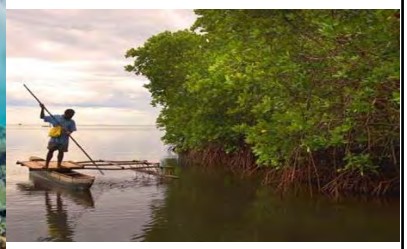
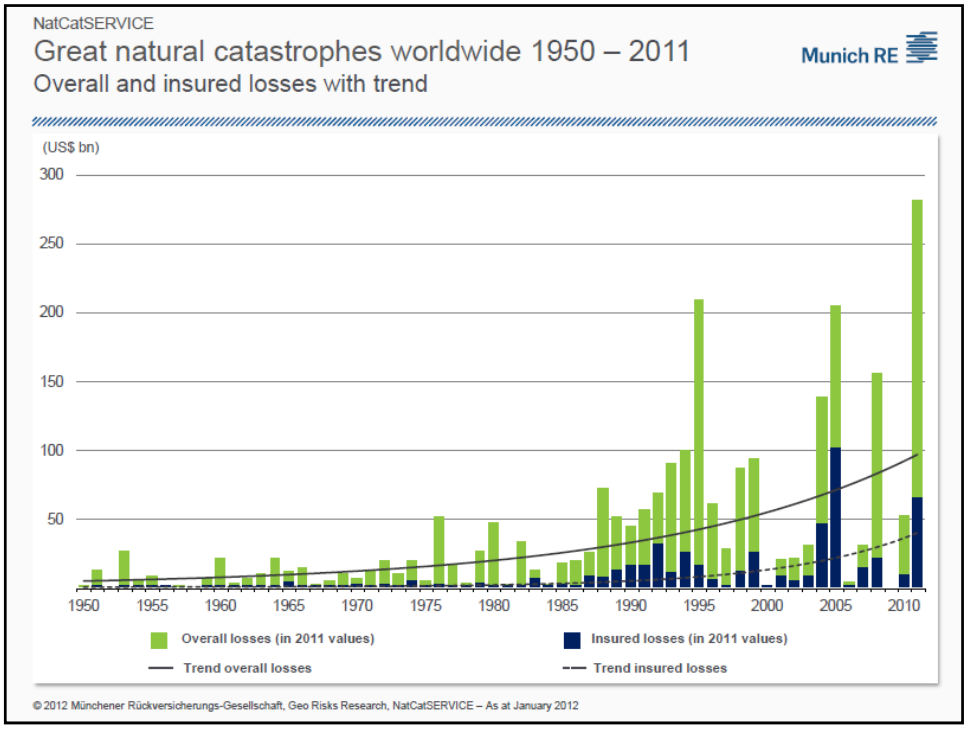
The Ecology, Engineering & Economics of Natural Coastal Defenses

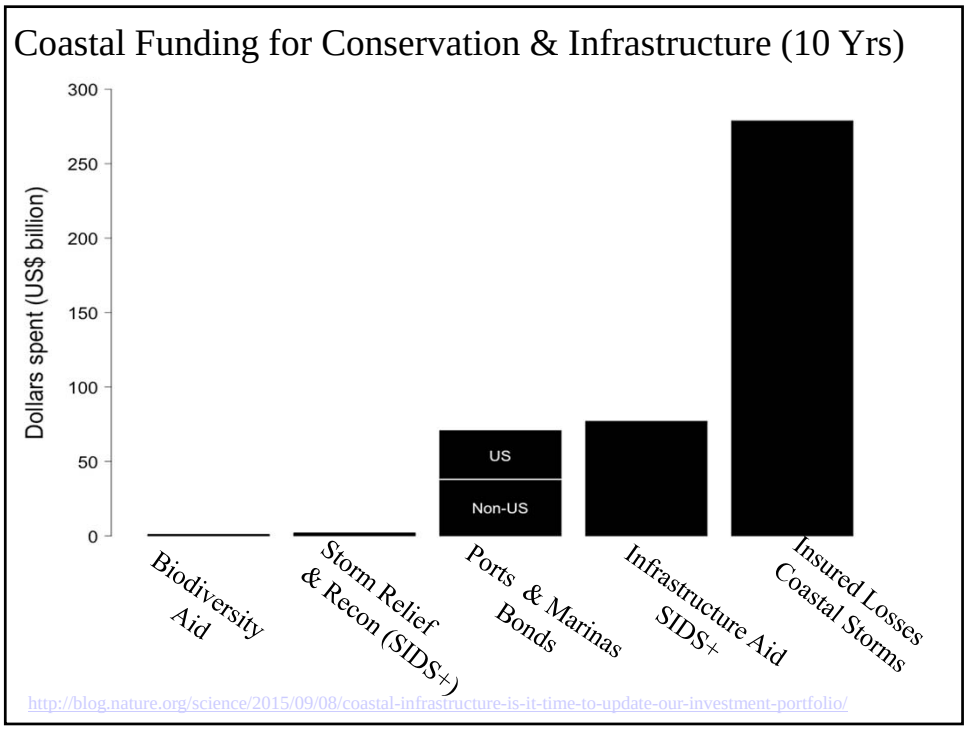


Michael W. Beck &
Borja Reguero
Sid Narayan

IH cantabria INSTITUTO DE HIDRÁULICA AMBIENTAL
Swiss Re
THE WORLD BANK
UNIVERSITY OF CALIFORNIA SANTA CRUZ
SNAP
WAVES
The Nature Conservancy Protecting nature. Preserving life.

Why Coastal Protection Services? Coastal Hazards Are Real & Rising


NatCatSERVICE
Great natural catastrophes worldwide 1950 – 2011
Overall and insured losses with trend
Munich RE
(US$ bn)
300
250
200
150
100
50
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Overall losses (in 2011 values)
Insured losses (in 2011 values)
Trend overall losses
Trend insured losses
© 2012 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE – As at January 2012


Coastal Funding for Conservation & Infrastructure (10 Yrs)
Dollars spent (US$ billion)
300
250
200
150
100
50
0
US
Non-US
Biodiversity Aid
Storm Relief & Recon (SIDS+)
Ports & Marinas Bonds
Infrastructure Aid SIDS+
Insured Losses Coastal Storms
http://blog.nature.org/science/2015/09/08/coastal-infrastructure-is-it-time-to-update-our-investment-portfolio/

Climate Risk & Resilience Goal

Mainstream Natural Infrastructure to Reduce Risk from Flooding, Storms, & Sea Level Rise

By 2020, change 10% of coastal infrastructure spending to reduce risks and increase habitat restoration & conservation.

The Nature Conservancy — Protecting nature. Preserving life.

United Nations University — UNU-EHS — Institute for Environment and Human Security

DIGITAL COAST

USGS — science for a changing world

Alliance Development Works

natural capital PROJECT

The University of Southern Mississippi

isr

esri

Zach Ferdaña
Lead Coastal Resilience Manager
The Nature Conservancy

Laura Flessner
Spatial Analyst
The Nature Conservancy

Coastal Resilience

Approach

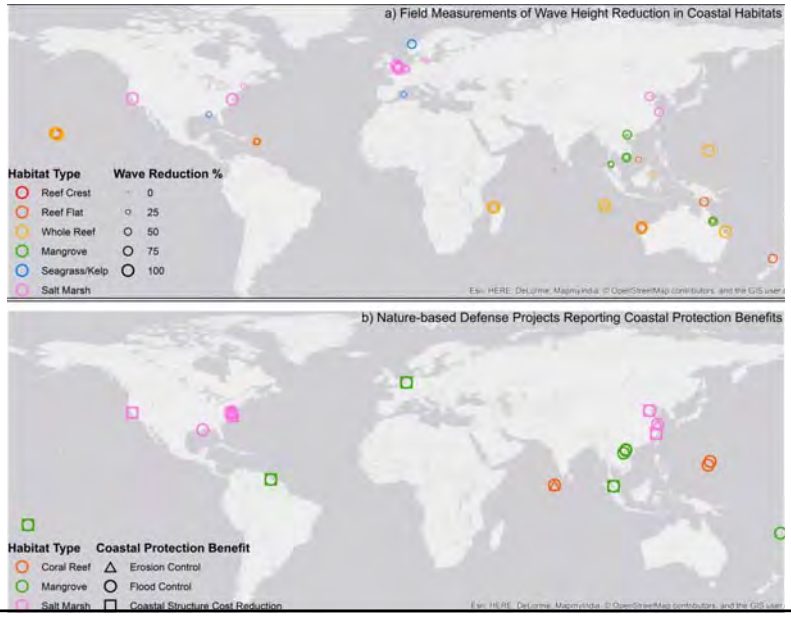
SNAP Coastal Defenses

Leading ecologists, economists, engineers & policy wonks

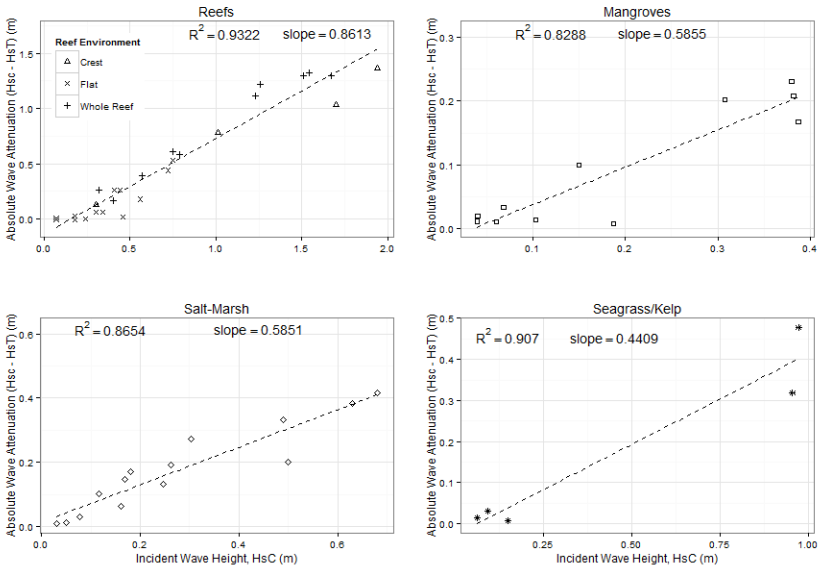
- Identify where natural defenses are cost-effective;
- Develop practical guidance for decision-makers
- Identify incentives for reducing risks to people and nature

The Nature Conservancy · Wildlife Conservation Society · NCEAS National Center for Ecological Analysis and Synthesis · University of California Santa Cruz · The World Bank · Deltares Enabling Delta Life · IH cantabria · United Nations University UNU-EHS Institute for Environment and Human Security · UC Davis University of California · US Army Corps of Engineers · The Rockefeller Foundation · CH2MHILL · Guy Carpenter · EKO Asset Management Partners

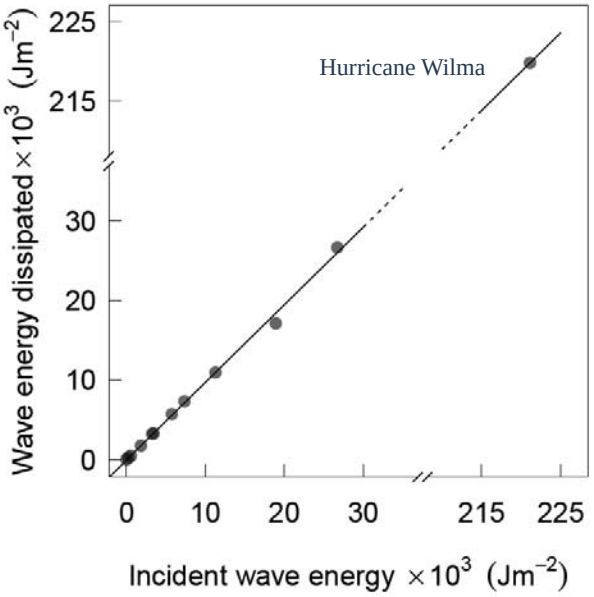
Global review of coastal protection by habitats



Total wave attenuation versus incoming wave heights – all habitats



Chapter 3: Reefs &Coastal Protection

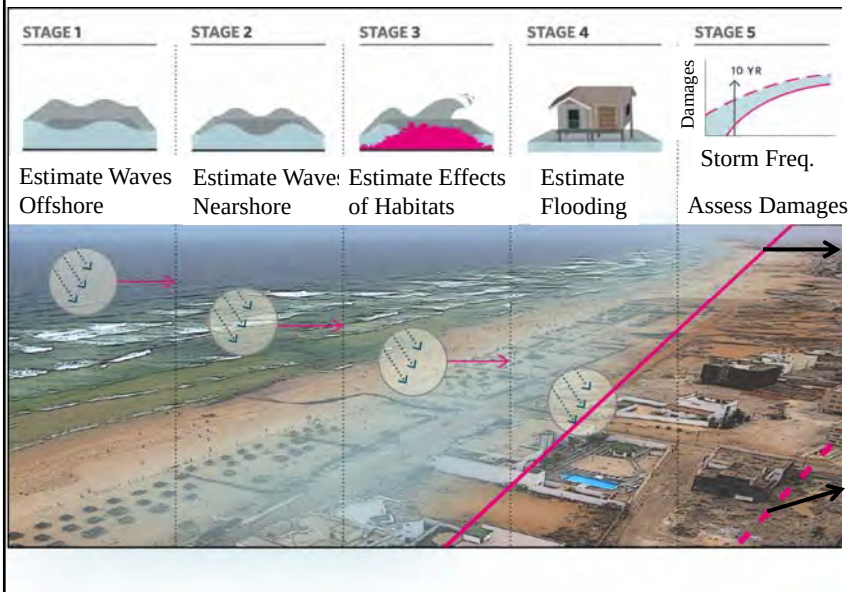


Adapted from Ferrario, Beck et al. 2014. *Nature Communications*

Table 6: Use of Protection from Reefs & Mangroves in Policy & Practice

Location	Decision Target(s)	Type of Information	Key Factors & Lessons Learned
Philippines	Senate Bill 2179, Coastal Greenbelt Act of 2014	• Literature-based Values	• Act under consideration for protection of mangroves for conservation & risk reduction. • Senator Aquino's introduction letter includes values of mangroves for reductions in waves and storm surge. • Act includes long-term program for community-based restoration.
Belize	Belize CZM Plan	• Scenario Analysis	• The CZMAI tasked with developing a CZM plan. Assessed alternatives with InVEST. • Scenario analysis helped identify likely trade-offs. • Difficult to get stakeholder input on alternative scenarios

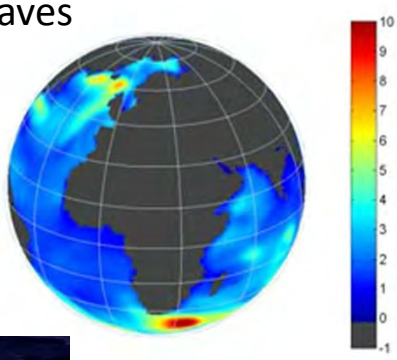
Chapters 4 & 5: Recommended Approach for Assessing Coastal Protection Value: Expected Damage Function



The Global Built Capital and Population Flooded by Coral Reef Loss

Reefs

Waves



Assets

Reguero et al., 2012; 2013.

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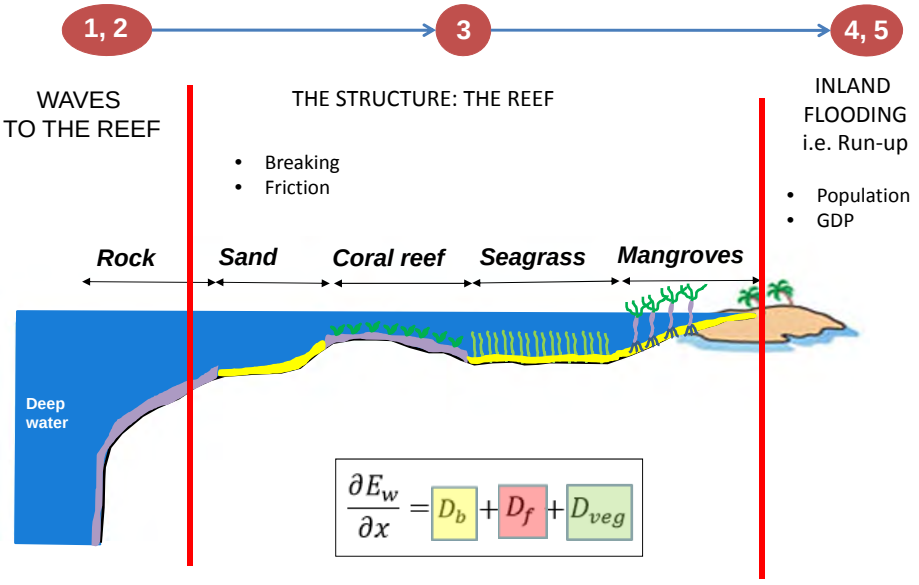
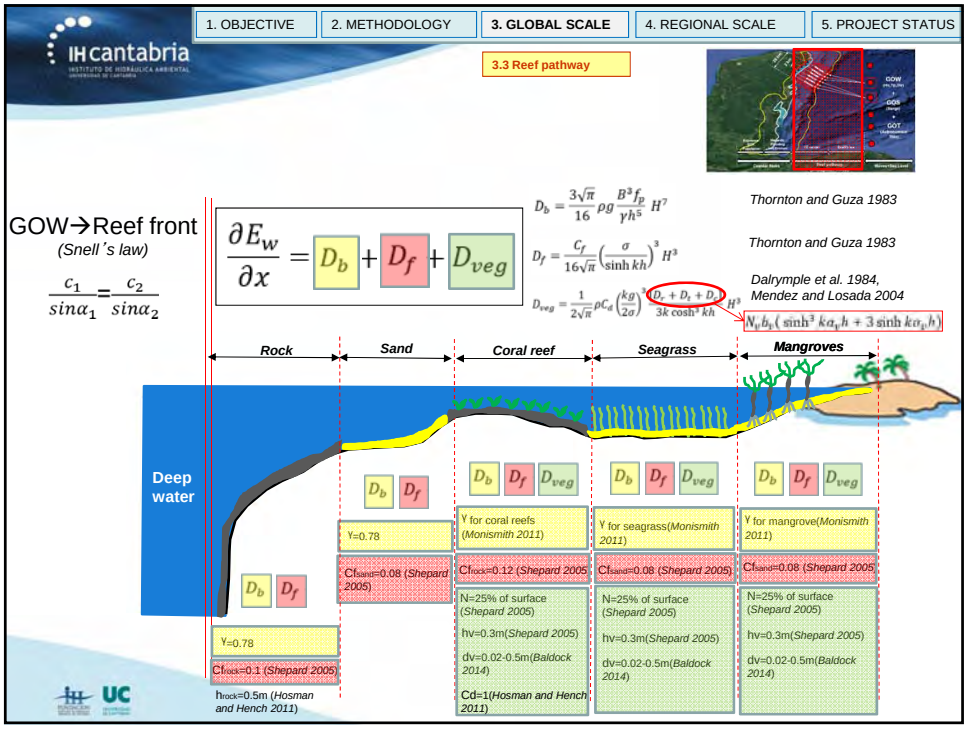
Framework for Estimating Coastal Protection Values

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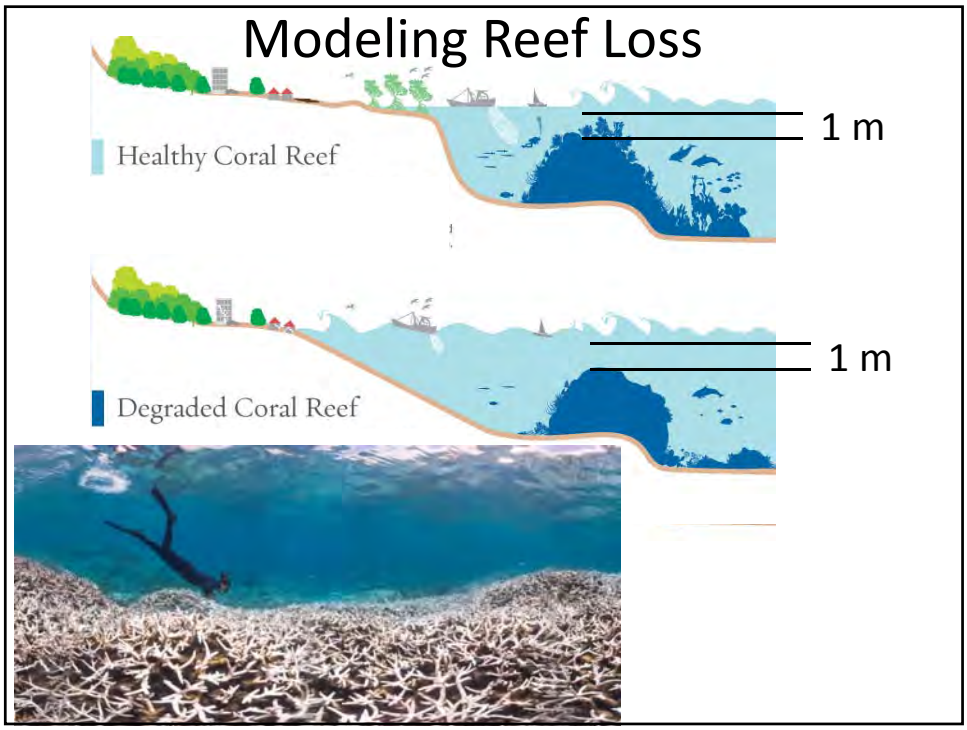
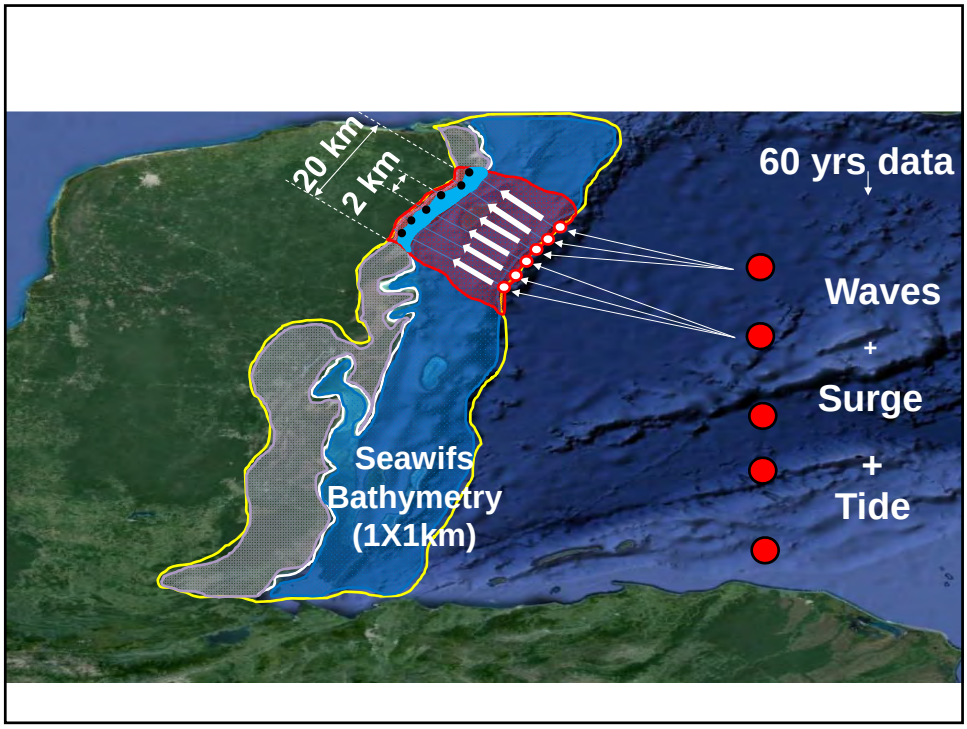
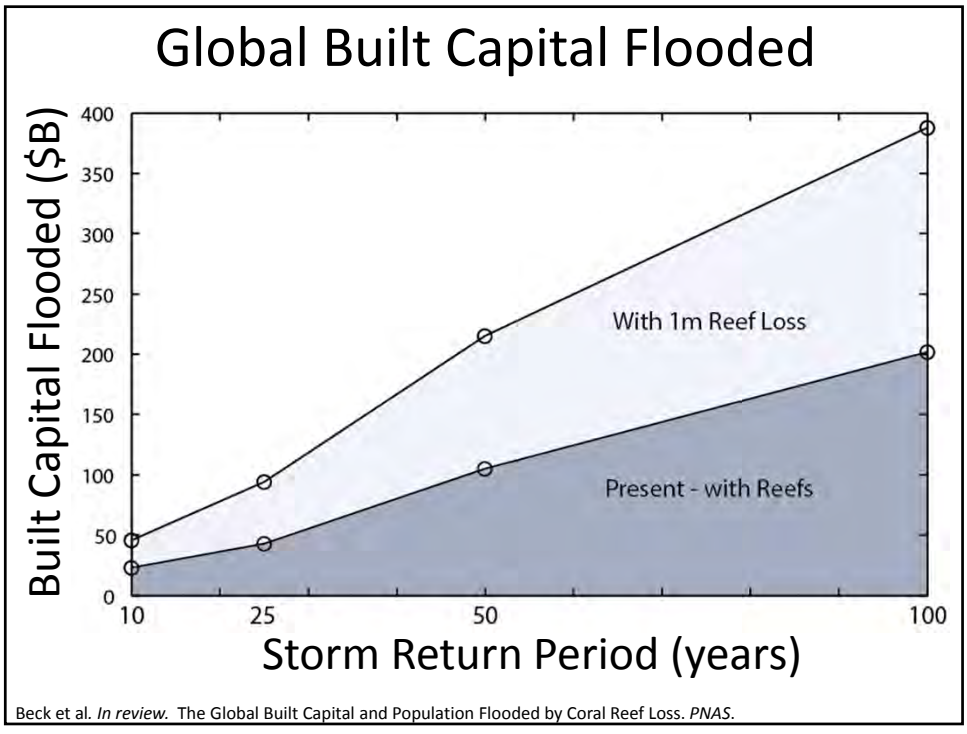
1. OBJECTIVE
2. METHODOLOGY
3. GLOBAL SCALE
4. REGIONAL SCALE
5. PROJECT STATUS
3.3 Reef pathway
GOW→Reef front
(Snell´s law)
$\frac{c_1}{sin\alpha_1} = \frac{c_2}{sin\alpha_2}$
$\frac{\partial E_w}{\partial x} = D_b + D_f + D_{veg}$
$D_b = \frac{3\sqrt{\pi}}{16}\rho g \frac{B^3 f_p}{\gamma h^5} H^7$
Thornton and Guza 1983
$D_f = \frac{C_f}{16\sqrt{\pi}}\left(\frac{\sigma}{\sinh kh}\right)^3 H^3$
Thornton and Guza 1983
$D_{veg} = \frac{1}{2\sqrt{\pi}}\rho C_d \left(\frac{kg}{2\sigma}\right)^3 \frac{D_x + D_z + D_y}{3k\cosh^3 kh} H^3$
$N_v b_v (\sinh^3 k\alpha_v h + 3\sinh k\alpha_v h)$
Dalrymple et al. 1984, Mendez and Losada 2004
Rock
Sand
Coral reef
Seagrass
Mangroves
Deep water
Y=0.78
Cf_rock=0.1 (Shepard 2005)
h_rock=0.5m (Hosman and Hench 2011)
Cf_sand=0.08 (Shepard 2005)
Y for coral reefs (Monismith 2011)
Cf_rock=0.12 (Shepard 2005)
N=25% of surface (Shepard 2005)
hv=0.3m(Shepard 2005)
dv=0.02-0.5m(Baldock 2014)
Cd=1(Hosman and Hench 2011)
Y for seagrass(Monismith 2011)
Cf_sand=0.08 (Shepard 2005)
Y for mangrove(Monismith 2011)
UC

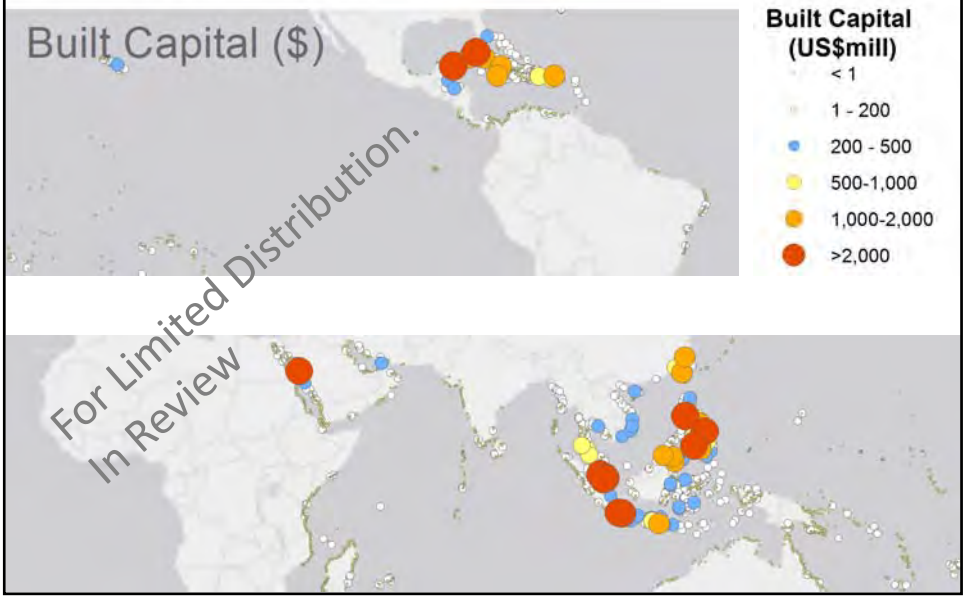

Modeling Reef Loss
Healthy Coral Reef
1 m
Degraded Coral Reef
1 m





Beck et al. *In review.* The Global Built Capital and Population Flooded by Coral Reef Loss. *PNAS*.

Built Capital Flooded with Reef Loss in a 100-year event



Built Capital Flooded with Reef Loss in a 100-yr event

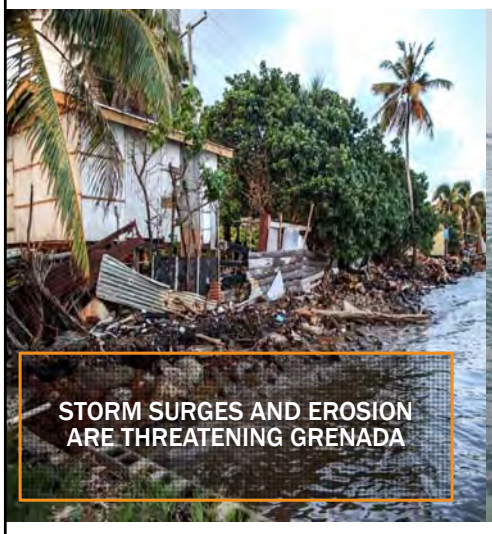
(Billions)

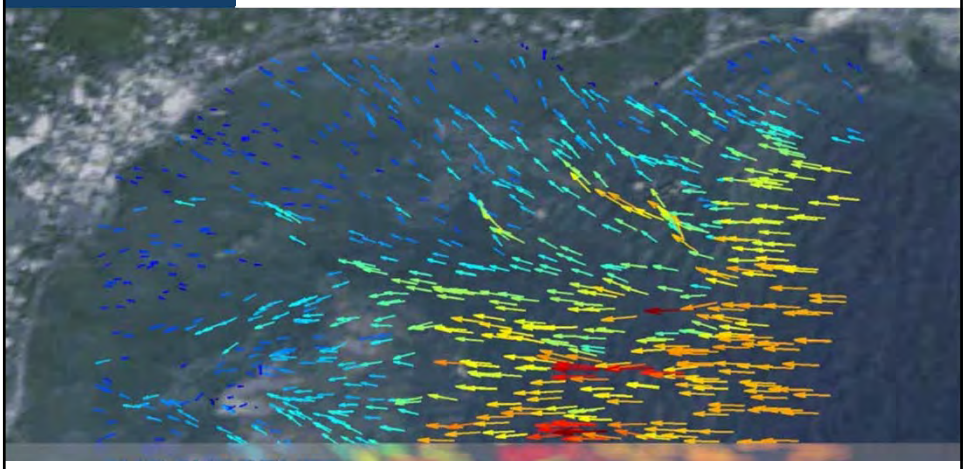
1	Indonesia	36.5
2	Philippines	31.1
3	Malaysia	27.1
4	China	26.8
5	Mexico	18.9
6	Cuba	9.2
7	UAE	7.8
8	Saudi Arabia	7.3
9	**USA**	**6.5**
10	Thailand	2.9
11	Vietnam	2.3
12	Jamaica	2.0
13	Taiwan	1.8
14	Dom. Republic	1.8

Annual Expected Benefit ($) from Coral Reefs In Avoided Flood Damages to Infrastructure

		Millions
1	Indonesia	639
2	Philippines	590
3	Malaysia	452
4	Mexico	452
5	Cuba	401
6	Saudi Arabia	138
7	Dom Rep	96
8	Puerto Rico	77
9	Taiwan	61
10	Jamaica	46
11	Vietnam	42
12	Myanmar	33
13	Thailand	33
14	United States	17

Global to Local Connection
PILOT PROJECT: GRENVILLE BAY, GRENADA





Wave Height

UNIVERSITY OF CALIFORNIA SANTA CRUZ

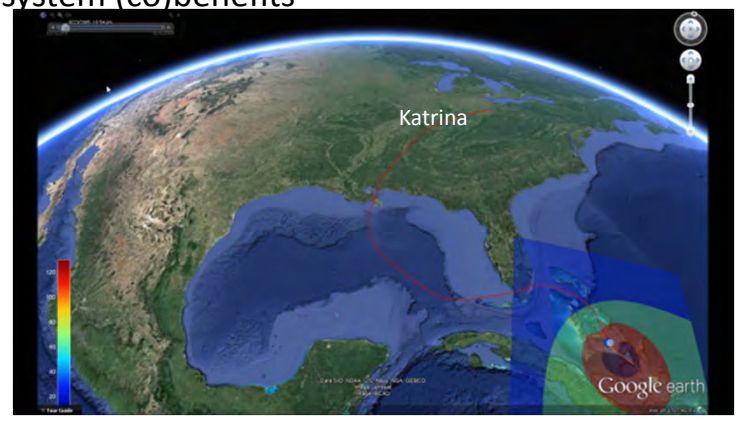
2-tier pilot submerged breakwater structure (this one with blocks) with corals from the nursery placed along their sides

Partnership with Swiss Re

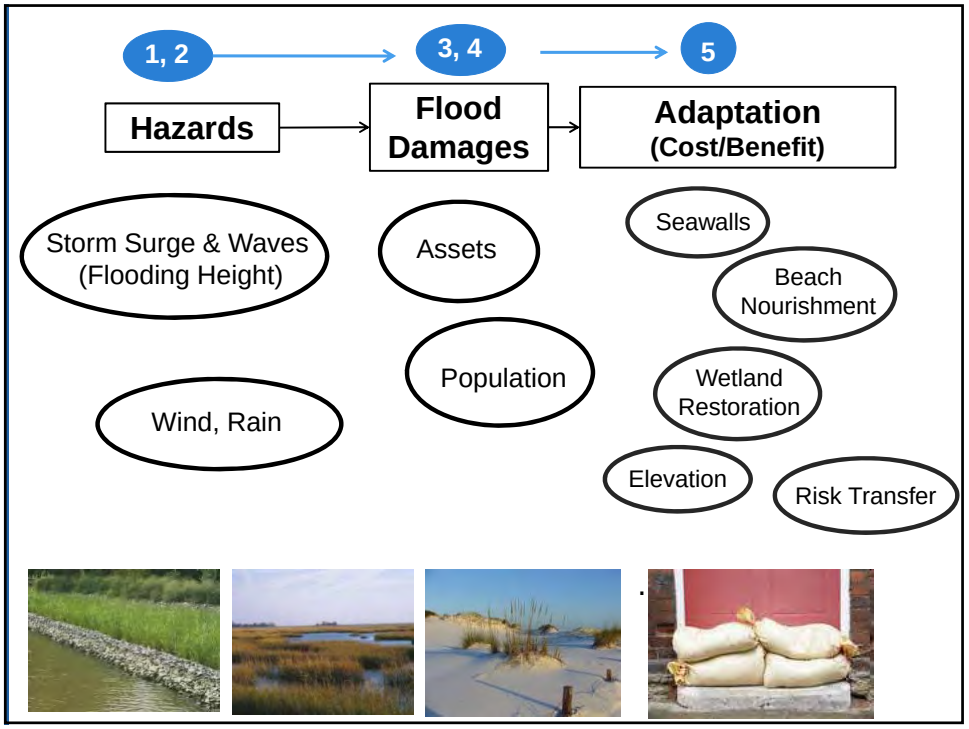
Where are nature-based defenses cost effective?

Aims

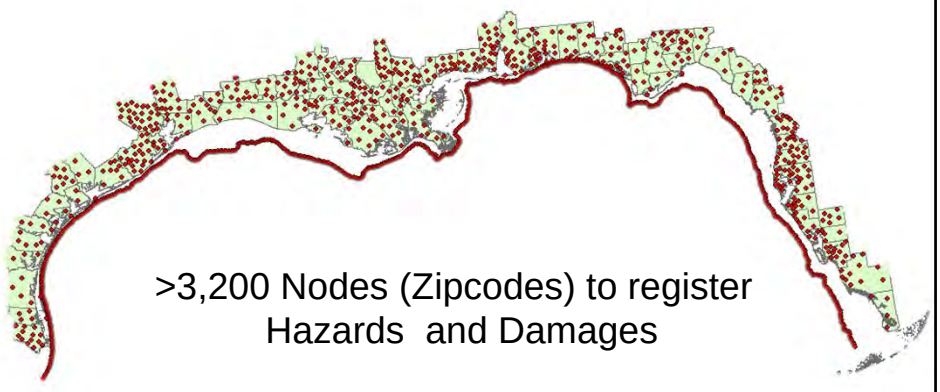
- Work with worlds 2nd largest re-insurer
- Public cost effectiveness model that includes nature
- Add ecosystem (co)benefits



Reguero, Bresch, Beck et al. 2015. *Coastal Eng. Proc. &* in review *Scientific Reports*



The regional domain: The Gulf Coast of US



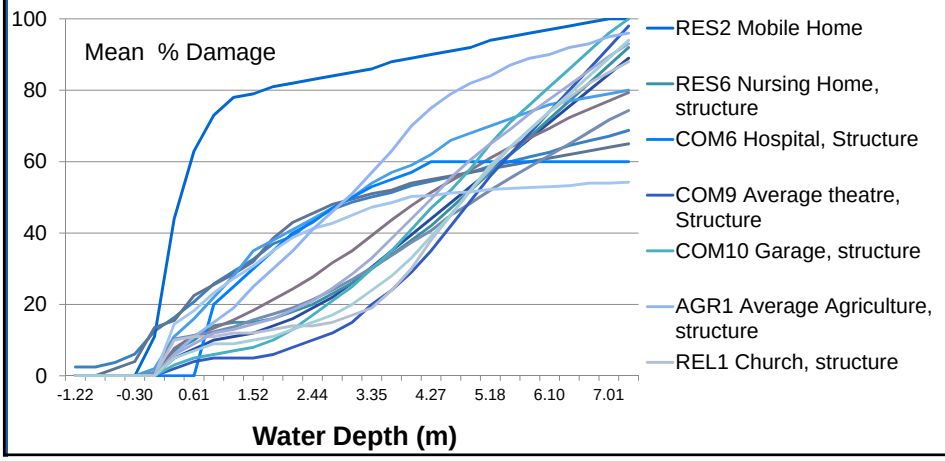
>3,200 Nodes (Zipcodes) to register Hazards and Damages

Damages Curves

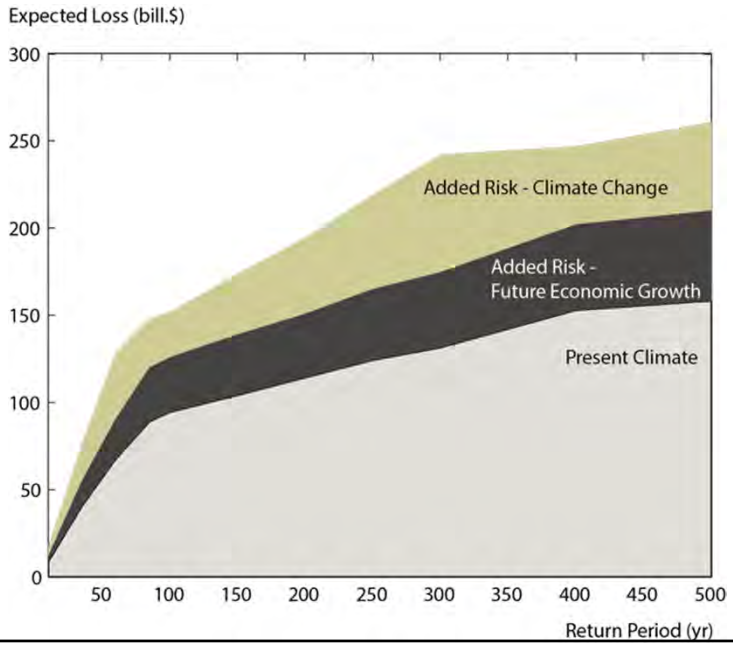
Damage curves (water depth) for different types of buildings

Aggregated into 17 types from the full USACE-FEMA catalogue

Wind Damage curve used from Climada default wind model



Effects of Economic Growth & Climate Change on Losses

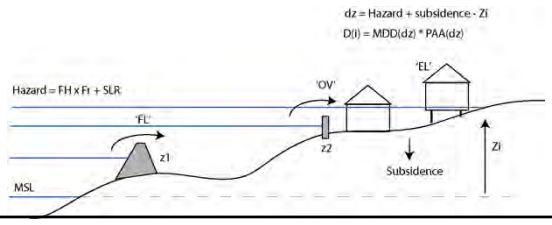


Risk Reduction Measures

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

- **Adaptation Parameterization**

MEASURE	SCENARIO 1 (CONSERVATIVE)			
	% Wave Reduction	% Surge Reduction	hazard elevation cutoff (m)	type cutoff
Local levees - homes	20	0	1.8	overtopping
Levees	60	0	6	frontline
Sandbags	0	0	0.6	overtopping
Beach Nourishment	75	0	0	
Local Floodwalls	0	0	1.2	overtopping
Home Elevation	0	0	3	elevation
Wetland restoration	30	10	0	
Barrier island restoration	20	5	0	
Oyster reef restoration	20	0	0	



Oyster Reef Restoration

1050 miles of Oyster Reefs restored in 24 counties with high restoration suitability

***see* Restoration Explorer in www.maps.coastalresilience.org**

Penetration varied 15% to 50%

Unit Cost of Measure :

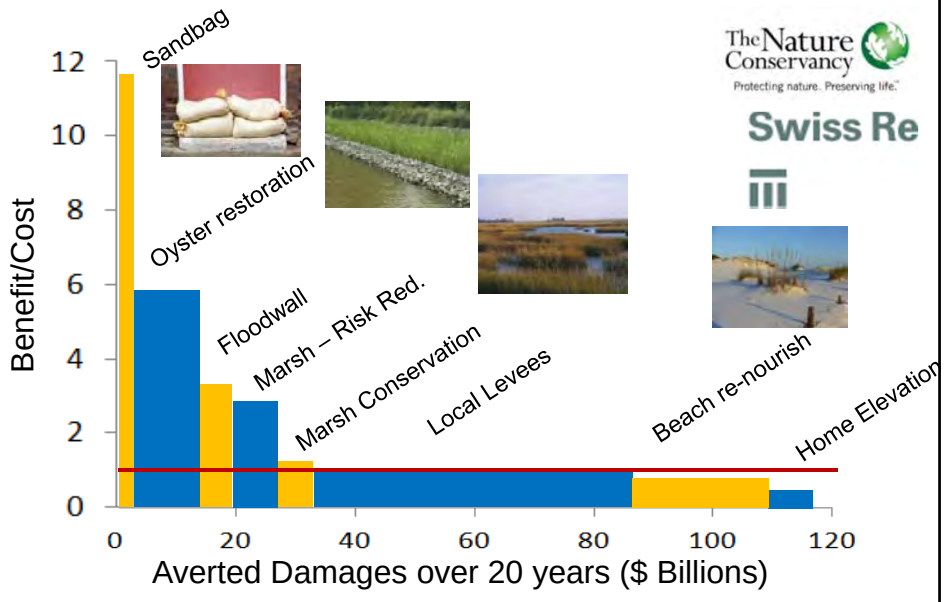
$1,500,000/mile of protected shoreline

Total Cost : $1.6 Billion

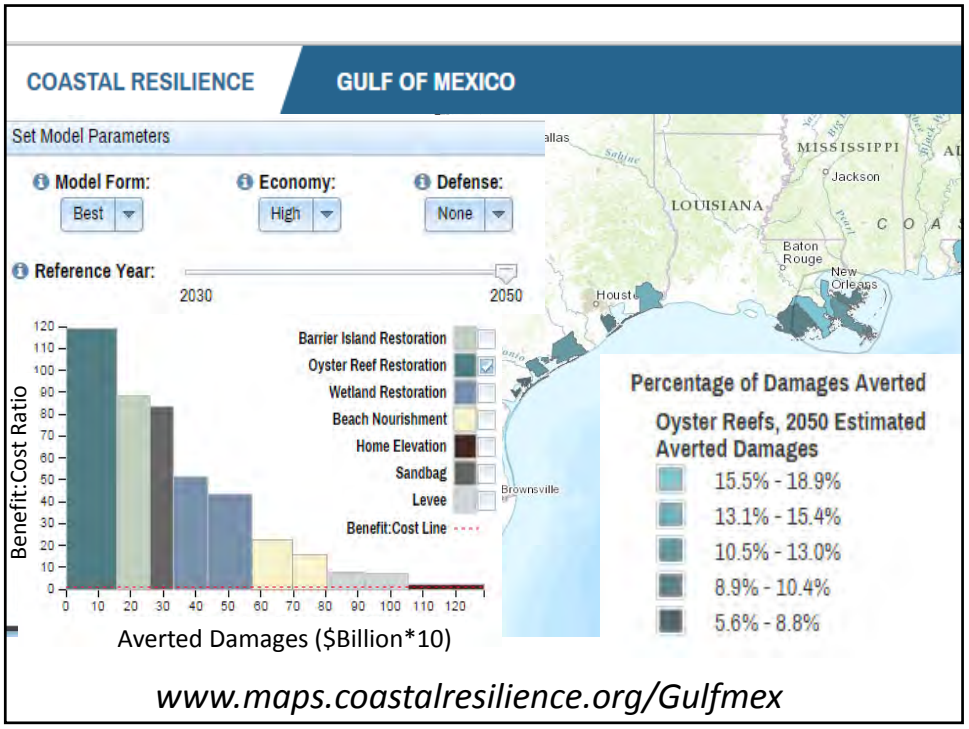
Co-Benefits of Oyster Reefs to Fisheries:

$**23,241/ mile of reef restored / year.**

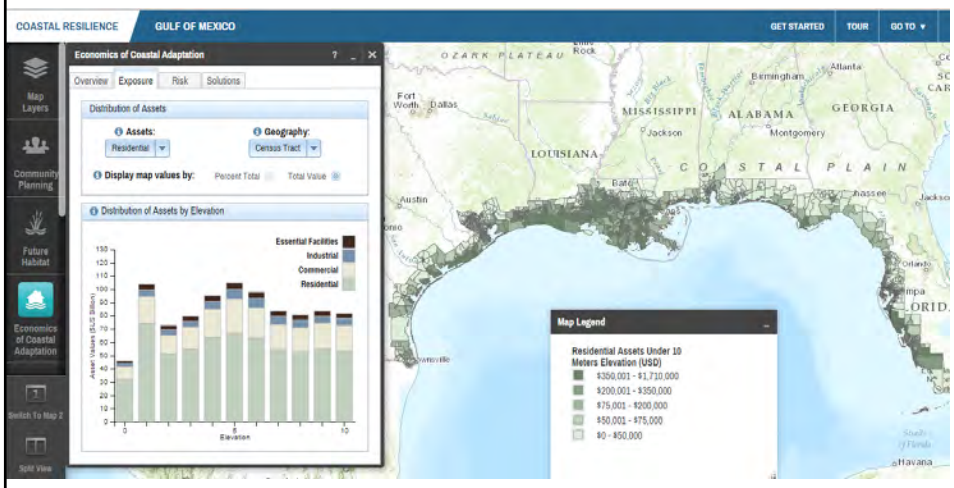
Benefit: Cost Analysis – Measures for Climate Adaptation

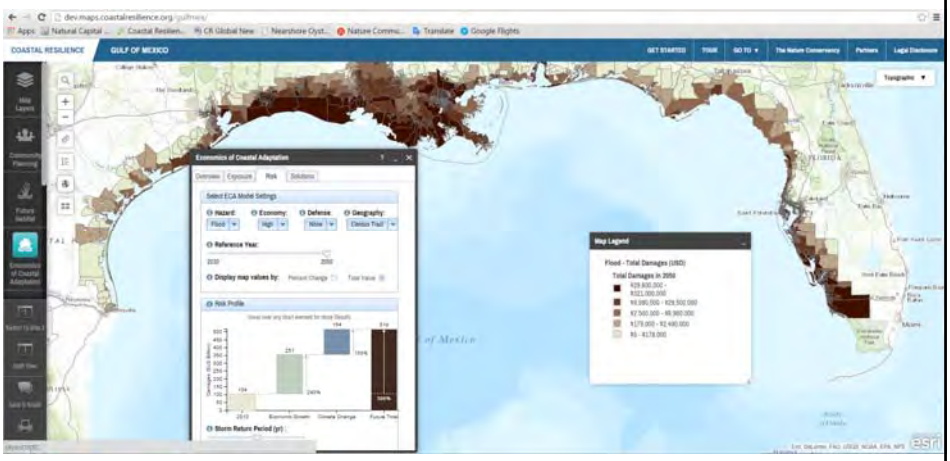


Reguero, Bresch, Beck et al. 2015. *Coastal Eng. Proc. &* in review *Scientific Reports*



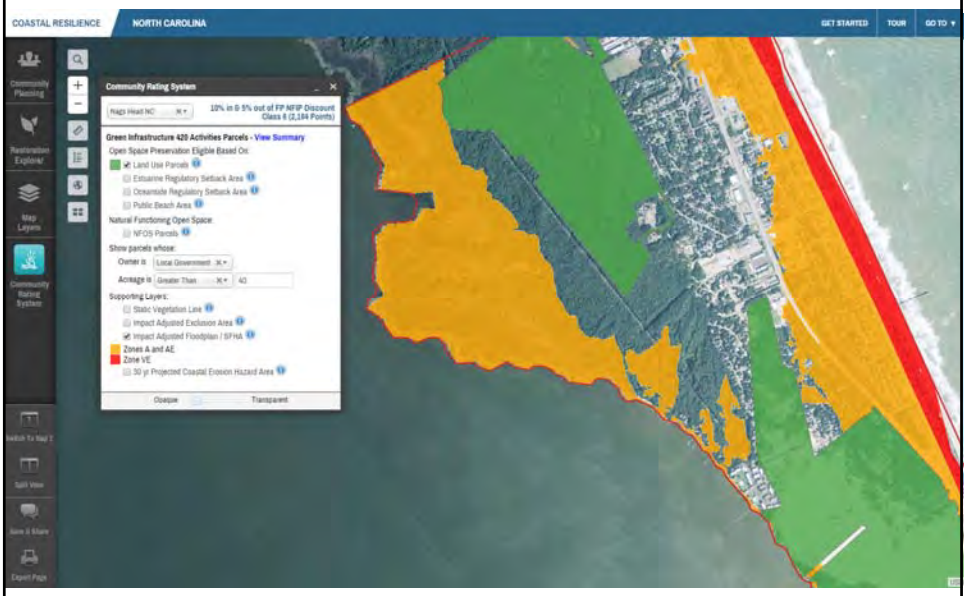
www.maps.coastalresilience.org/Gulfmex




COASTAL RESILIENCE
GULF OF MEXICO
Economics of Coastal Adaptation
Map Legend

Coastal Resilience

Outer Banks
North Carolina



Training Videos

www.coastalresilience.org/economics-of-coastal-adaptation/

www.coastalresilience.org/training

Coastal Defense App www.youtube.com/watch?v=VZkstFZedAg

Grenada Reef Restoration Video- http://coastalresilience.org/world-premier-video-mapping-the-reef-in-grenada/

Preview: Economics of Coastal Adaptation

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