Integrated Assessment of Shoreline Protection Options

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• Worldwide, coastal communities face threats of shoreline change.
• A warming climate, rising sea levels have resulted in the permanent inundation of residences and businesses.

• Coastal communities must consider whether
  ➢ to stabilize the shoreline with gray or green methods, or
  ➢ to leave the shoreline alone, implying a more rapid retreat from the coast.
Green vs. Gray Options

Shoreline armoring can accelerate erosion and loss of beaches and tidal wetlands (Gittman et al. 2015).

Ecosystem Services

- Protection of coastlines from storm surges and waves
- Reduction of shoreline erosion
- Cycling of nutrients
- Carbon sequestration

- Water quality maintenance
- Nursery habitats
- Tourism and recreation
- Health benefits
- Symbolic of coastal heritage

https://www.delawarelivingshorelines.org/what-is-a-living-shoreline

Economic Analysis

Cost-Benefit Analysis of a coastal green infrastructure project: 
\[ B > C \text{ or } \frac{B}{C} > 1 \text{ ?} \]

- Effectiveness of storm resistance
- Changes in ecosystems
- Storm event probability
- Avoided damages
- Added ecosystem service values
- Benefits
- Costs

Graph showing benefits and costs for Wetlands and Oyster Reefs.
## Case Studies

### Benefit and Cost of Green Solution for Coastal Protection

<table>
<thead>
<tr>
<th>Location</th>
<th>Gray solution cost</th>
<th>Green solution cost</th>
<th>Difference</th>
<th>Ecosystem benefits</th>
<th>B-C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenway</td>
<td>5.42</td>
<td>7.14</td>
<td>1.72</td>
<td>4.85</td>
<td>2.82</td>
</tr>
<tr>
<td>Constitution Beach</td>
<td>7.81</td>
<td>12.92</td>
<td>5.11</td>
<td>5.91</td>
<td>1.16</td>
</tr>
<tr>
<td>Suffolk Downs</td>
<td>7.97</td>
<td>23.74</td>
<td>15.77</td>
<td>95.02</td>
<td>6.02</td>
</tr>
</tbody>
</table>

Costs and benefits are discounted sums over 25 years at 3% discount rate in 2017 $millions.

*Research in collaboration with UMass Boston and Woods Hole Group*

### Study Sites in East Boston

- A: Greenway
- B: Constitution Beach
- C: Suffolk Downs

Low to moderate energy environment is suitable for living shoreline.

https://coast.noaa.gov/digitalcoast/stories/casco.html
Summary: Green Infrastructure

- Green options are economically justifiable in many public projects
- Location: must consider living shoreline suitability (low to moderate energy environment)
- Hybrid system offers both ecological and economic benefits (moderately high energy environment).
- Must consider coastal population and assets (damage avoided)
- Cost-benefit results affected by the resilience of green options under sea level rise (oyster reefs grow with SLR)

- Private benefits associated with green options typically < public benefits

https://www.sacredheart.edu/academics/colleges--schools/college-of-arts--sciences/departments/biology/living-shorelines-in-connecticut/
Geoeconomic Analysis

Geological Model: Natural Physical Changes in Coastal Domain

Sea-Level Rise (exogenous)

Waves and Storms (exogenous)

Human-Induced Physical Changes to Coastal Domain

Human Behavior

Coordinated

Un-coordinated

Socio-Economic Optimization Model

Choices of managed beach widths under environmental uncertainty

Erosion

\[ \gamma = f(x) \]

\[ \Pi(y, s) = B(y) - C(s) \]

Value function

\[ V(y) = \max_s \ E_t \int_0^\infty \Pi(y, s)e^{-\delta(\tau-t)} \, d\tau \]

Dynamics of beach width

\[ dy = [s - f(x)] \, dt + \sigma y \, dz \]

\[ z(t) \text{ is a Wiener process} \]

\[ dz = \kappa_t \, \sqrt{dt} \]

The variance of the change in a Wiener process grows linearly with time (t)

www.nagsheadnc.gov
Choices of managed beach widths under environmental uncertainty

Risk aversion can affect a coastal property owner's choice of beach width in contradictory ways: the expected benefits of hazard protection must be balanced against the expected costs of repeated nourishment actions.
Can coastal communities continue to hold the line?

Engineered coastal berm-dune renourishment in New Jersey (Kolodin et al. 2021)

A geoeconomic model of the natural and anthropogenic processes that shape beach and dune morphology. The model results suggest:

- Coastal communities may exhibit significant differences in their capabilities to maintain engineered dunes depending on stakeholder wealth and risk perception.
- Communities with strong preferences for ocean views are less likely to maintain large-scale berm-dune structures over the long term.

Shoreline Change Response Strategies

*We should view sea-level rise adaptation from the context of sustainable hazard mitigation, to reduce the long-term risk to life and property from hazards.*

- In the near term (< 30 years): improve the resilience of coastal communities (gray and green coastal protection, disaster training and education).
- Over the long term: consider the overall effect of mitigation efforts on current and future generations. Managed retreat is likely to be the only course of action available in many places.

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