Monitoring marsh-sill stabilization projects in North Carolina: Results and Recommendations
Carolyn Currin, NOAA NCCOS Beaufort Lab
What we’ve learned about Ecosystem Monitoring

Ecosystems are:
- Open
- Regulated by processes outside boundaries
- **Exhibit multiple end points**
- Have multiple successions
- Subject to natural disturbances
- Incorporate humans and their effects

Likens 1994

Habitat Restoration Monitoring Basics
- Reference and Control Sites
- Random (stratified) sampling
- Structural parameters that predict function
- Cost-effective, indicator parameters

e.g. Neckles

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**Functional Trajectories**

- Fish
- Plants
- Sed OM, N cycling, infauna
- Elevation ?

Craft, Currin, Levin, Piehler, Simenstad, Zedler, etc.
Carteret County NC

Impact of marsh sills on fringing marsh surface elevation, sediment accretion and vegetation

Natural reference marsh

4 paired sites with upper and lower SETs measured twice yearly initially
Root Zone

Elevation
Change

Zone of
Shallow
Subsidence
(Compaction, Decomposition)

Deep Subsidence

Accretion

Feldspar
Marker
Horizon

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.

Measuring marsh elevation change in Living Shoreline Sites
• 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 CCFHR - NCNERRS partnership
SET Results Natural Fringing Marshes
Carteret County, NC

Each point is mean of 36 pin positions/SET
SET Results Marsh  Sill Marshes  
Carteret County, NC

Each point is mean of 36 pin positions/ SET
### Analysis of Natural and Sill marsh SET data 2005 - 2014

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

<table>
<thead>
<tr>
<th>Marsh</th>
<th>Elevation</th>
<th>mm/yr</th>
<th>n (SETS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nat</td>
<td>Lower</td>
<td>-6.0*</td>
<td>4</td>
</tr>
<tr>
<td>Nat</td>
<td>Upper</td>
<td>-0.1</td>
<td>4</td>
</tr>
<tr>
<td>Sill</td>
<td>Lower</td>
<td>3.4*</td>
<td>4</td>
</tr>
<tr>
<td>Sill</td>
<td>Upper</td>
<td>3.2*</td>
<td>4</td>
</tr>
</tbody>
</table>

* $p< 0.02$
• 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
DEM Change Analysis confirms SET results on impact of sills on surface elevation change
- Upper portions of Sill marshes lost *Spartina alterniflora*, replaced with upper marsh spp.
- Elevation changes reflected in vegetation change, loss of lower marsh habitat

**Compare changes in DEM over time (2007-2010)**
North Inlet Marsh SC  
Source: J.T. Morris, USC

### Accretion Rate

<table>
<thead>
<tr>
<th>Time Span</th>
<th>(cm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-1999</td>
<td>0.52</td>
</tr>
<tr>
<td>1997-2000</td>
<td>0.46</td>
</tr>
<tr>
<td>1998-2001</td>
<td>0.30</td>
</tr>
<tr>
<td>1999-2002</td>
<td>-0.06</td>
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<tr>
<td>2000-2003</td>
<td>-0.16</td>
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<tr>
<td>2001-2004</td>
<td>-0.23</td>
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<tr>
<td>2002-2005</td>
<td>0.09</td>
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<tr>
<td>2003-2006</td>
<td>0.19</td>
</tr>
<tr>
<td>2004-2007</td>
<td>0.18</td>
</tr>
<tr>
<td>2005-2008</td>
<td>0.09</td>
</tr>
<tr>
<td>2006-2009</td>
<td>0.11</td>
</tr>
</tbody>
</table>

All Years Mean 0.12

Accretion rate was negative in 3 of 11 periods. Hence, there was a 27% chance of calling the wrong trend.
Effect of oyster reefs on fringing marsh surface elevation change

Surface elevation change (mm)

-150
-100
-50
0
50
100
150

Oyster Reef
Non-Oyster
Unconsolidated Oyster

Upper

Lower

CL
NCMM
MM

Effect of oyster reefs on fringing marsh surface elevation change
Pivers Island

Pine Knoll Shores

**Sills**
- Increase sediment accretion rates
- Replace subtidal habitats

Design for site conditions

... use oysters instead?
Conclusions

Monitoring General Concepts

• Utilize Reference Sites and (stratified) Random Sampling protocols

• Use parameters that are inexpensively obtained, and reflect short-term and long-term trajectories.

• Incorporate Citizen Science into Monitoring Programs; Obtain long-term data

• Develop consistent approach for comparative analysis

Volunteer Monitoring Hours by Task

- Elevation
- Fyke Nets
- Mapping
- Sediment
- Vegetation
- Administrative

Currin et al. 2007 WEM
More Conclusions

Living shoreline Design & Implementation

- Minimize size of stone sill breakwaters to avoid ‘perched beach’, and erosion of adjacent shoreline. Match project design to site wave energy, sediment supply.

- Natural fringing marshes currently not keeping up with SLR, though no loss in vegetation ... yet.

Impact of stone sills on fringing salt marshes

- Sills increase sediment accretion, leading to an increase in Elevation Capital, but a loss in low marsh *Spartina alterniflora* habitat

- Accumulation of mineral sediment dominates surface elevation change

- Oyster reefs are viable alternative to stone sills in many NC settings