Ecological Effects of Estuarine Shoreline Stabilization and Alternate Approaches

July 2013

Problem: Estuarine Shorelines Erode

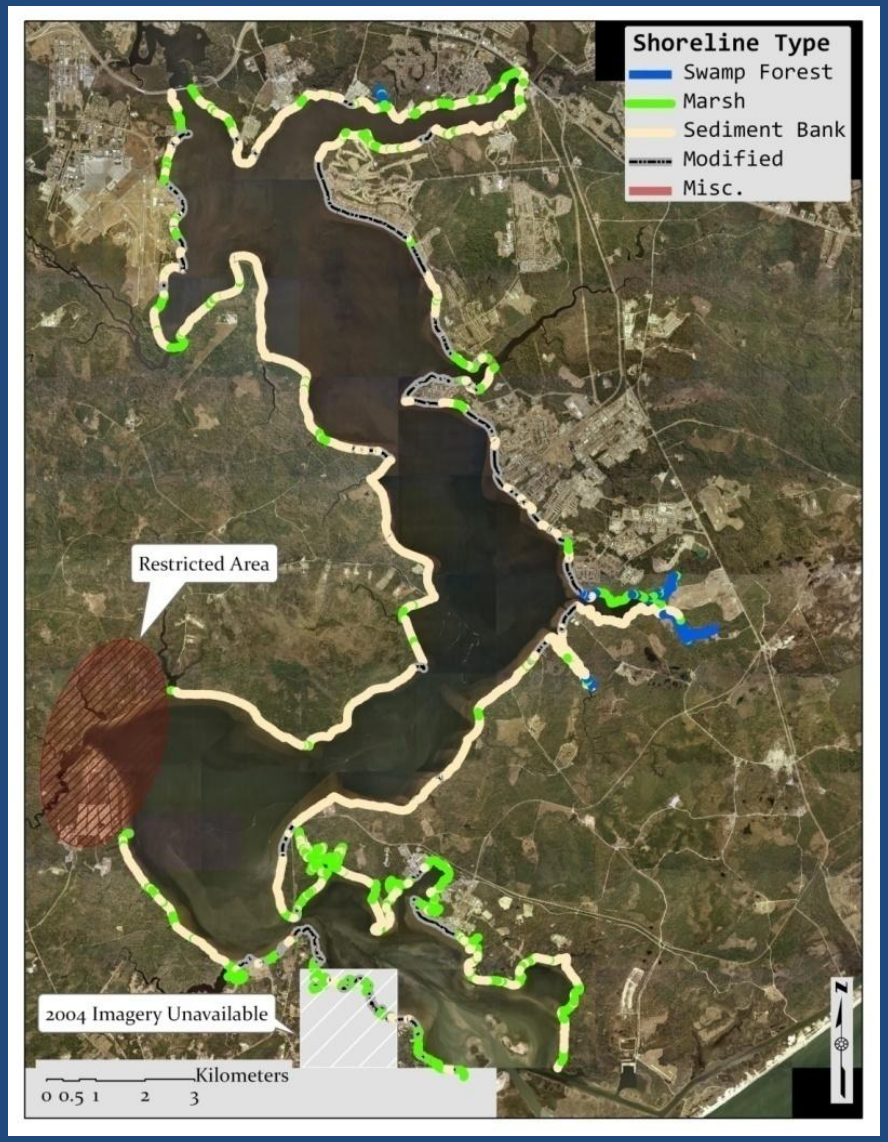
SLR, Storms , Boat wakes, and Coastal Development exacerbate problem

Increased demand for Shoreline Stabilization

Shoreline Hardening Reduces **Ecosystem Services** of Natural Shorelines

Solution: 'Living Shorelines' ?? ??

Shoreline Type and Change Rate Mapping
New River Estuary, MCBCL



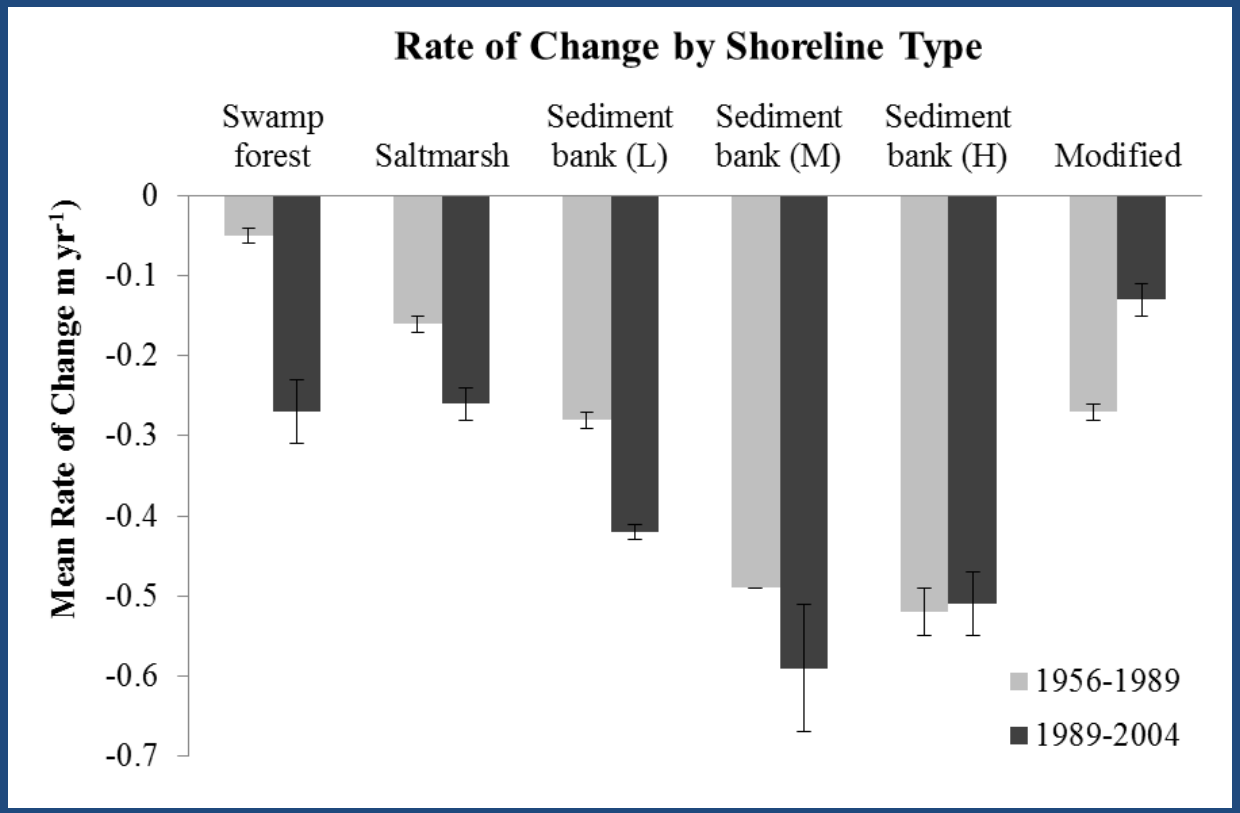
Entire shoreline mapped from small boat equipped with survey grade dGPS

Follow NC DCM mapping protocols with slight modification

Shoreline Change Rate in the New River Estuary

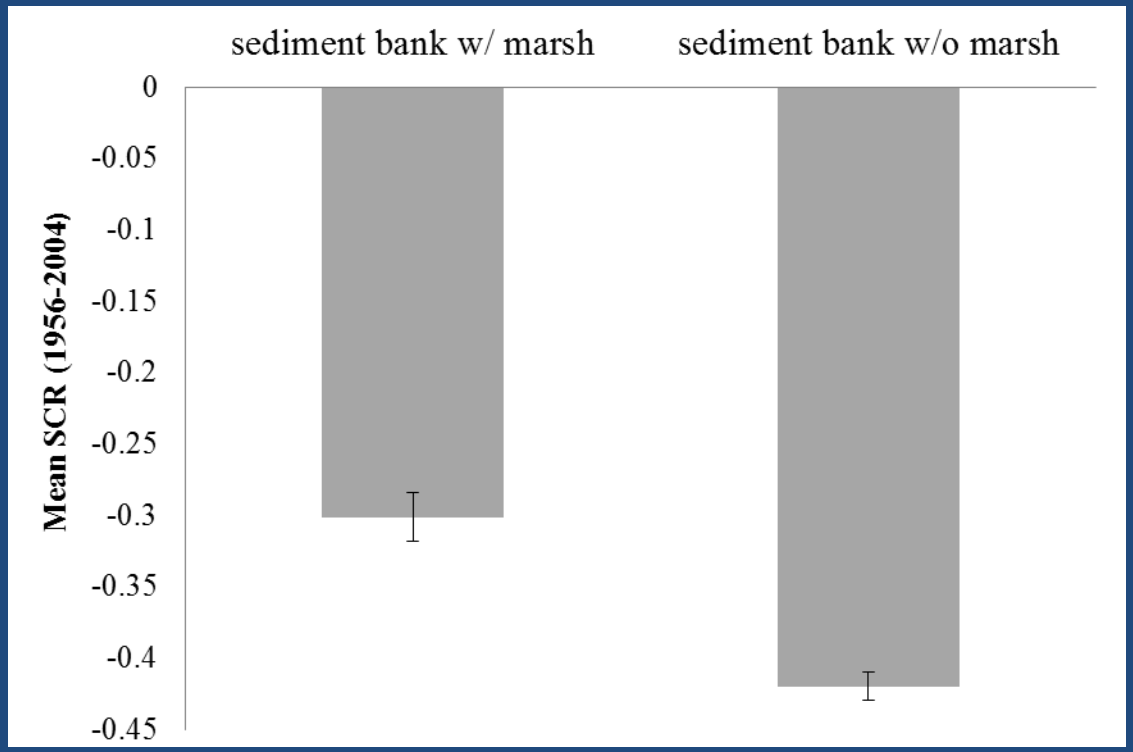
- Shoreline type determined by ground-truthing with small boat
- Shoreline change rate determined by aerial photography (1956, 1989, 2004)

Modified



- SCR ***not*** highly correlated with site long-term wave energy
- Overall results point to storm events, importance of underlying geology, and role of boat wakes in narrow channels (ICW) in determining SCR

Comparison of shoreline change along sediment banks with and without fringing marsh.

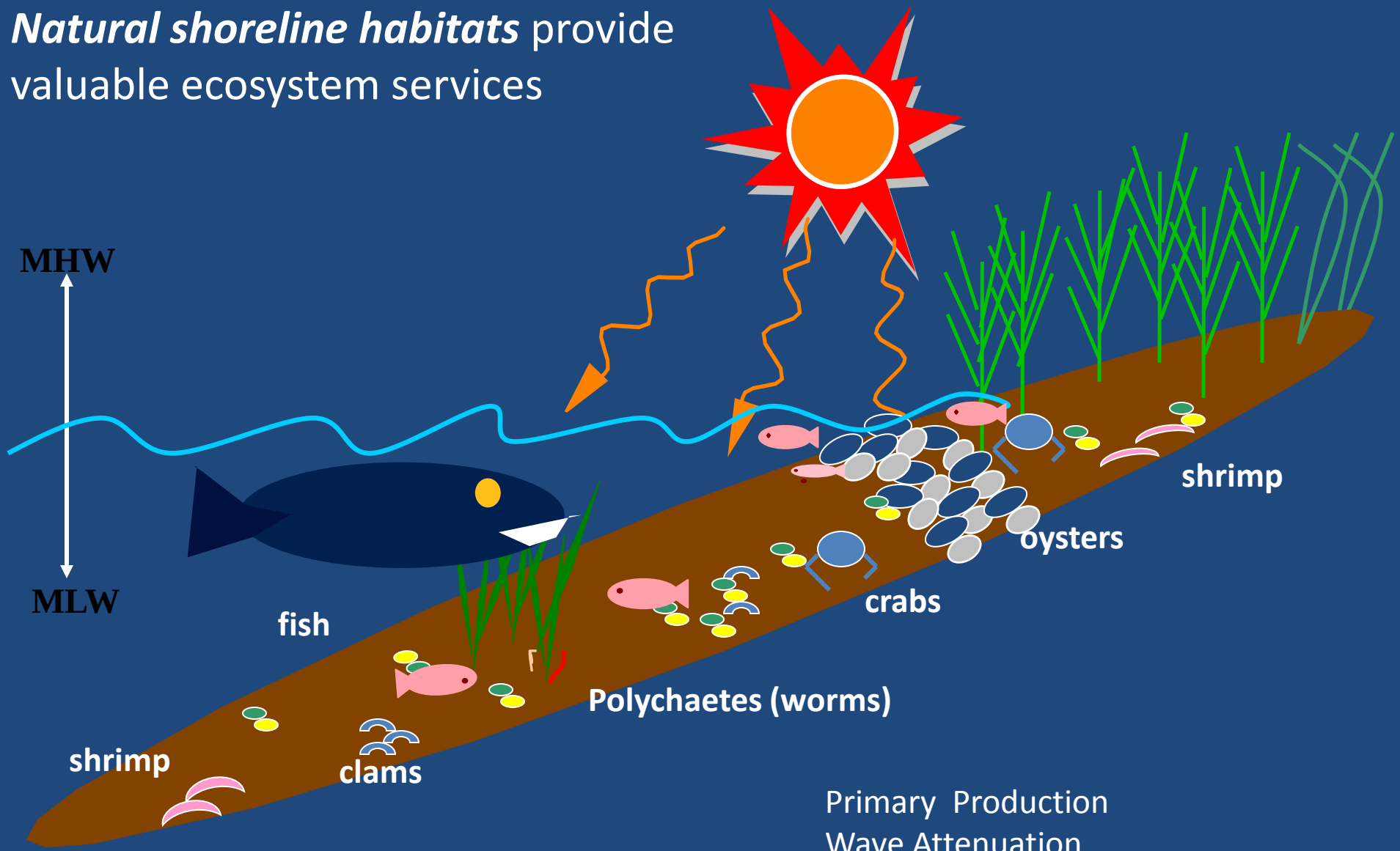


Fringing marsh significantly reduces sediment bank erosion

(irrespective of wave class)

Currin, Cowart, Fonseca, Malhotra & Davis
DCERP Final Research Report, Msc in prep

Natural shoreline habitats provide valuable ecosystem services



Primary Production
Wave Attenuation
Sediment Trapping
Habitat for Fish and Shellfish
Nutrient and Contaminant Removal

Fringing Marshes

Estuarine ecosystem services:

- **Wave attenuation and sediment trapping**
  (Knutson et al.1982, Christiansen et al. 2000, Leonard et al. 2002)
- **Fisheries habitat**
  (Hettler 1989, Minello et al. 1994, Peterson and Turner 1994, Currin et al. 2007)
- **Primary production** (Morris et al. 1990)
- **Nitrogen cycling**
  (Lyons et al. 1995, Currin and Paerl 1998,Tobias et al. 2001, Davis et al. 2004)
- **Carbon sequestration**
  (Duarte and Cebrian 1996, Gattuso et al. 1998, Choi and Wang 2004, Duarte et al. 2005)

Citizen monitoring protocol to assess natural and stabilized fringing salt marshes in North Carolina

Currin, Delano & Valdes-Weaver
WME 2008 16: 97-118

-Compared 3 paired sill and reference marshes
-Fish abundant, similar immediately, expensive to sample
-Vegetation similar after 3 yrs
-**Hurricane Isabel assoc with sediment deposition**
-**Sediment elevation increased greater in marshes behind sills**

NC ~230,000 acres of salt marsh

Carteret County Fringing Marsh Study

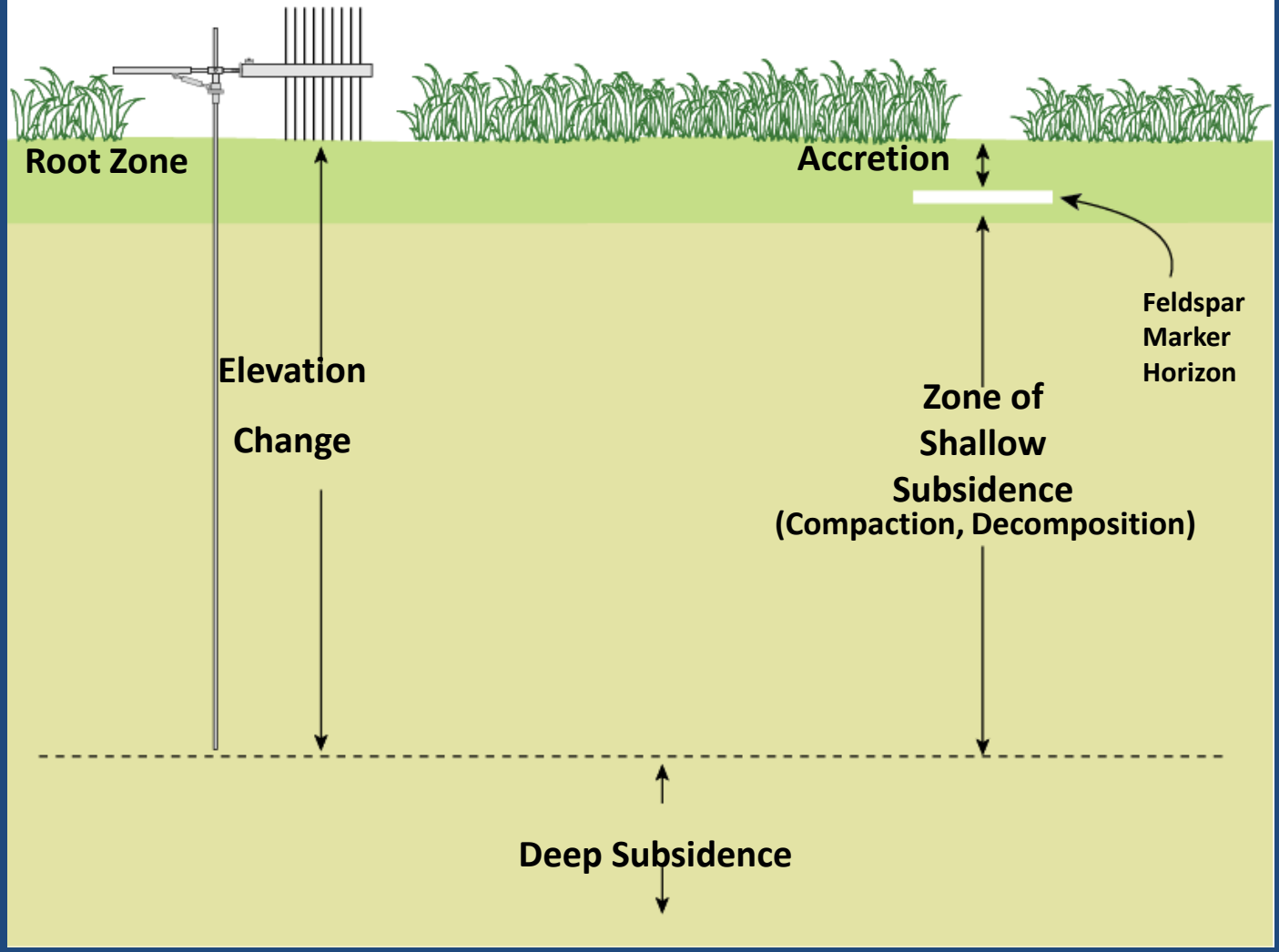
7 sites
29 SETs
52 vegetation transects
2004-2011 (4 sites only)

Questions:

- ❑ What factors affect surface elevation change and vegetation in fringing marshes?
- ❑ Do stone sills or intertidal oyster reefs alter sediment accretion or marsh vegetation in fringing marshes?
- ❑ Will fringing marshes keep up with SLR?

Surface Elevation Table (SET)

Used simultaneously, SETs and Marker horizons can provide information on below ground processes occurring above the base of the SET benchmark that influence elevation change



Cahoon, D., Reed, D., Day, J. 1995. Marine Geology 128:1-9.

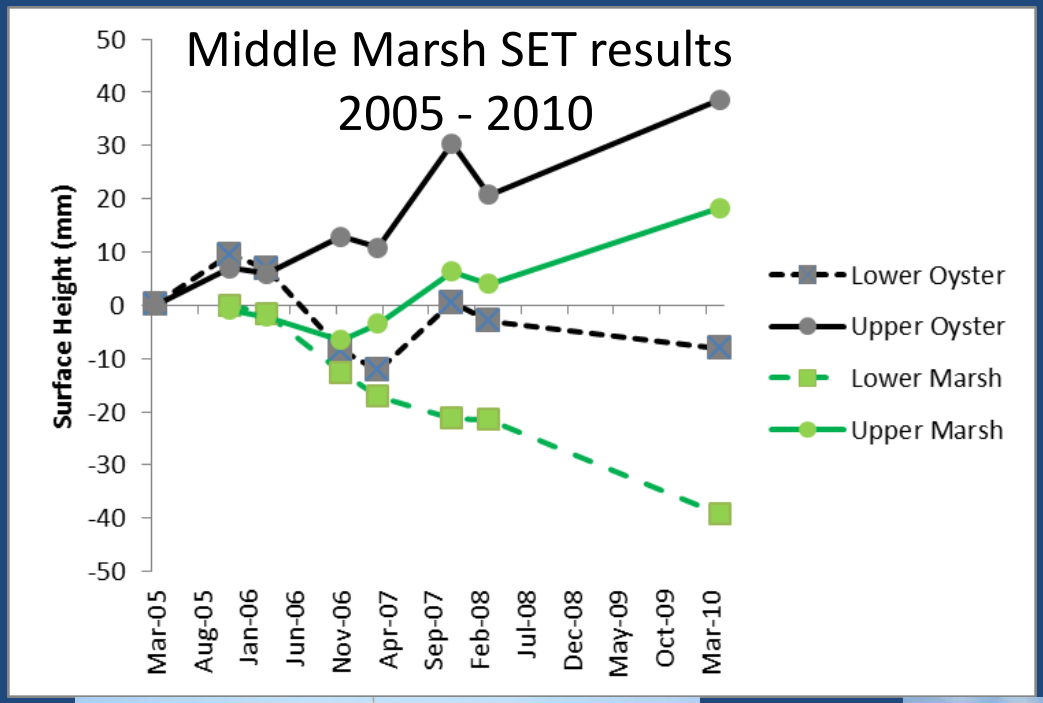
USGS
science for a changing world

<u>4 paired reference and stone sill sites</u>
Pivers Island (NOAA/DUML)
Harkers Island
NC Maritime Museum
NC Aquarium at PKS

<u>3 paired oyster/no oyster sites</u>
Middle Marsh (NERRS)
Cape Lookout (Natl Park)
Mill Creek (Natl Forest)

Pine Knoll Shores (PKS)
-sill, natural fringing, natural long
-veg plots at -1, 0, 5, 10, 15, 20, …30, 40 m

Effect of oyster reef on marsh surface elevation change



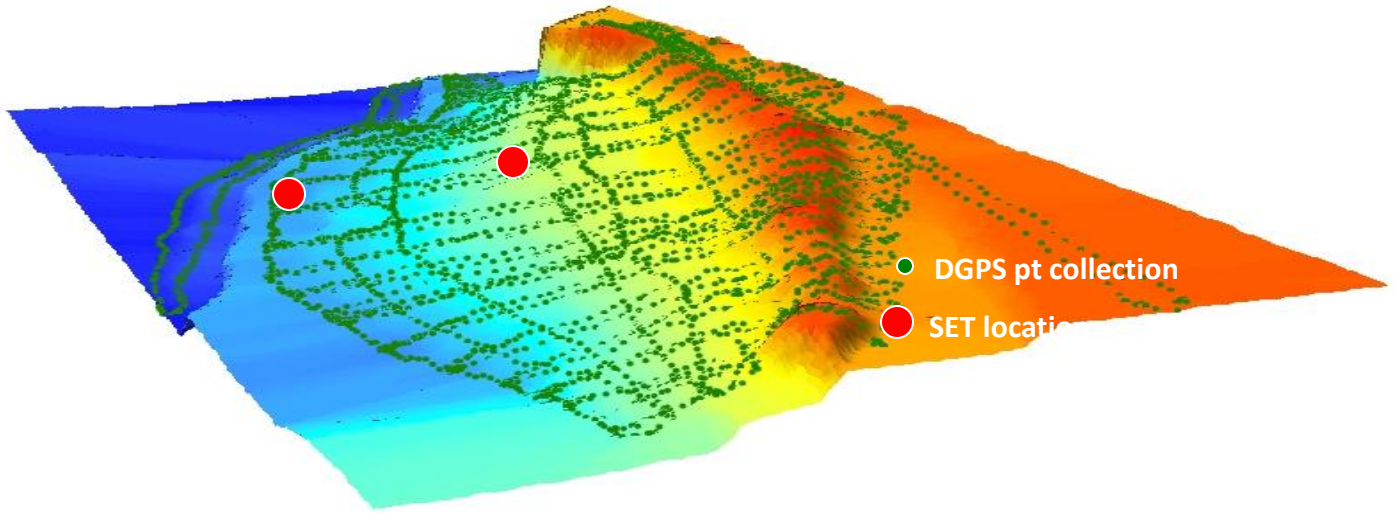
Elevation Change	mm / yr
OYST Low	-1.71 *
OYST Upper	8.13 ***
MARSH Low	-8.79 ***
MARSH Upper	4.10 **

* p<0.030
** p<0.002
*** p<0.0001

Similar results at Cape Lookout Natl Seashore site

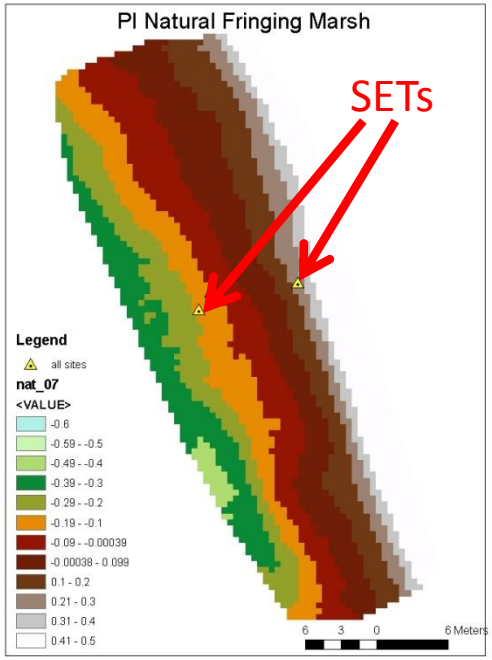
marshes

- NOAA NOS CCFHR
- NOAA NGS
- NOAA COOPS

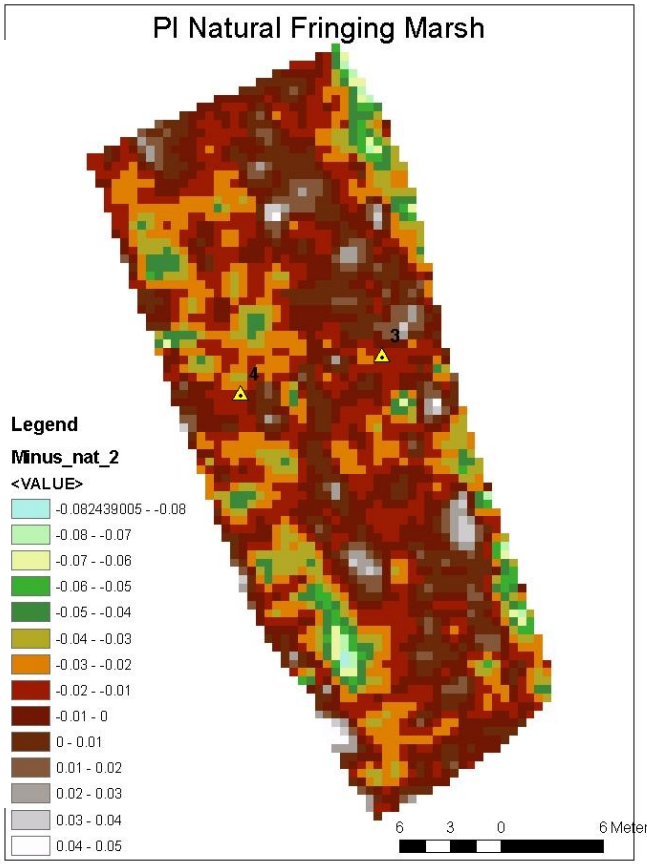


- Bike works well in firm, sandy marshes

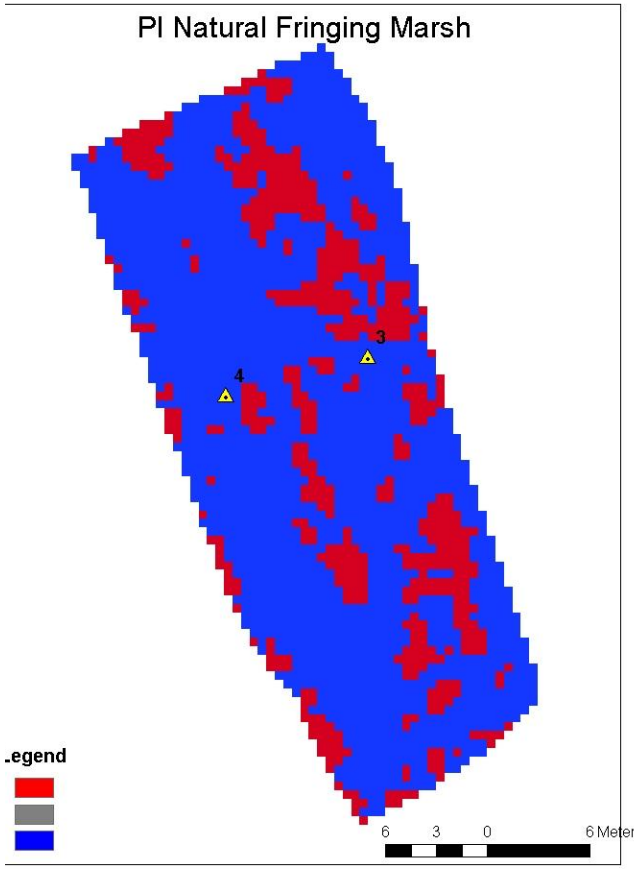
2007 DEM



2007-2010 DEM change analysis



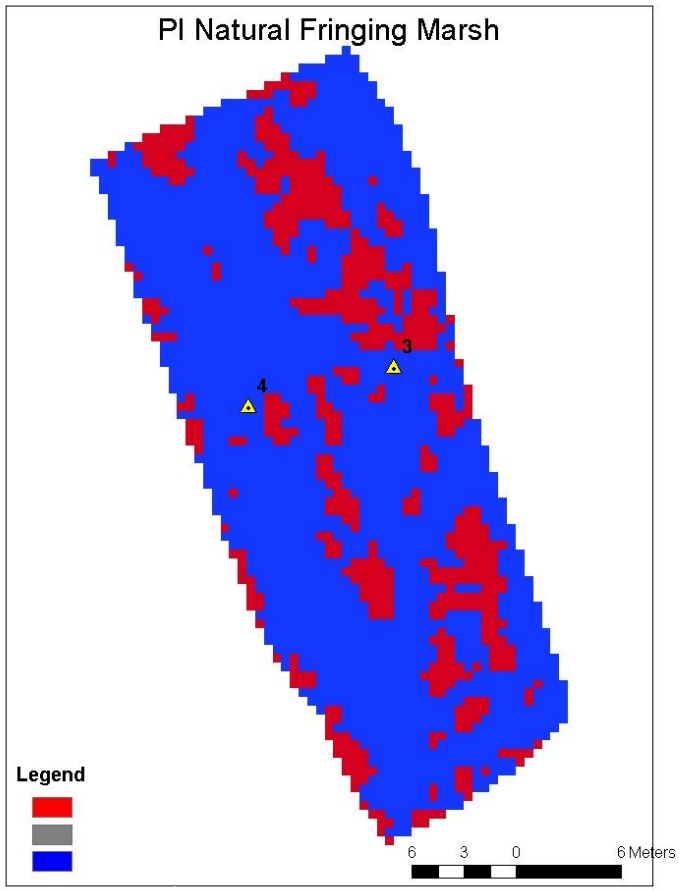
2007-2010 DEM cut-fill



DEM change analysis confirms SET results with loss of marsh elevation at lower edge and increase in elevation at upper edge

Total area = 670 m^2 Net Volume Change = -8.3 m^3 Mean loss = - 0.01 m elevation

2007 – 2010 DEM Change Analysis



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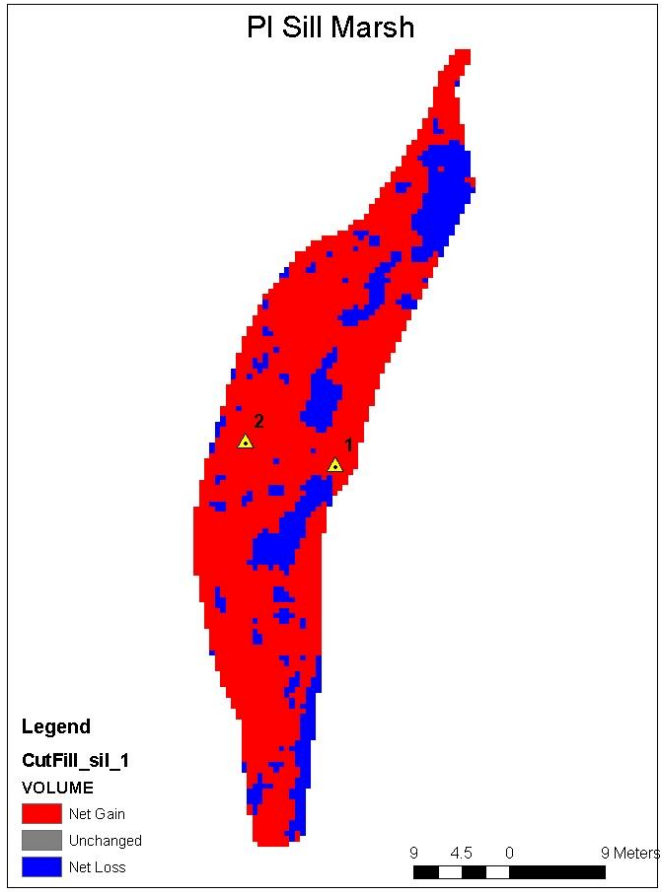
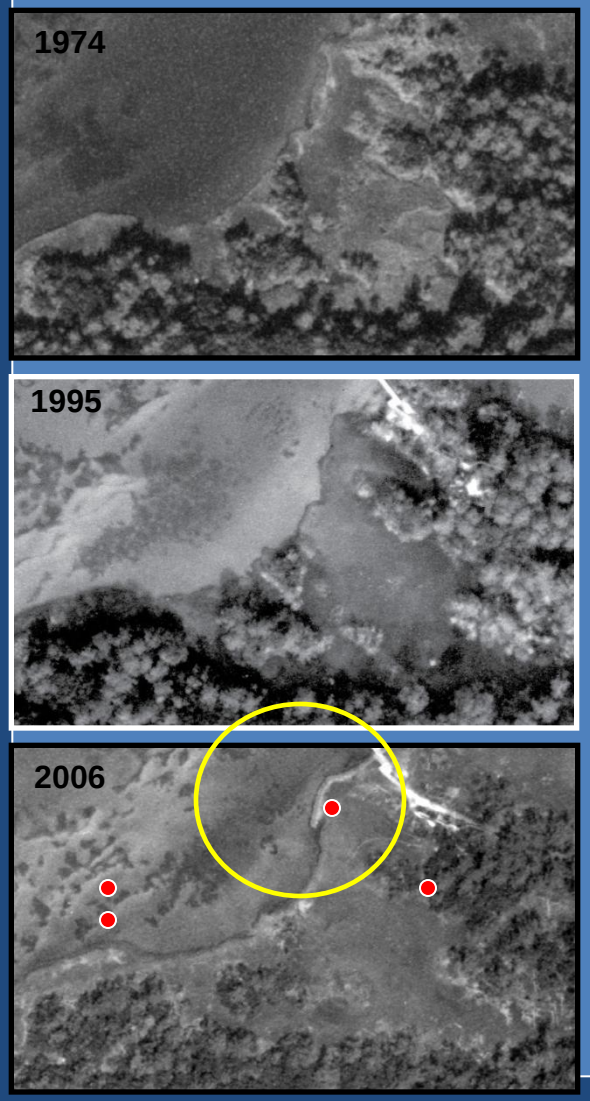
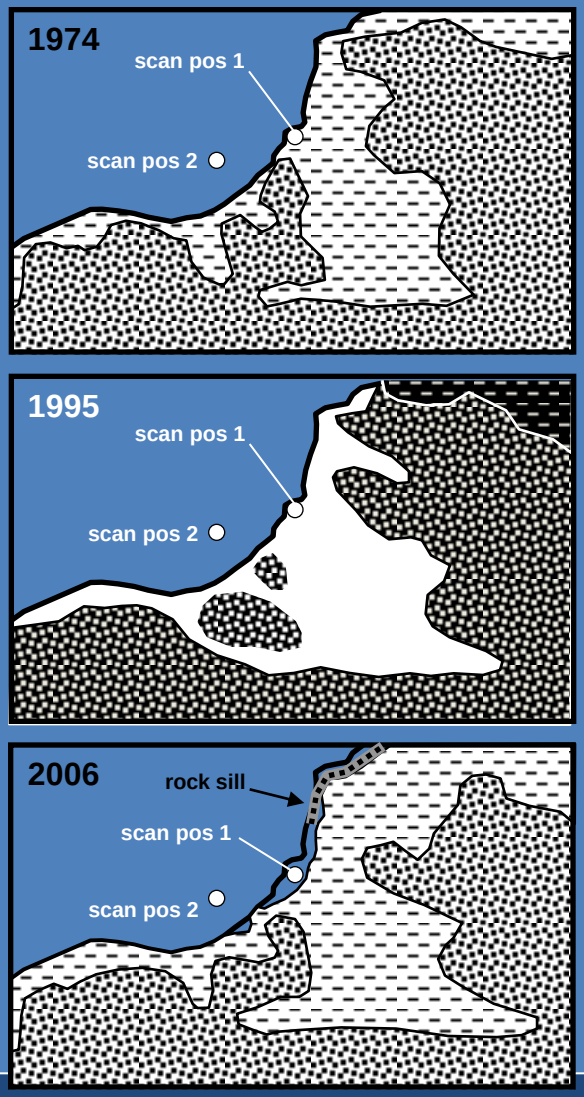


Total area = 740 m^2
Net Volume Change = 10.4 m^3
Mean gain = 0.01 m elevation

Also used to determine horizontal change in elevation contour line

Shoreline erosion adjacent to PKS aquarium stone sill





1974-1995 virtually no change in shoreline

20 m

Upland

Marsh

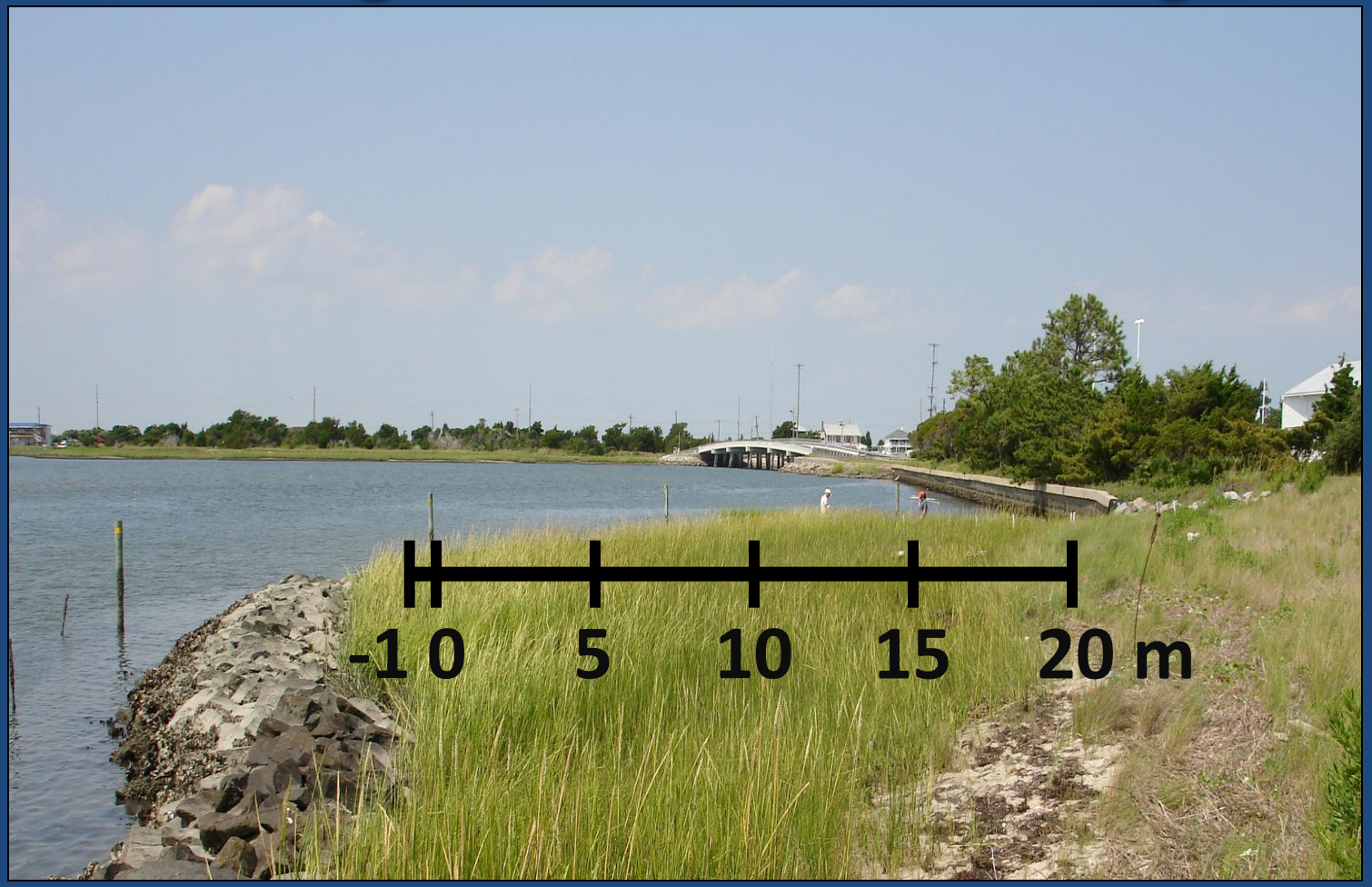
SET location

Post sill-construction significant erosion to adjacent shoreline

From Mattheus et al. 2011

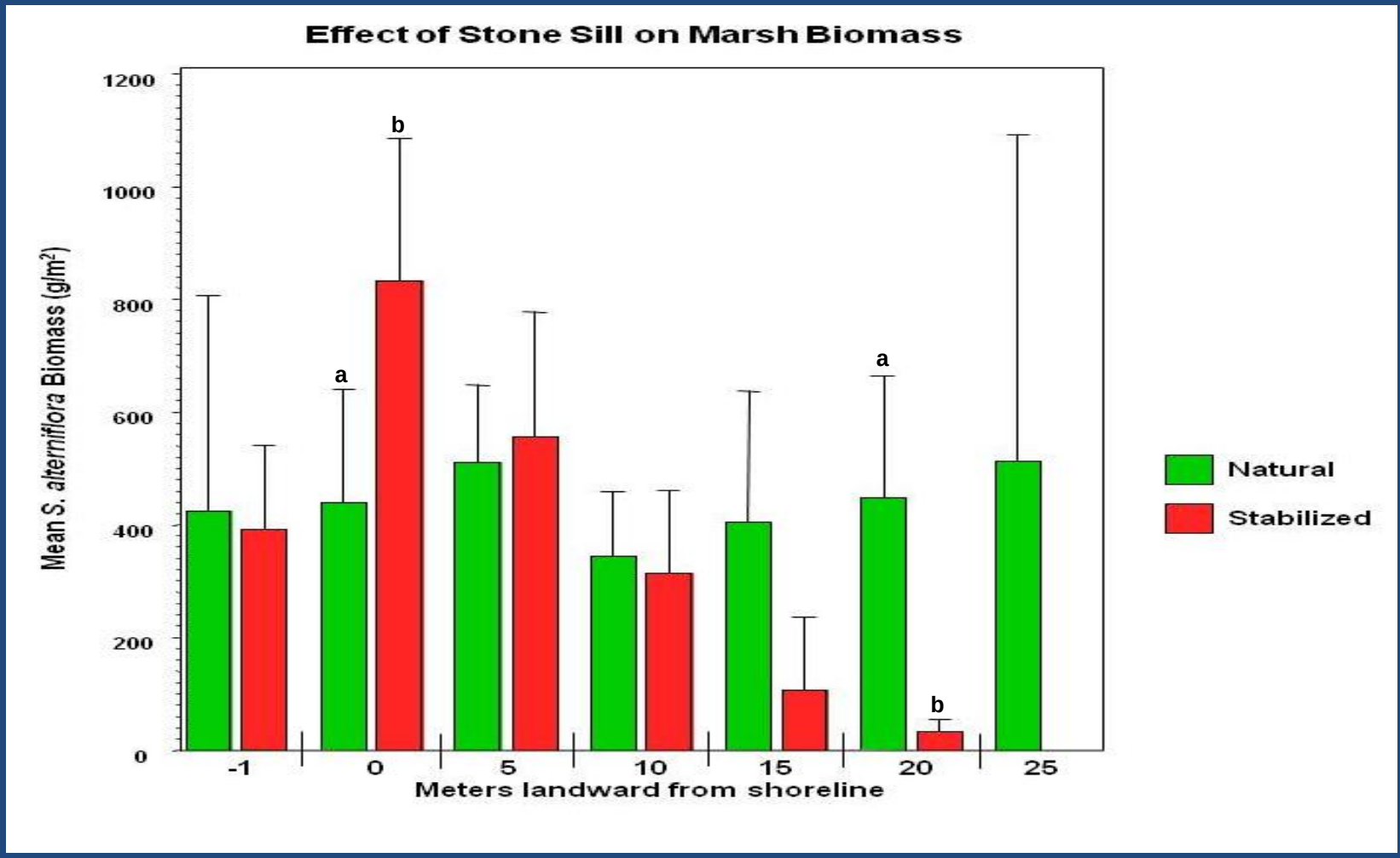
PKS April 2011

Vegetation Transect Design



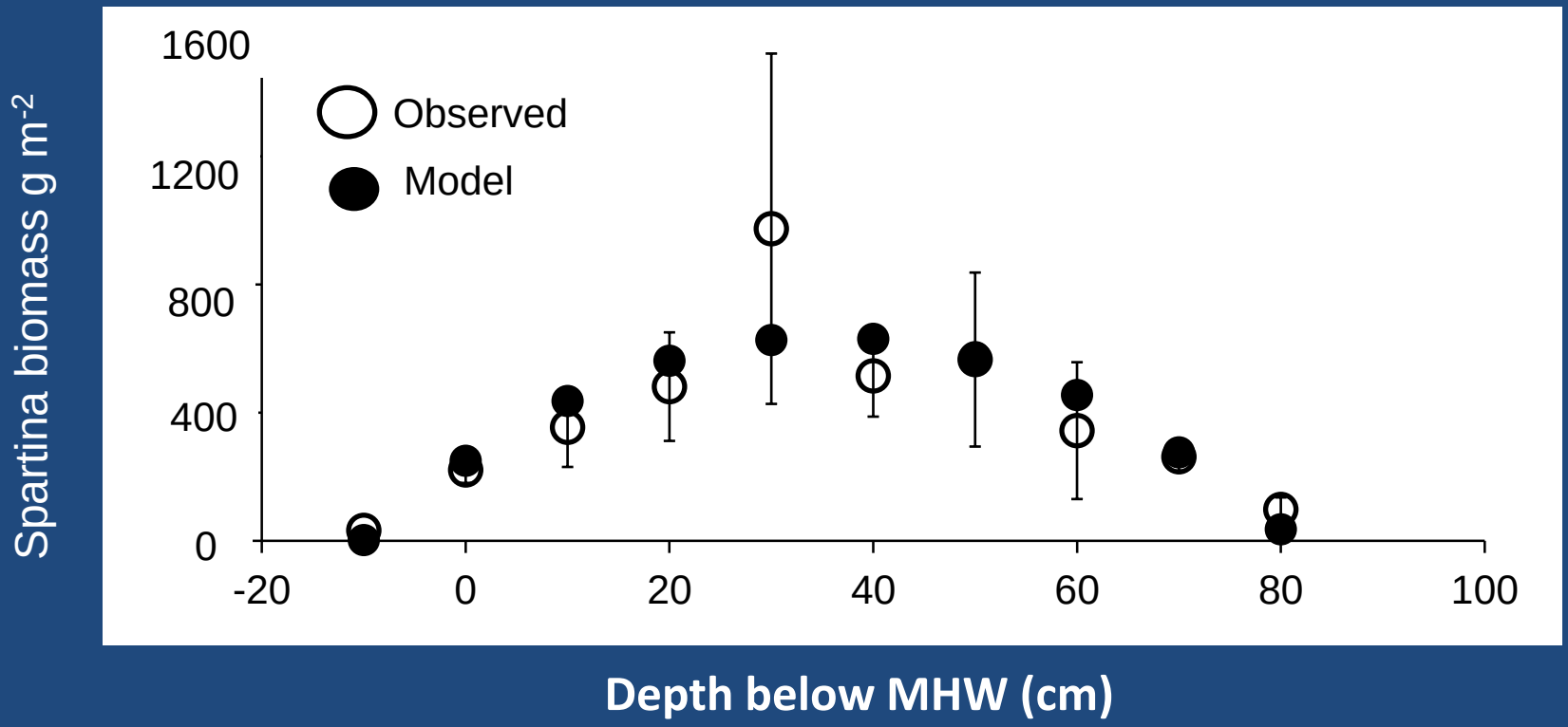
- 4 – 6 transects per marsh, perpendicular to shore
- Restricted random sampling design, repeated measure
- Annual *Spartina* stem density, stem ht., plant spp. % cover, snail density
- Determine biomass – elevation relationship

- NOAA- NCNERRS partnerhsip



- Significant treatment difference at 0 m
  sill > natural by 500.9 g/m^2
- Significant treatment difference at 20 m
  natural > sill by 414.8 g/m^2

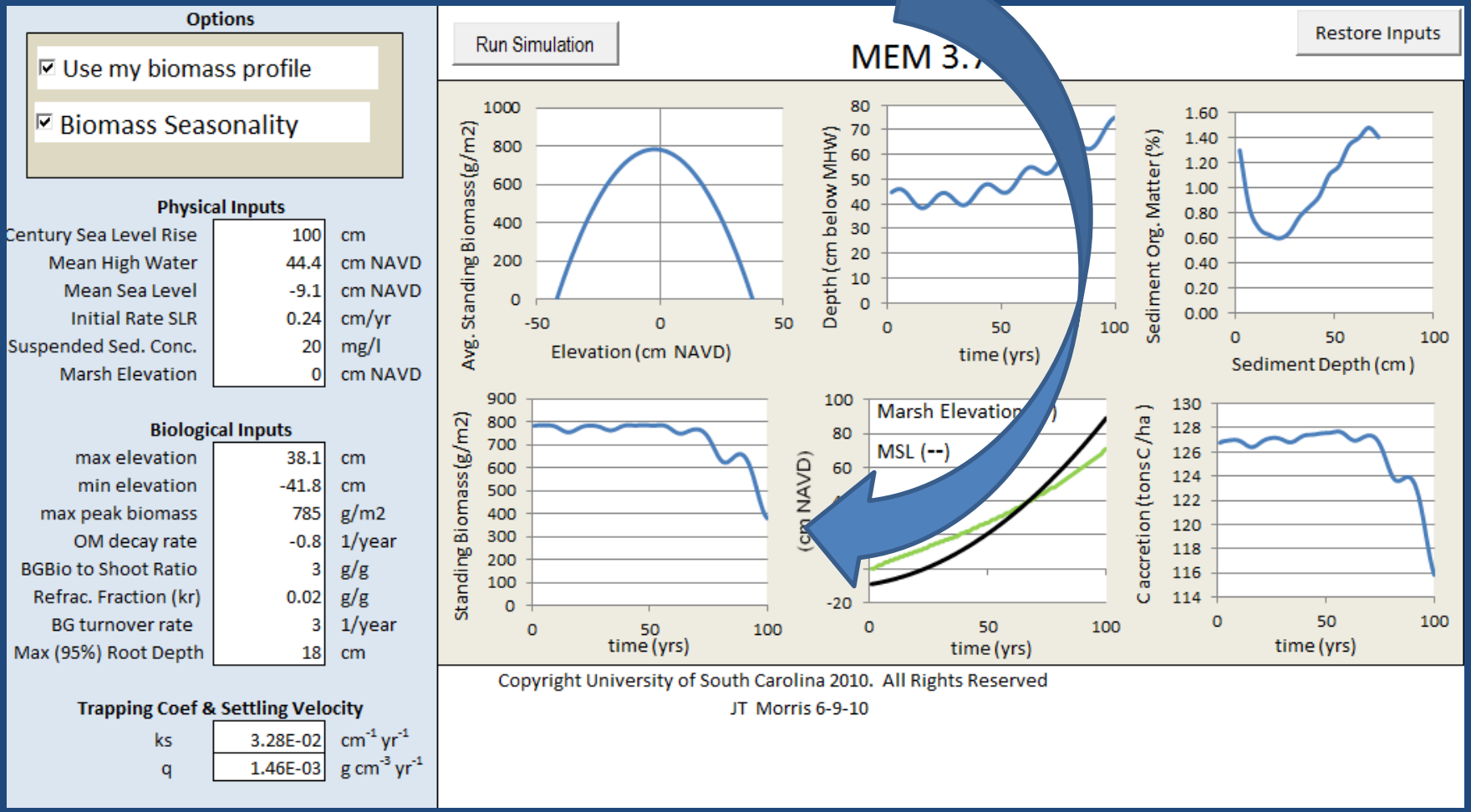
Distribution of *Spartina* biomass across intertidal elevation in NC fringing salt marshes



Biomass a predictor of marsh surface elevation change, provides input for models predicting SLR response (Morris et al. 2002)

Marsh Equilibrium Model (MEM) predictions:

- 0 m elevation fringing marsh will persist 100 yrs with 24 cm SLR
- 0 m elevation marsh will begin steep decline after 75 yrs with 100 cm SLR



No wave energy
No transgression

Currin, Delano, Fear & Morris In Review

Salt Marsh Rebound Model

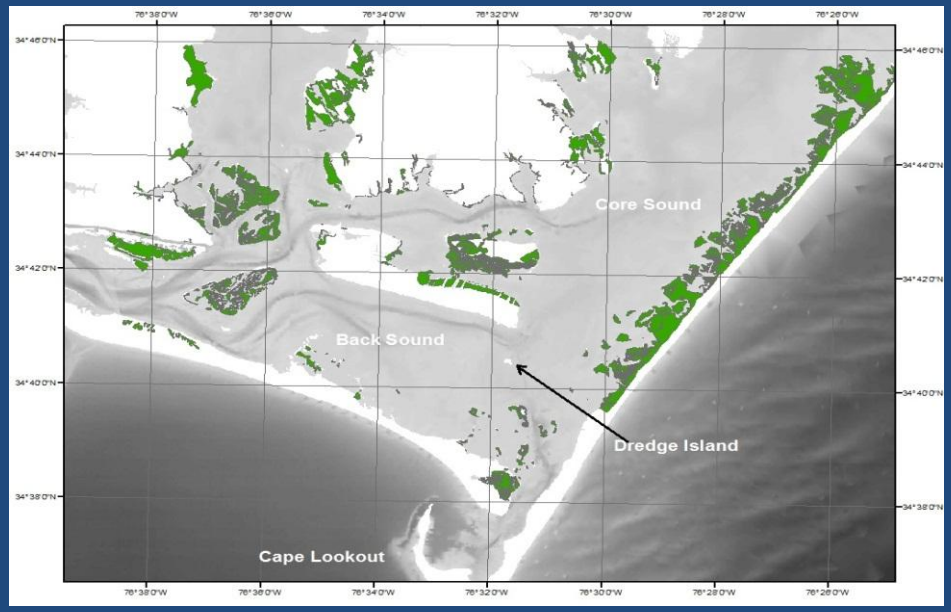
High Marsh (short *Spartina/ Salicornia /Juncus*, high OM) erodes

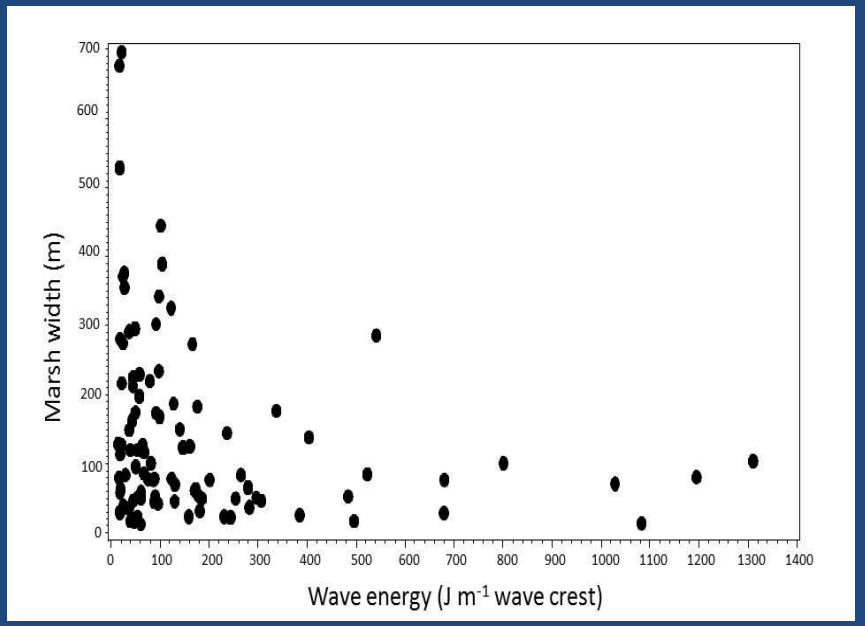
Low Marsh (low OM) fills in

Low marsh (high stem ht),

High marsh (short *Spartina*)

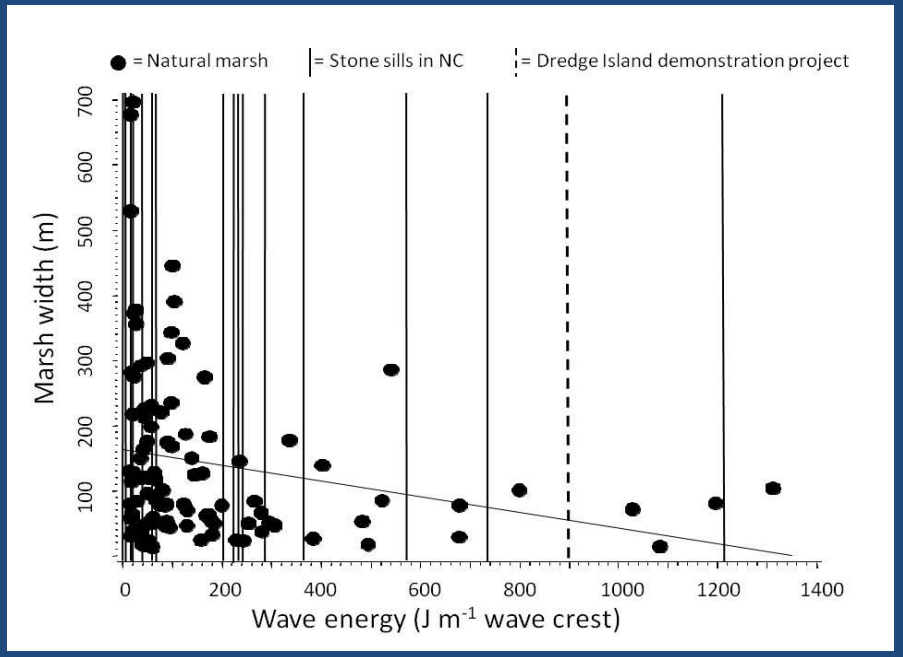
Analysis of Wave Energy setting of salt marsh habitat in Carteret County





M. Fonseca, A. Malhotra

Wave energy setting of sills



Sills increase sediment accretion rates
Lose lower intertidal habitats
Design for site conditions

… use oysters instead of stone when possible

Sustainable Estuarine Shoreline Stabilization: Research, Education and Public Policy in NC

How do bulkheads impact ecosystem services of shoreline habitats?

Wave reflection, sediment suspension and elevation	C.Currin, M. Fonseca, G. Piniak NOAA CCFHR
Marsh vegetation	J. Fear NC NERR
Groundwater and nutrient cycling	M. Piehler UNC Institute Marine Sciences
Infauna response	M. Posey UNC-Wilmington
Fish utilization of shoreline habitats	C. Peterson UNC-CH Institute Marine Sciences

North Carolina coastal area, showing the NoCo (tidal range < 0.1m), CeCo (tidal range ~1m), and SoCo, (tidal range ~2m) study areas. Six sites have been established in each study.

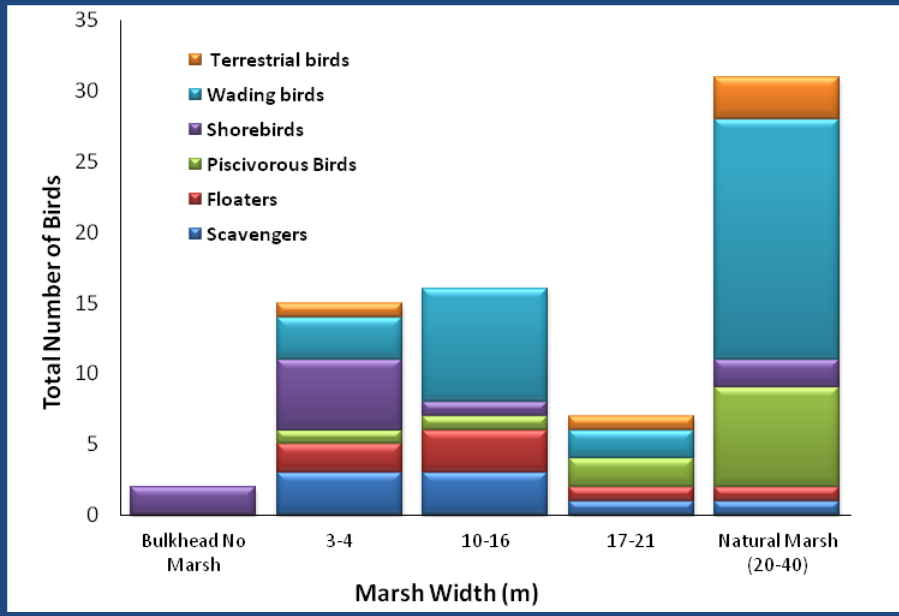
CICEET Project Key Findings:.

Bulkheaded sites

- Lower in elevation than sites with marsh.
- Decreased wave attenuation; bulkhead alone may have higher wave energy due to wave reflection
- Denitrification decreases with decrease in marsh area
- Infauna species composition altered in bulkheaded sites.

- Bulkheaded sites supported a lower abundance of birds compared to natural marshes. Bulkheads without marsh had much lower bird diversity
- .Marsh nekton abundance increases with increasing marsh width.

- Small narrow marshes in front of bulkheads provided a higher level of ecosystem services than expected, per unit area.



Shoreline response to Hurricane Irene

Pivers Island Shoreline marsh sites:

no erosion of marshes, net sediment accumulation

scouring behind bulkheads and base of revetments

UNC study in APES: No observed loss to marsh shorelines
76% of bulkhead shorelines showed damage
(Gittman et al. submitted)

NERRS study of marsh sills: No observed damage
(J. Fear, NC NERRS)

Research Results to guide shoreline stabilization policy

- Estuarine shoreline erosion rates controlled by habitat type (banks>marsh>swamp forest), wind wave & boat wake energy, and geomorphology. Can be important sediment source

- Marsh fringe effectively reduces sediment bank erosion

- Bulkheaded shorelines reduce marsh, leading to loss in elevation, wave attenuation, fish and bird habitat, and N cycling capacity of shoreline

- Stone sills increase sediment accretion and surface elevation change in fringing salt marshes by 2-3x. A change in vegetation from *S. alterniflora* to upper marsh occurs with this change in elevation.

- Fringing oyster reefs stabilize marsh edges and decrease elevation loss

Shoreline Stabilization Research Results

•Stone sills projects need to be matched to physical setting of site

Fringing oyster reef-marsh installation viable alternative in many settings (demo site Carrot Island)

Marshes have provided erosion protection from recent hurricanes