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

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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)

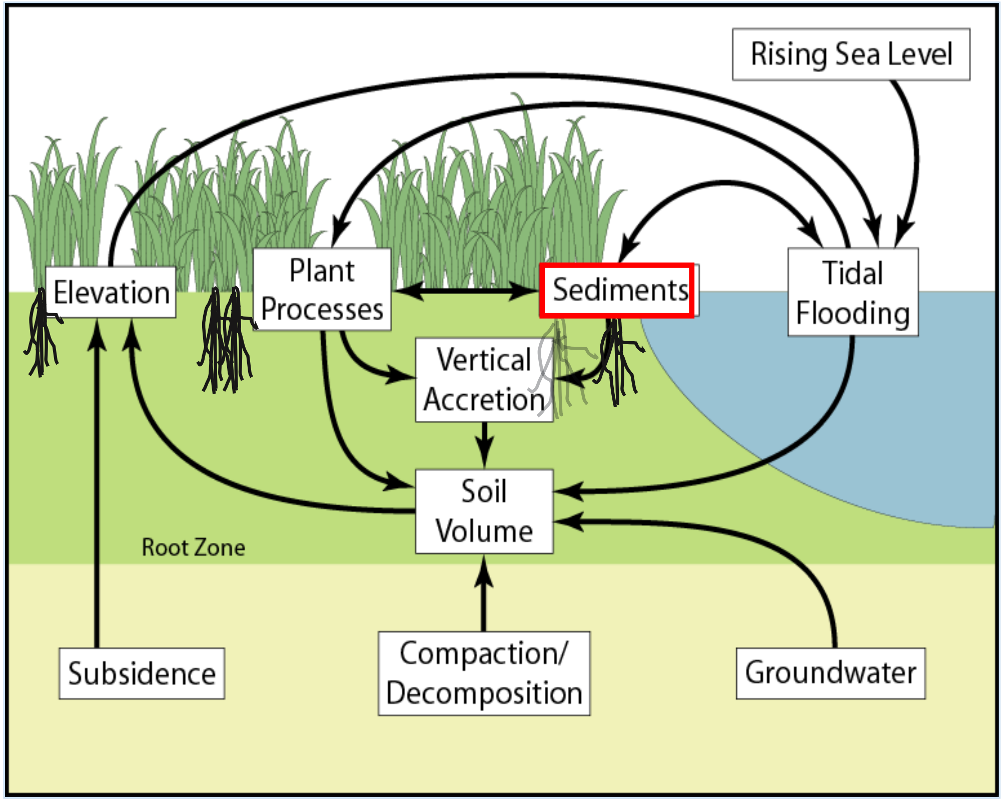
- Wave energy reduction increases with plant biomass

- 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



Modified from: Cahoon, DR., J.W. Day, Jr., and D. J. Reed. 1999.

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

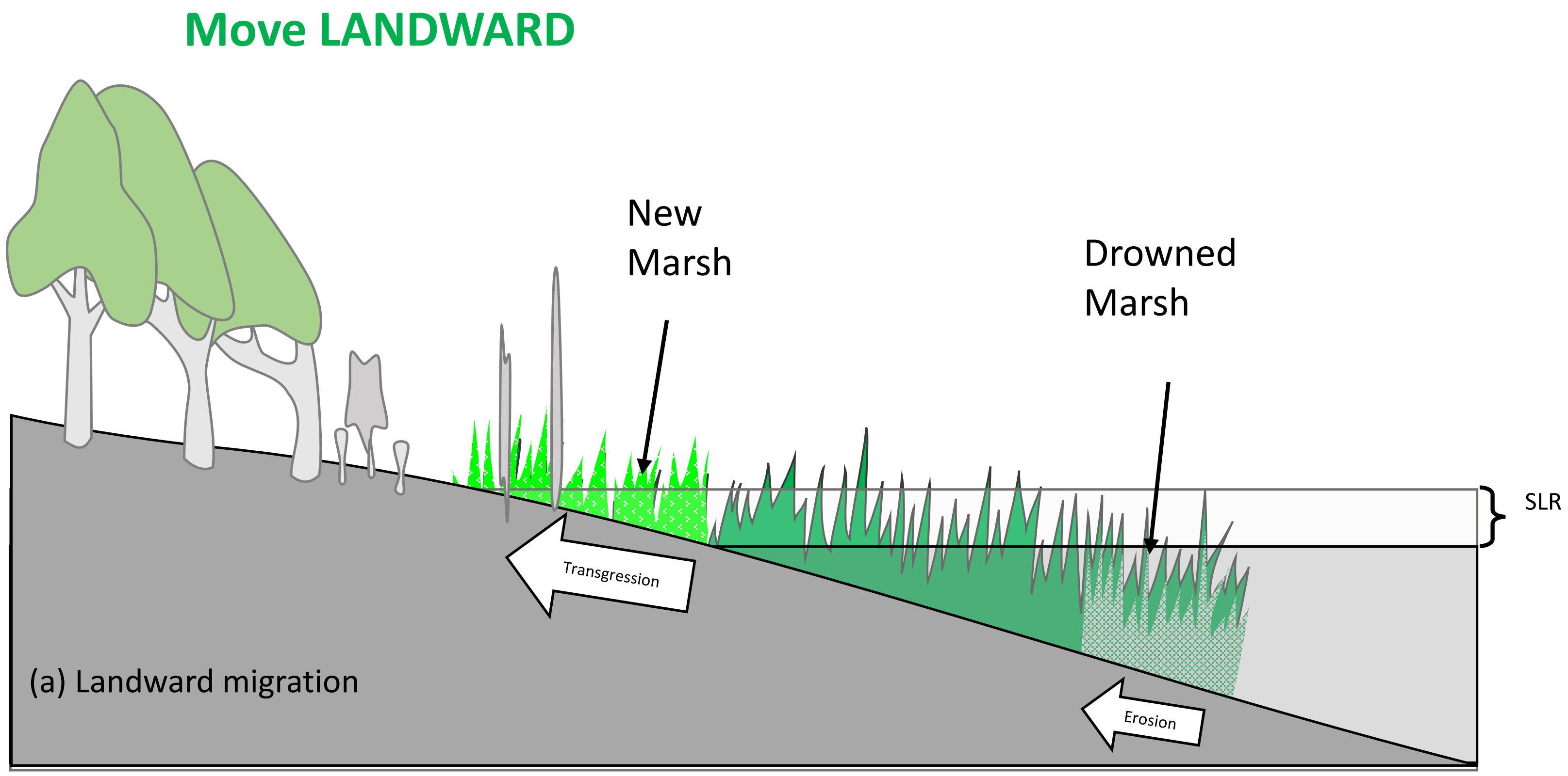
Sediment supply is crucial parameter

Oyster Reefs Can Keep Up with SLR in some settings

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

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

Marsh transgression in response to SLR



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

Hardening

Living Shoreline

NWP 54-compliant LS

NOAA Defined LS

NNBF

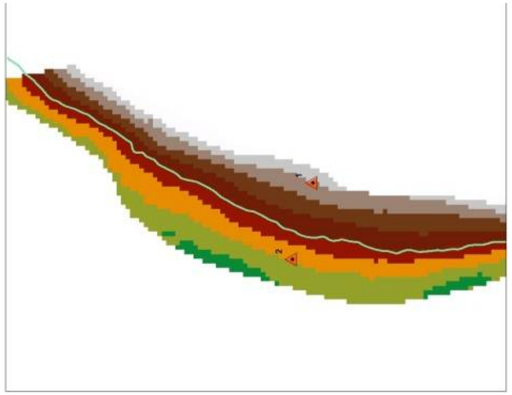
Wave Energy, Cost, Permitting Time

Measuring marsh elevation change in NC Living Shoreline Sites

4 Marsh-Sill and 4 Natural Fringing Marsh Sites

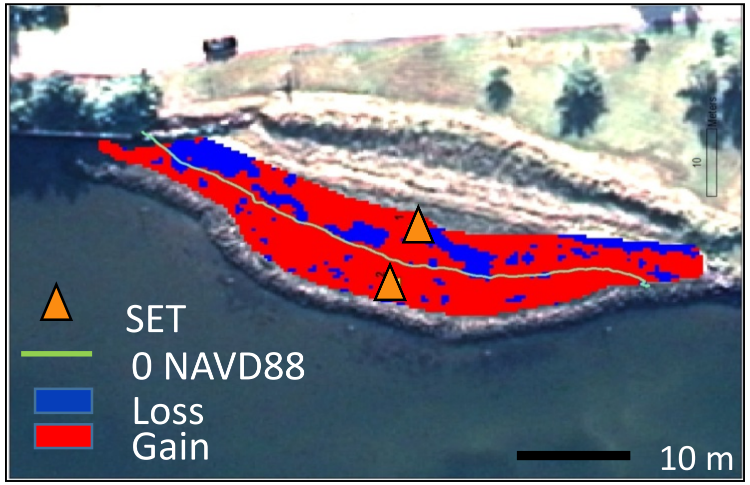
Surface Elevation Table

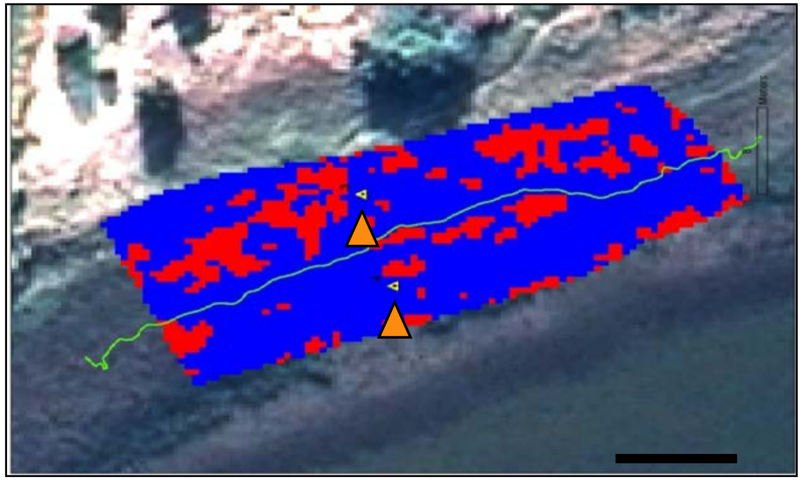
RTK GPS



Digital Elevation Models

- Surface elevation increase greater in Sill marshes than Natural at both upper and lower edges (p<0.025)

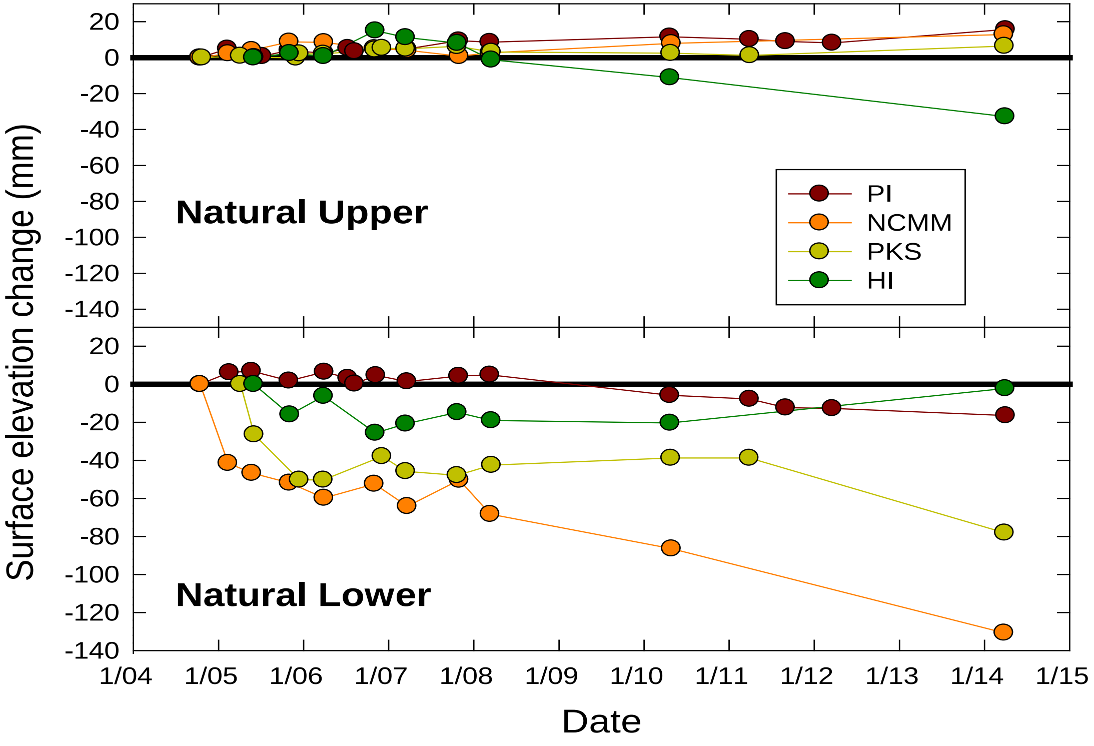


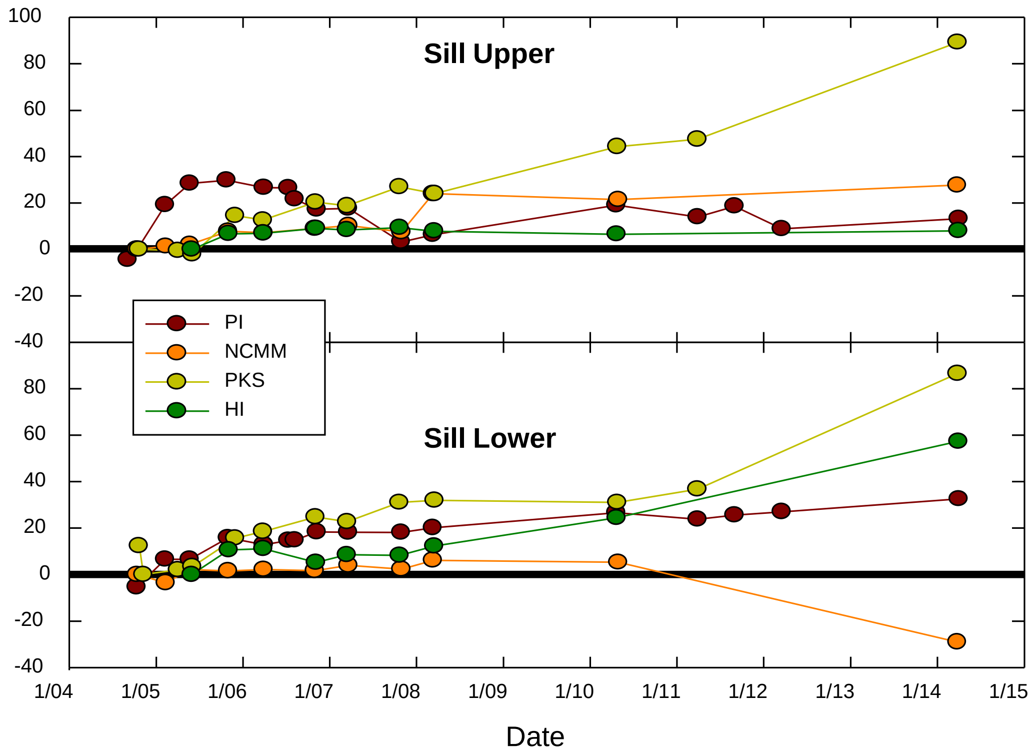


- Surface elevation change in Natural marshes significantly different at Upper marsh than Lower marsh edge

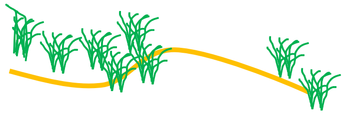
SET Results Fringing Salt Marshes   Carteret County, NC

Surface elevation change mm / year





Surface elevation change in Living Shorelines is dynamic

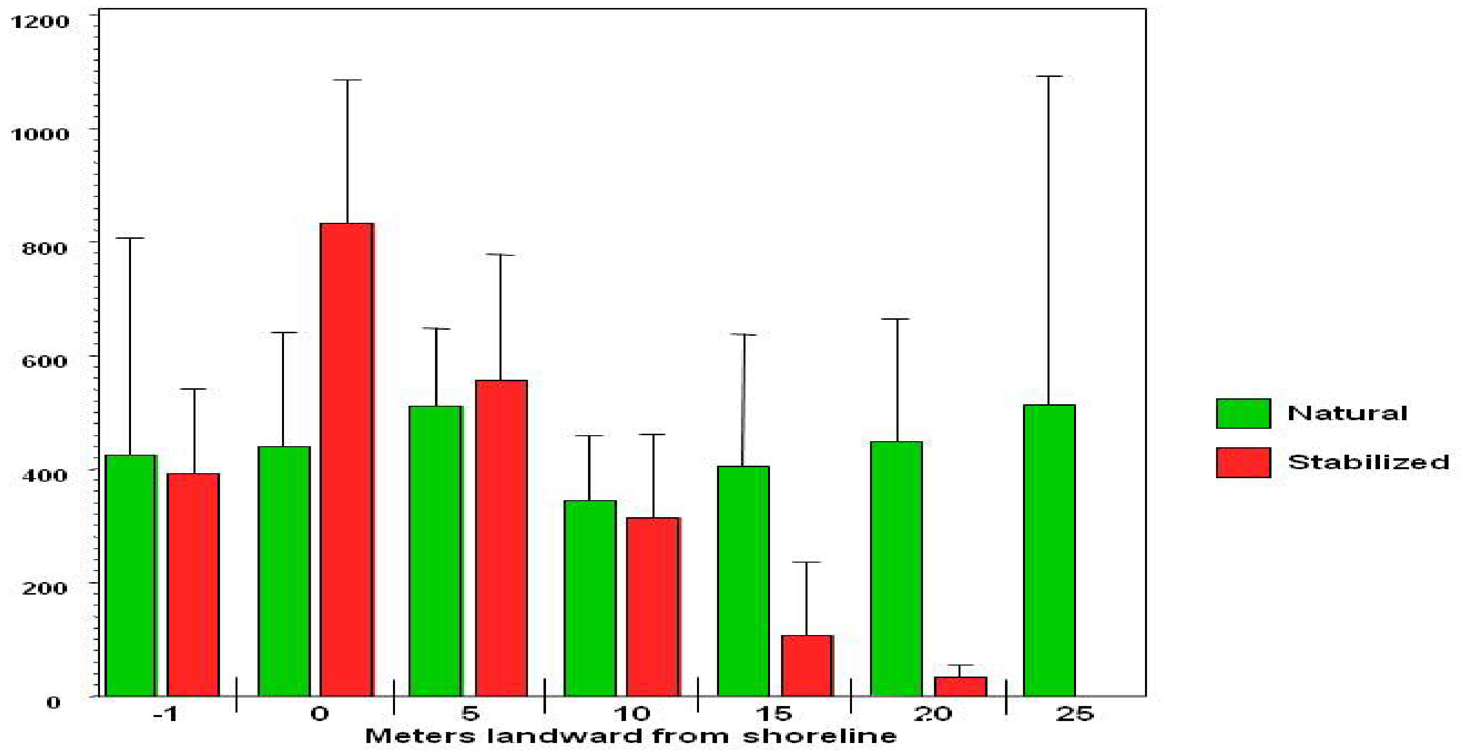


Long-term SET data collection is difficult to maintain

Marsh vegetation in Living Shoreline Sites

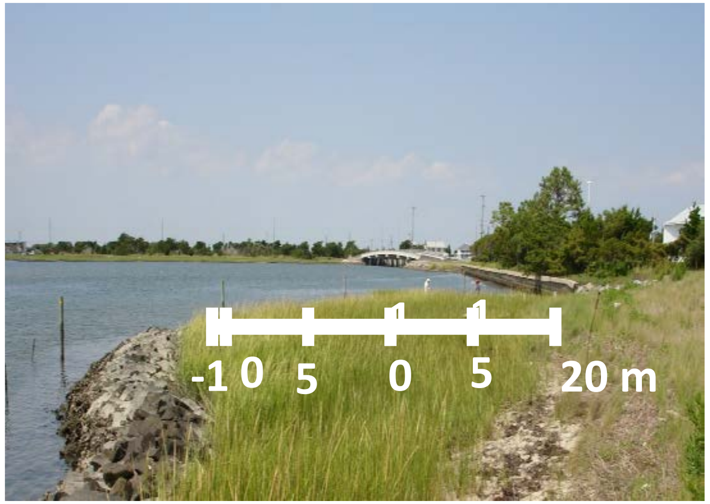
2011

S. alterniflora Biomass (g/m)



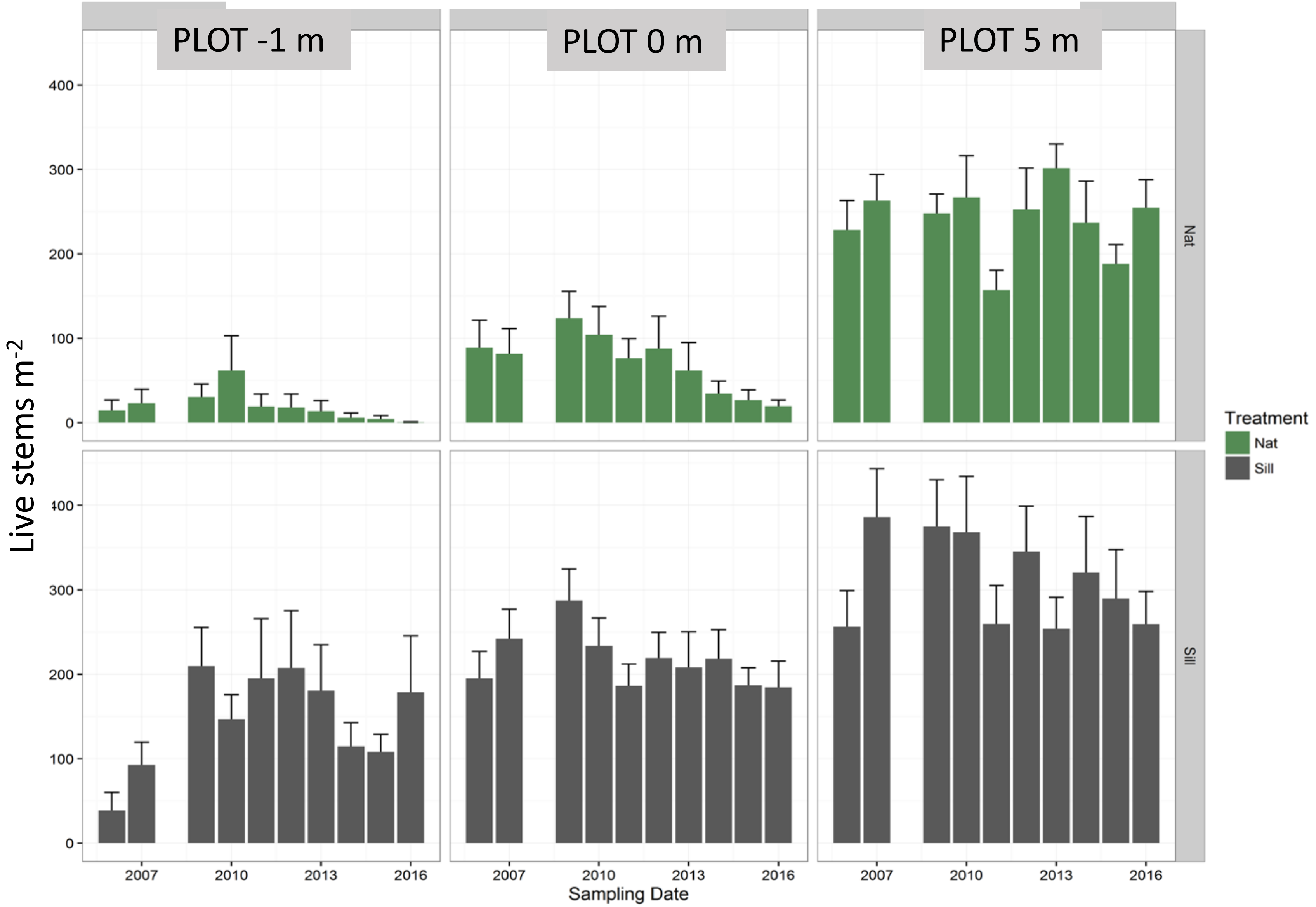
(m) landward of shoreline

Sill sediment accretion results in increased *Spartina* biomass at lower edge, loss of *Spartina* habitat at upper edge

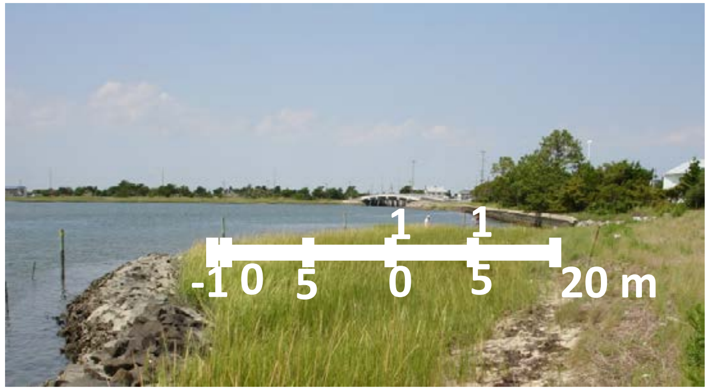


Permanent Vegetation Plots 2006 -2016

Mean *S. alterniflora* Stem Density



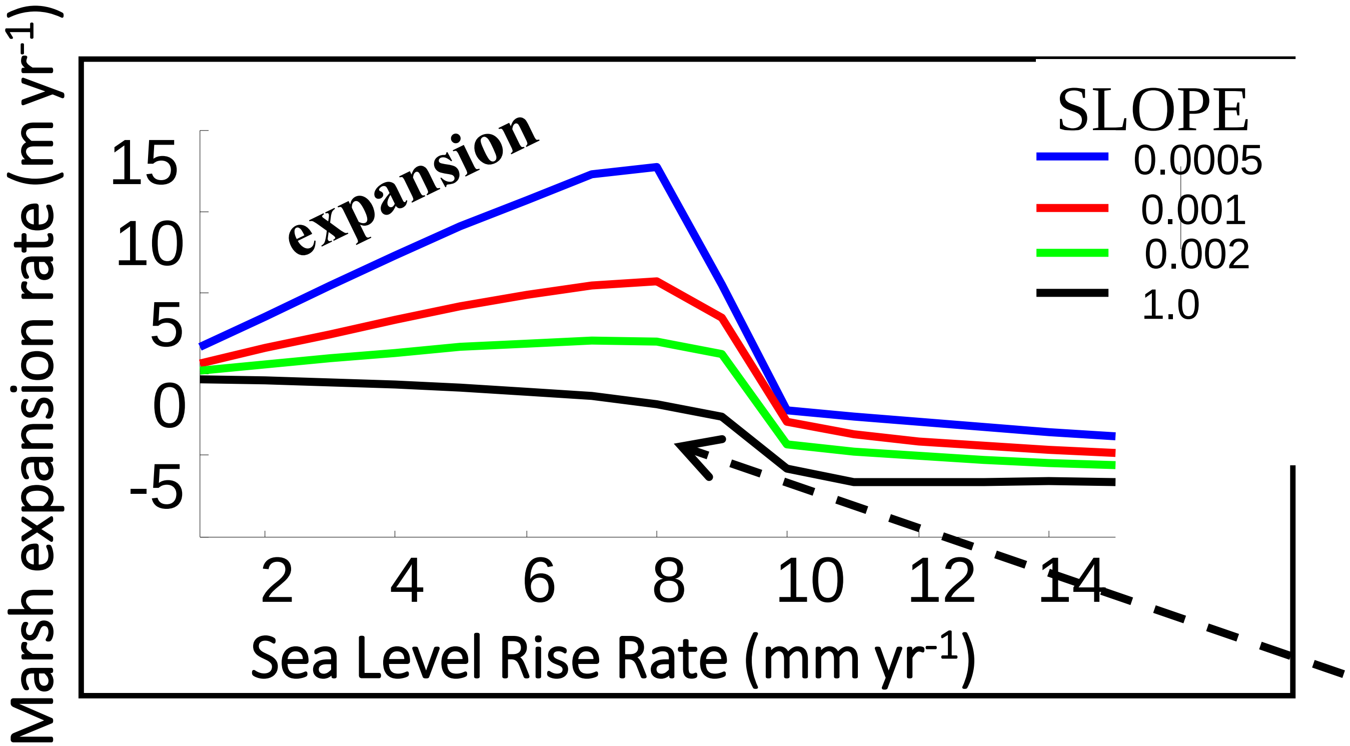
Loss of vegetation at lower edge
Maintained interior vegetation



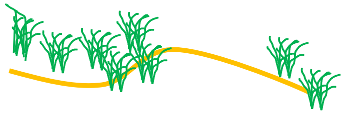
Increase in vegetation at lower edge
Maintained interior vegetation

Marsh transgression in response to SLR

Slope and SLR rate determine marsh area expansion

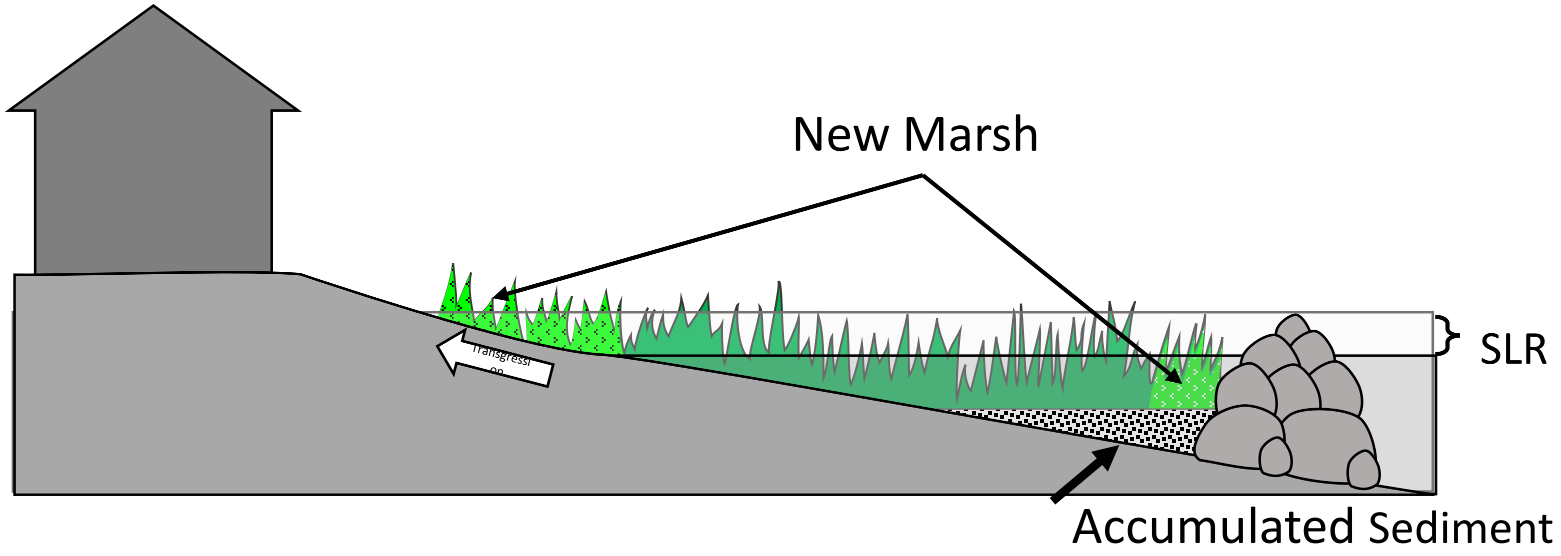


Scenario with human barriers to migration



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**

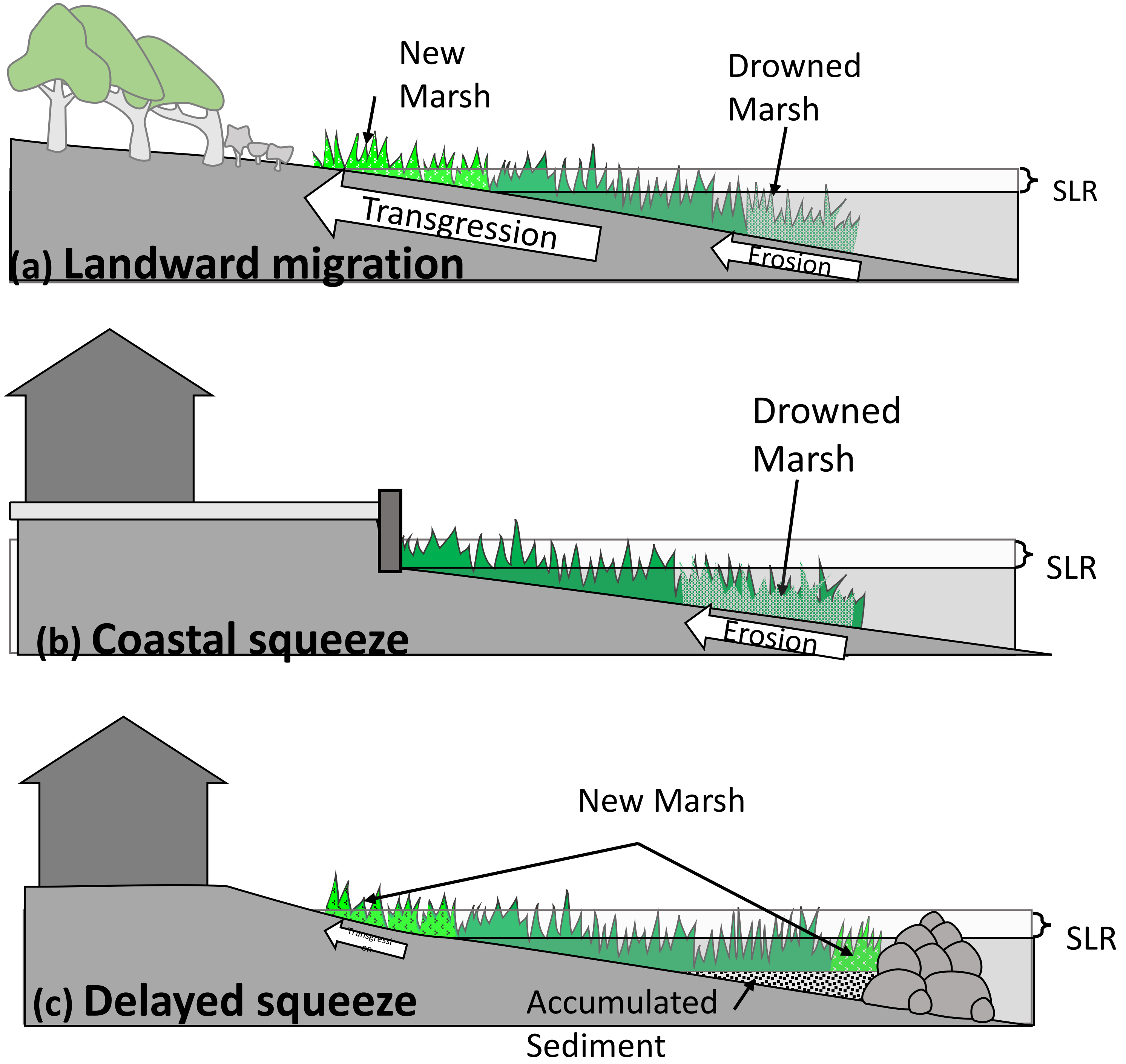
High Marsh

- Less faunal utilization
- Reduced denitrification
- Reduced Sediment trapping
- Lower C sequestration

- **Greater SLR resiliency**
- **Greater plant biodiversity**

Using Living Shorelines to protect property and Infrastructure

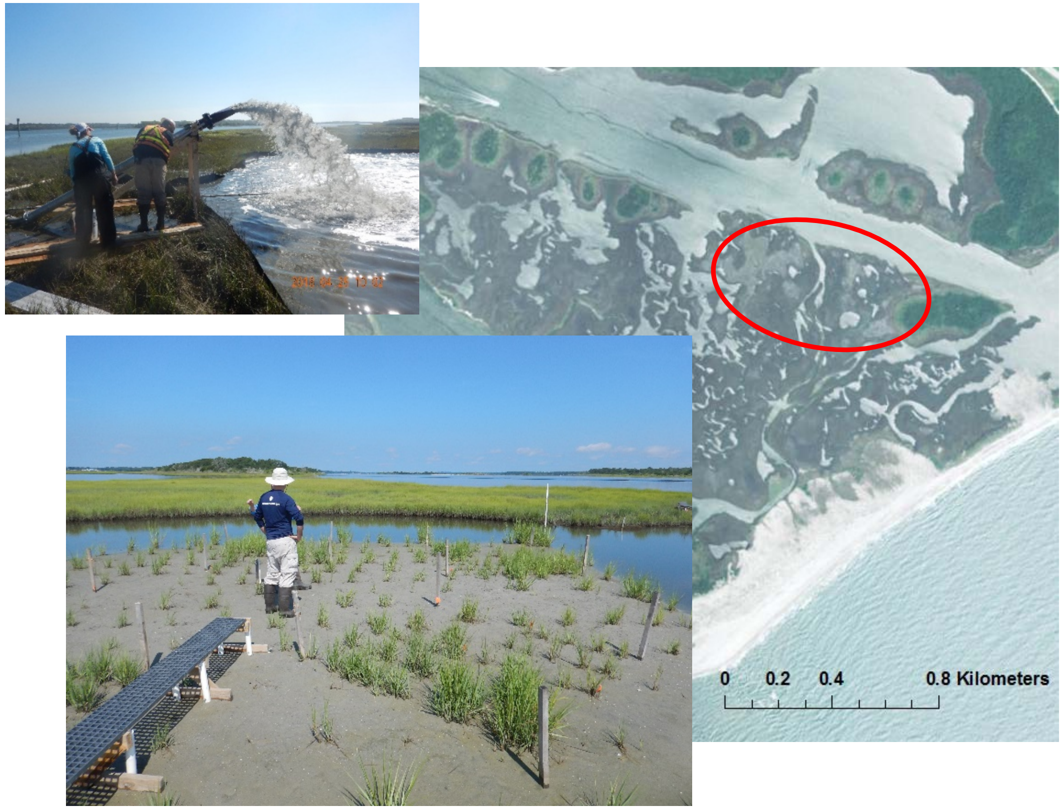
A longer view…



Thin Layer Application of Dredged Sediment to Vulnerable Salt Marshes

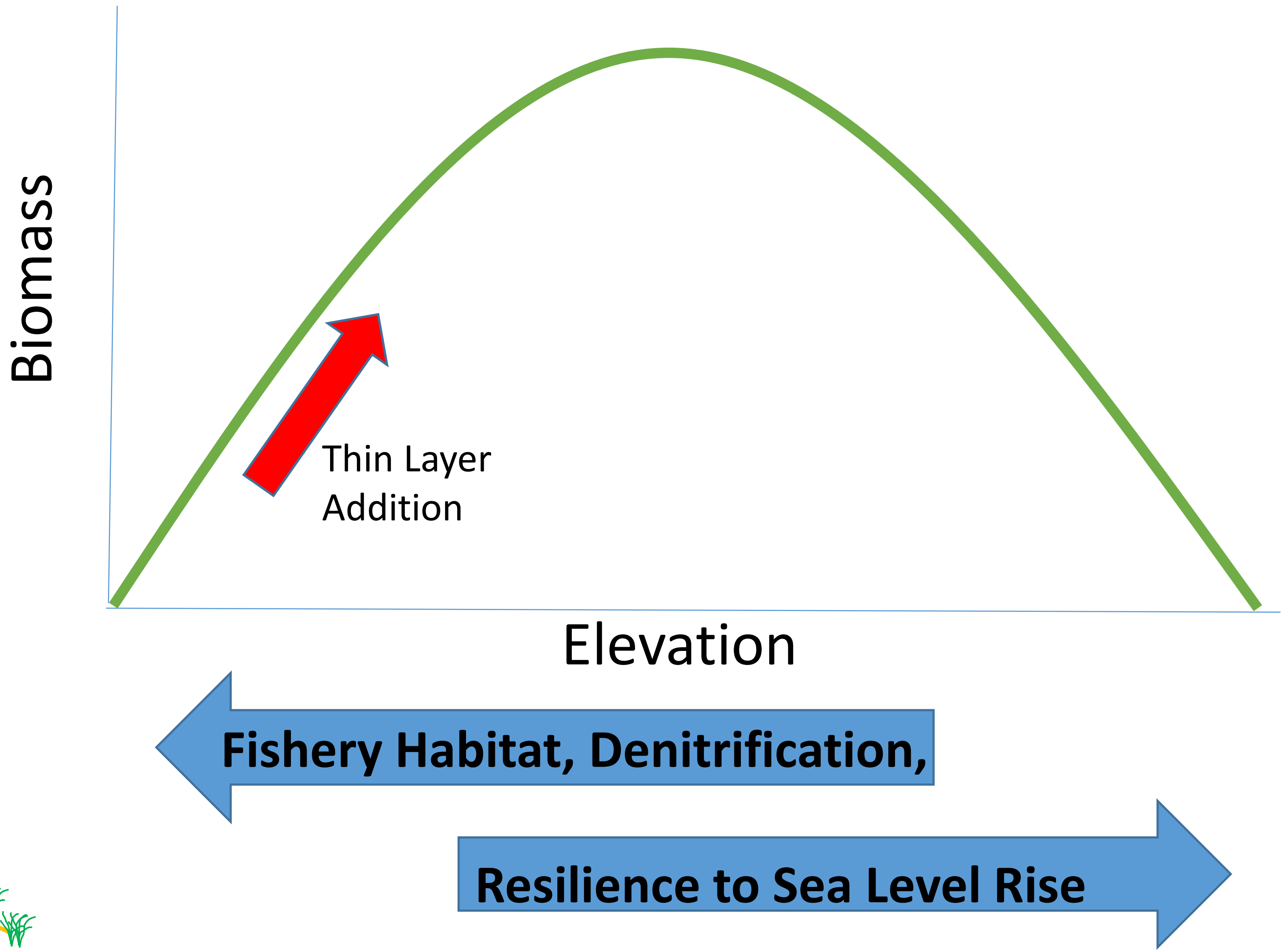
Two pilot projects on Marine Corps Base Camp Lejeune, North Caroline

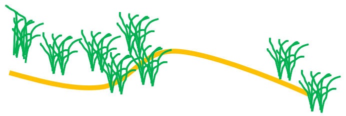
Raising elevation of low-lying salt marsh



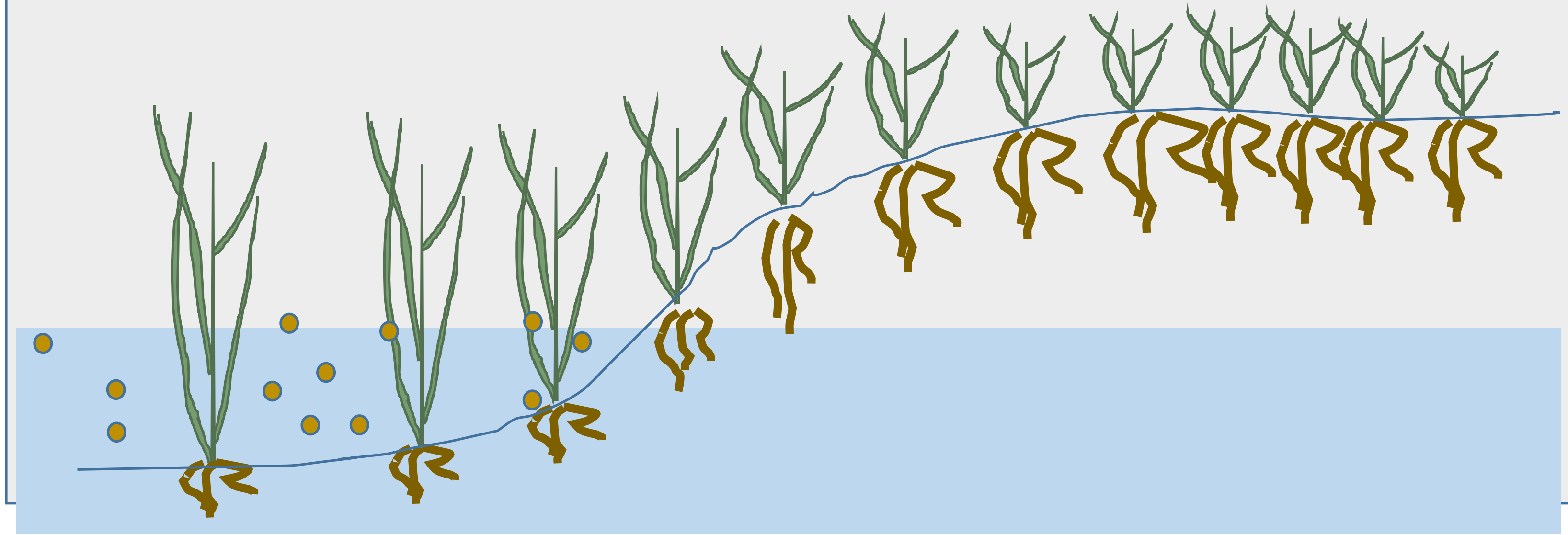
Dredged sediment added to ponded areas in fragmented marsh, *Spartina* planted

Spartina alterniflora biomass : elevation distribution





Thin Layer application and Ecosystem Services



Will thin layer addition impact C burial?

Greater input?

Greater turnover?

SUMMARY

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