Coastal Habitats
7. Mangrove Restoration

DEFINITION

Mangrove ecosystems are a form of coastal wetlands found in tropical and subtropical regions. These systems support halophytic (salt-loving) trees, shrubs, and other plants, and are dominated by mangrove trees. In the continental United States there are three mangrove tree species: red mangrove (*Rhizophora mangle*), which grows along the shoreline where conditions are harshest and is easily recognized by its arching prop roots; black mangrove (*Avicennia* sp.), which often grows more inland and at higher elevation than red mangrove and has root projections called *pneumatophores* to supply the plant with air in submerged soils; and White Mangroves (*Laguncularia racemosa*), which often grow inland with no outstanding root structures. (EPA 2022; Shepard et al. 2022). Restoring degraded or destroyed mangrove systems typically involves restoring natural hydrology and, in some cases, planting mangrove trees.

TECHNICAL APPROACH

While mangrove site restoration techniques vary, the following steps are generally used to restore the site's structure and function to a more natural state:

1. **Hydrological restoration:** Restoring mangrove systems revolves around restoring the natural hydrology of the site. Hydrological restoration techniques will differ based on the site, but can involve interventions like clearing and restoring tidal creeks, installing culverts or channels beneath roads or other structures that impede tidal flow, diverting excessive freshwater flows, and/or removing structures that have previously blocked tidal flow (Figure 1; Lewis and Brown 2014, Botero and Salzwedel 1999, Teutli-Hernández et al. 2020).

2. **Removing disturbance:** After hydrology is restored, it is important to rid the site of any factors that would potentially harm or slow the regeneration of mangroves. These steps could include actions such as removing undesired species that might outcompete mangroves, removing trash, leveling out the ground, fencing out grazing livestock, setting up protective netting, and amending soil (Lewis and Brown 2014).

3. **Revegetation:** Reestablishment of mangrove trees can occur in two primary ways:

   - **Natural regeneration (also called *passive restoration*):** Relying on naturally dispersed mangrove propagules (seeds) to restock the degraded area (Lewis and Brown 2014, Teutli-Hernández et al. 2020).

   - **Artificial regeneration (also called *active restoration*):** Direct planting of mangrove propagules (seeds) or seedling trees that were grown in a nursery (Figure 2; Lewis and Brown 2014, Teutli-Hernández et al. 2020).

Figure 7.1 Hydrologic restoration for a mangrove forest

Photo courtesy US Army Corps of Engineers South Atlantic Division

OPERATIONS AND MAINTENANCE

After a mangrove restoration project is completed, it is important to regularly remove trash and debris that could inhibit seedling growth. If grazing occurs in the area, access to the site should be controlled to limit grazing damage. Minor hydrological repairs may be needed over time to maintain tidal flows, and new mangrove seedlings or propagules may need to be planted as well.

FACTORS INFLUENCING SITE SUITABILITY

- ✓ Mangroves thrive in intertidal areas where soil salinity ranges from 3–27 ppt (Thorhaug 1990; Kairo et al. 2001; Kaly and Jones 1998; Smithsonian, n.d.)
- ✓ Mangroves can also grow in enclosed lagoons on inland depressions that are only periodically flushed by tides (such as Indian River Lagoon in Florida)
- ✓ Mangroves survive best in low wave energy areas (Teas 2009)
- ✗ Mangroves do not survive well in areas where there is frost or extended cold periods; however, their range is shifting northward in the United States because of climate change (Shepard et al. 2022)

Figure 7.2 Red mangrove seedling

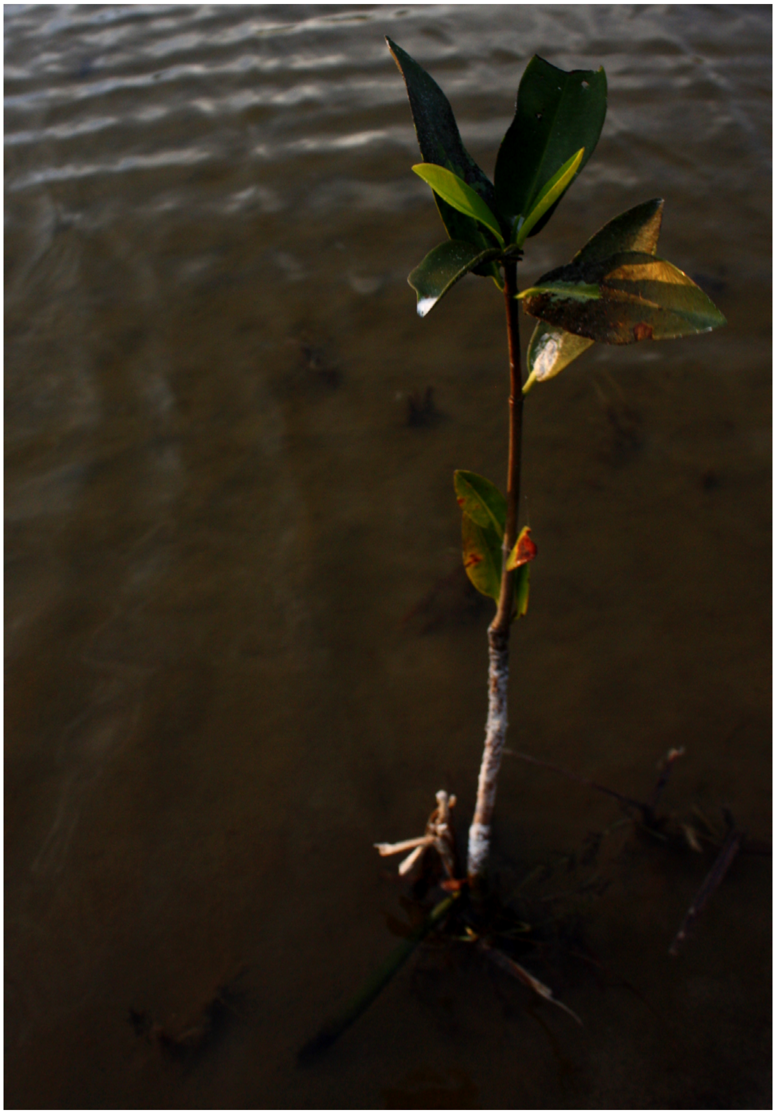

Photo courtesy Big Cypress National Preserve

TOOLS, TRAINING, AND RESOURCES FOR PLANNING AND IMPLEMENTATION

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
Ecological Mangrove Rehabilitation	Guidebook	2014	Roy R "Robin" Lewis III & Ben Brown	Global	Detailed guide describing the types of assessment needed to determine the best plan for mangrove restoration. Also includes implementation guidance.	✓	—	✓	✓
Ensuring a Future with Mangroves	Guidebook	2022	The Nature Conservancy	Gulf of Mexico	Handbook for coastal communities and public agencies that can inform the protection, management, and restoration of mangroves. Focuses primarily on high-level policy guidance.	—	—	—	✓
Mangrove Ecological Restoration Guide: Lessons Learned	Guidebook	2020	Center for International Forestry Research	Global	Detailed guide on the steps needed to plan, implement, and monitor mangrove restoration. Includes detailed site characterization as part of the planning process.	✓	—	✓	✓
The Guidelines of Mangrove Restoration for the Western Indian Ocean Region	Guidebook	2020	UN Environment Programme	Western Indian Ocean	Detailed guide on the steps needed to plan and implement mangrove restoration, plus case studies with lessons learned from projects in the Western Indian Ocean region.	✓	—	✓	✓
Mangrove Restoration Guide	Guidebook	2015	Global Nature Fund	Global	Detailed guide on community-based mangrove restoration, focused on restoring hydrological processes to facilitate natural mangrove regeneration.	✓	—	—	—

GRAY INFRASTRUCTURE ALTERNATIVES

Mangrove restoration can be an alternative to several gray infrastructure approaches that reduce the effects of shoreline erosion and coastal flooding: dikes, seawalls, and artificial breakwaters. The ability of a mangrove restoration project to replace or supplement one of these gray infrastructure types depends strongly on the project's location and whether it is designed to create the necessary outcomes. Certain environmental conditions may require gray infrastructure rather than mangrove restoration. See the gray infrastructure alternative tables in Section 1 for a comparison of mangrove restoration to these alternatives.

LIKELY BENEFITS AND OUTCOMES

Primary objectives for each strategy are highlighted.

Climate Threat Reduction

- **Reduced flooding:** Mangroves can attenuate storm surges and their associated peak water level height and waves; therefore, they have the potential to reduce coastal flooding height and extent during storm events (Dasgupta et al. 2019; Krauss et al. 2009; Gijsman et al. 2021; Menéndez et al. 2018, 2020; Montgomery et al. 2019; Narayan et al. 2019). The extent to which mangroves can reduce flood height and area depends on differing factors such as storm and mangrove forest characteristics (Dasgupta et al. 2019; Krauss et al. 2009; Gijsman et al. 2021; Menéndez et al. 2018, 2020; Montgomery et al. 2019; Narayan et al. 2019).
- **Carbon storage and sequestration:** Mangroves systems store and sequester carbon at very high rates (Macreadie et al. 2021).
- **Sea level rise adaptation and resilience:** Mangroves can directly and indirectly contribute to soil accretion processes through production of organic material as well as retention of sediments. It is possible that, in some areas, mangroves could help reduce the impacts of sea level rise through their ability to accrete soils along the coast. However, this is dependent on many factors (Krauss et al. 2013).

Social and Economic

- **Recreational opportunities (fishing):** Mangroves support a large diversity of fish and shellfish that use the habitats created by mangrove roots. Many species use mangrove sites as nurseries, thus nearby fishing is often very productive (Manson et al. 2005).
- **Property and infrastructure protection:** Mangroves can reduce the height and extent of coastal flooding, which in turn protects properties and infrastructure along the coast (Narayan et al. 2019).
- **Food security:** In locations where subsistence fishing makes up an important part of people's diets, productive mangrove-based fisheries can support food security (FAO 2010).

- **Tourism:** In locations where tourism infrastructure exists (e.g., hotels, boat rentals, and related services) mangrove sites can support the local tourism economy by drawing tourists to these areas (Spalding and Parrett 2019).
- **Cultural values (Moore et al. 2022):**
  - **Education and research:** Mangrove sites present opportunities to support research; some sites are locations that environmental education programs visit.
  - **Local culture/ traditions:** Mangrove systems can be important for people's sense of place, and they support activities (e.g., fishing, boating) important to local culture.
  - **Green space access:** Accessible mangroves provide a good setting for outdoor activities.

Ecological

- **Enhanced biodiversity:** Mangroves support a wide array of animal life including fish, shellfish, crustaceans, birds, and mammals (Macintosh and Ashton 2002).
- **Supports wildlife:** Mangroves support a large diversity of fish and shellfish. Many species use mangrove sites as nurseries due to the protection that these habitats can provide (Manson et al. 2005).

BARRIERS AND SOLUTIONS FOR PRACTITIONERS

Common Barriers

Several barriers are common across many of the nature-based solutions strategies; these are described in more detail in Section 1 of the Roadmap. Additional notes about barriers specific to mangrove restoration are included here.

- **Expense**
- **Capacity**
- **Public opinion:** Community support for a project can influence whether it is implemented or not (Global Nature Fund 2015, Friess et al. 2022).
- **Conflict with other land uses**
- **Regulation**
- **Lack of effectiveness data**

Ecological

- **Project failure:** There are many occurrences of mangrove restorations failing—this mainly occurs when large-scale planting efforts are conducted in sites with unsuitable environmental conditions or in locations without community support (Lovelock et al. 2022; Friess et al. 2022).

EXAMPLE PROJECTS

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Aguirre State Forest Mangrove Restoration Project	Puerto Rico	National Oceanic and Atmospheric **Administration (NOAA)** National Estuarine Research Reserve System (NERRS), The Ocean Foundation	Hydrological restoration	695	Estimated at least $1 million	Ongoing	Largest mangrove habitat restoration in Puerto Rico. Nursery established to support the project.	Loss of mangroves has exposed important infrastructure to damage from storm winds and flooding	No—project is just starting
Fruit Farm Creek Mangrove Restoration Project	Florida	NOAA NERRS, Florida Fish and Wildlife Commission, Florida Department of Environmental Protection, City of Marco Island	Hydrological restoration—culvert installation, clearing of tidal creeks	>200	~$3 million	More than 13 years from project planning to implementation	Restoring hydrological conditions to restore collapsed mangroves and relieve stress on current trees	No	No

Bolding indicates DOI affiliates.

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