Climate Adaptation & Disaster Risk Reduction
Building *Coastal Resilience*

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The Nature Conservancy &
Univ. of California Santa Cruz

www.nature.org &
www.coastalresilience.org

The Nature Conservancy
Protecting nature. Preserving life.

Many Staff and Partners







- TNC Global and North America Marine and Freshwater Programs
- **TNC chapters** – USA, Mexico, Caribbean
- **Partners-** Univ. So. Miss., NOAA, USGS, United Nations U., NASA- Goddard, ASFPM, UCSC, Nat Cap Project

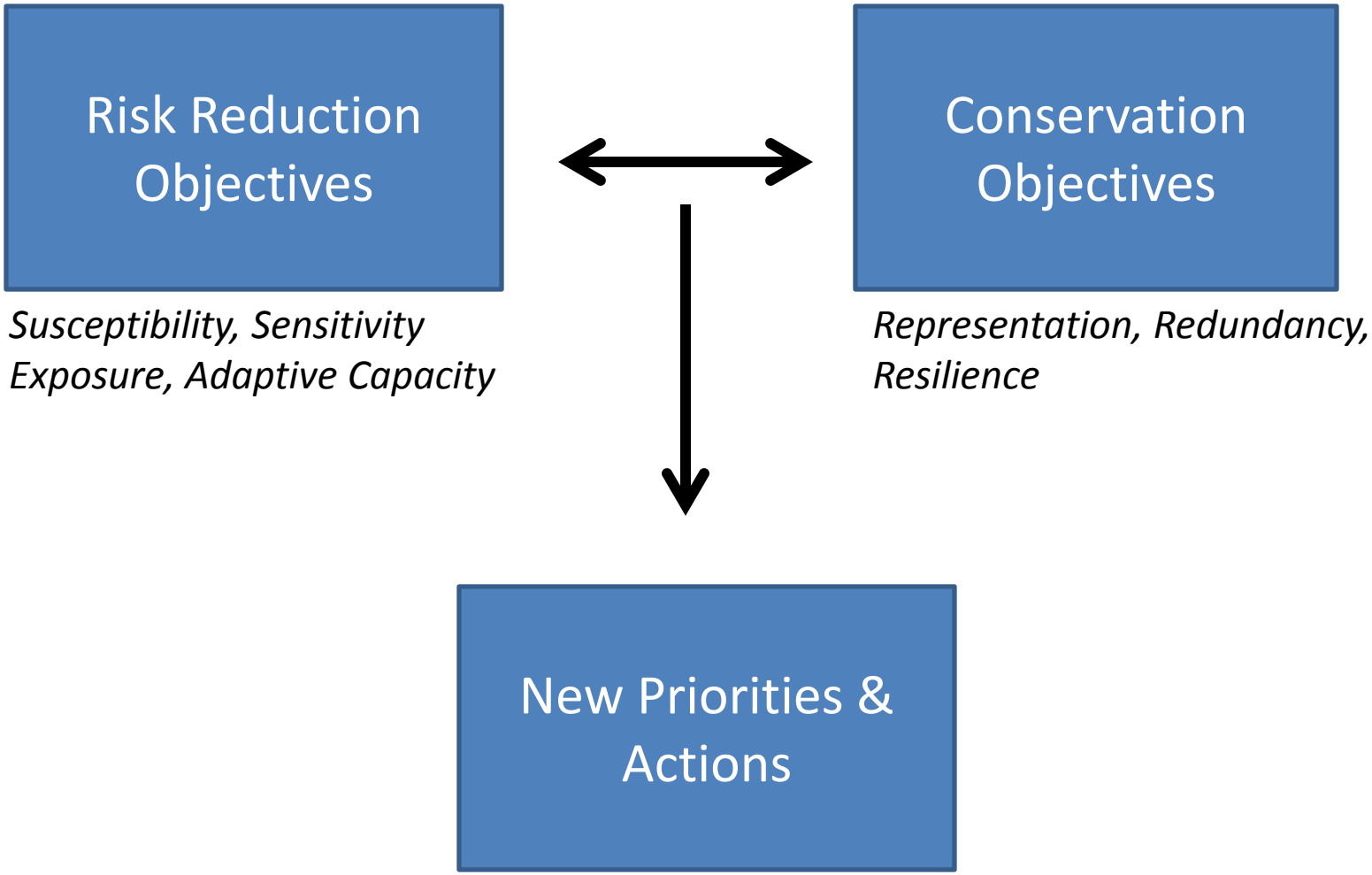




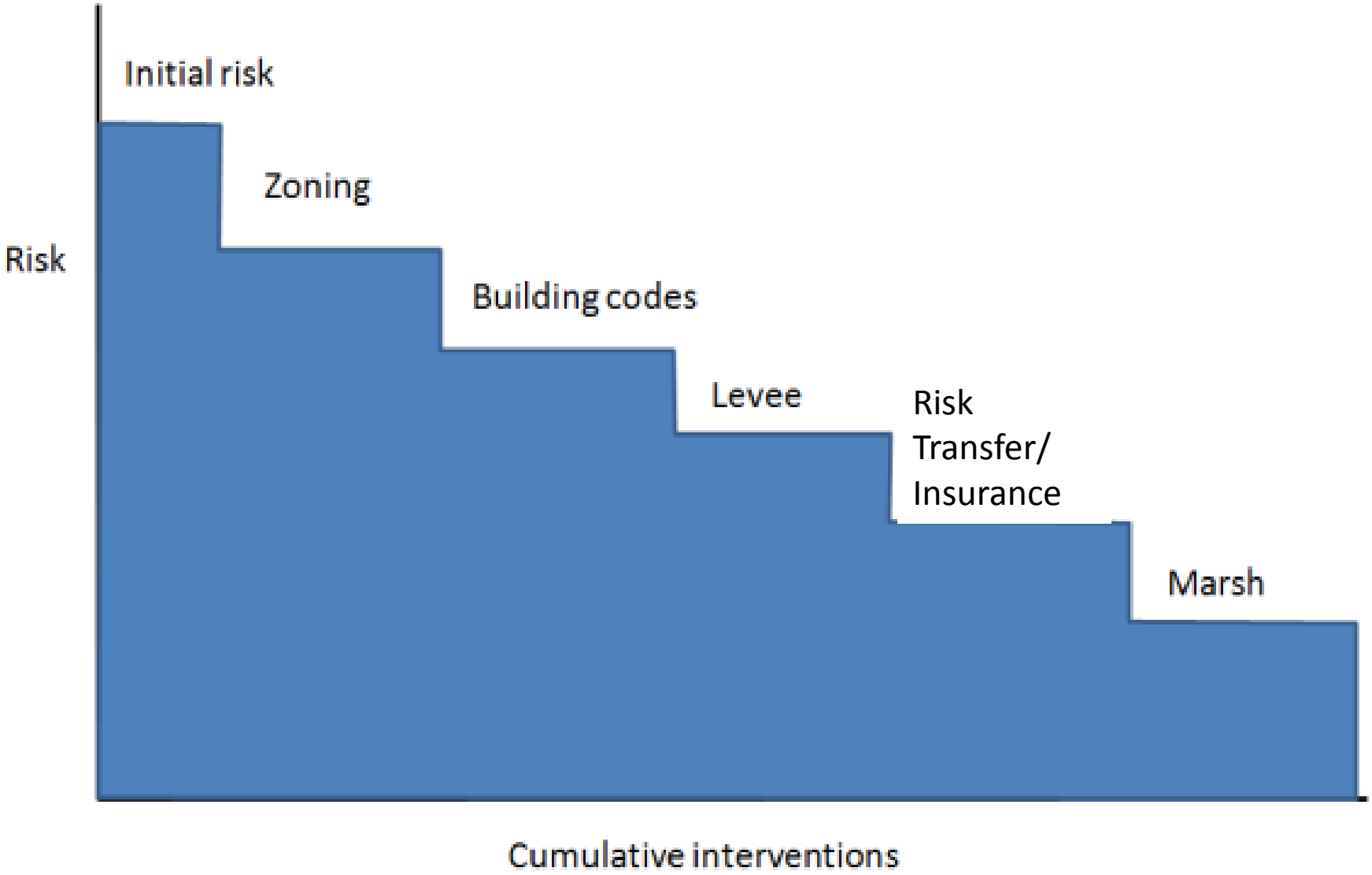




Meeting Multiple Management Objectives



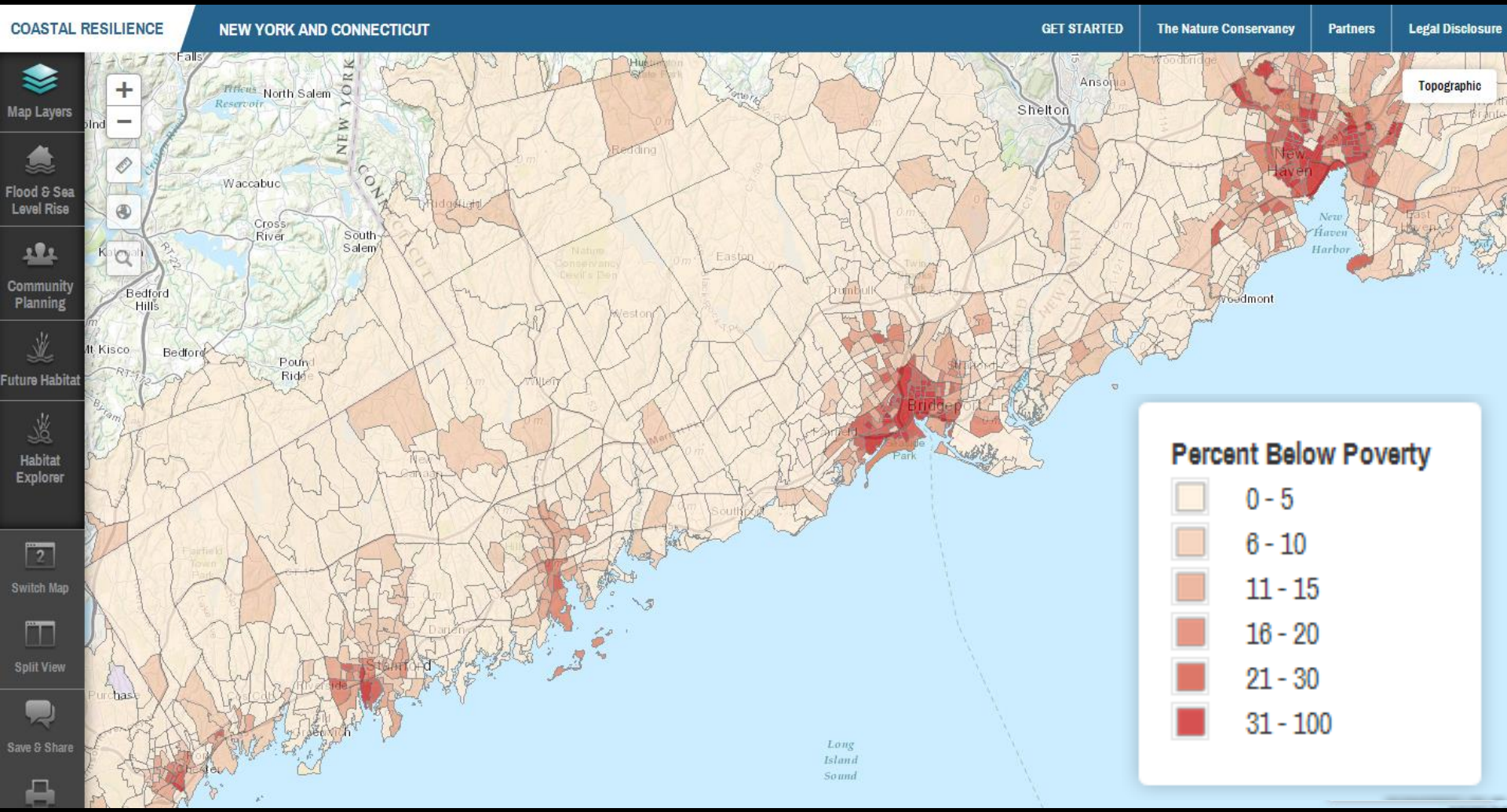
Risk Reduction- Many Steps



Coastal Resilience: Long Island Sound

maps.coastalresilience.org/NYCT

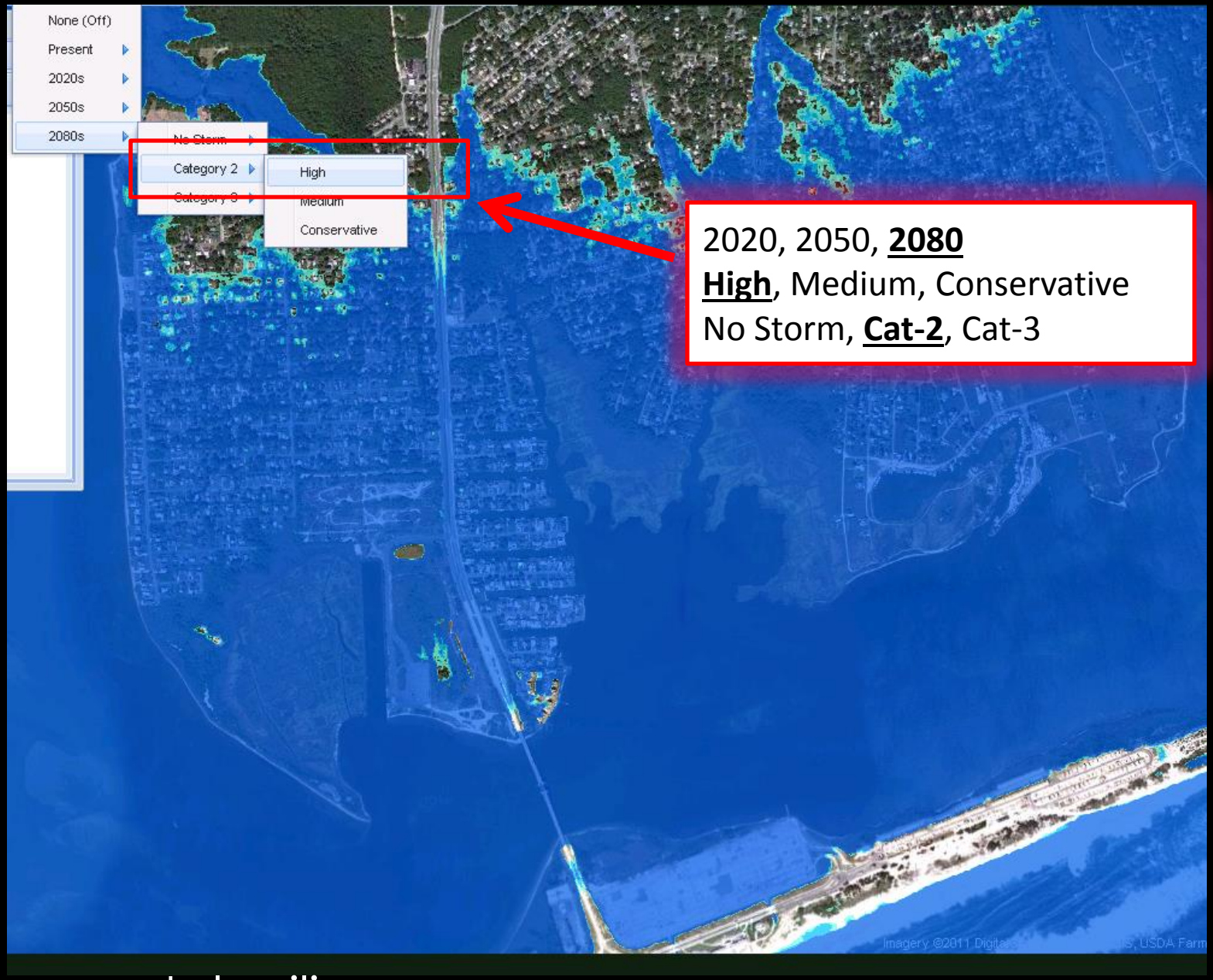
social vulnerability



sea-level rise and storm surge scenarios

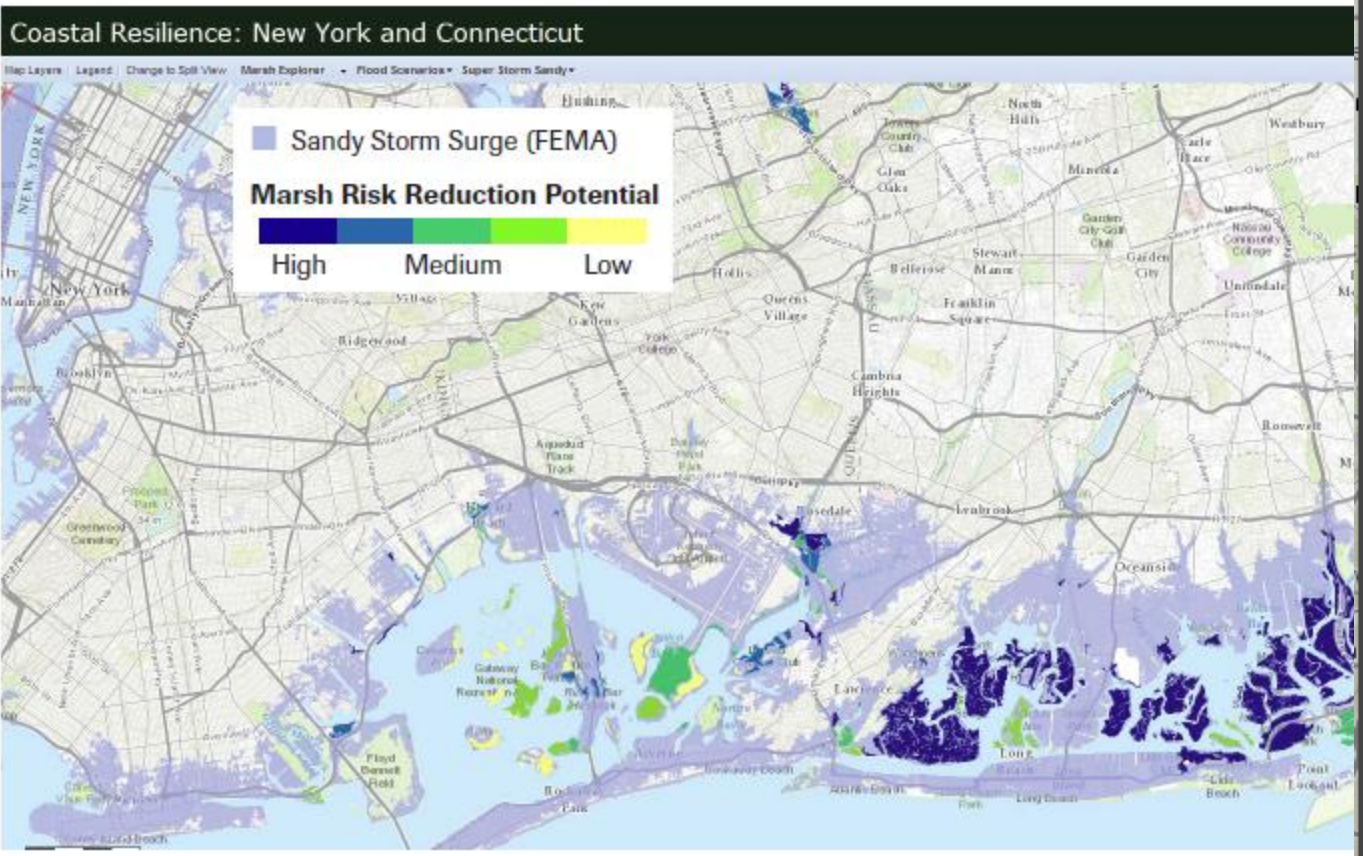
maps.coastalresilience.org

sea-level rise and storm surge scenarios



maps.coastalresilience.org

Assessing Solutions: Which marshes might provide the most risk reduction benefits in NY and CT

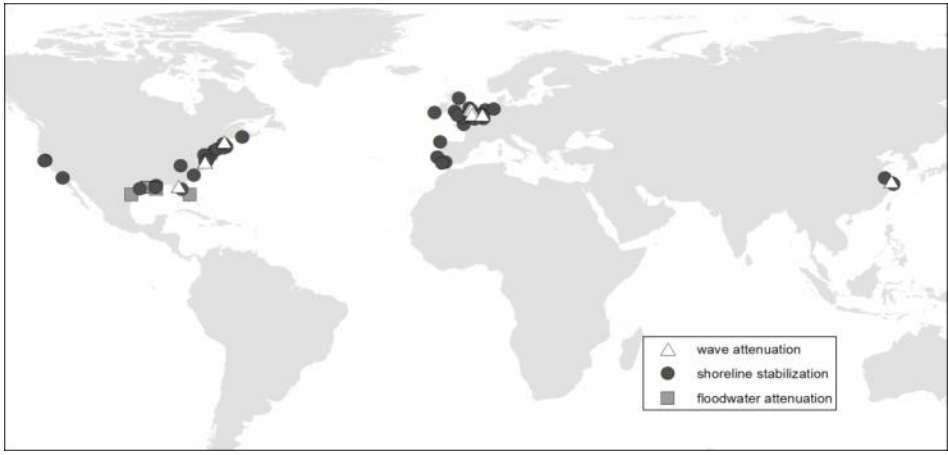


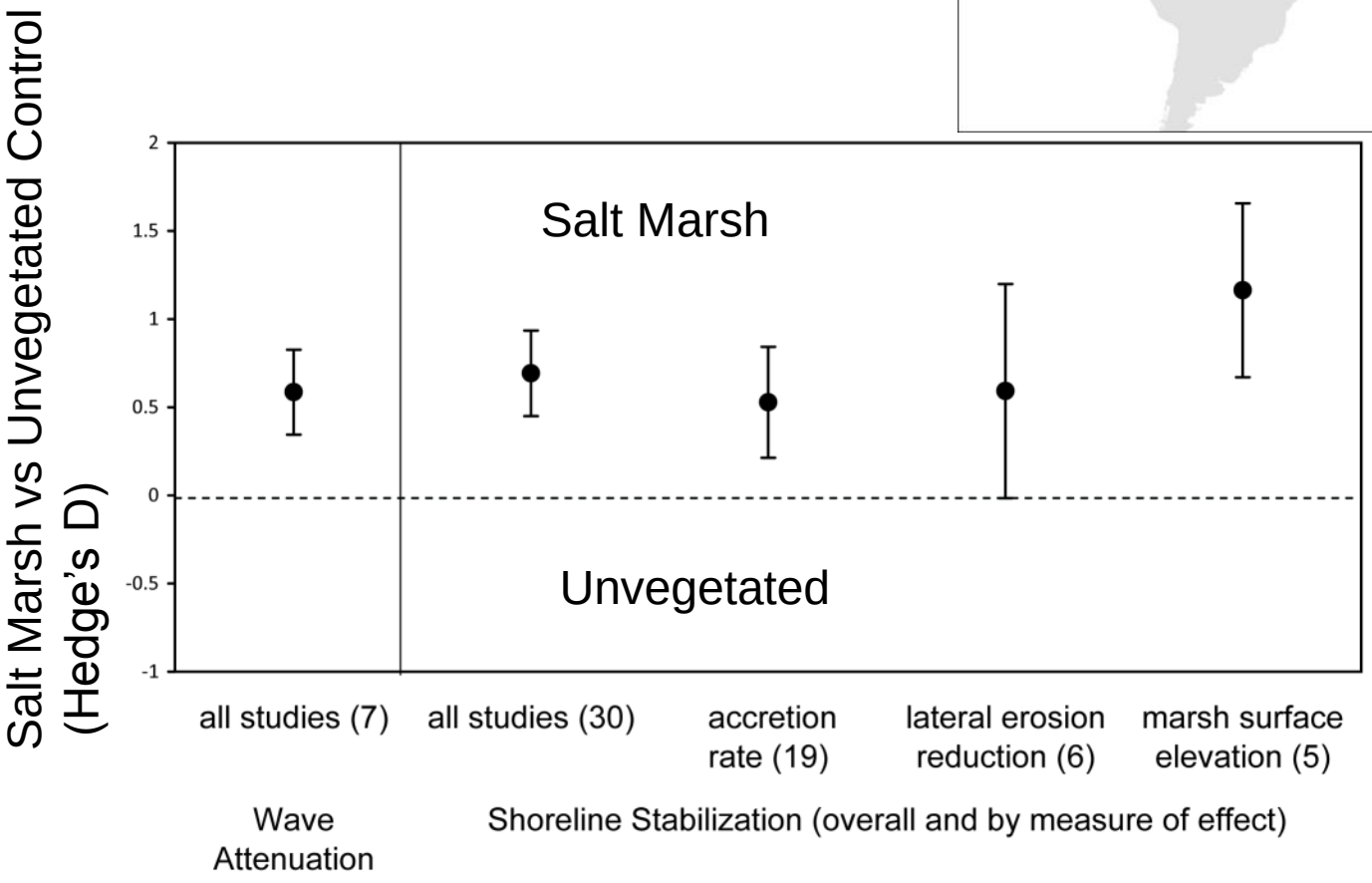
Socio-Economics Behind Marshes

- **$19 billion in building replacement costs**
- **321,000 people**
- **1,700 miles of roads**
- **138 critical facilities**

maps.coastalresilience.org/nyct

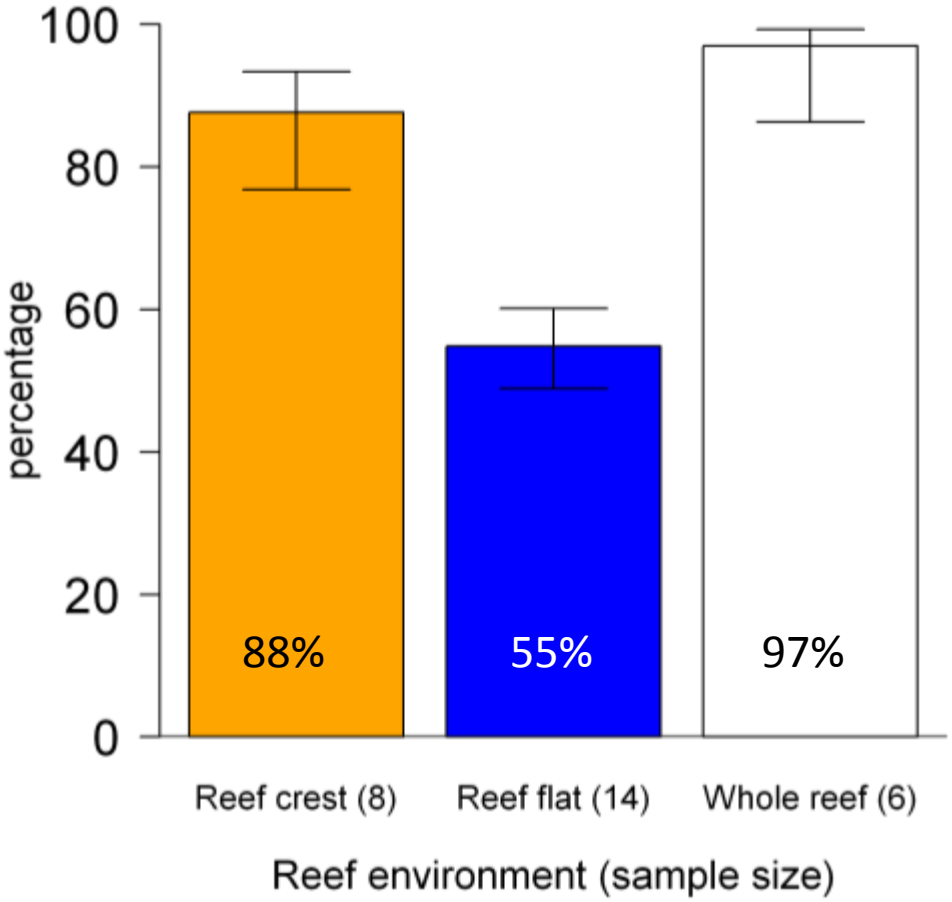
Meta-analysis: Coastal protection by salt marshes

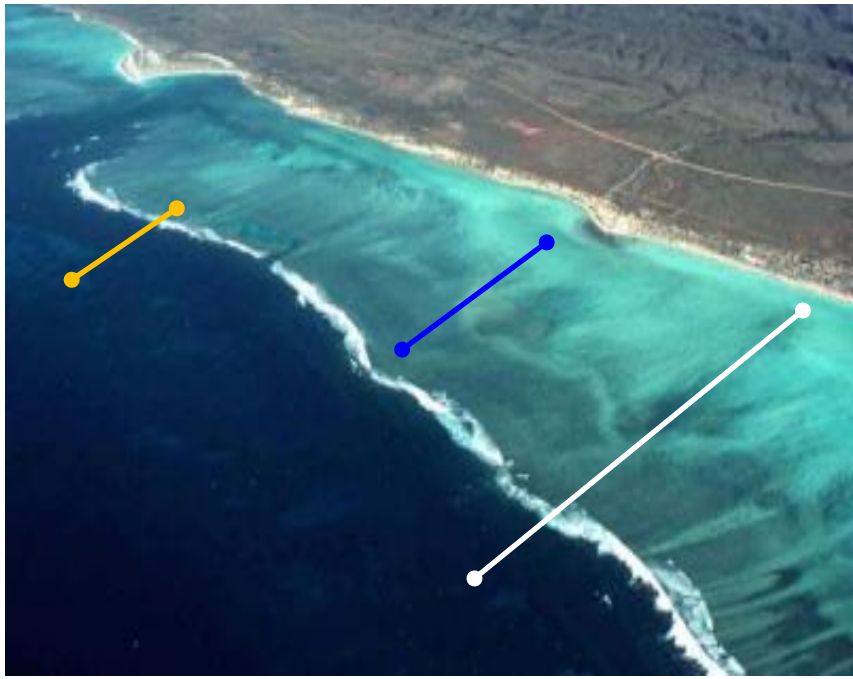




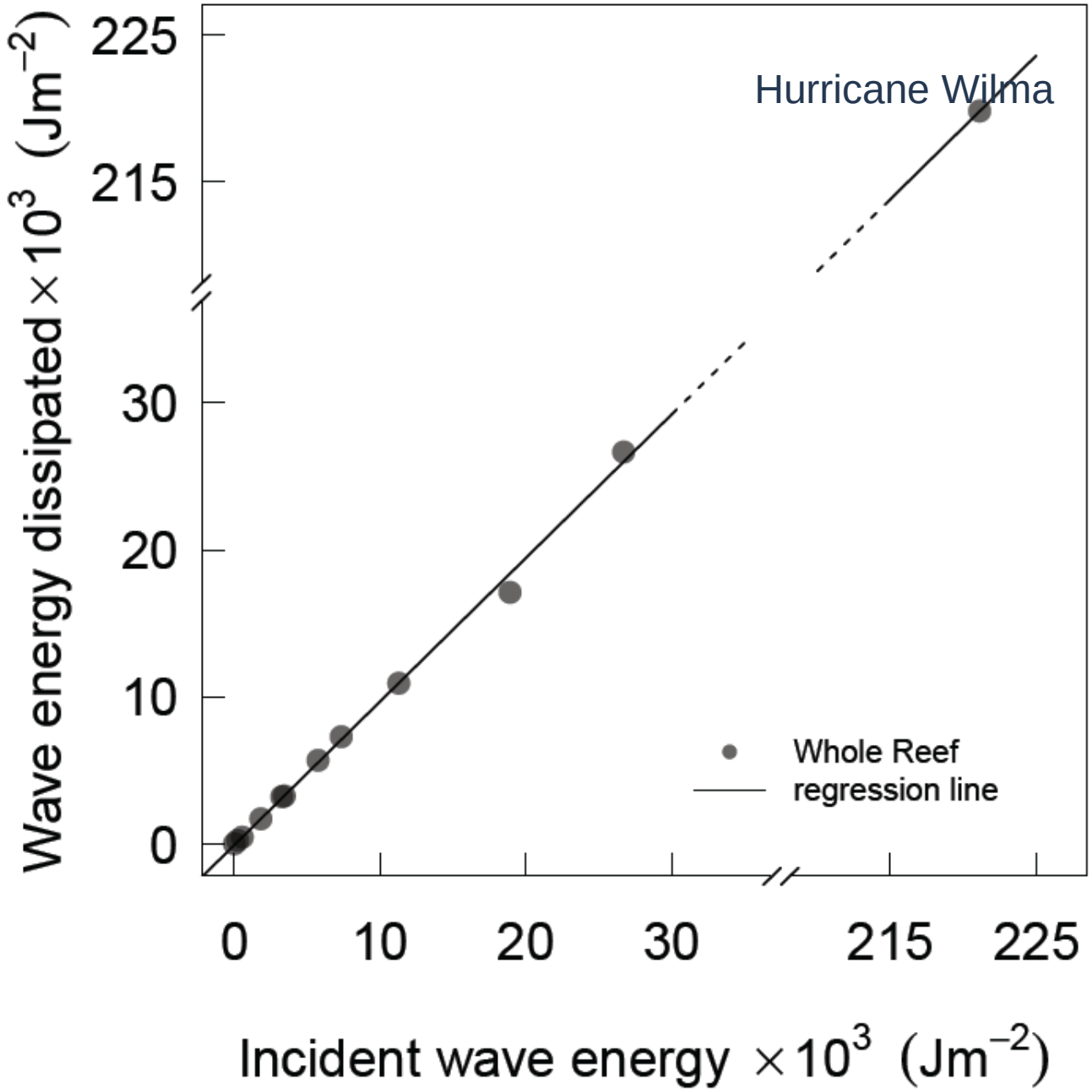
Shepard, Crain, Beck. 2011. PloS One 6: e27374

Wave Energy Reduction By Coral Reefs





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



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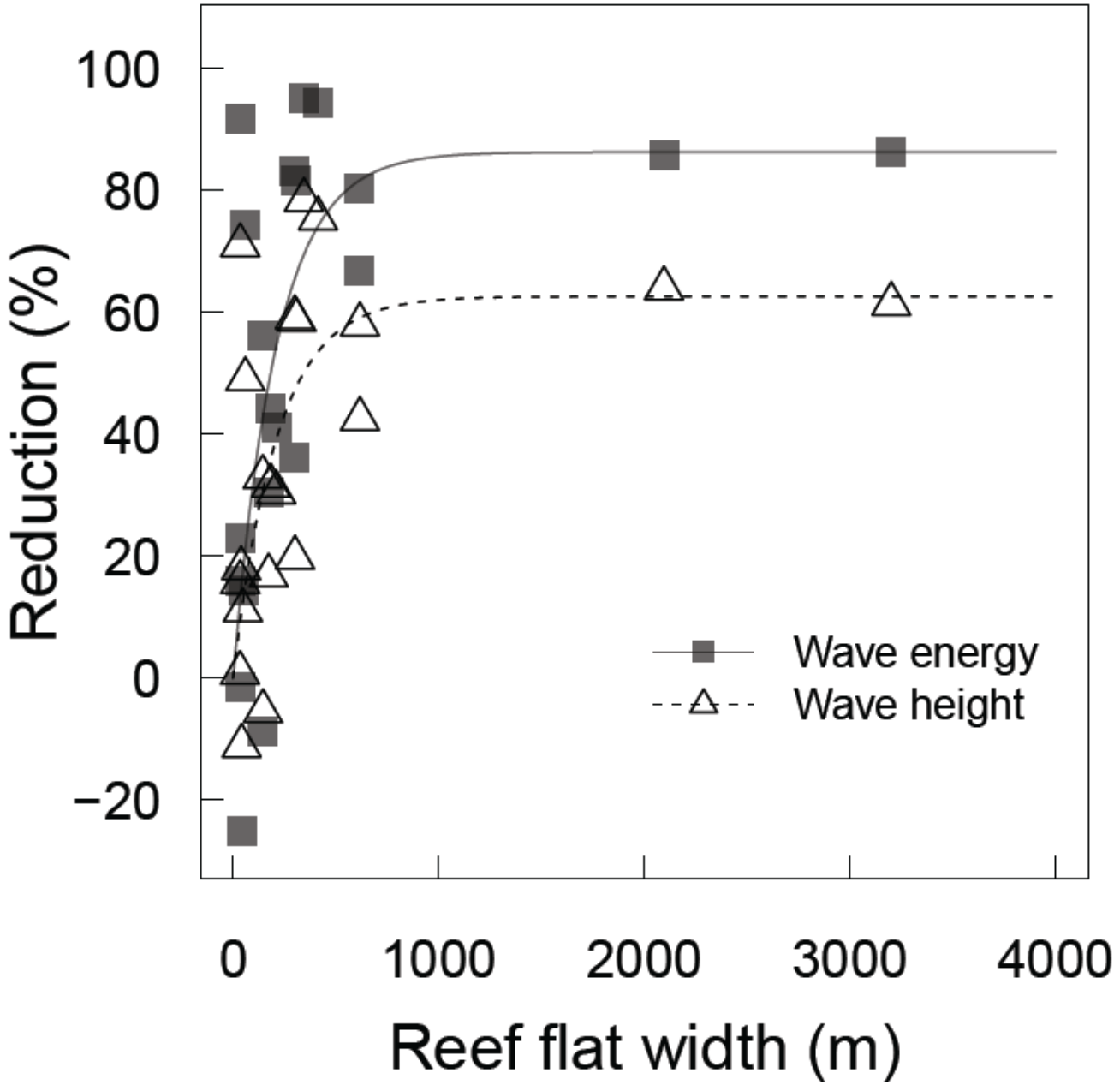
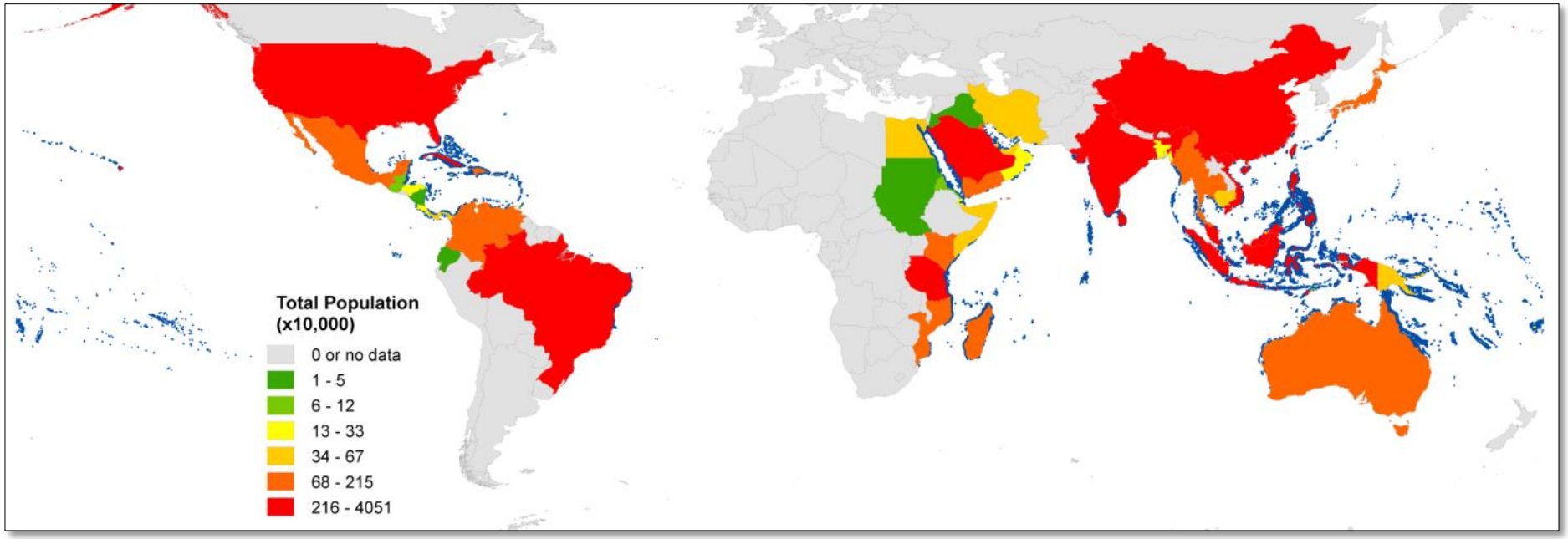


Ferrario, Beck et al. 2014. *Nature Communications*

Coral Reefs and Risk Reduction



197 million people live in at-risk coastal areas (below 10m elevation) and within 50km of coral reefs

World Risk Report 2012 & *Nature Communications* 2014

Table 1 | Costs of construction or significant maintenance intervention for tropical breakwaters.

Location	Source (refs)	Length (*m*)	Year	Original cost ($)	Cost* 2012 ($)	2012 Unit cost ($ m^{-1})
Sri Lanka	64	16,000†	1994‡	13,400,000	20,759,511	1,297
Maldives	16	1§	1997‡	10,000	14,305	14,305
Haleiwa, Hawaii	65	58	1975	150,000	640,132	11,037
Hilo, Hawaii	65	3,073	1946	1,500,000	17,661,077	5,747
Kalaupapa, Hawaii	65	35	1967	95,000	653,037	18,658
Kawaihae, Hawaii	65	808	1973	6,000,000	31,026,216	38,399
Manele, Hawaii	65	143	1965	742,850	5,414,410	37,863
Nawiliwili, Hawaii	65	152	1959	1,000,000	7,889,828	51,907
Pohoiki, Hawaii	65	27	1979	335,500	1,061,003	39,296
Auasi, Samoa	65	206	1981	1,166,300	2,945,825	14,300
Aunuu, Samoa	65	27	1981	2,018,400	5,098,048	188
Tau, Samoa	65	88	1981	2,020,400	5,103,099	
Agana, Guam	65	221	1977	1,220,550	4,624,273	
Sungai, Malaysia	66	1§	2008	428	456	
Korea	67	3,000	2010	124,000,000	130,561	,520
Nakhon Si Thammarat, Thailand	68	40	2012	180950	18	4524

Median/m = $20,924

Table 2 | Costs of coral reef restoration projects.

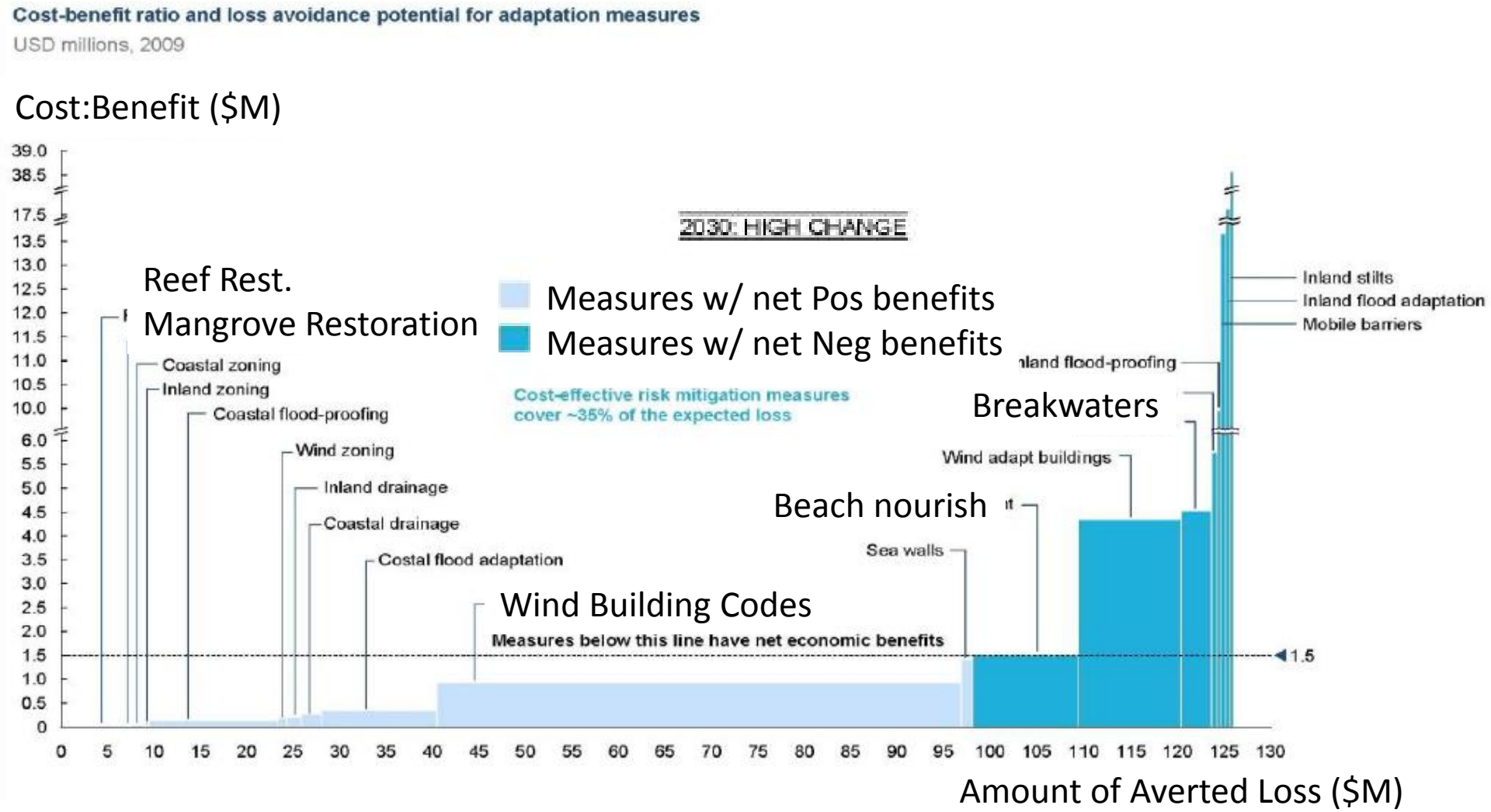
Restoration technique	Location	Source (refs)	Year	Original cost ($ m^{-2})	2012 Unit cost* ($ m^{-2})	2012 Linear unit cost† ($ m^{-1})
Paving slabs + chain-link fencing	Maldives	62	1994	40	62	620
Armorflex	Maldives	62	1994	103	159	1,590
Armorflex + coral transplantation	Maldives	62	1994	151	233	2,330
Concrete Blocks	Maldives	62	1994	328	508	5,080
Concrete structures + coral transplantation	Florida	69	1991	550	927	927
Concrete structures + coral transplantation	Florida	69	1994	10,000	15,500‡	155,000
Rock stabilization	Indonesia	70	2005	5	6	60
Reef Ball	Various	70	2005	40	47	
EcoReef	Various	70	2005	70	82	
Biorock	Various	61	2005	1.6–110	2–129	

Median/m = $1,290

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

Barbados

Examining Costs:Benefits of Coastal Adaptation Approaches



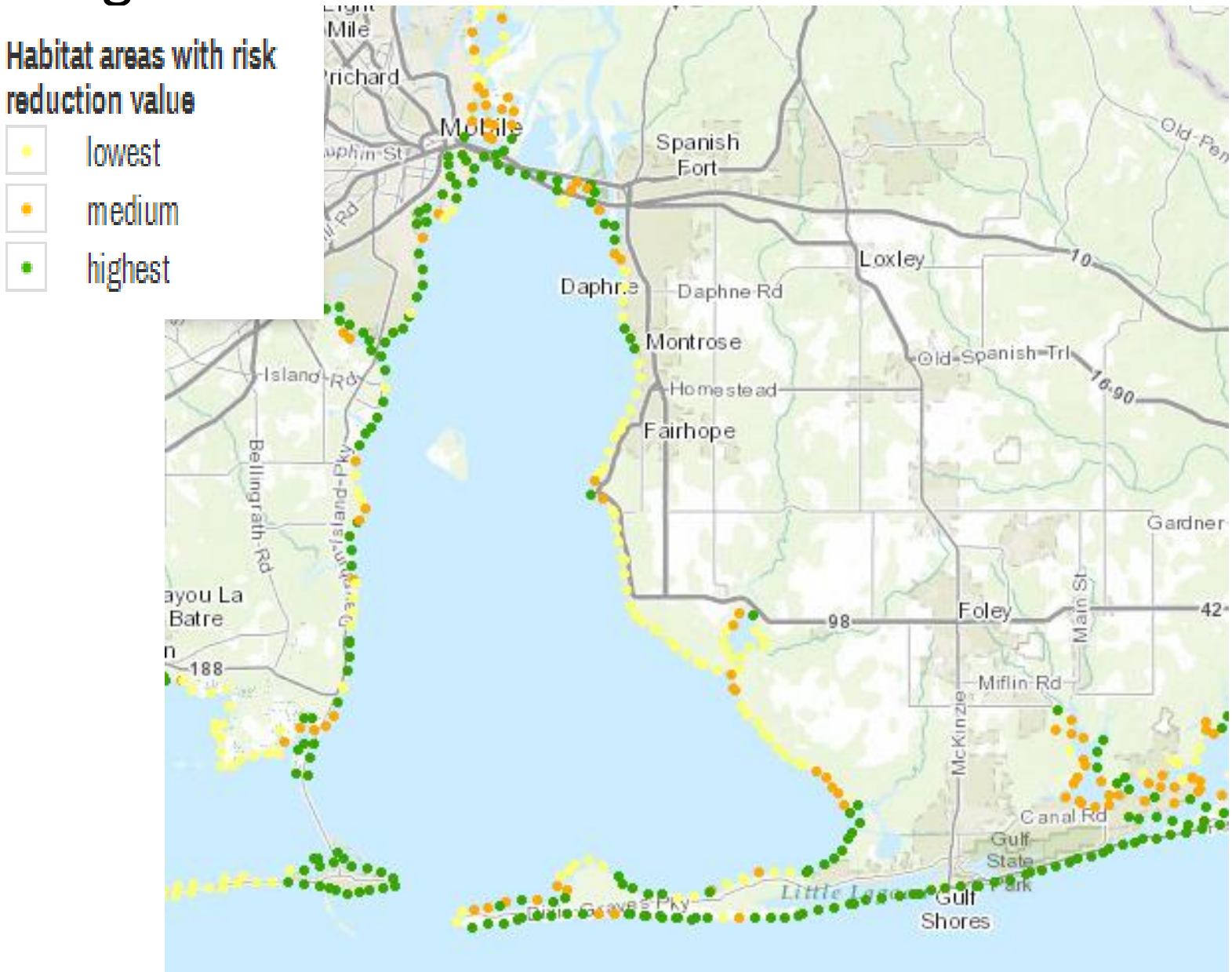
Based on work by Economics of Climate Adaptation working group- Swiss Re climada model

Risk Assessment

www.maps.coastalresilience.org/gulfmex

Arkema et al. 2013. *Nature Climate Change*

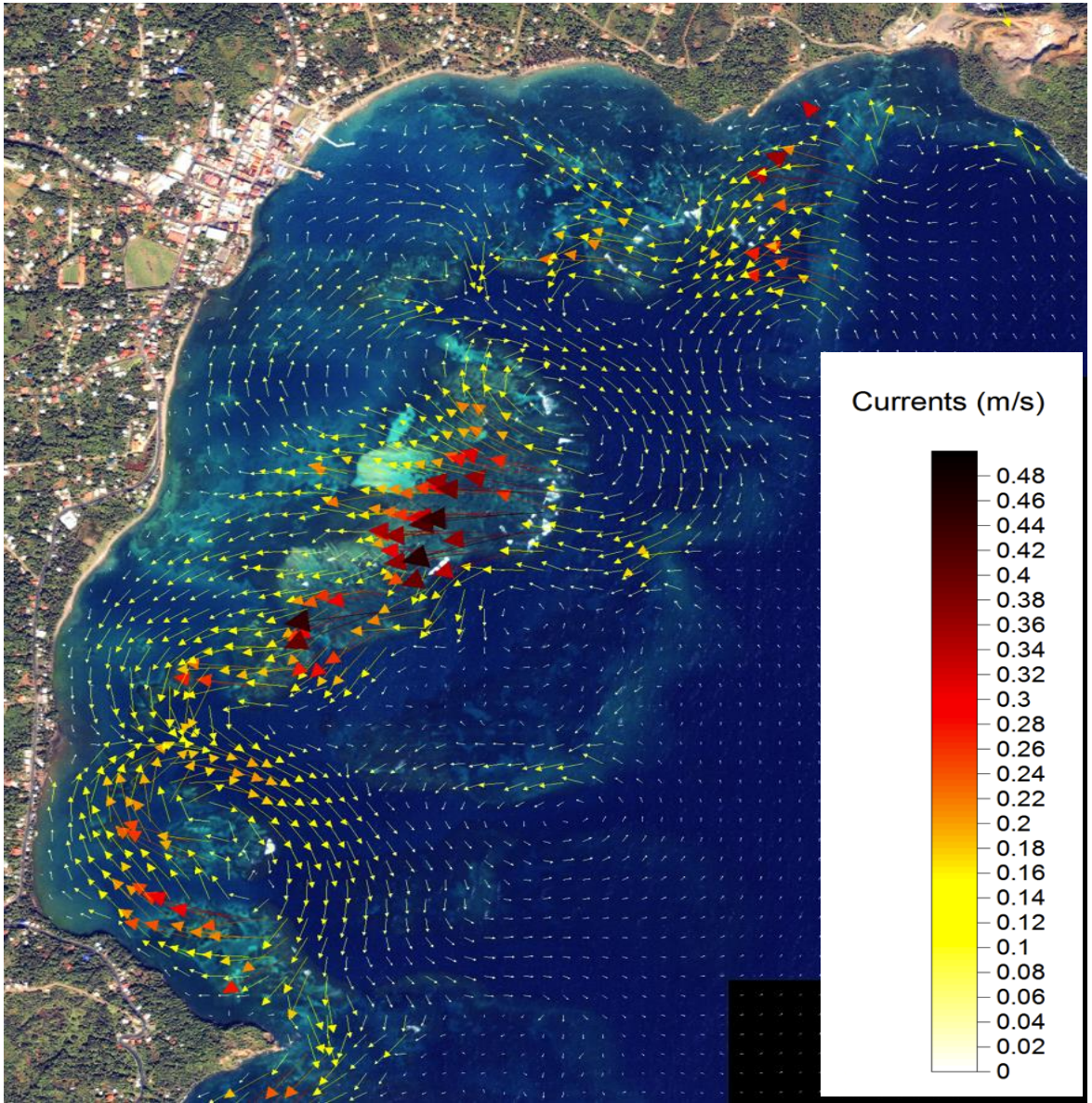
Where may oyster reef restoration have the greatest effect on risk reduction



Grenville, Grenada Reef Restoration

Detailed Nearshore Hydrodynamics Analysis

Currents

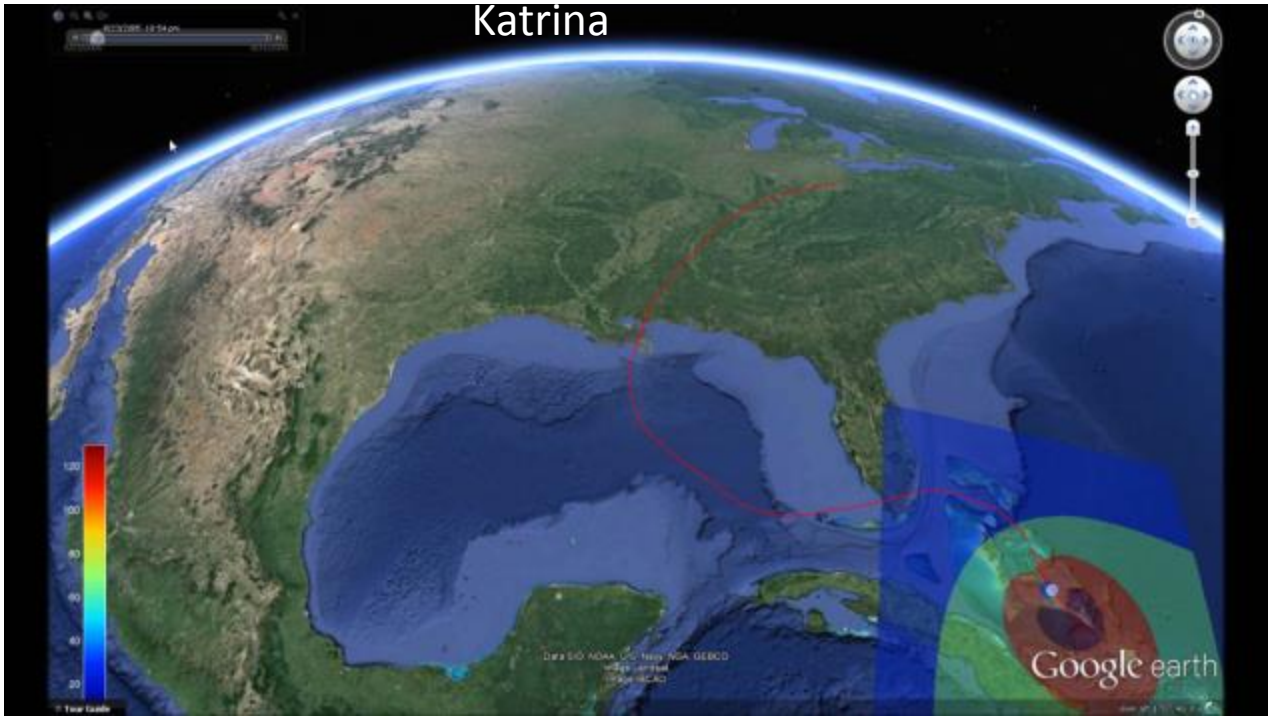


Partnership with Swiss Re

Where are nature-based defenses cost effective for risk reduction?

Aims

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



The FRAMEWORK

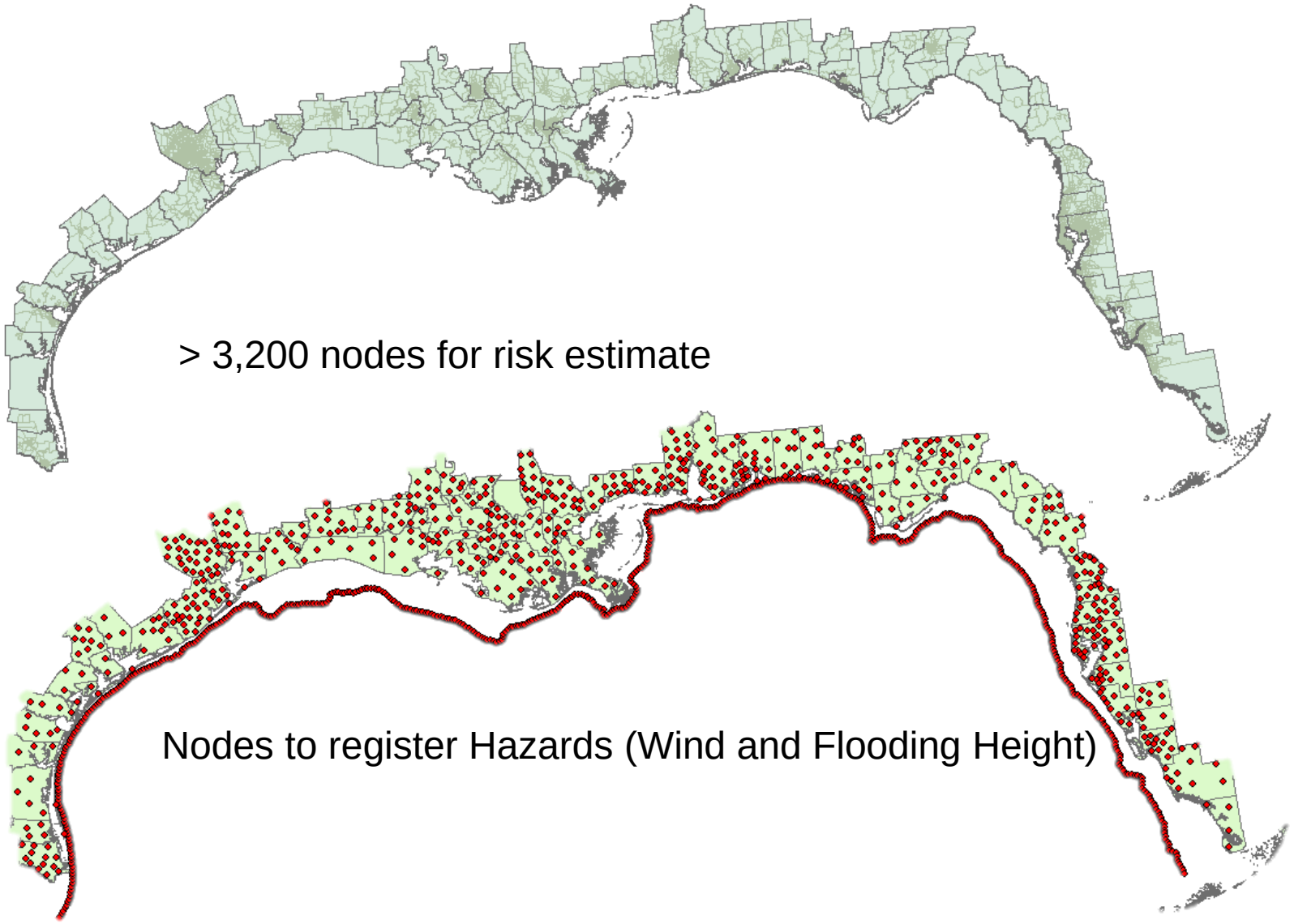
Hazards → **Damages** → **Adaptation (Cost/Benefit)**

- Wind
- Rainfall
- Storm Surge & Waves (Flooding Height)
- Assets
- Population
- Seawalls
- Beach Nourishment
- Wetland Restoration
- Elevation
- Risk Transfer

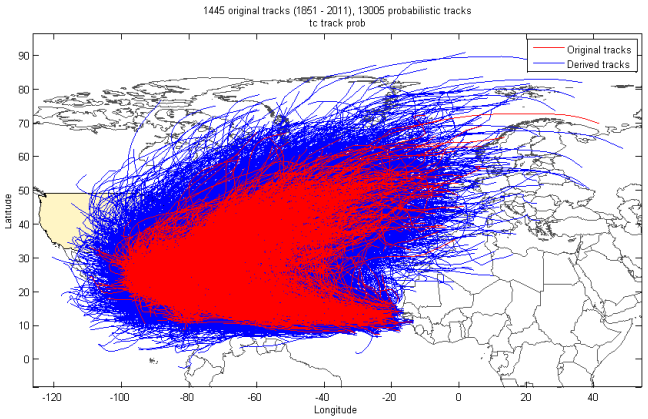


…

The regional domain: The Gulf Coast of US

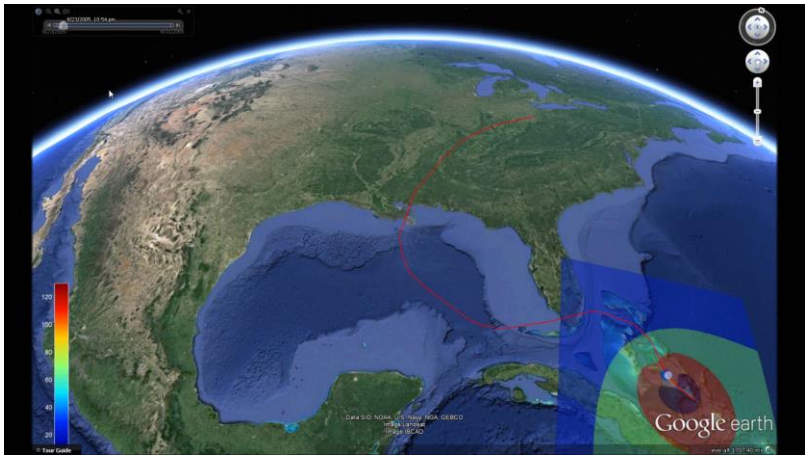


Storms



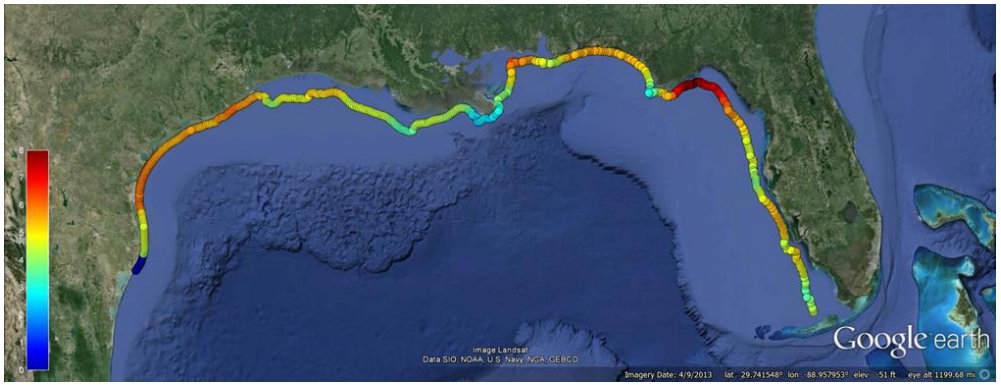
1. Simulate Storms

Random walks using the historical record 1851-2011



2. Footprint of each storm

Wind, Rainfall, Waves and Storm Surge from parametrical models



3. Reconstruct the statistics associated with return periods

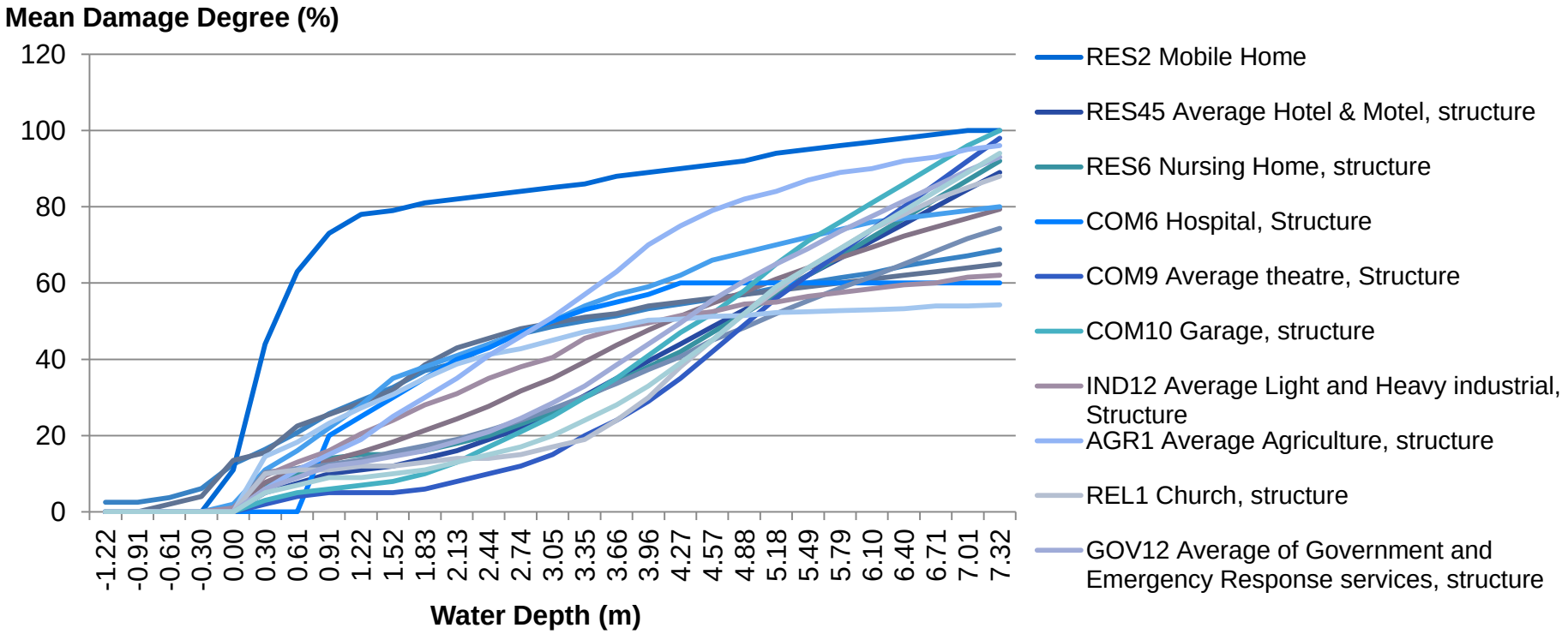
Calculate frequency of each hazard event

Damages Curves

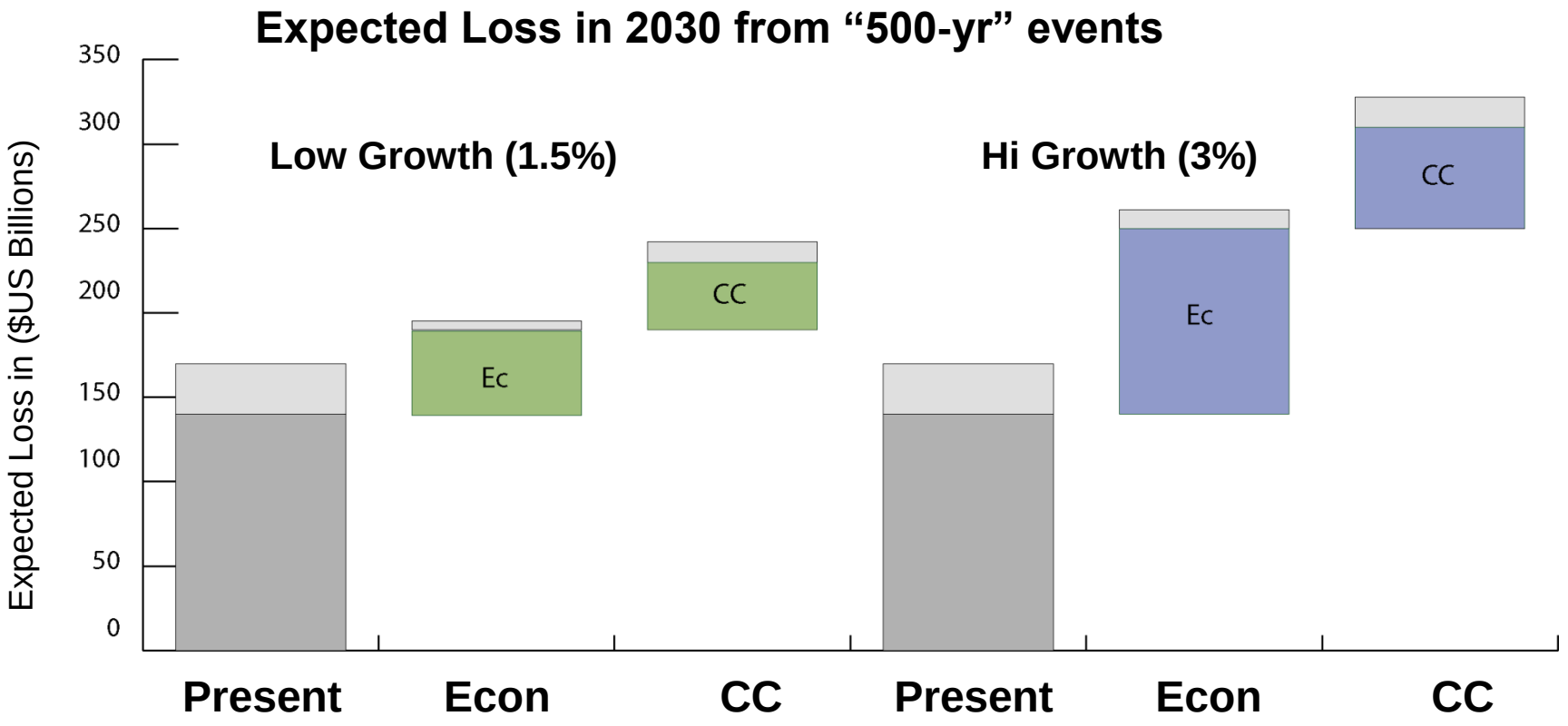
Damage curves (water depth) for different types of buildings

Aggregated into 17 types from the full catalogue from USACE – FEMA

Wind Damage curve used from Climada default wind model

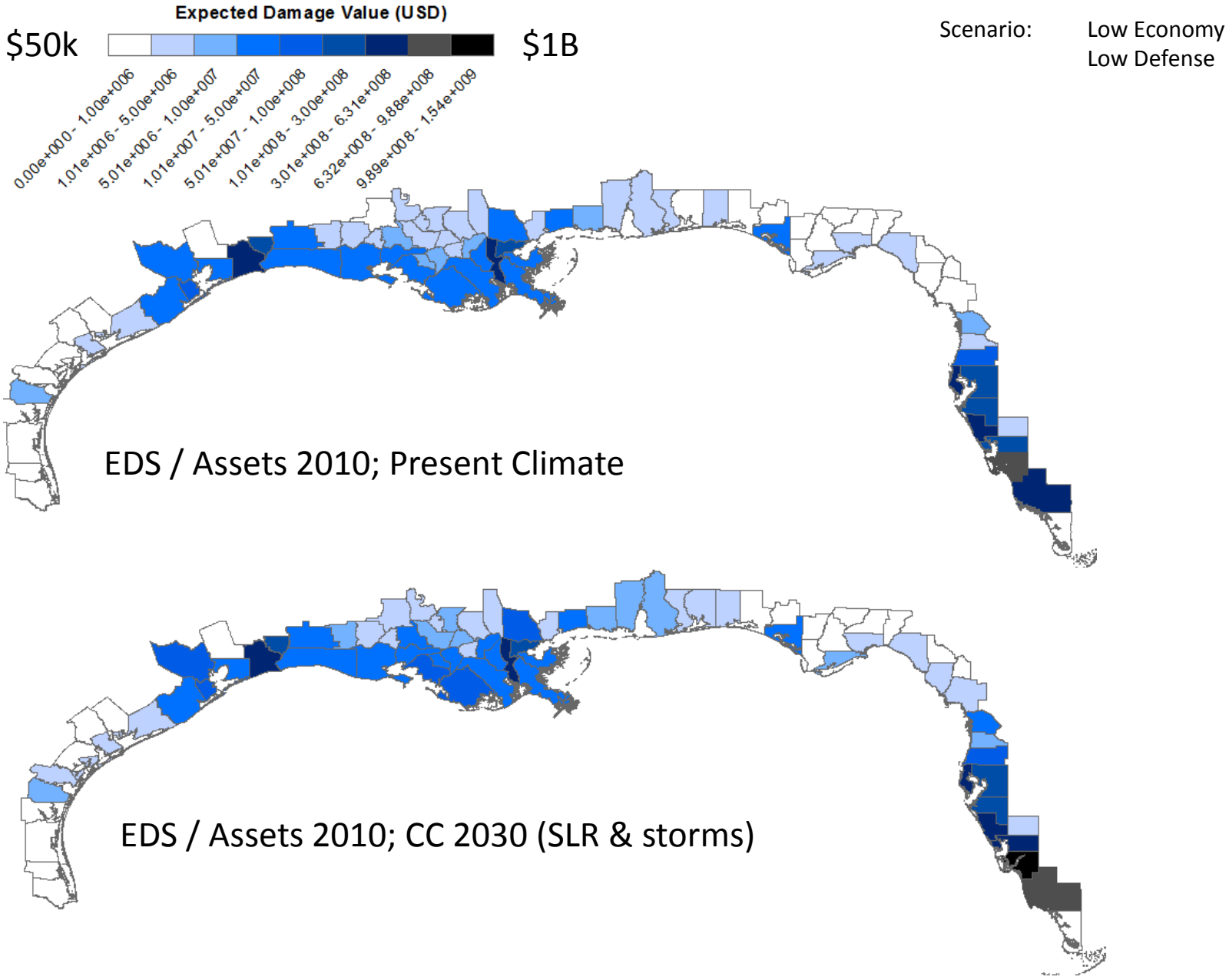


Effects of Economic Growth & Climate Change on Future Losses



Differences between bathtub and landscape defenses

- Annual Expected Damage by County



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
Local Levees Remaining	6 ft “hills” built to protect 3,400,000 existing houses on the remaining 77 counties from the study area.
Sandbags	Sandbags used as barriers in 2.9 million houses for all Category 3 hurricanes across all counties in the study area.
Local Floodwalls	Concrete blocks (4 ft Structures) built to protect 1.9 million houses across all counties and parishes in the study area.
Levees	20 ft levees constructed in high risk areas around Houma, LA and New Orleans, LA covering 340 linear miles.
Barrier Island Restoration	Mississippi Coastal Counties (Hancock, Harrison, and Jackson)
Oyster Reef Restoration	Nearly 1000 miles of Oyster Reefs restored in all counties with high restoration suitability as identified by Restoration Explorer.
Beach Nourishment	All Coastal Counties in Texas.
Home Elevation Existing Homes High Priority	Elevate 481,841 existing houses by 8ft on the top 6 counties that experience the most damages
Home Elevation Existing Homes Low Priority	Elevate 3,037,869 existing houses on the remaining 77 counties from our study area by 8ft.
Home Elevation New Homes High Priority	Elevate 98,000 new houses by 10ft on the top 6 counties that experience the most damages according to our mode
Home Elevation New Homes Low Priority	Elevate 1,565,894 new by 10ft on 77 counties

TNC Measure: Oyster Reef Restoration

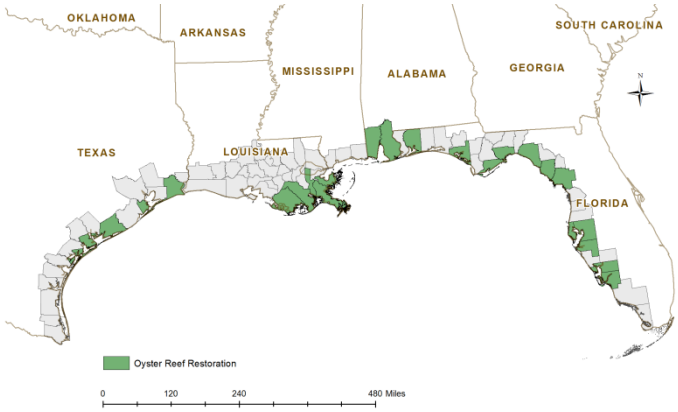
1050 miles of Oyster Reefs restored in 24 counties with high restoration suitability as identified by Restoration Explorer[1]:

Alabama: Baldwin and Mobile.

Florida: Bay, Charlotte, Dixie, Franklin, Hillsborough, Lee, Levy, Manatee, Pinellas, Santa Rosa, Taylor, Wakulla, and Jefferson.

Louisiana: Lafourche, Plaquemines, St. Bernard, Terrebonne, Aransas.

Texas: Calhoun, Galveston, Jefferson, and Matagorda.



Penetration (% of assets that will benefits from measure)

15% to 50%

Unit Cost of Measure :[2]

$1,500,000/mile of protected shoreline

Total Cost : $1.6 Billion

Co-Benefits of Oyster Reefs to Fisheries [3]:

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

Sources:

1 – Restoration Explorer: //maps.coastalresilience.org/gulfmex/

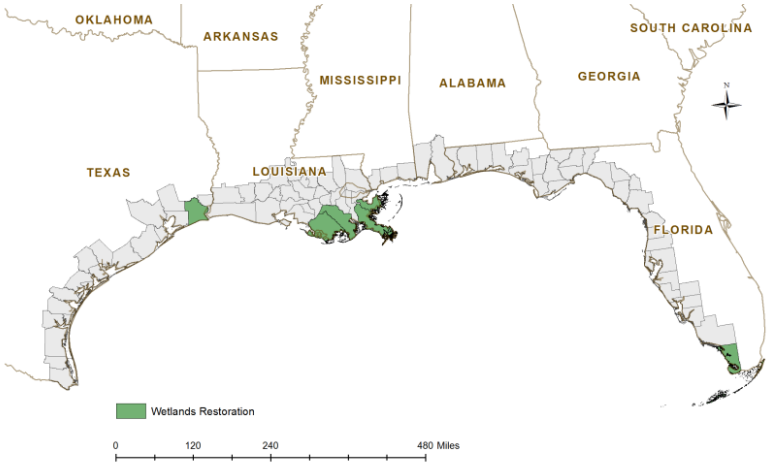
2 – TNC's Global Marine Team Calculations (see backup slide #1)

3 - Kroeger and Guannel (in prep).

TNC Measure: Wetland Restoration (Conservation Priority)

125 miles of Wetlands Restored in the following Counties:

Monroe, FL	**25 miles**
La Fourche, LA	**25 miles**
Plaquemines, LA	**25 miles**
St. Bernard, LA	**25 miles**
Jefferson, TX	**25 miles**



Penetration (% of assets that will benefits from measure)

50% of Assets protected for all counties above.

Unit Cost of Measure – assumes restoration projects are 0.5 miles deep by 1 mile accross:[1]

$25,000,000/mile[1]

Total Cost : $3,1Billion

Co-Benefits of Wetlands to Fisheries[2]:

$28,734 / mile of shoreline protected / year.

Sources:

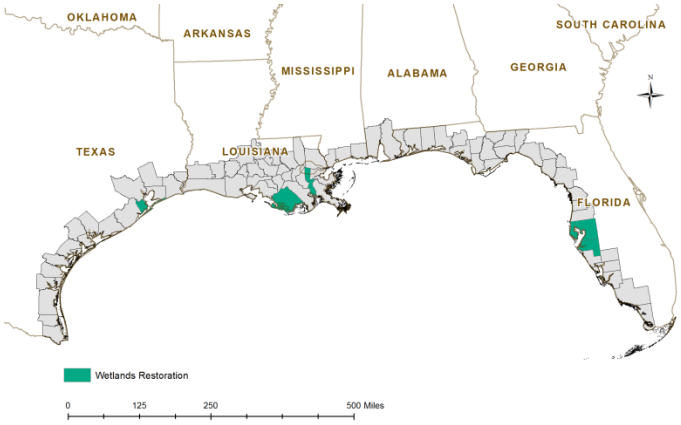
1 – TNC's Global Marine Team Calculations (see backup slide #1)

2 - Adapted from Woodward & Wui (2000)

TNC Measure: Wetland Restoration (Risk Reduction Priority)

100 miles of Wetlands Restored at the 6 Counties with the highest losses in assets and where at least 25 miles of salt marsh could be restored) by bay:

Hillsborough, Pinellas and Manatee, FL	**25 miles**
Galveston, TX	**25 miles**
Terrebonne , LA	**25 miles**
Jefferson, LA	**25 miles**



Penetration (% of assets that will benefits from measure)

50% of Assets protected at all counties above.

Unit Cost of Measure – assumes restoration projects are 0.5 miles deep by 1 mile accross:[1]

$25,000,000/mile[1]

Total Cost : $2,5Billion

Co-Benefits of Wetlands to Fisheries[2]:

$28,734 / mile of shoreline protected / year.

Sources:

1 – TNC's Global Marine Team Calculations (see backup slide #1)

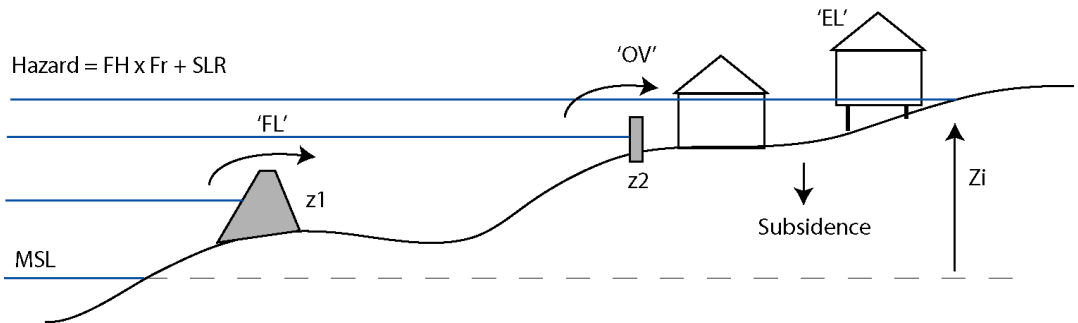
2 - Adapted from Woodward & Wui (2000)

Adaptation Parameterization

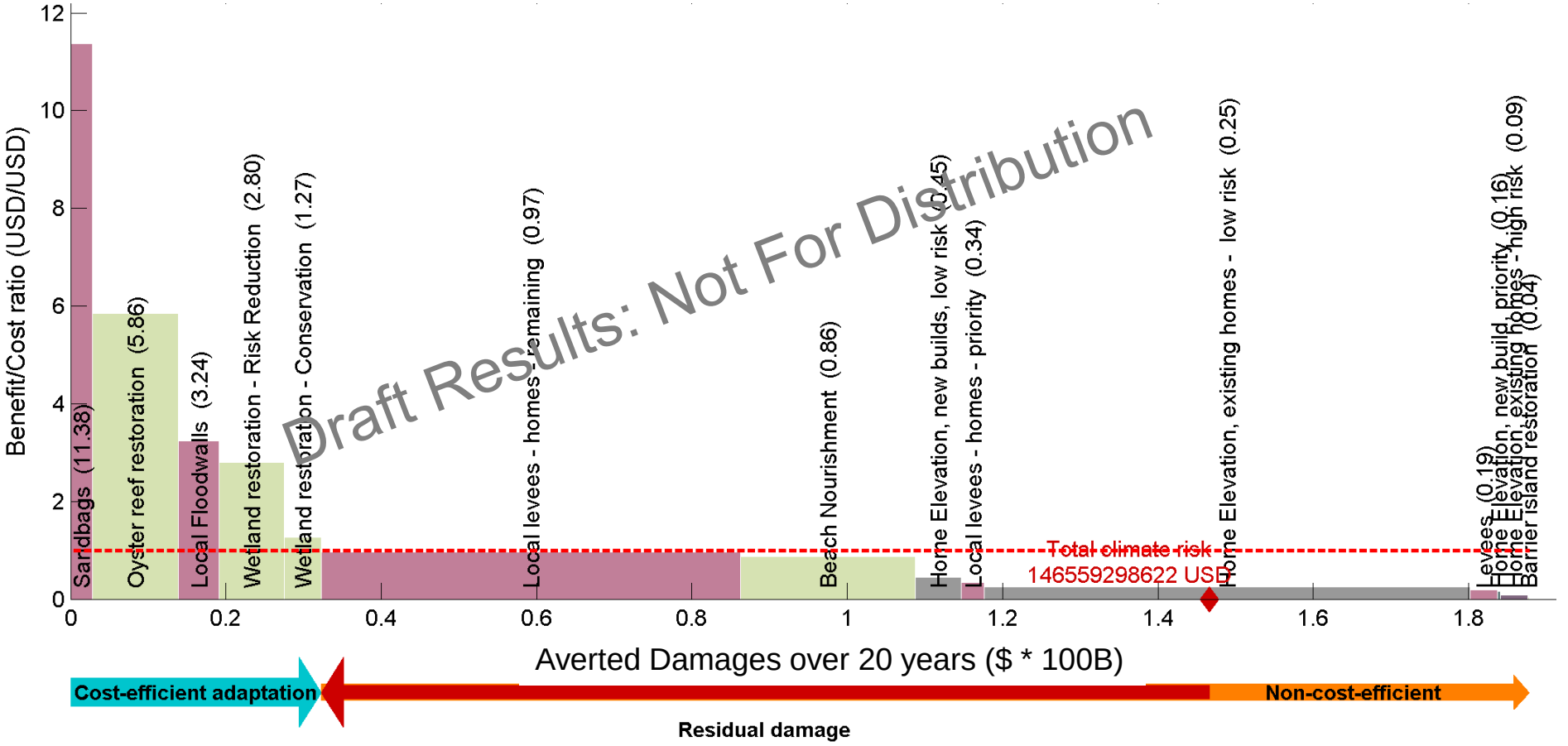
MEASURE	SCENARIO 1 (CONSERVATIVE)			
	% Wave Reduction	% Surge Reduction	hazard elevation cutoff (m)	type cutoff
Local levees - homes	20	0	1.8	overtopping
Levees	60	0	6	frontline
Sandbags	0	0	0.6	overtopping
Beach Nourishment	75	0	0	
Local Floodwalls	0	0	1.2	overtopping
Home Elevation	0	0	3	elevation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

dz = Hazard + subsidence - Zi

D(i) = MDD(dz) * PAA(dz)



Benefit:Cost Analysis – Measures for Risk Reduction



Analysis – 2030, Low Econ Growth, Conservative estimates NbD cost and effectiveness

SNAP Group on Coastal Defenses

TNC, WCS and NCEAS

Bringing together leading ecologists, economists, engineers and policy wonks to

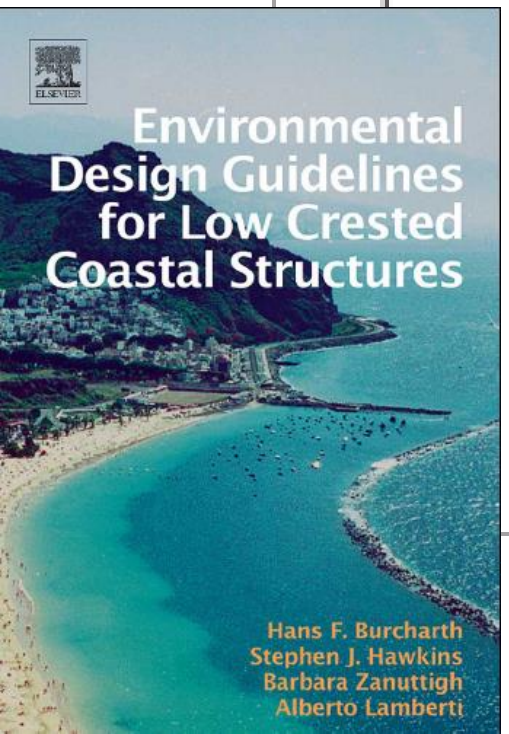
- Provide evidence & databases on when, where and how investments in natural defenses are cost-effective;
- Develop practical guidance for decision-makers & practitioners to implement solutions;
- Identify policy and financial incentives that lead to reduced risks for people and nature.

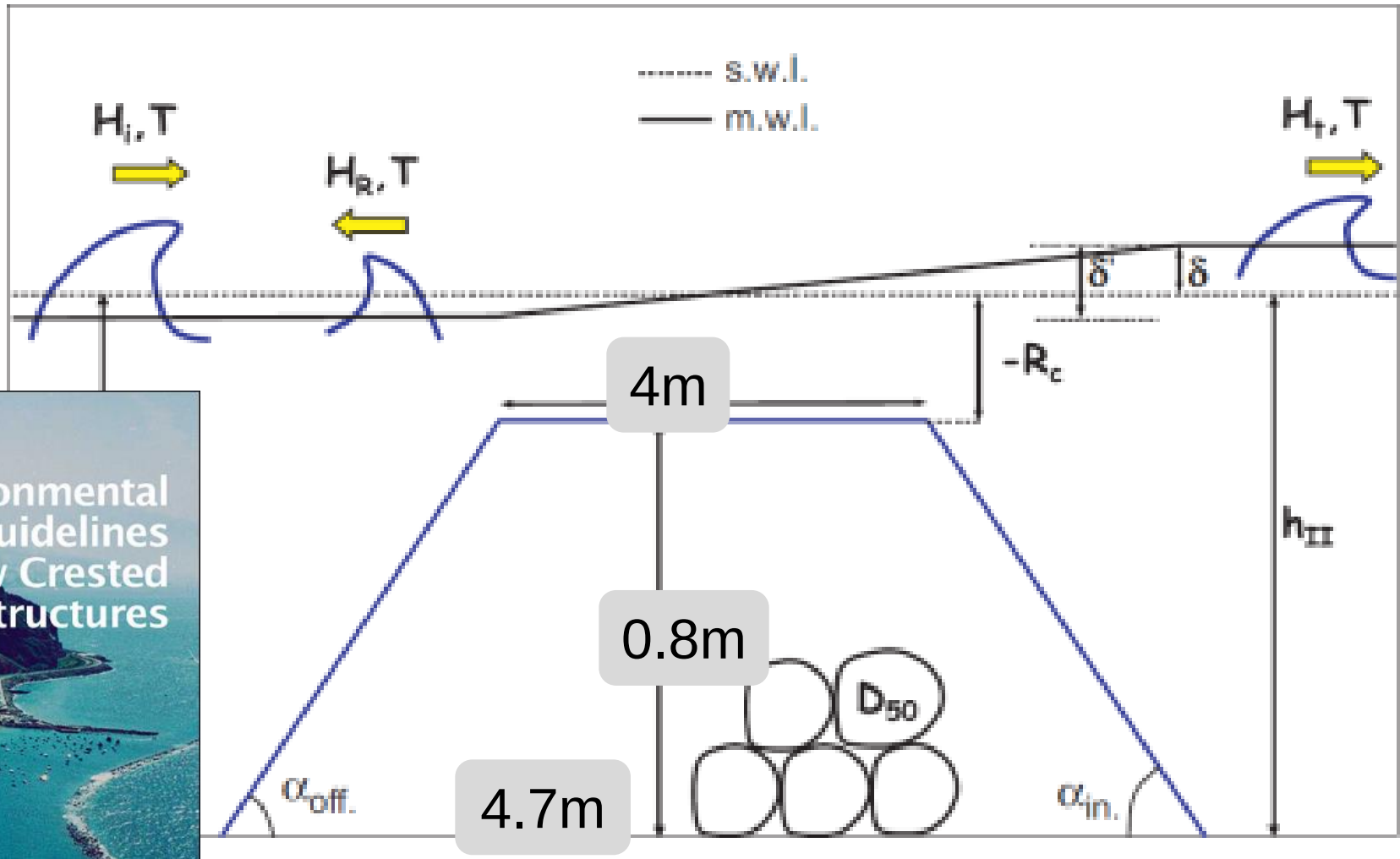
www.snap.is

Summary

- Jointly focus on hazard mitigation & conservation
- Changing How We Work
- Nature-based defenses can be cost-effective
- Opportunity to re-focus $Billions in Hazard Mitigation & Adaptation-
- Partnerships in Engineering, Re-Insurance & Aid
- Connecting Science, Tools, Policy & Demos to build *Coastal Resilience*

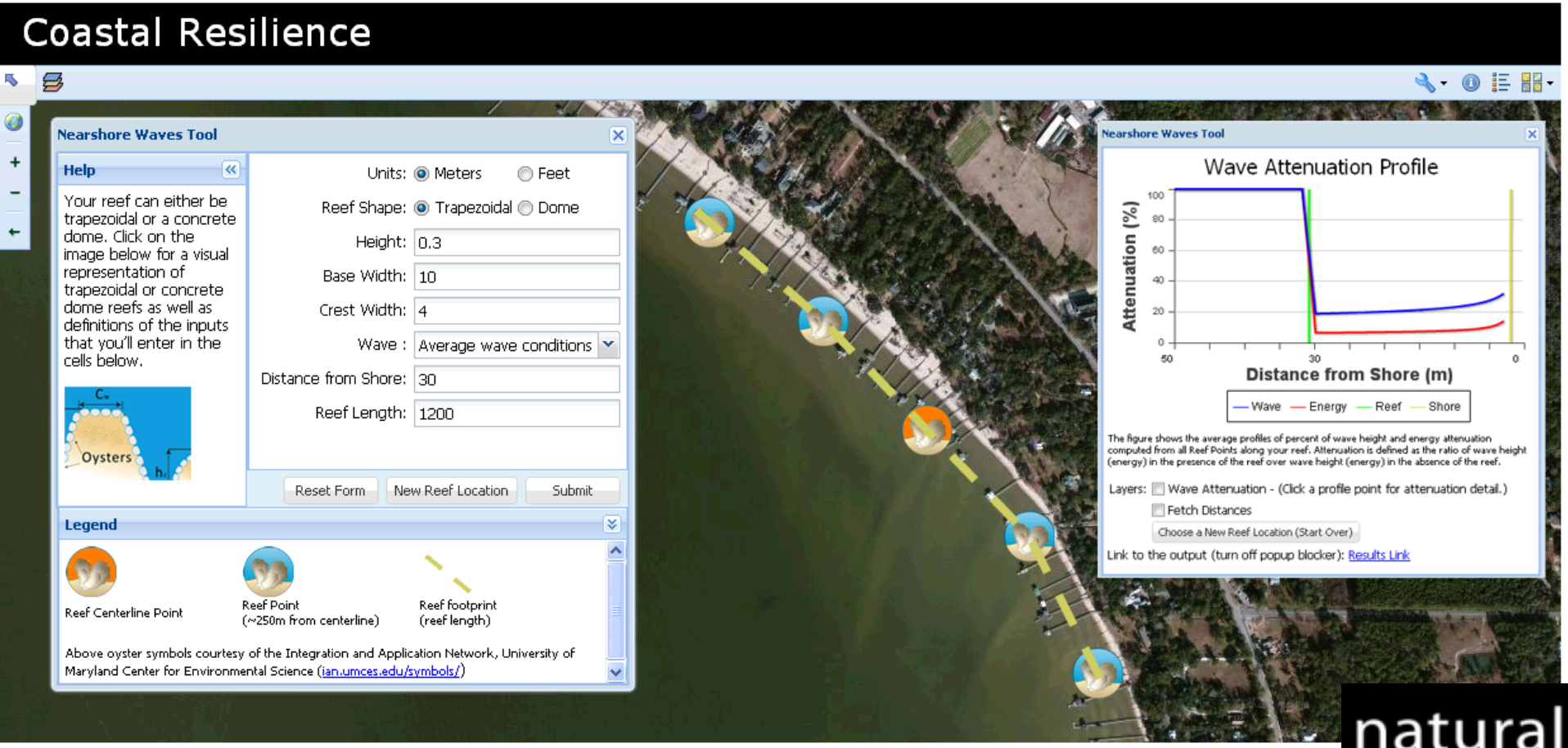
Engineering Reefs





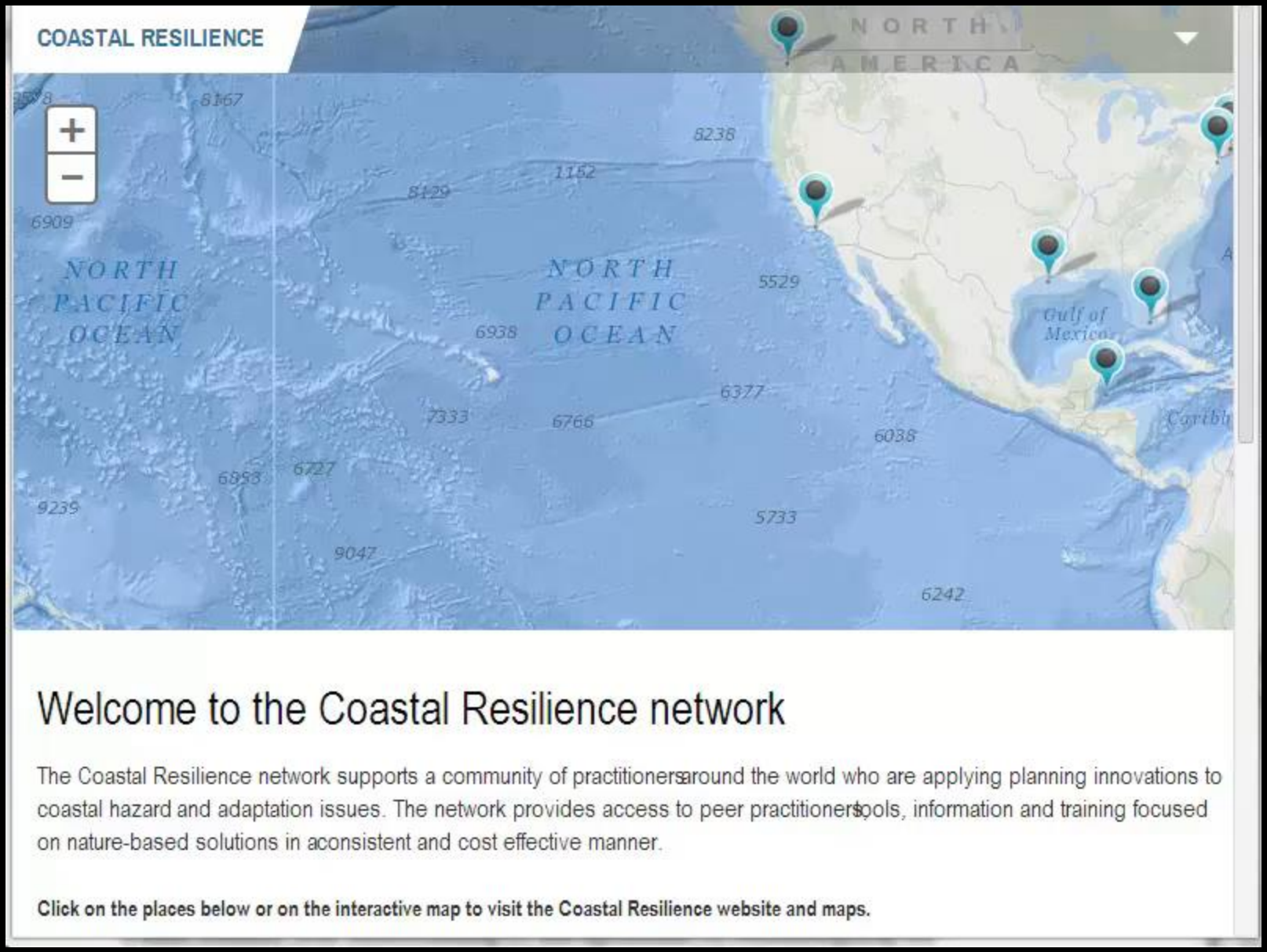
natural capital PROJECT

Designing Oyster Reefs as Breakwaters



www.maps.coastalresilience.org/Gulfmex

natural capital PROJECT



Welcome to the Coastal Resilience network

The Coastal Resilience network supports a community of practitioners around the world who are applying planning innovations to coastal hazard and adaptation issues. The network provides access to peer practitioners, tools, information and training focused on nature-based solutions in a consistent and cost effective manner.

Click on the places below or on the interactive map to visit the Coastal Resilience website and maps.