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Nature-based Solutions for Coastal Resilience

A Compendium of Case Studies for Sustainable Shorelines

NATIONAL INSTITUTE OF URBAN AFFAIRS
Nature-based Solutions for Coastal Resilience:
A Compendium of Case Studies for Sustainable Shorelines
January, 2025

National Institute of Urban Affairs

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Supported by:
Global Environmental Facility(GEF)

Led by:
United Nations Environment Programme(UNEP)

In partnership with:
Ministry of Housing and Urban Affairs

National Institute of Urban Affairs

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URBAN SHIFT

About UrbanShift Country Project

The Sustainable Cities Impact Program (SCIP) with the brand name UrbanShift was launched by Global Environment Facility (GEF) in 2016. Under its 7th financing round, GEF is supporting the United Nations Environment Programme (UNEP) and the National Institute of Urban Affairs (NIUA), to jointly implement the "Livable cities in India: Demonstrating Sustainable Urban Planning and Development through Integrated Approaches" project.

The project aims to support sustainable cities where knowledge exchange and capacity development inform the implementation of compact, nature-positive, climate resilient, inclusive, and gender-sensitive approaches across 4 cities in India and support scale up nationally.

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Foreword

India, with its vast and diverse coastline, is uniquely positioned to harness the potential of Nature-based Solutions (NbS) to safeguard our shorelines and coastal communities. Rising sea levels, increasing frequency of extreme weather events, and the degradation of coastal ecosystems have underscored the urgent need for innovative, sustainable, and inclusive approaches to resilience building. Application of NbS can play a pivotal role in mitigating risks, enhancing biodiversity, and ensuring the well-being of coastal population in a sustainable, effective and inclusive manner. By focusing on solutions that integrate natural ecosystems such as mangroves, coral reefs and salt marshes, this resource underscores the multifaceted benefits of NbS, including carbon sequestration, habitat preservation, and the promotion of sustainable livelihoods.

At the NIUA, we firmly believe that fostering resilient coastal communities requires a collaborative approach that transcends disciplines, sectors, and geographies. By integrating knowledge, expertise, and local insights, we can create solutions that not only address immediate challenges but also ensure long-term sustainability for our coastal regions.

It gives me great pleasure to introduce the publication, titled "Nature-based Solutions for Coastal Resilience: A Compendium of Case Studies for Sustainable Shorelines." This compendium offers tools and knowledge to adopt, adapt, and scale NbS as a central strategy for coastal resilience planning. By emphasizing the use of natural ecosystems to combat the impacts of climate change, this publication highlights pathways for integrating biodiversity conservation with economic development and disaster risk reduction.

I appreciate the efforts of my colleagues from the UrbanShift Country Project for their dedication in bringing this compendium to fruition. Their work significantly contributes to the collective mission of building sustainable and climate-resilient shorelines.

I am confident that this compendium will inspire city officials, practitioners, and policymakers to embrace NbS as a transformative approach for sustainable coastal development. Together, we can ensure that our coastal ecosystems continue to thrive, protecting communities and enriching lives for generations.

Dr. Debolina Kundu
Director , National Institute of Urban Affairs

Foreword

Rich in biodiversity, India's coastal ecosystems serve as a vital support system for millions of people. However, the escalating impacts of climate change, rising sea levels, and ecosystem degradation demand innovative and sustainable solutions. In this context, "Nature-based Solutions for Coastal Resilience: A Compendium of Case Studies for Sustainable Shorelines", becomes an invaluable resource, showcasing the transformative potential of NbS in addressing these pressing challenges.

NbS offer a viable pathway to protect our shorelines while delivering critical co-benefits for climate mitigation and adaptation. By harnessing the power of natural ecosystems and indigenous knowledge, these solutions demonstrate that sustainable development and ecological conservation can go hand in hand. This compendium brings together diverse best practices and actionable insights for embedding NbS into coastal resilience strategies. It emphasizes the importance of collaboration and inclusivity in designing and implementing solutions that address immediate challenges and long-term sustainability goals.

As the Team Lead of the UrbanShift Country Project at NIUA, I have had the privilege of working with an exceptional team who are deeply committed to championing NbS for resilient urban development. This publication is a reflection of their dedication and collective action.

The compendium aims to establish a strong foundation for scaling NbS and driving transformative change in our coastal regions. I hope this resource inspires Indian coastal cities and communities to reimagine how we manage and safeguard our coastal ecosystems.

Sarika Chakravarty
Team Lead, UrbanShift Country Project
National Institute of Urban Affairs (NIUA)

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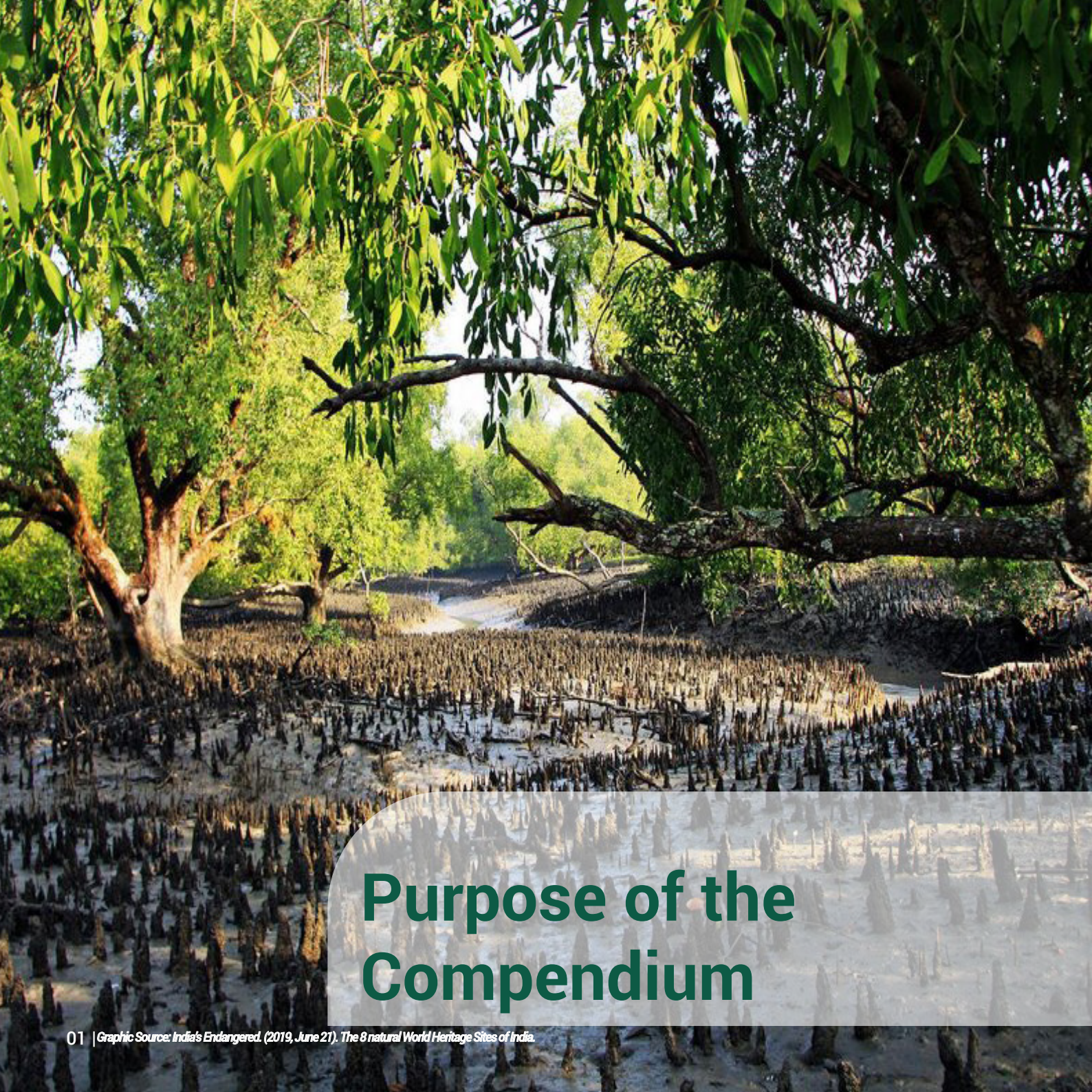


Purpose of the Compendium

 | *Graphic Source: India's Endangered. (2019, June 21). The 8 natural World Heritage Sites of India.*

The Compendium is a knowledge repository of case studies of Nature-Based Solutions (NbS) for enhancing the resilience of coastal areas and communities. Designed to support UrbanShift partner cities and other Indian coastal cities, it offers valuable insights into successful NbS applications that can provide actionable guidance for addressing climate change challenges like rising sea levels, storm surges, erosion, etc. The Compendium will serve as a reference for training programs and educational initiatives organised under the UrbanShift Country Project, fostering the adoption of sustainable NBS approaches in coastal resilience planning.

While coastal ecosystems and land forms are diverse, this Compendium focuses on five key types: mangroves, sandy shores, seagrass meadows, coral reefs, and salt marshes. It also includes information and case studies on the concept of living shorelines, highlighting their role in enhancing coastal resilience.

India's Coastal & Marine Biodiversity

India has a number of areas of high biodiversity including the Gulf of Mannar and Gulf of Kachchh; areas with extensive mangroves such as the Sunderbans, Bhitarkanika, Coringa and Pichavaram as well as the Nicobar Islands.

A mega-biodiverse country, India supports about 8% of the world's biodiversity. Coasts and islands form 2.8% of India's total geographical area. Coastal ecosystem consists of 43,230 km² of coastal wetlands with 97 major estuaries and 34 major lagoons; 6,740 km² of mangroves with 31 mangrove areas and 5 coral reef areas[1]. Towards protection and management, India has designated 25 Marine Protected Areas (MPA) in peninsular India covering 8,231 km2 and 106 MPAs in the Andaman & Nicobar and Lakshadweep Islands[1].Coastal species diversity comprises of over thirteen thousand plants and animals species consisting of marine algae (844), seagrass (14), mangroves and associates (2,321), crustaceans (2,934), molluscs (3,370), echinoderms (765), hard corals (218), fishes (2,546), reptiles (31), marine mammal (25)[1].

India is home to about 10% of world's species that includes 91,000 species of animals and 45,500 species of plants and is recognized as one among the 17 "mega-diverse" countries in the world. In the case of marine biodiversity, about 15,000 marine species of flora and fauna have been reported in India which is about 5.33% of the world's marine diversity[1]. Around the world, at least 35 areas qualify as biodiversity hotspots. These sites support nearly 60% of the world's plant, bird, mammal, reptile, and amphibian species, with a very high share of endemic species[1].

Information Source: 1- MOEFCC, (2018). CLIMATE CHANGE AND THE VULNERABLE INDIAN COAST Edited by Ramesh. R, Bhatt J.R. Ministry of Environment, Forest and Climate Change, New Delhi.

The Coastal Resilience Challenge

 | *Graphic Source: Gates, D. (2020, November 10). Unpack Habitat: Mangrove Forests. OzFish.*

01

The Indian coastline is amongst the world's most vulnerable to climate change impacts, including extreme temperatures, changes in precipitation patterns, increased incidence of extreme weather events and sea-level rise. Almost 250 million people reside within 50 km of the coast (i.e. 3.5 % of world's population). Ecosystem degradation due to natural causes and human-induced factors, has a detrimental effect on the lives and livelihoods of these vulnerable communities putting them at risk from drought, saline intrusion, coastal flooding and erosion, etc., leading to a decline in the productivity of fisheries, agriculture and aquaculture.

The challenges faced by coastal ecosystems largely stem from the impacts of climate change. The consequences of climate change are evident through rising sea levels and increased Greenhouse Gas (GHG) emissions. Some facts:

- Globally, over the past 100 years, nearly 50% of coastal wetlands have been lost due to a combination of localised human pressures, sea level rise, and extreme climate events[1].

- Between 1901 and 2018, the global mean sea level rose by 0.20 meters, with a range of 0.15 to 0.25 meters[1]. The primary drivers of sea level rise are the increase in global net GHG emissions, the thermal expansion of seawater as the ocean warms and the increased mass of water from the melting of mountain glaciers and the ice sheets in Antarctica and Greenland[1].The impacts of rising sea levels are significant and include inundation, flooding, wetland loss, erosion, saltwater intrusion, coral bleaching, increased property damage, elevated flood risks, potential loss of life, and damage to coastal infrastructure. Additionally, rising sea levels threaten tourism, recreation, and transportation functions in coastal areas[2]. India is also identified as one of the 20 countries most at risk from sea-level rise and a sea-level rise of about 1 meter could displace nearly 7 million people from coastal areas in India[3].

- The ocean had absorbed more than 93% of the excess heat from (GHG) emissions since the 1970s, causing ocean temperatures to rise adversely affecting marine species and ecosystems[4]. Rising temperatures cause coral bleaching and the loss of breeding grounds for marine fishes and mammals.

- The ocean absorbs around 27% of the atmospheric CO2 derived from burning fossil fuels and-land use changes. With the increase in CO2 emitted into the atmosphere, more and more CO2 is getting dissolved in sea water causing several chemical changes to occur. This 'ocean acidification' is reducing the calcification of the coral skeletons leading to decrease in the structural integrity of the reefs, making coastal communities increasingly vulnerable to wave exposure and storm surge[5].

 Information Source: 1.Intergovernmental Panel on Climate Change [IPCC],2021 2.IBID 3.Intergovernmental Panel on Climate Change [IPCC], Summary for policymakers, 2019 4.US EPA,2025 5. IUCN,2017

- India has lost 40% of its mangrove area in the last century, mainly due to agriculture, aquaculture, tourism, urban development and overexploitation[6]. As a consequence, important ecosystem goods and services (e.g. natural barrier, carbon sequestration, biodiversity) provided by mangrove forests will be diminished or lost.

- Globally, more than 40,000 large dams (> 15 m high) are in operation impounding 14% of runoff. Constructions of dams, reservoirs, water diversion projects etc. arrest sediment flux and decrease its supply to the coast. Coastal erosion, shifting of the river mouth and marine bar are geomorphological manifestations of reduced sediment influx[7].

- Between the mid-1980s and 2017, there was a total addition of 1249.78 km² of land reclaimed in the 16 megacities[8].Land reclamation directly changes the local coastal morphology, causing potential ecological consequences impacting coastal and near-shore habitats and species.

India's coastline faces significant challenges from climate change, human activities, and ecosystem degradation. It is crucial to adopt NbS to protect coastal ecosystems, enhance resilience, and support communities. Prioritizing sustainable development, reducing emissions, and restoring habitats are essential for safeguarding India's coastal future.

Information Source: 6. Mangrove Area Assessment in India: Implications of Loss of Mangroves,2015 8. Building beyond land: An overview of coastal land reclamation in 16 global megacities,2018
7. International Commission on Large Dams (ICOLD),2021

Coastal Pressures

 Information Sourc e: Thermal Custom Packaging. (2025, July 2). Guide to emergency disaster preparedness – Hurricane edition.

02

Factors affecting Coastal Resilience	Casuses	Effect
Climate change Induced Factors	Sea-level Rise, Coastal flooding, Storm Surge and Cyclones	Soil erosion
		Saline intrusions into estuaries and groundwater aquifers decreasing water quality
		Inundation of deltas
		Altered tidal ranges
		Loss of marshes and wetlands
		Increased property damage in coastal areas.
	Rise in Ocean Temperature	Increased coral bleaching leading to coral reef decay.
	Ocean Acidification	Adverse effects on marine species.
Anthropogenic Factors	Deforestation	Soil Erosion
		Decrease of C02 absorption
		Decreased protection against Natural Hazards
		Depletion of Mangroves: Indiscriminate exploi¬tation for timber, firewood, charcoal and tanning
	Shoreline development	Decrease water quality
	Damming	Reduced sediment flow
		Increases erosion due to modified sediment transport along coast
		Disturbs coastal biogeochemical cycles
	Land Reclamation	Destruction of coral reefs, mangroves and other critical habitat
		Reduced biodiversity, coastal wetlands, and ecosystem
	Disposal of untreated sewage (Domestic and Industrial)	The increase in pollutants impacts ecosystems and organisms.
		Reduced oxygen levels in water starving aquatic life.
		Suspended solids covering seabed prevent respiration in benthic plants and animals.
		Excess nutrients in sea water leading to eutrophication.
		Marine mammals are affected by harmful pathogens and viruses.
		Coral bleaching leading to reef destruction

Factors affecting Coastal Resilience	Casuses	Effect
Anthropogenic Factors	Agriculture Pollution	Fertilizers, pesticides, and residues harm aquatic ecosystems and disrupt the food chain.
		Coastal ecosystem loss due to forest and grass-land conversion.
	Coastal Minning	Saline intrusion into coastal aquifer
		Reduced groundwater capacity
		Habitat loss and reduced biodiversity
		Erosion leading to increased disaster risk
		Damages coastal scenery
		Altering natural sedimentation patterns
	Land-use change	Variations in coastline.
		Land use changes degrade coastal ecosystems, reducing forests, grasslands, and wetlands.
		Increased habitation raises vulnerability and risk.
	Population Increase	Increase dependance natural resources
		Loss of existing ecosystem & landcover due to increase habitation
	Increase demand for Tourism	Increased and unsustainable coastal development
		Increased solid-waste generation
		Increased boat traffic releases more pollutants into the waters
	Uncontrolled fishing and Aquaculture	Depletion of species due to overharvesting
		Destructive harvesting methods affects seafloor ecosystem and reef destruction
		Loss of mangrove cover for aquaculture.
		Depletion of existing species

Role of NbS in building Coastal Resilience

 Information Source: Sustainable Agriculture Network. (2024, February 1). Sustaining wetlands: The crucial role of agriculture in conservation.

03

NATURE-BASED SOLUTIONS (NbS)

According to the International Union for Conservation of Nature (IUCN), NbS leverage nature and the power of healthy ecosystems to protect people, optimise infrastructure and safeguard a stable and biodiverse future. NbS address societal challenges through actions to protect, sustainably manage, and restore natural and modified ecosystems, benefiting people and nature at the same time. They target major challenges like climate change, disaster risk reduction, food and water security, biodiversity loss and human health, and are critical to sustainable development.

USD 57 billion

in flooding damages averted by mangroves in China, India, Mexico, US and Viet Nam each year

One third

of climate mitigation needed to meet the goals of the Paris Agreement can be provided by NbS

USD 170 billion

estimated global benefits in ecosystem services from NbS focused on climate

NBS have largely evolved from older concepts and can also be defined as solutions based on the creation, enhancement or restoration of ecosystems in cities. They also deliver multiple benefits related to different policy targets, for instance, health and wellbeing, biodiversity, urban regeneration, storm water and wastewater management and climate adaptation/mitigation.

Information Source: Surfrider Foundation. (2022, October 31). Nature-Based Solutions on our Coasts: A Frontline Defense Against Climate Change.

NbS offers a promising pathway for effective climate action, especially in coastal areas where they out perform grey infrastructure in mitigating flood and storm damage. UNEP highlights NbS as locally tailored approaches that restore ecosystems while benefiting human well-being and biodiversity. Natural systems like mangroves, reefs, and salt marshes not only protect coastlines but also support economies, absorb wave energy, reduce erosion, and enhance resilience. Additionally, coastal NbS provide co-benefits such as carbon sequestration, improved water quality, habitat preservation, and support for tourism and recreation industries.

NbS is a challenging endeavour because it requires collaboration across disciplines to strengthen the resilience of socio-ecological systems. A key challenge lies in the varying levels of awareness and understanding among stakeholders about NbS applications and their effectiveness. Ignoring these differences, or the trade-offs between stakeholders' values especially when some groups are underrepresented in decision making—can lead to conflicts and resistance to policies. To address this, it's crucial to consider stakeholders' perceptions and preferences when designing and implementing solutions. By understanding the environmental attitudes and behaviors of diverse stakeholders, NbS initiatives can become more inclusive, reducing resistance and enhancing their effectiveness.

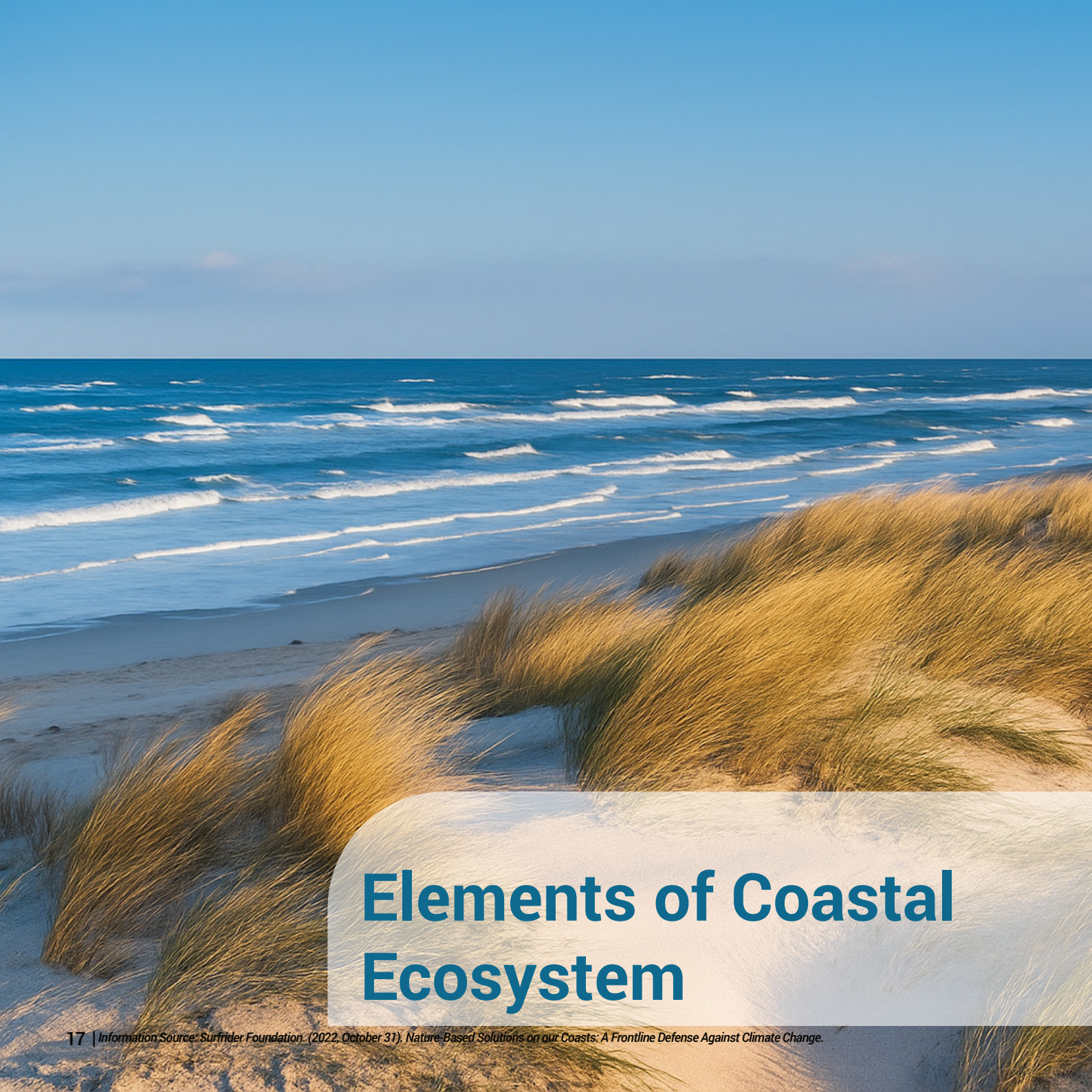
Community stakeholders can bridge the gap between theoretical potential and successful implementation of NbS by actively contributing to strategy development and execution. Their roles include,

- Building trust in decision-making for improved planning and outcomes;
- Promoting bottom-up approaches for policy success over top-down methods;
- Fostering ownership of project planning and results;
- Integrating local knowledge across all stages of NbS projects;
- Encouraging inclusive, equitable, and reciprocal collaborations; and
- Overcoming apprehensions by demonstrating tangible NbS benefits.

Engaging communities ensures that coastal NbS are not only effective but also widely accepted, sustainable, and resilient in the face of climate challenges.

Another significant barrier to the widespread adoption of NbS is securing adequate financial support. To overcome this challenge, sustainable finance tools such as green bonds and impact investments must be leveraged more effectively by municipalities, corporations, and financial institutions. These tools can help generate the necessary funding to ensure the feasibility and long-term success of large-scale NbS projects.

Graphic Source: IUCN. (2025, July 23). Enhancing coastal resilience through mangrove restoration: Aquaculture areas, Cà Mau.



Elements of Coastal Ecosystem

 Information Source: Surfrider Foundation. (2022, October 31). Nature-Based Solutions on our Coasts: A Frontline Defense Against Climate Change.

04

Introduction to Coastal Ecosystems

Coastal ecosystems represent the dynamic interface between terrestrial and marine environments. These ecosystems are characterised by unique interactions among land, sea, and atmosphere, supporting some of the richest biodiversity on the planet. They provide critical services to human communities, such as storm protection, food resources, carbon sequestration, and water filtration. However, coastal ecosystems are also among the most vulnerable to human-induced and natural disturbances:

Climate Change: Rising sea levels, ocean acidification, and warming temperatures alter habitat conditions, often leading to ecosystem degradation.

Urbanisation and Industrial Development: Coastal construction and land reclamation destroy habitats and disrupt ecological processes.

Pollution: Agricultural runoff, plastics, oil spills, and untreated wastewater impact water quality and marine biodiversity[1].

Exploitation: Activities like overfishing, coral mining, and deforestation of mangroves strain ecosystems beyond recovery capacity.

Significance of Coastal Ecosystems

Coastal ecosystems serve as natural barriers against extreme weather events, reduce coastal erosion, and support livelihoods through fisheries, tourism, and aquaculture. Additionally, they play an essential role in mitigating climate change by storing significant amounts of "blue carbon" — carbon sequestered in coastal and marine habitats. Despite their importance, these ecosystems face rapid degradation due to climate change, urban development, pollution, and overexploitation.

This foundational understanding of coastal ecosystems sets the stage for exploring restoration techniques tailored to each type. These restoration efforts are critical to preserving ecosystem functions, ensuring resilience, and sustaining the benefits they provide to human and natural systems alike.

 Information Source: Plastic waste inputs from land into the ocean, Jambeck et al, 2015

Information Source: Surfrider Foundation. (2022, October 31). Nature-Based Solutions on our Coasts: A Frontline Defense Against Climate Change.

Mangroves

Type: Intertidal forested wetlands found along tropical and subtropical coastlines.

Role: Act as natural buffers against coastal erosion, storm surges, and tsunamis while supporting rich biodiversity.

Sand Dune

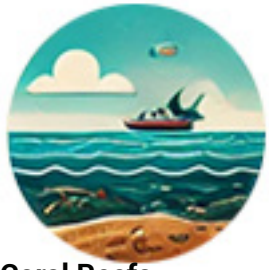
Type: Coastal landforms formed by the accumulation of wind-blown sand stabilized by vegetation.

Role: Serve as natural barriers protecting inland areas from storm surges, saltwater intrusion, and coastal flooding.

Sea Grass

Type: Submerged flowering plants found in shallow coastal waters.

Role: Stabilize sediments, provide food and habitat for marine life, and act as carbon sinks.



Coral Reefs

Type: Marine ecosystems formed by calcium carbonate structures secreted by coral polyps.
Role: Act as natural breakwaters, reduce coastal erosion, and provide habitat for a quarter of all marine species.

Beach Nourishment

Type: Dynamic, sedimentary systems formed by the deposition of sand, gravel, or pebbles along the shoreline.

Role: Provide recreational spaces, habitats for nesting turtles, and protection against wave energy.

Living Shoreline

Type: Hybrid ecosystems that combine natural elements like vegetation and reefs with engineered structures for coastal protection.

Role: Stabilize shorelines, reduce wave energy, and enhance sediment deposition.

Salt Marsh

Type: Coastal wetlands dominated by salt-tolerant grasses, sedges, and shrubs, found in intertidal zones of temperate regions.

Role: Function as carbon sinks, water filters, and nurseries for fish and shellfish species.

Graphic Source: Author | 22

Case Studies

 Graphic Source: Surfrider Foundation. (2022, October 31). Nature-Based Solutions on our Coasts: A Frontline Defense Against Climate Change.

05

Mangroves

 Graphic Source: MarAlliance. (2025, January). The secret life of mangroves: Exploring the rich biodiversity of these ecosystems.

Ecosystem Overview

Mangroves are unique coastal ecosystems comprising salt-tolerant trees and shrubs that flourish in tropical and subtropical intertidal zones. These ecosystems are characterized by dense forests that thrive in saline and brackish waters, adapting to challenging conditions such as waterlogged and oxygen-deficient soils.
Mangroves possess specialized root structures, including prop roots and pneumatophores, which provide stability, facilitate gas exchange, and enable their survival in harsh, saline environments.

Function

Coastal Protection: Mangrove roots trap sediments, stabilize shorelines, and buffer wave energy, reducing coastal erosion.

Flood Mitigation: Mangroves absorb storm surges and tidal floods, minimizing inland damage.

Carbon Sequestration: They are highly effective carbon sinks, storing up to four times more carbon than tropical rainforests.

Biodiversity Support: Mangroves provide nursery habitats for fish, crabs, and other marine species while also supporting bird populations.

Benefits

° Reduces the impact of cyclones and storm surges on coastal communities.
° Enhances fisheries and aquaculture by providing breeding grounds for marine species.
° Mitigates climate change impacts by capturing and storing carbon.

Restoration Techniques

° **Replanting Native Species:** Collect seeds or propagules from native mangrove species and plant them in degraded or deforested areas.
Common species include Rhizophora, Avicennia, and Sonneratia.
° **Hydrological Restoration:** Restoring natural water flow patterns that are disrupted by construction or drainage. This helps mangroves thrive by ensuring proper salinity and nutrient levels.
° **Community-based Conservation:** Engage local communities in reforestation efforts by providing them with economic incentives.Encourage sustainable aquaculture practices to reduce human-induced damage.
° **Protecting Existing Mangroves:** Implementing buffer zones and banning illegal felling or land reclamation in sensitive areas.

Information Source: Surfrider Foundation. (2022, October 31). Nature-Based Solutions on our Coasts: A Frontline Defense Against Climate Change.

Case Study 1: Community-Based 'Mangrove Plantation and Disaster Risk Reduction' (MP/DRR) Project.

Northern Vietnam

8,961 ha planted and preserved

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Mining
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ department
- National Governments/ Department
- NGOs
- Research/Academia
- Private sector
- Community

 Information Source: IFRC & Vietnam Red Cross (2011). Mangrove plantation in Viet Nam: Measuring impact and cost benefit.

16 Years | 76.2 Cr | Tropical Monsoon Climate | 3,260 km | 2.52 lakh Ha

Project Description

Understanding the Challenge

Vietnam's northern coastal provinces are highly vulnerable to climate-related disasters, frequently facing typhoons, storm surges, and floods. Economic pressures and increasing extreme weather have led to deforestation and the conversion of mangroves into shrimp farms, raising disaster risks. The country experiences six to eight typhoons annually, and by 2100, sea levels in coastal regions are projected to rise by 65 to 100 centimeters, inundating 4.4% of coastal areas and affecting six million people (7.3% of the population). These risks are compounded by rapid population growth, urbanisation, and land-use changes driven by the Doi Moi economic reforms of 1986.

Information Source: International Federation of Red Cross and Red Crescent Societies. (2022). The multiple benefits of mangrove restoration: Lessons from Viet Nam

Strategies Implemented

- **Afforestation and coastal rehabilitation:** Large-scale mangrove forest planting along dykes and coastal zones to enhance natural barriers and reduce storm surge impacts.
- **Community-based Disaster Risk Reduction (DRR):** Disaster preparedness training conducted to improve community resilience and readiness.
- **Reinforcement of dykes:** Approximately 100 km of sea dykes strengthened and protected with mangroves, minimizing repair costs after storms.
- **Local capacity building:** Active community involvement in planting and maintenance, ensuring skill transfer and fostering ownership.

Outcomes and Impact

Social:
The project improved disaster resilience for 350,000 direct beneficiaries across 166 communes. Training programs equipped communities to manage risks and reduce disaster-induced injuries and fatalities. Local ownership and government support strengthened sustainability.

Environmental:
Approximately 8,961 hectares of mangroves were restored, providing biodiversity habitats, sequestering CO2 (valued at $218 million), stabilizing shorelines, and attenuating floods.

Economical:

- Increased aquaculture yields, such as shells and oysters, providing alternative incomes for coastal communities.
- Economic benefits from aqua-product collection and honey bee farming were estimated between USD 344,000 and USD 6.7 million.
- Sea dykes protected by mangroves required less repair after typhoons, leading to cost savings.

E.g.- In Thai Binh province, typhoon-related damage to dykes decreased from USD 400,000 in 1996 to USD 180,000 in 2006 due to mangrove protection.

 Information Source: International Federation of Red Cross and Red Crescent Societies. (2022). The multiple benefits of mangrove restoration: Lessons from Viet Nam

Graphic Source: Earth.Org. (2024, December 12). Vietnam approves $9-billion development within mangrove reserve.

Case Study 2: Ecosystem Recovery Project Aimed at Restoring Vital Mangrove Habitats for Biodiversity and Coastal Protection.

Ecuador

1.5 lakh ha protected and 4,850 ha restored.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- **Development Agencies/ Multi-Donor Funds**
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- **Deforestation**
- Land Reclamation
- Coastal Mining
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- **Land-Use Change**
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- **Increase Tourism**
- **Uncontrolled fishing and Aquaculture**

Stakeholders Involved

- State Governments/ Department
- **National Governments/ Department**
- **NGOs**
- Research/Academia
- Private Sector
- Community

 | *Information Source: Bauza, V. (2024, July 26). In Ecuador, a 'milestone' effort to protect mangroves — and people.*

6 Years | 393.6 Cr | Temperate Climate | 2,000 km | 1.62 lakh Ha

Project Description

Understanding the Challenge

Ecuador's mangrove ecosystems, once lush and abundant, have been significantly depleted over the past few decades, leaving coastal communities more vulnerable to the devastating impacts of climate change. Mangroves serve as natural shields, protecting the coastline from storms, rising sea levels, and erosion. With their loss, these areas are increasingly exposed to dangerous flooding, unstable shorelines, and a harsher environment. A key driver is the growth of shrimp farming. Vast areas of mangrove forests have been cleared to make way for shrimp ponds, creating a ripple effect of environmental harm. This has led to the loss of vital biodiversity, damaged local ecosystems, and reduced the land's ability to store carbon, further fueling global warming. For the people who call these coastal areas home, the disappearance of mangroves has made life harder.

Information/Graphic Source : Bauza, V. (2024, July 26). In Ecuador, a 'milestone' effort to protect mangroves — and people.

Strategies Implemented

- **Soft defence system:** Replacing a failing sea dyke with a combination of sand dunes and foreshore nourishment to enhance coastal protection.
- **Alignment with National Policy:** Adopting sand-based solutions for erosion control and flood protection, in line with national coastal management goals.
- **Ecological and recreational benefits:** Providing ecological advantages and recreational opportunities while minimizing environmental impact.
- **Climate adaptability:** Ensuring the system's adaptability to climate changes.
- **Stakeholder support:** Securing strong backing from stakeholders and following proven coastal management methods.

Outcomes and Impact

Social:

- The initiative directly benefits 200,000 residents living in coastal areas by reducing their vulnerability to climate change impacts, such as storms, sea-level rise, and flooding, ensuring safer and more resilient communities.
- By protecting and restoring mangrove ecosystems, the project safeguards the cultural and social practices of local communities that have historically relied on these environments for their way of life, fostering long-term social stability.

Environmental:

- The initiative restores critical mangrove ecosystems, creating habitats for diverse species and enhancing biodiversity, which is vital for maintaining ecological balance.
- Mangrove restoration contributes to climate change mitigation by increasing carbon sequestration capacity and reducing greenhouse gas emissions, thus playing a key role in combating global warming.

Economical:

- The project promotes sustainable livelihoods by supporting eco-friendly activities, such as fishing, ecotourism, and sustainable aquaculture, creating income opportunities while pre serving natural resources.
- It incorporates responsible shrimp farming practices that improve productivity and economic returns while minimizing environmental harm, ensuring a balance between economic growth and ecosystem health.

 Information Source: Bauza, V. (2024, July 26). In Ecuador, a 'milestone' effort to protect mangroves — and people.

Graphic Source : Global Environment Facility. (n.d.). Mangroves: Spotlight | 34

Case Study 3: Building with Nature for Safe, Prosperous, and Adaptive Coastlines.

Indonesia

60 ha protected and 119 ha restored.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Mining
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-use change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State governments/ department
- National governments/ department
- NGOs
- Research/Academia
- Private sector
- Community

 Information Source: Building with Nature in Indonesia, Restoring an eroding coastline and inspiring action at scale (2015 - 2021)

6 Years | 91.03 Cr | Tropical Climate | 81,000 km | 2.67 million Ha

Project Description

Understanding the Challenge

Indonesia's coastlines, particularly in Northern Java's Demak district, are facing severe erosion and flooding due to mangrove destruction for aquaculture, land subsidence from excessive groundwater extraction, and poorly designed infrastructure like sea walls. These issues are compounded by climate change, which raises sea levels and intensifies storm surges, putting over 30 million people in Java at risk. Agriculture and aquaculture have incurred billions in losses, with villages submerged or isolated. In Demak, coastal retreat has consumed rice fields and over 500 hectares of aquaculture ponds, as traditional defenses like sea walls have failed to prevent the damage.

Information/Graphic Source: Building with Nature in Indonesia, Restoring an eroding coastline and inspiring action at scale (2015 - 2021) |

Strategies Implemented

- **Permeable Structures:**Demak's coastline features nine kilometers of mud-trapping, semi-permeable grids to reduce wave impacts and restore soil profiles, enabling mangrove rehabilitation for long-term erosion defense.
- **Mangrove Greenbelts:** Abandoned aquaculture ponds were converted into 80 hectares of mangrove green belts, promoting natural regeneration with contributions from 20 farmers.
- **Community Training:**Coastal Field Schools enhance aquaculture using organic methods to improve pond fertility.
- **Bio-rights Program:**Providing financial and technical aid, the program engaged 268 individuals to improve
- aquaculture, develop livelihoods, and support conservation projects.

Outcomes and Impact

Social:

- Social cohesion in Demak's coastal villages improved with the creation of the community Ocean Forum (BINTORO).
- Coastal Field Schools boosted farmers' skills, strengthening community resilience through sustainable aquaculture, improved livelihoods, and alternative incomes.

Environmental:

- 20 km of coastline were restored.
- 119 hectares were dedicated to mangrove restoration, with an additional 60 hectares better protected.
- 66 species of water birds now rely on the restored mangroves.
- Erosion was reduced, and biodiversity increased, with significant mangrove recovery and improved fish populations.

Economical:

- Farmers' income from aquaculture tripled.
- Coastal Field Schools introduced best practices that boosted aquaculture productivity and income.
- Mangrove recovery improved fisheries and increased wild catch.
- Alternative livelihoods, including eco-tourism and non-timber products, were developed to adapt to environmental changes.

Sand Dunes

 Graphic Source: PreventionWeb. (2023, November 15). Climate change threatens beach tourism.

Ecosystem Overview

Sand dunes are dynamic natural landforms created by the accumulation of wind-blown sand along coastlines. These ridges are shaped and maintained by wind and wave action, with vegetation playing a vital role in their stability. Native plants trap sand particles and anchor the dunes with their extensive root systems, preventing erosion and ensuring the dunes' resilience against environmental forces.

Function

Barrier Against Storm Surges: Dunes act as buffers, absorbing wave energy during storms.

Erosion Control: Vegetation roots stabilize sand, preventing wind erosion.

Biodiversity Habitat: They provide habitats for various dune-adapted species like insects, birds, and reptiles.

Benefits

° Protects coastal communities and infrastructure from flooding and erosion.
° Enhances natural landscapes, which can attract ecotourism..
° Supports local ecosystems by maintaining native plant and animal species.

Restoration Techniques

° **Replanting Native Species:** Plant grasses like Ammophila arenaria (marram grass) or Spinifex littoreus to stabilize dunes.
° **Sand Fencing:** Install fences to trap windblown sand and promote dune formation.
° **Erosion Control Structures:** Use biodegradable mats or coir logs to prevent dune erosion while allowing vegetation growth.
° **Public Access Management:** Restrict human activities like trampling and vehicular traffic to protect fragile dune systems.

Information Source: NetworkNature. (2021, August 19). Riches of the dunes: Measuring and protecting coastal dune biodiversity through Nature-based Solutions.

Case Study 4: ReDuna Project – Ecological Restoration of Sand Dunes at São João da Caparica and Cova do Vapor Beaches.

Portugal

1 km of Coastline Restored

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 | *Information Source: European Commission. REDUNA – Restoration of S. João da Caparica Sand Dunes. Oppla*

2014-Ongoing

0.88 Cr - 4.42 Cr

Mediterranean Climate

648 km

60 % of Coastline

Project Description

Understanding the Challenge

The Portuguese city of Almada, facing sea-level rise, erosion, and storm surges, initiated the ReDuna project in 2014 to restore its dune ecosystem, destroyed by winter storms. The restoration, covering 1 km of the Costa da Caparica coastline, involved planting 100,000 native plants and installing willows, fences, and pathways. The project highlights the successful use of Nature-based Solutions (NbS) to combat coastal erosion, benefiting Almada, which is otherwise threatened by coastal retreat.

Information/Graphic Source: European Commission. REDUNA – Restoration of S. João da Caparica Sand Dunes. Oppla

Strategies implemented

- **Restoration & Stabilization:** Sand nourishment and willow sand fences restored the beach profile and stabilized dunes, aided by planting 100,000 native species for stronger ecosystems.
- **Biodiversity:** Promoted recolonization of native flora and fauna, boosting biodiversity and ecological balance.
- **Community Involvement:** Engaged locals, NGOs, and schools in maintenance and replanting efforts, fostering support and knowledge sharing.
- **Impact Mitigation:** Installed pathways and fences to reduce human disturbance and protect sensitive areas. Sustainability: Continuous monitoring and adaptive strategies ensured long-term dune health and re silience.

Outcomes and impact

Social:

- The Reduna project involved over 100 US students who volunteered in activities such as maintaining dunes, planting native species, and removing invasive plants.
- These efforts not only helped stabilize the dunes but also provided participants with hands-on experience in NbS.
- The project is part of the NbS EduWORLD network, fostering education and practical engagement in NbS. By involving local and international students, the project raises awareness of climate change and promotes sustainable thinking for future generations, while strengthening community collaboration among various stakeholders. cessful use of Nature-based Solutions (NbS) to combat coastal erosion, benefiting Almada.

Environmental:

- The dune restoration enhanced the local ecosystem, with the planting of 100,000 native plants and the arrival of 49 new animal species.
- This increased biodiversity supports natural processes that protect the coast from erosion and storms. NbS measures also stabilise sediment dynamics, reduce erosion risks, and help the dunes act as carbon stores, contributing to greenhouse gas reduction.

Economical:

- The dune restoration has economic benefits for Almada, a key tourist destination attracting 8 million visitors annually.
- By preventing coastal erosion and preserving beaches, the ReDuna project supports tourism infrastructure. It also creates local jobs in dune maintenance, reforestation, and invasive species control, providing long-term employment opportunities.

Information/Graphic Source: Oppla. (n.d.). NBSEduworld case study: ReDuna project – Ecological restoration of sand dunes at São João da Caparica and Cova do Vapor beaches.

Case Study 5: Environmental Restoration of the Maspalomas Dune System (MASDUNAS Project)

Spain

400 ha of Beach Area Restored

Funding source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- **Natural Disasters**
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- **Shoreline Development**
- Disposal of untreated sewage
- Land-Use Change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- **Population Increase**
- **Increase Tourism**
- Uncontrolled fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source: ADAPTECCA. (n.d.). Environmental restoration of the Maspalomas dune system: MasDunas project.

1.6 Years | 10.2 Cr | Mediterranean Climate | 4,964 km | Over 50 ha of Sand Dunes.

Project Description

Understanding the Challenge

Environmental degradation in the Natural Reserve and surrounding areas, driven by urban-tourist development, has disrupted natural wind systems and worsened due to climate change impacts like coastal erosion, flooding, and rising sea levels. The climate emergency, combined with human activities, threatens the Maspalomas dune system and Nature Reserve if no action is taken.

Graphic Source: ADAPTECCA. (n.d.). Environmental restoration of the Maspalomas dune system: MasDunas project.

Key issues include:

- Sedimentary erosion due to wind disturbances, leading to sand loss, increased vegetation, and shrinking dunes.
- Loss of balancones (Traganum moquinii), which are vital for sand transport and the formation of character istic dunes.
- Biodiversity decline from environmental degradation, uncontrolled public use, and invasive species disrupt ing the ecosystem.
- Landscape alteration from new trails, vegetation trampling, litter, and disruption of dune dynamics, harming the local environment.

Strategies implemented

Sand loss prevention and restoration:

- Restoring sand by transferring over 60,000 m³ from Punta de la Bajeta to Playa del Inglés through dredging.
- Installing sand collectors designed for arid conditions and reintroducing balancones specimens.

Environmental Quality Improvement:

- Enhancing biodiversity by restocking balancones from germination or cuttings and reducing invasive plant species.
- Eliminating non-native wooden and rock shelters from restricted and exclusion zones.

Public use management and conservation:

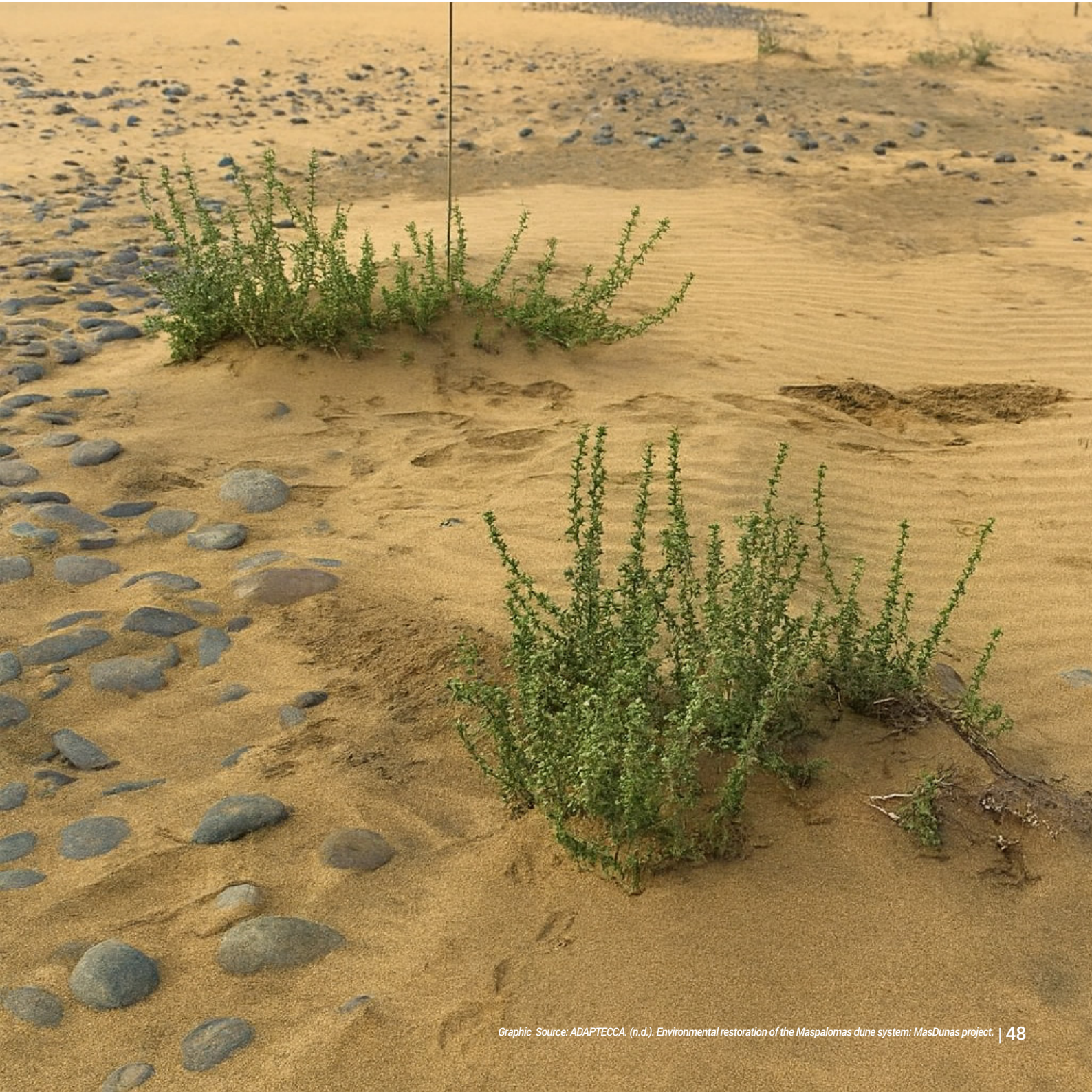
- Re-signaling trails to balance responsible public use with the conservation of the dune system.

Outcomes and impact

Social:
Raised awareness among local residents and tourists about the importance of dune conservation, fostering community involvement and responsible use of the area.

Economical:
Strengthened sustainable tourism practices, ensuring long-term benefits for the local economy while preserving the natural heritage of the Maspalomas Nature Reserve.

Environmental: Restoration of over 60,000 m³ of sand to the dune system, reintroduction of native plant species like Balancones, reduction of invasive species, and improvement of overall ecosystem resilience and biodiversity.



Graphic Source: ADAPTECCA. (n.d.). Environmental restoration of the Maspalomas dune system: MasDunas project.

Beach Nourishment

 Graphic Source: Montanari, A. (2017, May 2). Nature based solutions for coastal protection. University of Bologna.

Ecosystem Overview

Beaches are dynamic coastal ecosystems where the land meets the sea, creating vital habitats for a diverse range of species, including shorebirds, crabs, and sea turtles. These environments play a critical role in facilitating interactions between marine and terrestrial ecosystems, supporting biodiversity and contributing to coastal resilience.

Function

Shoreline Stabilisation: Adding sand restores eroded beaches and mitigates further loss.

Wave Dissipation: Wider beaches reduce the energy of incoming waves, minimizing damage.

Tourism and Recreation: Beaches serve as economic hubs for coastal communities.

Benefits

° Prevents loss of land due to erosion, protecting property and infrastructure.
° Supports local economies through tourism and recreational activities.
° Improves habitats for shorebirds and intertidal organism.

Restoration Techniques

° Sand Replacement: Import sand from offshore sources or nearby land to replace eroded materials.
° Vegetative Stabilization: Planting grasses or shrubs along the beach edges to stabilize sand movement.
° Artificial Reefs: Construct reefs offshore to reduce wave energy and encourage sand deposition.

Graphic Source: European Environment Agency. (n.d.). Beach and shoreface nourishment. Climate-ADAPT.

Case Study 6: Sand Motor – Building with Nature Solution to Improve Coastal Protection Along Delfland Coast

The Netherlands

40 km of coastline restored.

Funding source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline development
- Disposal of untreated sewage
- Land-Use Change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 | *Information Source: Climate adapt .European Environment Agency. (2019, February 15). Sand Motor – building with nature solution to improve coastal protection along Delfland coast (the Netherlands).*

20 Years

598.34 Cr

Temperate maritime climate

350 km

250 km of Sand Shores

Project Description

Understanding the Challenge

The Netherlands, with 350 km of coastline and low-lying regions, faces significant flooding risks due to erosion and rising sea levels (0.65–1.3 m by 2100). Rijkswaterstaat uses 12 million m³ of sand annually for coastal protection, but accelerating sea level rise may demand more. Since 2006, innovative strategies like 'mega-nourishment,' involving large-scale sand deposition guided by natural forces, have been explored, with South Holland piloting a plan in 2009.

Graphic Source: Climate adapt .European Environment Agency. (2019, February 15). Sand Motor – building with nature solution to improve coastal protection along Delfland coast (the Netherlands).

Strategies Implemented

- **Mega-Nourishment:** Used large sand deposits, like the 2011 Sand Motor (21.5 million m³, 128 ha peninsula), to combat erosion and sea level rise.
- **Building with Nature:** Applied eco-friendly methods to enhance coastal dynamics, support habitats, and promote recreation.
- **Morphological Evolution**: Designed systems for natural sand redistribution, creating sustainable features like sand spits and lagoons.
- **Environmental Focus**: Integrated ecological designs for groundwater protection, dune growth, and conservation.

Outcomes and Impact

Social: The Sand Motor has created new leisure opportunities, including bathing, surfing, dog walking, and hiking, enhancing the quality of life for residents and visitors. The area has become a hub for outdoor activities, fostering community engagement and tourism.

Environmental: The project fosters natural dune growth, improving coastal protection and creating diverse habitats for flora and fauna. Sheltered ecotopes in the lagoon and intertidal zones support benthic life and bird species, enhancing biodiversity. This dynamic area also acts as a natural buffer against sea-level rise.

Economical: The Sand Motor offers long-term economic benefits by reducing costs through its 20-year lifespan, minimizing the need for frequent sand nourishment. It boosts tourism via new recreational spaces, supports fisheries through enhanced biodiversity, and generates valuable knowledge for cost-effective coastal management. Additionally, it positions South Holland as a leader in sustainable infrastructure, attracting investment and interest in innovative solutions.

 Information Source: Climate adapt .European Environment Agency. (2019, February 15). Sand Motor – building with nature solution to improve coastal protection along Delfland coast (the Netherlands).

Graphic Source: EcoShape. (n.d.). Sand Motor Delfland Coast | 54

Case Study 7 : Uswetakeiyawa Beach Nourishment.

Uswetakeiyawa, Western Province, Sri Lanka

1.8 km of coastline restored.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source: Ratnayake, N. P., Ratnayake, A. S., Azoor, R. M., Weththasinghe, S. M., Seneviratne, I. D. J., Senarathne, N., Premasiri, R., & Dushyantha, N. (2019). Erosion processes driven by monsoon events after a beach nourishment and breakwater construction at Uswetakeiyawa beach, Sri Lanka.

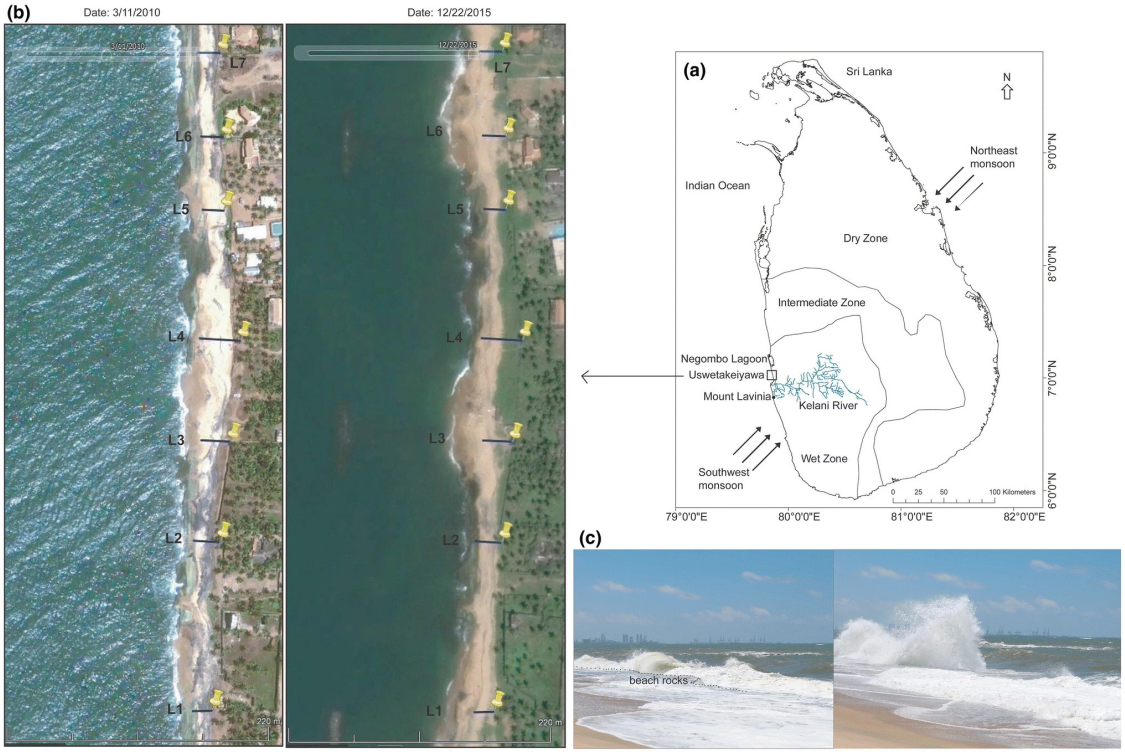
2012 onwards (long-term initiative).

2,460 Cr

Tropical Climate

1,340 km

1,000 km of Sandy Shores



Project Description

Understanding the Challenge

The Uswetakeiyawa beach nourishment project represents a pioneering soft engineering intervention in Sri Lanka, aimed at stabilizing shorelines and mitigating coastal erosion. This initiative was implemented as part of the Coastal Zone Management Plan by the Coast Conservation and Coastal Resources Management Department. The project focuses on artificially replenishing sand along the eroded sections of the Uswetakeiyawa beach and surrounding areas, including Negombo Lagoon and Kelani River, to preserve critical coastal ecosystems and support local livelihoods.

Graphic Source: Climate adapt Ratnayake, N. P, Ratnayake, A. S., Azoor, R. M., Weththasinghe, S. M., Seneviratne, I. D. J., Senarathne, N., Premasiri, R., & Dushyantha, N. (2019). Erosion processes driven by monsoon events after a beach nourishment and breakwater construction at Uswetakeiyawa beach, Sri Lanka.

Strategies Implemented

- **Artificial beach nourishment:** Replenishment of 300,000 m³ of offshore sand over a 1.8-km stretch to restore beach width and stabilize the coastline.
- **Breakwater construction:** Installation of three breakwaters approximately one year after nourishment to reduce wave energy and minimize sediment loss.
- **Geomorphological surveys**: Conducted using Leica Total Station and GPS systems to monitor beach profiles and elevation changes.
- **Sediment analysis**: Assessed grain size distribution using GRADISTAT software to evaluate the compatibility of nourishment sand with native sediments.
- **Monitoring programs**: Continuous monitoring of sand volume, beach width, and wave data over seasonal cycles.
- **Pilot Projects**: Developed as test cases to inform future beach nourishment programs.

Outcomes and Impact

Social:

Knowledge Advancement, Collected valuable data and insights on beach dynamics and the effectiveness of breakwater structures, contributing to the design and implementation of future coastal protection projects.

Environmental :

- Maintained the delicate balance of the beach ecosystem, supporting local fisheries, protecting marine biodiversity, and fostering a thriving natural environment.
- Effectively managed wave energy by strategically placing breakwaters, reducing wave-induced erosion and protecting the beach from further damage.
- Successfully reduced shoreline erosion and stabilised Uswetakeiyawa beach, ensuring the long-term sustainability of its natural ecosystems and minimising further coastal degradation.

Economical:

Tourism Development: Preserved the scenic beauty of the beach, enhancing its appeal as a tourist destination and supporting local economic growth through increased visitor activities and related businesses.

 Information Source: Ratnayake, N. P., Ratnayake, A. S., Azoor, R. M., Weththasinghe, S. M., Seneviratne, I. D. J., Senarathne, N., Premasiri, R., & Dushyantha, N. (2019). Erosion processes driven by monsoon events after a beach nourishment and breakwater construction at Uswetakeiyawa beach, Sri Lanka

Graphic Source: Sandee, LLC. (n.d.). Uswetakeiyawa Beach, Sri Lanka – All you need to know.

Salt Marshes

 Graphic Source: EcoShape. (n.d.). Growing salt marshes

Ecosystem Overview

Salt marshes are coastal wetlands located in estuaries and bays, characterized by the dominance of salt-tolerant plant species such as grasses, sedges, and reeds. These vital ecosystems play a key role in filtering pollutants, storing carbon, and offering essential habitats for a variety of wildlife.

Function

Flood Regulation: Salt marshes act as sponges, absorbing and slowing down floodwaters.

Erosion Prevention: Their dense root systems stabilize sediments and prevent coastal erosion.

Water Filtration: Salt marshes filter pollutants, improving water quality in coastal zones.

Carbon Sequestration: They store significant amounts of carbon in their soils.

Benefits

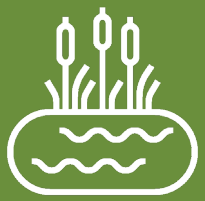
° Mitigates storm surge impacts on coastal communities.
° Enhances biodiversity by supporting fish, shellfish, and bird populations.
° Improves water quality, benefiting adjacent marine ecosystems.

Restoration Techniques

° **Planting Salt-Tolerant Vegetation:** Reintroduce species like Spartina alterniflora (cordgrass) to degraded areas.
° **Tidal Flow Restoration:** Remove barriers like levees to restore natural tidal flooding.
° **Sediment Addition:** Add sediments to raise marsh elevation and combat subsidence or sea-level rise.

Case Study 8: Saltmarsh Recreation by Managed Realignment at Hesketh Out Marsh

Hesketh Out Marsh, Lancashire, United Kingdom



322 Ha restored

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source: European Environment Agency. (2016, June 7). Saltmarsh recreation by managed realignment, Hesketh Out Marsh – UK. Climate-ADAPT.

7 Years

63.93 Cr

Temperate Maritime Climate

220 km

34500 Ha

Project Description

Understanding the Challenge

The Hesketh Out Marsh project is a large-scale habitat recreation initiative aimed at restoring intertidal saltmarsh habitats through managed realignment. This project reconnected 300 hectares of former farmland to the estuary by breaching existing sea walls, allowing tidal waters to inundate the area. The initiative addressed biodiversity loss, enhanced coastal resilience, and contributed to the broader conservation goals of the Ribble Estuary.

Graphic Source: European Environment Agency. (2016, June 7). Saltmarsh recreation by managed realignment, Hesketh Out Marsh – UK. Climate-ADAPT.

Strategies implemented

- **Managed Realignment:** Strategically breached the sea walls to allow natural tidal flows to reclaim the land.
- **Hydrological Design:** Ensured appropriate elevation gradients and hydrodynamics to support saltmarsh for mation and prevent erosion.
- **Vegetation Restoration:** Promoted natural colonization of native saltmarsh plants while monitoring invasive species.
- **Community Engagement:** Collaborated with local stakeholders, landowners, and conservation organisations to align project goals with community interests.
- **Biodiversity Conservation:** Designed habitats to support bird populations, fish nurseries, and other estua rine species.

Outcomes and impact

Social:

The project engaged local stakeholders, fostering ownership, environmental stewardship, and community ties.It created recreational spaces like walking trails and bird-watching areas, enhancing local quality of life. Additionally, it offered educational opportunities and revitalised cultural and historical connections to the estuarine environment.

Environmental:

- Biodiversity Restoration: Restored 300 hectares of vital saltmarsh habitat, benefiting bird species like redshanks and lapwings, as well as aquatic organisms.
- Coastal Defence: Enhanced flood protection for inland areas by reducing wave energy and improving sediment accretion.
- Carbon Sequestration: Increased capacity for carbon storage, contributing to climate mitigation efforts.

Economical:

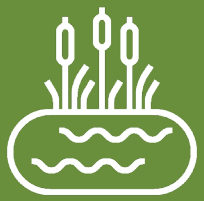
The project boosted local tourism, attracting nature enthusiasts and bird watchers, which spurred economic activity. It created jobs in construction, environmental management, and maintenance. Property values increased due to the enhanced landscape and reduced flood risks. Natural flood protection reduced reliance on costly infrastructure, yielding long-term savings. Local businesses benefited from increased tourism, and the saltmarsh's carbon sequestration contributed to climate mitigation efforts, potentially offering economic gains through carbon credits.

 Information Source: European Environment Agency. (2016, June 7). Saltmarsh recreation by managed realignment, Hesketh Out Marsh – UK. Climate-ADAPT.

Graphic Source: European Environment Agency. (2016, June 7). Saltmarsh recreation by managed realignment, Hesketh Out Marsh – UK. Climate-ADAPT. | 64

Case Study 9: Pioneer Salt Marsh Restoration for Coastal Protection

Eastern Scheldt, The Netherlands



300 m² of Spartina mats deployed across three sites

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- **Development Agencies/ Multi-Donor Funds**
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- **Disposal of Untreated Sewage**
- Land-Use Change
- Warmer ocean Temperature
- **Damming**
- **Agriculture Pollution**
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- **NGOs**
- **Research/Academia**
- Private Sector
- **Community**

 Information Source: European Commission, CINEA. (n.d.). Salt marsh restoration Eastern Scheldt (LIFE06 NAT/NL/000077).

12 Years | 7.77 crore | Temperate maritime | 451 km | 2,000 Ha

Project Description

Understanding the Challenge

This project focuses on restoring pioneer salt marshes in the Eastern Scheldt to enhance coastal protection, biodiversity, and ecosystem functioning. The initiative employs Spartina anglica (cord grass) plants pre-grown in coconut fibre mats. By re-establishing these salt marshes, the project aims to stabilize sediments, reduce wave energy, and foster ecological health in the high intertidal zones.

Salt marshes play a critical role in coastal ecosystems by providing a buffer against storm surges and wave action. They stabilize shorelines through sediment binding and reduce coastal vulnerability to erosion and sea level rise. Additionally, they contribute to nutrient cycling and serve as habitats for a variety of fauna, supporting ecological biodiversity and fisheries. Historically, the Netherlands relied on hard infrastructure such as seawalls for coastal protection, often at the expense of natural ecosystems. This project represents a shift toward integrating nature-based solutions into coastal management.

The Eastern Scheldt faces significant erosion of intertidal flats due to changes caused by the construction of storm surge barriers and compartmentalization dams in the 1980s. These structures disrupted sediment supply and led to the decline of salt marshes. The pilot initiative seeks to reverse these effects by reintroducing Spartina anglica, a pioneer species capable of thriving in challenging intertidal environments,

Graphic Source: EcoShape. (n.d.). Pioneer salt marsh restoration for coastal protection – Eastern Scheldt.

Strategies implemented

- **Vegetation Establishment:** Pre-grown Spartina anglica mats were installed in three test locations,i.e—Rat tekaai, Sint Annaland, and Dortsman under varying hydrodynamic conditions.
- **Eco-Friendly Substrate**: Coconut fibre mats provided a stable anchoring medium for plant roots, preventing dislodgement during initial establishment.
- **Pilot Comparisons:** Compared the performance of Spartina mats with individual plantings at various distances from marsh edges and man-made cliffs.
- **Monitoring Programs:** Assessed plant survival, growth, and sediment deposition to refine methods.
- **Integrated Approach:** Placed mats at different intertidal zones to assess the combined impact of hydrodynamic forces and sediment availability on plant establishment.

Outcomes and impact

Social:

- Community Involvement: Engaged locals in monitoring and maintenance, fostering stewardship.
- Educational Value: Promoted awareness of NbS and sustainable practices.
- Livelihood Support: Enhanced local fisheries through improved habitats.

Environmental:

- Biodiversity Boost: Created habitats for diverse species, improving ecosystem health.
- Coastal Protection: Reduced wave energy and storm surge impacts.
- Sediment Stability:Trapped sediments, reducing erosion and supporting intertidal ecosystems.
- Climate Benefits: Contributed to carbon sequestration efforts.

Economical:

- Cost Savings: Provided a sustainable, low-maintenance alternative to seawalls.
- Tourism Potential: Increasd ecotourism through restored natural landscapes.
- Skill Development: Advanced expertise in ecological engineering.
- Job Creation: Generated employment in related fields.

Graphic Source: EcoShape. (n.d.). Pioneer salt marsh restoration for coastal protection – Eastern Scheldt. | 68

Living Shoreline

 Graphic Source: NOAA Fisheries. (2022, July 20). Living shorelines provide nature-based approach to coastal protection. U.S. Department of Commerce.

Ecosystem Overview

Living shorelines combine natural elements such as salt marshes, mangroves, seagrasses, and oyster reefs with engineered structures like rocks or coir logs, forming hybrid systems that enhance coastal protection.

Function

Wave Energy Dissipation: Vegetation and reefs absorb wave energy, reducing erosion.

Habitat Creation: Supports a variety of aquatic and terrestrial species.

Sediment Accumulation: Natural materials trap sediments, promoting shoreline stability.

Benefits

° Provides a sustainable alternative to seawalls and other hard infrastructure.
° Maintains the ecological integrity of coastal zones.
° Enhances recreational opportunities, like birdwatching and kayaking.

Restoration Techniques

° **Planting Vegetation:** Use native marsh grasses or mangroves to stabilise shorelines.
° **Adding Oyster Reefs or Coir Logs:** Construct reefs or logs to dissipate wave energy and promote sediment deposition.

Information Source: NOAA Fisheries. (2022, July 20). Living shorelines provide nature-based approach to coastal protection. U.S.

Case Study 10 : San Francisco Bay Living Shorelines Project.

San Francisco Bay, California, USA, focusing on two primary locations: San Rafael Bay and Hayward

Approximately 8 acres of subtidal and intertidal habitats restored.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private sector
- Community

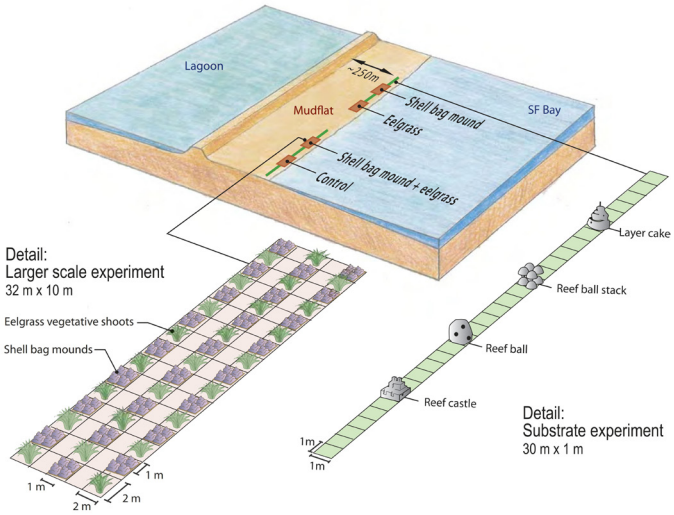
 Information Source: Latta, M., Boyer, K., Miller, J., Pinnell, C., Moderan, J., Kiriakopolos, S., ... & Zabin, C. (2016). San Francisco Bay Living Shorelines Project: 2016 annual monitoring report summary. California State Coastal Conservancy.

5 Years

30.01 Cr

Mediterranean Climate

1,287 km



Project Description

Understanding the Challenge

The San Francisco Bay Living Shorelines Project is an innovative coastal restoration initiative designed to enhance shoreline resilience and ecological integrity. By integrating eelgrass and native oyster habitats, the project aims to stabilize shorelines, reduce wave energy, and improve biodiversity. This pilot project builds upon lessons from previous efforts and contributes to regional strategies for sustainable coastal management.

Information/Graphic Source: Latta, M., Boyer, K., Miller, J., Pinnell, C., Moderan, J., Kiriakopolos, S., & Zabin, C. (2016). San Francisco Bay Living Shorelines Project: 2016 annual monitoring report summary. California State Coastal Conservancy.

Strategies implemented

- **Subtidal Habitat Restoration:** Established eelgrass beds and oyster reefs to provide essential ecosystem services.
- **Living Shoreline Design:** Constructed structures such as shell bag mounds, reef balls, and eelgrass units to support habitat formation.
- **Phased Approach:** Conducted initial substrate experiments to assess feasibility before scaling up to larger treatment plots.
- **Monitoring Programs:** Implemented biological and physical monitoring to evaluate habitat effectiveness and refine restoration techniques.
- **Community Engagement:** Partnered with local organizations and volunteers to support project implementation and outreach.

Outcomes and impact

Social:

- Community Engagement: Involved local communities and volunteers in restoration activities, fostering environmental stewardship and awareness.
- Education and Outreach: Strengthened public knowledge through partnerships with research institutions and NGOs, creating a model for community-led conservation.
- Coastal Resilience for Residents: Enhanced protection for nearby urban areas, safeguarding livelihoods and infrastructure from coastal erosion and rising sea levels.

Environmental:

- Biodiversity Enhancement: Created habitats that support fish, birds, and invertebrates, with a 15% increase in species richness.
- Wave Attenuation: Demonstrated the ability to reduce wave energy and prevent erosion along restored shorelines.
- Carbon Sequestration: Contributed to climate mitigation by enhancing eelgrass coverage, which stores carbon.

Economical:

- Cost-Effective Coastal Management: Demonstrated the efficacy of nature-based solutions as a sustainable and cost-efficient alternative to traditional hard infrastructure.
- Job Creation: Supported local employment opportunities during project implementation, monitoring, and outreach phases.

 Information Source: Latta, M., Boyer, K., Miller, J., Pinnell, C., Moderan, J., Kiriakopolos, S., ... & Zabin, C. (2016). San Francisco Bay Living Shorelines Project: 2016 annual monitoring report summary. California State Coastal Conservancy.

Information/Graphic Source: Latta, M., Boyer, K., Miller, J., Pinnell, C., Moderan, J., Kiriakopolos, S.,& Zabin, C. (2016). San Francisco Bay Living Shorelines Project: 2016 annual monitoring report summary. California State Coastal Conservancy.

Case Study 11: Pointe au Chien Indigenous Community Oyster Restoration Project.

Pointe-au-Chien, Louisiana, USA

3,100 square feet of shoreline protected and stabilized.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private sector
- Community

 Information Source: Nature-based Solutions Initiative. (n.d.). Pointe au Chien Indigenous Community Oyster Restoration Project.

2 Years

20 lakh

Subtropical Climate

770 Km

Project Description

Understanding the Challenge

The Pointe-au-Chien Cultural Heritage Protection Reef project is a coastal restoration initiative developed to protect ancient tribal mounds of cultural significance. It involves constructing a living shoreline using natural oyster reefs to mitigate coastal erosion, stabilize the shoreline, and provide ecological benefits. The project was spearheaded by the Pointe-au-Chien Indian Tribe (PACIT) in collaboration with local and regional partners.

Information/Graphic Source: Parker, H. (2022, September 30). A Louisiana tribe is losing cultural sites to coastal erosion. Oyster reefs

Strategies implemented

- **Living Shoreline Installation:** Constructed 3,100 square feet of nearshore oyster breakwaters using shell bags and oyster castles.
- **Oyster Shell Recycling:** Utilized locally sourced, recycled oyster shells from restaurants, treated and pre pared for reef construction.
- **Community Engagement**: Involved the PACIT and local volunteers in planning, material preparation, and installation activities.
- **Erosion Control**: Designed the reef to reduce wave energy and protect the integrity of the shoreline.
- **Habitat Creation**: Established oyster reefs to support aquatic species and enhance biodiversity.

Outcomes and impact

Social:

- Cultural Preservation: Safeguarded six ancient tribal mounds of the Pointe-au-Chien Indian Tribe, ensuring the protection of their cultural heritage.
- Community Engagement: Involved the local community in planning and installation, fostering stewardship and cultural pride.
- Educational Opportunities: Highlighted indigenous practices and ecological restoration techniques, promoting knowledge sharing.

Environmental:

- Biodiversity Enhancement: Created habitats for oysters, fish, shrimp, and crabs, boosting local biodiversity.
- Water Quality Improvement: Enabled oysters to filter water, reducing sediment and nutrient levels.
- Shoreline Stabilization: Reduced erosion and wave energy, protecting vulnerable coastal areas.

Economical:

- Cost Savings: Provided a sustainable, low-maintenance alternative to seawalls.
- Tourism Potential: Increased ecotourism through restored natural landscapes.
- Skill Development: Advanced expertise in ecological engineering.

 Information Source: Nature-based Solutions Initiative. (n.d.). Pointe au Chien Indigenous Community Oyster Restoration Project.

Graphic Source: Parker, H. (2022, September 30). A Louisiana tribe is losing cultural sites to coastal erosion. Oyster reefs

Case Study 12 : Oyster Reef Shoreline Stabilization Project

North Carolina, USA, focusing on several sites along the state's estuarine shoreline.

Hundreds of linear feet of estuarine shoreline across multiple sites.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of untreated sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source: Rich, B. (2015, July 27). Report Cites Benefits of Living Shorelines. Coastal Review.

5 Years

N/A

Humid Subtropical

3,375 Km

Project Description

Understanding the Challenge

The Oyster Reef Shoreline Stabilization Project is a nature-based solution aimed at mitigating coastal erosion and enhancing ecosystem services along North Carolina's estuarine shorelines. By deploying oyster reefs as living shorelines, the project stabilizes sediments, reduces wave energy, and fosters habitat creation. The initiative integrates community engagement and cost-effective practices to ensure scalability and affordability. Oyster reefs serve as natural breakwaters, dissipating wave energy while promoting sediment accretion. Beyond coastal protection, they provide habitat for various marine species, improve water quality through filtration, and support local fisheries. This approach contrasts traditional hard infrastructure like bulkheads and seawalls, which often exacerbate erosion and habitat loss.

Information/Graphic Source:Rich, B. (2015, July 27). Report Cites Benefits of Living Shorelines. Coastal Review.

Strategies implemented

- **Reef Construction:** Oyster shells and reef balls were used to create submerged and intertidal reefs, strategically placed to reduce wave energy and stabilize sediments.
- **Community Involvement:** Engaged local residents, fishers, and volunteers in reef construction and monitoring activities.
- **Cost-Effective Materials**: Recycled oyster shells and other locally sourced materials were utilized to minimize costs.
- **Adaptive Design**: Tailored designs to site-specific conditions, including wave energy, sediment availability, and ecological context.
- **Monitoring Programs**: Conducted regular assessments of shoreline stability, reef growth, and biodiversity enhancement.

Outcomes and impact

Social:

- Community Engagement: Encouraged active participation from local residents, fishers, and volunteers, fostering a sense of stewardship and environmental responsibility.
- Educational Opportunities: Provided learning experiences about coastal ecosystems and restoration techniques for communities and stakeholders.
- Coastal Protection: Reduced the vulnerability of coastal communities to erosion and storm surges, enhancing their safety and resilience.

Environmental:

- Shoreline Stabilization: Reduced erosion rates, protecting adjacent properties and infrastructure.
- Biodiversity Enhancement: Created habitats for fish, crabs, and other estuarine species, boosting ecosystem health.
- Water Quality Improvement: Filtered pollutants and nutrients, enhancing water clarity quality.

Economical:

- Support for Local Fisheries: Enhanced marine habitats bolstered local fisheries, contributing to economic sustainability.
- Cost-Effectiveness: Provided a long-term, affordable alternative to hard infrastructure, with lower maintenance costs and improved ecological benefits.

 Information Source: Rich, B. (2015, July 27). Report Cites Benefits of Living Shorelines. Coastal Review.

Graphic Source:North Carolina Coastal Federation. (2020, September 2). Sunset Beach Living Shoreline

Coral Reefs

 Graphic Source: Institute of Marine Affairs. (2023, March 3). How partnerships can help protect coral reefs. Caribois.

Ecosystem Overview

Coral reefs are vibrant marine ecosystems constructed from calcium carbonate structures created by coral polyps, typically thriving in warm, shallow waters. They support extraordinary levels of biodiversity and serve as natural barriers that protect coastlines from erosion.

Function

Wave Energy Reduction: Reefs act as natural barriers, absorbing wave energy and reducing its impact on shorelines.

Biodiversity Hotspot: Reefs provide habitat for over 25% of marine species.

Sustainable tourism: Reefs support local economies through diving tourism and sustainable fishing.

Benefits

° Protects coastal areas from storm surges and erosion.
° Supports marine biodiversity, enhancing ecosystem services.
° Contributes to livelihoods of coastal communities through tourism and fisheries.

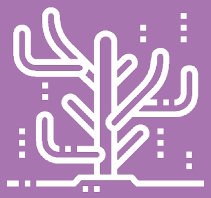
Restoration Techniques

° **Coral Gardening:** Grow coral fragments in nurseries and transplant them to degraded reefs.
° **Artificial Reefs:** Deploy structures like concrete blocks to promote coral growth.
° **Rehabilitation of Water Quality:** Reduce pollution and sedimentation to create favorable conditions for coral survival.

InformationSource:Boström-Einarsson, L., Babcock, R. C., Bayraktarov, E., Ceccarelli, D., Cook, N., Ferse, S. C. A., ... & McLeod, I. M. (2020). Coral restoration: A systematic review of current methods, successes, failures and future directions.

Case Study 13: Empowering Community Resilience Through Reforestation and Coral Reef Restoration.

Vanuatu



5,000 Ha area restored.

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private sector
- Community

 Information Source: Kiwa Initiative. (n.d.). LAMACCA Ecosystem Restoration and Conservation Project.

1.6 Years | 75.32 Lakh | Tropical Climate | 2,528 km | 40,800 Ha

Project Description

Understanding the Challenge

Environmental issues have become increasingly pressing due to the compounded effects of climate change, deforestation, rapid development, and over-harvesting of resources driven by a growing population in Vanuatu. These activities disrupt the delicate balance of ecosystems, leading to the degradation of essential services such as water filtration, carbon storage, and biodiversity maintenance, which are vital for human survival and well-being. Marine and natural resources are particularly at risk, as they face overexploitation and habitat loss, leaving them unable to regenerate or sustain the demands placed upon them. Furthermore, vulnerable and endangered species are under heightened threat, with many teetering on the brink of extinction due to the de-

Information/Graphic Source:Kiwa Initiative. (n.d.). LAMACCA Ecosystem Restoration and Conservation Project.

struction of their habitats and ecosystems. To address these multifaceted challenges, there is an urgent need for comprehensive strategies that prioritize the restoration, protection, and preservation of ecosystems. Such efforts must aim to promote sustainable resource management practices and ensure the long-term conservation of biodiversity, creating a harmonious balance between human needs and ecological integrity.

Strategies implemented

- **Capacity Building and Awareness:** Enhance knowledge among vulnerable citizens in South Malekula, Vanuatu, on best practices in agriculture, forestry, and fisheries, emphasizing the sustainable use of biodiversity resources and ecosystem services.
- **Community Strengthening:** Strengthen rural communities to achieve a 20% increase in sustainable use of biodiversity and ecosystem services by 2025, while empowering community conservation committees to effectively manage, monitor, and conserve biodiversity resources, including vulnerable species.
- **Nature based Solutions**: Empower rural communities to adopt cost-efficient,NbS that are rights-based, gender-sensitive, and socially inclusive, aiming for a measurable 15% improvement in climate change adaptation outcomes by 2030.

Outcomes and impact

Social:

- Empowered 1,000 individuals with practical skills in sustainable agriculture, forestry, and fisheries, enabling them to support biodiversity conservation and ecosystem restoration.
- Trained 450 community leaders to champion environmental sustainability through enhanced technical and managerial expertise.
- Strengthened rur`al communities in South Malekula to sustainably utilize biodiversity and ecosystem services by 20% by 2025, while equipping conservation committees to monitor resources and protect vulnerable species.

Economical:

- Empowering rural communities to employ cost-efficient nature-based solutions to achieve rights-based, gender-sensitive and socially inclusive with measurable benefits for climate change adaptation by 15% in 2030.

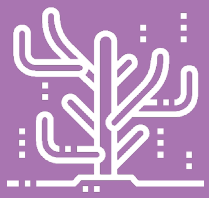
Environmental:

- By 2030, 80% of South Malekula's biodiversity ecosystem services will be restored, protected, and sustainably managed, positioning it as a leading eco-tourism destination.
- Reforestation: Distributed 3,000 seedlings to combat deforestation, restore degraded landscapes, sequester carbon, and enhance biodiversity.
- Protected Areas: Established new conservation zones to safeguard habitats, vulnerable species, and ecosystem resilience.

Information/Graphic Source:GSAP. (n.d.). Coral Gardening for Climate Change Adaptation in Vanuatu. GSAP SKILLS Online Knowledge Platform.

Case Study 14 : Restoring Coral Reefs in the Face of Climate Change in the Seychelles.

Seychelles (Praslin and Cousin Islands)



Large-scale reef restoration covering approximately 5,200 m².

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source: Reef Resilience Network. (2022, July 15). Seychelles – Coral Restoration.

8 Years | 8,69 Crore | Tropical climate | 40 km | 9.5 lakh Ha

Project Description

Understanding the Challenge

Coral reefs are vital to the Seychelles, supporting food security, local livelihoods, and economic growth while serving as natural barriers that protect coastal communities from the impacts of sea level rise and extreme weather events such as storms and wave-induced flooding. However, these ecosystems face significant threats from rising temperatures and carbon dioxide emissions, leading to coral bleaching and reef degradation.The USAID/Southern Africa Regional Mission, in collaboration with the non-governmental organization Nature Seychelles, has initiated the Reef Rescuers Project. This project aims to restore damaged coral reefs in the Seychelles, enhancing their resilience and safeguarding coastal communities from climate-related risks, including storms, floods, and rising seas. By focusing on coral reef restoration, the initiative contributes to ecosystem recovery and community adaptation, ensuring a sustainable future for both people and nature in the region.

Information/Graphic Source:Reef Resilience Network. (2022, July 15). Seychelles – Coral Restoration.

Strategies implemented

- **Scale for Impact:** The project focused on large-scale reef transplantation (~5,200 m²) to restore critical ecosystem services like coastal protection.
- **Minimize External Threats:** Project sites were selected to reduce risks from factors such as overfishing and pollution, which could hinder coral recovery.
- **Enhance Resilience:** The project tested the hypothesis that transplanting coral fragments resilient to the 1998 El Niño bleaching event would improve the overall resilience of the restored reefs.
- **Allow Time for Evaluation:** Significant resources were invested in monitoring the effectiveness of the transplantation process, with an extension granted to assess the impact of the 2014-2016 regional bleaching event on the restored sites.

Outcomes and impact

Social: Coral reefs in the Seychelles are vital for food security, providing fish as a primary protein source in a country with the world's third-highest per-capita fish consumption. They also support livelihoods in tourism, fisheries, and marine conservation. Restoration efforts have trained over 40 individuals in reef restoration, equipping communities with valuable skills. Additionally, these initiatives enhance community resilience by reducing vulnerability to storms and rising sea levels, ensuring coastal safety and stability.

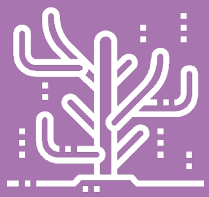
Environmental: Restored coral reefs in the Seychelles act as natural buffers, reducing wave energy by over 95% and mitigating erosion and flood risks, comparable to seawalls. Biodiversity conservation efforts, including coral nurseries, have cultivated around 40,000 coral fragments from 32 species, increasing coral cover by ~700% in project areas. These restored reefs enhance marine habitats, boosting fish abundance fivefold and species diversity threefold. To build climate resilience, "super corals" resistant to bleaching are being cultivated, ensuring long-term reef health and adaptability to environmental changes.

Economical: Coral reefs in the Seychelles boost tourism by attracting divers and snorkelers, supporting local businesses and the economy. Cost-effective strategies like reef restoration offer sustainable alternatives to seawalls. Partnerships with hotels and diving centers ensure economic sustainability, while initiatives like restoration tours and volunteer programs generate funding for conservation.

Information/Graphic Source:Reef Resilience Network. (2022, July 15). Seychelles – Coral Restoration.

Case Study 15: Locally-Managed Marine Protected Areas and Artificial Coral Reefs in Bali.

Pemuteran, Western Bali



Large-scale reef restoration covering approximately 2550 Ha .

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source: Nature-based Solutions Initiative. (n.d.). Locally-managed Marine Protected Areas and artificial coral reefs in Bali [Case study].

8 Years | 8,69 Crore | Tropical climate | 1000 km | 9.5 lakh Ha

Project Description

Understanding the Challenge

Indonesia's coral reefs, crucial for fishing, tourism, and mariculture, are severely degraded, with only 5% in excellent condition. In Pemuteran, a once-poor fishing village, reef loss has threatened livelihoods and well-being. Restoring reefs and developing alternative livelihoods are key to the area's resilience. Pemuteran, which relies on tourism, balances economic growth with eco-conscious development in line with traditional Hindu values. While tourism has improved living standards, sustaining this balance remains a challenge. In 1998, destructive fishing practices devastated Pemuteran's reefs, collapsing its fishing and ecotourism industries. In response, the community partnered with the Global Coral Reef Alliance in 2000 to restore reefs using Biorock technology. The project, funded by local hotels and community efforts, has transformed once-barren reefs into thriving ecosystems, supported by ecotourism and visitor donations.

Information Source : Jamison, N. (2023). The role of Biorock artificial coral reefs in the sustainable governance of marine protected areas: A case study of Pemuteran, Bali (Unpublished MSc dissertation). Global Coral.

Graphic Source : Coral Reef Care. (n.d.). Reef protection & restoration, Pemuteran (Indonesia).

Strategies implemented

- **Biorock Technology:** Uses low-voltage electrical currents on steel frames to accelerate coral growth, powered by renewable energy, improving growth rates and survival.
- **Coastal Protection:** Biorock reduces beach erosion by absorbing wave energy and promoting sand deposition, aiding both reef restoration and coastal protection.
- **Pemuteran's Project:** The Pemuteran Bay Coral Protection Foundation has restored coral reefs using Biorock, covering two hectares with over 70 structures, the largest global reef restoration project.
- **Community Involvement:** Locals manage the Biorock Centre, monitor restoration efforts, and receive training in tourism, funded by ecotourism revenues.
- **Reef Gardeners Programme:** Underwater coral sculpture gardens inspired by Balinese temples attract dive tourism, with proceeds funding reef restoration.
- **Marine Protection & Water Quality:** Pemuteran strengthens its protected area with patrols and enforces regulations against destructive fishing, while addressing water quality through waste management and erosion control.

Outcomes and impact

Social: Coral restoration has generated new jobs, particularly in tourism, benefiting youth and women. Women have gained financial independence and taken on empowered roles within the community. Local enforcement of marine protection laws has played a key role in ensuring the project's success.

Environmental: Fisheries and ecotourism have thrived, boosting income and employment opportunities. Revenues from ecotourism fund local conservation efforts and skills training programs, ensuring long-term economic sustainability.

Economical: Fisheries and ecotourism have flourished, leading to increased income and employment opportunities. The revenues generated from ecotourism contribute to supporting local conservation efforts and skills training programs, thereby promoting long-term economic sustainability.

 Information Source: United Nations Development Programme. (2013). Pemuteran Bay Coral Protection Foundation, Indonesia [Equator Initiative Case Study Series]. UNDP.

Graphic Source : Women + Waves Society. (2024, November 12). Women And Waves work with Mossy Earth to restore coral reefs in Bali.

Sea Grass

 Graphic Source:Seagrass beats rainforests as carbon sink. (2018, December 20).

Ecosystem Overview

Seagrass meadows are underwater ecosystems composed of flowering plants such as Posidonia and Zostera. They play a vital role in carbon storage and serve as essential habitats for marine life.

Function

Sediment Stabilisation: Seagrass roots anchor sediments, preventing erosion and improving water clarity.

Carbon Sequestration: Seagrass beds store significant amounts of “blue carbon” in their biomass and soils.

Biodiversity Support: They provide habitats for fish, shellfish, and marine mammals like dugongs.

Benefits

° Improves water quality and clarity by trapping sediments and nutrients.
° Supports fisheries and marine biodiversity.
° Helps mitigate climate change through effective carbon storage.

Restoration Techniques

° **Seed Planting:** Collect and disperse seeds to encourage natural regrowth.
° **Transplantation:** Physically transplant seagrass mats to areas needing restoration.
° **Reducing Anthropogenic Impacts:** Implement Marine Protected Areas (MPAs) to limit boating, fishing, and pollution.

Information Source : Seagrass Restoration Guideline. (n.d.). WIOSAP Seagrass Restoration Guideline (v06 Revision). Western Indian Ocean Sustainable Aquatic Projects. Nairobi Convention.

Case Study 16 : Dugong and Seagrass Conservation Project

Indonesia, Madagascar, Malaysia, Mozambique, the Solomon Islands, Sri Lanka, Timor-Leste and Vanuatu

10 lakh ha of seagrass under improved conservation management

Funding Source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local Communities

Coastal Pressures Addressed

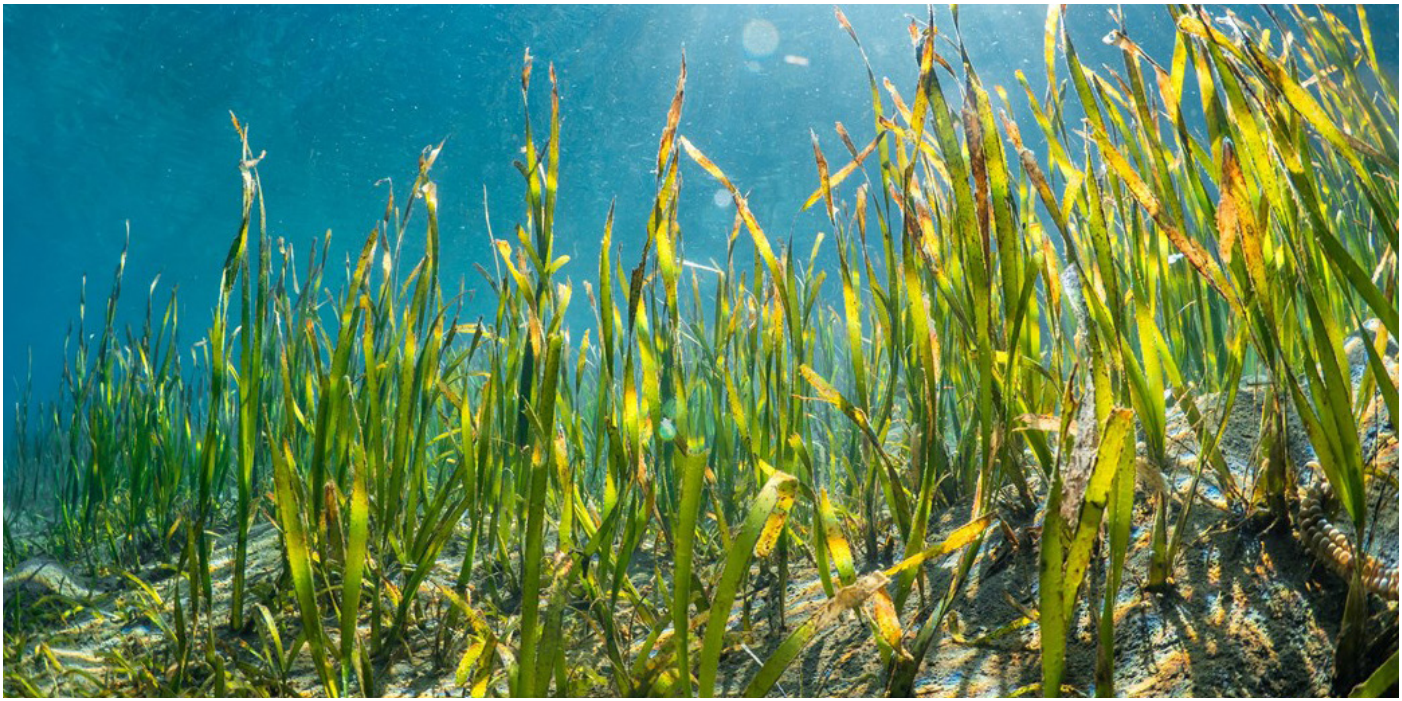
- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increase Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source:Dugong & Seagrass Conservation Project. (n.d.). Indonesia.

4 Years | 849.08 Cr | Tropical Climate | 54,716 km | NA



Project Description

Understanding the Challenge

This project is the first coordinated global effort to conserve dugongs and their seagrass habitats. At the heart of the project lies the ambition to mobilise community participation and ownership of dugong and seagrass conservation, focusing on introducing sustainable fisheries practices and innovative financial incentives, establishing Locally Managed Marine Protected Areas (LMMPA), and mainstreaming dugong and seagrass conservation priorities into national and regional policies and planning.

Information/Graphic Source : Dugong & Seagrass Hub. (n.d.). The First Asian Regional Dialogue on Seagrass and Dugong Conservation.Convention.

Strategies implemented

The Dugong and Seagrass Conservation Project focuses on safeguarding dugongs and their seagrass ha bitats through four key approaches:

- **Incentives for conservation:** The project develops and implements innovative management and economic incentives to encourage sustainable practices in dugong habitats. This involves engaging local communi ties, promoting alternative livelihoods, and supporting sustainable use of marine resources to reduce pres sures on these ecosystems.
- **Research and monitoring:** To guide conservation efforts, the project prioritises filling critical knowledge gaps about dugongs and their seagrass habitats. This includes conducting research on dugong populations, seagrass distribution, and threats, as well as monitoring ecosystem health to ensure data-driven conserva- tion planning.

Outcomes and impact

Social

Encourage community involvement in and responsibility for targeted protected areas by:

- Establishing community based governance structures.
- Building capacity for communities and raising awareness.
- Developing community monitoring and conservation management plans.

Environmental

Encourage sustainable fisheries practices among local fishing communities by:

- Introducing a range of innovative incentive mechanisms and management tools.
- Raising awareness and marketing sustainable practices as viable alternatives

Remove barriers to the knowledge needed for effective conservation by:

- Identifying critical gaps in knowledge and initiating surveys to gather information
- Developing good practice guidelines
- Collating and sharing conservation-relevant information and guidance

Incorporate dugong and seagrass conservation priorities and measures into national and regional policy, planning and regulatory frameworks by:

- Identifying knowledge gaps and developing recommendations
- Building capacity to develop and implement advocacy programmes for improved nation al and regional conservation policies, planning and management.
- Improving the national and regional capacity to contribute to global policy processes.

 Graphic Source:Seagrass beats rainforests as carbon sink. (2018, December 20).

Graphic Source : Dugong & Seagrass Conservation Project. (n.d.). Improving national awareness and research of dugong and seagrass in Indonesia (ID2).

Case Study 17 : Solent Seagrass Restoration.

England, United Kingdom

7 Ha restored

Funding source

- Governments/ Municipalities
- Multilateral Development Bank
- Foundations/ NGOs
- Development Agencies/ Multi-Donor Funds
- Businesses
- Local communities

Coastal Pressures Addressed

- Natural Disasters
- Deforestation
- Land Reclamation
- Coastal Minning
- Increased Ocean Acidification
- Shoreline Development
- Disposal of Untreated Sewage
- Land-Use Change
- Warmer Ocean Temperature
- Damming
- Agriculture Pollution
- Population Increase
- Increased Tourism
- Uncontrolled Fishing and Aquaculture

Stakeholders Involved

- State Governments/ Department
- National Governments/ Department
- NGOs
- Research/Academia
- Private Sector
- Community

 Information Source:Endangered Landscapes Programme. (2024, August 22). Solent Seascape: The UK's first seascape-scale restoration project receives international recognition from the United Nations.

4 Years

USD 5 million (~INR 42.88 cr)

Temperate maritime climate

52,200 ha

185 Ha

Project Description

Understanding the Challenge

The Solent Seascape Project aims to restore seven hectares of seagrass meadows within the Solent region, a vital marine ecosystem that has suffered significant decline due to pollution, coastal development, and climate change. The restoration efforts focus on replanting seagrass in areas where it has been lost, improving water quality, reducing sedimentation, and enhancing overall habitat conditions. By restoring these meadows, the project seeks to enhance marine biodiversity, provide critical habitat for endangered species like the European eel, and increase carbon sequestration. The restoration is a key part of a broader strategy to rebuild and reconnect coastal ecosystems, supporting the long-term resilience of the region's marine environment.

Graphic Source : Endangered Landscapes Programme. (2024, August 22). Solent Seascape: The UK's first seascape-scale restoration project receives international recognition from the United Nations.

Strategies implemented

- **Seagrass Transplantation:** Transplanting seagrass to degraded areas for long-term growth through careful site selection
- **Water Quality Improvement:** Enhancing water quality by reducing pollution and sedimentation, focus ing on better land and agricultural runoff management.
- **Stakeholder Collaboration**: Engaging local communities, stakeholders, and conservation groups to support sustainable restoration efforts.
- **Monitoring & Adaptation**: Ongoing monitoring of water quality, seagrass health, and biodiversity to adjust strategies as needed.
- **Marine Protected Areas (MPA):** Establishing MPAs around restoration sites to protect seagrass from human activities.
- **Public Engagement**: Raising awareness and involving the public in conservation to promote responsibility for marine ecosystems.

Outcomes and Impact

Social:

- **Coastal Protection:**Restored seagrass meadows serve as natural buffers, protecting communities from coastal erosion and storm surges caused by climate change.
- **Community Engagement:**The project raises awareness and fosters a shared sense of responsibility for conservation among local communities and stakeholders.
- **Empowerment:**Collaboration with fishermen, conservation groups, and residents empowers communities to actively participate in marine protection and restoration.

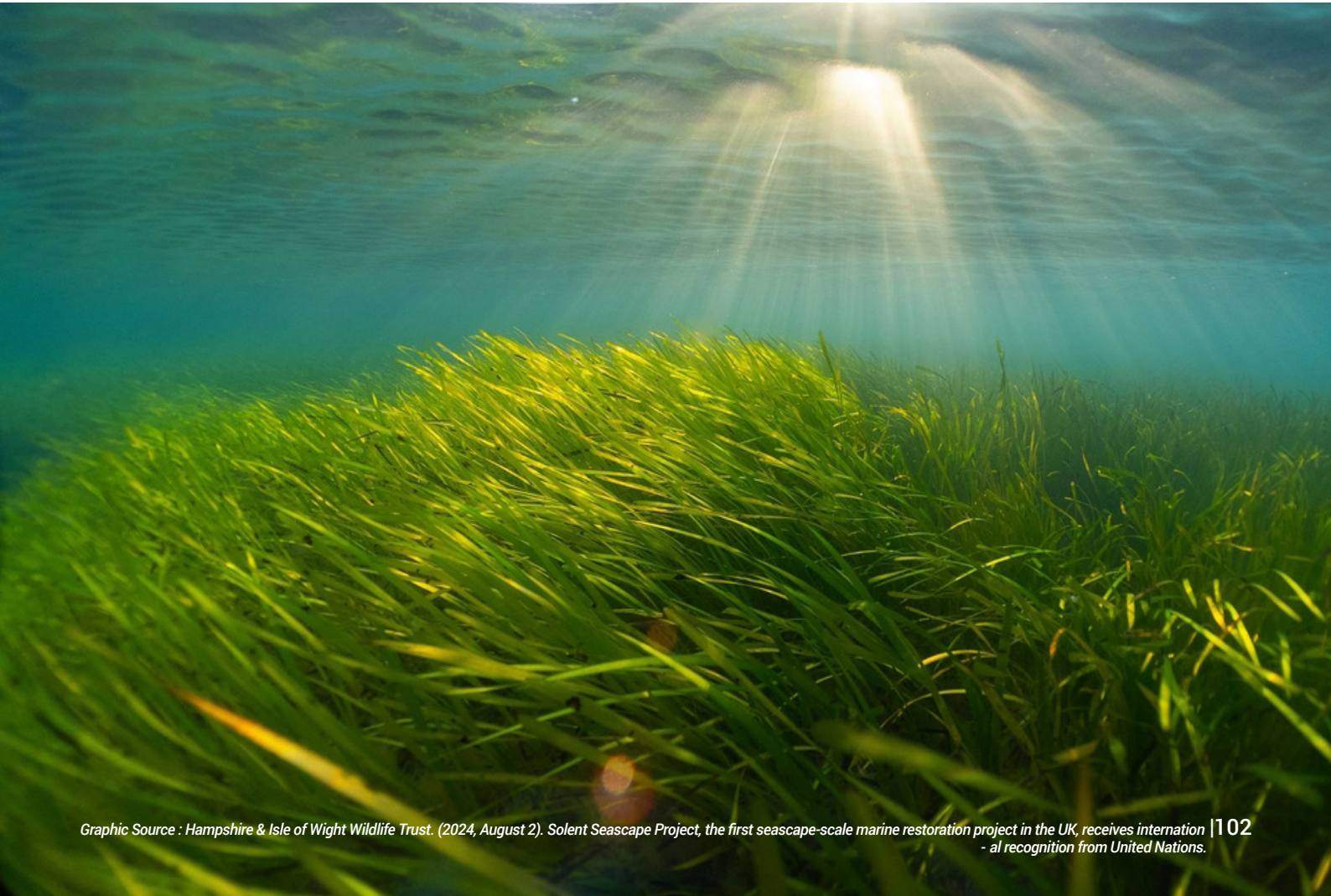
Environmental:

- **Marine Biodiversity:** Restored seagrass meadows provide crucial habitats for endan gered species, supporting a healthy marine food web.
- **Water Quality:** Seagrass meadows reduce sedimentation and nutrient levels, promo ting clearer water essential for ecosystem health.
  Carbon Sequestration: Seagrass acts as a carbon sink, capturing and storing carbon dioxide to help mitigate climate change.
- **Coastal Resilience:** Restoration strengthens coastal resilience by reducing wave action and storm surges, protecting ecosystems and communities.

 Information Source:Endangered Landscapes Programme. (2024, August 22). Solent Seascape: The UK's first seascape-scale restoration project receives international recognition from the United Nations.

Economical

- **Support for sustainable fisheries**: By improving marine habitats, the project helps support local fisheries, boosting fish stocks and providing economic benefits to fishermen and related industries.
- **Boost to eco-tourism:** The restored seagrass meadows make coastal areas more attractive for eco-tourism and recreational activities such as diving and wildlife watching, contributing to local economic growth.
- **Job creation and Local usiness support:** Increased eco-tourism generates income for local businesses, creates new jobs, and promotes sustainable tourism practices in the



Graphic Source : Hampshire & Isle of Wight Wildlife Trust. (2024, August 2). Solent Seascape Project, the first seascape-scale marine restoration project in the UK, receives internation - al recognition from United Nations.

Conclusion

Information Source:Endangered Landscapes Programme. (2024, August 22). Solent Seascape: The UK's first seascape-scale restoration project receives international recognition from the United Nations.

06

Harnessing Nature-based Solutions (NbS) in India

India's diverse landscapes and rich ecosystems present an unparalleled opportunity to leverage NbS to address the pressing challenges posed by climate change, urbanisation, and ecosystem degradation. Recognising this potential, governments across India have been actively promoting NbS interventions through various schemes at the central, state, and city levels.

At the national level, initiatives such as the Smart Cities Mission, AMRUT, Nagar Van Scheme, and Jal Shakti Abhiyan are driving climate-resilient projects. These include lake restoration and rejuvenation, urban forest development, and natural circular economy approaches for wastewater treatment and reuse. States, too, are making significant strides; Maharashtra's Maajhi Vasundhara Abhiyan focuses on environmental conservation, while Kerala's Horticulture Mission promotes urban farming with subsidies. Cities like Bengaluru, Bhopal, Delhi, and Madurai are integrating blue-green infrastructure into their development plans, while Surat has adopted heat and clean air action plans. However, embedding NbS into mainstream planning and development, and scaling up NbS in the Indian context comes with its unique set of challenges.

A major challenge is the lack of awareness among policymakers, stakeholders, and communities about the potential of NbS to mitigate issues such as coastal flooding, urban heat islands, and water scarcity. Policies and regulations, while well-intended, often create barriers for implementing NbS due to rigid frameworks or lack of integration with natural infrastructure approaches. To propagate the use of NbS, government facilities and public landholdings should be transformed into living models of NbS adoption. For instance, urban parks, riverfronts, and floodplains can be restored to serve as natural buffers against extreme weather events. Public projects such as highways, railways, and ports should incorporate green infrastructure like bio-swales, rain gardens, and mangrove belts to demonstrate the feasibility and effectiveness of NbS.

Engaging local communities in the planning and managing these projects will ensure co-benefits like livelihood creation and equitable resource sharing. Tribal communities, in particular, hold valuable traditional knowledge that can inform sustainable NbS practices.

Additionally, navigating financial mechanisms for NbS remains complex, especially for communities that lack resources or expertise. India must integrate NbS into existing funding programs such as the National Adaptation Fund on Climate Change and the Compensatory Afforestation Fund. Multilateral funds and public-private partnerships should also be leveraged to catalyse NbS implementation.

Simplifying the funding process is key. Unified application processes, better coordination between central and state funding schemes, and targeted financial assistance for vulnerable communities will help. Innovative financing mechanisms such as green bonds, impact investing, and insurance incentives should be explored to mobilise private sector participation.

Another critical gap is the shortage of a skilled workforce to design, implement, and maintain NbS projects. Many regions lack trained professionals in areas such as urban planning, ecology, and sustainable engineering. This skills deficit can delay projects or deter investment in NbS initiatives. Moreover, the technical uncertainties around the long-term benefits and cost-effectiveness of NbS can make investors hesitant, further complicating the permitting and execution process.

Scaling NbS in India requires a paradigm shift in how we perceive and manage our natural resources. By aligning policies, unlocking funding, fostering a skilled workforce, and prioritizing research and innovation, India can position NbS as a cornerstone of its climate resilience and sustainable development strategies. With concerted efforts across all levels of government, private sector participation, and community engagement, NbS can provide a transformative pathway for India to tackle climate change, safeguard biodiversity, and build a sustainable future for generations to come.

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Abbreviations

AMRUT: Atal Mission For Rejuvenation And Urban Transformation
BwN: Building with Nature
C3: Community Centred Conservation
CMS: Convention on Migratory Species
Cr: Crores
CRCL: Coalition to Restore Coastal Louisiana
DRR: Disaster Risk Reduction
ELSP: Endangered Landscapes & Seascapes Programme
FDCAN: The Canary Islands Development Fund
GCRA: Global Coral Reef Alliance
Govt: Government
GOMA: Gulf of Mexico Alliance
GEF: Global Environment Facility
GPS: Global Positioning System
Ha: Hectare
INR: Indian Rupees
IPCC: Intergovernmental Panel on Climate Change
IUCN: International Union for Conservation of Nature
ICOLD: International Commission on Large Dams
KM: Kilometers
MPA: Marine Protected Areas
MoU: Memorandum of understanding
NBS: Nature Based Solutions
NERRS: National Estuarine Research Reserve System
NIUA: National Institute of Urban Affairs
NOAA: National Oceanic and Atmospheric Administration
NGO: Non- Governmental Organizations
PACIT: Pointe-au-Chien Indian Tribe
RSPB: Royal Society for the Protection of Birds
UNEP: United Nations Environment Programme
USD: United States dollar
USAID: Unites States Agency for International Development
UNDP: United Nations Development Programme
WWF: World Wildlife Fund

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