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U.S. coastal marsh restoration: The role of sediment placement

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ABSTRACT:
Coastal marshes are important ecosystems that provide numerous services but are rapidly becoming more vulnerable to degradation and erosion due to the effects of climate change. These effects jeopardize erosion control and storm protection, wildlife habitat, water quality, carbon sequestration, recreation, and other coastal-marsh benefits. As a result, determining marsh health and optimizing delivery of these services represents an important endeavor for coastal scientists, engineers, and managers. One option for improving marsh resilience and ecosystem function is sediment placement for expanding or restoring marshlands. However, coastal marshes in the United States vary in size, shape, and vegetation depending on the climate, boundary conditions such as geology, sediments, influx of freshwater, and external forces including wind, waves, currents, and tidal range. Coastal marshes in the Northeast, Mid-Atlantic, Southeast, Gulf Coast, California, Pacific Northwest, and noncontiguous U.S. are described, including their extent, value, and restoration needs. Examples of sediment placement marsh restoration projects in these regions are provided. Outlined is the current state of knowledge about sediment placement in coastal marshes, as well as current approaches to sediment placement across the United States. There is also a discussion of current best management practices (BMPs), including limitations of these projects.

KEYWORDS: Beneficial use; best management practices, thin layer placement.

Coastal marshes are important ecosystems that provide numerous services but are rapidly becoming more vulnerable to degradation and erosion due to the effects of climate change — specifically sea level rise (SLR) (Mendelssohn and McKee 1998; Kennish 2001; Morris *et al.* 2002; Silvestri *et al.* 2005; Mitsch and Gosselink 2007; Barbier *et al.* 2011; Shepard *et al.* 2011; Kirwan *et al.* 2012; Kirwan and Megonigal 2013; Dahl and Stedman 2013; Davis *et al.* 2015; NOAA 2023a). These effects jeopardize erosion control and storm protection, wildlife habitat, water quality, carbon sequestration, recreation, and other coastal-marsh benefits. As a result, determining marsh health and optimizing delivery of these services represents an important endeavor for coastal scientists, engineers, and managers. One option for improving marsh resilience and ecosystem function is using sediment placement for expanding or restoring marshlands. Sediment placement is the purposeful placement of suitable dredged material (sediment) in a manner that produces a desired elevation allowing for the growth of functional marsh ecosystems. This white paper outlines the current state of knowledge surrounding sediment placement in coastal marshes, which are defined as saltwater or brackish-water marshes subject to tides. This white paper organizes and documents current efforts at studying, implementing, and regulating sediment placement in coastal marshes. In doing so, we identify common BMPs for multiple stages of the design and construction processes, as well as the limitations of BMPs. The goal of this paper is to be a resource for coastal practitioners on the value of coastal marsh ecosystems and related restoration projects and provide suggestions for implementing sediment placement in coastal marsh habitats.

In an era of a rapidly changing climate, the ecosystem and economic services offered by coastal marshes make these systems an essential component in improving and/or maintaining coastal resilience. For a wide variety of wildlife, coastal marshlands provide vital habitat for feeding, breeding, and nesting (Barbier *et al.* 2011; Shepard *et al.* 2011). For humans and wildlife, they act as a buffer against wave action and storm surges. The vegetation and creek networks filter water (including runoff and stormwater) to improve water quality and overall environmental health (Barbier *et al.* 2011). Carbon sequestration in marshes is a valuable service in balancing the global carbon budget (Hopkinson *et al.* 2012; Davis *et al.* 2015). Recreational and economic benefits of marshes to humans include birding, boating, fishing, aquaculture, and hunting. Considering this diverse and extensive array of benefits, coastal marshes serve a critical role in maintaining the ecological and economic health and resilience of coasts (Barbier *et al.* 2011; Shepard *et al.* 2011).

Tidal marshes have a relatively narrow elevation range and are sensitive to the frequency and duration of tidal flooding, which make the marshes especially vulnerable to accelerating sea-level rise. Tidal marshes are stable if the rate of sedimentation is equal to the relative sea level rise (RSLR; a function of sea level rise and subsidence). Regionally, RSLR and sedimentation rates vary, which results in areas such as the South Atlantic, where sedimentation rates can often keep pace with RSLR, and the Gulf of Mexico, where tidal marshes in Louisiana cannot keep pace with RSLR which results in the marsh drowning. Due to direct and indirect anthropogenic influences, much of the United States' vegetated coastal marshes are already subject to degradation or will be subject to conversion to open-water habitat, and will be so in the coming decades (Kennish 2001; Barbier *et al.* 2011; Hopkinson *et al.* 2012; Kirwan and Megonigal 2013). Hazards to marshlands include coastal erosion from waves and currents, RSLR, and increased tidal flooding; changes to hydrology resulting in less frequent tidal cycling and natural sediment deposition; and direct anthropogenic impacts, such as development and pollution. In the United States between 2004 and 2009, there was an estimated 6,441,272 acres of intertidal wetland remaining with measured losses of 2.4% of vegetated intertidal wetlands annually (Dahl and Stedman 2013).

Marsh health can be assessed in several ways depending on the location and uses of the marsh for wildlife and humans. Both short- and long-term monitoring of vegetation, erosion, soil, water quality, fauna, and human impacts can help establish baseline conditions for comparison against management goals. Vegetation is critical to coastal marsh health, as it provides a structure to reduce erosion rates. Three reasonable measures for vegetation conditions are the ratio of vegetated to unvegetated marsh, the community structure, and density. Soil health can be assessed using such factors as organic matter content, pH, and nutrient levels. Water quality is often assessed using salinity, pH, dissolved oxygen, and nutrient levels. The presence of fauna is a useful indicator of marsh health,

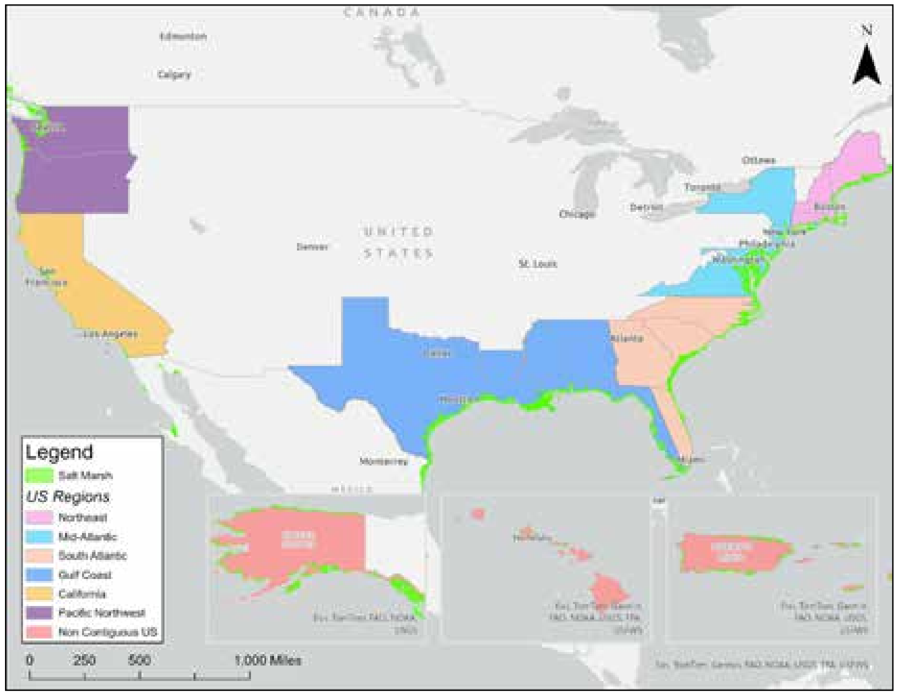

Figure 1. Map of U.S. with coastal marshes highlighted and broken up by region.

as most healthy marshes can support a diverse population of fish, shellfish, migratory birds, mammals, amphibians, and reptiles. Finally, human impacts can be observed by quantifying point-source pollution, development/encroachment, and land-use changes, most of which will adversely impact the marsh.

The primary goal of marsh restoration is to support healthy, productive marshes capable of providing a full suite of ecosystem services. One of the most important constraints on marshes is elevation (Materne *et al.* 2022). Because of marshes' intertidal nature, changes in elevation caused by RSLR in turn trigger cascading changes in vegetation, habitat availability, and erosion (Mendelssohn and McKee 1998; Silvestri *et al.* 2005; Mitsch and Gosselink 2007; Kirwan *et al.* 2012; Kirwan and Megonigal 2013). Most species of marsh vegetation need both wet and dry periods for growth (Silvestri *et al.* 2005; Kirwan *et al.* 2012). When RSLR is greater than the accretion of the marsh, vegetated areas become over-inundated, often resulting in a net-degradational state in which the relative elevation of vegetation decreases on the marsh and there is greater potential for conversion of habitat to open water or mudflats (Orson *et al.* 1985; Mitsch and Gosselink, 2007; Stagg and Mendelssohn 2011; Kirwan and Megonigal 2013; Cahoon *et al.* 2019). In marshes bordered by uplands, coastal squeeze and total loss of the marsh plant community is possible (Morris *et al.* 2002). Sediment placement projects allow plant communities to withstand increases in RSLR by supplementing degraded marshes with local or imported sediment and increasing the elevation of the marsh platform to mimic natural aggradation (i.e., at a rate that allows for the re-establishment of native vegetation; Raposa *et al.* 2020). Sediment placement projects are designed to restore natural hydroperiods and increase the "elevation capital" of a marsh, by increasing the elevation of the marsh platform (Cahoon *et al.* 2019; Raposa *et al.* 2023). When marshes are drained or elevation is increased rapidly, intertidal vegetation is under-inundated, damaging its ability to function. As a result of these changes in hydrological function, invasive species like Phragmites often colonize rapidly and disrupt the native community structure, resulting in the need for marsh restoration projects that focus on elevation manipulation and improving hydrology through the infilling of man-made ditches or lagoons.

Sediment placement is the purposeful placement of suitable dredged material (sediment) in a manner that produces a desired elevation allowing for the growth of functional marsh ecosystems. It has been used since the 1970s both intentionally and accidentally (VanZomeren and Piercy 2019). Regionally, sediment placement is referred to by various names with similar meanings: thin layer placement, marsh enhancement, sediment enrichment, or marsh creation. This paper uses the phrase "sediment placement."

Sediment placement has been described as sediment thickness that does not change the ecological function of the receiving habitat (Wilbur 1992); sediment placed in layers with thickness ranging from a few inches to a few feet (VanZomeren *et al.* 2018); and as the purposeful placement of thin layers of sediment to achieve a target elevation of thickness (the U.S. Army Corps of Engineers [USACE]; Berkowitz *et al.* 2019). Placement is completed most often using either a high-pressure hose to disperse the sediment broadly by continually moving the spray or using a low-pressure slurry delivered through a pipe suspended above the marsh such that thick deposits are avoided. Novel techniques continue to be developed and tested. The layers that are deposited using the aforementioned methods typically range from inches to a few feet, depending on site conditions and project objectives. In this purposeful placement, the sediment used is often sourced from locally dredged material — and project participants often use the well-known acronym BUDM, which stands for Beneficial Use of Dredged Material. The USACE has broad categories of what constitutes BUDM, based on the usage of the sites (DOTS-ERDC 2023).

The relationship between marsh accretion, RSLR, and ecosystem functionality is based on relatively well-understood basic scientific research (Crotty *et al.* 2020). However, the current state of sediment placement projects implemented as a method for mitigating the effects of climate change and other anthropogenic impacts is less known. Across the United States, some pilot projects and studies have been completed on an ad hoc basis in response to degraded or destroyed marsh ecosystems in locations where funding is available. There are currently no known attempts to coordinate repetitive sediment placement for combating climate change and SLR. The USACE, National Oceanographic and Atmospheric Administration (NOAA), U.S. Environmental Protection Agency (USEPA), and many state agencies have all made efforts to complete marsh restoration projects involving sediment placement, in an attempt to restore coastal marsh area.

REGIONAL COASTAL MARSH VARIATION

Coastal marshes in the United States vary — in size, shape, and vegetation depending on the climate; in boundary conditions, such as geology, sediments and influx of freshwater; and in external forces, including wind, waves, currents, and tidal range.

The sections to follow contain region-specific descriptions of coastal marshes in the Northeast, Mid-Atlantic, Southeast, Gulf Coast, California, Pacific Northwest, and noncontiguous U.S. These descriptions detail their extent, value, and restoration needs, and include examples of marsh restoration projects in these regions (Figure 1). From Dahl and Stedman (2013), it is estimated that the Atlantic coast contains 2,377,691 acres of saltwater intertidal wetlands, the Gulf of Mexico coast 3,349,788 acres, and the Pacific coast 713,793 acres.

Northeast

Coastal marshes in the Northeast (ME, NH, MA, RI, and CT) are located at the mouths of rivers and along the shores of coves and bays across the region. These marshes are dominated by salt-tolerant grasses such as salt marsh cordgrass, salt hay, giant cordgrass, and salt grass. The various grasses found in the Northeast marshes support a range of organisms, including snails, crabs, and juvenile fish. Economically important species, such as flounder, lobster, and crabs, use these coastal marshes for food, shelter, spawning, and nursery habitat.

Regionally, the coastal marshes of the Northeast are most threatened by RSLR, increased erosion, and anthropogenic influences that alter hydrology and constrain marsh extent. Many coastal marshes do not have adequate accretion to maintain pace with RSLR, have previously had dredged material placed that altered their hydrology and vegetation, or are constrained by neighboring development that limits migration.

Examples of successful restoration in the Northeast include the Sachuest Point National Wildlife Refuge (NWR) Maidford River Saltmarsh Restoration, and John H. Chafee NWR, both in Rhode Island. The Maidford River Saltmarsh Restoration project, administered by the U.S. Fish and Wildlife Service (USFWS), restored 11 acres of intertidal marsh where, previously, elevation prevented proper drainage at low tide. The project placed 11,000 cubic yards (cy) of material in layers ranging from 1 to 12 inches (in) of thickness. Planting of native marsh grass occurred in areas thicker than 4 in. The addition of sediment to the marsh resulted in improved drainage and numerous co-benefits, including reduced nearby flooding and improved habitat for important species (DOTS-ERDC 2017a). The John H. Chafee NWR project was also administered by the USFWS and consisted of a 14-acre restoration of coastal marsh in the Narrow River Estuary that had been degraded by a combination of SLR and storm impacts. The restoration consisted of approximately 4 in of BDUM sediment in areas with signs of stressed vegetation and expanding ponds. Planting of native marsh grass was completed in areas receiving more than approximately 3 in of sediment (DOTS-ERDC 2017b). This restoration resulted in improved ecosystem services, a more resilient plant community, and improved hydrology (Myszewski *et al.* 2017).

Mid-Atlantic

The Mid-Atlantic is one of the most densely populated regions of the country, and is therefore highly developed. Vast salt marshes comprise much of the back bays in the Mid-Atlantic (NY, NJ, DE, and MD), with the largest proportions lying in the estuarine areas of New Jersey and Maryland. Each state has seen tremendous loss of salt marsh due to development and degradation; particularly in New York, the remaining salt marshes exist in the most densely populated regions of the state (lower Hudson River, Atlantic coast, and Long Island Sound). The salt marshes of the Mid-Atlantic are dominated by salt-tolerant grasses, such as smooth cordgrass, salt hay grass, giant cordgrass, and switchgrass. These areas are critical habitat for many species, including wood duck, muskrat, cattail, and swamp rose, while other species (e.g., striped bass, peregrine falcon, and white-tailed deer) rely on healthy salt marshes throughout their lifecycle. Salt marshes in this region are an important source of food for aquatic animals and, by proxy, an import source of food for people of this region and beyond. They are critical habitat for estuarine and marine fishes (e.g., menhaden, bluefish, flounder, seatrout, spot, mullet, croaker, and striped bass) and shellfish (e.g., blue crab, oysters, clams, and shrimp) (Tiner 1987).

The Mid-Atlantic region faces higher rates of RSLR than the worldwide average, and in almost all cases the marshes in this region will not be able to maintain the required elevation to survive (Weis *et al.* 2021; Haaf *et al.* 2022; Sweet *et al.* 2022). A myriad of factors play into the overall health and resilience of these marshes, including anthropogenic activities such as mosquito ditching, overfertilization, and wake action from boaters. Both population density and a high incidence of development leads to coastal squeeze on the marshes of this area and a general inability for them to migrate inland. Absent of the ability to migrate, the other option for the persistence of marshland is the natural accretion of sediment onto the marsh platform through wave and storm action. Unfortunately, again, anthropogenic activities have generally decreased the amount of natural sediment that could supply to the majority of the marshes in this area. In many cases, these wetlands are already degrading or are predicted to degrade over time. Therefore, it will be necessary to artificially elevate these marshes with sediment to increase the resilience of these wetlands for the future.

BUDM for marsh restoration has been used for nearly a decade in the Mid-Atlantic states and has been performed successfully at multiple relatively small sites in New Jersey, including Fortescue Marsh, Avalon, Ring Island, and Good Luck Point, and Poplar Island in Maryland. Good Luck Point in Berkeley Township, NJ, is at the north end of the Edwin B. Forsythe National Wildlife Refuge, a microtidal area of Barnegat Bay. Approximately 13,000 cy of sediment had been identified as needing to be dredged from 1.6 miles of nearby state navigation channels. In 2020, the project ultimately restored 5.2 acres of marsh with approximately 6,000 cy of mixed dredged material. The project goal was to reach a general target elevation of +0.7 ft (feet) NAVD88, which would have required greater capacity than what was available; therefore, this target elevation was not reached. Within one year of placement, *Spartina alterniflora* had naturally colonized and revegetated. Test plantings of *Spartina patens* showed greater success at the edge of the marsh than in the center. Coarse dredge material (6,000 cy) was used for a 1,700-linear-foot (LF) habitat beach replenishment (15 ft wide and 4 ft high at crest) and was accomplished by pumping material onto the marsh edge and into the nearshore to be transported naturally into the system. One year after restoration, approximately 42% of the material remained in the nearshore system.

Figure 2. Monitoring placement of dredged sediment at Jekyll Island (Photo courtesy Clay McCoy, USACE Jacksonville).

Poplar Island in Maryland represents a very different use case of dredge material. Since the 1990s, sediment dredged from the channels of Baltimore Harbor has been used to restore a remote island habitat in the Chesapeake Bay at Talbot County that had degraded from 1,100 acres to about 4 acres of small clusters of low marshy knolls and tidal mudflats. Island perimeter containment dikes were constructed of sand, rock, and stone, and the first dredged material was placed in 2001. Immediately after the first placement wildlife, including a large variety of birds and terrapins, began inhabiting the area. Restoration efforts at Poplar Island focus on developing wetlands (low and high marsh, bird nesting islands, and open water ponds) for improved water quality and valuable habitat. The original project was expanded and once completed will ultimately contain 68 million cy of material and result in 1,715 acres of restored habitat (776 acres of tidal wetlands and 829 acres of upland habitat that will encompass a significant portion of the sediment) (Poplarislandrestoration.com 2021).

South Atlantic

The South Atlantic states (NC, SC, GA, and FL east coast) contain the majority of Atlantic coastal salt marsh habitat. The South Atlantic marshes are incredibly productive ecosystems dominated by smooth cordgrass, which is highly tolerant to saltwater and makes up the majority of the material decomposed by bacteria during the winter months. These marshes provide habitat for species important to the fishing industries, such as shrimp, blue crab, sheepshead minnow, as well as shore birds and other aquatic organisms. Marshes are an important breeding ground for fish populations and provide nursery habitat for at least 70% of Florida's marine fisheries that support the state economy and commercial fishing industry. On the Atlantic coast, salt marshes are dominant from the coast of North Carolina to Daytona Beach, Florida. From Daytona to Tampa Bay, mangroves replace salt marshes as the dominant intertidal ecosystem. Southeastern coastal marshes are highly susceptible to the adverse impacts of SLR and urban development. South Atlantic marshes are delicate ecosystems facing such issues as degraded water quality, loss of acreage due to filling, erosion, and other losses of ecosystem functionality due to the construction of hard structures (such as dikes) that divert flow (University of Georgia 2023, FDEP 2023; SCDNR 2015).

The USACE Chief of Engineers established a goal to increase BUDM to 70% by 2030 (USACE 2023). Two examples of BUDM to restore coastal marsh habitat at regional USACE districts include the Wanchese Marsh, South Carolina, restoration project and the Jekyll Island, Georgia, sediment placement project. The USACE Wilmington District and the State of North Carolina administered the Wanchese Marsh restoration project. The project included the BUDM from maintenance dredging of the Manteo-Oregon Inlet and side channel to Wanchese. The dredged material was beneficially reused to restore 12 acres of marsh habitat, while a stone dike was constructed to protect 8 acres of marsh habitat (USACE 2012).

The Jekyll Island BUDM sediment placement project was administered by a number of contributors, including the USACE Savannah and Jacksonville Districts, USACE Regional Sediment Management Program, Georgia Department of Natural Resources Coastal Resources Division, Jekyll Island Authority, The Nature Conservancy, NOAA, the USFWS, and the U.S. EPA. This multi-agency effort is a fantastic display of federal and local dedication to improving these innovative engineering methods. The pilot project tested the performance of 5 acres of sediment placement on Jekyll Island


Figure 3. Lake Hermitage marsh creation (Photo courtesy NOAA Gulf Spill Restoration 2023).

with dredged material from the Georgia Atlantic Intracoastal Waterway (Figure 2; DOTS-ERDC 2019).

Gulf Coast

The U.S. coastline that surrounds the Gulf of Mexico (FL west coast, AL, MS, LA, and TX) is approximately 1,600 miles long from the southern tip of Florida's peninsula to the border between Texas and Mexico.

Regionally, the coastal wetlands of the Gulf coast are threatened by a multitude of stressors including RSLR, which outpaces accretion; increased land loss from erosion; wetland loss due to saltwater intrusion; compaction and subsidence due to oil and gas extraction; frequent and intense storms; marsh loss from invasive species like nutria; and altered hydrology and fragmented marshes from oil and gas pipeline and navigation canals. In April 2010, 210 million gallons of oil escaped from the Deepwater Horizon well over a period of approximately three months. The Deepwater Horizon oil spill exacerbated the impacts of all the ongoing stressors, causing unmeasurable devastation and damage to the ecology and the resource-dependent economy of the Gulf region. According to the Deepwater Horizon Oil Spill Phase I Early Restoration Plan and Environmental Assessment (2012), the spill resulted in the oiling of more than 1,000 miles of the shoreline along the Gulf coast.

Examples of successful marsh restorations in the region include the Lake Hermitage Marsh Creation, the Pensacola Bay Living Shoreline Project, and Carancahua Cove within the Galveston Island State Park in the back-bay marsh of Galveston Island. The Lake Hermitage Marsh Creation Project is located in Barataria Basin, which is southeast of Lake Hermitage, in Plaquemines Parish, Louisiana, near the community of West Pointe à la Hache. Based on the U.S. Geological Survey land-water data from 1985 and 2006, the project area had an annual marsh loss rate of -1.64% and was expected to lose 28% of its marsh area by 2050. The purpose of the Lake Hermitage Marsh Creation Project was to create an intertidal brackish marsh in the Barataria Basin and restore the eastern Lake Hermitage shoreline in order to reduce erosion and prevent breaching into the interior marsh. Completed in 2014, the project created a total of 795 acres of marsh in open water using dredged material from the Mississippi River and restored approximately 6,106 LF of shoreline in the eastern part of the project area (Figure 3; Deepwater Horizon Natural Resource Trustees 2012).

The Pensacola Bay Living Shoreline Project was led through a partnership with NOAA and the Florida Department of Environmental Protection. The project, completed in 2022, restored approximately 9.2 acres of salt marsh habitat and created 3.5 acres of oyster reef breakwater along the urban Pensacola Bay shoreline. Existing fully submerged breakwaters and marsh were present at the site from a previous marsh restoration project constructed in 2007. A new marsh habitat was created behind the existing breakwaters using hydraulic discharge of approximately 47,000 cy of coarse sand sourced from nearby borrow sites. Borrow material was discharged into coalescing mounds 20 ft in diameter at two different elevations within the high and low marsh planting range for local marsh vegetation species (NOAA 2023b). This method allowed for natural processes to reshape the mounded material forming inter-tidal channels within low, high, and fringe marsh habitat. Additional discharge was focused in three areas of the project, with smaller coalescing mound clusters in each area. This layout provided main open water channels as well as smaller secondary channels to allow for circulation. A series of wide, low-crested intertidal rock breakwaters were constructed seaward of the discharge areas and partially on existing structures to provide increased wave attenuation and benthic habitat.

The first marsh restoration and protection project performed on the bay side of Galveston Island State Park was led by the Texas Parks and Wildlife Department in 1998. Roughly 100 acres of marsh terrace grids, grid cells ranging between 400 ft and 1,600 ft in perimeter, were constructed by excavators using in situ material in Carancahua Cove (the southern portion of the park). Similarly, a ridge protecting approximately 3,800 LF of marsh in Dana Cover (the northern portion of the park) was constructed using the same construction methods. To provide protection from future wave forcing, a chain of five geotextile-tube breakwaters were also installed spanning the entire bay side of the park (Moseley *et al.* 2000).

In 2010, as part of the Recovery Act: Restoring Estuarine Habitat in West Galveston Bay project, the Texas General Land Office and Texas Parks and Wildlife Department partnered together to further restore marsh habitat in Carancahua Cove. Using approximately 810,300 cy of locally sourced material, emergent marsh mounds of approximately 120 ft to 300 ft in diameter at the waterline were constructed via hydraulic placement around and inside the previously constructed marsh terraces (Krecic *et al.* 2011). In 2017, marsh restoration and protection efforts in Carancahua Cove were continued through the West Galveston Island Bayside Marsh Restoration Project, managed by the Texas General Land Office, Texas Parks and Wildlife Department, and the National Fish and Wildlife Foundation. Approximately 321,400 cy of material was hydraulically placed in addition to the work completed in 2010, creating a total of roughly 99 acres of individual and coalescing emergent marsh mounds. The diameter of the mounds at the waterline were between 130 ft and 170 ft. Approximately 750 to 1,000 smooth cordgrass sprigs were planted within the intertidal range of the mounds, and 5,415 LF of rock breakwater was constructed over the remnants of the original geotextile-tube breakwater. Ongoing monitoring efforts in Galveston Island State Park have reported a 90% median vegetative coverage in the recently constructed marsh (Galveston Bay Estuary Program 2017).

California

California has lost more than 90% of its historical wetlands and 95% of its coastal wetlands (USEPA 2023). Today, the remaining coastal wetlands are threatened by agriculture, filled for development, or disturbed by modifications to the watershed such as dams or water diversions. Climate change poses a significant threat, as many wetlands today are dependent on artificial water delivery systems or high groundwater levels and may be impacted by changing climatic conditions. Further, wetlands along the coast face flooding from potential RSLR (Dahl 1990).

The California Aquatic Resource Classification System provides information about the likely functions or services of different wetlands. Tidal wetlands stabilize shorelines by binding the soils along the shoreline together with strong systems of plant roots. They also provide storm protection by creating a natural barrier to the elements and shielding coastal communities. Wetland vegetation works as a sediment trap and locks up nutrients and contaminants, thereby preventing concentration downstream that can result in algal blooms or hazards to human health. Marine wetlands occur along the outer coast of California. They depend on regular tidal action, ocean waves, or frequent ocean spray. The plants that inhabit marine wetlands are salt-tolerant. In contrast with estuarine wetlands, marine wetlands are minimally influenced by the freshwater from rivers or streams. Eelgrass beds are one particularly important kind of marine wetland in this region. They develop in the lower limits of the intertidal zone, where they function as nurseries for a variety of marine fishes, as well as feeding areas for fish, birds, seals, and other marine mammals. Eelgrass beds are subject to special protection in California (NOAA, 2014). Estuarine wetlands form along the tidal reaches of California's rivers and streams, and along the margins of estuarine bays and straits. They depend on regular tidal flooding, although the timing and degree of tidal flooding might be managed with tide gates, weirs, and other water control structures.

One example of estuarine wetland restoration in Southern California is Seal Beach NWR Thin-Layer Salt Marsh Sediment Augmentation Pilot Project, which encompasses an area of 8 acres of low salt marsh in the center of the refuge. It is the first known application of marsh sediment placement on the west coast of the U.S. (California State Coastal Conservancy 2014). The site's cordgrass-dominated salt marsh habitat has been adversely affected by RSLR and alteration of natural sediment inputs. From December 2015 to March 2016, a 10-in layer (plus/minus an average of 2 in) of dredged material was placed over 8 acres of low-elevation salt marsh. Approximately 17,000 cy of clean dredged material from the Main Channel west of Sunset/Huntington Harbor was placed on the site via rainbow sprayer and end-of-pipe baffle impingement. A hay bale barrier and a 6-acre vegetated buffer was maintained between the sediment placement site and adjacent channels in order to reduce sediment runoff and avoid impacts to marine species, including eelgrass beds and marine mammals (DOTS-ERDC 2016).

Farther up the coast in central California, Elkhorn Slough is one of the largest estuaries in the state. The slough provides important habitat for an exceptionally broad range of resident and migratory birds, fish, and other wildlife, and plays a crucial role in the local estuarine and nearshore food web. Elkhorn Slough is located on the central California coast, in Monterey County. The Elkhorn Slough Tidal Marsh Restoration Project will ultimately restore about 147 acres of salt marsh ecosystem in Monterey County. Phase I. completed in 2019, restored 47 acres of degraded marsh and created 14 acres of new marsh and 5 acres of upland ecotone and native grassland within the buffer area. Phase II will restore about 26 acres of marsh, create 3 acres of new marsh and 5 acres of perennial grassland. Phase III will restore 29 acres of degraded marsh, and 3 acres of perennial grassland. The remaining 15 acres of the borrow area will be restored to perennial grassland as funding permits. The project seeks to restore a resilient coastal ecosystem, from tidal creeks to marsh plain and adjacent coastal grassland. These formerly ecologically rich habitats, which hosted a variety of native species and provided essential filtering function between the upland agricultural fields and the waters of Elkhorn Slough, were in a landscape that had been degraded due to human land uses, primarily the diking and draining of wetlands (Fountain *et al.* 2023).

A third example in California is the Montezuma Wetlands project in the San Francisco Bay Area. It is a private initiative that has successfully begun to address two important societal challenges: historic loss of wetlands and an ongoing question about how to determine a responsible and beneficial use for millions of cubic yards of sediments dredged annually from San Francisco Bay ports, harbors, and channels. This wetland restoration project is located in Suisun Marsh, a nationally important brackish water marsh situated between San Francisco Estuary and the Sacramento-San Joaquin River Delta. This 2,400-acre project will beneficially reuse up to 17.5 million cy of sediment over time. This first of its kind project received permits in 1999 from four agencies to use dredged sediment to restore elevations on former tidal wetlands such that marsh plants can colonize and restore to a healthy tidal marsh with seasonal wetlands, and adjacent upland connections. It is also unique in that it is the only wetland restoration project in the Bay Area designed to take dredged sediment with elevated levels of contaminants and sequester them from ecologically sensitive wildlife. In 2021, the first phase of the project restored tidal action to a large portion of the site, as plants and wildlife quickly established themselves there. Phase II is currently under way and accepting dredged sediment from San Francisco Bay navigation projects.

Pacific Northwest

Marshes in the Pacific Northwest (OR and WA) provide biodiverse ecosystems for a range of plants, birds, and fish and

Figure 4. Kunz Marsh Restoration Experiment mid-cell time series, from left to right: 1996, 1999, and 2002 (Cornu 2005).

other aquatic wildlife. The Puget Sound in Washington accounts for the largest concentration of salt marsh habitat in the region (Collins and Sheikh 2005). Oregon marshes historically have shorter flushing times compared to the longer duration flushes in Washington (Adamus 2005). Pacific Northwest coastal marshes are subject to a mixed-tidal system that can experience between one and two tides a day. Marsh acreage in the Pacific Northwest has declined over the past century due to repurposing land for local agriculture or community development. Dikes, dams, and pipes are used to alter the natural flow of rivers, while excavating and filling ceases all flow of the channel. Marsh systems are also struggling to accrete sediment at a pace adequate to decelerate RSLR. The USACE Sea Level Change Curve Calculator was used to estimate about 2 ft of RSLR by the year 2100 for the Willow Creek Daylight Project Edmonds, Washington, according to the NOAA Low-to-Intermediate and USACE Intermediate estimates (Cline 2019).

Examples of successful restoration in the Pacific Northwest area include the Jetty Island Beneficial Use Project in Puget Sound, Washington, and the Kunz Marsh Restoration Experiment in South Slough, Oregon. The USACE Seattle District and the Port of Everett, Washington, administered the Jetty Island Beneficial Use Project. Jetty Island is a 200-acre port-owned intertidal island at the mouth of the Snohomish River. This project did not involve direct material placement on a marsh. However, dredged material from the Port of Everett was used for beach nourishment, specifically to create 1,800 LF of protective sand berm that allowed for the formation of salt marsh, lagoon, and backshore dune habitats on Jetty Island. Between 1990 and 1998, a total of 562,000 cy of dredged material was placed, along with salt marsh plantings, to help create salmonid and forage-fish rearing habitat. Post-project monitoring data collected by the port showed that saltmarsh habitat development greatly exceeded expectations and justified beach nourishment (USEPA and USACE 2007).

The NOAA South Slough National Estuarine Research Reserve conducted the Kunz Marsh Restoration Experiment in 1996. The Kunz Marsh is a five-acre saltwater marsh located inside a tidal bend of Winchester Creek, Oregon, that was converted to cropland and pasture in the early 1900s. A dike and tide-gate system with ditches resulted in about 30 in of subsidence in the marsh. The restoration experiment tested the active adjustment of marsh surface elevations in the subsided marsh. Approximately 13,000 cy of dredged material was excavated from the Kunz Marsh dike and distributed across four experimental sections by means of sediment placement. Experimental sections of the marsh were created with a high, middle (Figure 4), and low intertidal marsh elevation. The middle-marsh elevation performed the most favorably, and the staff concluded that manipulating marsh surface elevation is a viable method for accelerating the recovery of subsided saltwater marshes (Cornu 2005).

Noncontiguous U.S.

The non-contiguous United States (PR, HI, and AK) contain a wide variety of coastal marshes covering many important areas that serve a wide array of purposes ecologically and culturally. In Alaska, there are more than a million acres of coastal wetlands largely contained in coastal river deltas (U.S. Forest Service 2023). Hawai'i contains approximately 15,000 acres of coastal wetlands (Dahl 1990). In Puerto Rico, estuarine marsh land cover is relatively small and consists of a narrow transitional habitat near estuarine wetlands and coastal plains (Adams *et al.* 1999). Coastal marshes cover close to 14,500 acres in Puerto Rico; they consist primarily of sawgrass and several halophyte species such as turtleweed and sea purslane. Emergent wetland coverage is approximately 18,000 acres and is made up of predominantly mangrove forest (Helmer *et al.* 2002). While mangrove habitat can be found along Puerto Rico's coastline, marsh associated with saltwater flats and ponds are found mostly on the southern coast (USACE 2011). Coastal marsh and wetlands represent part of Puerto Rico's rich biodiversity, supporting approximately 860 species, with roughly 9% endemic to the island. These habitats serve as coastal buffers from tropical storms and hurricane-driven surge and flooding, provide economic stimulus to local fishing industries, and provide recreational opportunities for residents and tourists alike (Adams and Hefner 1994). Anthropogenic development through agricultural practices during the first part of the 20th century and later urbanization in recent decades have reduced palustrine and estuarine wetland habitat coverage in Puerto Rico. Environmental influences — primarily hurricanes, heavy rains, and RSLR — also result in marsh and wetland habitat destruction and/or habitat conversion (Branoff 2018).

A new coastal management strategy plan approved by NOAA in 2022 has promoted conservation and restoration of coastal habitats in Puerto Rico to provide enhanced resilience to coastal communities (Velez-Sanchez 2022). Currently, studies on marsh and wetland restoration are being performed at five sites that suffered extensive damage from Hurricane Maria, to determine restoration needs, management practices, and natural vegetation recovery rates. These five areas are located across the island close to urban or other critical infrastructure: Punta Tuna in Maunabo, Punta Santiago in

Humacao, Piñones in San Juan, Ciénaga Las Cucharillas en Cataño, and Jobos in Isabela (Branoff *et al.* 2018).

In Hawai'i, BUDM has yet to be practiced for marsh restoration. Although the 2012 Kawainui Marsh Wetland Restoration project — administered by the State of Hawai'i Department of Land and Natural Resources (DLNR) and USACE Honolulu District — addressed erosion, created habitat for several endangered bird populations, and improved public access to the marsh, the use of dredged sediment was not part of the restoration of the largest remaining wetland in Hawai'i (Hawai'i DLNR 2011). Future restoration projects that utilize dredged sediment are likely to focus on biocultural restoration of indigenous aquaculture and wetlands agroecology systems (Winter 2023).

Underpinning these restoration goals is the concept of ecomimicry, "a strategy for developing and managing cultural landscapes, built upon a deep understanding of the structure and function of ecosystems, that harnesses ecosystem processes for the purpose of balancing and sustaining key ecosystem services, rather than maximizing one service to the detriment of others" (Winters *et al.* 2020). Practiced by pre-contact Hawaiian communities, their social-ecological systems integrated a variety of ecomimicry schema to engender a complex system of adaptive resource management that enhanced biocultural diversity and supported resilient food systems, ultimately sustaining a thriving human population (Winter *et al.* 2020).

Alaskan coastal wetlands serve as a critical stopover for waterfowl and shorebirds in the Pacific Flyway, provide linkages for fish and wildlife populations, and are vital to the Pacific Ocean's fisheries. Due to the wide variation in latitude of coastal marshes, there are numerous species that dominate marshes, depending on geography (Alaska Department of Fish and Game 2006).

BEST MANAGEMENT PRACTICES

Successful sediment placement projects should follow general BMPs for wetland, estuarine, and riparian habitats as they already exist. Sediment placement projects specifically formulated for salt marsh systems bring additional challenges like long-term water level and sedimentation changes, among others. Raposa *et al.* (2020; Table 1) provides a BMP framework for developing objectives for monitoring protocols for sediment placement in marshes (Table 1). Additionally, monitoring should include site visits to conduct qualitative monitoring, as some issues can be identified before they are measured. The BMPs below summarize the framework, with some additions, for implementing sediment placement in coastal marsh habitats.

All sediment placement projects in marshes should include monitoring of elevation and vegetation changes before and after construction. Observations can be made using in situ or remote sensing methods and should last for a period of at least five years following project completion. As resources allow, additional monitoring protocol should be included to account for individualized concerns in marsh condition between sites.

Additional BMPs for sediment placement projects focus on resilience, hydrology, ecological function, community engagement, and compliance. Although the overarching goals of most sediment placement projects are to mitigate imbalances in sediment budget or reductions in functionality, individual projects will bring unique concerns. For instance, resilience to SLR will be dependent on the tidal range and projected future water levels for a particular site. Hydrological and ecological functionality are necessarily site-specific, as are community engagement and compliance.

Elevation and resilience to SLR

Determining a project design elevation and accounting for resilience to future SLR go hand-in-hand. Design elevations should be formulated based on local tidal datums and project-specific goals. Thicker sections of fill can trigger a longer recovery period for native vegetation, but may provide greater resilience against future water level increases. Balancing the logistical and budgetary constraints of a particular sediment placement project against these considerations is an important step in the project planning process. The life expectancy of projects will vary significantly by site conditions and threats. Ideally, sediment placement projects will deliver protection against projected future RSLR. Comparing the expected lifetime of a project against recent local RSLR rates can help planners and managers determine the necessary thickness of sediment and other needs in the project planning stage.

Monitoring the elevation and resilience to RSLR for a particular project is largely accomplished through elevation surveys. These may be performed using in situ or remote methods but should account for elevation changes at local as well as landscape scales (TNC 2024). That is, the resolution of an elevation model for monitoring sediment placement in marshes should be as fine as possible (+/- 2 in) across as large an area as practicable. Site-specific constraints like access, water depth, and size will determine whether manual GPS surveys or remote sensing methods involving unmanned aerial vehicles (UAVs) or other craft should be used for a particular project.

Vegetation and hydrology

Projects can use target elevations to facilitate rapid recovery of native species of flora (Mendelssohn and Kuhn 2003) and should consider potential time lags between elevation changes and re-establishment of native plant communities (Raposa *et al.* 2023). Some sites may require an emphasis on lower marsh vegetation, while others require middle- or high-marsh vegetation to re-establish a functional system in the years following project completion. The tide range and wave climate of a site may also affect the attainable fill thickness, insofar as heavy equipment or dredges may only be able to access a portion of the fill area during particular times of day (TNC and NJDEP 2021; Ray 2007).

Additional considerations beyond those listed above include project timing and sediment characteristics. For instance, unvegetated tidal flats exposed during high-energy hurricane or nor'easter events can erode quickly and remove fill faster than anticipated. Certain types of vegetation or certain areas may take multiple growing seasons to fully re-establish and should be considered when developing an adaptive monitoring and mitigation plan for a particular project (Raposa *et al.* 2023; TNC and NJDEP 2021).

The size, distribution, and character of sediments placed also impacts vegetation recovery. Geotechnical analysis can be used to determine compaction rates and soil chemistry, and ensure the material is a match for the placement area (Chesapeake Bay Program 2000). Soils with different geotechnical or chemical properties may affect plant

Table 1.
Recommended framework to develop sediment placement projects; adapted from Raposa *et al.* 2020.

Category	General objective	Example monitoring approaches
Elevation	Achieve desired elevation target during initial construction and maintain it for a certain amount of time (i.e., no major loss in elevation due to erosion/compaction during the identified time period).	• Field surveys along permanent transects or across a grid network • Remote sensing and GIS
Resilience to sea level rise	Sediment placement initially builds the marsh platform to heights amenable for withstanding an extended period (e.g., decades) of projected SLR; marsh elevation gain after sediment placement tracks at least the current rate of local SLR.	• Surface elevation tables and marker horizons • Landscape-scale surveys • Quantify elevation capital by pairing marsh elevations with a local tidal datum.
Vegetation	Achieve desired marsh cover and community composition relatively rapidly (through survival and regrowth of existing plants, colonization by seeds, or by targeted plantings), and maintain this for at least a few decades.	• Field surveys using transects and quadrats • Remote sensing (e.g., aerial photos, UAVs) • Focused assessments • Repeat photography to track changes in vegetation over time • Soil characteristics and chemistry
Hydrology and inundation	Establish appropriate tidal flooding regimes and adequate drainage to promote healthy and sustained plant growth.	• Collect data from water level loggers • Remote sensing
Ecological functions	Establish ecological functionality at levels similar to or better than reference marshes, or at appropriate levels to achieve desired ecosystem services or support needs of particular species.	• Assess desired animal communities • Flora surveys for density and diversity
Community engagement	Engage local communities and other relevant stakeholders to increase their sense of ownership in coastal ecosystem restoration, and their understanding of coastal processes and ecosystem services.	• Community participation through numerous stakeholder opportunities
Regulatory compliance	Avoid unintended negative consequences resulting from sediment placement, as dictated by relevant regulations and authorities.	• Water quality (turbidity) • Sedimentation outside of project area • Federally listed species changes

community composition, and thus long-term growth rates and erosion potential for a site (Cahoon *et al.* 2019; Wigand *et al.* 2014). At the same time, there is evidence that using off-site upland soils or mixing different soil types — so long as the resultant mixture resembles marsh sediment — can yield similar positive results as using locally sourced materials (Raposa *et al.* 2023).

It is also important to restore functional hydrological conditions to encourage more rapid recovery of native vegetation. This concern is intertwined with those of elevation and resilience to SLR insofar as an ideal tidal flooding regime may need to be balanced against resilience and/or elevation goals for a particular project. Historical manipulation of tidal creeks and channels in marshes on Long Island, for instance, altered the tidal prism and ultimately long-term Mean Higher High Water (MHHW) datums (Cahoon *et al.* 2019). Projects should endeavor to facilitate adequate drainage of the marsh basin to avoid these types of situations in the future.

Coastal squeeze has restricted the available space for certain marsh plant communities as SLR has progressed over the last century and is expected to increase in the coming decades. Ensuring that a project can withstand projected SLR while maintaining proper elevations for native low-, middle-, and high-marsh communities, in proper proportion to one another, is a necessary step towards ensuring functional hydrological cycling and avoiding unwanted inundation. Monitoring and measuring hydroperiods in adjacent stands of marsh vegetation, and systematically measuring elevations, helps to ensure a project will mimic natural conditions, which increases the probability of success in the long run.

Additional considerations involving hydrology include more detailed technical specifications. Projects can be formulated to allow sediments to settle naturally, provide microtopography mimicking natural conditions, or remove/install containment structures (NRCS 2021). In some locations, unconfined placement of dredged material is acceptable; in other locations, both primary and secondary containment structures are required to permit marsh restoration.

Ecological functions

Marshes are highly productive ecosystems that can deliver a suite of benefits to adjacent plant and animal communities when functioning properly. Determining the appropriate types and levels of various plant and animal communities, geochemical properties, or carbon sequestration for a particular project is an important step in drawing up construction and monitoring plans.

As in the cases of elevation and vegetation, comparing the project site to nearby "functional" systems is the preferred method for determining the end goals for a sediment placement project. Distinct plant or animal communities will deliver specific types of services and functions, and will necessarily look different in monitoring data. So determining targets and species for monitoring is a key step. In some locations, popular fish or birds may drive project goals; in others, endemic grass or shrub species may be more important. Pre-project assessments and comparisons against adjacent communities are a useful way to ensure a particular project is resulting in positive impacts.

Additionally, carbon sequestration is an ecological function that is a critical result of marsh restoration. Carbon sequestration activities include managing, preserving, enhancing, and restoring ecosystems that result in either a reduction of anticipated greenhouse gas emissions or an increase in the ecosystem's ability to capture and store greenhouse gasses in soils and plants.

Community engagement

A crucial step in planning and implementing sediment placement projects is building and maintaining support from key stakeholders at multiple levels. Community engagement comes in many forms, and often it might take more effort than is expended in traditional beach or dune restoration projects; but early and frequent engagement will lead to more successful projects. Involving the public, especially marginalized and tribal communities, provides a more solid basis for projects at the earliest stages. Such involvement enables practitioners to consider recommendations involving knowledge from local, indigenous, and/or disenfranchised communities that may be able to offer a more nuanced perspective on flooding or storm-related issues of a project site.

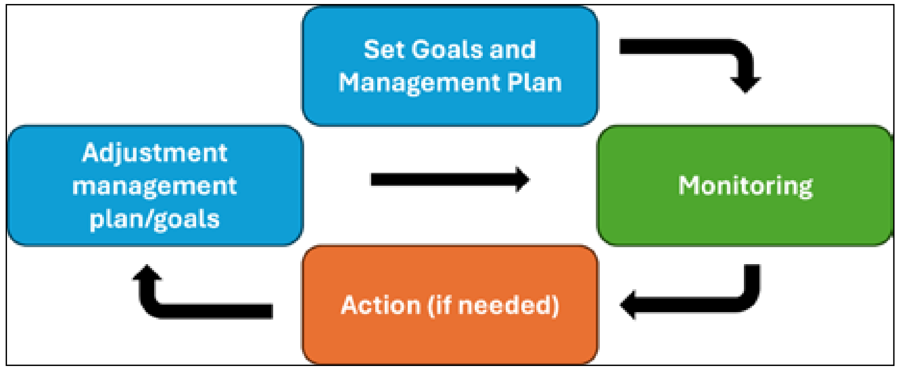

Figure 5. Flow chart of adaptive management.

As is evidenced by previous sediment placement projects, continuing public engagement beyond the initial stages is an important lesson learned. (TNC and NJDEP, 2021) Such public engagement enables practitioners to employ a more adaptive approach in assessing and re-implementing the placement of material.

Regulatory compliance

Protected species and their habitats occupy a significant portion of the United States' coastal wetland area and are a necessary consideration for any project plan. There are a number of seasonal and habitat-based restrictions on activities in marshes (SARBO 2020), which include direct impacts from burial or disturbance as well as indirect impacts like those triggered by changes in turbidity and sedimentation. For purposes of construction, sediment placement projects must adhere to these protections and capitalize on non-affected time windows, as well as potential weather and recreational windows. Fortunately, these types of constraints are already familiar to many professionals working on sediment placement projects in coastal habitats. Additionally, future project approvals in many jurisdictions may need revisions to prescriptive restrictions on dredge material disposal and excavations in estuarine waters/tidal creeks. There will have to be more acceptance of manipulating natural habitats to effect marsh maintenance in submerging coasts. Presently, in some jurisdictions, proposals to perform sediment placement using shoal sediments from natural channels are challenged or dismissed before their first reading by critics opposed to marsh restoration projects. Successful projects will require early coordination with personnel at numerous levels of government.

Logistics (constructability)

Included in logistics, or the ability to construct a successful project, are site and engineering preparations in an attempt to complete sound, cost-effective projects. Additionally, geotechnical properties are also important for project logistics. Where possible, barges can be used to deliver heavy equipment to work sites that may be otherwise unreachable from high ground. Where barges are not possible, dedicated corridors for heavy equipment may be necessary to limit damage to healthy marsh areas. When applicable, containment dikes used to dewater material can be used to provide high-ground tracks around placement areas. Many coastal marsh sediment placement projects use side-cast dredges, as long as enough freeboard is available to allow the vessel within cast range of the placement area (Ray 2007). Projects should consider the pump distance from a dredge to a placement site, and how local conditions like topography, water levels, and cut depth will affect production rates (TNC and NJDEP 2021). Attention to these considerations can increase the probability of success and minimize adverse impacts for sediment management projects by preventing unnecessary delays during construction or reducing the frequency of sediment placement efforts.

Adaptive management

Adaptive management is a structured, iterative decision-making process designed to optimize project outcomes in spite of uncertainty (Figure 5; Holling 1978). This approach is quite common in many field sciences, where one must simply "learn by doing" (Robinson 2020).

By revisiting project goals and objectives repeatedly during the planning and implementation process, managers can ensure a higher probability of success when construction is complete. Because sediment placement projects are by definition incremental efforts, the approach lends itself to an adaptive strategy in which continual reassessment allows managers to make adjustments based on what they learn as the project moves forward.

If, during the course of planning and implementation, it is determined that a particular sediment placement effort will not deliver positive benefits, or will trigger negative impacts within adjacent areas, the pace of sediment placement projects allows the above considerations to be revisited before the larger effort becomes a net-negative.

After projects are implemented and construction has finished, monitoring must occur to ensure project goals are being met over the long term. If there are issues with the site, action should be taken (i.e. modifications to hydrology, additional planting, etc.) to rectify the issues and ensure the long-term health of the marsh and success of the restoration project.

SUMMARY

Coastal marshes are critically important ecosystems that are vulnerable to degradation and erosion because of climate change and other anthropogenic impacts. These effects put at risk many of the ecosystem services, including storm protection, habitat, and carbon sequestration, among others. Marsh health is assessed in several ways depending on the location and purpose of the marsh. Across the continental United States, along with Alaska, Hawai'i, and Puerto Rico, marshes vary significantly in size, composition, and purpose. To protect these marshes, one of the best options to restore and improve marsh resilience is to utilize sediment to restore function and provide the marshes with an edge against climate and other anthropogenic impacts. The addition of sediment allows for an increased elevation, which in turn provides resilience to storms and resistance to sea-level rise. Vegetation can be inundated in the proper cycles as opposed to being over-inundated, which improves hydrology for the marsh system; and ecological function can be restored or improved to both better the marsh and increase the ecosystem services it provides.

The results of this white paper have culminated in the form of BMPs that are suggested to practitioners, planners, or those interested in restoring a degraded marsh environment. It is suggested that successful sediment placement projects should follow the outlined BMPs along with the general objectives of each BMP and complete the subsequently suggested monitoring approaches. The categories that practices are framed around include elevation; resilience to sea-level rise; vegetation; hydrology and inundation; ecological functions; community engagement; and regulatory compliance (Table 1). However, even with all BMPs followed closely, an adaptive management plan is necessary to ensure the project area is monitored and adjustments are made as required based on parameters that ensure the BMPs are implemented.

When projects are first being created and conceptualized, the outlining of project goals and application of BMPs is critical to ensure the best outcome for the restoration project and the marsh. For many practitioners who have completed numerous marsh restorations, the task of outlining all goals and implementation of BMPs may seem trivial. However, the number of partners required on projects to ensure both a smooth construction process and also sufficient monitoring strongly supports the need for these categories to be addressed from the start. As more projects are completed and more information becomes available in the form of lessons learned, BMPs will require modification and improvement to ensure the most up-to-date information is being considered and implemented.

NEXT STEPS

To continue the progress made in coastal marsh restoration as reported in literature and evidenced by completed restorations that provide lessons learned, the American Shore & Beach Preservation Association's Science and Technology Committee recommends that a national database of sediment placement activities (akin to the national beach nourishment database) be created.

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