E.3. Restoration Approach Core and Objective-Specific Performance Monitoring Parameters

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

This list of core- and objective-specific monitoring parameters expands upon Section 2.4.4 and Attachments E.2–E.8 of the MAM Manual Version 1.0 and supplemental monitoring guidance developed for additional restoration approaches. It provides additional guidance on the development of the monitoring section of the MAM Plan. All core and objective-specific performance monitoring parameters across the subset of Restoration Approaches covered in the MAM Manual Version 1.0 as well as the monitoring guidance subsequently released for additional monitoring approaches are combined into an alphabetized list below and are numbered for ease of reference. The Restoration Approaches addressed to date include:

- Create, restore, and enhance coastal wetlands
- Create, restore, and enhance barrier and coastal islands and headlands
- Restore and enhance dunes and beaches
- Restore and enhance submerged aquatic vegetation
- Protect and conserve marine, coastal, estuarine, and riparian habitats
- Reduce nutrient loads to coastal watersheds
- Reduce pollution and hydrologic degradation to coastal watersheds
- Restore and enhance submerged aquatic vegetation
- Restore oyster reef habitat
- Enhance public access to natural resources for recreational use
- Enhance recreational experiences
- Promote environmental stewardship, education, and outreach

Additional monitoring parameters for consideration, such as those needed for additional Restoration Approaches identified in the PDARP (DWH NRDA Trustees, 2016a) and adaptive management or validation monitoring parameters listed in the monitoring guidance for each Restoration Approach, are not included in this list at this time. Each parameter in the alphabetized list includes guidance on measurement unit(s) and monitoring methods, with a crosswalk to the Restoration Approach(es) for which the parameter is identified as a core or objective-specific performance monitoring parameter, but not if the parameter is listed only as a parameter for consideration. Some parameters are measured directly while others are calculations (e.g., Oyster Reef Volume). Guidance on monitoring locations, frequencies, and durations of sampling are also included. For some parameters, additional guidance for potential analyses using that monitoring parameter (see Section 2.4.6 of the MAM Manual Version 1.0) is also provided. Although metric units are listed in the parameter descriptions, standard units are also acceptable.

This section is subject to change at the discretion of the Trustees, potentially as a result of newly identified and/or developed monitoring parameters, methods, and technologies. The monitoring parameters identified in a project MAM Plan should be consistent with the monitoring guidance outlined in this attachment, wherever appropriate. However, t content of the MAM Plan, including identification of Restoration Approaches, monitoring objectives, monitoring parameters, and budget is at the discretion of the TIG that is conducting restoration planning (Section 10.3.2 of SOP; DWH NRDA Trustees, 2016b). Monitoring frequency and duration may vary by project due to objectives, performance criteria, project-level decisions, and/or the need for corrective actions.

Section E.3 Table of Contents

E.3.1. Area

Parameter Type: Measured, Calculated, or Modeled

Units: square meters (m^2) or square kilometers (km^2)

Definition

Area may be defined three different ways depending on the project objectives. Projects should indicate which definition(s) is being used. Additional area definitions may also be developed for specific projects, as needed.

Area of Project Footprint: the maximum areal extent of restoration activities.

Area of Project Influence: the area affected by restoration activities as determined by the Implementing Trustee. This area may extend beyond the project footprint.

Area of Habitat: the summed area, by habitat type, of habitat patches within the project footprint.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Enhance Public Access to Natural Resources for Recreational Use
- Restore and Enhance Submerged Aquatic Vegetation (SAV)
- Restore Oyster Reef Habitat

Potential Methodologies

Potential Field-Based or Remote Sensing Methodologies

Method 1: Project and habitat boundaries can be mapped based on aerial imagery collected by airplane, helicopter, unmanned aerial systems (UAS); high-resolution satellite imagery; or other appropriate remote sensing platforms. Imagery used to map wetland boundaries should include true color and infrared bands, and have a spatial resolution of 1 meter (m) or less. For comparison of different remote sensing platforms commonly used for wetland mapping, see Klemas (2011) and Klemas (2013). For additional information on the use of UAS for wetland mapping, see Klemas (2015), Madden et al. (2015), Zweig et al. (2015), and Samiappan et al. (2017). Source imagery should be orthorectified [i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation; see Rufe (2014)]. Collected imagery should be imported to spatial analysis software to digitize the perimeter of the project footprint and the boundaries of habitat areas within the project footprint. Additional guidance on using aerial imagery can also be found in Anders and Byrnes (1991), Crowell et al. (1991), Morton (1991), and FLDEP (2014). For coastal wetland projects, see Steyer and Llewellyn (2000) and Dahl and Bergeson (2009) for wetland habitat mapping procedures. For guidance on mapping SAV, see Kirkman 1996 and Vittor & Associates, 2016.

Method 2: Ground surveys can be used to map an area for smaller projects. Use a real-time kinematic Global Positioning System (RTK GPS) to take continuous measurements while walking, boating around, flying, or digitizing the perimeter of the project and along the boundaries of specific habitats within the project footprint. For wetlands, standard field wetland delineation techniques should be considered for areas where wetlands transition into non-wetland habitats (Federal Interagency Committee for Wetland Delineation, 1989). For SAV projects that aim to promote regrowth of native SAV, ground surveys should focus on areas targeted for regrowth.

Method 3: For SAV aerial mapping where airborne remote sensing cannot detect the deep edge of bed, towed underwater video can provide reliable estimates of seagrass area (Christiaen et al. 2016). New techniques for mapping SAV continue to be developed and piloted in localized applications.

Method 4: For intertidal oyster reefs, the footprint may be measured using a surveyor's measuring wheel, laser rangefinder, or transect tape (Baggett et al. 2014).

Method 5: For subtidal oyster reefs, the footprint may be measured using side-scan or multi-beam sonar (Baggett et al. 2014) or professional/survey grade echo sounder.

Method 6: For subtidal oyster reefs, the footprint may be measured using a sounding pole in conjunction with GPS (Baggett et al. 2014)

For many methods, the resulting data should be analyzed using spatial analysis software to calculate the area of habitat created, restored, enhanced, or protected. For habitat protection, conservation, or other habitat projects, the habitat type(s) should also be documented. For coastal wetland projects, Cowardin et al. (1979) provides an example for wetland classification standards.

Monitoring Locations for Field-Based or Remote Sensing Methodologies

Area of habitat built or enhanced should be determined for the entire project footprint. Some data, such as aerial photography, may be collected over larger areas. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration for Field-Based or Remote Sensing Methodologies

For projects that do not include construction, project monitoring is suggested before and after project implementation. In general, for projects including construction activities, monitoring is proposed pre-construction, immediately after construction (as-built), and post-construction. A baseline pre-construction condition could be established based on data obtained during the Engineering and Design (E&D) period.

Beaches, dunes, and barrier islands: Monitoring is proposed immediately after construction (as-built) and every 3 years up to 10 years post-construction.

Coastal wetlands: Monitoring is proposed immediately after construction (as-built), with at least 1–2 additional monitoring events over the monitoring period. For further guidance and recommendations on wetland monitoring frequency and duration, see Tiner (1999), Neckles et al. (2002), and NAS (2017).

Submerged Aquatic Vegetation (SAV): Monitoring is proposed immediately after construction (as-built), 1 year post construction, and with additional monitoring every 5 years over the monitoring period (Neckles et al. 2012; Vittor & Associates, 2016). Seasonal sampling may be needed for species that exhibit high inter- and intra-annual variance due to seasonally changing environmental conditions.

Oyster reefs: Baggett et al. (2014) suggest monitoring occur pre-construction, within three months after construction, 1-2 years post-construction, and 4-6 years post-construction (a more ecologically relevant time scale, considering the oyster disease Dermo and salinity are correlated at a periodicity of 4 years (Soniat et al. 2009)) and after any event that may alter the habitat within the project footprint. For further guidance on oyster reef monitoring frequency and duration see Baggett et al. (2014) and NAS (2017).

Funding for one additional contingency monitoring event could be included in the monitoring budget, which could be implemented as needed to account for storm impacts.

Modeling Methodologies

Area of coastal wetlands with hydrology restored by the project will be estimated or modeled based on other parameters, including depth, duration, and frequency of flooding.

Method 1: The area influenced by a hydrologic restoration project can be estimated based on hydrodynamic modeling prior to project implementation. The area of influence should be estimated prior to project implementation to establish the restoration target. See MacBroom and Schiff (2012) for a review of commonly used 1- and 2-dimensional hydraulic modeling approaches for tidal restoration projects. Models should document assumptions and limitations in estimating the area of influence.

Method 2: Post-restoration, the area influenced can be calculated as the area over which the target depth, duration, and frequency of flooding has been achieved, based on water-level measurements, elevation data, ground survey and/or remote sensing data, and compared to projections from the hydrodynamic model.

Monitoring Locations for Modeling Methodologies

The location of monitoring should be estimated/modeled across the area surrounding the restoration project. The modeled area should extend slightly beyond the area where any influence is expected as a result of the project.

Guidance on Frequency and Duration for Modeling Methodologies

The area influenced by the project could be estimated prior to project implementation to establish a baseline. The area of influence could be calculated/modeled immediately after project implementation (as-built) and annually for up to five years following implementation, based on water level data and/or elevation data collected for the project. Additional measurements could be taken after events that could alter habitat within the project footprint (e.g., severe storms, sedimentation events).

Other Potential Analyses

Area measurements may also be used in conjunction with other parameters listed herein (e.g., elevation, vegetation percent cover and composition) to perform the following calculations and analyses: habitat type changes, shoreline change, land loss or gain, beach and dune profile change, volume change, bathymetric profile change, and sediment movement. Area measurements can also be used to help assess habitat or landscape connectivity and/or reductions in habitat fragmentation. Water depth and light availability may also be particularly relevant for understanding regrowth potential of SAV.

E.3.2. Bird Abundance, Density, and Community Composition

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none

Density Units: number per unit area (see **E.3.1 Area** for units)

Community Composition Units: none

Definition

Abundance is the total number of birds within a defined area of interest. Density is abundance divided by area. Community composition is the diversity and relative abundance of bird species within the area of interest.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore Oyster Reef Habitat

Potential Methodologies

Conway (2011) provides a Standardized North American Marsh Bird Monitoring Protocol. This protocol, which employs a combination of point counts and call back surveys, was used to survey marsh birds in all affected states during the DWH oil spill.

Monitoring Location

Conway (2011) provides a discussion of survey site selection. The protocol recommends the establishment of permanent survey sites along a survey route.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-restoration (once, if applicable) and annually for five years, or longer, after restoration. Conway's (2011) methods include three surveys or more during the peak marsh bird breeding season. Surveys are usually conducted during the morning or evening.

E.3.3. Channel Dimensions

Parameter Type: Measured

Units: meters (m)

Definition

The cross-sectional profile (e.g., width and depth) of channels intended to convey water for the restoration project.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

Method 1: For shallower channels, cross-sectional profiles can be measured using advanced survey instrumentation, such as RTK GPS or Total Station; traditional survey instrumentation, such as a level and rod; or using a measuring tape or equivalent linear measurement device. Special care should be taken to not damage the escarpments.

Method 2: In deeper water that cannot be measured with topographic survey techniques, a bathymetric survey can be conducted using a depth finder fitted with a differential GPS or another acoustic method as appropriate.

The position of the profiles should be carefully marked so that the same cross-sections can be repeatedly monitored following restoration. See Roegner et al. (2008) and U.S. Geological Survey (USGS, 2011) for more information on potential methodologies.

Method 3: For hardened channels or culverts, dimensions can be measured using a measuring tape or equivalent linear measurement device.

Monitoring Location

Cross-sectional profiles should be measured in the channels specifically targeted by the hydrologic restoration within the project area. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction (as-built), and post-construction. A baseline pre-construction condition could be established based on information obtained during the E&D. Sampling could be conducted pre-construction (once), immediately following construction (as-built), and annually thereafter. Monitoring is proposed for five years post-construction or longer to ensure channel dimensions are being maintained sufficiently to meet performance criteria. For fixed or hard structures such as culverts, additional monitoring following as-built measurements may not be necessary because the dimensions are assumed to be stable. However, additional sampling may be needed after large storm events.

Other Potential Analyses

Channel dimensions may also be used to calculate the cross-sectional area in square meters (m^2) or volume in cubic meters (m^3).

E.3.4. Debris

Parameter Type: Measured

Units: none (count of items) or weight in kilograms (kg)

Definition

The amount, source, location, movement and/or impact of marine debris.

Restoration Approach

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Enhance Recreational Experiences

Potential Methodologies

For coastal projects, information about marine debris can be collected using shoreline surveys, benthic trawls, or floating litter survey operations (Cheshire et al., 2009). There are a number of different survey methods, including comprehensive and rapid beach assessments, and debris assessment and standing stock surveys [see Cheshire et al. (2009), Opfer et al. (2012), and Lippiatt et al. (2013)]. Surface water and at-sea surveys can also be conducted (Ryan et al., 2009).

Monitoring Location

Location of collecting debris is, in part, dependent on accessibility of the site and available equipment. Sampling should focus on areas where debris is suspected to accumulate, but may be stratified by factors such as land use, proximity to river mouths, substrate, tourism, fishing pressure, oceanic current patterns, bathymetry, and hydrodynamics (Lippiatt et al., 2013). For shoreline surveys, Opfer et al. (2012) developed walking patterns to ensure the entire shoreline site or transect is covered.

Guidance on Frequency and Duration

The amount of sampling necessary to assess debris concentrations depends on the spatial variability of the debris, the desired level of detection, and whether the project's objective is to estimate flux rate (accumulation rate of litter) or just standing crop (quantity of litter per unit area or length of transect) (Cheshire et al., 2009). Collection events every 28 days provide good estimates of monthly averages (Lippiatt et al., 2013), while collection events every three months allow for the interpretation of seasonal changes. Collection could also take place before/after cleanup events as applicable.

Other Potential Analyses

A pre-restoration assessment could be conducted to characterize conditions before cleanup.

E.3.5. Discharge

Parameter Type: Calculated

Units: cubic meters per second (m^3/s)

Definition

The volume of water through a channel (e.g., stream, river, or tidal creek) within a given time period, typically in units of cubic meters per second (m^3/sec) or cubic feet per second (cfs). In general, discharge is calculated by multiplying the velocity of the water (e.g., m/s) by the cross-sectional area (m^2).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

Method 1: Calculate discharge by multiplying the water velocity by the cross-sectional area (m^2) of the channel (see Section E.9.29 Velocity, Water; and Section E.9.3 Channel Dimensions).

Method 2: An Acoustic Doppler Current Profiler (ADCP) can be used to measure both water velocity and water depth within a stream. Typically, the ADCP is mounted to a small water craft and guided along the stream channel to take the measurements.

Method 3: For streams where a stream gage is installed, the discharge can be calculated based on a stage-discharge relation. The development of a stage-discharge relation requires numerous discharge measurements at the given reach across all ranges of streamflow (Rantz et al., 1982; Turnipseed and Sauer, 2010). However, the stage-discharge relationship cannot be applied to tidally affected areas.

Method 4: Installation of Acoustic Doppler Velocity Meters (ADVMs) at index-velocity stream gages. Discharge is calculated using the index velocity method (Levesque and Oberg, 2012). This approach is best to calculate discharge in reaches with unsteady streamflow that prevents the development of a stage-discharge relationship.

See Steyer and Llewellyn (2000) and Olson and Norris (2007) for more information on potential methodologies.

Monitoring Location

Discharge should be measured or calculated for channels within the project area that are an important component of the project design. If discharge is calculated by multiplying the water velocity by the cross-sectional area, these two measurements should be taken in the same area. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and post-construction. A baseline pre-construction condition could be established based on information obtained during the E&D. Sampling could be conducted pre-construction (once), immediately following construction (once), and annually thereafter. Additional sampling may be needed after large storm events.

For projects with tidal influence, if continuous recorders are used, data could be collected for two weeks or longer during a sampling event to be able to capture one lunar cycle of spring and neap tides, but longer time periods (e.g., 3–4 months or year-round) are preferred. For discrete measurements, the discharge could be assessed over several tidal cycles.

For projects with riverine influence, sampling events could be designed to capture both high- and low-flow events. If continuous recorders are used, data could be collected for two weeks or longer during high- and low-water conditions, but year-round data collection for one or more years is preferred to fully capture the seasonal variability in flow conditions. For discrete measurements, the discharge could be assessed over a few weeks during both high- and low-flow conditions.

Other Potential Analyses

Discharge data may also be needed to model the area influenced by hydrologic restoration.

E.3.6. Dissolved Oxygen (DO)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

DO represents the concentration of oxygen mixed and dissolved into the water column.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

A DO meter, water quality sonde, or data logging system can be used to record measurement data taken with a DO sensor. Data collection and calibration procedures of data sondes will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See USGS (2013).

E.3.7. Educational Materials

Parameter Type: Measured

Units: none (count) or as appropriate based on the nature of the materials

Definition

Number of, type, nature and/or extent of educational materials developed and/or distributed to promote environmental stewardship, education, and outreach. Materials may include flyers, pamphlets, videos, interactive learning screens, programs, or teacher-led activities.

Restoration Approach

- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

Collection methods will vary depending on the type of educational materials developed. For example, if educational flyers are developed, the collection technique may be documenting the number of flyers printed, the number of types of flyers developed, etc. The information collected should include the type and number of educational materials, as well as a summary of the information presented in the educational materials.

Monitoring Location

Materials should be monitored at their distribution location(s). This could include location of sign posts, flyer distribution points, or locations where education activities occur, such as a school.

Guidance on Frequency and Duration

Materials could be monitored for the period in which they are produced. The materials will be distributed according to project specifications and the rate at which materials are distributed should be tracked throughout the distribution period and updated when needed.

Other Potential Analyses

Knowledge of the number of materials produced along with the frequency in which they are accessed by the public can help determine user preferences toward educational materials.

E.3.8. Elevation

Parameter Type: Measured, Calculated, or Modeled

Units: meters (m)

Definition

Elevation of the created or restored area/habitat relative to geodetic datums, tidal datums, or surrounding area.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)
- Restore Oyster Reef Habitat

Potential Methodologies

Topographic Methodologies

To evaluate the effectiveness of the restoration on the elevation and area of beach, dune, oyster reef, SAV, and adjacent subtidal areas, measurements will be compared with previous measurements of shoreline position, elevation, beach and dune profile changes, and volumetric changes within the system when combined with bathymetric surveys as appropriate to the restoration approach. For guidance on elevation monitoring for beach, dune, and barrier island habitats, see FLDEP (2014). For guidance on elevation (reef height) monitoring for oysters, consult Baggett et al. (2014). For marsh habitats, topography and associated hydrologic regime are key determinants of the distribution and composition of marsh vegetation and faunal communities. To evaluate the effectiveness of the restoration design, targeted elevations should consider the desired wetland habitat.

Method 1: Topographic profiles can be done to measure land elevation by using RTK GPS surveys. Elevation is measured at evenly spaced distances along transects or on a grid, and interpolated using spatial analysis software to create a Digital Elevation Model (DEM). See CPRA (2016) for an example protocol for conducting RTK GPS ground surveys within restoration projects.

Method 2: Airborne topographic Light Detection and Ranging or Laser Imaging Detection and Ranging (LIDAR). This is an optical remote sensing technology that can measure the distance to targets by illuminating the target with laser light and analyzing the backscattered light. Ground control points should be established to calculate accuracy and ground surveys may be needed to develop ecosystem-specific correction factors in densely vegetated marshes. For additional information on the use of LIDAR to monitor marsh elevations, see Brock et al. (2002), Schmid et al. (2011), Hladik and Alber (2012), Heidemann (2014), Buffington et al. (2016), and Medeiros et al. (2015).

Method 3: Photogrammetric surveys along transects. Collect elevation data using stereo aerial photogrammetry, coupled with control point elevation measurements collected with RTK GPS (Smith and Vericat, 2015; Smith et al., 2016).

Method 4: For more frequent measurements of elevation to determine sediment compaction rates, settlement plates may be installed during project construction (Dunnicliff, 1993). Elevation of the plates and top of the structure can be measured using advanced surveying instrumentation (e.g., RTK GPS) and as-built elevation compared to elevation in years post-construction.

Method 5: Traditional survey equipment (level and rod or transit pole and self-leveling laser) (Baggett et al. 2014).

Method 6: Ruler, meter stick, or graduated rod (Baggett et al. 2014).

Regardless of method employed, the elevation should be measured relative to geodetic and/or tidal datums (Rydlund and Densmore, 2012). Vertical error should be summarized for all elevation measurements, regardless of the data collection method used. Remotely sensed elevation data should have vertical error reporting that adhere to American Society for Photogrammetry and Remote Sensing (ASPRS) standards, the general standards for gauging vertical error in DEMs.

Monitoring Location for Topographic Methodologies

Topographic profiles should be collected along the entire project footprint (typically collected for a larger area). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration for Topographic Methodologies

For beaches, dunes, barrier island, oyster reef, and SAV projects, data collection could occur pre-construction, immediately after construction (as-built), and at an appropriate frequency and duration relevant to project-specific conditions. A baseline pre-implementation condition could be established based on information obtained during the E&D.

For marsh restoration projects, monitoring could occur immediately after construction (as-built), and post-construction at an appropriate frequency and duration relevant to project-specific conditions. Funding could also be included for an additional contingency data collection, to be implemented as needed, in response to storm impacts.

Bathymetric Methodologies

Bathymetric surveys can be performed to collect water depth information by using:

Method 1: RTK GPS in shallow waters.

Method 2: Single-beam sonar.

Method 3: Multi-beam sonar.

Method 4: Topobathymetric LIDAR surveys along transects.

Method 5: Echo-sounder (Baggett et al. 2014).

Method 6: Depth finder (Baggett et al. 2014).

Method 7: Sounding pole (Baggett et al. 2014).

For potential guidance on performing Methods 1 and/or 2, see Sallenger et al. (2003), Morton et al. (2005), Stockdon et al. (2009), Guy and Plant (2014), Heidemann (2014), and Smith et al. (2016). Elevation data acquired from remote sensing should have vertical error reporting and adhere to the ASPRS standards, the general standards for gauging vertical error in DEMs.

Monitoring Locations for Bathymetric Methodologies

Bathymetric profiles should be collected along the entire project footprint (typically to be collected for a larger area). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration for Bathymetric Methodologies

In general, monitoring is proposed pre-construction, immediately after construction (as-built), and post-construction. A baseline pre-construction condition could be established based on profiles obtained during the E&D. Collections could be conducted pre-construction, immediately after construction (as-built), and post-construction at an appropriate frequency and duration relevant to site-specific conditions. Funding could also be included for an additional contingency data collection, to be implemented as needed in response to storm impacts or other factors that may influence elevation.

Other Potential Analyses

For beaches, dunes, and barrier islands, additional potential analyses using elevation data include shoreline change, habitat change, beach and dune profile change, volume change, bathymetric profile change, volume change, and sediment movement. For marshes, elevation data could be used to support calculation of the area of habitat built or enhanced within a particular elevation zone and to calculate the sediment compaction rate.

E.3.9. Enterococci

Parameter Type: Measured

Units: concentration expressed as the most probably number per hectoliter (MPN/100 L) or as Colony-Forming Units per deciliter (CFU/100 mL)

Definition

Pathogenic bacteria, or indicator species, are indicators of recent fecal matter contamination and that pathogens dangerous to human beings may be present.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

For methods on assessing Enterococci, see IDEXX Enterolert (Baird et al., 2017; and U.S. EPA, 2017). Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

Other Potential Analyses

Coliphages are additional pathogens that could be assessed as indicators of recent fecal matter contamination and exposure likelihood.

E.3.10. Epibenthos and Infaunal Abundance, Density, Composition, and Mass

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none (count) or catch per unit effort (CPUE)
Density Units: number of individuals per square meter (individuals/m^2)
Composition Units: none
Mass Units: grams (g)

Definition

Epibenthic and infaunal organism abundance, density, and composition on the inundated marsh platform, in tidal channels and ponds, oyster reefs, and/or adjacent unvegetated bottom habitat.

Restoration Approach

- Restore Oyster Reef Habitat

Potential Methodologies

Fisheries-independent monitoring approaches should be used to measure epibenthic organism abundance/density in and around restored marshes. Sessile epifaunal invertebrates may be sampled with the quadrat method used for oyster density sampling. Infaunal invertebrates may be sampled with cores (15 cm diameter, 15 cm depth), washing samples over a 2mm or smaller mesh.

Method 1: Use the quadrat sampling method for hard substrates to sample sessile invertebrates (see Oyster Density for methods).

Method 2: Use cores (15 cm diameter x 15 cm depth) to sample infaunal invertebrates, washing samples over a 2 mm or smaller mesh (Baggett et al. 2014).

Optionally, length and biomass may be measured for all or a subset of the sample. Data should be presented as density (individuals/m^2), wet weight (g/m^2), and/or length (cm) per species, as appropriate.

Monitoring Location

Collections should occur in the areas and habitats specifically targeted by the restoration (e.g., marsh edge, interior marsh, ponds, creeks, bay). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction and post-construction. Monitoring could be conducted for three years post-construction or longer in order to be able to adequately capture the changes in community composition at the project site. Sampling could be conducted seasonally, during the spring and fall, both pre- and post-construction, or more frequently. Monthly sampling for two–three years pre-restoration and at two–three-year intervals post-restoration may be needed to evaluate changes associated with the restoration project.

E.3.11. *Escherichia coli* (*E. coli*)

Parameter Type: Measured or Calculated

Units: concentration expressed as the most probable number per hectoliter (MPN/100 L) or as Colony-Forming Units per deciliter (CFU/100 mL)

Definition

E. coli are indicators of recent fecal matter contamination, and that pathogens dangerous to human beings may be present.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

For methods on detection of *E. coli* in water samples, see IDEXX Colilert, IDEXX Colilert-18, EPA 1604, SM 9223 B (U.S. EPA, 2002, 2017; and Baird et al., 2017). Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.12. Fecal Coliform Bacteria

Parameter Type: Measured

Units: Colony-Forming Units per deciliter (CFU/100 mL)

Definition

A subset of total coliform bacteria, which are more fecal-specific in origin, are indicators that pathogenic bacteria, viruses, or protozoans dangerous to human beings may be present.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

Standard Methods for the Examination of Water and Wastewater (Baird et al., 2017; and U.S. EPA, 2017) provide analytical techniques for the determination of water quality. Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.13. Infrastructure or Habitat Constructed and/or Enhanced and Completed as Designed

Parameter Type: Measured

Units: none or units for measured deviations, as appropriate

Definition

Determination as to whether the infrastructure (e.g., artificial reef, educational facility, signs) was constructed or the habitat was enhanced (e.g., asphalt removed, trail enhanced) and completed as designed.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Enhance Recreational Experiences
- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

The type of infrastructure will vary depending on the project objective(s) and the specific item or process that is being enhanced. The contractor is responsible for collecting this information and should record this as a part of their reporting and on-site inspections. Comparisons of as-built plans/reports and site inspections to construction drawings or other planning materials may be necessary.

Monitoring Location

This information is collected at the project site.

Guidance on Frequency and Duration

Infrastructure could be monitored for three years post-construction or longer. For artificial reefs, pre-construction monitoring might be related to siting and determining there is no hard substrate already present. Post-construction monitoring could occur annually for two years or longer. Depending on the project-specific objectives, other hard structures could be monitored more frequently and/or for a longer duration to evaluate weathering of the infrastructure.

E.3.14. Nekton Abundance, Density, Composition, Length, and Mass

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none (count) or catch per unit effort (CPUE)
Density Units: number of individuals per square meter (individuals/m^2)
Composition Units: none
Length Units: millimeters (mm) or centimeters (cm)
Mass Units: grams (g)

Definition

Nekton organism abundance, density, and composition on the inundated marsh platform, in tidal channels and ponds, oyster reefs, and/or adjacent unvegetated bottom habitat.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands
- Restore Oyster Reef Habitat

Potential Methodologies

Fisheries-independent monitoring approaches should be used to measure nekton and epibenthic organism abundance/density in and around restored marshes. Sampling gears are designed to target specific sizes, species, and habitat(s). As such, different gears are recommended under specific circumstances. Nekton density on the marsh surface could be measured using drop samplers, lift nets, or throw traps. Nekton abundance along the marsh edge and within tidal creeks and adjacent open water areas may also be measured using trawls, but these methods do not provide density estimates, and abundance in open water habitat does not necessarily indicate nekton utilization of the marsh surface.

Density:

Method 1: Use drop samplers to sample small/medium crustaceans and fish on the marsh platform and in shallow open water habitat. Drop samplers allow for quantitative estimates of density and biomass. Potential methods are discussed in Zimmerman et al. (1984) and Minello (2000).

Method 2: Use lift nets to sample small/medium crustaceans and fish on the marsh platform and in shallow open water habitat. Potential methods are discussed in Rozas (1992).

Method 3: Use throw traps to sample small/medium crustaceans and fish on the marsh platform and in shallow open water habitat. Potential methods are discussed in Kushlan (1981) and Jordan et al. (1997). Throw traps are not as effective in areas of dense vegetation – drop samplers or lift nets are preferable gears for such conditions (Rozas and Minello, 1997).

Method 4: Use lift nets to sample small/medium crustaceans and fish on oyster reefs (Crabtree and Dean 1982; Tolley and Volety, 2005; Boudreaux et al 2006; Wenner et al 2006).

Abundance (catch per unit effort):

Method 1: Seines or hand trawls can be used if sampling small/medium crustaceans and fish along the marsh edge or in shallow open water habitat. However, these sampling devices are not suitable for sampling the marsh platform. Seines do not provide an accurate estimate of fish density, but can be used to measure abundance. The length of the seine/trawl and the distance traveled should remain constant from one sampling event to another in order to consistently sample the same area.

Method 2: Beam trawls should be used in open water habitat that is typically greater than 2 m in depth to sample juvenile and adult fish or large crustaceans. They may be less effective at sampling small crustaceans and fish than seines and drop samplers.

Method 3: Gill nets may be used to sample larger transient fish. The mesh size will vary depending on the size of the target species. Nets should be set 1 hour before sunrise and left in place for 2 hours. Data should be presented as the number of individuals of each species caught per hour (Baggett et al. 2014).

Note that data collected using different sampling gears are not always comparable. Generally, data collected using methods that measure density can be standardized and adjusted for recovery efficiency, but cannot easily be compared to data collected using methods that only measure abundance. See Rozas and Minello (1997) for a review of sampling gear in shallow estuarine habitats.

Optionally, in addition to determining species composition and abundance, measure length and biomass for all or a subset of the sample as grams (g) wet weight. Data should be presented as density (individuals/m^2), wet weight (g/m^2), and length-frequency distributions per species. For large collections (50 individuals or more of the same species), a subset of the entire sample for a given species may be measured and extrapolated to remaining individuals of the same species.

See Neckles and Dionne (2000) and Steyer and Llewellyn (2000) for more information on potential methodologies.

Monitoring Location

Nekton collections should occur in the areas and habitats specifically targeted by the hydrologic restoration (e.g., marsh edge, interior marsh, ponds, creeks, bay). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction and post-construction. Monitoring could be conducted for three years post-construction or longer in order to be able to adequately capture the changes in community composition at the project site. Sampling could be conducted seasonally, during the spring and fall, both pre- and post-construction, or more frequently. Monthly sampling for two–three years pre-restoration and at two–three-year intervals post-restoration may be needed to evaluate changes associated with the restoration project.

Other Potential Analyses

Used to calculate measures of **Nekton Diversity (E.3.15)**.

E.3.15. Nekton Diversity

Parameter Type: Calculated

Units: none

Definition

Diversity is related to the species number and abundance within a particular location. There are a number of measurements and indices related to species diversity.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

Based on **Section E.3.14 Nekton Abundance, Density, Composition, Length, and Mass**, many measures of diversity can be calculated.

Method 1: Species richness: The simplest measure of diversity, the total number of species present in a sample.

Method 2: Shannon-Wiener Index (Bradshaw and Brook, 2010).

Method 3: Simpson's Index (Bradshaw and Brook, 2010).

Monitoring Location

The monitoring location would vary based on project-specific objectives.

Guidance on Frequency and Duration

Whenever nekton sampling occurs.

E.3.16. Number of Improvement Practices Implemented

Parameter Type: Measured

Units: none (count)

Definition

Count of the number of water quality or wetland improvement practices that were implemented as part of the project.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats

Potential Methodologies

Count of improvements implemented.

E.3.17. Oyster Density

Parameter Type: Measured

Units: number of individual oysters per square meter (oysters/m^2)

Definition

The number of oysters, including recruits, per unit area. The density of live and dead oysters should be calculated separately. The age or size of recruits is project-specific and should be clearly defined.

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Method 1: Place a quadrat on the reef and excavate all live and dead oysters within the quadrat. For rigid structures, place a quadrat on the surface of the reef structure and excavate to a depth necessary to collect all live oysters within the quadrat. For reefs constructed of bagged shell, take random samples by removing a bag of shell; the area sampled is the areal coverage of the bag. Convert densities to number per m^2. If placed along a shoreline, also report a number per linear meter of shore. Stratify samples as appropriate, such as by reef height, orientation to mainland, or distance from shore. For more information see Baggett et al. (2014).

Method 2: Use hydraulic patent tongs to sample the oyster reef. Like quadrats, they sample a known area and density can be calculated. For more information see Chai et al. (1992).

Monitoring Location

Samples may be taken over the entire area of the reef. See Baggett et al. (2014) for guidance on the appropriate number of samples.

Guidance on Frequency and Duration

Pre-restoration (once, if applicable), and at least annually for 5 years after restoration. Density should be measured after the growing season unless project objectives dictate otherwise.

Other Potential Analyses

Density of large oysters (brood stock) may be calculated using density and the oyster size frequency distribution. “Large” is defined for each project as appropriate.

E.3.18. Oyster Mortality

Parameter Type: Calculated or Modeled

Units: percentage (%)

Definition

The proportion of dead oysters on a reef expressed as a percentage.

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Divide the number of dead oysters by the total number of live and dead oysters and express as a percentage.

Monitoring Locations

Samples may be taken over the entire area of the reef or control sites if appropriate habitats exist in the area. Control areas could consist of natural reefs, non-reef areas, or other restoration projects depending on the restoration goals. See Baggett et al. (2014) for guidance on the appropriate number of samples and "oyster density" above.

Guidance on Frequency and Duration

Recommended frequency: Pre-restoration (once, if applicable), and at least annually for 5 years after restoration. Sampling should be performed at the end of the oyster growing season in conjunction with sampling for oyster density. If possible, sampling should occur after newly settled oysters have grown to a size greater than 10 mm and can be confidently classified as recruits (Baggett et al., 2014).

E.3.19. Oyster Larval Settlement

Parameter Type: Calculated

Units: number of spat per square meter per day (spat/m^2·day), number of spat per square meter (spat/m^2), number of spat per liter of shell (spat/L of shell), number of spat per weight of shell (spat/kg of shell), or number of spat per individual shell (spat/shell), depending on the method used

Definition

Settlement is defined as the point at which a larva attaches to the substrate or metamorphoses into benthic form (Wildish and Kristmanson, 1997; Baggett et al., 2014). This differs from recruitment, which includes settlement and some period of post-settlement survival (Baggett et al., 2014).

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Method 1. Settlement Plates or Shell Strings

Deploy settlement plates or shell strings. Collect and replace plates every 3 or 4 weeks. More frequent replacement will yield finer-scale temporal patterns of settlement. Report as # of spat/m^2 unit area per day.

Method 2. Quadrat

Estimates of settlement may be obtained from quadrat samples used for density estimates. The number of oyster spat/quadrat should be expressed in #/m^2 so that density can be compared between project types and sites. If the project is a living shoreline or is designed to protect a marsh shoreline, then also report the number of spat per linear meter of shoreline.

Method 3. Shell Bags

If sampling with mesh bags filled with oyster shell, bags should be placed adjacent to or directly on the site of interest. Record the number and volume of bags of cultch material. Report as #spat/L of pre-deployed shell, # spat/individual shell, or # spat/weight of pre-deployed shell.

Method 4. Oyster Dredge

For an oyster dredge, tow for a specified time and method (e.g., linear or circular tow direction, speed). Measure the dredge width and tow distance to calculate the area swept. Correct for dredge efficiency as appropriate. Report as, # spat/L of shell, or average # spat/individual shell.

Monitoring Location

Samples may be taken across the entire reef area as appropriate.

Guidance on Frequency and Duration

Deploy plates or shell strings annually beginning the first week of April. Collect and replace plates or strings at least every 3 or 4 weeks until the end of the known settlement season for the area. Quadrat, shell bag, and dredge sampling may be conducted annually, preferably after fall settlement

E.3.20. Oyster Reef Volume

Parameter Type: Calculated

Units: cubic meters (m^3)

Definition

The space occupied by an oyster reef

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

These methods assume that the reef is not harvested.

Method 1: Reef volume may be calculated by multiplying reef area by elevation (mean reef height).

Method 2: Data from a combination of sources may be used to calculate reef volume. Data from side-scan sonar can be digitized into raster data and analyzed in ArcGIS or other software. Reef elevation data can be gathered from a scientific echo sounder (or other appropriate sonar devices like multibeam or interferometric sides scan sonar). Pre- and post-restoration elevation data allows the elevation above surrounding non-reef areas to be determined. Area * mean height = reef volume.

Monitoring Location

Reef volume may be calculated for the entire area occupied by the reef.

Guidance on Frequency and Duration

Reef volume could be calculated immediately after project implementation and annually for up to five years following implementation. Additional measurements could be taken after events that could alter reef volume, such as storms, or extended periods of water quality detrimental to oyster survival (e.g., low salinity events).

Other Potential Analyses

Reef volume may be used to calculate a shell budget for the reef.

E.3.21. Oyster Size Frequency Distribution

Parameter Type: Measured

Units: millimeters (mm)

Definition

Oyster shell height measured from the umbo to the opposite edge of the shell.

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Measure the shell height (umbo to opposite edge) of each live and dead oyster collected.

Monitoring Locations

Samples may be taken over the entire area of the reef. Measure at least 50 oysters per sample, or enough oysters to equal 250 per reef (Baggett et al. 2014).

Guidance on Frequency and Duration

Pre-restoration (once, if applicable), and at least annually for 5 years after restoration. Sampling should be performed at the end of the oyster growing season in conjunction with sampling for oyster density. If possible, sampling should occur after newly settled oysters have grown to a size greater than 10 mm and can be confidently classified as recruits (Baggett et al., 2014).

E.3.22. pH (acidity)

Parameter Type: Measured

Units: Standard Units (pH)

Definition

Measure of acidity or potential activity of hydrogen ions (H+).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

pH can be measured using:

Method 1: An electronic pH meter.

Method 2: A litmus paper strip coated in a pH-indicating dye.

Method 3: pH dye testing kit for liquids.

Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.23. Recreational Activities Utilized by Public

Parameter Type: Measured, Calculated, or Modeled

Units: none (counts by activity), person-hours/days/nights per activity, or none (average rating), depending on the nature and extent of the evaluation

Definition

Amount of recreational use on the land and/or water, organized by category, where the activities take place, and for how long or how often.

Restoration Approach

- Enhance Public Access to Natural Resources for Recreational Use

Potential Methodologies

Monitoring could be conducted using key location or onsite surveys, as well as offsite regional telephone or mail surveys.

Use direct observations of recreational use activities (e.g., to determine if visitors are swimming, using the beach).

Conduct surveys. These surveys should be conducted at key locations across the recreational use area. Surveys may include the following types of questions:

How often do you visit the acquired land?

With whom are you visiting the acquired land (commercial tour operator vs. family/friends/self)?

What is your motivation for visiting the site?

What benefits do you expect from visiting the site?

What activities are you participating in (could provide a list based on what recreational activities the land may be used for, with an option for “other”)?

How long are you at the acquired land (hours, overnight, days)?

How would you rate the amount of influence that various setting features had on your experience?

See Moscardo and Ormsby (2004), U.S. Census Bureau et al. (2011), Louisiana Department of Culture, Recreation, and Tourism (2014), and Miller et al. (2014) for additional information.

Monitoring Location

Selection of respondents could use some systematic random sampling procedure within the units chosen for study. This procedure is intended to ensure that the respondents within a location have an equal probability of being asked to participate and, that the choice of target respondents is determined by the sampling system and not by the interviewers.

Guidance on Frequency and Duration

The survey could be conducted pre- and post-construction or more often depending on the objectives of the project. If appropriate for the project, monitoring should aim to cover different seasons and include weekdays, weekends, and holidays.

E.3.24. Right of Entry

Parameter Type: Calculated

Units: days

Definition

The right of entry to a project area is measured in terms of the number of days the area was open and closed to the public. This only applies to projects that can be closed or opened, and not to areas/projects that are always open.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

Document the number of days the project area is open and closed using beach closure information, information on restrictions in place due to severe weather, or other similar information.

Monitoring Location

The information is collected at the location for which access can be restricted.

Guidance on Frequency and Duration

Duration and frequency will ultimately depend on site specific conditions, project objectives, and the monitoring period identified in the project-specific MAM plan.

Other Potential Analyses

The information can help inform trends in visitor use. For example, if severe weather prevents the opening of a facility, visitor use numbers will decline during that period. This additional piece of information will help explain these patterns in visitor use.

E.3.25. Salinity

Parameter Type: Measured or Modeled

Units: parts per thousand (ppt), Practical Salinity Units (PSU), or unitless. These systems of units are interchangeable, by design.

Definition

The concentration of dissolved salts in water reported as parts per thousand (ppt), practical salinity units, or may be unitless (indicating the use of the Practical Salinity Scale).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Surface water salinity may be measured continuously with an in-situ salinity/conductivity sonde and data logger.

Method 2: Take discrete samples using a hand-held salinity/conductivity probe or refractometer.

See Neckles and Dionne (2000), Steyer and Llewellyn (2000), Wagner et al. (2006), and U.S. EPA (2014) for additional information on salinity monitoring protocols.

Monitoring Location

Spatial distribution of salinity measurements will depend on the project type and hydrologic characteristics of the project area. Salinity measurements could be taken near the source of the hydrologic restoration, within the boundary of the area influenced by the project, near the edge of boundary, and outside the boundary if adjacent to other habitats. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and post-construction. A baseline pre-construction condition could be established based on information obtained during the E&D. Recommend sampling immediately following construction (as-built) and annually thereafter.

If the parameter is linked to a performance criterion, it could be monitored until the criterion has been met and then sustained for three years. Otherwise, establish a monitoring period long and frequent enough to satisfy project objectives. This may involve capturing annual/inter-annual variability based on factors that could influence salinity at the project site (e.g., precipitation, freshwater inflow).

E.3.26. Scarring

Parameter Type: Measured or Calculated

Count Units: none
Length Units: meters (m)
Depth Units: centimeters (cm)
Area Units: square meters (m^2)

Definition

Disturbed or damaged SAV and surrounding sediments as a result of boat propeller damages or other human impacts. Measurement includes counts, lengths, depths, and areas of scars.

Restoration Approach

- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Scar boundaries, number, length can be mapped based on aerial imagery collected by airplane, helicopter, unmanned aerial systems (UAS); high-resolution satellite imagery; or other appropriate remote sensing platforms. Recommended landscape-scale monitoring is 1: 9,600 scale to effectively estimate bare patches (< 2-3 m2, Dunton and Pulich 2007). Imagery used to establish SAV boundaries should include true color and infrared bands, and have a spatial resolution of 1 meter (m) or less. Source imagery should be orthorectified [i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation; see Rufe (2014)]. Collected imagery should be imported to spatial analysis software to digitize the perimeter of the project footprint and the boundaries of habitat areas within the project footprint. Additional guidance on using aerial imagery can also be found in Anders and Byrnes (1991), Crowell et al. (1991), Morton (1991), and FLDEP (2014).

Method 2: Ground surveys can be used to map the area of small scars. Use a real-time kinematic Global Positioning System (RTK GPS) to take continuous measurements while walking the perimeter of the project and along the boundaries of specific habitats within the project footprint. If taking depth measurements, record depth of scar at various waypoints while mapping the area of the scar.

Method 3: Grid mapping can be used to calculate the area of prop scars; it is best used when scarring is linear (EBAP and FLDEP 2015). A fiberglass measuring tape is extended down the midline of the scar from two anchor points located at each end of the scar. At specified intervals (~1 m) length measurements are taken at right angles from the centerline to the edges of the scar (Hudson and Goodwin 2001). Using this information, a graphical representation of the injury can be made by plotting measured points on a Cartesian plane from which the area of the scarring can be calculated.

Method 4: GPS/Trimble Method is best used on wide scars, or scars that may have merged to form larger patches (EBAP and FLDEP 2015). NOAA and the FLDEP utilize this method to collect data about areas with high boat traffic. The Trimble receiver collects points while being walked around the perimeter of the scar or being dragged in a float. The total number of points recorded is dependent on the complexity of the scar; more complex features will require more points to accurately represent the shape. The points are then connected to create a polygon feature in ESRI ArcView or Trimble Pathfinder Office. From that, the area of scarring can be calculated.

Monitoring Location

Area of habitat impacted should be determined for the entire project footprint. Some data, such as aerial photography, may be collected over larger areas. If using signage and/or buoys to mark boundaries of the project, scarring should be monitored within the boundaries.

Guidance on Frequency and Duration

In general, monitoring is proposed twice a year, once in the growing season (approximately April through October) and once again in the dormant season, allowing data collection to coincide with the yearly minimum and maximum seagrass densities (EBAP and FLDEP 2015). In general, monitoring is proposed pre-restoration, immediately after restoration, and post-restoration.

Other Potential Analyses

Scarring measurements may also be used in conjunction with other parameters listed herein (e.g., elevation, vegetation percent cover and composition, turbidity) to perform the following calculations and analyses: habitat type changes, bathymetric profile change, and sediment movement.

E.3.27. Shoreline Position

Parameter Type: Measured, Calculated, or Modeled

Units: positions should be georeferenced (latitude, longitude, elevation) or relative changes may be measured in meters (m)

Definition

The location of the boundary between the land and water at a particular tidal elevation. Calculations of shoreline position will allow for documentation of shoreline change over time, including in response to particular disturbance events.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Restore Oyster Reef Habitat

Potential Methodologies

The shoreline position can be measured using high-resolution, near-vertical aerial imagery, RTK GPS survey data, or by measuring shoreline locations along established transects. Comparing shoreline position over time provides information on shoreline change. Any shoreline measurement may be tied to a relevant tidal datum [e.g., mean sea level (MSL), mean high water (MHW), mean low water (MLW)]. Shoreline change should be calculated between shorelines tied to the same tidal datum.

Method 1: Delineate the shoreline based on orthophotography collected by aerial survey (see Sections E.9.1 Area and E.9.8 Elevation for methods). Aerial surveying is a method of collecting geomatics or other imagery by using airplanes, helicopters, UAS, or other aerial methods. Imagery acquired should be orthorectified (i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation). For guidance on collecting aerial orthoimagery please see Rufe (2014). Orthoimagery for monitoring shoreline change should have a spatial resolution of at least 1 m. Additional guidance on using aerial imagery can also be found in Anders and Byrnes (1991), Crowell et al. (1991), Morton (1991), and FLDEP (2014).

Method 2: RTK GPS ground surveys can be used for smaller projects to measure land elevation. Walk the shoreline while taking continuous measurements using an RTK GPS. Import the spatial information into ArcGIS and map the shoreline position. For wetlands, the shoreline is defined as the lower/seaward extent of the emergent marsh vegetation. Import and analyze the data using spatial analysis software. Determine the shoreline loss/gain in meters per year. See Steyer and Llewellyn (2000) for more information on this method.

Method 3: Establish permanent base stakes along the length of the shoreline at least 10 m inward of the marsh edge and determine the GPS coordinates of each base stake. Measure the linear distance from the base stake to the marsh edge along an established compass direction. The marsh edge is defined as the lower/seaward extent of the emergent marsh vegetation. Import and analyze the data using spatial analysis software. Determine the shoreline loss/gain in meters per year. See Steyer and Llewellyn (2000) for more information on this method.

For additional information on shoreline mapping methods, see Morton et al. (2005), Fearnley et al. (2009), Martinez et al. (2009), FLDEP (2014), and Guy (2015).

Repeated measurements of the shoreline position over time enables calculations of shoreline change, including erosion or seaward expansion. Several references are available for calculating shoreline change over time (e.g., Moore, 2000; Ramsey et al., 2001; Boak and Turner, 2005; Morton et al., 2005; Thieler et al., 2009; Gens, 2010; Rangoonwala et al., 2016).

Monitoring Location

The shoreline change should be determined for the entire project footprint. For some collection techniques, such as aerial photography, the data will be collected for a larger area. A reference and/or control site could be established, where appropriate and applicable, to calibrate and validate remote sensing data. Spatial variation in the direction and magnitude of shoreline displacement can be measured by selecting reference and/or control points that are surveyed repeatedly over time.

Guidance on Frequency and Duration

In general, monitoring should be conducted pre-construction, immediately following construction, and post-construction. A baseline pre-construction condition should be established based on data obtained during the E&D. For beaches, dunes, and barrier islands, data collection could occur immediately following construction (as-built) and frequently enough to satisfy project objectives. For coastal wetlands projects, data collection could occur immediately following construction (as-built) and one–two more times over the monitoring period, or longer. In some cases, sampling throughout the year may be useful to identify seasonal patterns in erosion or accretion. Funding for contingency data collection could be included to evaluate storm impacts, as needed.

The duration will ultimately depend on site-specific conditions, project objectives, and the monitoring period identified in the project-specific MAM Plan.

Other Potential Analyses

Shoreline erosion rate, habitat type changes, shoreline change, habitat change, beach and dune profile change, volume change, bathymetric profile change, volume change, and sediment movement.

E.3.28. Specific Conductance

Parameter Type: Measured

Units: microsiemens per centimeter (µS/cm)

Definition

Measure of how well water can conduct an electrical current.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Specific conductance can be measured using a multi-parameter water quality sonde.

Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See Wagner et al. (2006).

E.3.29. Structural Integrity and Function of Constructed Features

Parameter Type: Qualitative or Measured

Units: none or as appropriate for the dimensions or functions evaluated

Definition

A series of observations and/or measurements to evaluate the integrity and function of constructed project features, such as breakwaters, weirs, culverts, tidal channels/creeks and/or access control measures such as signs, boardwalks, and fencing. The consolidation of a structure over time may also be monitored through repeated elevation measurements. The integrity of the structure, and its foundation and function are evaluated so that appropriate maintenance or alternative actions can be taken if the constructed feature is not performing as constructed or designed.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Conduct visual observations and photograph the project site. Visual surveys may be used subjectively to record the overall conditions, integrity, and effectiveness of the structure, including observations of material movement, changes in profile, change in habitat, etc. For hydrologic connectivity projects in which culverts are used, this should include checking for any obstructions to flow through the culvert. For recreational use projects, this may include an inspection of the project features such as entry points, parking lots, signage, and self-registration booths. For barrier island, dune, or beach projects, this may include an inspection of the project features such as dune walkovers, bollards and cable functioning, and other habitat protection features. For SAV projects, this may include inspection of bird stakes used to enhance nutrient levels (Powell et al. 1991), signage, and/or buoys which delineate the edges of the restoration zone, or breakwaters which could include oyster reefs or bio-engineered products.

Method 2: Use imagery collected during aerial surveys (see Section E.9.1 Area) to measure changes to the structure.

Method 3: Conduct an elevation and/or bathymetric survey of the structure to describe its outer surface geometry and measure changes over time. Measure the elevation of 2–10 points on the structure in relation to an established datum.

- Composition: Position and size of unstable pieces, including major voids and exposures to core or underlayer
- Element composition: shape, size, and position of armor stone, including any fractures.

See Chapter 10 of CIRIA et al. (2007).

Monitoring Location

Along the entire length of the structure.

Guidance on Frequency and Duration

Post-construction observations could be made immediately following construction (as-built) and annually for five years post-construction. Additional observations may be needed following extreme weather events. Intervals between monitoring could be predetermined by the risk associated with particular failure mechanisms, structural elements, foundation conditions, exposure conditions, and design criteria.

Other Potential Analyses

Repeated measurements of the elevation of a structure can be used to calculate a consolidation rate.

E.3.30. Targeted Injured Species Abundance or Density

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none (count)

Density Units: individuals per square meter (number/m^2) or individuals per square kilometers (number/km^2)

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

The appropriate sampling methodologies will be dependent on the species targeted by the project.

Monitoring Location

The restoration project. A reference and/or control site could be established, where appropriate and applicable. Specific sampling locations will depend on the species targeted.

Guidance on Frequency and Duration

In general, monitoring is proposed pre- and post-construction, and is proposed for three years post-construction to adequately capture the changes in community composition at the project site. Monitoring frequency and seasonal timing will depend on the species targeted.

E.3.31. Temperature

Parameter Type: Measured or Modeled

Units: degrees Celsius (°C)

Definition

A measure of the warmth or coldness of water with reference to some standard value.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Can be obtained using a thermometer or temperature probe. Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See also Wagner et al. (2006).

E.3.32. Terms of conservation/management plan met

Parameter Type: Qualitative

Units: none

Definition

Determination as to whether the terms of the conservation and/or management agreement, as applicable, have been met.

Restoration Approaches

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats

Potential Methodologies

If the project includes a management agreement, the contractor would be responsible for collecting this information and should record this as a part of their reporting and on-site inspections. Comparisons of management reports and site inspections or other planning materials may be necessary. If the project includes a conservation agreement (e.g., easement), the implementing Trustee would determine if the conservation agreement terms were being met through a site visit or discussions with the managing agency or party.

E.3.33. Total Nitrogen (TN)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

The sum of organic and inorganic forms of nitrogen in a water sample.

Restoration Approaches

- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

For guidance on potential methodologies to measure TN, see ASTM D5176 (ASTM, 2013a, 2013b) and USGS-NWQL I-2650-03. However, in some cases, directly-measured TN may not be statistically comparable to TKN + NO_2 + NO_3 (Patton and Kryskalla, 2003).[3] See also the U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data (https://water.usgs.gov/owq/FieldManual/). TN and total phosphorus (TP) measurements are the United States Environmental Protection Agency's preferred metrics for evaluating nutrient concentrations in waters of the United States (Stoner, 2011). Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See the U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data (https://water.usgs.gov/owq/FieldManual/).

Other Potential Analyses

Loads and depth of the sample and collection method could be recorded. Further, TKN, NH_4-N (ammonium nitrogen), NO_2-N + NO_3-N (nitrite plus nitrate), NO_2-N (nitrite), and NO_3-N (nitrate) could be analyzed from the samples.

E.3.34. Total Phosphorous (TP)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

The measure of the sum of all forms of phosphorus, including inorganic and organic forms.

Restoration Approaches

- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

For guidance on potential methodologies to measure TP, see EPA 300.0, EPA 365.2, EPA 365.3, EPA 300.1, SM 4110C, SM 4110B, and USGS-NWQL I-4650-03. Data

1. 3 TKN + NO_2 + NO_3 has been traditionally used by some agencies as an estimate of TN, but that practice is changing due to the development of less labor-intensive procedures (Walker 2014) and more precise methods (Smart et al. 1981).

collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

Other Potential Analyses

Soluble reactive-P (orthophosphate phosphorus) and chlorophyll *a* may also be analyzed.

E.3.35. Total Suspended Solids (TSS)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

The dry weight of sediment from the known volume of a sub-sample of the original water sample.

Restoration Approaches

- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

For methods on collection of TSS, see EPA 160.2. Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.36. Turbidity

Parameter Type: Measured

Units: nephelometric turbidity unit (NTU)

Definition

A measure of intensity of light scattered by a sample, or the cloudiness or haziness of a sample.

Restoration Approaches

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

For methods on assessing water turbidity see EPA 180.1 and Wagner et al. (2006).

Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.37. Velocity

Parameter Type: Measured, Modeled, or Calculated

Units: meters per second (m/s)

Definition

The speed of water moving in a particular direction. Flow velocity can be measured for constrained flow within channels or structures (e.g., culverts), but can also be measured for sheet flow. Velocity can also be measured for bi-directional tidal flows, where flow in the opposite direction has a negative velocity.

Restoration Approaches

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

Method 1: Measure water velocity (typically in units of m/s) within a channel with a current meter. Typically, multiple velocity measurements should be taken both across the stream and at different depths.

Method 2: An ADCP can used to measure both water velocity and water depth within a stream. Typically, the ADCP is mounted to a small water craft and guided along the stream channel to take the measurements.

Monitoring Location

Water velocity should be measured for channels within the project area that are an important component of the project design, or at other locations within the project footprint where the maintenance or restoration of hydrologic flows is important. Water velocity can be measured at a reference and/or control site, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and post-construction. A baseline pre-implementation condition could be established based on information obtained during the E&D. Propose conducting sampling pre-construction (once), immediately following construction (once), and annually thereafter. Additional sampling may be needed after large storm events.

For projects with tidal influence and if continuous recorders are used, the data could be collected for two weeks or longer during a sampling event to be able to capture one lunar cycle of spring and neap tides, but longer time periods (e.g., three–four months or year-round) are preferred. If discrete measurements are taken, the water velocity could be assessed over several tidal cycles.

For projects with riverine influence, sampling events could be designed to capture both high- and low-flow events. If continuous recorders are used, the data could be collected for two weeks or longer during high- and low-water conditions, but year-round data collection for one or more years is preferred to fully capture the seasonal variability in flow conditions. If discrete measurements are taken, the water velocity could be assessed over a few weeks during both high- and low-flow conditions.

If velocity measurements will be used to calculate discharge (volume of flow), velocity could be measured at about the same time the channel dimensions are measured.

Other Potential Analyses

Can be used with **Channel Dimensions (Section E.3.3)** to calculate the flow volume, or **Discharge (Section E.3.5)**.

E.3.38. Vegetation Density

Parameter Type: Calculated

Units: number of individual plants per square meter (number/m^2) or number of individual plants per square kilometer (number/km^2)

Definition

Abundance of vegetation in a given area (typically in units of number of individuals or objects per m^2). The term refers to the closeness of individual plants to one another.

Restoration Approaches

- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches

Potential Methodologies

Use a quadrat to estimate plant species density within a defined area (e.g., 1 x 1-m plots or 2 x 2-m plots). Data recorded by collecting number of plants per unit area in the planted area will include:

- Species identification
- Density of native species
- Density of invasive species if present.

Monitoring Location

Data could be collected throughout the entire project footprint and at a reference and/or control site, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed (pre-construction, immediately after construction, and post-construction). A baseline pre-construction condition should be established if possible. Data collections could occur pre-construction, immediately after construction (could be included in as-built), and every three years for the minimum monitoring period. One additional contingency data collection could be included in the monitoring plan to be implemented as needed to account for storm impacts.

E.3.39. Vegetation Percent Cover or Composition

Parameter Type: Calculated or Modeled

Units: percentage (%)

Definition

The proportion of ground area in a sampling unit covered by the canopy (leaves, stems, etc.).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Establish plots within the project area and record plot locations with a GPS and/or mark the plots with corner poles to allow for revisiting over time. Estimate percent cover as defined in the project MAM Plan. Percent cover of each species or species category of interest (e.g., native, invasive, herbaceous layer) may also be collected during this time if Vegetation Species Composition is a parameter of interest, as defined in the project MAM Plan. See U.S. EPA (2011) for additional guidance on performing visual estimates of vegetation percent cover. Typical plot sizes for SAV are 0.25 to 1 m^2, herbaceous vegetation are 1 to 4 m^2 plots and for trees, 50 to 100 m^2 plots or greater, but will be project-dependent. Data collected will vary based on the project but would typically include:

- Visual assessment of total vegetation percent cover of target and undesirable species
- Percent cover by layer (e.g., herbaceous, shrubs, canopy), percent cover of native species, or percent cover of invasive species, if present.
- Percent cover of individual species, if also collecting Vegetation Species Composition.

For additional information on measuring and analyzing plant cover and composition, see Knapp (1984), Elzinga et al. (1998), Coulloudon et al. (1999), Bonham (2013), and Folse et al. (2014).

For SAV, monitoring often requires SCUBA divers to assess composition and percent cover along transects. Permanent transects are often used, with photographs along the transect line recommended for future comparisons (Kirkman 1996, Neckles et al. 2012, Short et al. 2006). For shallow water monitoring, an aquascope or ‘fish eye’ can provide an accurate means of quantifying seagrass cover and composition without physically entering the water and disturbing sediments (Jackson and Nemeth 2007, Thayer et al. 2005).

Method 2: Conduct a visual field inspection with ground photographs and/or high-resolution aerial photography to document that the performance criteria related to percent cover have been met. Note dominant species and the presence or absence of invasive species and any targeted species, along with their relative abundance. This method may be appropriate in some cases when it can be determined with high confidence based on visual inspection that the performance criteria for the project are being met. Note that it may not be appropriate to combine data collected using this method with data collected using Method 1.

Method 3: For SAV percent cover, analyze video footage of quadrats along transects to detect change in cover (McDonald et al. 2006). This method is particularly useful in fragile environments when there is a need to minimize disturbance to the site, although it may not be applicable in turbid areas.

Method 4: For areas with no or limited visibility, establish 100 m transects and use a rake to sample every 10 m and recording presence/absence. Species may also be recorded if also collecting **Vegetation Species Composition** (Johnson and Newman 2011, Rodusky et al. 2005).

Monitoring Location

Vegetation percent cover should be measured throughout the entire project footprint. For hydrologic restoration projects, transects typically go from areas of higher hydrologic influence (such as close to creeks) to areas of lower hydrologic influence (such as interior marshes). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and annually post-construction until performance criteria are met and sustained for three years. Baseline pre-construction conditions could be established based on information obtained during the E&D. Monitoring could occur pre-construction, immediately after construction (as-built), and then once a year at the peak of the growing season (mid- to late summer).

More frequent monitoring is proposed during the first five years following restoration to allow for the identification of problems and the implementation of adaptive management actions as needed. As the restoration project stabilizes, less-frequent monitoring may be appropriate. Monitoring should be conducted following disturbances to assess impacts and implement adaptive management actions, if needed.

While five years of monitoring is usually sufficient to demonstrate achievement of vegetation performance criteria for herbaceous vegetation, longer monitoring durations are generally needed for forested wetlands to demonstrate successful establishment of the plant community.

Other Potential Analyses

Vegetation volume may also be calculated by estimating the percent cover (and of each species if also interested in **Vegetation Species Composition**) and multiplying by height to provide a measure of aboveground structure. Vegetation percent cover when used in conjunction with **Vegetation Species Composition** can also be used to assess biological diversity, species richness, and evenness. Community composition metrics include (see Matthews et al., 2009; Magurran and McGill, 2011; and references therein for more information on these metrics):

- Simpson's diversity index
- Shannon-Wiener index
- Mean coefficient of conservatism

- Floristic quality index (FQI) or Forested floristic quality Index (FFQI)
- Community diversity index.

E.3.40. Vegetation Species Composition

Parameter Type: Measured or Calculated

Units: none

Definition

The collection of plant species within the vegetation. Can be expressed as list of individual species or proportion of each species within a given area.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

See Section **E.3.39 Vegetation Percent Cover or Composition** for relevant methods and references.

E.3.41. Vegetation Survival

Parameter Type: Calculated

Units: percentage (%)

Definition

Count, estimated percentage, or calculation of surviving planted individuals, used to evaluate whether additional plantings are needed to promote and establish appropriate vegetation communities.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Count the total number of planted plants, and the number of live or dead plantings within established plots. Field sampling could include quadrats, transects, or point surveys. Data collected will be used to calculate vegetation survival.

See Section E.9.31 Vegetation Percent Cover and Composition for additional methods and references.

Method 2: Conduct a visual field inspection with ground photographs and/or high-resolution aerial photography to document that performance criteria related to percent cover have been met. Note dominant species and the presence or absence of invasive species and any targeted species, along with their relative abundance. This method may be appropriate in some cases when it can be determined with high confidence based on visual inspection that the performance criteria for the project are being met. Note that it may not be appropriate to combine data collected using this method with data collected using Method 1.

Monitoring Location

Plots could be distributed over the entire planted area.

Guidance on Frequency and Duration

For projects with a planting component, survival/mortality of marsh grasses may be assessed for at least one full year following the initial installation. Monitoring could occur twice during the first growing season after planting (recommend 30 days and 90 days post-planting) and again one year after planting, while seasonal sampling may be needed for species that exhibit high inter- and intra-annual variance due to seasonally changing environmental conditions. Additional monitoring may be needed if replanting is required. Survival/mortality of planted trees (e.g., mangroves) should be monitored for three years or longer (Lewis, 2005, 2009). Once the planted vegetation has become established, vegetation monitoring could focus on cover and composition (see Section E.9.31 Vegetation Percent Cover and Composition).

E.3.42. Visitor Satisfaction

Parameter Type: Qualitative

Units: none

Definition

Visitor behavior in, and satisfaction with, project areas.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Enhance Recreational Experiences
- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

Social indicator monitoring systems can be used to measure visitor satisfaction with restoration project areas, and monitor response behavior toward restoration activities. Surveys may include information on visitor satisfaction depending on project objectives (Moscardo and Orsmby, 2004).

Monitoring Location

Selection of respondents should use a systematic random sampling procedure within the units chosen for study. This is intended to ensure that the respondents within a location have an equal probability of being asked to participate, and the choice of target respondents is determined by the sampling system and not by the interviewers. An offsite regional telephone survey, a key locations survey, or an onsite survey may be used (Moscardo and Orsmby, 2004).

Guidance on Frequency and Duration

The survey could be conducted pre- and post-implementation or more often depending on the design of the project. Monitoring should aim to cover different seasons and include weekdays, weekends, and holidays.

Other Potential Analyses

Visitor satisfaction and behavior may be influenced by an array of outside drivers. Consideration of these factors during the survey can help interpret survey responses:

- Visitor characteristics, especially motives and levels of experience with both the places visited and activities participated in, and cultural background
- Visitors' perceptions of the quality of the physical environment, especially judgments of scenic beauty and human impacts on the setting
- Interactions with other people, including tour and park staff
- Effectiveness of programs or activities available
- Perceived quality of the service provided
- Perceived quality of the facilities and built infrastructure.

Visitor satisfaction surveys could also be designed to collect information on visitor impact on acquired lands for protection or restoration. Sampling strategies for determination of impacts within visitor nodes (e.g., sites) and linkages (e.g., trails) are well-developed and have been extensively reviewed [e.g., Hammitt and Cole (1998), Monz (2000), and others] and applied (Monz and Leung, 2006). The National Park Service (NPS) Visitor Impact Phase 1 and 2 Reports can provide additional guidance on monitoring methods (Monz and Leung, 2003a, 2003b). This information could also be used to inform potential wildlife behavior responses resulting from visitor use.

E.3.43. Visitor Use/Access

Parameter Type: Measured

Units: none (count) or number of visitors per unit of time (day, month, year, etc.)

Definition

Public access to the natural resources or project area and/or the number of visitors using the recreational area.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches

Potential Methodologies

Method 1: Direct observations, including staff observations on-site using hand counters or recording forms, camera recordings, remote sensing, aerial surveys.

Method 2: On-site counters, including devices or sensors used to generate counts, such as pressure pads, turnstiles, light beams, active or passive infra-red, or acoustic data loggers.

Method 3: Review registrations, including voluntary registrations or permit records, such as track registers, site visitor books, registration or entrance fees, or trip bookings.

Method 4: Inferred counts, including indirect counts, such as interviews or counts of elements linked to visitor use such as car park counts, litter, or trail deterioration.

For guidance and methodologies of how to measure visitor use/access, see Cessford and Muhar (2003), Moscardo and Ormsby (2004), FWS (2005), Leggett (2015, 2017), and Horsch et al. (2017).

Monitoring Location

Visitor use patterns may vary depending on the activity, the number of individuals engaged, and the areas these activities take place. As a result, counting locations should be identified at strategic locations that are representative of the whole recreational use area. Priority sites may include:

- Places of specific management concern
- Places where specific management actions are under consideration
- Places that are considered representative of broader management issues
- Access points such as entrances to public areas/parks
- Locations that represent the diversity of activities such as along beaches, swimming areas, etc. (particularly if completing a survey).

Sampling locations could include a mixture of permanent sites, rotating sites according to needs, and flexible sites identified on case-by-case locations for short-term needs (Cessford and Muhar, 2003).

Guidance on Frequency and Duration

Data collection is proposed pre-implementation, immediately after implementation (as-built), and at an appropriate frequency and duration relevant to project-specific conditions. The variety of monitoring options to meet differing needs and site situations will impact the timing and frequency of monitoring. Generally, counts should be representative of as full a range of site conditions as possible, taking into account varying times of the day, week, or year; seasonal variations; weather variation; and special use occasions such as holidays or community events. Counts may also be established as a continuous and long-term process at a site, depending on the method utilized.

Other Potential Analyses

Visitor use counts should consider the number of days the acquired land is accessible/closed in order to accurately interpret changes in visitor use patterns. Project managers should also track the number of days the area is open or closed and the reasons for closure (e.g., beach closures due to water quality concern). See **Section E.3.24 Right of Entry**.

E.3.44. Water Level

Parameter Type: Measured or Modeled

Units: meters (m)

Definition

Elevation of the water surface, measured or modeled, relative to a geodetic or tidal datum. Water level measurements or estimates can be used to characterize the flooding regimes across the range of habitats restored, including the depth, frequency, and duration of flooding on the marsh surface and within any channels. When channels are an important feature of the project design, water level in the channel(s) should be measured or calculated at mean low tide to evaluate access to marsh surface for marine organisms.

Restoration Approach

- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

The elevations of water level recorders and/or staff gauges should be determined and referenced to an appropriate vertical datum to obtain a relationship to marsh surface elevation. Water-level data can also be used to calculate the frequency and duration of flooding at specific locations within the restored area.

Method 1: Deploy multiple water level recorders to collect continuous measurements across the restored habitats.

Method 2: Collect elevation/bathymetry data (see **Section E.3.8 Elevation**) and install a single water level recorder to monitor the water surface elevation at one point, and calculate water levels across the marsh surface based on the elevation data. Assumes hydrologic connectivity is uniform across project area.

Method 3: Collect elevation/bathymetry data (see **Section E.3.8 Elevation**) and utilize data from an existing permanently deployed water level recorder(s) within or near the project site to calculate water levels across the marsh surface based on the elevation data.

Method 4: Install staff gauges at specific locations and make measurements by visual inspection, in combination with installation of one or more continuous water level recorders.

Method 5: To evaluate water level in narrow channels, take in-situ measurements using water level loggers along the created channel during mean low tide, including the channel openings or on either side of culverts, or other features that could constrict flow.

See Neckles and Dionne (2000), Steyer and Llewellyn (2000), and Sauer and Turnipseed (2010) for more information on potential methodologies.

Monitoring Location

Spatial distribution of water level recorders will depend on the project type and the hydrologic characteristics of the project area. Potential locations for water level recorders include near the source of restored hydrologic flows, within the project boundary, near the edge of the influenced area, and outside the influenced area, if adjacent to other habitats. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

Frequency and duration will be project-dependent based on objectives and the need for corrective actions, but in general monitoring is proposed pre-construction, immediately after construction (as-built), and annually post-construction.

If continuous recorders are used, data could be collected for two weeks or longer during a sampling event to capture one lunar cycle of spring and neap tides, but longer time periods (e.g., three–four months or year-round) are preferred. Frequency of measurement from continuous recorders (tide gauges and water level loggers) can vary from every five minutes to every hour, and could be selected based on the resolution needed to meet project objectives.

If discrete measurements are taken, the water level should be assessed over several tidal cycles.

For projects with riverine influence, sampling events could be designed to capture both high- and low-flow events. If continuous recorders are used, data could be collected for at least two weeks during high- and low-water conditions, but year-round data collection for one or more years is preferred to fully capture seasonal variability in the water level. If discrete measurements are taken, the water level should be assessed over a few weeks during both high- and low-flow conditions.

Other Potential Analyses

Bathymetric profile change, sediment movement, hydrologic connectivity, saturation of root zone, accessibility by fish or waterbirds, and meteorological events and conditions.

E.3.45. Waves

Parameter Type: Measured or Modeled

Units: wave heights should be measured in meters (m), directions should use compass headings, wave period should be measured in seconds (s).

Restoration Approach

- Restore and Enhance Submerged Aquatic Vegetation

Potential Methodologies

Wave generation in inland or sheltered coastal water bodies are influenced by wind speed and duration and available fetch such that heights and periods are generally less than those observed on open ocean coastlines (Miller et al. 2015). Instrumentation used in monitoring waves should thus be tailored to those capable of capturing these conditions.

Method 1: Field based measurements of wave heights, direction, and period can be collected using a number of instruments, depending on application, and include pressure gauges, accelerometer buoy, acoustic wave gauge, acoustic doppler current profilers, wave wires, and remote sensing techniques (Miller et al. 2015; Pandian et al. 2010)

Method 2: In conjunction with field data collection described in Method 1, wave models may also be used to evaluate wave conditions around the entire project site (e.g., Coast & Harbor Engineering 2015; Thomas and Dwarakish 2015). The use of models will also require calibration and validation procedures to ensure model results accurately reproduce the physical measurements (Miller et al. 2015).

Monitoring Location

The monitoring location will depend on the methods selected, as some deployments require certain depths or to be placed in an array, for example. Wave information should be collected on either side of constructed feature, if used, so that comparisons of wave heights can be made to determine whether performance criteria have been met. In modeling applications, monitoring locations may extend beyond the immediate project site in order to capture necessary boundary conditions.

Guidance on Frequency and Duration

The appropriate sampling interval and duration should be tied to the conditions the monitoring is intended to sample. Changes in weather patterns (especially winds) will affect wave conditions at a local site so monitoring frequency and duration may consider capturing the range of conditions most frequently experienced at the project site. Rapid response monitoring to capture extreme weather events (e.g., hurricanes) may also be considered for some projects.

For living shoreline projects that are intended to reduce wave heights, monitoring may be needed through several growing seasons of the living shoreline in order to achieve targeted wave reduction benefits.

Additional monitoring may also be needed if changes in the conformation of natural or constructed features that reduce wave energy occur. For example, a breakwater may partially collapse if undercut by scouring, resulting in changes in wave energy around the structure. This monitoring data could be used to inform decisions regarding potential corrective actions.

Other Potential Analyses

Wave energy, maximum wave height, wave attenuation, and other commonly used statistics can be calculated from measurements of wave heights, periods, and direction.

E.3.46. Wetland Edge

Parameter Type: Measured or Calculated

Units: positions should be georeferenced (latitude, longitude, elevation); relative differences between positions should be measured using meters (m) or kilometers (km); ratios are unitless

Definition

The boundary between the vegetated wetland surface and non-wetland areas, including water features such as tidal creeks, ponds, unvegetated bottom, or other open water areas.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

A number of different methods can be used to approximate the amount of wetland edge. Note that not all of these methods measure the same thing and they, therefore, may not produce comparable data.

Method 1: The linear distance of wetland edge and the total area of marsh habitat can be calculated based on imagery collected by airplane, helicopter, or UAS; high-resolution satellite imagery; or other appropriate remote sensing platform. Imagery used to map wetland boundaries should include true color and infrared bands, and have a spatial resolution of 1 m or less. Imagery acquired should be orthorectified imagery (i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation). For guidance on collecting aerial orthoimagery, please see Rufe (2014). The boundaries of wetland habitats and water features can be delineated and the linear length of wetland edge habitat can be measured using appropriate spatial analysis software. The ratio of linear wetland edge to total area of interior wetland habitat can then be calculated. For additional information and references related to mapping wetland boundaries based on remote sensing data, see Section E.9.1 Area.

Method 2: Conduct a field survey to map the boundaries of vegetated wetland habitat and water features within the project area. The length of the wetland edge, the total area of wetland habitat, and the ratio of marsh edge to interior marsh habitat can then be calculated. For additional information and references related to conducting ground surveys of wetland boundaries, see Section E.9.1 Area.

Method 3: Ratio of wetland habitat to open water (sometimes referred to as land:water ratio) is also used as a proxy for edge in habitat suitability index models. For additional methods on mapping wetlands, see Section E.9.1 Area. Note that this method does not result in an edge-to-interior ratio, and cannot be directly compared to data collected using Methods 1 and 2.

Method 4: A number of different fragmentation indices have been developed to quantitatively describe the configuration of wetland and water. See Suir et al. (2013) and Couvillion et al. (2016) for examples.

Monitoring Location

The entire project footprint. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

Monitoring is recommended immediately following construction (as-built) with one–two additional monitoring events, or more over the monitoring period. Funding for one additional contingency monitoring event could be included in the monitoring budget, which could be implemented as needed to account for storm impacts.

Other Potential Analyses

In some cases, this parameter can also be used as a proxy for landscape fragmentation.

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