Measuring the resilience of salt marshes used in Living Shorelines and other nature-based efforts to protect coastal infrastructure

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Harkers Island, NC
Salt marshes effectively attenuate wave energy and reduce erosion

- 50% of wave energy reduced within 5 m (15’) of marsh edge; >90% over 25 m of marsh (*S. alterniflora*)

- Belowground biomass binds sediments (and stores carbon)

- Wave energy reduction increases with plant biomass

- Linear Relationship between wave energy or wave power and marsh erosion over large scales, other factors important locally and regionally

- Wave energy reduction decreases as inundation depth exceeds canopy height

Research reviewed in Currin et al. 2017
*Response of salt marshes to wave energy provides guidance for successful living shoreline implementation.* In CRC Press
The Science and Management of Nature-based Coastal Protection
Salt marshes and oyster reefs are resilient ..... and vulnerable... to sea level rise

Worldwide 58% of salt marshes were adding elevation at rate > local SLR (Cahoon 2015)

Sediment supply is crucial parameter

Oyster Reefs Can Keep Up with SLR in some settings

Rodriguez et al (2014) showed NC oyster reefs can grow >1 cm yr⁻¹

• Landward transgression of salt marsh determined by topography and **absence of development**
• May preserve marsh habitat acreage even with accelerated SLR

Marsh transgression in response to SLR

Kirwan et al. 2016
Living Shorelines

- What are LS design impacts on resilience?
- Does increasing resilience to SLR and erosion alter ecosystem services provided by marsh habitats?
Measuring marsh elevation change in NC Living Shoreline Sites

4 Marsh-Sill and 4 Natural Fringing Marsh Sites

- Surface elevation increase greater in Sill marshes than Natural at both upper and lower edges (p<0.025)
- Surface elevation change in Natural marshes significantly different at Upper marsh than Lower marsh edge
Surface elevation change in Living Shorelines is dynamic

Long-term SET data collection is difficult to maintain
Sill sediment accretion results in increased *Spartina* biomass at lower edge, loss of *Spartina* habitat at upper edge.
Permanent Vegetation Plots 2006 -2016

Mean $S. \ alterniflora$ Stem Density

Loss of vegetation at lower edge
Maintained interior vegetation

Increase in vegetation at lower edge
Maintained interior vegetation
Marsh transgression in response to SLR

Slope and SLR rate determine marsh area expansion

Scenario with human barriers to migration

Kirwan et al. 2016 GRL
Habitat Change leads to Changes in Ecosystem Services

Stone Sills
- Reduce/eliminate shallow subtidal
- Reflect wave energy
- Non-native hard substrate; Invasives
- Fish habitat
- Oyster settlement
- Increase sediment trapping

Low Marsh
- Less SLR resiliency
- Lower plant diversity
- Absorb wave energy
- Faunal utilization
- Denitrification
- Sediment trapping
- C sequestration

High Marsh
- Less faunal utilization
- Reduced denitrification
- Reduced Sediment trapping
- Lower C sequestration
- Greater SLR resiliency
- Greater plant biodiversity

New Marsh
Accumulated Sediment
SLR
Using Living Shorelines to protect property and Infrastructure

A longer view...

(a) Landward migration

(b) Coastal squeeze

(c) Delayed squeeze
Thin Layer Application of Dredged Sediment to Vulnerable Salt Marshes

Two pilot projects on Marine Corps Base Camp Lejeune, North Carolina

Raising elevation of low-lying salt marsh

Dredged sediment added to ponded areas in fragmented marsh, *Spartina* planted
Spartina alterniflora biomass: elevation distribution

- Resilience to Sea Level Rise
- Fishery Habitat, Denitrification,
- Thin Layer Addition
- Resilience to Sea Level Rise
Thin Layer application and Ecosystem Services

Can we quantify habitat trade offs?

Will thin layer addition impact C burial?

Greater input?
Greater turnover?
Long-term Monitoring is needed to understand ecosystem impacts of Living Shorelines and TLA
• Choose parameters wisely (easy, cheap, meaningful)
• Use control and reference sites
• Form partnerships
• Use citizen scientists

Landward migration is crucial for maintaining future salt marsh habitat.
• Living Shoreline placement and design need to accommodate this function
• Avoid ‘Delayed Squeeze’

Adding marsh resiliency by increasing surface elevation alters habitats and ecosystem services
• Be clear about temporal and spatial scales when measuring ecosystem service changes