Appendix D – Monitoring and Adaptive Management (MAM) Plan

MONITORING AND ADAPTIVE MANAGEMENT PLAN FOR *DEEPWATER HORIZON* NRDA PROJECT:

LARGE-SCALE MARSH CREATION – UPPER BARATARIA COMPONENT Version 2.0

1.0 Introduction

The Deepwater Horizon (DWH) Louisiana Trustee Implementation Group (LA TIG)[1] developed this monitoring and adaptive management plan (MAM plan) for the Large-scale Marsh Creation – Upper Barataria Component (LSMC-UBC) Project (the Project), which represents one of three projects selected from within the broader Strategic Restoration Plan and Environmental Assessment #3: Restoration of Wetlands, Coastal, and Nearshore Habitats in the Barataria Basin, Louisiana (SRP/EA) in March 2018. The objective of the Project is the creation of approximately 1,183 acres (as-designed) of intertidal marsh and constructed water features (ponds and creeks) that would restore interspersed and ecologically connected coastal habitats in the Upper Barataria Basin. The purpose of this MAM plan is to identify monitoring activities that will be conducted to evaluate and document restoration effectiveness. This MAM plan includes performance criteria for determining whether restoration success has been achieved, or whether interim corrective action is needed (15 Code of Federal Regulations [CFR] 990.55(b)(1)(vii)). Where applicable, the MAM plan identifies key sources of uncertainty and incorporates monitoring data and decision points that address these uncertainties. It also establishes a decision-making process for incorporating adjustments where needed. There are three primary purposes for MAM plans:

1. Identify and document how restoration managers will measure and track progress toward achieving restoration goals and objectives.
2. Before a project begins, increase the likelihood of successful implementation through identification of potential corrective actions that could be undertaken if the Project does not proceed as expected.
3. In a systematic way, ensure the capture of lessons learned or new information acquired that can be incorporated into future project selection, design, and implementation.

The MAM plan is a living document and may be updated as needed to reflect changing conditions and/or new information. For example, the MAM plan may need to be revised should the Project design change,

[1] The LA TIG includes the following members: Louisiana State Trustees include the Louisiana Coastal Protection and Restoration Authority (CPRA); Louisiana Department of Environmental Quality (LDEQ); Louisiana Department of Wildlife and Fisheries (LDWF); Louisiana Department of Natural Resources (LDNR); and Louisiana Oil Spill Coordinator's Office. Federal Trustees include Department of the Interior (DOI), the National Oceanic and Atmospheric Administration (NOAA), U.S. Environmental Protection Agency (USEPA), and U.S. Department of Agriculture (USDA).

if initial data analysis indicates that the sampling design requires adjustment, or if any existing uncertainties are resolved or new uncertainties are identified during project implementation and monitoring. Any future revisions to the MAM plan will be made available through the Restoration Portal (https://www.diver.orr.noaa.gov/web/guest/home) and accessible through the DWH Natural Resource Damage Assessment (NRDA) Trustees' website (http://www.gulfspillrestoration.noaa.gov).

1.1 Project Overview

This Project is being implemented as restoration for the DWH oil spill Natural Resource Damage Assessment (NRDA), consistent with the Programmatic Damage Assessment and Restoration Plan (PDARP)/Programmatic Environmental Impact Statement (PEIS; DWH Trustees, 2016).

- **Programmatic Goal:** Restore and Conserve Habitat
- **Restoration Type:** Wetlands, Coastal, and Nearshore Habitats Restoration
- **Restoration Approach:** Create, restore, and enhance coastal wetlands.
- **Restoration Technique:** Create or enhance coastal wetlands through placement of dredged material.
- **TIG:** LA TIG
- **Restoration Plan:** *Strategic Restoration Plan and Environmental Assessment (RP/EA) #3.3 Large-Scale Barataria Marsh Creation: Upper Barataria Component (BA-207)*

This restoration Project is being implemented within the Upper Barataria Basin (Figure 1-1**Error! Reference source not found.**). Restoration activities involve:

- Excavation of up to 10.2 million cubic yards (MCY) of sediment from borrow areas in the Mississippi River, pipeline construction, and transport of the material along the 13.3-mile Long-Distance Sediment Pipeline access corridor;
- Construction of approximately 46,635 (as-designed) linear feet of earthen containment dikes using onsite (in-situ) borrow material to contain the created marsh platform;
- Discharge of borrow material into Marsh Creation Areas (MCAs) to create approximately 1,183 acres (as-designed), including roughly 132 acres of water features; and
- Gapping of earthen containment dikes to facilitate water exchange between MCAs and the tidal pond Project feature.

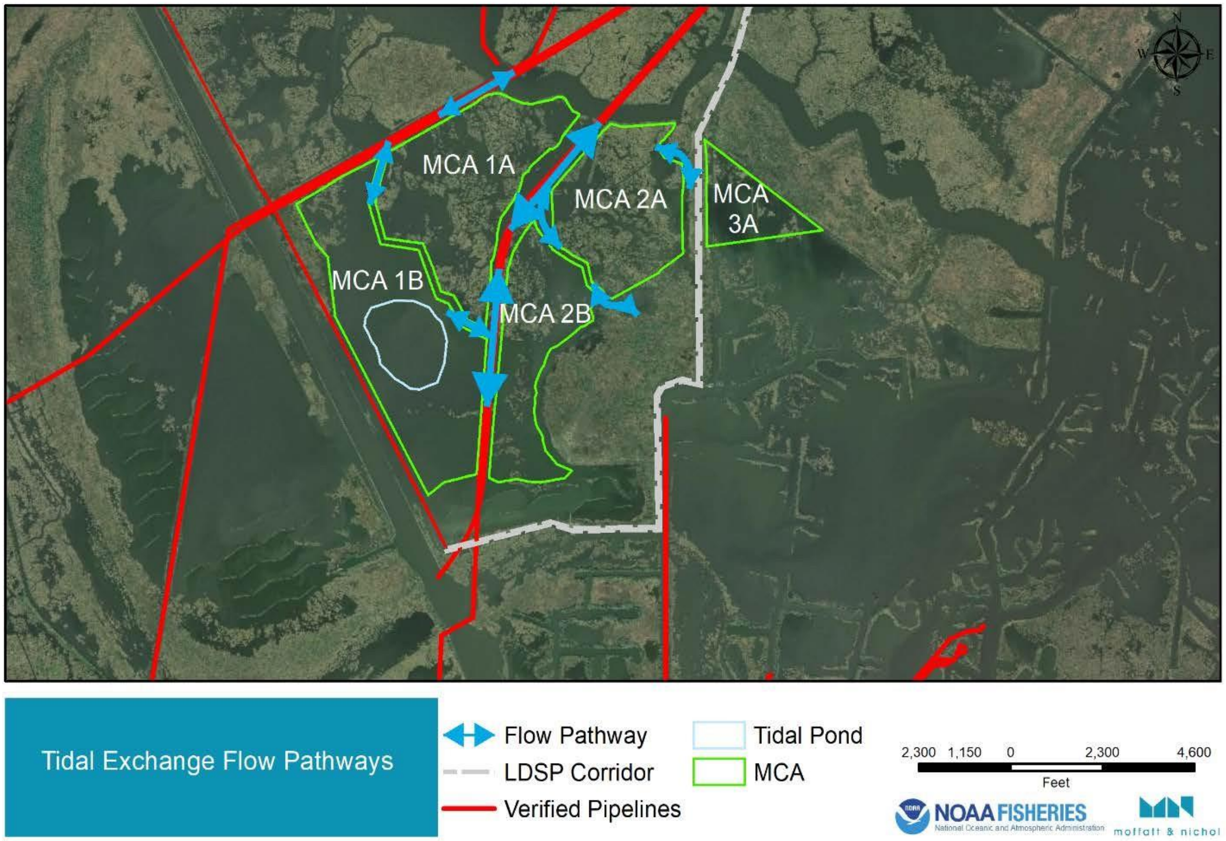

Figure 1-1. Project Area indicating locations of marsh creation areas (MCAs), flow pathways, approximate location of tidal pond, existing and verified pipelines, and the Long-Distance Sediment Pipeline (LDSP) corridor.

This Project is intended to restore habitats and resources of the same type injured as a result of the DWH oil spill, which included significant injuries to Louisiana's coastal marshes. Shrimps, crabs, fishes, oysters, birds, sea turtles, and marine mammals in the Barataria Basin depend on these marshes for one or more of their life stages (DWH Trustees, 2016). These injuries ranged from a threefold increase in coastal erosion in heavily oiled marshes, to decreased growth rates and mortality in some species. Additional ecosystem services are currently provided by these marshes, including protecting coastal areas from storm flooding and erosion, driving coastal food webs and fisheries, cycling nutrients, storing carbon, and even self-maintenance of the marshes (Barbier et al., 2011; NASM, 2017).

The implementing agency for the Project is the National Oceanic and Atmospheric Administration (NOAA).

1.2 Restoration Type Goals and Project Restoration Objectives

1.2.1 Restoration Type Goals

The overall programmatic goal for this project is to Restore and Conserve Habitat. The Restoration Type is Wetlands, Coastal, and Nearshore Habitats Restoration. The goals of this Restoration Type, outlined in Section 5.5.2.1 of the PDARP/PEIS are to (DWH Trustees, 2016):

- Restore a variety of interspersed and ecologically connected coastal habitats in each of the five Gulf states to maintain ecosystem diversity, with particular focus on maximizing ecological functions for the range of resources injured by the spill, such as oysters, estuarine-dependent fish species, birds, marine mammals, and nearshore benthic communities.
- Restore for injuries to habitats in the geographic areas where the injuries occurred, while considering approaches that provide resiliency and sustainability.
- While acknowledging the existing distribution of habitats throughout the Gulf of Mexico, restore habitats in appropriate combinations for any given geographic area. Consider design factors, such as connectivity, size, and distance between projects, to address injuries to the associated living coastal and marine resources and restore the ecological functions provided by those habitats.

1.2.2 Project Restoration Objectives

The primary goal of the Project is the creation and/or restoration of approximately 1,183 acres (as-designed) of intertidal marsh and constructed water features that would restore interspersed and ecologically connected coastal habitats in the Upper Barataria Basin (refer to Section 3 of the Draft RP/EA #3.3 for greater detail about the Project; LATIG, 2020). This project will restore tidal intermediate and brackish marshes along the degraded Barataria Land Bridge. The Land Bridge previously prevented saltwater intrusion into the Upper Barataria Basin from the Lower Barataria Basin, supported freshwater and intermediate tidal marsh habitat, and reduced the adverse impacts of coastal flooding and erosion. The Project will create marsh that will compensate, in part, for marsh losses in the Barataria Basin that resulted from the DWH oil spill. Specific project restoration objectives are identified below:

1. **Marsh creation:** Create approximately 1,183 acres (per final approved construction design) of intertidal marshes and water features in the Upper Barataria Basin. The Project is located south of The Pen in Jefferson Parish, Louisiana, and includes a 20-year Project monitoring life following construction. Using land loss rates and land:water ratios applied to the adjacent Bayou Dupont Ridge Creation and Marsh Restoration (BA-48) project, and assuming similar rates of ongoing subsidence and erosion over the Project life, the created marsh under the preferred alternative would have a net gain of 826 acres after 20 years (Donna Rogers, pers.comm.).
2. **Basin Connectivity:** Create and/or restore interspersed and ecologically connected marshes in the Upper Barataria Basin by constructing flow pathways between MCAs that will ensure hydrologic and biologic connection among MCAs.
3. **Productivity:** Increase vegetation and nekton productivity in the Project Area. Vegetation cover will be used to provide a measure of primary productivity, as indicated by vegetation community composition and vegetation vigor for the Project Area over time and for comparison to the reference site. Target nekton species standing stock (density, biomass) and other analytical approaches will provide a measure of secondary productivity in the Project Area compared to the reference site over time.

1.2.3 Learning Goals

In addition to goals and objectives, this Project will also support learning goals related to whether ecosystem services are enhanced by hydrologic and biological connectivity and by marsh edge type (e.g., unconfined and diked marsh edges, both of which would be created as part of the MCA construction). Learning goals are discussed in Section 5.0.

1.3 Conceptual Setting

The purpose of the conceptual setting within the MAM plan is to identify, document, and communicate interactions and linkages among system components in the Project Area and to understand how the system works and may be affected by the proposed restoration (see *MAM Manual*; DWH NRDA Trustees, 2021). The primary action is the placement of dredged material into MCAs to target elevations that are adequate to support colonization and establishment of intermediate and brackish marsh vegetation (Table 1-1).

Table 1-1. Conceptual Model for the Proposed Project.

Restoration Action	Design	Interim	Restoration Goal
Place hydraulically dredged sediments along existing subtidal areas to create a marsh platform	1,183 acres of marsh platform and water features	• Fill sediments compact and dewater. • Marsh vegetation community becomes established.	Intermediate and brackish marsh habitat is restored and provides ecological services that contribute to making the environment and the public whole for spill-related injuries to these habitats

Interactions and linkages among system components in the Project Area are critical to the marsh creation goal. A study of marsh loss in Louisiana by Schoolmaster (2018) indicated that “vegetation cover in prior year was the best single predictor of subsequent loss … followed by changes in percent land and tidal amplitude.” Other outside drivers of marshes, marsh processes, and stressors have been reviewed and described by numerous authors (e.g., Cahoon et al., 2009; Kneib et al., 2008; Schoolmaster et al., 2018) and include, but are not limited to, those listed below.

- Hydrologic regime
- Precipitation
- Subsidence
- Sea level rise
- Sediment accretion/erosion
- Invasive species
- Physical impacts (e.g., oil and gas infrastructure)
- Freshwater inflow
- Sediment input/load
- Nutrients
- Storms/wave energy
- Grazing/herbivory by nutria
- Adjacent land cover/landforms
- Chemical impacts (e.g., oil spills)

Implementation of the Project is designed to influence habitat, specifically marsh biodiversity, as well as productivity. Relationships between and among ecological components that are influenced by the Project, and/or influence the outcomes of the Project, make up the linkages between and among marsh physical and process components. Some of these linkages are listed below.

- Tides and freshwater flows at the terrestrial and aquatic interface
- Aquatic/terrestrial interface and nutrients, pollutants, and sediments
- Aquatic/terrestrial animals and marsh structure and processes, and nutrients, pollutants, and sediments

- Tides and water characteristics (e.g., salinity), inundation, nekton, and imported and exported productivity
- Nekton and nutrients, pollutants, and sediments, marsh structure and processes
- Marsh structure and processes and nutrients, pollutants, sediments, water characteristics, and productivity
- Erosion effects on production, decomposition, and accretion
- Accretion effects on compaction and subsidence, elevation, species biodiversity and productivity
- Compaction and subsidence effects on erosion and desiccation
- Production, biomass and decomposition effects on animal and emergent plant biodiversity and architecture.
- Marsh structure on water quality and characteristics, elevation, inundation, productivity, biodiversity

A simple diagrammatic conceptual model of drivers (white boxes), ecological factors or effects (tan boxes), and linkages (arrows) is provided in Figure 1-2. The most direct or strongest linkages are between ecosystem components, including those between ecosystem processes and the largely external environmental drivers, such as climatic, hydrogeomorphic, and anthropogenic drivers (Table 1-2). The condition of the overall system can be assessed by monitoring factors and functions that contribute to ecosystem services, such as water depth and duration, marsh morphology, and primary and secondary productivity.

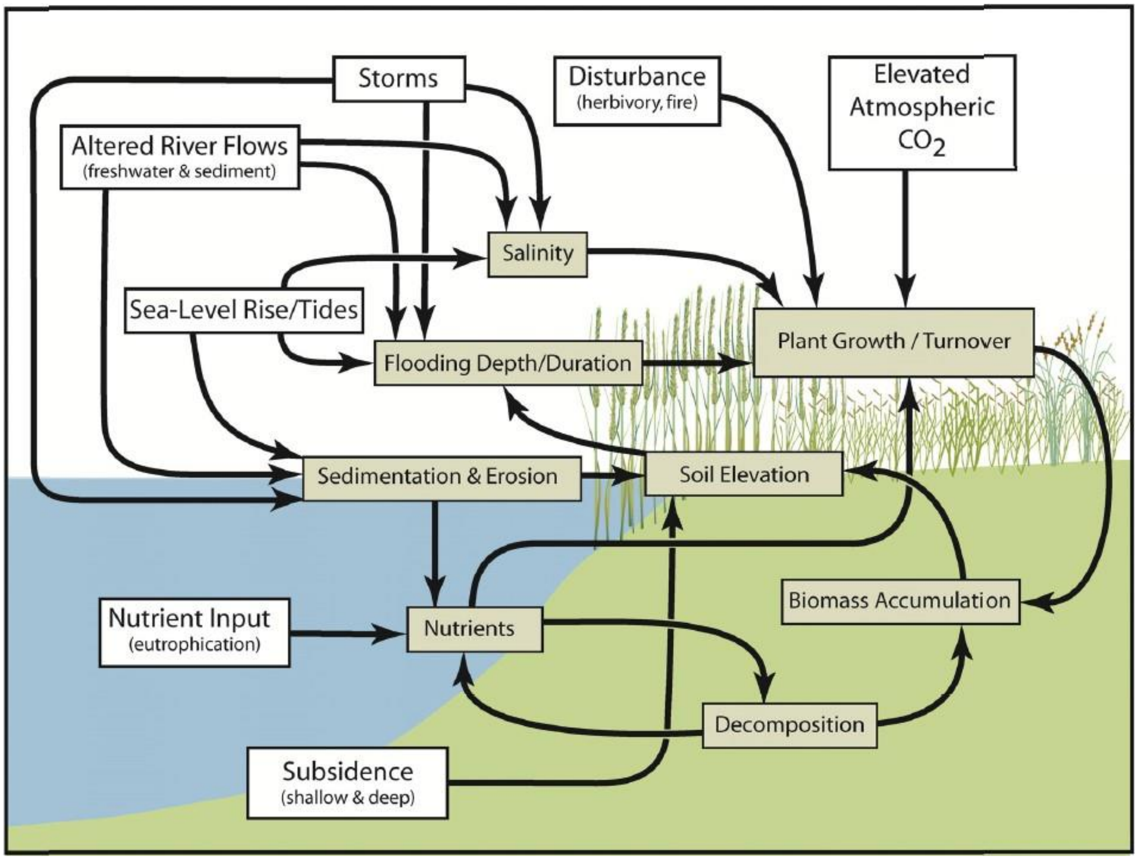

Figure 1-2. Conceptual model of a tidal marsh with substantial tidal inputs of sediment as influenced by environmental drivers (white boxes), factors (tan boxes) affecting accretion processes, and linkages (arrows). From Cahoon et al. (2009).

Table 1-2. Conceptual ecological model (modified after Allen et al., 2018).

Environmental Drivers	**Climatic** Carbon dioxide, sea level rise (SLR), temperature, precipitation	**Hydrogeomorphic** Hydrology, current and wave energy, compaction, faulting, tidal inundation	**Anthropogenic** Land use, pollution, restoration and management, hydrologic modification
Major Ecological Factors	**Abiotic** Hydrology (flood depth, duration, frequency), water quality, soils	**Ecosystem Structure** Marsh morphology (land fragmentation), plant and microbial community structure	**Ecosystem Function** Elevation change (submergent vulnerability), primary and secondary production, decomposition, biogeochemical cycling
Major Ecosystem Services	**Supporting** Habitat, sediment stability, marsh dispersion	**Regulating** Coastal protection (e.g., erosion), water quality, carbon sequestration	**Cultural** Aesthetic, recreation opportunities, commercial and subsistence fishing

1.4 Sources of Uncertainty

Potential uncertainties are defined as those that may affect the ability to achieve stated project restoration objective(s). Potential uncertainties associated with the Project are listed in Table 1-3. Monitoring activities can then be selected and implemented to inform these uncertainties and to select appropriate corrective actions in the event the Project is not meeting its performance criteria.

Table 1-3. Sources of project uncertainty and potential impacts.

Uncertainty	Potential Impact
Sea-level rise (SLR)	SLR uncertainty can result in poor hydrologic predictions and site selection, which may then result in Project failure due to too much or too little inundation.
Storm events or other large disturbances	Storm events after the Project is completed that are strong enough to breach earthen containment dikes can result in loss of sediment from MCAs, and ultimately Project failure or reduced performance.
Mid-Barataria Sediment Diversion (MBSD)	Implementation of the proposed MBSD and the subsequent sediment, freshwater, and nutrient inputs into the MCAs will likely affect accretion and primary productivity of the Project Area.
Invasive species	Targeted vegetation planting is not planned for the Project Area. Without targeted vegetation plantings, MCAs will quickly be colonized by surrounding vegetation, including potential invasive species that may outcompete native species and reduce biodiversity and the value of the habitat for fish and wildlife. The value of the invasive Eurasian haplotype of *Phragmites* (the haplotype which is expected to become dominant) as habitat and substrate stabilization would outweigh its adverse impacts.
Hydrology (e.g., depth, duration, flood frequency) for sustainable marsh	Hydrologic conditions will vary with rainfall, tidal fluctuations, freshwater diversion operations, and storm events, and may be as unpredictable as storm events.
Vegetation colonization and establishment	Without targeted planting, vegetation percent cover is expected to be the same as undisturbed marshes after about 2 years, although species diversity may be lower, based on recent nearby studies (Howard et al., 2019).
Land use changes and/or new barriers	Changes can alter hydrology, sediment inputs, and/or water quality.
Target elevations reached	Marsh platform will be low enough to receive tidal inundation and high enough to be exposed at low tide once sediments settle. If elevations are too high, it may take longer for marsh vegetation to establish and reach functional equivalency with the reference marsh (Stagg and Mendelssohn, 2011).
Timely Project completion	Important for availability of borrow material in advance of potential MBSD operation

2.0 Project Monitoring

Successful implementation of the Project will be measured by assessing the performance of the restored intermediate and brackish marsh habitat. Performance will be evaluated using both qualitative and quantitative measures related to the Project goals and objectives.

Information about each monitoring parameter is provided below, organized by objective (Table 2-1). For each of the identified monitoring parameters, information is provided on the intended purpose (e.g., Performance Monitoring to assess progress toward meeting one or more of the restoration objectives and/or support adaptive management, including corrective actions; or Context Monitoring (i.e., labeled as 'additional monitoring' in DIVER) for which data will be collected, but which at this time are not being identified as representing overt triggers for adaptive management; metric and data output, timing, frequency, and duration; sample size/sites; performance criteria; and potential corrective actions. Table 2-1 does not include all possible options for corrective actions; rather, it includes a list of potential actions for each individual parameter to be considered if the Project is not performing as expected once implemented. Additional monitoring parameters may be implemented to characterize the Project's effectiveness more fully.

Coastwide Reference Monitoring System (CRMS) station 0248 is identified as the primary reference site, however additional reference CRMS stations may be included for reporting purposes to better reflect the dynamics and trends of the broader ecosystem.

Target nekton species identified in this monitoring plan include: killifishes (as a guild consisting of multiple species inclusive of Rainwater killifish *[Lucania parva*], Gulf killifish *[Fundulus grandis*], Longnose killifish [*Fundulus similis*], Diamond killifish [*Fundulus xenicus*], Bayou killifish [*Fundulus pulvereus*], Least killifish [*Heterandria formosa*], Golden topminnow [*Fundulus chrysotus*], and Saltmarsh topminnow [*Fundulus jenkinsi*], Sailfin molly *[Poecilia latipinna*], and Sheepshead minnow [*Cyprinodon variegatus*]), blue crab (*Callinectes sapidus*), white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), other shrimp (i.e., grass shrimps and other members of infraorder Caridea), and red drum (*Sciaenops ocellatus*).

The proposed data collection and analysis methods for each monitoring parameter are included in Appendix A and will be updated as necessary.

Table 2-1. Project Objectives, Monitoring Purpose (i.e., Performance or Contextual data collection activities), Performance Criteria, and Potential Corrective Actions. Detailed analytical methods and protocols are provided in Appendix A.

Objective #1: Marsh creation: Create approximately 1,183 acres (per final approved construction design) intertidal marshes in the Upper Barataria Basin.						
Parameter	**Purpose**	**Metric & Data Output**	**Timing, Frequency, and Duration of Data Collection**	**Sample Size/Sites**	**Performance Criteria**	**Potential Corrective Actions**
#1 Spatial extent (acres) of created tidal marsh platform	**Performance:** This parameter will measure the acres of tidal marsh platform through delineation of land:water. Data from these metrics also inform marsh fragmentation and water level parameters of the created marsh	**Total land area** Output: JPG map, GIS raster files of delineated land:water, proportion [%] and area [acres] of land and water	Aerial imagery will be acquired, delineated, and analyzed for land:water and land area change before fill placement (2021) and after fill placement (2024) is completed as part of the construction. Further data collection will occur three additional times throughout the 20-year post construction monitoring periods as part of the coastwide aerial photo collection in the fall/winter. Additional aerial imagery may need to be collected following major events such as tropical storms, or changes to the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) program collection of coastwide imagery. Pre-construction spatial products from 2021 data acquisition will be delivered in 2024, then spatial products will be completed two years following each of the subsequent data acquisition events as follows. Acquisition date (product completion date): 2021(2024), 2024(2026), 2027(2029), 2033(2035), 2039(2041).	The spatial extent will capture the Project Area	The total created wetland (marsh, created water features) built in the Project Area is equal to or greater than 1,183 acres (per final approved construction design).	Contractor will build to design and resurvey to confirm. Project will not be accepted if it is not built to design specifications
		Land area change Output: Relative change in land area over time compared to total as-built land area (% $year^{-1}$)		The spatial extent will capture the Project Area	The total marsh platform area within the Project Area 20 years post-construction does not exhibit a higher rate of proportional land area loss than the reference marsh at CRMS0248.	Assess whether accelerated land loss is related absence of flood tolerant species. Plant species that can tolerate deeper water
		Marsh area elevation Output: Elevation at set points (ft NAVD88)	Four topographic surveys will be acquired: shortly after fill placement is completed (Year 2023, as-builts, by construction contractor), four years after construction (2027), and two more times over the Project life (once in ~2033 and once in ~2042) during the same year as aerial imagery, if possible. Settlement plate elevations will be surveyed during topographic surveys.	As-built topographic surveys will be completed for each MCA of the Project Area in Year 0 along transects spaced at ~500 ft. Additional surveys will follow different spatial alignments to intersect with vegetation cover monitoring stations (see Parameter #5).	The mean constructed marsh elevation for each MCA is + 3.0 - 0.5 ft NAVD88 immediately following construction (as-built surveys)	Contractor will build to design and resurvey to confirm. Project acceptance will be based upon surveys, acknowledging that some design specifications may change during construction.
		Marsh area settlement Output: Elevation at settlement plates (NAVD88). Used to calculate the rate of settlement under the fill material (ft $year^{-1}$)		A total of 33 settlement plates were installed in the MCAs for monitoring. The initial survey of settlement plates will be conducted post-construction by the construction contractor.	The constructed marsh for each MCA maintains a mean elevation of +1 ft NAVD88 at the end of the Project life	Identify errors in assumptions to inform future restoration planning. Identify causes of differential settlement (e.g., interior borrow, fill depth)
#2 Marsh fragmentation	**Context:** This parameter will measure the fragmentation of the marsh platform and evaluate its sustainability through the Project's 20-year life	**Marsh fragmentation** Output: FRAGSTAT statistics for project Area	A suite of fragmentation or "clumping" indices (including, but not limited to, edge density, patch density, and aggregation) will be calculated for imagery collected in 2021 (preconstruction), Year 1 (2024), and three more times over the Project life to align with collection of aerial imagery and land:water delineation efforts. If the Project marsh converts to freshwater marsh, then calculations will need to be based on aerial imagery collected during the spring or summer instead of fall/winter. Pre-construction spatial products from 2021 data acquisition will be delivered in 2024, then spatial products will be completed two years following each of the subsequent data acquisition events as follows. Acquisition date (product completion date): 2021(2024), 2024(2026), 2027(2029), 2033(2035), 2039(2041).	The spatial extent will capture the Project Area	NA (Context variable)	NA
Objective #2: Basin Connectivity: The Project will create tidal channels, tidal pond, and marsh that are hydrologically connected to the larger Barataria Basin ecosystem and new marsh sub habitats that are utilized by the target nekton species.						

#3 Water levels & salinity	**Context:** Water level measurements will be used to evaluate depth of water and tidal influence in the MCAs	**Tidal signal** Output: Water level (units: ft) (hourly) from CRMS0248	Water level data collected from reference site (CRMS0248) for one year pre-construction (Jan 2020-Jan 2021) and continuously for Project life (20 years); evaluation is dependent on publicly available CRMS water level data from CRMS0248	Data collected from a single station, the nearest CRMS station, CRMS0248, as representative of the Project Area	NA (Context variable)	NA
	Performance: Modeled inundation will be used to evaluate how often the constructed marsh is flooded and to what extent the area is flooded	**Modeled inundation** Output: Water level (units: ft) relative to the average Project Area marsh elevation; % time (hours per year) the marsh platform is above and below water level	Modeled inundation of the Project Area marsh platform will be calculated on an annual basis, incorporating new elevation data as it is acquired; evaluation is dependent on publicly available CRMS water level data from CRMS0248	Data collected from CRMS0248 as representative of the entire Project Area. Modeled inundation will be based on average elevation across the Project Area derived from elevation surveys	The modeled post-settlement marsh surface inundation in each MCA will have a 10 to 90 percent exceedance frequency for the 20-year project life	Identify errors in assumptions to inform future restoration planning. Identify causes of differential settlement (e.g., interior borrow, fill depth). An Operation and Maintenance (O&M) Plan may be added
	Context: Salinity will be used to interpret all biological metrics	**Salinity** Output: Salinity (hourly) from CRMS0248	Salinity data collected from reference site (CRMS0248) for one year pre-construction (Jan 2020-Jan 2021) and continuously for Project life (20 years); evaluation is dependent on publicly available CRMS water level data from CRMS0248	Data collected from a single station, the nearest CRMS station, CRMS0248, as representative of the Project Area	NA (Context variable)	NA
#4 Presence of target nekton species	**Performance:** The presence of target nekton species will be used to assess biological connectivity between MCAs and Barataria Basin via constructed tidal channels	**Presence of target nekton collected by 50 ft seine** Output (per target species): Presence/absence across all catches per monitoring year	Data collected for target nekton monthly from three sites (Fisheries Independent Monitoring Program [FIMP] stations 2173, 2174, 2175) between April 2020 and January 2022 pre-construction. Post-construction data collection begins in 2024 at three sites and is to occur on a monthly basis every other year until 2030 and every four years thereafter for the remainder of the project life (20 years)	Monitoring will include one sample collected from each of three sites located adjacent to the Project Area	Brown shrimp, white shrimp, other shrimps, and blue crab are present in habitat types sampled by 50 ft seines (marsh edge) at FIMP sites adjacent to the Project Area	Identify potential cause: Accessibility, comparison to abundance at reference sites. Evaluate monitoring protocols and substitute sampling gear types
		Presence of target nekton collected by 6 ft trawl Output (per target species): Presence/absence across all catches per monitoring year	Data for white and brown shrimp collected twice per month from three sites (FIMP stations 1081, 1085, 1086) from April to July 2020 and 2021 (and April-June 2022) pre-construction. Post-construction data collection for all target nekton species begins in 2024 at three sites and is to occur twice monthly every other year until 2030 and every four years thereafter for the remainder of the project life (20 years)	Monitoring will include one sample collected from each of three sites located adjacent to the Project Area	Brown shrimp, white shrimp, other shrimps, and blue crab are present in habitat types sampled by 6 ft trawls (shallow open water adjacent to marsh edge) at FIMP sites adjacent to the Project Area	Identify potential cause: Accessibility, comparison to abundance at reference sites. Evaluate monitoring protocols and substitute sampling gear types
		Presence of target nekton collected by fixed area sampling Output (per target species): Presence/absence per habitat type across all catches per monitoring year	Post-construction data collection begins in 2024 and is to occur every other year until 2030 and every four years thereafter for the remainder of the project life (20 years)	Monitoring will include collection of 1-3 samples from each of three target habitat types (marsh edge: open water, marsh edge: vegetated, and marsh interior) at 4-6 sites within the Project and 4-6 sites within the reference site (CRMS0248; 8-12 sites total, 24-108 samples total per effort). Number and location of each sampling site are to be determined prior to commencement of monitoring	Brown shrimp, white shrimp, other shrimps, killifishes*, and blue crab are present in habitat types sampled by fixed area samplers (marsh edge: open water, marsh edge: vegetated, and marsh interior) at the Project Area.	Identify potential cause: Accessibility, comparison to abundance at reference sites. Evaluate monitoring protocols and substitute sampling gear types. Consider conducting water level monitoring within the project area.
		Red drum utilization of Project Area by acoustic telemetry Output: Total # detections over monitoring duration, use of different constructed features	Acoustic tagging of red drum in 2026; acoustic receiver data collection continuously during post-construction 2026, 2027, and 2028. Year-round monitoring	Approximately 50 red drum will be tagged, and approximately 20 acoustic receivers will be placed around the perimeter and within the tidal channels and ponds of the Project Area. Specific receiver array locations to be determined through field testing	Target nekton (red drum) are detected in tidal channels, tidal ponds, and at the entrance choke points to the Project Area	Expand array and/or add additional year of array monitoring. Consider conducting water level monitoring within the project area.
	Context: Assemblage composition (e.g. Shannon-Weiner Diversity, richness, multivariate similarity)	**Assemblage composition of nekton collected by 50 ft seine** Output: Shannon-Weiner Diversity, richness, multivariate similarity across all catches per monitoring year	Data collected for target nekton monthly from three sites (Fisheries Independent Monitoring Program [FIMP] stations 2173, 2174, 2175) between April 2020 and January 2022 pre-construction. Post-construction data collection begins in 2024 at three	Monitoring will include one sample collected from each of three sites located adjacent to the Project Area	NA (Context variable)	NA

	of nekton will be assessed for 50 ft seine, 6 ft trawl, and fixed area sampling to evaluate how nekton assemblages change over the course of the project		sites and is to occur on a monthly basis every other year until 2030 and every four years thereafter for the remainder of the project life (20 years)			
		Assemblage composition of nekton collected by 6 ft trawl Output: Shannon-Weiner Diversity, richness, multivariate similarity across all catches per monitoring year	Data for white and brown shrimp collected twice per month from three sites (FIMP stations 1081, 1085, 1086) from April to July 2020 and 2021 (and April-June 2022) pre-construction. Post-construction data collection for all target nekton species begins in 2024 at three sites and is to occur twice monthly every other year until 2030 and every four years thereafter for the remainder of the project life (20 years)	Monitoring will include one sample collected from each of three sites located adjacent to the Project Area	NA (Context variable)	NA
		Assemblage composition of nekton collected by fixed area sampling Output: Shannon-Weiner Diversity, richness, multivariate similarity per habitat type across all catches per monitoring year	Post-construction data collection begins in 2024 and is to occur every other year until 2030 and every four years thereafter for the remainder of the project life (20 years)	Monitoring will include collection of 1-3 samples from each of three target habitat types (marsh edge: open water, marsh edge: vegetated, and marsh interior) at 4-6 sites within the Project and 4-6 sites within the reference site (CRMS0248; 8-12 sites total, 24-108 samples total per effort). Number and location of each sampling site are to be determined prior to commencement of monitoring	NA (Context variable)	NA
Objective #3: Productivity: The Project Area will increase vegetation and nekton productivity. Vegetation cover will be used to provide a measure of primary productivity, while nekton biomass will provide a measure of secondary productivity in the system.						
#5 Primary Productivity	**Performance:** Vegetation data will be used to assess the community composition and vigor of vegetation on the created marsh platform and berm and to compare this vegetation to vegetation in the reference marsh at CRMS0248	**Primary Productivity** Output: Average vegetation height; total vegetation % cover; % cover by species will be used to calculate vegetation indices for reporting: Floristic Quality Index to assess community composition and wetland condition (Cretini et al., 2012), and the Vegetation Volume Index used to assess vegetation vigor, a proxy for primary productivity (Wood et al., 2017).	Vegetation data collection is to occur during the four-month period between June 1 and September 30. Post construction monitoring will begin in 2024 and is to occur annually every other year until 2030 and every four years thereafter for the remainder of the project life (20 years).	A maximum of 180 vegetation cover stations (each 4 m^2) distributed across the Project Area and the reference site (CRMS0248). Vegetation station locations may change over the Project life.	Within six years of construction, marsh cover is not significantly less than reference marshes at CRMS0248. The marsh vegetation composition and vigor is typical of a healthy intertidal marsh with respect to inundation and salinity regime (reference marsh at CRMS0248 after three years)	Identify potential cause; plant vegetation if natural colonization does not occur. Evaluate porewater salinity, pH. Potential invasive species control. Plant desired species. Assess whether water salinity is leading to marsh conversion
	Context: Porewater and soil properties will be collected and used to interpret the vegetation data	**Porewater characteristics** Output: Specific conductance, pH, temperature.	Porewater data collection is to occur during the four-month period between June 1 and September 30. Post construction monitoring will begin in 2024 and is to occur annually every other year until 2030 and every four years thereafter for the remainder of the project life (20 years).	One porewater sample is to be collected from within each 4-m^2 vegetation harvest plot established in the Project Area and reference site (see Parameter #5) per sampling effort (maximum of 180 samples)	NA (Context variable)	NA
		Soil properties Output: Grain size distribution, bulk density, soil moisture, wet/dry volume, and % organic matter by depth.	Soil data collection is to occur during the four-month period between June 1 and September 30. Post construction monitoring will begin in 2024 and is to occur four times over the project life (20 years). Soil sampling will coincide with vegetation sampling during events in 2024, 2028, 2034, 2042.	One soil sample is to be collected from within a randomly selected 4-m^2 vegetation cover plot established in each habitat type within the Project Area and reference site (see Parameter #5) (maximum of 36 samples).	NA (Context variable)	NA
#6: Secondary productivity	**Performance:** Secondary productivity will include a measure of the changes in potential habitat-based dietary resources and	**CPUE, size distribution, and biomass of target nekton collected by 50 ft seine** Output (per target species): Catch per unit effort (CPUE); size (mm; total length, carapace width) of each	Same timing as presence of target nekton collected by 50 ft seine (see Parameter #4)	Same sample size and sites as presence of target nekton collected by 50 ft seine (see Parameter #4)	CPUE, size distribution, and biomass of target nekton species adjacent to the Project Area sampled using seine and trawl gear types are not significantly lower than values of the same metrics at surrounding reference sites by Year 8 (Hollweg et al., 2020)	Identify potential cause. Identify errors in assumptions to inform future restoration planning

	productivity (as biomass) of white shrimp, brown shrimp, and blue crab for comparison between the Project Area and the reference sites (fixed area sampling: CRMS0248; FIMP sampling: surrounding reference stations)	individual observed; biomass (g) of target nekton per sample				
		CPUE, size distribution, and biomass of target nekton collected by 6 ft trawl Output (per target species)**: Catch per unit effort (CPUE); relative abundance per size category (total length, carapace width)	Same timing as presence of target nekton collected by 6 ft trawl (see Parameter #4)	Same sample size and sites as presence of target nekton collected by 6 ft trawl (see Parameter #4)		
		Density, size distribution, and biomass of target nekton by fixed area sampling Output (per target species)**: Density (individuals per m^2); size distribution (total length, carapace width) per individual; biomass (g) of target nekton per sample	Same timing as presence of target nekton collected by fixed area sampling (see Parameter #4)	Same sample size and sites as presence of target nekton collected by fixed area sampling (see Parameter #4)	Density, size distribution, and biomass of target nekton species within the Project Area sampled using fixed area gear types are not significantly lower than values of the same metrics at the reference site by Year 8 (Hollweg et al., 2020)	
		Secondary productivity by overall production Output (per target species)**: Nekton productivity (lbs) of Project Area per year	Evaluating the associated performance criteria for this metric will rely on data collected for the abundance, size distribution, and biomass of target nekton by fixed area sampling metric. Frequency of evaluation will coincide with data availability.		Secondary productivity of target species is enhanced by marsh creation/restoration of the Project Area	Identify potential cause. Identify errors in assumptions to inform future restoration planning
		Secondary productivity by habitat resource index Output (per target species): JPG map of Habitat resource index (HRI) values for Project Area; % Project Area where HRI > 1.0	Evaluating the associated performance criteria for this metric will rely on land:water data collected for the Total land area metric. Frequency of evaluation will coincide with data availability	The spatial extent will capture the Project Area	With respect to target species, the habitat value of the Project Area evaluated by energetic landscapes is improved by marsh creation/restoration of the Project Area	Identify potential cause. Identify errors in assumptions to inform future restoration planning

*For the purposes of this monitoring plan, "killifishes" is inclusive of the following species: Rainwater killifish, Gulf killifish, Longnose killifish, Diamond killifish, Bayou killifish, Least killifish, Golden topminnow, and Saltmarsh topminnow.

**Biomass of killifishes is not possible due to a lack of available length:weight conversion factors and the variety of species included in this guild. Length:weight conversion factors may be developed as part of this monitoring effort.

3.0 Adaptive Management

Monitoring information collected at the project level can also inform adaptive management. Adaptive management is a form of structured decision-making applied to the management of natural resources in the face of uncertainty for an individual project (Pastorok et al., 1997; Williams & Brown, 2014). Within the LA TIG, an adaptive management framework has been developed that identifies and characterizes four main phases as illustrated within a representative management cycle (see Figure 3-1).

1. Goal-Setting Phase: Problem is identified or defined, and project goals and objectives are established based on multiple sources, including lessons learned, data and associated synthesis, and applied research from previous projects and from the knowledge base as a whole.
2. Development and Execution Phase: Project advances through select steps, including model development or refinement, identification and prioritization of uncertainties, plan formulation, engineering, design, and project construction.
3. Monitoring and Performance Phase: Project operations, maintenance, and monitoring plans are developed, and project assessment and evaluation criteria are identified.
4. Adaptive Management Coordination Phase: Project revisions are recommended and approved so that revisions result in alterations and redesign of project elements or changes to project operation and/or inform either the understanding of the overall problem statements or the refinement of attainable or realistic goals and objectives for future projects.

Where there are gaps in scientific understanding, project information collected and evaluated may be used to reduce key uncertainties and/or inform the selection, design, and optimization of future restoration projects.

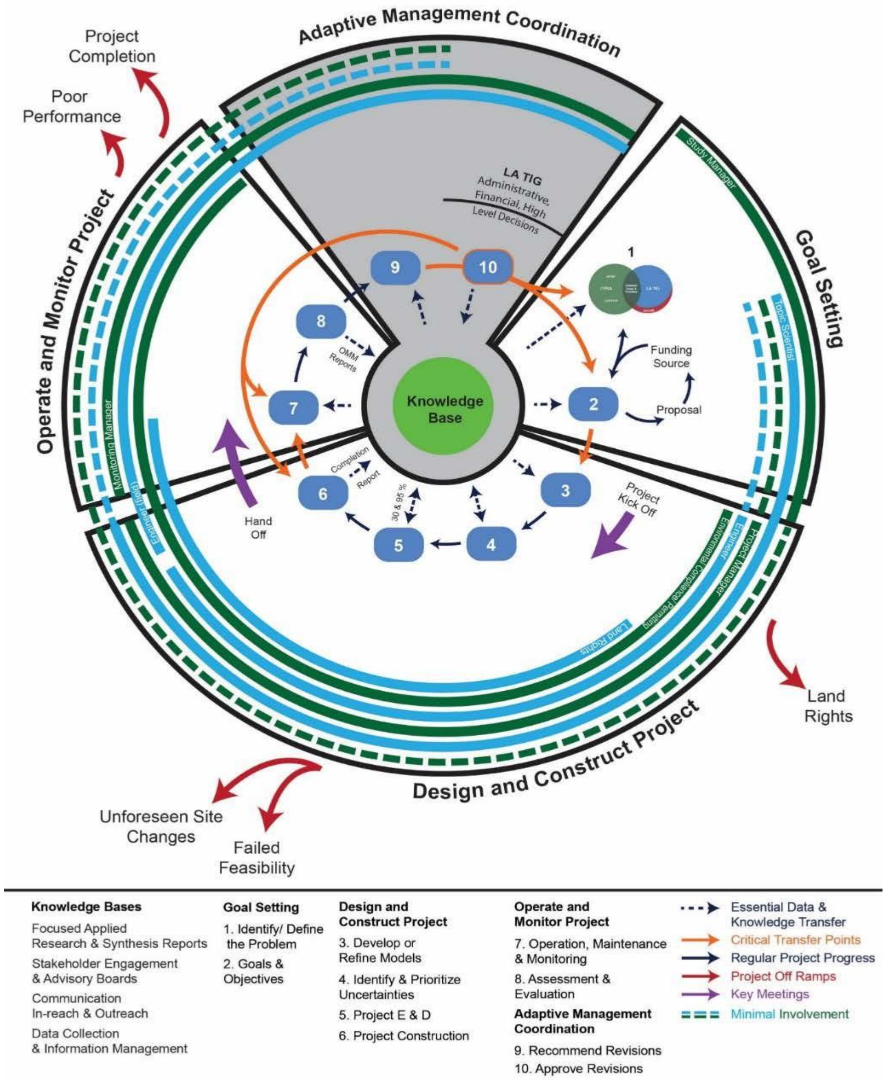

Figure 3-1. LA TIG Adaptive Management Cycle. Source: The Water Institute of the Gulf (2019).

4.0 Evaluation

Monitoring data will be evaluated to assess Project performance in meeting restoration objectives, resolving key uncertainties, and determining whether corrective actions are needed. The results of the Project evaluation analysis will be used to answer the following questions:

- Were the Project restoration objectives achieved? If not, is there a reason they were not met?
- Did the restoration Project produce unanticipated effects?
- Were there events unrelated to the restoration Project that potentially affected the monitoring results (e.g., hurricanes)?
- Were any of the uncertainties identified prior to Project implementation resolved?
- Were any new uncertainties identified?

Additional information on evaluation of each monitoring metric is provided in Appendix A. Results obtained during each monitoring year would be presented and evaluated in the annual monitoring report. This evaluation would provide recommendations regarding adaptive management and would report on progress made towards addressing the Learning Goals described in Section 5.0. The Implementing Trustee for the MAM plan will use these annual reports to assess if the Project is meeting its restoration objectives and can determine the need for adaptive management or corrective actions.

5.0 Learning Goals

In addition to performance indicators listed in Section 3.0, the soil, vegetation, and nekton data will also be evaluated to address learning goals.

- Determine whether densities of killifish in marsh edge habitats along flow paths (internal tidal channels between MCAs) of the Project Area differ from densities of killifishes in marsh edge habitats along the perimeter of the Project Area to evaluate whether incorporation of flow paths as a restoration design feature provides similar habitat value as determined by killifish densities.
- Determine whether densities of target nekton (blue crab, white shrimp, brown shrimp, other shrimp, and killifish) along unconfined marsh edge differ from densities along the confined (diked) marsh edge within the Project Area to evaluate whether edge habitat construction approach and respective physical conditions (e.g., marsh edge slope) influence target nekton densities.
- Primary productivity will be compared between the Project Area and the reference site (CRMS0248) to determine whether project size (total area footprint) and tidal flow (marsh inundation regime) are correlated with vegetation composition and vigor.
- Quantify how soil characteristics (organic content and grain size distribution) across the Project Area change over the life of the Project to increase the understanding of how constructed marsh soils evolve—with specific interest in understanding how such processes may be different within and across the Project Area MCAs based on source material origins.
- When the MBSD is constructed, changes in soil properties (organic content and grain size distribution) will be quantified to describe how the constructed marsh responds to changes in salinity and sediment availability.

6.0 Monitoring Schedule

Monitoring efforts will be aligned with other programmatic efforts after construction is completed. Coastwide aerial photo surveys are flown that year and once per three years thereafter. Much of the monitoring schedule is aligned to have multiple parameters sampled during the same year (Table 6-1 and Table 6-6-2).

Table 6-1. Monitoring schedule for Year -1-10. Note: X's indicate required data acquisitions.

			Post-Execution Monitoring									
Metric	**Pre-Execution Monitoring Year -1 (2021)**	**As-Built Monitoring Year 0 (2023)**	**Year 1 (2024)**	**Year 2 (2025)**	**Year 3 (2026)**	**Year 4 (2027)**	**Year 5 (2028)**	**Year 6 (2029)**	**Year 7 (2030)**	**Year 8 (2031)**	**Year 9 (2032)**	**Year 10 (2033)**
Objective #1: Marsh creation												
Total land area and Land area change	X		X			X						X
Marsh area elevation and Marsh area settlement		X				X						X
Marsh fragmentation	X		X			X						X
Objective #2: Basin connectivity												
Tidal signal, Inundation, and Salinity	X	X	X	X	X	X	X	X	X	X	X	X
Nekton sampling (50 ft seine and 6 ft trawl)	X		X		X		X		X			
Nekton sampling (fixed area)			X		X		X		X			
Red drum telemetry					X	X	X					
Objective #3: Productivity												
Vegetation (primary productivity, porewater)			X		X		X		X			
Soil			X				X					
Secondary productivity assessment (based on nekton sampling)			X		X		X		X			
Secondary productivity assessment (based on land:water delineation)			X									X

Table 6-6-2. Monitoring schedule for Year 11-20. Note: X's indicate required data acquisitions.

	Post-Execution Monitoring									
Metric	**Year 11 (2034)**	**Year 12 (2035)**	**Year 13 (2036)**	**Year 14 (2037)**	**Year 15 (2038)**	**Year 16 (2039)**	**Year 17 (2040)**	**Year 18 (2041)**	**Year 19 (2042)**	**Year 20 (2043)**
Objective #1: Marsh creation										
Total land area and Land area change						X				
Marsh area elevation and Marsh area settlement									X	
Marsh fragmentation						X				
Objective #2: Basin connectivity										
Tidal signal, Inundation, and Salinity	X	X	X	X	X	X	X	X	X	X
Nekton sampling (50 ft seine and 6 ft trawl)	X				X				X	
Nekton sampling (fixed area)	X				X				X	
Red drum telemetry										
Objective #3: Productivity										
Vegetation (primary productivity, porewater)	X				X				X	
Soil	X								X	
Secondary productivity assessment (based on nekton sampling)	X				X				X	X
Secondary productivity assessment (based on land:water delineation)						X				

7.0 Data Management

7.1 Data Description

Qualitative and quantitative data will be collected as part of this MAM plan. The type of data to be collected, as well as how those data will be collected, processed, reviewed, stored, and shared, will follow the data standards outlined in the *MAM Procedures and Guidelines Manual Version 2.0* and this MAM plan for the LSMC-UBC (DWH Trustees, 2016).

All data will be collected either by hand on monitoring or survey forms or by tablet on electronic forms. If data are recorded on hardcopy field datasheets, these entries will be scanned to a Portable Document Format (PDF) file and archived, along with the hardcopy. All photographs, datasheets, notebooks, and revised data files will be retained. Metadata will be developed for consistency for all data collected electronically. All electronic files will be stored in a secure location, such as on Data Integration Visualization Exploration and Reporting (DIVER), in such a way that the LA TIG will have guaranteed access to all versions of the data. The final versions will be available through DIVER as files or links to CRMS or another database.

Data will be collected via site visits, field surveys, in situ continuous recorder devices, and remote sensing. Data types include hydrologic (e.g., water level), bathymetric/topographic (e.g., land/water area, elevation settlement), biological (e.g., fish, invertebrates, vegetation), and GIS (e.g., vector, raster, aerial and satellite imagery). Some data will be collected as part of existing programs, including those coordinated by CPRA (e.g., CRMS, System-Wide Assessment and Monitoring Program [SWAMP]) or other agencies (e.g., Louisiana Department of Wildlife and Fisheries [LDWF], U.S. Geological Survey [USGS], NOAA).

7.2 Data Review and Clearance

A Quality Assurance Project Plan (QAPP) will be required by the LA TIG prior to Project implementation. This QAPP will outline the appropriate quality assurance/quality control (QA/QC) process in accordance with the data management section of the *MAM Manual* (DWH NRDA Trustees, 2021). The data management plan developed for this Project will adhere to NOAA's established data standards and meet the LA TIG requirements of the QAPP.0

7.3 Data Storage and Accessibility

Data collected for this MAM plan will be stored in the DIVER Restoration Portal. Data will be submitted as soon as possible, but no more than one year from when the data were collected. Data storage and accessibility will be consistent with the guidelines in Section 3.1.3 of the *MAM Manual* (DWH NRDA Trustees, 2021).

7.4 Data Sharing

The LA TIG will ensure that data sharing follows standards and protocols set forth in the Open Data Policy (DWH Trustees, 2016; Section 10.6.6). No data release can occur if it is contrary to federal or state laws (DWH Trustees, 2016; Section 10.6.4). The DWH NRDA Trustees will provide notification to the

Cross-TIG MAM work group when new data and information packages have been uploaded to DIVER (DWH Trustees, 2016). In the event of a public records request related to Project data and information that are not already publicly available, the Trustee to whom the request is addressed will provide notice to the other LA TIG Trustees prior to releasing any Project data that are the subject of the request.

As noted in Sections 7.0 and 8.0, the Project's data will be stored in the DIVER Restoration Portal. These data will be shared with the public by publishing the data to the Trustee Council website (DWH Trustees, 2016; Section 10.6.6). For further instructions on this process, see the *DIVER Restoration Portal User Manual* at https://www.diver.orr.noaa.gov/.

Some of the data collected may be protected from public disclosure under federal and state law (e.g., personally identifiable information under the Privacy Act) and therefore will not be publicly distributed.

8.0 Reporting

Reporting should follow the guidelines set forth in Section 2.6.3 and Attachment D of the *MAM Manual* (DWH Trustees, 2016). Project MAM activities will be reported annually through the DIVER Restoration Portal. In addition, MAM Interim Synthesis Reports should be submitted following the schedule outlined in Table 8-1 aligned with the monitoring schedules described in Table 6-1 and Table 6-6-2. These synthesis reports will describe the results of MAM activities conducted to date. Any additional reports deemed necessary as a result of corrective actions that require an extension of the monitoring period or other Project changes should be submitted as a MAM Interim Synthesis Report(s) in addition to those identified above.

Table 8-1. Anticipated schedule and content of MAM Interim Synthesis Reports during the life of the project.

Report Number	Monitoring Years Synthesized	Year Completed	Content
1	2018-2024	2025	Synthesis of pre-construction and as-built monitoring data; synthesis of short-term ecological change immediately post-construction
2	2018-2028	2029	Synthesis of intermediate ecological change 6 years post-construction; results of red drum acoustic tagging
3	2018-2033	2034	Synthesis of first decade of monitoring efforts; interim conclusions on ecological recovery; and recommendations for adaptive management of monitoring to be included as identified
4	2018-2038	2039	Synthesis of long-term ecological change 15 years post-construction
5	2018-2043	2044	Final synthesis report

9.0 Roles and Responsibilities

The LA TIG is responsible for addressing MAM objectives that pertain to their restoration activities and for communicating information to the Trustee Council or Cross-TIG MAM work group (DWH Trustees, 2016). This includes reviewing and approving MAM plans, identifying MAM priorities for the Louisiana Restoration Area, ensuring that MAM implementation is compatible with the MAM Manual guidelines and that data are submitted to the DIVER Restoration Portal, aggregating, and evaluating MAM data, ensuring quality control of MAM data, and communicating regarding implementation status and results of MAM with the Trustee Council and Cross-TIG MAM work group.

As the implementing Trustee, NOAA is responsible for developing the MAM plan, conducting all monitoring activities, evaluating project progress toward restoration objectives using the identified performance criteria, identifying and proposing corrective actions to the LA TIG, and submitting MAM data and project information into the DIVER Restoration Portal in accordance with the data management procedures outlined within this MAM plan (DWH Trustees, 2016).

The Project proponent, NOAA, is responsible for all maintenance activities and costs related to the LSMC-UBC Project, including any repairs needed over the life of the Project.

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MAM Plan Revision History

Old Version #	Revision Date	Changes Made	Reason for Change	New Version #
1.0	June 2024	Replacement of crab trap and minnow trap monitoring with fixed-area sampling; replacement of aboveground and belowground vegetation biomass sampling with aboveground vegetation cover; revision of sampling frequency; revision of nekton-related performance criteria; revision of learning goals; development of analytical framework appendix; document re-formatting	Improve specificity and clarity of monitoring activities prior to commencement Vegetation – increase sample size to more appropriately characterize larger than expected project Nekton monitoring – change in gear to focus on marsh edge communities with a stronger quantitative approach	2.0

Appendices

APPENDIX A. MONITORING METHODOLOGY AND EVALUATION

To the extent possible, the monitoring methods used for the Project will be consistent with the methods implemented by other monitoring agencies currently implementing long-term ecological monitoring across Louisiana's coastal basins. This includes protocols developed by Louisiana's Coastal Protection and Restoration Authority (CPRA) and LDWF (LDWF, 2018). CPRA currently maintains monitoring programs that provide ecological data and research to support the planning, design, construction, evaluation, and adaptive management of Louisiana's wetland restoration projects (Folse et al., 2020). This Coastwide Reference Monitoring System (CRMS) (http://lacoast.gov/crms2/Home.aspx) was developed and implemented to improve the monitoring program's effectiveness in evaluating individual restoration projects, as well as the combined effects of multiple projects, by providing a network of reference sites where data are collected on a regular basis (Steyer et al., 2003).

A.1. Objective #1: Marsh Creation

A.1.1. Metric: Total land area

Methods

The constructed marsh area within the Project Area will be assessed using high-resolution, near vertical, orthorectified aerial imagery. Using aerial orthophotographs, the perimeters of land area and water features within the Project Area will be digitized following the same methods used for the CRMS datasets (protocols detailed in the U.S. Geological Survey (USGS) Digital Orthoimagery Base Specification V1.0 https://pubs.usgs.gov/tm/11/b5/pdf/tm11-B5.pdf). In brief, Digital Orthophoto Quarter Quadrangles (DOQQs) flown in 2018 and subsequent years (coastwide aerials flown by the state every three years during fall/winter) are to be classified into land and water categories using a threshold of the near infrared (NIR) band, followed by supervised and unsupervised classification. Initial classification results are revised by multiple image analysts to identify and manually recode errors. The resulting datasets, in the form of raster image datasets with 1-m classified pixels, are published as a USGS data release following internal USGS review and creation of a map displaying the orthophotographs and the land water dataset.

Additional aerial imagery may need to be collected following major events such as tropical storms, or changes to the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) program collection of coastwide imagery. If the Project's marsh area converts from intermediate and brackish marsh to freshwater marsh, then land:water delineation and assessment will need to be based on aerial imagery collected during the spring or summer instead of fall due to difficulties in delineating freshwater vegetation in mid-late fall.

Analysis

The resulting polygon output derived from land:water delineation will be analyzed to determine total land and total water area (acres, % of total area) within the Project Area boundary. Additional analyses will be conducted using the resulting data to inform restoration project performance against specified criteria over the life of the Project.

A.1.2. Metric: Land area change

Methods

Data collection methods follow the protocols provided under **Metric: Total land area**.

Analysis

Proportion of land derived from land:water assessment of the Project Area and reference sites (CRMS0248 and CRMS0225) will be compared between years to identify trends in relative land area change (gains and losses) over time. Linear regression will be used to identify the rate of change (% $year^{-1}$) for each location, and analysis of variance (ANOVA) will be used to determine whether rates of change between sites are statistically different.

A.1.3. Metric: Marsh area elevation

Methods

Post-construction as-built (Year 0) topographic surveys of the Project Area will be collected by the construction contractor using Real Time Kinematic (RTK) Global Position System (GPS) methods and/or other equivalent methods. Surveys within each Marsh Creation Area (MCA), as conducted by the construction contractor, will be organized along transects spaced approximately every 500 ft. Subsequent surveys occurring over the life of the Project will use similar methods but may deviate from original spatial transect alignment and/or consider emerging technology (e.g. LiDAR as they are developed).

Analysis

Average (± SD) elevation of the marsh surface within the Project Area will be evaluated to determine whether the average marsh target elevation remains at the target elevation (average 1 ft NAVD88) throughout the Project life. Elevation will also be used to assess **Metric: Inundation** (see Parameter #3).

A.1.4. Metric: Marsh area settlement

Methods

Settlement plates embedded within the marsh platforms of each MCA will be surveyed alongside RTK elevation transects. As-built surveys of settlement plates will be conducted by the construction contractor. Post-construction monitoring of elevation and settlement plates will align temporally with instances of aerial photography to the extent practicable.

Analysis

Elevation data of settlement plates will be used to record/document the magnitude and rate of settlement (ft $year^{-1}$) under the fill material over the life of the Project.

A.1.5. Metric: Marsh fragmentation

Methods

The FRAGSTATS program will be used to classify fragmentation metrics describing the shape, isolation, and configuration of habitat patches for multiple polygons (zonal outputs) within the Project Area using methods developed by McGarigal & Marks (1995) and available at https://www.fs.usda.gov/pnw/pubs/pnw_gtr351.pdf.

Analysis

Degraded or degrading marshes typically demonstrate evidence of increased erosion, increased open water, and increased fragmentation across the landscape, however it is well established that marsh edge habitats are important for production of target nekton populations. Evaluation of fragmentation metrics for marsh area degradation will be balanced against potential habitat benefits provided to nekton species.

A subset of all FRAGSTAT metrics will be evaluated over time to assess overall marsh performance, including patch area/total marsh area (AREA, ha), total edge (TE, m), edge density (ED, m/ha), number of patches (NP), patch density (PD/100 ha), and aggregation index (AI). The identified indices and metrics are known to influence target nekton populations (Feagin & Wu, 2006; Hensgen et al., 2014; James et al., 2021; Lowe & Peterson, 2014; Roth et al., 2008). The values of each index will be reported and visualized over time. Additional statistical analyses (i.e., redundancy analysis [RDA] or constrained correspondence analysis [CCA] followed by permutational ANOVA on the marginal effects to determine the amount of variance explained in the nekton abundance data by each individual FRAGSTAT metric) may be conducted once sufficient data are collected.

A.2. Objective #2: Marsh Connectivity

A.2.1. Metric: Tidal signal

Methods

Continuously collected hourly water level data collected at the nearest CRMS station (CRMS0248) by CRMS protocols (Folse et al., 2020) will be used to describe water level variation for the Project Area.

Analysis

Hourly water level data (ft) will be examined for each year of monitoring to calculate the tidal range (i.e., amplitude; ft year^{-1}), maximum and minimum water level observed (ft) per season, and annual average water level (ft) observed at CRMS0248. Data will be analyzed using a tidal harmonic analysis to extract tidal amplitude, frequency, and phase for each tidal constituent (i.e., M2, S2, K1, O1, etc.). By comparing the size of tidal amplitudes over time, the effect of tide on water level changes will be evaluated.

If the tidal channels, tidal pond, and constructed marsh of the Project Area are hydrologically connected to the larger Barataria Basin ecosystem, the water levels may demonstrate a tidal signal. However, tidal oscillation usually dominates the water level variation in the summer, whereas tides are driven primarily by wind in the winter (Li et al., 2011). Consequently, differences in tidal signals pre- and post-construction may not be apparent depending on seasonality or other physical forcings in the area.

A.2.2. Metric: Inundation

Methods

Continuously collected hourly water level data (see **Metric: Tidal signal**) will be used alongside average Project area elevation (see **Metric: Marsh area elevation**) to describe inundation of the Project Area.

Analysis

Hourly water level data (ft) spanning January 1 through December 31 of a given project year will be used alongside the most recent average marsh elevation value for the Project Area to identify whether the

Project Area is meeting the desired inundation frequency described in the performance criteria (10-90% per year). The total amount of time within a given year that observed water levels are greater than the average Project Area marsh elevation will be calculated (% $year^{-1}$); if the amount of time the Project Area is inundated falls between 10 and 90%, the performance criteria will be met.

A.2.3. Metric: Salinity

Methods

Continuously collected salinity data collected at the nearest CRMS station (CRMS0248) by CRMS protocols (Folse et al., 2020) will be used to describe salinity variability of the Project Area.

Analysis

Salinity data spanning January 1 through December 31 of a given project year will be used to describe yearly and seasonal average salinity (± SD) for the Project Area.

A.2.4. Metric: Presence of target nekton collected by 50 ft seine

Methods

Louisiana Department of Wildlife and Fisheries (LDWF) will use a 50 ft bag seine with 3/16 inch square mesh to sample the presence of target species along the shoreline and shallow marsh edge habitats adjacent to the Project Area (Fisheries Independent Monitoring Program [FIMP] stations 2173, 2174, and 2175). Methodology follows LDWF protocols. In brief, the 50 ft seines will be set out from the vegetated shoreline and pulled inward to meet the edge. All individuals collected will be identified and counted. Up to 30 individuals of the target species will be measured to the nearest millimeter (mm) in total length (TL) or carapace width (CW, blue crabs).

Analysis

Target species abundance data (catch per unit effort, CPUE) will be used to determine presence/absence of the target species at each FIMP site for each sampling effort as associated with the Project Area to evaluate project performance against associated performance criteria. Additional comparisons will be made to surrounding FIMP 50 ft seine stations (2002, 2008, 2177, 2011, 2004, 2007) to assess Project performance against broader ecological patterns in the Basin.

A.2.5. Metric: Presence of target nekton collected by 6 ft trawl

Methods

LDWF will use a 6 ft balloon otter trawl to sample the presence of target species in the shallow marsh edge habitats and interior water bodies adjacent to the Project Area (FIMP stations 1081, 1085, and 1086). Methodology follows modified LDWF protocols such that all target species (brown shrimp, white shrimp, other shrimp, killifishes, and blue crab) will be identified and counted. Up to 30 individuals of the target species will be measured to the nearest millimeter (mm) in total length (TL) or carapace width (CW, blue crabs). Pre-construction data collection protocols will follow routine LDWF protocols (only identifying and measuring brown and white shrimp) and will only be modified starting in Project Year 1.

Analysis

Target species abundance data (CPUE) will be used to determine presence/absence of the target species at each FIMP site for each sampling effort as associated with the Project Area to evaluate project performance against associated performance criteria. Additional comparisons will be made to surrounding FIMP 6ft trawl stations (1080, 1009) to assess Project performance against broader ecological patterns in the Basin.

A.2.6. Metric: Presence of target nekton collected by fixed area sampling

Methods

This Project will implement detailed fixed area sampling methods and protocols as developed under the *Monitoring the Effects of Coastal Wetland Restoration on Fish and Invertebrates* MAM Activity Implementation Plan (DIVER ID# 299). Briefly, fixed area sampling by 1 m^2 drop samplers or other similar gear type (e.g., throw trap) will be conducted within the Project Area as well as at the reference site (CRMS0248). Number and exact locations of each sampling site are to be determined prior to the commencement monitoring based on site access, long-term feasibility, and sufficient marsh expanse to support sampling of up to three target habitat types: (1) marsh edge: open water, (2) marsh edge: vegetated, and (3) marsh interior: >1 m landward from marsh edge. Marsh edge types are further characterized by two construction approaches: (1) confined created marsh edge and (2) unconfined marsh edge. Fixed area sampling will also be conducted within the constructed marsh pond to confirm the presence of target nekton within this habitat feature.

Water quality data (water temperature, salinity, dissolved oxygen, and turbidity) are to be measured using a YSI multiprobe prior to initiating any sampling activity. Water depth (cm) and vegetation stem density data are to be recorded from within the fixed area sampling unit at the time of sampling to support data analysis and interpretation.

Analysis

Target species abundance data (density, indiv. m^{-2}) will be used to assess presence/absence of the target species at each fixed area sampling site associated with the Project Area as well as the reference site to evaluate project performance against associated performance criteria.

A.2.7. Metric: Red drum utilization of Project Area by acoustic telemetry

Methods

Acoustic telemetry will be used to assess utilization of the Project Area by red drum. An acoustic array of at least 20 Vemco receivers (Vemco VR2W) will be established across the Project Area to collect detection data from at least 50 total juvenile and adult red drum tagged within the Project Area. The acoustic array will span multiple habitat types: tidal pond, interior tidaposl channels, and Project Area access points as determined by field range tests of the acoustic array. To deploy the array, receivers will be cable-tied to polyvinyl chloride (PVC) pipes driven forcibly into the sediments of the Project Area; receivers will be serviced and downloaded semi-annually, noting when loss of a receiver occurs. Following methodology outlined in Moulton et al., (2017), initial array sensitivity will be tested with synchronization transmitters (“sync tags”; Vemco V13-1H) programmed with a random delay of 500-700 s co-located with each receiver to calibrate and correct for time drift of the receiver internal clocks. The initial array is to be adjusted based on the findings of calibration and sensitivity testing prior to final array deployment.

It is important that red drum are to be captured via hook-and-line within close vicinity of the Project site (M. Dance, pers. comm.). Tagging of red drum will follow methods outlined in Moulton et al., (2017). Briefly, transmitters (Vemco V9-1H) programmed with a random delay of 400-500 s (estimated battery life 530 days) will be inserted surgically into each caught fish following protocols by Reese Robillard et al. (2015). Fish TL will be measured to the nearest mm used to assign each fish a year class based on a species-specific age length key (Porch et al., 2002). Hallprint dart tags offering anglers a reward for reporting recaptured fish will be applied at the junction of first and second dorsal fins. Individual fish will be observed for a short time period (15 min in an oxygenated cooler) following surgery and released only if they exhibited normal behavior throughout.

Analysis

Acoustic data (detections) will be used to calculate short-term (daily) and long-term (seasonal) movement patterns of tagged red drum within and around the Project Area (Moulton et al., 2017). Depending on data resolution, it may be possible to calculate average Euclidean distance-based analysis (EDA) ratios per sub-habitat (pond, channel, choke point, hard edge, unconsolidated edge, etc.) to tease apart finer scale habitat use. Acoustic data will be provided annually for each year of telemetry data collection and data will be evaluated at the end of the array deployment period. Presence of tagged red drum at target locations within the Project Area (choke points, channels, and tidal pond) for each year of monitoring will be used to evaluate project performance against associated performance criteria.

A.3. Objective 3: Marsh productivity

A.3.1. Metric: Primary Productivity

Methods

Vegetation cover stations (2 m x 2 m) will be established across the Project Area and at the reference site (CRMS0248) following modified CRMS site establishment protocols (Folse et al., 2020). Vegetation stations established at the reference site will be positioned such that monitoring activities do not interfere with CPRA monitoring at CRMS0248. Data collection within each vegetation cover station will follow methods established in (Folse et al., 2020) for evaluation of total percent cover, vegetation height, and percent cover by individual vegetation species.

Analysis

Vegetative cover (total % cover, % cover by species, vegetation height) will be measured and used to calculate standard indices to assess community composition, Floristic Quality Index (Cretini et al., 2012), and vigor, Vegetation Volume Index (Wood et al., 2017). These indices will be compared between the Project Area and reference site (CRMS0248) for each year of monitoring to evaluate project performance against associated performance criteria. Additional analyses may be used to evaluate key environmental drivers of vegetation composition and vigor at the Project Area (e.g., soil characteristics, inundation, salinity) should significant differences be found between Project and reference sites.

A.3.2. Metric: Porewater characteristics

Methods

Collection of porewater samples will occur in parallel with sampling for **Metric: Primary Productivity** at the Project Area and the reference site (CRMS0248). Methods will follow methods outlined in Folse et al., (2020).

Analysis

Porewater samples will be evaluated for salinity (specific conductance), pH, and temperature. Data will be analyzed alongside primary productivity (and other metrics as identified) as a context variable.

A.3.3. Metric: Soil properties

Methods

Soil cores will be collected following CRMS methods (Folse et al., 2020) and will occur in parallel with sampling for **Metric: Primary Productivity.**

Analysis

Soil cores will be analyzed for grain size distribution, bulk density, soil moisture, wet/dry volume, and percent organics by loss on ignition consistent with CRMS protocols (Folse et al., 2020). Data will be analyzed alongside primary productivity (and other metrics as identified) as a context variable.

A.3.4. Metric: CPUE, size distribution, and biomass of target nekton collected by 50 ft seine

Methods

See description for **Metric: Presence of target nekton collected by 50 ft seine** for details about abundance and size distribution data collection. Abundances (CPUE) and associated size distribution data will be used to calculate total biomass (g) of each target species per sample based on length:weight conversions provided in Brown et al., (2013). Note: due to lack of available length:weight conversion equations for killifishes, analysis and comparison of biomass will only be conducted for white shrimp, brown shrimp, other shrimp, and blue crab.

Analysis

Summary statistics including average catch (average CPUE ± SD) and average biomass (total g $catch^{-1}$ ± SD) per season and per year will be calculated for each target species. Abundance (CPUE), size distribution, and total biomass of target nekton from 50 ft seine FIMP stations adjacent to the Project Area (FIMP stations 2173, 2174, and 2175) will be compared to other sites in the LDWF network (reference 50 ft seine FIMP stations: 2002, 2008, 2177, 2011, 2004, 2007) using Cohen's *d* to evaluate nekton recovery trajectories over time. Cohen's *d* (also commonly termed Hedges' *d*) will be used to calculate an effect size to compare CPUE, size distribution, and total biomass at the Project Area and the reference sites for each year of monitoring. The calculation of *d* will follow the methods outlined in Weinstein et al., (2019) and will be used to evaluate project performance against associated performance criteria; *d* is considered significantly different from zero (no difference between reference site and Project Area) if its 95% confidence interval (CI) does not bracket zero. Average *d* and associated 95% CIs will be calculated for CPUE, size distribution, and total biomass at the Project Area and from reference stations to summarize and compare the overall effects of restoration based on 50 ft seine data. Additional multivariate analyses may be incorporated over time to determine the distance for which an influence of restoration can be detected for the target nekton species away from the Project Area.

A.3.5. Metric: CPUE, size distribution, and biomass of target nekton collected by 6 ft trawl

Methods

See description for **Metric: Presence of target nekton collected by 6 ft trawl** for details about abundance and size distribution data collection. Abundances (CPUE) and associated size distribution data will be used to calculate total biomass (g) of each target species per sample based on length:weight conversions provided in Brown et al., (2013). Note: due to lack of available length:weight conversion equations for killifishes, analysis and comparison of biomass will only be conducted for white shrimp, brown shrimp, other shrimp, and blue crab.

Analysis

Summary statistics including average catch (average CPUE ± SD) and average biomass (total g $catch^{-1}$ ± SD) per season and per year will be calculated for each target species. Abundance (CPUE), size distribution, and total biomass of target nekton from 6 ft trawl FIMP stations adjacent to the Project Area (FIMP stations 1081, 1085, 1086) will be compared to other sites in the LDWF network (reference 6 ft trawl FIMP stations: 1080, 1009) using Cohen's *d* to evaluate nekton recovery trajectories over time. Due to differences in total species identified from routine FIMP station monitoring, comparisons with reference sites may be limited to only brown and white shrimp. Cohen's *d* (also commonly termed Hedges' *d*) will be used to calculate an effect size to compare CPUE, size distribution, and total biomass at the Project Area and the reference sites for each year of monitoring. The calculation of *d* will follow the methods outlined in Weinstein et al., (2019) and will be used to evaluate project performance against associated performance criteria; *d* is considered significantly different from zero (no difference between reference site and Project Area) if its 95% confidence interval (CI) does not bracket zero. Average *d* and associated 95% CIs will be calculated for CPUE, size distribution, and total biomass at the Project Area and from reference stations to summarize and compare the overall effects of restoration based on 6 ft trawl data. Additional multivariate analyses may be incorporated over time to determine the distance for which an influence of restoration can be detected for the target nekton species away from the Project Area.

A.3.6. Metric: Density, size distribution, and biomass of target nekton collected by fixed area sampling

Methods

See description for **Metric: Presence of target nekton collected by fixed area sampling** for details about density and size distribution data collection. Density and associated size distribution data will be used to calculate total biomass (g) of each target species per sample based on length:weight conversions provided in Brown et al., (2013). Due to lack of available length:weight conversion equations for killifishes, analysis and comparison of biomass will only be conducted for white shrimp, brown shrimp, other shrimp, and blue crab.

Analysis

Summary statistics including average density (average individuals m^{-2} ± SD) and average biomass (total g m^{-1} ± SD) per season and per year will be calculated for each target species for each target habitat type at the Project Area and reference site. Density, size distribution, and total biomass of target nekton from fixed area sampling within the Project Area will be compared to data collected from the reference site (CRMS0248) to evaluate nekton recovery trajectories over time. Cohen's *d* (also commonly termed Hedges' *d*) will be used to calculate an effect size to compare variables by habitat type and across all habitat types for each year of monitoring. The calculation of *d* will follow the methods outlined in Weinstein et al., (2019) and will be used to evaluate project performance against associated performance criteria; *d* is considered significantly different from zero (no difference between reference site and Project Area) if its 95% confidence interval (CI) does not bracket zero. Average *d* and associated 95% CIs will be calculated for density, size distribution, and total biomass at the Project Area and from the reference site to summarize and compare the overall effects of restoration based on fixed area sampling data. Additional multivariate analyses may be incorporated over time.

A.3.7. Metric: Secondary productivity by overall production

Methods
Nekton density and biomass of individuals per unit area collected for **Metric: Presence of target nekton collected by fixed area sampling** will be used to estimate enhancement of nekton production by construction and restoration of habitat. Analysis will follow methods developed by Zu Ermgassen et al., (2021) and/or other relevant calculation methodologies (e.g., Cebrian et al., 2020) as appropriate.

Analysis
Assessment of secondary productivity is to be conducted at Project Year 20 (2043) with potential additional analyses after 10 years of data collection (Project Year 11, 2034) when nekton densities may have sufficiently equilibrated post-construction and that densities are not different than the reference site (Hollweg et al., 2020).

A.3.8. Metric: Secondary productivity by habitat resource index

Methods
Spatially explicit energetic resource maps (E-scapes; James et al., 2022) display species-specific resource use information onto the landscape in order to classify areas based on energetic importance to the target species. This is calculated first as an index of energetic importance (IEI) based on the ratio of relative resource contribution to relative habitat cover, and then as a habitat resource index (HRI) that conveys the relative value of a landscape foraging unit for producing the necessary resources a consumer relies on. The resulting E-scape map projects HRI values onto the landscape where a location with a value of 1 indicate the target species could receive optimal energetic resources based on Barataria-specific stable isotope mixing models, home ranges, and habitat information (Nelson et al., 2019).

E-scapes will be developed based on USGS land:water delineated maps produced for the Project Area (see **Metric: Total land area**). Simple GIS calculations will be used to create rasters of habitat maps for the main basal dietary resources for the target nekton species: (1) emergent vegetation (*Spartina* and mangrove combined), (2) algae (suitable habitat for benthic algal production is assumed to be within 1 m of emergent marsh edge; Litvin et al., 2018; Wainright et al., 2000), and (3) particulate organic matter (POM; open water). Static input values for each target species' home range and dietary contributions are provided in Table 9-1.

Table 9-1. Species-specific data inputs for development of E-scapes based on methodology outlined in James et al., (2022).

		Dietary Contributions of Basal Resources to Consumer (%)			
Species	**Home range (m)**	Emergent Vegetation (Spartina + Mangrove)	Algae	Particulate Organic Matter (POM)	**Citation**
Blue crab	1000 (range: 10 to over 1000)	15	57	28	(Hines, 2007; Nelson et al., 2019)
White shrimp	200	13	49	38	(Nelson et al., 2019; Rozas & Minello, 1997; Webb & Kneib, 2004)
Brown shrimp	100	9	46	45	(Haas et al., 2004; Nelson et al., 2019)
Killifishes*	100	17	49	34	(Jensen et al., 2019; Nelson et al., 2019)

*The Gulf killifish species is used as a representative of the broader killifish guild due to a lack of available data for other species.

Analysis

E-scapes created for each year of land:water delineation (including pre-construction) could be used to evaluate changes in landscape-level average HRI values for each target nekton species (blue crab, white shrimp, brown shrimp, and killifishes [based on values derived for the Gulf killifish species]). T-tests will be used to compare post-construction HRI values for each target nekton species against pre-construction baseline values for each year of new data collection to evaluate project performance against associated performance criteria.