The Ecology, Engineering & Economics of Natural Coastal Defenses

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SANTA CRUZ

LLOYD'S
TERCENTENARY RESEARCH FOUNDATION

Swiss Re

GUY CARPENTER

The Nature Conservancy
Coastal Funding for Conservation & Infrastructure (10 Yrs)

$300
$198
$214
$4
$14

Dr. McCrless & Beck. In review. Rethinking our global coastal investment portfolio. *Journal of Ocean & Coastal Economics*
Chapters 4 & 5: Recommended Approach for Assessing Coastal Protection Value: Expected Damage Function

STAGE 1: Estimate Waves Offshore
STAGE 2: Estimate Waves Nearshore
STAGE 3: Estimate Effects of Habitats
STAGE 4: Estimate Flooding
STAGE 5: Assess Damages

10 yr with Habitat
10 yr w/out Habitat

Storm Freq.
Chapter 3: Reefs & Coastal Protection

Hurricane Wilma

Incident wave energy $\times 10^3$ (Jm$^{-2}$)

Wave energy dissipated $\times 10^3$ (Jm$^{-2}$)

Adapted from Ferrario, Beck et al. 2014. *Nature Communications*
Coastal Wetlands and Flood Damage Reduction: Using Risk Industry-based models to Assess Natural Defenses in the Northeast US

www.lloyds.com/coastalresilience
Scenario I: Present-day Wetlands

Wetlands with roughness coefficients of 0.04 - 0.1
Scenario II: Wetland Loss to Open Water

All wetlands as open water with roughness of 0.02
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Difference in Flood Damages Between Wetland Scenarios

- 625 Million US$
- 12 States

www.lloyds.com/coastalresilience
### Wetland Effects on Property Damage Reduction during Hurricane Sandy

#### Difference in Flood Damages Between Wetland Scenarios

<table>
<thead>
<tr>
<th>State</th>
<th>At Present ($)</th>
<th>With Wetland Loss ($)</th>
<th>Absolute Difference ($)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>2,181,600,000</td>
<td>2,181,000,000</td>
<td>400,000</td>
<td>0.02</td>
</tr>
<tr>
<td>Delaware</td>
<td>228,100,000</td>
<td>251,900,000</td>
<td>23,800,000</td>
<td>10.43</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1,452,300,000</td>
<td>1,458,600,000</td>
<td>6,300,000</td>
<td>0.43</td>
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<tr>
<td>Maryland</td>
<td>15,500,000</td>
<td>20,000,000</td>
<td>4,500,000</td>
<td>29.03</td>
</tr>
<tr>
<td>Maine</td>
<td>17,600,000</td>
<td>17,600,000</td>
<td>3,000*</td>
<td>0.02</td>
</tr>
<tr>
<td>North Carolina</td>
<td>9,500,000</td>
<td>8,800,000</td>
<td>-600,000</td>
<td>-6.47</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>29,600,000</td>
<td>30,500,000</td>
<td>900,000</td>
<td>3.04</td>
</tr>
<tr>
<td>New Jersey</td>
<td>14,014,600,000</td>
<td>14,443,300,000</td>
<td>428,700,000</td>
<td>3.06</td>
</tr>
<tr>
<td>New York</td>
<td>32,314,600,000</td>
<td>32,452,800,000</td>
<td>138,200,000</td>
<td>0.43</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>174,400,000</td>
<td>188,000,000</td>
<td>13,700,000</td>
<td>7.86</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>72,100,000</td>
<td>72,400,000</td>
<td>300,000</td>
<td>0.42</td>
</tr>
<tr>
<td>Virginia</td>
<td>195,400,000</td>
<td>205,300,000</td>
<td>9,900,000</td>
<td>5.07</td>
</tr>
</tbody>
</table>
Wetland Effects on Public Infrastructure
Surge Height Reduction by Wetlands on Highways and Major Roads

<table>
<thead>
<tr>
<th>State</th>
<th>Length of Roads Protected (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>30.26</td>
</tr>
<tr>
<td>Delaware</td>
<td>502.60</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>94.63</td>
</tr>
<tr>
<td>Maryland</td>
<td>435.81</td>
</tr>
<tr>
<td>Maine</td>
<td>0.80</td>
</tr>
<tr>
<td>North Carolina</td>
<td>28.49</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>40.07</td>
</tr>
<tr>
<td>New Jersey</td>
<td>333.13</td>
</tr>
<tr>
<td>New York</td>
<td>300.63</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>41.68</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>17.06</td>
</tr>
<tr>
<td>Virginia</td>
<td>403.95</td>
</tr>
<tr>
<td>Total</td>
<td>2,228.94</td>
</tr>
</tbody>
</table>
Key Findings

Flood Reduction Benefits from Wetlands

1. Catastrophic Events:
   - >625 Million US$ during Hurricane Sandy
   - >10% on average where wetlands remain

2. Annual Flooding Losses:
   - Properties with marshes save >20%
   - Benefits most significant in low elevation, high-risk areas

3. Wetland Conservation and Restoration:
   - Can reduce risk from extreme event flooding
   - Can provide benefits to communities upstream
Partnership with Swiss Re

Where are nature-based defenses cost effective?

Aims

- Work with worlds 2\textsuperscript{nd} largest re-insurer
- Public cost effectiveness model that includes nature
- Add ecosystem (co)benefits

The regional domain: The Gulf Coast of US

>3,200 Nodes (Zipcodes) to register Hazards and Damages
Effects of Economic Growth & Climate Change on Losses

Expected Loss (bill.$)

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Present Climate

Added Risk - Future Economic Growth

Added Risk - Climate Change

Return Period (yr)
## Risk Reduction Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetland Restoration</td>
<td>6 Counties with the highest losses in assets where at least 25 miles of salt marsh could be restored by bay.</td>
</tr>
<tr>
<td>Wetland Conservation</td>
<td>125 miles of wetlands protected</td>
</tr>
<tr>
<td>Local Levees Priority</td>
<td>6 ft “hills” built to protect 532,000 existing houses on the 6 counties that experience most damages</td>
</tr>
<tr>
<td>Sandbags</td>
<td>Used in 2.9 million houses for all Cat 3 hurricanes across all counties in the study area.</td>
</tr>
<tr>
<td>Local Floodwalls</td>
<td>Concrete blocks (4 ft) built to protect 1.9 million houses across all counties</td>
</tr>
<tr>
<td>Levees</td>
<td>20 ft levees constructed around Houma &amp; New Orleans, LA - 340 miles.</td>
</tr>
<tr>
<td>Barrier Island Restoration</td>
<td>All Mississippi coastal counties</td>
</tr>
<tr>
<td>Oyster Reef Restoration</td>
<td>1000 miles restored in all counties with high suitability</td>
</tr>
<tr>
<td>Beach Nourishment</td>
<td>All Coastal Counties in Texas.</td>
</tr>
<tr>
<td>Home Elevation</td>
<td>Elevate 481,841 existing houses by 8ft in 6 counties that experience the most damages</td>
</tr>
</tbody>
</table>
Benefit: Cost Analysis – Measures for Climate Adaptation

Averted Damages over 20 years ($ Billions)

Benefit/Cost

Sandbag
Oyster restoration
Floodwall
Marsh – Risk Red.
Marsh Conservation
Local Levees

COASTAL RESILIENCE

GULF OF MEXICO

Set Model Parameters

Model Form: Best
Economy: High
Defense: None
Reference Year: 2030

Barrier Island Restoration
Oyster Reef Restoration
Wetland Restoration
Beach Nourishment
Home Elevation
Sandbag
Levee

Benefit:Cost Line

Averted Damages ($Billion*10)

Percentage of Damages Averted
Oyster Reefs, 2050 Estimated Averted Damages

15.5% - 18.9%
13.1% - 15.4%
10.5% - 13.0%
8.9% - 10.4%
5.6% - 8.8%

www.maps.coastalresilience.org/Gulfmex
GIS Layers for Roads and Infrastructure – Road line classes broken down into 5-m segments
GIS Layers for Roads and Infrastructure – Road line classes broken down into 5-m segments
Hi Resolution Valuation of Coral Reef Protection Across the USA

TNC  UCSC  USGS
Summary

- Coastal Habitats - a First Line of Defense
- We can Account for Natural Defenses
- They are Cost Effective
- Decision support tools can inform their use
Thanks