Living Shorelines: Benefits & Limitations

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Living Shorelines for Erosion Control on Estuarine Shorelines workshop
Coastal Studies Institute, ECU Outer Banks Campus, Wanchese, NC
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Outline

• What are living shorelines?
• Estuarine ecosystems/habitats
• Estuarine shoreline change
• Shoreline protection options
• Protection performance - living shorelines vs. no protection and hardened structures
• Living shoreline resilience to SLR
• Limitations of living shorelines
What are living shorelines?

A living shoreline 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. (NOAA 2015)

Photo source: NC Division of Coastal Management. How to Protect Your Property from Shoreline Erosion: A handbook for estuarine property owners in North Carolina
Estuarine ecosystems - oysters

In NC, the native oyster is the eastern oyster (*Crassostrea virginica*).

Characteristics:
Submerged or intertidal piles of living oysters and oyster shells

Distribution controlled by environmental factors:
• temperature - 10 to 30°C
• salinity - 6-35 ppt
• require DO above 2 mg L⁻¹
• tolerant of moderate turbidity
Estuarine ecosystems - marshes

Characteristics:
• Marshes are wetlands continuously inundated by water, characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions
• They are found between high tide and mean sea level across a range of salinities
• Community of plants determined by salinity
• Distribution of species across a marsh follows small changes in elevation
• Belowground biomass can equal or exceed aboveground biomass

MTL – mean tide line
MHW – mean high water line
ULW – upper limit of wetlands; extreme tide line

General guidance for plant selection in the Chesapeake Bay

Salt and brackish marsh zones and plants

In NC, estuarine lunar tidal range varies between 20 cm and 100 cm, with higher values in the south. Wind tides also have strong influence.

**Extreme tide line**
- *Juncus roemerianus* – Black needlerush
- *Distichlis spicata* – Seashore/inland saltgrass

**High tide line**
- *Spartina patens* – Salt meadow hay

**Mean tide line**
- *Spartina alterniflora* - Smooth cordgrass

**Water**
- Mean high water (MHW) < 100 cm / 3.2 ft
- Mean low water (MLW)

Photo source: NC DEQ
Freshwater marsh plants

*Scirpus americanus* – Olney threesquare

*Spartina cynosuroides* – giant cordgrass

Also cattails and black needlerush
Invasive marsh plant - *Phragmites australis*

**PLANT CHARACTERISTICS**
- outcompetes native *Spartina* and *Juncus*
- colonizes disturbed areas
- clonal/rhizome growth allows invasion of saline soils
- greater above and belowground biomass
- removal efforts often fail

**ECOSYSTEM IMPACTS**
- builds surface elevation
- altered fish and wildlife habitat
- high primary production
- reduced viewscape
- fire hazard

? Wave attenuation
? C sequestration
? Keeps up with SLR

Slide from Currin and Gittman Living Shoreline presentation for NERR/NCCR
A few of many human benefits/ecosystem services provided by coastal ecosystems

<table>
<thead>
<tr>
<th>Coastal ecosystem providing human benefit/ecosystem service</th>
<th>Human benefit/ecosystem service</th>
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<tbody>
<tr>
<td>Oysters and marshes</td>
<td>Attenuate wave energy</td>
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<tr>
<td>Oysters and marshes</td>
<td>Habitat for marine and estuarine organisms including fish and waterfowl</td>
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<tr>
<td>Oysters and marshes</td>
<td>Filtration – sediment and/or nutrients</td>
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<td>Oysters and marshes</td>
<td>Denitrification</td>
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<tr>
<td>Marshes</td>
<td>Carbon storage</td>
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Estuarine ecosystem distribution and habitat value

Marsh distribution includes narrow fringing marshes along many shorelines, including those with landward development.

Generally, in locations with fetch < 9 km (5 miles) and wave heights < 0.2 m (0.66 ft)
Benefits - wave energy attenuation

Marsh
• 50% of wave energy reduced within 5 m (15’) of marsh edge (Leonard and Croft 2006)
• >90% over 30 m of marsh (S. alterniflora) (Knutson et al. 1982)
• Wave energy reduction increases with plant biomass

Oyster reefs
• 17% wave energy reduced behind oyster reefs (Wiberg et al. 2018)

Wave energy reduction decreases as water depth exceeds canopy/reef height
Benefits - dynamic and resilient

They shift inland and raise in elevation with sea level rise

Marshes grow sediment volume over time
• dissipate energy and trap sediment
• vegetative growth above and below ground
• storm events are often a SOURCE of sediment to marshes, rather than a loss

Living oyster reefs grow in elevation over time

Coastal shoreline change

NC has 19,200 km (~12,000 miles) of estuarine shoreline

Estuarine shorelines are eroding
- Outer Banks study- Corbett and others (unpublished; figure at right)
  - Most estuarine shorelines are showing net erosion
- New River Estuary (Currin et al. 2015)
  - -0.3 m yr\(^{-1}\) - average rate
- Neuse River Estuary (Cowart et al. 2010)
  - 93% eroded; 6.6% accreted; 0.4% no change over 40 years
  - -0.6 m yr\(^{-1}\) - average rate
- Albemarle-Pamlico Sound (Riggs and Ames 2003)
  - -0.8 m yr\(^{-1}\) - average rate

Figure source: Corbett, unpublished
Broader sites of erosion and accretion or little change are numbered in red (#1-6) and green (#7-9), respectively.
Factors that determine erosion rates

Wind wave energy
- Dictated by fetch, bathymetry, wind speed, and relative wind direction
- Sea level rise shifts the zone exposed to wave energy inland
- Storm events
- Disruption in sediment supply
- Changes in shoreline topography
- Removal of vegetation
- Boat wakes
Shoreline protection options – hardened structures

- Bulkhead
- Breakwater
- Riprap revetment
- Sea wall
- Groin/jetty

Photo source: NC Division of Coastal Management. How to Protect Your Property from Shoreline Erosion: A handbook for estuarine property owners in North Carolina
Shoreline protection options – hardened structures

What is lost?

- Shallow Refuge
- Tidal Marsh
- Bulkhead
- Reflected Waves
- Scour

- Sediment transport & particle-size change
- Vegetation loss
- Benthic Fauna, Birds, Fish abundance reduced
- Other ecosystem services impacted
  - Denitrification capacity reduced

Changes occur **BELOW** the mean high water line:

..and have a negative impact on public trust resources

Slide from Currin and Gittman Living Shoreline presentation for NERR/NCCR
Shoreline protection options – living shorelines

A living shoreline 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. (NOAA 2015)

Photo source: NC Division of Coastal Management. How to Protect Your Property from Shoreline Erosion: A handbook for estuarine property owners in North Carolina
Shoreline wind erosion protection performance: living shorelines vs. no protection

- 17 living shorelines in NC
- 12 showed reduced erosion
- Of 12 with reduced erosion, 6 accreted
Shoreline storm protection performance: living shorelines vs. no protection and bulkheads

Hurricane Irene (2011)
Marshes with and without sills protect estuarine shorelines from erosion better than bulkheads during a Category 1 hurricane
Rachel K. Gittman a,*, Alyssa M. Popowich a,*, John F. Bruno b, Charles H. Peterson a, b

Hurricane Matthew (2016)
Living shorelines enhanced the resilience of saltmarshes to Hurricane Matthew (2016)
Carter S. Smith c,1,4 Brandon Puckett c,2 Rachel K. Gittman d,3 and Charles H. Peterson1
Hurricane Irene - 2011
Landfall at Cape Lookout, NC
August 27, 2011
Category 1

Shoreline storm protection performance: living shorelines vs. no protection and bulkheads

- 75% of bulkheads damaged in area with greatest surge and sustained winds (OBX); 12% in Bogue Banks (area with marsh sites for comparison)
- No loss in elevation at marsh sites (living shorelines with sills and natural)
Bulkheads vs. Living Shorelines Bogue Sound
Shoreline storm protection performance: living shorelines vs. no protection and bulkheads

Hurricane Matthew Hovered offshore of NC for 24 hours October 2016 Category 1

- 3 of 4 bulkheads were damaged and repaired (thus higher landward elevation)
- LSs showed accretion shoreward and little change landward following storm

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

Carter S. Smith,1,4 Brandon Puckett,2 Rachel K. Gittman,1,3 and Charles H. Peterson1

Pre- and Post- Florence monitored living shorelines
Landfall near Wrightsville Beach, NC
Sept 14, 2018
Category 1

- 1. Morris Landing Rock Sill- Wilmington
- 2. Morris Landing Oyster Sill- Wilmington
  {No post storm images for this site}
- 3. Springers Point Rock Sill- Ocracoke
- 4. Woodall Rock Sill- Ocracoke
- 5. Cahoon-Davis Oyster Sill- Ocracoke
- 6. Chowan River Boat Ramp Rock Sill- Edenton
- 7. St. James Oyster Sill- Wilmington
- 8. Southport Rock Sill- Wilmington

Map courtesy of B. Puckett

Radar image of the eye of Hurricane Florence approaching the Wilmington area early Friday September 14, 2018. (Courtesy Unisys)
Average scour of 9cm

Average sill width increased by 25cm

Average vertical erosion of 3cm

Average sill height decreased by 4cm

Average marsh edge horizontal erosion 30cm

Average loss of 14% of marsh vegetation coverage

LIVING SHORELINE EROSION POST HURRICANE FLORENCE

Diagram By: B. Puckett

Slide Courtesy of B. Puckett
Morris Landing rock sill - Wilmington

**OCTOBER**
{1 MONTH POST STORM}

**AUGUST**
{1 MONTH PRE STORM}

Slide Courtesy of B. Puckett
St. James oyster sill - Wilmington

NOVEMBER
{2 MONTHS POST STORM}

AUGUST
{1 MONTH PRE STORM}

Slide Courtesy of B. Puckett
Springers point rock sill - Ocracoke

DECEMBER
{3 MONTHS POST STORM}

AUGUST
{1 MONTH PRE STORM}

Slide Courtesy of B. Puckett
Cahoon-davis oyster sill - Ocracoke

DECEMBER
{3 MONTHS POST STORM}

AUGUST
{1 MONTH PRE STORM}

Slide Courtesy of B. Puckett
Shoreline-stabilizing resilience with SLR

Salt Marshes and Oyster Reefs Can Keep Up with recent and past rates of SLR

Cahoon (2015) examined data worldwide
- 58% of salt marshes were adding elevation at rate > local SLR

Sediment supply is crucial parameter

Rodriguez et al (2014) showed NC oyster reefs grow >1 cm yr\(^{-1}\)


Limitations of living shorelines for erosion protection

Useful tool to determine if a living shoreline would be a feasible protection option:

http://sagecoast.org/

| Table 11.1 Current Recommended Guidelines for Living Shoreline Site Suitability |
|-------------------------------------------------|---------------------------------|-----------------------------|
| Region                                          | LS Type                         | Fetch Criteria              | Additional Comments              |
| North Carolina⁷                                 | Vegetation Hybrid              | <1 mile (1.6 km)            | May be longer if sandbars/mudflat present |
|                                                |                                 | 1–3 miles (1.6–4.8 km)      |                                           |
| Virginia‡                                     | Vegetation Hybrid              | <1000 ft (<0.3 km)          | Average and maximum fetch. Nearshore depth of <3 ft |
|                                                |                                 | 1000 ft to 5 miles          |                                           | (0.3–8.0 km) |
|                                                |                                 |                             |                                           |
| Gulf Coast³                                   | Vegetation Hybrid              | <0.5 miles (<0.8 km)        | Nearshore depth <1 ft                  |
|                                                |                                 | 1–2 miles (1.6–3.2 km)      | Nearshore depth <2 ft                  |
| Delaware⁴                                     | Vegetation Hybrid              | <0.5 miles (<0.8 km)        | Vegetation with minimal structure like biologs |
|                                                |                                 | 0.5–1.0 miles (0.8–1.6 km)  |                                           |             |
|                                                | Hybrid                         | >1 mile (<0.8 km)           | Limited success without structural reinforcement |
| New Jersey⁵                                   | None                            |                             | Erosion history, tidal range, wave height, offshore depth, and other factors instead of fetch |
| Washington State⁶                             | Vegetation                      | 1–5 miles (1.6–8.0 km)      | With southerly fetch, multiply by 0.5 if north facing. May require log breakwater as well |
|                                                |                                 |                             |                                           |

⁷ North Carolina Division of Coastal Management (2011).
‡ Hardaway et al. (2010).
³ Gulf Alliance Training Program (2010).
⁴ Partnership for the Delaware Estuary (2012).
⁵ Millier et al. (2015).
⁶ Johannessen et al. (2014).

Natural shorelines and coastal ecosystems, including oyster reefs and marshes, are found along the estuarine coast across a range of environmental conditions (salinity, elevation, and wave energy).

These estuarine ecosystems provide benefits to humans, including erosion protection.

Marsh vegetation effectively reduces waves, stabilizes sediments, and increases sedimentation, thereby reducing net erosion of some shorelines.

Rock or oyster ills further increase sediment accretion and elevation gain.

Coastal shorelines are eroding extensively, threatening property and estuarine ecosystems.

Hardened structures (bulkheads/riprap) protect shorelines from erosion but may not perform well during storms, will not keep up with rising sea level, and do not provide ancillary human benefits such as habitat provision.

Living shorelines offer sustainable shoreline protection with added benefits to many estuarine shorelines, but there are limitations to their efficacy for protection in high energy environments.
Thank you! Questions?

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