GUIDANCE FOR THIN-LAYER SEDIMENT PLACEMENT AS A STRATEGY TO ENHANCE TIDAL MARSH RESILIENCE TO SEA-LEVEL RISE

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Prepared by:
Researchers from eight National Estuarine Research Reserves (NERRs) collaborated on a two-year NERRS Science Collaborative-funded field experiment investigating thin-layer placement of sediment in tidal marshes, beginning in Fall 2017. An expert Advisory Committee for the two-year project was convened that helped prepare these guidance documents.

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RECOMMENDED MONITORING FOR THIN-LAYER SEDIMENT PLACEMENT PROJECTS IN TIDAL MARSHES

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CHAPTER 4: RECOMMENDED MONITORING FOR THIN-LAYER SEDIMENT PLACEMENT PROJECTS IN TIDAL MARSHES

INTRODUCTION

Most marsh thin-layer sediment placement (TLP) projects share overarching objectives such as increasing elevation, supporting desired foundational vegetation communities, and sustaining key ecological functions and processes. Comprehensive monitoring is essential for any TLP project in tidal marshes in order to evaluate to what extent, and how rapidly, the project met its objectives. Additionally, monitoring data may shed light on the mechanisms behind restoration success or failure, and thereby inform adaptive management of the project or similar projects to be implemented in the future. Although every project will include some specific objectives or questions that are only relevant locally, it is possible to provide general monitoring recommendations that are broadly applicable across systems.

This document represents the first set of universal guidelines for monitoring indicators of TLP project success. It is intended to be useful for TLP projects in diverse types of tidal marshes and geomorphic settings anywhere in the world. Another purpose of this document is to increase standardization in monitoring approaches across future projects, which will facilitate syntheses and meta-analyses to determine the conditions under which TLP represents an effective approach for enhancing the resilience of tidal marshes in the face of sea-level rise. It was developed by teams at the Narragansett Bay and Elkhorn Slough National Estuarine Research Reserves (NERRs), with input from a key group of TLP advisors and practitioners from diverse programs across the US.

These guidelines do not include detailed monitoring instructions; instead we set out to identify broad categories of objectives that all TLP projects should address with monitoring and provide some general suggestions and resources for how specifically to go about monitoring. For each monitoring category, we provide a general rationale and objective for inclusion in monitoring programs as well as examples of how these may in turn be applied specifically to a TLP project. The objectives we present for each category are intended to serve as guidance; we recognize that objectives for some real-world projects may need to accommodate some degree of flexibility to reflect site-specific issues. Examples include when enhanced compaction and subsidence from large amounts of added sediment leads to tempering of initial elevation objectives, or when unsuitable sediment chemistry hinders early plant survival and necessitates altered vegetation objectives. Identifying specific quantifiable objectives is key for any project; monitoring may then help determine whether set objectives were met. It is also important to implement a sound monitoring approach and plan that is developed in conjunction with TLP designs to improve coordination between monitoring and construction and ensure monitoring data are not compromised. Finally, we provide for each category one or more examples of different approaches to monitoring that include references to detailed existing protocols, when available.

TEMPORAL AND SPATIAL CONSIDERATIONS FOR SETTING MEASURABLE OBJECTIVES AND MONITORING

Any TLP project must have explicit and quantitative objectives. These objectives will be instrumental in shaping the general design of the project and in preparation of detailed construction plans. A TLP project may serve to restore conditions more typical of the past, as an enhancement of desired services or conditions, or both.

For restoration projects, objectives typically involve reversing aspects of human-driven degradation to return a site or system toward the range of conditions documented for historic or prehistoric times. Many marshes have lost elevation due to human alterations to natural wetland hydrology, and TLP may be used as a tool to restore lost elevation, associated vegetation, and functions. Thus, past conditions at the focal restoration site (such as marsh extent calculated from historic photos or maps) may serve to set quantitative objectives, and time series data at the site may be used to determine if they are met post-restoration (Figure 1).

For enhancement projects, objectives typically involve improvement of a particular process or function. For instance, TLP may be used to create more acreage of a particular type of marsh habitat critical to endangered bird, fish or mammal species. TLP may also be used to enhance resilience to climate change and accelerating rates of sea-level rise by increasing marsh surface elevations or creating gentle slopes that allow for migration.

Whether a project is conducted for restoration or enhancement, the use of reference sites may inform the setting of numeric objectives and be incorporated into monitoring (Figure 2). Sites in the region that have not been degraded may also serve as references for restoration. Regional sites may also be used as references for enhancement projects if they currently achieve the desired

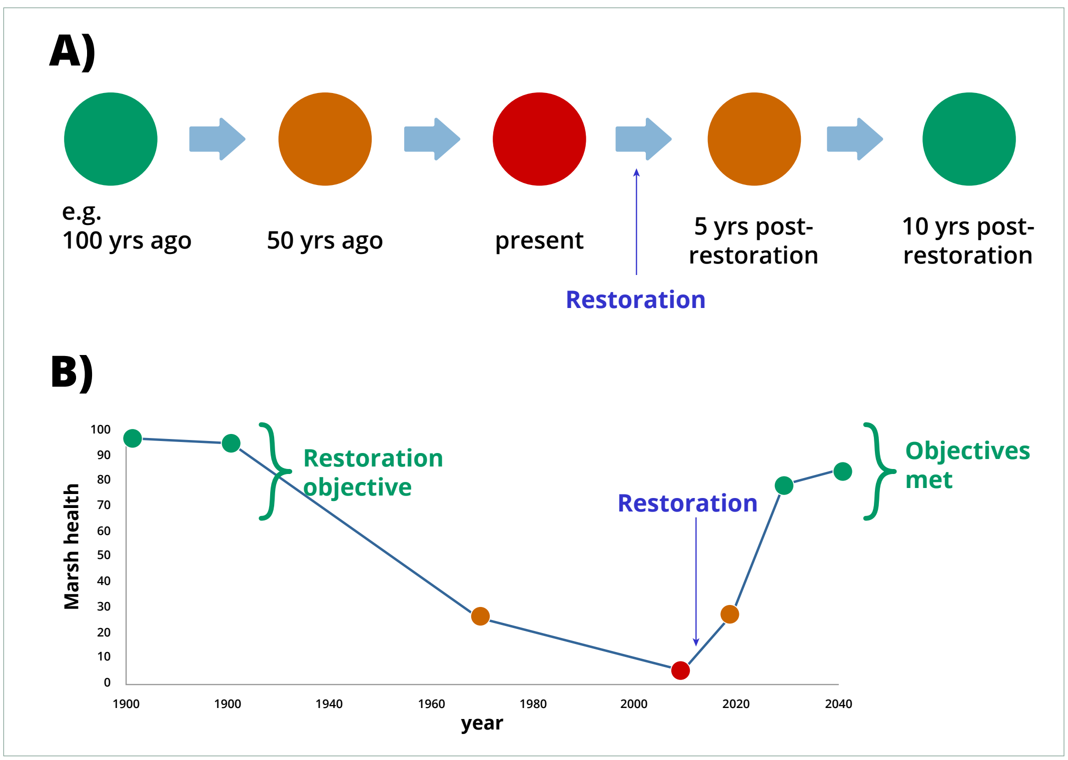

Figure 1. Temporal changes at focal site. Past conditions at the focal restoration site are used to set objectives, and comparison of conditions before/after restoration is used to monitor restoration success. A) Conceptual model of sequence of changes at focal site, where conditions were healthy (green) in the past, were degraded (red), but then restored to health through restoration. B) Example of time series of data from this site, quantifying past conditions (which are the restoration objectives), degraded conditions, and restored conditions. The X axis represents time; the Y axis may be any indicator of marsh health, such as percent vegetated cover, elevation, density of a target nesting bird species (e.g., Clapper Rail, *Rallus longirostris*), etc.

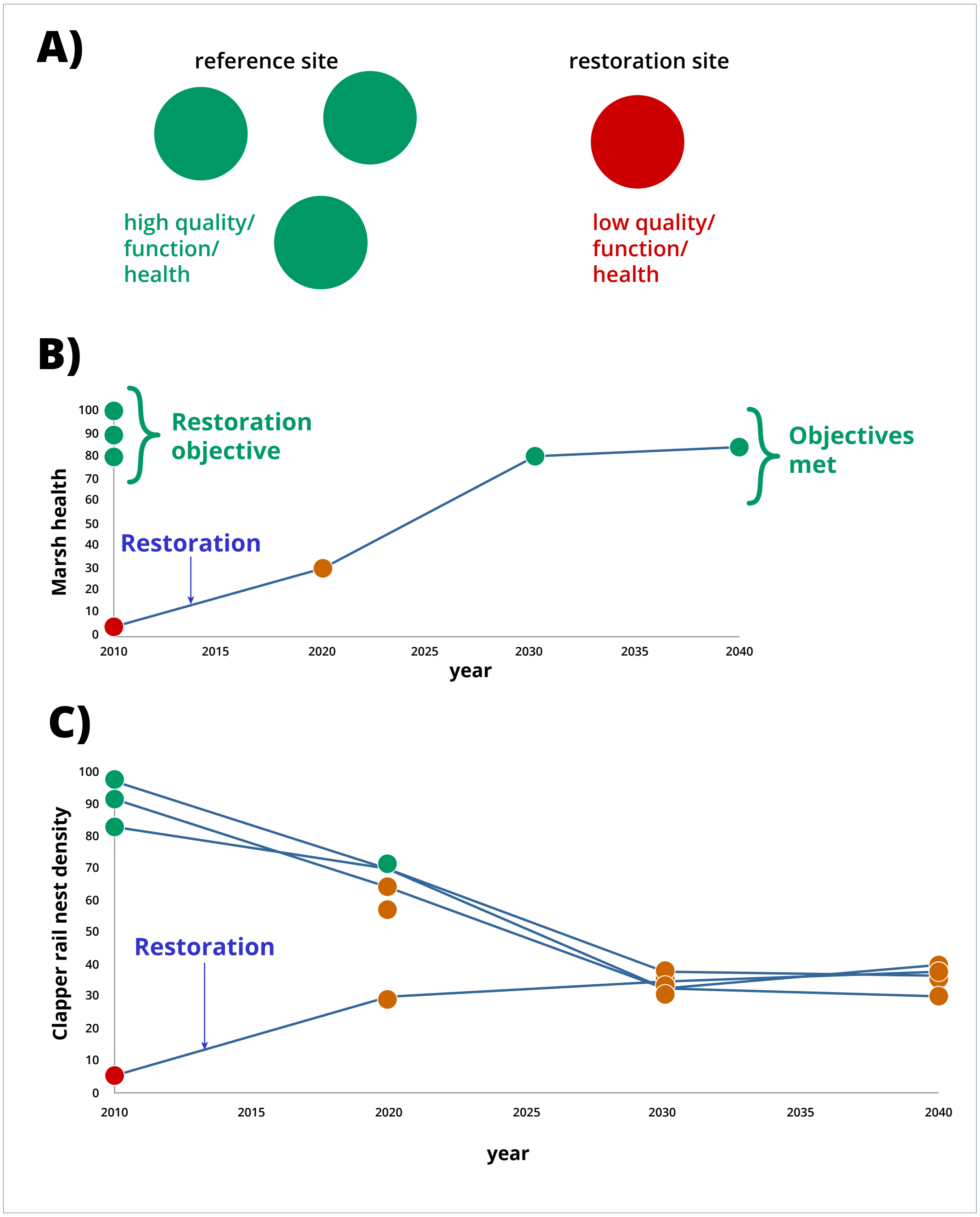

Figure 2. Spatial comparisons of focal site to healthier reference sites. Conditions at reference sites are used to set objectives, and comparison of conditions before/after restoration is used to monitor restoration success at the focal site relative to these reference sites. If current conditions at reference sites are presumed to resemble past conditions, then the actions at the focal site represent restoration in a strict sense of the word. Reference sites may also be chosen to represent desired ecosystem services or functions, regardless of past conditions (e.g., high carbon sequestration rates, support for endangered species), in which case the actions at the focal site represent enhancement. A) Conceptual model where conditions are healthy (green) at reference sites and used to set quantitative objectives for restoration site, which is degraded (red). B) Example of restoration monitoring, quantifying conditions at reference sites initially, and restoration site over time, to determine whether objectives have been met. For an attribute of marsh health such as elevation, rate of change is slow at reference sites, and just the initial measurement is sufficient (reference sites do not need to be monitored over time). C) For a dynamic attribute of marsh health, such as Clapper Rail breeding density, it is important to also monitor the reference sites over time. In this example, there has been a decline in reference sites, making it unlikely that the restoration site can meet the original objectives, but it may do as well as the reference sites.

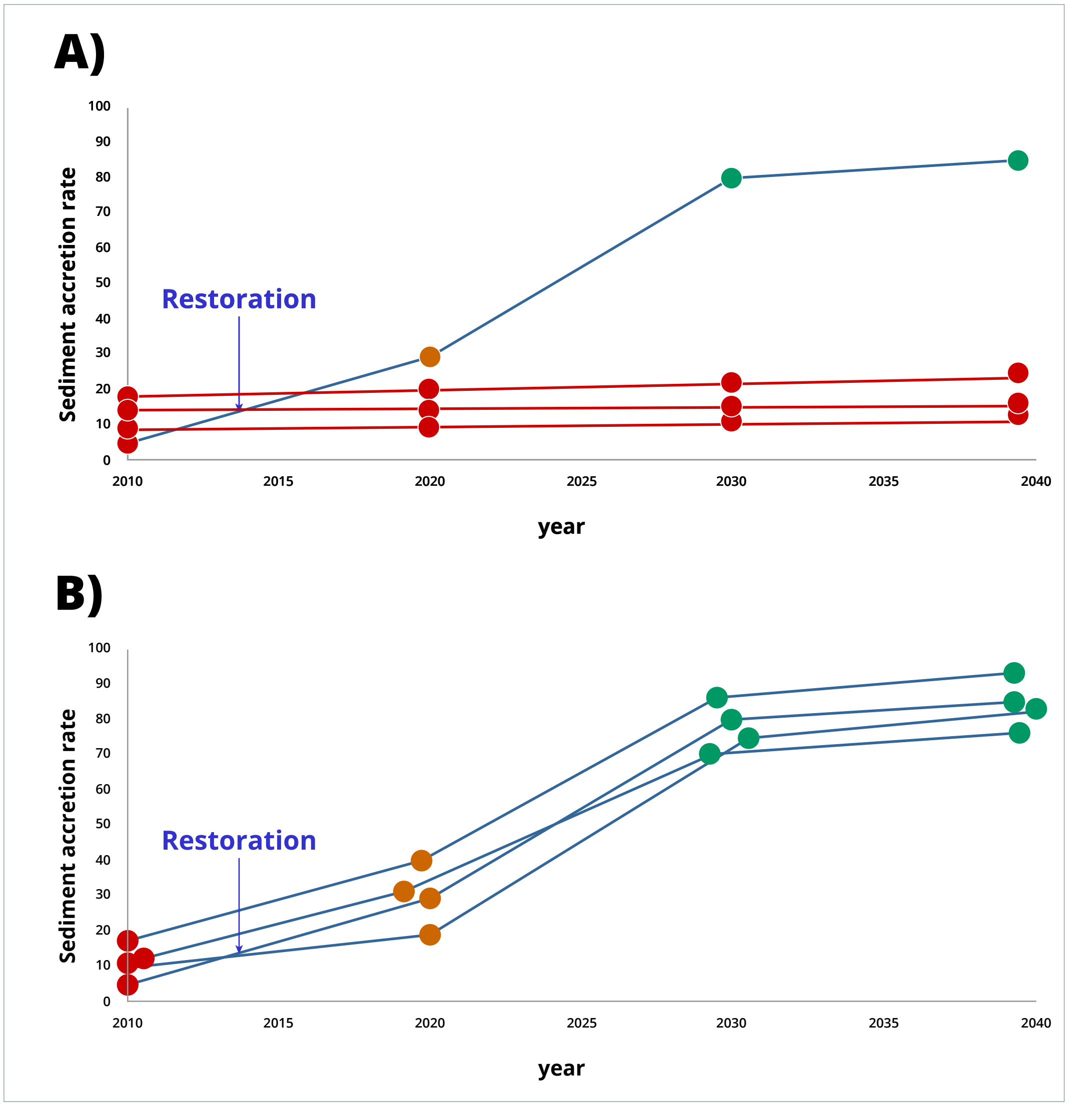

Figure 3. Spatial comparisons of focal site to degraded control sites. For dynamic parameters that show considerable temporal variation, changes at the focal restoration site may also be compared to changes at unrestored control sites. This is important for distinguishing changes due to restoration actions from changes due to broader regional factors or other drivers. This type of monitoring is called Before-After-Control-Impact (BACI) monitoring. A) For example, sediment accretion rate may start low at both the focal restoration site and other degraded sites in the region. However, if restoration restores healthier processes to the site, accretion rates will increase only at the focal site and not control sites. The cause of the improvement in this marsh health parameter is likely to be the restoration activity. B) In this example, an increased sediment accretion rate occurred at all sites, perhaps due to dam removal on a nearby river which enhanced sediment supply to the entire region. Here, improvements at the restoration site cannot be attributed to the restoration activity. (Note that in these examples, there is a single point for the restoration site, but in reality, multiple measurements should be taken there).

functions. For instance, desired elevations, vegetation cover, composition or height, or animal densities may be determined at these reference sites and be used to set quantitative objectives for the project area.

Temporal and spatial comparisons may be important not just for setting objectives, but also for monitoring (Figures 1-3). The development of a statistical approach for monitoring of indicators may incorporate comparisons over time, comparisons over space, neither or both (Figure 4).

- **Project area after construction only:** some objectives may only involve conditions at the project area after construction. For example, an objective might be to have 50 acres within defined boundaries at the project site occur above the elevation corresponding to Mean Higher

TEMPORAL SAMPLING					
	past baseline	current	1 yr post restoration	5 yr post restoration	10 yr post restoration
SPATIAL SAMPLING	**1920**	**2015**	**2020**	**2025**	**2030**
Restoration site					
station 1					
station 2					
station 3					
etc.					
Reference site					
site 1					
site 2					
site 3					
etc					
Control site					
site 1					
site 2					
site 3					
etc					

Figure 4. Summary of spatial and temporal sampling options. When designing a monitoring plan, it may be helpful to prepare a table with the full scale of temporal and spatial possibilities for data collection. Then, for each parameter, the team may determine what sort of spatial and temporal sampling is needed by placing an "X" in the appropriate boxes. For some objectives, such as "create at least 50 hectares of marsh platform higher than Mean Higher High Water," you only need a single X for assessing this once, across the entire restoration site, after restoration. For other objectives, such as Clapper Rail breeding density, your table would have an "X" in many boxes, as this parameter is dynamic in space and time, so you would need monitoring data from multiple years before and after restoration and at multiple sites within and outside the restoration area.

High Water when construction is complete. Monitoring must be conducted to determine if the construction contractor meets this goal, but no time series and no spatial comparisons are necessary (though temporal and spatial data likely were used to set this objective in the first place).

- **Project area before/after construction:** many objectives are likely to involve a comparison of the project area before vs. after restoration. For example, a project may have a quantitative objective of increasing area of tidal marsh by 20 acres by three years post-construction. This may be monitored only at the restoration site; there is no need for monitoring of major vegetation increases at other sites without TLP since there is no mechanism that would make this likely.
- **Project vs. control sites:** some objectives relate to improvements at the project area vs. similarly degraded areas without projects. For example, a project may have a quantitative objective of increasing denitrification rates relative to similar areas. Since these are variable spatially, monitoring may be conducted at replicate sites within the project area and at multiple control sites post-restoration to ensure that rates are higher in the project area than comparable sites. The more spatial variability there is in the indicator, the larger the number of replicate sites needed to have confidence in the results. If there is also high temporal variability in the indicator due to processes unrelated to the management action, a before-after-control-impact (BACI) design may prove useful, effectively combining the above two approaches. Changes in the project area are compared to changes in control sites to ensure that the rate of change in the former is greater than in the latter (Figure 3).

- **Project vs. reference sites:** some objectives involve the project area achieving levels comparable to those in systems that were not degraded or are supporting desired species or functions. For example, a project might have as an objective to support as many nesting pairs of a given target bird species (e.g., Clapper Rail, *Rallus longirostris*) per mile of shoreline as healthy reference sites did in a recent monitoring year. In this case, monitoring could occur post-restoration at the project area vs. reference sites to determine if the objective was met. Alternatively, the temporal trajectory may be monitored using a before-after design as above (in this case hopefully showing a dramatic increase in the number of Clapper Rails at the project area and no major changes at the reference sites), or with a tool such as the Restoration Performance Index (RPI) (Moore et al. 2009; Raposa et al. 2018).

Project managers and scientists must work together from the outset to develop objectives based on an understanding of the project area and/or other regional sites. Decisions should be made in advance about which indicators need to be monitored repeatedly vs. once, which need to be monitored before and after restoration or just after restoration, and which need to be monitored at control or reference sites or only at the project area. There are no universal answers to these questions since they depend on the restoration objectives.

The above discussion of objectives focuses on the desired outcomes that motivated the project to begin with, typically related to increasing marsh health and sustainability. In addition to these sorts of objectives, TLP projects will also have objectives related to environmental compliance. These are both about avoiding inadvertent harm during the course of construction and about long-term goals.

TLP OBJECTIVES AND MONITORING

All of the categories listed in this section are valuable for inclusion in TLP monitoring programs to evaluate project trajectories if key objectives are met. However, we recognize that many projects will not have the resources to include each category and therefore ***recommend that all TLP projects include a critical minimal amount of monitoring focused on elevation and vegetation,*** with other categories added on as resources allow. Specifically, the recommended minimum monitoring would be comprised of monitoring elevation and percent cover of all plant species present at representative spots throughout the restoration site, with a density of at least one measurement spot per hectare, and measurements taken at least once prior to sediment addition, once immediately after sediment addition, once one year later, and once five years later.

ELEVATION

General objective: achieve desired elevation target (e.g., optimal elevations for plant growth) 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).

Examples of specific objectives: lower 30% of marsh platform (or 'marsh plain' as it is sometimes referred to) ranges from 20-40 cm above MHW; upper 70% of marsh platform ranges from 40-60 cm above MHW; elevation remains within 10% of the level achieved at the end of construction for the first two years; at least 50 hectares of project area have elevation at or above +1.5 m NAVD88 for at least 5 years.

Monitoring approaches:

- **Field surveys along permanent transects or across a grid network** that spans the entire elevational range of the marsh platform using leveling surveys from permanent benchmarks, or real-time kinematic (RTK) GPS or Terrestrial Laser Scanner. This method is appropriate for collecting high-resolution data with either centimeter (RTK-GPS) or sub-centimeter (levelling equipment) accuracy but it can be spatially limited, especially when a small number of points is collected. Examples of protocols for monitoring elevations across marshes include Neil et al. (2017) for RTK-GPS and Cain and Hensel (2018) for digital leveling.
- **Remote sensing and GIS** for landscape-scale elevation changes using commercial LiDAR or unmanned aerial

vehicle (UAV) imagery with ground control points (GCPs). In recent years, the creation of digital elevation models (DEMs) produced from Structure-from-Motion (SfM) principles (i.e., creating a 3-D structure from a series of overlapping and offset images) has emerged as a low cost and highly accurate alternative to aerial LiDAR surveys (Westoby et al. 2012). While both are capable of producing DEMs that may be used to assess change, UAV flights may be performed on a much more frequent basis and can produce DEMs with sub-decimeter resolution for identifying small-scale change in a marsh. Establishing permanent or semi-permanent GCPs, using either RTK or terrestrial laser scanning, may also vastly improve the accuracy of the DEMs. Examples of using LiDAR and UAVs to remotely assess tidal marsh elevations include Kalacska et al. (2017) and Buffington et al. (2016).

RESILIENCE TO SEA-LEVEL RISE (SLR)

General objective: TLP initially builds the marsh platform to heights amenable for withstanding an extended period (e.g., decades) of projected SLR; marsh elevation gain after TLP tracks at least the current rate of local SLR.

Examples of specific objectives: elevation is high enough for new marsh to withstand at least 30 years of projected SLR; current annual rate of marsh elevation gain does not fall below the rate of recent local SLR.

Monitoring approaches:

- Surface Elevation Tables (SETs) and marker horizons to track fine-scale changes in elevation over time in discrete locations in a marsh. Accurately measuring marsh surface elevation change is best accomplished with paired deep and shallow surface elevation tables (SETs), and partitioning change due to different processes is possible by also using replicated marker horizons established in conjunction with SETs (Cahoon et al. 2011). Guidelines for using the paired SET and marker horizon technique in tidal marshes are provided by a collaboration between the National Park Service (NPS), US Geological Survey (USGS), and National Geodetic Survey (NGS) (Lynch et al. 2015).
- Landscape-scale surveys. One drawback of SETs is that they are spatially very limited; each SET covers approximately 1 m^2 of marsh. Repeated surveys using sub-centimeter digital leveling may provide the same accuracy as SETs for monitoring marsh elevation change, but at a much greater spatial coverage. Details are provided in Cain and Hensel (2018). Yet another approach is the use of unmanned aerial vehicles (UAV) to collect elevations across entire marsh landscapes.
- Quantify elevation capital by pairing marsh elevations with a local tidal datum. Any marsh monitoring program should include tracking elevations of the marsh over time, but alone this does not indicate where the marsh sits relative to local water levels. By also calculating a site-specific tidal datum (see 'Hydrology and Inundation' section below), elevations of the marsh and tidal water may be related to one another and used to calculate elevation capital (how high the marsh is relative to tidal water). Guidance for calculating tidal datums and linking with marsh elevations to explore elevation capital are provided by NOAA (2003), Cahoon and Guntenspergen (2010), and Rasmussen et al. (2017).

VEGETATION

General objective: 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.

Examples of specific objectives: at least 50% of new TLP areas are covered with native plants within three years; invasive species cover is less than 5% of total vegetation coverage of new TLP areas after three years; species composition is statistically similar to high-functioning reference sites after 10 years; canopy height of the marsh dominant is appropriate to support Clapper Rail breeding; 80% survival rate by rare marsh plants planted into high marsh at the end of the first year.

Monitoring approaches:

- Field surveys using transects and quadrats. This is a classic way to monitor plants in tidal marshes and it may provide quantitative data on vegetation species composition, cover, canopy height, and stem density. Typically, monitoring is conducted along established transects that stretch from water to upland and encapsulate the entire vertical extent of the marsh platform; vegetation is then surveyed from within replicated quadrats spaced along the transects using various techniques (e.g., point-intercept, visual/ocular). Detailed guidelines for this type of vegetation monitoring are provided by Roman et al. (2001), which has since been refined and adopted by the National Estuarine Research Reserve System (Moore 2017).

- **Remote sensing (e.g., aerial photos, UAVs)** to assess entire marsh landscapes. This is similar to remote sensing for elevation as described above, but instead uses cameras mounted to an aircraft or UAV to take a series of high-resolution georeferenced photographs for mapping vegetation and habitats across an entire marsh, or representative areas for very large marshes. Resultant maps are typically comprised of general vegetation and habitat types (e.g., low marsh vs. high marsh) and may include quantitative data on individual plant species cover and health. For example, multispectral imagery (e.g., 4-band NAIP imagery and some UAV imagery using near-infrared sensors) enables us to map and quantify vegetation based on a unique spectral signature. Other example methods for monitoring marsh vegetation and habitats with remote sensing techniques include Ballanti and Byrd (2018) and Ganju et al. (2017).
- **Focused assessments** to quantify the success of newly-planted areas. A common approach to accelerate TLP marsh plant colonization and regrowth is to use targeted planting of key species at appropriate elevations. In some cases, however, planted areas are placed distant to field survey plots to help distinguish the natural recolonization process from success of plantings; this therefore requires the use of separate assessments focused specifically on newly planted areas. In the first months after planting, survival of individual flagged plants may be quantified. Later, transects through the planted areas may provide data on changes in cover of different plant species or different experimental treatments (e.g., soil amendments).
- **Repeat photography to track changes in vegetation over time.** At the landscape scale, photo stations where landscape scale photographs may be taken (e.g., PVC posts where a camera is mounted at the same location each time) allow for oblique landscape views of vegetation changes to complement aerial images. At a closer scale, photographs taken of the monitoring quadrats or of planted individuals may be useful for visualizing changes in growth or cover over time.
- **Soil characteristics and chemistry.** In many cases, it may also be useful to collect ancillary data on soil characteristics (e.g., bulk density, percent organic, grain-size composition) and porewater chemistry (e.g., sulfide concentrations, pH, salinity) in conjunction with vegetation monitoring. It is not uncommon for plant colonization and/or survival to differ among various types of sediment or to suffer in early stages of TLP projects, especially when sulfidic sediments become exposed to air and lead to acidic conditions harmful to some plants. Soil data may therefore help explain why certain vegetation objectives may not have been met, or to help adjust these objectives accordingly.

HYDROLOGY AND INUNDATION

General objective: establish appropriate tidal flooding regimes and adequate drainage to promote healthy and sustained plant growth.

Examples of specific objectives: percent of time marsh surface is inundated is similar to a nearby reference marsh; water levels drop below expected plant root zone depth during at least 90% of low tides for at least 20 years into the future; density and structure of tidal creeks similar to reference sites supporting desired nekton communities and not eroding substantially over time.

Monitoring approaches:

- **Collect data from water level loggers** deployed either in shallow subtidal areas adjacent to the marsh or in shallow wells inserted directly into the marsh platform to quantify short-term tidal datums, surface inundation, and drainage. Reference water levels or the exact elevation of these loggers should be measured with precise surveying so that orthometric heights may be linked to tidal datums. These two hydrologic indicators – frequency and duration of inundation and drainage — are key to establishing and maintaining healthy marsh plants. The National Park Service (NPS) has two guides for using water level loggers adjacent to a marsh (Curdts 2017; Rasmussen et al. 2017) and the US Fish and Wildlife Service (USFWS) provides guidelines for how to install and use them in shallow wells in the marsh (Neckles et al. 2013). If using purchased water level loggers is not an option, data from a nearby NOAA tide station may also be used (https://tidesandcurrents.noaa.gov/) under the assumption that tidal datums at the tide station are very similar to the marsh.
- **Remote sensing** to track the evolution of new tidal creeks and other hydrologic features in new TLP sites. This may be especially useful if a project objective is to establish a certain areal coverage of key aquatic habitats favorable for nekton and birds (e.g., shallow creeks and pools). Mapping these features may be accomplished in conjunction with vegetation and habitat mapping using remote sensing techniques as described above.

ECOLOGICAL FUNCTIONS

General objective: 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.

Examples of specific objectives: nekton density and richness is ≥75% of nearby reference marshes after five years; marsh bird community composition is statistically indistinct from reference marshes after three years; numbers of an endangered marsh mouse double in the first five years; carbon sequestration rates exceed 200 g/m^2/year.

Example monitoring approaches:

- **Assess desired animal communities** of regional importance (e.g., sea otters for CA, horseshoe crabs for the western Atlantic) or species of concern that may cause negative impacts (e.g., crabs, geese). Fish, birds, and wildlife are often conspicuous and charismatic components of marshes. They not only represent integrative indicators of marsh health, but are also easily relatable to the general public and key user groups. Example monitoring protocols and guidelines include James-Pirri et al. (2012) for nekton, the Saltmarsh Habitat & Avian Research Program (SHARP; https://www.tidalmarshbirds.org/) and Conway (2011) for marsh birds, and Tinker et al. (2018) for otters. Conversely, some of these animals, even native species, may elicit negative impacts to marshes, and potentially to TLP projects, often through herbivory. For monitoring some of these species, the documents listed above may suffice, but more targeted monitoring for specific species or in certain habitats may require alternate methods (e.g., extensive burrow counts or pitfall trapping for crabs; Wasson et al. 2019).
- **Carbon sequestration.** "Blue carbon," the carbon sequestered in tidal marshes, has become an important ecosystem service. Carbon storage by vegetation may be quantified by collecting standing stock of aboveground vegetation (harvesting, drying, and weighing all tissue in a quadrat of known size), or for below-ground vegetation. Coastal soils tend to store more carbon than vegetation, so taking cores and quantifying carbon in known areas is an important part of quantifying carbon storage. To assess rates of carbon sequestration, changes in carbon content over time must be quantified, in repeat cores (e.g., before vs. after vegetation grows at a TLP site) or at the surface by analysis of carbon in newly accumulated sediment. Carbon sequestration may also be estimated using measures of carbon dioxide exchange using open-path sensors coupled with anemometers (the eddy covariance method; Baldocchi et al. 2001) although this method may overestimate carbon sequestration relative to soil and vegetation-based methods as it does not account for lateral fluxes of carbon via tidal advection. Emissions of other potent greenhouse gases (nitrous oxide and methane) may also be measured with open path or chamber-based methods to ensure that the benefits of carbon sequestration are not outweighed by methane or nitrous oxide emissions. Details on all of these methods may be found in Howard et al. (2014).
- **Denitrification or other biogeochemical functions.** Denitrification is the conversion of bioavailable nitrogen to inert nitrogen gas. Because tidal marshes provide the anoxic conditions and high organic matter inputs necessary to support denitrification, reductions in dissolved nitrogen concentrations and improved water quality are often expected to result from restoration. Denitrification potential or actual denitrification rates may be quantified with a range of methods, appropriate to the question under consideration (Groffman et al. 2006).

COMMUNITY ENGAGEMENT

General objective: 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.

Examples of specific objectives: at least 100 volunteer hours devoted to monitoring TLP marsh responses; three presentations given to regional government agencies and nonprofits; at least 60 local school children involved in marsh planting; at least five citizen scientists trained in collecting monitoring data at the site; at least two articles in local newspapers about the project.

Example monitoring approaches:

- **Community participation.** Monitor/quantify volunteer hours, school group visits, media stories, community meetings, information sessions, etc. as part of a TLP project.
- **Landscape development.** Repeat photography at photo stations or from aerial photographs is instrumental for conveying to the community the changes that the landscape has undergone over time.

COMPLIANCE

General objective: avoid unintended negative consequences resulting from TLP, as dictated by relevant regulations and authorities.

Examples of specific objectives: avoid turbidity spikes in adjacent channels, where suspended sediment concentrations exceed pre-construction annual average by more than one standard deviation for more than one week; avoid sedimentation of adjacent eelgrass beds; avoid disturbance to threatened or endangered species.

Example monitoring approaches:

- **Turbidity.** Grab samples for suspended sediment or water quality sondes measuring turbidity in an adjacent channel.
- **Sedimentation.** Install traps in eelgrass beds or other adjacent habitats sensitive to sedimentation and track the amount of sediment deposition during and immediately post-construction.
- **Federally-listed species.** Conduct surveys before and during construction, with experts or trained biologists.

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