NOTE FOR THE READER OR PRESENTER:

Talking points and additional resources are in the "notes" section of each slide

Bold text highlights main points that should be read aloud, while non-bold text provides additional supporting information

WORLD RESOURCES INSTITUTE

THE WORLD BANK

GFDRR
Global Facility for Disaster Reduction and Recovery

NATURE-BASED SOLUTIONS FOR DISASTER RISK MANAGEMENT

Coastal Flooding and Erosion Protection

Photo credit: flickr/ Northshore school of art

MANY TERMS FOR "NATURE-BASED SOLUTIONS"

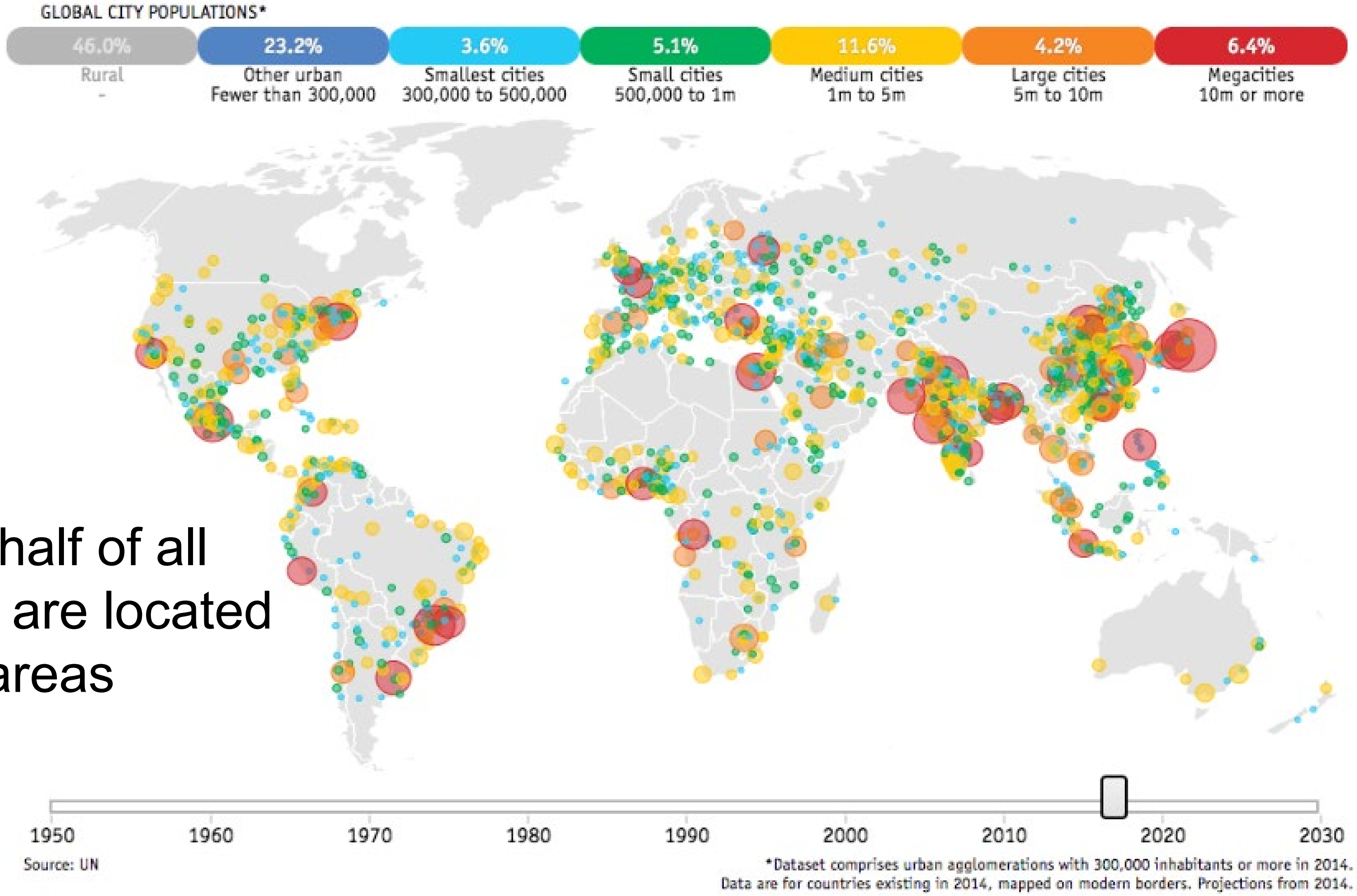
Source: Cohen-Shacham et al. 2016; UNEP et al. 2014; EC 2015; Lo 2016; WWF 2017; USACE n.d.; EcoShape 2018; WBCSD 2017

COASTAL REGIONS

- Represent **9%** of global land area
- House **28%** of the global population (1.9 billion people)
- Produce **42%** of global GDP

Photo credit: Flickr/Anh Dinh; Source: Kummu et al. 2016

URBANIZATION: 2018



More than half of all megacities are located in coastal areas

Source: The Economist 2015

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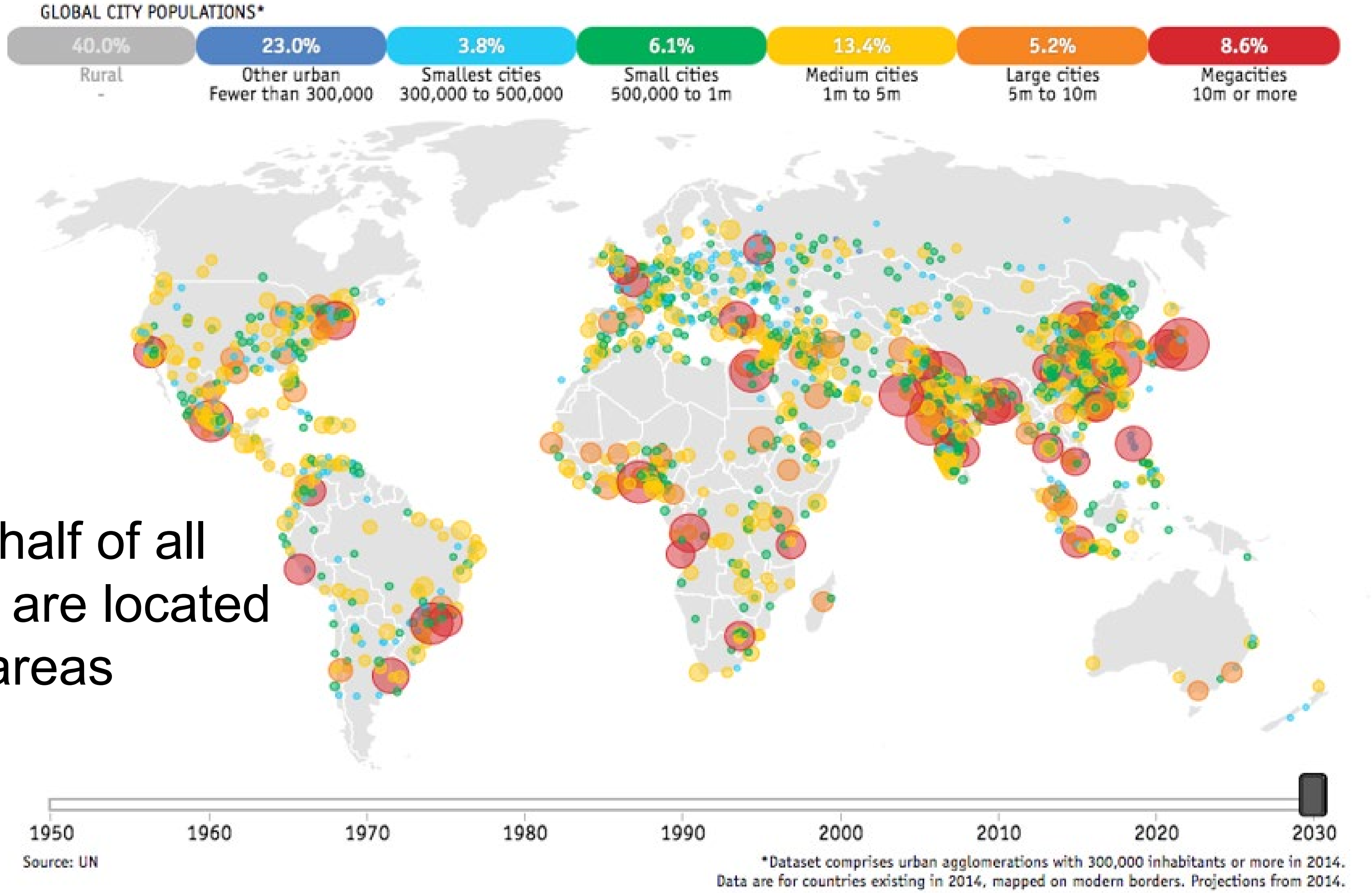
URBANIZATION: 2030



More than half of all megacities are located in coastal areas

Source: The Economist 2015

FLOODING AND EROSION ARE TWO IMPORTANT HAZARDS FACING COASTAL COMMUNITIES

Contributing factors:

- Development decisions
- Ecosystem degradation
- Sea level rise
- Changing weather patterns
- Natural disasters

Photo credit: Flickr/Mohamed Malik

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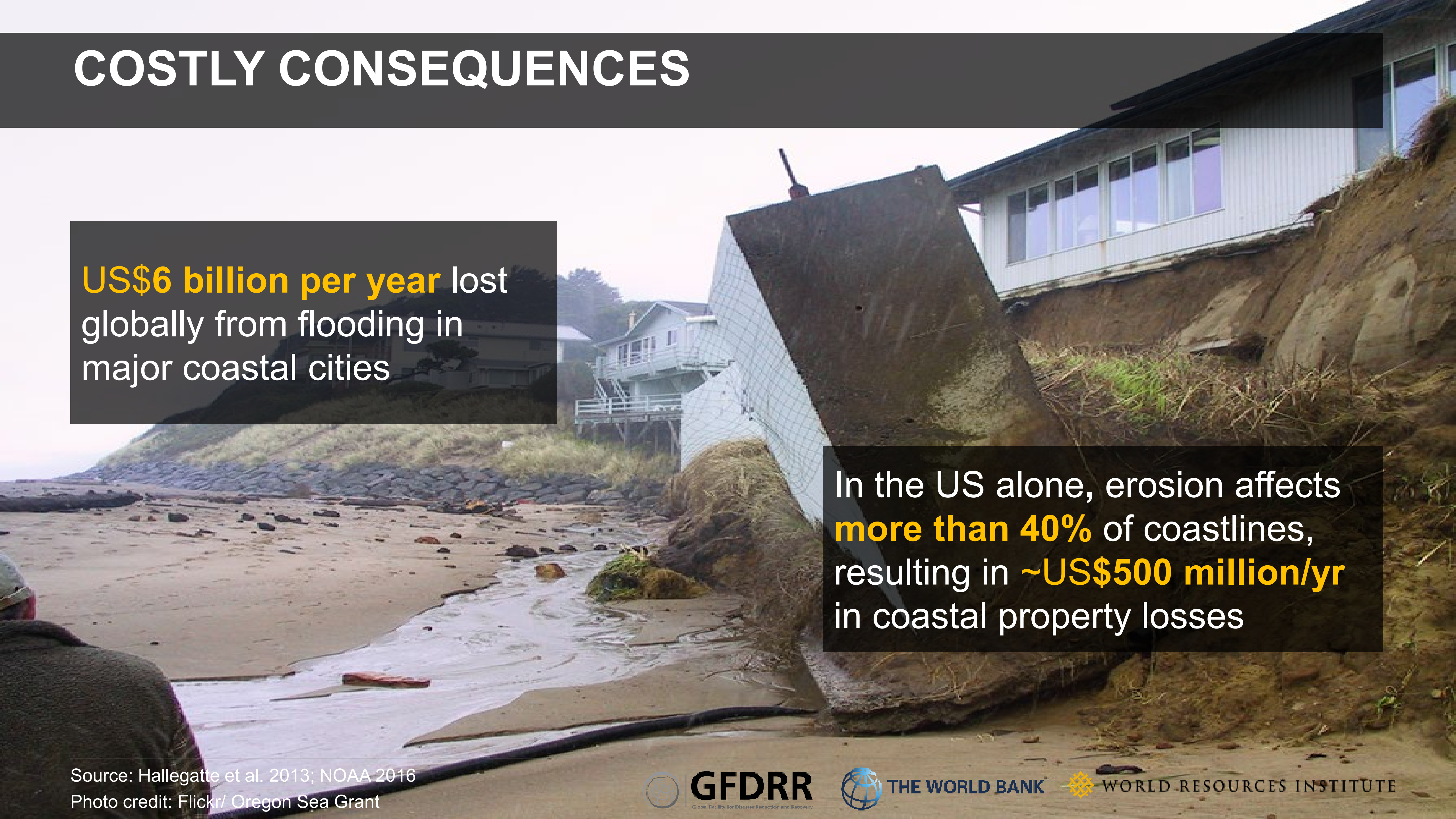


COSTLY CONSEQUENCES

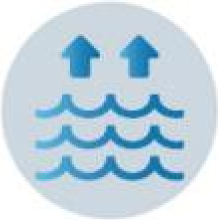
US$6 billion per year lost globally from flooding in major coastal cities

In the US alone, erosion affects **more than 40%** of coastlines, resulting in ~**US$500 million/yr** in coastal property losses

Source: Hallegatte et al. 2013; NOAA 2016
Photo credit: Flickr/ Oregon Sea Grant

WORLD BANK INVESTMENT PORTFOLIO: DISASTER RISK MANAGEMENT (DRM)

Invested **~US$49 billion** (FY2012-2017) in more than **600 DRM projects** globally

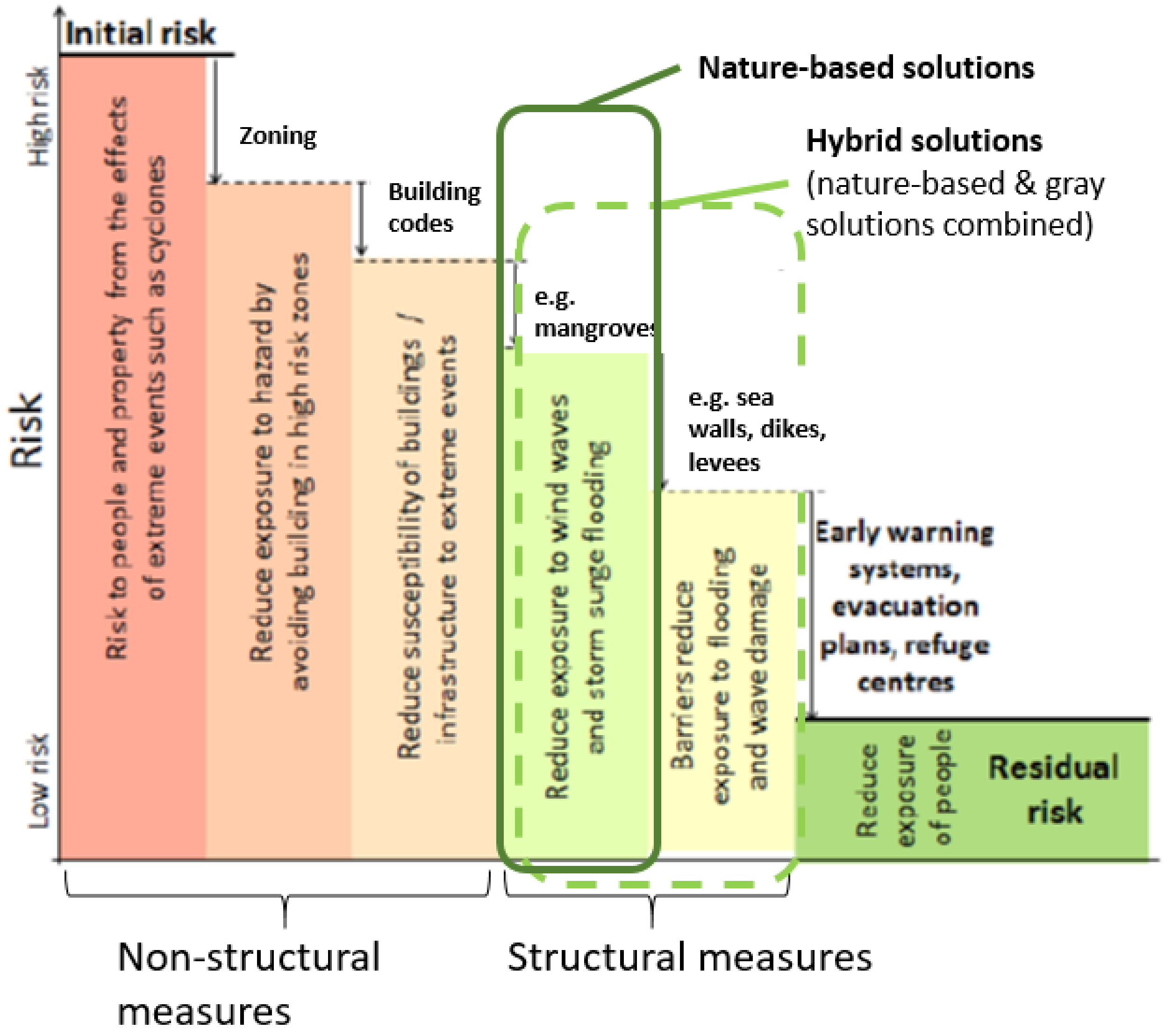


61 projects have targeted **coastal flooding** with around **US$3.78 billion** committed

123 projects have targeted **coastal erosion** with **US$20.4 billion** in committed

Source: GFDRR internal data analysis 2018

COASTAL RISK REDUCTION MEASURES INCLUDE NBS



Source: USACE 2013; Spalding et al. 2014

STRUCTURAL STRATEGIES

	Nature-based Solutions (NBS)	
Built	**Hybrid**	**Natural**
Hard, gray, engineered structures built to address development objectives	Combination of ecosystem elements and hard engineering interventions for addressing development objectives	Creation, protection or restoration of only ecosystem elements for addressing development objectives

Source: World Bank 2017

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CONVENTIONAL: 'BUILT' INFRASTRUCTURE

Coastal solutions include:

- Offshore breakwaters
- Dikes
- Seawalls
- Groins
- Concrete or rock embankments

Photo credit: Flickr/Ecks Ecks

NBS: 'NATURAL' INFRASTRUCTURE

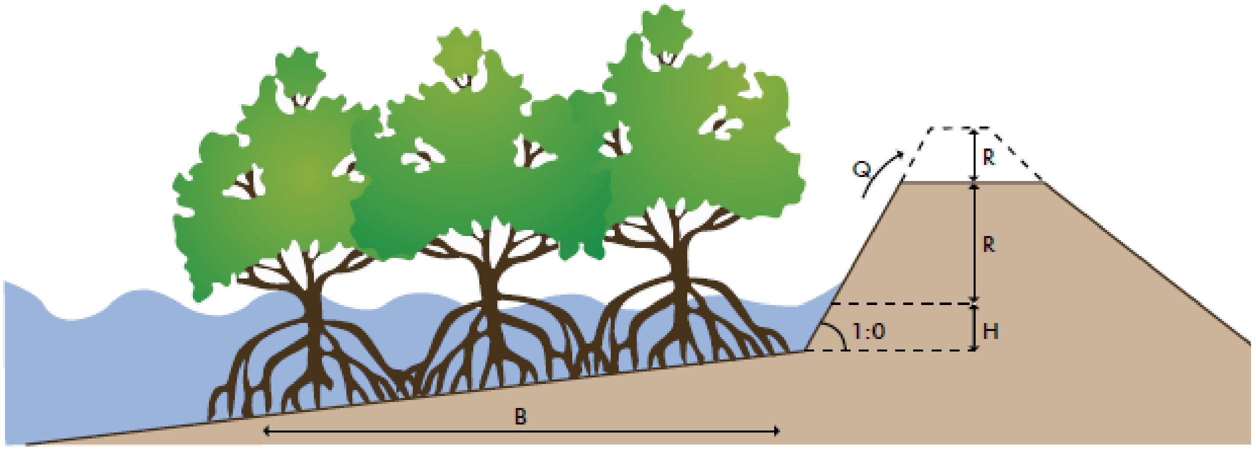
Ecosystems include:

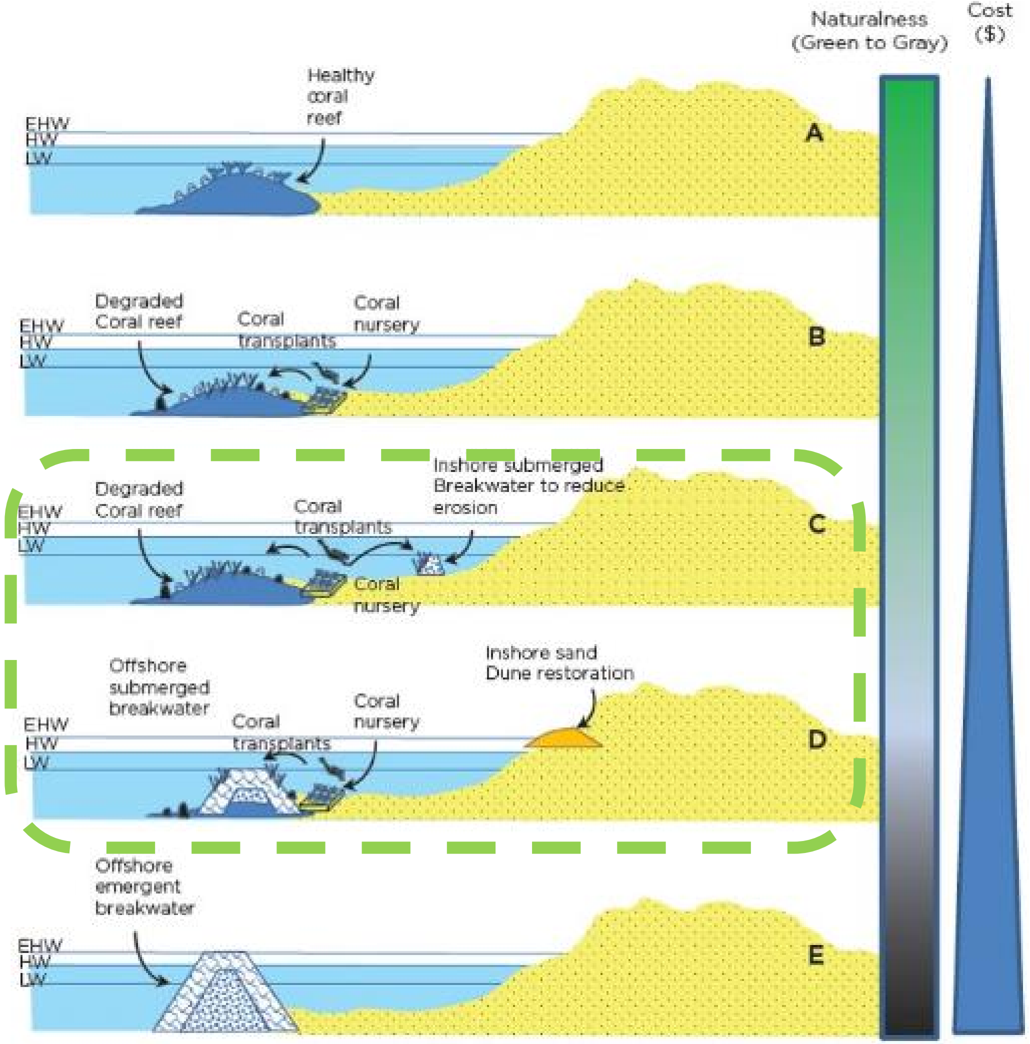
- Mangroves
- Coral reefs
- Oyster beds and reefs
- Seagrasses
- Sandy beaches and dunes
- Coastal marshlands and other wetlands

Photo credit: Flickr/Ed Hunsinger

‘HYBRID’ INFRASTRUCTURE

Hybrid setup of mangroves and dikes can reduce necessary dike height and costs





Sources: World Bank 2016; Spalding et al. 2014

ADVANTAGES OF NATURE-BASED SOLUTIONS

- Can be more **cost-effective**
- **Able to adapt** and **regenerate**
- Provide **wide range of additional co-benefits** beyond flooding and erosion protection

Photo credit: Flickr/Synecdoche

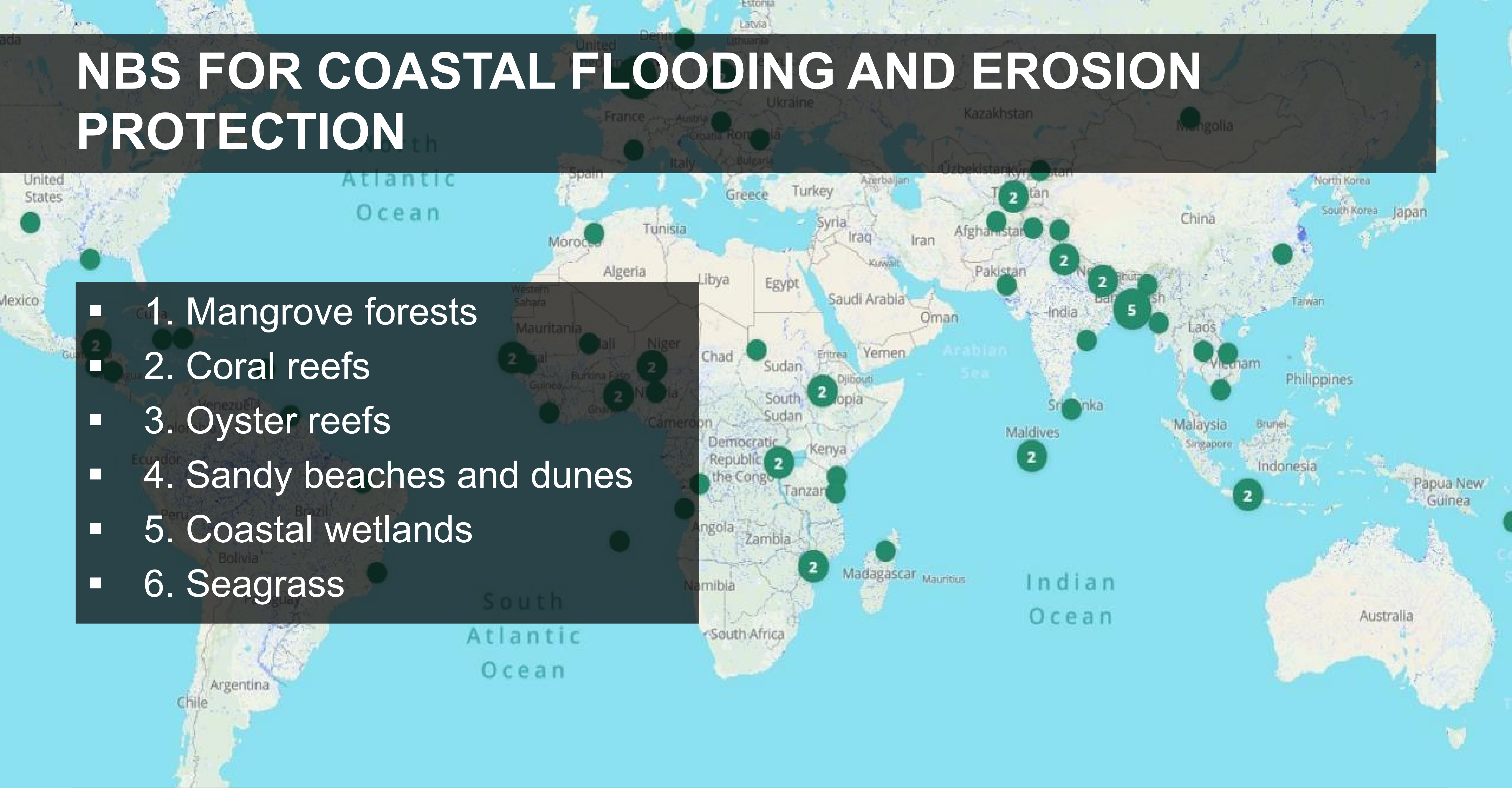
WORDS OF CAUTION

Appropriate use of NBS is highly context specific, requiring careful evaluation, planning and design of project components

Photo credit: Flickr/Peter Counsell

NBS FOR COASTAL FLOODING AND EROSION PROTECTION

- 1. Mangrove forests
- 2. Coral reefs
- 3. Oyster reefs
- 4. Sandy beaches and dunes
- 5. Coastal wetlands
- 6. Seagrass



Source: World Bank https://naturebasedsolutions.org/

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1. MANGROVE FORESTS

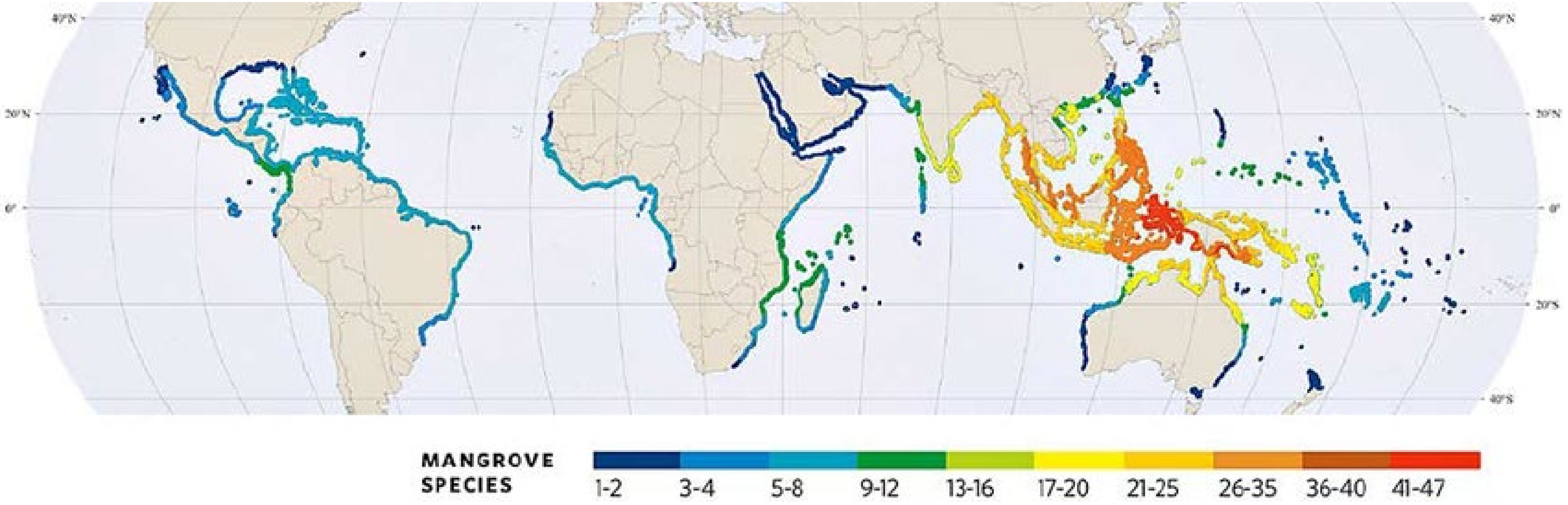
Mangroves are **species of trees and shrubs** that live in **coastal intertidal zones** with low-oxygen soils and slow-moving waters

Approaches for implementation include:

- Conserving existing mangroves
- Enabling conditions for natural regeneration
- Planting new mangrove forests

Photo credit: Flickr/mopar05ram

MANGROVE DISTRIBUTION AND NUMBER OF SPECIES



70 species of mangroves grow in **tropic and sub-tropical latitudes** and approximately **123 countries and territories**

Graphic credit: US Dept. of Commerce 2014

Sources: McOwen et al. 2016; Kathiresan and Bingham 2001

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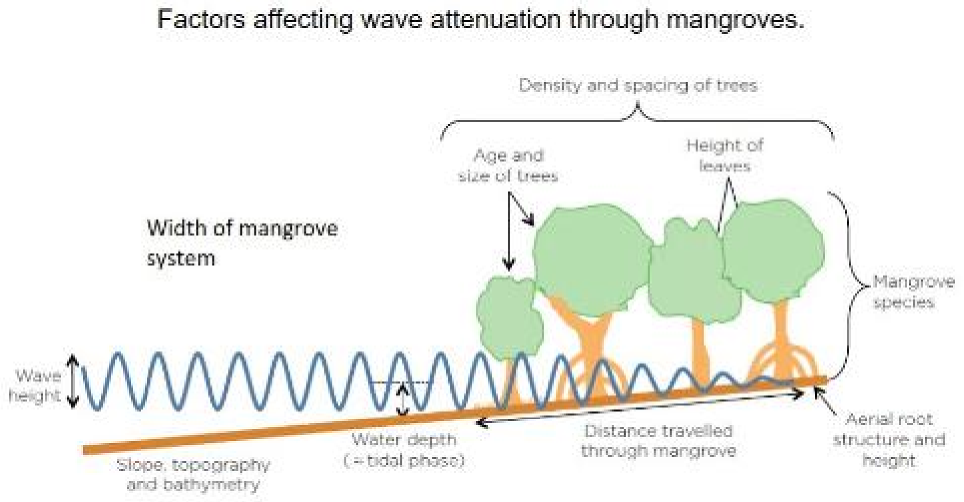
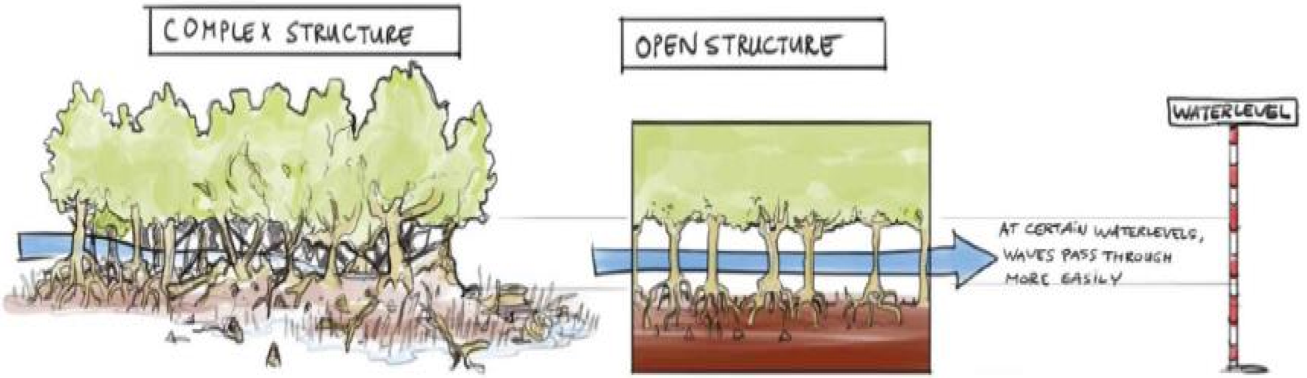
RISK REDUCTION BENEFITS

- **Wave attenuation:** speed and crest height reduction
- **Sediment trapping:** shoreline stability and expansion, and soil elevation





Mangroves are estimated to **reduce wave heights** by an average of **31%**

ADDITIONAL BENEFITS

- Valuable forest products
- Tourism and recreation
- Fisheries
- Water purification
- Carbon sequestration
- Biodiversity

Photo credit: Flickr/deslaco

CONSIDERATIONS FOR USING MANGROVES AS COASTAL DEFENSE

- **Integrate** with other risk reduction measures
- **Incorporate valuation results** into coastal planning and management decisions
- **Prevent conversion** and **maintain wide forests** to extent possible
- **Leverage natural regeneration processes** by restoring biophysical and social conditions
- **Follow and mimic nature** in species selection and location if planting

Natural regeneration can occur in 15-30 years

Sources: Spalding et al. 2014; Deltares 2016
Photo credit: Flickr/PNUD Panama

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WHAT DO MANGROVES COST?

Mangrove restoration can be **2-5x cheaper than submerged breakwaters** for equivalent wave heights up to half a meter

Median mangrove restoration cost estimate value is **~US$9,000/hectare**

Photo credit: Flickr/David Copeland

Sources: IFRC n.d.; Deltares 2016; Bayraktarove et al. 2015

DISASTER RISK MANAGEMENT WITH MANGROVE PLANTATION IN VIETNAM

- **US$15 million** in total avoided risk savings
- **US$80,000-295,000** reduced storm damages to dike system
- **200-800% additional income** for beneficiary communities

Source: IFRC n.d.

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2. CORAL REEFS

Coral reefs are **limestone-like physical structures** built up in tropical waters from deposits made by ~**800 species of reef-building corals** and other algae organisms

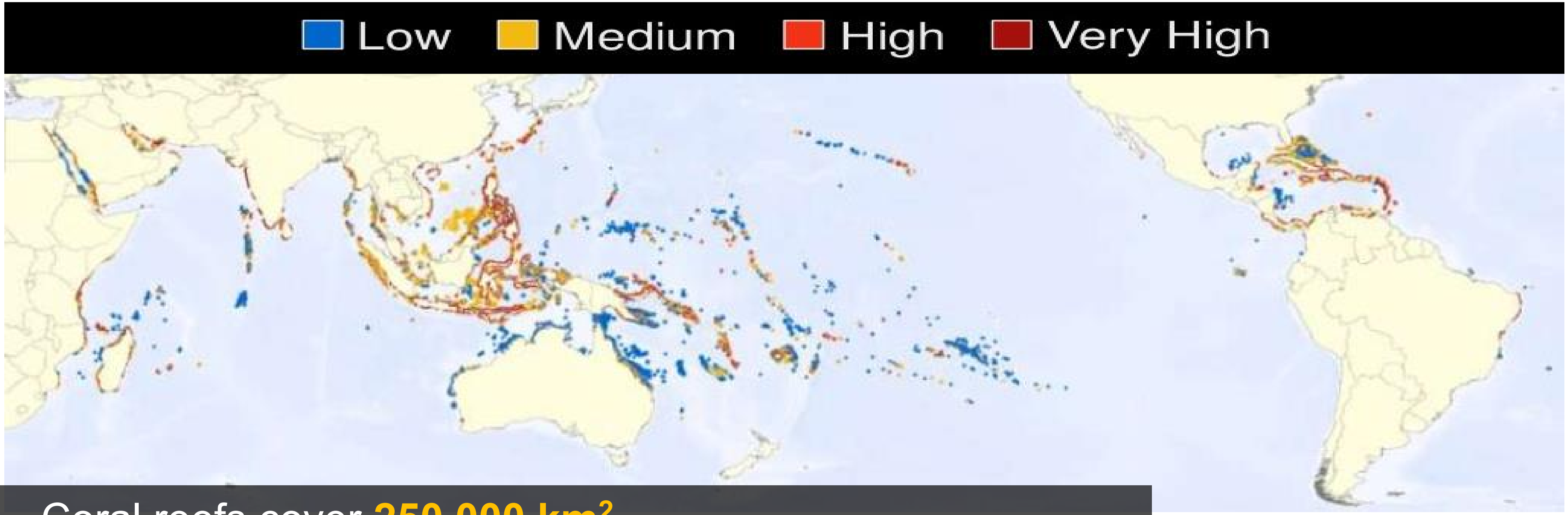
Approaches for implementation include:

- Conserving integrity of existing reefs
- Repairing reef structural integrity (width/height)
- Recovering the coral species diversity and structure, transplanting from farms or donor sites
- Using nature-based artificial material structures—e.g., reef balls, bio-rock, eco-reefs

Photo credit: Flickr/Eric Baker

Source: Paulay 1997; Burke et al. 2011

CORAL REEFS OF THE WORLD CLASSIFIED BY LOCAL THREAT LEVEL



- Coral reefs cover **250,000 km^2**
- **75% are threatened** by local human activities (e.g., overfishing, pollution) and global climate-related stressors combined

Source: McAllister 1995; Burke et al. 2011

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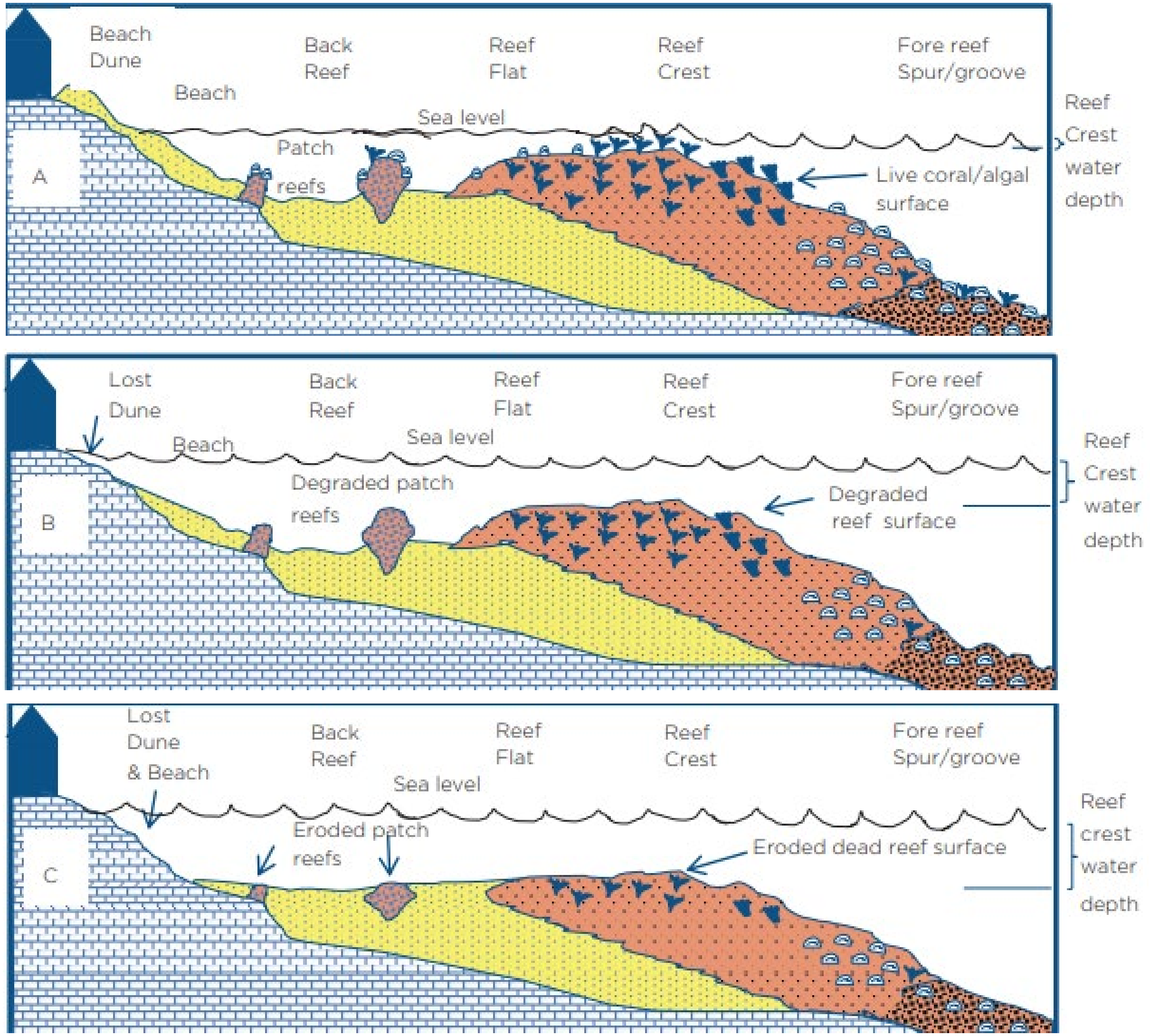
RISK REDUCTION BENEFITS

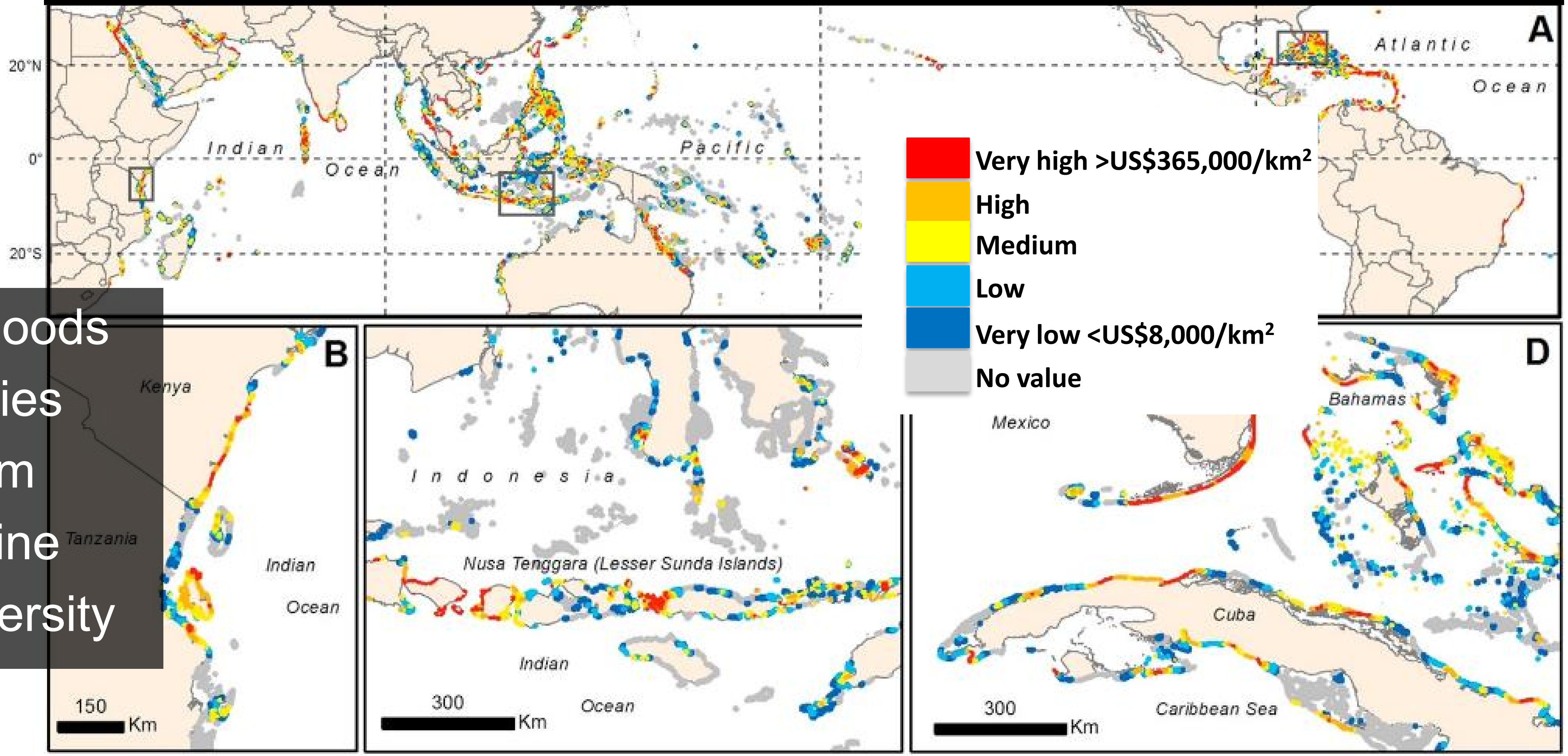
- **Mitigate wave energy,** diminishing speed and crest height
- Reduce **associated erosion** and **wave-induced flooding**

Coral reefs are estimated to **reduce wave heights** by an avg. **70%** and **wave energy by 75-95%**



ADDITIONAL BENEFITS

US$36 Billion Annually from Tourism



- Livelihoods
- Fisheries
- Tourism
- Medicine
- Biodiversity

Source: Spalding et al. 2017 (graphic); Burke et al. 2011

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CONSIDERATIONS FOR USING CORAL REEFS AS COASTAL DEFENSE

- **Effectively manage** and protect **existing reefs**
- **Integrate** coral restoration with **other structural and non-structural** risk reduction strategies
- **Incorporate valuation results** into coastal planning and management decisions
- **Reduce local and global threats**

Corals can take 3-8 years to reach sexual maturity

Photo: Kanenori / Pixabay

WHAT DO CORAL REEFS COST?

Median cost of restoring coral reefs is estimated to be **~US$165,600 per hectare**

Cost of structural restoration measures **can be significantly less expensive** than building tropical breakwaters

Graphic Credit: World Bank 2016
Source: Bayraktarove et al. 2015

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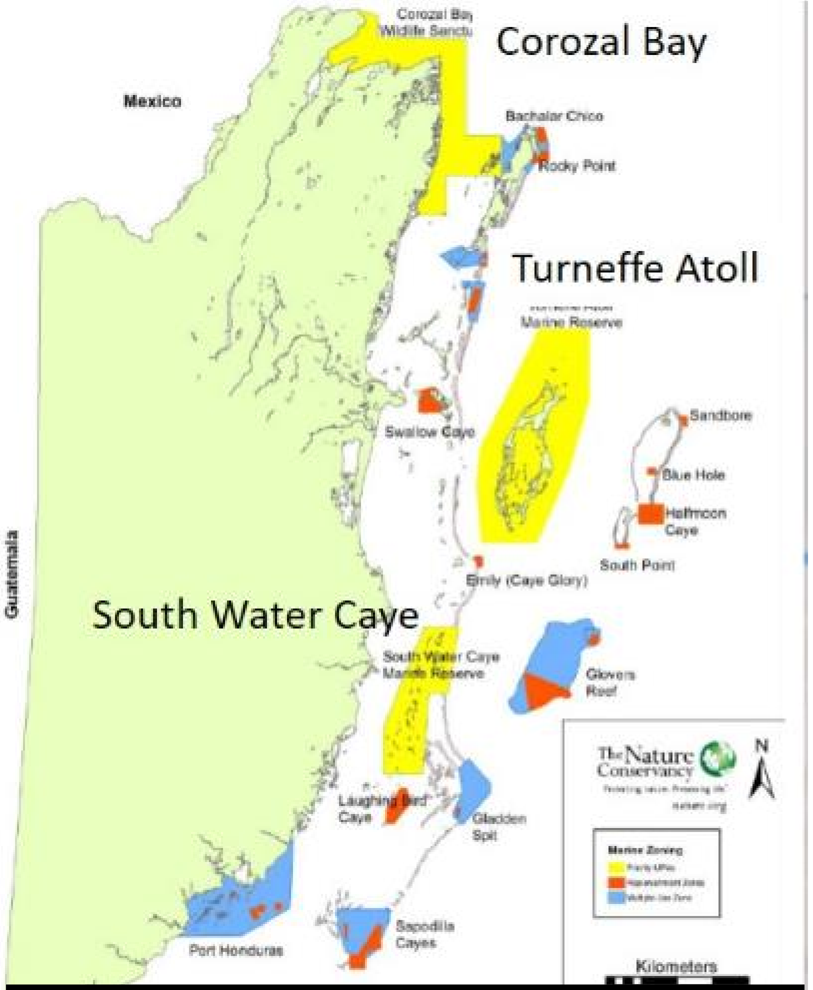
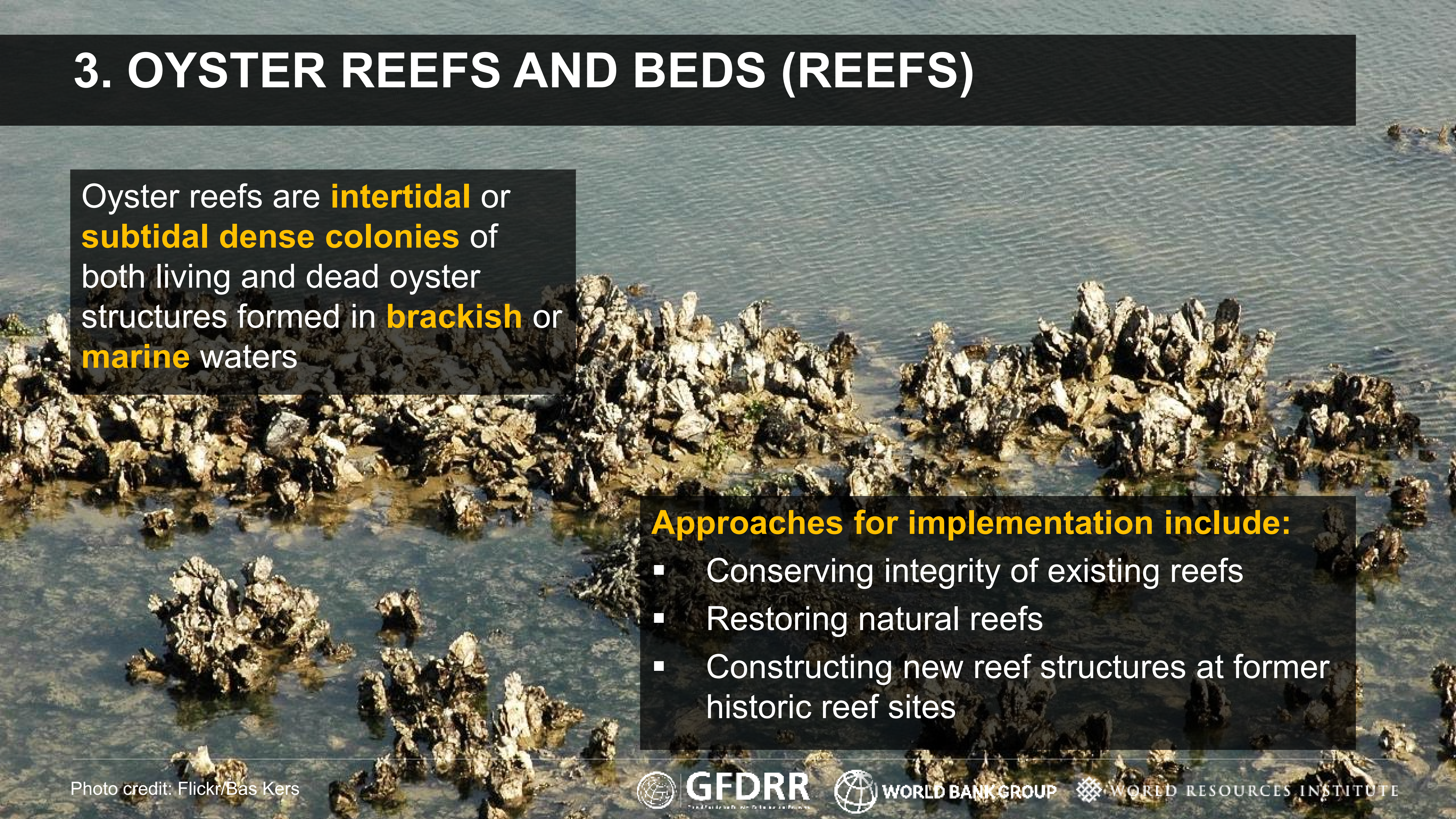
DISASTER RISK MANAGEMENT WITH CORAL REEF RESTORATION IN BELIZE

- **Objective:** build on artificial reef creation successes to strengthen climate resilience, reduce flooding and erosion
- **Cost: US$300,000** for **coral activities** out of US$6 million project budget
- **Expected outcome:** reefs will help decrease overall wave action



Project Locations in Yellow

3. OYSTER REEFS AND BEDS (REEFS)



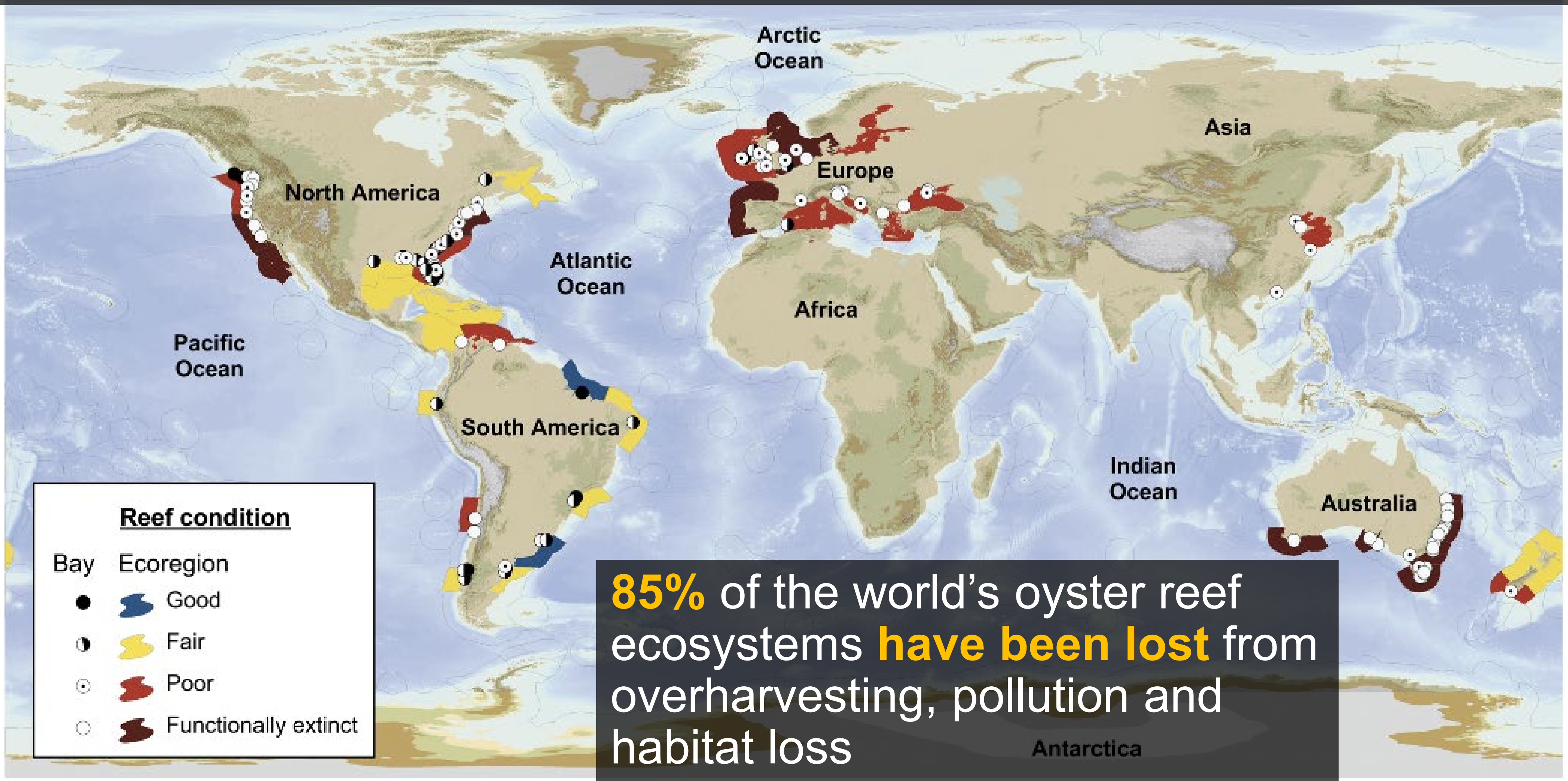
Oyster reefs are **intertidal** or **subtidal dense colonies** of both living and dead oyster structures formed in **brackish** or **marine** waters

Approaches for implementation include:

- Conserving integrity of existing reefs
- Restoring natural reefs
- Constructing new reef structures at former historic reef sites

Photo credit: Flickr/Bas Kers

GLOBAL CONDITION OF OYSTER REEFS IN BAYS AND ECOREGIONS



85% of the world's oyster reef ecosystems **have been lost** from overharvesting, pollution and habitat loss

Source: Beck et al 2011

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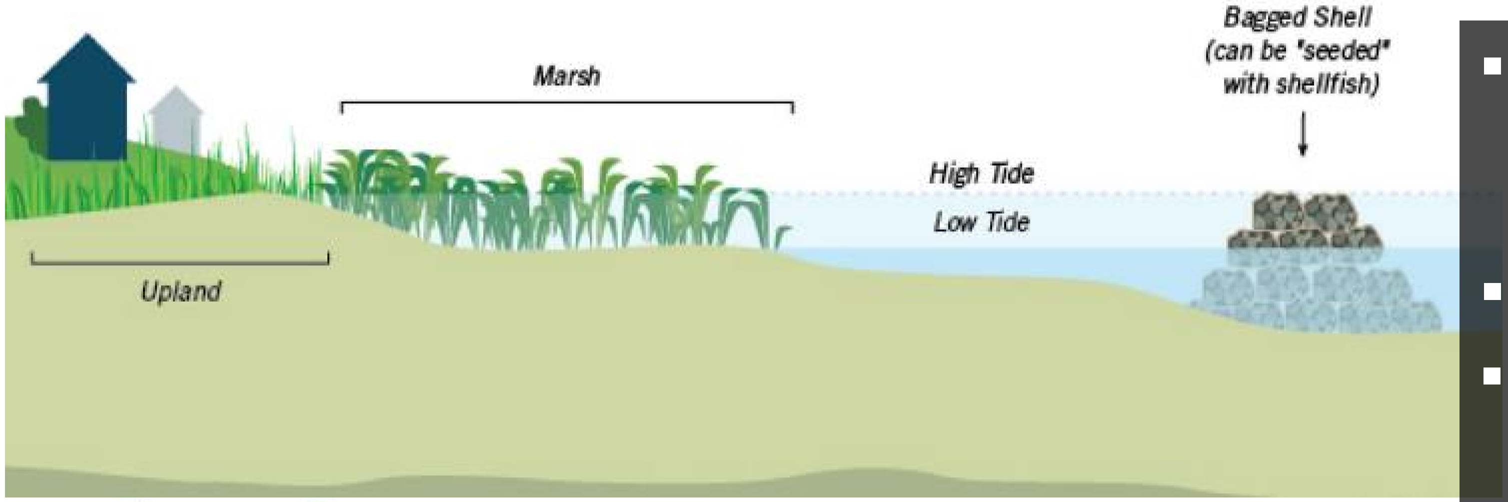
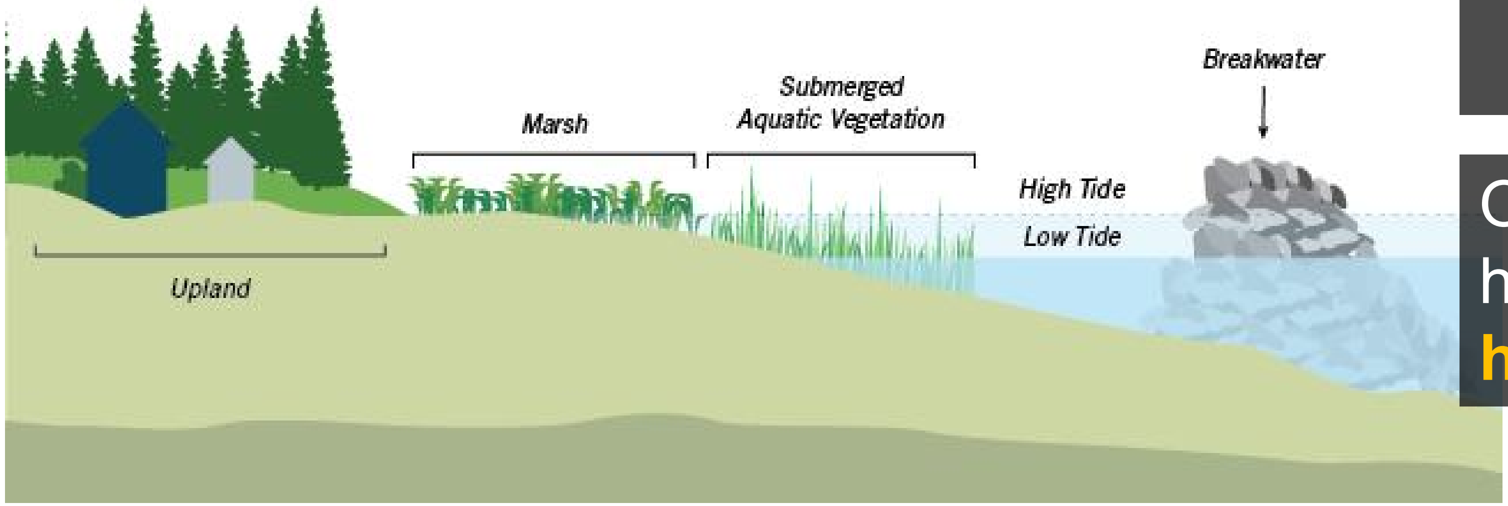
RISK REDUCTION BENEFITS





- Protect **adjacent habitats** with risk reduction properties
- Reduce **wave energy**
- Enhance **shoreline stability, expansion and elevation**

Oyster reefs in Alabama have **reduced wave heights** on average **53-91%**

Graphic credit: TNC 2018

ADDITIONAL BENEFITS

- Livelihoods
- Fisheries
- Water quality
- Biodiversity

Photo credit: Flicker/UNC IMS

CONSIDERATIONS FOR USING OYSTER REEFS AS COASTAL DEFENSE

- **Effectively manage** and protect **existing reefs**
- **Integrate** reef restoration planning with **other** risk reduction strategies
- **Understand local site context** for best site selection and restoration design
- **Incorporate valuation results** into coastal planning and management decisions

Oysters reach sexual maturity in 1 year

Photo credit: Flickr/USACE NY

WHAT DO OYSTER REEFS COST?

Costs of reef restoration measures have been **found to be significantly less expensive** than building tropical breakwaters

Median oyster reef restoration cost estimate value is **~US$66,900/hectare**

Photo: Sarah Hall-Kirchner / Macdill Airforce Base

Source: Bayraktarove et al. 2015

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DISASTER RISK MANAGEMENT WITH OYSTER REEF RESTORATION IN THE GULF OF MEXICO

5.9 kilometers of restored oyster reefs in Mobile Bay, Alabama has:

- **Reduced wave height and energy:** the average and top 10% of waves by 53-91% and 76-99%, respectively
- **Produced marine food supply:** 3,100kg of finfish, crab and 3,460 kg of oyster meat/yr
- **Purified water:** removing 1,888 kg of nitrogen/yr from surrounding nearshore waters

Project locations in Mobile Bay, Gulf of Mexico.

4. SANDY BEACHES AND VEGETATED DUNES

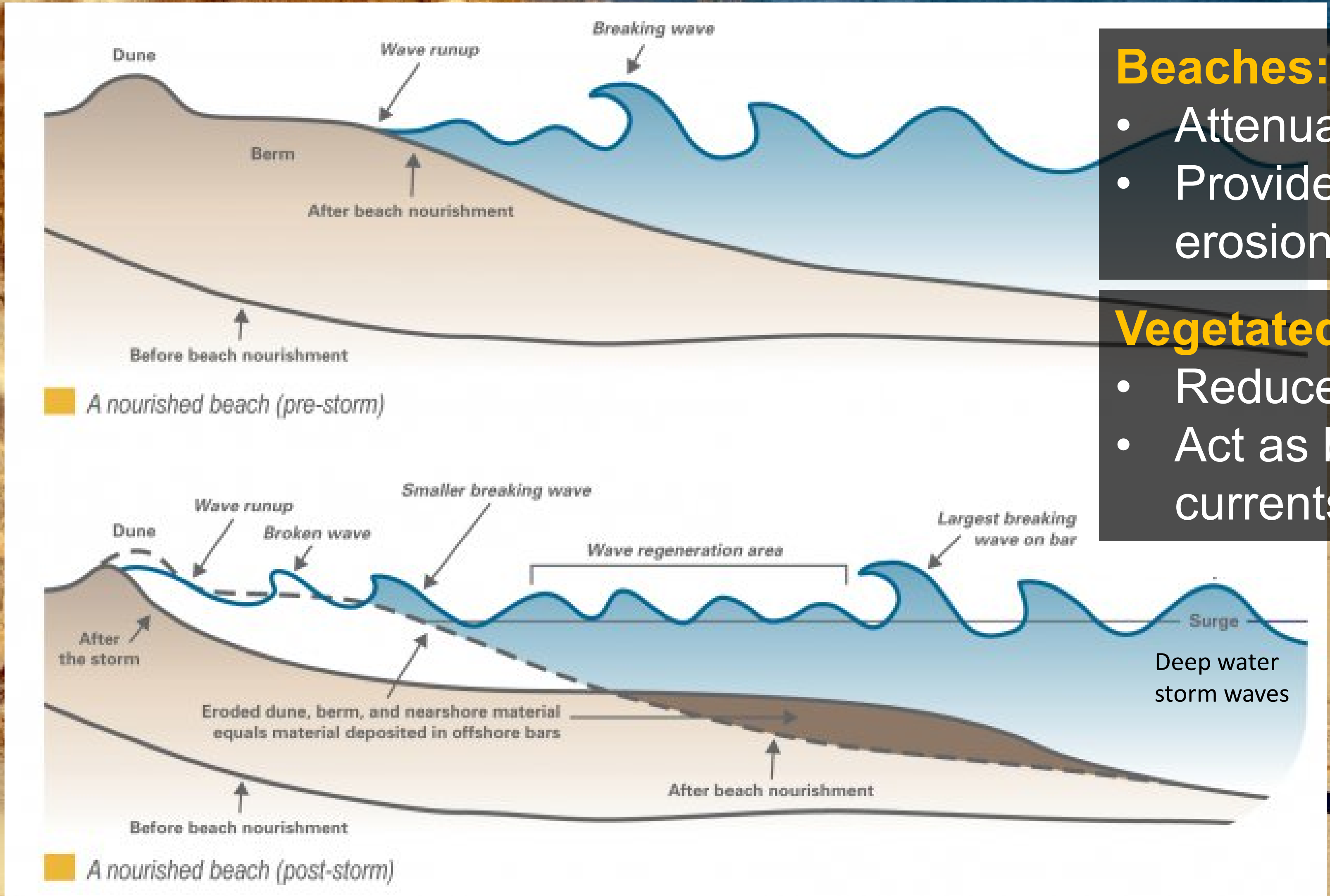
Sandy beaches and dunes occur at all latitudes, **covering ~34-40%** of ice-free coastline

Approaches for implementation include:

- Beach nourishment or replenishment through artificial replacement of sand to grow shoreline
- Replenishing and protecting integrity of existing sand dunes
- Constructing new sand dunes

Photo: W & J / Flickr
Source: Schwartz 2006

RISK REDUCTION BENEFITS



Beaches:
- Attenuate waves
- Provide shoreline stability and erosion reduction

Vegetated dunes:
- Reduce wind speed
- Act as barriers against waves, currents, storm surges

Photo credit: Dave Gingrich / Flickr
Graphic credit: Ward 2015

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ADDITIONAL BENEFITS

- Tourism and recreation
- Groundwater storage and supply
- Biodiversity and wildlife

Photo credit: Flickr/Ian

CONSIDERATIONS FOR USING SAND NOURISHMENT AND VEGETATED DUNES AS COASTAL DEFENSE

- **Regional distinctions** and site characteristics
- **Integrity of artificial dunes** vs. preserving and reinforcing existing dunes
- **Different design vulnerabilities** under same storm and wave characteristics
- **Incorporate valuation results** into coastal planning and management decisions

Nourishment can be required every 3-5 years

Photo: Patrick Bloodgood

WHAT DO BEACHES AND DUNES COST?

Cost of **beach nourishment** has been found between **US$2,000-5,000/linear ft.** and **vegetated dunes US$.03k-5,000/linear ft.**

Cost of constructing a **tropical breakwater per linear foot** is estimated to be **US$5,000-10,000**

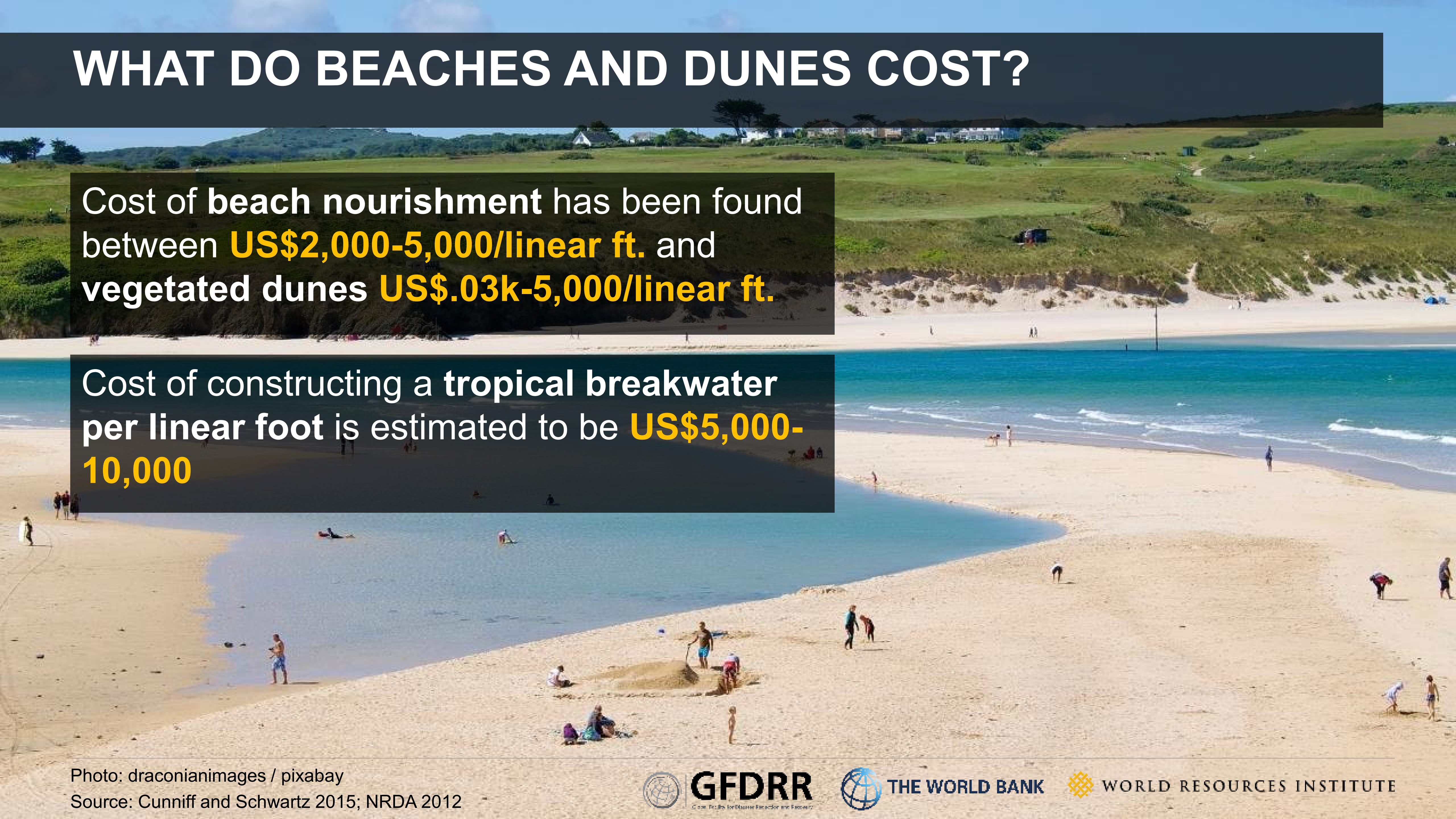

Photo: draconianimages / pixabay

Source: Cunniff and Schwartz 2015; NRDA 2012

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DISASTER RISK MANAGEMENT WITH MEGA-SAND NOURISHMENT IN THE NETHERLANDS

- **21.5 million m^3 of sand deposited** to build resilient shoreline as first line of defense
- **Cost: €70 million** for nourishment operation
- **Expected outcome:** fewer nourishment operations required over a 20-year time horizon, dune reinforcement, and less disturbance of coastal ecosystem

Photo: Flickr/Anthony Tong Lee

Source: Rijkswaterstaat 2013; Tall et al. 2016

5. COASTAL WETLANDS

Salt marshes are located in the **intertidal zone** of sheltered marine and estuarine coastlines, commonly found at **temperate** and **high latitudes**, and comprise **salt-tolerant plants** like herbs, grasses and shrubs

Approaches for implementation include:

- Conserving existing marshes
- Rehabilitating a degraded marsh
- Re-establishing a destroyed marsh

Photo credit: Flickr/USFWS

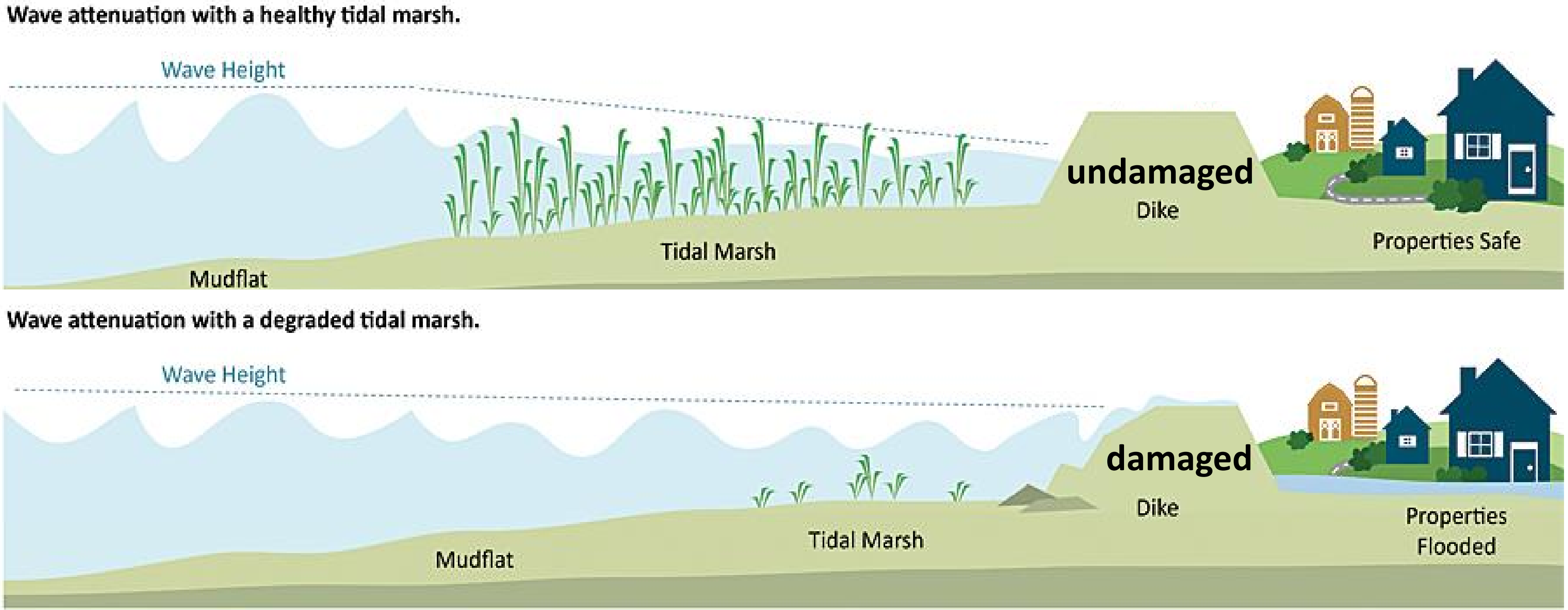
GLOBAL DISTRIBUTION OF COASTAL WETLANDS

Source: Mcowen et al. 2017

RISK REDUCTION BENEFITS

- **Sediment stabilization** facilitated by root systems
- **Wave energy dissipation** and **attenuation**

Salt marshes are estimated to **reduce non-storm wave heights** by an avg. of **72%** and **wave energy by up to 60%**



Graphic Source: Ferdana et al. 2014

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ADDITIONAL BENEFITS

- Livelihoods
- Water quality
- Carbon sequestration
- Biodiversity and habitat

Photo credit: Flickr/ Bureau of Land Management

CONSIDERATIONS FOR USING WETLANDS AS COASTAL DEFENSE

- **Adaptive nature** can keep pace with sea level rise and recover from weather events
- **Integrated** coastal management **strategies**
- Focus on **local species** with **preferable** vegetation **characteristics**
- **Incorporate valuation results** into coastal planning and management decisions

Photo credit: Flickr/ Alaska USFWS

WHAT DO COASTAL WETLANDS COST?

Wetland restoration can be **2-5x cheaper than submerged breakwaters** for equivalent wave heights up to half a meter

Median salt marsh restoration cost estimate value is ~USS**$67,100/hectare**

Photo credit: Flickr/ Chesapeake Bay Program

Source: Narayan et al. 2016; Bayraktarove et al. 2015

DISASTER RISK MANAGEMENT WITH SALT MARSH RESTORATION IN NARRAGANSETT BAY

- **200 acres** under restoration
- **Expected outcome:** Improving tidal flow, water quality, and reinvigorating high and low marsh plants to restore ecosystem services and adaptive protective benefits

Photos: Save the Bay Project (1996-2002)

6. SEAGRASS BEDS

Seagrasses are **dominant** forms of **shallow sub-tidal vegetation** found across the world, from **tropical to arctic latitudes**

Approaches for implementation include:

- Protecting existing seagrass beds
- Enabling water quality and protective conditions for natural regeneration
- Transplanting or broadcasting seeds from laboratories or plants from donor sites

Photo credit: Flickr/Dugong Seagrass

GLOBAL DISTRIBUTION OF SEAGRASS

Less than 60 species of seagrass exist, but species have ranges that can **extend for thousands of kilometers** of coastline

Graphic source: UNEP 2017
Source: Short et al. 2007

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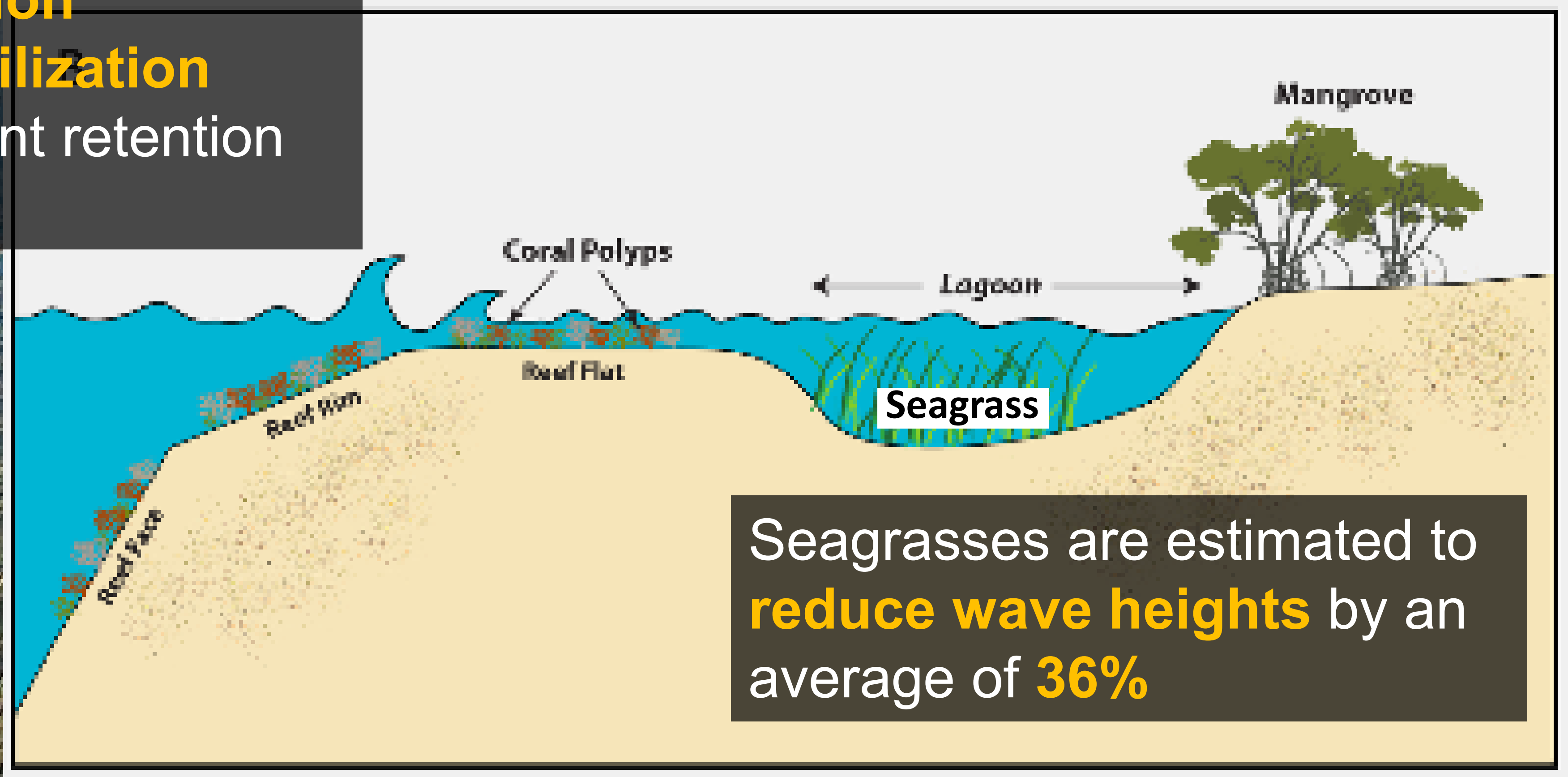
RISK REDUCTION BENEFITS

- **Wave attenuation**
- **Shoreline stabilization** through sediment retention and deposition



Seagrasses are estimated to **reduce wave heights** by an average of **36%**

Photo credit: Flickr/budak
Graphic credit: Guannel et al 2016

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ADDITIONAL BENEFITS

- Livelihoods
- Fisheries
- Water quality
- Carbon sequestration
- Biodiversity

Seagrass provide an estimated **US$1.9 trillion/yr** in the form of nutrient cycling

Photo: Jayhem / Flickr

CONSIDERATIONS FOR USING SEAGRASS AS COASTAL DEFENSE

- **Susceptibility** to sea level rise
- **Enhanced risk mitigation** when combined with other ecosystem strategies
- **Targeted value** for high-frequency, smaller scale events
- **Incorporate valuation results** into coastal planning and management decisions

Photo credit: Flickr/Dugong Sea Grass

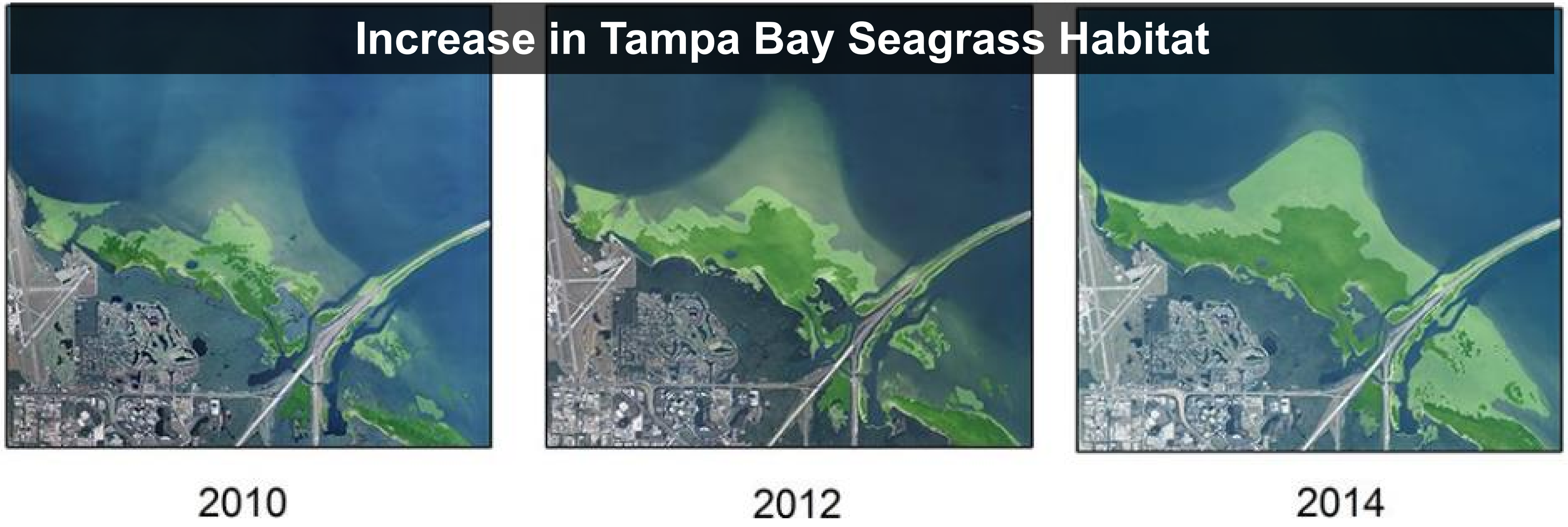
WHAT DO SEAGRASS BEDS COST?

Median seagrass restoration cost estimate value is **~US$106,800/hectare**

Photo credit: Elisa Alonso Aller

Source: Bayraktarove et al. 2015

DISASTER RISK MANAGEMENT WITH SEAGRASS RESTORATION IN TAMPA BAY



- **40,000 acres** were successfully restored
- **Expected outcome:** bring water quality improvements, buffer against erosion waves

Images: Smithsonian Ocean Portal, Tampa Bay Estuary Program Annual Report 2016

THANK YOU

For more information, contact:

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Photo credit: Flickr/Stuart Hamilton

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