The Ecology, Economics and Engineering of Natural Coastal Defenses
Michael W. Beck, Borja Reguero, Siddharth Narayan
Iñigo Losada, Pelayo Menéndez
Coastal Funding for Conservation & Infrastructure (10 Yrs)

- International aid
- US
- Building infrastructure
- Relief & reconstruction
- Insured
- Total

*Journal of Ocean & Coastal Economics*
Recommended Approach: 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:**
- Storm Freq.
- Assess Damages

- 10 yr with Habitat
- 10 yr w/out Habitat

**Guidelines for Valuing Coastal Protection Services from Mangroves and Reefs**

M W. Beck & G-M Lange (eds)
Role of Mangroves and Reefs

nature.org/GlobalMangrovesRiskReductionTechnicalReport
nature.org/GlobalMangrovesRiskReductionSummaryReport
Step 3: Effects of Habitat
What happens when waves/surge encounter a mangrove?

https://www.youtube.com/watch?v=29tLtykLkTM&feature=youtu.be
Estimating Flooding Globally

With Mangrove

Without Mangrove

50-year flood

Flood Height (m)

3

0

Mangrove
Annual Expected Benefit from Mangroves

(Regular Climate)

People Flooded (Millions)

Return Period (years)

- Pink line: Without Mangroves
- Green line: With Mangroves
Global Annual Expected Benefits from Mangroves

People Flooded (Millions)

Property Damaged ($ Billions)

- With mangroves
- Without mangroves

With mangroves:
- 39%

Without mangroves:
- 16%
Annual Flood Reduction Benefits from Mangroves
### Countries Where Mangroves Provide Greatest Annual Flood Reduction Benefits

<table>
<thead>
<tr>
<th>People Protected (millions)</th>
<th>Property Protected (US $ Billions)</th>
<th>Property Protected per GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam</td>
<td>8.1</td>
<td>China</td>
</tr>
<tr>
<td>India</td>
<td>3.3</td>
<td>United States</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1.3</td>
<td>India</td>
</tr>
<tr>
<td>China</td>
<td>0.8</td>
<td>Mexico</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.7</td>
<td>Vietnam</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.4</td>
<td>Guyana</td>
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<tr>
<td>Nigeria</td>
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<td>Mozambique</td>
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<tr>
<td>Indonesia</td>
<td>0.3</td>
<td>Saudi Arabia</td>
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<tr>
<td>Mozambique</td>
<td>0.3</td>
<td>Bangladesh</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.3</td>
<td>Bahamas</td>
</tr>
</tbody>
</table>

- Vietnam: 8.1 million people, 19 US $ billions of property protected, per GDP of Guyana.
- India: 3.3 million people, 13 US $ billions of property protected, per GDP of Belize.
- Bangladesh: 1.3 million people, 9 US $ billions of property protected, per GDP of Bahamas.
- China: 0.8 million people, 9 US $ billions of property protected, per GDP of Suriname.
- Philippines: 0.7 million people, 7 US $ billions of property protected, per GDP of Mozambique.
- Brazil: 0.4 million people, 7 US $ billions of property protected, per GDP of Vietnam.
- Nigeria: 0.4 million people, 2 US $ billions of property protected, per GDP of Guinea-Bissau.
- Indonesia: 0.3 million people, 2 US $ billions of property protected, per GDP of Madagascar.
- Mozambique: 0.3 million people, 2 US $ billions of property protected, per GDP of Benin.
- Mexico: 0.3 million people, 2 US $ billions of property protected, per GDP of Sierra Leone.
Greatest Mangrove Benefits
Reduced Flood Exposure & Vulnerability (WorldRiskIndex)
Greatest Mangrove Benefits
Reduced Flood Exposure & Vulnerability (WorldRiskIndex)
Annual Expected Benefits from Coral Reefs

Avoided Flood Damage, $US millions/20 km

Benefits of Coral Reefs for Risk Reduction (1in100yr flood)
Annual Expected Benefits from Coral Reefs

Avoided Flood Damage, $US millions/20 km

The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA

A modelling study in partnership with the risk insurance sector

Siddharth Narayan (UCSC), Michael W. Beck (TNC/UCSC), Paul Wilson (RMS), Christopher J. Thomas (RMS), Alexandra Guerrero (RMS), Christine C. Shepard (TNC), Borja G. Reguero (UCSC/TNC), Guillermo Franco (GC), Jane Carter Ingram (WCS) & Dania Trespalacios (TNC)
Study Questions and Methodology

• Can coastal wetlands *reduce flooding* during extreme events?

• When and where do these *reductions translate to savings* in property damages?

• Can we use these *savings to incentivize conservation* for risk reduction, and how?

Beck & Lange, 2016.
Study: Wetlands as Natural Defenses During Hurricane Sandy

Hurricane Sandy:
• Made US landfall in New Jersey on October 29th 2012
• Widespread losses in Jamaica, Haiti, Dominican Republic and Puerto Rico
• In US, storm surge affected 12 coastal states, caused $50 B in damages

Narayan et al., 2016. Scientific Reports 7, 9463
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Scenario I: Flood Damages with Present-day Wetlands
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Scenario II: Flood Damages with Wetland Loss
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Flood Model Example for Delaware Bay
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Difference in Flood Damages Between Wetland Scenarios

- 625 Million US$
- 12 States
Study: Effect of Salt Marsh Presence on Annual Flood Losses in Ocean County

Annual flood losses in Barnegat Bay, NJ

Locations behind marsh versus locations with no marsh

~2000 storm events
Effect of Salt Marshes on Annual Flood Damages

Locations With Marsh see lower annual flood losses by >15%
Financing Natural Infrastructure
For Coastal Flood Damage Reduction

• Increase conservation action in post-disaster recovery funding
• Shift to pre-disaster preparedness
• Use mix of private and public funding
• Have ‘shovel ready’ projects

www.lloyds.com/coastalresilience
Resilient Communities and Healthy Ecosystems

• We know what we gain from our coastal marshes and how to measure these values

• We know what these marshes need to remain healthy

• We can act now to achieve these goals
Hurricane Flood Losses With & Without Mangroves
Economics of Climate Adaptation

Aims

• Work with world's 2\textsuperscript{nd} largest re-insurer
• Public cost effectiveness model that includes nature
• Identify where nature-based defenses are cost effective
Risk in 2030
High Economic Growth (3%)

Scenario: High - Economy

Damages ($ Billions)

- 2010: 170
- Growth: 130 (+75%)
- Clim Change: 70 (+43%)
- 2030: 370 (+119%)
Economics of Coastal Adaptation

Benefit to Cost ratio

Averted Damages ($ Billions)

Implications and Opportunities

• Include Nature in Industry Risk Models

• **Private incentives**- Insurance, Resilience Bonds

• **Public incentives**- Pre- and Post- disaster spending (special purpose tax districts, FOPREDEN)

• **Prioritizing Natural Infrastructure in Policy** (Philippines Greening Program, US ACoE)
SUMMARY

• Wetlands reduce flood risks

• We can rigorously values these benefits to:
  o Inform adaptation & development planning
  o Support Natural Infrastructure Projects
Thanks to the Funders
Questions?

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