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Living Shorelines Achieve Functional Equivalence to Natural Fringe Marshes Across Multiple Ecological Metrics

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What was the NSF Coastal SEES project?

• 5-year effort to integrate the social and ecological systems of living shorelines.

• Ecological question: How do living shorelines compare to natural fringing marshes?
How did we define living shoreline?

- Marsh sills
  - Stone sill
- Clean sand backfill and grading
- Planted *Spartina alterniflora* in the low marsh and *S. patens* in the high marsh
What did we measure?

• Soils
  • Carbon
  • Nitrogen
  • Phosphorus
  • Organic Matter

• Plants
  • S. alterniflora Density

• Invertebrates
  • Ribbed Mussels
  • Oysters
  • Periwinkles
  • Burrowing Crabs

• Nekton
  • Fish Biomass
  • Crab Biomass
  • Shrimp Biomass
  • Fish Abundance
  • Juvenile Fish Abundance
  • Forage Fish Abundance
  • Fish Diversity

• Herons
  • Use

• Terrapin
  • Density
Where did we measure it?

- 13 Paired Living Shoreline and Natural Fringe Marshes
- Ages 2 – 16 (c. 2018)
- A variety of shorescape settings, from urban to rural
How did we analyze the data?

• We used a Z-score approach: \[
\frac{\bar{\mu}_{LSi} - \bar{\mu}_{NMi}}{\sigma_{LS, NM}^*}
\]

* The SD could either be local or regional

\[
\sigma_{Locali} = \sqrt{\frac{\sigma_{LSi}^2 + \sigma_{NMi}^2}{2}}
\]

\[
\sigma_{Regional} = \sqrt{\frac{\sigma_{LS}^2 + \sigma_{NM}^2}{2}}
\]
What did we find? - Soils

• Soils at our living shoreline sites are still not the same as those at natural marshes, even after 16 years.

  • Carbon: $Z = -2.61$; 0 – 63 years to equivalence

  • Nitrogen: $Z = -2.60$; 0 – 31 years to equivalence

  • Phosphorus: $Z = -1.76$; 0 – 23 years to equivalence

  • Organic Matter: $Z = -1.86$
What did we find? - Nekton

- There was no observable difference between LS and NM.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Z-score</th>
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<tbody>
<tr>
<td>Fish biomass</td>
<td>0.85</td>
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<tr>
<td>Crab biomass</td>
<td>0.46</td>
</tr>
<tr>
<td>Shrimp biomass</td>
<td>0.28</td>
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<tr>
<td>Fish Abundance</td>
<td>0.48</td>
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<tr>
<td>Juvenile Fish Abundance</td>
<td>0.09</td>
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<tr>
<td>Forage Fish Abundance</td>
<td>0.09</td>
</tr>
<tr>
<td>Fish Diversity</td>
<td>-0.12</td>
</tr>
</tbody>
</table>
What did we find? – Herons and Terrapin

- They use both types equally
  - Herons: 0.55
  - Terrapin: 0.27
What did we find? – Plants and Inverts

• Plants and Inverts were basically the same*
  • *Spartina*: $Z = -0.14$
  • Mussels: $Z = -0.80$
  • Oysters: $Z = 0.28$
  • Periwinkles: $Z = -0.12$
  • Burrows: $Z = 0.01$
Mussels in living shorelines

Atmospheric N, Runoff, Fertilizer

Phytoplankton

Nitrogen gas (N₂)

Filter feeding

Aerobic

Anaerobic

Organic nitrogen

Ammonium (NH₄⁺)

Nitrite (NO₂⁻)

Nitrate (NO₃⁻)

Ammonium (NH₄⁺)

Nitrate (NO₃⁻)

N₂O, N₂
What did we find? - Overall

• Overall, living shorelines were functionally equivalent to natural fringing marshes.
  • Overall Z-score: $-0.36 \pm 1.11$

• Neither all sites nor all metrics were equivalent at the pair-level
  • John’s Point vs. Tolar scored -1.86 overall
  • Martin’s vs. River Road scored 1.46 overall
  • The Wilson’s Creek pairs: Fish abundance: 1.94; Carbon: -1.96
What about age?

Bayesian p: 0.87
Age > 0
What does it mean?

• Can living shorelines provide the same levels of ecological function as natural marshes?
  • YES

• Will every living shoreline provide the same levels of function?
  • NO

• How long will it take a newly constructed living shoreline to reach functional equivalence?
  • It depends…
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