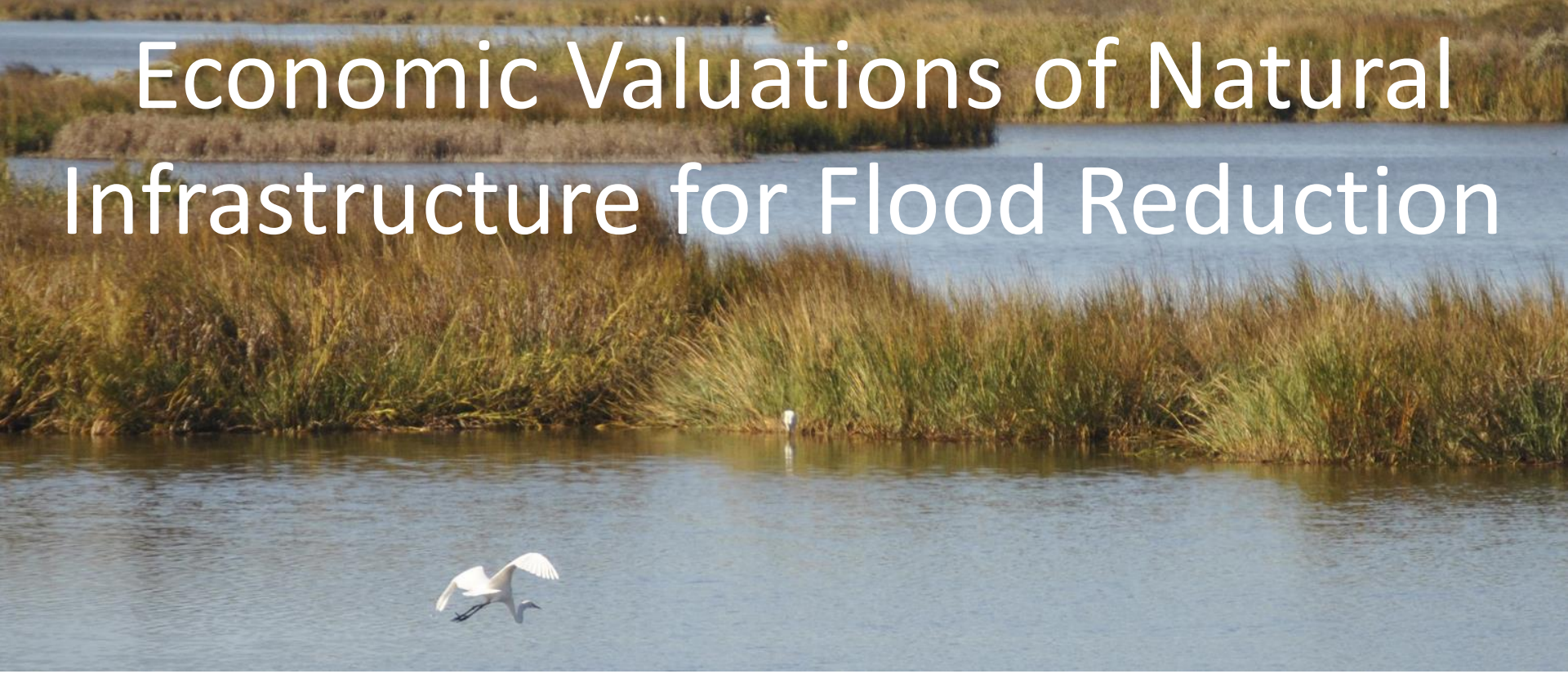
Economic Valuations of Natural Infrastructure for Flood Reduction



Michael W. Beck

UCSC Research Professor

TNC Lead Marine Scientist

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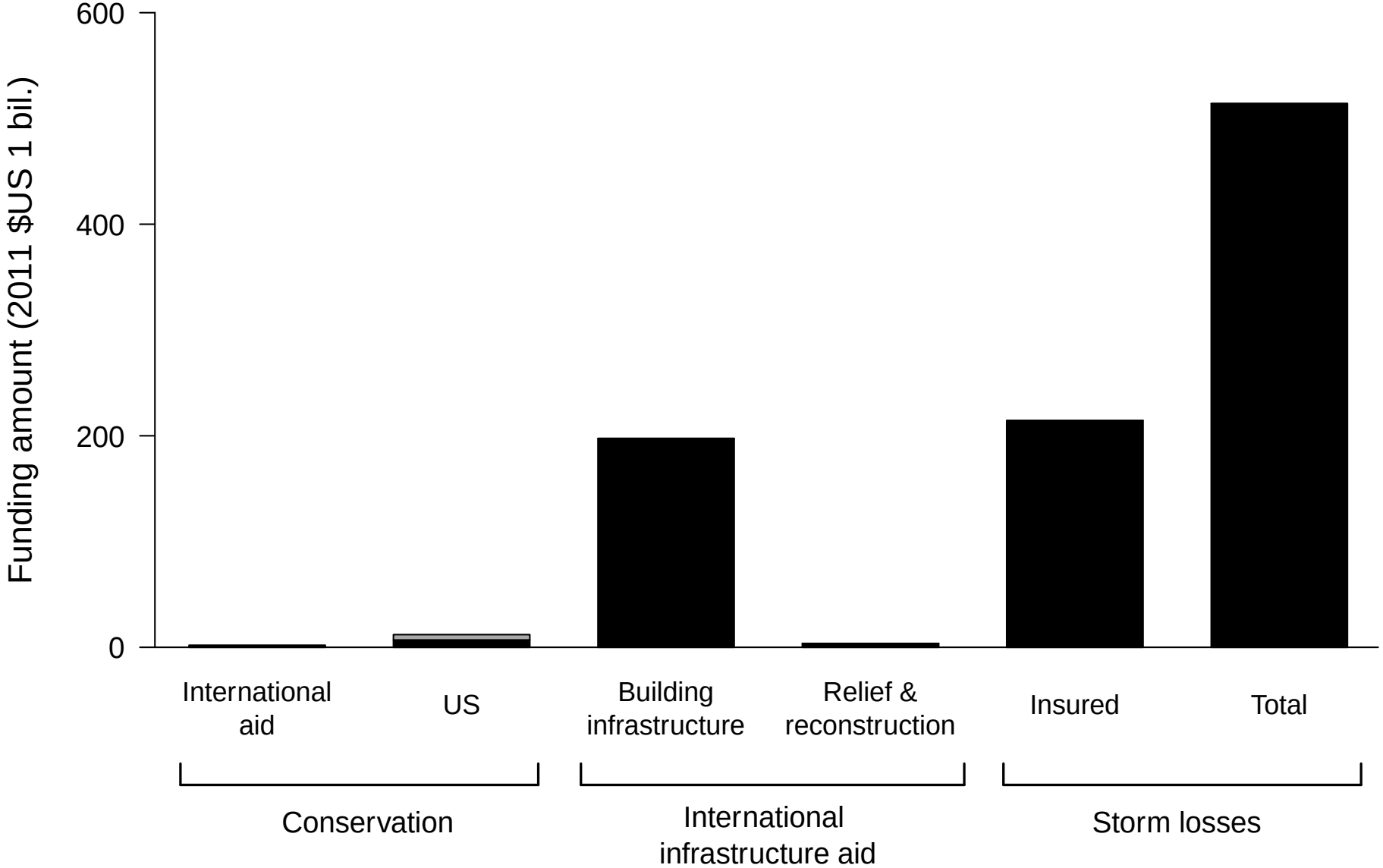
SANTA CRUZ

Coastal Funding for Conservation & Infrastructure (10 Yrs)

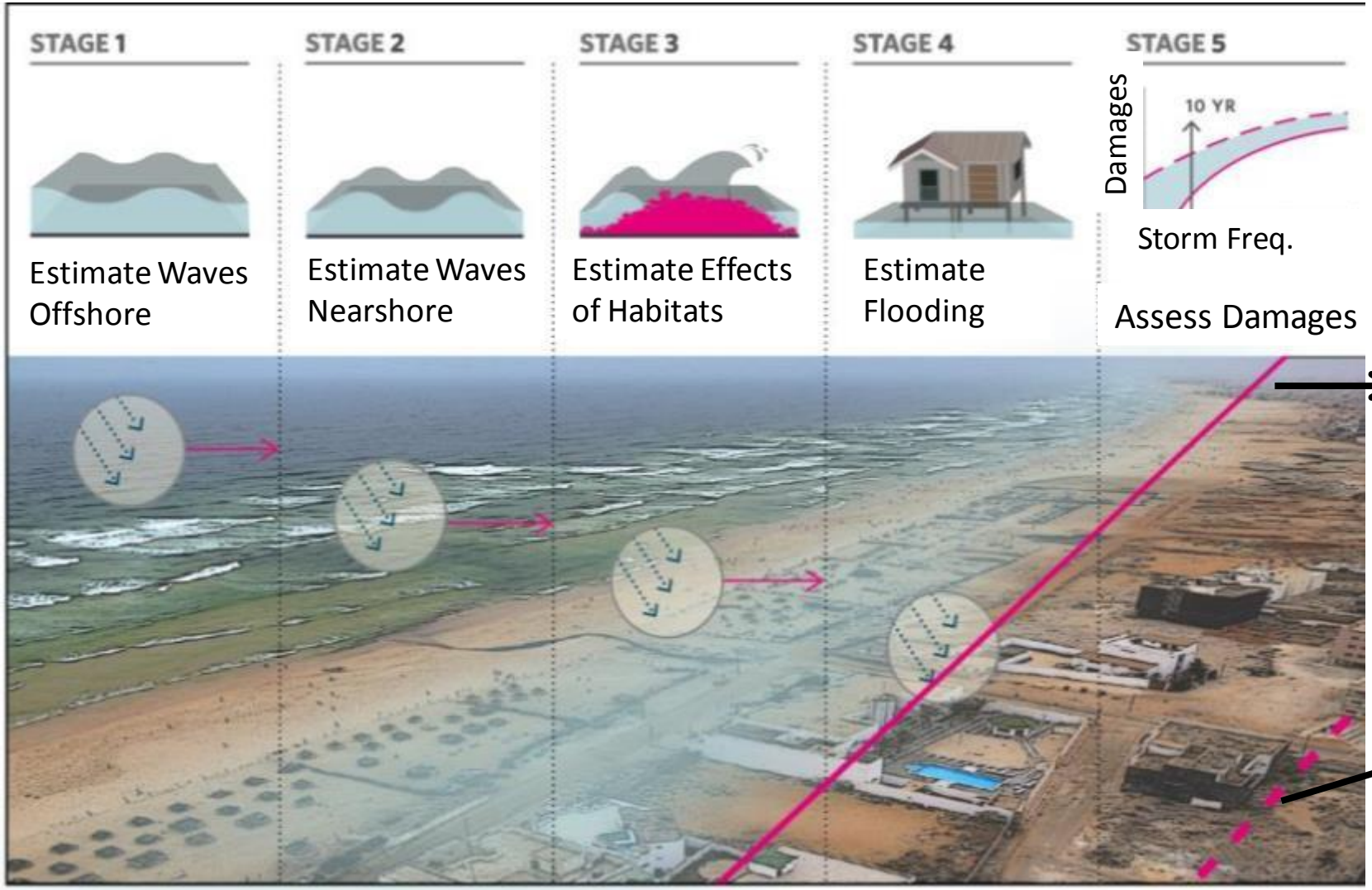


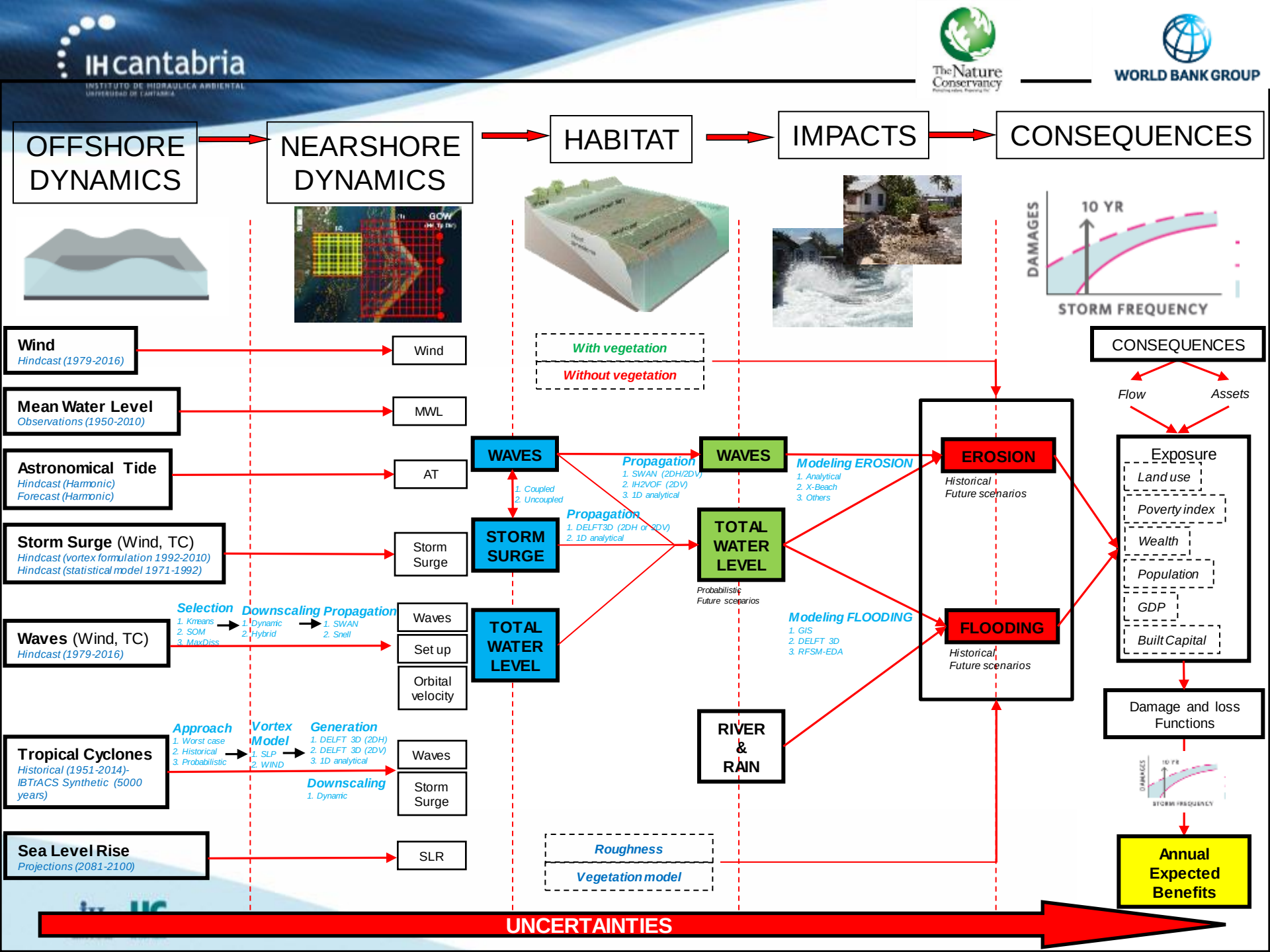
McCreless & Beck. 2017. Rethinking our global coastal investment portfolio.
Journal of Ocean & Coastal Economics

Guidelines for Valuing Coastal Protection Services from Mangroves and Reefs

M W. Beck & G-M Lange (eds)

Recommended Approach: Expected Damage Function

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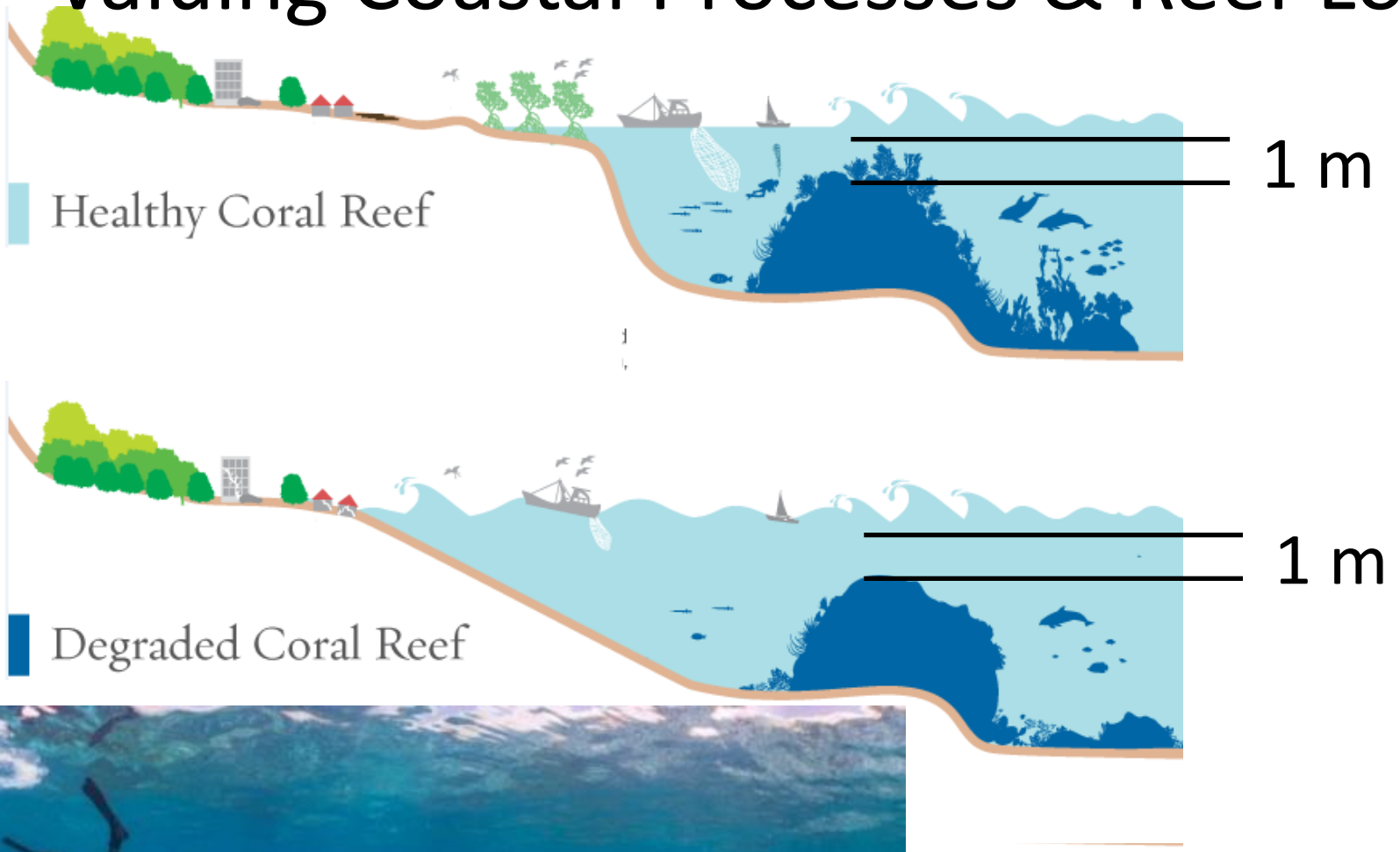
UNIVERSIDAD DE CANTABRIA
The Nature Conservancy
WORLD BANK GROUP
OFFSHORE DYNAMICS
NEARSHORE DYNAMICS
HABITAT
IMPACTS
CONSEQUENCES
GOW
10 YR
DAMAGES
STORM FREQUENCY
Wind
Hindcast (1979-2016)
Mean Water Level
Observations (1950-2010)
Astronomical Tide
Hindcast (Harmonic)
Forecast (Harmonic)
Storm Surge (Wind, TC)
Hindcast (vortex formulation 1992-2010)
Hindcast (statistical model 1971-1992)
Waves (Wind, TC)
Hindcast (1979-2016)
Tropical Cyclones
Historical (1951-2014)-IBTrACS Synthetic (5000 years)
Sea Level Rise
Projections (2081-2100)
Wind
MWL
AT
Storm Surge
Waves
Set up
Orbital velocity
Waves
Storm Surge
SLR
Selection
1. Kmeans
2. SOM
3. MaxDiss
Downscaling
1. Dynamic
2. Hybrid
Propagation
1. SWAN
2. Snell
Approach
1. Worst case
2. Historical
3. Probabilistic
Vortex Model
1. SLP
2. WIND
Generation
1. DELFT 3D (2DH)
2. DELFT 3D (2DV)
3. 1D analytical
Downscaling
1. Dynamic
WAVES
1. Coupled
2. Uncoupled
STORM SURGE
TOTAL WATER LEVEL
With vegetation
Without vegetation
Roughness
Vegetation model
Propagation
1. SWAN (2DH/2DV)
2. IH2VOF (2DV)
3. 1D analytical
Propagation
1. DELFT3D (2DH or 2DV)
2. 1D analytical
WAVES
TOTAL WATER LEVEL
Probabilistic
Future scenarios
RIVER & RAIN
Modeling EROSION
1. Analytical
2. X-Beach
3. Others
Modeling FLOODING
1. GIS
2. DELFT 3D
3. RFSM-EDA
EROSION
Historical
Future scenarios
FLOODING
Historical
Future scenarios
CONSEQUENCES
Flow
Assets
Exposure
Land use
Poverty index
Wealth
Population
GDP
Built Capital
Damage and loss Functions
Annual Expected Benefits
UNCERTAINTIES

Valuing Coastal Processes & Reef Loss

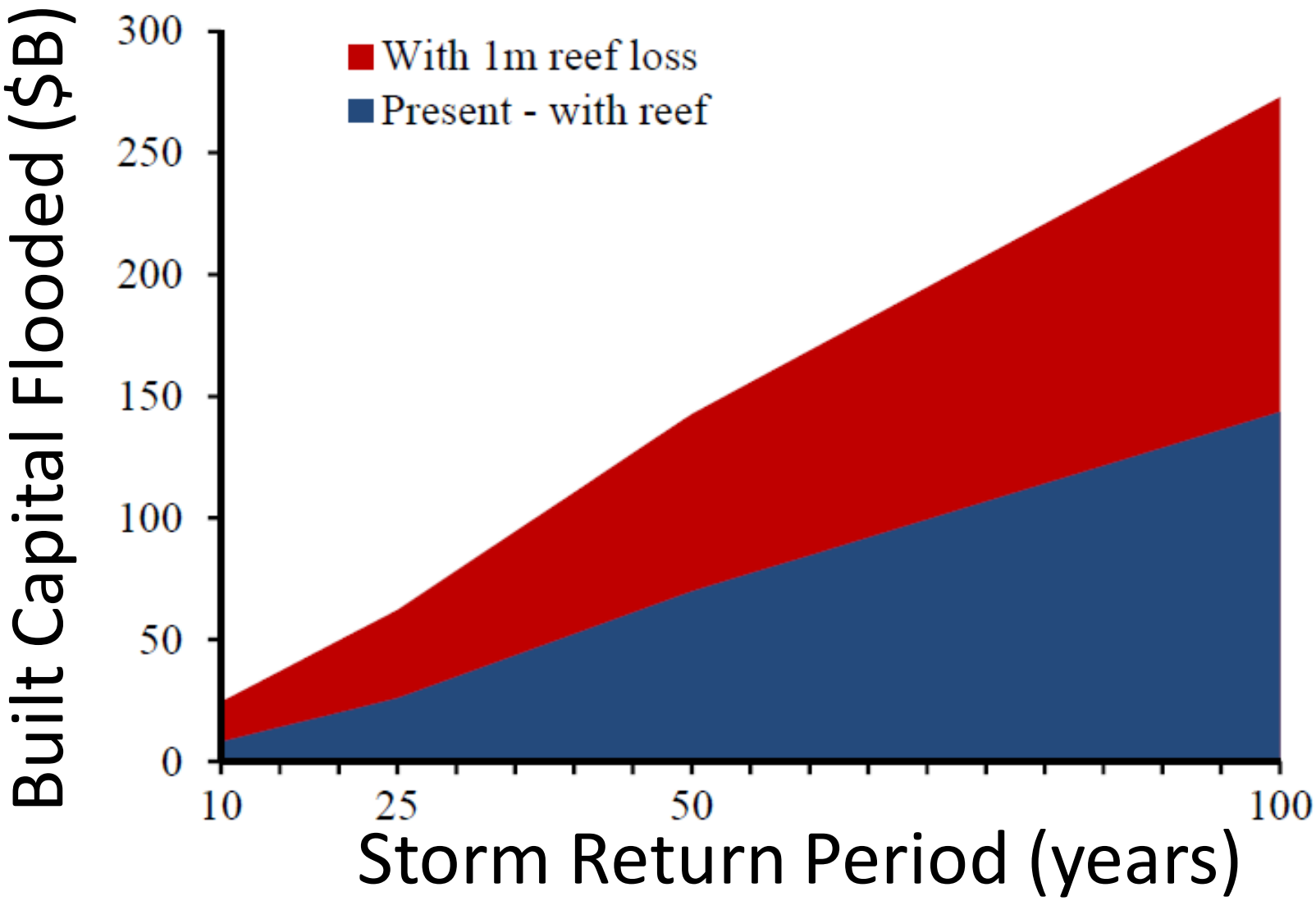


Flooding (25 - Year Event)

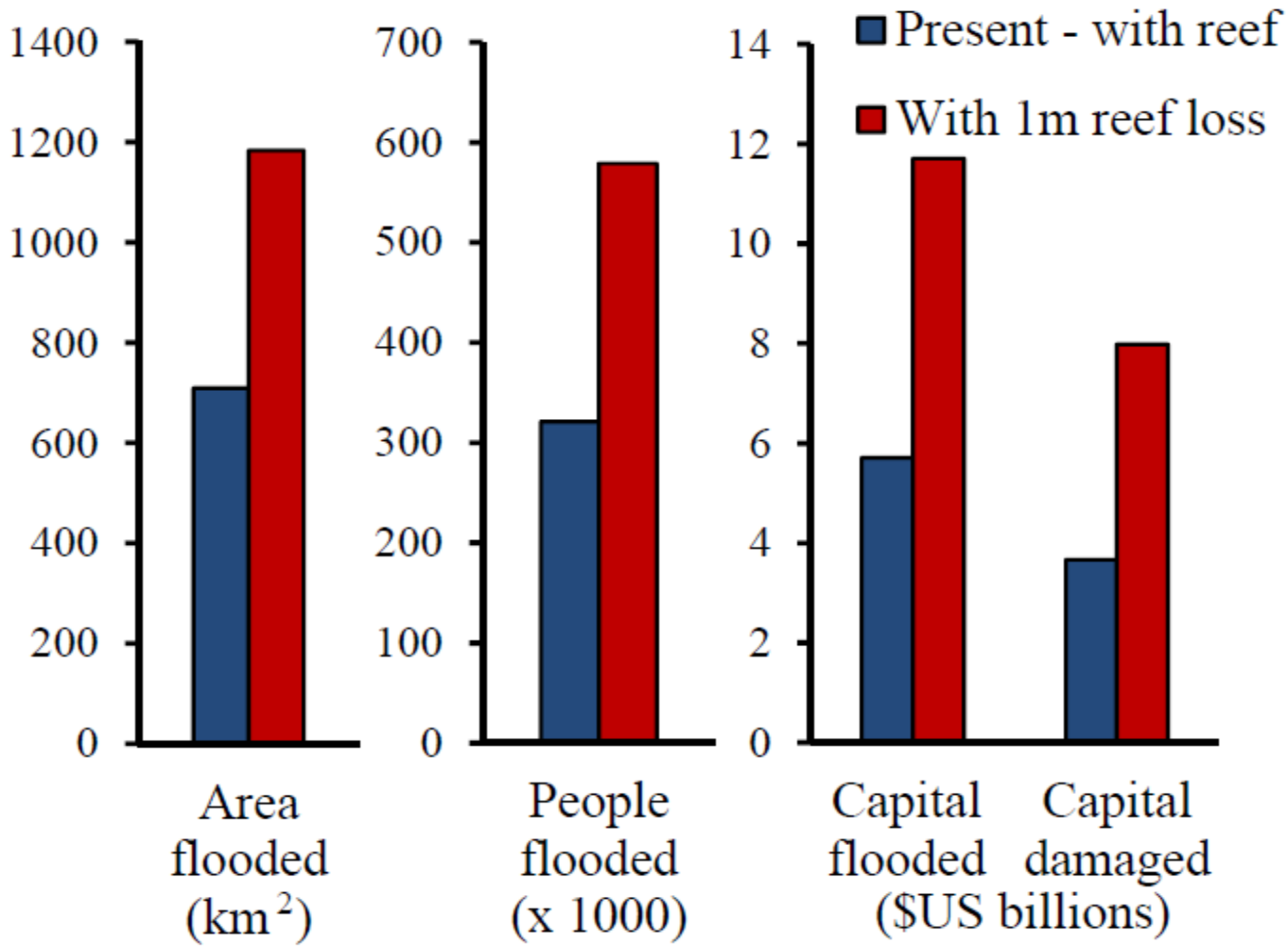
- Current Flooding
- Flooding With 1m Reef Loss

Playa del Carmen

Global Flood Protection Savings from Coral Reefs

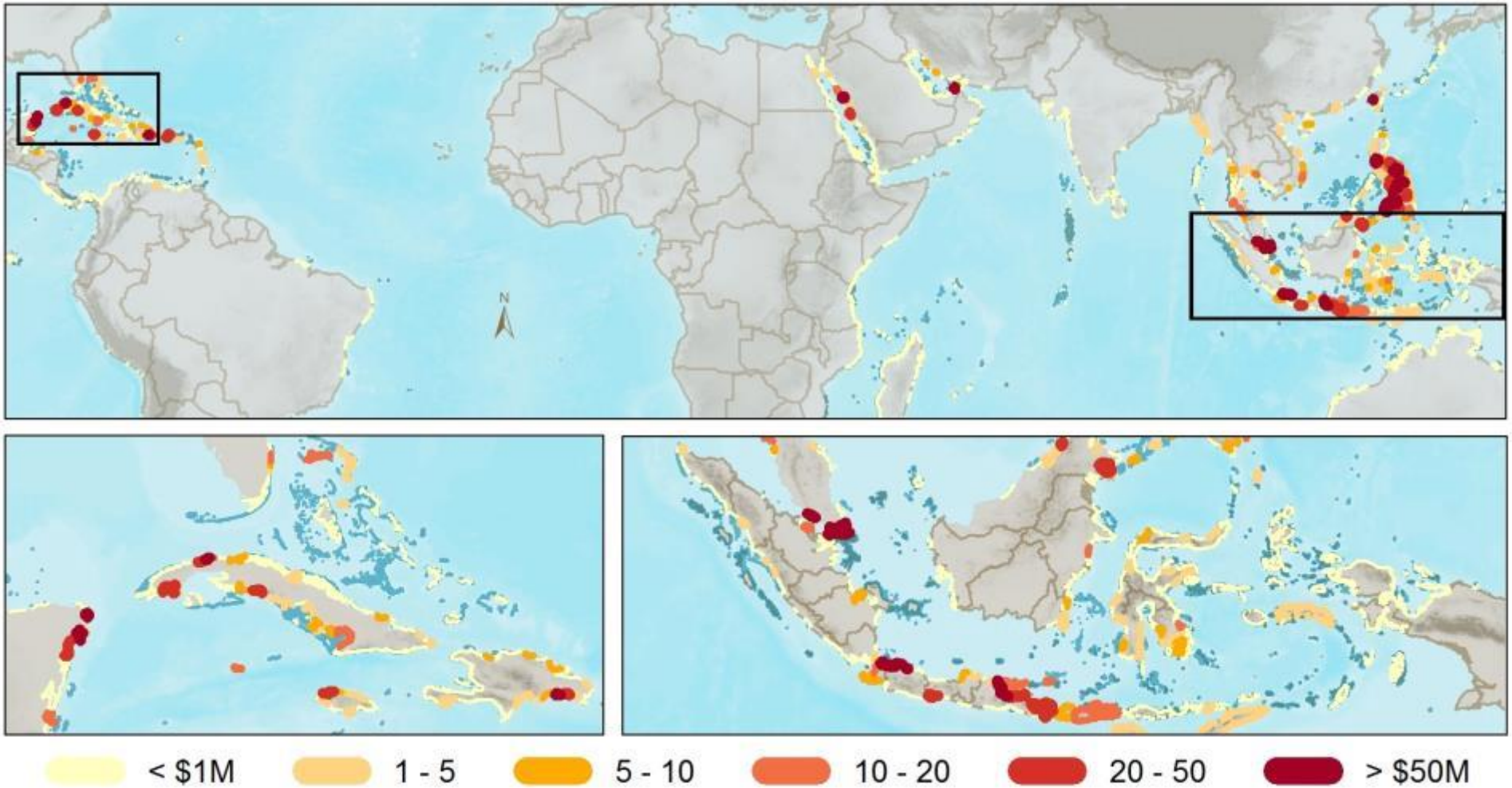


Annual Benefits of Reefs for Flood Reduction



Beck et al. 2018. *Nature Communications*.

Annual Expected Benefits from Reefs:
Avoided Flood Damage in $M/20 km coastline



Beck et al. 2018. *Nature Communications*.

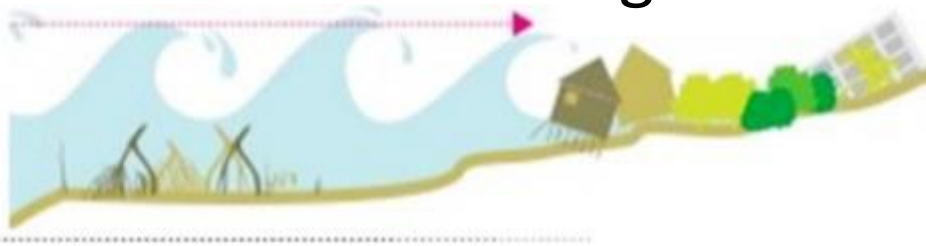
Annual Expected Benefits of Reefs for Flood Protection

	Annual Averted Damages ($Millions)		Annual Averted Damages/GDP	
1	Indonesia	639	Cayman Islands	0.98
2	Philippines	590	Belize	0.37
3	Malaysia	452	Grenada	0.30
4	Mexico	452	Cuba	0.25
5	Cuba	401	Bahamas	0.16
6	Saudi Arabia	138	Jamaica	0.14
7	Dominican Republic	96	Philippines	0.13
8	United States	94	Antigua and Barbuda	0.13
9	Taiwan	61	Dominican Republic	0.11
10	Jamaica	46	Malaysia	0.09
11	Vietnam	42	Seychelles	0.06
12	Myanmar	33	Turks and Caicos	0.06
13	Thailand	32	Guadeloupe	0.05
14	Bahamas	14	Indonesia	0.04
15	Belize	9	Solomon Islands	0.04

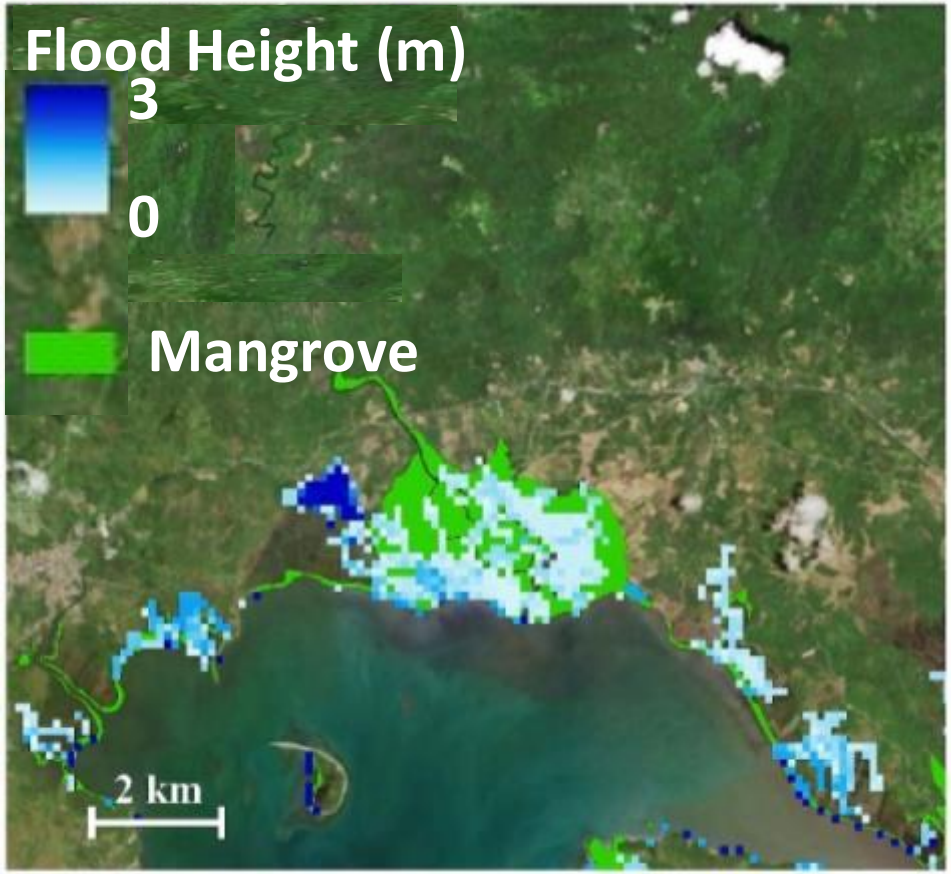
Estimating Flooding Benefits Globally

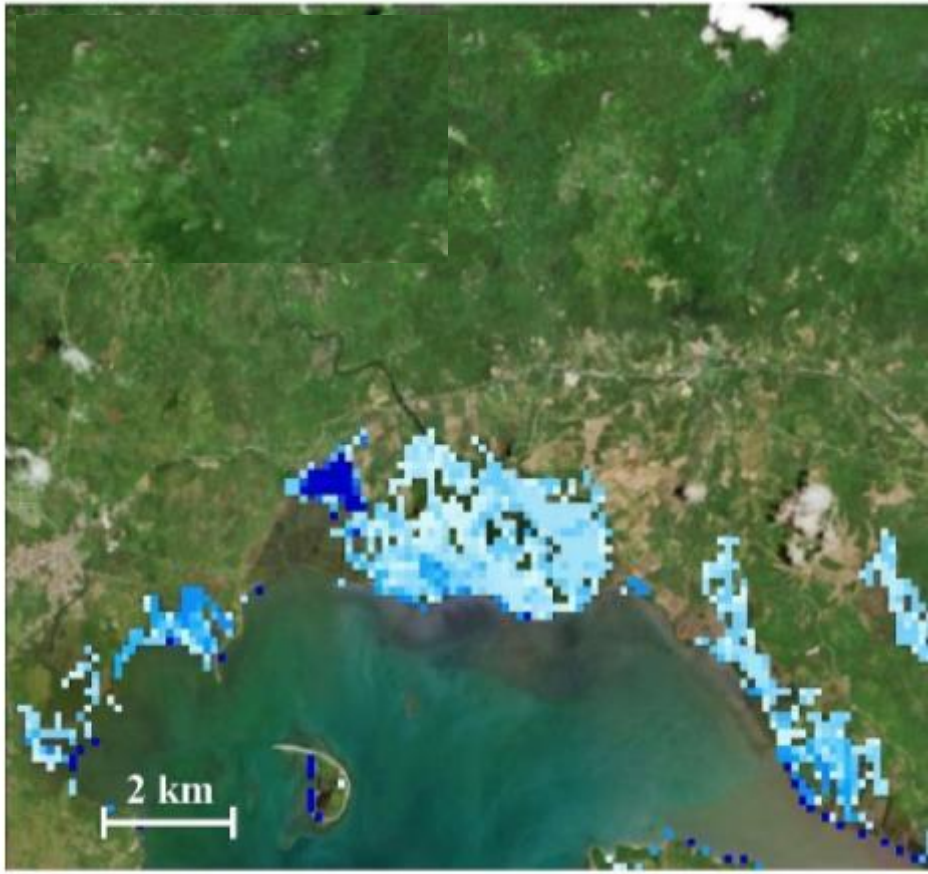
With Mangrove

Without Mangrove

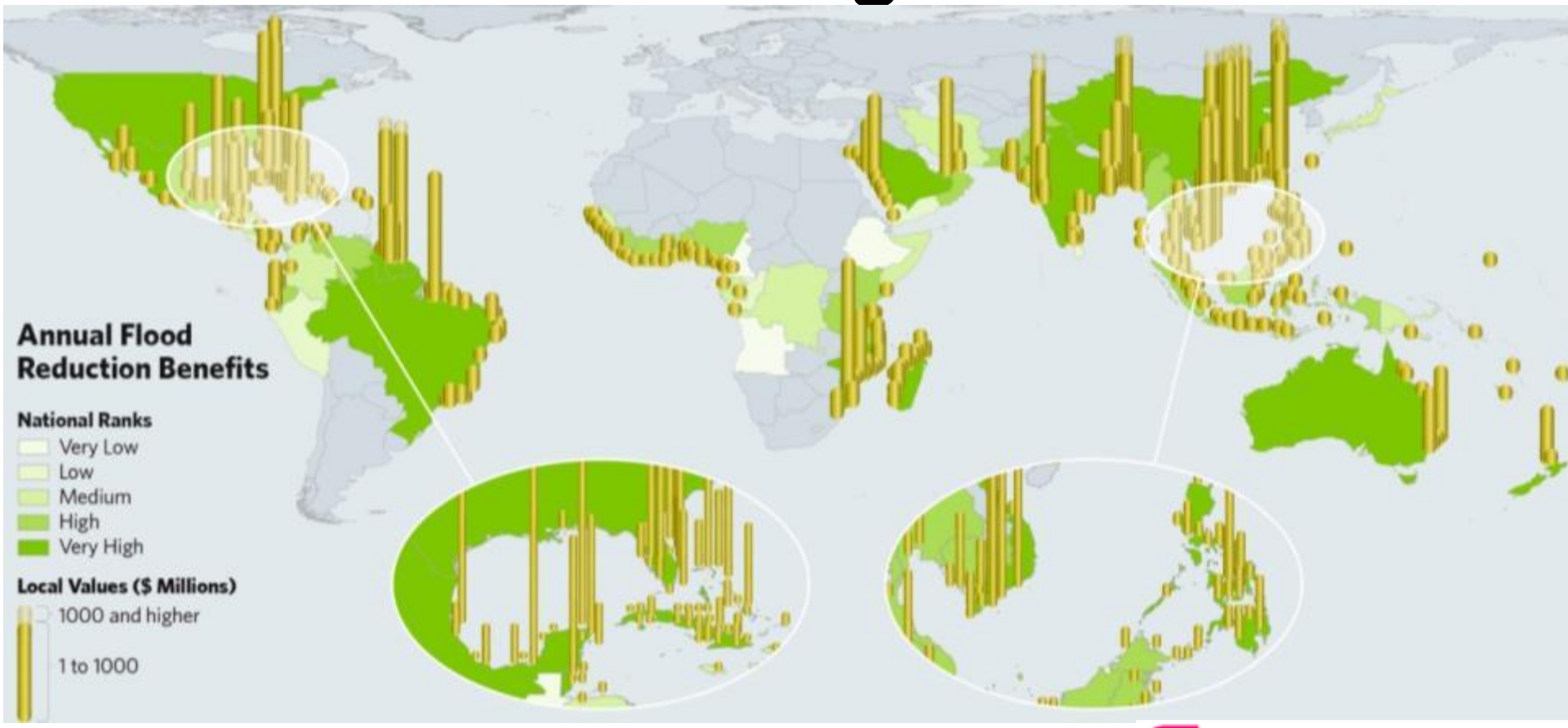


50-year flood





Annual Flood Reduction Benefits from Mangroves



Losada, Beck etal. 2018. [The global value of mangroves for risk reduction](). TNC, Berlin.

Bündnis Entwicklung Hilft

Gemeinsam für Menschen in Not.

Countries Where Mangroves Provide Greatest Annual Flood Reduction Benefits

People Protected (millions)		Property Protected (US $ Billions)		Property Protected per GDP
Vietnam	8.1	China	19	Guyana
India	3.3	United States	13	Belize
Bangladesh	1.3	India	9	Bahamas
China	0.8	Mexico	9	Suriname
Philippines	0.7	Vietnam	7	Mozambique
Brazil	0.4	Guyana	7	Vietnam
Nigeria	0.4	Mozambique	2	Guinea-Bissau
Indonesia	0.3	Saudi Arabia	2	Madagascar
Mozambique	0.3	Bangladesh	2	Benin
Mexico	0.3	Bahamas	2	Sierra Leone

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

www.lloyds.com/coastalresilience

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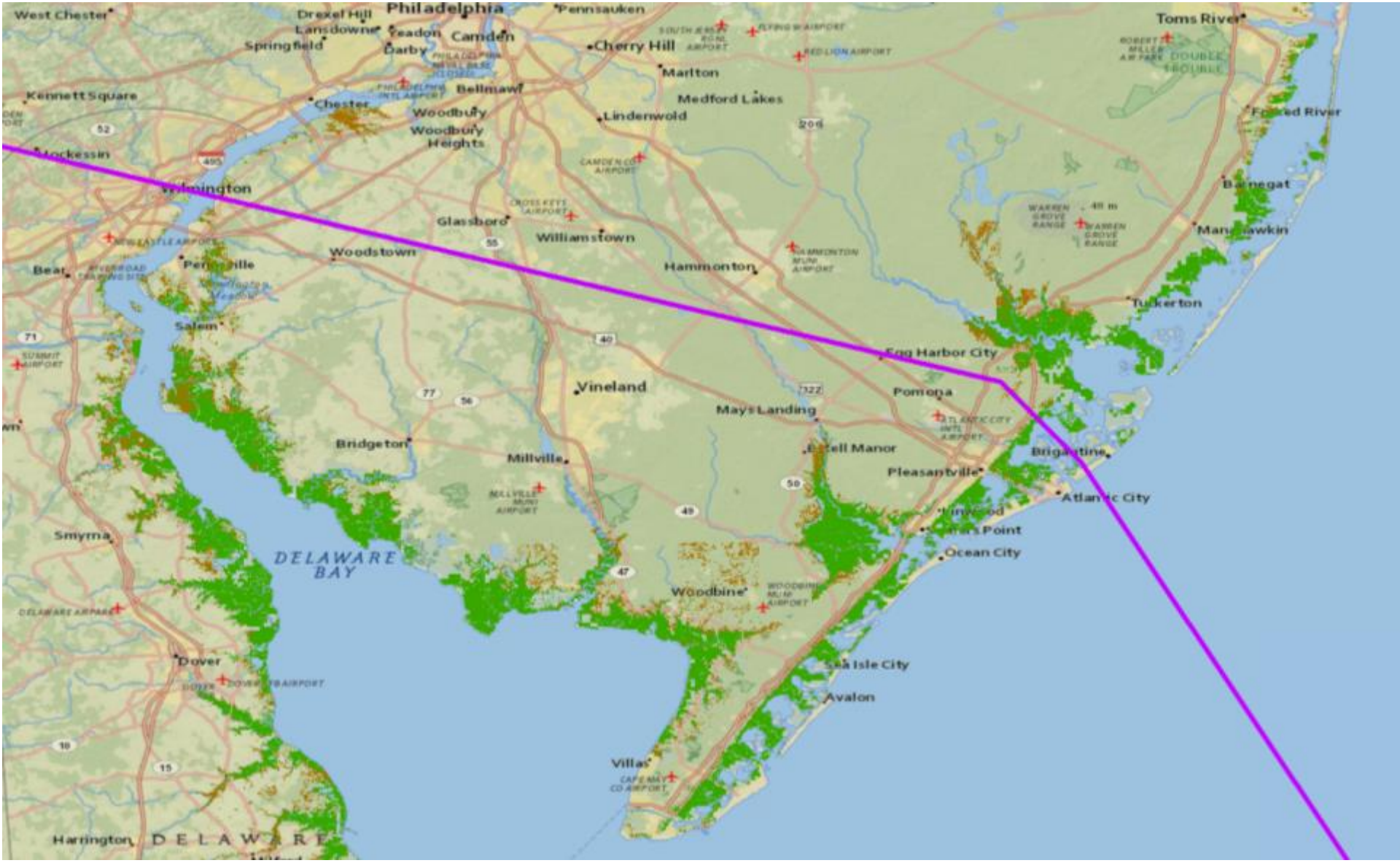
Wildlife Conservation Society

GUY CARPENTER

RMS

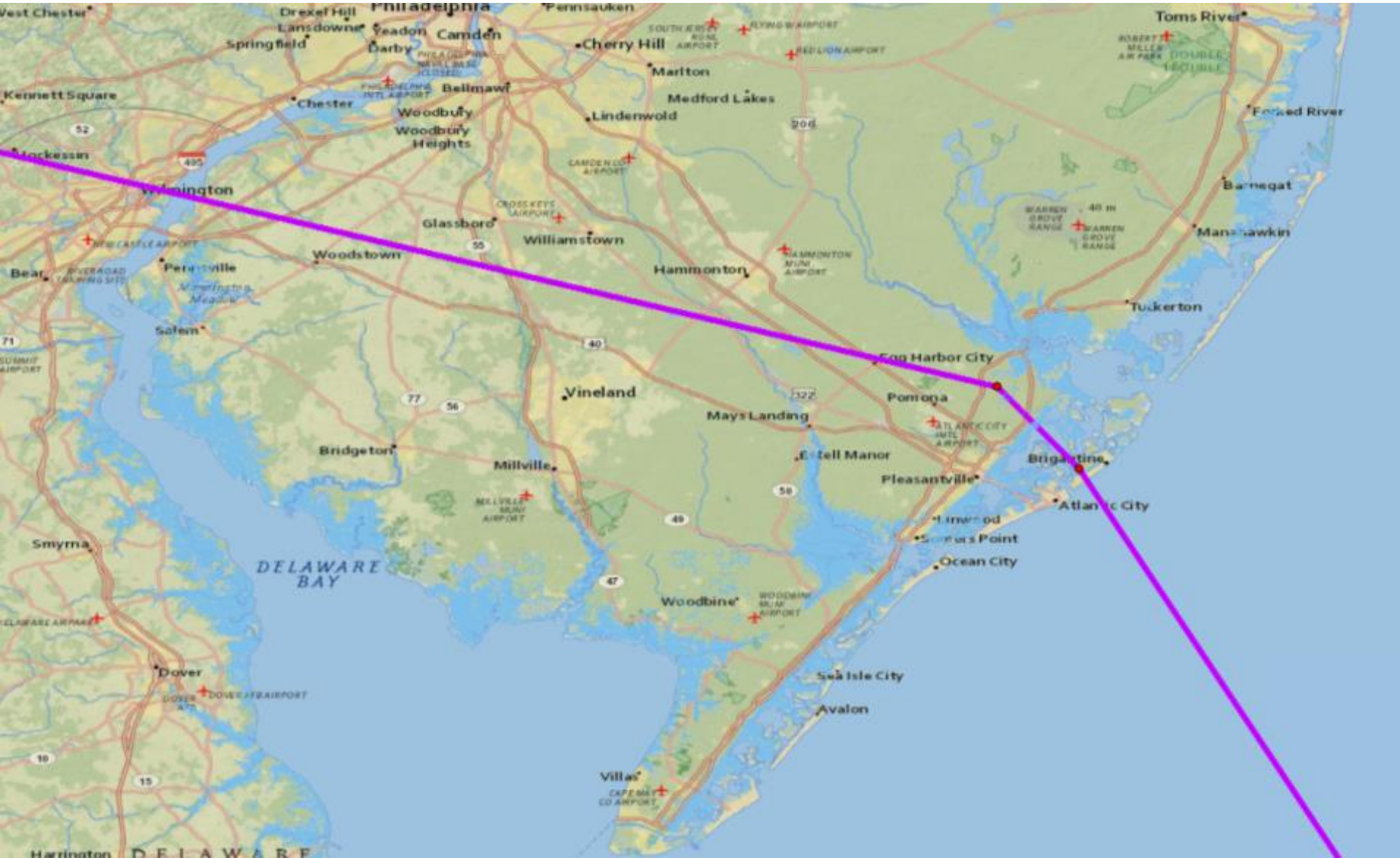
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Scenario I: Flood Damages with Present-day Wetlands

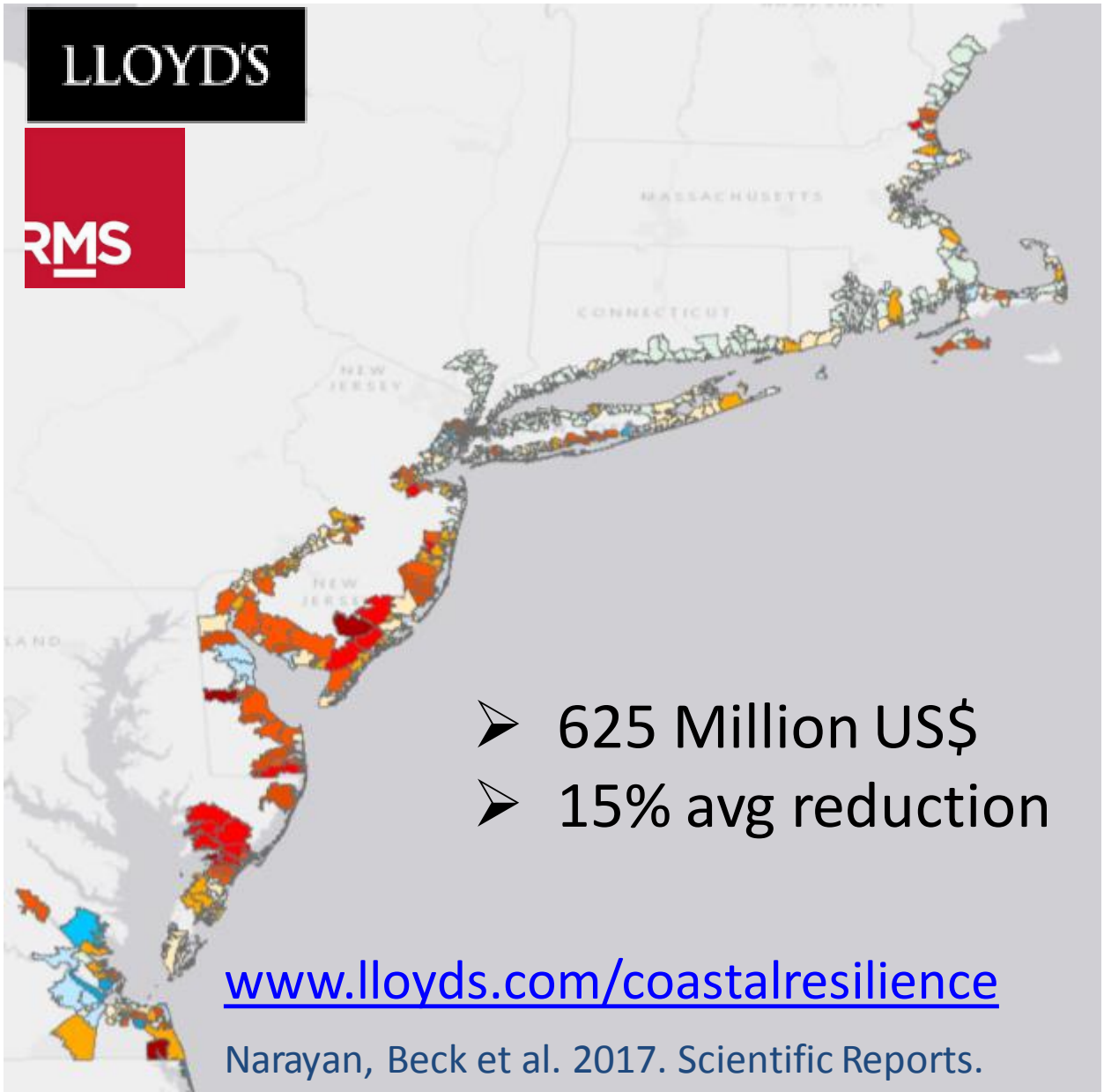


Wetland Effects on Property Damage Reduction during Hurricane Sandy

Scenario II: Flood Damages with Wetland Loss



Effects of Marshes on Sandy Flood Damages



- 625 Million US$
- 15% avg reduction

www.lloyds.com/coastalresilience

Narayan, Beck et al. 2017. Scientific Reports.

Difference in Losses (%)

- <-60
- -60 to - 50
- -50 to -25
- -25 to -10
- -10 to -5
- -5 to -0.5
- 0
- 0.5 to 5
- 5 to 10
- 10 to 25
- 25 to 50
- 50 to 100
- >100

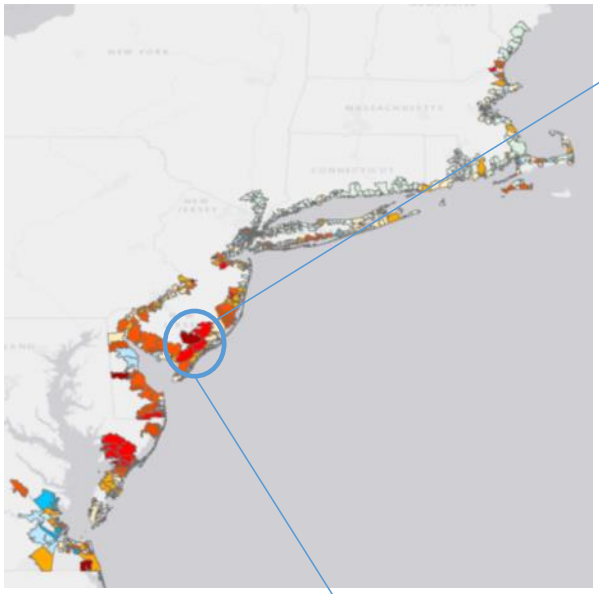
Wetland Effects on Property Damage Reduction during Hurricane Sandy

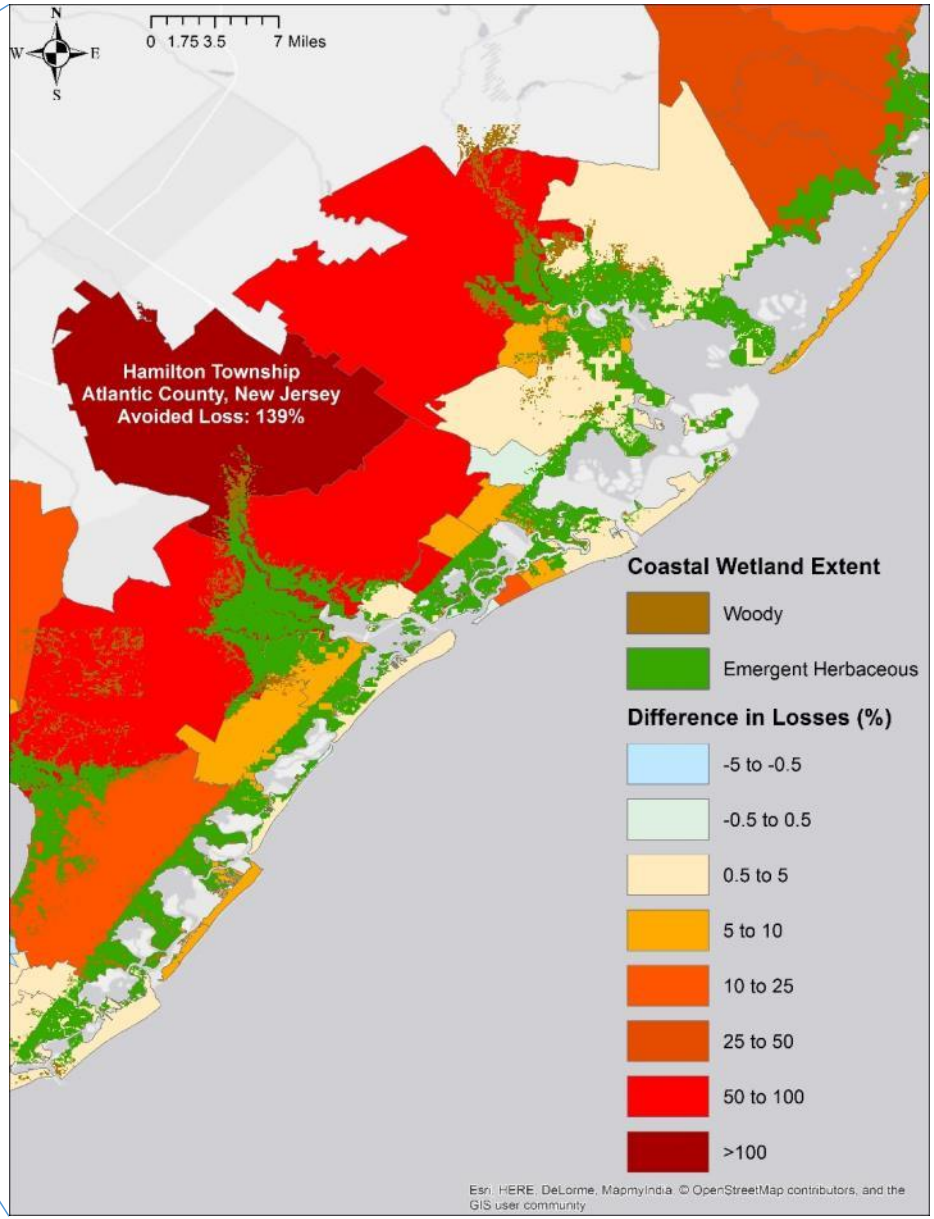
Difference in Flood Between Wetland Scenarios

State	At Present ($)	With Wetland Loss ($)	Absolute Difference ($)	% Difference
Connecticut	2,181,600,000	2,181,000,000	400,000	0.02
Delaware	228,100,000	251,900,000	23,800,000	10.44
Massachusetts	1,452, 300,000	1,458,600,000	6,300,000	0.43
Maryland	15,500,000	20,000,000	4,500,000	29.07
Maine	17,600,000	17,600,000	3,000*	0.02
North Carolina	9,500,000	8,800,000	-600,000	-6.47
New Hampshire	29,600,000	30,500,000	900,000	3.06
New Jersey	14,014,600,000	14,443,300,000	428,700,000	3.06
New York	32,314,600,000	32,452,800,000	138,200,000	0.43
Pennsylvania	174,400,000	188,000,000	13,700,000	7.85
Rhode Island	72,100,000	72,400,000	300,000	0.43
Virginia	195,400,000	205,300,000	9,900,000	5.06

Wetland Effects on Property Damage Reduction during Hurricane Sandy

Key Findings: Cumulative effects upstream

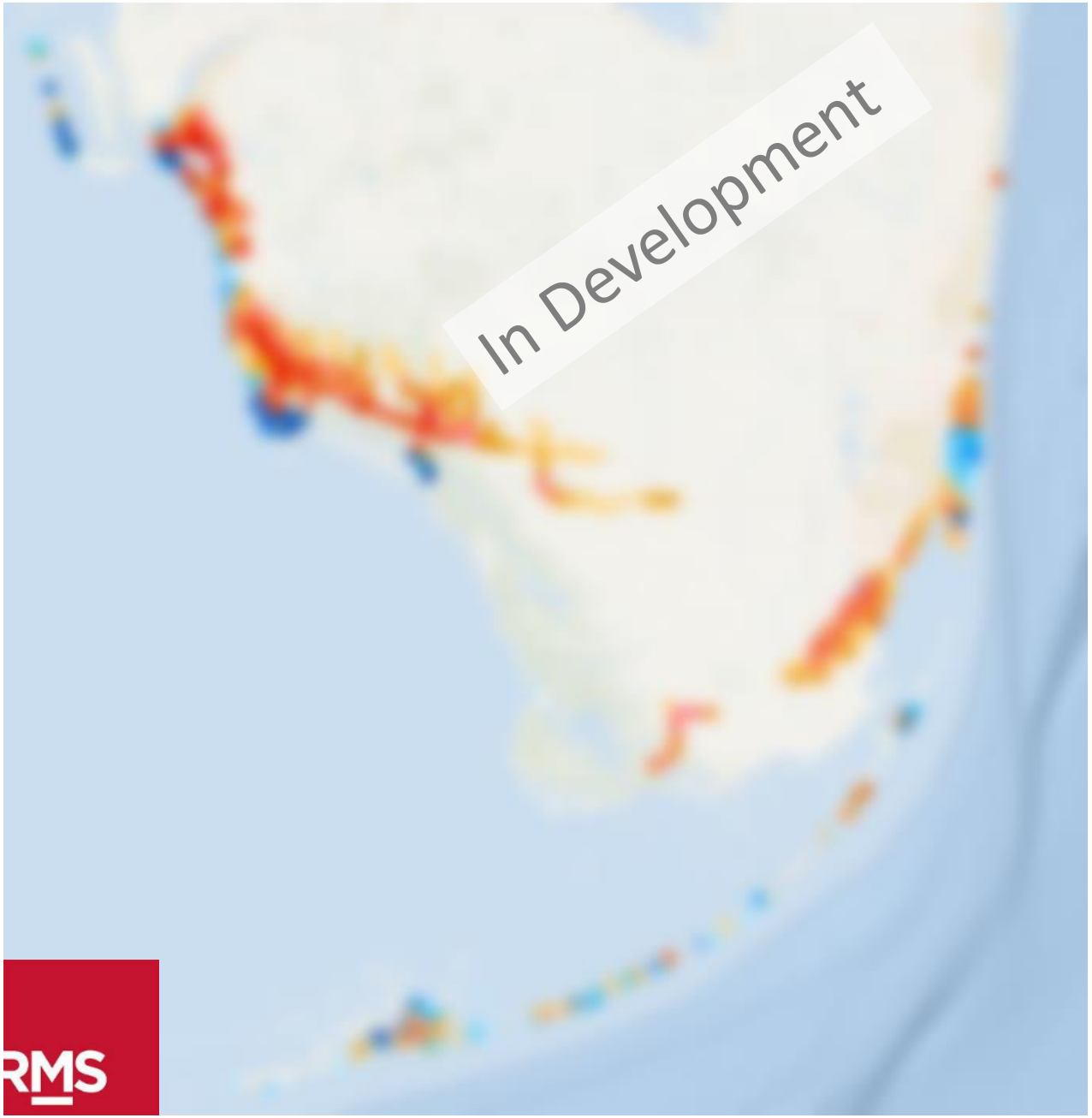




Middle Township, NJ

Photo credit: Metthea Yepsen, TNC

Property Damage Reduction By Mangroves During Hurricane Irma



Catalyzing Public and Private Investment In Reef Restoration

- Significant Funding
- Insurance opportunities
- Recovery Funding is biggest source
- Need critical data on benefits & costs
- All approaches for funding gray infra open to Nat Infra

Financing Natural Infrastructure
For Coastal Flood Damage Reduction

LLOYD'S

www.lloyds.com/coastalresilience

Middlebury Institute of International Studies at Monterey
Center for the Blue Economy

University of California Santa Cruz

The Nature Conservancy

Wildlife Conservation Society

Swiss Re

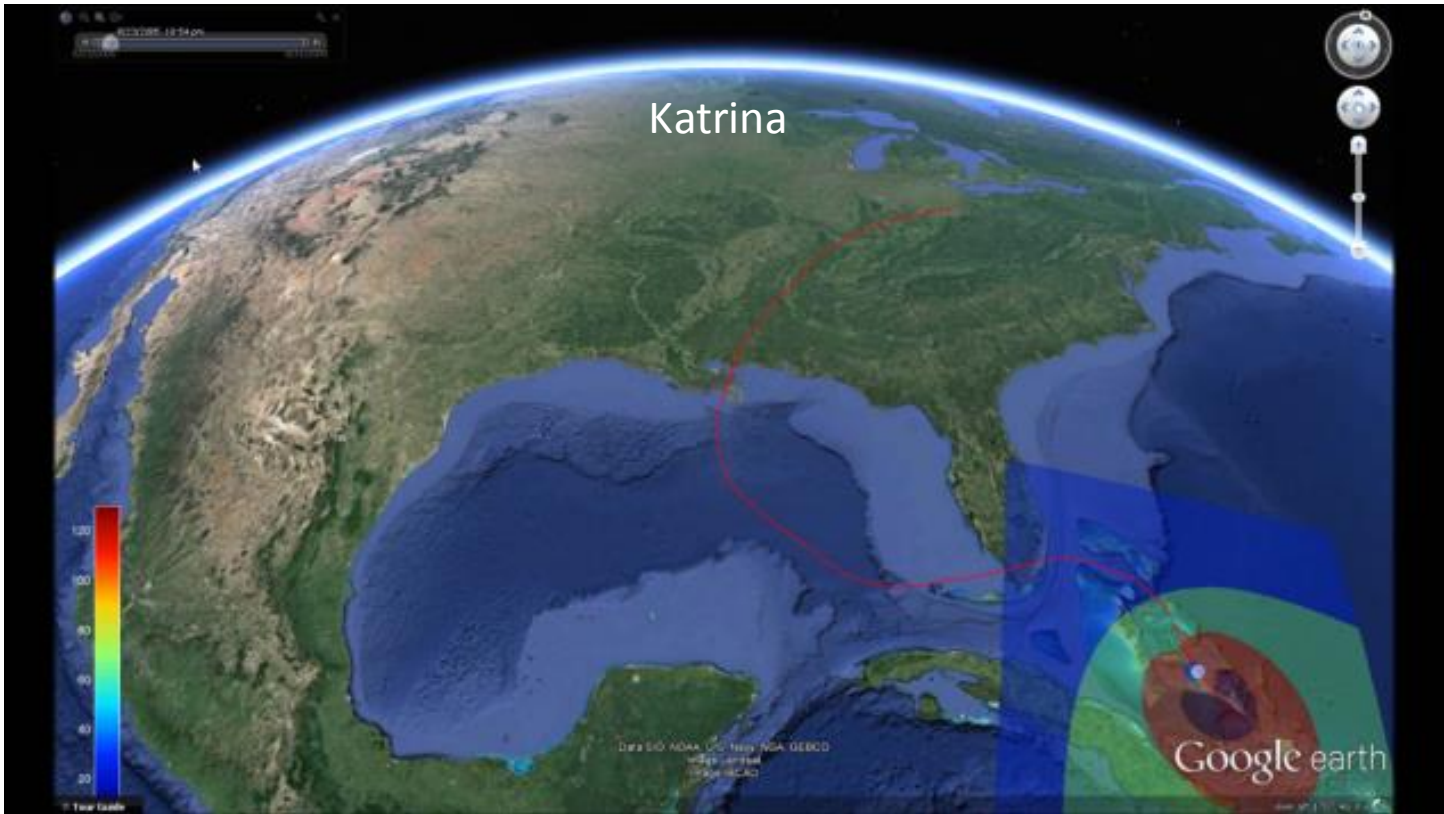
The Nature Conservancy
Protecting nature. Preserving life.

Economics of Climate Adaptation

ETH zürich

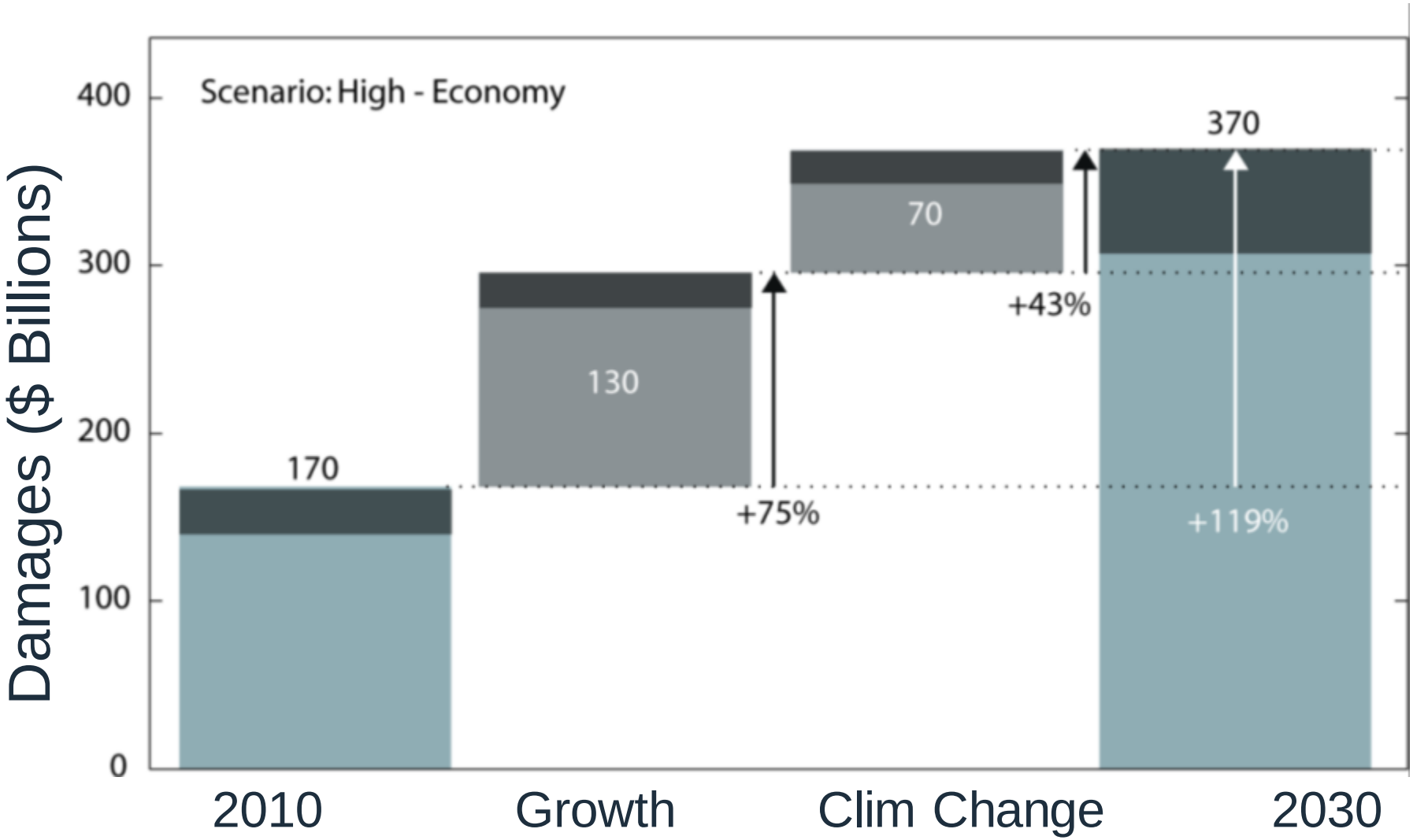
Aims

- Work with worlds 2nd largest re-insurer
- Public cost effectiveness model that includes nature
- Identify where nature-based defenses are cost effective



Risk in 2030

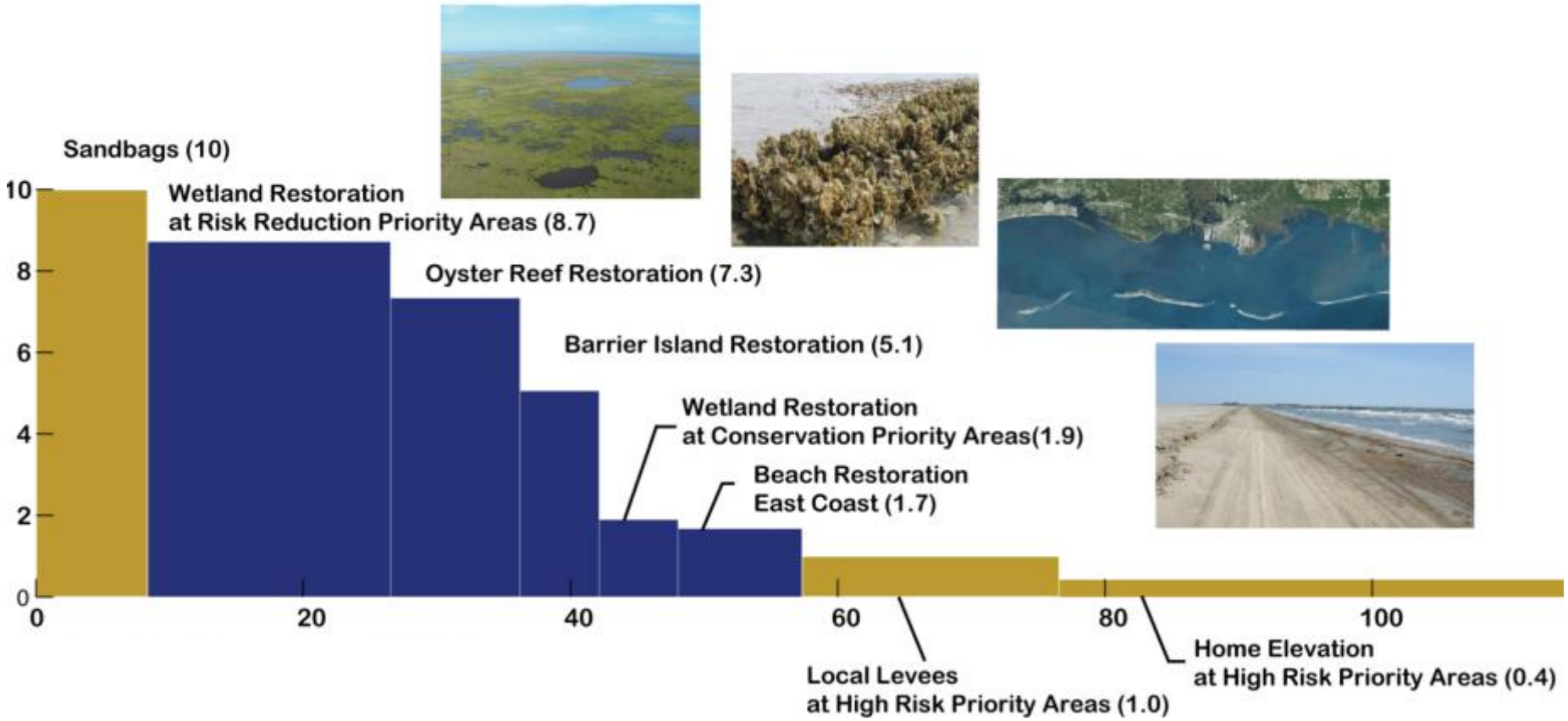
High Economic Growth (3%)



Economics of Coastal Adaptation

Swiss Re | The Nature Conservancy — Protecting nature. Preserving life. | ETH zürich | UNIVERSITY OF CALIFORNIA SANTA CRUZ

Benefit to Cost ratio



Averted Damages ($ Billions)

Reguero, Beck et al (2018). PLOS ONE

REEF RESILIENCE & INSURANCE FUND
IN QUINTANA ROO, MEXICO

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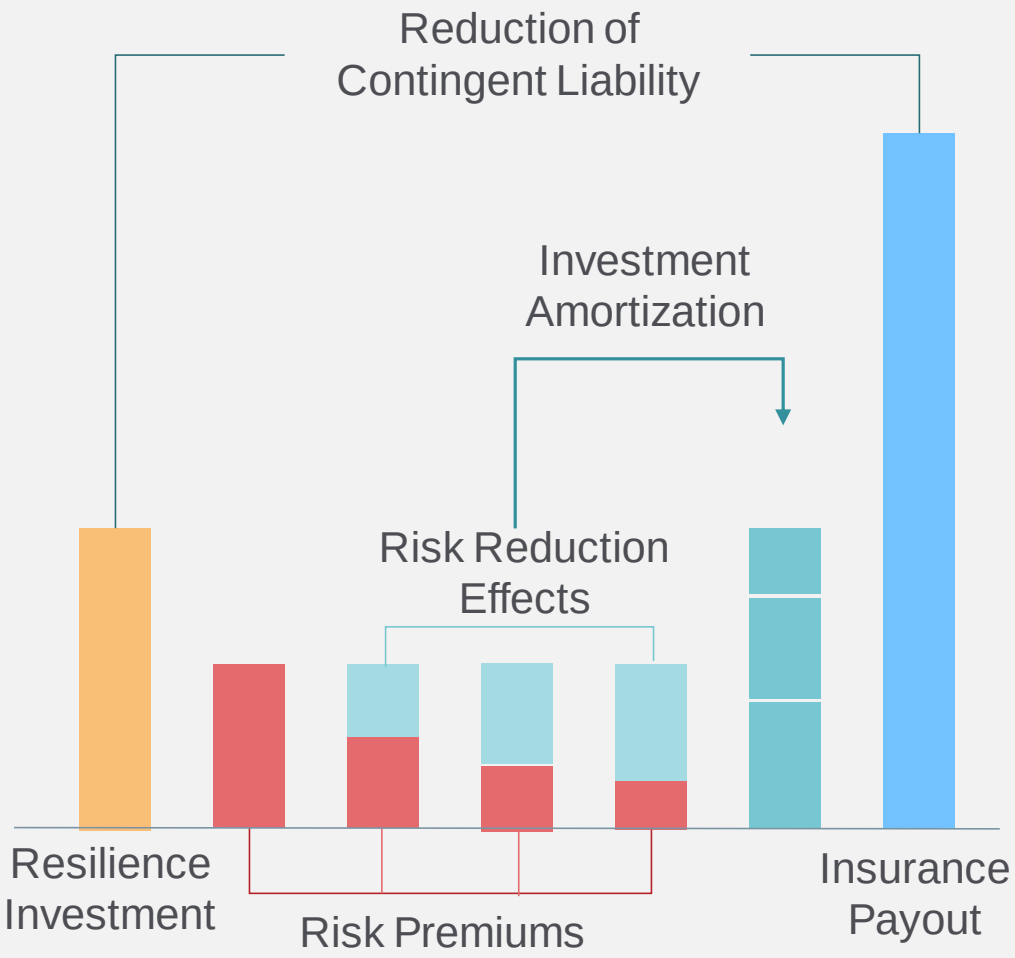
Combining Reef Restoration & Insurance to Build Resilience

Munich RE

The Nature Conservancy

A resilience insurance solution overcomes trade-off between risk reduction & risk transfer:

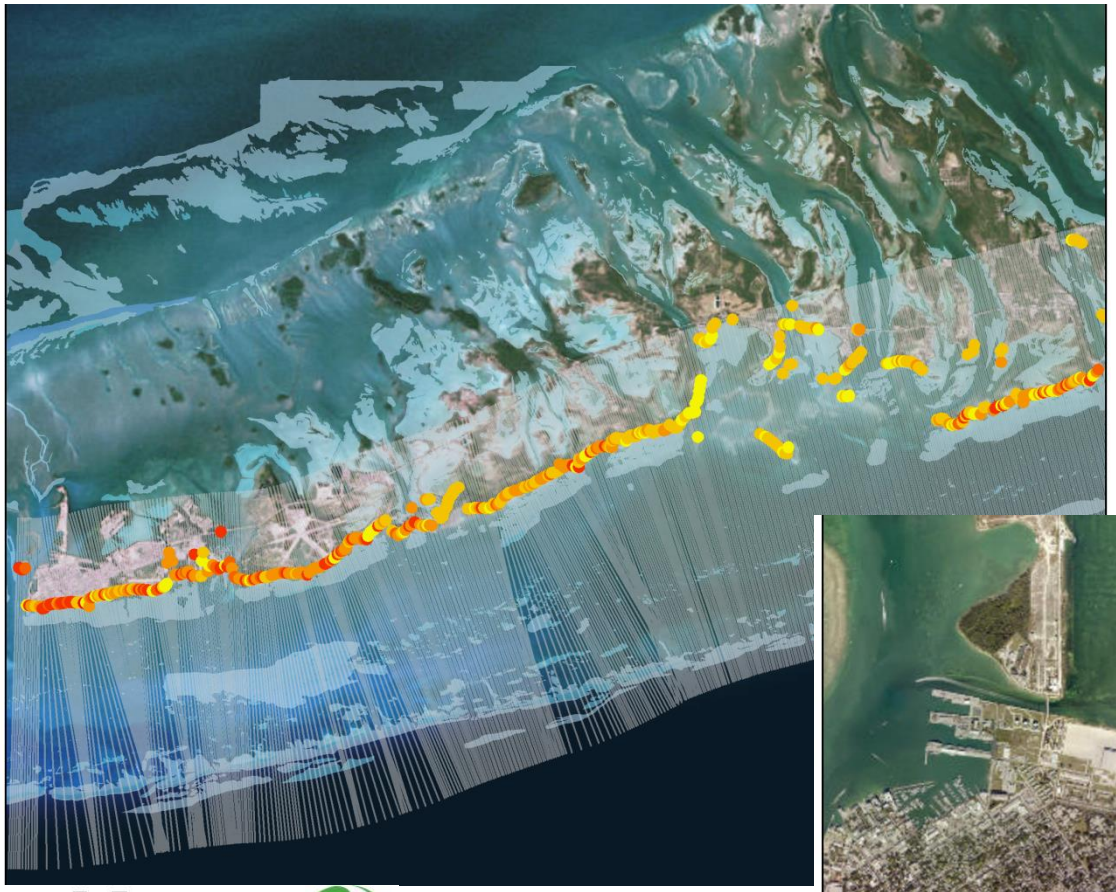
- Up front reef restoration investment reduces risk
- The risk mitigating impact reduces premiums
- An incentive is created for restoration & risk transfer



1-in-100yr

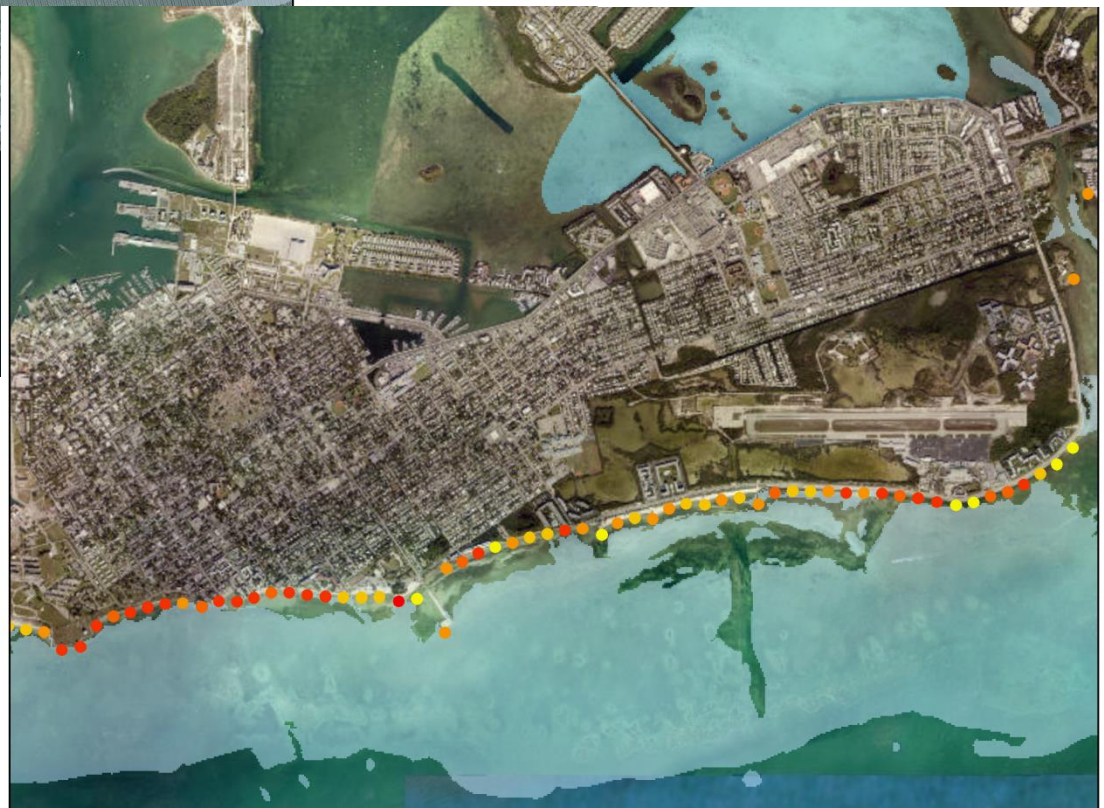
Legend
RP100yr_wrf
RP100yr_worf
Transects_KeyWest_070617
Miles
0 0.1 0.2 0.4 0.6 0.8
Floodplain 1-in-100yr

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



Flood Reduction (%)

- <=0 - 5%
- 6% - 15%
- 16% - 25%
- 26% - 30%
- 31% - 50%
- 51% - 85%



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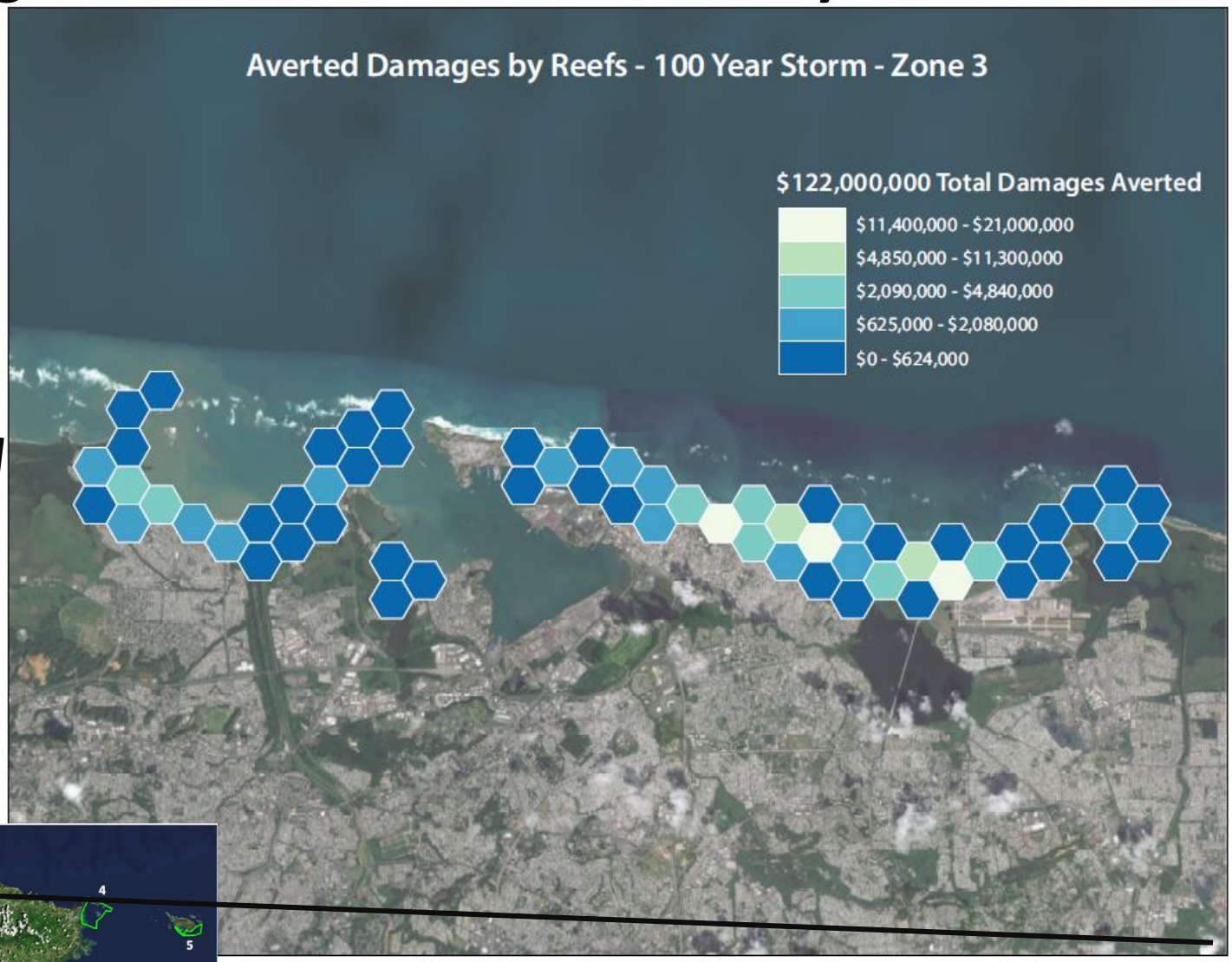
Benefits of Coral Reefs for Risk Reduction

Informing FEMA & Puerto Rico Recovery Efforts



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 and reefs reduce flood risks
- We can rigorously values these benefits
- Better values drive critical funding opportunities

Thanks

mbeck@tnc.org

Contact after January 1

mwbeck@UCSC.edu

UCSC Research Professor

U.S. DEPARTMENT OF THE INTERIOR MARCH 3, 1849

USGS science for a changing world

SNAPP Science for Nature and People PARTNERSHIP

THE PEW CHARITABLE TRUSTS

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

International Climate Initiative

GLOBAL RESILIENCE PARTNERSHIP

CONVENED BY THE ROCKEFELLER FOUNDATION AND USAID

KINGFISHER FOUNDATION

WORLD BANK GROUP

WAVES Wealth Accounting and Valuation of Ecosystem Services

Margaret A. Cargill PHILANTHROPIES

MAPPING OCEAN WEALTH

LLOYD'S TERCENTENARY RESEARCH FOUNDATION

Extra Slides Follow

Flood Reduction Benefits from Wetlands

1. Catastrophic Events:
   - >625 Million US$ during Hurricane Sandy
   - >11% on average where wetlands remain
2. Annual Flooding:
   - Properties with marshes save >15% in average annual losses

CLAIMS JOURNAL

Study Finds $600M Plus in Property Losses Averted by Coastal Wetlands

October 31, 2016

STANDARDS AND FINANCE TO SUPPORT COMMUNITY RESILIENCE

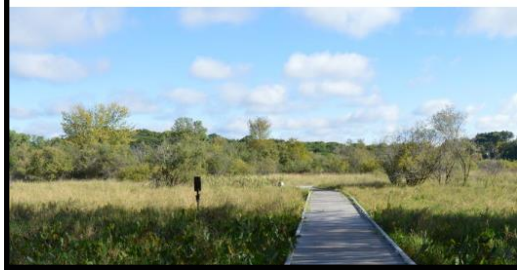
December 2016

In addition to adjustments to the built environment, intact and functioning natural systems can provide protective and buffering services against sea level rise and damage from coastal storms. According to a new study supported by Lloyd's of London, coastal wetlands provide important natural protection during hurricanes, reducing property damage by about $625 million in the Northeast during Hurricane Sandy in 2012. Where wetlands remain, the average damage reduction from Sandy was greater than 10%, with wetlands in Maryland reducing property damages by nearly 30%. In New Jersey, wetlands prevented $425 million in property damages, according to the study. The study also found that the conservation of salt marshes in Ocean County, N.J., is expected to reduce average annual coastal property losses by more than 20%.[xxii]

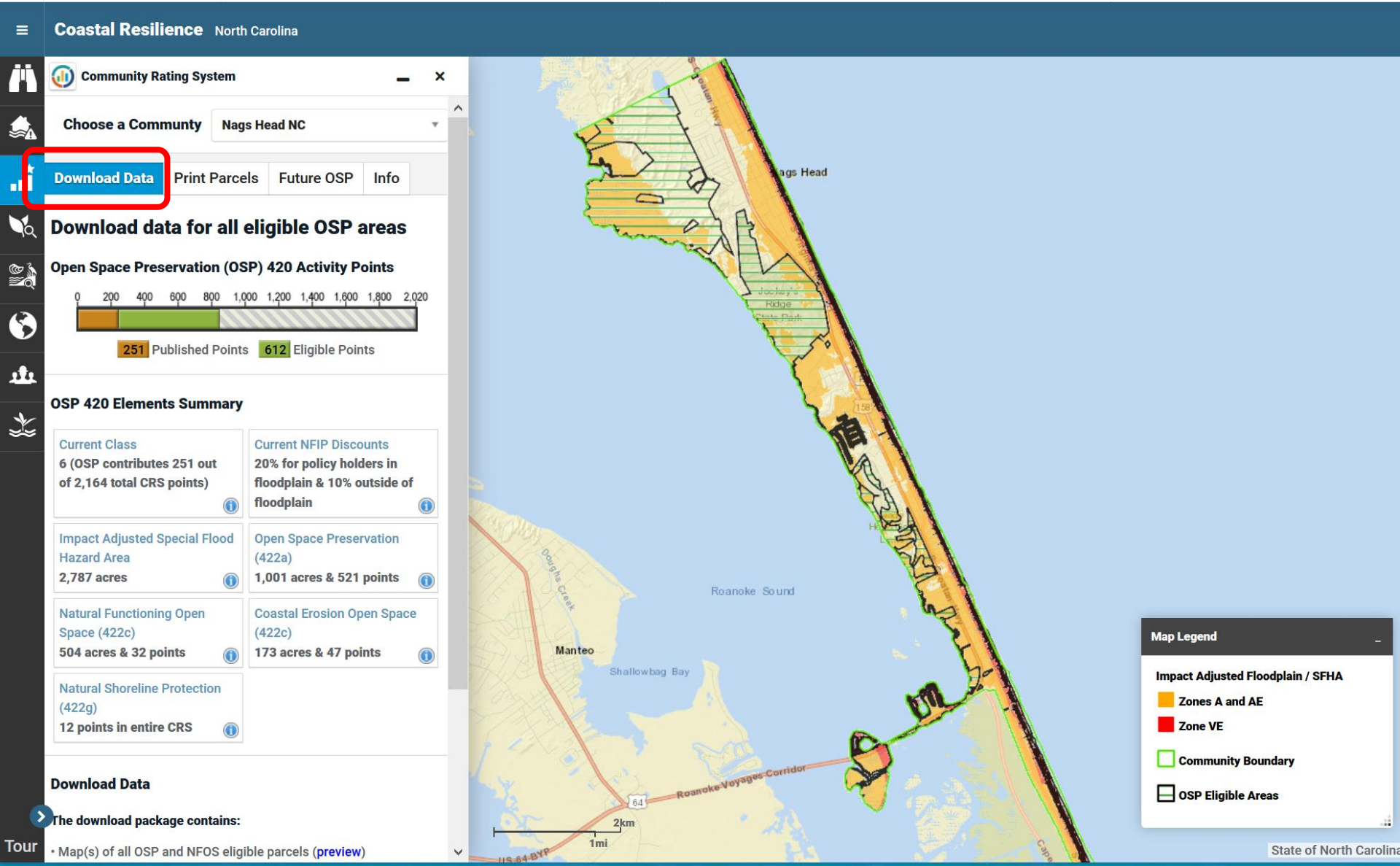
INSURANCE JOURNAL

Coastal Wetlands Found to Reduce Hurricane Property Damage by 10%-30%

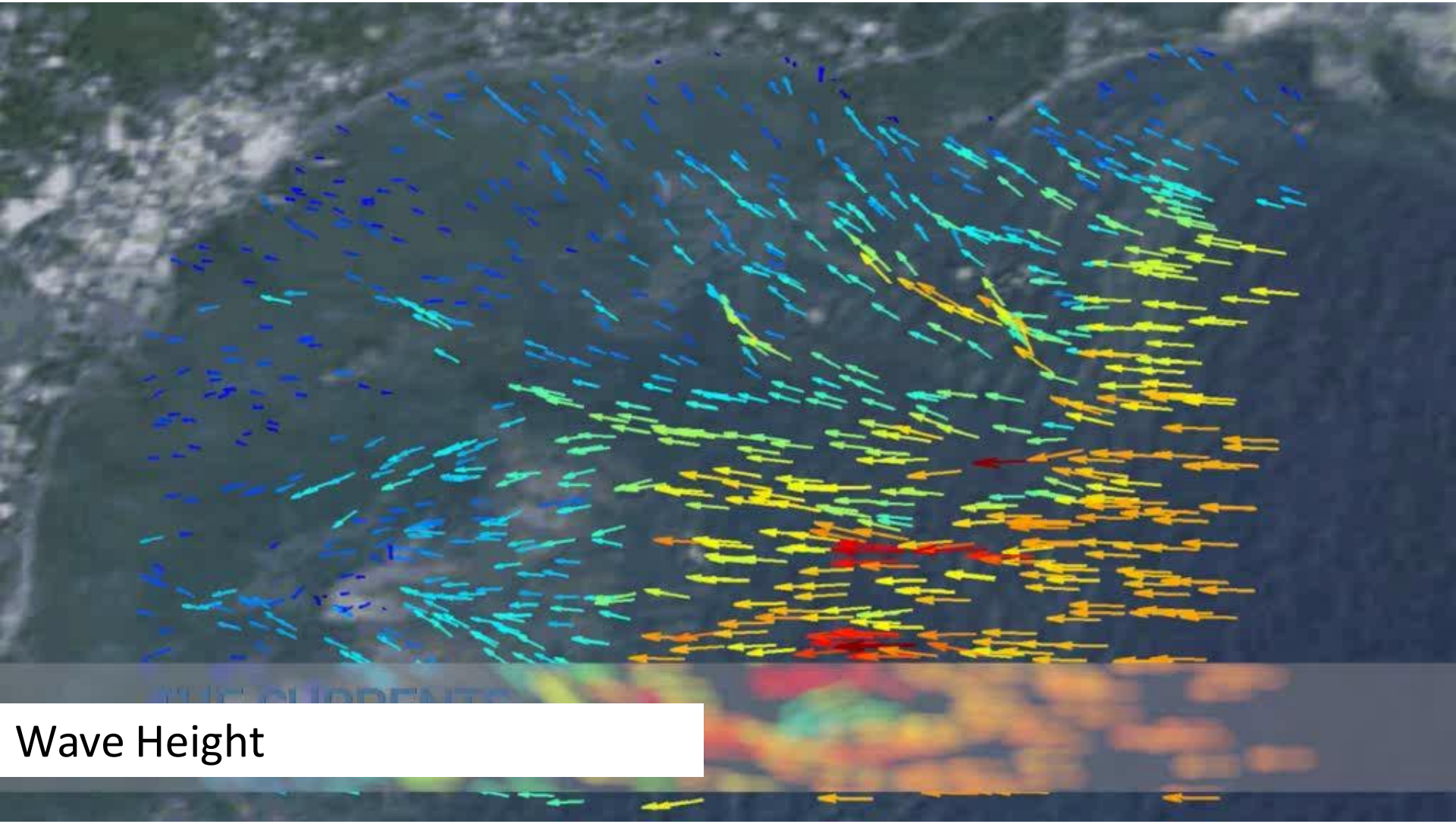
October 27, 2016



FEMA National Flood Insurance Program (NFIP) Community Rating System Explorer



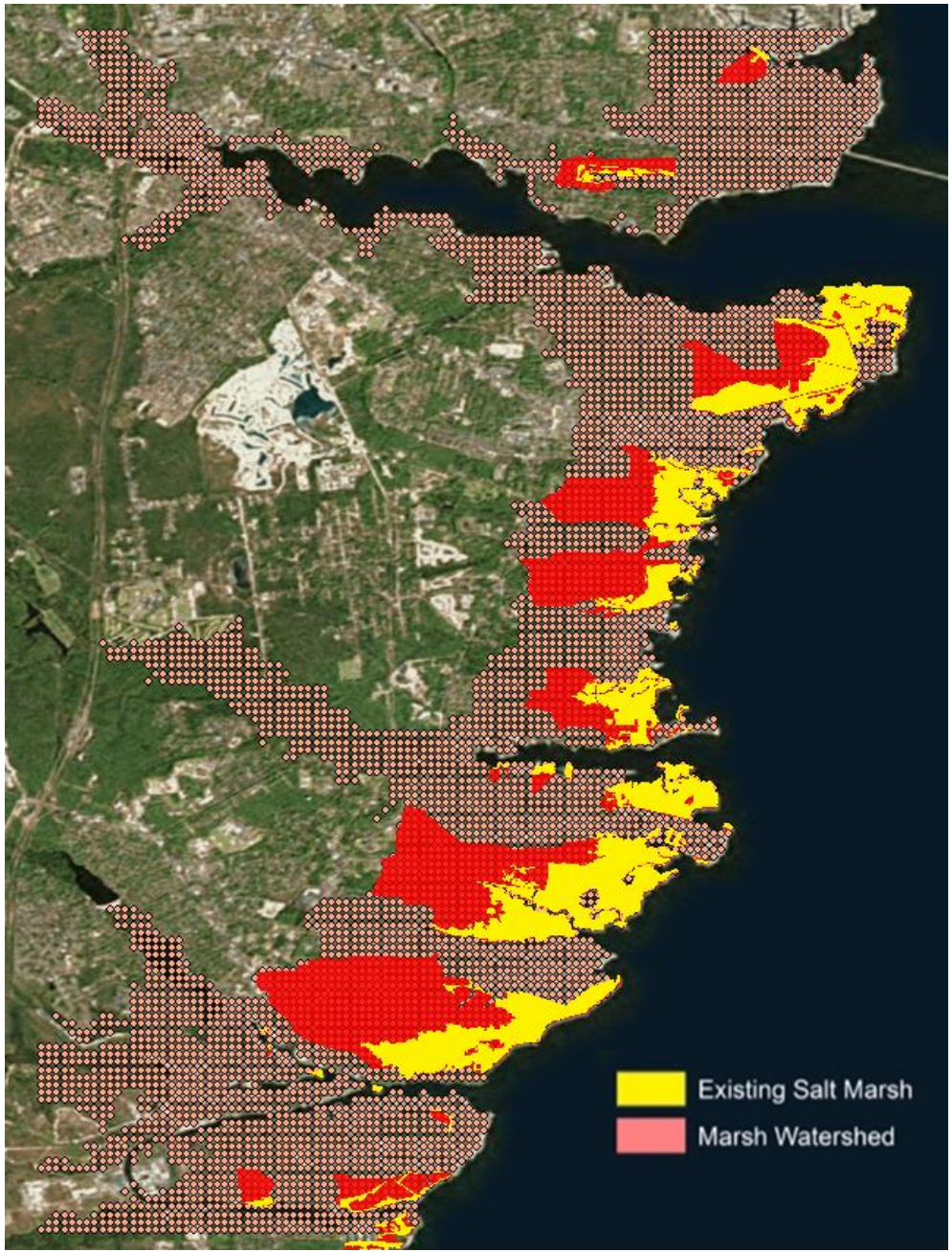
Pilot Project - Reef Restoration for Risk Reduction
Grenville, Grenada



Reguero, Beck, et al.. 2018. J. Env. Mgmt. 210:146-161.

The reef at low tide

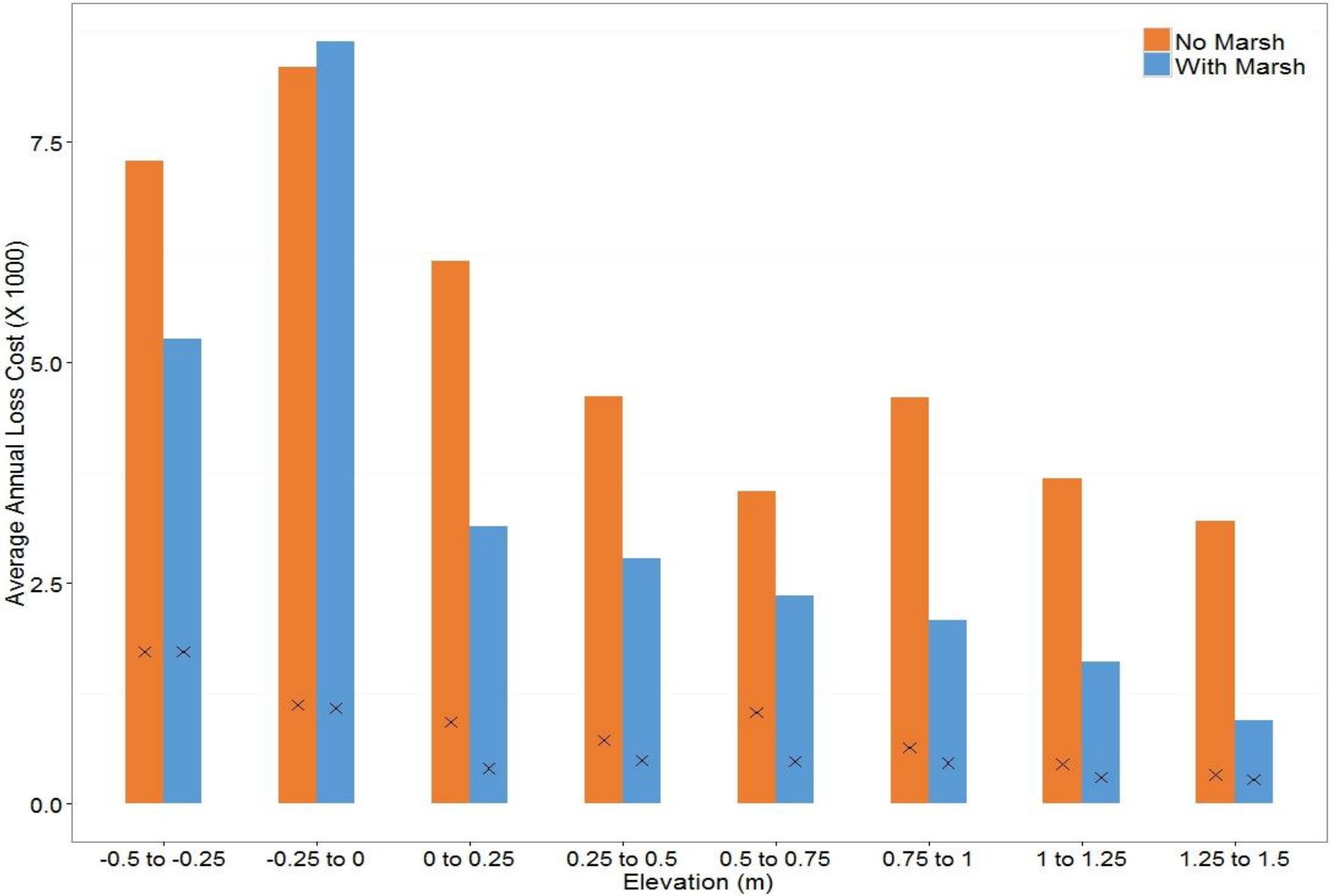
Effect of Salt Marshes on Annual Flood Damages to Properties



1. *Storm parameters*: ~2000 events
2. *Annual flood losses for grid of properties*
3. *Marsh presence*: Marshes and watersheds by Shepard et al. using GIS
4. *Control for various factors*

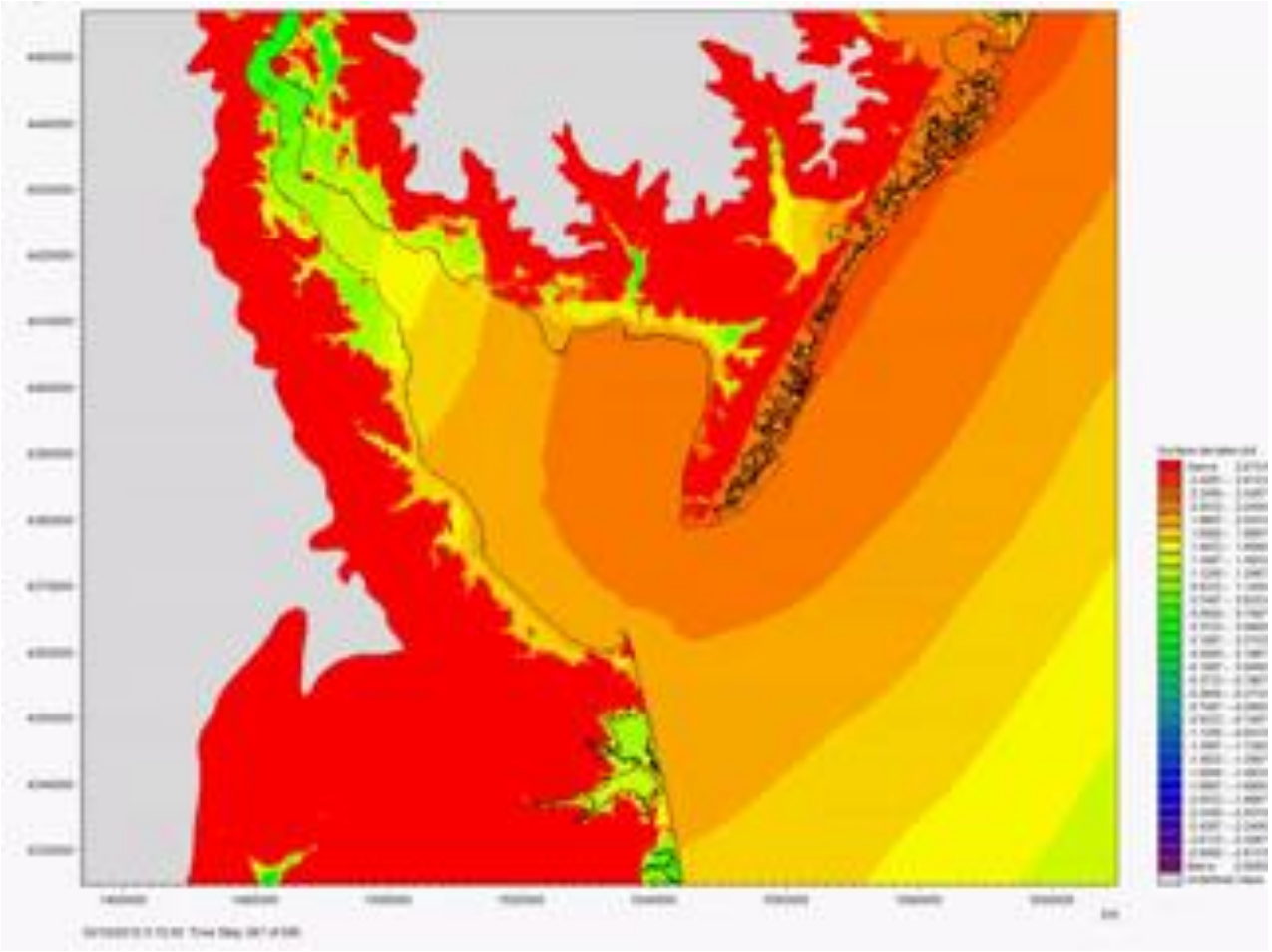
Effect of Salt Marshes on Annual Flood Damages to Properties

Key Findings: Properties With Marsh see lower losses across most elevations



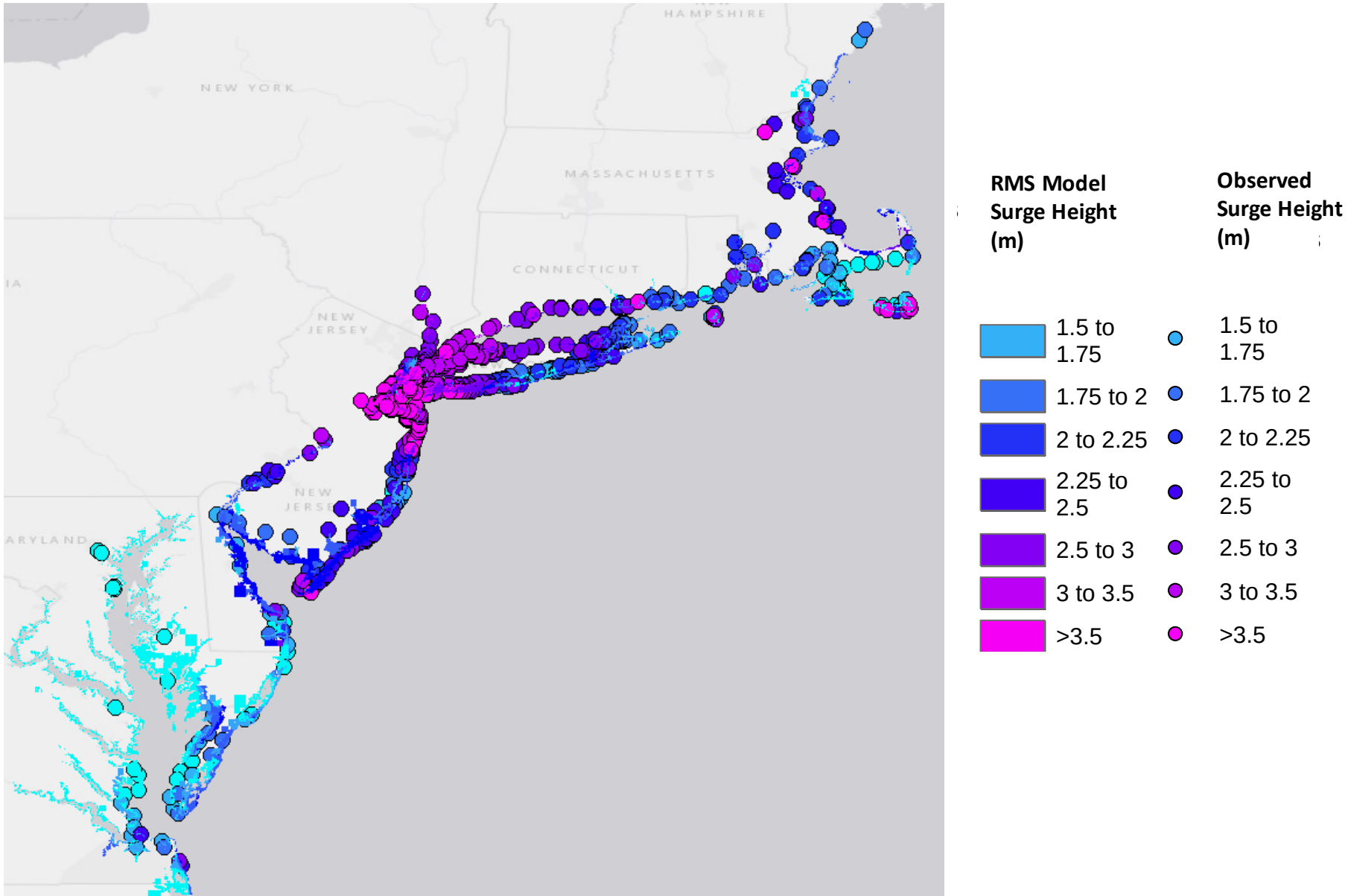
Wetland Effects on Property Damage Reduction during Hurricane Sandy

Flood Model Example for Delaware Bay



Wetland Effects on Property Damage Reduction during Hurricane Sandy

Model Validation: Observed versus Predicted Surge Heights for Sandy (m)



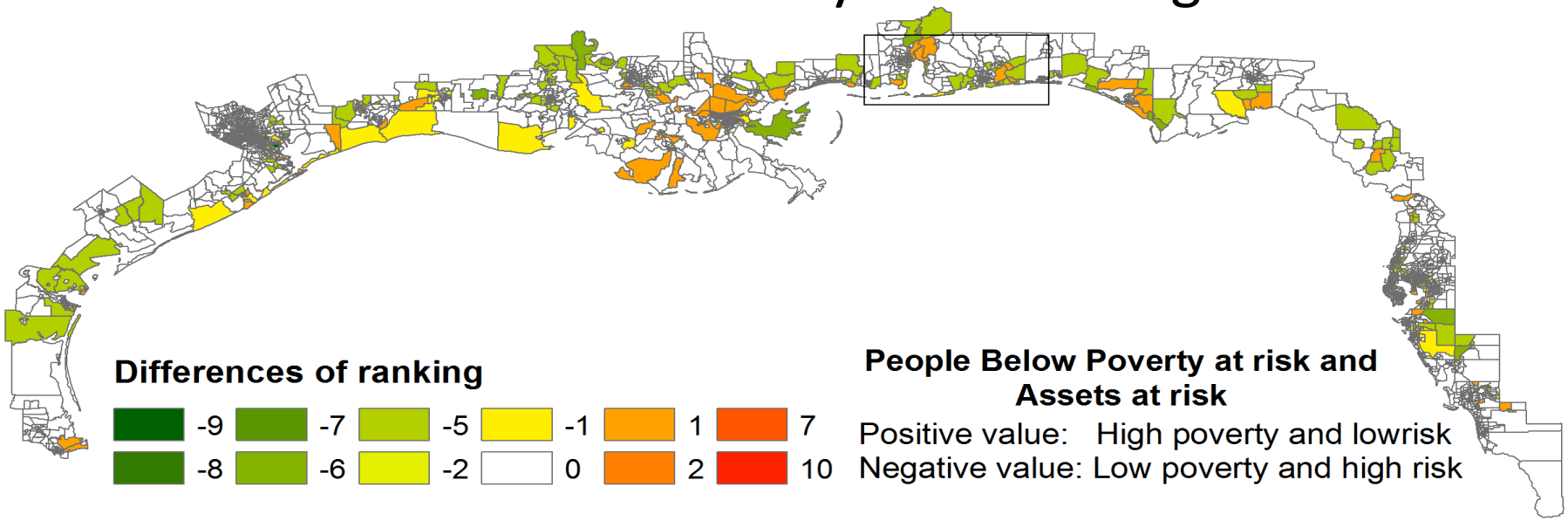
Study: Wetlands as Natural Defenses During Hurricane Sandy

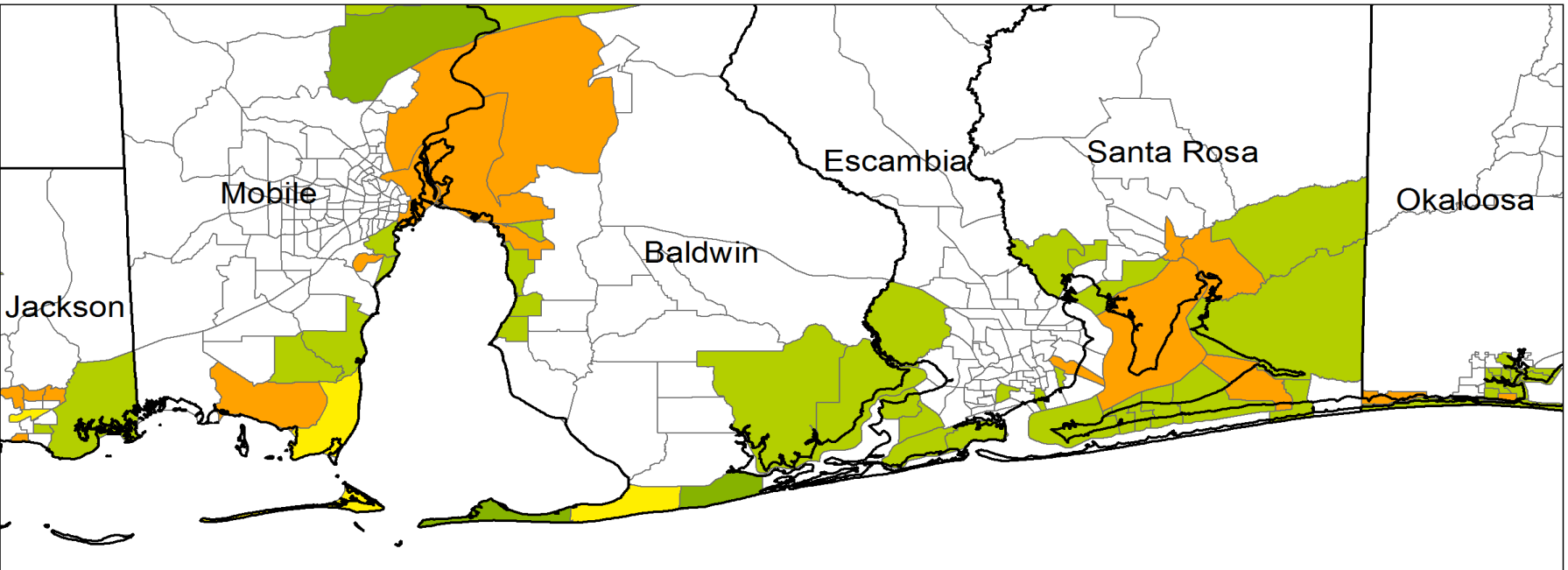
Hurricane Sandy:

- 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

The Difference in Risk Assessed Socially vs Economically Would Our Priority Areas Change?





Meet Multiple Management Objectives

Adaptation & Risk Reduction Objectives

*Risk = Exposure * Social Vulnerability*

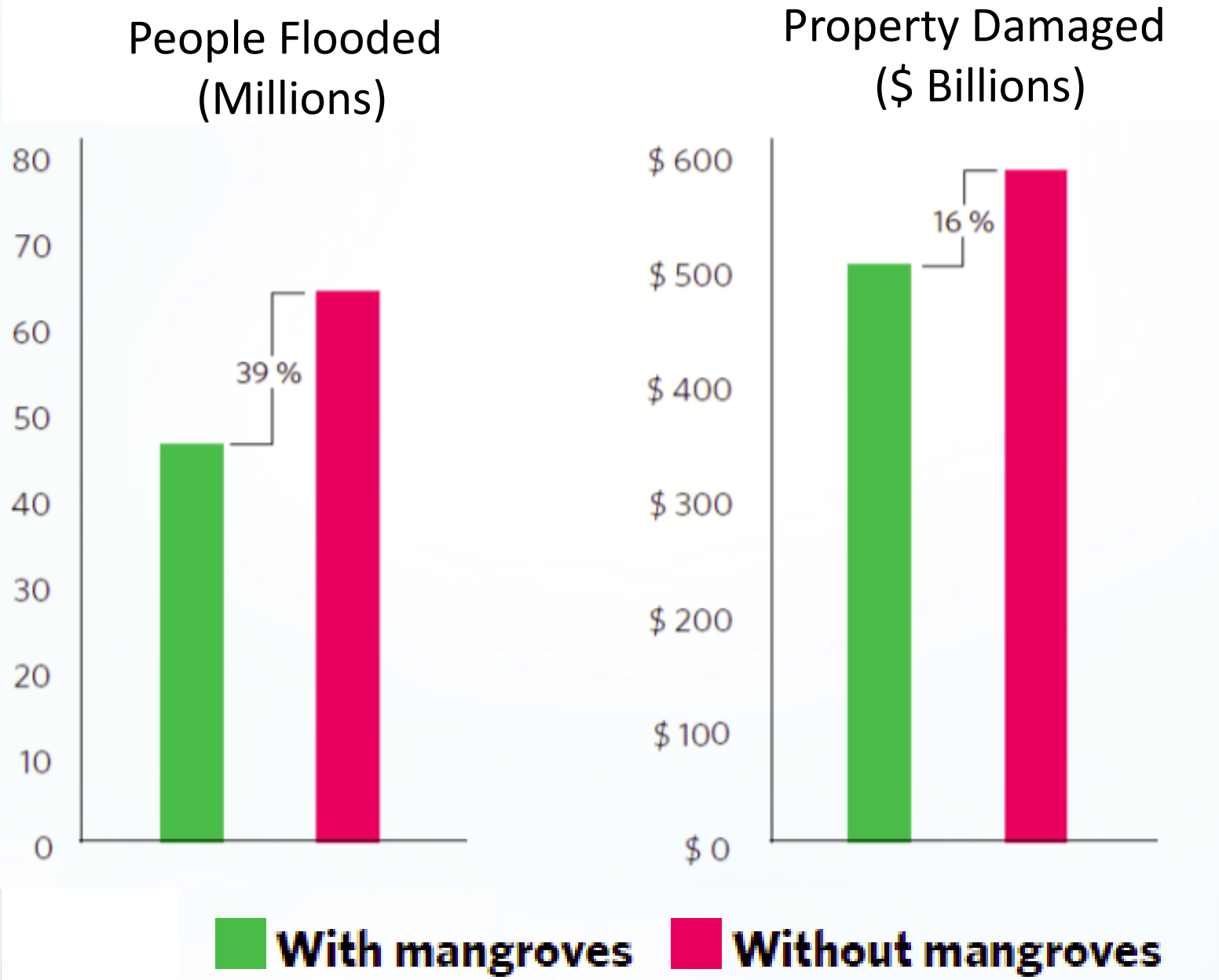
Vulnerability =
Susceptibility,
Coping Capacity
Adaptive Capacity

Conservation Objectives

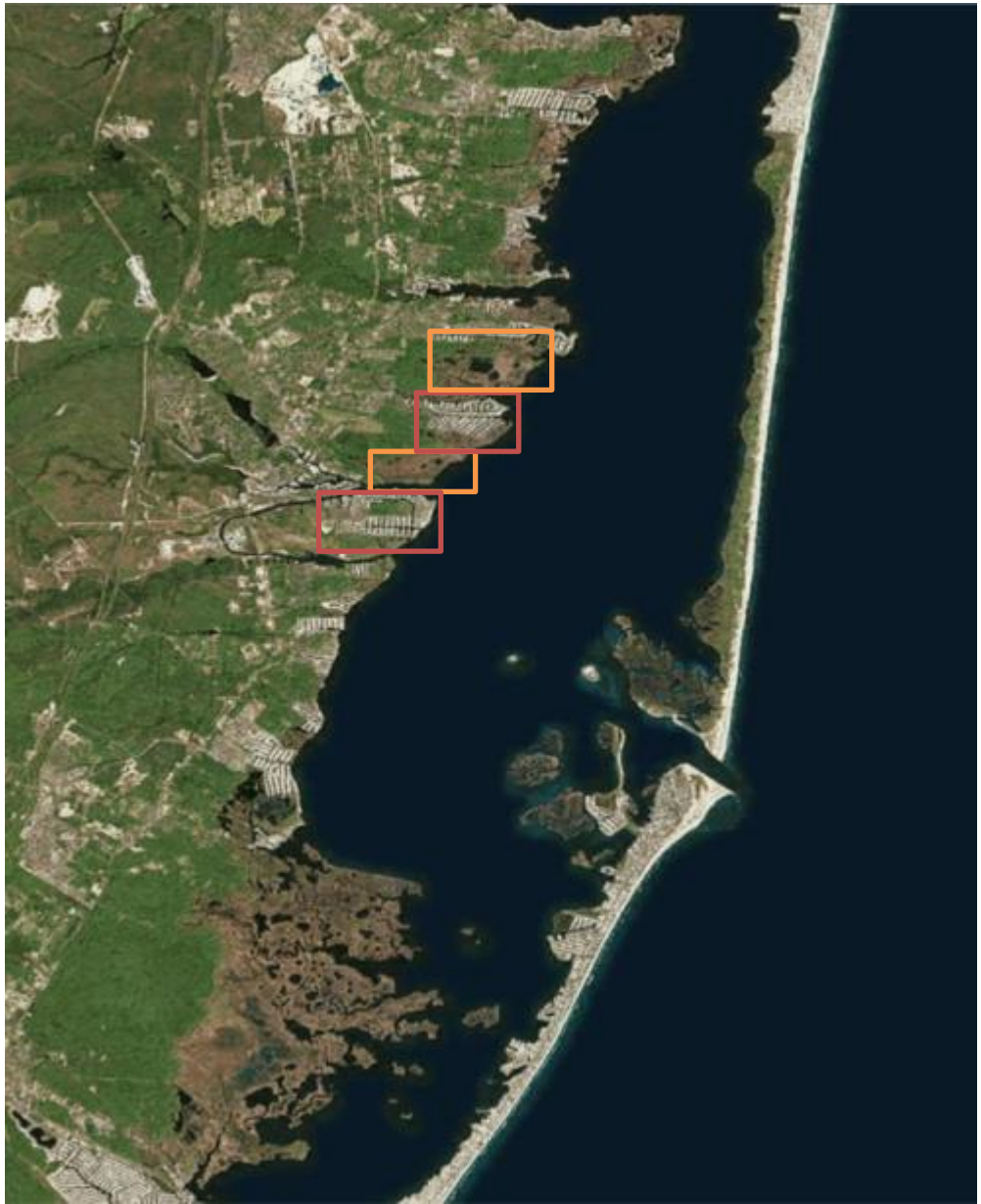
Representation
Redundancy
Resilience

New Priorities & Actions

Global Annual Expected Benefits from Mangroves



Study: Effect of Salt Marsh Presence on Annual Flood Losses in Ocean County



Behind Marsh

No Marsh

Annual flood losses in Barnegat Bay, NJ

Locations behind marsh versus locations with no marsh

~2000 storm events