Coastal Habitats
3. Coastal Marsh Restoration

DEFINITION

Coastal marshes, also frequently called *salt marshes*, are partially flooded wetlands that are inundated by salt water brought in by the tides but can vary in salinity levels (NOAA 2023). They occur where fine sediments accumulate along shoreline protected from the open ocean. Halophytes (salt-tolerant species) dominate the ecosystem, especially smooth cordgrass and saltmarsh hay on the Atlantic and Gulf coasts and American glasswort, California cordgrass, and big bulrush on the Pacific Coast of the United States (Zedler et al. 2008). Around half of coastal marshes globally have been lost or significantly degraded (DiGiacomo 2020). Prominent drivers of this decline include polluted stormwater runoff, erosion, invasive species, drought, and sea level rise (Morganello 2021). Coastal marsh restoration varies regionally, but typically includes isolating an area via dikes and pumping in sediment, planting native vegetation, and diverting nearby rivers to flow through the marsh (Olander et al. 2021).

TECHNICAL APPROACH

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

1. **Restoring tidal exchange by removing any existing dikes and excavating canals and culverts Billah et al. 2022):** In many cases, the entirety of the dike does not need to be removed, but only breached in strategic spot. This will allow tidal inundation of the marsh, facilitating better conditions for salt marsh plants to grow (Hood 2004).

2. **Adding sediment to restore natural sediment characteristics and the marsh's elevation profile (Figure 1):** Organic soils, often from mangroves, are sometimes mixed into the existing topsoil to restore sediment characteristics (Billah et al. 2022), and dredged sediment from nearby channels can be used to build up marsh elevation (Kutcher et al. 2018). Using the sediment gathered during these projects for salt marsh restoration helps limit the cost of dredging sand. It also lessens the environmental impact of dredging and reduces the amount of dredged material in landfills (USACE n.d.).

3. **Vegetative restoration to remove invasive species, if necessary (Xie et al. 2019), and revegetation with native species, most commonly *Spartina* spp. and *Juncus roemerianus* along the Eastern seaboard of the United States (Craft et al. 2003):** One of the most prevalent invasive species in coastal marshes, the common reed (*Phragmites australis*), cannot grow in anoxic or high salinity conditions (Bart and Hartman 2002). In addition to promoting unfavorable conditions

for *Phragmites,* mechanical removal, applying herbicides, mowing, grazing, flooding the area, or prescribed burns can be used to repel invasions (Hazelton et al. 2014). Once invasive species removal is completed, replanting of native salt marsh plants can occur (Figure 2). While many planting strategies can be used, plugs (young plants grown in individual containers) or field transplants are the most effective methods (Rabinowitz et al. 2023).

OPERATIONS AND MAINTENANCE

Restored coastal marshes are likely to need periodic invasive species removal and may require occasional replanting with native species.

Figure 3.1 Adding sediment to Maidford Marsh at Sachuest Point National Wildlife Refuge in Rhode Island

Photo courtesy US Fish and Wildlife Service, Northeast Region

FACTORS INFLUENCING SITE SUITABILITY

- ✓ **Low elevation gradient (shallow slope):** Allows tidal flooding and generally promotes restoration success (NOAA 2023, Wolters et al. 2008).
- ✓ **Hydrodynamics:** Should allow for tidal exchange to reach most of the marsh, but marshes must be relatively sheltered from high-energy waves and strong currents, which will destabilize the vegetation (Steinigeweg et al. 2023).
- ✓ **Elevation within the tidal frame:** Ideally, restoration sites occur between the mean high water of neap tides and the level of the highest astronomical tides (Balke et al. 2016).
- ✓ **High salinity:** Baseline salinity levels of the surrounding waters must be conducive to salt marsh plants—generally between 18 and 35 ppt, depending on the elevation within the marsh (Odum 1988).
- ✓ **Sedimentation:** Sediment availability influences the marsh's ability to keep pace with rising sea levels caused by climate change, depending on the rate of increase (IPCC 2007). Measuring all sediment fluxes in the marsh is the best indicator of marsh resilience to sea level rise (Fagherazzi et al. 2020).
- × **High wave energy:** Wave energy greater than 1.2 m/s will prevent plant growth (van Loon-Steensma et al. 2012).

Figure 3.2 Newly planted salt marsh cordgrass in Chesapeake, VA

Photo courtesy US Army Corps of Engineers, Norfolk District

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?
New York City Parks Salt Marsh Restoration Design Guidelines	Guidebook	2018	City of New York Parks & Recreation	Written for New York City based on New York State restoration guide but most information is more broadly applicable	Detailed guide to planning, design, construction, and maintenance of constructed and restored salt marshes. Intended as a how-to guide for those new to marsh restoration or as a reference for experienced practitioners.	✓	✓	✓	—
Salt Marsh Restoration Handbook: Britain & Ireland	Guidebook	2021	Environment Agency (United Kingdom)	Written for salt marshes in Britain and Ireland but most of the information is more broadly applicable	Detailed guide about site selection, project planning, benefits calculation, community engagement and construction and monitoring of restored salt marshes. Intended to provide practical guidance to those restoring or creating salt marsh habitat.	✓	—	✓	—
New York State Salt Marsh Restoration and Monitoring Guidelines	Guidebook	2000	New York State Department of Environmental Conservation	Written for the Northeast region but most information is more broadly applicable	Guidance document that details the characteristics of salt marsh habitat, human disturbance, and restoration and monitoring methods. Intended to provide a framework for salt marsh restoration and address common shortcomings in past projects.	✓	✓	✓	—
Gulf of Maine Association Project Planning: Salt Marshes	Website	n.d.	Gulf of Maine Association	Written for the Northeast region but most information is more broadly applicable	Overview webpage outlining funding, restoration techniques, invasive species removal, design considerations, and potential obstacles to restoration. This resource focuses on practical concerns, such as finding contractors and funding opportunities.	✓	✓	✓	✓

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
Handbook for Restoring Tidal Wetlands	Guidebook	2001	Joy B. Zedler, Ed.	Applicable nationally, though all the case studies are from California	A technical guide focused on the details of coastal marsh restoration. Section topics include setting restoration goals, wetland topography and soils, planting vegetation, fish, invertebrates, and using geographic information system in salt marsh restoration.	✓	✓	✓	✓
Saltmarsh Management Manual	Guidebook	2007	UK Environment Agency	Written for salt marshes on the British Isles but most of the information is more broadly applicable	Guidance document to help maintain a healthy salt marsh for years after restoration has been completed. Topics covered include managed realignment, management techniques, and measuring change.	✓	—	✓	—
Maintaining Salt Marshes in the Face of Sea Level Rise—Review of Literature and Techniques	Guidebook	2019	US Army Corps of Engineers (USACE)	National	Review of salt marsh restoration practices with a special emphasis on adaptative management for sea level rise. Topics covered include erosion reduction, modelling sea level rise, and engineering considerations for salt marsh restoration.	✓	—	✓	—

GRAY INFRASTRUCTURE ALTERNATIVES

Coastal marsh restoration can be an alternative to gray infrastructure approaches that address coastal flooding and erosion, such as dikes, seawalls, and breakwaters. The ability of a coastal marsh restoration project to replace or supplement these gray infrastructure approach 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 coastal marsh restoration. See the gray infrastructure alternative tables in Section 1 for a comparison of salt marsh restoration to these alternatives.

LIKELY BENEFITS AND OUTCOMES

Primary objectives for each strategy are highlighted.

Climate Threat Reduction

- **Reduced flooding:** Studies have shown coastal marshes can reduce the height of large waves by as much as 18%, making them a vital defense against storm surges (Moller et al. 2014). Coastal marshes limit coastal flooding by providing a greater linear distance between the open ocean and anthropogenic development. This is paired with marshes' ability to attenuate floodwater, with one acre of marsh able to hold up to one million gallons of water (Shepard et al. 2011). Coastal marshes also promote shoreline stabilization, where the vegetation traps sediments and increases the elevation of the coast.
- **Storm protection:** When large storms hit the coast, coastal marshes can absorb significant amounts of water, thus reducing inland flooding and associated property damage (Narayan et al. 2017).
- **Sea level rise adaptation and resilience:** Coastal marshes can continue to add elevation due to the accumulation of sediments, therefore protecting other habitats and developed areas behind the salt marsh from increased flooding due to sea level rise (Baustian et al. 2012). However, this process depends on the marsh being adequately vegetated, which coastal marsh restoration can bolster.
- **Carbon storage and sequestration:** Coastal marshes have anaerobic soil, meaning that organic carbon is broken down over a longer period and therefore kept out of the atmosphere (NOAA 2023).

Social and Economic

- **Property and infrastructure protection:** Intact coastal marshes provide a buffer for the coast against storm surge by absorbing much of the water and wave energy (Mason et al. 2018).
- **Mental health and well-being:** Coastal marshes can serve as public green space, which helps improve residents' mental health.
- **Resilient fisheries:** Because coastal marshes reduce algae blooms, increase the primary productivity of phytoplankton, and serve as nursery habitat for many gamefish species, they also increase the populations of both finfish and shellfish, increasing opportunities for harvest.

- **Food security:** Increased availability of fish and shellfish for harvest provides food security for residents who rely on wild harvest for a part of their food supply.
- **Recreational opportunities:** Coastal marsh restoration makes an area more suitable for many recreational activities, including kayaking, bird watching, and fishing.
- **Jobs:** Workers will need to be hired to perform the restoration activity, boosting the local economy.
- **Increased property values:** Studies have shown that property values increase as the amount of coastal marsh preserved on the property also increases (Gardner 2021).
- **Cultural values:** Coastal marsh restoration can increase local knowledge of the marsh ecosystem and provide aesthetic values that increase sense of place.

Ecological Benefits

- **Improved water quality:** Coastal marsh habitat traps sediments that flow across the marsh, reducing the turbidity of nearby waterbodies. Coastal marshes also prevent excess nutrients, like nitrogen, from entering nearby waterbodies. As less nutrients are available, the severity of algae blooms will decrease. Reducing algae blooms protects water quality by increasing dissolved oxygen and reducing the concentration of toxins produced by algae (Mason et al. 2018)
- **Increased primary productivity:** Because the water is less turbid, more light will penetrate further below the surface, resulting in an increase in phytoplankton primary productivity (Mason et al. 2018).
- **Supports wildlife:** Phytoplankton are the base of the food chain and support many fish species that will benefit from the increase in primary productivity.

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 coastal marsh restoration are included here.

- **Expense:** Thin-layer placement of dredge material is expensive because dredge material is heavy and cumbersome to transport. There must be suitable material near to the restoration site for projects using dredged sediment to rebuild marsh elevation to be economically viable. Many projects have used material dredged from widened shipping lanes (TNC 2023).
- **Capacity**
- **Public opinion**
- **Conflict with other land uses:** Community members may oppose coastal marsh restoration due to the mutually exclusive nature of wetland conservation and property development. However, properties built on historical coastal marshes have a high risk of flooding.

- **Regulation**
- **Lack of effectiveness data**

Ecological

- **Invasive species:** Even after a coastal marsh has been restored, it is common that invasive species will recolonize the area.
- **Sea level rise:** Although the natural process of sedimentation allows for coastal marshes to gain elevation, this is often outpaced by sea level rise (Fagherazzi et al. 2020). When marsh plants become submerged for long periods of time, they die off (Schuerch et al. 2013). This can limit the longevity of salt marsh restoration projects.
- **Diversity and function:** Restored salt marshes may struggle to achieve the same level of species diversity as they did before anthropogenic degradation occurred. This lack of diversity also has the potential to reduce certain wetland functions. However, this may only be a temporary phenomenon, with some marshes taking more than a decade to recover (Callaway 2005).

EXAMPLE PROJECTS

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Great Meadows Restoration Project	Steward B. McKinney NWR, Stratford, CT	National Oceanic and Atmospheric Administration, **US Fish and Wildlife Service (USFWS)**	Increasing marsh elevation using dredged sediment	34	4.65 million	10 months	USFWS increased the marsh elevation by adding sediment, constructed tidal channels to restore tidal exchange, removed invasive species and planted native vegetation.	Sea level rise, increased storm severity	Tidal channels are needed to ensure that native turtles and fish can successfully enter the salt marsh.
Herring River Tidal Restoration Project	Cape Cod National Seashore, MA	**National Park Service (NPS), USFWS**	Dike removal to restore tidal exchange, invasive species and debris removal	1,100	60 million	4 years (expected)	To restore the tidal exchange that feeds salt marshes around the Herring River, workers are removing a dike that blocked the tidal exchange and replacing it with sluice gates. Debris and invasive species removal will also occur.	Sea level rise, increased storm severity	Significant controversy about changing a freshwater habitat back to a brackish one kept this project in the planning stage for decades.
The Nature Conservancy (TNC) Middle Township Restoration Project	Middle Township, NJ	TNC	Increasing marsh elevation using dredged sediment	60	Not provided	2 years	TNC used dredged sediment that was being removed to deepen a waterway to increase the elevation of salt marshes. This protects them against sea level rise.	Sea level rise, increased storm severity	Collaborating with other agencies to see if sediment is being dredged for other reasons helps reduce the cost of acquiring sediment.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Assateague Island Restoration Project	Assateague Island National Seashore, MD and VA	**NPS**	Refilling ditches during the 20th century and installing native plants	400	Not provided	3 years	Workers filled in ditches that were created in a failed attempt to eradicate mosquitos from the island. This restored the hydrology and native plants were installed to boost the ecosystem's recovery.	Increased storm severity	It is important to use low impact equipment in delicate and often remote restoration sites.
Jamaica Bay Restoration Project	Gateway National Recreation Area, New York City, NY	**NPS,** USACE, New York State Department of Environmental Conservation	Increasing marsh elevation using dredged sand and installing native plants	62	11.5 million	3 years	To reverse the pervasive decline of this salt marsh due to sea level rise, workers raised the elevation using dredged sand and planted native vegetation.	Sea level rise, increased storm severity	Fencing was needed to protect the plantings from foraging geese.
Seal Beach Restoration Project	Seal Beach NWR, CA	**USFWS, US Geological Survey,** USACE	Increasing marsh elevation using dredged sediment	14	3.3 million	1 year	A 10-inch-thick layer of dredged sediment was placed on the salt marsh to keep up with sea level rise.	Sea level rise	A hay bale encircled the restoration site to prevent sediment runoff.
Ni-les'tun Marsh Restoration Project	Brandon Marsh NWR, OR	**USFWS,** Confederated Tribes of the Siletz	Excavated tidal channels, removed dikes and tidal gates	400	10 million	2 years	Workers filled in irrigation canals and dug natural tidal channels. Next, they removed tide gates and dikes to reconnect the marsh.	No	Restoration had to be paused multiple times as items of archeological significance were found on the site.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Long Island Restoration Project	Wertheim, Seatuck and Lido Beach NWRs, Long Island, NY	**USFWS**	Excavated tidal channels, filling in mosquito ditches, installing coir logs	567	8.23 million	3 years	USFWS began this initiative as a response to the intense damage that Hurricane Sandy caused. Workers excavated channels, installed coir logs, filled mosquito ditches, graded dredge material, removed invasive species and planted native species.	Sea level rise, increased storm severity	Even after restoration, control measures for *Phragmites australis* were still needed.
Oxnard Restoration Project	Oxnard, CA	**Reclamation,** City of Oxnard, TNC	Constructed surface flow wetland near wastewater discharge site	1,000	55 million	3 years	In an experiment to streamline the city's wastewater treatment facility, the City of Oxnard have restored salt marshes near a wastewater discharge site to purify the water naturally.	Drought	Despite the large amount of waste entering the salt marsh, the plants can mask the odor.

Bolding indicates DOI affiliates.

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