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# Water, Water Everywhere: How Nature Can Help

Joy Brown
Marine Program Manager
South Carolina Chapter

# LIVING SHORELINES

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# NOAA's Definition

# Guidance for Considering the Use of Living Shorelines (2015)

## DEFINING LIVING SHORELINES

**Living shoreline is a broad term that encompasses a range of shoreline stabilization techniques along estuarine coasts, bays, sheltered coastlines, and tributaries. A living shoreline has a footprint that is made up mostly of native material. It incorporates vegetation or other living, natural "soft" elements alone or in combination with some type of harder shoreline structure (e.g. oyster reefs or rock sills) for added stability. Living shorelines maintain continuity of the natural land–water interface and reduce erosion while providing habitat value and enhancing coastal resilience.**

https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf

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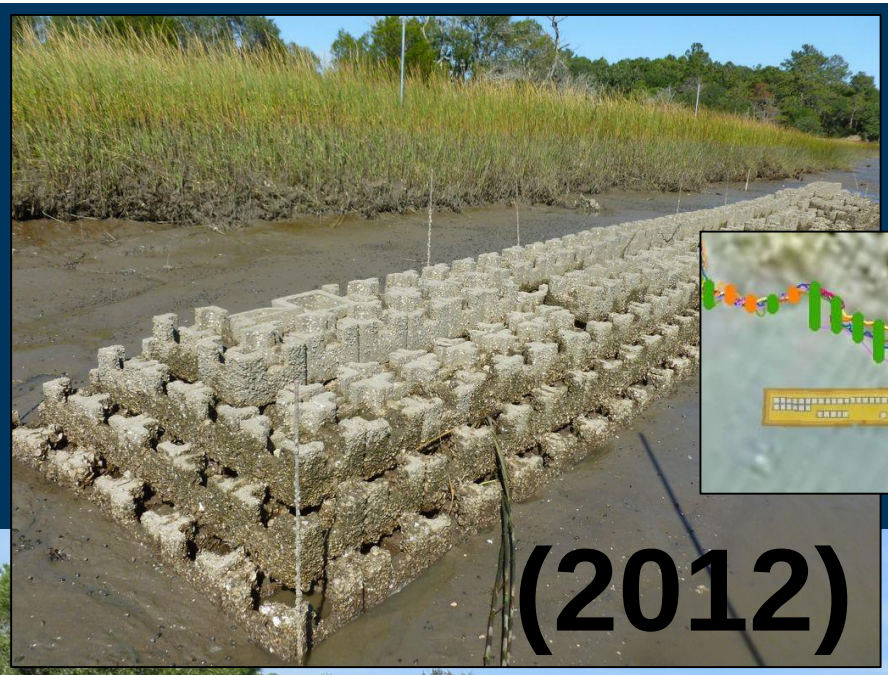
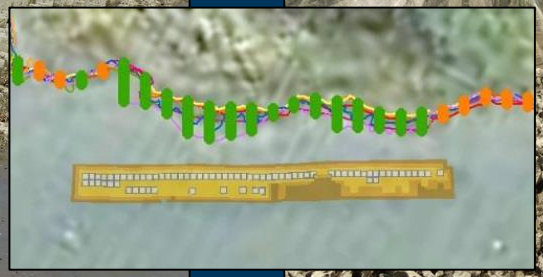
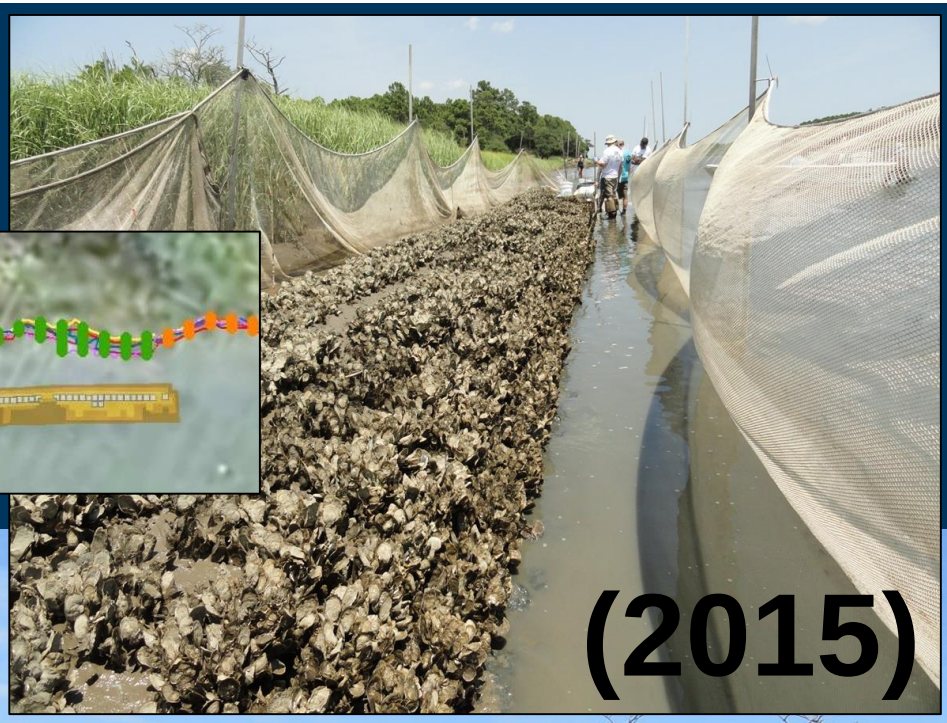
# SC Example



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# Storm Tested

Rock sill LS/natural marsh/hard shorelines  Hurricane Matthew, NC (2015 – 2017)

*(Smith et al 2018, Eco App)*

- Better resistance to landward erosion (HM) & maintained elevation  (2 yr)
- Enhance *S. alterniflora* vs nat'l marsh

Defense concept by Corps – North Atl Comprehensive Coastal Study (2015)

- Risk reduction performance summary: coastal erosion, floods, wave attenuation (sm & med), storm surge

NOAA LS Support Resilient Communities

- 15' of marsh can absorb 50% of incoming wave energy
- 33% of US shorelines will be hardened by 2100
- Hard structures prevent marsh migration inland & create seaward erosion

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# Cost Comparison

2016 GSAA LS Summit – GA by Ed Hoffman @ Greenworks, LLC

## Concrete Bulkhead - 200LF

| | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 7500 | 7500 |
| Precast Concrete Sheetpile | 1 | LS | 60000 | 60000 |
| Concrete Pile Cap | 15 | CY | 500 | 7500 |
| Tie Backs | 10 | EA | 1500 | 15000 |
| Weephole Drains/Gravel | 10 | EA | 500 | 5000 |
| Fabric | 1 | LS | 600 | 600 |
| Type 1 Rip Rap(Toe Protection) | 100 | TN | 70 | 7000 |
| Labor | 300 | HR | 120 | 36000 |
| Equipment | 1 | LS | 20000 | 20000 |
| Fuel | 1 | LS | 5000 | 5000 |
| Subtotal | | | | **163600** |
| Company Overhead | | | | 24540 |
| Estimated Company Return | | | | 16360 |
| Total | | | | **204500** |
| | **Cost/LF** | | **$1,023** | |

## Rip Rap Type 3 w/ Type 1 Toe - 200LF w/ 18' slope

| | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 5000 | 5000 |
| Rip Rap (embankment)(18") | 350 | TN | 65 | 22750 |
| Rip Rap (toe) | 100 | TN | 70 | 7000 |
| Equipment | 1 | LS | 6500 | 6500 |
| Labor | 200 | HR | 120 | 24000 |
| Tiebacks | | EA | 1500 | 0 |
| Filter Fabric | 1 | LS | 1200 | 1200 |
| Fuel | 1 | LS | 4500 | 4500 |
| Subtotal | | | | **70950** |
| Company Overhead | | | | 10643 |
| Estimated Company Return | | | | 7095 |
| Total | | | | **88688** |
| | **Cost/LF** | | **$443** | |

## Vinyl Bulkhead - 200LF

| | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 4500 | 4500 |
| Vinyl Sheetpile | 1 | LS | 26000 | 26000 |
| Timber Pile Cap | 1 | LS | 3000 | 3000 |
| Tie Backs | 10 | EA | 1500 | 15000 |
| Weephole Drains/Gravel | 10 | EA | 500 | 5000 |
| Fabric | 1 | LS | 600 | 600 |
| Labor | 240 | HR | 120 | 28800 |
| Type 1 Rip Rap(Toe Protection) | 100 | TN | 70 | 7000 |
| Equipment | 1 | LS | 15000 | 15000 |
| Fuel | 1 | LS | 4500 | 4500 |
| Misc | 1 | LS | | 5000 |
| Subtotal | | | | 114400 |
| Company Overhead | | | | 11440 |
| Estimated Company Return | | | | 11440 |
| Total | | | | 137280 |
| | **Cost/LF** | | **$686** | |

## Living Shoreline - 200 LF

| | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 4500 | 4500 |
| Oyster Shell | 350 | TN | 60 | 21000 |
| Prep and Grade | 1 | LS | 1500 | 1500 |
| Anchors | 10 | EA | 150 | 1500 |
| Geotech | 1 | LS | 1200 | 1200 |
| Labor | 120 | HR | 120 | 14400 |
| Recycled Concrete Toe | 100 | TN | 65 | 6500 |
| Equipment | 1 | LS | 5000 | 5000 |
| Fuel | 1 | LS | 4500 | 4500 |
| Subtotal | | | | 60100 |
| Company Overhead | | | | 6010 |
| Estimated Company Return | | | | 6010 |
| Total | | | | 72120 |
| | **Cost/LF** | | **$361** | |

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# Cost Comparison

| Technique | Estimated Cost of Materials |
|---|---|
| ***Nature-Based Living Shoreline*** | **Coir Log (coconut fiber)** 12" X 10' $100.00—$150.00 per log |
| ***Beach Restoration*** | **Sand Replenishment** $7.00-17.50 per cubic yard |
| ***Marsh Sill*** | $75.00-$150.00 per linear ft. |

| Technique | Estimated Cost of Materials |
|---|---|
| ***Ecologically Enhanced Revetment*** | $90.00-$150.00 per linear ft. |
| ***Bulkhead*** | $80-$1,200 per linear ft. |

| Technique | Estimated Cost of Materials |
|---|---|
| ***Living Reef Breakwater*** | $100.00-$150.00 per linear ft. |
| ***Breakwater*** | $90.00-$150.00 per linear ft. |

Seachange Consulting, 2011, Rella, A., & Miller, J. PhD., 2012, and Hafner, S., 2012

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# Permitting & Policy

## Army Corps of Engineers

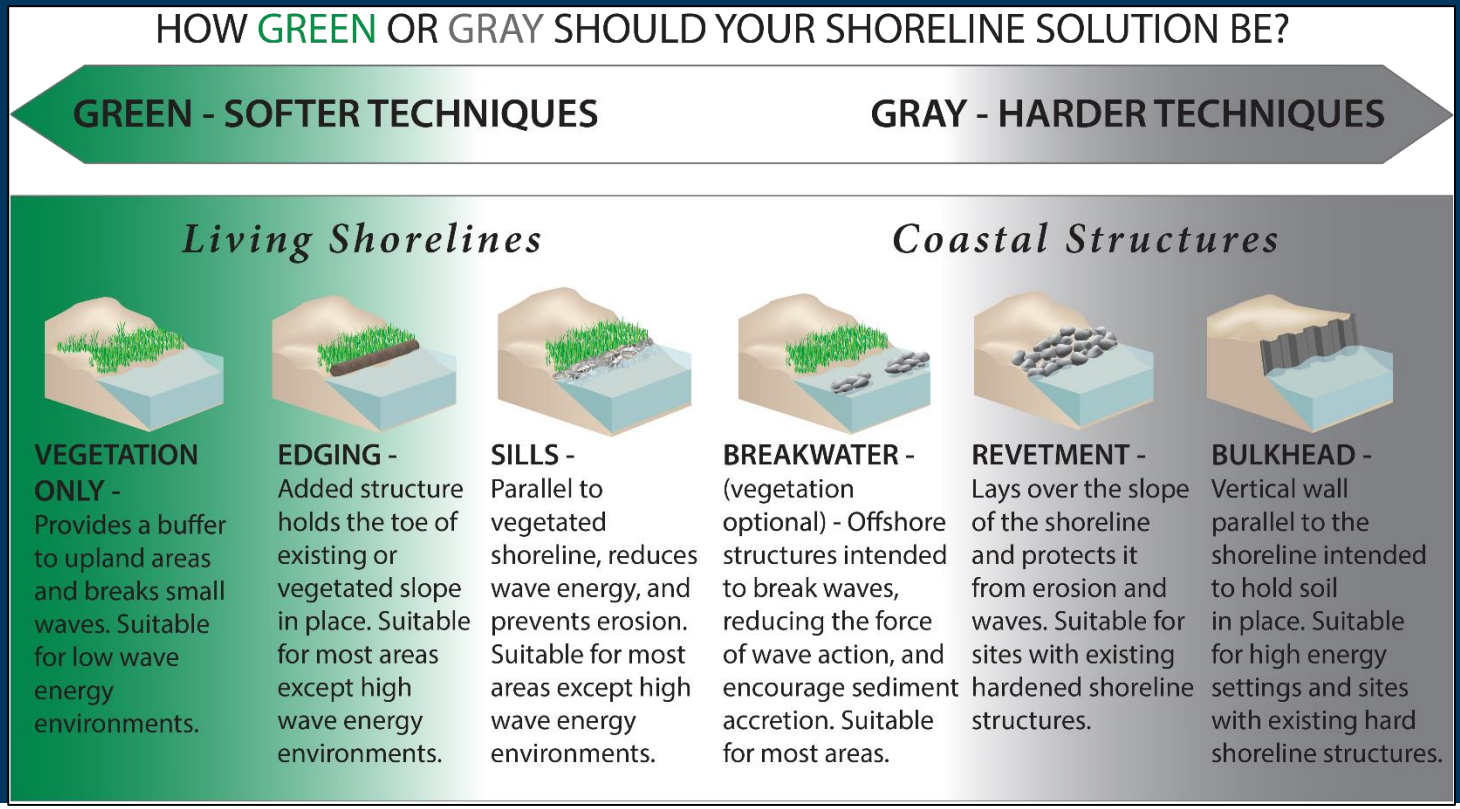
- NWP 54 (2017)
- NWP 13 & 27

## SC GP

Under development (2020-2021)

## NC GP

Riprap Revetments for Wetland Protection in Estuarine & Public Trust Waters; Marsh (Rock) Sills



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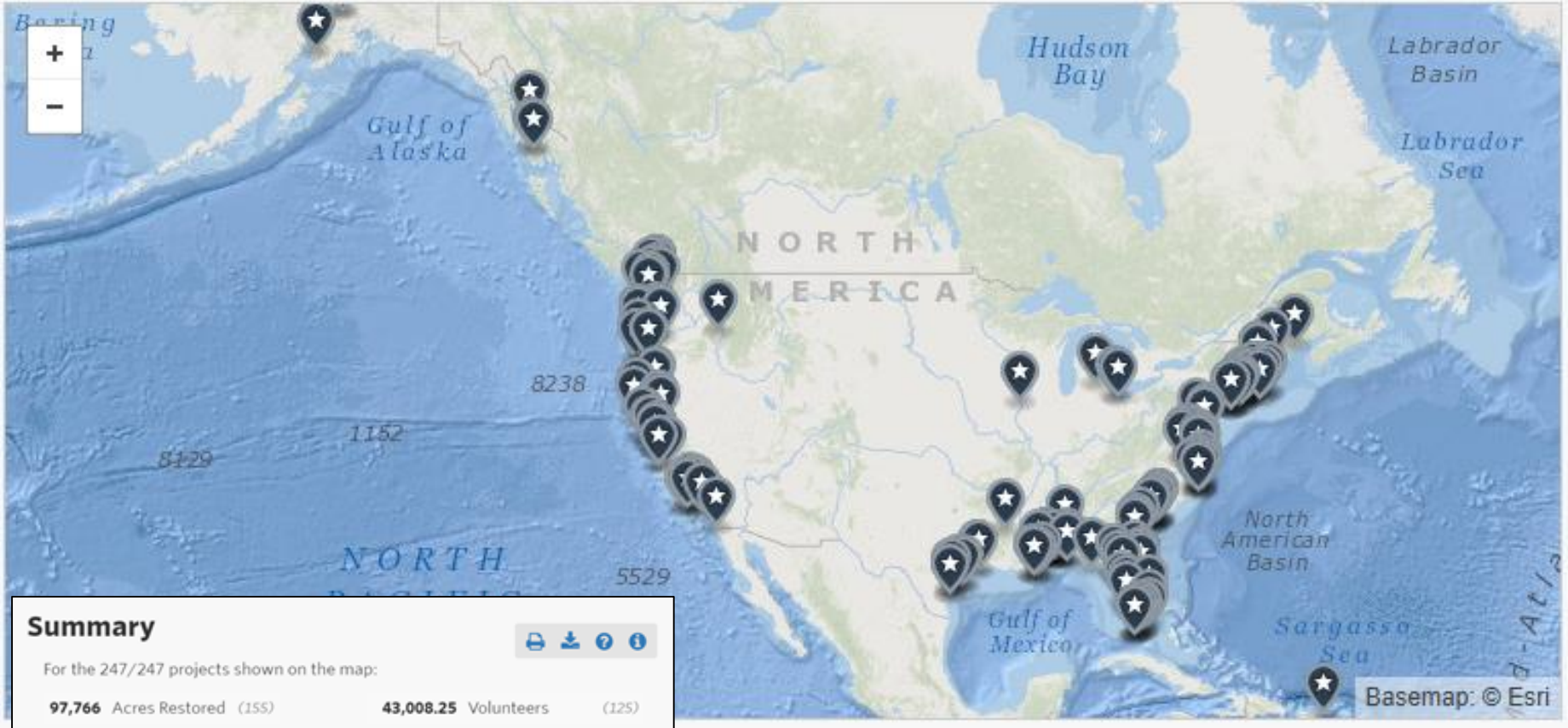
# TNC's Coastal Restoration

## NATURAL INFRASTRUCTURE + RESTORATION PROJECTS

http://projects.tnc.org/coastal/




**Summary**

For the 247/247 projects shown on the map:

| | | | |
|---|---|---|---|
| **97,766** | Acres Restored (155) | **43,008.25** | Volunteers (125) |
| **1,165** | Miles Restored (48) | **137,631.25** | Volunteer Hours (131) |

*Number of reporting projects shown in parentheses

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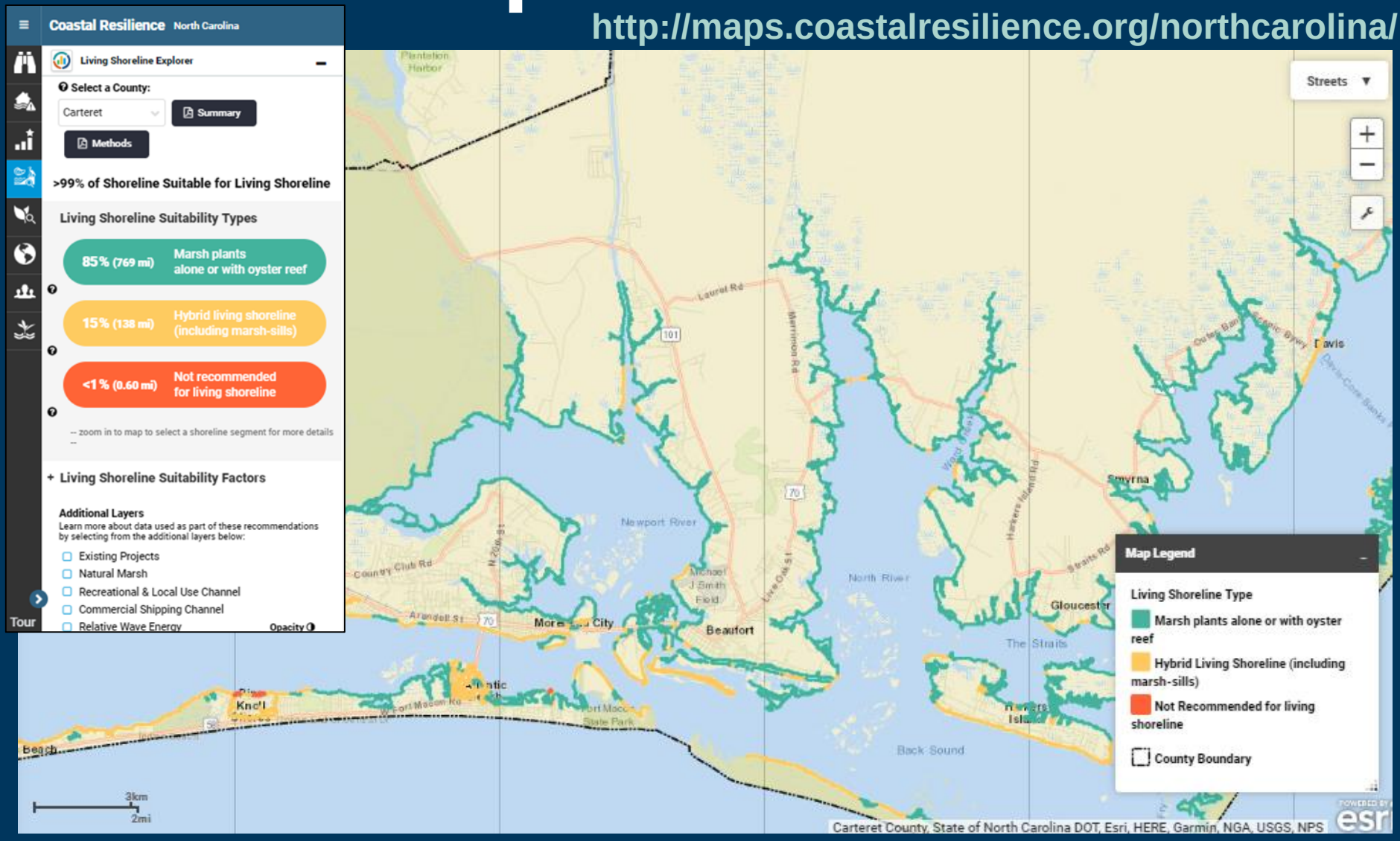
# CR.org/NC/LS Explorer

http://maps.coastalresilience.org/northcarolina/



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# Living Shoreline Academy

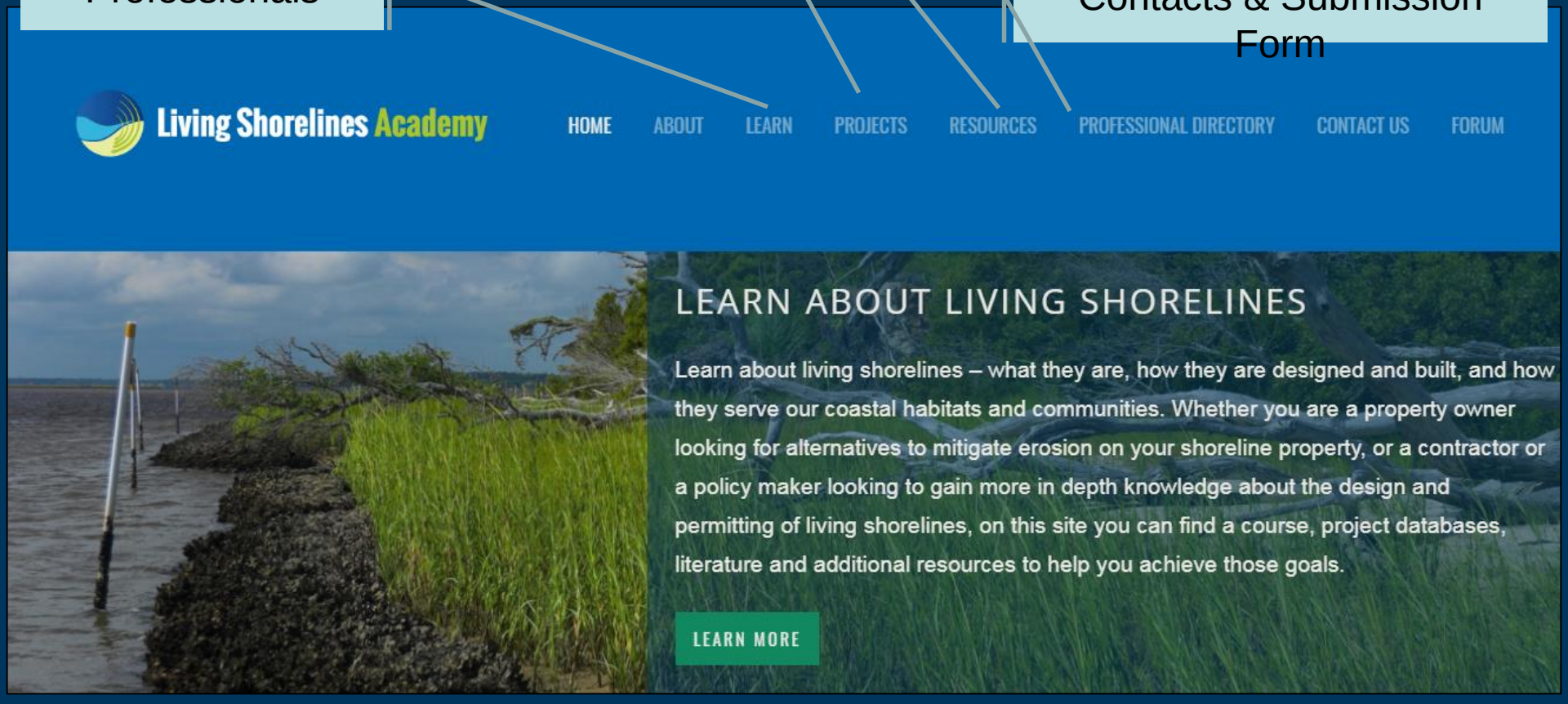
https://livingshorelinesacademy.org/

Interactive Map, Database & Submission

Literature, Online, Powerpoints, Videos, Workshops/Webinars

Property Owners & Professionals

Existing Professional Contacts & Submission Form



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# Websites & Sources of Additional Information

- NOAA's Guidance for Considering the Use of Living Shorelines (2015)
- TNC's Coastal Resilience site – Projects & Mapping Portal
- Living Shoreline Academy
- NC Coastal Federation – How they are making LS the go-to erosion control
- Island Free Press – 10.23.18 – NC Lawmakers Enable Use of Living Shorelines for Hurricane Recovery
- NC Coastal Federation – photo slide show of LS vs bulkheads after Hurricane Florence
- SC DHEC LS Working Group
- LS: The Science & Management of Nature-Based Coastal Protection
- Sustainable Adaptive Gradients (SAGE)
- SAGE Searchable Project Database
- LS Legislative Initiatives – State and Regional

# Websites & Sources of Additional Information (cont)

- Living shorelines enhances the resilience of saltmarshes to Hurricane Matthew (2016)
- The time to start is now: How implementing natural infrastructure solutions can improve and protect our coasts
- Lowcountry Land Trust: Living Shorelines Support Resilient Communities
- A Community Resource Guide for Planning Living Shorelines Projects
- How to Protect Your Property from Shoreline Erosion: A handbook for estuarine property owners in North Carolina
- A Comparative Cost Analysis of Ten Shore Protection Approaches at Three Sites Under Sea Level Rise Scenarios
- Beach Stabilization: Structure and Beach Renourishment Alternatives

# Communication

*Ecological Applications*, 28(4), 2018, pp. 871–877


## Living shorelines enhanced the resilience of saltmarshes to Hurricane Matthew (2016)

Carter S. Smith [1,4] Brandon Puckett [2] Rachel K. Gittman [3] and Charles H. Peterson [1]

[1]*Institute of Marine Sciences, University of North Carolina at Chapel Hill, 3431 Arendell Street, Morehead City, North Carolina 28557 USA*
[2]*North Carolina Coastal Reserve and National Estuarine Research Reserve, Beaufort, North Carolina 28516 USA*
[3]*Department of Biology and Institute for Coastal Science and Policy, Eastern Carolina University, Greenville, North Carolina 27858 USA*

Evaluated rock sill living shorelines compared to natural marshes and hardened shorelines (i.e. bulkheads) in NC

Analyzed changes in surface elevation, *Spartina alterniflora* stem density, and structural damage from 2015 to 2017, including before and after Hurricane Matthew (2016)

Living shorelines exhibited better resistance to landward erosion during Hurricane Matthew than bulkheads and natural marshes

Living shorelines were more resilient than hardened shorelines (maintained landward elevation over the two-year study period with any repair)

Rock sill living shorelines were able to enhance *S. alterniflora* stem densities over time when compared to natural marshes

# The time to start is now: How implementing natural infrastructure solutions can improve and protect our coasts

*By*

Shannon E. Cunniff
*Environmental Defense Fund*
*scunniff@edf.org*

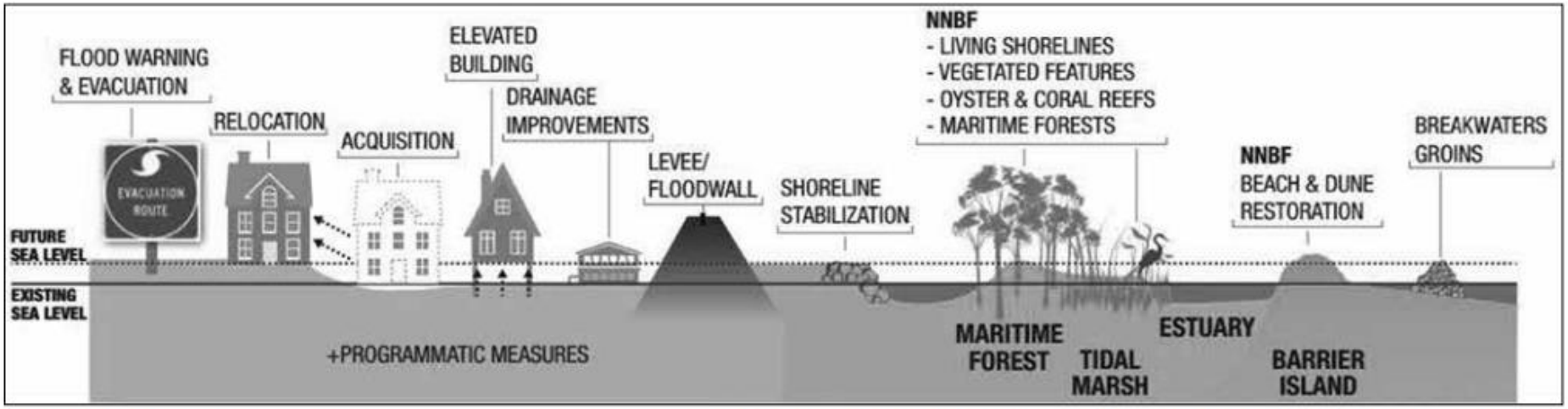



**Figure 1: Multiple lines of defense concept as presented by the Corps of Engineers' North Atlantic Comprehensive Coastal Study (2015).**

## Table 1.

**Natural defenses: Summary of risk reduction performance. Factors effecting risk reduction performance include storm intensity, track, forward speed, surrounding local bathymetry and topography.**

**Key**
**- = Low confidence, feature not likely to address**
**+ = High confidence, data available**
**~ = Limited confidence refinement needed**
**Blank = no confidence or no data**

| Strategy | RISK REDUCTION PERFORMANCE: Reduce coastal erosion/ shoreline stabilization | Nuisance floods (high tides with sea level rise) | Short wave (<2') attenuation (stabilize sediment) | Reduce force & height of medium waves (2'-5') | Storm surge (low frequency extreme events) |
|---|---|---|---|---|---|
| **Structural** | | | | | |
| Groins | + | - | + | | |
| Breakwaters | + | - | + | + | |
| Seawalls/revetments/bulkheads | + | + | | + | + |
| Surge barriers | - | | | + | + |
| **Existing natural** | | | | | |
| Wetlands | + | | + | ~ | ~ |
| Mangroves/coastal forest | + | | + | + | + |
| Vegetated dunes | + | | + | + | + |
| **Nature-based** | | | | | |
| Beach nourishment | + | + | + | + | |
| Vegetated dune creation | + | + | + | + | + |
| Barrier island restoration | + | + | + | + | + |
| Small-scale edging and sills (living shorelines) | + | ~ | + | | |
| Restored oyster/shellfish reefs | + | | + | ~ | |
| Restored/created coral reefs | + | | + | ~ | |
| Restored maritime forests (including mangroves) | + | + | + | + | + |
| Restored wetlands | + | + | + | ~ | ~ |

# The Costs of Shoreline Stabilization

Traditional,  Hard Structure Impacts:

Maintenance costs are significant and ongoing expenses when a hard defense is selected and therefore likely to result in significant levels of investment through a project's lifetime

Construction and maintenance costs are likely to increase into the future in response to sea level rise

Smooth, vertical seawalls are the least effective at dissipating wave energy and can create a loss of marsh

"Living shorelines are crucial to habitat development and to the conservation of fish, birds and other wildlife. We must continue to promote these kinds of restoration activities as they are vital to sustaining the delicate ecological system."

-Tom Kelsch, Director of Conservation Programs for the National Fish and Wildlife Foundation.

Visit PDF for additional information Living Shoreline Impacts and Benefits

# The Costs of Shoreline Stabilization

| Concrete Bulkhead - 200LF | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 7500 | 7500 |
| Precast Concrete Sheetpile | 1 | LS | 60000 | 60000 |
| Concrete Pile Cap | 15 | CY | 500 | 7500 |
| Tie Backs | 10 | EA | 1500 | 15000 |
| Weephole Drains/Gravel | 10 | EA | 500 | 5000 |
| Fabric | 1 | LS | 600 | 600 |
| Type 1 Rip Rap(Toe Protection) | 100 | TN | 70 | 7000 |
| Labor | 300 | HR | 120 | 36000 |
| Equipment | 1 | LS | 20000 | 20000 |
| Fuel | 1 | LS | 5000 | 5000 |
| Subtotal | | | | 163600 |
| Company Overhead | | | | 24540 |
| Estimated Company Return | | | | 16360 |
| Total | | | | 204500 |
| | Cost/LF | | $1,023 | |

| Rip Rap Type 3 w/ Type 1 Toe - 200LF w/ 18' slope | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 5000 | 5000 |
| Rip Rap (embankment)(18") | 350 | TN | 65 | 22750 |
| Rip Rap (toe) | 100 | TN | 70 | 7000 |
| Equipment | 1 | LS | 6500 | 6500 |
| Labor | 200 | HR | 120 | 24000 |
| Tiebacks | | EA | 1500 | 0 |
| Filter Fabric | 1 | LS | 1200 | 1200 |
| Fuel | 1 | LS | 4500 | 4500 |
| Subtotal | | | | 70950 |
| Company Overhead | | | | 10643 |
| Estimated Company Return | | | | 7095 |
| Total | | | | 88688 |
| | Cost/LF | | $443 | |

| Vinyl Bulkhead - 200LF | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 4500 | 4500 |
| Vinyl Sheetpile | 1 | LS | 26000 | 26000 |
| Timber Pile Cap | 1 | LS | 3000 | 3000 |
| Tie Backs | 10 | EA | 1500 | 15000 |
| Weephole Drains/Gravel | 10 | EA | 500 | 5000 |
| Fabric | 1 | LS | 600 | 600 |
| Labor | 240 | HR | 120 | 28800 |
| Type 1 Rip Rap(Toe Protection) | 100 | TN | 70 | 7000 |
| Equipment | 1 | LS | 15000 | 15000 |
| Fuel | 1 | LS | 4500 | 4500 |
| Misc | 1 | LS | | 5000 |
| Subtotal | | | | 114400 |
| Company Overhead | | | | 11440 |
| Estimated Company Return | | | | 11440 |
| Total | | | | 137280 |
| | Cost/LF | | $686 | |

| Living Shoreline - 200 LF | | | | |
|---|---|---|---|---|
| Mobilization | 1 | LS | 4500 | 4500 |
| Oyster Shell | 350 | TN | 60 | 21000 |
| Prep and Grade | 1 | LS | 1500 | 1500 |
| Anchors | 10 | EA | 150 | 1500 |
| Geotech | 1 | LS | 1200 | 1200 |
| Labor | 120 | HR | 120 | 14400 |
| Recycled Concrete Toe | 100 | TN | 65 | 6500 |
| Equipment | 1 | LS | 5000 | 5000 |
| Fuel | 1 | LS | 4500 | 4500 |
| Subtotal | | | | 60100 |
| Company Overhead | | | | 6010 |
| Estimated Company Return | | | | 6010 |
| Total | | | | 72120 |
| | Cost/LF | | $361 | |

# LIVING SHORELINES SUPPORT RESILIENT COMMUNITIES

Living shorelines use plants or other natural elements—sometimes in combination with harder shoreline structures—to stabilize estuarine coasts, bays, and tributaries.

**One square mile** of salt marsh stores the carbon equivalent of **76,000 gal of gas** annually.

Marshes trap sediments from tidal waters, allowing them to **grow in elevation** as sea level rises.

Living shorelines improve **water quality**, provide fisheries **habitat**, increase **biodiversity**, and promote **recreation**.

Marshes and oyster reefs act as natural **barriers** to waves. **15 ft** of marsh can **absorb 50%** of incoming wave energy.

Living shorelines are **more resilient** against storms than bulkheads.

**33%** of shorelines in the U.S. will be **hardened** by **2100**, decreasing fisheries habitat and biodiversity.

Hard shoreline structures like **bulkheads** prevent natural marsh migration and may create seaward **erosion**.

The National Centers for Coastal Ocean Science | coastalscience.noaa.gov

Some graphics courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

# Fisheries Habitat Impacts of Marsh Sills as a Shoreline Stabilization/Restoration Alternative to Bulkheads

Surveys of 25 marsh sills in NC and assessment of the shoreline stabilization of marsh sills relative to traditional stabilization structures

Fish and crustaceans were quantified and compared between marsh sills, bulkheads, and the control (unstabilized) marshes

Post Hurricane Irene damage survey found that over 1/3 of the approximately 20km of bulkheads along the Outer Banks back-barrier shoreline were damaged or had collapsed completely

No damage was observed to marsh sill or riprap shorelines

Nekton abundance, biomass, and diversity are greater in the marsh at sill sites than control sites

Nekton using habitat directly adjacent to bulkheads are less abundant, have less biomass, and are less diverse than nekton found adjacent to sills


Provides community leader, citizens, and contractors with guidance on key factors that should be considered when embarking on a living shoreline project and links to additional resources that could be consulted during the planning process

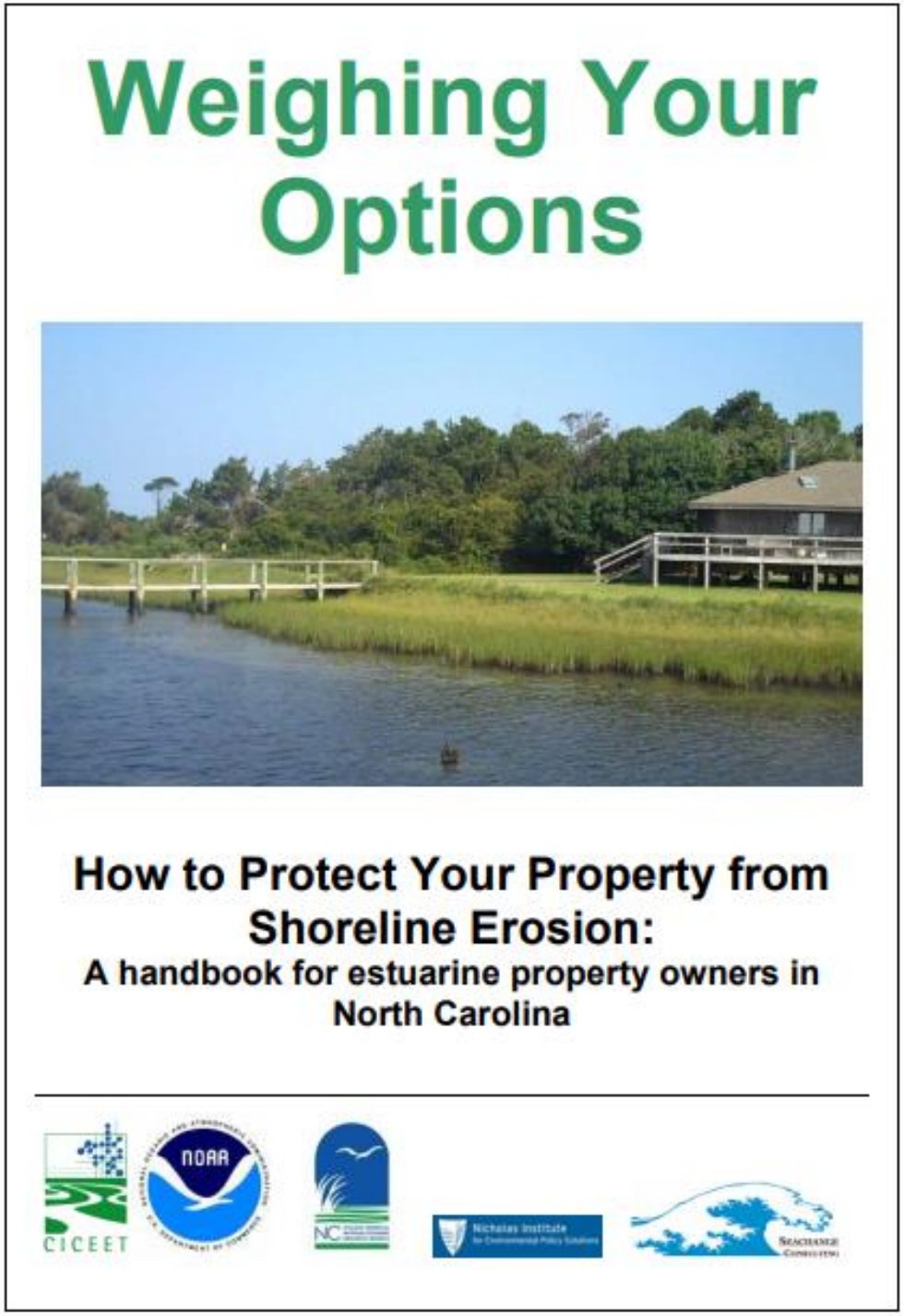
Guide to be used with TNC's Coastal Resilience Tool

Grey infrastructure can reflect wave energy and in some cases, results in erosional threats to neighboring coastal areas and to the upland shoreline directly in front of and behind the structure

The average cost data included in the table are sample estimates for the materials of living shorelines (adapted from Seachange Consulting, 2011, Rella, A., & Miller, J. PhD., 2012, and Hafner, S., 2012 and discussed in the following slides)

| Technique | Estimated Cost of Materials | Additional Benefits and Factors to Consider |
|---|---|---|
| ***Nature-Based Living Shoreline*** | **Coir Log (coconut fiber)** 12" X 10' $100.00—$150.00 per log | This is the most natural shoreline restoration option and it is only applicable in low energy areas. Additional factors to consider include accessibility of oyster and/or clam shell (price of shell bags does not include cost of shell), and the procurement of a bio-log. Please note, that if using bagged shell as part of the design, the state of New Jersey does not currently allow oysters to be "planted" in waters closed to shellfish harvest. More information on cost and construction of nature-based living shorelines can be found in the Partnership for the Delaware Estuary's Practitioner's Guide. |
| ***Beach Restoration*** | **Sand Replenishment** $7.00-17.50 per cubic yard | Depending on the location, beach restorations can also provide habitat for shorebirds and other key species that also provide ecotourism opportunities (e.g., Red Knots and horseshoe crabs). Factors to consider include slope of the beach, wave energy, storm frequency, beach density (volume/unit length) and granular fill, access to and transportation of material and labor. |
| ***Marsh Sill*** | $75.00-$150.00 per linear ft. | Marsh sills are more appropriate in low and moderate energy environments. Although marsh sills are able to function in a wide array of energy environments, it's important to consider site specific conditions. In addition, the cost of shell bags do not include the cost of the clam or oyster shell, which can be donated by local restaurants or purchased. |

| Technique | Estimated Cost of Materials | Additional Benefits and Factors to Consider |
|---|---|---|
| ***Living Reef Breakwater*** | $100.00-$150.00 per linear ft. | Breakwaters attenuate more energetic waves further off of the shore, ultimately reducing shoreline edge erosion. If living reef breakwaters are designed to promote oyster habitat, the development of three-dimensional reef habitat can improve water quality and support important fish species. Decisions to use bagged-shell, oyster castles, rock or marl need to take into account the need to stabilize the structures, as well as the ability of the substrate (i.e., the ground the breakwater will be sitting on) to withstand the weight of the structures. In addition, the cost of shell bags do not include the cost of the clam or oyster shell, which can be donated by local restaurants or purchased. In addition, the state of New Jersey does not currently allow oysters to be "planted" in waters closed to shellfish harvest.** |
| ***Breakwater*** | $90.00-$150.00 per linear ft. | Implementation of rock breakwaters in higher energy wave environments requires a scrutiny of the lower soil substrate conditions (i.e., what type of ground will the breakwater be sitting on). Breakwaters will reduce wave energy but careful attention should be placed on monitoring bottom scour, which can result in negative unforeseen consequences affecting neighboring coastal areas.** |
| ***Ecologically Enhanced Revetment*** | $90.00-$150.00 per linear ft. | Although ecologically enhanced revetments can be used in a wide range of energy environments, this technique lacks inherent environmental benefits associated with lower impact living shoreline projects. In addition, this technique stabilizes shorelines but lacks a component of sediment accretion. Therefore, it should mostly be considered in high energy environments and/or areas where other techniques will not work. |
| ***Bulkhead*** | $80-$1,200 per linear ft. | Bulkheads are considered a hard armoring traditional approach. Wave energy is reflected and not absorbed, which can result in bottom scour and loss of vegetation. The natural shoreline is eliminated, resulting in a loss of upland and shallow water habitat. |




Main erosion control methods used for shorelines in NC estuaries: vegetation, oyster reeds, marsh sills, riprap, breakwaters, bulkheads

This guide gives information about the out-of-pocket costs and tangible benefits of each option as well as “hidden” costs and benefits

This guide was used as a reference in the “A Community Resource Guide for Planning Living Shorelines Projects” for the cost data (in the previous slides)

# A Comparative Cost Analysis of Ten Shore Protection Approaches at Three Sites Under Two Sea Level Rise Scenarios

Prepared for:

Hudson River Valley Greenway

Hudson River National Estuarine Research Reserve

As a part of:

The Hudson River Sustainable Shorelines Project

Prepared by:

Andrew J. Rella, &

Jon K. Miller, Ph.D.

July 2012

STEVENS INSTITUTE of TECHNOLOGY THE INNOVATION UNIVERSITY

THE CENTER FOR MARITIME SYSTEMS

HUDSON RIVER SUSTAINABLE SHORELINES

The project generated information about the performance, cost, and natural benefits of different shoreline management options, in the context of the Hudson River Estuary's human and natural setting

A comparative cost assessment of ten different shoreline stabilization approaches at three sites, under two sea level rise scenarios with a seventy year time frame.

The ten approaches included: timber bulkhead, steel sheet pile bulkhead, bio-walls, revetments, riprap, joint planting, vegetated geogrids, timber cribbing, live crib walls, and sills

This analysis was used as a reference in the "A Community Resource Guide for Planning Living Shorelines Projects" for the cost data (in the previous slides)


Coastal Overview
- Coastal Processes
- Coastal Development

Beach Stabilization Structures
- Hard Structure
- Soft Structure

Beach Nourishment
- Methods

Backpassing and Bypassing
- Economics

Cost estimates given for the examples

This analysis was used as a reference in the "A Community Resource Guide for Planning Living Shorelines Projects" for the cost data (in the previous slides)