The Nature Conservancy

ENSURING A FUTURE WITH MANGROVES

Mangrove Engagement, Restoration, and Management in the Gulf of Mexico and on the Southeast Atlantic Coast

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Ensuring a Future with Mangroves:

Mangrove Engagement, Restoration, and Management in the Gulf of Mexico and on the Southeast Atlantic Coast

I. Executive Summary

This handbook provides practical information for coastal communities and public agencies to inform the protection, management, and potential use of mangroves to sustain coastal ecosystems and enhance the resilience of coastal areas. Climate change and rising sea levels will influence the distribution of mangroves by increasing their range in some locations while threatening their survival in others. Decisions about how to manage mangroves should be informed by considerations and predictions of where these changes in mangrove range and extent are likely to occur.

Mangroves are a group of shrubs and small trees that are uniquely adapted to marine and estuarine tidal conditions in tropical and subtropical climates. In the continental United States, mangroves historically have been prevalent along the coast of the Florida Peninsula, south of Cedar Key on the Gulf Coast; south of Cape Canaveral on the east coast; and in south Texas. Three species of mangroves are present along these shorelines: red mangroves, black mangroves at somewhat higher elevations, and white mangroves.

Mangroves have multiple ecological and societal benefits:

- They provide important habitat for many coastal species. The tangled prop roots of red mangroves and the pneumatophores (exposed root structures) of black mangroves provide shelter for many marine organisms, including juvenile fish, shrimp, and crabs. Without mangroves, there would be fewer fish to catch and less seafood for our tables.
- Mangroves filter and cycle nutrients along the coast. At some locations, oysters attach to mangrove prop roots and further filter the surrounding water.
- They protect shorelines and communities from tropical storms by buffering wave, surge, and wind energy.
- Mangrove roots trap sediments. Under the right conditions, they can help to counter the impacts of sea-level rise, coastal erosion, and land loss.
- Mangrove forests store substantial amounts of carbon, which can help offset carbon emissions that drive climate change.
- Mangroves are popular areas for recreation, including birdwatching, kayaking, stand-up paddling, and fishing.

In recent years, poleward migration of black and red mangroves has been documented in Texas, Louisiana, the Mississippi barrier islands, and the Florida coastlines. The northern limit of mangroves in this region is typically limited by the frequency and intensity of freeze events that damage or kill mangroves. It is thought that climate change is enabling this northern movement. The likely transition of some coastal marshes into mangroves in the southeast United States would have important ecological, economic, and cultural impacts that must be carefully managed. This management will only be effective if we bring together regional science and models of mangrove range expansion, monitor results from past and future mangrove restoration projects, and gather community input to assess the design and desirability of new mangrove protection and management initiatives. Among other things, this will require us to share lessons learned across the Gulf and southeast states.

Toward that end, this Mangrove Engagement, Restoration, and Management handbook identifies 10 approaches that should be considered components of effective mangrove stewardship across the Gulf and Atlantic coasts of the United States. We also provide brief case studies summarizing a project or effort that is representative of each approach. Taken together, these considerations can be the basis for public and private actions that ensure that mangroves will contribute to the future health of coastal ecosystems and the resilience of coastal communities in the southeastern United States.

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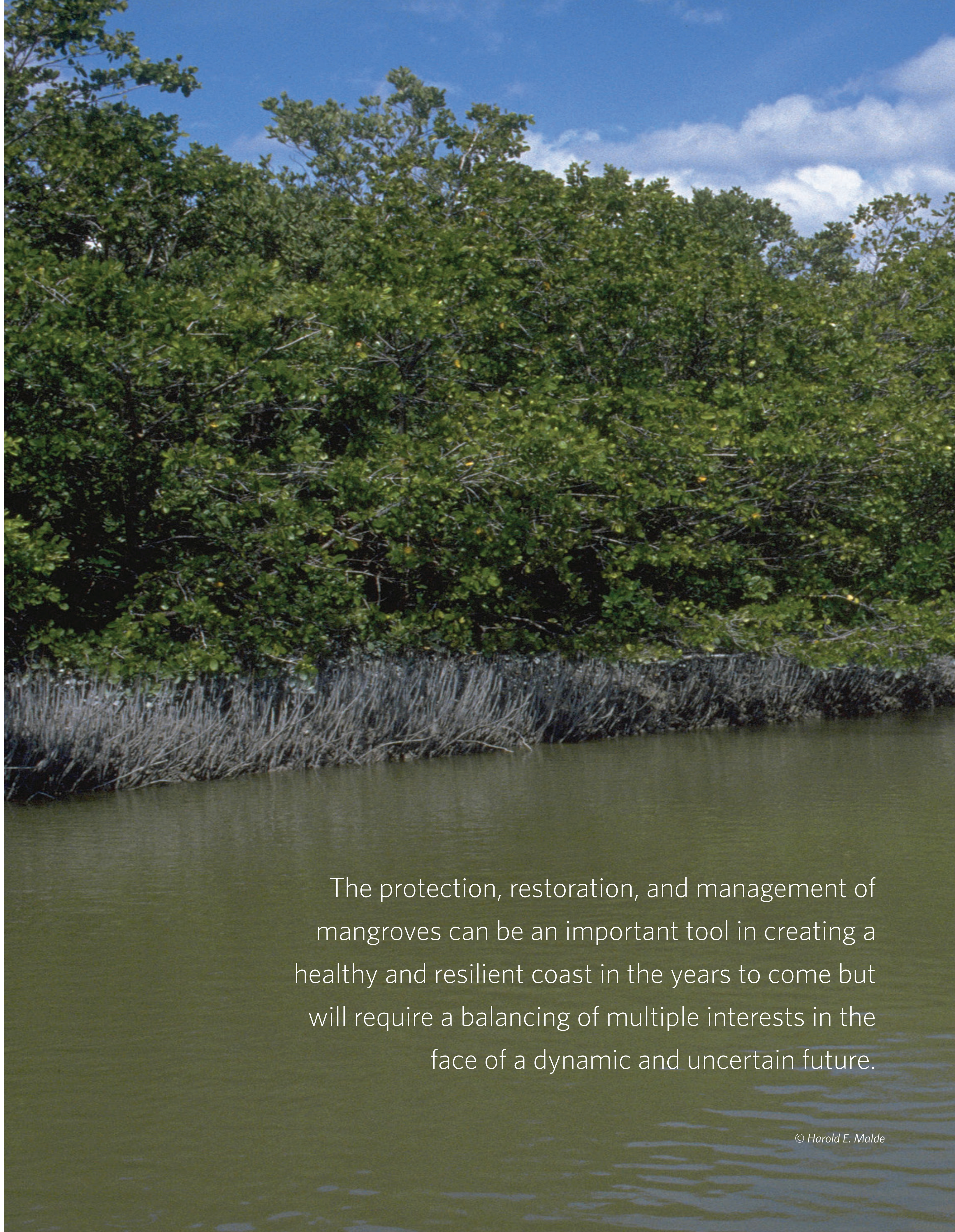
Approaches for Mangrove Restoration and Conservation

1. **Monitoring range expansion:**
   Tracking the expansion of mangroves latitudinally along coastal counties or tracking the inland migration of mangroves with rising sea levels.
2. **Wetland protection:**
   Conserving mangroves and mangrove migration pathways through wetland protections such as conservation easements, land acquisition, wetland buffers, and land use regulations. Mangrove migration pathways can be lateral to the coast in response to a warming climate or landward in response to rising sea levels.
3. **Hydrologic restoration**:
   Modifying coastal areas to return the flow of water to a more natural state and connect impaired mangroves with the sea, lagoons, and/or estuaries through channels and culverts.
4. **Reforestation:**
   Planting root stock grown in a nursery or conducting aerial seeding of propagules into degraded areas to establish or reestablish mangrove forest.
5. **Incorporating mangroves into nature-based solutions (NBS):**
   Projects that use NBS and incorporate mangroves alone or in combination with other habitat types to enhance long-term coastal protection.
6. **Monitoring mangrove project performance:**
   Assessing mangrove extent, community structure, status, and/or health. Monitoring can take place before, during, and/or after a restoration project.
7. **Research:**
   Investigating the drivers of changes in mangrove extent and condition, restoration and conservation outcomes, and the ecosystem services and species habitat provided or affected by mangroves.
8. **Policy:**
   Regulating management of mangroves as proposed or adopted by a government.
9. **Blue carbon:**
   Exploring opportunities associated with restoring and protecting mangroves as carbon sinks.
10. **Innovative finance mechanisms:**
    Developing innovative mechanisms for funding mangrove restoration and conservation.



The protection, restoration, and management of mangroves can be an important tool in creating a healthy and resilient coast in the years to come but will require a balancing of multiple interests in the face of a dynamic and uncertain future.

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II. Introduction to Mangroves in the Continental United States

Mangroves: What are they and where are they found?

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Red mangrove *(Rhizophora mangle):* Growing along the edge of the shoreline where conditions are harshest, the red mangrove is easily distinguished from other species by its tangled, reddish prop roots. These prop roots originate from the trunk with roots growing downward from the branches. Extending three feet (1 m) or more above the surface of the soil, prop roots increase the tree's stability and supply oxygen to underground roots.

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Black mangrove *(Avicennia germinans):* This species is characterized by long horizontal roots and root-like projections known as pneumatophores. It grows at slightly higher elevations than the red mangrove, where tidal change exposes the roots to the air. The pencil-shaped pneumatophores originate from underground horizontal roots projecting from the soil around the tree's trunk, providing oxygen to the underground and underwater root systems. Black mangroves are the most cold-tolerant of the three species.

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White mangrove *(Laguncularia racemosa):* The white mangrove has no visible aerial roots, unlike the black mangrove which has pneumatophores and the red mangrove which has prop roots. However, when it grows in oxygen-depleted sediments or land that is flooded for extended periods of time, it often develops peg roots. White mangroves are the least cold-tolerant of the three species.

Mangrove species profiles adapted from the Florida Museum of Natural History

Mangroves have multiple ecological and societal benefits

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- Mangroves filter and cycle nutrients along the coast. At some locations, oysters attach to mangrove prop roots and filter the surrounding water.
- Mangroves protect shorelines and communities from tropical storms by buffering wave, surge, and wind energy.
- Mangrove roots trap sediments. Under the right conditions, they can help to counter the impacts of sea-level rise, coastal erosion, and land loss.
- Mangrove forests store substantial amounts of carbon, which can offset carbon emissions that drive climate change.
- Mangroves are popular areas for recreation, including birdwatching, kayaking, stand-up paddling, and fishing.

The range of mangroves is expanding north with climate change

Mangroves are sensitive to freezing temperatures, and periodic cold snaps have limited the extent of their range in the continental United States because they can be damaged or killed by hard freezes. However, in recent years, poleward migration of black and red mangroves has been documented in Texas, Louisiana, the Mississippi barrier islands, and the Florida coastlines. It is thought that climate change and warming winters are enabling this northern movement.

The expansion of mangrove species throughout the northern Gulf of Mexico is creating ecotones where salt marsh and mangrove ranges overlap. Both habitats provide similar ecosystem services, including shoreline stabilization, critical nursery habitat, storm protection, carbon sequestration, and nutrient filtration. However, mangroves and salt marshes are habitat for different species, and the expansion of mangroves into marshes can impact marsh-dependent species such as whooping cranes. Mangrove range expansion in our region follows global patterns of tropicalization with warming climates. Mangroves have been shown to outcompete marsh species in the absence of freezes, though additional factors may limit mangrove expansion on a local to regional basis. The ecological and economic implications of this continued expansion are not well understood, but the conversion of marsh to mangrove is anticipated within the next 20 years for some areas, if not sooner, based on temperature and precipitation trends.

Threats to mangroves

Despite the value that they provide, mangroves have been damaged or removed by extensive shoreline development in their historical range and now face the additional threats of sea-level rise, more frequent coastal storms, and other extreme weather, such as the freezing temperatures that occurred in Texas and Louisiana in 2021. If sea-level rise continues to accelerate, mangroves could have difficulty keeping up in growth and land formation, and in some locations, mangrove areas could be lost as they become open water.

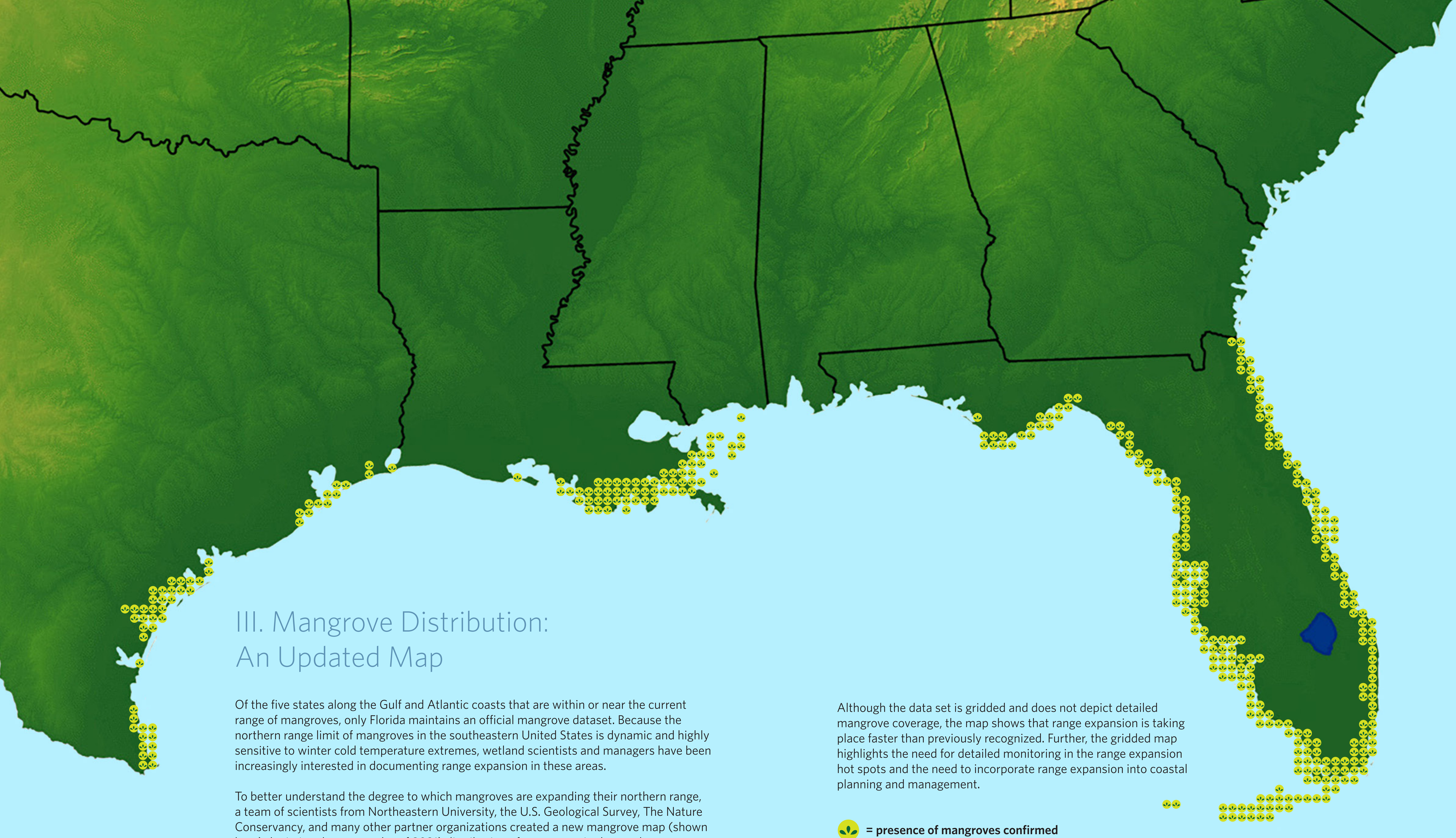
While mangroves are effective at reducing wave action, more frequent tropical storms can inflict severe damage on mangrove forests. Mangroves can recover from storm impacts, but it can take years for them to do so, even under the best of circumstances. In Florida, recognition of the importance of mangroves has led to state and local laws limiting or prohibiting the cutting or destruction of mangroves, although mangroves can still be removed with permitting and mitigation. As mangroves expand into marshes in the northern Gulf and south Atlantic, policies and conservation action may be needed to continue to protect both kinds of coastal wetlands and enable their adaptation to rising sea levels.

III. Mangrove Distribution: An Updated Map

Of the five states along the Gulf and Atlantic coasts that are within or near the current range of mangroves, only Florida maintains an official mangrove dataset. Because the northern range limit of mangroves in the southeastern United States is dynamic and highly sensitive to winter cold temperature extremes, wetland scientists and managers have been increasingly interested in documenting range expansion in these areas.

To better understand the degree to which mangroves are expanding their northern range, a team of scientists from Northeastern University, the U.S. Geological Survey, The Nature Conservancy, and many other partner organizations created a new mangrove map (shown here) depicting the current (as of 2021) distribution of mangroves in the southeastern United States, based on a synthesis of existing datasets and expert knowledge. Each grid cell has a resolution of 0.125 degrees, or approximately 14 x 16 km, within which the presence or absence of mangroves has been independently determined using existing datasets and expert knowledge. These data provide a baseline for continued monitoring of the distribution and abundance of mangroves throughout the southeastern United States.

Although the data set is gridded and does not depict detailed mangrove coverage, the map shows that range expansion is taking place faster than previously recognized. Further, the gridded map highlights the need for detailed monitoring in the range expansion hot spots and the need to incorporate range expansion into coastal planning and management.



Source: Bardou, R., et al. 2022. Mangrove distribution in the southeastern United States in 2021: U.S. Geological Survey data release, https://doi.org/10.5066/P9Y2T0K4.

IV. Approaches for Ensuring the Future Distribution of Mangroves

The future of mangroves along the Gulf of Mexico and southeast Atlantic coasts depends on the choices that people make and the actions they take today. Although mangroves in the continental United States are threatened by sea-level rise, tropical storms, and development, we can secure their future by engaging coastal landowners and decision makers on the extent and value of mangroves, both now and in the future.

In the table that follows, we outline approaches and activities that, if implemented strategically, could facilitate the long-term survival of mangrove species. An essential component of all of these approaches is stakeholder engagement, because it is necessary to understand people's attitudes and beliefs regarding mangroves, as well as the multiple and sometimes opposing drivers of mangrove management. Stakeholder engagement can inform what management approaches are appropriate and likely to be successful at multiple scales, ranging from individual shoreline parcels to entire regions like the Gulf of Mexico.

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Approaches for Mangrove Restoration and Conservation
1. Monitoring range expansion: Tracking the expansion of mangroves latitudinally along coastal counties or tracking the inland migration of mangroves with rising sea levels. *Example: Mangrove Survey Network (MSN)*
2. Wetland protection: Conserving mangroves and mangrove migration pathways through wetland protections such as conservation easements, land acquisition, wetland buffers, and land use regulations. (Mangrove migration pathways can be lateral to the coast in response to a warming climate or landward in response to rising sea levels.) *Example: Mapping mangrove migration pathways in Florida to inform conservation planning*
3. Hydrologic restoration: Modifying coastal areas to return the flow of water to a more natural state and connect impaired mangroves with the sea, lagoons, and/or estuaries through channels and culverts. *Example: Jensen Beach Impoundment Project, Florida*
4. Reforestation: Planting root stock grown in a nursery or conducting aerial seeding of propagules into degraded areas to establish or reestablish mangrove forest. *Example: Mangrove planting in Southeast Louisiana*
5. Incorporating mangroves into nature-based solutions (NBS): Projects that use NBS and incorporate mangroves alone or in combination with other habitat types to enhance long-term coastal protection. *Example: Picnic Island, Tampa Bay, Florida*
6. Monitoring mangrove project performance: Assessing mangrove extent, community structure, status, and/or health. Monitoring can take place before, during, and/or after a restoration project. *Example: Clam Bay, southwest Florida*
7. Research: Investigating the drivers of changes in mangrove extent and condition, restoration and conservation outcomes, and the ecosystem services and species habitat provided or affected by mangroves. *Example: Predicting the future distribution of mangroves*
8. Policy: Regulating management of mangroves as proposed or adopted by a government *Example: Florida Mangrove Trimming and Preservation Act*
9. Blue carbon: Exploring opportunities associated with restoring and protecting mangroves as carbon sinks *Example: Blue Carbon Resilience Credits in Texas*
10. Innovative finance mechanisms: Developing innovative mechanisms for funding mangrove restoration and conservation. *Example: Evaluating the feasibility of insuring mangroves*

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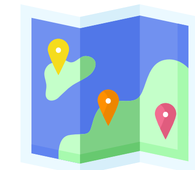
V. Case Studies

Here we provide brief case studies highlighting example projects and activities that are representative of each action that can be taken to conserve and protect future mangroves. In many cases, the successful conservation of mangroves, and the resulting benefits, will require coordinated research, policy, stakeholder engagement, funding mechanisms, and implementation.

The intent of these case studies is to highlight efforts that are underway or that have taken place at one or more locations along the Gulf and Atlantic coasts that could be replicated and/or systematically applied at the landscape scale to facilitate healthy mangroves in the future. Following each case study, we note key takeaways from each category of action.



1. Monitoring range expansion: Mangrove Survey Network

Effective long-term comprehensive watershed monitoring is critical for evaluating ecosystem status and trends, informing future restoration and management efforts, and demonstrating programmatic success. The Mangrove Survey Network (MSN) was established in 2018 by researchers at Mississippi State University to track the expansion of mangroves along northern Gulf of Mexico coastal counties, including Harrison and Jackson in Mississippi; Mobile and Baldwin in Alabama; Escambia along the Alabama/Florida border; and Santa Rosa, Okaloosa, Walton, Bay, Gulf, and Franklin in Florida. MSN participating partner leads include representatives from academic institutions, Sea Grant Extension, National Estuarine Research Reserves, and community organizations. In 2021, the Pensacola and Perdido Bays Estuary Program adopted the role of lead coordinator for the MSN. Long-term monitoring is needed for programs such as this one, which is a non-regulatory science-based program in the northern Gulf of Mexico, to help inform the needs of local communities, educate the public on key issues affecting watersheds, and build consensus among groups to set achievable goals and objectives for long-term success.

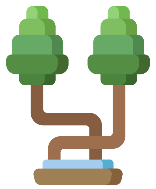
The MSN is an example of successful voluntary collaboration across multiple states, counties, and water bodies that allows for enhanced data collection and tracking. To date, there has been a lack of dedicated long-term funding for this effort so some partners have utilized local citizen science programs to assist in completing the annual surveys. This approach encourages community members to become educated and engaged with conservation throughout the coastal bays, bayous, and sounds.

Shoreline surveys along 100-meter transects are conducted annually and data are collected using either the iNaturalist application on mobile devices (a community-driven online platform for tracking biodiversity) or by filling out standardized datasheets developed by the MSN coordinator in collaboration with team leads. Surveys for mangrove recruitment in these areas are conducted using one or a combination of methods, including walking (on sandy sediments and beaches), using paddleboards (in muddy environments and wetlands), and/or using kayaks or motorboats (to access barrier islands). Each year, team leads, in collaboration with survey coordinators, conduct in-person or virtual trainings on mangrove ecology and identification, survey methods, datasheet parameters, and safety precautions for the field.

The data collected during each survey (if there are any mangroves present) include species, GPS location (latitude and longitude), surrounding dominant vegetation, tree height, crown diameter, herbivory quantification, shoreline buffer distance (distance from an individual tree to the limit of shoreward vegetation), aerial root density (0.25-m^2 quadrat), and seed or seedling number. When possible, environmental conditions are recorded and two photographs of each mangrove are taken for positive species identification. After each survey is complete, team leads guide the reporting of the findings to the project page in iNaturalist or to the MSN coordinator directly.

It is critical that this network of dedicated volunteers and team leads continues to track the expansion of mangroves into Gulf of Mexico salt marshes. To improve survey methodology and data collection, the MSN coordinator and project leads will continue to expand and edit monitoring activities as data needs and new collaborations are identified. This information will help inform future restoration and management efforts across the watersheds. Estuary Programs can help bridge the gap by coordinating monitoring efforts lead by state and federal agencies, local and non-governmental organizations, and community science groups. Coordination of monitoring is key to reducing duplication of efforts, increasing spatial and temporal coverage, and improving data-sharing opportunities.

Coordinated monitoring of mangrove range expansion is critical to inform future restoration and management; citizen or community science can make an important contribution to the monitoring process. Multi-year government funding is also needed to coordinate this effort and to compile the data collected so that they are usable by environmental managers and policy makers.



2. Wetland protection: Mapping mangrove migration pathways in Florida to inform conservation planning

The Florida Ecological Report Card (2020) was developed through a collaborative process led by a partnership between the Florida Fish and Wildlife Conservation Commission and the U.S. Fish and Wildlife Service. The Report Card was created to better understand where valued marine assets, such as mangroves, occur and where they are of high conservation priority. As part of the Report Card process, a set of conservation indicators was selected to assess the condition of proposed marine assets and support future conservation planning by the state and other conservation partners. Multiple indicators were identified in the Report Card for mangroves, including mangrove extent and potential inland migration.

Potential inland migration of mangroves was characterized by using a GIS approach to extract mangrove areas from the Florida Cooperative Land Cover Map and then create a 300-meter buffer around the mangroves. This buffer was then intersected with the Simplified Land Use layer (also from the Florida Cooperative Land Cover Map), and each land class within the buffer was further categorized as having "low," "moderate," or "high" potential as a suitable future location for mangroves. This information was mapped to indicate where land may need to be protected to secure inland migration of mangroves with sea-level rise. A similar analysis was also applied for salt marshes in the state.

The assessment found that the majority of potential mangrove migration pathways have either "low" or "high" potential for inland migration. Nearly half (45.56%) of the habitat is considered "low" due to coastal squeeze from urban areas blocking migration pathways (21.23%) and rising estuarine waters (21.29%). The remaining half (51.7%) of the habitat adjacent to or within 300 meters of mangrove swamp is considered to have "high" migration potential. Most of these "high" potential areas adjacent to existing mangroves are classified as natural habitat and are associated with Everglades and Big Cypress protected areas.

The mangrove inland migration maps and information found in the Report Card can help inform conservation planning to identify areas of high potential for inland migration that are not currently protected from development. It is worth noting that the 300-meter buffer approach is likely missing areas that have the potential to become mangrove areas in the future due to latitudinal range expansion (mangroves moving north with warming temperatures). The findings can also be used to explore where hybrid, engineered living shoreline designs could be implemented in areas of low migratory potential to help facilitate the persistence of mangroves in areas that lack substantial room for inland migration. The Florida Ecological Report Card's forward-looking method for considering the future locations of Florida coastal assets can help inform the development of approaches for conserving current and future mangrove areas across the Gulf of Mexico and Atlantic coasts.

Wetlands, including mangroves, can potentially migrate inland as sea levels rise. However, they can only migrate if their migratory pathways are protected.

3. Hydrologic restoration: Jensen Beach Impoundment (JBI) Project, Florida

Located on Florida's east coast, Martin County is home to many aquatic ecosystems, including sensitive estuarine tidal systems. One way to minimize the damage from storms is to create more resilient natural systems that can store excess water, dissipate storm energy, and provide invaluable habitat. The Jensen Beach Impoundment (JBI) is one such area. It is located on Hutchinson Island, a barrier island along the Indian River Lagoon. The JBI is a 170-acre mangrove wetland area that spans Jensen Beach to Jupiter Inlet Aquatic Preserve. Decades ago, officials encircled the area with a berm to control black saltmarsh mosquito breeding (Aedes taeniorhynchus). The berm also blocked fish from moving between the estuarine and the shallow mangrove habitats. Interior channels and culverts were added later to better facilitate water circulation and fish movement through the impoundment and into the estuary. The JBI provides critical mangrove habitat in the Indian River Lagoon that reduces flooding in low-lying, vulnerable coastal areas, and thanks to the mangroves' complex root structure, it provides essential storm protection and shoreline stabilization for the barrier island.

After Hurricane Irma in 2017, over 50 acres of primarily red mangrove habitat was lost in the JBI due to high water levels and poor water circulation. Without adequate circulation, oxygen levels became depleted and created an anoxic environment that

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killed the remaining mangroves. In response, Martin County secured funding from a State Wildlife Grant and from the National Oceanic and Atmospheric Administration in 2020 to improve water flow in and out of the impoundment. The hydrological restoration involved removing blockages and returning the channels to their intended depth. To reduce the potential for low-oxygen events to recur and to enhance the flow channels, redundant circulation paths were created by installing three new interior culverts and one additional culvert connection to the lagoon. New mangrove plantings were added to the restored impoundment to jumpstart growth, thereby improving the JBI's mangrove ecosystem and flood protection capacity. Since its completion in late 2021, the project is being monitored for success.

Hydrologic restoration can improve water circulation in impaired mangrove wetland areas to improve mangrove health and enhance the ecosystem services or benefits the mangroves provide to nature and people.

4. Reforestation: Mangrove planting in Southeast Louisiana

In Louisiana, the conversion of coastal wetlands to open water is a major issue that threatens both habitats and built infrastructure. On average, the state loses approximately 16 mi2 of land annually. This is largely the result of a very high rate of relative sea-level rise (sea-level rise plus a subsiding coastal platform) and local factors like alterations in the delivery of freshwater and sediment and hundreds of miles of canals dredged into coastal wetlands. These factors and others reduce the resilience of coastal habitats in Louisiana and increase the risk to those living there.

Mangroves have been present in Louisiana since at least the 1700s but their distribution has expanded and contracted in response to freeze events. In more recent times, mangroves (black mangroves) have taken hold and spread by propagules in the southernmost reaches of the state's coastline. For instance, the salt marshes around Grand Isle have seen a rapid increase in the coverage of black mangrove. In response to the land loss described above, the Louisiana Department of Agriculture and Forestry planted mangroves to secure shorelines and increase resilience. The planted mangroves were root stock grown in a nursery.

The success of planted root stock has been highly variable. Some projects report 62% survival of black mangrove seedlings nearly two years after planting. Others report that storms, including hurricanes, shortly after planting wiped out the entire effort because the land where the seedlings were planted was completely washed away. In sites where mangroves have recruited naturally (such as at Grand Isle), plants have been lost when the banks of the marsh were undercut and sloughed off. This "cutbank" situation is created when natural erosional forces are not offset by the accretion of sediment. Because the Mississippi River is leveed, no new sediment carried by the river is available to nourish the state's coastal wetlands.

Unlike mangrove planting projects in south Florida, where extensive mangroves have been documented for over a century, most mangrove planting efforts in Louisiana are not intended to replace historic populations that have been lost to development or conversion to open water. Instead, the efforts in Louisiana are an experiment to explore the viability of capitalizing on changing climatic conditions to better understand whether mangroves could be strategically planted or encouraged to stabilize a rapidly eroding coastline.

Research indicates that southeastern Louisiana has the lowest freeze risk in the state and therefore the most potential for planting mangroves for coastal resilience benefits. However, the freeze risk in this region is still moderate and there is concern that planted mangroves might be killed or damaged in a future freeze event. This uncertainty has led to approaches in which salt marsh grasses (which are more tolerant to freeze conditions) are planted in areas where mangrove propagules are abundant to facilitate mangrove establishment and growth. It is thought that salt marsh grasses can help facilitate mangrove restoration by stabilizing substrates and in some cases creating conditions that can help newly established mangroves survive freeze events.

As mangroves have expanded into new areas, so has interest in planting mangroves to strategically target coastal land loss. This strategy has potential, but the results have been variable, and we need to do careful monitoring and evaluation of planting projects to better understand the benefits and risks associated with planting mangroves to increase resilience.

5. Incorporating mangroves into nature-based solutions (NBS): Picnic Island, Tampa Bay, Florida

The Nature Conservancy, the City of Tampa, and the University of Miami are partnering on a demonstration project at Picnic Island Park that will use NBS to minimize erosion at the park, reduce flood risk for Port Tampa City, and enhance up to 492 acres of habitat for fish and wildlife on Tampa Bay. Conceptual NBS will include living breakwaters with suitable substrate for oyster recruitment, longshore bars with intertidal zones for marsh/mangrove recruitment and upland zones for shorebird nesting habitat, enhanced areas for seagrass recruitment through placement of fill in dredge holes, and expansion of dune and coastal hammock habitats where appropriate to minimize park user conflicts.

These NBS, including the use of mangroves, were selected on the basis of their existing but limited presence at the 98-acre Picnic Island Park, their regional significance for restoration of Tampa Bay, and their potential to expand and/or enhanced at Picnic Island Park and on adjacent public lands that are also owned by the City of Tampa. The adjacent 394-acre parcel is characterized by fringing mangroves, remnant marsh, and upland areas, where mosquito/drainage ditches facilitate landward penetration of storm surge and sea-level rise. These features provide opportunities for immediate transferability and scalability of conceptual NBS developed for Picnic Island Park. Topographic restoration of wetlands and incorporation of a horizontal levee planted with coastal hammock species in upland areas of the adjacent public lands will likely further reduce flood risk to Port Tampa City and neighboring MacDill Air Force Base, as well as improving habitats for fish and wildlife by creating wetland migration space over the next 20 to 30 years.

Mangroves are considered an integral component of the conceptual NBS proposed for Picnic Island Park because a large acreage of mangroves already exists on the adjacent lands. These mangroves provide significant flood protection benefits to the community. Using global asset data, high-resolution structure data, and building-specific damage curves, The Nature Conservancy and its partners found that the present value of mangroves for flood protection in Florida is an estimated $50 billion (2020 USD) using a 4% discount rate. The present value of mangroves for flood protection in the Tampa Bay region is estimated to be between $500,000 and $1 million (2020 USD) per hectare.

Mangroves have proliferated in the Tampa Bay region in response to climate change. They have also successfully recruited along the south shoreline at Picnic Island Park where previous habitat restoration activities were conducted. Therefore, incorporating mangroves into one or more living breakwaters, longshore bars, and other intertidal features at Picnic Island Park or planning for recruitment of mangroves on/within these features is likely to effectively enhance coastal resilience benefits for the community. This project could also include several types of NBS to compare their performance for minimizing erosion, reducing flood risk for Port Tampa City, and improving coastal habitat for wildlife.

Given the expanding range of mangroves, scientists, engineers, and coastal managers are considering whether, where, and to what extent mangroves could be used intentionally as natural infrastructure to counter the impacts of climate change, sea-level rise, and coastal erosion. In areas like Tampa Bay where mangroves have been well established, there are clear benefits from the use of mangroves as a component of NBS planning. However, in areas of new mangrove range expansion, there are risks and benefits to their intentional use, and project design and monitoring should account for and document tradeoffs between risks and benefits.

6. Monitoring mangrove project performance: Clam Bay, southwest Florida

Monitoring metrics for restoration projects, including mangrove projects, are typically tied to the goals of the project and are measured before and after the project takes place. Mangrove restoration generally includes a detailed assessment and restoration of hydrology and tidal flow patterns and sometimes includes the location of additional plantings. In many cases, the condition of actively restored sites is monitored in relation to a nearby reference ecosystem. Pre-restoration monitoring includes gathering the baseline data from which to assess changes over time and identifying areas that may serve as reference ecosystems.

The Clam Bay mangrove assessment conducted by the Conservancy of Southwest Florida has a good description of monitoring developed over a period of more than two decades in the Gulf of Mexico region. The project is located just north of Naples in

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Collier County and involved passive restoration by addressing the altered hydrology at the root of a large mangrove die-off. Monitoring was conducted to track the recovery of the areas that had lost mangroves and to assess the general condition of the mangroves in the system to compare pre- and post-restoration conditions throughout the system. Development along the boundary of the mangrove area permanently affected the landscape and subsequently the hydrology and mangrove health. Dredging of drainage ditches was conducted to improve tidal flow.

Annual monitoring was conducted in 12 circular plots (6-m diameter) across a gradient of conditions. Mangrove trees were identified and visually scored for condition, and diameter at breast height was recorded. Seedlings were identified and measured. A plant canopy imager was used to measure leaf cover and photosynthetically active radiation for annual comparison and calculation of net primary productivity to assess mangrove health over time. The purpose of the monitoring was not only to compare pre- and post-restoration recovery but also to evaluate the health of the Clam Bay mangrove system over time and gauge recovery in the areas that had died out. Importantly, monitoring of mangrove projects can also help inform adaptive management in which adjustments are made to both the restoration project and the entire restoration program over time, based on monitoring results and improved scientific understanding.

It is important to monitor mangrove restoration projects to understand the recovery trajectories of restored mangroves and to move toward unified monitoring indicators and metrics for mangroves along the Gulf and Atlantic coasts.

7. Research: Predicting the future distribution of mangroves

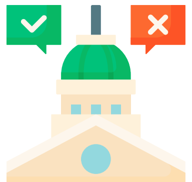
Global change is causing shifts in the distribution of many species, both on land and in the sea. On the Gulf and south Atlantic coasts, a prime example of such shifts are tropical mangroves that are expanding into temperate salt marshes as winter warming alleviates past geographic limits set by cold intolerance. To better understand how freeze events impact mangrove distribution, the Mangrove Migration Network established a network of sites at the northern range of mangrove distribution where in situ temperature and plant community measurements are collected in concert to better quantify the effects of extreme winter temperature upon black mangrove performance and mangrove-salt marsh interactions.

Changes in the distribution and abundance of habitat-providing plant species such as mangroves can have important cascading effects on ecosystems and the human communities that depend on their ecosystem services. Future mangrove distribution and abundance, in turn, will be influenced by human actions, such as decisions to inhibit (through removal or trimming) or promote (through planting for living shorelines) mangrove expansion. Thus, mangrove range expansion in the Gulf of Mexico provides a prime opportunity to use a social–ecological systems approach to understand the effects of range expansions on ecosystem function and services and the feedback from management and homeowner decisions.

In 2020, researchers from Northeastern University, the U.S. Geological Survey, and The Nature Conservancy initiated a research project to map the future distribution of mangroves along the Gulf and south Atlantic coastlines of the continental United States. This project seeks to synthesize existing knowledge on current mangrove distribution (the map displayed in this handbook), abundance, and ecosystem function; more holistically understand and communicate the local, state, and federal policies influencing mangrove distribution; and identify and understand the social drivers or constraints on mangrove expansion. These factors will be integrated to protect ecosystem structure and function in the future Gulf and Atlantic coasts in light of both changing temperatures and continued human impacts.

The resulting map of future mangrove distribution will allow coastal managers to identify the ecosystem functions associated with areas of existing and future mangroves, as well as the unique local and regional social constraints on those mangrove-associated functions. The ultimate goal of the project is to inform which ecological and human communities may be especially impacted by continued mangrove expansion and determine where conservation approaches might be necessary to ensure that mangroves persist along the future shorelines of the southeastern United States.

Research is needed to better understand how climate change and coastal management actions will affect future mangrove distribution and to inform actions related to mangrove conservation and, more broadly, coastal resilience policies and practices. While the range of mangroves will expand with warming temperatures, mangroves at some locations may be lost to sea level rise.



8. Policy: Florida Mangrove Trimming and Preservation Act

Mangroves are native to Florida and have existed historically on the Florida peninsula south of Cedar Key on the Gulf coast and south of Cape Canaveral on the east coast. As the climate has warmed, mangroves have begun to advance northward on the peninsula and have also appeared at several locations on Gulf coast barrier islands. Given the rapid development of the coast of the Florida peninsula over the last 50 years, there have been significant losses of mangrove habitat from bulkheading and other coastal construction, dredging, filling, and clearing to enhance views from residential and commercial properties. To reverse this loss, in 1996 the Florida Legislature passed the Mangrove Trimming and Preservation Act.

This legislation:

- Recognized the ecological, storm protection, and economic value of mangroves
- Expressed the intent of the Legislature to "protect and preserve mangrove resources valuable to our environment and economy from unregulated removal, defoliation and destruction"
- Strictly limited the locations and circumstances where mangroves could be removed, trimmed, or otherwise damaged
- Set out the conditions where and how mangroves could be trimmed to maintain views but encouraged waterfront property owners "to voluntarily maintain mangroves, encourage mangrove growth and plant mangroves along their shorelines."
- Identified "professional mangrove trimmers" who are permitted to trim mangroves within the boundaries of the law
- Established penalties for trimming or removal of mangroves not permitted under the law

This bill sharply reduced the loss of mangroves in Florida and encouraged their planting and management as a living asset to the Florida environment and economy. In doing so, it gave formal recognition to the important role of mangrove habitat in the future of Florida's coast. For the most part, citizens have accepted and supported this statute. Recent studies have revealed the benefits of mangroves in reducing storm damage to nearby development, and these findings have further strengthened public support for mangrove protection.

Although there are multiple federal laws that impact mangroves, Florida is the only state to pass legislation to protect mangroves as they move into new areas. As mangroves continue to move into new areas outside Florida, it is important for other states to consider similar legislation to protect and manage mangroves for their multiple values.

9. Blue carbon: Blue Carbon Resilience Credits in Texas

Mangroves, seagrasses, and tidal marshes line vast stretches of the Texas coastline and provide many ecosystem services, including enhanced water quality, recreational fishing opportunities, climate mitigation, and increased resiliency to storms and flooding. Carbon stored in these habitats represents a significant carbon sink and is referred to as blue carbon. Blue carbon provides an opportunity to bring in additional funding support for coastal restoration and protection. By quantifying the value of carbon sequestered and stored in coastal wetlands, projects can generate carbon offsets for sale on the voluntary carbon market. Companies can purchase such blue carbon credits help to offset their carbon emissions, and the sale of the purchase generates funding that can go back into the project.

Methodologies are available to account for the greenhouse gas fluxes within these systems and connect coastal wetland projects to carbon finance. Successful demonstration of blue carbon projects that legitimately provide climate mitigation benefits can help to catalyze this emerging market, thus creating new funding opportunities to support coastal wetland restoration and conservation at a larger scale.

Recently, The Nature Conservancy worked with Verra (formerly the Verified Carbon Standard) to develop the framework for validating a resilience credit, which can be stacked on top of a blue carbon credit then sold at a higher premium. Blue carbon resilience credits can be generated through actions to protect and restore coastal wetlands that are not only sequestering carbon but also reducing flood risk for people and built infrastructure.

In Texas, The Nature Conservancy is scoping market feasibility for blue carbon resilience credits while also increasing awareness and capacity for developing pilot blue carbon resilience credit projects. The Nature Conservancy is working with local partners and state agencies to identify high-priority areas to assess the feasibility for this financing mechanism across a broad range of resotration and conservation approaches being utilized in Texas. Because of their size, growth rate, and root structure, mangroves store substantial amounts of carbon and may be an effective implementation tool for blue carbon–financed projects.

Wetlands, including mangroves, are increasingly recognized for the climate mitigation and storm protection benefits they provide to coastal communities. There is an opportunity to quantify these benefits at a local scale and develop blue carbon resilience credits that can be sold on the voluntary carbon market to generate an additional funding stream for coastal landowners and restoration practitioners engaged in wetland conservation, restoration, and management.

10. Innovative finance mechanisms: Evaluating the feasibility of insuring mangroves

Insuring natural assets, such as coastal ecosystems, is a novel and innovative approach to repairing habitat damage following storms or other weather events. An insurance product for coral reefs in Mexico—the first for coastal habitats—was launched by The Nature Conservancy and its partners in 2019. Premiums are paid by the Coastal Zone Management Trust, which was established by the Government of Quintana Roo State in Mexico. These costs are paid in part by regional hotel bed taxes. In addition to paying annual premiums, the Coastal Zone Management Trust also provides for science-based restoration and maintenance that ensure the health of the reef and adjacent beaches. Hurricane Delta in 2020 triggered the first coral reef insurance payout of approximately $800,000 USD, which was made available for reef repairs. Mobilizing shortly after a storm event is critical for reattaching or repairing broken and overturned coral colonies, and it allows the reef to recover more quickly and continue providing its protective services to nearby coastal communities.

Like coral reef insurance in Mexico, mangrove insurance appears to be most feasible in locations where mangroves offer significant protective benefits to nearby communities, most likely measured in terms of avoided losses to physical assets from storm events. However, there may also be opportunities for mangrove insurance where mangroves offer significant economic benefits to nearby communities that rely on fisheries or ecotourism.

An insurance product for mangroves could be set up in several ways. First, the product could be based on a parametric insurance approach. With parametric insurance, the mangrove insurance would pay out immediately following a triggering event, which could be the documentation of excessive wind speeds in an area, as is the case for coral reef insurance in Mexico. The payout, which would be immediately available to use for post-storm clean-up and restoration of the mangroves, would not be based on assessed damages to mangroves. Instead, it would be pre-determined based on the estimated extent of damages caused by a given windspeed.

Alternatively, the mangrove insurance product could be a combined parametric-indemnity insurance product. In that case, some portion of the payout would be available immediately following the triggering event. The second portion of the payout would be available later and would be based on assessed damages to mangroves. The delayed indemnity payment could allow for additional restoration and maintenance of, for example, hydrological systems in the mangrove forest where damage may not be immediately obvious post-storm.

The Nature Conservancy is conducting a market analysis in Mexico, Florida, and the Bahamas to identify specific locations where a mangrove insurance product could be piloted. Financing these restoration activities through innovative solutions like an insurance product could be critical to sustaining the protective, economic, and ecological benefits of mangroves in the future. A future of increasing severity and frequency of hurricanes in the Atlantic Basin and rising sea levels will impact mangroves and their capacity to protect and sustain coastal communities. Insurance and other innovative strategies can mitigate those impacts.

Mangroves are increasingly recognized for the coastal protection benefits they can provide to communities. In some places, this benefit is likely great enough to justify insuring mangrove forests so that storm impacts to mangrove systems can be mitigated as quickly as possible after an insurance-triggering event.

VI. The Future of Mangroves Depends on Actions We Take Now

Mangroves are a key element of America's southern coasts and provide fisheries, recreation, and shoreline protection benefits to many coastal communities. Given the expanding range of mangroves and the many benefits they provide, coastal managers are now considering whether, where, and to what extent mangroves should be further protected and used intentionally as natural infrastructure to counter the impacts of climate change, sea-level rise, and coastal erosion along the Gulf and south Atlantic coasts of the United States. Because the expansion of mangroves northward and the potential use of mangroves to counteract the impacts of climate change are only now being explored, there is a lack of public policy governing mangrove planting and protection across much of these coastal areas outside Florida.

There are tradeoffs associated with facilitating, ignoring, or mitigating mangrove expansion in the southeastern United States. Many of these tradeoffs are related to the profound ecological, visual, and cultural change associated with the conversion of marshes to mangroves that often occurs when mangroves expand into marsh areas. There are risks and uncertainty regarding the likelihood of freezes that limit mangrove expansion, the ability of marshes and mangroves to keep pace with sea-level rise, and what role, if any, mangroves could and should play as natural infrastructure on the future coast.

The case studies in this handbook reaffirm the importance of existing mangrove habitat for the multiple benefits they provide for people and nature and offer guidance for weighing the tradeoffs associated with mangrove expansion in policy and practice. To summarize, lessons learned from recent and emerging research, monitoring, and restoration activities include:

- In a warming climate, mangroves are expanding north on their own on the Gulf and Atlantic coasts. Documenting, understanding, and predicting that range expansion are essential to assessing the current and future role of mangroves in overall coastal resilience and better planning for impacts to salt marshes and salt marsh dependent species.
- Mangroves can potentially move inland in rising sea level. If mangroves are to survive in the face of sea level rise and continue providing all their benefits, there must be room for them to move inland. This will require concerted action by government and coastal communities, including land or easement purchases in mangrove migration corridors.
- In some locations, the overall health of existing mangroves can be improved through hydrologic restoration alone.
- The experience of planting and seeding mangroves in predominantly marsh areas in Louisiana reveals that this is new applied science. We must learn from successes and failures in planting and seeding projects and distribute that information in a systematic way.
- All mangrove restoration projects should include systematic monitoring both to adaptively manage the projects themselves and to contribute knowledge to broader mangrove management strategies.
- As mangroves become more widespread in the Gulf, other states could build on Florida's example of managing mangroves to maintain their ecological values while addressing concerns of coastal communities and landowners.
- In urbanized areas where mangroves provide particularly important protection from storms and sea-level rise, insurance vehicles that fund restoration or rapid repair of mangrove tracts following tropical storms may be an important tool.
- Mangroves store carbon and thus combat climate change. Quantifying carbon storage and the creation of blue carbon credits based on carbon sequestration could add another component to financing mangrove restoration or habitat creation.

Protecting, restoring, and managing mangroves can be an important tool in creating a healthy and resilient coast in the years to come but will require a balancing of multiple interests in the face of a dynamic and uncertain future. The climate-driven expansion of mangroves and the actions taken in advance or in response to these changes are very important coastal management issues that require bringing together the best science, based on ongoing monitoring, with broad community engagement. While this handbook attempts to offer useful information, management of mangroves in the future will involve complex decisions that require additional research and discussion at the local, state, and regional scales.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The Nature Conservancy
and other's efforts related to mangroves
on the Gulf of Mexico and Atlantic coasts
of the United States, please visit
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