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

February 20, 2019

Coastal Studies Institute
A Multi-Institutional Research Partnership

The University of North Carolina at Chapel Hill

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)

Vegetation — *Vegetation with coir logs* — *Vegetation with oysters* — *Vegetation with rocks*

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

Source: NC Sea Grant

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

Species	Inundation Zone	Salinity Range
Spartina alterniflora	MTL – MHW	5 – 30 ppt
Spartina patens	MHW – ULW	5 – 30 ppt
Spartina cynosuroides	MHW – ULW	0 – 5 ppt
Distichlis spicata	MHW – ULW	10 – 30 ppt
Scirpus americanus	MHW – ULW	0 – 15 ppt
Juncus roemarianus	above MHW	10 – 25 ppt
Iva frutescens	near ULW	5 – 30 ppt
Baccharis halimifolia	near ULW	0 – 30 ppt
Panicum virgatum	above ULW	0 – 25 ppt
Myrica cerifera	above ULW	0 – 30 ppt

Table 1. Zonation and salinity levels for common wetland plants (see text for zone abbreviations).

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

Source: Priest III, W. I. 2008. Design Criteria for Tidal Wetlands. *In:* Erdle, S.Y., J.L.D. Davis, and K.G. Sellner, eds. Management, Policy, Science and Engineering of Nonstructural Erosion Control in the Chesapeake Bay: Proceedings of the 2006 Living Shoreline Summit. CRC Publ. No. 08-164, Gloucester Point, VA 136pp.

Salt and brackish marsh zones and plants

Extreme tide line | **High tide line** | **Mean tide line** | **Water**

Juncus roemerianus – Black needlerush

Distichlis spicatq – *seashore/inland saltgrass*

Spartina patens – Salt meadow hay

Spartina alterniflora - Smooth cordgrass

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

MHW

< 100 cm / 3.2 ft

MLW

Photo source: NC DEQ
https://deq.nc.gov/about/divisions/coastal-management/coastal-management-estuarine-shorelines/wetlands/get-to-know-coastal-wetlands

Freshwater marsh plants

Scirpus americanus –
Olney threesquare

Spartina cynosuroides –
giant cordgrass

© DCR-DNH, Gary P. Fleming

Spartina cynosuroides Gary P. Fleming

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

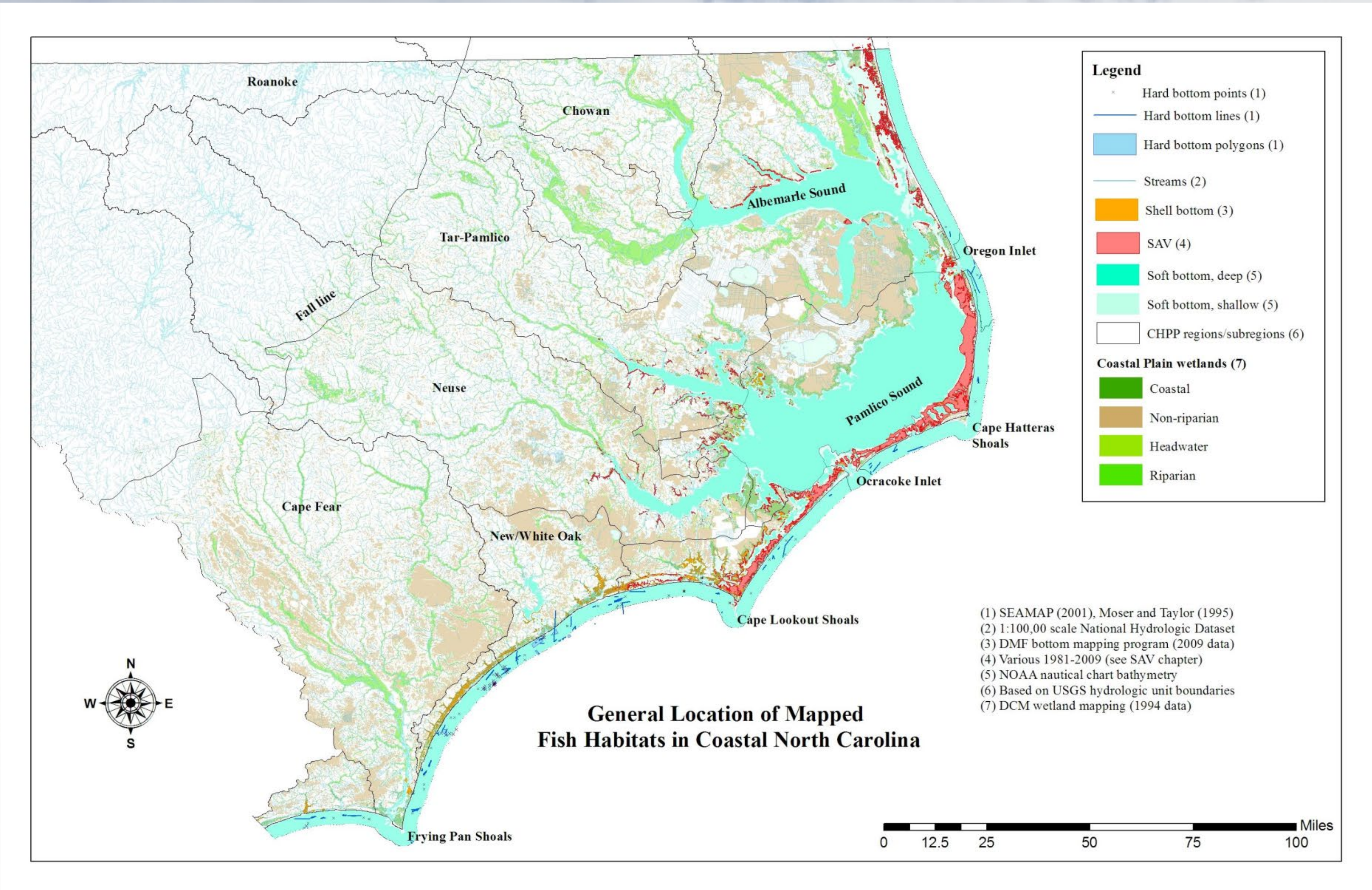
? Wave attenuation
? C sequestration
? Keeps up with SLR

Slide from Currin and Gittman Living Shoreline presentation for NERR/NCCR

A few of many human benefits/ecosystem services provided by coastal ecosystems

Coastal ecosystem providing human benefit/ecosystem service	Human benefit/ecosystem service
Oysters and marshes	Attenuate wave energy
Oysters and marshes	Habitat for marine and estuarine organisms including fish and waterfowl
Oysters and marshes	Filtration – sediment and/or nutrients
Oysters and marshes	Denitrification
Marshes	Carbon storage

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

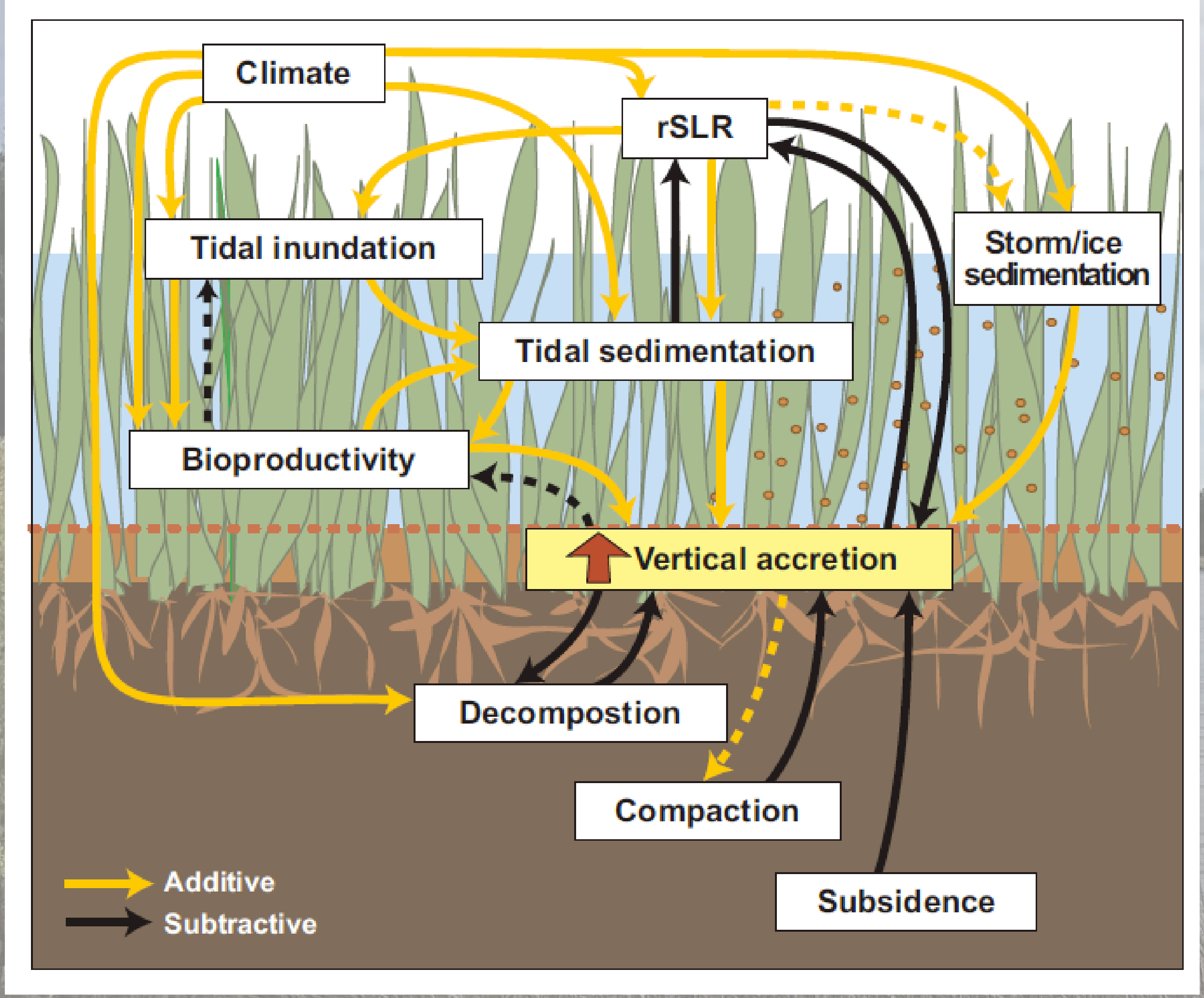
- 50% of wave energy reduced within 5 m (15’) of marsh edge (Leonard and Croft 2006)
- >90% over 30 m of marsh (*S. alterniflora*) (Knutson et al. 1982)
- Wave energy reduction increases with plant biomass

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



D. M. FitzGerald, M.S. Fenster, B.A. Argow, and I.V. Buynevich. 2008. Coastal Impacts Due to Sea-Level Rise. Annu. Rev. Earth Planet. Sci. 36:601–47

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

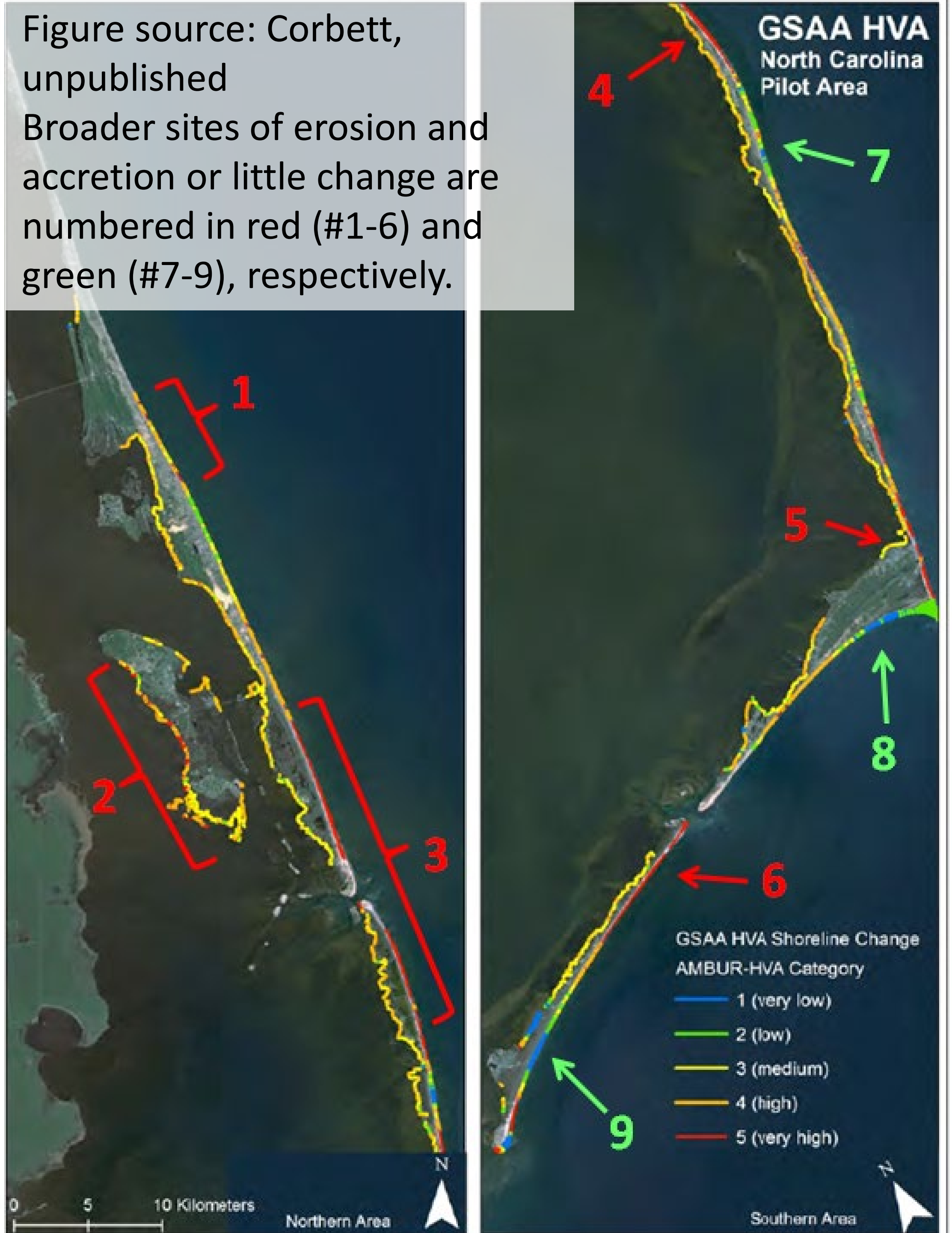
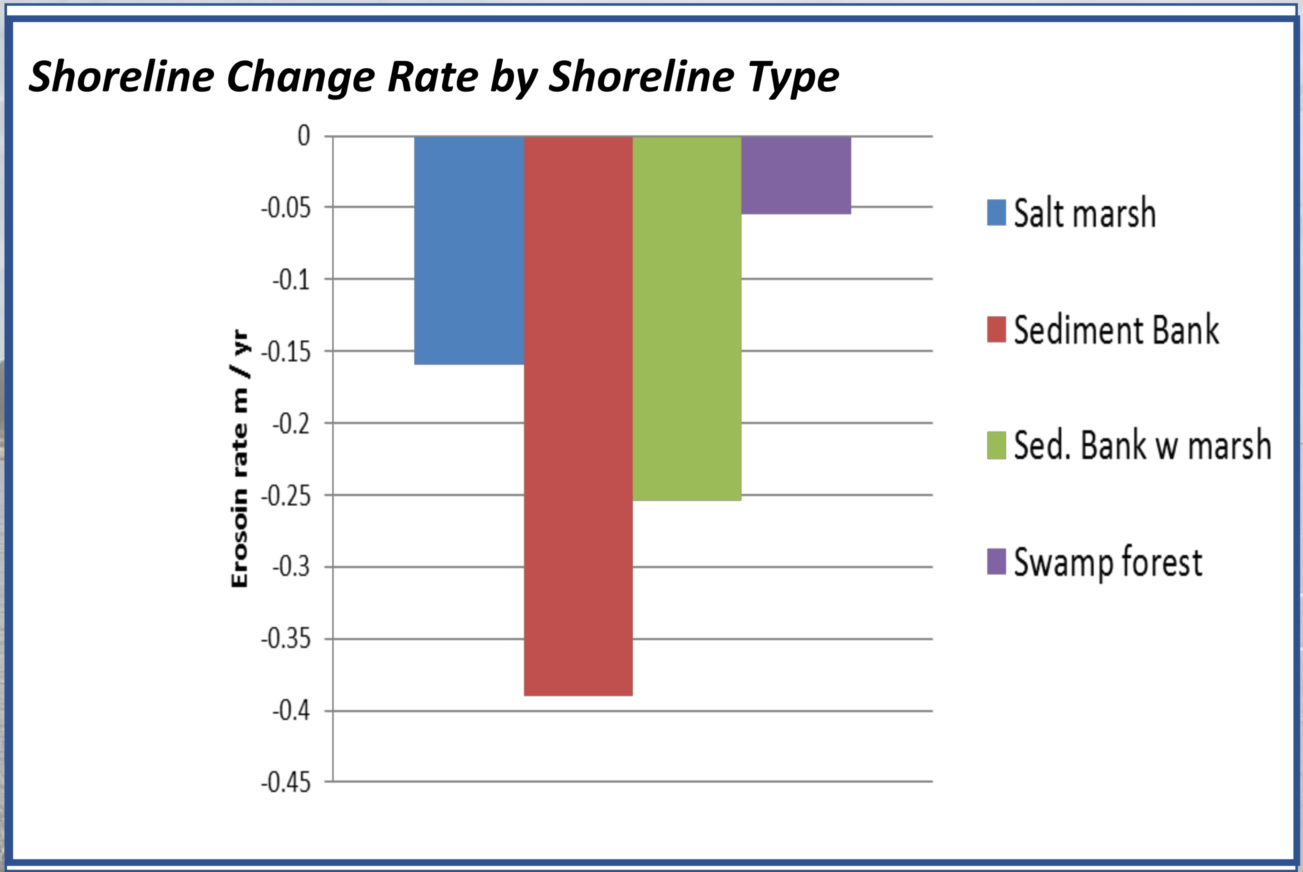


Figure source: Corbett, unpublished
Broader sites of erosion and accretion or little change are numbered in red (#1-6) and green (#7-9), respectively.

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



Currin et al. 2015 Journal Coastal Research

Shoreline protection options – hardened structures

Bulkhead constructed using vinyl, Pivers Island, N.C.

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

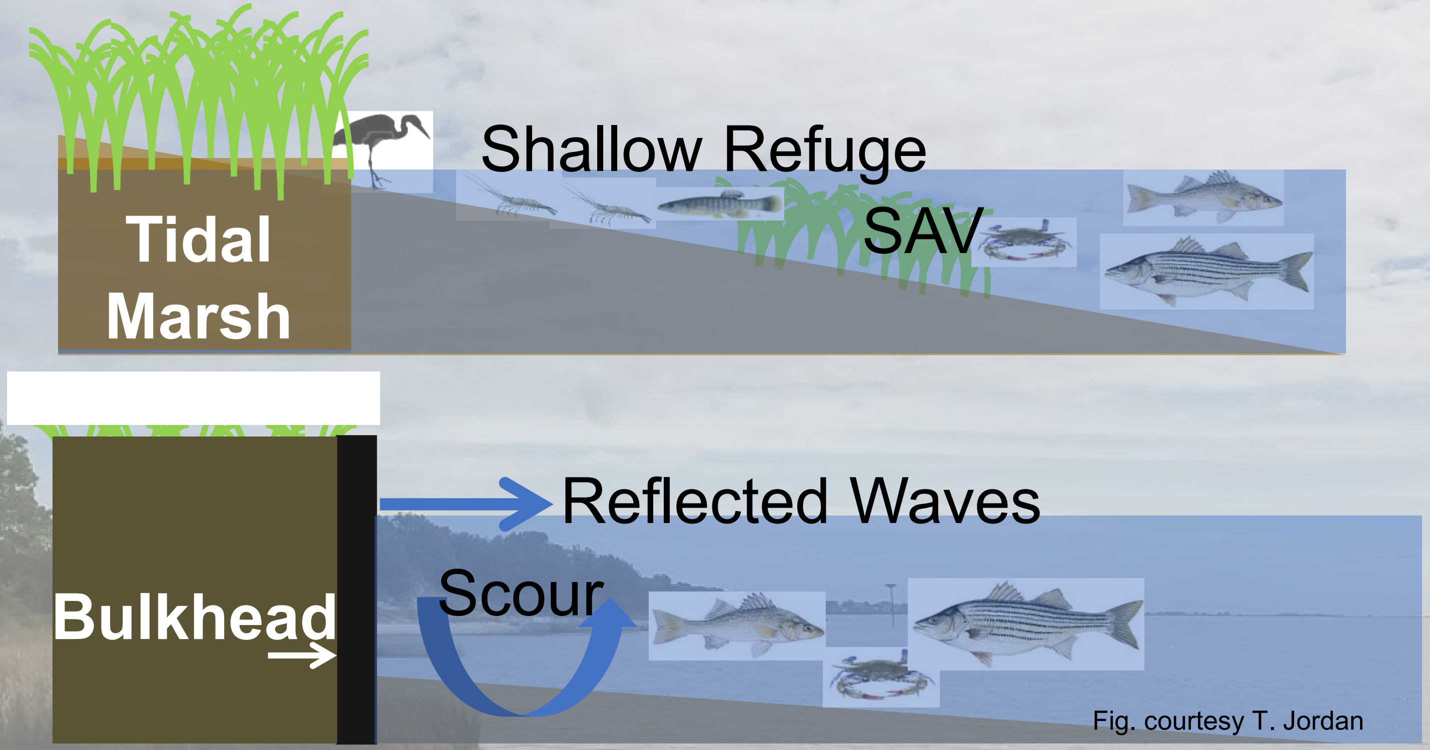
Breakwaters, Bogue Sound, N.C.

Riprap revetment with grasses and lawn, N.C.

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?



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

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

..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)

Vegetation

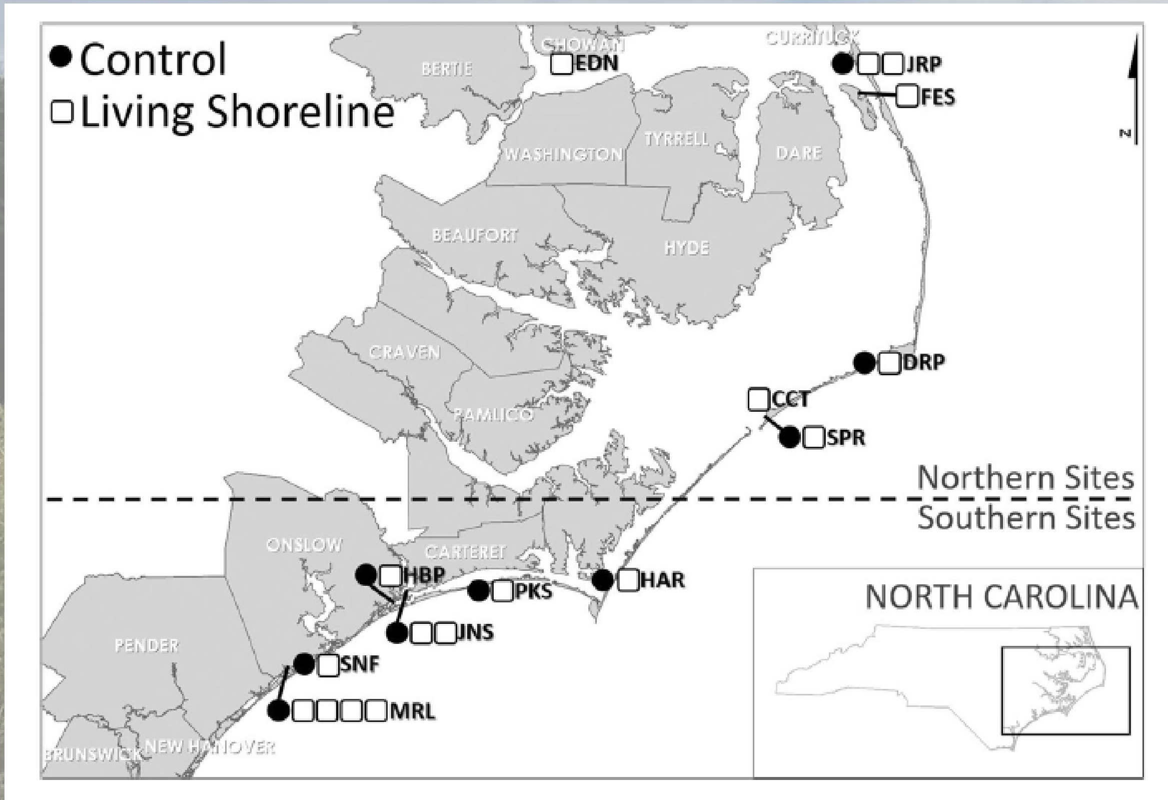
Vegetation with coir logs

Vegetation with oysters

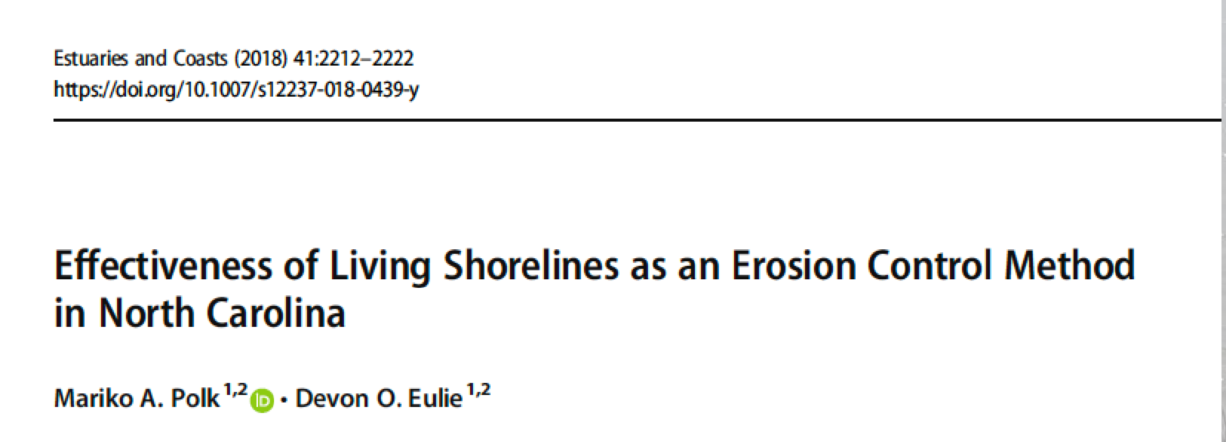
Vegetation with rocks

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



Estuaries and Coasts (2018) 41:2212–2222
https://doi.org/10.1007/s12237-018-0439-y

Effectiveness of Living Shorelines as an Erosion Control Method in North Carolina

Mariko A. Polk[1,2] • Devon O. Eulie[1,2]

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

Hurricane Irene (2011)

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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, 1], John F. Bruno [b], Charles H. Peterson [a, b]

Hurricane Matthew (2016)

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

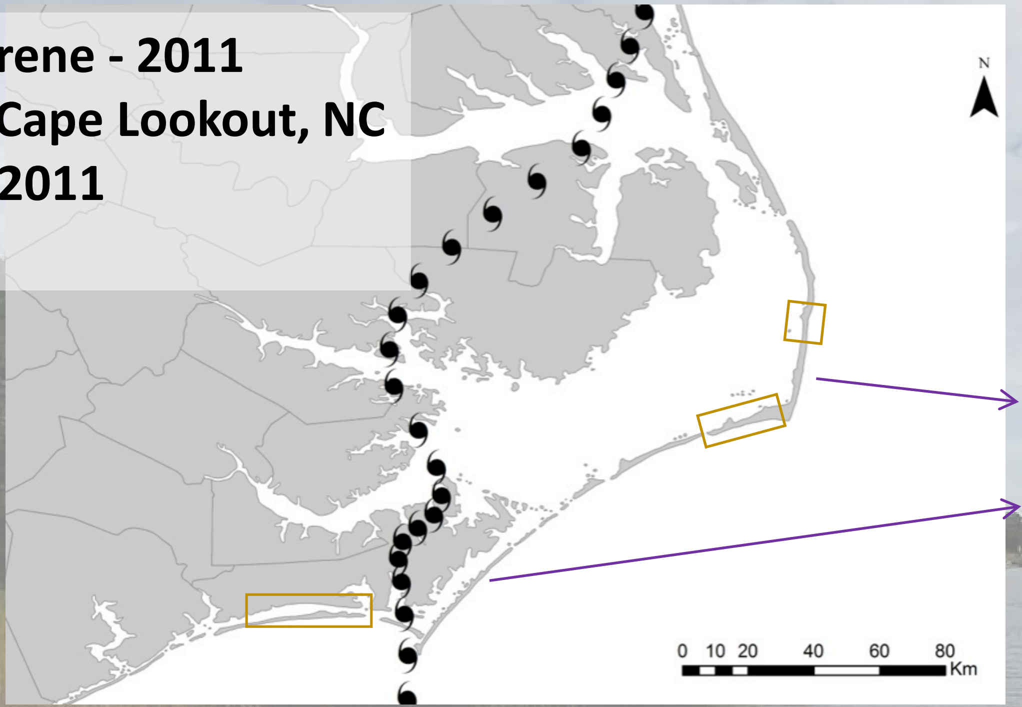
Living shorelines enhanced the resilience of saltmarshes to Hurricane Matthew (2016)

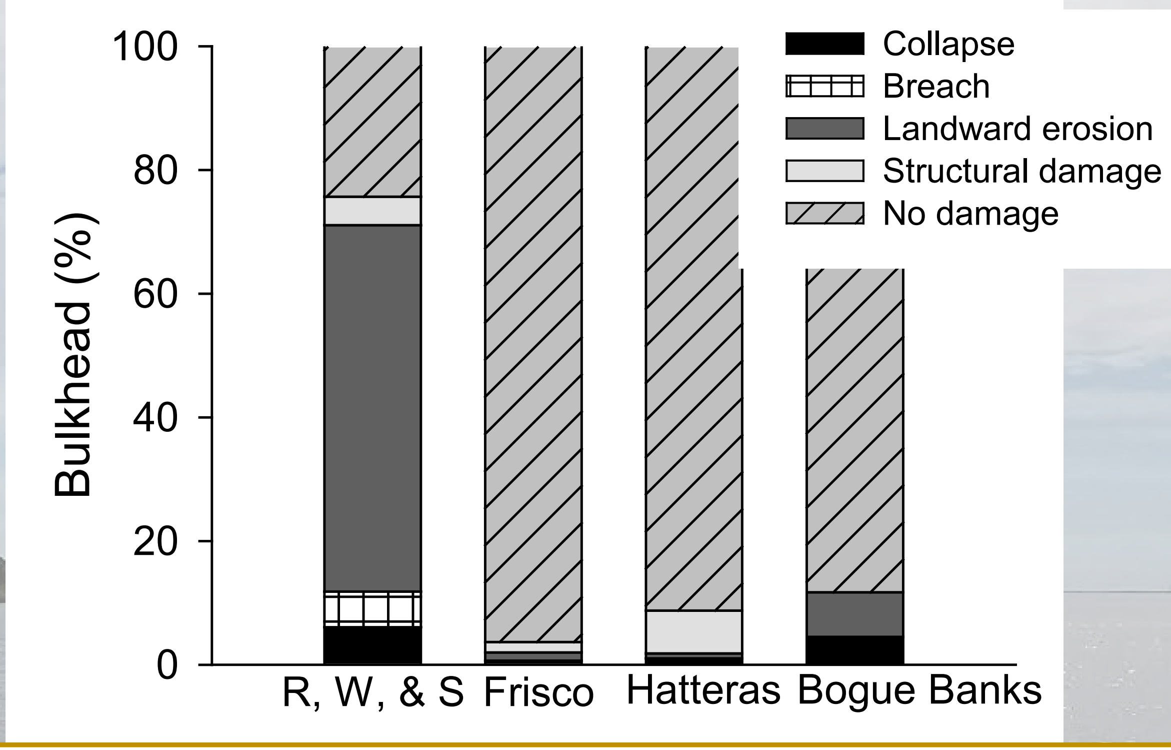
CARTER S. SMITH [1,4] BRANDON PUCKETT [2] RACHEL K. GITTMAN [3] AND CHARLES H. PETERSON [1]

Hurricane Florence (Puckett, unpublished)

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

Hurricane Irene - 2011
Landfall at Cape Lookout, NC
August 27, 2011
Category 1





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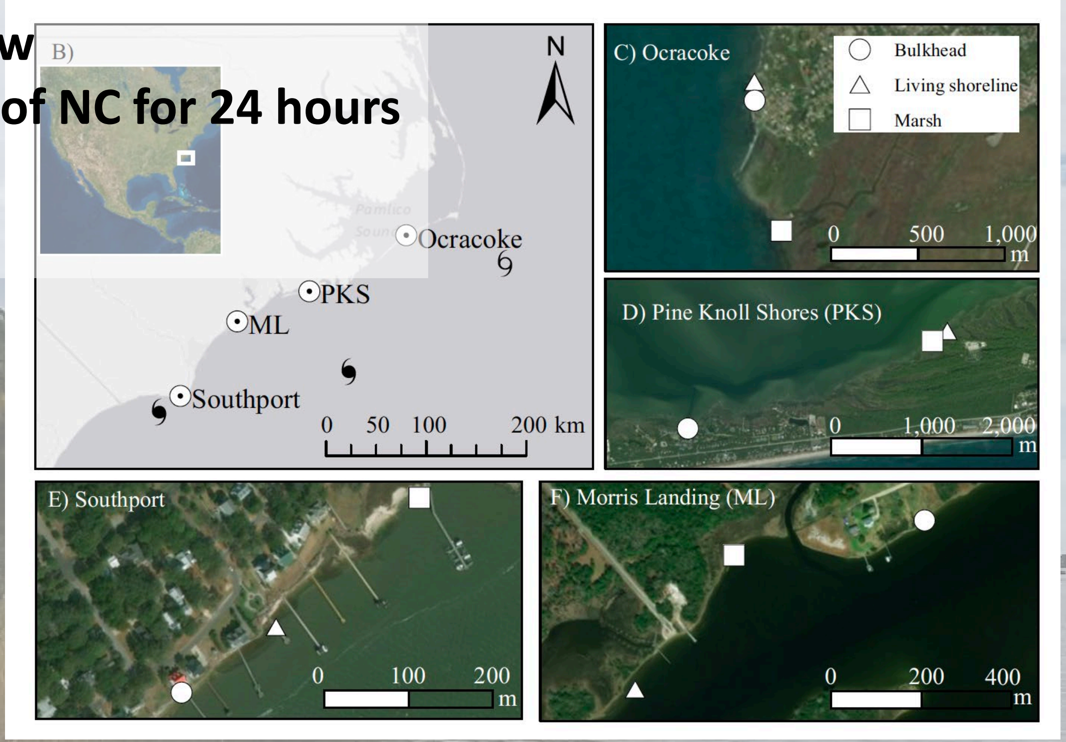
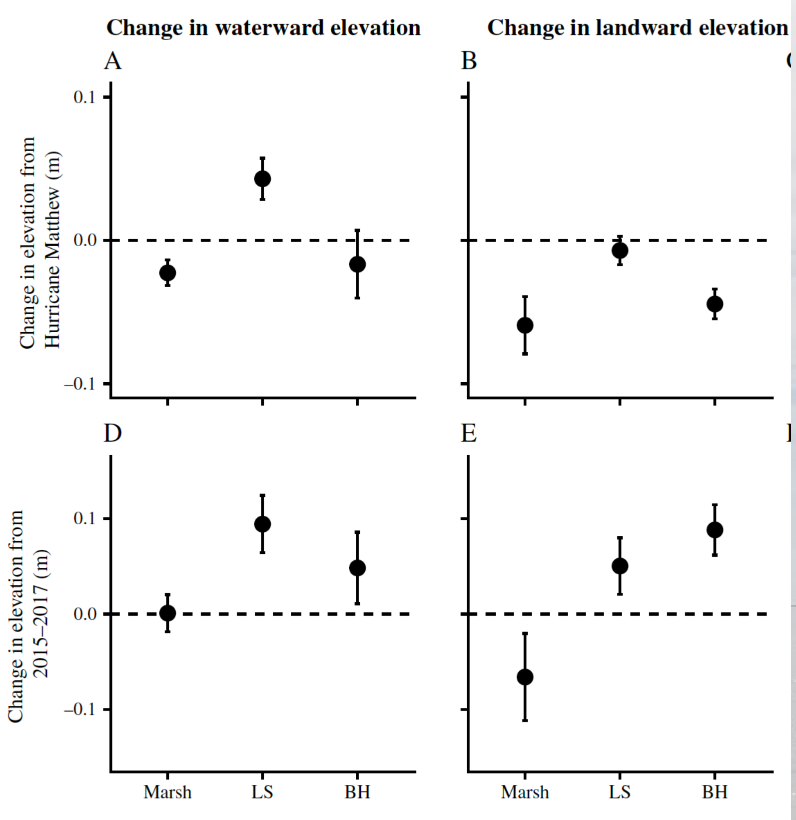
- 75% of bulkheads damaged in area with greatest surge and sustained winds (OBX); 12% in Bogue Banks (area with marsh sites for comparison)
- No loss in elevation at marsh sites (living shorelines with sills and natural)

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

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

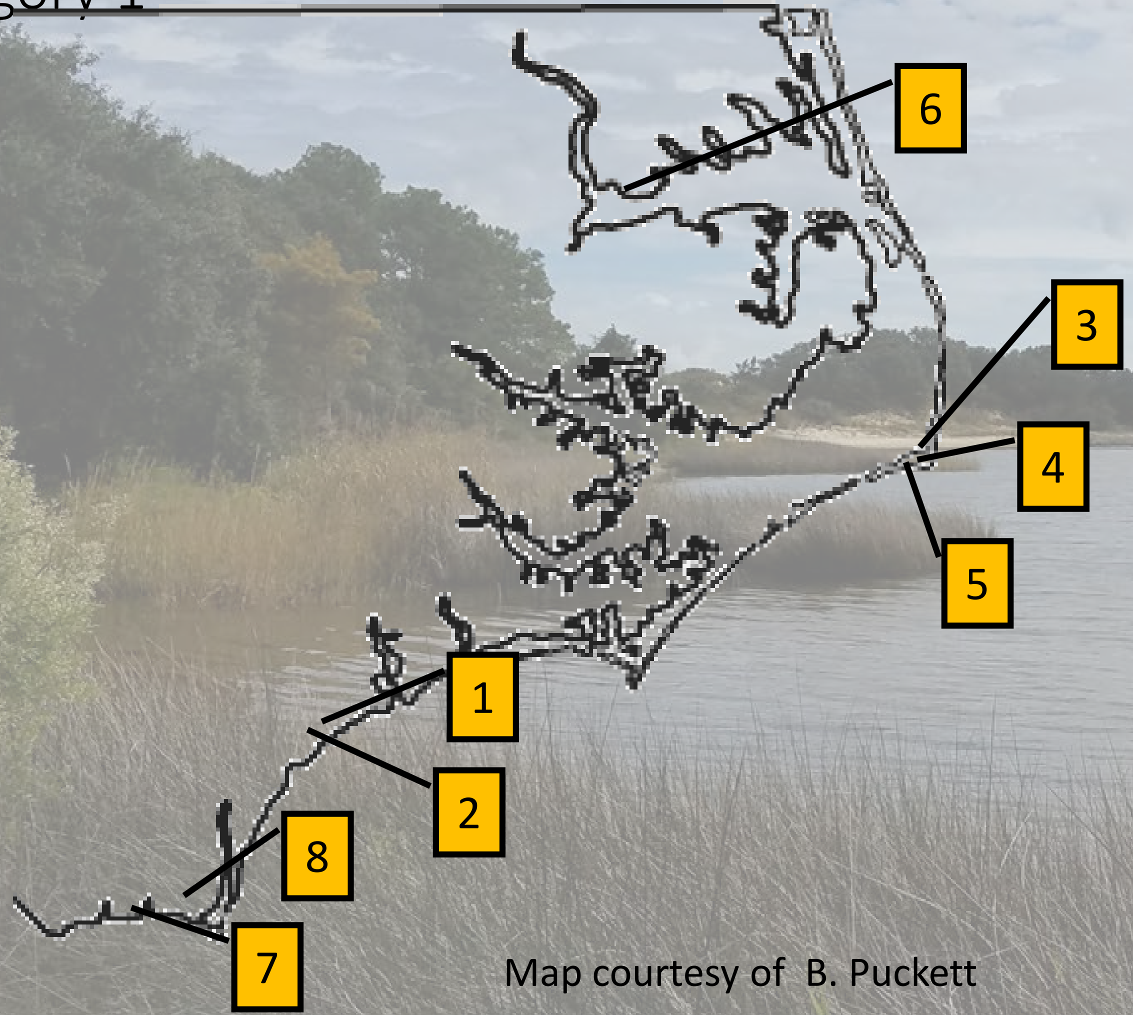
Carter S. Smith[1,4] Brandon Puckett[2] Rachel K. Gittman[3] and Charles H. Peterson[1]

Pre- and Post- Florence monitored living shorelines

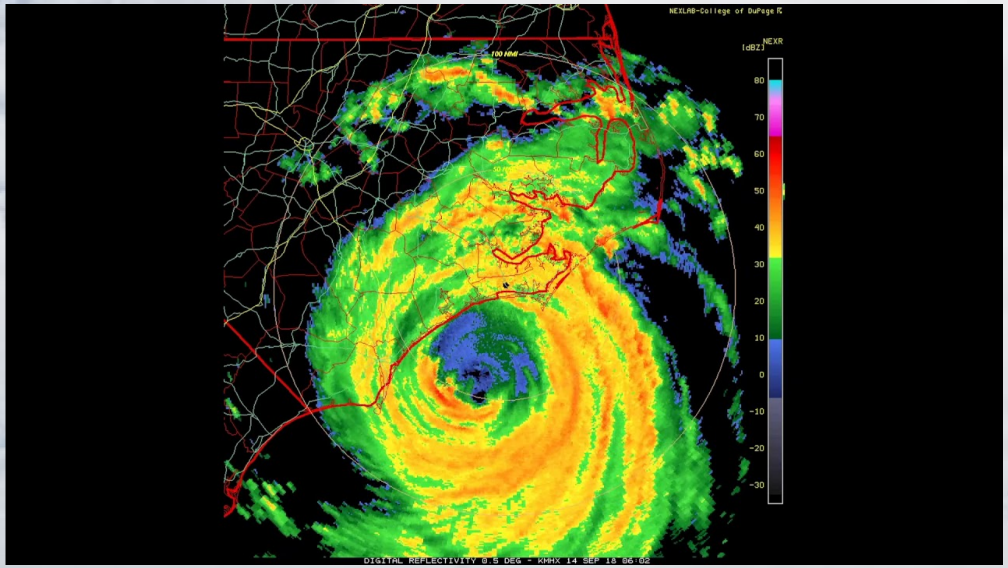
Landfall near Wrightsville Beach, NC

Sept 14, 2018

Category 1



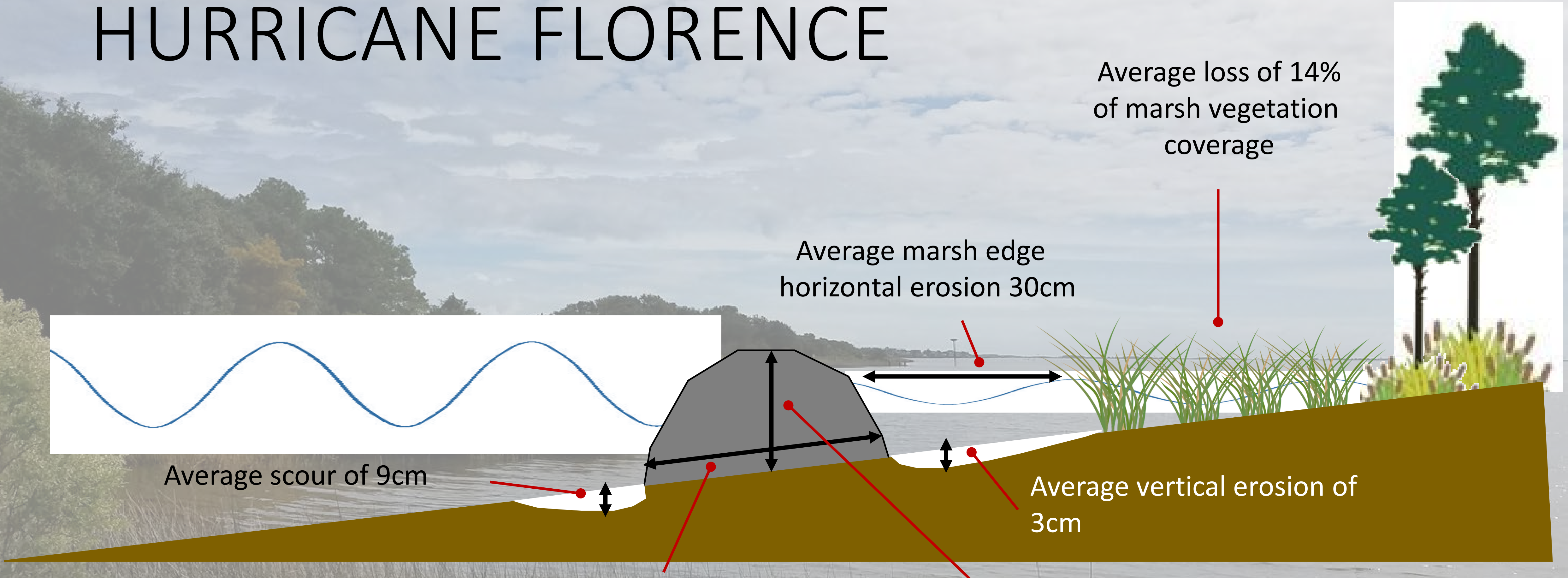
Map courtesy of B. Puckett



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

- 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

LIVING SHORELINE EROSION POST HURRICANE FLORENCE



Slide Courtesy of B. Puckett

Diagram By: 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

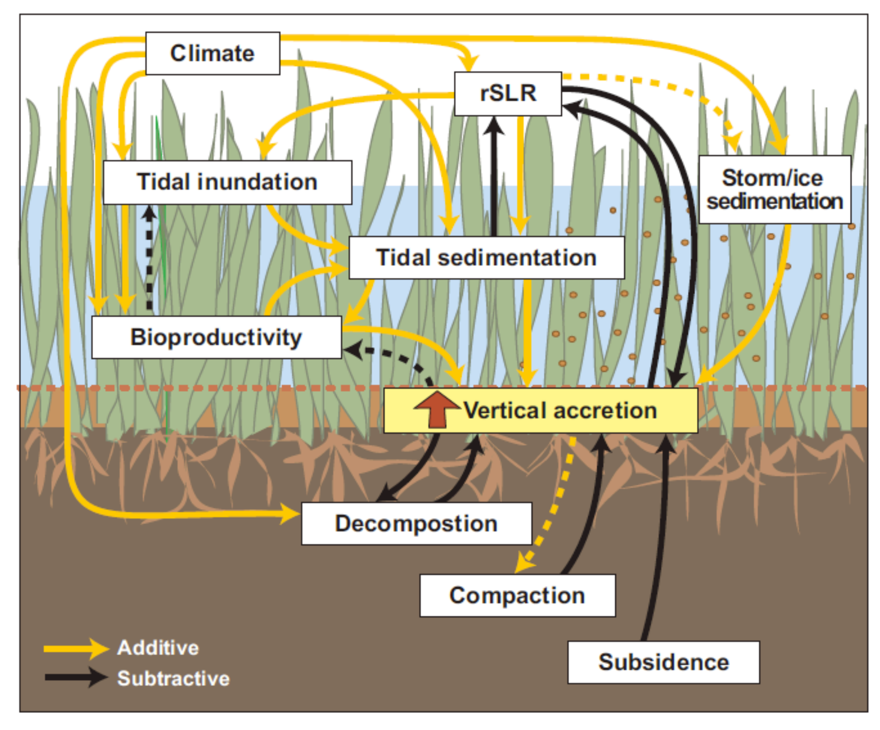
Shoreline-stabilizing resilience with SLR

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



D. M. FitzGerald, M.S. Fenster, B.A. Argow, and I.V. Buynevich. 2008. Coastal Impacts Due to Sea-Level Rise. Annu. Rev. Earth Planet. Sci. 36:601–47

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

Cahoon, D. 2015 Estuaries & Coasts 38:1077-1084 ; Rodriguez, A. et al. 2014. Nature Climate Change DOI: 10.1038/NCLIMATE2216

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 Carolina[a]	Vegetation	<1 mile (1.6 km)	May be longer if sandbars/mudflat present
	Hybrid	1–3 miles (1.6–4.8 km)	
Virginia[b]	Vegetation	<1000 ft (<0.3 km)	Average and maximum fetch. Nearshore depth of <3 ft
	Hybrid	1000 ft to 5 miles (0.3–8.0 km)	
Gulf Coast[c]	Vegetation	<0.5 miles (<0.8 km)	Nearshore depth <1 ft
	Hybrid	1–2 miles (1.6–3.2 km)	Nearshore depth <2 ft
Delaware[d]	Vegetation	<0.5 miles (<0.8 km)	
	Hybrid	0.5–1.0 miles (0.8–1.6 km)	Vegetation with minimal structure like biologs
	Hybrid	>1 mile (<0.8 km)	Limited success without structural reinforcement
New Jersey[e]		None	Erosion history, tidal range, wave height, offshore depth, and other factors instead of fetch
Washington State[f]	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

[a] North Carolina Division of Coastal Management (2011).
[b] Hardaway et al. (2010).
[c] Gulf Alliance Training Program (2010).
[d] Partnership for the Delaware Estuary (2012).
[e] Miller et al. (2015).
[f] Johannessen et al. (2014).

Source: Currin, Carolyn & Davis, Jenny & Malhotra, Amit. (2018). Chapter 11 response of Salt Marshes to Wave energy provides Guidance for Successful Living Shoreline Implementation.

Summary

- 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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Acknowledgements:
This presentation was influenced by a previous presentation by Currin and Gittman to a NERR/NCCR Living Shoreline workshop in 2016