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
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”

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
More than half of all megacities are located in coastal areas.
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
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.
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
## Nature-based Solutions (NBS)

<table>
<thead>
<tr>
<th>Built</th>
<th>Hybrid</th>
<th>Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard, gray, engineered</td>
<td>Combination of ecosystem elements and</td>
<td>Creation, protection or restoration of only</td>
</tr>
<tr>
<td>structures built to</td>
<td>hard engineering interventions for addressing</td>
<td>ecosystem elements for addressing development</td>
</tr>
<tr>
<td>address development</td>
<td>development objectives</td>
<td>objectives</td>
</tr>
<tr>
<td>objectives</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: World Bank 2017
Coastal solutions include:
- Offshore breakwaters
- Dikes
- Seawalls
- Groins
- Concrete or rock embankments
Ecosystems include:
  • Mangroves
  • Coral reefs
  • Oyster beds and reefs
  • Seagrasses
  • Sandy beaches and dunes
  • Coastal marshlands and other wetlands
‘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
Appropriate use of NBS is highly context specific, requiring careful evaluation, planning and design of project components.
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

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
70 species of mangroves grow in **tropic and sub-tropical latitudes** and approximately 123 countries and territories.
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
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
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 **~$9,000/hectare**.
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.
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
Coral reefs cover **250,000 km²**

75% are threatened by local human activities (e.g., overfishing, pollution) and global climate-related stressors combined
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

Livelihoods
Fisheries
Tourism
Medicine
Biodiversity

US$36 Billion Annually from Tourism

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

- Livelihoods
- Fisheries
- Water quality
- Biodiversity
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
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**.
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:** 3,100 kg of finfish, crab and 3,460 kg of oyster meat/yr
- **Purified water:** removing 1,888 kg of nitrogen/yr from surrounding nearshore waters
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
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
ADDITIONAL BENEFITS

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

- Livelihoods
- Water quality
- Carbon sequestration
- Biodiversity and habitat
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
WHAT DO COASTAL WETLANDS COST?

Wetland restoration can be \textbf{2-5x cheaper than submerged breakwaters} for equivalent wave heights up to half a meter.

Median salt marsh restoration cost estimate value is ~\textbf{US$67,100/hectare}
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
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
Less than 60 species of seagrass exist, but species have ranges that can extend for thousands of kilometers of coastline.
RISK REDUCTION BENEFITS

- Wave attenuation
- Shoreline stabilization through sediment retention and deposition

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

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

Seagrass provide an estimated **US$1.9 trillion/yr** in the form of nutrient cycling.
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
Median seagrass restoration cost estimate value is ~US$106,800/hectare
DISASTER RISK MANAGEMENT WITH SEAGRASS RESTORATION IN TAMPA BAY

Increase in Tampa Bay Seagrass Habitat

- 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:

Denis Jordy: djordy@worldbank.org
Brenden Jongman: bjongman@worldbank.org
Brenden Van Zanten: bvanzanten@worldbank.org