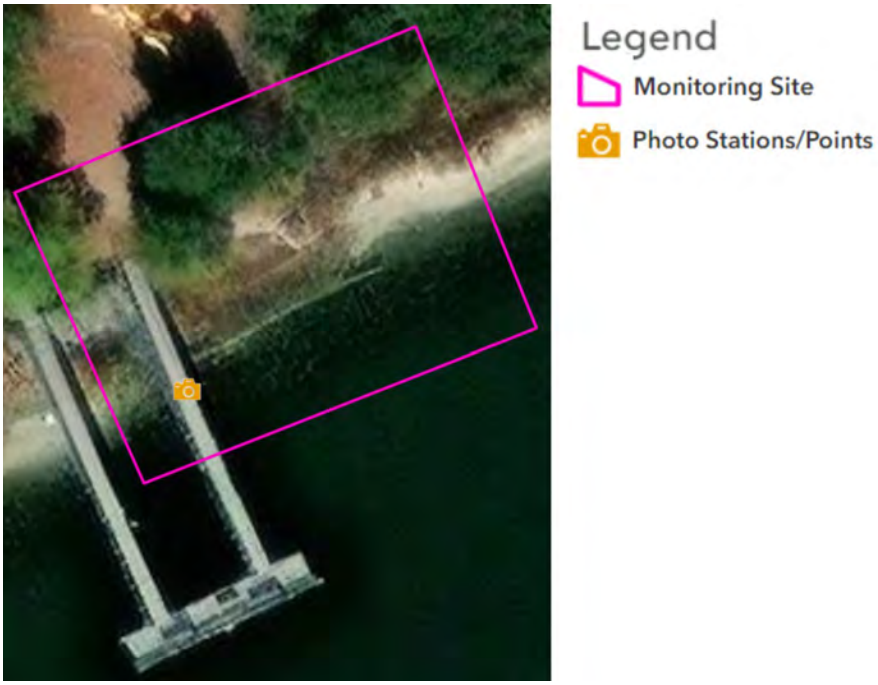
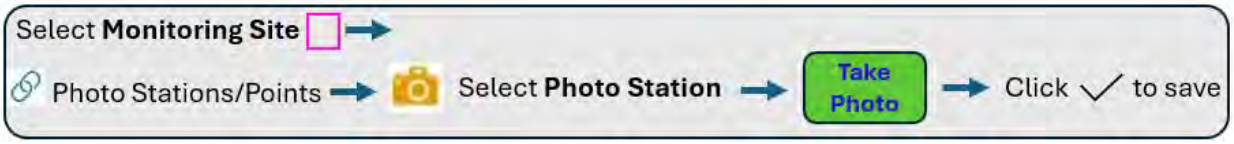


Figure 8. ShoreWatch App view including a fixed photo station point.

MONITORING: PHOTO OBSERVATIONS



- Take photos (landscape orientation) of the Monitoring Site at fixed photo stations **(Fig 9)**
  - Select photo station point(s) in the ShoreWatch App
  - Review past photos or notes to take a similar photo (*Refer to Appendix A*)
    - If there are no notes, be sure to include notes for future users

Fig 9. Fixed photo station and photo taken. The fixed photo station at this Monitoring Site is a large rock that is easy to locate for photos during a routine monitoring event. From this point, the majority of the Living Shoreline Treatment (Marsh with Rock Sill) is captured.

Site Performance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Fixed location Photo(s)	Project changes over time or in response to storm events	Site: Image(s) (jpg)

4. LIVING SHORELINE TREATMENT

At the Living Shoreline Treatment level, users will outline the area of the Living Shoreline Treatment(s) to be monitored, trace the length of each structure providing shoreline protection, establish locations for fixed sampling of structure integrity and oyster growth, outline any planted marsh to document the amount of newly created marsh, outline the area of each marsh vegetation zone including existing and planted marsh, and establish plot locations for fixed sampling in the marsh and riparian zone.

In many instances, there will be only a single living shoreline treatment (e.g., Marsh with Rock Sill), but for those shorelines with multiple treatments (e.g., a shoreline reach treated with Marsh with Rock Sill and a Marsh with Oyster Structure), the steps are followed separately for each treatment so that the performance on the individual living shoreline treatments can be assessed. This monitoring protocol is suitable for living shorelines that incorporate marsh vegetation and/or oysters.

Living Shoreline (LS) Treatment: A type of nature-based shoreline protection. Multiple treatments may be applied along a long reach of shoreline. For example, Treatment 1: Marsh with Rock Sill; Treatment 2: Marsh with Oyster Structure.

Living Shoreline Treatment Types

Marsh with Rock Sill: Planted or existing marsh with fronting rock sill structure.

Marsh with Oyster Structure: Planted or existing marsh with fronting oyster reef structure.

Marsh with Coir Logs: Planted or existing marsh with one or more coir logs fronting or within the marsh.

Marsh with Mixed Treatments: Planted or existing marsh with multiple fronting structures (e.g., coir logs and bagged oyster shell).

Beach with Breakwater: Nourished or existing beach with offshore breakwater. *Note: These monitoring protocols are most applicable to a vegetated living shoreline treatment. The Beach with Breakwater is included for monitoring those projects that include marsh vegetation plantings or have had marsh plant colonization.*

Marsh: Planted marsh with no fronting structure.

SET-UP: DELINEATE LIVING SHORELINE TREATMENT(S)

- In the ShoreWatch App, create a Living Shoreline Treatment polygon by indicating the Living Shoreline Treatment type and then adding points that outline the Living Shoreline Treatment **(Fig 10)**
    - O Indicate the type of Living Shoreline Treatment On Site (*See Appendix C for pictures and detailed definitions)*
        - Note: These monitoring protocols are most applicable to a vegetated living shoreline treatment. The Beach with Breakwater is included for monitoring those projects that include marsh vegetation plantings or have had marsh plant colonization

IMPORTANT

Always make sure the Monitoring Site is selected when adding features.

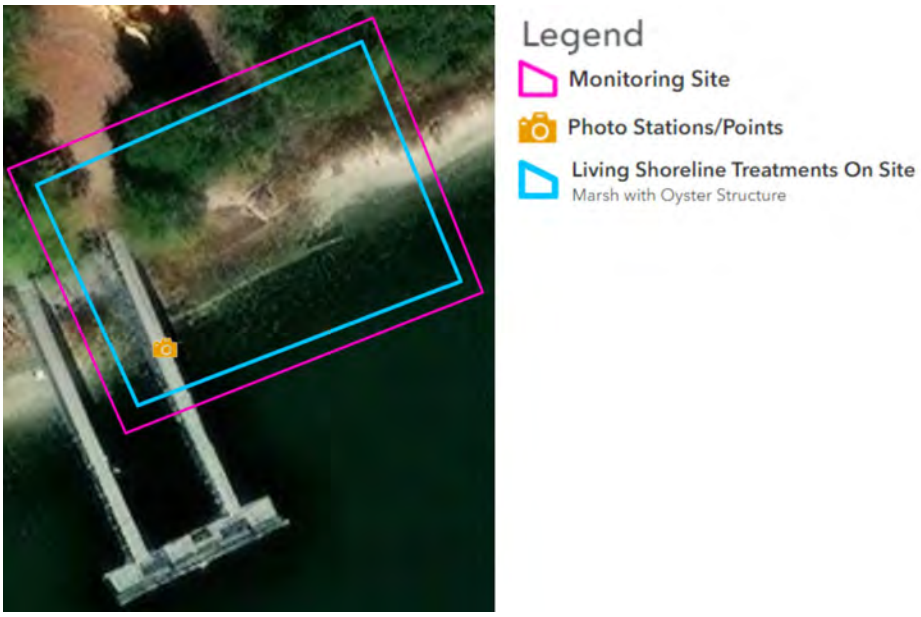


Figure 10. ShoreWatch App view including a delineated living shoreline treatment.

- Start by drawing the polygon from the channelward side **(Fig 11)** of the structure and moving towards the riparian zone, capturing all the marsh in between
    - Living Shoreline Treatment polygon(s) should be nested within the Monitoring Site polygon

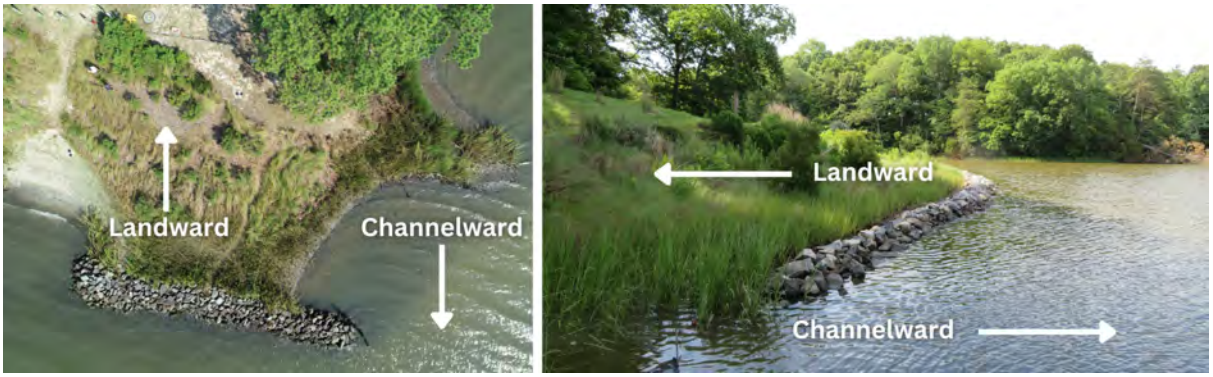


Figure 11. Illustration of channelward and landward directions.

Channelward = Towards the water. Landward =Towards the land.

- Record if marsh vegetation was planted, sand fill was added, and/or riparian plantings were installed for the Living Shoreline Treatment
- Record the status of Chesapeake Bay WIP Nutrient/Sediment Reduction Credits and VA Nonpoint Source Nutrient Bank Credits for the treatment
- Record associated Permit Information
- Repeat for each Living Shoreline Treatment within a Monitoring Site if applicable
    - Most sites will have a single Living Shoreline Treatment, but a Monitoring Site may contain multiple Living Shoreline Treatments **(Fig 12)**

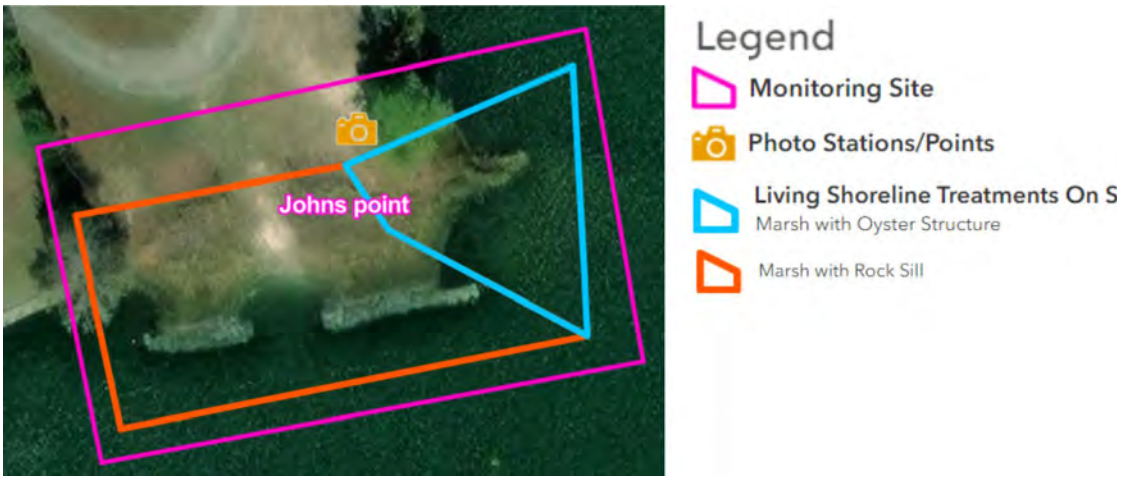


Fig 12. Monitoring site with two living shoreline treatments (marsh with oyster structure and marsh with rock sill)

MONITORING: WITHIN THE LIVING SHORELINE TREATMENT(S)

Set-Up and Monitoring steps 5 to 13 apply to each living shoreline treatment within a Monitoring Site. In many instances, there will be only a single living shoreline treatment (e.g., Marsh with Rock Sill), but for those shorelines with multiple treatments (e.g., a shoreline reach treated with Marsh with Rock Sill and a Marsh with Oyster Structure), the steps are followed separately for each treatment so that the performance on the individual living shoreline treatments can be assessed. This monitoring protocol is suitable for living shorelines that incorporate marsh vegetation and/or oysters.

5. INDICATE TIDE STAGES

The tide level can play a crucial role in the ability to collect monitoring data. For example, it may be difficult to assess oyster cover on a structure at high tide when a portion of the structure may be submerged.

High Tide: The state of the tide when at its highest daily level.

Low Tide: The state of the tide when at its lowest daily level.

Ebb Tide: The period between high tide and low tide; water flows toward the ocean.

Flood Tide: The period between low and high tide; water flows away from the ocean.

- Add a tide stage for each Living Shoreline Treatment
  - Record the current tide stage
  - Record the date and time for the predicted low tide
  - Notes field to describe further (e.g., extremely low tide)

6. STRUCTURES

Long-term monitoring of living shoreline structures allows for the assessment of changes in structure integrity, water levels, reef expansion with oyster growth over time, and resilience. Reef areal dimensions, or the project footprint, are used to estimate the amount of restored area and reef persistence. For reefs to become sustainable, oyster growth must surpass sediment deposition and shell degradation rates. Attached algae on the structure prevents oysters from settling on the structure. These measurements will track oyster growth and expansion and help determine if the oyster structures are keeping pace with sea level rise **(Fig 13)**.

Structure: Engineered component placed channelward and parallel to the shoreline to reduce wave energy and protect existing or planted marsh vegetation (e.g., rock sill, bagged oyster shell).

Adult Oyster: *Crassostrea virginica* with a shell height that measures greater than or equal to 25 mm (~1 in).

Oyster Recruit: *Crassostrea virginica* with a shell height that measures greater than or equal to 10 mm (~0.4 in) but less than 25 mm (~1 in). These oysters are considered to have survived to annual census (typically at the end of the growing season).

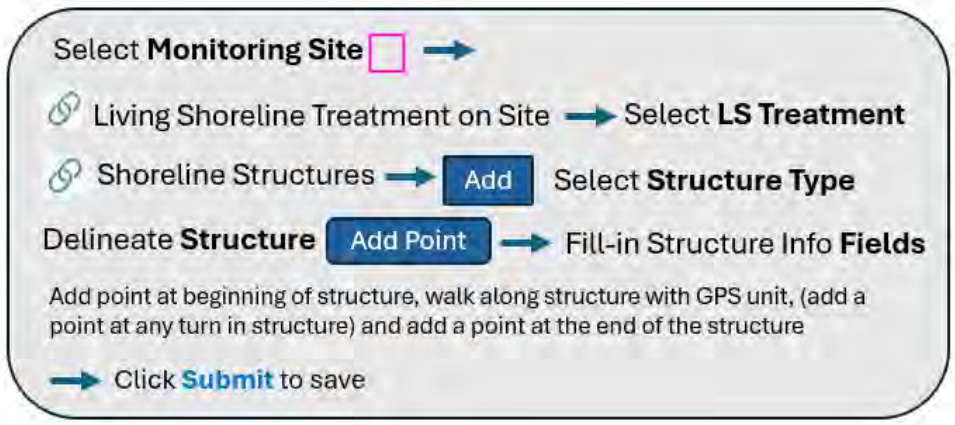
Settlement: Occurs once the larva has become permanently attached to the substrate or has metamorphosed into its final benthic form.

Recruitment: Includes settlement and some period of post-settlement survival.

Attached Algae: Algae that is clinging to a living shoreline structure and has not simply floated there.

Fig 13. Oyster growth on oyster castles pre- and post-project completion.
(Photos by CBF Staff and Sue Mangan Photography, respectively).

SET-UP: DELINEATE STRUCTURE LENGTHS



- Select the Shoreline Structure Type (Rock Sill, Oyster Reef Structure, Coir Logs, Breakwater)
- Delineate structure
    - In the ShoreWatch App, delineate the alongshore length of the Shoreline Structure **(Fig 14)**
    - If safe, walk alongside the structure while using the ShoreWatch App and holding a GPS or Bad-Elf unit in the same position above the structure
    - Add a Shoreline Structure GPS point at one end of the structure then walk to the other end to add a GPS point there
        - If a structure meanders dramatically, add additional GPS points while walking to the other end to capture the change in direction
        - If a structure has gaps, the structures should be delineated separately (i.e., if a 300 m rock sill system has gaps every 100 m, then three separate rock sill lines will be created and data collection will be done separately)
        - The ShoreWatch App will create a line based on the points added, but these lines may be adjusted if needed *(more detailed guidance in Appendix A)*
    - If unsafe to walk alongside the structure (e.g., a large rock sill), the structure may be delineated manually in the ShoreWatch App by adding additional points

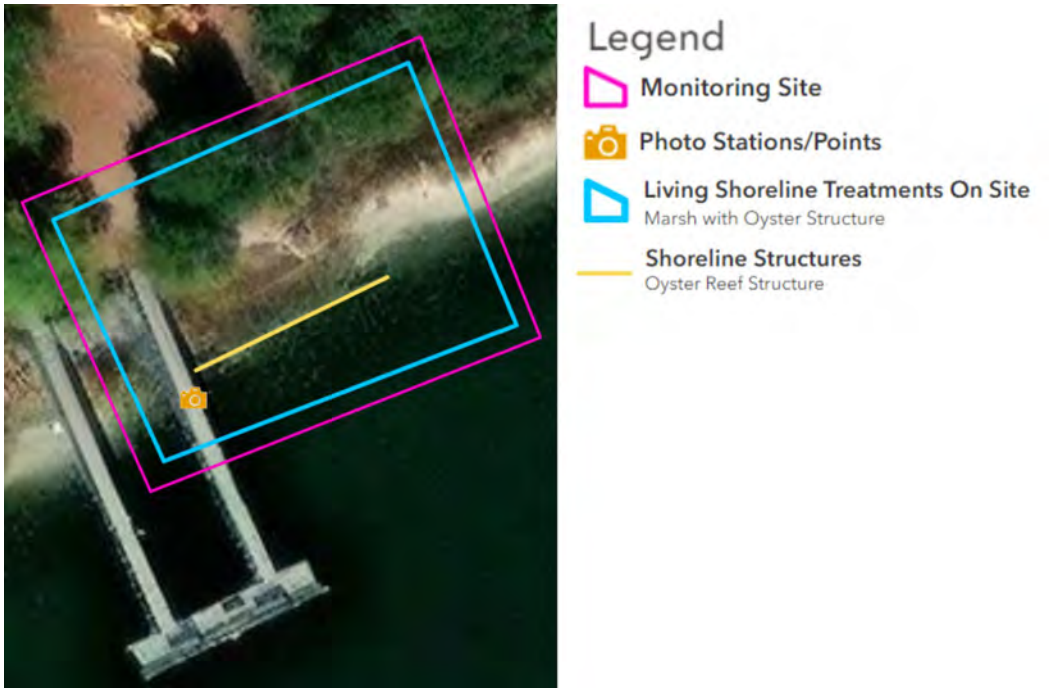


Fig 14. ShoreWatch App view including a delineated shoreline structure.

Delineated length of a shoreline structure (Oyster Reef Structure).

- <u>Record Structure Information</u>
  - For **ALL** structure types, record:
    - VMRC permit information (Number and Type)
    - Whether backshore structures are present, which is an indication of marsh migration potential
    - Date the structure was installed
    - Any relevant Notes
  - If an **Oyster Reef Structure**, record:
    - Specific Oyster Structure Type (e.g., Loose Shell, Oyster Castles) ***(picture examples and definitions in Appendix C)***
      - Arrangement of Oyster Structure (e.g., Interlocking, Free Standing) ***(will only appear for applicable oyster structure types)***
  - If **Coir Logs**, record
    - Coir Logs Grade, Type, and Arrangement
- Repeat for each Structure in the Living Shoreline Treatment, as needed

MONITORING: STRUCTURE OBSERVATIONS

Record observations about the overall structure.

- Percent Cover of Oysters on Structure
    - The percent cover range should be selected for the oyster coverage on the entire structure, not just what is visible above the water line
- Structural Integrity
    - Identifying if the structure is stable or if there are missing sections, dislodged, or collapsed materials can signal a need for maintenance
- Fauna Observed on the Structure
    - The presence or absence of oysters and mussels are indicators of ecosystem services, while the percentage of attached algae plays a role in the ability of bivalves to attach to the structure

Site Performance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Length of each stabilization structure (e.g., rock sill, bagged oyster shell)	Extent of shoreline protected with a living shoreline structure	Structure: Linear extent (m) of each structure Treatment: Total Linear extent of all structures (m)
Structure integrity	Structure failure or need for repair/maintenance	Treatment: Missing section, dislodged or collapsed materials, stable
Percent Cover of Oysters on Structure	Oyster establishment	Structure: Percent cover ranges
Fauna Observed	Ecosystem function	Structure: Presence/Absence

7. STRUCTURE PLOT POINTS (ADVANCE MONITORING)

Monitoring oyster and mussel populations on oyster reef or rock sill structures at set sampling (plot) locations allows for the tracking of oyster growth and reef expansion over time.

Counting or recording the presence or absence of adult oysters and oyster recruits will represent if there are multi-year successful recruitments. Counting oyster recruits (with sizes between ≥10 mm and < 25 mm), as opposed to oysters that have only recently settled (< 10mm), allows for a measure of oysters that are more likely to survive to adulthood. The mean density of live oysters will provide information concerning oyster population size, survivorship, and recruitment of oysters. For an oyster reef to persist, the rate of shell accretion must exceed the rate of shell loss.

When counting the number of adult oysters and oyster recruits within a plot, if an oyster is in between sizes (~25 mm or ~1 in), count the oyster as a recruit. A ruler or calipers may also be useful to distinguish between an adult and a recruit. This survey should take place at low tide when the structure is the most exposed. Oysters will be most abundant in the low-water zone of the structures, where they are inundated for at least 50% of the day **(Fig 15)**.

Fig 15. Low-water zone of a rock sill where oyster growth is high.

Tracking the percent cover of oysters on a structure will allow for the tracking of reef growth over time.

The Chesapeake Bay Oyster Metrics Workgroup established Bay-wide, science-based, consensus success criteria for oyster restoration (Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries 2011). The following success metrics can serve as guideposts for engineered oyster reefs:

Oyster density and reef cover

Minimum threshold = 15 oysters per m^2 over 30% of the reef area
Target = 50 oysters per m^2 over 30% cover of the reef area

Multiple year classes

Presence of multiple-year classes on the reef, as defined by oysters in adult and recruit classes

SET-UP: ESTABLISH STRUCTURE PLOT POINTS

Establish locations (*Structure Plot Points*) where data collection will occur along each oyster reef or rock sill structure during a routine monitoring event. At these locations, **structure measures** will be collected (e.g., height and width of oyster structures) and plots (0.25 m^2 quadrats) will be placed to collect **oyster measures**.

For coir logs, only the height and width of the structure will be recorded to monitor the rate of degradation.

Creation of Structure Plot Points only needs to be done once during the initial set-up site visit. During routine site visits, data will be collected at the same locations to assess changes over time. Additional Structure Plot Points may be added during a routine monitoring event, if necessary.

If a **Rock Sill** or **Oyster Reef Structure**:

- Decide on an interval (distance in meters) between measurements that is appropriate for the length of the structure
    - An interval of ~6 m (20 ft) is appropriate for average-sized structures (e.g., ~100-125 ft in length), but this interval may be increased, if the structure is very long or uniform, to result in less frequent measurements. Alternatively, the interval may be reduced if more frequent measurements are desired (e.g., every 1 m (3 ft))
    - Ensure that the interval encapsulates the ends and middle of the structure, and not just where oyster growth is highest

- Add Structure Plot Points at the interval (distance) along the structure using the ShoreWatch App connected (via Bluetooth) to a GPS Unit (e.g., Bad-Elf) **(Fig 16)**
    - Using a tape measure, indicate the distance (m) in the app, starting from the left end of the structure, when facing the water, to the created Structure Plot Point
    - Structure Plot Points should be located on the channelward side of the structure
    - If possible, place a pole or stake to physically mark Structure Plot Point Locations
    - Click Submit (upper right-hand corner of app) between the addition of each Structure Plot Point

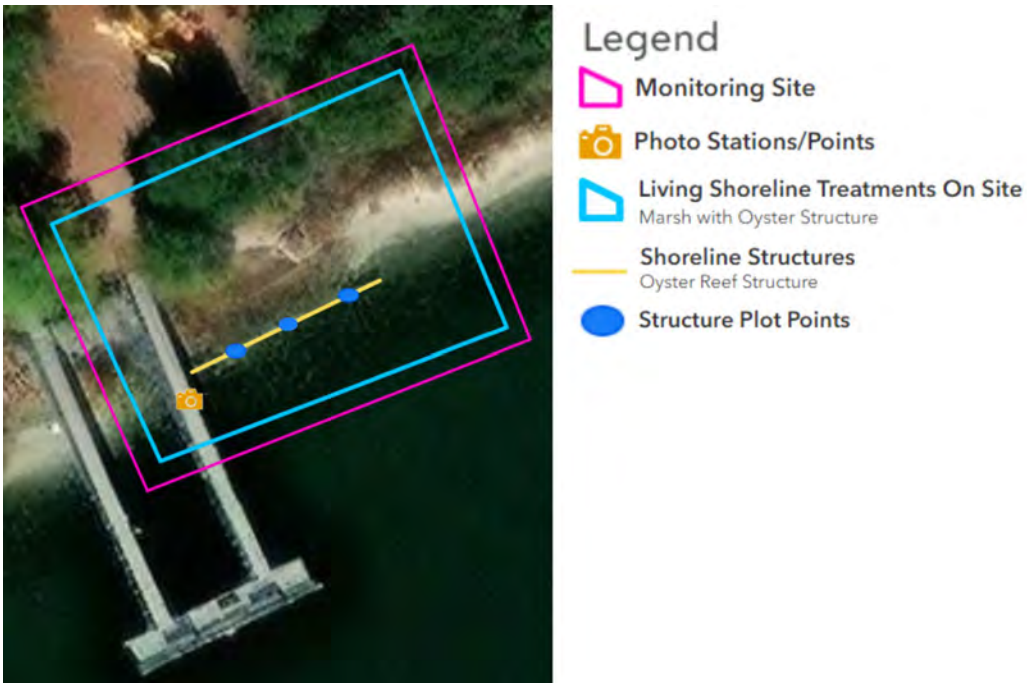


Fig 16. ShoreWatch App view including structure plot points.

Structure Plot Points at two ends of a shoreline structure (Oyster Reef Structure).

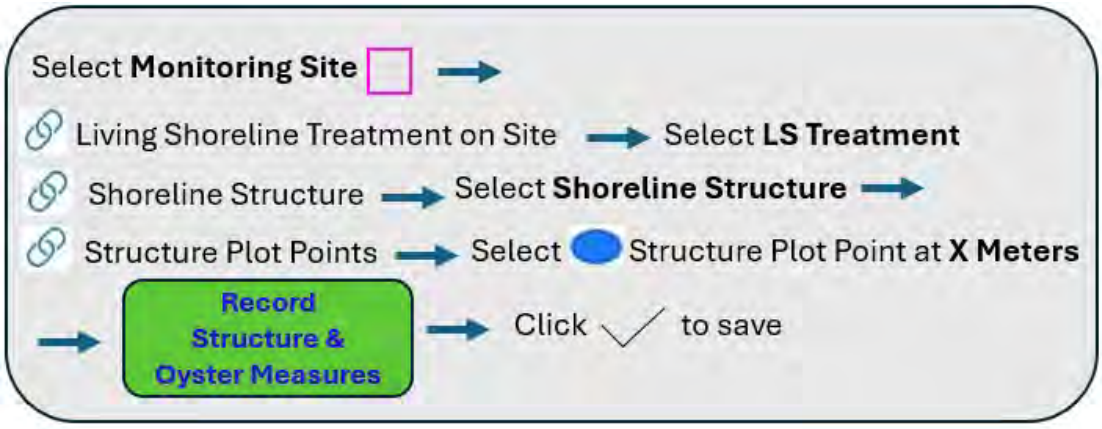
If **Coir Logs**:

- Create Structure Plot Points to record structure height and width at both ends and in the middle of the line of coir logs using the ShoreWatch App and holding a GPS or Bad-Elf Unit and indicate the distance (m) in the app
    - Click Submit (upper right-hand corner of app) between the addition of each Structure Plot Point

If an offshore **Breakwater**:

- Creation of Structure Plot Points is not recommended as it will be difficult to safely collect data from a larger structure

ADVANCED MONITORING: RECORD STRUCTURE AND OYSTER MEASURES



Specific information collected for each structure type at structure plot points during routine monitoring site visits is described below. Complete the list of monitoring elements for each Structure Plot Point before moving to the next Structure Plot Point.

Height: The vertical distance from the seafloor to the top of the structure or oyster growth

High-Water Mark: the vertical distance between the high-water line and the top of the structure (i.e., the height of the lighter-colored portion of the top of the structure).

Live Oyster Density: The number of live oysters, including recruits, per m^2.

Project Footprint: Areal extent of the reef. Achieved by collecting structure length and widths.

Oyster Reef Structures and Rock Sills

- Locate Plot Points
  - To identify Plot Points on the structure for collecting structure and oyster measures, consult the Plot Points recorded in the app during the initial set-up site visit. These points are labeled in meters to indicate their location relative to the left end of the structure while facing the water
  - To find Plot Points on the structure, such as one at 20 m, measure 20 m from the left end of the structure, facing the water, towards the opposite end of the structure, and proceed accordingly
  - Plot Points may have also been marked on-site using poles or stakes. Ensure accuracy by cross-verifying the Plot Point locations with measurements, even if they were previously marked with poles or stakes
- Record Structure and Oyster Measures in the ShoreWatch App for each Plot Point
  - Structure Measures

- Record any structural integrity problems
    - Select the status (e.g., stable, missing sections)
- Take a measurement (cm) for the structure's height and width **(Fig 17)**
- For both Oyster Reef and Rock Sill Structures, record the high-water mark **(Fig 18)**
    - The mean high-water line will not be discernible if the structure is submerged at mean high-water. In this case, record 0 **(Fig 19)**

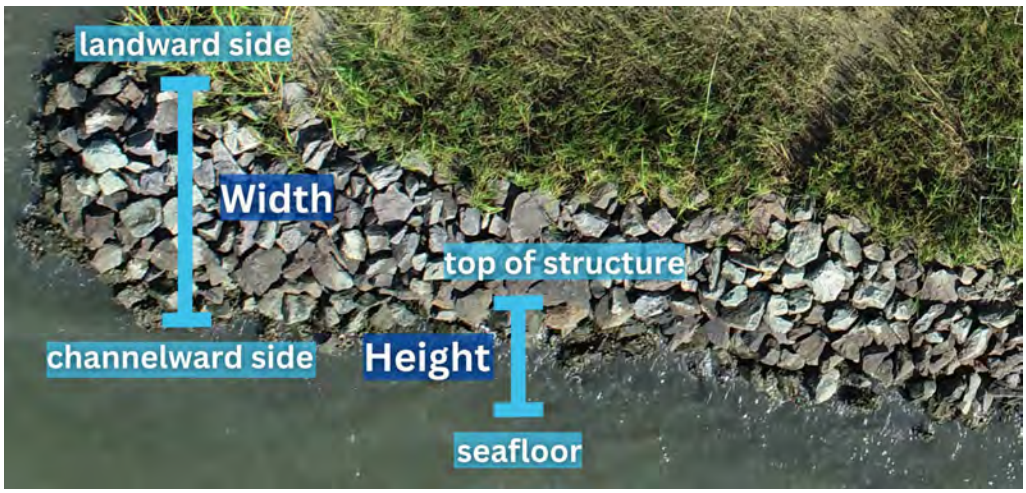


Fig 17. Height and width on a rock sill structure.

Height: The vertical distance from the seafloor to the top of the structure or oyster growth.

Width: The distance from the channelward side to the landward side of the structure.

Fig 18. Structure measures on a rock sill and oyster reef structure.

The high-water mark is measured from the high-water line to the top of the structure (i.e., the light-colored portion on top of the structure). For the Oyster Reef Structure, the high-water mark is not discernible.

The width is measured from the landward side to the channelward side of the structure.

The height is measured from the seafloor to the top of the structure or oyster growth. All measurements are in centimeters.

Fig 19. Oyster structure with non-discernible high-water mark.

Oyster pyramids (Ready Reef) submerged at high tide. A high-water mark will not be discernible on structures that are submerged daily with the tides (Photo credit: VIMS).

- Oyster Plot Measures
  - At the Plot Point, place a Plot (0.25m^2 quadrat preferred) on the channelward side of the structure in the low-water zone (~mean sea level to low water/seafloor) **(Fig 20)**

Fig 20. Structure sampling plot placement.

Placing a 0.25 m^2 quadrat (recommended plot size) on the channelward side of the structure in the low-water zone to collect oyster and mussel counts along with the percent cover of attached algae. An up-close view of a 0.25 m^2 quadrat on bagged oyster shell and a rock sill.

    - If it is unsafe to place a plot on the channelward side of a structure, the plot can be placed on the landward side of the structure in the low water zone (~mean sea level to low water/seafloor). However, oyster density will be highest on the channelward side
  - Indicate the size of the plot (0.25 m^2 (preferred), 0.5 m^2, 1 m^2)
  - Specify which side of the structure the plot was placed (Channelward, Landward)
  - Specify where the plot was placed (Low Water Zone, Mid-Height, Crest-Height).
  - Record Fauna Observed on Structure
    - Indicate presence or absence of each fauna (Live Oyster Recruits, Live Adult Oysters, Live Mussels, Attached Algae)
    - Record number counts of present fauna
      - *Note: You may record presence or absence only, but recording count is preferred*
  - Record percent cover of attached algae if present
  - Take a photo(s) in the ShoreWatch App
- Repeat measures for each Plot Point along the structure

- *Optional, for more intensive data collection*, if the structure is excessively large or tall, additional plots may be placed at different heights and/or both sides of the structure to capture oyster growth
    - Using the same plot points and distance along the structure, open a new "Record Structure & Oyster Measures" form for each additional plot configuration (different height and/or side)

COIR LOGS

- Locate Plot Points
    - To identify Plot Points, consult the Plot Points recorded in the app during the initial set-up site visit. These points are labeled in meters to indicate their location from the left end of the structure while facing the water. Generally, these Plot Points are located at both ends and the middle of the structure.
- Select the appropriate Plot Point for the location in the ShoreWatch App to Record Coir Logs Information
    - Coir Logs Status (e.g., Decayed/Absent)
- Record Structure Measures **(Fig 21)**
    - Take a measurement (cm) for the structure height and width
- Record Structural Integrity
    - Structure Status (e.g., Missing Sections)
    - Structural Integrity Notes (e.g., Stakes not in place)
- Take a photo(s) in the ShoreWatch App

Fig 21. Structure measures on coir logs.

Height and width on a coir logs. The width is measured from the landward side to the channelward side of the structure. The height is measured from the seafloor to the top of the structure. All measurements are in centimeters.

Structure Performance Measures		
Living Shoreline Measures	**What the measure indicates**	**Data Output**
Structure height	Structure changes over time or in response to storm events	**Plot:** Height (cm) from seafloor to top of structure **Treatment:** Average height (cm) of all structures
Structure width	Structure changes over time or in response to storm events	**Plot:** Width (cm) measured perpendicular to shore **Treatment:** Average width (cm) of all structure
Structure high-water mark	Structure changes over time and indication of changing water levels	**Plot:** Distance (cm) from high-water mark to top of structure **Treatment:** Average distance (cm) from high-water mark to top of structure
Structural integrity	Structure failure or need for repair/maintenance	**Treatment:** Missing section, Dislodged or collapsed materials, Stable

Oyster Performance Measures		
Living Shoreline Measures	**What the measure indicates**	**Data Output**
Adult oyster density	Oyster production; water filtration capacity; reef resilience	**Plot:** # live adult oysters/m^2 **Treatment:** Average no. live adult oysters/m^2
Recruit oyster density (between 10 and 25mm in size)	Evidence of successful recruitment	**Plot:** # live recruit oysters/m^2 **Treatment:** Average no. live recruit oysters/m^2
Total oyster density	Oyster production; water filtration capacity; reef resilience	**Plot:** # live adult & recruit oysters/m^2 **Treatment:** Average no. live adult & recruit oysters/m^2
Mussel density	Water filtration capacity; reef diversity	**Plot:** # live mussels/m^2 **Treatment:** Average no. live mussels/m^2
Percent cover of attached algae	Potential for biofouling interference of oyster settlement	**Plot:** Percent cover: 0, 1-5, 5.1-25, 25.1-50, 50.1-75, >75% **Treatment:** Average of midpoints of each % cover measure
Oyster reef areal extent	Amount of restored area; reef persistence and expansion	**Treatment:** Total length x average width (m^2)
Oyster reef cover	Oyster production; percentage of reef with oyster growth	**Treatment**: Percent cover

8. PLANTED MARSH AREAS

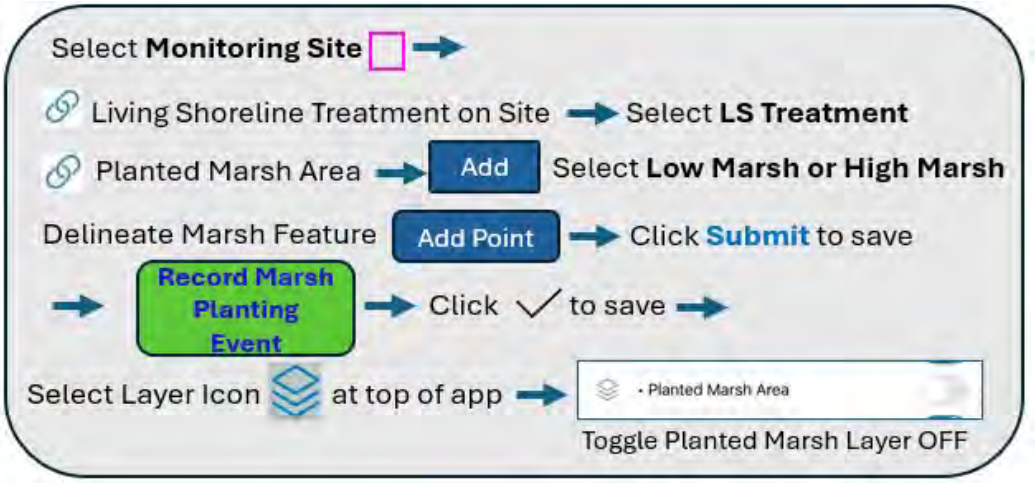
Estimating the area of planted marsh allows for the tracking of the amount of newly restored marsh and represents an addition of benefits to the system. In addition, knowing the footprint of the newly planted marsh can serve as a baseline to assess the evolution of marsh plant growth and expansion.

In some instances, the planted area may be the same extent as the marsh vegetation zones if the entire site was planted following construction (**Fig 22)**. In other instances, planting may be used to enhance an existing marsh and the newly planted area will be smaller than the delineated marsh vegetation zones. Any planted area must be delineated independently of the marsh zones, even if the entire marsh zone is planted. If an area is replanted, this process can be followed during routine site visits. In the case of replanting, create a new Planted Marsh polygon instead of editing an existing polygon.

Skip this step if Monitoring Site Setup does not occur right after construction, or if the original planted marsh area is no longer clearly defined. Do not guess, estimate, or use permit drawings to delineate planted marsh area.

Fig 22. Planted area in low marsh.
Above is an instance where the entire low marsh was planted. Low marsh planted area would be the same area as the low marsh vegetation zone, however these are delineated separately.

SET-UP: DELINEATE PLANTED MARSH AREAS



- Delineate the planted areas following the same guidance for delineating the marsh vegetation zones (i.e., creating a GPS point in each corner) **(Fig 23)**

Fig 23. ShoreWatch App view including a delineated planted marsh area.

The figure on the left shows a site where the low and high marsh planted areas are the same as the low marsh and high marsh vegetation zone delineations.

The figure on the right shows a site where only a small portion of the low marsh was planted.

MONITORING: PLANTED MARSH AREAS INFORMATION

After submitting the Planted Marsh Polygon, record Marsh Planting Event information for each Planted Marsh Area. If unknown, information may be included in tidal shoreline permit applications.

  - Date of Marsh Planting
  - Phase of this Planting (e.g., Initial Planting, Replanting)
  - Extent of Plant Coverage (e.g., Spot Plantings, Complete Coverage)
  - Configuration of Plantings (e.g., Rows, Clumping)
  - Who planted this marsh? (e.g., Volunteers, Professionals)
  - Source of Plantings (e.g., Nursery stock, Transplants)
  - Species Planted
  - Sand Fill Applied
  - Substrate of Planting Area (e.g., Sand, Mud)
- Take a photo using the ShoreWatch App

9. MARSH VEGETATION ZONES

A healthy plant community is fundamental to living shoreline projects by providing stability, energy reduction, improved water quality, habitat creation, and biodiversity. By tracking marsh vegetation zone characteristics (Low Marsh/High Marsh), shifts in marsh structure and function can be documented. Plant communities are good indicators of elevation and water levels, habitat provision capacity for fishes, invertebrates, and wildlife, nutrient removal and carbon storage potential, and storm risk reduction. Plant-derived benefits are achieved when plants are well-rooted into the soil growing and reproducing normally. The above and below-ground plant biomass acts to attenuate waves, reduce erosive energy from surface flow, slow floodwaters and storm waves, as well as retain sediment and organic matter. Generally, tall dense plants within wide marsh areas are most effective at wave dampening. Connected plant communities from the shallows-to-intertidal-to-upland help reduce wave energy and support habitat migration upslope in response to sea level rise. Tracking the total percent vegetation cover can show if the marsh is healthy and growing. Invasive plants, such as *Phragmites australis,* may rapidly spread into disturbed areas and may crowd out desirable native plants that were introduced as part of the living shoreline project.

Measuring the widths of the low marsh and high marsh zones will provide an indication of how those zones are expanding or shrinking. As sea level rises, the marsh may migrate landward. The marsh width indicates the capacity to reduce wave energy, storm, and flood risk. Marsh vegetation and wetland areas serve as a buffer from flooding by absorbing some excess water and slowing the rate water accumulates on land from flash floods, storm surges, and tidal flooding. Marshes also trap suspended sediment from daily tides and storm flooding which helps slow erosion and improve water clarity.

Low Marsh: The area of marsh that is flooded daily during high tides. This marsh zone traps sediment and provides important aquatic habitat for small fishes and crabs while it is flooded. During low tides, the low marsh zone is exposed, which provides access to food and cover for wetland and terrestrial animals **(Fig 24)**.

High Marsh: The area of marsh that is flooded during extreme high tides and storm events. This marsh zone provides valuable storm protection and a buffer to intercept and filter stormwater runoff and groundwater flowing from the adjacent upland. There is greater plant diversity in this zone compared to the low marsh due to less flooding **(Fig 24)**.

Dominant Species: A species that dominates >50% of the marsh.

Salt & Brackish Marsh | Virginia Institute of Marine Science (vims.edu) (citation)

Fig 24. Marsh vegetation zones and boundaries.

Pictures showing an aerial delineation of the low marsh zone and high marsh zone as well as the low marsh-high marsh boundary and high marsh-upland boundary.

The low marsh zone is typically dominated by *Spartina alterniflora*, which tolerates daily inundation. The high marsh is typically dominated by *Spartina patens*, which prefers higher elevations that are inundated infrequently.

SET-UP: DELINEATE MARSH VEGETATION ZONES

DELINEATE THE LOW MARSH AND HIGH MARSH

- Using the ShoreWatch App connected (via Bluetooth) to a GPS Unit (e.g., Bad-Elf), delineate the low marsh and high marsh by adding GPS points while walking the boundary of the low marsh and high marsh zones separately **(Fig 25)**
    - Add a GPS point at one corner of the marsh vegetation zone and walk to another corner of the zone, without cutting through the vegetation, to add a GPS point there, until there is at least 1 point in each corner
        - If the vegetation line meanders dramatically, add additional GPS points
        - Include both existing and planted marsh in the delineation
        - If there are marsh zone areas that are disconnected, (e.g., interrupted by infrastructure such as a boat ramp), multiple polygons may have to be delineated (**Fig 26**).
        - If there is no clear vegetation pattern between high and low marsh zones, use best judgment to delineate the entire marsh area and choose either high or low marsh based on extent of daily high tide flooding.
    - Review the polygons created in the ShoreWatch App and adjust any points as needed to capture the extent of the marsh vegetation zones *(detailed instructions in Appendix A Editing Features insert page number)*

IMPORTANT

When delineating marsh vegetation zones, include all marsh (planted and existing)

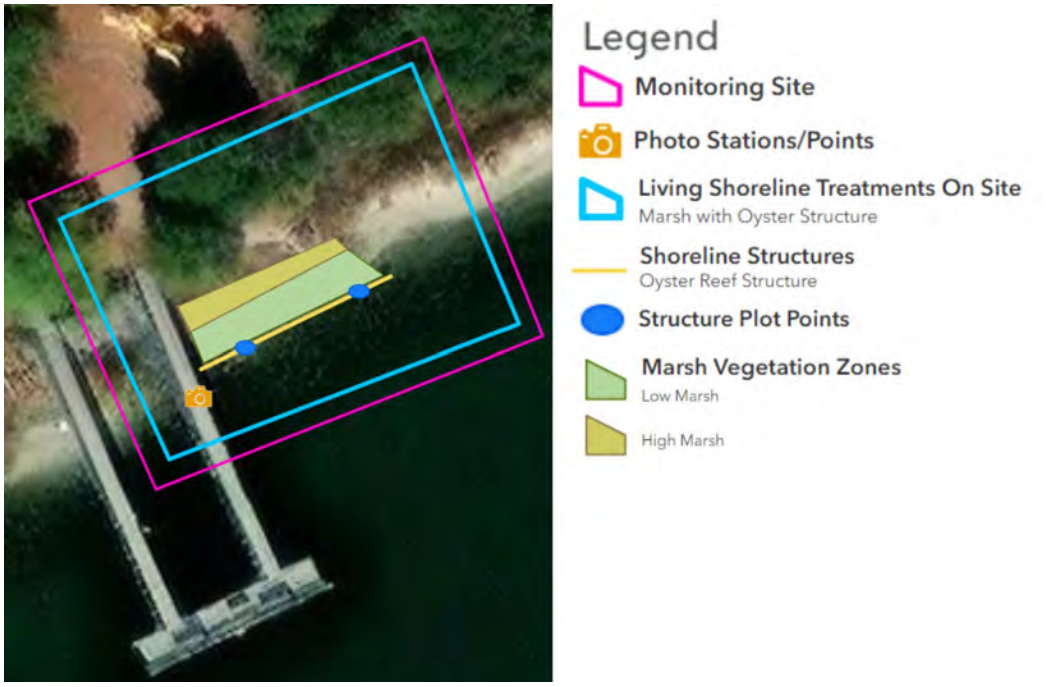


Fig 25. ShoreWatch App view including delineated marsh vegetation zones. Delineated low marsh and high marsh behind a shoreline structure (Oyster Reef Structure). Marsh vegetation zones connect but do not overlap.

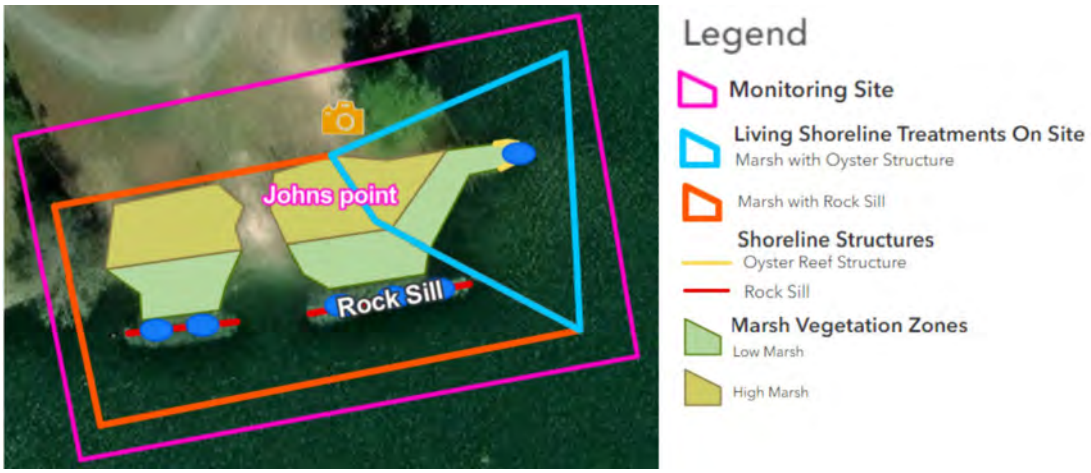


Fig 26. ShoreWatch App view of a site with disconnected marsh vegetation zones. Within the Marsh with Rock Sill (Living Shoreline Treatment), the low marsh and high marsh vegetation zones are disconnected by a sandy area between the Rock Sills (Shoreline Structures). Multiple polygons had to be delineated to represent the marsh vegetation zones.

MONITORING: MARSH VEGETATION ZONE OBSERVATIONS

- Record Marsh Measures for each Marsh Vegetation Zone:
  - Total Percent Vegetative Cover in Marsh **(Fig 27)**
    - Should account for all species with a marsh vegetation zone
  - Dominant Plant Species in Marsh *(Plant identification guides in Appendix E)*
  - Percent Cover of Phragmites in Marsh
    - If not present, record 0%
  - Trees Present in Marsh (e.g., Live, Dead/Dying) (High Marsh only)
  - Indicate whether monitoring will include sampling along the transects
    - If not, record the presence or absence of fauna in the marsh zone(s) (Live Mussels, Live Periwinkle Snails, Fiddler Crab Burrows, Live Oysters)
  - Take a photo(s) in the ShoreWatch App

Fig 27. Total percent vegetative cover in marsh examples.
The photo on the right is representative of a marsh with <25 percent cover. The photo on the left is representative of a marsh with >75 percent cover.

Marsh Zone Performance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Low marsh zone plant cover	Marsh establishment, stability, health, ecosystem function	Treatment: Percent cover: 0, 1-5, 5.1-25, 25.1-50, 50.1-75, >75%
High marsh zone plant cover	Marsh establishment, stability, health, ecosystem function	Treatment: Percent cover: 0, 1-5, 5.1-25, 25.1-50, 50.1-75, >75%
Low marsh zone dominant plant species	Marsh stability and function; water levels	Treatment: Species that dominates (i.e., >50%)
High marsh zone dominant plant species	Marsh stability and function; water levels	Treatment: Species that dominates (i.e., >50%)
Phragmites presence and cover in low marsh zone	Invasive species colonization; marsh stress	Treatment: Presence/absence; % cover
Phragmites presence and cover in high marsh zone	Invasive species colonization; marsh stress	Treatment: Presence/absence; % cover
Presence of live or dead/dying trees in high marsh zone	Water levels; change over time could indicate shifting water levels	Treatment: Presence/absence

10. TRANSECTS & PLOTS (ADVANCED MONITORING)

Transect: A line that bisects the site from the water or nearshore structure through the riparian zone to capture the intertidal and different vegetation zones (e.g., the low marsh and high marsh).

Plot: A defined sample area to collect data. For this protocol, 0.25 m^2 quadrat plots are used for measuring marsh vegetation and oyster density and 12.5 m^2 circular plots are used to measure riparian vegetation.

One of the standard ways to track and evaluate the performance of a living shoreline is to establish permanent transects and collect data from plots placed along the transects.

Key indicators of project effectiveness and ecosystem development are the plants. The extent, cover, and plant composition all represent how the site is performing. Measuring the vegetation within a sampling plot, also known as a quadrat, will show how well the plants are growing. Another great indicator of positive ecosystem development and function is the presence of primary marsh species, like ribbed mussels (*Geukensia demissa)*, fiddler crabs, and marsh periwinkle snails **(Fig 28)**.

They all play critical roles in many salt marsh processes. Ribbed mussels attach to the roots and rhizomes of *Spartina alterniflora* in clumps and help to stabilize the marsh platform. The plants and mussels have a mutualistic relationship, benefiting one another. Mussels fertilize the plants with their biodeposits and plants shade and provide refuge for the mussels. Mussels are very efficient filter feeders and enhance the removal of nitrogen in the marsh, which improves water quality. Fiddler crabs (*Uca* spp) and marsh periwinkles (*Littoraria irrorate*) are important links in the food webs – they consume marsh primary production, and that energy is transferred when predators eat them – like blue crabs.

Fig 28. Presence of marsh health indicators.

Mussels, periwinkle snails, fiddler crabs, and fiddler crab burrows.

TRANSECTS

Transects allow for repeated visits at the same locations to track changes over time in a quantitative way that is relatively easy to implement. The number of transects will depend on the size of the living shoreline treatment. Transects are to be set at the initial set-up site visit, but additional transects may be added at future routine monitoring site visits if necessary.

At least 1 permanent transect every 30 m (~100 ft) should be established per living shoreline treatment that can be re-visited during routine monitoring site visits. However, establishing 3 to 5 transects across an average-size living shoreline (~100 to 200 ft) is recommended to best assess conditions throughout the marsh. Pacing a set distance from one transect to the next helps to randomize the transect selection process. Generally, the transects should be placed no closer than 5 m (~15 ft) apart. *As an example, for a Living Shoreline Treatment 36 meters (~120 ft) in length with plans to establish 4 transects, it is recommended that the transects be spaced approximately 10 meters (~30 ft) apart*

IMPORTANT

For an average size living shoreline (~100 to 200 ft), establishing 3 to 5 transects is a good rule

When only establishing 1 transect for a living shoreline treatment, a good approach is to randomly place the transect within an area of the marsh that seems representative of the entire marsh vegetation zone. A sill system with gaps or openings is considered a single living shoreline treatment. If possible, it is recommended to place at least 1 transect behind each sill structure. If only doing 1 transect behind each structure, place the transect near the center of the structure. Be sure to avoid placing transects behind the openings between each structure.

PLOTS

Along each transect, plots will be sampled within the low marsh, high marsh, and riparian zones. Living shoreline marsh vegetation zones are typically relatively narrow bands of habitat along the shoreline; therefore, collecting data for each transect from 2 plots within the low marsh (at water/structure edge and 1 m landward) and 2 plots within the high marsh (at the transition from low to high marsh and 1 m landward from the transition) is typically sufficient to capture the variation in plant cover and composition within each zone. This number of plots allows for the calculation of the mean and standard deviation (variation) of data being collected and to better represent overall marsh zone conditions, whereas a single plot does not.

Collecting data from the same plot locations allows for the tracking of shifts in plant cover and species over time, indications of ecosystem performance and project stability. Notably, the vast majority of marsh ribbed mussels are found within the first 2 m of the low marsh (Bilkovic et al.

2021, https://doi.org/10.1002/ecs2.3402), where data collection will occur. Along each transect a single riparian plot (~12.5 m^2) will be sampled to assess shrubs and saplings near the marsh. At the most central riparian transect plot, data on trees will also be collected.

SET-UP: ESTABLISH TRANSECT PLOT POINTS

- Establish transects in the field **(Fig 29, Fig 30)**
  - Use the approximate length of the living shoreline treatment as a guide to determine the total number of transects to establish. A good rule of thumb is to set 3 to 5 transects for an average-sized project (~100 to 200 ft)
  - Mark the location of the transect by placing a bamboo pole, PVC pole, or tomato stake at the low marsh-water/structure edge. Push or hammer the pole/stake deep enough into the substrate so that it is partially hidden but still visible when looking for it
  - If laying multiple transects, begin on the left-hand side of the marsh, when facing the water
  - Pace a set distance from the first transect to the next and mark the location of the second transect by placing a bamboo pole, PVC pole, or tomato stake at the low marsh-water/structure edge. Continue until all transects are marked in the low marsh-water/structure edge. Generally, the transects should be placed no closer than 5 m (~15 ft) apart
  - The ShoreWatch App allows for data collection along a maximum of 10 transects per living shoreline treatment.

Fig 29. Detailed depiction of transects and plot locations for a monitoring site with one living shoreline treatment (*marsh with rock sill).*

Plot locations from low marsh-water/structure edge to riparian zone (LM0, LM1, HM0, HM1, Rip or Rip + Trees).

Marsh measures will occur at LM0, LM1, HM0, and HM1 plots. Riparian measures will take place at Rip or Rip + Trees plots. Additional information is collected at Rip + Trees plots.

Fig 30. Detailed depiction of transects and plot locations for a monitoring site with two living shoreline treatments (*marsh with rock sill* and *marsh with oyster structure*).

Plot locations from low marsh-water/structure edge to riparian zone (LM0, LM1, HM0, HM1, Rip or Rip + Trees).

Marsh measures will occur at LM0, LM1, HM0, and HM1 plots. Riparian measures will take place at Rip or Rip + Trees plots. Additional information is collected at Rip + Trees plots. If monitoring only involves one transect, such as this Marsh with Oyster Structure treatment, the riparian plot should be labeled Rip +Trees.

- For each transect:
    - Lay a 100 m (~325 ft) tape measure from the low marsh-water/structure edge pole to the riparian zone in a straight line to represent the transect line
        - Be sure to walk on the left-hand side of the tape measure, when facing the water, to avoid walking on the side where sampling plots will be placed
    - Mark Plot Points along each transect: Place a bamboo pole, PVC pole, or tomato stake at 4 additional locations along the transect (i.e., tape measure) where plots will be placed to collect data
        - Transect pole/stake locations and labels:
            - Low marsh-water/structure edge **(LM0)**
            - Low marsh (1 m landward from the water/structure edge) **(LM1)**
            - Low marsh/high marsh boundary (transition zone where high marsh species begin to dominate) **(HM0)**
            - High marsh (1 m landward of the low marsh/high marsh boundary) **(HM1)**
            - High marsh/upland boundary (riparian zone measures) **(Rip)**
                - Center transect high marsh/upland boundary (riparian zone measures) **(Rip + Trees)**
                *If a site only involves establishing one transect, the riparian plot should be labeled **Rip + Trees**
        - These poles/stakes should remain on site permanently for long-term monitoring to track changes in vegetation over time
        - Push or hammer the poles/stakes deep enough into the substrate so that they are partially hidden but still visible when looking for them

    - While one person places poles/stakes, another person may go behind them and add Plot Points of pole/stake locations in the ShoreWatch App connected (via Bluetooth) to a GPS Unit (e.g., Bad-Elf) **(Fig 31)**
        - Create Plot Points starting at **LM0** moving landward
        - All points along the same transect should be assigned the same number (1-10)
        - Assign each point a Plot Location ID (LM0, LM1, HM0, HM1, Rip, Rip + Trees)
            - For Plots **HM0** and **Rip** (and/or **Rip + Trees**), indicate the distance (m) from the start of the transect tape at water/structure edge

Click Submit (upper right-hand corner) between addition of each Plot Point

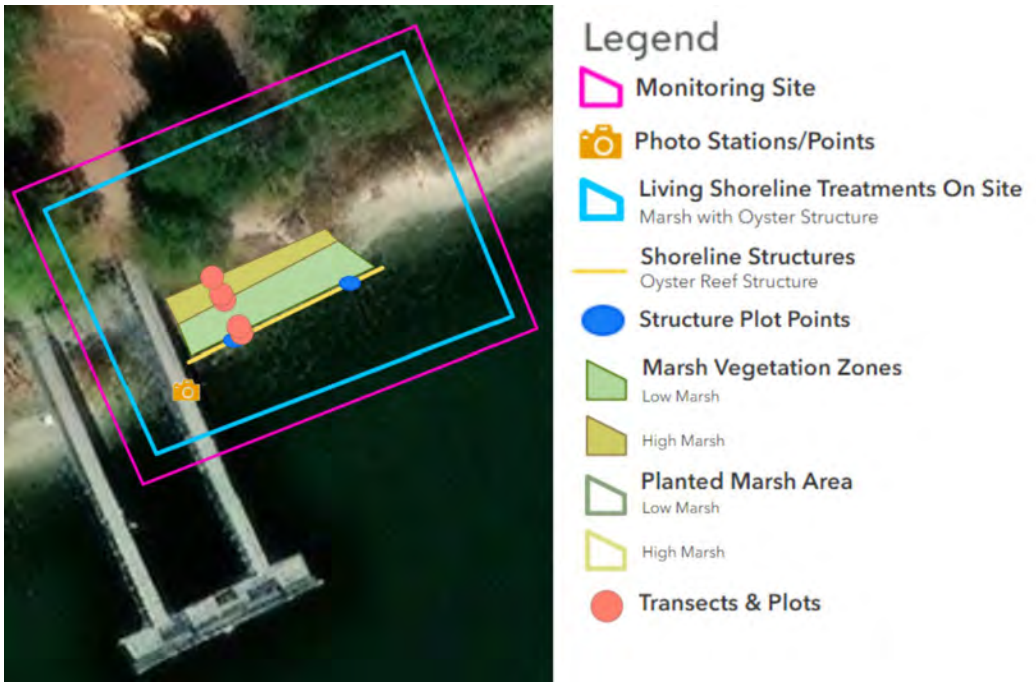


Fig 31. ShoreWatch App view including plot points along a transect.

ADVANCED MONITORING: RECORD TRANSECT PLOT MEASUREMENTS

Locate the marks (e.g., bamboo stake, PVC pole) set for each permanent transect and lay a 100 m (~325 ft) tape measure from the low marsh-water/structure edge mark location to the riparian zone mark location. If there are no marks in the field, locations of the mark may be found in the ShoreWatch App. Be sure to walk on the left-hand side of the tape measure, when facing the water, to avoid walking on the side where sampling plots will be placed.

1. Low marsh-water/structure edge **(LM0)**
2. Low marsh (1 m landward from the water/structure edge) **(LM1)**
3. Low marsh/high marsh boundary (transition zone where high marsh species begin to dominate) **(HM0)**
4. High marsh (1 m landward of the low marsh/high marsh boundary) **(HM1)**
5. High marsh/upland boundary (riparian zone measures) **(Rip)**
6. Center transect high marsh/upland boundary (riparian zone measures) **Rip + Trees**

- In the field, set plots (0.25 m^2 quadrat preferred) at the previously established plot locations (LM0, LM1, HM0, HM1) (i.e., locations of poles/stakes or based on Plot Points in the ShoreWatch App)
    - The upper left-hand corner of the quadrat should be flush with the stake, when facing the water
    - Pull the vegetation through the plot, so that the plot may lay flat on the ground without any stems from outside the plot pulled through
    - Plot should be placed in the same location for each monitoring site visit
    - Remember to walk on the left-hand side of the transect, when facing the water, to avoid walking where the plots are placed
- In the ShoreWatch App record the following for each Plot Point in the marsh:
    - Size of plot used (0.25 m^2 (preferred), 0.5 m^2, 1 m^2)
    - Dominant Sediment Type
    - Marsh Fauna Present **(Fig 32)**
        - Record number of fauna (*optional, for more intensive data collection*)
    - Percent Cover of All Vegetation in Plot **(Fig 33)**
        - Percent cover is reported in ranges rather than an exact percentage, as observers may have slightly different perceptions
        - Only include live plants with visible green tissue
        - If the percent cover seems to be on the cusp of two ranges, select the lesser range
    - Plant Species Observed in Plot
    - *Optional, for more intensive marsh data collection:*
        - Record the number of stems in each plot for:
            - *Spartina alterniflora*
            - *Spartina patens*
        - Record the height (cm) observed in each plot in 3 representative spots for:
            - *Spartina alterniflora*
            - *Spartina patens*

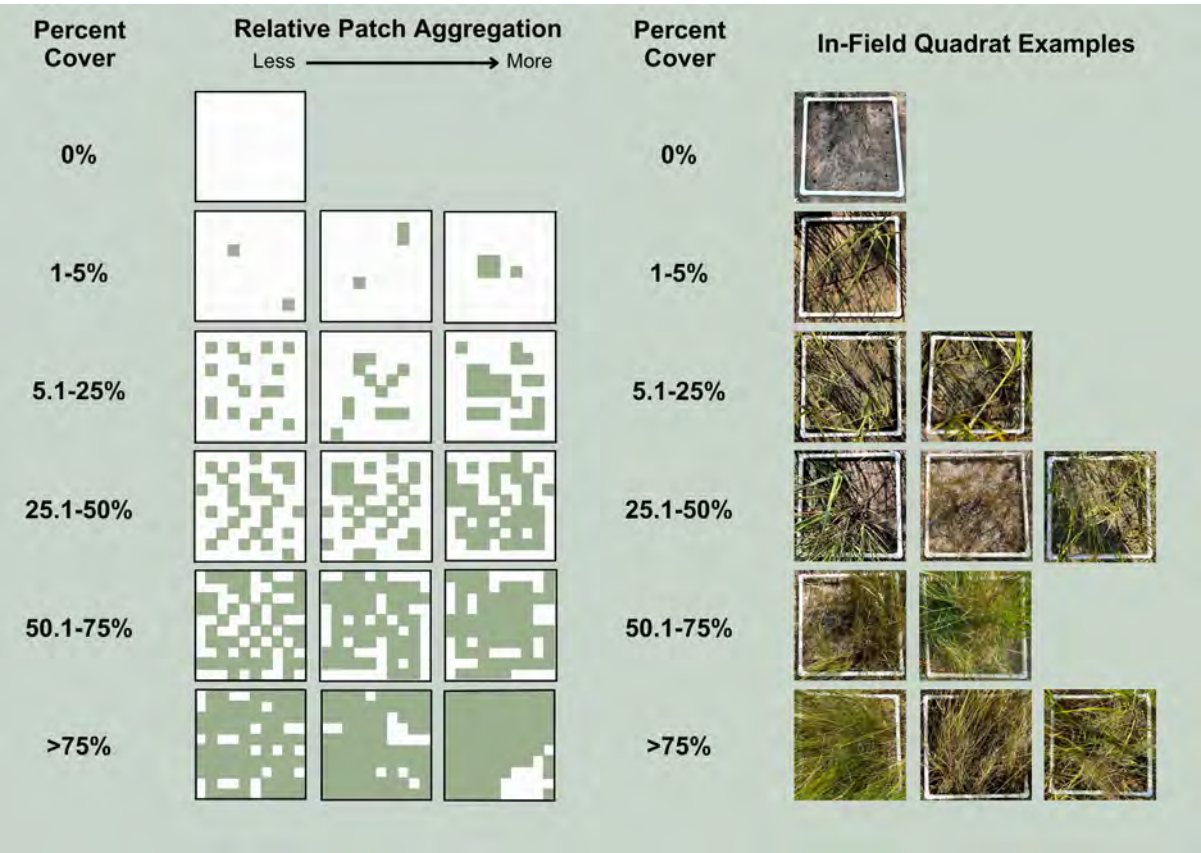


Fig 33. Digital and In-Field Depictions of Percent Cover.

Percent Cover: The portion of the ground surface that is covered by the aerial portions (leaves and stems) of a plant species when viewed from above.

- Record Marsh Width Measurements (m) **(Fig 34)**
  - For the low marsh, measure the width from the low marsh-water/structure edge to the start of the high marsh (i.e., dominant marsh species transitions from *Spartina alterniflora* to *Spartina patens*)

Record Marsh Width Measurements - Marsh Plots **LM1** and **HM1** Only

- For the high marsh, measure the width from the start of the high marsh to the start of the upland or riparian zone

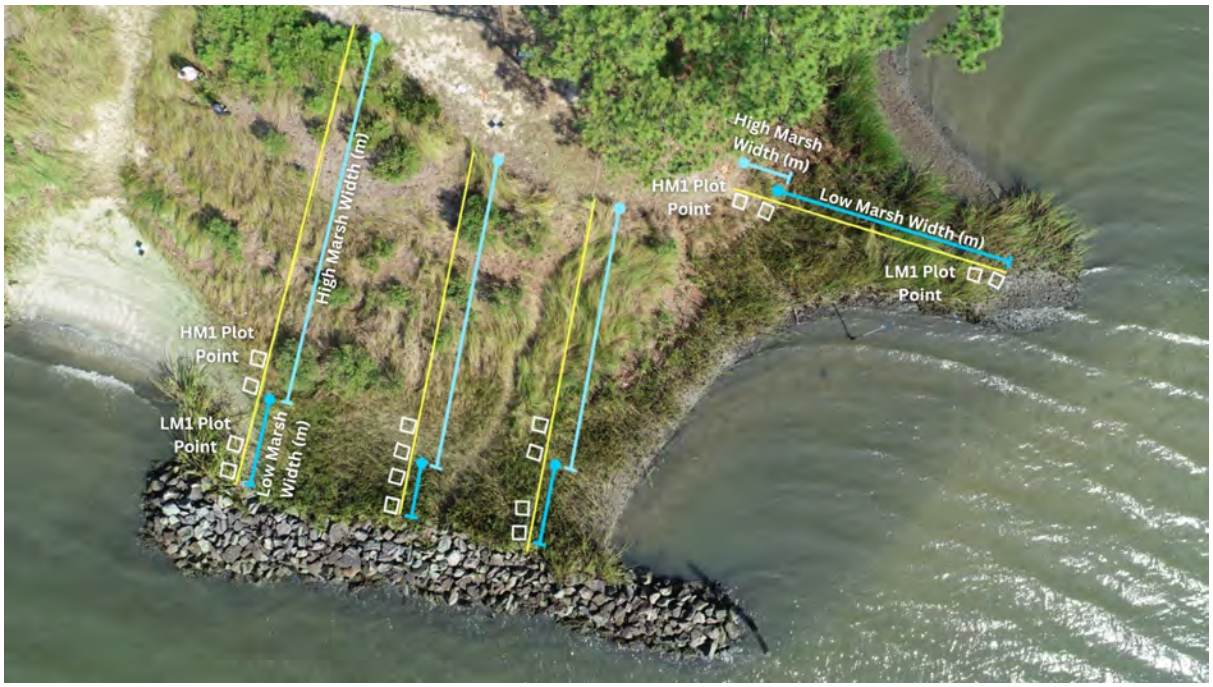


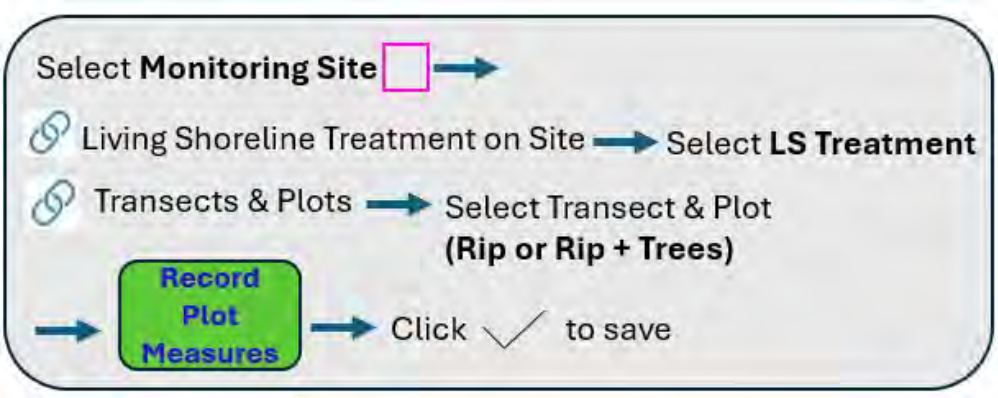
Fig 34. Width measurements for marsh vegetation zones.

For routine monitoring visits occurring soon after the initial site set-up visit, marsh widths may be measured based on locations of poles/stakes along a transect.

The width of the marsh vegetation zones can be measured based on how far the growth of *Spartina alterniflora* and *Spartina patens* extends landward. The pole/stake locations may not always be representative of the width as zones shift over time. The width of the low marsh zone and high marsh zone should be taken for each transect. Record the low marsh width under the LM1 plot point. Record the high marsh width under the HM1 plot point.

Marsh Performance Measures –Transect/Plots		
Living Shoreline Measures	What the measure indicates	Data Output
Marsh plant cover (all species combined) in low and high marsh	Marsh establishment, stability, health, ecosystem function	Plot: Percent cover: 0, 1-5, 5.1-25, 25.1-50, 50.1-75, >75% Treatment: Average of midpoints of each % cover measure
Low marsh plant composition	Diversity, marsh resilience	Plot: Number of species Treatment: Average number of species
High marsh plant composition	Diversity, marsh resilience	Plot: Number of species Treatment: Average number of species
Low marsh width	Flood/storm risk reduction	Transect: Width (m) measured perpendicular to shore from marsh edge to low-high marsh boundary Treatment: Average width (m) of all low marsh measures
High marsh width	Flood/storm risk reduction	Transect: Width measured perpendicular to shore (m) from low-high marsh boundary to high marsh-upland boundary Treatment: Average width (m) of all high marsh measures
Dominant sediment type	Richness of soil (organic carbon)	Plot: Sand, mud, sand-mud mix, peat, or cobble Treatment: Most common sediment type
Presence of key marsh species (ribbed mussels, fiddler crab burrows, periwinkle snails, oysters)	Primary marsh species contributing to marsh function are an indicator of positive ecosystem development	Plot: Presence or absence of each Treatment: Presence or absence of each

RIPARIAN PLOT SAMPLING



The riparian condition can affect living shoreline performance, especially when there is a well-developed forested zone immediately adjacent to the shoreline. Forested riparian zones have well-documented benefits to water quality from intercepting groundwater with uptake from their root systems. A densely vegetated riparian zone (that does not excessively shade and interfere with marsh growth) can be an indication of water quality function, habitat availability, and shore stabilization.

Riparian: An upland zone or area along the water that interacts cross-shore with the lands waterward and landward.

Characterize Riparian Zone

- Record the presence or absence of *Phragmites*
- For Rip + Trees Plot Points only,
  - Record general condition (e.g., Mowed, Fenced)
  - Record ground condition (e.g., Applied Mulch, Natural Leaf Litter)
- Record Woody Shrubs and Saplings Count
  - For each transect, take two steps (~6 ft) from the high marsh-upland boundary pole/stake into the riparian zone. Be careful to watch for any poison ivy

- Holding a meter stick (1 m) with an outstretched arm (~1 m), spin in a circle and record the number of woody shrubs and saplings that are at chest height or taller within the circle (~12.5 m^2) **(Fig 35)**
  - It is recommended to pick a visual start and end point when spinning to avoid overcounting
  - Following the same guidance, count the woody shrubs and saplings that fall below chest height
- Take a photo(s) of the riparian plot(s) vegetation using the ShoreWatch App

Fig 35. Shrub and sapling count.

Spinning with a meter stick in hand to collect shrub and sapling count.

- If a Rip Plot Point, click the ✓ (in the bottom right-hand corner)n
  - If a Rip + Trees Point, continue filling out the form

Count Trees

- Record the number of trees in the riparian zone
  - Find the transect closest to the center of the living shoreline treatment then stand at the high marsh-upland boundary facing the riparian zone
    - If the riparian zone is on a bank or sloped above the marsh, walk up the slope or bank **(Fig 36)**

Fig 36. Riparian measures on a sloped bank.

If the riparian zone is on a bank or sloped above the marsh, do not count the trees with the Cruz angle from the high marsh-upland boundary (a). Instead, walk up the slope or bank (b) so that the trees are being measured with an arm parallel to the ground and the Cruz angle is angled at the breast height of the trees.

- Hold the end of a Cruz angle chain to your nose with your other arm stretched out in front of you parallel to the ground
  - A Cruz angle gauge is used to estimate the average basal area at a site
    - Basal area is the cross-sectional area of trees at breast height. Each of the openings on the gauge (5, 10, 20, and 40) represents a different basal area factor. Basal area (ft^2) is estimated by multiplying the basal area factor used (e.g., 10) by the number of trees counted **(Fig 37)**
  - If you do not have a Cruz angle, you may use your outstretched thumb
- Turn in a circle and count the number of trees in the riparian zone that fill the number 10 opening, representative of 6 cm DBH (diameter breast height), and are at least 1.5 m (~5 ft) away
  - If using your thumb, only count trees that are not obscured by your thumb
  - Count should be done at breast height, not by the base of the tree
  - If a tree splits and has two trunks around breast height view, consider them separately
- Take a photo(s) of trees measured with the Cruz angle

- *Optional, for more intensive data collection:*
  - *Presence or absence of dead and/or dying trees*
  - *List up to 5 of the most dominant riparian trees present*
  - *Indicate invasive plants observed*

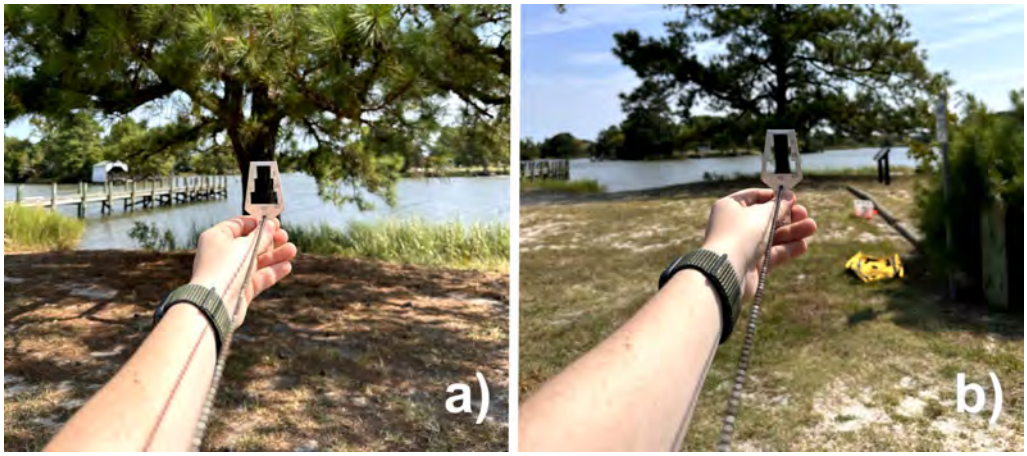


Fig 37. Riparian tree count using a Cruz angle.

a) Example of a tree that would be included in the tree count, as it fills in the number 10 opening.
b) Example of a tree that would not be included in the tree count, as it does not fill the number 10 opening.

Riparian Performance Measures		
Living Shoreline Measures	Data Output	What the measure indicates
Woody shrubs & sapling density	Plot: No. of shrubs and saplings/m^2 Treatment: average no. shrubs and saplings/m2	Bank stability, diversity, habitat provision
Tree abundance and basal area	Treatment: No. of trees, basal area (ft^2) of trees	Bank stability, diversity, habitat provision
Ground condition	Treatment: Natural leaf litter, Applied mulch, Turf/grass, Bare ground, or Impervious	Bank stability
General condition	Treatment: Mowed, Landscape gardens, Wooded, or Developed	Potential stressors; marsh migration capacity
Phragmites australis	Treatment: Presence or absence	Invasive species colonization risk

11. UPLAND BANK CONDITIONS

Bank: The interface between the shoreline and the upland; may be gradual or steep.

A stable bank has uniformly spread vegetation while an eroding bank may have little to no vegetation. The plant roots help to stabilize the sediment on the slope.

Bank height can serve as an indication of erosion or stability and the potential for future landward marsh migration.

Bank slope can determine marsh plant growth suitability. A more gradual slope allows for wave "run-up" and dissipation of wave energy, allowing for a better foundation for vegetation growth. Steep bank slopes lead to increased erosion as the waves strike the bank toe. A gentle

(low or sloping) slope (6:1) is optimal for plant growth and has the highest likelihood of marsh migration. A mid-range slope (3:1) accommodates marsh plant growth and some wave attenuation. A steep slope exceeds what is suitable for marsh plant growth.

- Record Vegetative Coverage (e.g., Dense, Patchy, Absent)
- Record Vegetation Type (e.g., Trees only, Trees/Shrubs only, All herbaceous, Mixed woody/herbaceous)
    - Herbaceous plants are those that do not have a woody stem above the ground
- Record Bank Height
    - Make a visual estimate and select a height category **(Fig 38)**
        - Low: 0 - 1.5 m (0 - 5 ft)
        - Medium: 1.5 – 4.6 m (5 – 15 ft)
        - High: 4.6 - 9.1m (15 - 30 ft)
        - Bluff: >9.1 m (> 30 ft)
- Record Bank Slope
    - Place a meter stick flat on the ground from the base of the bank (i.e., at the high marsh-upland boundary) towards the riparian zone
    - Open an inclinometer app on a phone or tablet and lay the device on the meter stick, either flat or+ on its edge
        - There are numerous free apps available for download (e.g., Bubble Level)
    - Based on the degrees shown on the app, select the slope category **(Fig 39)**
        - Flat: <2.9 degree slope
        - Low Slope: 2.9 - 10 degree slope
        - Moderate Slope: >10 - 20 degree slope
        - Steep Slope: >20 - 45 degree slope
        - Very Steep: >45 degree slope

Fig 38. Example images of different bank height categories.

Low bank height is 0 – 1.5 m (0 – 5 ft), medium bank height is 1.5 – 4.6 m (5 – 15 ft), high bank height is 4.6 – 9.1 m (5 – 30 ft), and a bluff is >9.1 m (>30 ft).

Upland Bank Condition Performance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Vegetative coverage	Erosion or stability	Treatment: Dense, Patchy, or Absent
Vegetation type	Erosion or stability	Treatment: Trees only, Trees/Shrubs only, All herbaceous, Mixed woody/herbaceous
Bank height	Erosion or stability	Treatment: Low bank ~0-1.5 m (0-5 ft), Medium bank ~1.5-4.6 m (5-15 ft), High bank ~4.6-9.1 m (15-30 ft), or Bluff >~9.1 m (>30 ft)
Bank slope	Marsh plant growth suitability	Treatment: Degree of slope (Flat Slope (<2.9 degrees), Low Slope (2.9-10 degrees), Moderate Slope (>10-20 degrees), Steep Slope(>20-40 degrees), or Very Steep Slope (>45 degrees))

ADVANCED SET-UP: ESTABLISH SPECIFIC BANK MEASUREMENT POINTS

Establish Specific Bank Measurement Points at locations along the bank where you want to measure bank height and slope.

- Give the point a unique Bank Measurement ID/Name

ADVANCED MONITORING: RECORD BANK MEASUREMENTS

- Record Bank Height
  - Using a tape measure or meter stick measure the bank height
- Record Bank Slope
  - Place a meter stick flat on the ground from the base of the bank (i.e., at the high marsh-upland boundary) towards the riparian zone **(Fig 40)**
  - Open an inclinometer app on a phone or tablet and lay the device on the meter stick, either flat or+ on its edge
- Add any relevant Notes about the bank at this location

- Take a photo of the bank at this location

Fig 40. Measuring bank slope.

Measuring the degree of the bank slope by placing a meter stick flat on the ground from the high marsh-upland boundary towards the riparian zone. The phone is placed on its side with its edge resting on top of the meter stick.

12. EROSION & OTHER PROBLEM AREAS

Shoreline erosion is a natural coastal process that helps sustain natural habitats like marshes and beaches, but in areas with human infrastructure close to shore, excessive erosion may increase flooding risk. Living shorelines maintain natural processes while reducing erosion. Tracking signs of erosion will indicate if the site is improving or if the project is not performing as well as hoped.

Other problem areas may include bare spots within the marsh, damage caused by wildlife, or excessive trash build-up. Highlighting these areas can signal the need for maintenance or additional attention.

If corrective measures are taken to fix these areas, the status of the point can be Resolved to indicate that the issue was resolved.

SET-UP: ESTABLISH EROSION & PROBLEM AREA POINTS

This is where delineation goes.

- Add a new Erosion or Issue Point
    - To create the Point, navigate to Erosion & Problem Area Points and hit add to mark the location, then indicate the type of erosion (Marsh Edge or Bank), or describe the other issue, and name the point.

MONITORING: RECORD EVIDENCE OF EROSION OR OTHER PROBLEMS

- Record Evidence of Erosion
    - Status of Erosion Area
    - Erosion Evidence **(Fig 41)**
    - Notes field to describe further
    - Take a photo(s) using the ShoreWatch App
- Record Status of Other Problem Area (Active, Stable)
    - Notes field to describe further
    - Take a photo(s) using the ShoreWatch App

Fig 41. Sites with evidence of erosion.

a) Eroding bank with bank slumps, fallen trees, and exposed roots.
b) Eroding bank with bank slumps and surface runoff channels.
c) Eroding marsh edge and bank with exposed roots.
d) Eroding marsh edge with scarp and exposed peat.

Marsh Edge and Bank Stability Performance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Marsh edge erosion	Marsh integrity and/or need for further assessment/maintenance	Treatment: Geolocation, photo, description (Fallen clumps, Scarp, and/or Exposed peat/former low marsh)
Bank erosion	Erosion or stability	Treatment: Geolocation, photo, description (Bank slumps, Fallen trees, Exposed roots, and/or Surface runoff channels)

13. GRAZING EXCLUSION STATUS

Temporary grazing exclusion devices are meant to prevent grazers from eating freshly planted or growing marsh plants in the project area. These devices should be installed after planting and left until the marsh has become well-established **(Fig 42)**.

- Record grazing exclusion status and any need for repairs or removal
  - Select the status type
    - If Present, still necessary?
      - If still necessary, select the condition type
      - A grazing exclusion device that needs repair may have fences knocked over or holes in the netting. If the marsh is well-established, the grazing exclusion device may no longer be necessary.

- Take a photo(s) using the ShoreWatch App

Fig 42. Examples of grazing exclusion devices.

Set-up may include fences, poles, string, netting, or other barriers.

14. WILDLIFE OBSERVATIONS

The abundance and diversity of wildlife in living shoreline systems are indicators of ecological processes necessary to achieve water quality improvement and shoreline protection. If the plant communities are healthy, they can support a diverse, productive fish and wildlife community with unique ecological processes that contribute to living shoreline performance. In return, marsh animals may assist plant growth. For example, fiddler crab burrows help aerate the soil around marsh plant roots, while clusters of ribbed mussels attached to grass blades increase wave tolerance and provide nutrients to the plant roots. The presence of mammals may indicate energy flow between systems.

- Record Wildlife Observations (e.g., Fish, Shorebirds) **(Fig 43)**
- Record Evidence of Wildlife Presence
- Notes field to describe further

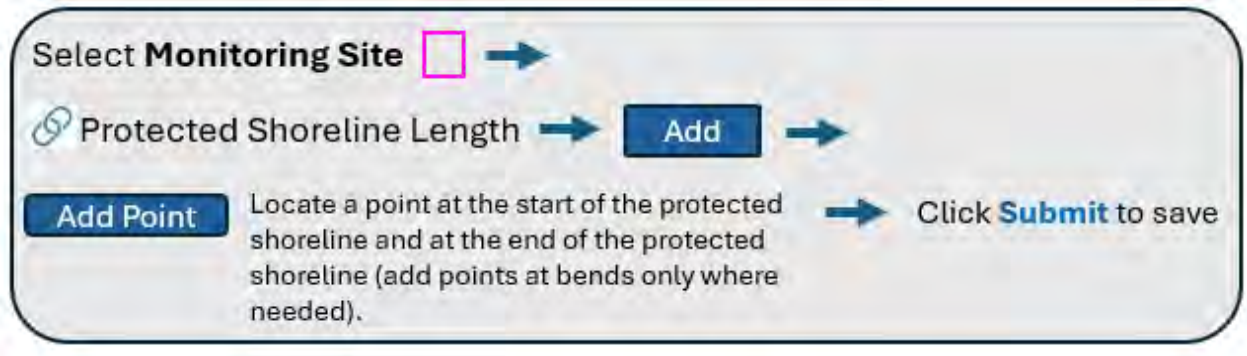
- Take a photo(s) using the ShoreWatch App

Fig 43. Wildlife seen at living shoreline systems: blue crab, otters, and a great blue heron.

General Living Shoreline Observations		
Living Shoreline Measures	What the measure indicates	Data Output
Grazing Exclusion Status	Maintenance needs	Treatment: Status – Not applicable, Present, Removed, Not present but needed
Presence of wildlife evidence	Marsh habitat support for wildlife	Site: Wildlife observations and evidence

15. PROTECTED SHORELINE LENGTH

By documenting the length of shoreline that is protected by each living shoreline treatment, users can begin to track how much of Virginia's shoreline is protected by living shorelines.



- In the ShoreWatch App, delineate the length of protected shoreline by adding points to create a line parallel to the protected shoreline **(Fig 44)**
    - Line should be drawn slightly offshore, not touching the shoreline, but still within the Monitoring Site
    - Lines should be drawn as straight as possible, only having bends where needed **(Fig 45)**
    - Protected Shoreline Length may be longer than structure length, as Protected Shoreline Length accounts for all living shoreline treatments and structures at a site

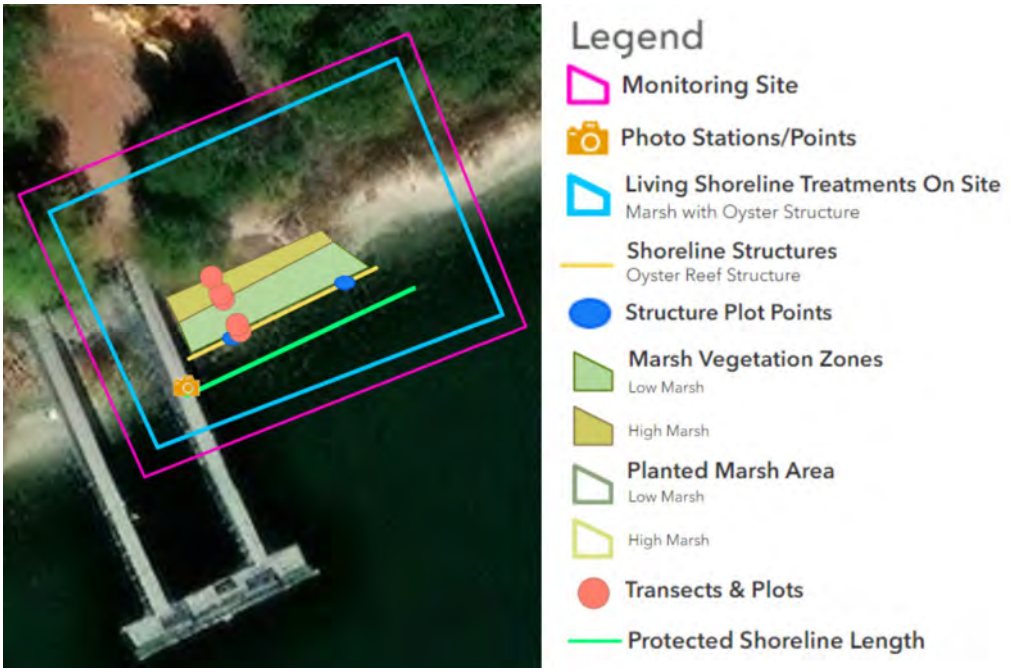


Fig 44. ShoreWatch App view including a delineated protected shoreline length.

Fig 45. Straight versus bent protected shoreline length.

The figure on the left has a straight protected shoreline length that follows the length of the shoreline structure (Oyster Reef Structure).

The figure on the right has a bent protected shoreline length that encompasses two shoreline structures (Oyster Reef Structure & Rock Sill). Only one protected shoreline length should be delineated per Monitoring Site.

MAINTENANCE

While all the performance measures included in this manual represent an aspect of the site's performance, select measures may be used to quickly assess the need for maintenance or further investigation of the site's performance. There is a standard expected trajectory for most tidal marsh and oyster-based living shorelines. Delays or deviations from the normal expected evolution may suggest unsuitable conditions that may require active interventions. Generally, planted tidal marshes should have increasing cover, stem height, and flowering shoots for the first several years; established marshes usually will have >70% total vegetation cover. Positive indicators in fish and wildlife responses include diverse species typically associated with natural tidal marshes. Successful oyster-based projects have live oysters of different ages and living reef expansion vertically and horizontally.

Maintenance Measures		
Living Shoreline Measures	What the measure indicates	Data Output
Fixed location Photo(s)	Project changes over time or in response to storm events	Site: Image(s) (jpg)
Structure integrity	Structure failure or need for repair/maintenance	Treatment: Missing section, dislodged or collapsed materials, stable
Low Marsh plant cover	Marsh establishment, stability, health, ecosystem function	Treatment: % cover: 0, 1-5, 5.1-25, 25.1-50, 50.1-75, >75%
High Marsh plant cover	Marsh establishment, stability, health, ecosystem function	Treatment: % cover: 0, 1-5, 5.1-25, 25.1-50, 50.1-75, >75%
Phragmites presence and cover in low/high marsh or riparian	Invasive species colonization; marsh stress	Treatment: presence/absence; % cover
Marsh edge erosion	Marsh integrity and/or need for further assessment/maintenance	Treatment: geolocation, photo, description (fallen clumps, scarp, or exposed peat/former low marsh)
Bank erosion	Erosion or stability	Treatment: geolocation, photo, description (bank slumps, fallen trees, exposed roots, and/or runoff channels)
Storm impacts	Need for further assessment/maintenance	Site: Y/N/uncertain: tidal flooding, excessive rain, strong winds, debris damage
Grazing Exclusion Status	Maintenance needs	Treatment: Status – e.g., Not present/needed (good condition), present/needed (needs repairs)

SUMMARY

Community-based monitoring of shoreline restoration projects will contribute to the collection of vital information on the performance of living shorelines around the Commonwealth of Virginia. The intent of this manual is to provide guidance to the living shoreline community on the collection of standardized data that can be used to inform project performance within different settings and for varied project designs, with a focus on living shorelines that incorporate tidal marsh and/or oysters. The protocols are designed to be relatively rapid and low-cost. Applying the protocols through use of the companion ShoreWatch App allows for the data to be easily collected and then viewed and exported via an online **Living Shoreline Monitoring Data Dashboard** in easy-to-understand performance metrics. These metrics can be used by the living shoreline community to ensure project designs meet both ecological and stabilization goals, compare sites, trigger maintenance, and track changes overtime or following storm events. As awareness and use of living shorelines increases, monitoring information will be invaluable to guide their design and implementation for resilient shorelines.

Acknowledgements. The Living Shoreline Monitoring ShoreWatch App and manuals were developed by a team from the Center for Coastal Resources Management (CCRM) at Virginia Institute of Marine Science, including – Christine Tombleson (App Creator), Jessica Fergel and Sean Gregory (lead authors of the manual and appendix material), Karen Duhring, David Stanhope, Kory Angstadt, and Donna Marie Bilkovic. Early versions of the App were informed by discussions with James River Association and Living Shoreline Collaborative members, and we thank them for lending their time and expertise, including Shereen Hughes, Stacie McGraw, Aaron Wendt, Kati Grigsby, Jameson Brunkow, Lucy Deignan and Ryan Walsh. Funding support was provided by the James River Association.