THE ROLE OF NATURE:
UNDERSTANDING HOW NATURAL FEATURES CONTRIBUTE TO COASTAL RISK REDUCTION

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• Our mission supports the practical, relevant and timely application of state-of-the-art science and engineering, providing solutions that benefit society.
**PROGRESS?**

**GENERAL COASTAL RISK REDUCTION PERFORMANCE FACTORS:**
STORM INTENSITY, TRACK, AND FORWARD SPEED, SURROUNDING LOCAL BATHYMETRY AND TOPOGRAPHY

<table>
<thead>
<tr>
<th>Dunes and Beaches</th>
<th>Vegetated Features</th>
<th>Oyster and Coral Reefs</th>
<th>Barrier Islands</th>
<th>Maritime Forests/Shrub Communities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits/Processes</strong></td>
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<td>Wave attenuation and/or dissipation</td>
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<td>Attenuation of wave energy</td>
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<td>Sediment stabilization</td>
<td>Shoresline erosion stabilization</td>
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<td>Slow inland water transfer</td>
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<td>Soil retention</td>
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<td>Increased infiltration</td>
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<td>Beach height and width</td>
<td>Marsh, wetland, or SAV elevation and continuity</td>
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<td>Beach slope</td>
<td>Vegetation type and density</td>
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<td>Sediment grain size and supply</td>
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<td>Dune height, crest, and width</td>
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<td>Presence of vegetation</td>
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Understanding How Natural Features Contribute to Coastal Risk Reduction
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NRC, 2014
Much is known about the capacity of nature-based features to reduce coastal erosion from smaller storms, but additional research is needed to better understand and quantify the effects of natural features (other than beaches and dunes) on storm surge, wave energy, and floodwater inundation. In general, the level of risk reduction provided by oyster reefs and seagrasses appears much lower than that provided by constructed dunes and hard structures, and most of the benefits are associated with reductions in wave energy during low- to moderate energy events. Research has documented reductions in peak water levels from salt marshes and mangroves, but certain storm conditions and large expanses of habitat are needed for these to be most effective.

NRC, 2014
Reducing Erosion by Waves

Geomorphology

Low High Resistance to change

Energy Regime

Low High

Resistance to change

Seawalls/ revetments
Coral Reefs
Barrier islands
Beaches
Groins
Breakwaters
Oyster Reefs
Seagrass
Salt marshes
Freshwater wetlands

‘Resilience’ Conceptualization

Understanding How Natural Features Contribute to Coastal Risk Reduction
WHAT DO WE KNOW?

Reviewed ~80 separate studies
  – Field, lab, modeling
  – Waves, surge

Across coastal environments:
• Barrier island
• Coastal Forests
• Coral reefs
• Marshes

• Oyster reefs
• SAV
• Sand dunes
INCREASING UNDERSTANDING?

Understanding How Natural Features Contribute to Coastal Risk Reduction
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SITE/SPECIES SPECIFIC RESPONSE

Average Wave Reduction in % per meter (Low energy environment)

- Thalassia testudinum
- Kandelia candel, Sonneratia sp.,...
- Salicornia spp
- Spartina anglica, Salicornia spp.
- Spartina anglica, Salicornia spp.
- Atriplex portulacoides, Salicornia...
- Atriplex portulacoides, Spartina...
- Puccinellia maritima, Salicornia...
- Aster, Suaeda, Puccinellia,...
- Aster, Suaeda, Puccinellia,...
- Limonium vulgare, Aster Tripolium,...
- Spartina alterniflora
- Thalassia testudinum
- Spartina alterniflora

Data from Anderson et al. 2011
Understanding How Natural Features Contribute to Coastal Risk Reduction

**Mangroves**

Different Species

- **With mangroves**
  - Brinkman, 1997

- **Without mangroves**
  - Mazda et al., 2006

**Quartel et al., 2007**

- **With mangroves**
- **Without mangroves**

**Increasing age of trees**

- **With mangroves**
- **Without mangroves**
Mangroves

Cyclone waves
Varying factors for roots, stems and canopies

Suzuki et al., 2012
Fig. 6. Percent change in (A) inundation distance, (B) maximum velocity at the shoreline, and (C) maximum wave height at the shoreline relative to no reef as a function of reef width. The three curves are for a tsunami arriving at low tide (0.5 m below msl; green curve), mid tide (msl; red curve), and high tide (0.5 m above msl; black curve).

Fig. 7. Percent change in (A) inundation distance, (B) maximum velocity at the shoreline, and (C) maximum wave height at the shoreline relative to no reef as a function of reef width. The three curves are for a tsunami traveling over a reef with low roughness ($n = 0.02$; green curve), medium roughness ($n = 0.05$; red curve), and high roughness ($n = 0.0962$; black curve).
When do the events occur?

When does the ecosystem act to reduce the effect?

Koch et al., 2009
Wave attenuation over coastal salt marshes under storm surge conditions

Iris Möller, Matthias Kudella, Franziska Rupprecht, Tom Spencer, Maike Paul, Bregie K. van Wesenbeeck, Guido Wolters, Kai Jensen, Tjeerd J. Bouma, Martin Miranda-Lange and Stefan Schimmels

Figure 1 | Experimental set-up and photographs of excavation. a. General experimental set-up in the wave flume, with position of recording equipment relevant to reported results. b. Excavation of marsh blocks, northern German Wadden Sea (53° 42.754' N, 7° 52.963' E). c. Marsh blocks with Elymus vegetation cover before positioning in the flume test section. d. Reassembled salt marsh inside the 5-m-wide flume, looking towards the wave generator; lamps are mounted at about 3 m above the soil surface.
• Reduction in dissipation for regular waves exceeding 0.3m in height - a change in behavior of the marsh vegetation.
• Under low incident waves (H < 0.3 m; T < 3.6 s), the plants swayed and interacted with wave motion throughout the wave
• For larger waves (stronger currents stems bent over to angles >50 during the forward wave motion
• Allows the flow for part of the wave cycle to skim over, rather than travel through the vegetation, thus retaining energy and reducing dissipation
Wave attenuation in mangroves: A quantitative approach to field observations

E.M. Horstman a,b,c,1, C.M. Dohmen-Janssen a,1, P.M.F. Narra c,2, N.J.F. van den Berg b,d,3,4, M. Siemerink b,d,5,6, S.J.M.H. Huyscher a,1

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d Water Engineering and Management, University of Twente, The Netherlands

Fig. 4. Variation of the vegetation cover with elevation above the forest floor. (A) Horizontal vegetation coverage [%] significantly reduces with increasing elevation above the forest floor. (B) Characteristic vegetation in the Avicennia-Sesuvium zone (TKII). (C) Characteristic vegetation in the Rhizophora zone (TKIIP). The marks on the bamboo in (B) and (C) are 0.50 m apart and stand at 0.50 m above the bed.
VEGETATION CHARACTER

Understanding how natural features contribute to Coastal Risk Reduction

WAVE ATTENUATION

KANTANG

A

B

C

wave attenuation $\Delta H/\Delta x \times 10^{-3}$

wave height [m]

mudflat zone
fit: $d(\Delta H/\Delta x)/dH = 2.01e-03$

Avicennia zone
fit: $d(\Delta H/\Delta x)/dH = 2.36e-03$

Rhizophora zone
fit: $d(\Delta H/\Delta x)/dH = 6.09e-03$

PALIAN

D

E

F

wave attenuation $\Delta H/\Delta x \times 10^{-3}$

wave height [m]

mudflat zone
fit: $d(\Delta H/\Delta x)/dH = 1.92e-03$

Avicennia zone
fit: $d(\Delta H/\Delta x)/dH = 3.24e-03$

Rhizophora zone
fit: $d(\Delta H/\Delta x)/dH = 1.20e-02$
SUMMARY THOUGHTS

• Laboratory studies enable control of waves and detailed measurements
• Limitations on scale
• Marsh vegetation vs. marshes
SUMMARY THOUGHTS

• Scaling up
  – Lab to field
  – Plants to landscapes
  – Point measurements to landscape dynamics
  – Theory to practice
Role of coastal marshes in response to increases in relative sea level.

(A) Contemporary natural shoreline.
(B) Natural shoreline w/SLR.
(C) “Holding the line”
(D) Hybrid interventions where space is allowed for the maintenance of natural coastal defenses

Spalding et al., 2013
TAKE HOME

• The effects are real
  – There is a contribution from nature
• The effects are site/event specific
  – Beware ‘benefits transfer’
• Ecosystem benefits
  – Risk reduction is one of many
  – ‘Lagniappe’…..
• Erosion and flooding are part of nature
  – Our buildings and businesses are not
THANK YOU

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