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LOUISIANA TRUSTEE IMPLEMENTATION GROUP

GUIDANCE FOR COASTAL ECOSYSTEM RESTORATION AND MONITORING TO CREATE OR IMPROVE BIRD-NESTING HABITAT

Suggested Citation

Deepwater Horizon Louisiana Trustee Implementation Group. 2023. *Guidance for Coastal Ecosystem Restoration and Monitoring to Create or Improve Bird-Nesting Habitat*. Baton Rouge, Louisiana.

EXECUTIVE SUMMARY

NEED

This guidance is intended to provide specific and detailed information on designing ecosystem restoration projects to support nesting birds, provided at the scale of an individual ecosystem restoration project. **The primary audience is ecosystem restoration project teams**, and this guidance is intended to be used during planning, designing, implementing, and monitoring of projects. **The first entry point for these teams is a series of tables in Section 2**. These are supported by comprehensive background information and associated resources as well as best professional judgment (where appropriate) from Subject Matter Experts (SMEs) in the fields of avian ecology and coastal engineering (**Sections 3 and 4**).

CONTEXT

The information and guidance build upon the high-level goals and strategic frameworks of Natural Resource Damage and Assessment, the Louisiana Trustee Implementation Group, and the Gulf of Mexico Avian Monitoring Network Strategic Bird Monitoring Guidelines and were developed to assist in the creation and/or enhancement of preferential bird-nesting habitat within coastal Louisiana. The scope of this guidance focuses specifically on nesting habitat, primarily resulting from currently available information. However, reference is made to foraging and loafing habitat as well as to subsequent breeding and breeding success. **To make the guidance directly applicable to coastal ecosystem restoration projects it is structured around bird use of habitats for nesting: shrub-nesting birds, marsh-nesting birds, and ground-nesting birds**. The bird groupings were intentionally developed from the perspective of project teams and how they could address (design, construct, maintain) bird habitat needs.

DEVELOPING THIS GUIDANCE

More than 100 facilitated calls and working sessions were conducted over a period of more than two years. These conversations included input from bird SMEs, ecosystem restoration project team members (including project engineers and project managers), and state and federal agency representatives involved in programmatic and project-based coastal restoration. Initially, information was synthesized on preferential nesting bird habitat, then constraints and opportunities within planning, construction, operation, and maintenance of restoration projects were collated for coastal marsh creation, barrier island restoration, and ridge restoration projects constructed in coastal Louisiana. Finally, lessons learned were summarized to determine targeted data or knowledge gaps to improve understanding of linkages between project design and construction and potential habitat value for bird nesting. The overall goals in developing this guidance were to:

Synthesize preferential nesting habitat requirements for target coastal nesting birds.

Design guidance for ecosystem restoration project planning, engineering and design, construction, and operations and maintenance to support nesting of target coastal bird species.

Develop monitoring guidance to quantify bird nesting that will support programmatic and project scale planning and reporting, as well as inform adaptive management of ecosystem restoration projects to maximize habitat for birds from ecosystem restoration in coastal Louisiana.

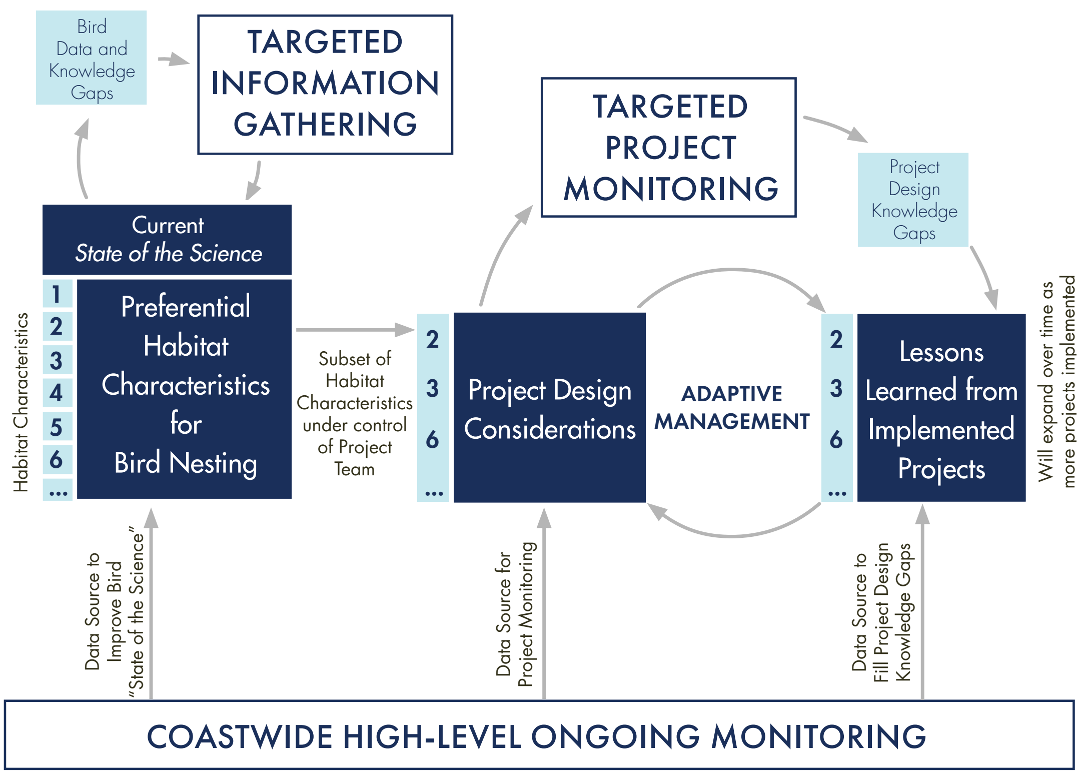
APPLICABLE TYPES OF RESTORATION AND NESTING BIRDS

The guidance primarily applies to the following ecosystem restoration project types: barrier island /headland restoration, marsh creation, and ridge restoration that are within, or consistent with, the Louisiana Coastal Master Plan (CPRA, 2017a). Because the purpose of this guidance is specifically to inform coastal restoration project teams, every effort was made to facilitate transfer of data and knowledge from the avian literature, as well as best professional judgment, into terminology and frameworks that apply to ecosystem restoration project planning, engineering and design, construction, and operations and maintenance. For this reason, a non-taxonomic bird grouping was used, focused on how these species potentially use created or restored habitat for nesting; these three groups are shrub-nesting birds, marsh-nesting birds, and ground-nesting birds.

Shrub-nesting birds: coastal bird species including (but not limited to) herons and pelicans[1] that primarily nest on, in, or among woody vegetation occurring in coastal wetlands (forest, scrub/shrub, and fresh-saline marsh), coastal bay islands (saline marsh and scrub/shrub), and barrier islands/headlands (saline marsh and scrub/shrub).

Marsh-nesting birds: coastal bird species including (but not limited to) rails and waterfowl[2] that inhabit and nest exclusively in coastal wetlands (fresh intermediate marsh and brackish-saline marsh), coastal bay islands (saline marsh), or barrier islands/ headlands (saline marsh).

Ground-nesting birds: coastal bird species including (but not limited to) terns and oystercatchers[3] that primarily nest on the ground, either directly on bare ground or in nests created and lined with vegetation and other organic materials. This group of birds nests on barrier islands/headlands (meadow, dune, beach, and saline marsh), overwash fans (unvegetated flat and meadow), coastal bay islands (saline marsh), and coastal wetlands (brackish-saline marsh).



Linkages between summarized information (from all data and knowledge sources) and guidance, monitoring, and information gathering in support of active adaptive management of coastal ecosystem restoration.

1 Refer to **Section 3.1**; **Table 14** for a complete list of target shrub-nesting birds.
2 Refer to **Section 3.2**; **Table 17** for a complete list of target marsh-nesting birds.
3 Refer to **Section 3.3**; **Table 20** for a complete list of target ground-nesting birds.

STRUCTURE AND FORMAT OF THIS GUIDANCE

Primary Guidance Summary Tables (Section 2)

Four fundamental information components are presented in **Section 2**: (1) habitat characteristics for target bird-nesting groups, (2) design considerations necessary to achieve target bird-nesting habitat characteristics, (3) lessons learned from previously implemented projects or conceptualized coastal ecosystem restoration projects, and (4) bird data gaps and information needs. Hyperlinks are strategically placed within this document and these tables to facilitate the project team's ability to retrieve supporting information and associated resources easily and efficiently. Fundamental information components are described in more detail below.

Supporting Bird Information (Section 3)

Section 3 provides additional background and supporting information about target bird species. This section explores life histories and nesting ecology for a suite of target bird species and provides context and literature to support the information provided in **Section 2**. Information regarding habitat characteristics is cross-linked to relevant cells within the tables in **Section 2** to allow the reader to easily navigate between the text and tables. In addition, photographs of bird species are provided in this section for reference.

Monitoring (Section 4)

Two scales of monitoring are covered in this guidance (**Section 4**). The first is broad spatial scale (referred to as high-level monitoring), repeated monitoring with standardized approaches for high-level programmatic reporting and planning. This section includes a recommendation for metrics that can be applied in a cost-effective way across coastal Louisiana and the northern Gulf of Mexico. The second scale is site-scale monitoring to be carried out at an individual project site (or sites) that will address targeted knowledge gaps or inform specific adaptive management questions.

This guidance is intended to be a living document and the information and guidance will be updated at least every five years. Therefore, this guidance can be the basis for an active adaptive management process with respect to habitat for nesting birds for coastal ecosystem restoration.

ACKNOWLEDGMENTS

Information and key findings included within *Guidance for Coastal Ecosystem Restoration and Monitoring to Create or Improve Bird-Nesting Habitat* were developed collaboratively with avian and coastal engineering Subject Matter Experts that have extensive working knowledge and experience throughout Louisiana's coastal zone. Deliberate and targeted input was requested from project managers and engineers with the Coastal Protection and Restoration Authority, the principal implementing agency for coastal restoration in the State of Louisiana and the lead state agency for the Louisiana Trustee Implementation Group. Extensive input was also received from Louisiana Trustee Implementation Group representatives, primarily from the Department of Interior and Louisiana Department of Wildlife and Fisheries. Online meetings (2020–2022) amongst team members were the primary information source, consisting of more than 100 multi-agency calls to develop this technical document. The term "Guidance" in this report refers to provision of information to coastal restoration project teams implementing projects with potential to benefit avian resources throughout Louisiana's coastal zone and the broader northern Gulf of Mexico.

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LIST OF ACRONYMS

BBS	Breeding Bird Survey
BICM	Barrier Island Comprehensive Monitoring
BTNEP	Barataria-Terrebonne National Estuary Program
CBC	Christmas Bird Count
CIMS	Coastal Information Management System
CPRA	Coastal Protection and Restoration Authority
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
DWH	*Deepwater Horizon*
GoMAMN	Gulf of Mexico Avian Monitoring Network
GPS	Global Positioning System
HSI	Habitat Suitability Index
LA TIG	Louisiana Trustee Implementation Group
LDNR	Louisiana Department of Natural Resources (LA TIG Trustee)
LDWF	Louisiana Department of Wildlife and Fisheries (LA TIG Trustee)
MAM	Monitoring and Adaptive Management
NAVD88	North American Vertical Datum of 1998
NRCS	Natural Resource Conservation Service
NRDA	Natural Resource Damage Assessment
PDARP	Programmatic Damage Assessment and Restoration Plan
SMEs	Subject Matter Experts
SOP	Standard Operating Procedure
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WVA	Wetland Value Assessment

UNIT TABLE

Unit Abbreviation	Unit
ac	acre
cm	centimeter
°C	degrees Celsius
ft	feet
ha	hectare
hr	hour
in	inch
km	kilometer
m	meter
mi	mile
mm	millimeter
mph	miles per hour
oz	ounce
ppt	parts per thousand

Note: Where possible, units were converted to imperial.

1 BACKGROUND AND CONTEXT

This document meets a need identified by restoration practitioners and coastal restoration managers for guidance on ecosystem restoration and monitoring to create or improve bird-nesting habitat. It is focused on informing design of ecosystem restoration projects to create or restore habitat for target[1] coastal nesting birds, either within or consistent with the Louisiana Coastal Master Plan (CPRA, 2017a). The primary audience is coastal ecosystem restoration project teams. This guidance is specifically developed to address questions raised by restoration teams throughout all project phases (planning, engineering and design, construction, and operations and maintenance). Therefore, most of the information is focused at the spatial and temporal scale of individual restoration projects. The information and guidance build upon the high-level goals and strategic frameworks of Natural Resource Damage and Assessment (NRDA), the Louisiana Trustee Implementation Group (LA TIG), and the Gulf of Mexico Avian Monitoring Network (GoMAMN) Strategic Bird Monitoring Guidelines and were developed to assist in the creation and/or enhancement of preferential bird nesting habitat (i.e. habitats that provide the greatest suitability/nesting success for breeding birds) within coastal Louisiana (Brush et al., 2019; CPRA, 2017a; DeMaso et al., 2019; DWH NRDA Trustees, 2016, 2017a; Frederick & Green, 2019; Jodice et al., 2019; LA TIG, 2021; Woodrey et al., 2019).

What is this Guidance?

This guidance is intended to help answer the question:

"How can coastal ecosystem restoration projects more effectively benefit bird-nesting habitats?"

To make the guidance directly applicable to coastal ecosystem restoration projects, it is structured around the way that target bird groups use habitat. Target birds:

Shrub-nesting birds,

Marsh-nesting birds, and

Ground-nesting birds.

Where is the Information I Need?

Technical guidance is summarized in a series of tables in Section 2 (Habitats and Bird Groups). The information is based on published literature and project implementation experience.

Detailed supporting information is linked throughout the tables and can be found directly in Section 3 (Supporting Information: Bird Ecology) and Section 4 (Supporting Information: Bird Monitoring for Ecosystem Restoration).

Is the Information up to Date?

Based on the current state of the science, this guidance is a living document intended to be updated at least every five years as part of an active adaptive management process.

1 The term "target" is used to reference the species within each bird group that were considered in developing this guidance. Note that this guidance was developed specifically for those species and does not necessarily apply to all shrub-, marsh-, and ground-nesting birds.

1.1 NEED FOR THIS GUIDANCE

Ongoing large-scale land loss (e.g., transition of emergent coastal marshes, bay and barrier islands, and mainland beaches to open water) continues to reduce habitat for a broad range of bird species that nest in coastal Louisiana (Couvillion et al., 2011; Remsen et al., 2019). Compounding this long-term trend, large-scale bird injury was documented within coastal Louisiana and the broader northern Gulf of Mexico in association with the Deepwater Horizon (DWH) oil spill, which resulted in expansive acute and chronic bird mortality (DWH NRDA Trustees, 2016; Table 4.7-3). The NRDA component of the DWH settlement in 2016 approved specific funds for bird restoration to be managed by the Trustees of LA TIG. LA TIG bird restoration funds totaled $148.5 million in the final settlement (DWH NRDA Trustees, 2016). In addition to the funds targeted specifically for bird restoration, LA TIG is responsible for $4 billion to restore wetlands, coastal, and nearshore habitats that have a high potential to benefit coastal nesting birds (LA TIG, 2021).

The Programmatic Damage and Assessment Restoration Plan provides overall guidance to Trustees for restoration planning, implementation, maintenance, and monitoring (DWH NRDA Trustees, 2016). The Strategic Framework for Bird Restoration Activities further refined the data and information needs to inform monitoring and active adaptive management (DWH NRDA Trustees, 2017a). In parallel with the NRDA process, a self-organized group of federal, state, academic, and NGO (non-governmental organization) scientists and managers, through GoMAMN, developed comprehensive Strategic Bird Monitoring Guidelines for the Northern Gulf of Mexico for different bird groups (e.g., seabirds [Jodice et al., 2019]; wading birds [Frederick & Green, 2019]; marsh birds [Woodrey et al., 2019]). These documents are intended to provide Trustees with the technical background needed for the development of bird-specific restoration performance goals. Although comprehensive, the existing framework and strategy documents are high-level and primarily focus on a programmatic scale of restoration goal setting, monitoring, and reporting.

This guidance is intended to provide specific and detailed information on designing ecosystem restoration projects to support nesting birds, provided at the scale of an individual ecosystem restoration project. The primary audience is coastal ecosystem restoration project teams, and this guidance is intended to be used during planning, designing, implementing, and monitoring of projects.

Three specific needs for coastal ecosystem restoration project teams are:

- Synthesize preferential nesting habitat requirements for target coastal nesting birds.
- Design guidance for ecosystem restoration project planning, engineering and design, construction, and operations and maintenance to support nesting of target coastal bird species.
- Develop monitoring guidance to quantify bird nesting that will support programmatic and project-scale planning and reporting, as well as inform active adaptive management of ecosystem restoration projects to maximize habitat for birds from ecosystem restoration in coastal Louisiana.

1.2 DEVELOPING THIS GUIDANCE

Through more than 100 facilitated calls and working sessions over a period of more than two years, bird Subject Matter Experts (SMEs), ecosystem restoration project team members (including project engineers), and agency representatives involved in programmatic coastal restoration synthesized preferential nesting bird habitat information. The information and knowledge gained from these discussions, including a broad literature survey, were used to develop this *Guidance for Coastal Ecosystem Restoration and Monitoring to Create or Improve Bird-Nesting Habitat*. To provide habitat for target coastal nesting birds through ecosystem restoration, information is needed during all aspects of project planning, design, construction, maintenance, and monitoring. Of critical importance is that coastal ecosystem restoration project teams can easily and efficiently locate the information to inform their established decision-making processes.

This guidance primarily applies to the following ecosystem restoration project types: barrier island /headland restoration, marsh creation, and ridge restoration that are within, or consistent with, the Louisiana Coastal Master Plan (CPRA, 2017a). Much of the guidance and synthesized information provided is also relevant to a wide range of coastal ecosystem restoration project types along the northern Gulf of Mexico including sediment diversions, crevasses, and marsh terrace creation.

This guidance does not directly address aspects of habitat use for birds other than for the purposes of nesting (i.e., migratory stopover/staging and/or wintering [Bianchini et al., 2020; Laughlin et al., 2013; Paruk et al., 2014; Patton et al., 2020; Scherr et al., 2010]). The guidance does, however, have utility for project planning and program management. There are several high-level geographic and geologic constraints on occurrence of some bird species that nest in coastal Louisiana. While a project team may not have control over project location, the implications of project location are included in this guidance to provide information about the potential utilization by target coastal nesting species of created or restored nesting habitat.

1.3 HOW TO USE THIS GUIDANCE

Although this effort was envisioned to benefit multiple end users, the primary audience is coastal ecosystem restoration project teams (project managers, engineers, construction contractors, etc.). The first entry point for these teams is provided in the tables in **Section 2**. This is supported by comprehensive background information and associated resources as well as best professional judgment (where appropriate) from SMEs in the fields of avian ecology and coastal engineering (**Section 3** and **Section 4**).

1.3.1. Primary Guidance Summary Tables (Section 2)

Four fundamental information components are presented: (1) habitat characteristics for target bird-nesting groups, (2) design considerations necessary to achieve target bird-nesting habitat characteristics, (3) lessons learned from previously implemented projects or conceptualized coastal ecosystem restoration projects, and (4) bird data gaps and information needs (**Figure 1**). Hyperlinks are strategically placed within these tables to facilitate the retrieving of supporting information and associated resources easily and efficiently. Fundamental information components are described in more detail below.

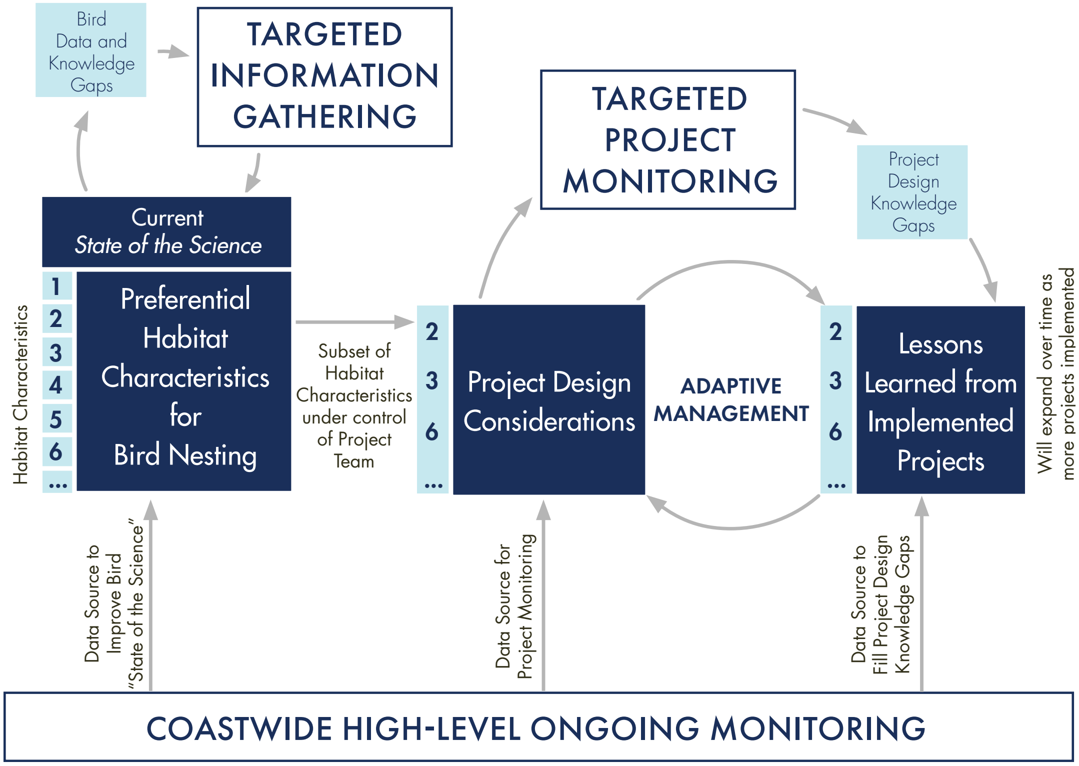

Figure 1. Linkages between summarized information (from all data and knowledge sources) in support of active adaptive management of coastal ecosystem restoration.

Habitat characteristics[2]
Summarizes the current state of knowledge from a bird biology and ecology perspective, focused on habitat characteristics that have most frequently been observed to support successful bird nesting within coastal Louisiana. The information presented includes preferential bird-nesting habitat characteristics, a description of each characteristic, a biological reason to explain why the characteristic is important, and the bird species for which the nesting habitat characteristic is relevant.

Design considerations[3]
Summarizes aspects of project planning, engineering and design, operation and maintenance, and implementation that are within the control of the project team. It directly links to habitat characteristics and is organized by the same list of preferential bird-nesting habitat characteristics. Overall, the table details the design considerations that have been, or could be, used within a project. Project examples are identified along with specific key project documents and associated information. It is noted if bird nesting was a primary objective of the project. Finally, a primary contact (usually project manager) for further information on each project is provided.

Lessons learned and project engineering and design data gaps and information needs[4]
Summarizes lessons learned from implemented restoration projects in coastal Louisiana. This table is organized by the same list of preferential bird-nesting habitat characteristics to help identify the data gaps/information needs relation to project E&D aimed at increasing the habitat value for nesting birds. The project ID and name are detailed, as well as specific document and page number references to specific information source(s).

Data gaps or information needs to better understand nesting bird biology and ecology[5]
Summarizes the current state of knowledge and/or assumptions related to bird biology or ecology relevant to ecosystem restoration projects. The table is organized by the same list of preferential bird-nesting habitat characteristics. This table presents data gaps and the information needed to reduce uncertainty in understating the restoration benefits for bird nesting. The aim of this table is to focus information-gathering efforts toward addressing targeted questions that will directly inform engineering design to increase bird-nesting success through coastal restoration projects.

It is intended that this will be a living document and the information and guidance will be updated at least every five years. Therefore, this guidance can be the basis of an active adaptive management process with respect to creation or retention of habitat for nesting birds from coastal ecosystem restoration.

1.3.2. Supporting Bird Information (Section 3)

Section 3 provides additional background and supporting information about target bird species. This section explores life histories and nesting ecology for a suite of target bird species and provides context and literature to support the information provided in **Section 2**. Information regarding habitat characteristics is cross-linked to relevant cells within the tables in **Section 2** to allow the reader to easily navigate between the text and tables. In addition, photographs of bird species are provided in this section for reference.

1.3.3. Monitoring (Section 4)

Two scales of monitoring are covered in this guidance (**Section 4**). The first is broad spatial scale (referred to as high-level ongoing monitoring), repeated monitoring with standardized approaches for high-level programmatic reporting and planning. This section includes a recommendation for metrics that can be applied in a cost-effective way across coastal Louisiana and the northern Gulf of Mexico. The second is site-scale (or targeted) monitoring which can be carried out at an individual project site (or sites) that will address targeted knowledge gaps or inform specific adaptive management questions.

2 See **Table 2** (shrub-nesting birds), **Table 6** (marsh-nesting birds), **Table 10** (ground-nesting birds).
3 See **Table 3** (shrub-nesting birds), **Table 7** (marsh-nesting birds), **Table 11** (ground-nesting birds).
4 See **Table 4** (shrub-nesting birds), **Table 8** (marsh-nesting birds), **Table 12** (ground-nesting birds).
5 See **Table 5** (shrub-nesting birds), **Table 9** (marsh-nesting birds), **Table 13** (ground-nesting birds).

1.3.3.1. High-Level Ongoing Monitoring

High-level ongoing monitoring consists of programmatic ecosystem restoration that requires standardized approaches to multi-year and coastwide data collection and analysis to effectively report on programmatic and large-scale restoration. Along the northern Gulf of Mexico, including within coastal Louisiana, systematic bird monitoring using aerial photography of bird-nesting colonies is currently being implemented on a semi-regular basis (see **Section 4.3.1.**). Collected data are intended to provide high-level assessments specific to the status and trends of colonial nesting waterbirds. Systematic bird monitoring using aerial photography of bird-nesting colonies is memorialized within the LA TIG Monitoring and Adaptive Management (MAM) strategy, which addresses SMART (Specific, Measurable, Achievable, Relevant, and Timely) objectives and is specifically intended to inform ongoing active adaptive management efforts and needs for LA TIG (see Table 8 in the LA TIG Monitoring and Adaptive Management Strategy; LA TIG, 2021).

1.3.3.2. Targeted Information Gathering and Monitoring

In addition to high-level ongoing monitoring, targeted monitoring (either site-specific or event-based) can be utilized to address avian-specific goals and fill identified knowledge gaps. These knowledge gaps may relate to bird biology, either of a particular species or a particular group of nesting birds (e.g., ground-nesting birds). Alternately, these knowledge gaps may specifically inform bird-nesting response to a project design feature or construction/maintenance approach. Depending on the question, this additional monitoring may include a broad set of metrics to increase understanding of, for example, not only the number of birds that nest, but also fledging success or measures of bird health and many other identified data and knowledge needs (e.g., Ottinger et al., 2019, [Table 10.1]). Many of these additional targeted monitoring goals and objectives are included within the strategic frameworks of NRDA and LA TIG as well as the GoMAMN Strategic Bird Monitoring Guidelines (Brush et al., 2019; CPRA, 2017a; DeMaso et al., 2019; DWH NRDA Trustees, 2016, 2017a; Frederick & Green, 2019; Jodice et al., 2019; LA TIG, 2021; Woodrey et al., 2019).

1.3.4. Adaptive Management

The habitat characteristics presented in this guidance are intended to inform creation or enhancement of bird-nesting habitat. They represent the current state of the science with clearly defined knowledge gaps and information needs. In so doing, the document is intended as an engagement point to focus the science community toward addressing targeted ecosystem management questions that will directly inform engineering design to increase bird-nesting success through coastal restoration projects. This provides an opportunity for the science community to target ecosystem management questions that will improve knowledge of coastal birds specifically related to improving outcomes (e.g., increasing bird-nesting opportunities) from coastal restoration (**Figure 1**). High-level ongoing monitoring data (and analysis) also have the potential to add to the increasing state of understanding of coastal nesting birds. For design considerations that can be built to accommodate habitat for coastal nesting birds, with an appropriate feedback mechanism, targeted monitoring can provide input to adaptive management over time (DWH NRDA Trustees, 2021). Selection of the most successful project design features to create or restore bird-nesting habitat can also be informed through analysis of high-level ongoing monitoring (**Figure 1**). To successfully inform an ongoing adaptive management process, this guidance needs to be a living document that updates the lessons learned and adds to the state of the science of coastal bird nesting at least on a five-year cycle.

2 HABITATS AND BIRD GROUPS

2.1 INTRODUCTION

The primary audience for this document includes coastal ecosystem restoration project teams. Ecological nesting requirements for birds were synthesized amongst shrub-, marsh-, and ground-nesting birds. These groupings link to those used within NRDA, LA TIG, and the GoMAMN Strategic Bird Monitoring Guidelines (Brush et al., 2019; CPRA, 2017a; DeMaso et al., 2019; DWH NRDA Trustees, 2016, 2017a; Frederick & Green, 2019; Jodice et al., 2019; LA TIG, 2021; Woodrey et al., 2019).

The bird groupings were intentionally developed from the perspective of coastal ecosystem restoration project teams and how they could address (design, construct, maintain) bird habitat needs. The information presented was linked (where appropriate) to established coastal landscape features and ecological habitats (**Table 1**) and follows related engineering terminology utilized by the Coastal Protection and Restoration Authority (CPRA).[6] This approach aims to facilitate effective and efficient coastal ecosystem project implementation with the goal of creating or restoring preferential bird-nesting habitats throughout coastal Louisiana.

Table 1. Summary of landforms and habitats used to describe location and occurrence of coastal nesting birds. (Note: marsh habitats were adapted from Chabreck (1970), and all other habitat types were adapted from CPRA[6]).

Landform	Habitat
Coastal Wetland	Forest Scrub/shrub Fresh-intermediate marsh Brackish-saline marsh
Coastal Bay Islands	Saline marsh Scrub/shrub
Barrier Island/Headland	Saline marsh Scrub/shrub Meadow Dune Beach Intertidal
Overwash Fans (within Barrier Islands/Headlands)	Intertidal Unvegetated flat Meadow

Descriptions for all non-marsh habitat types (forest, scrub/shrub, meadow, dune, beach, intertidal, and unvegetated flat) were adapted directly (or slightly modified) from the Louisiana Barrier Island Comprehensive Monitoring (BICM) Program habitat classifications (Enwright et al., 2020). Marsh-type habitats (fresh, intermediate, brackish, and saline) are based on vegetation species predicted to occur at each location[7] (based on Chabreck, 1970).

The definitions of habitats in **Table 1** describe the location and occurrence of coastal nesting birds:

6 Landforms and habitat types used, with the exception of the marsh habitats, were adapted from the Louisiana Barrier Island Comprehensive Monitoring Program habitat classifications (Enwright et al., 2020).

7 For a visual depiction of the spatial aspect of marsh types, see **Figure 5**.

Beach includes supratidal bare or sparsely vegetated areas (that is, above the extreme high water spring tide level) located along coastlines with high wave energy (that is, gulf-facing shorelines). Vegetation cover is generally less than 30 percent. Beach transitions into dunes, meadows, or unvegetated flats where overwash is evident.

Brackish marsh vegetation communities include saltmeadow cordgrass (*Spartina patens*), three-square bulrush (*Schoenoplectus americanus*), saltmarsh bulrush (*Bolboschoeunus robustus*), and dwarf spikerush (*Eleocharis parvula*).

Dunes are supratidal features (that is, above the extreme high-water spring tide level) developed via aeolian processes. Dunes are often located above typical stormwater levels and have a well defined relative elevation (that is, upper slope or ridge). Dunes can be vegetated or unvegetated but vegetated dunes (with greater than 10 percent vegetation cover) are more suitable for nesting birds.

Forest includes areas where woody vegetation height is greater than 6 m. Woody vegetation coverage generally is greater than 30 percent.

Fresh marsh vegetation communities include maiden cane (*Panicum hemitomon*), pennywort (*Hydrocotyle* sp.), cattail (*Typha latifolia*), pickerelweed (*Pontederia cordata*), bulltongue (*Sagittaria lancifolia*), and alligatorweed (*Alternanthera philoxeroides*). All species can grow in permanent standing water.

Intermediate marsh vegetation communities include saltmeadow cordgrass (*Spartina patens*), wild cow pea (*Vigna* sp.), bulrush (*Schoenoplectus* sp.), and common reed (*Phragmites australis*).

Intertidal includes bare or sparsely vegetated areas located between the extreme low-water and extreme high water spring tide levels. Vegetation cover is generally less than 30 percent. The intertidal area includes the foreshore zone of a beach.

Meadow includes supratidal areas (that is, above the extreme high-water spring tide level) with sparse to dense herbaceous vegetation located in areas leading up to dunes on gulf-facing shorelines or between the backslope of dunes and supratidal, barrier flat habitat). Vegetation coverage is generally greater than 30 percent. Classification of meadow habitat is restricted by geomorphic settings. Meadow is reserved for areas located on unvegetated flats of barrier islands, backslopes of dunes, or transitional vegetated areas in dune/beach habitats.

Saline marsh vegetation communities include smooth cordgrass (*Spartina alterniflora*), black needlerush (*Juncus roemerianus*), saltwort (*Batis maritima*), saltgrass (*Distichlis spicata*), and black mangrove (*Avicennia germinans*).

Scrub/shrub includes areas where woody vegetation height is greater than about 0.5 m, but less than 6 m. Woody vegetation coverage generally is greater than 30 percent.

Unvegetated flat includes flat or gently sloping supratidal unvegetated or sparsely vegetated areas (i.e., areas located above extreme high-water spring tide level) that are located on the backslope of dunes, unvegetated overwash fans, and along low energy shorelines. Vegetation cover is generally less than 30 percent.

The three bird nesting groups targeted in this guidance are:

- **Shrub-nesting birds** (**Figure 2**): coastal bird species including (but not limited to) herons and pelicans[8] that primarily nest on, in, or among woody vegetation occurring in coastal wetlands (forest, scrub/shrub, and fresh-saline marsh), coastal bay islands (saline marsh and scrub/shrub), and barrier islands/headlands (saline marsh and scrub/shrub).

8 Refer to **Section 3.1**; **Table 14** for a complete list of target shrub-nesting birds.

Figure 2. Example of a shrub-nesting bird: Green Heron on nest (photo credit Robert Dobbs, LDWF).

- **Marsh-nesting birds** (**Figure 3**): coastal bird species including (but not limited to) rails and waterfowl[9] that inhabit and nest exclusively in coastal wetlands (fresh intermediate marsh and brackish-saline marsh), coastal bay islands (saline marsh), and barrier islands/headlands (saline marsh).

Figure 3. Example of a marsh-nesting bird: Mottled Ducks on nests in a saline marsh (photo credit: Eva Windhoffer, the Institute).

9 Refer to **Section 3.2**; **Table 17** for a complete list of target marsh-nesting birds.

- **Ground-nesting birds** (**Figure 4**): coastal bird species including (but not limited to) terns and oystercatchers[10] that primarily nest on the ground, either directly on bare ground or in nests created and lined with vegetation and other organic materials. These species nest on barrier islands/headlands (meadow, dune, beach, and saline marsh), overwash fans (unvegetated flat and meadow), coastal bay islands (saline marsh), and coastal wetlands (brackish-saline marsh).

Figure 4. Example of a ground-nesting bird: Wilson's Plover on nest on Caminada Headland, Louisiana (photo credit: Delaina LeBlanc, BTNEP).

The classifications of shrub-nesting, marsh-nesting, and ground-nesting birds are based upon known and observed bird-nesting characteristics at a site-specific and local scale (i.e., <3 ft spatial scale). In addition, there are several broad geographic and ecological features that influence the distribution of these three nesting bird groups across coastal Louisiana. The distribution of shrub-, marsh-, and ground-nesting birds across habitats and landforms (refer to **Table 1**) are graphically depicted in **Figure 5**. Shrub-nesting birds nest within coastal wetlands (forest, scrub/shrub, and fresh to saline marsh), coastal bay islands (saline marsh and scrub/shrub), and barrier islands/headlands (saline marsh and scrub/shrub; Keller et al., 1983). Marsh-nesting birds nest in coastal wetlands (fresh-intermediate marsh and brackish-saline marsh), coastal bay islands (saline marsh), and barrier islands/headlands (saline marsh; Byerly et al., 2020; Woodrey et al., 2019). Ground-nesting birds nest on barrier islands/headlands (meadow, dune, beach, saline marsh, and overwash fans consisting of unvegetated flat and meadow), coastal bay islands (saline marsh, shell rakes), and coastal wetlands (brackish-saline marsh; Visser & Peterson, 1994).

What follows in **Sections 2.2, 2.3, and 2.4** are a series of tables that outline select habitat characteristics and associated design considerations, lessons learned, and data gaps and information needs for shrub-nesting,[11] marsh-nesting,[12] and ground-nesting[13] birds. The information presented in these tables is intended to provide coastal ecosystem restoration project teams and resource managers with guidance toward the creation and/or restoration of preferential bird-nesting habitats within coastal ecosystem restoration projects.

10 Refer to **Section 3.3**; **Table 20** for a complete list of target ground-nesting birds.
11 For shrub-nesting bird tables, see **Table 2**, **Table 3**, **Table 4**, **Table 5**.
12 For marsh-nesting bird tables, see **Table 6**, **Table 7**, **Table 8**, **Table 9**.
13 For ground-nesting bird tables, see **Table 10**, **Table 11**, **Table 12**, **Table 13**.

LANDFORMS

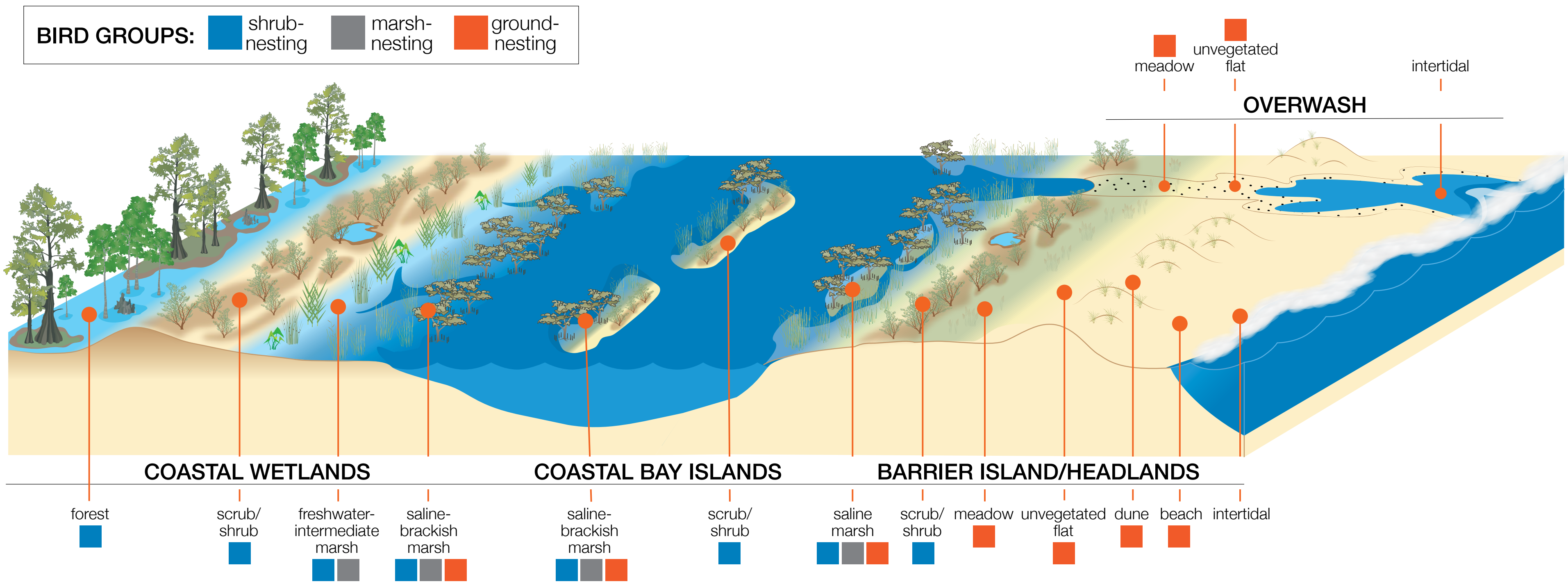

Figure 5. Overview of generic habitat distribution by shrub-, marsh-, and ground-nesting birds across coastal Louisiana.

2.2 SHRUB-NESTING BIRD TABLES

The information provided in the following tables relates to shrub-nesting birds (see the definition for this bird group in Section 2.1). Each table is based upon a set of determined habitat characteristics for shrub-nesting birds, which are described in Table 2 (this table also includes the reason each habitat characteristic is important for shrub-nesting birds and the specific species of birds where they apply). Table 3 provides design examples and context for each of the habitat characteristics, including project examples (where applicable) and information on whether those projects were targeted bird restoration projects. Table 4 provides *project-specific* lessons learned relating to each habitat characteristic and any data gaps or existing information needs that can inform project design. Finally, Table 5 highlights current data gaps and information needs relating to *bird-specific* knowledge with regard to each habitat characteristic.

Table 2. Habitat characteristics for shrub-nesting birds. Additional information is provided in Section 3.1.2.

Preferential Avian Nesting Habitat Characteristic	Consideration	Reason for Consideration	Species/ Grouping
1. Proximity to Human Activity and Mammalian Predators	Not in close proximity (suggested >4 mi) to any development or intense human activity and mammalian predators.	Human activity increases both the likelihood of disturbance (which can lead to nest abandonment) and presence of mammalian predators including raccoons and coyotes (which can negatively affect nesting success and survival).	All
2. Proximity to Previously Used Nesting Site	Prioritize project sites within ≤3 mi of previously used nesting sites, with a strong preference for project sites at the exact locations of previous nesting.	Individual species usually return to the same geographic locations to nest every year.	All
3. Proximity to Water	Barrier Islands/Headlands, Coastal Bay Islands, Coastal Wetlands: Within 12 mi of open waters (estuary or gulf waters that separate landforms and harbor large fish). Intertidal waters near nest sites may also be used for loafing by sub-adults and chicks.	Foraging habitat for Brown Pelicans and Neotropic Cormorants.	Brown Pelican and Neotropic Cormorant
	Barrier Islands/Headlands, Coastal Bay Islands, Coastal Wetlands: Within 6–9 mi vicinity of shallow (<0.5 m) water with abundant fish/invertebrate prey resources.	Foraging habitat for wading species.	All Egrets, Herons, and Ibis
4. Island Size	Barrier Islands/Headlands + Coastal Bay Islands: Islands <50 ac unless predator control implemented or known to be low threat; it is suggested that nesting habitat should encompass a minimum area of 5 ac.	Mammalian predation generally increases as island size increases.	All
5. Ground Elevation	Barrier Islands/Headlands + Coastal Bay Islands: Suggested average elevation of at least 3 ft (Landin and Engler 1986) or average elevation of 1 ft above mean sea level at the nearest gauge. This metric was calculated by pooling scrub-shrub and mangrove thicket islands (Visser et al., 2005).	Elevation should be high enough to prevent nest flooding during nesting season and low enough to limit erosion from wind. Nest areas on islands must remain permanently emergent during high tide and frequent storm events during nesting season. Elevation is also influenced by nesting vegetation requirements (e.g., mangrove vegetation may have different flood tolerance than groundsel bush; Osland et al., 2020).	All
6. Vegetation Cover and Composition	Prioritize planting of dense shrub/tree species on barrier islands/headlands (groundsel tree, black mangrove, matrimony vine, and marsh-elder) and coastal wetlands (cypress, tupelo, buttonbush, and wax myrtle). Additionally, grasses planted on Queen Bess Island have also performed well under storm conditions to limit erosion of sediments from overwash; field observations have also shown abundant pelican nesting activity in the grassy areas lacking shrub vegetation.	Higher nest success is associated with close/communal nesting, and dense shrubs are more likely to support greater avian species richness; however, CPRA and LDWF personnel have observed frequent pelican nesting in grassy areas of Queen Bess Island as well.	All
7. Vegetation Height	Provide shrub species capable of achieving a minimum 5 ft above ground height. Note that vegetation of this size either needs to have sufficient lead time in planting contracts or this will take time to occur naturally if juvenile vegetation planted. Some target birds establish nesting colonies within varying vegetation heights and as vegetation establishes over time.	Elevated nests (i.e., not directly on the ground) are generally more successful due to protection during high storm/inundation events.	All
8. Sediment Structure	Finer, non-cohesive sand sediments (>0.125 mm on Wentworth scale; Table 25) on elevated, supratidal areas of islands may inhibit plant colonization due to wind energy and lack of nutrients. More cohesive silt/clay sediment types (<0.06 mm on Wentworth scale; Table 25) provide ideal substrate for shrub vegetation.	Sediment necessary for shrub vegetation to establish.	All
9. Substrate and Nest Materials	Access to sticks/natural debris.	For nest building.	All

Table 3. Design considerations for shrub-nesting birds.

Preferential Avian Nesting Habitat Characteristic	Examples and Context	Project Examples	Bird-Targeting Project?
1. Proximity to Human Activity and Mammalian Predators	This habitat characteristic is not typically influenced by design decisions. To date, all constructed or ongoing CPRA projects specifically intended for restoration of avian habitat have occurred on existing rookeries or locations of high avian presence and thus, due to natural preference, occurred in isolated island locations such as Rabbit Island (CS0080), Queen Bess Island (BA0202), and Terrebonne Houma Navigation Canal Island Restoration (TE0165). Greer et al. (1988) assert that these locations possess critical attributes that are highly beneficial in support of productive colonial waterbird colonies: these islands are usually small in size, remote in location, and maintain dense vegetation and expansive beach nesting and loafing substrates. The Caminada Headland, Grand Isle, and Portions of the Cameron Parish shoreline are the only areas with permanent human presence and direct access on the Louisiana coast. The vast majority of other ground-nesting bird habitat restoration, which has occurred indirectly through other coastal restoration projects, also has occurred in locations well removed from human activity and typically have not included measures to prevent human presence. Avian habitat restoration in situations where human presence is likely should consider the installation of measures such as signage and/or barriers to prevent human interference with nesting areas in coordination with local representatives.	CS-0080 Rabbit Island Restoration.	Yes
		BA-0202 Queen Bess Island Restoration.	Yes
			Yes
		TE-0165 Terrebonne Houma Navigation Canal Island Restoration.	Yes
2. Proximity to Previously Used Nesting Site	Various groups have attempted the creation of new colonial waterbird (namely Brown Pelican) nesting habitat within coastal Louisiana. Of the 10 documented attempts to create bird islands, the majority (only 4 of 10 noted as persistent colonies) have been unsuccessful. The most successful restoration attempts have occurred at historical Brown Pelican colonies, such as Raccoon, Rabbit, and Queen Bess islands.	(Visser et al., 2005) (McNease et al., 1992) (Louisiana Trustees, 2018).	Yes
3. Proximity to Water	Project teams should consider the location of likely or intended avian nesting and foraging areas relative to existing water features. Elevation and nesting area location should be designed in such a way that minimizes incidence of nest inundation associated with high-energy wave areas, where overwash may occur. Shallow ponds (<1.6 ft / 0.5 m) and like features (tidal ponds, flats, areas protected from waves, and tidal creeks) can be constructed during or after construction, or through preservation of existing features via containment dikes during construction. Collectively, these features have been shown to be heavily utilized by herons, egrets, and shorebirds. Project teams should also consider the risks standing water can pose for potential disease transmission. Depending on the borrow type, sediment placement may take extended amounts of time to dewater, causing excessive ponding. Finer-grained, cohesive sediments are more likely to cause excessive ponding than sand borrow.	Queen Bess Island employed several measures: shoreline armoring and access ramps to estuarine waters as well as preservation of existing shallow ponds by excluding them from designed fill areas. BA-0202 Queen Bess Island Restoration (Section 2.5 of final design report, Plan sheets 12, 16, 17 in bid package).	Yes
		CS-0080 Rabbit Island Restoration (Section 5.2, 6 of final design report, Plan sheets 6, 7 in bid package).	Yes
4. Island Size	Observations of successful shrub-nesting bird colonies noted typical island sizes ranged between 25–193 acres (Visser et al., 2005; Note that larger sites are more likely to harbor mammalian predators). Island size is frequently established through an iterative process using project design milestones. Therefore, in determining island size, the project team's decision-making process must balance determining factors including available funding, morphologic function, and site considerations constraining construction such as local bathymetry and topography, available sediment quantity and characteristics, existing avian habitat and nesting areas, and other ecological and habitat goals for the project beyond those that maximize nesting bird habitat (e.g., tradeoffs with other ecological functions).	For CS-0080 Rabbit Island Restoration (95% Design Report), designers discuss the iterative process used when considering existing avian habitat on the island, budget, sediment availability, and project work windows to arrive upon the chosen island size for construction.	Yes

Preferential Avian Nesting Habitat Characteristic	Examples and Context	Project Examples	Bird-Targeting Project?
5. Ground Elevation	Project design teams may seek guidance on upper elevation limits (to consider rising seas, changing storm conditions, subsidence over a project life of 20 or more years, and other ecological and habitat goals for the project beyond those that maximize nesting bird habitat [e.g., tradeoffs with other ecological functions]), as well as for lower elevation limits (to consider inundation frequency and its impacts on nest washout versus colony survival). Unfortunately, no rule of thumb or universally agreed-upon threshold exists within the scientific and engineering community and, to date, restoration projects with specific avian habitat restoration goals have approached design elevations on a case-by-case basis depending on the project's constructibility, available funding, and design team's risk tolerance. Two of the largest threats to Brown Pelicans and other shrub-nesting birds throughout coastal Louisiana are nest flooding and loss of preferential nesting habitat (McNease et al., 1992; Walter et al., 2013). Ground elevation is a critical determinant in lessening these stated impacts. For cheniers, ridges, and coastal bay islands, elevation design has been historically determined by balancing island inundation exceedance probability for vegetation and nest survival with construction cost. Island inundation exceedance probability is the likelihood that the nesting areas/elevations will be flooded during nesting season (conservatively using data April–July). Project teams such as those on Queen Bess Island selected the 10% exceedance probability water surface elevation, which means the island's designed nesting areas would remain dry in all but infrequent tropical cyclone type events. However, there is a theoretical tipping point where an overabundance of supratidal habitat can increase the likelihood of avian predator presence. Past projects have used both coarse (sands) and fine-grained (silts and clays) fill to achieve varied elevations (elevation heterogeneity) within a project footprint for both coastal bay islands, barrier islands, and ridge with marsh projects.	CS-0080 Rabbit Island Restoration (Section 5.2, 6 of final design report, Plan sheets 6, 7 in bid package).	Yes
		BA-0202 Queen Bess Island Restoration (Section 6.1.3 of final design report, Plan sheets 12, 14, 16, 17 in bid package).	Yes
	Ridge and chenier projects have had a wider array of design elevations and construction methods employed: generally, ridge elevations have been set such that the crest elevation remains supratidal at the end of the projects' design life. Ridge crest elevations generally range from 4.5 ft up to 8 ft North American Vertical Datum of 1988 (NAVD88) depending on a 20- or 50-year design life). Ridges have been constructed utilizing both coarse-grained materials pumped from long distances, such as sand from the Mississippi River, and cheaper, fine-grained in-situ material in the form of enlarged containment dikes that are not degraded post-construction. Ridge slopes using non cohesive, coarse-grained materials will likely have shallower slopes (20H:1V or more) due to the sandy material's ability to stack, whereas fine-grained materials may stack at slopes (4H:1V to 7H:1V), which is often governed by containment dike slope stability geotechnical design).	BA-0068 Bayou Grand Liard Marsh and Ridge Restoration (pgs. 23, 25, 36–39 of design report, Plan sheets 10–13, 15, 21–23 in bid package).	No
		BA-0203 Spanish Pass Marsh and Ridge Restoration (pgs. 47–51, Plan sheet 19 in bid package).	No
		BA-0048 Bayou Dupont Marsh and Ridge Restoration (pgs. 23–24 of design report, Plan sheets 28–30 in bid package).	No
6. Vegetation Cover and Composition	Information available to designers would include required and ideal characteristic descriptions for a number of vegetation-related topics such as dredge slurry salinity or planting spacing strategies. At present, the data synthesis and studies to provide conclusive guidance do not exist. Data are potentially available to support such studies, such as BICM habitat and vegetation monitoring and project-specific Operations, Maintenance & Monitoring annual reports. CPRA does not have specific design directives for plantings as they do for other project aspects (such as survey, geotechnical investigations, or design of the earthen project features). There are, however, several resources available for project teams to consult when designing a project planting scheme. Gulf Coast Natural Resource Conservation Service (NRCS) Plant Material Centers, especially those in Texas, Louisiana, and Mississippi, produce a wealth of literature on planting schemes for avian habitat (https://www.nrcs.usda.gov/plant-materials/publications/search). Examples of past CPRA vegetative planting designs are noted, but by no means should they be viewed as prescriptive.	BA-0202 Queen Bess Island Restoration (pgs. 25–27 of plan sheets, Technical Specifications TS 7, 8, 9 in bid package).	Yes
		CS-0080 Rabbit Island Restoration vegetative plantings (pgs. 1–6 of plan sheets, Technical Specifications TS 1012, 1202, 1203 in bid package).	Yes
		BA-0048 Bayou Dupont Marsh and Ridge Restoration vegetative plantings project (pgs. 4–5 of plan sheets, Special Provision SP 16, Technical Specifications TS 1001, 1220, 1221 in bid package).	No
		BA-0068 Bayou Grand Liard Marsh and Ridge Restoration vegetative plantings project (pgs. 4–5 of plan sheets, Special Provision SP 16, Technical Specifications TS 1001, 1220, 1221 in bid package).	No

Preferential Avian Nesting Habitat Characteristic	Examples and Context	Project Examples	Bird-Targeting Project?
6. Vegetation Cover and Composition (continued).	**Table 1** lists habitats that provide important nesting habitat for shrub-nesting birds found most commonly in intertidal wetland areas with a median annual salinity around 25 ppt and areas that do not receive severe frosts (Visser et al., 2017). Black mangroves have undergone a rapid expansion in high-salinity coastal areas of Louisiana such as within salt marsh areas in southern Jefferson, Lafourche, and Terrebonne parishes since the 1990s (Day et al., 2020). Black mangroves are commonly found within intertidal salt marsh areas (see Figure 1 in Osland et al., 2020). Of note, Queen Bess and Rabbit Island projects were seeded initially as a means of principally reducing sediment loss. Grasses and soil have a mutually beneficial relationship. Soil provides the nutrients necessary for grasses to grow and thrive. In turn, grasses spread their fibrous roots into the dirt, helping retain and rebuild soil. Residual benefits include increased nesting opportunities for target shrub-nesting birds and limiting erosion.	BA-0202 Queen Bess Island Restoration did not plant black mangroves with project funds; however, volunteer groups planted some post-construction. Per communications with CPRA, this planting and all prior known plantings (TE-0040 Timbalier Dune/Marsh Creation, two attempts on TE-0050 Whiskey Island Restoration, BA-0040 Riverine Sand Mining/Scofield Island Restoration, and BA-0110 Shell Island East Restoration) have had limited success because the mangroves encountered high mortality rates, were unable to produce nesting habitats quickly, and were often overwhelmed by other natural colonization.	Yes
7. Vegetation Height	To ensure plants are grown to acceptable size, project teams should consider amendments to plant specifications and pre-project bid items such that nurseries could begin growing required species while project design and construction are completed. Furthermore, project teams may have to reasonably acknowledge that some habitat may not be fully functional for avian habitat immediately post-construction.	CS-0080 Rabbit Island Restoration vegetative plantings (pgs. 1–6 of plan sheets, Technical Specifications TS 1012, 1202, 1203 in bid package). Rabbit Island had a plant contract completed prior to engineering and design completion to allow for large plants, a lesson learned from execution of Queen Bess island restoration.	N/A
8. Sediment Structure	Finer non-cohesive sand sediments (>0.125 mm on Wentworth scale; **Table 25**) in elevated, supratidal areas of islands may inhibit plant colonization due to wind energy and lack of nutrients. More cohesive silt/clay sediment types (silts and clays <0.06 mm on Wentworth scale; **Table 25**) provide ideal substrate for shrub vegetation but take longer to dewater and can cause excessive ponding. These characteristics are most commonly found in-situ in non-sandy water bottoms of coastal Louisiana. For both sediment types, salt content in the dredge slurry may inhibit or slow vegetation growth and should be anticipated in planning; however, the Queen Bess and Rabbit Island projects were planted and vegetated (30 40% survival in one year) with little issue. Past projects generally have placed a veneer of fine-grained sediment in the area where shrub species are desired. Please note, some shrub nesters may also nest on the ground. If nesting on the ground is a consideration, there may be a need for non-cohesive sediment so it will not adhere to or smother eggs.	BA-0048 Bayou Dupont Marsh and Ridge Restoration (pgs. 23–24 of design report, Plan sheets 28–30 in bid package).	No
		BA-0068 Bayou Grand Liard Marsh and Ridge Restoration (pgs. 23, 25, 36–39 of design report, Plan sheets 10–13, 15, 21–23 in bid package). CPRA project managers have noted that BA-0202 Queen Bess Island Restoration had initial low survival of planted species in its sandy, non-cohesive soils. CPRA project managers also noted that the CS-0080 Rabbit Island Restoration project, which was constructed with finer, cohesive silts and clays, made planting difficult and were slow to dewater.	No
	Consideration must be given to the timing for initial field investigation (survey, geotechnical analysis) and all construction field activities versus the breeding season (**Table 14**). Often, projects will require construction activity to be completed during the non-nesting season. If the project intent is to have the restored site ready for the nesting season immediately post-construction, designers must allow for time for the dredged fill areas to dewater and settle. Project planners, when considering project goals and performance, should acknowledge that the first (or first few) nesting seasons post-construction may be sub-par due to a variety of factors including the relationship between sediment type used, dewatering, settlement, and vegetation growth. Designers and planners must consider balancing constructibility with nesting season disturbances: past projects have proven the best chance of completing a restoration project within a single non-nesting season results from sand usage, which settles and dewaters quickly.	BA-0202 Queen Bess Island Restoration; CS-0080 Rabbit Island Restoration. (Project manager personal communications).	Yes
9. Substrate and Nest Materials	Placement of organic debris (sticks, twigs, plant stalks and leaves, and similar vegetative material [e.g., hay bales]) immediately after construction can be beneficial to support nesting before natural materials accumulate.	BA-0202 Queen Bess Island Restoration and CS-0080 Rabbit Island Restoration. From lessons learned presentation from CPRA Project Managers: sticks and vegetative debris were imported through local volunteer groups after construction because these materials are not present in abundance on island naturally or immediately after construction.	Yes

Table 4. Lessons learned and project engineering and design data gaps or information needs for shrub-nesting birds. Bold type indicates key messages.

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gap or Information Need for Project Engineering and Design
1. Proximity to Human Activity and Mammalian Predators	N/A	N/A	N/A	No data gap or information needed
2. Proximity to Previously Used Nesting Site	CS-0080 Rabbit Island Restoration	Rabbit Island LA TIG White Paper (Louisiana Trustees, 2018), personal communication with CPRA and SMEs	**Increase in preferential bird-nesting habitat is most likely to occur via restoration or expansion of existing colonies rather than attempts to create new colonies.**	Data gaps and information needs are numerous and span other table entries; multiple gaps concerning vegetation growth and success and nesting elevation (described further in this table) all require further information.
3. Proximity to Water	N/A	N/A	N/A	No data gap or information needed
4. Island Size	N/A	N/A	N/A	No data gap or information needed
5. Ground Elevation	CS-0080 Rabbit Island Restoration	Rabbit Island LA TIG White Paper, personal communication with CPRA staff	**Nest inundation at high tides is considered the primary cause of colonial waterbird nest mortality**. A variety of island elevations (from 3–3.5 ft mean sea level down to intertidal) with mature vegetation (~3.5–5 ft) were determined to be optimal in supporting a broad range of shrub-nesting birds and other colonial species. In the first season post-construction, shrub-nesting birds initially nested within the historical habitat; an area that has significantly lower elevation resulting in extensive nest inundation. Following repeated (n=4) overwash events, birds eventually relocated to the island's newly restored and higher elevations, re-nesting on hay bales as vegetation was not yet mature.	**Further information is required** to document successful and unsuccessful nesting habitat elevations **to determine the ideal range of Annual Exceedance Probability water surface elevations likely to be inundated by frequent, non-tropical events.**
	All observations	Personal communication with SMEs	Most observations from the Visser et al., 2005 literature have undergone significant and frequent geomorphic changes due to storm impacts, broader land loss processes, or both. Queen Bess Island, prior to its restoration in 2020, may be the only observed location of sustained island elevation on a decadal timescale.	**More information is required to determine ideal and acceptable elevation ranges for preferential bird-nesting habitat**, as well as triggers and corrective actions is needed.
	BA-0202 Queen Bess Island Restoration, CS-0080 Rabbit Island Restoration	Personal communication with SMEs	Project team learned on Queen Bess Island that they needed to think about maintaining elevation differently for bird island restoration projects than what is common for typical barrier island restorations. On barrier islands, it is expected and accepted that the sand will move around and off the island because it will eventually benefit other islands in the chain via longshore or cross-shore transport. **For bird projects, elevation is critical toward limiting the incidence of nest inundation as well as establishing target vegetation. Erosion protection was another key variable to ensure newly deposited sand would remain in place. This required erosion prevention measures that are tailored to not pose risks to birds (as sand fencing and silt fencing eventually would). Several examples include seeding the island with select grass species and whole hay bale placement. Of note, both of these items have been utilized by shrub-nesting birds as nesting material; however, the seeded grasses have outcompeted the other vegetation species in some cases.**	No data gap or information need.

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gap or Information Need for Project Engineering and Design
6. Vegetation Cover and Composition	BA-0202 Queen Bess Island Restoration	CPRA Lessons Learned slide presentation	**Certain preferential nesting species, such as matrimony vine, are infrequently grown or procured from commercial nurseries in Louisiana, creating specification and implementation hurdles.**	Perform reconnaissance regarding available species and communicate with local nurseries who may be interesting in bidding on the project early in design phase to allow for time for growth.
		CPRA Lessons Learned slide presentation	**Plant size specifications could not be achieved in time, so smaller plants were planted. Pelicans pulled up select smaller plantings for nest construction**. Post-completion events placed supplementary organic nesting material (sticks and vegetative debris) on the island in support of future nesting events.	Although many coastal plant preferences have been well studied, a further need exists to create explicit information regarding timing to produce specific heights or cover conducive to.
	TE-0050 Whiskey Island Restoration, BA-0040 Riverine Sand Mining/Scofield Island Restoration, and BA-0110 Shell Island East Restoration)	Personal communication with CPRA and SMEs	All known CPRA attempts to plant black mangroves for restoration purposes have failed to create a colonization level and closed canopy cover conducive for colonial waterbird nesting. **As such, project teams are focused on enhancement of existing mangrove island features along with planting of select scrub-shrub species (e.g., Iva, Baccharis, Lycium) in support of colonial waterbird nesting.**	Further information and studies for planting techniques such as Yando et al. (2019) are required for establishing black mangrove that produce the closed canopy cover suitable for nesting in a predictable, timely, and cost-effective manner
	CS-0080 Rabbit Island Restoration	Personal communication with CPRA and SMEs	**Certain species, such as matrimony vine, are infrequently grown or procured from commercial nurseries in Louisiana, creating specification and implementation hurdles. The Project Island team sought early funding approval to bid planting items, because engineering was still ongoing, such that plants were afforded more growing time prior to installation at the project site.**	No data gap or information need.
	Port Fourchon wetland mitigation area	BTNEP, 2016. Port Fourchon Maritime Ridge Marsh Restoration	**Although soils dewatered post-construction, they remained high in saline content, which may require soil treatment or years of freshening via rainfall to reduce. Initially, these soils were not suitable for several desirable, low-salinity, planted vegetation species and several planting projects resulted in suboptimal outcomes** (BTNEP, 2016). It should also be noted that there have been plantings (30–40% survival after one year) of Queen Bess Island and Rabbit Island under similar conditions.	Few studies exist concerning vegetative planting success across coastal projects in Louisiana. In certain instances, such as the Greater Lafourche Port Commission's construction of the Port Fourchon maritime forest and ridge mitigation project, highly saline soils from areas near the Gulf of Mexico used for ridge construction were found to be problematic. The salinity content of the fill slurry can also play a role in vegetation colonization success (saline soils can inhibit woody species growth). Little monitoring exists to determine woody species colonization and survival success based on fill material properties
7. Vegetation Height	BA-0202 Queen Bess Island Restoration	CPRA Lessons Learned slide presentation	**Plant size specifications could not be achieved in time, so smaller plants were planted. Pelicans pulled up some select plantings to use as nesting material.**	Although many coastal plant preferences have been well studied, explicit information regarding timing to produce specific heights or cover conducive to nesting is not available.
8. Sediment Structure	Port Fourchon wetland mitigation area, BA-0202 Queen Bess Island Restoration, CS-0080 Rabbit Island Restoration	BTNEP, 2016. Port Fourchon Maritime Ridge Marsh Restoration	**Project managers noted that finer sands facilitate greater construction speed on Queen Bess Island, whereas silts/clays provided for vegetation to more readily establish on Rabbit Island.**	No data gap or information need.

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gap or Information Need for Project Engineering and Design
9. Substrate and Nest Materials	BA-0202 Queen Bess Island Restoration	CPRA Lessons Learned slide presentation	**Organic nesting material (sticks, twigs, plant stalks and leaves, etc.) was not immediately present post-construction. Pelicans pulled up select juvenile plantings and hay bale pieces for nest construction.** Post-completion volunteer events were executed to place supplementary organic nesting material/beach wrack on the island in support of future nesting events.	No data gap or information need.

Table 5. Data gaps or information needs to better understand shrub-nesting bird biology and ecology

Preferential Avian Nesting Habitat Characteristic	Consideration	Species/ Grouping	Notes	Data Gaps or Information Needs for Shrub-Nesting Bird Biology and Ecology
1. Proximity to Human Activity and Mammalian Predators	Not in close proximity (suggested >4 mi) to any development or intense human activity and mammalian predators	All	There is information showing that human disturbance and associated mammalian predators contribute to nest failure.	No data gap or information needed
2. Proximity to Previously Used Nesting Site	Prioritize project sites within ≤3 mi of previously used nesting sites, with a strong preference for project sites at the exact locations of previous nesting.	All	Data and observation-based.	What is the significance of previously used nesting sites in determining likelihood of colony site establishment for shrub-nesting birds in Louisiana? What are the characteristics of projects not explicitly designed for birds that do get used by shrub nesters?
3. Proximity to Water	Barrier Islands/Headlands, Coastal Bay Islands, Coastal Wetlands: Within 12 mi of open waters (estuary or gulf waters that separate landforms and harbor large fish). Intertidal waters near nest sites may also be used for loafing by sub adults and chicks.	Brown Pelican and Neotropic Cormorant	Based on foraging needs of the species and observed nest sites in Louisiana (primarily Brown Pelican).	Does distance to water influence nest success or nest site selection for Brown Pelicans and Neotropic Cormorants in Louisiana?
	Barrier Islands/Headlands, Coastal Bay Islands, Coastal Wetlands: Within 6–9 mi vicinity of shallow (<0.5 m) water with abundant fish/invertebrate prey resources.	All Egrets, Herons, and Ibis	Based on foraging needs of the species and anecdotal knowledge as well as some out-of-state literature.	Does distance to water influences nest success or nest site selection for wading birds in Louisiana?
4. Island Size	Barrier Islands/Headlands + Coastal Bay Islands: Islands <50 ac unless predator control implemented or known to be low threat; nesting habitat should encompass a minimum area of 5 ac.	All	Based largely on (Landin & Engler, 1986).	Quantify nest success, nest locations, and prevalence of mammalian predation, relative to island size to determine if island size is a determinant of nesting success for shrub-nesting birds in Louisiana.
5. Ground Elevation	Barrier Islands/Headlands + Coastal Bay Islands: Suggested average elevation of at least 3 ft (Landin and Engler, 1986) or average elevation of 1 ft above mean sea level at the nearest gauge. This metric was calculated by pooling scrub-shrub and mangrove thicket islands (Visser et al., 2005).	All	Based on (Landin & Engler, 1986)	Quantify various restoration design elevations and nest abundance and success at those elevations to clarify ground elevation requirements for successful shrub-nesting bird islands in Louisiana.

Preferential Avian Nesting Habitat Characteristic	Consideration	Species/ Grouping	Notes	Data Gaps or Information Needs for Shrub-Nesting Bird Biology and Ecology
6. Vegetation Cover and Composition	Prioritize planting of dense shrub/tree species on barrier islands/ headlands (black mangrove, matrimony vine, and marsh-elder) and coastal wetlands (cypress, tupelo, buttonbush, and wax myrtle). Additionally, grasses planted on Queen Bess Island have also performed well under storm conditions to limit erosion of sediments from overwash; field observations have also shown abundant pelican nesting activity in the grassy areas lacking shrub vegetation.	All	Largely unknown/based on anecdotal observation. Planting distance recommendation from (Soots & Landin, 1978).	Quantify vegetation densities associated with highest abundances and greatest nesting success rates for shrub-nesting birds to refine restoration planting recommendation (ideally specifying vegetation species).
7. Vegetation Height	Provide shrub species to support future colonial waterbird nesting. Sufficient lead time in planting contracts has been shown to be highly beneficial in contractor's ability to provide vegetation of the correct size and survivability. Some target birds establish nesting colonies within varying vegetation heights and as vegetation establishes over time.	All	Minimum height is approximate and based on literature (mostly out-of-state) for multiple species in this group and is not indicative of nest success. Some target species will nest on the ground. This generally results in greater nest failure, although exceptions do exist; CPRA and LDWF personnel have observed multiple nesting instances on the ground at Queen Bess Island.	Quantify the relationship of nest elevation (from ground level) to nest success of shrub-nesting birds in Louisiana.
8. Sediment Structure	Finer, non-cohesive sand sediments (>0.125 mm on Wentworth scale) on elevated, supratidal areas of islands may inhibit plant colonization due to wind energy and lack of nutrients. More cohesive silt/clay sediment types (<0.06 mm on Wentworth scale) provide ideal substrate for shrub vegetation.	All	Based largely on (Landin & Engler, 1986) and best professional judgment.	Through data synthesis and/or field sampling, document the sediment types that are needed by various shrub-vegetation species to establish, and the relationship between sediment types and ground elevation (or at least subsidence rate).
9. Substrate and Nest Materials	Access to sticks/natural debris.	All	Mostly anecdotal data/best professional judgment.	Continue to observe and document nest material composition.

2.3 MARSH-NESTING BIRD TABLES

The information provided in the following tables relates to marsh-nesting birds (see the definition for this bird group in Section 2.1). Each table is based upon a set of determined habitat characteristics for marsh-nesting birds, which are described in Table 6 (this table also includes the reason each habitat characteristic is important for marsh-nesting birds and the specific species of birds where they apply). Table 7 provides design examples and context for each of the habitat characteristics, including project examples (where applicable) and information on whether those projects were targeted bird restoration projects. Table 8 provides *project-specific* lessons learned relating to each habitat characteristic and any data gaps or existing information needs that can inform project design. Finally, Table 9 highlights current data gaps and information needs relating to *bird-specific* knowledge with regards to each habitat characteristic.

Table 6. Habitat characteristics for marsh-nesting birds. Additional information is provided in Section 3.2.2.

Preferential Avian Nesting Habitat Characteristic	Consideration	Reason for Consideration	Species/Grouping
1. Proximity to Human Activity and Mammalian Predators	Not in close proximity (suggested >4 mi) to any human development or activity or mammalian predators.	Human activity increases both the likelihood of disturbance (which can lead to nest abandonment) and presence of mammalian predators including raccoons and coyotes (which can negatively affect nesting success).	All
2. Elevation/Topography	Elevation heterogeneity within the tidal range (see Section 3.2 for additional discussion) will support more marsh-nesting birds and wetland-reliant wildlife species across more water levels than uniform elevation design. Elevation variation outside of tidal range could all be too high or too low and not serve the intended purpose.	Elevational heterogeneity is a key habitat feature that allows for a variety of vegetation types which supports nesting and water habitats for foraging (see Section 3.2 for additional discussion).	All
3. Land/Water Interspersion and Edge Features	All marsh types: Recommend approximately 30–60% open water to land cover ratio; including 10% deeper water (3–5 ft). For reference, this cover ratio generally corresponds to WVA interspersion classes 2 and 3, which are familiar to many marsh restoration practitioners. These habitats also include features such as shallow slopes adjacent to deep water edges and topographic heterogeneity.	The presence of open water areas, the recommended ratio of tall, dense vegetation and open water, and edge provides habitat diversity and variability as well as increases availability of suitable loafing and foraging habitat (both within the open water and along edge habitat).	All
4. Hydrologic Connectivity	Incorporate temporary/seasonal shallow (<6–8 in) pools. Connectivity to deeper (3–5 ft) ponds and hydrologic connectivity (e.g., tidal creeks) to the surrounding estuary for all marshes.	Hydrologic exchange and circulation within the marsh allow for ingress and egress of aquatic species important to avian diet and are also important for overall waterbody health. Bird access to both shallow and deeper water areas will provide foraging sites for multiple marsh-nesting birds. Foraging areas/habitat should be accessible from nest sites and/or situated on the landscape within the movement distance of adult pairs or fledglings.	All
5.Vegetation Requirements	Fresh-Intermediate: Generally, the most suitable nesting habitat occurs in the first 1–2 years following creation or disturbances that remove/set back dense emergent cover. Diverse herbaceous vegetation coverage of should range from moderate (30%) to high (80%).	Early successional habitat may be more suitable for marsh-nesting birds due to a greater plant diversity and interspersed shallow pools and deeper ponds used for foraging (see hydrologic connectivity). After 3–4 years, pools (<6–8 in) and ponds (<3–5 ft) may be lost due to spreading vegetation, and woody vegetation may become established resulting in unsuitable nesting habitat or transition to primarily open water habitat (i.e., suboptimal habitat). These events reduce the potential benefits for the target suite of species (i.e., create suboptimal habitat; Section 3.2.2.5).	Purple Gallinule, Common Gallinule, Least Bittern, King Rail, Pied-billed Grebe, Mottled Duck, King Rail, Black-necked Stilt, Black Rail, Clapper Rail
	Brackish-Saline Marsh: Generally, the most suitable nesting habitat occurs 3–4 years post-construction, although salinity levels keep vegetation composition relatively stable.	In the years immediately following construction, vegetation may not be established or tall and dense enough to provide suitable or optimal nesting habitat. Preferential nesting habitat for bird species in brackish-saline marshes includes emergent vegetation with interspersed shallow pools and deeper ponds (see hydrologic connectivity). If there is no variation in elevation across the tidal range, select habitats may transition to mostly open water over time largely due to relative sea-level rise.	Mottled Duck, Black-necked Stilt, Black Rail, Clapper Rail, Seaside Sparrow

Table 7. Design considerations for marsh-nesting birds.

Preferential Avian Nesting Habitat Characteristics	Examples and Context	Project Examples	Bird-Targeting Project
1. Proximity to Human Activity and Mammalian Predators	**This habitat characteristic is not typically influenced by design decisions.**	N/A	N/A
2. Elevation/Topography	All marsh creation project designs contain geotechnical information about the predicted relationship between marsh elevation and inundation ranges over time, commonly referred to as *settlement curves*. Ideally, designers try to select marsh fill elevations that will settle over time while remaining within intertidal elevation thresholds for as long as possible over the project's life. Often, designers provide marsh restoration contractors with elevation tolerances (often +/- 0.5–1.0 ft or similar) because construction of homogeneous elevations can be difficult in soft dredged material. CPRA typically requires 80% of post-construction survey points of the newly restored marsh to be within the established tolerance. Numerous marsh creation projects have used unconfined or semi-confined dredge fill to create elevation heterogeneity, marsh/water interspersion, and edge habitat. Project designers could consider broader marsh elevation acceptance survey tolerances (presuming they will allow for functional marsh at the end of the project life and remain within the ideal inundation range) to allow for greater elevation heterogeneity. Elevation heterogeneity should be constrained to within the tidal range (between the mean high water and mean low water datums), which will vary by site, to help maintain a combination of water (shallow [<0.5–0.75 ft]) and deeper [3–5 ft] habitats) and emergent vegetation (see land/water interspersion) and promote vegetation heterogeneity. The Turtle Bay project utilized a semi-confined dredge containment strategy coupled with strict specifications for maximum dredge discharge rates within predetermined zones of the project area to create a transitional zone that gently sloped from elevation 0 ft/0 m NAVD88 to the target marsh elevation of 1.5 ft/0.5 m NAVD88 across a roughly 375 ft/115 m span encircling the marsh area.	BA-0125 Turtle Bay Marsh Creation 95% Design Report, Section 5 (pg. 28); Bid Package Technical Specifications (TS 400 - all subsections).	No.
3. Land/Water Interspersion and Edge Features	Recommend approximately 30–60% open water/land cover ratio along with as much edge as possible for the creation of preferential bird-nesting habitat within the restoration footprint. For reference, this cover ratio generally corresponds to WVA interspersion classes 2 and 3, which are familiar to many marsh restoration practitioners. Project teams should take into consideration wind fetch and of other location-specific characteristics that could drive marsh edge erosion, and practitioners should account for waterbody expansion over the lifespan of the project when considering benefits (see **Figure 33**). Land/water interspersion in marsh is known to increase available edge habitat, which further supports loafing, foraging, and habitat variability all of which benefits wetland-reliant species including marsh-nesting birds. Some projects, such as BA-0125, have created marsh edge through non-uniform, unconfined dredge material placement, which leads to a variety of nonuniform edge features. Other projects have created edge mechanically through excavation of material to form specific edge elements.	BA-0125 Turtle Bay Marsh Creation.	No, but avian features included in design.
		PO-0104 Bayou Bonfouca Marsh Creation 95% Design Report, Section 7.3.	No, but avian features included in design.
		PO-0075 LaBranche East Marsh Creation 95% Design Report, Section 8.	No, but avian features included in design.

Preferential Avian Nesting Habitat Characteristics	Examples and Context	Project Examples	Bird-Targeting Project
4. Hydrologic Connectivity	Marsh birds have been shown to extensively utilize tidal creeks and small, isolated, shallow ponds for foraging. Collectively, these features provide hydraulic exchange allowing for ingress and egress of aquatic species important to avian diet; flow exchange is also important for overall waterbody health. Several projects implemented by CPRA have integrated these connected features within construction: 1. Building containment dikes around the area(s) designated to be ponds to prevent dredge slurry from filling them (PO-0104, CS-0059), 2. Filling the entire area with dredge slurry to a uniform elevation and excavating connected ponds after fill operations have ceased (PO-0104), and 3. Pre-excavating or pre-compressing areas to be deeper than everything in proximity and then placing a uniform dredge fill layer on top, which will result in elevation variability as the material settles (PO-0075, CS-0059). This option is basically the reverse of Option 2. Such features may often form naturally due to differential settlement and elevation heterogeneity within the fill tolerance. Maximum habitat productivity may not be recognized for some time (years) after construction.	PO-0104 Bayou Bonfouca Marsh Creation 95% Design Report, Section 7.3.	No, but avian features included in design.
		PO-0075 LaBranche East Marsh Creation 95% Design Report, Section 8.	No, but avian features included in design.
		CS-0059 Oyster Bayou Marsh Creation Bid Documents, Special Provisions SP3.6, Technical Specifications TS3.1.4, 6.1, 7.1, 7.2.	No, but avian features included in design.
5. Vegetation Requirements	All marsh types: Maximizing time during which the marsh elevation is intertidal will, by nature, minimize the amount of time the restored area's elevation is supratidal. This action in design will minimize the amount of time non-marsh vegetation species (such as woody species) have to colonize the restored area.	N/A	N/A

Table 8. Lessons learned and project engineering and design data gaps or information needs for marsh-nesting birds. Bold type indicated key messages.

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gaps or Information Needs for Project Engineering and Design
1. Proximity to Human Activity and Mammalian Predators	**This habitat characteristic is not typically influenced by design lessons learned**	N/A	N/A	N/A
2. Elevation/Topography	BA-0125 Turtle Bay Marsh Creation	BA-0125 Turtle Bay Marsh Creation 95% Design Report, Section 5 (pg. 28); Bid Package Technical Specifications (TS 400 - all subsections)	**To achieve the desired project template, specific dredge discharge controls had to be put in place and memorialized within the project bid documents.** Successful project implementation was attributed to CPRA's increased planning, monitoring, and coordination with the dredge contractor.	Explicit investigation of elevation heterogeneity within restored marsh areas, associated construction acceptance tolerances, and impacts to habitat, constructibility, and avian species outcomes is needed in conjunction with CPRA's Engineering and Project Management divisions. Further coordination with CPRA is required to develop standardized methods and contract language appropriate for attempting to achieve elevation heterogeneity goals. Each project has specific borrow qualities, which may or may not work in agreement with methods such as dredge discharge control or unconfined dredge fill placement for the desired outcome. Adjusting dredge controls, fill elevation tolerances, or dredge fill confinement strategies also may result in increased budget required for project construction. A wealth of data including as-built surveys and bid document information exists to support further investigation.
3. Land/Water Interspersion and Edge Features	BA-0125 Turtle Bay Marsh Creation	Small Bird Group personal communication during document generation	Construction of marsh creation projects in Louisiana has often resulted in continuous wetland areas with little water interspersion immediately after construction. This approach is the most cost-effective way to maximize land area within intertidal elevations over the project lifespan, which is a common primary goal of both individual projects and of CPRA's Coastal Master Plan, but may not maximize project benefits for wetland- reliant wildlife species such as marsh-nesting birds or for other LA TIG ecosystem and habitat goals, especially in the near term. **In general, maximum habitat value for marsh-nesting birds will result from the greatest area of marsh edge, ponding, and channels, occurring over the greatest length of time.** However, identified benefits may be short-lived if that marsh erodes and is converted to open water more rapidly.	No explicit investigation has been done on the performance of the tidal creek and pond construction methodologies (pre-fill excavation, post-fill excavation, and marsh buggy tracking). **Information gathering about the relative performance of the features for habitat purposes as well as from a construction strategy standpoint is required in conjunction with CPRA's Engineering and Project Management divisions**. Further coordination with CPRA is required to develop standardized methods and contract language appropriate for attempting to achieve land/water interspersion and edge goals. Each project has specific borrow qualities, which may or may not work in agreement with noted construction methods for the desired outcome. Adjusting construction methods also may result in increased budget required for project construction A wealth of data including as-built surveys and bid document information exists to support further investigation.
4. Hydrologic Connectivity	CS-0059 Oyster Bayou Marsh Creation	CS-0059 Oyster Bayou Marsh Creation Project Bid Documents, Special Provisions SP3.6, Technical Specifications TS3.1.4, 6.1, 7.1, 7.2	Constructing channels throughout the marsh fill area can be accomplished in a number of ways, similar to the pond construction (1-ac ponds) items in the PO-75 project. In this case, t**he project team chose the approach of pre-compression rather than excavating after marsh fill operations, pre-excavating, or using containment dikes. This involved tracking marsh buggies repeatedly in the alignment of designed creeks and ponds and then filling the entire containment cell with a uniform depth of marsh fill and allowing differential settlement to generate the channels.**	**Although a pond size of 1 ac was chosen, there is little monitoring or design-related guidance on pond size performance for issues such as vegetation incursion or marsh edge erosion.**

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gaps or Information Needs for Project Engineering and Design
4. Hydrologic Connectivity (continued)	PO-0075 LaBranche East Marsh Creation	PO-0075 LaBranche East Marsh Creation 95% Design Report, Section 8	From report "Several ideas were discussed which include: 1) digging pre-fill, 2) digging post-fill, 3) using a marsh buggy to create controlled ruts post-fill, and 4) allowing for natural connectivity. **The project team designed the main tidal creek to be excavated pre-fill to a 7-foot elevation based on settlement calculations of the marsh creation fill. The connection between ponds consisted of marsh buggy tracks after the marsh creation area reaches design elevation, which allowed water movement once the sheet pile structure was removed in Year 3.** Any ponds that are not connected with tracks would remain isolated until natural tidal creeks form in the marsh creation area. Ultimately, the project team decided to have 13 ponds, approximately one acre in size, and spaced at about 1,000 feet apart. The tidal creek connects to the southwest corner of the marsh creation area and connects to 3 centrally located ponds, which is 3,275 linear feet. The three ponds then connect to additional 8 ponds via tracks from the marsh buggy and the remaining 2 ponds are not connected to the tidal creek."	**Presently, there are too few project examples to measure the relative effectiveness of one strategy versus the others listed.** No explicit information has been collected on the performance of the competing tidal creek and pond construction methodologies (pre-fill excavation, post-fill excavation, and marsh buggy tracking). Investigation into the relative performance of the features for habitat purposes as well as from a construction strategy standpoint is required.
	CS-0059 Oyster Bayou Marsh Creation	Personal communication with project designers	**Avian species have been found to be present in both the designed shallow ponds as well as accidental ephemeral ponds that developed due to heterogeneous fill heights and differential settlement. Ephemeral ponds are not straightforward to design, and in actuality occur more so due to the ingredients for them being present (elevation heterogeneity within fill area).**	N/A
5. Vegetation Requirements	LA-0039 Coastwide Vegetative Planting Project	LA-0039 2021 Operations, Maintenance, and Monitoring Report, Section XXIV	The Lessons Learned section notes **shoreline plantings in energetic environments were less successful and have not proven effective in providing secondary benefits (to avian-specific vegetation use), such as shoreline erosion reduction.** Therefore, focusing the resources on protected locations may increase planting success. **Protected locations that are continuously flooded interior areas with diminished tidal cycles, however, may not be favorable to smooth cordgrass (*Spartina alterniflora*) because that species has failed when planted in such locations.** Smooth cordgrass has repeatedly been successful for terrace construction, marsh creation, and naturally accreting mudflats as a pioneer species.	Quantify vegetation densities associated with highest abundances and greatest nesting success rates for marsh-nesting birds to refine restoration planting recommendation (ideally specifying vegetation species, planting layout arrangement and density).

Table 9. Data gaps or information needs to better understand marsh-nesting bird biology and ecology.

Preferential Avian Nesting Habitat Characteristic	Consideration	Species/Grouping	Notes	Data Gaps of Information Needs for Marsh-Nesting Bird Biology and Ecology
1. Proximity to Human Activity and Mammalian Predators	Not in close proximity (suggested >4 mi) to any human development or activity or mammalian predators.	All	Most of this information pertains to ground- or shrub-nesting birds.	Is human development/activity at various distances from nesting sites related to marsh-nesting bird success and overall productivity of individual species?
2. Elevation/Topography	Elevation heterogeneity within the tidal range (see **Section 3.2** for additional discussion) will support more marsh-nesting birds and wetland-reliant species than uniform elevation.	All	Anecdotal information is currently being collected.	How does heterogeneous elevation influences marsh-nesting bird site selection and overall habitat suitability of selected species?
3. Land/Water Interspersion and Edge Features	All marsh types: Recommend approximately 30–60% open water to land cover ratio; including 10% deeper water (3–5 ft). For reference, this cover ratio generally corresponds to WVA interspersion classes 2 and 3, which are familiar to many marsh restoration practitioners. These habitats also include features such as shallow slopes adjacent to deep water edges and topographic heterogeneity.	All	Anecdotal information currently being collected.	How does distance to edge and/or edge:area ratio influence marsh bird nest site selection and habitat suitability of selected species?
4. Hydrologic Connectivity	Incorporate temporary/seasonal shallow (<6–8 in) pools. Connectivity to deeper (3–5 ft) ponds and hydrologic connectivity to the surrounding estuary for all marshes.	All	Anecdotal information currently being collected.	Characterize importance of hydrologic connectivity influence on marsh-nesting bird site selection, home range size, and overall habitat suitability (including foraging suitability).
5.Vegetation Requirements	Fresh-Intermediate: Generally, the most suitable nesting habitat occurs in the first 1–2 years following creation or disturbances that remove/set back dense emergent cover. Diverse herbaceous vegetation coverage of should range from moderate (30%) to high (80%).	Purple Gallinule, Common Gallinule, Least Bittern, King Rail, Pied-billed Grebe, Mottled Duck, King Rail, Black-necked Stilt, Black Rail, Clapper Rail	Anecdotal information currently being collected.	Determine the specific habitat parameters in fresh-intermediate marshes that influence nest site selection in Louisiana (i.e., habitat suitability at nest sites for select species).
	Brackish-Saline Marsh: Generally, the most suitable nesting habitat occurs 3–4 years post-construction, although salinity levels keep vegetation composition relatively stable.	Mottled Duck, Black-necked Stilt, Black Rail, Clapper Rail, Seaside Sparrow	Anecdotal information currently being collected.	Determine the specific habitat parameters in brackish-saline marshes that influence nest site selection in Louisiana (i.e., habitat suitability at nest sites for select species).

2.4 GROUND-NESTING BIRD TABLES

The information provided in the following tables relates to ground-nesting birds (see the definition for this bird group in **Section 2.1**). Each table is based upon a set of determined habitat characteristics for ground-nesting birds, which are described in **Table 10** (this table also includes the reason each habitat characteristic is important for ground-nesting birds and the specific species of birds where they apply. **Table 11** provides design examples and context for each of the habitat characteristics, including project examples (where applicable) and information on whether those projects were targeted bird restoration projects. **Table 12** provides *project-specific* lessons learned relating to each habitat characteristic and any data gaps or existing information needs that can inform project design. Finally, **Table 13** highlights current data gaps and information needs relating to *bird-specific* knowledge with regards to each habitat characteristic.

Table 10. Habitat characteristics for ground-nesting birds. Additional information is provided in ***Section 3.3.2.***

Preferential Avian Nesting Habitat Characteristic	Consideration	Reason for Consideration	Species/Grouping
1. Proximity to Human Activity and Mammalian Predators	Not in close proximity (suggested >4 mi) to any development or intense human activity and mammalian predators.	Human activity increases both the likelihood of disturbance (which can lead to nest abandonment) and presence of mammalian predators including raccoons and coyotes (which can negatively affect nesting success).	All
2. Island Size	Islands should be <5–50 ac (in addition to isolation from mainland) unless predator control implemented or mammalian predators are known to be low threat.	Mammalian predation generally increases as island size increases.	All
3. Proximity to Water	Barrier Islands/Headlands: <160–300 ft from high tide line and/or ephemeral pools or tidal flats.	Water (i.e., shorelines) should be accessible by foraging adults and chicks while minimizing the potential for nest inundation.	All
4. Ground Elevation and Slope	Barrier Islands/Headlands + Coastal Bay Islands: 3–10 ft.	Elevation necessary to minimize nest flooding during high tides.	All
	Barrier Islands/Headlands + Coastal Bay Islands: gradual slope (the rise in elevation from the upper swale to the dome) of <98:3 grade to water edge (a rise of 3 ft over a linear distance of 98 ft).	Gradual slopes help ensure the presence of elevated sites and vegetation heterogeneity. Gradual slopes may be used for loafing and nesting if the substrate is stable.	All
	Barrier Islands/Headlands + Coastal Bay Islands: Small areas of supratidal elevation (e.g., 165 x 165 ft) within lower elevation features (e.g., overwash fans).	Higher elevations within unvegetated flats and meadows provide platforms for nesting that are safe from tidal inundation.	Wilson's Plover, Common Nighthawk, Snowy Plover, American Oystercatcher, Least Tern, Black Skimmer, Gull-billed Tern
5. Access to Vegetation and Vegetation Cover	Patches of low (<1.6–3.3 ft maximum mature height) herbaceous vegetation within 33 ft of nest site.	Observed nesting near vegetation. Vegetation patches also provide refuge for chicks.	Least Tern, Black Skimmer, Wilson's Plover
	Bare ground with sparse cover (<25%) of low-height (max growth <1.6 ft) herbs/vegetation.	Nesting frequently observed in locations with this vegetation cover.	Least Tern, Gull-billed Tern, Black Skimmer, Royal Tern, Sandwich Tern, Caspian Tern, Snowy Plover, Wilson's Plover, American Oystercatcher
	Medium coverage (25–75%) clumped/not evenly distributed low-height (max growth <1.6 ft) meadow (herbs) vegetation.	Nesting frequently observed in locations with this vegetation cover.	Wilson's Plover, Common Nighthawk, American Oystercatcher
	Dense coverage (75–100% cover) of mature herbaceous vegetation within meadow or intermediate/brackish/saline marshes (preference for additional presence of deposited vegetation debris and sticks).	Nesting frequently observed in locations with this vegetation cover.	Forster's Tern, Laughing Gull

Preferential Avian Nesting Habitat Characteristic	Consideration	Reason for Consideration	Species/Grouping
6. Sediment Structure	Gravel (e.g., crushed No. 8 or No. 57 limestone). Reference sources available from LADOTD Qualified Products List (QPL 2), a USACE MVN supplier list for limestone aggregate, and LADOTD Standard Specification Section 1003.04.	Nesting observed on gravel.	Gull-billed Tern, Black Skimmer, American Oystercatcher, Least Tern, Royal Tern, Sandwich Tern, Caspian Tern, Wilson's Plover
	Medium sand (0.25–0.5 mm). Coarse sand (0.5–1.0 mm) with shell/pebble/limestone fragments. Very coarse sand (1–2 mm). Very fine pebble (2–4 mm).	Nesting observed more on coarser (e.g., <0.25 mm) sediments than fine-grained cohesive material.	Gull-billed Tern, Black Skimmer, Royal Tern, Sandwich Tern, Caspian Tern, Snowy Plover, American Oystercatcher, Least Tern
7. Substrate and Nesting Materials	Shell and shell mounds, shell rakes.	Often used for nesting substrate.	Black Skimmer, Royal Tern, Sandwich Tern, American Oystercatcher, Wilson's Plover
	Beach wrack/drift with <5% sand/shell.	Often used for nesting substrate.	Forster's Tern, Laughing Gull

Table 11. Design considerations for ground-nesting birds.

Preferential Avian Nesting Habitat Characteristic	Examples and Context	Project Examples	Bird-Targeting Project?
1. Proximity to Human Activity and Mammalian Predators	This habitat characteristic is not typically influenced by design decisions. To date, all constructed or ongoing CPRA projects specifically intended for restoration of avian habitat have occurred on existing rookeries or locations of high avian presence, and thus, due to natural preference, occurred in isolated island locations such as Rabbit Island (CS-0080), Queen Bess Island (BA-0202), and Terrebonne Houma Navigation Canal Island Restoration (TE-0165). The Caminada Headland, Grand Isle, and Portions of the Cameron Parish shoreline are the only areas with permanent human presence and direct access on the Louisiana coast. The vast majority of other ground-nesting habitat restoration, which has occurred indirectly through other coastal restoration projects, also has occurred in locations well removed from human activity and typically has not included measures to prevent human presence. Avian habitat restoration in situations where human presence is likely should consider the installation of measures such as signage and/or barriers to prevent human interference with nesting areas.	CS-0080 Rabbit Island Restoration.	Yes
		BA-0202 Queen Bess Island Restoration.	Yes
			Yes
		TE-0165 Terrebonne Houma Navigation Canal Island Restoration.	Yes
2. Island Size	Island size is frequently established through an iterative process through project design milestones. Therefore, in determining island size, the project team's decision-making process must balance determining factors including available funding, morphologic function, other ecosystem restoration goals, and site considerations constraining construction such as local bathymetry and topography, available sediment quantity and characteristics, existing avian habitat and nesting areas, etc.	For CS-0080 Rabbit Island Restoration (95% Design Report), designers discuss the iterative process used when considering existing avian habitat on the island, budget, sediment availability, and project work windows to arrive upon the chosen island size for construction.	Yes
3. Proximity to Water	Designers should consider the location of likely or intended avian nesting areas relative to water features. Design of ephemeral features, given the unpredictable nature of weather and evaporation, is difficult. Allowing for small variations in elevation heterogeneity in the design, coupled with soil and sublayer considerations (e.g., permeable vs. impermeable soils, geofabric use) can set the stage to allow for such features. Elevation and nesting area location should also be designed in such a way that provides protection for nesting areas near high-energy wave areas, where overwash may occur.	BA-0202 Queen Bess Island Restoration employed several measures: shoreline armoring and access ramps to estuarine waters as well as preservation of existing shallow ponds by excluding them from designed fill areas. BA-0202 Queen Bess Island (Section 2.5 of final design report, Plan sheets 12, 16, 17 in bid package).	Yes
4. Ground Elevation and Slope	Project design teams may seek guidance on upper elevation limits (to consider rising seas, changing storm conditions, and subsidence over a design life of 20 or more years), as well as for lower elevation limits (to consider inundation frequency and its impacts on nest washout versus colony survival). Unfortunately, no rule of thumb or universally agreed-upon threshold exists within the scientific and engineering community. Incorporation of elevation heterogeneity (see **Section 3.3.2.3** for additional discussion) within project design requires balancing project cost, other ecosystem restoration goals, sediment availability, morphologic function, and risk of overwash to provide areas where nests will likely remain dry during nesting season from all but infrequent events. For barrier islands, elevations are driven by morphologic concerns, such as resistance to breaching during the design life of the project. For coastal bay islands, elevation design is based upon balancing island inundation exceedance probability with cost; however, there is a theoretical tipping point where an overabundance of supratidal habitat can increase the likelihood of avian predator presence. Little guidance exists for ideal feature elevations based on water surface elevation exceedance probability of the island's nesting areas during nesting season for a given probabilistic threshold.	CS-0080 Rabbit Island Restoration (Section 5.2, 6 of final design report, Plan sheets 6, 7 in bid package).	Yes
		BA-0202 Queen Bess Island Restoration (Section 2.5 of final design report, Plan sheets 12, 16, 17 in bid package).	Yes
		TE-0100 Caillou Lake Headlands Restoration (Section 4 of final design report, Plan Sheets 15 18 in bid package.)	No

Preferential Avian Nesting Habitat Characteristic	Examples and Context	Project Examples	Bird-Targeting Project?
	Barrier islands are designed with an initial post-construction slope from the submerged toe of the restored shoreface up to the beach or dune crest. Upon completion of construction (and often before completion), waves rework the placed sediment and the shoreface at and below the water adjusts to a more natural state. Louisiana coastal sands generally all adjust to a natural angle of repose that is shallow and conducive to avian access in the intertidal portions of barrier islands. Supratidal portions of the islands, whose design is dictated by the engineer and achieved through earth-moving equipment, should conform to ideal slopes (generally shallower than 30H:1V) for avian species.	BA-0111 Shell Island-West Restoration (Section 11 of final design report).	No
		TE-0100 Caillou Lake Headlands Restoration (Design report Sections 4.2, 7.4.2).	No
		TE-0052 West Belle Pass Headland Restoration (Section 14 of final design report pgs. 66-80).	No
	Design of small areas (<1 ac in size) where construction contractor reworks placed material into small platforms.	CS-0080 Rabbit Island Restoration included proposed mounds in its alternatives analysis (Section 2 of final design report, pg. 17).	Yes
		Galveston Island State Park Marsh Restoration (NOAA, 2007) employed designed mounds specifically to provide avian habitat in salt marsh environments.	Yes
5. Access to Vegetation and Vegetation Cover (refer to **Table 25**)	CPRA does not have specific design directives for plantings as they do for other project aspects (such as survey, geotechnical investigations, or design of the earthen project features). There are, however, several resources available for project teams to consult when designing a project planting scheme. Gulf Coast Natural Resource Conservation Service (NRCS) Plant Material Centers, especially those in Texas, Louisiana, and Mississippi, produce a wealth of literature on planting schemes for avian habitat (https://www.nrcs.usda.gov/plant-materials/publications/search). Examples of past CPRA vegetative planting designs are noted, but by no means should they be viewed as prescriptive. Unwanted and excessive vegetation may be managed with various control techniques to maintain optimal habitat (see BA-0202 Queen Bess Island Restoration).	TE-0100 Caillou Lake Headlands Restoration vegetative plantings (pgs. 1 5 of plan sheets, Technical Specifications 1020, TS 1030, TS 1060, TS 1070, TS 1220 of bid package).	No
		BA-0045 Caminada Headland Restoration Phase I vegetative plantings (pgs. 7-8 of plan sheets, Technical Specifications TS 5, TS 6 in bid package).	No
		LA-0039 Coastwide Vegetative Plantings - East Grand Terre Island (pgs. 1-4 of plan sheets, Technical Specifications TS 2 in bid package).	No
		BA-0143 Caminada Headland Restoration Phase II vegetative plantings (pgs. 7-8 of plan sheets, Technical Specifications TS 3, TS 4 in bid package).	No
		LA-0039 Coastwide Vegetative Plantings - Lost Lake (pgs. 1-5 of plan sheets, Technical Specifications TS 1010, 1060 in bid package).	No
		CS-0080 Rabbit Island Restoration vegetative plantings (pgs. 1-6 of plan sheets, Technical Specifications TS 1002 in bid package).	Yes
		BA-0143 Caminada Headland Restoration Phase II vegetative plantings (pgs. 7-8 of plan sheets, Technical Specifications TS 4 in bid package).	No
6. Sediment Structure (refer to **Table 26**)	Place imported No. 8, No. 57, or an equivalent grade of limestone or sandstone in 2 inch to 6-inch thickness over a sand base or over a geotextile separator fabric to provide habitat type.	BA-0202 Queen Bess Island Restoration (Section 1.5-pg. 6, Section 6-pg. 51 of final design report, Plan sheet 16, in bid package).	Yes
		Evaluation of Bird Nesting Use on Substrate-Enhanced Beach Habitat: Final Report (LeBlanc et al., 2018).	Yes

Preferential Avian Nesting Habitat Characteristic	Examples and Context	Project Examples	Bird-Targeting Project?
	Use of offshore sand sources, which generally contain low single-digit gravel or debris content (gravel and/or debris are often used in geotechnical boring logs as parlance for broken shell or non-sand content). Mississippi River sand has little to no shell content. Offshore sand sources with shell content will undergo winnowing after placement: wind and wave action will naturally remove finer-grained material from the surface, leaving a lag deposit with high shell content on the surface, forming a crust at some time after placement.	BA-0045 Caminada Headlands (personal communication with CPRA SMEs).	No
	Utilization of local sand source (offshore, Mississippi River) for project implementation. Smaller grain sizes with higher silt contents (approximate range of 0.09–0.15 mm median grain size with silt content above 10%; **Table 25**) will be present in nearshore Gulf deposits, whereas larger grain sizes (approximate median grain size of 0.15-0.25 mm with single digit silt content percentage) will be present in the Mississippi River and major offshore remnant shoals such as St. Bernard, Ship, Tiger, and Trinity Shoals.	TE-0052 West Belle Pass Headland Restoration (95% Design Report, Section 17 - pgs. 148-150; additional information in 30% Design Report, pg. 66).	No
		TE-0100 Caillou Lake Headlands Restoration (Design Report Section 7.4.2).	No
		BA-0111 Shell Island-West Restoration (Section 7- pg. 21 of final design report).	No
	Designers and planners must consider balancing constructibility with nesting season disturbances: past projects have proven the best chance of completing a restoration project within a single non-nesting season results from sand usage, which settles and dewaters quickly.	BA-0202 Queen Bess Island Restoration.	Yes
7. Substrate and Nesting Materials	N/A	N/A	N/A

Table 12. Lessons learned and project engineering and design data gaps or information needs for ground-nesting birds. Bold type indicates key messages.

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gaps or Information Needs for Project Engineering and Design
1. Proximity to Human Activity and Mammalian Predators	N/A	N/A	N/A	No data gap or information need.
2. Island Size	N/A	N/A	N/A	No data gap or information need.
3. Proximity to Water	N/A	N/A	N/A	No data gap or information need.
4. Ground Elevation and Slope	BA-0111 Shell Island-West Restoration	Final Design Report, Section 11	**Designed post-construction slopes typically range from 1V:25H to 1V:90H due to available sand characteristics and field construction experience. Smaller grain sizes with higher silt contents** (approximate range of 0.09-0.14 mm median grain size with silt content above 10%) **will yield shallower slopes and angles of repose, whereas larger grain sizes** from the Mississippi River or Ship Shoal (approximate median grain size of 0.15–0.25 mm with single digit silt content %) will yield steeper slopes.	No data gap or information need.
	TE-0100 Caillou Lake Headlands Restoration	Design Report Sections 4.2, 7.4.2		
	TE-0052 West Belle Pass Headland Restoration	Final Design Report, Section 14		
5. Access to Vegetation and Vegetation Cover	N/A	N/A	**Coastal vegetative planting projects generally require plant installation following a linear or gridded scheme, with distance requirements between each plant within a row and between each row. This guidance may be contrary to observed avian preference**, which often is for clumped plants and foliage at irregular spacing and intervals.	Further information required to determine planting outcomes versus avian use. **Few studies exist concerning vegetative planting success across coastal projects in Louisiana.** BICM data are available as are project closeout and monitoring reports from CPRA, but these monitoring efforts tend to quantify habitat as a whole rather than investigating or monitoring planting success from distinct projects. See sediment structure lessons learned below for information about Bermuda grass.
	TE-0100 Caillou Lake Headlands Restoration	Personal communication with SME	**Non-linear habitats support higher densities of nesting than linear habitats.** Non-linear habitats tend to be more common in the deltaic plain (barrier islands) compared to chenier plain. Non-linear habitats do occur in the chenier plain, but linear habitats are the general rule in the chenier plain. Non-linear habitats tend to be higher quality because they are more heterogeneous. **It is thought that heterogeneity in dunes structure and vegetation allows more territories to occur in closer proximity** (because the birds do not see each other as well), and that, after hatching, adults engage in group defense; thus, more adults are able to defend their young, leading to higher juvenile survival. Whiskey had one of the highest densities of WIPL before the Caillou Lake Headlands TE-100 project occurred.	**This observation is presently anecdotal and although noted by SMEs**, is not presently captured quantitatively in literature. **Further scientific verification required**. A multitude of coastal projects have had associated planting plans and specifications developed. Although all **planting bid documents have uniformly instructed plantings following a linear/grid scheme, the spacing guidance varies.** Spacing guidance standardization may be useful for each commonly implemented plant species in coastal Louisiana. This guidance should communicate expected plant growth extents for a mature plant to inform spacing guidance and be compared to existing NRCS guidance for conformity.

Preferential Avian Nesting Habitat Characteristic	Project ID and Name	Reference Document and Page Number	Lesson Learned	Data Gaps or Information Needs for Project Engineering and Design
6. Sediment Structure	BA-0202 Queen Bess Island Restoration	CPRA Lessons Learned slide presentation	**Gravel stone material performing as intended. Wind-blown sand settled into the limestone gravel creating a mixture,** although some nest flooding occurred from heavy rain exceeding percolation rates in discrete locations. **Windblown sand also brought grass seeds with it. There now exists difficult to control, widespread Bermuda grass throughout the ground-nesting habitat, however, select bird species have been observed to nest on it.** The grass is low, so it does not seem to be inhibiting ground-nesting activity yet, and it appears that **grasses may have reduced erosion associated with tropical weather**.	No data gap or information need.
		Personal communication with CPRA staff	**Geotextile fabric was installed below the 6 in layer of #8 limestone gravel in the ground-nesting area on QBI. It may be more trouble than it was worth. Following significant tropical storms, large pieces of geofabric were exposed which had the potential to be hazardous to the birds**, but only shallow-rooted grasses have grown in that area. Collectively, seeded grasses did not appear to inhibit ground-nesting birds in years 1 and 2 post construction, however, they may be more problematic in the future and require adaptive management. Controlled burns and herbicide treatments have been used on Queen Bess to manage vegetation growth and enhance ground-nesting bird opportunities.	No data gap or information need.
	BA-0045 Caminada Headland Restoration Phase I	Personal communication with project staff	Although geotechnical logs showed 2% or less of shell and other non-sand particulate in the borrow material, **two years after placement, windblown processes had created a layer of shell hash across vast areas.**	No data gap or information need.
	Evaluation of Bird Nesting Use on Substrate-Enhanced Beach Habitat (LeBlanc et al., 2018)	Evaluation of Bird Nesting Use on Substrate-Enhanced Beach Habitat (LeBlanc et al., 2018)	Plots treated with No. 57 limestone had a higher number of nests when compared to plots with no treatment or plots with sandstone substrate. Least Terns appeared to preferentially nest on limestone versus the untreated substrate; however, this did not generate any sort of effect on nest success, reduced predation, increased Daily Survival Rate, or number of chicks produced. However, the small sample size for this study coupled with the very high predation rate limited the capacity of producing a strong relationship between any of these factors. (LeBlanc et al., 2018).	Further observation points needed to confirm findings.
7. Substrate and Nesting Materials	N/A	N/A	N/A	No data gap or information need.

Table 13. Data gaps or information needs to better understand ground-nesting bird biology and ecology.

Preferential Avian Nesting Habitat Characteristic	Consideration	Species/Grouping	Notes	Data Gaps or Information Needs for Ground-Nesting Bird Biology and Ecology
1. Proximity to Human Activity and Mammalian Predators	Not in close proximity (suggested >4 mi) to any development or intense human activity and mammalian predators.	All	There is information showing that human disturbance and associated mammalian predators contribute to nest failure.	No data gap or information need.
2. Island Size	Islands should be <5–50 ac (in addition to isolation from mainland) unless predator control implemented or mammalian predators are known to be low threat.	All	This is based on Landin & Engler, 1986. Note that Raccoon Island (a major nesting site for most of these species) is nearly 200 ac; however, is >15 mi from the mainland.	Quantify nesting locations, island size, and reproductive success of ground-nesting birds in Louisiana to determine if island size is related to reproductive success.
3. Proximity to Water	Barrier Islands/Headlands: <160–300 ft from high tide line and/or ephemeral pools or tidal flats.	All	This recommended distance is an approximation based off of recorded nest distances from high tide lines for some species in this group, but is not necessarily indicative of all species or of nest success. Also, the necessary distance to ephemeral pools and tidal flats may be different than distance to high tide line.	Quantify the distance of successful ground nests on barrier islands to particular areas of water (high tide line, ephemeral pools, and tidal flats) for multiple ground-nesting species to determine if distance to water is related to nest success.
4. Ground Elevation and Slope	Barrier Islands/Headlands + Coastal Bay Islands: 3–10 ft.	All	This is based on Landin & Engler, 1986.	Determine elevation/slope requirements for successful ground nests in Louisiana.
	Barrier Islands/Headlands + Coastal Bay Islands: gradual slope (the rise in elevation from the upper swale to the dome) of <98:3 grade to water edge (a rise of 3 ft over a linear distance of 98 ft).	All	This is based on Landin & Engler, 1986.	Determine elevation/slope requirements for successful ground nests in Louisiana.
	Barrier Islands/Headlands + Coastal Bay Islands: Small areas of supratidal elevation (e.g., 165 x 165 ft) within lower elevation features (e.g., overwash fans).	Wilson's Plover, Common Nighthawk, Snowy Plover, American Oystercatcher, Least Tern, Black Skimmer, Gull-billed Tern	This is mostly anecdotal out-of-state data/best professional judgment.	Specifically observe and document elevation and slope preferences (quantified as frequency of occurrence) of Wilson's Plover, Common Nighthawk, American Oystercatcher, Snowy Plover, and Least Tern.
5. Access to Vegetation and Vegetation Cover	Patches of low (<1.6–3.3 ft maximum mature height) herbaceous vegetation within 33 ft of nest site.	Least Tern, Black Skimmer, Wilson's Plover	This is somewhat anecdotal. Distance to vegetation is based on Gull-billed Tern, Black Skimmer, Royal Tern, and Sandwich Tern monitoring on Raccoon Island.	Quantify frequency of occurrence (as a proxy for preference) of Least Tern and Wilson's Plover nest-site vegetation parameters. Note that this should be quantified at locations other than Raccoon Island for Black Skimmer.
	Bare ground with sparse cover (<25%) of low-height (max growth <1.6 ft) herbs/vegetation.	Least Tern, Gull-billed Tern, Black Skimmer, Royal Tern, Sandwich Tern, Caspian Tern, Snowy Plover, Wilson's Plover, American Oystercatcher	This is somewhat anecdotal. Based on Gull-billed Tern, Black Skimmer, Royal Tern, and Sandwich Tern monitoring done on Raccoon Island.	Quantify frequency of occurrence (as a proxy for preference) of Least Tern and Caspian Tern nest-site vegetation parameters in Louisiana. Note that this should be quantified at locations other than Raccoon Island for other species (Gull-billed Tern, Black Skimmer, Royal Tern, and Sandwich Tern).

Preferential Avian Nesting Habitat Characteristic	Consideration	Species/Grouping	Notes	Data Gaps or Information Needs for Ground-Nesting Bird Biology and Ecology
	Medium coverage (25–75%) clumped/not evenly distributed low-height (max growth <1.6 ft) meadow (herbs) vegetation.	Wilson's Plover, Common Nighthawk, American Oystercatcher	This is mostly anecdotal data based on observations or out-of-state references.	Information pertaining to Wilson's Plover, Common Nighthawk, American Oystercatcher nest-site vegetation preferences in Louisiana.
	Dense coverage (75–100% cover) of mature herbaceous vegetation within meadow or intermediate/brackish/saline marshes (preference for additional presence of deposited vegetation debris and sticks).	Forster's Tern, Laughing Gull	This is largely anecdotal or outdated. Forster's Tern nesting data are from the 70s–90s.	Quantify frequency of occurrence (as a proxy for preference) of Least Forster's Tern and Laughing Gull nest-site vegetation parameters in Louisiana.
6. Sediment Structure	Gravel (e.g., crushed No. 8 or No. 57 limestone).	Gull-billed Tern, Black-skimmer, American Oystercatcher, Least Tern, Royal Tern, Sandwich Tern, Caspian Tern, Wilson's Plover	This is mostly anecdotal out-of-state data/best professional judgment.	Document sediment information at successful nesting sites in Louisiana, using frequency of occurrence as a proxy for preference (at least of available options).
	Medium sand (0.25–0.5 mm). Coarse sand (0.5–1.0 mm) with shell/pebble/limestone fragments. Very coarse sand (1–2 mm). Very fine pebble (2–4 mm). (Using Wentworth Scale classifications, see **Table 25**)	Gull-billed Tern, Black Skimmer, Royal Tern, Sandwich Tern, Caspian Tern, Snowy Plover, American Oystercatcher, Least Tern	This is somewhat anecdotal, somewhat based on information collected on Raccoon Island.	Document sediment information at successful ground-nesting sites in Louisiana (other than Raccoon Island), using frequency of occurrence as a proxy for preference (at least of available options).
7. Substrate and Nesting Materials	Shell and shell mounds.	American Oystercatcher, Wilson's Plover	This is mostly anecdotal data/best professional judgment.	Document nesting materials used by American Oystercatcher and Wilson's Plover, potentially through experimental choice trials (e.g., this would have been possible on Queen Bess Island) to identify preferred nesting materials for these species in Louisiana.
	Beach wrack/drift with <5% sand/shell.	Forster's Tern, Laughing Gull	This is mostly anecdotal data/best professional judgment.	Information pertaining to Forster's Tern and Laughing Gull, potentially through experimental choice trials (e.g., this would have been possible on Queen Bess Island) to identify preferred nesting materials for these species in Louisiana.

3 SUPPORTING INFORMATION: BIRD ECOLOGY

3.1 SHRUB-NESTING BIRDS

Shrub-nesting birds (**Figure 6**) are target coastal nesting bird species that primarily nest on, in, and among woody vegetation (**Figure 5**; see also **Section 2.1, Introduction**, for a concise definition). Suitability of habitats for shrub-nesting birds can be influenced by geographic considerations (e.g., proximity to previously successful historical nesting sites as well as availability and proximity to foraging habitat) and vegetation characteristics.[1]

Figure 6. Brown Pelican nest and chicks on Raccoon Island, Louisiana (photo credit: Eva Windhoffer, the Institute).

Seasonal occurrences of target shrub-nesting birds in coastal Louisiana are provided in **Table 14**. The documented breeding windows listed include the approximate period of courtship, from colony/territory establishment until chicks have fledged (i.e., are flight capable). This information is provided to project teams toward informing construction timelines (i.e., to limit potential disturbance of shrub-nesting bird-nesting activities).

1 For more information about shrub-nesting bird habitat characteristics and considerations, see **Section 3.1.2**.

Table 14. Shrub-nesting bird group (for reference photos of these species, their nests, and young, refer to page 55).

Common Name	Scientific Name	Breeding Window in LA	Residence in Coastal LA	Reference Photos (see Section 3.1.3)
Brown Pelican	*Pelecanus occidentalis*	February–August	Year-round	Figure 8 Figure 9
Reddish Egret	*Egretta refescens*	March–July	Year-round	Figure 10 Figure 11
Great Blue Heron	*Ardea herodias*	February–July	Year-round	Figure 12
Green Heron	*Butorides virescens*	March–August	Year-round	Figure 13
Cattle Egret	*Bubulcus ibis*	April–August	Year-round	Figure 14
Roseate Spoonbill	*Platalea ajaja*	April–July	Year-round	Figure 15
Tricolored Heron	*Egretta tricolor*	March–July	Year-round	Figure 16
Little Blue Heron	*Egretta caerulea*	March–July	Year-round	Figure 17 Figure 18
Great Egret	*Ardea alba*	February–July	Year-round	Figure 19 Figure 20
Snowy Egret	*Egretta thula*	March–July	Year-round	Figure 21
Black-crowned Night Heron	*Nycticorax nycticorax*	March–August	Breeding	Figure 22
Yellow-crowned Night Heron	*Nyctanassa violacea*	March–August	Year-round	Figure 23
Neotropic Cormorant	*Nannopterum brasilianum*	March–June	Year-round	Figure 24
White Ibis	*Eudocimus albus*	April–July	Year-round	Figure 25
White-faced Ibis	*Plegadis chihi*	April–August	Year-round	Figure 26
Glossy Ibis	*Plegadis falcinellus*	April–August	Year-round	Figure 27

Note: Breeding window of target shrub-nesting birds in coastal Louisiana encompasses approximate courtship period and colony/territory establishment and concludes with chick fledging (i.e., are flight capable). In addition, a subset of individuals for species with "year-round" residency in Louisiana migrate out of Louisiana for the non-breeding period; therefore, there may be some variation in the total populations that remain in Louisiana throughout the year.

The majority of these birds are in the order Pelicaniformes, which include pelicans, herons, egrets, ibis, and spoonbills (Winkler et al., 2020). However, Neotropic Cormorant was recently re-categorized as a result of molecular analysis and now belongs to the order Suliformes (Chesser et al., 2010; P. G. P. Ericson et al., 2006). Shrub-nesting birds are primarily fish eaters and thus inhabit areas with water for foraging. However, Cattle Egrets are unique in their use of foraging habitats (i.e., frequently forage in more arid upland sites) and diet (e.g., amphibians, reptiles, and small mammals; Telfair II, 2020).

3.1.1. Nesting Ecology

Louisiana ranks highest among the five states in the northern Gulf of Mexico in terms of importance for supporting nesting populations of Brown Pelican and Tricolored Heron, and ranks third for Reddish Egret (Remsen et al., 2019). In the Gulf of Mexico, shrub-nesting birds typically nest between early March through late July, with some differences in timing of nesting between species, as well as some year-to-year variation (Soots & Landin, 1978; **Table 14**). The majority of shrub-nesting birds, with the exception of Reddish Egret and Yellow-crowned Night Heron, are year-round residents in coastal Louisiana (Billerman et al., 2020). As such, foraging habitats may be utilized by these species outside their breeding window (refer to **Table 15**). Outside the breeding season, birds will often disperse and utilize other seasonal residences (e.g., crawfish farms, commercial baitfish ponds) away from the breeding sites.

Shrub-nesting birds preferentially nest on woody vegetation (i.e., trees and shrubs) in scrub/shrub and saline marshes on coastal bay islands and barrier islands/headlands (see **Figure 5**). Most of these species, with the exception of Brown Pelicans and Reddish Egrets, will also nest farther inland in bottomland hardwood forests, as well as in freshwater to brackish-saline marshes (Keller et al., 1983). Although some shrub-nesting birds, such as Brown Pelicans, will nest on the ground (Spendelow & Patton, 1988; Visser et al., 2005), the reproductive success of ground nests is often lower than that of elevated shrubs due to tidal flooding on low-elevation islands (McNease et al., 1992; Walter et al., 2013). Therefore, design considerations for shrub-nesting birds should prioritize creating or restoring woody vegetation that elevate potential nest sites off the ground. See **Section 3.1.2.4** for more information about vegetation considerations that benefit nest success.

Table 15 provides a summary of nesting and foraging habitats used by shrub-nesting birds (for definitions of these marsh habitats, refer to **Section 2.1, Introduction**). Both nesting and foraging habitats are required to support the reproductive cycle including nest success. For the purposes of this document, nesting habitat for shrub-nesting birds refers to areas containing trees and shrubs whereas foraging habitat explicitly refers to areas principally containing water. The importance of foraging habitats in relation to nesting success is discussed in **Section 3.1.2.2**.

Table 15. Landforms and habitats used by the shrub-nesting birds for nesting and foraging. Note: Brown Pelican and Neotropic Cormorant will also feed in open Gulf waters (Shields, 2020; Telfair II, 2020b).

Landform	Habitat	Species that Nest in this Landform	Species that Forage in this Landform
Barrier Island/Headlands	Scrub/Shrub (vegetation cover >30%)	All	None
	Saline Marsh	All	All
Coastal Bay Islands	Scrub/Shrub (vegetation cover >30%)	All	None
	Saline Marsh	All	All
Coastal Wetlands	Brackish-Saline Marsh (salinity >4.5 ppt)	All	All
	Fresh-Intermediate Marsh (salinity <4.5 ppt)	All except Brown Pelican, Reddish Egret	All
	Scrub/Shrub (vegetation cover >30%)	All except Brown Pelican, Reddish Egret	None
	Forest (woody vegetation >6 m; vegetation cover >30%; typically flooded or surrounded by water)	All except Brown Pelican, Reddish Egret	All except Brown Pelican, Reddish Egret

3.1.2. Habitat Characteristics and Considerations

Habitat characteristics that influence the suitability for shrub-nesting birds include the availability of, and proximity to, high-quality foraging habitat as well as habitat characteristics and provide some protection from predators (Hafner, 2000). **Figure 7** provides a conceptual depiction of key direct and indirect habitat characteristics that improve nesting habitat suitability for shrub-nesting birds. Of these, several principal features have the potential to greatly influence nesting habitat suitability including geographic considerations (e.g., proximity to historical nesting sites and foraging habitat) as well as vegetation height and density. Some of these considerations can be controlled during project site selection (location) and others may be controlled or accounted for during project engineering, design, and implementation.

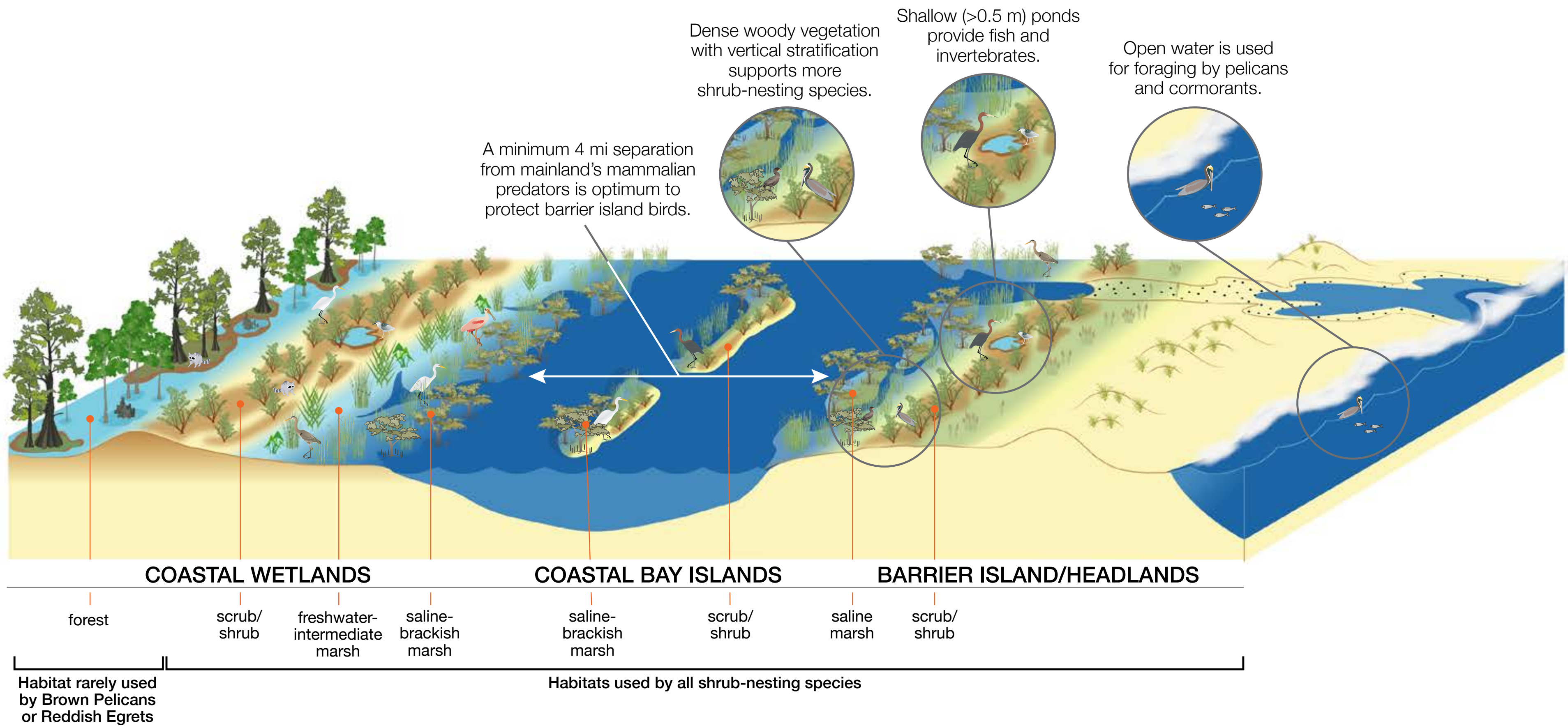

Figure 7. Conceptual depiction of key direct and indirect habitat characteristics that improve nesting and foraging habitat suitability for shrub-nesting birds.

Habitat characteristics from **Table 2** and their applications during project design and construction are discussed in the following sections. Louisiana-specific information along with SME best professional judgment was prioritized within this guidance. Related resources that encompass this bird group within the greater Gulf of Mexico region and/or broader home range may also have been utilized, where appropriate. In all cases, information was cited appropriately. Further, identification of data gaps and prioritization of information needs were also considered (**Table 5**). Collectively, information presented is considered state of the science for shrub-nesting birds within coastal Louisiana at the time of publication.

3.1.2.1. Proximity to Human Activity, Mammalian Predators, and Island Size

Once colonies and nests have been established, primary threats to nest success for shrub-nesting birds are human disturbance and mammalian predation (see **Table 2, Proximity to Human Activity and Mammalian Predators**). Human disturbance is known to negatively affect colony persistence and nest success (Carney & Sydeman, 1999; Nisbet, 2000; Rodgers & Smith, 1995). Nesting sites that are farther away from human disturbance (>4 mi) have been observed to be used repeatedly by shrub-nesting birds, such as Brown Pelicans (Visser et al., 2005). Nearby urban environments are also problematic because they tend to harbor artificially inflated mammalian predator populations that may access islands via land or water (Dueser et al., 2013). Depredation of eggs and nestlings by mammals (e.g., principally raccoons, coyotes) can influence nest success and, as such, the suitability of nest sites for shrub-nesting birds (Post, 1990). To minimize these impacts, project teams should prioritize the creation or restoration of nesting sites to prevent or deter access by mammalian predators, particularly during low tide (Hingtgen et al., 1985) or include consideration of active predator management. Therefore, it is suggested that established best management practices should be utilized, where appropriate, to limit the potential impacts of this activity on future shrub-nesting bird reproductive success and survival.

Mammalian predation is also more likely to occur on larger islands that have extensive dense, herbaceous cover and islands that provide direct connectivity to the mainland (i.e., source of mammalian predators). There is less opportunity for mammalian populations to establish on islands <50 ac (see **Table 2, Island Size**), particularly if these islands are >2 mi away from the mainland (Golder et al., 2008; Landin & Engler, 1986). Terrestrial or urban environments typically have a higher density of mammalian predators that can access islands via land or water (Dueser et al., 2013). When a project is either >50 ac or <2 mi from the mainland, project teams should plan accordingly (i.e., predator management) in support of future colony establishment, and maximizing nest success will require annual/routine predator management (Beerens et al., 2017; Butler & Vennesland, 2000).

3.1.2.2. Proximity to Previously Used Nesting Sites and Water

Shrub-nesting birds often return to the same locations to breed year after year (i.e., strong site fidelity; Keller et al., 1983; Visser & Peterson, 1994; Walter et al., 2013). As such, prioritization of historical nesting areas provides a targeted and cost-effective means to generate resource benefits (i.e., nesting, foraging, loafing) for these species. Project sites that are close (≤3 mi; Custer et al., 1980) to previously used nesting sites and meet other habitat characteristics (e.g., availability of foraging habitat and minimal disturbance/predation) should be taken into account when considering restoration projects for shrub-nesting birds (see **Table 2, Proximity to Human Activity and Mammalian Predators**). However, deliberate attempts to relocate Brown Pelican nesting colonies to nearby islands after improving nesting habitat conditions have met with mixed success (Louisiana Trustees, 2018). Remaining knowledge gaps related to habitat structural features and bird behavioral response to relocation efforts continue to result in less than optimal outcomes (Louisiana Trustees, 2018).

Proximity to water can influence nest site suitability because intertidal waters and pools are often used by young birds for loafing. However, given that shrub-nesting birds almost exclusively forage in or around water, water depth as well as the proximity of water bodies to potential nest sites must be considered in project design (see **Table 2, Proximity to Water**). The creation or maintenance of productive foraging areas is an essential habitat consideration for shrub-nesting birds to ensure desirable prey availability for adults and hatched chicks (Frederick & Green, 2019; Kelly et al., 2008; Leberg et al., 2007; Short & Cooper, 1985). Brown Pelican colonies on islands are generally established in areas with open water within 12 mi (Visser et al., 2005). Brown Pelicans plunge-dive whereas Neotropic Cormorants are pursuit divers in open waters for large forage fish (e.g., Gulf menhaden). Conversely, other shrub-nesting species forage while wading in shallow water (<0.5 m) to find a variety of aquatic and sometimes non aquatic prey (e.g., insects, amphibians, reptiles, and small mammals; Briggs et al., 1983; Powell, 1987; Regidor & Terroba, 2001; Visser et al., 2005). A summary of shrub-nesting bird primary dietary items as well as foraging method and locations is provided below in **Table 16**.

Table 16. Differences in the diets, foraging methods, and foraging locations of shrub-nesting birds.

Species	Primary Diet	Foraging Method	Foraging Location
Brown Pelican, Neotropic Cormorant	Open water fishes	Plunging, diving	Open water in fresh-saline marshes
Great Blue Heron, Green Heron, Cattle Egret, Roseate Spoonbill, Tricolored Heron, Little Blue Heron, Great Egret, Snowy Egret, Black crowned Night-Heron, Yellow-crowned Night-Heron, Neotropic Cormorant, White Ibis, White-faced Ibis, Glossy Ibis	Shallow water fishes, crustaceans, marine invertebrates, insects, amphibians, aquatic reptiles	Wading	Shallow water (<0.5 m) in fresh saline marshes, coastal wetland forests

3.1.2.3. Ground Elevation and Sediment Structure

As previously discussed, elevated shrub- and tree-nesting habitats should be prioritized over ground-nesting habitats for these target shrub-nesting birds due to potentially higher nest success for elevated (i.e., off-the-ground) nests. However, another feature that project teams should consider is ground elevation (see **Table 2, Ground Elevation**). Landin & Engler (1986) note that restored islands should maintain an elevation that minimizes flooding and suggested an elevation of 3–10 ft above mean sea level (although 10 ft is notably unrealistic for Louisiana's coastal island habitats and associated shrub vegetation). More recently, an elevation of 1 ft above mean sea level has been associated with Brown Pelican nests in Louisiana. This metric was calculated by pooling scrub-shrub and mangrove thicket islands. (Visser et al., 2005).

Sediment should be considered with respect to its ability to support shrub and tree vegetation at ideal ground elevations (see **Table 2, Sediment Structure**). Information about sediment types that are most ideal for shrub vegetation is limited. However, some decisions regarding sediment type and placement for barrier islands/headlands created for shrub-nesting birds should be based on the ground elevation of the island. Finer, non-cohesive sand sediments at higher elevations are more prone to be unstable as a result of wind energy and, therefore, may result in challenges supporting the establishment of target shrub species such as groundsel bush or marsh-elder (Landin & Engler, 1986). **Table 3** and **Table 4** provide further information on remedial measures, such as placement of grass plantings and hay bale placement, that have been used on past projects to stabilize non-cohesive sediments. Black mangroves, another desirable species for shrub-nesting birds, take root in fertile, silty soils in intertidal areas.

3.1.2.4. Vegetation Cover and Height

Shrub-nesting birds often nest together in close vertical or horizontal aggregations (colonies) within stands of trees or shrubs (Beaver et al., 1980; Kushlan & Hancock, 2005; Soots & Landin, 1978). Black mangrove, marsh-elder, and groundsel bush are three plant species commonly used by shrub-nesting birds in barrier island/headland and coastal bay islands in Louisiana (Gaston & Johnson, 1977; Visser et al., 2005). Plant species used by shrub-nesting birds in fresher coastal wetland habitats include cypress, tupelo, buttonbush, and wax myrtle. However, other shrubs and tree species can support shrub-nesting birds as long as the plants are structurally stable enough to support nests (Beaver et al., 1980). Colony size and species richness of shrub-nesting birds have been linked to the density and availability of shrub vegetation (Beaver et al., 1980), and the number of nesting individuals within a colony can vary as a result. Colonies in Louisiana have been observed to consist of less than 100 to 10,000 adults (Keller et al., 1983; Michot et al., 2003). Creation or restoration of dense stands of woody/shrub vegetation provides potential to support a higher number of shrub-nesting birds (see **Table 2, Vegetation Cover**). Actual use by shrub-nesting birds of these areas still relies on successful control of mammalian predators that generally inhabit these densely vegetated areas or the consideration of distance to mainland during the design phase to reduce the likelihood of mammalian colonization. More information is needed regarding the precise vegetation coverage that will support shrub-nesting bird-nesting success; however, spacing propagules of shrubs and trees approximately 6.5 ft apart has been suggested (Soots & Landin, 1978) to maximize plant growth. Project teams should consider how to best achieve dense stands of shrub vegetation given the vegetation type and availability of space at each project site.

Within nesting colonies where vertical stratification is possible due to taller vegetation, certain bird species will nest at different heights than other species (Beaver et al., 1980; Soots & Landin, 1978). For example, Black-crowned Night-Herons and White Ibis usually nest closer to the ground (approx. 20 in above ground; (Burger, 1979; Chapman et al., 1981), whereas larger species such as Great Egrets nest higher up (<15 m) in shrub or tree canopies (Butler, 1992; Kushlan & Hancock, 2005; Portnoy, 1977). This stratification results in greater species diversity and higher nest densities within a given unit area (e.g., per acre). Some shrub-nesting birds will occasionally nest on the ground; however, ground nests are more prone to failure due to overwash events (Collins et al., 2021; Walter et al., 2013). As such, prioritizing vegetation that allows for nest sites to be elevated off the ground will help to maximize nesting habitat suitability for this group of birds (see **Table 2, Vegetation Height**). It should be noted that this process takes time to occur if plantings of seedlings or younger vegetation species are done. Transplanting mature shrubs and the creation of artificial nesting structures will provide the desired heights; however, it will likely take the birds some time to use these areas for nesting, lack availability, and be cost prohibitive.

3.1.2.5. Substrate and Nest Materials

Nests of shrub-nesting birds are often constructed out of natural debris including dead tree branches, sticks, and twigs (see **Table 2**, **Substrate and Nest Materials**). This need for nesting materials is applicable for all target shrub-nesting species. Evaluating the availability of these materials at project sites and potentially supplementing nest materials on a project site, where appropriate, can increase potential nesting habitat suitability (Short & Cooper, 1985).

3.1.3. Shrub-Nesting Bird Reference Photos

Figure 8. Brown Pelican adult (photo credit: Eva Windhoffer, the Institute).

Figure 9. Brown Pelican chicks on nest (photo credit: Eva Windhoffer, the Institute).

Figure 10. Reddish Egret adults (photo credit: Robert Dobbs, LDWF).

Figure 11. Reddish Egret adult, white morph (photo credit: Robert Dobbs, LDWF).

Figure 12. Great Blue Heron adult (photo credit: Robert Dobbs, LDWF).

Figure 13. Green Heron adult on nest (photo credit: Robert Dobbs, LDWF).

Figure 14. Cattle Egret adult (photo credit: Robert Dobbs, LDWF).

Figure 15. Roseate Spoonbill adult (photo credit: Robert Dobbs, LDWF).


Figure 16. Tricolored Heron adult (photo credit: Robert Dobbs, LDWF).


Figure 17. Little Blue Heron adult (photo credit: Robert Dobbs, LDWF).

Figure 18. Little Blue Heron juvenile (photo credit: Robert Dobbs, LDWF).

Figure 19. Great Egret adult (photo credit: Robert Dobbs, LDWF).

Figure 20. Great Egret chicks on nest (photo credit: Eva Windhoffer, the Institute).

Figure 21. Snowy Egret adult (photo credit: Robert Dobbs, LDWF).

Figure 22. Black-crowned Night Heron adult (photo credit: Robert Dobbs, LDWF).

Figure 23. Yellow-crowned Night Heron adult (photo credit: Robert Dobbs, LDWF).

Figure 24. Neotropic Cormorant adult (photo credit: Robert Dobbs, LDWF).

Figure 25. White Ibis adult (photo credit: Robert Dobbs, LDWF).

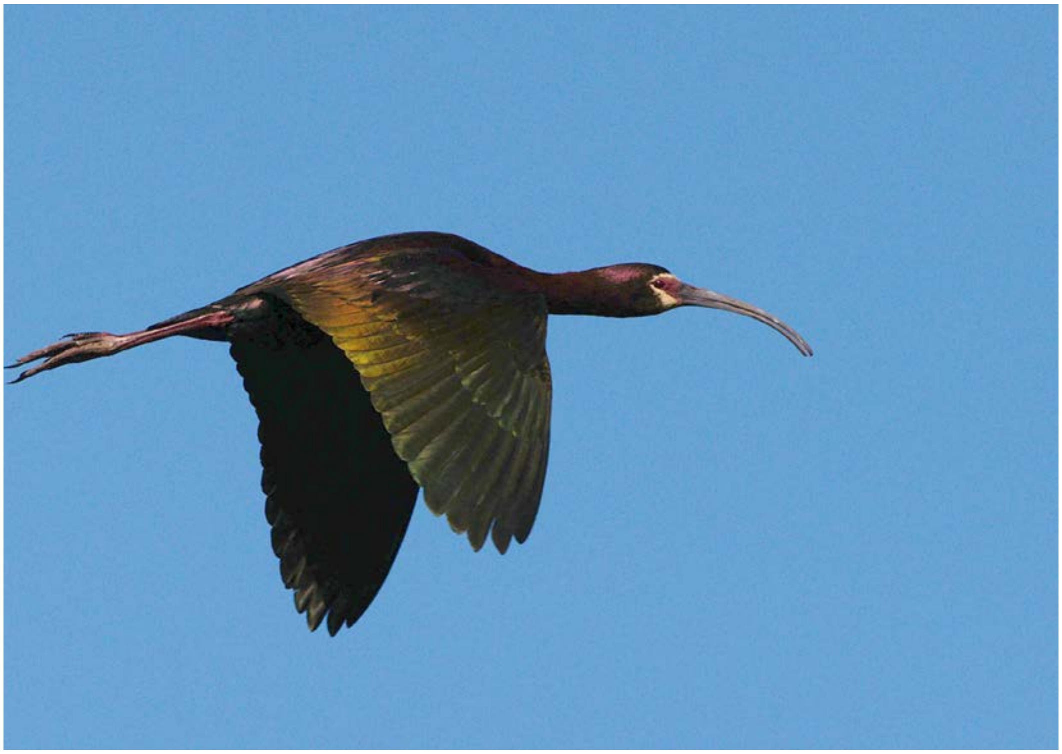

Figure 26. White-faced Ibis adult (photo credit: Robert Dobbs, LDWF).

Figure 27. Glossy Ibis adult (photo credit: Rick Davidson).

3.2 MARSH-NESTING BIRDS

Marsh-nesting birds (**Figure 28**) are target coastal bird species that inhabit and nest exclusively in marshes in coastal wetlands, coastal bay islands, or barrier islands/headlands **Figure 5**; see also **Section 2.1, Introduction**, for a concise definition). Suitability of habitats for marsh-nesting birds can be influenced by elevation heterogeneity, land and water interspersion, hydrologic connectivity, vegetation characteristics, and proximity to human activity.[2] The incorporation of these target habitat characteristics into existing project design, construction, maintenance, and related items in CPRA's Marsh Creation Design Guidelines (CPRA, 2017b) has the potential to create high value habitat for wetland-dependent wildlife species including marsh-nesting birds. This would be a significant step in further accomplishing the broader objectives and principles (Flood Protection, Coastal Habitats, Cultural Heritage) of the state's Coastal Master Plan.

Figure 28. Nests of marsh-nesting birds in Louisiana: A) Seaside Sparrow nest with a canopy (photo credit: Phillip Vasseur, LDWF) and B) Purple Gallinule nest (photo credit: Joseph A Youtz, LSU).

Seasonal occurrences of marsh-nesting birds in coastal Louisiana are provided in **Table 17**. The documented breeding windows listed include the approximate period of courtship through colony/territory establishment until chicks have fledged (i.e., are flight capable). This information is provided to project teams toward informing construction timelines (i.e., to limit potential disturbance of nesting activities of marsh-nesting birds).

Marsh-nesting birds represent multiple taxonomic orders including Gruiformes, Charadriiformes, Anseriformes, Podicipediformes, Pelicaniformes, and Passeriformes (Hackett et al., 2008; Winkler et al., 2020). Many of the marsh-nesting birds are collectively referred to as secretive marsh birds, which describes their cryptic nature and low detection rates during surveys, because they spend most of their lives foraging, nesting, and seeking cover within dense marsh vegetation (Eddleman et al., 1988; Woodrey et al., 2019).

2 For more information about marsh-nesting bird habitat characteristics and considerations, see **Section 3.2.2**.

Table 17. Marsh-nesting bird group (for reference photos of these species, their nests, and young, refer to page 74).

Common Name	Scientific Name	Breeding Window in LA	Residence in Coastal LA	Reference Photos (see Section 3.2.4)
Purple Gallinule	*Porphyrio martinica*	May–July	Breeding	Figure 34, Figure 35
Common Gallinule	*Gallinula galeata*	May–August	Year-round	Figure 36
Least Bittern	*Ixobrychus exilis*	March–July	Breeding	Figure 37, Figure 38
King Rail	*Rallus elegans*	March–July	Year-round	Figure 42
Pied-billed Grebe	*Podilymbus podiceps*	March–July	Year-round	Figure 39
Mottled Duck	*Anas fulvigula*	March–July	Year-round	Figure 40
Black Rail	*Laterallus jamaicensis*	Unknown*	Year-round	Figure 44
Black-necked Stilt	*Himantopus mexicanus*	April–August	Year-round	Figure 41
Clapper Rail	*Rallus crepitans*	March–July	Year-round	Figure 43
Seaside Sparrow	*Ammospiza maritima*	March–July	Year-round	Figure 45, Figure 46

*The determination of Black Rail breeding windows in Louisiana is ongoing; see E. I. Johnson & Lehman (2021).

Coastal Louisiana contains approximately 40 percent of the coastal marshes in the lower 48 states of the U.S. (5,663 square miles in 2010; Couvillion et al., 2011). Therefore, Louisiana coastal marshes provide critical habitat for nesting populations of Clapper Rail, Mottled Duck, and Seaside Sparrow (Remsen et al., 2019). Marsh-nesting birds have a wide range of nesting habitat needs, which presents a challenge for project design and management (Rush & Cooper, 2010). For instance, Mottled Duck ducklings generally leave the nest within a few days. Their movements may be restricted by surrounding habitats that include barriers such as roads or high-elevation levees (Rigby, 2008). For other species, such as Seaside Sparrows, chicks are not able to leave their nests for approximately two weeks after hatching, making them vulnerable to flooding and depredation (Newsome et al., 2021). Therefore, if project teams aim to provide a diversity of habitat characteristics, it should maximize the potential for suitable nesting habitats for target species of marsh-nesting birds.

3.2.1. Nesting Ecology

As a group, marsh-nesting birds utilize a wide variety of marsh types (**Table 18**; for definitions of these marsh habitats, refer to **Section 2.1, Introduction**). Some species, such as the Mottled Duck, frequent and regularly nests in all marsh types (from fresh to saline). Other species, such as Purple Gallinule, are generally restricted to freshwater marshes while Seaside Sparrow only utilize brackish-saline marshes (Enloe et al., 2017; Remsen et al., 2019; Rush et al., 2009).

Table 18. Habitat distributions of marsh-nesting birds by marsh type.

<table>
<tr><th>Common Name</th><th colspan="3">Marsh Type</th></tr>
<tr><td>Purple Gallinule</td><td rowspan="7">Fresh Marsh</td><td rowspan="10">Intermediate Marsh</td><td rowspan="4"></td></tr>
<tr><td>Least Bittern</td></tr>
<tr><td>King Rail</td></tr>
<tr><td>Pied-billed Grebe</td></tr>
<tr><td>Common Gallinule</td><td rowspan="7">Brackish-Saline Marsh</td></tr>
<tr><td>Least Turn</td></tr>
<tr><td>Mottled Duck</td></tr>
<tr><td>Black Rail</td><td rowspan="4"></td></tr>
<tr><td>Black-necked Stilt</td></tr>
<tr><td>Clapper Rail</td></tr>
<tr><td>Seaside Sparrow</td><td></td></tr>
</table>

Due to the variety of marsh-nesting bird nest types, heterogeneous sites with areas of relatively contiguous dense marsh vegetation interspersed with areas of open water have the highest potential for supporting a range of target marsh-nesting bird species (O'Connell & Nyman, 2010). In contrast to many of the shrub-nesting and ground-nesting birds (**Sections 3.1 and 3.3**), the target species of marsh-nesting birds are all solitary nesters. For this reason, the density of nests per unit area is, on average, much lower and so the cumulative number of birds potentially benefited by a given restoration project tends to be much lower than projects that potentially support dense nesting colonies of shrub- or ground-nesting birds. Some marsh-nesting birds (e.g., rails, gallinules, Seaside Sparrows) create bowl-shaped nests constructed out of marsh vegetation (e.g., *Spartina* sp.) that are often concealed by dense, surrounding vegetation forming an overhead dome or canopy (see **Figure 28**). These nests are generally elevated (approx. 1–3 ft) from the surface of the water so that they are generally protected during tidal fluctuations and from mammalian predators (Hunter et al., 2016; Newsome et al., 2021). Other species, including Black-necked Stilts and Pied-billed Grebes, construct floating nest platforms directly on the water's surface by using buoyant emergent vegetation (e.g., bulltongue arrowhead, yellow pond-lily, widgeon grass). These floating nests are often in open water and have been observed in Louisiana at distances of up to 600 ft from the nearest stand of vegetation (Chabreck, 1963).

3.2.2. Habitat Characteristics and Considerations

Marsh-nesting birds are adapted to living in highly dynamic coastal environments (Benvenuti et al., 2018; Weller & Spatcher, 1965). However, increased rates of sea-level rise and marsh habitat loss (due to erosion, subsidence) in the Gulf of Mexico represent significant challenges for marsh-nesting birds (Hughes, 2004; Thorne et al., 2012). The complex and dynamic nature of marsh habitats reinforces the need for providing a range of habitat characteristics through marsh restoration (Eddleman et al., 1988; Tozer et al., 2010). In general, a more diverse habitat will provide suitable nesting habitat for a greater number of marsh-nesting birds (Hunter et al., 2017; Rush et al., 2010). In Louisiana, information is currently being collected to better understand the nesting ecology of marsh-nesting birds and has been ongoing since 2019,[3] including the characterization of preferential nesting and foraging habitats for the more secretive (i.e., difficult-to-detect) species such as rails. Black Rails, for example, have only recently been detected for the first time during the breeding season in Louisiana (E. I. Johnson & Lehman, 2021).

Section 3.2.2 highlights targeted habitat characteristics (**Table 6**) identified by SMEs that, when incorporated, could greatly benefit the ability of project teams to design and construct high-value habitats for wetland-reliant wildlife species emphasizing marsh-nesting bird habitats (**Table 7**).

Louisiana-specific information along with SME best professional judgment was prioritized within this guidance. Related resources, which encompass marsh-nesting birds within the greater Gulf of Mexico region, and/or broader geographic range of these species may also have been utilized, where appropriate. Further, identification of data gaps, as well as prioritization of information needs, was also included (**Table 9**). Collectively, information presented is considered state of the science for Louisiana marsh-nesting birds at the time of publication.

3.2.2.1. Proximity to Human Activity and Mammalian Predators

Disturbance by humans and depredation of eggs and nestlings by mammalian predators (e.g., raccoon and coyote) that often associate with human activity have the potential to negatively influence nest success of marsh-nesting birds (Schwarzbach et al., 2006). Coastal marshes in proximity to urban/suburban environments are also problematic because these areas tend to harbor a greater diversity and density of mammalian predator populations that can access coastal marshes (Dueser et al., 2013). Therefore, it is suggested that established best management practices should be utilized, where appropriate, to limit the potential negative impacts of these two factors on marsh-nesting bird survival and reproductive success and survival (see **Table 6, Proximity to Human Activity and Mammalian Predators**).

3.2.2.2. Elevation Heterogeneity /Topography

Incorporation of elevation heterogeneity (or a range of marsh elevations in the predicted tidal range over time) for project design and construction has been shown to increase habitat suitability for wetland-reliant species, particularly marsh-nesting

3 (2019) LA TIG (MAM) Secretive Marsh Birds; LA-2019-016.

birds. In addition, this practice improves overall marsh health relative to historical methods (uniform elevation; J. A. M. Smith & Pellew, 2021; Valdes et al., 2016).

From this, a diverse array of beneficial habitat characteristics is created including shallow water pools for foraging rails, deeper ponds for gallinules, and robust/diverse emergent vegetation providing nesting habitat and protective cover for adults, subadults/immatures, fledglings (see **Table 6, Elevation/Topography**). Maximizing the period that marsh elevation stays within the tidal range (due to the combination of initial constructed elevation, settlement over time, and marsh vertical accretion) and maximizing elevation heterogeneity within the predicted intertidal window over time will provide the greatest area of potential nesting habitat over time (see **Table 6, Land/Water Interspersion and Edge Features**; **Figure 29**). A proven methodology generates increased habitat value for marsh-nesting birds as well as contributing to overall marsh health (Smith & Pellew, 2021; Valdes et al., 2016). Project teams can allow for greater post-construction survey acceptance tolerances while still constraining the post-construction elevation of marsh projects to remain within intertidal range for as much of the project life as possible when geotechnical conditions allow (**Figure 29**). In so doing, highly productive nesting habitats for marsh-nesting birds are likely to be created including robust/diverse emergent vegetation that supports cover and nest creation/protection, as well as productive foraging habitats for rails (shallow water pools) and gallinules (deeper ponds). Therefore, it is suggested that, to maximize the potential habitat value for wetland-reliant marsh bird species, elevation heterogeneity should be included within future marsh creation project design and construction. It should be caveated, however, that allowing contractors higher tolerances for finished marsh fill elevations could lead to cost tradeoffs; depending on the payment method for the contract (paying based on the filled template versus the excavated template quantity), a contractor may be incentivized unintentionally to fill to the maximum elevation allowed, driving up project cost. Furthermore, marsh creation project elevation is often constrained by containment dike design and stability, and any increased elevation tolerance would need to account for containment dike stability limitations. Methods for varying the elevation acceptance tolerance are dictated by the type of fill being used:

> Fine, cohesive fill dewaters slowly and limits or prohibits mechanical reworking immediately after placement. In these cases, alternative strategies may include slowing the rate of pumping, semiconfined fill placement, or subdivision of fill cells into various elevation targets.
>
> Coarser, non-cohesive fill dewaters more quickly. In addition to strategies mentioned above, some mechanical reworking of material immediately after placement may be possible to achieve desired elevation heterogeneity.

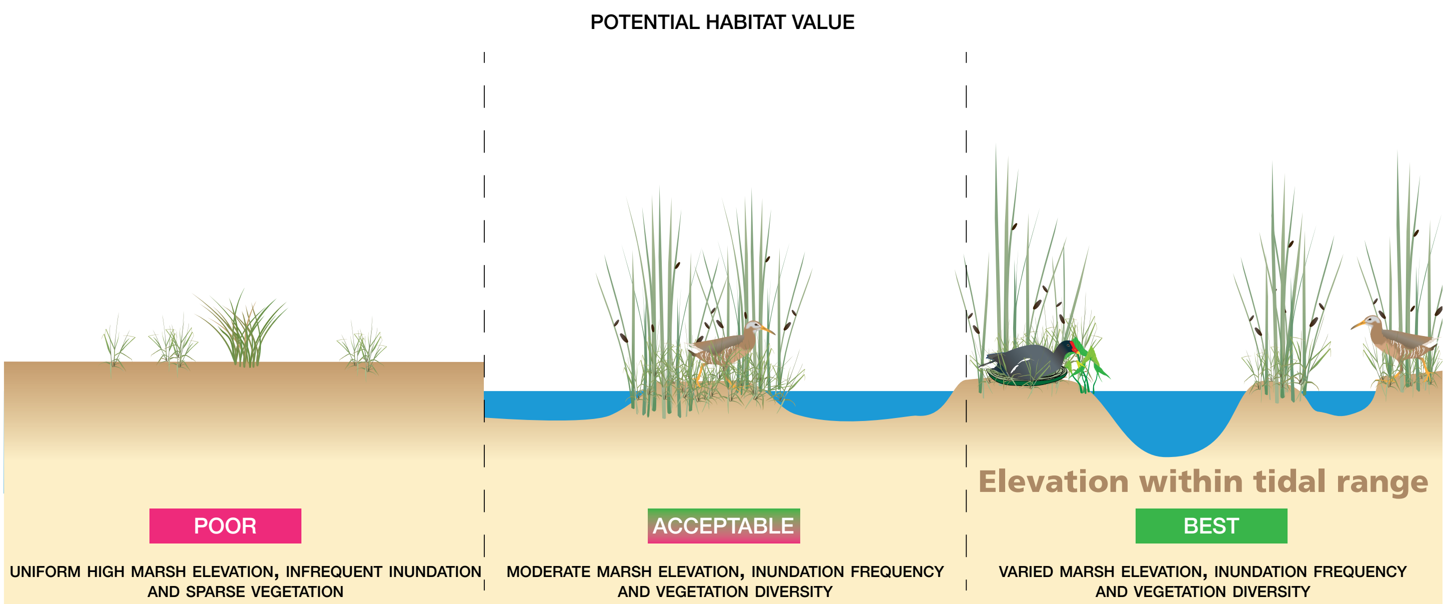

Figure 29. Marsh-nesting bird habitat suitability relating to elevation.

3.2.2.3. Land/Water Interspersion and Edge Features

Louisiana marsh creation primarily focuses on the establishment of new contiguous wetlands in open water areas such as bays, ponds, and canals. Fragmented marshes are vulnerable to land loss due to erosion from wave activity (Sapkota & White, 2019). Although target marsh-nesting birds will utilize non-contiguous marshes (Baker, 1983; Benoit & Askins, 2002), areas of emergent marsh interspersed with water features (i.e. terraces and ponds) and areas close to marsh edges generally support greater densities of marsh bird species (O'Connell & Nyman, 2010; Patton et al., 2020). This is likely due, in part, to water features such marsh edge providing valuable foraging areas for these birds.

Due to the dynamic nature of marsh habitats, water to land cover ratios increase or decrease over time depending upon human use, environmental conditions, and management (or lack thereof). For example, in fresh/intermediate marshes, shallow water areas can rapidly fill with robust emergent plants (e.g., broadleaf cattail and common reed). Whereas within brackish/saline marshes, open water can increase with subsidence, erosion, or through the combination of both. To maximize potential habitat value for wetland-reliant wildlife species emphasizing marsh-nesting birds, project teams should endeavor to maximize the duration within the project lifespan of an open water to land cover ratio of 30–60 percent over the project lifetime (20 years) via design and construction (**Figure 30**). See **Table 6**, **Land/Water Interspersion and Edge Features**, for more information. Land cover ratio is a characteristic which, on a case-by-case basis, is something that may develop naturally over time or be required to be present on a benefits timeline which differs from a natural progression via subsidence and erosion. Depending on the project's specific goals and objectives, planners and designers may consider creation of specific features such as ponds and tidally connected creeks.

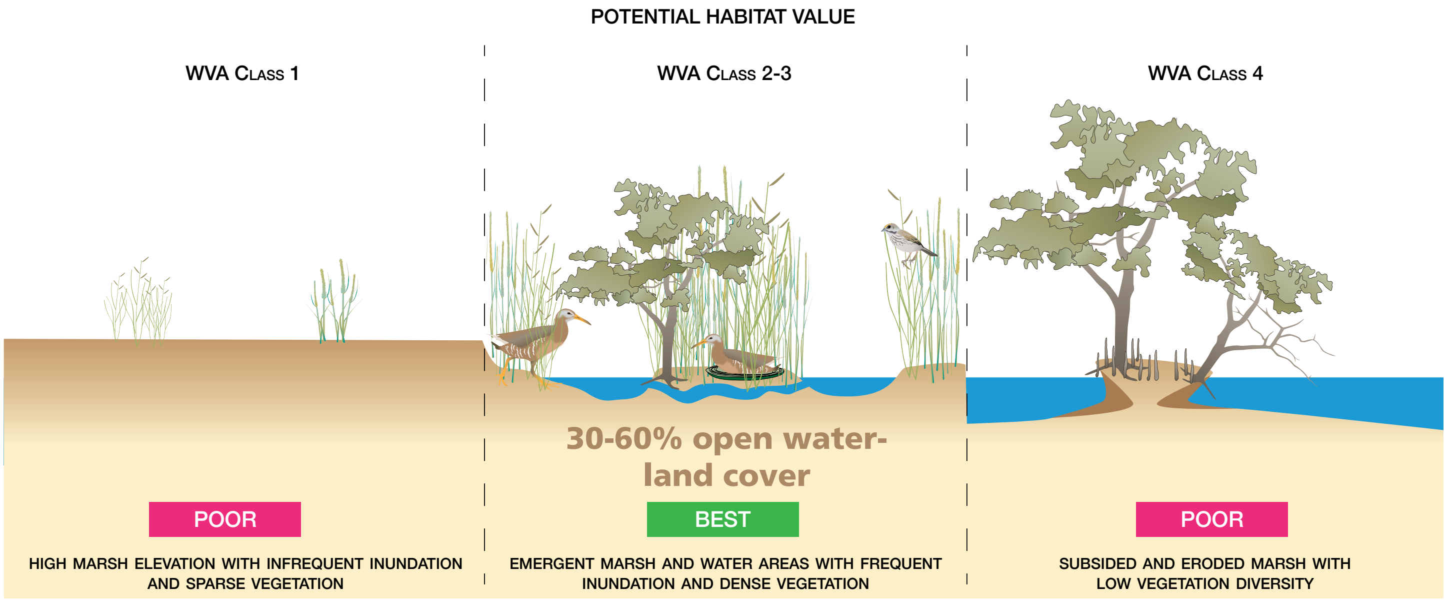

Figure 30. Marsh-nesting bird habitat suitability relating to land/water interspersion. WVA = Wetland Value Assessment.

3.2.2.4. Hydrologic Connectivity

Hydrologic connectivity highly influences overall habitat suitability for marsh-nesting birds. The primary reason is that the ebb and flow of marsh waters into surrounding estuaries facilitates movement of nekton and other food items, thereby increasing foraging opportunities for marsh-nesting birds that forage for aquatic species (**Table 19**). Therefore, it is suggested that hydrologic connectivity to shallow (<6–8 in) pools and deeper (3–5 ft) ponds should be prioritized for marsh-nesting birds to increase foraging habitat (see **Table 6, Elevation/Topography**). Achievement of this characteristic may be accomplished via mindful layout of marsh fill cells and containment dike gapping post-construction as well as the specific design and construction of tidally connected creeks or trenasses. One consideration when including open water habitats in fresh marshes is the potential for encroachment of invasive water hyacinth, a plant species that can dominate such open water areas and thus inhibit foraging potential and nesting suitability for birds. There is evidence of winter mortality for water hyacinth in Louisiana; however, project teams are encouraged to incorporate biological control to suppress further invasion (Nesslage et al., 2016).

Table 19. Diet and primary foraging locations of marsh-nesting birds

Common Name	Diet	Primary foraging locations
Purple Gallinule	Aquatic plant matter	Around submerged and emergent vegetation, open water
Common Gallinule	Aquatic plant matter	Around submerged and emergent vegetation, open water
Least Bittern	Invertebrates, small fish	Along emergent vegetation and open water along marsh edge
King Rail	Crustaceans, insects, small vertebrates	Within emergent vegetation, marsh edges, mudflats
Pied-billed Grebe	Crustaceans, invertebrates, small fish	Underwater among submerged and emergent vegetation
Mottled Duck	Aquatic plant matter and invertebrates	Within emergent vegetation in open water
Black Rail	Invertebrates, plant matter	Within emergent vegetation, marsh edges
Black-necked Stilt	Invertebrates	Shallow, open water
Clapper Rail	Crustaceans, insects, small vertebrates	Within emergent vegetation, marsh edges, mudflats
Seaside Sparrow	Invertebrates	Within marsh grasses, shallow pools

3.2.2.5. Vegetation

Habitat suitability for marsh-nesting birds will change over time and vary depending on the location of the site and the marsh type (i.e., fresh/intermediate or brackish/saline marshes; see **Table 6, Vegetation**). In fresh-intermediate marshes, vegetation communities change over time (i.e., succession) influencing habitat suitability and subsequent occupancy of marsh-nesting birds as plants transition toward primarily dense, monospecific communities of non-herbaceous species (Rush et al., 2009). Restored fresh-intermediate marsh habitats tend to be most suitable 1–2 years post-project construction. These areas then tend to become less suitable over the following years (in the absence of disturbance) as vegetation increases in density and typically becomes dominated by a single plant species (**Figure 31**). Thus, regular vegetation management through disturbance (e.g., controlled burning) is recommended to extend both project life and associated resource benefits (Baker, 1983; Johnson & Lehman, 2021). For example, the occupancy of Clapper and King Rails within intermediate marshes was greater in sites that were burned to reduce vegetation density (Tallie & Moorman, 2019). Failure to manage vegetation can result in either uniform vegetation and/or establishment of dense woody vegetation that may deter many marsh-nesting bird species, such as Purple Gallinules, Common Gallinules, and Least Bitterns (Valente et al., 2011). Project teams are encouraged to manage marsh creation projects toward generating diverse vegetation at moderate to high density (30–80 percent).

3.2.3. Adapting Existing Design Process to Improve Nesting Habitat while Achieving State Coastal Master Plan Objectives and Principles

This section includes examples from the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) Wetland Value Assessment (WVA) models and CPRA Master Plan Habitat Suitability Indices (HSIs). Marsh-creation projects are an important component of the restoration project team's ability to achieve the Louisiana Coastal Master Plan's stated objectives and principles (e.g., maximize land area, reduce flood risks to coastal communities; CPRA, 2017a). Historically, project goals for this restoration type have been focused on maximizing the amount of wetland acreage at elevations that fall within the tidal range over the project lifespan. This was achieved through creation of continuous wetland areas with little water interspersion immediately after construction. These constructed marsh platforms are designed to settle to intertidal elevations within a few years of construction. This settlement usually occurs at varying rates across the project footprint, with some ponds and creeks emerging in the process. Post-construction operations and maintenance activities prioritize promoting hydrologic connectivity and establishment of marsh vegetation. Created and restored marshes initially have less-than-ideal ecological value for many of the state's wetland-dependent wildlife species. Emphasizing marsh-nesting birds and considering

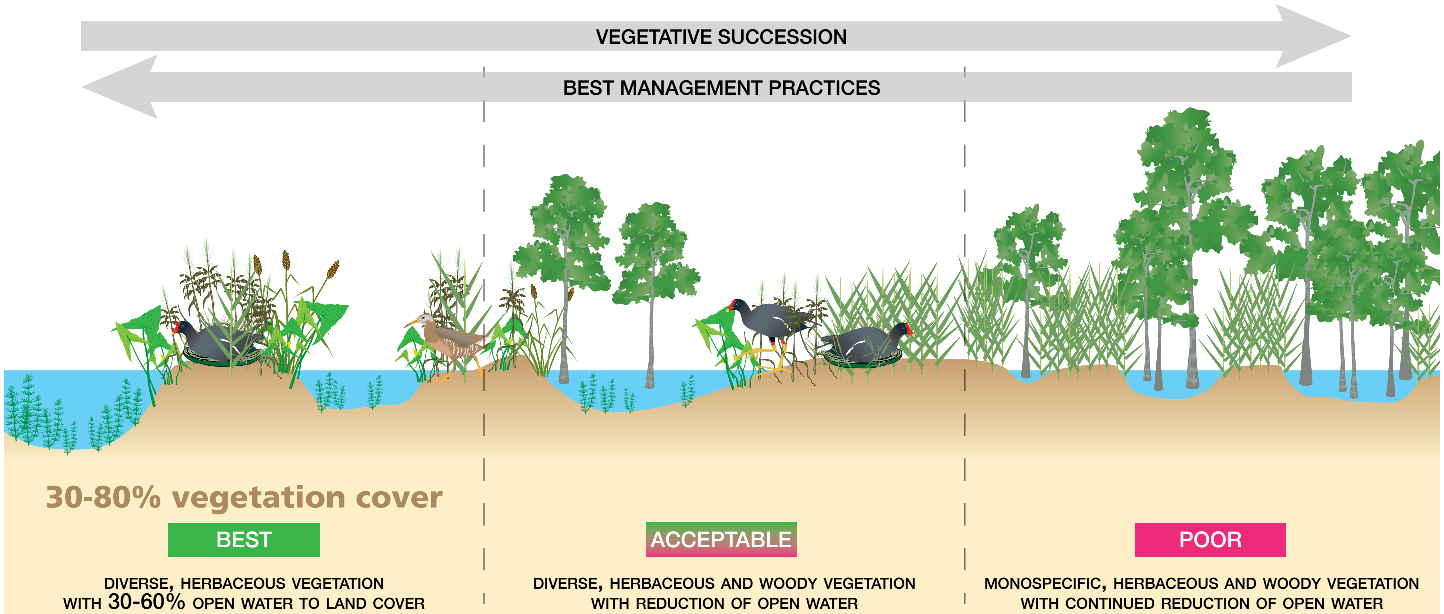

Figure 31. Marsh-nesting bird habitat suitability relating to vegetative succession in fresh-intermediate marshes

long-term marsh-nesting habitat needs during design, construction, and the operations/maintenance phases could lengthen the quality and duration of those benefits. SMEs (avian ecologists and project teams) were charged with evaluating existing marsh creation planning and design processes and identifying means (existing/novel) by which the latter could also be addressed (i.e., Louisiana-focused restoration teams' ability to design, construct, and maintain high ecological value marsh habitats that benefit wetland-reliant wildlife species while emphasizing marsh-nesting birds). Examples are provided below.

3.2.3.1. Land/Water Interspersion Classes

Avian SMEs found these established metrics to be excellent indicators of habitat quality for marsh-nesting birds (**Table 6**). Further, using these classes, avian SMEs found an effective means to convey critical marsh-nesting bird habitat characteristics (e.g., maintain an open water to land cover ratio of 30 to 60 percent over the project lifetime. See **Table 7, Land/Water Interspersion and Edge Features**).

3.2.3.2. Wetland Value Assessment Marsh Model

WVA models represent one of the most commonly utilized tools within Louisiana's project planning and permitting phases. These rubrics represent a community-oriented approach that attempts to quantify changes in fish and wildlife habitat quality and quantity (i.e., ecological score[4]) that are expected to result from a proposed wetland restoration project. However, prioritizing construction of WVA Class 1 marsh (see **Figure 30** and **Figure 33**) *may not* translate into high-value habitat for wetland-dependent wildlife species unless and until settlement and hydrologic connectivity increase over time.

3.2.3.3. Coastal Protection and Restoration Authority Master Plan Habitat Suitability Indices

Although not a direct driver of project selection within CPRA master planning, juvenile nekton HSIs provide an example of a common coastal planning tool that uses percent of wetland cover versus percent of open water within a restoration area (percent land) as an indicator of habitat value (Carruthers et al., 2021). A range of juvenile nekton HSIs are based upon the greatest habitat value being between 25 and 80 percent (**Figure 32**): Blue Crab (O'Connell et al., 2017a); Brown Shrimp (O'Connell et al., 2017b); White Shrimp (O'Connell et al., 2017c); Gulf Menhaden (O'Connell et al., 2017d); Spotted Seatrout (Sable et al., 2017a); and Bay Anchovy (Sable et al., 2017b). This is based upon moderate percent land being most suitable habitat in contrast to the WVA-identified preferred marsh land/water Category 1 (highest percentage land; **Figure 33**). With the land/water cover goal for nesting bird habitat, however, comes potential tradeoffs. Increasing total surface water acreage within a restoration project's footprint may require expanding said footprint to achieve the project's intertidal land

4 Note: Ecological scores can be highly influenced by project-specific habitat characteristics that can be controlled by project teams (Roy, 2006)

acreage creation goals. The avian SME team acknowledges the potential conflicts between preferred marsh-nesting avian habitat restoration objectives (i.e., increasing both habitat quantity and quality) and broader restoration goals within coastal Louisiana that attempt to maximize the project time and acreage spent within the tidal range. The team suggests that special consideration in the WVA system be given to shallow water areas within restoration footprints in order to capture their potential benefits for target wetland-dependent avian species.

In total, the avian SMEs' review of existing marsh creation processes prioritized maintaining select existing tools (i.e., Land/Water Interspersion Classes) and associated terminology, which continues to benefit effective cross-coordination amongst resource stakeholders. Additionally, the reviewers highlighted the need for incorporating more effective means (e.g., implementation of targeted habitat characteristics, **Section 3.2.2**) versus existing methods alone (i.e., WVA marsh model) to ensure benefits for wetland-reliant wildlife species are more fully realized within future marsh creation design and construction activities. Incorporation of this collective guidance and related items (e.g., identification and acceptance of specified project implementation language by the contractor, **Table 8: Lessons Learned**) represents a significant step forward toward the ability of restoration teams to more broadly accomplish stated objectives and principles outlined within Louisiana's Coastal Master Plan.

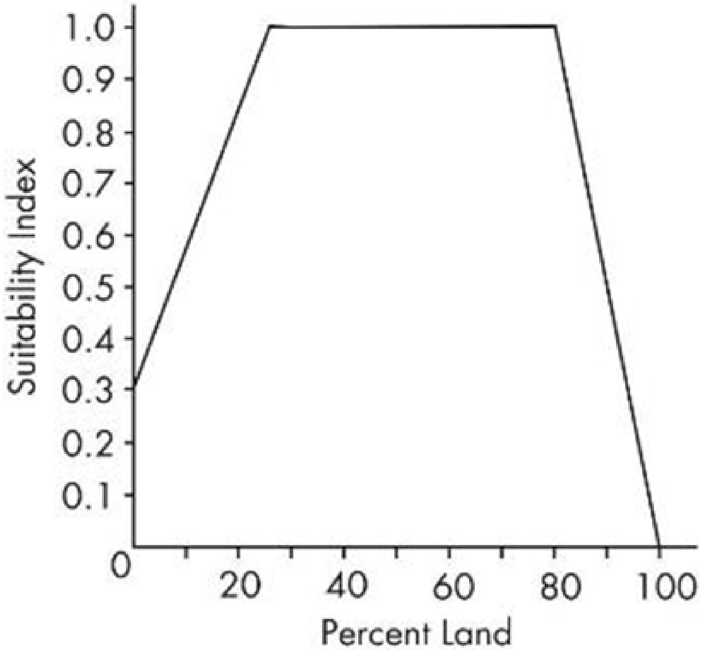

Figure 32. Example HSI relationship of percent land (versus open water within a given restoration area) to the Habitat Suitability Index for a range of juvenile nekton (O'Connell et al., 2017a).

Figure 33 shows examples of CWPPRA marsh/water interspersion classes and a qualitative relationship diagram with a common tool found in all marsh design efforts: geotechnical settlement curves predicting the marsh elevation change after construction. Marshes can be classified according to the amount of open water/vegetation interspersion. These classes are temporally variable and can be viewed as different degrees of marsh degradation (moving from WVA class 1-4) or natural progression in healthy marshes (moving from WVA class 4-1). Class type can be correlated with habitat quality for marsh-nesting birds, although flooding patterns and landscape context, among other factors, also impact these relationships. **Figure 33** provides a conceptual illustration showing that the peak avian habitat value of a marsh restoration project often may not occur until several years after construction is completed and interspersion features form naturally rather than being constructed directly. In addition, **Figure 33** shows that designers may allow for elevation heterogeneity while having the project's elevation remain in the tidal frame for the greatest possible period to maximize the potential for edge and land/water interspersion.

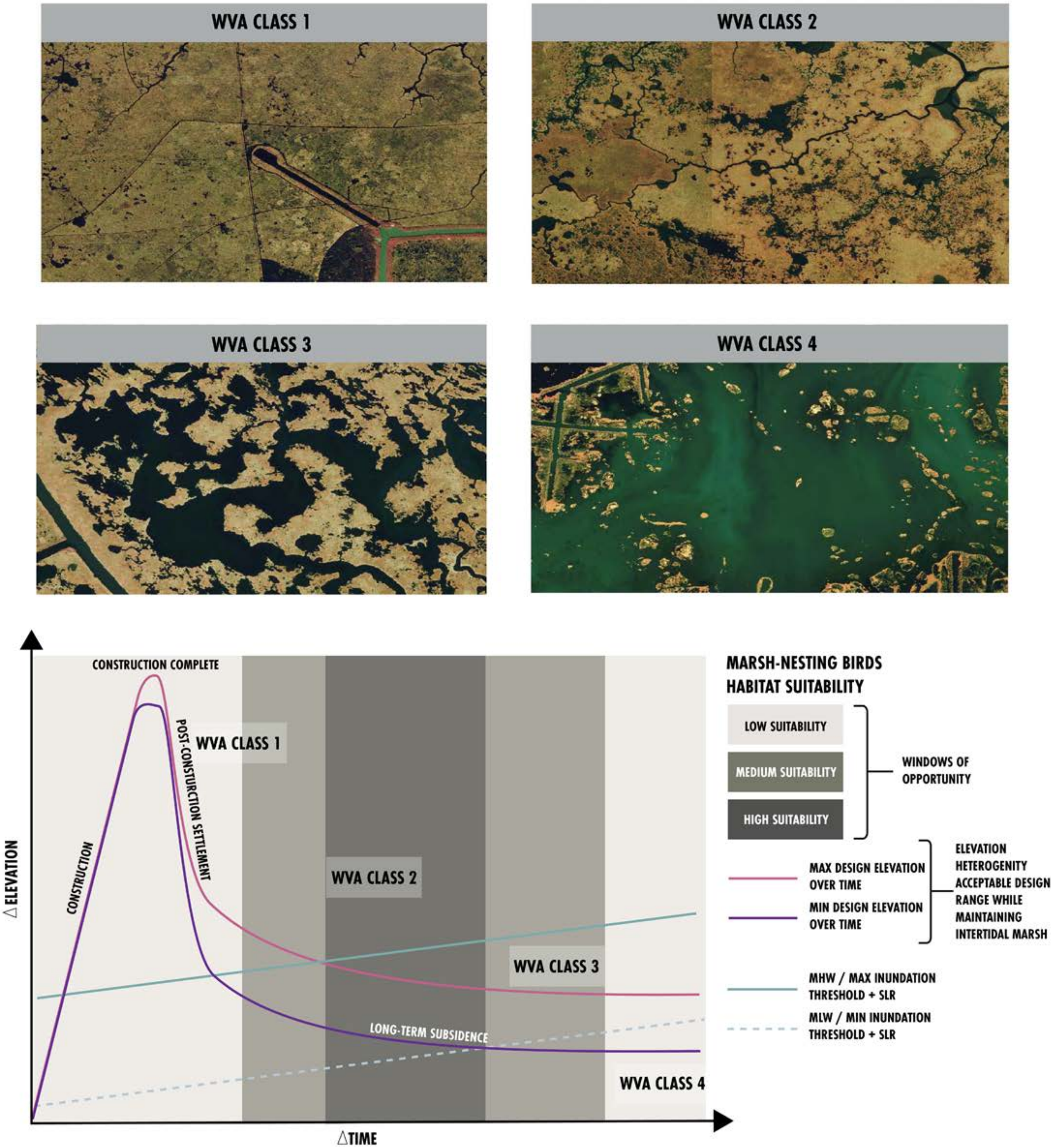

Figure 33. Changes in marsh-nesting bird habitat suitability across changes in elevation over time and associated land/water distributions based on WVA classes. Designers, rather than try to build all marsh in a project to either the pink or purple line (e.g., a homogeneous elevation target with some tolerance), may instead consider varying marsh elevation between the pink and purple lines for as long as possible because they are both within tidal range (and healthy marsh platform range). The heterogeneity within the upper and lower estimated settlement limit lines can be specified through careful design and specification of elevation guidelines engineers provide to contractors; however, this figure is theoretical. A project's estimated settlement curves may not allow for such a wide range of elevations that meet all stated goals.

3.2.4. Marsh-Nesting Bird Reference Photos

Figure 34. Purple Gallinule adult (photo credit: Robert Dobbs, LDWF).

Figure 35. Purple Gallinule chick (photo credit: Robert Dobbs, LDWF).

Figure 36. Common Gallinule chick (left) and adult (right) (photo credit: Robert Dobbs, LDWF).

Figure 37. Least Bittern adult (photo credit: Robert Dobbs, LDWF).

Figure 38. Least Bittern nest (photo credit: Joseph A Youtz, LSU).

Figure 39. Pied-billed Grebe (photo credit: Phillip Vasseur, LDWF).

Figure 40. Mottled Duck nest (photo credit: Phillip Vasseur, LDWF).

Figure 41. Black-necked Stilt adults (photo credit: Robert Dobbs, LDWF).

Figure 42. King Rail adult (photo credit: Robert Dobbs, LDWF).

Figure 43. Clapper Rail adult (photo credit: Eva Windhoffer, the Institute).


Figure 44. Black Rail adult (photo credit: Erik I Johnson, Audubon Delta).


Figure 45. Seaside Sparrow adult (photo credit: Phillip Stouffer, LSU AgCenter).

Figure 46. Seaside Sparrow nest (photo credit: Phillip Vasseur, LDWF).

3.3 GROUND-NESTING BIRDS

Ground-nesting birds are target coastal bird species that primarily nest either directly on bare ground or create nests on the ground with vegetation and other organic materials (**Figure 47**; see also **Section 2.1, Introduction**, for a concise definition). Within this group, sediment type, vegetation cover, proximity to and availability of foraging habitat, and predation-risk are all factors with the potential to influence nest site selection and nest success.

Figure 47. Nests of ground-nesting birds on Raccoon Island, Louisiana: A) bare ground nest of a Black Skimmer and B) a vegetation-built nest of a Gull-billed Tern (photo credit: Eva Windhoffer, the Institute).

Seasonal occurrences of target ground-nesting birds in coastal Louisiana are provided in **Table 20**. The documented breeding windows listed encompass approximate period of courtship through colony/territory establishment until chicks have fledged (i.e., are flight capable). This information is provided to project teams specifically for informing construction timelines (i.e., limit potential disturbance of ground-nesting bird-nesting activities).

Table 20. Ground-nesting birds (for reference photos of these species, their nests, and young, refer to page 90).

Common Name	Scientific Name	Breeding Window in LA	Residency in Coastal LA	Reference Photos
Black Skimmer	*Rynchops niger*	May–September	Year-round	**Figure 52**, **Figure 53**
Gull-billed Tern	*Gelochelidon nilotica*	May–August	Year-round	**Figure 54**, **Figure 55**
Royal Tern	*Thalasseus maximus*	April–August	Year-round	**Figure 58**, **Figure 59**
Sandwich Tern	*Thalasseus sandvicensis*	April–August	Breeding	**Figure 56**, **Figure 57**
Caspian Tern	*Hydroprogne caspia*	May–August	Year-round	**Figure 60**
Wilson's Plover	*Charadrius wilsonia*	April–July	Breeding	**Figure 61**, **Figure 62**
Common Nighthawk	*Chordeiles minor*	April–August	Breeding	**Figure 63**, **Figure 64**
Forster's Tern	*Sterna forsteri*	March–July	Year-round	**Figure 65**
Laughing Gull	*Leucophaeus atricilla*	May–July	Year-round	**Figure 66**, **Figure 67**
Least Tern	*Sternula antillarum*	April–August	Breeding	**Figure 68**, **Figure 69**
American Oystercatcher	*Haematopus palliates*	April–August*	Year-round	**Figure 70**, **Figure 71**
Snowy Plover	*Charadrius nivosus*	April–August*	Year-round	**Figure 72**, **Figure 73**

*Some breeding windows in Louisiana have not yet been determined or are uncertain.

The majority of the target ground-nesting birds are small- to medium-sized birds (approx. 1.4 oz–17.6 oz) that generally breed and forage near bodies of water (Colwell, 2010; P. G. Ericson et al., 2003). Most ground-nesting birds are in the order Charadriiformes. However, the Common Nighthawk is in the order Caprimulgiformes and has several characteristics that distinguish it from the other species considered in this group. For example, the Common Nighthawk is primarily nocturnal, meaning it is less active during the day. It is also an obligate aerial insectivore (i.e., feeds exclusively on flying insects) and therefore, unlike the other ground-nesting birds, this species is not dependent on habitats associated with water (Brigham et al., 2020). The Common Nighthawk is included within this group because it frequently nests on barrier islands/headlands in habitats similar to those used by nesting Wilson's Plover (Bergstrom, 1982; Leumas, 2010). Laughing Gull and Forster's Tern are also included within the ground-nesting birds. These two species exhibit similar behaviors, diet, and distribution to the rest of the ground-nesting birds, but tend to nest in dense vegetation within marshes and dunes (Montevecchi, 1978; Spendelow & Patton, 1988). Laughing Gulls and Forster's Terns are distinct from birds within the marsh-nesting bird guild, but do exclusively nest in vegetated marsh habitats (see **Section 3.2** for more information about marsh-nesting birds).

3.3.1. Nesting Ecology

Louisiana provides nesting habitat for anywhere between 10 and 70 percent of the global breeding populations of Sandwich, Royal, and Forster's Tern, Black Skimmer, and Wilson's Plover (Remsen et al., 2019). These ground-nesting birds nest during spring and summer, mainly from April through July, with re-nesting birds often continuing into August. Note there is substantial variation in timing of nesting among species, as well as year-to-year variation (Portnoy, 1977; **Table 20**); in some years, re-nesting efforts may even continue into early September. Most ground-nesting birds are generally restricted to the coastal habitats and landforms depicted in **Figure 48** (for definitions of these marsh habitats, refer to **Section 2.1, Introduction**). Ground-nesting birds are known to utilize many landforms for nesting including coastal wetlands, coastal bay islands, and barrier islands/headlands (Brush et al., 2019). As shown in **Figure 48** (see also **Table 21**), some species only nest in a small number of habitats on barrier island/headlands while others are observed across a wide range of landforms and habitats (Visser & Peterson, 1994). For example, American Oystercatchers will occasionally nest in marsh vegetation; however, they will also nest on bare ground (Lauro & Burger, 1989). It should be noted here that intertidal areas of barrier islands/headlands are not typically used for nesting by species in this group; however, availability of intertidal areas is important for both foraging and loafing for these ground-nesting birds.

Table 21. Landforms and habitats utilized by ground-nesting birds for nesting, foraging, and loafing.

Landform	Habitat	Species that Nest in this Landform	Species that Forage in this Landform	Species that Loaf in this Landform
Barrier Island/ Headlands	Intertidal (vegetation cover <30%)	None	American Oystercatcher, Wilson's Plover, Snowy Plover	All
	Beach (vegetation cover <30%)	Sandwich Tern, Royal Tern, Gull-billed Tern, Least Tern, Caspian Tern, Black Skimmer, Wilson's Plover, Snowy Plover, Common Nighthawk	Wilson's Plover, Snowy Plover, Common Nighthawk	All
	Dune (vegetation cover >10%)	Sandwich Tern, Royal Tern, Gull-billed Tern, Caspian Tern, Least Tern, Black Skimmer, Wilson's Plover, Common Nighthawk	None	All

Landform	Habitat	Species that Nest in this Landform	Species that Forage in this Landform	Species that Loaf in this Landform
	Meadow (vegetation cover >30%)	American Oystercatcher, Laughing Gull, Forster's Tern	None	American Oystercatcher, Laughing Gull, Forster's Tern
	Saline Marsh	American Oystercatcher, Laughing Gull, Forster's Tern	American Oystercatcher	American Oystercatcher, Laughing Gull, Forster's Tern
Overwash Fan (within Barrier Islands/ Headlands)	Unvegetated Flat (vegetation cover <30%)	Gull-billed Tern, Black Skimmer, Least Tern, Wilson's Plover, Snowy Plover, Common Nighthawk, American Oystercatcher	American Oystercatcher, Wilson's Plover, Snowy Plover	Gull-billed Tern, Black Skimmer, Least Tern, Wilson's Plover, Snowy Plover, Common Nighthawk
	Meadow (vegetation cover >30%)	American Oystercatcher, Laughing Gull, Forster's Tern	None	American Oystercatcher, Wilson's Plover, Snowy Plover
	Intertidal (vegetation cover <30%)	None	American Oystercatcher, Wilson's Plover, Snowy Plover	All
Coastal Bay Islands	Scrub/Shrub (vegetation cover >30%)	None	None	None
	Brackish-Saline Marsh	American Oystercatcher, Laughing Gull, Forster's Tern	American Oystercatcher (intertidal areas)	American Oystercatcher, Laughing Gull, Forster's Tern
Coastal Wetlands	Brackish-Saline Marsh	American Oystercatcher, Laughing Gull, Forster's Tern	American Oystercatcher (intertidal areas)	American Oystercatcher, Laughing Gull, Forster's Tern
	Fresh-Intermediate Marsh	None	American Oystercatcher (intertidal areas)	American Oystercatcher, Laughing Gull, Forster's Tern
	Scrub/Shrub (vegetation cover >30%)	None	None	None
	Forest (woody vegetation >6 m; vegetation cover >30%)	None	None	None

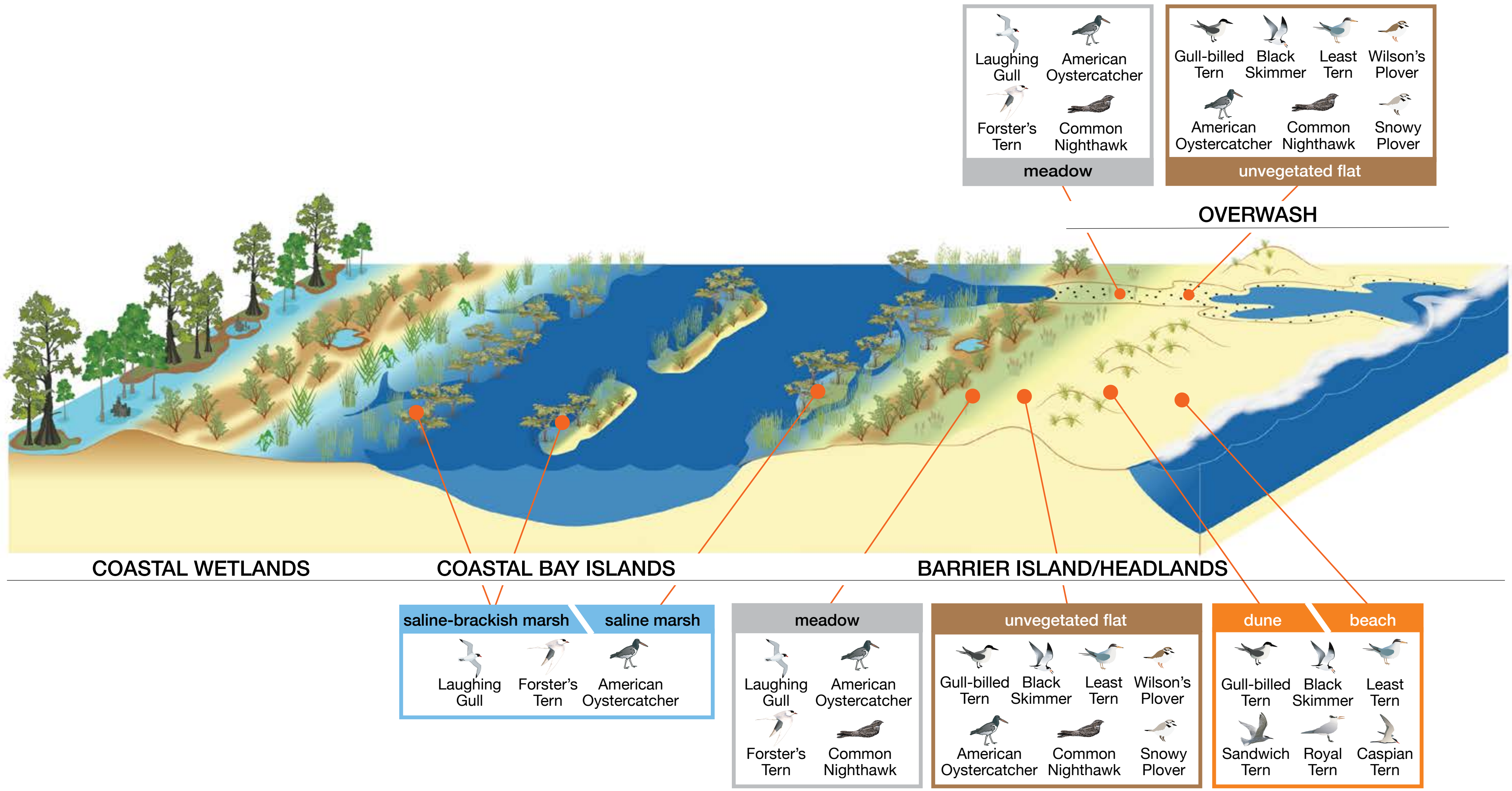

Figure 48. Conceptual depiction of landforms and habitats used for nesting and foraging by ground-nesting birds along a wetland or island beach profile.

As shown in **Figure 49**, some ground-nesting birds such as Royal Terns and Sandwich Terns nest in mixed-species colonies of up to 8,000 nesting pairs (Windhoffer, 2017). Forester's Terns, however, have been observed with solitary nests, as well as within larger conspecific nesting colonies (semi-colonial). Other species, including American Oystercatchers and Wilson's Plovers, are considered solitary nesting species that establish closely defended territories (Bergstrom, 1982; Clay et al., 2014). For a complete list of solitary, colonial, and semi-colonial ground-nesting birds, refer to **Table 22**.

Figure 49. Example of colonial ground-nesting birds: a Sandwich Tern (black bills; at front of photo) and Royal Tern (red bills; interspersed farther back) colony on Raccoon Island, Louisiana (photo credit: Eva Windhoffer, the Institute).

Table 22. Ground-nesting birds that are solitary nesters (nesting in seclusion from other birds), colonial nesters (nesting in groups), or semi-colonial nesters (nesting either in seclusion or in groups).

Solitary Ground-Nesting Birds	Colonial Ground-Nesting Birds	Semi-Colonial Ground-Nesting Birds
Wilson's Plover, Common Nighthawk, American Oystercatcher, Snowy Plover	Black Skimmer, Gull-billed Tern, Royal Tern, Sandwich Tern, Caspian Tern, Laughing Gull, Least Tern	Forster's Tern

3.3.2. Habitat Characteristics and Considerations

Examples of habitat characteristics that influence suitability for ground-nesting birds include protection from predators, proximity to and availability of foraging areas, vegetation spatial coverage and accessibility, and sediment structure (Brush et al., 2019; Iglecia & Winn, 2021). Some of these characteristics can be controlled or accounted for during project site selection (location) and others may be controlled or accounted for during project engineering, design, and implementation. Habitat characteristics from **Table 10** and their applications during project design and construction are discussed in the following sections. Louisiana-specific information along with SME best professional judgment was prioritized within this guidance. Related resources that encompass this bird group within the greater Gulf of Mexico region and/or broader geographic range may also have been utilized, where appropriate. Further, identification of data gaps as well as prioritization of information needs were also included (**Table 13**). Collectively, information presented is considered state of the science for Louisiana ground-nesting birds within coastal Louisiana at the time of publication.

3.3.2.1. Proximity to Human Activity, Mammalian Predators, and Island Size

Once colonies and nests have been established, primary threats to the nesting success of ground-nesting birds are human disturbance and depredation by mammalian predators (see **Table 10, Proximity to Human Activity and Mammalian Predators**). Mammalian predators, including raccoons, feral hogs, red foxes, coyotes, nutria, and feral cats, can independently or collectively lead to site abandonment and sometimes nesting failure (Brush et al., 2019; Iglecia & Winn, 2021; Owen & Pierce, 2013; Windhoffer & Pierce, 2021). Terrestrial or urban/suburban environments tend to harbor a greater diversity and density of mammalian predators that may readily access nesting area (Dueser et al., 2013). Therefore, it is suggested that established best management practices should be utilized, where appropriate, to limit the potential impacts of both human disturbance and mammalian predators on ground-nesting bird reproductive success and survival.

Mammalian predation is more likely to occur on larger islands, islands that have extensive dense, woody herbaceous cover, and islands that provide connectivity to the mainland (i.e., source population of mammalian predators). There is also less opportunity for mammalian populations to establish on islands <50 ac (see **Table 10, Island Size**), particularly if these islands are isolated (>2 mi) from the mainland (Golder et al., 2008; Landin & Engler, 1986). For island restoration projects >50 ac, mammalian predators are more likely to be present, and predator management techniques such as eradication or electric fencing may be necessary to increase nest success of the target species (E. I. Johnson et al., 2019; Windhoffer & Pierce, 2021). In addition, if the project area is publicly accessible by foot, boat, or vehicle, additional conservation efforts (e.g., public outreach, signage, post-n-rope, law enforcement) that eliminate, minimize, or mitigate human disturbance may also contribute to increased nest success (E. I. Johnson et al., 2019; Kwon et al., 2021; Sanders et al., 2008).

3.3.2.2. Proximity to Water

Proximity to water (e.g., tide lines, ephemeral pools; see **Table 10, Proximity to Water**) influences likelihood of nest success because target ground-nesting birds (with the exception of Common Nighthawk) forage in or around water. Access to foraging habitat can have demonstrable benefits to ground-nesting bird reproduction (McIntyre & Heath, 2011). For example, increased brood survival of American Oystercatchers has been documented in areas with direct access to foraging sites that include tidal creeks and mudflats (Schulte & Simons, 2015). Species-specific prey preferences, foraging behavior, and foraging locations for target ground-nesting birds are shown in **Table 23**. In general, nest sites within 100–300 ft of high tide lines or ephemeral pools and tidal flats provide sufficient access for foraging without compromising nests due to flooding or overwash events (Himes et al., 2006; Raynor et al., 2012; Windhoffer et al., 2017).

Table 23. Ground-nesting bird diets, foraging methods, and foraging locations.

Species	Primary Diet	Foraging Method	Foraging Location
Wilson's Plover, Snowy Plover	Insects, crustaceans, marine invertebrates	Probing	Intertidal zone, overwash fans, mudflats
American Oystercatcher	Mollusks, crustaceans	Probing	Intertidal zone, overwash fans, mudflats
Royal Tern, Sandwich Tern, Caspian Tern, Least Tern, Forster's Tern, Laughing Gull, Black Skimmer, Gull billed Tern	Fish, crustaceans	Diving or skimming	Coastal marine waters, marsh channels
Common Nighthawk	Insects	Flying	In the air

3.3.2.3. Ground Elevation and Slope

Another important consideration for suitable nesting habitat is provision for sufficient elevation and gradual slope; two habitat characteristics that are prioritized in the creation and/or enhancement of preferential nesting habitats for ground-nesting birds.

Ground elevation plays a critical role in determining potential risk of nest inundation during high tides (see **Table 10, Ground Elevation & Slope**). An indicative value for avoiding nest inundation for restored barrier islands/headlands is an elevation of 3–10 ft (Soots & Landin, 1978). Of note, certain species, including Wilson's Plover, have even been observed nesting on overwash fans among which they will nest on raised platforms, thus further limiting nest inundation during overwash events (Zinsser et al., 2017).

In tandem with ground elevation, gradual sloping benefits the ability of ground-nesting birds to reduce nest inundation as well as yield additional benefits such as accessibility and loafing as well as contributing to vegetative heterogeneity. A gradual slope of >98:3 ft will provide suitable nesting habitat for ground-nesting birds (Golder et al., 2008). Often, the fine-grained sediments along the Louisiana coast have an even lesser angle of repose that can be upward of 270:3 ft along barrier island/headland shorelines. Of note, steep slopes may result in unstable substrate or surfaces for nests and vegetation development.

3.3.2.4. Access to Vegetation and Vegetation Cover

Vegetation characteristics, including accessibility from nest sites and percent vegetative cover, influence the nesting suitability for ground-nesting birds (see **Table 10, Access to Vegetation and Vegetation Cover**). Chicks of ground-nesting birds are semi- to fully precocial, meaning they can leave the nest either immediately after hatching or within 3–4 days. However, chicks still require parental investment (i.e., protection from weather and predators) and are not fully independent from adults for >3 weeks (Burger, 1980; Quinn, 1990; Quintana & Yorio, 1997). Until chicks are able to leave the nest and fly (i.e., fledged), they are extremely vulnerable to predators. As such, chicks (prior to fledging) often utilize patches of vegetation in relative proximity to the nest site for refuge and loafing and resting in shade (Bergstrom, 1988). Further, vegetation within 33 ft of nest sites has the potential to reduce erosion during high water or overwash events, which stabilizes the surrounding substrate and reduces potential nest and chick loss (Raynor et al., 2012).

Although some species rely on access to vegetation for concealing vulnerable hatchlings, some ground-nesting birds such as the Gull-billed Tern will not nest in an area that has dense vegetation (>75 percent vegetation cover; Windhoffer et al., 2017). Vegetation cover for suitable nesting sites varies greatly among species in this group (from bare sand to >75 percent vegetation cover; **Table 24**). Some species, including Gull-billed Tern, Black Skimmer, and Royal Tern, will nest in dune or beach habitats on bare ground or areas with sparse vegetation coverage (<25 percent cover). Other species including Common Nighthawk and American Oystercatcher will nest in flats with low to moderate vegetative cover (25 to 75 percent cover), whereas species including Forster's Tern and Laughing Gull will nest in wet meadows and brackish saline marsh habitats with high vegetative cover (>75 percent).

Table 24. Ground-nesting bird vegetation cover classifications, adapted from Soots & Parnell (1975).

Description	Percent Cover
Bare	0%
Sparse	<25%
Medium	25 – 75%
Dense	>75%

Vegetation cover and local topography can also influence nest density. For example, dune and meadow habitats with variable topography and vegetation cover support more Wilson's Plover nests compared to habitats with uniformly distributed patches of vegetation and open spaces (Zdravkovic, 2013). Heterogeneous topography and non-uniform vegetation distribution provide higher quality nesting habitat because they allow for more isolated (as opposed to overlapping) territories. Both habitat characteristics (heterogeneous topography and non-uniform vegetation distribution), specifically those that are accompanied by occasional overwash events, will help support target ground-nesting birds including Wilson's Plover, Common Nighthawk, Snowy Plover, and American Oystercatcher.

3.3.2.5. Sediment Structure

Ground-nesting birds have been observed to nest on a variety of sediment types (see **Table 10, Sediment Structure**). Sediment classifications referenced are a subset of the Wentworth (1922) scale for gravel and sand grain sizes, as shown below in **Table 25**.

Table 25. Grain size classification, by Wentworth (1922); note this is a subset of those classes most relevant to ground-nesting birds.

Millimeters	Size Class	
64–256	Cobble	Gravel
4–64	Pebble	
2–4	Granule	
1–2	Very Coarse Sand	Sand
0.50–1	Coarse	
0.25–0.50	Medium	
0.125–0.25	Fine	

Most of the ground-nesting birds, including Royal and Sandwich Tern, will nest in medium (0.25–0.50 mm) or very coarse (1–2 mm) sand or shell as well as larger-sized gravel (e.g., crushed No. 8 or No. 57 limestone). It should be noted that, although the full Wentworth scale is discussed, in coastal Louisiana, local sand sources from both offshore and the Mississippi River are predominantly fine sand with some medium-fine sand. However, fine-sand sediments (0.125–0.25 mm) and smaller particles (e.g. clay) may not be suitable for ground-nesting birds because eggs can stick to the ground during rain events (B. C. Thompson & Slack, 1982).

3.3.2.6. Substrate and Nesting Materials

In addition to sediment type and size, some ground-nesting birds use additional materials for nest building (see **Table 10, Substrate and Nesting Materials**). For example, Forster's Tern and Laughing Gull use vegetation and other natural materials (such as beach wrack or shoreline organic debris transported out of the intertidal zone) to construct their nests. Conversely, American Oystercatchers frequently nest on shell mounds (**Figure 50**; Sanders et al., 2008). In Louisiana, American Oystercatcher nests on shell mounds are often adjacent to marsh habitat, as shown in **Figure 51**.

Figure 50. American Oystercatcher nest on a shell mound in Chandeleur Sound (photo credit: Robert Dobbs, LDWF).

Figure 51. Example of American Oystercatcher shell mound nesting habitat in Chandeleur Sound (photo credit: Robert Dobbs, LDWF).

3.3.3. Ground-Nesting Bird Reference Photos

Figure 52. Black Skimmer adult (photo credit: Robert Dobbs, LDWF).

Figure 53. Black Skimmer chick and eggs (photo credit: Eva Windhoffer, the Institute).

Figure 54. Gull-billed Tern adult (photo credit: Robert Dobbs, LDWF).

Figure 55. Gull-billed Tern chick (photo credit: Eva Windhoffer, the Institute).

Figure 56. Royal Tern adults in colony (photo credit: Eva Windhoffer, the Institute).

Figure 57. Royal Tern chick (photo credit: Eva Windhoffer, the Institute).

Figure 58. Sandwich Tern adult on nest (photo credit: Eva Windhoffer, the Institute).

Figure 59. Sandwich Tern chick (photo credit: Eva Windhoffer, the Institute).

Figure 60. Caspian Tern adult (photo credit: Robert Dobbs, LDWF)

Figure 61. Wilson's Plover adult (photo credit: Delaina LeBlanc, BTNEP).

Figure 62. Wilson's Plover nest and chick (photo credit: Delaina LeBlanc, BTNEP).

Figure 63. Common Nighthawk adult (photo credit: Robert Dobbs, LDWF).

Figure 64. Common Nighthawk chick (photo credit: Delaina LeBlanc, BTNEP).

Figure 65. Forster's Tern adult (photo credit: Eva Windhoffer, the Institute).

Figure 66. Laughing Gull adults mating (photo credit: Delaina LeBlanc, BTNEP).

Figure 67. Laughing Gull chick and eggs in nest (photo credit: Eva Windhoffer, the Institute).


Figure 68. Least Tern adult on nest (photo credit: Delaina LeBlanc, BTNEP).


Figure 69. Least Tern chick and egg (photo credit: Delaina LeBlanc, BTNEP).

Figure 70. American Oystercatcher adult (photo credit: Delaina LeBlanc, BTNEP).

Figure 71. American Oystercatcher chick (photo credit: Eva Windhoffer, the Institute).

Figure 72. Snowy Plover adult (photo credit: Delaina LeBlanc, BTNEP).

Figure 73. Snowy Plover chick (photo credit: Eva Windhoffer, the Institute).

4 SUPPORTING INFORMATION: BIRD MONITORING FOR ECOSYSTEM RESTORATION

4.1 QUICK REFERENCE FOR STANDARD OPERATING PROCEDURES

Standard Operating Procedures for High-Level Ongoing Bird Monitoring

- Monitoring Activities for Ground-Nesting and Shrub-Nesting Birds: Aerial Surveys
- Description of Aerial Surveys and Bird Quantification
- Description of Call-Back Survey Approach for Marsh-Nesting Birds
- Standard Operating Procedures for Aerial Surveys for Ground-Nesting and Shrub-Nesting Bird Monitoring
- Standard Operating Procedures for Bird Quantification of Ground-Nesting and Shrub-Nesting Aerial Photographs
- Standard Operating Procedures for Call-Back Surveys for Marsh-Nesting Birds

Standard Operating Procedures for Targeted Research and Monitoring

- Standard Operating Procedures for Presence/Absence or # of Nesting Pairs
- Standard Operating Procedures for Reproductive Success
- Standard Operating Procedures for Survival (adults, juveniles, and/or chicks)

4.2 BIRD MONITORING FOR ECOSYSTEM RESTORATION AT PROGRAMMATIC AND PROJECT SCALES

4.2.1. Frameworks and Approaches Included Within this Guidance

This monitoring guidance is for the explicit purpose of assessing value of ecosystem restoration projects in providing habitat for nesting birds in coastal Louisiana with potential applications throughout the broader northern Gulf of Mexico. Monitoring approaches and metrics presented in this guidance build upon the extensive and comprehensive management publications on monitoring coastal birds along the northern Gulf of Mexico. These include the:

Programmatic Damage and Assessment Restoration Plan (PDARP; DWH NRDA Trustees, 2016),

NRDA Strategic Framework for Bird Restoration Activities (DWH NRDA Trustees, 2017a),

Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico (National Academies of Sciences, Engineering, and Medicine et al., 2017), Chapters of the GoMAMN Strategic Bird Monitoring Guidelines,

Seabirds (Jodice et al., 2019),

Shorebirds (Brush et al., 2019),

Marsh birds (Woodrey et al., 2019),

Waterfowl (DeMaso et al., 2019), and

Wading Birds (Frederick & Green, 2019).

The information, approaches, and metrics provided in this guidance are consistent with the following reports and documents:

- NRDA Monitoring and Adaptive Management Procedures and Guidelines Manual Version 2.0 (DWH NRDA Trustees, 2021),
- LA TIG Monitoring and Adaptive Management Strategy (LA TIG, 2021),
- The Open Ocean Trustee Implementation Group Monitoring and Adaptive Management Strategy (Deepwater Horizon Open Ocean Trustee Implementation Group, 2020), and
- The Louisiana Adaptive Management Status and Improvement Report: Vision and Recommendations (DWH NRDA Trustees, 2017b; LA TIG, 2021; The Water Institute of the Gulf, 2020).

At the time of publication of this report, the remaining TIGs had not finalized MAM Strategies. It is expected that these additional TIG MAM Strategies will also be highly consistent with the above documents. However, it may be necessary in future revisions of this guidance to incorporate additional new information or relevant guidance based upon the MAM Strategies of the remaining DWH NRDA TIGs.

The approaches and metrics for both programmatic and project-specific bird monitoring presented in this guidance are largely based upon the PDARP (DWH NRDA Trustees, 2016), NRDA Strategic Framework for Bird Restoration Activities (DWH NRDA Trustees, 2017a), and the DWH MAM manual (DWH NRDA Trustees, 2017b). However, additional detail was included, where needed, to link to specific Standard Operating Procedures (SOPs) for monitoring target species of shrub-nesting, marsh-nesting, and ground-nesting birds. To achieve this, the shrub-nesting, marsh-nesting, and ground-nesting categories were cross-walked to bird groupings within the Strategic Framework for Bird Restoration Activities and the GoMAMN Strategic Bird Monitoring Guidelines for the Northern Gulf of Mexico (Wilson, 2019; see **Table 26**). The target bird species in this guidance are included in three of the NRDA Strategic Framework bird groups: Colonial Water Birds, Solitary Beach Nesting Birds, and Marsh Birds (**Table 26**). This guidance focuses on monitoring approaches or metrics specifically relevant to the selected target species of shrub-nesting, marsh-nesting, and ground-nesting birds. Other bird groups and monitoring approaches were not considered further in this guidance (**Table 27**).

There is no single bird survey methodology (and/or protocol) that is recommended for all species at all spatial and temporal scales. The protocols and associated metrics found within this section are meant to be used as examples for monitoring and are extensive (and general), but not exhaustive. Where appropriate, caveats are made for certain species that may require unique considerations.

This guidance is focused specifically on ecosystem restoration approaches; as such, the relevant restoration approach within the Strategic Framework for Bird Restoration Activities was to Restore and Conserve Bird Nesting and Foraging Habitat. It was assumed that monitoring for restoration projects under the approach Establish or Re-establish Bird Breeding Colonies would be covered without the need for specific additional information. There are several approaches and relevant metrics for monitoring ecosystem restoration to Restore and Conserve Bird Nesting and Foraging Habitat for Colonial Water Birds, Solitary Beach Nesting Birds, and Marsh Birds that are not directly related to the abundance or number of nests of identified target species (**Table 27**). Finally, metrics specifically related to overall DWH NRDA and Restoration governance or accounting, for example, habitat area (i.e., acres) or number of projects implemented, were assumed to be reported through other NRDA programmatic mechanisms and are outside the scope of this effort and therefore were not considered further here (**Table 28**).

Table 26. Cross-walk of bird species and nesting groups (Columns 1 and 2) for the Restore and Conserve bird-nesting and foraging habitat restoration approach used in this guidance, as detailed in Strategic Framework for Bird Restoration Activities (Column 3, titled "NRDA"; DWH NRDA Trustees, 2017a) and the GoMAMN Strategic Monitoring Plans (Column 4; Brush et al., 2019; DeMaso et al., 2019; Frederick & Green, 2019; Jodice et al., 2019; Woodrey et al., 2019).

Common Name	Nesting Group	NRDA	GoMAMN
Brown Pelican	Shrub-nesting Bird	Colonial Water Bird	Seabird
Reddish Egret	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Great Blue Heron	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Green Heron	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Cattle Egret	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Roseate Spoonbill	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Tricolored Heron	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Little Blue Heron	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Great Egret	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Snowy Egret	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Black-crowned Night Heron	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Yellow-crowned Night Heron	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Neotropic Cormorant	Shrub-nesting Bird	Colonial Water Bird	Seabird
White Ibis	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
White-faced Ibis	Shrub-nesting Bird	N/A	Wading Bird
Glossy Ibis	Shrub-nesting Bird	Colonial Water Bird	Wading Bird
Purple Gallinule	Marsh-nesting Bird	Marsh Bird	Marsh bird
Common Gallinule	Marsh-nesting Bird	Marsh Bird	Marsh bird
Least Bittern	Marsh-nesting Bird	Marsh Bird	Marsh bird
King Rail	Marsh-nesting Bird	N/A	Marsh bird
Pied-billed Grebe	Marsh-nesting Bird	Marsh Bird	Marsh bird
Mottled Duck	Marsh-nesting Bird	Marsh Bird	Waterfowl
Black Rail	Marsh-nesting Bird	N/A	Marsh bird
Black-necked Stilt	Marsh-nesting Bird	Marsh Bird	Marsh bird
Clapper Rail	Marsh-nesting Bird	Marsh Bird	Marsh bird
Seaside Sparrow	Marsh-nesting Bird	Marsh Bird	Marsh bird
Black Skimmer	Ground-nesting Bird	Colonial Water Bird	Seabird
Gull-billed Tern	Ground-nesting Bird	Colonial Water Bird	Seabird
Royal Tern	Ground-nesting Bird	Colonial Water Bird	Seabird
Sandwich Tern	Ground-nesting Bird	Colonial Water Bird	Seabird
Caspian Tern	Ground-nesting Bird	Colonial Water Bird	Seabird
Wilson's Plover	Ground-nesting Bird	Solitary Beach Nesting Bird	Shorebird
Common Nighthawk	Ground-nesting Bird	N/A	Land bird
Forster's Tern	Ground-nesting Bird	Colonial Water Bird	Seabird
Laughing Gull	Ground-nesting Bird	Colonial Water Bird	Seabird
Least Tern	Ground-nesting Bird	Colonial Water Bird	Seabird
American Oystercatcher	Ground-nesting Bird	Solitary Beach Nesting Bird	Shorebird
Snowy Plover	Ground-nesting Bird	Solitary Beach Nesting Bird	Shorebird

Table 27. Summary of metrics considered within this guidance.

Approach	NRDA Strategic Framework	Metrics
Restore and conserve bird-nesting and foraging habitat	Colonial Waterbirds	Presence/absence or abundance of focal species
		Presence/absence or # of nesting pairs
		Reproductive success (e.g., # of nests, fledglings, etc.)
		Survival (adults, juveniles, and/or chicks)
		Density, abundance, and/or availability of prey species
Restore and conserve bird-nesting and foraging habitat	Solitary Beach Nesting Birds	Presence/absence or abundance of focal species
		Presence/absence or # of nesting pairs
		Reproductive success (e.g., # of nests, fledglings, etc.)
		Survival (adults, juveniles, and/or chicks)
Restore and conserve bird-nesting and foraging habitat	Marsh Birds	Presence/absence or abundance of focal species
		Presence/absence or # of nesting pairs
		Reproductive success (e.g., # of nests, fledglings, etc.)
		Survival (adults, juveniles, and/or chicks)

Table 28. Summary of metrics not considered within this guidance because the species either do not occur in coastal Louisiana or the metrics are not the primary focus of bird-related coastal ecosystem restoration outcomes (i.e., out of scope).

Approach	NRDA Strategic Framework	Metrics Not Considered
Restore and conserve bird-nesting and foraging habitat	Colonial waterbirds	# of nests protected
		# of sites with targeted predation management[1]
		# of acres of habitat created, restored, managed, and/or under increased stewardship [1]
		# of education/ outreach materials distributed[1]
Establish or re establish breeding colonies[1]	Colonial waterbirds	Survival (adults, juveniles, and/or chicks)[2]
		# of established/re-established colonies[2]
Prevent incidental bird mortality	Colonial waterbirds	not considered in this guidance
Restore and conserve bird-nesting and foraging habitat	Solitary beach nesting birds	# of nests protected/# of sites with targeted predation management[1]
		# of acres of habitat created, restored, managed, and/or under increased stewardship[1]
		Nest location/habitat preference(s) of nesting pairs[1]
		# of education/outreach materials distributed or people reached[1]
Prevent incidental bird mortality	Solitary beach nesting birds	Not considered in this guidance
Restore and conserve bird-nesting and foraging habitat	Marsh birds	# of acres of habitat created, restored, managed, and/or under increased stewardship[1]
N/A	Osprey	Not considered in this guidance
N/A	Non-GOM nesting birds	Not considered in this guidance
N/A	Northern nesting shorebirds	Not considered in this guidance
N/A	Prairie pothole nesting species	Not considered in this guidance
N/A	Boreal forest nesting species	Not considered in this guidance
N/A	Caribbean nesting species	Not considered in this guidance
N/A	Pelagic species	Not considered in this guidance

[1]Indicates metrics not considered here because they only indirectly provide potential benefits to birds, and they are standardly captured through other mechanisms; primarily they relate to governance and/or accounting for quantity of restoration and therefore are not included in this guidance.
[2]Indicates metrics not specifically considered here, but it is assumed these methodologies are covered with Restore and Conserve bird-nesting and foraging habitat.
GOM:Gulf of Mexico.

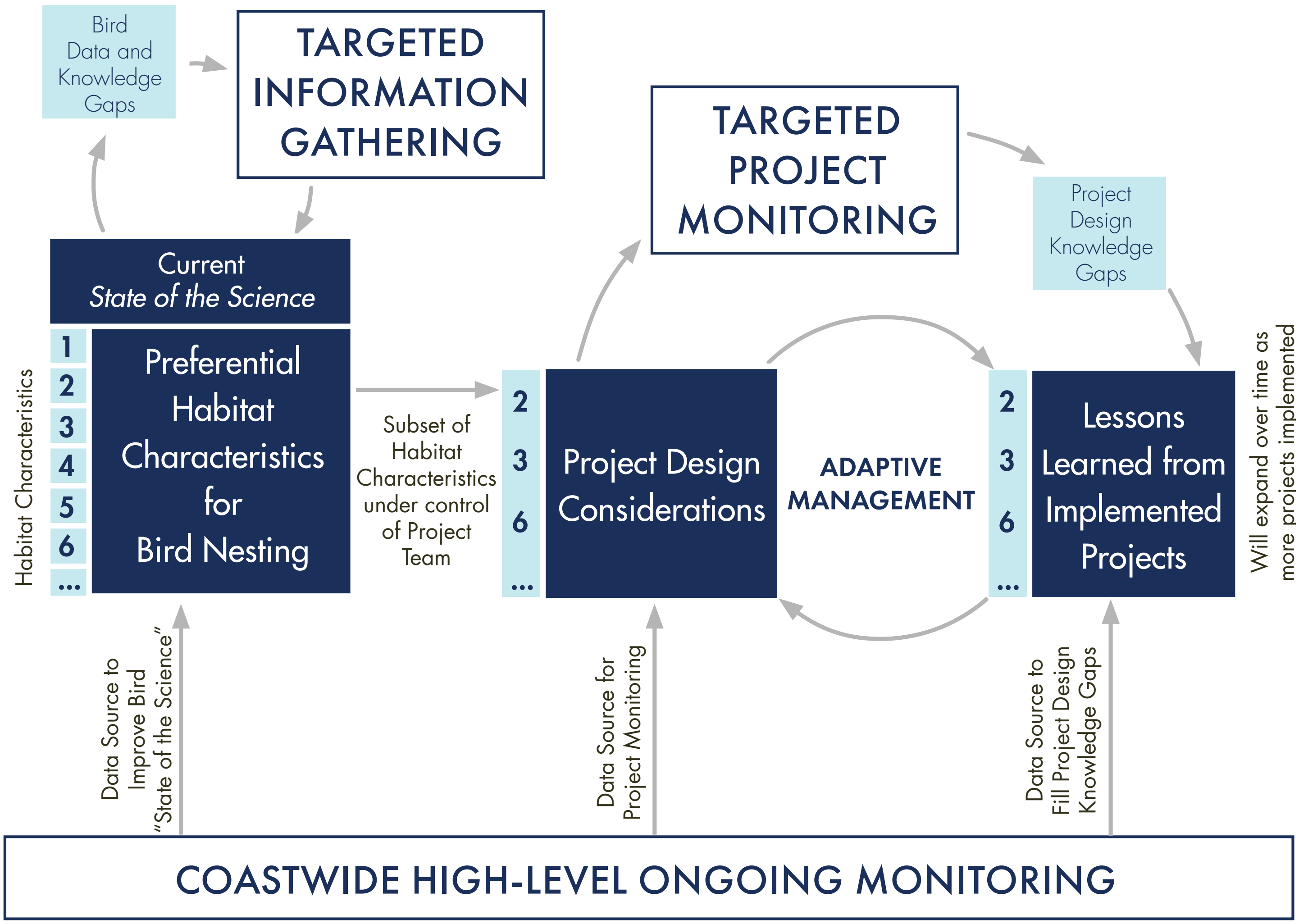

Figure 74. Framework for optimizing habitat for birds through coastal restoration, adaptive management, coastwide high-level ongoing monitoring, and targeted project-scale monitoring (also included as Figure ES1).

4.2.2. Two Scales of Monitoring

Two scales of monitoring are covered in this guidance (**Figure 74**). The first is high-level or broad spatial scale, which consists of repeated monitoring with standardized approaches for high-level programmatic reporting and planning. This typically includes a small number of metrics that could be applied in cost effective ways across coastal Louisiana and more broadly across the DWH restoration area in the northern Gulf of Mexico. The second is targeted project-level monitoring (aka targeted monitoring), to be carried out at an individual project site (or sites). This targeted monitoring will address knowledge gaps to inform MAM priorities including future restoration planning and design, adaptive management, and unknown future conditions.

4.2.2.1. High-Level Ongoing Monitoring

Evaluating the effectiveness of programmatic and large-scale restoration requires the implementation of standardized data collection and analyses over time (years) and area (coastwide; **Figure 74**). Relative to many northern Gulf of Mexico states, much of coastal Louisiana has limited accessibility (barrier islands, remote shorelines, expansive marsh), thereby requiring specific approaches to inform current performance and future adaptive management actions. For shrub-nesting and select ground-nesting birds, aerial photography and nest counting (dotting) analyses are the principal means by which select metrics (e.g., individual bird numbers by species, total number of nests by species) are documented. These efforts are done on a semi-regular basis appropriate to the management planning and restoration assessment needs (e.g., annual or every five or ten years, for different geographies during different stages of implementation). Additional ground-nesting birds (Solitary Nesting Shorebirds) utilizing Louisiana's remote shorelines are documented by boat or walking surveys utilizing the established Breeding Bird Methodology (Barataria-Terrebonne National Estuarine Program [BTNEP]/U.S. Geological Survey [USGS]). These efforts may be done annually within specific areas associated with individual projects and are consistently done every five years for the majority of the state's coastlines. Methodologies for marsh-nesting birds are actively being developed with data collection and analysis within Louisiana to refine currently available protocols (Conway, 2011; D. H. Johnson et al., 2009). A deliverable of the current marsh-nesting bird project (LA-2019-016; DIVER Project ID 205) will include fully developed SOPs for those methodologies, along with recommendations on desirable spatial and temporal scales of monitoring to inform ecosystem restoration project planning and assessment for Louisiana's coastal marshes with potential application for the northern Gulf of Mexico. The high-level ongoing monitoring for shrub-nesting, marsh-nesting, and ground-nesting birds is intended to provide high-level reporting and planning.

4.2.2.2. Targeted Monitoring

In addition to high-level ongoing monitoring, targeted monitoring (either project-level or event-based) is highly beneficial toward addressing identified as well as future, currently unknown, knowledge gaps or related to future unknown ecosystem conditions (**Figure 74**). These knowledge gaps may relate to bird biology, either of a particular species or a particular group of nesting birds or may specifically inform bird response to a particular engineering approach or project design feature(s) (e.g., ground-nesting birds). Targeted monitoring has the potential to fill these specific knowledge gaps and be utilized within the adaptive management framework (**Figure 74**). Depending on the objectives, feasibility, and funds available, targeted monitoring may include a broad suite of avian response metrics. These could include measures such as daily nest survival rate, hatching success, fledging success, or measures of bird health (e.g., Ottinger et al., 2019: Table 10.1; Rotella, 2007; Schmidt et al., 2010; Weiser, 2021). Targeted monitoring efforts will often be essential to fully evaluate project design features; these efforts should be question-driven, carefully designed, and appropriately scaled in space and time to enable conclusions and future application (see **Section 4.6** for additional information).

4.2.2.3. Adaptive Management

The habitat characteristics for bird nesting presented in this guidance represent the current state of knowledge, including known gaps in data available as well as our knowledge gaps (i.e., species-specific nest site selection processes). This is intended as an engagement point to focus information gathering efforts toward addressing targeted ecosystem management questions that will directly inform engineering design to increase bird-nesting success through coastal restoration projects. (**Figure 74**). High-level ongoing monitoring data (and data analyses) also have potential to increase the state of understanding of coastal nesting birds. Where ecosystem restoration project design considerations can be controlled, they provide a primary point for adaptive management to maximize habitat value for nesting birds (see DWH NRDA Trustees, 2021). Selection of the most successful project design features that maximize potential response by nesting birds can be informed through analysis of monitoring data and application of lessons learned from previously implemented restoration projects (**Figure 74**).

This guidance was developed to be consistent with the LA TIG MAM Strategy (LA TIG, 2021), as well as the NRDA MAM Manual (DWH NRDA Trustees, 2017b, 2021). The priorities within the LA TIG MAM Strategy explicitly include priority for development of an interactive lessons learned database that should be updated at least every five years and is anticipated to include lessons learned for all resource types (LA TIG, 2021). For successful adaptive management to maximize bird nesting on coastal habitat restoration projects, this guidance needs to be a living document that revises the lessons learned, as well as the state of the science of coastal bird nesting at least every five years.

4.2.3. Metrics Included Within this Guidance

This guidance covers two levels of monitoring for coastal shrub-nesting, marsh-nesting, and ground-nesting birds (**Figure 74**).

- Firstly, high-level ongoing monitoring for programmatic and project planning and reporting (**Section 4.2.2.1**), and
- Secondly, targeted monitoring for improving project design over time through adaptive management (**Section 4.2.2.2**).

Different metrics and methodologies are appropriate for these two scales of monitoring and the questions to be addressed at large (generally defined here as >10 km) and small (generally defined here as <10 km) spatial scales (**Figure 75**). For monitoring at very large spatial scales (such as coastal Louisiana or the northern Gulf of Mexico), it is necessary to identify methodologies that are both relatively easy to rapidly implement for data collection and that are cost effective. Approaches such as aerial surveys of nesting birds for colonial or solitary ground-nesting and shrub-nesting birds, or systematic call-back surveys for marsh-nesting birds, can meet these needs at large spatial scales (**Figure 75**). When a specific knowledge gap is identified or an aspect of project design is being specifically assessed to determine its effect on nesting birds, targeted monitoring is appropriate to support adaptive management (**Figure 74**). Because these questions apply at relatively small spatial scales, usually within a project site (i.e., <10 km scale), the greater cost is rewarded though an increase in value of complex and very explicit information, with a high return on investment. These explicit avian response metrics include bird productivity, fledging success, and nest success (**Figure 75**).

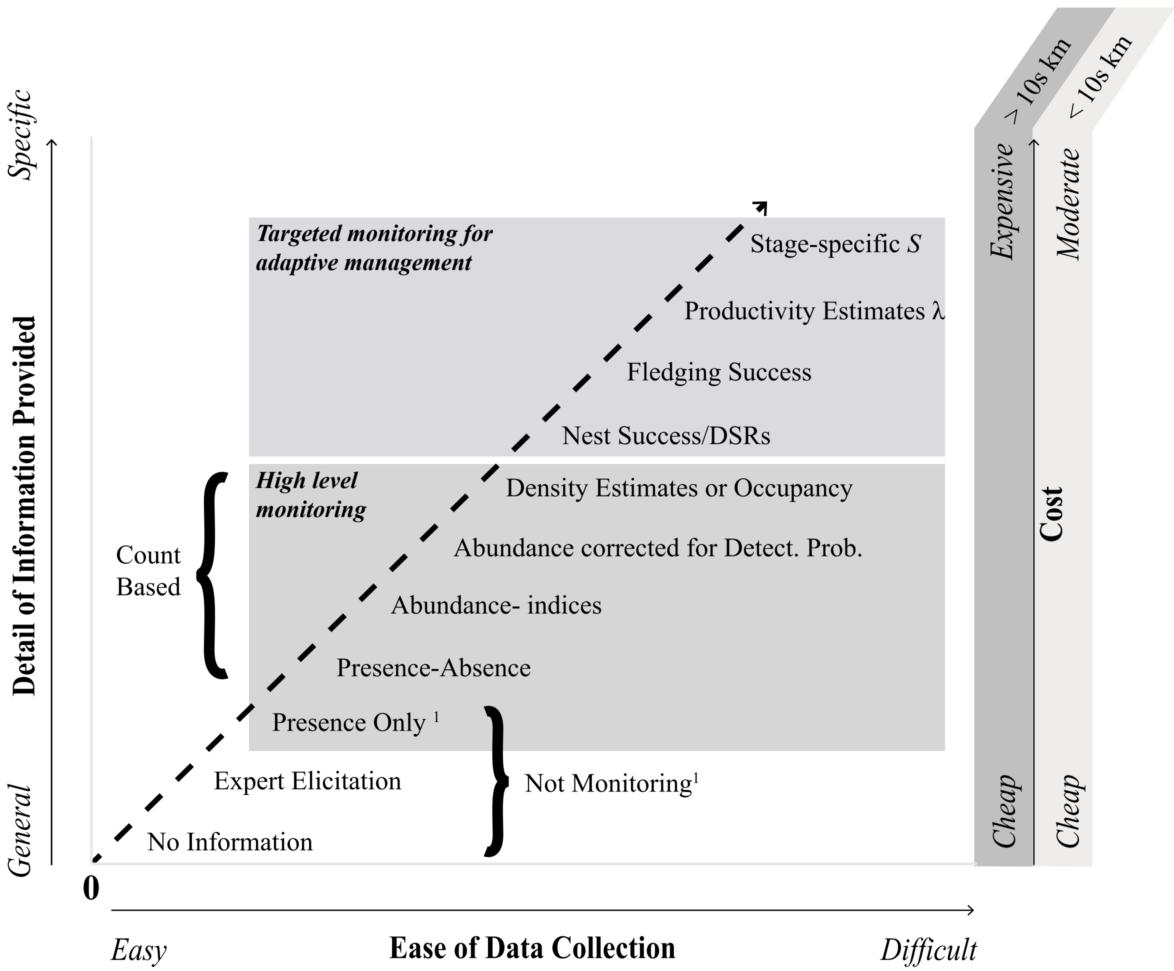

Figure 75. Relationship between ease of implementation, information value, and cost at different spatial scales of a series of approaches and metrics for bird monitoring. High-level monitoring is appropriate for large spatial scales (i.e., >10s km) and ongoing semi-regular (e.g., annual to five-year) monitoring. Targeted monitoring is appropriate for adaptive management to meet identified knowledge gaps and is appropriate at small (i.e., <10s km) spatial scales for a fixed time period (Figure 1; Section 1.2). Note: DSR = Daily Survival Rate.[1,2]

[1]Presence-only data collection can be considered monitoring if the sampling is repeated in space and time, as well as being collected with clear objectives, standardized protocols, robust sampling design, and an effort to actually analyze the data (e.g., Pearce and Boyce, 2006).

[2]Figure adapted from J. Takekawa presentation to the Gulf of Mexico Avian Monitoring Network (5-7 April 2016) in Cedar Key, Florida, as modified by J. Gleason (2 August 2016).

Table 29. Monitoring metrics for the Restore and Conserve bird-nesting and foraging habitat restoration approach as detailed in the Strategic Framework for Bird Restoration Activities (DWH NRDA Trustees, 2017a) and the GoMAMN Strategic Monitoring Plans (Brush et al., 2019; DeMaso et al., 2019; Frederick & Green, 2019; Jodice et al., 2019; Woodrey et al., 2019). Shaded cells indicate inclusion of metrics in either high-level ongoing or targeted monitoring efforts.

DWH Strategic Framework Guidance Categories			Categories of Measurement Strategic Framework for Bird Restoration Activities	Metrics GoMAMN Strategic Monitoring Plans	High-Level Ongoing Monitoring	Targeted Monitoring for Adaptive Management (and/or Targeted Information Gathering)
Colonial Waterbirds	Solitary Beach-Nesting Birds	Marsh Birds	Presence/absence or abundance of focal species	Abundance (Index)	■	
				Abundance (corrected for effort)[1,2]	■	
				Abundance (corrected for detection probability) [1,2]	■	
				Species Composition	■	
				Community Assemblage	■	
			Presence/absence or # of nesting pairs	Nest Density	■	
			Reproductive success (e.g., # of nests, fledglings, etc.)	Nest Success[2]	■	■
				Fledging Success[2]		■
			Survival (adults, juveniles, and/or chicks)	Fledgling/1st Year Survival[2,3]		■
				Juvenile/Subadult Annual Survival[2,3]		■
				Adult Annual Survival[2,3]		■
			Density, abundance, and/or availability of prey species	TBD - out of scope for this guidance		

[1]Replication, randomization, and control(s) are relevant and important when designing ecological field experiments and/or evaluating effectiveness of management actions or restoration projects(see D. R. Anderson et al., 2001; Block et al., 2001; Eberhardt and Thomas, 1991; Hurlbert, 1984; Michener et al., 1997; Underwood, 1991, 1992).

[2]During the project planning stage, consideration of an a priori power analysis should be considered for parameters/metrics of interest (D. R. Anderson et al., 2001; Cherry, 1998; Gerrodette, 1987). It is extremely important to consider precision (variance, Standard Error, Coefficient of Variation), as well as bias. It is suggested that use of 95% Confidence Interval about parameter estimates or parameter point estimates (D. R. Anderson et al., 2001; Cherry, 1998; C. J. Johnson et al., 2002; D. H. Johnson, 2002) be included. Unbounded, single point estimates without some estimates of precision or bias have very high uncertainty and are therefore very difficult to interpret; interpret with caution.

[3]Survival can be estimated as either Apparent or True Survival. The former tends to be negatively biased as it does not account for permanent emigration of marked individuals from the study area. The latter is more challenging to estimate; hence, many/most studies estimate Apparent Survival (Gilroy et al., 2012; Schaub & Royle, 2014).

To identify a subset of monitoring metrics for restoration evaluation/assessment of target bird species in coastal Louisiana, the principles of cost-effort-data specificity-spatial scale (**Figure 75**) were applied. Firstly, the target shrub-nesting, marsh-nesting, and ground-nesting bird species in Louisiana were compared with groupings presented in the PDARP (DWH NRDA Trustees, 2016), NRDA Strategic Framework for Bird Restoration Activities (DWH NRDA Trustees, 2017a), Seabirds (Jodice et al., 2019), Shorebirds (Brush et al., 2019), Marsh birds (Woodrey et al., 2019), Waterfowl (DeMaso et al., 2019), and Wading Birds (Frederick & Green, 2019) chapters of the GoMAMN Strategic Bird Monitoring Guidelines (Wilson, 2019) as presented in **Table 26**. Secondly, the comprehensive listing of potential monitoring categories presented within the Strategic Framework for Bird Restoration Activities and the Seabirds, Shorebirds, Marshbirds, Waterfowl, and Wading Birds chapters of the GoMAMN Strategic Bird Monitoring Guidelines was summarized to identify potential metrics to include in this guidance, based upon **Table 27** (Brush et al., 2019; DeMaso et al., 2019; DWH NRDA Trustees, 2017a; Frederick & Green, 2019; Jodice et al., 2019; Woodrey et al., 2019). Thirdly, the list of metrics related to shrub-nesting, marsh-nesting, and ground-nesting birds was divided between high-level ongoing monitoring and targeted monitoring for adaptive management (targeted monitoring or targeted information gathering) in **Table 29**. **Table 29** provides the structure for the theoretical considerations and SOPs presented in the remainder of this monitoring guidance.

4.3 STANDARD OPERATING PROCEDURES FOR HIGH-LEVEL ONGOING BIRD MONITORING

4.3.1. Monitoring Activities for Shrub-Nesting and Ground-Nesting Birds: Aerial Surveys

Bird monitoring guidance builds upon the LA TIG MAM Strategy (High-level and SMART [Specific, Measurable, Achievable, Relevant, and Timely] Objectives) in tandem with several large-scale monitoring efforts currently underway in Louisiana and across the northern Gulf of Mexico. Collectively, these efforts are being utilized to (1) document utilization of restored habitats for nesting, (2) population census activities within coastal Louisiana and the broader northern Gulf of Mexico, and (3) informing Trustees in the development/implementation of science-based tools (e.g., correction factor for egrets and herons) to further refine project performance (individual project or region wide).

The following documents are available on CPRA's Coastal Information Management System (CIMS; cims.coastal.la.gov) and/or DIVER (diver.orr.noaa.gov) information portals.

Monitoring efforts collecting related data include:

(2021) Regionwide TIG (MAM) Colonial Waterbird Monitoring	DIVER Project ID 257
(2018) LA TIG (MAM) Colonial Waterbird Monitoring	LA-2018-009 DIVER Project ID 178
(2018) LA TIG (MAM) Colonial Waterbird Analysis	LA-2018-019

Implemented habitat creation projects with relevant bird monitoring information:

(2020) Queen Bess Island Restoration Project	BA-0202
(2018) Caminada Headland Beach and Dune Restoration	BA-0143; BA-0045 – monitoring ongoing
(2018) Caminada Headland Back Barrier Marsh Creation	BA-0193 – monitoring ongoing
(2010) Whiskey Island Restoration Project	TE-27 – monitoring ongoing
(2010) Whiskey Island Back Barrier Marsh Creation	TE-0050 – monitoring ongoing
(2021) Rabbit Island Restoration	CS-0080

4.3.2. Description of Aerial Surveys and Bird Quantification

The principal means by which Louisiana monitors shrub- and select ground-nesting species is aerial photographic nest surveys. Aerial overflight methodology was chosen for Louisiana and applied more broadly across the northern Gulf of Mexico to achieve a methodology that could be uniformly and cost effectively applied at very large geographic scales. More specifically, georeferenced photographic surveys are carried out from a fixed-wing aircraft, with two photographers taking both contextual habitat as well as individual nesting colony photographs specifically for enumerating nests and number of nesting pairs by species within a defined area (**Figure 76**). Nests are then manually dotted (i.e., counted) on individual photographs and assigned to species and the nesting status. Principal endpoints include distribution trends, relative abundance, nest abundance, and breeding status (**Figure 75**). Individual nests are identified, and species and nesting status are determined, a process called dotting (Colibri Ecological Consulting & R. G. Ford Consulting Company, 2015). Due to their specific biology and nesting habits, species of herons and egrets require some additional correction factors for quantification.

SOPs and/or examples:

Bird Colony Aerial Photography Protocol — **Section 4.3.4.1**
Bird Quantification (i.e., Dotting) Protocol — **Section 4.3.5.1**

Figure 76. Aerial photographic nest surveys: Implementation of fixed-wing aircraft surveys (peak breeding season, e.g., May–June) to assess colonies and document associated nesting via dotting (photo credit: Jeff Davis, Colibri Consulting).

4.3.3. Description of Call-Back Survey Approach for Marsh-Nesting Birds

The principal means by which Louisiana monitors marsh-nesting birds is point surveys using an established call-back survey protocol (Conway & Gibbs, 2005; Conway, 2009, 2011; Conway & Nadeau, 2010; Conway & Nadeau, 2006; D. H. Johnson et al., 2009; **Figure 77**). In addition, current efforts (LA-2019-016) are measuring habitat and hydrologic characteristics as a potential means to interpret habitat modifications that influence occurrence and abundance of marsh-nesting birds. Project sampling locations are principally collocated with many of the State's Coastwide Reference Monitoring System (CRMS; reference site controls) sites, as well as created marsh sites of different ages. Collectively, these data are intended to inform future marsh creation design, construction, and management to generate optimized habitats that benefit (e.g., nesting, forage) marsh-nesting birds as well as other wetland-reliant wildlife species.

4.3.3.1. Current Data Collection Approach for Marsh-Nesting Birds: Call-Back Surveys

A large-scale monitoring effort is currently underway in Louisiana and across the northern Gulf of Mexico aiming to (1) refine marsh-nesting bird monitoring practices, and (2) track and report on bird resource restoration.
The following documents are available on CPRA's CIMS (cims.coastal.la.gov) and/or DIVER (diver.orr.noaa.gov) information portals.

Monitoring efforts collecting relevant data include:
(2019) LA TIG (MAM) Secretive Marsh Birds — LA-2019-016 DIVER Project ID 205

Implemented habitat creation projects with relevant bird monitoring information: NA

SOPs and/or examples:
Call-Back Survey Protocol — **Section 4.3.6**

Figure 77. Secretive marsh bird surveys using a point-based call-back methodology for marsh-nesting birds (photo credit: Sammy King, USGS).

4.3.4. Standard Operating Procedures for Aerial Surveys for Shrub-Nesting and Ground-Nesting Bird Monitoring

The protocol described herein was provided by Colibri Ecological Consulting and R. G. Ford Consulting Company (2015). For additional information, see also Capitolo et al., 2019, 2014; and Golightly et al., 2017.

4.3.4.1. Bird Colony Aerial Photography Protocol (Colibri Ecological Consulting, LLC)

Aerial photographic nest surveys used to census waterbird breeding colonies follow methods developed since 2010 by Colibri Ecological Consulting, LLC (Colibri) and R.G. Ford following the Deepwater Horizon oil spill. These methods were adapted from those their staff had used during long-term monitoring of seabird colonies in California with aerial photographic nest surveys. The list of colonies and islands surveyed in any year is based on a colony inventory that is updated by Colibri and R.G. Ford as new colonies are discovered and as past colonies become inactive or submerged. Past colonies are generally still approached, but at cruise speed so that time investment is not significant. Survey maps are further refined by reviewing most-recent satellite imagery to look for new potential colony habitat to survey as the landscape changes. Observers in the aircraft are also searching the surroundings for potential habitat or active colonies as they transit between known colonies. Local federal and state biologists may also provide colony locations to be surveyed, as was done in 2021 for Least Terns nesting on Mississippi and Florida mainland beaches.

Aerial photographic nest surveys are carried out from a fixed-wing, twin engine, high-wing Partenavia (PN68) aircraft with a belly port for vertical/nadir photography, configured such that two photographers can work simultaneously. Photographers familiar with both aerial survey protocols and image analysis protocols are critical so they can determine immediately whether photograph quality is adequate for purposes of counting. Surveys are carried out between 700 and 1,000 ft above ground level at a ground speed less than 90 knots. As of 2021, full frame, digital SLR cameras equipped with zoom and telephoto lenses (focal length range = 16 300 millimeter,) are used to acquire photographs. Crop-sensor cameras were used in previous years. Aircraft waypoints and time are recorded automatically at 5-second or shorter intervals. Photograph times are downloaded from EXIF data, and image file names are interpolated into tracklines to estimate the position of each photograph. As of 2021, latitude and longitude coordinates of photographs are also among EXIF data, using a Global Positioning System (GPS) unit attached to the cameras.

Crews consist of a pilot, a navigator/data recorder in the co-pilot's seat, and two photographers in the back of the plane. The navigator coordinates with the pilot to determine the sequence of colony visits. One photographer takes context photographs showing a relatively wide-area view of the colony, while the other photographer concentrates on more detailed close-up shots. The context photographer also typically zooms in to obtain mid-focal length coverage, often useful for counting nests and birds. The navigator records when the aircraft is approaching a colony, when it is leaving, and the range of frame numbers shot over that colony.

As the aircraft approaches a target colony, the crew determines the spatial distribution of birds on the colony. Photographers, navigator, and pilot confer to determine the best angle of approach and the ideal altitude for photographic census. The Observer model of the Partenavia has a plexiglass nose, allowing the pilot and navigator to see breeding groups of birds and efficiently approach them. For colonies of large birds such as the Brown Pelican, an altitude around 1,000 ft may be acceptable, while a lower altitude of around 700 ft is preferable for smaller species such as terns. Decisions about flight paths and altitudes are based on the extent of the colony, the species present at the colony, the strength and direction of the wind, vegetation around the colony, and angle of the sun. Lower altitudes are not needed and are avoided to prevent disturbance to breeding birds. Multiple approaches from different directions or altitudes may be necessary to best obtain sufficient high-quality photographs that are representative of the species composition in the colony. Photography should be conducted from approximately 3 hours after sunrise to 3 hours before sunset, when solar altitude is at least approximately 35 degrees. Photograph files (jpegs) are downloaded daily to external back-up devices.

4.3.5. Standard Operating Procedures for Bird Quantification of Shrub-Nesting and Ground-Nesting Aerial Photographs

The protocol described herein was provided by Colibri Ecological Consulting and R. G. Ford Consulting Company (2015). For additional information, see also Capitolo et al., 2019, 2014; and Golightly et al., 2017. This protocol is a continuation of the protocol presented in **Section 4.3.4**.

4.3.5.1. Bird Enumeration Protocol (Colibri)

Aerial photographs are analyzed using methods developed in the study area in 2010–2013 (Colibri Ecological Consulting & R. G. Ford Consulting Company, 2015) and subsequent years. Photographs from May and June surveys are evaluated for their representation of peak breeding by species at each colony. For some species, such as Brown Pelican and Great Egret, photographs from May surveys may represent peak breeding numbers and will be selected for analysis. For other species, especially Black Skimmer, photographs from June surveys will better represent peak numbers and will be used for analysis. Often, especially for Brown Pelican, Royal Tern, and Sandwich Tern, well-developed colonies may be counted using May photographs, but additional large nesting groups that form after the May survey will be counted from June photographs and summed with May counts to get a total number of nests. To increase confidence in annual counts, two surveys per year are required.

All images of each individual colony are inspected for clarity, location within the colony, and extent of colony coverage. Those best suited for determining nest counts and collectively comprising all breeding areas are analyzed using counting software (Image-Pro, Media Cybernetics®). Nests and birds are marked manually, and the software automatically tallies total counts for each category. Although the primary objective is to determine numbers of nests, individual adult and subadult birds within colonies are also counted.

For Brown Pelicans, nests are categorized based on stage of development. These stages include:

- Well Built Nest (with attending adult typically in incubation posture),
- Poorly Built Nest (pre egg-laying, but considered a breeding pair),
- Nest with Chicks, with attending adults,
- Nest with Chicks, without attending adults,
- Brood (dependent chicks away from an obvious nest and not attended by an adult),
- Abandoned Nest (with eggs, but unattended),
- Empty Nest (unattended and without eggs or chicks), and
- Territory (in breeding habitat and territorial spacing, but not judged to be a breeding pair).

Together, these categories can provide numbers of pelican nests at a colony from a single aerial photographic nest survey, even though egg-laying dates may span a period of months, given that chicks do not fledge until approximately 3 months old. However, additional breeding groups may form by the June survey that need to be counted and summed with May counts for the best estimate of breeding population size. Empty Nests and Territories are not summed in a Colony Nest Total because they are not considered to have been or to have later become egg laying sites and, therefore, are not considered appropriate to include in a breeding population estimate.

For all other species, a bird in incubation posture is categorized as a "Site," replacing the Well Built Nest used for Brown Pelicans, because for all other species a nest structure is not consistently detectable in aerial photographs. Using 2021 image analyses, the other detailed nest categories used for Brown Pelicans were also used consistently whenever possible for all other species. However, because of small body size (e.g., terns and gulls), scrape-nesting habits (e.g., terns and skimmers), or partial concealment by vegetation (e.g., waders and gulls), the various categories cannot always be identified for other species, in which case the Site category is used. However, when the Site category is used, confidence is high that the Site represents a breeding pair. For example, it is the principal category used for gulls and terns.

Beyond nests, a dot is used to mark other birds of all species. These may include the mate of another adult at a nest; the other adult is accounted for by the Nest Category that was marked. Other birds along the shoreline or within colony areas not obviously associated with a breeding territory are also marked as Birds. Doing so allows the total number of birds in attendance at the time of the survey to be summed and forces the image analyst to inspect all attending birds closely for possible breeding status. Exceptions may include roosting birds in non-breeding habitat. It may be decided to not count these birds based on time constraints. However, these areas are still closely inspected to ensure they do not include chicks that have wandered away from nests that have otherwise not been counted.

Using the software, unique symbol-color combinations are assigned to different nest and bird categories for each species. These unique combinations are not necessarily standardized across images, given the large number of species categories encountered, but are defined with each analyzed image. Where overlapping images are used to analyze portions of a colony, one or more lines are drawn on the selected image to delineate the area to be counted using that image. Areas outside any such lines are counted from different images. This process continues until the colony is counted completely with available photographs.

4.3.5.2. Archiving Data

After analyzing an image with the software, a screen capture of the analyzed image is saved as a jpeg file. The screen captures show all data, including image number, all symbols that marked nests and birds, total counts for each category, colony name, area number, the initials of the biologist who analyzed the image, the date the image was analyzed, and any other annotations the biologist added. All screen captures are saved with standardized file names and archived in colony-specific folders. All data from each screen capture are manually entered into a Microsoft® Access database. The database also includes a table with qualitative descriptions of colonies and a query for summing colony counts. All data will be delivered with appropriate metadata in either ISO or FDGC format.

4.3.5.3. Summarizing Data

For each species at each colony, a total number of nests is determined with a database query defined as follows:

- Nests: Sum([WBN]+[ChickNest]+[ChickNestw/outAdult]+[AbandNest]+[PBN]+[Site]+[Brood])

Note that Empty Nests and Territories are not included. If images are analyzed from both surveys, May and June totals may need to be summed for a complete colony total. Multiplying the Nest Total by 2 would yield a Breeding Population Estimate (# of breeding birds), unadjusted by correction factors that could account for nests active outside the survey window and for detection probabilities (Carter et al., 1992; M. Steinkamp et al., 2005).

The total number of birds of each species in attendance at each colony are summed with this query:

- Birds: Sum([WBN]+[ChickNest]+[PBN]+[Territory]+[Site]+[OtherBirds])

Note that nest categories without an attending adult are not included as it is not assumed they were or became sites where eggs were laid. Occasionally Empty Nests can be appropriate to include if the young of the year away from nests cannot be readily counted with the Brood category.

Typically, statistical analyses of aerial nest photographic survey Nest Totals generate 95% confidence intervals and period and per annum estimates of percent change for both individual colonies or colony complexes and for regions of interest (Capitolo et al., 2019, 2014; and Golightly et al., 2017). Models for the Gulf of Mexico data have not yet been determined.

4.3.6. Standard Operating Procedures for Call-Back Surveys for Marsh-Nesting Birds

The protocols described herein were developed by Sammy King and Aylett Lipford at Louisiana State University. It is recommended to contact primary authors prior to implementation.

4.3.6.1. Sampling Protocol

The monitoring team will conduct surveys within a 1 km radius of selected CRMS stations. Surveys will consist of four established points (located randomly within ArcGIS) around each selected CRMS station with the stipulation that each point is separated by ≥250 m, in order to minimize the potential for repeated counts of individuals, and located <75 m from the shoreline, for access. At least four bouts of repeated point count surveys per year will be performed, using an established call-back survey protocol as described by Conway, 2011) during the 2021–2023 breeding seasons (March–June). The number of times each point is sampled may increase to at least five depending on preliminary results from data collected during the first field season. In Year 1, the contractor will sample as many selected CRMS stations as possible (logistics and habitat conditions pending) to facilitate an understanding of habitat conditions and bird responses to marsh restoration across the region.

Upon arrival at a sampling location, observers will implement a five-minute resettling period to allow for birds to adjust to their presence. Observers will then use a handheld speaker system (Foxpro® Inferno, Lewistown, Pennsylvania, USA) to broadcast calls from focal marsh bird species for 30 seconds followed by 30 seconds of silence in accordance with the Standardized North American Marsh Bird Monitoring Protocol (Conway, 2011). Calls will be broadcast and all visual or auditory responses from those focal species[5] will be recorded by observers with training in call recognition within Louisiana marshes. Observers will use a visual range finder to estimate the distance of each detection and place detections into distance bands of 0–25 m, 25–50 m, 50–75 m, 75–100 m, and >100 m (Buckland et al., 2001, 2015; MacKenzie et al., 2018; MacKenzie, 2005; Thomas et al., 2010). Surveys will be conducted from 30 minutes prior to sunrise until 9:30 a.m. central time (rarely up to10:30 a.m. for very remote sites) and will not be conducted during periods of inclement weather (i.e., heavy rain, winds >20 miles per hour [Conway, 2011]). Each point will be marked to maintain consistency between survey events. Observers and sampling times will be rotated throughout the season to minimize observer bias (Conway & Gibbs, 2011). The contractor will use flagging tape to ensure that each observer visits a site no more than once per season (the four visits per season are conducted by four separate observers) and that all stations are visited early in the morning at least once. Observers will be trained in species identification and distance estimation prior to the start of each field season.

4.3.6.2. Habitat and Hydrologic Characteristics

The monitoring team will use a combination of habitat characteristics collected from the field and from remote sensing databases across various temporal and spatial scales (e.g., CRMS). Protocols for collection of fine-scale habitat characteristics will follow the methodology of Pickens and King (2014), which are summarized here. Fine-scale habitat measures may include percent of open water, water depth (in centimeters), length of open water-vegetation edge (in meters), presence or absence of a linear marsh feature (i.e., pipeline canal, oil and gas transportation feature, spoil piles, ditch) and a vegetation density index for between site comparison (still being fully developed). Between mid-March and mid-April each year, water depth (corrected for stage height) will be measured and recorded at each bird survey point; comparative long-term comparative data from CRMS will be used for context and comparison. Pickens and King (2014) recorded water depth every 10 m along three 50 m

5 American Bittern, Least Bittern, King Rail, Clapper Rail, Common Gallinule, Purple Gallinule, and Pied-billed Grebe.

transects (5 points/transect=15 depth measurements). One transect was oriented perpendicular to the survey point, and two transects were at 20 degree angles from the point. No water depths were measured ≤10 m from levees or ditches; transects were extended when levees or ditches impeded measurements. The contractor will measure multiple water depths at each site. Land cover information from the Wetlands Mapper® Database (available from http://www.fwsprimary.wim.usgs.gov) will be used as an initial classification of marsh habitat from which focal marsh bird species occurrences were collected. These classifications will be proofed by comparing them to those generated by intensive annual vegetation surveys performed at each selected CRMS station to ensure that survey locations are accurately classified. In addition, remote sensing data will be utilized where possible to refine vegetation assessments. The variable of wetland type may be informative for understanding a species capacity to occur across several marsh types and could reflect resilience or susceptibility to localized habitat changes. This dataset will also be used to produce land/water ratio and wetland edge predictor layers using ArcGIS® version 10.8 software. Landsat® 8 satellite imagery available from the Earth Explorer® database (available from https://earthexplorer.usgs.gov) will be used to understand the influence of temporally variable vegetative conditions on the occupancy and relative abundance of focal taxa. Images will be taken from the date closest to each survey and will only include those images with minimal cloud cover.

The contractor will use hydrological information from the Global Surface Water Explorer® database (available from http://www.global-surface-water.appspot.com/; Pekel et al., 2016) to understand the influence of several water features on the occupancy and relative abundance of our focal taxa. Finally, marshes are also influenced by precipitation regimes, but these are not captured with environmental layers developed from satellite imagery. The climate data from the Worldclim® database (available from http://www.worldclim.org; Fick and Hijmans, 2017) will be utilized toward understanding the influence of local-scale environmental factors on distribution and abundance of secretive marsh birds. All environmental predictor layers will be clipped in ArcGIS® to the extent of the study area and generated at a 1 km resolution.

4.4 ANALYSIS OF HIGH-LEVEL DATA

High-level monitoring is a repeated process that utilizes standardized approaches for high-level programmatic reporting and planning (see **Figure 74**). High-level monitoring includes several calculated metrics that can be applied across coastal Louisiana and the northern Gulf of Mexico.

The following sections describe calculated metrics that are applicable for high-level ongoing monitoring and analysis for shrub-nesting, marsh-nesting, and ground-nesting birds. Modified monitoring or data collection methodologies are also provided for specific sub-groupings of birds as defined in other documents (i.e., landbirds, seabirds, shorebirds, wading birds, marsh birds, and waterfowl). Cross-links to text descriptions of each metric and bird group are provided in **Table 30**.

The following sections provide examples of existing bird surveys (e.g., Breeding Bird Survey [BBS], Christmas Bird Count [CBC]) and citizen-science bird data collection (e.g., eBird) that likely do a reasonable job of tracking population trends, trajectories, and/or species' abundances through time at the scale of a Bird Conservation Regions, state, region (e.g., SE U.S.), or continentally. However, these examples are not meant to represent a replacement for a well-thought-out study design (that accounts for both survey effort and a myriad of detection-related issues) for project level bird monitoring.

Table 30. Section headings (cross-linkages) for calculated high-level analysis metrics information across bird groups.

	Metrics				
Section Heading	**Abundance (Index)**	**Abundance (corrected for effort)**	**Abundance (corrected for detection probability)**	**Species Composition**	**Community Assemblage**
Shrub-nesting High-Level	4.4.1	4.4.2	4.4.3	4.4.4	4.4.5
Refined for shrub-nesting seabirds	4.4.1.1	4.4.2.1	4.4.3.1	N/A	N/A
Refined for shrub-nesting wading birds	4.4.1.2	4.4.2.2	4.4.3.2	N/A	N/A
Marsh-nesting High-Level	4.4.1	4.4.2	4.4.3	4.4.4	4.4.5
Refined for marsh birds	4.4.1.3	4.4.2.3	4.4.3.3	N/A	N/A
Refined for waterfowl	4.4.1.4	4.4.2.4	4.4.3.4	4.4.4.1	4.4.5.1
Ground-nesting High-Level	4.4.1	4.4.2	4.4.3	4.4.4	4.4.5
Refined for landbirds	4.4.1.5	4.4.2.5	4.4.3.5	N/A	N/A
Refined for seabirds	4.4.1.6	4.4.2.6	4.4.3.6	N/A	N/A
Refined for shorebirds/ solitary beach-nesting birds	4.4.1.7	4.4.2.7	4.4.3.7	N/A	N/A

4.4.1. Calculated Metrics: Abundance (Index)

Definition: Abundance as an index (presence-only) frequently employs a convenience sampling design that tends to be highly variable and does not account for sampling effort, variation among observers, or detection probability (β). The abundance index assumes that the count (C) is representative and/or correlated with relative abundance ($\check{N}$) for a given species in a given area; therefore, the count(s) is assumed to be a surrogate for population size or density (Pearce & Boyce, 2006). Johnson et al. (2008) notes that calculations where $\check{N} = C$ and $\check{N}$ = abundance and C = count either do not take into account β or explicitly/ implicitly assume $\beta = 1$ (100% detection) and thus may not account for observer bias. However, it should be understood that Relative Abundance and Absolute Abundance are different, where Relative Abundance is # of detections per unit area (D. R. Anderson, 2003).

4.4.1.1. Refinements for Shrub-Nesting Seabirds

Guidance applies to Brown Pelican and Neotropic Cormorant. Refer to abundance (index) metric refinements for ground-nesting seabirds.

4.4.1.2. Refinements for Shrub-Nesting Wading Birds

Guidance applies to Great Egret, Little Blue Heron, Reddish Egret, Tricolored Heron, White Ibis, Snowy Egret, Cattle Egret, Great Blue Heron, Green Heron, Roseate Spoonbill, Yellow-crowned Night Heron, Black-crowned Night Heron, Glossy Ibis, and White-faced Ibis. Metrics of abundance (index) include C or N species-1, C or N nesting pairs species-1, and C or N nests species-1. Methodology includes ground based or boat/canoe/kayak-based surveys of known or historical colonies (e.g., Texas Colonial Waterbird Database). Aerial (fixed-wing or helicopter) surveys of known or historical colonies can also be conducted. Aerial surveys can also include additional follow-up ground-based counts to determine any detection probability limitations (e.g., South Carolina Department of Natural Resources; Dodd and Murphy, 1995). Effort must be made to account for sampling variance, error, or bias or factors related to variation in environmental conditions, variation among observers, or estimating detection probability. Colony-based surveys are considered to be the most reliable in estimating species-specific population trends (Frederick & Green, 2019). Existing surveys (e.g., eBird, BBS, CBC) likely do a relatively poor job of abundance estimation and estimating species-specific population trends for many species of wading birds due to limited access to colonies or known concentration areas.

4.4.1.3. Refinements for Marsh-Nesting Marsh Birds

Guidance applies to Pied-billed Grebe, Black Rail, Clapper Rail, King Rail, Purple Gallinule, Common Gallinule, Least Bittern, Seaside Sparrow, and Black-necked Stilt. Metrics of abundance (index) include C or N species-1, C or N nesting pairs species-1, and C or N nests species-1. Generally, ground-based surveys lack a formal sampling design and instead are structures using a convenience sample design conducted along line transects or segments or may use sample plots within marshes. Effort must be made to account for sampling variance, error, or bias or factors related to variation in environmental conditions, variation among observers, or estimating detection probability. Due to the secretive nature of the target species and the habitat type, existing surveys (e.g., eBird, BBS, and CBC) likely do a very poor job of estimating species-specific population trends (see Woodrey et al., 2019). It is important to note that unlike other taxa, a well-known and universally accepted survey design and associated protocols and methodologies are available for sampling secretive marsh birds. Almost by default, monitoring of secretive marsh birds requires adhering to a rigorous survey design (e.g., Johnson et al., 2009) and standardized protocols and methodologies (e.g., Conway, 2009, 2011).

4.4.1.4. Refinements for Marsh-Nesting Waterfowl

Guidance applies to Mottled Duck. Metrics of abundance (index) include C or N species-1, C or N nesting pairs species-1, and C or N nests species-1. In some areas, ground-based counts (e.g., USFWS Four Square Mile Breeding Pair Survey; Reynolds et al., 2006, 2001) are used. For sampling wintering waterfowl, aerial surveys lacking a formal sampling design, i.e., convenience sample design, cruise surveys, or surveys along line segments in known waterfowl concentration areas (e.g., Mid-Winter Inventory; (Reinecke et al., 1992; Sharp et al., 2002; Whitaker et al., 2019) are considered not as robust as other waterfowl aerial surveys (e.g., Pearse et al., 2008). For additional information regarding limitations related to Mid-Winter Waterfowl Surveys, refer to Eggeman and Johnson (1989), Heusmann (1999), and Pearse (2007). Effort must be made to account for sampling variance, error, or bias or factors related to variation in environmental conditions, variation among observers, or estimating detection probability (Andersson et al., 2015, 2018; Soulliere et al., 2013). Existing surveys (e.g., eBird, BBS, and CBC) likely do a reasonable job of estimating species-specific population trends for at least some species of waterfowl, e.g., Wood Duck (see DeMaso et al., 2019).

4.4.1.5. Refinements for Ground-Nesting Landbirds

Metrics of abundance (index) include C or N species-1, C or N singing males species-1, C or N nests species-1, or C or N breeding territories mapped species-1. Generally, ground-based surveys for ground-nesting landbirds lack a formal sampling design, instead employing a convenience sample design along line transects or segments or sample plots. When practicable, bird monitoring/surveys should account for sampling effort (e.g., duration of survey, # of sample points, length of transect, # of times surveyed), sampling variance, error, or bias or factors related to variation in environmental conditions (and how they might influence the detection process), among-observer variation when possible, and applicable estimating detection probabilities (by species). Attempts to address all of these challenges should be considered during the study design phase, during data collection, and prior to analyses of data or during all three phases. Previous surveys (e.g., eBird, BBS, and CBC) can be used for reference as they likely do a good job of estimating species-specific population trends (i.e., BBS) for many landbird species (and most songbird species; i.e., BBS; Ellingson & Lukacs, 2006; Hutto & Young, 2002; Ralph et al., 1995; Ralph et al., 1993; Verner, 1985; Zenzal et al., 2019). However, the BBS may not be appropriate for monitoring crepuscular and nocturnal species like Common Nighthawk, especially at site- or project-scale spatial scales. For nightjars in particular, we recommend users follow the survey dates, moonlight conditions, and monitoring protocols developed by the Nightjar Survey Network.

4.4.1.6. Refinements for Ground-Nesting Seabirds

Guidance applies to Least Tern, Gull-billed Tern, Royal Tern, Sandwich Tern, Black Skimmer, Caspian Tern, Forster's Tern, and Laughing Gull. Metrics of abundance (index) include C or N species-1, C or N nesting pairs/species-1, or C or N nests species-1. Some form of vessel-based transect methodology and associated protocols are frequently employed; however, survey designs can vary. Vessel-based seabird surveys also suffer from many of the same issues, limitations, and caveats similar to various other land-based surveys. Every effort should be made to account for survey effort, survey transect width, and environmental and viewing conditions as well as species-specific detection issues (e.g., Program Distance;

Buckland et al., 2015). However, seabird sampling survey software is currently available (e.g., SEASCRIBE: Ballance & Force, 2016; Gilbert et al., 2016) that reduces (but does not eliminate) such sampling issues. When practicable, bird monitoring/surveys should account for sampling effort (e.g., duration of survey, # of sample points, length of transect, # of times surveyed), sampling variance, error, or bias or factors related to variation in environmental conditions (and how they might influence the detection process), among-observer variation when possible, and applicable estimating detection probabilities (by species). Ground-based or vessel-based surveys in or near breeding colonies or known concentration areas near the breeding colonies are likely more reliable than surveys occurring well away from colonies (i.e., mixing of same species from multiple breeding colonies or distant breeding locations) in estimating species-specific or colony-specific population trends (Jodice et al., 2019). Existing surveys (e.g., eBird, BBS, CBC) likely do a relatively poor job of abundance estimation and estimating species-specific population trends for several species of seabirds due to limited access (i.e., spatial sampling restrictions) to colonies or known concentration areas. Colony-counts may be conducted using some combination of ground, boat/skiff/kayak, and aerial surveys. It should be noted that in large, dense, multi-species breeding colonies numbers may be estimated and recorded in groups of 10 or 100 (e.g., Corcoran, 2013).

4.4.1.7. Refinements for Ground-Nesting Shorebirds/Solitary Beach-Nesting Birds

Guidance applies to American Oystercatcher, Wilson's Plover, and Snowy Plover. Metrics of abundance (index) include C or N species^{-1}, C or N nesting pairs/species-1, or C or N nests/species-1. Most frequently some form of ground-based survey is used with different methodologies and protocols employed for breeding versus staging or wintering shorebirds, respectively. Effort must be made to account for sampling variance, error, or bias or factors related to variation in environmental conditions, variation among observers, or estimating detection probability. Existing surveys (e.g., eBird, BBS, and CBC) likely do a reasonable job of estimating species-specific population trends for at least some species (see Brush et al., 2019). An example of a comprehensive breeding shorebird monitoring program includes the Florida Shorebird Alliance (https://flshorebirdalliance.org/resources/monitoring-guidance/) and associated methodologies (Brush et al., 2016).

4.4.2. Calculated Metrics: Abundance (Corrected for Effort)

Definition: Abundance corrected for effort is similar to the metric of abundance by presence-only. However, in this case, abundance/density accounts for survey effort as a function of time (min, hr), distance (e.g., mi, km), distance bins (e.g., 100 m intervals), area (e.g., ac, ha), # of observers, etc. Ideally, this metric would account for all variables (time, distance, area, etc.) simultaneously. For additional information, see Burnham et al. (1980), Seber (1986, 1992), Buckland et al. (1993), Schwarz and Seber (1999), Buckland et al. (2001), Bart et al. (2004). However, abundance (corrected for effort) generally does not account for detection probability, $\check{N} = C$, where $\check{N}$ = abundance and C = count; this metric does not take into account β (detection probability) or explicitly/implicitly assumes β = 1 (100% detection).

4.4.2.1. Refinements for Shrub-Nesting Seabirds

Guidance applies to Brown Pelican and Neotropic Cormorant. Refer to abundance (corrected for effort) metric refinements for ground-nesting seabirds.

4.4.2.2. Refinements for Shrub-Nesting Wading Birds

Guidance applies to Great Egret, Little Blue Heron, Reddish Egret, Tricolored Heron, White Ibis, Snowy Egret, Cattle Egret, Great Blue Heron, Green Heron, Roseate Spoonbill, Yellow-crowned Night Heron, Black-crowned Night Heron, Glossy Ibis, and White-faced Ibis. Metrics include C or N species-1 hr^{-1} or km^{-1} or ha^{-1}; C or N nesting pairs/species-1 hr^{-1} or km^{-1} or ha^{-1}; C or N nests/species-1 hr^{-1} or km^{-1} or ha^{-1}. The specific avian response metric(s) will depend on monitoring objectives, study design, and survey methods and protocols. Abundance (corrected for effort) is usually expressed as C or N nesting pairs/species-1 or C or N nests/species-1 for individual colonies and all known colonies surveyed per year. See also Gibbs et al. (1988), Dodd and Murphy (1995), Rodgers et al. (1995), Frederick et al. (1996) for more information on ground versus aerial surveys for wading birds. See also Rodgers et al. (2005), Green et al. (2010), and Gawlik et al. (1998). For more information on breeding season survey techniques for seabirds and colonial wading birds, refer to Steinkamp et al. (2003).

4.4.2.3. Refinements for Marsh-Nesting Marsh Birds

Guidance applies to Pied-billed Grebe, Black Rail, Clapper Rail, King Rail, Purple Gallinule, Common Gallinule, Least Bittern, Seaside Sparrow, and Black-necked Stilt. Almost by default, monitoring of secretive marsh birds requires adhering to a rigorous survey design (e.g., Johnson et al., 2009) and standardized protocols/methodologies (e.g., Conway, 2009, 2011).

4.4.2.4. Refinements for Marsh-Nesting Waterfowl

Guidance here only applies to breeding Mottled Ducks. Metrics include C or N species-1 hr^{-1} or km^{-1} or ha^{-1}; C or N nesting pairs^{-1} hr^{-1} or km^{-1} or ha^{-1}; C or N nests^{-1} hr^{-1} or km^{-1} or ha^{-1}. The specific avian response metric(s) will depend on monitoring objectives, study design, and survey methods and protocols. Population size can be estimated using a combination of C-M-R methods (Lukacs, Dreitz, et al., 2004; Lukacs, Franklin, et al., 2004; Otis et al., 1978; K. Pollock, 1991) and Lincoln-Peterson estimator with subsequent correlations to count data (index values; e.g., Laysan Duck- Reynolds et al. 2015).

4.4.2.5. Refinements for Ground-Nesting Landbirds

Metrics of abundance (corrected for effort) include C or N species-1 time interval^{-1}, transect length^{-1}, or unit area^{-1}; C or N species singing males^{-1} species time interval^{-1}, transect length^{-1}, or unit area^{-1}; C or N breeding territories mapped species-1 time interval^{-1}, transect length^{-1}, or unit area^{-1} usually via fixed-radius point counts (e.g., Hutto et al., 1986) or fixed width transect surveys (e.g., Conner and Dickson, 1980). The specific avian response metric(s) used will depend on monitoring objectives, study design, and survey methods and protocols. By design, existing surveys (e.g., eBird, BBS, and CBC) likely do a good job of estimating species-specific population trends (i.e., BBS) for many, if not most, species.[6]

4.4.2.6. Refinements for Ground-Nesting Seabirds

Guidance applies to Least Tern, Gull-billed Tern, Royal Tern, Sandwich Tern, Black Skimmer, Caspian Tern, Forster's Tern, and Laughing Gull. Metrics of abundance (corrected for effort) include C or N species hr^{-1} or km^{-1} or ha^{-1}; C or N nesting pairs species-1 hr^{-1} or km^{-1} or ha^{-1}; C or N nests species-1 hr^{-1} or km^{-1} or ha^{-1}. The specific avian response metric(s) used will depend on monitoring objectives, study design, and survey methods and protocols. For individual colony assessments, this metric is usually expressed as C or N nesting pairs species-1 or C or N nests species-1 (Seavy & Reynolds, 2009). Surveys may be conducted using some combination of ground, boat/skiff/kayak, and aerial survey methods. The timing of seabird-nesting surveys is critically important (see Johnson and Krohn, 2001). Surveys should be conducted during peak nesting time for target species as part of standardized protocols. For more information on breeding season survey techniques for seabirds and colonial wading birds, refer to Steinkamp et al. (2003).

4.4.2.7. Refinements for Ground-Nesting Shorebirds/Solitary Beach-Nesting Birds

Guidance applies to American Oystercatcher, Wilson's Plover, and Snowy Plover. Metrics of abundance (corrected for effort) C or N species-1 hr^{-1} or km^{-1} or ha^{-1}; C or N nesting pairs species-1 hr^{-1} or km^{-1} or ha^{-1}; C or N nests species-1 hr^{-1} or km^{-1} or ha^{-1}. The specific avian response metric(s) will depend on monitoring objectives, study design, and survey methods and protocols. This metric is usually expressed as C or N nesting pairs/species-1 or C or N nests/species-1 for colonial-nesting shorebirds and all known colonies surveyed year^{-1}. There are existing shorebird-specific, season-specific, large spatial-scale standardized surveys (e.g., International Shorebird Survey [ISS]: Howe et al., (1989), Morrison et al. (1994); Program for Regional and International Shorebird Monitoring Arctic [PRISM]: Bart and Johnston (2012), PRISM (2018). In addition, there are regional standardized surveys for both breeding (e.g., Howe et al., 2000) and staging/wintering shorebirds (e.g., Audubon Coastal Bird Survey, 2015; Brush et al., 2016; FWC, 2022; Manomet, 2018).

4.4.3. Calculated Metrics: Abundance (Corrected for Detection Probability)

Definition: For the metric Abundance (corrected for detection probability), abundance/density (presence absence, occupancy estimation) accounts for potential observer bias and estimates detection probability, thus providing more rigorous abundance and density estimates for species with low (or unknown) detection probability (i.e., particularly species considered elusive or rare); refer to Lancia et al. (1994), Bart and Earnst (2002), MacKenzie and Kendall (2002), Williams et al. (2002),

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6 The BBS may not be appropriate for monitoring crepuscular and nocturnal species like Common Nighthawk, especially at site- or project-scale spatial scales. For nightjars in particular, we recommend users follow the survey dates, moonlight conditions, and monitoring protocols developed by the Nightjar Survey Network.

Royle and Nichols (2003), Tyre et al. (2003), MacKenzie and Nichols (2004), Thompson (2004), Field et al. (2005), MacKenzie (2005), Buckland et al. (2008), Thomas et al. (2010), Buckland et al. (2015), MacKenzie et al. (2018). This metric accounts for both effort and detection-related issues for which $\check{N} = C / \beta$, where $\check{N}$ = abundance, C = count, and β = detection probability. All methods to estimate bird abundance require estimation of detection probability associated with the count statistic; the assumption of β = 1 or 100% detection is derived and/or tested, as are factors affecting detection probability (β).

4.4.3.1. Refinements for Shrub-Nesting Seabirds

Guidance applies to Brown Pelican and Neotropic Cormorant. Refer to abundance (corrected for detection probability) metric refinements for ground-nesting seabirds.

4.4.3.2. Refinements for Shrub-Nesting Wading Birds

Guidance applies to Great Egret, Little Blue Heron, Reddish Egret, Tricolored Heron, White Ibis, Snowy Egret, Cattle Egret, Great Blue Heron, Green Heron, Roseate Spoonbill, Yellow-crowned Night Heron, Black-crowned Night Heron, Glossy Ibis, and White-faced Ibis. Metrics include C or N species-1 after accounting for both effort and β. Wading birds are often surveyed at colonies using aerial (helicopter or airplane) surveys, observers on foot, or via flight-line surveys from a boat/airboat. Survey methods using aerial (helicopter or airplane) or observers on foot have some known biases that must be addressed and acknowledged during survey design, as well as for data analysis and interpretation.

4.4.3.3. Refinements for Marsh-Nesting Marsh Birds

Guidance applies to Pied-billed Grebe, Black Rail, Clapper Rail, King Rail, Purple Gallinule, Common Gallinule, Least Bittern, Seaside Sparrow, and Black-necked Stilt. Metrics include C or N species-1 after accounting for both effort and β. Almost by default, monitoring of secretive marsh birds requires adhering to a rigorous survey design (e.g., Johnson et al., 2009) and standardized protocols/methodologies (e.g., Conway, 2011, 2009). In reality, the survey design and protocols selected depend on the targeted species (e.g., Black Rails is a challenging species to survey, particularly in the east-southeast U.S. due to extremely low densities [Atlantic Coast Joint Venture, 2020]).

4.4.3.4. Refinements for Marsh-Nesting Waterfowl

Guidance applies to Mottled Ducks only. Metrics include C or N species-1 after accounting for both effort and β. Waterfowl are frequently counted using ground-based counts (e.g., Aagaard et al., 2015) or aerial surveys. A modified Midwinter Waterfowl Inventory Aerial Survey with a statistical sampling frame can facilitate estimation of precision (Giudice et al., 2010; Pearse et al., 2009) and reduces potential biases (e.g., Eggeman et al., 1997; Hennig et al., 2017; Pearse et al., 2008; Zipkin et al., 2014). A number of states have decided to no longer participate in the Midwinter Waterfowl Inventory and some states have employed a modified winter waterfowl aerial survey. USFWS/Canadian Wildlife Service annually conduct the May Breeding Population and Habitat Survey via aircraft along transect lines within ~52 survey strata in the traditional survey area, as well as ~20 additional survey strata in eastern Canada (Graham et al., 1995; see https://www.ducks.org/conservation/waterfowl-surveys/2018/duck-numbers). These waterfowl aerial surveys attempt to address many of the biases and detection-related issues (e.g., via VCFs [Visibility Correction Factors]) not commonly considered in other aerial surveys. For more information, see Smith (1995). A similar methodology has been used for the Western Population of Mottled Ducks since ca. 2009 (USFWS, 2018). Population size for some species of waterfowl in North America can be estimated using the Lincoln-Peterson method, which involves a combination of banding and harvest data (e.g., Alisauskas et al., 2009, 2014; Sedinger et al., 2019).

4.4.3.5. Refinements for Ground-Nesting Landbirds

Guidance applies to Common Nighthawk. Metrics include C or N species-1 after accounting for both effort and β (Etterson et al., 2009; Farmer et al., 2012; Farnsworth et al., 2005; Kry, 2008; Royle, 2004; Schmidt et al., 2013).

4.4.3.6. Refinements for Ground-Nesting Seabirds

Guidance applies to Least Tern, Gull-billed Tern, Royal Tern, Sandwich Tern, Black Skimmer, Caspian Tern, Forster's Tern, and Laughing Gull. Metrics include C or N species-1 after accounting for both effort and β. Most frequently surveyed either via vessel-based at-sea surveys (strip-transect or fixed-width) or counts of breeding pairs and/or nests at colonies using standardized protocols.

4.4.3.7. Refinements for Ground-Nesting Shorebirds/Solitary Beach-Nesting Birds

Guidance applies to American Oystercatcher, Wilson's Plover, and Snowy Plover. Metrics include C or N species-1 after accounting for both effort and β. Shorebirds are often surveyed using ground-based counts (line-transect, distance-based methods, plot-based methods, etc.), aerial surveys, and boat-/raft-/kayak-based platforms depending on the time of year, targeted life-history period of study, and local habitat related factors.

4.4.4. Calculated Metrics: Species Composition

Definition: Total number of species detected or otherwise present (and associated count by species and/or percent by species) within a defined area during a given sampling interval/sampling frame. This guidance applies to ground- and shrub-nesting birds without refinement.

4.4.4.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies to Mottled Duck. Examples of ground-based counts are provided in Naugle et al. (2012) and Vrtiska and Powell (2011).

4.4.5. Calculated Metrics: Community Assemblage

Definition: A measure or index of the diversity of the avian community within a defined area during a given sampling interval/effort. This can include species richness (total number of species detected; see Boulinier et al., 1998) or species diversity indices (α, β, or γ diversity must be specified). A number of different equations/formulae are used to estimate different types of diversity, e.g., Shannon-Weiner ($H' = - [\Sigma \text{ Pi ln Pi }]$) and Simpson's ($D1 = 1\text{-}\{\Sigma n\ (n-1)\ N\ (N-1)\}$). Evenness (E) can be calculated from H´ where $E = H'/\log(S)$, where S is Species Richness. This guidance applies to ground- and shrub-nesting birds without refinement.

4.4.5.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies to Mottled Duck. Additional examples and resources for surveying community assemblage of marsh-nesting waterfowl are provided in Nudds (1980), Nudds (1982), Nudds (1983), Nudds (1992), Nudds and Bowlby (1984), Nudds and Wickett (1994), Nudds et al. (1994), Pys et al. (1994), and Bell et al. (1997).

4.5 STANDARD OPERATING PROCEDURES FOR TARGETED INFORMATION GATHERING AND MONITORING

4.5.1. Standard Operating Procedures for Presence/Absence or Abundance of Nesting Pairs

This included protocol is adapted from the Breeding Bird Survey Protocol from BTNEP Quality Assurance Project Plan (Contract No. 19-10 and 20-15), 2021. It is recommended to contact primary authors prior to implementation. This SOP applies to ground- and shrub-nesting birds. For marsh-nesting bird presence/absence SOP, refer to **Section 4.3.6.1**. Nest Density Quantification Protocol.

4.5.1.1. Coverage

For the breeding bird surveys, up to three individuals will cover all beach habitats depending on the width of the beach/dune/open flat habitats.

4.5.1.2. Methods

Instructions for data collection are as follow:

1. All field data sheets will be on Rite in the RainTM paper and labeled with a pencil to prevent the loss of information should the sheet come in contact with water.
2. Entry errors or changes will be crossed out with a single line, dated, and initialed by the person making the correction.
3. Please fill out all blanks at the top of the datasheet, ESPECIALLY YOUR GPS UNIT #!

4. Be sure to enter start and end time and take both a start waypoint and end waypoint.
5. For each encounter of a focal species, record a waypoint. You do NOT need to create a unique name for the waypoint, just record the automatically assigned waypoint number on your GPS.

Focal Species documented include the following species (with bird species alpha code):

- American Oystercatcher
- Black Skimmer
- Black-crowned Night Heron
- Brown Pelican
- Caspian Tern
- Common Nighthawk
- Forster's Tern
- Great Egret
- Gull-billed Tern
- Laughing Gull
- Least Tern
- Little Blue Heron
- Piping Plover
- Reddish Egret
- Red Knot
- Roseate Spoonbill
- Royal Tern
- Sandwich Tern
- Snowy Plover
- Sooty Tern
- Tri-colored Heron
- Wilson's Plover

6. Record coordinates of nests on datasheet.
7. Only one waypoint is necessary for a group of birds that appear associated with one another (a feeding or roosting group).
8. Confirm the species.
9. Take an accurate count of the focal species (enter in Total # in group column).
10. When entering information under the Location and Activity columns, please choose the description that applies to your immediate observation… where and what was the bird doing when you first observed it. Additional Location and Activity may be added – please put the initial observation first.
11. Locations[7] are defined as follows:

7 Refer to **Section 2**, **Figure 5** for a geographical depiction of coastal habitats.

- G (Gulf) – This location includes the gulf shoreline and tidal (saltwater and brackish) zones.
- B (Bay) – This location includes bay flats and back shorelines.
- O (Open) – This location is everything in between the gulf and bay.

12. Record all uniquely marked individuals present after recording the total number of banded/marked individuals in # Banded column.
13. Record any other item of interest in the Notes column on the backside of the datasheet. If you take photos of marked individuals, this is the place to record your camera's photo#.
14. TAKE AS MANY ROWS AS YOU NEED TO COMPLETE THE OBSERVATION. It is not important how many rows you need to take to make sure you have complete information for each waypoint.

4.5.1.3. Uniquely Marked Individuals

- Red Knots will (should) always have a flag with a 3-digit code on an upper leg if they are marked. The most likely flag colors expected on this survey are light green with black lettering or dark green with white lettering. However, some of the codes have faded over time or the engraving filled with dirt making them hard to read. There is a chance you could encounter a different color flag.
- Piping Plovers may have a uniquely coded leg flag or an uncoded leg flag with a series of other color bands on other parts of the legs. Wilson's Plovers have recently been marked with coded leg bands (not flags), and you may also encounter American Oystercatchers marked in this way.
- Please use the following methodology for recording marked individuals:
    - "F" for flag, followed by the color of the flag. For example, "FY" would mean a yellow flag.
    - If the flag (or band) is coded, please add the code in parentheses following the flag. For example, "FY(XYZ)."
    - "B" for alphanumeric band with code added in parentheses following the "B". For example, "BY(XYZ)."
    - If you cannot read the entire code, please use a "?" to denote that a digit is present but unreadable. For example, "FY(X?Z)" if you could not read the second digit.
    - Notation should be based on reading top to bottom of each "half" of the leg, from left to right (bird's perspective). Here are some examples:
        - FG(027):-/-:m This would mean a dark green flag with code 027 on the upper left, nothing on the lower left, nothing on the upper right, and a metal band on the lower right.
        - m:RY/FY:Bb This would mean a metal upper left, a red over yellow band lower left, an unmarked yellow flag upper right, and a dark blue over light blue band lower right.
    - Note: if you are 100% certain of a unique flag code, it is less important for you to also write down all the other color bands if present. Conversely, if you confirm all color bands including the color of the flag, it is less important for you to confirm the code on the flag.
    - It is sometimes easier to record band combinations by sketching a cross, which creates four quadrants. Then put the associated information in each quadrant (upper left, lower left, etcetera). That can be transcribed later.
    - Please notate somewhere on your datasheet any abbreviations (particularly for band information). For example: K= Black or B=Blue or b=Light Blue Data sheets for focal species will be printed on cardstock. An additional Shorebird Survey data sheet will be

provided to track non-focal species. These data are to be reported to eBird (an online database of bird observations used by scientists and amateur naturalists). Focal species data sheets will be collected. Non-focal species data will be collected by photographing data sheets and/or data notebook pages to provide as a record of this data collection. Data recorded on the field data sheets will be confirmed and agreed upon by all present as a means of quality control. Digital photographs will be used to confirm data collected in the field.

4.5.1.4. Non-Focal Species

A general survey datasheet has been provided to record all other species present if needed. It is not necessary to record any specific location data for these observations. Treat this portion of the survey as appropriate, for example, a Christmas Bird Count or an eBird checklist (with numbers of individuals for each species). BECAUSE THE INTENT FOR THIS SURVEY IS TO CAPTURE DATA FOR BREEDING BIRD FOCAL SPECIES, IT IS IMPORTANT TO KEEP FOCUS ON THIS TASK. For example, if a large mixed flock of *Calidris* sandpipers are observed, time should not be invested trying to decipher between species. In said situation, report the number of *Calidris* sp.

4.5.1.5. Safety

Please maintain awareness of the surroundings at all times between departing and returning to the dock. Always stay seated or braced with railings while underway on the boat and pay heed to any instructions given by the boat captain. The individual working the gulf side will be responsible for recording all data on Least Tern. The individual working the bay side will record all Wilson's Plover data. The individual in the middle will help both recorders during pair counts (Least Tern) and encounters with breeding pairs (Wilson Plover) as defined below.

The person in the middle will assist the other two surveyors through communication and will not be responsible for recording data on breeding birds. Assisting for Wilson's Plover (WIPL) includes helping keep track of individuals in a group defense situation. Assisting for Least Tern (LETE) includes averaging counts when the group stops every 300 paces/yards in a colony situation.

The individual in the middle will ideally be responsible for collecting information on each nest encountered by the team. As other team members encounter nests (individual on gulf side and individual on bay side), they will communicate with the middle team member pointing the nest out. If the conditions warrant (Example: If the team is located within a Least Tern colony and multiple Wilson's Plovers are in group defense, then it might be best for the individual who finds the nest to record the information). This will need to be worked out in the field. Data collected on each nest include GPS coordinates, species, and number of eggs or chicks. The GPS waypoint requires no special identification meaning that the waypoint ID generated automatically by the GPS will be used as well as documented on the form. No other information needs to be recorded (such as # or breeding criteria).

4.5.1.6. Wilson's Plover Protocol

An effort should be made to identify individual pairs/territories. If a pair is encountered, document pair in the comments section.

In some cases, additional male(s) or female(s) – (three or more) may be encountered – known as group defense. In this case, document the number of birds and sex of each, collect a GPS coordinate, and document that on the form. For instance, if six birds, three males and three females, are encountered, establish the GPS coordinates, documenting that site as three pairs. If an odd number of birds is encountered, collect the GPS coordinates and document the number/sex. If, after collecting/documenting the data and you begin moving along the beach and encounter the missing bird, adjust the data sheet by changing the number of birds and writing in the comments a description of why the additional bird was added (flew in, hidden behind dune, etc.). Additional birds are only added if one is detected less than 20 to 30 yards (steps) from the initial waypoint reading. Do NOT change the data in the GPS – only on the data sheet.

Example: three males and two females are detected – waypoint taken. An additional female is detected less than 30 yards of the prior waypoint on the back edge of vegetation. Add said female to the group of five by adjusting the number on the data sheet to read "6" and indicating in comments section "additional female located 10 yards away from group at edge of back bay vegetation." Be sure that said female is not associated with another male before adding her to the former group.

4.5.1.7. Least Tern Protocol

Pair counts for Least Tern should be compared between all three surveyors to ensure the best estimate. Depending on colony size, there will be up to two waypoints assigned for groups of Least Tern that indicate (a) beginning of colony and (b) end of a colony. When a colony is detected, a waypoint is recorded and an estimate of the number of pairs is reached by the two- to three-member team. For Least Tern colonies, no pair number will be included in the waypoint ID. Only the sequential waypoint number, Site ID, and Species ID will be used. For large colonies, an initial waypoint will be collected, the number of pairs will be estimated, and the surveyors will walk 150 paces/yards and take another count. The surveyor working the gulf side of the beach will be in charge of pacing distance and communicating with the rest of the team. The number of birds counted will be divided in half to determine number of breeding pairs at each stop and that number will be added in the notes section. An additional 150 paces/yard segments will be taken until birds are no longer following the surveyors. Once the surveyor counting paces recognizes that birds are no longer following, he/she should stop and record an end waypoint. Additionally, the final waypoint should include a note in the comments that specifies how many yards had been traveled before birds were no longer following the surveyor after the last 150-yard segment.

4.5.2. Standard Operating Procedures for Reproductive Success

The nest success SOP for ground- and shrub-nesting birds (**Section 4.5.2.1**) has been adapted and modified from Louisiana's Coastal Stewardship Program 2016 Summary Report from the National Audubon Society (see Johnson et al., 2017). This SOP applies to ground- and shrub-nesting birds without refinement.

The nest success SOP for marsh-nesting birds (**Section 4.5.2.2**) has been adapted and modified from Walters et al. (2001) and Hart et al. (2021). This SOP applies to marsh-nesting birds without refinement.

It is recommended to contact primary authors prior to implementation.

4.5.2.1. Nest Success Quantification Protocol for Ground- and Shrub-Nesting Birds

Adapted from Louisiana's Coastal Stewardship Program 2016 Summary Report from the National Audubon Society (see Johnson et al., 2017).

For each focal species, nest searches are done to determine nesting success, and known nests are revisited ideally every 3-4 days (depending on weather and other logistical limitations). Nests are marked with a GPS, and a numbered popsicle stick is placed approximately 2 m away for reference.[8] Strict protocols are followed when nest searching and monitoring including the use of Scent-a-way spray on closed-toe footwear, never walking directly toward a nest, and only making gradual curving turns when walking through a nesting area. These strategies minimize the likelihood of coyotes or other mammalian predators following surveyor footsteps and leading them to nests. A nest is considered successful if one or more egg hatches.

For nests that fail, the cause of failure is determined through a variety of clues, including eggshell fragments and footprints/tracks. Indeed these are not perfect determinations as more recent false evidence (e.g., coyote footprints) could overshadow a prior depredation event (e.g., from a ghost crab); however, general management conclusions can be drawn from a large enough sample as broad patterns emerge.

4.5.2.1.1. Fledging Success Quantification Protocol – Least Terns and Wilson's Plovers

For Least Terns and Wilson's Plovers, banding young enhances the ability to track individual birds and estimate their likelihood of fledging. To calculate the number of fledged Least Terns for each site, the following formula is used:

8 For shrub-nesting birds, nests can be marked with horizontally placed numbered flags attached to metal posts (Sachs & Jodice, 2009).

# of nests found × proportion of found nests to unfound nests × hatching success × # chicks hatched/nest x % banded chicks that fledged

- "# of nests found" – All marked nests, including those with unknown fates.
- "Proportion of found nests to unfound nests" – If it is not possible to determine how many nests are not marked in a colony, rough estimates that consider the number of incubating pairs in a colony each week can be used.
- "Hatching success" – Note that this is biased high because it does not account for nests that failed before they were found.
- "# of chicks hatched/nest" – Based on nest visitation observations.
- "% banded chicks that have fledged" – Based on band re-sighting of chicks >15 days old. Although this is about a week before true fledging, survivorship to fledging at this point should be high, and movements away from the study area create problems for underestimating fledging rates, thus this can be expected to be biased low because of imperfect detection probability.

This estimate is then divided by the total number of pairs at each site, producing the number of fledglings/nesting pair. Note that variables (3) and (5) are biased estimators, but likely roughly off-set each other. Future analyses will use mark-recapture techniques to estimate daily nest success and daily apparent survivorship.

For Wilson's Plovers, the fledgling success is tracked of individual territories through marked adults, marked young, or both, where possible. Not all individuals of a territory are marked if they can be distinguished from family groups. Ultimately, young are considered fledged if they are confirmed as seen for at least 20 days and/or parents continue to show territorial/parental behavior beyond 25 days. These relatively early dates are used for fledgling because survivorship rates should be fairly high, and low detection probabilities and fledgling dispersal biases fledging estimates downward when using 28 or more days as the criterion. In some cases, the number of young in a territory cannot be accurately counted, but it may be possible to ascertain the presence of at least one based on protective and/or territorial behavior by the adults. In this case, a range of possible estimates for that pair are created. If it is not possible to successfully assess the fate of every single pair that is found, breeding productivity can be calculated from a subset of territories with suspected (by behavior and territory stability) or confirmed nesting pairs (with nests or young found) and with known breeding success fates (i.e., whether or not chicks fledged).

4.5.2.2. Nest Success Quantification Protocol for Marsh-Nesting Birds

Adapted from Walters et al. (2001).

Areas are systematically searched by two to seven people walking 2–3 m apart and beating the vegetation with polyvinyl chloride poles to flush nesting females. Searches are conducted between 8 a.m. and 3 p.m. to increase likelihood of females being on the nest. Areas are searched two to five times at approximately 3-week intervals. Nests are permanently marked with a numbered polyvinyl chloride pole 5 m due north. At each nest, the number of eggs and estimated embryonic development by candling eggs are recorded. Nests are monitored at 7- to 10-day intervals until fate can be determined. Nest fate is determined as successful (≥one egg hatched), depredated, flooded, abandoned, or abandoned due to observer activities, which includes all nests where the female never uncovers her eggs after the nest is first found. Nests are excluded from analyses of success if they were abandoned due to observer activities, had only infertile eggs, or fate could not be determined.

Adapted from Hart et al. (2021).

Nests are monitored annually from 15 March to 30 June; this timeframe encompasses the majority of the Seaside Sparrow nesting season in this region. Nests are located by systematic searching and using behavioral cues from adult Seaside Sparrows. Seaside Sparrows have 12-day incubation and 9-day nestling periods and a modal clutch size of three eggs (range one to four; 132 of 252 nests had three eggs). Nests are monitored every 2–3 days until fate can be determined. Nests are classified as having fledged at least one nestling as determined by: (1) sighting of fledglings near the nest, (2) adults carrying food to the area after the predicted fledge date, (3) begging sounds of fledglings in the surrounding vegetation, (4) the presence of fledgling fecal matter in or on the rim of the nest or on the surrounding vegetation, or (5) documentation of fledging via video monitoring. Nests are classified as failed if: (1) eggs or nestlings disappear from the nest before fledge day with no evidence of early fledging, (2) eggshells or nestling remains are present, or (3) nests are torn, tilted, flooded, or otherwise destroyed before the fledge date. Continuously recording camera systems are used on a subset of nests to identify nest predators. Nests are randomly selected for video monitoring after first constraining the list of available nests to ones that are: (1) in incubation stage or with nestlings no older than 5 days (to avoid the risk of abandonment or early fledging), and (2) in locations without temporary standing water (which makes installing recording systems difficult). The monitoring system consisted of a small (ca. 12 x 6 cm) security camera with infrared LEDs for nighttime recording mounted on a garden stake (typically no more than 20 cm away due to dense vegetation) and a waterproof case containing a digital video recorder and batteries placed 25 m from the nest. Batteries and data storage cards are replaced every 5–7 days as long as the nest is active.

4.5.3. Standard Operating Procedures for Survival (Adults, Juveniles, and/or Chicks)

This SOP for adult survival quantification is adapted and modified from Liechty et al. (2017). It is recommended to contact primary authors prior to implementation. This SOP applies to ground- and shrub-nesting birds without refinement.

4.5.3.1. Fledgling/1st Year Survival Quantification Protocol

Unable to find a generalizable SOP for data collection.

4.5.3.2. Juvenile/Subadult Annual Survival Quantification Protocol

Unable to find a generalizable SOP for data collection.

4.5.3.3. Adult Annual Survival Quantification Protocol for Ground- and Shrub-Nesting Birds

Adapted from Liechty et al. (2017)

Banding and resighting: Adult Royal and Sandwich Terns are captured from breeding colonies by hand or using dip nets, during late incubation and early chick-brooding (between 21 May and 18 June), when they strongly defend their young chicks. All terns are banded with a USGS aluminum band and three plastic color bands in unique combinations to create field-readable marks. Plastic color bands are sealed with acetone and heat-sealed with a portable battery-powered soldering iron. Field-readable color band combinations eliminate the need for physical recapture; recaptures and re-sightings are referred to collectively as re-encounters. All breeding colonies are surveyed approximately once per week during the breeding season (April through July) to locate previously banded individuals. Using 8 × 42 binoculars and 20–60 spotting scopes, observers survey terns loafing near colonies, brooding eggs in colonies, and feeding and guarding chicks in crèches. Due to the difficulty of spotting banded terns within the large, densely packed colonies, many re-sightings include birds loafing near the periphery of the colony area. These individuals are assumed to be local breeders.

4.6 ANALYSIS OF TARGETED INFORMATION GATHERING AND MONITORING DATA

Targeted monitoring is generally project-level or event-based and addresses knowledge gaps to inform an adaptive management framework (**Figure 74**). These priorities include future restoration project planning and design, adaptive management, and unknown future conditions.

Depending on the objectives, feasibility, and funds available, targeted information gathering and monitoring may include a broad suite of avian response metrics. The following sections describe calculated metrics that are applicable for targeted monitoring and analysis for ground-nesting, shrub-nesting, and marsh-nesting birds. Modified monitoring or data collection methodologies are also provided for specific sub-groupings of birds (i.e., shorebirds and waterfowl). Cross-links to text descriptions of each metric are provided in **Table 31**.

Table 31. Section headings (cross-linkages) for calculated targeted analysis metrics information across bird groups.

Section Heading	Metrics					
	Nest Density	Nest Success	Fledging Success	Fledgling / 1st Year Survival	Juvenile Subadult Annual Survival	Adult Annual Survival
Shrub-nesting High Level	4.6.1.1	4.6.2.1	4.6.2.2	4.6.3.1	4.6.3.2	4.6.3.3
Marsh-nesting High-Level	4.6.1.1	4.6.2.1	4.6.2.2	4.6.3.1	4.6.3.2	4.6.3.3
Refined for waterfowl	4.6.1.1.1	N/A	4.6.2.2.1	4.6.3.1.1	4.6.3.2.1	4.6.3.3.1
Ground-nesting High-Level	4.6.1.1	4.6.2.1	4.6.2.2	4.6.3.1	4.6.3.2	4.6.3.3
Refined for shorebirds/ solitary beach-nesting birds	N/A	4.4.2.7	N/A	N/A	N/A	N/A

4.6.1. Presence/Absence or # of Nesting Pairs

Pursuant to FWC (2022) presence/absence surveys are conducted to indicate whether or not there are nests in a given area. Areas marked as present indicate that there is at least one nest, whereas areas marked as absent indicate zero nests. Direct Counts are used to detect adults, nests, and chicks and can be used for solitary or colonial ground-nesting birds. Counts for colonies, adults, and chicks require at least two counts, which are averaged together (it is helpful to have multiple observers to account for observer bias) and nests and chicks should be counted separately (i.e., not at the same time). If counting a colony, the observer should be positioned in an area where the entire colony is in view. If it is not possible to view the entire colony, an Extrapolated Count can be done. This approach requires a calculation to determine the total count based on the proportion of the colony that is visible. To do this, the observer must determine a count area in which they can perform a Direct Count, determine the percentage of the colony that this area covers, and then divide the Direct Count by that proportion to calculate the Extrapolated Count. An Extrapolated Count assumes that birds and/or nests are uniformly distributed across the extrapolated area, which may not always be the case.

4.6.1.1. Calculated Metrics: Nest Density

Definition: The number of nests in a given unit area (ac, ha) during a given sampling interval/effort. This guidance applies to ground- and shrub-nesting birds without refinement.

4.6.1.1.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies to Mottled Duck. This metric is the number of nests (per ac or ha) found, irrespective of nest stage or nest age when the nest was found, summed across all nests for a given species in a given year based on a sample of individually marked and frequently visited nests on the study area (Arnold et al., 2007; A. Klett et al., 1986). Refer to Holbrook et al. (2000) and Walters et al. (2001) for nest density estimates for Mottled Ducks.

4.6.2. Reproductive Success

4.6.2.1. Calculated Metrics: Nest Success

Definition: The proportion of clutches that produce young. This metric is generally thought of as a binary response variable: either a nest was successful or it was not. However, nests can have multiple fates. Nest success is not equivalent to hatching success. Some authors define a successful nest as a nest in which ≥one egg hatched (A. Klett et al., 1986, 1988). However, nest success is usually determined from a sample of marked and monitored nests calculating apparent, Mayfield, or Daily Survival Rates (e.g., Program MARK; Cooch & White, 2014, Chapter 17) with the latter considered most appropriate and least biased. For additional information, refer to Kellett and Alisauskas (2019), as well as Jehle et al. (2004), Thompson et al. (2001), Streby and Anderson (2011), Streby and Anderson (2013), Streby et al. (2014). For a review of Mayfield and other nest survival estimators, see Jones and Geupel (2007). This guidance applies to shrub-nesting birds and most ground-nesting birds without refinement.

4.6.2.1.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies only to Mottled Duck. A successful nest for marsh-nesting waterfowl is defined as a nest in which >one egg hatched (A. Klett et al., 1986, 1988). Estimating nest success include the following options in order from most to least biased, from least to most intensive, and from least to most rigorous apparent nest success (A. Klett et al., 1986), Mayfield nest success (D. H. Johnson, 1979; A. Klett et al., 1986, 1988), and daily survival rate of nests in Program MARK (Cooch & White, 2014, Chapter 17; Dinsmore et al., 2002; Dinsmore & Dinsmore, 2007; Kellett & Alisauskas, 2019; Rotella, 2009; Rotella et al., 2004). For Apparent Nest Success, P1 = Ns /(Ns + Nu); for Mayfield, P2 = (1 - Nu/E)h; and for Modified Mayfield, P3 = [P1 1(h-f)]h (see A. Klett et al. 1986, table B-3). Equations and more details for calculating daily survival rate can be found in Dinsmore et al. (2002). Refer to Bonczek and Ringelman (2021); Durham and Afton (2003); Holbrook et al. (2000); Walters et al. (2001) for Mayfield nest success estimates for Mottled Ducks.

4.6.2.1.2. Refinements for Ground-Nesting Shorebirds/Solitary Beach-Nesting Birds:

Guidance applies to American Oystercatcher, Wilson's Plover, and Snowy Plover. For additional information on estimating nest success for ground-nesting shorebirds, see Liebezeit et al. (2009). For additional information on hatching success, see Owen and Pierce (2013).

4.6.2.2. Calculated Metrics: Fledging Success

Definition: The number of fledglings leaving the nest^{-1}, number of fledglings/breeding pair^{-1}, or number of nestlings that survive to achieve flight stage and independence from the nest and/or adults. The definition of this metric should be explicitly defined any time this metric is used for additional clarity related to data interpretation (refer to Cooke et al. 1995). This term represents a specific life-history period or interval of time; the interval is species-specific and dependent upon a species' life-history strategy. This guidance applies to ground- and shrub-nesting birds without refinement.

4.6.2.2.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies only to Mottled Duck. This metric includes the number of ducklings known to have left the nest (i.e., ducklings leaving nest), summed across all nests for a given species in a given year, based on a sample of individually marked and frequently visited nests on the study area (e.g., Cooke et al., 1995; Gleason et al., 2004; Hoekman et al., 2002; Leafloor et al., 2000). This metric is really only relevant if nest-searching and nest-visitation span the entirety of the nesting sequence from nest initiation, egg-laying, and incubation through hatching and departure from nests.

4.6.3. Survival (Adults, Juveniles, and/or Chicks)

4.6.3.1. Calculated Metrics: Fledgling/1st Year Survival

Definition: Number of young raised to independence from adult care, survival for a given interval post fledging (30, 45, 60, 90, 120 days, etc.) or from nest departure to Age 1. The life-cycle interval or period for fledgling is frequently study-dependent; for example, refer to White and Burnham (1999) and Cooch and White (2014). Survival (S) is the probability that a marked individual survives some interval of time, (e.g., one year). S is frequently modeled as a function of some combination of sex (categorical/ main effects—IF KNOWN), site/area/colony/nest # (categorical/main effects), morphological measurements (continuous/covariate, e.g., Culmen 1, Total Tarsus, Flat Wing Length, 9th Primary, Head Length, and Body Mass or PC1 of some combination; see Dzubin and Cooch (1992), Brook et al. (2019), age-related (continuous/covariate, e.g., Hatch Date [Julian], Days Since Hatch, Days Since Peak Hatch), habitat or resource-related (categorical or continuous/covariate, e.g., wetland conditions like number of wet basins or wetland basin fullness, estimates of food abundance, salinity level, etc.), weather and/or environmental conditions (categorical or continuous/covariate, e.g., number of days ≥35 degrees Celsius (°C), number of days <10°C; number of precipitation days, hurricane impacts 1= yes, 2 = no), etc. The model should include only those biologically meaningful/relevant variables (and their interactions) that are relevant to the specific objectives/hypotheses and should take into account potential for both over- and under-fitting (Brownie et al., 1985; Burnham & Anderson, 2002; Cooch & White, 2014; Lebreton et al., 1992). For some species of birds, three age-class models (juvenile, subadult, adult) are likely more appropriate and realistic given their avian life-history versus two age-class models (juvenile and subadult pooled, adult; Dooley et al., 2019). This guidance applies to both ground- and shrub-nesting birds without refinement.

4.6.3.1.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies only to Mottled Duck. Duckling Survival (e.g., Gendron and Clark, 2002; Pietz et al., 2012) and Brood Survival (e.g., Krapu et al., 2000) are usually estimated for a given interval (e.g., 30 days) from transmittered hens (frequently identified with nasal markers) and daily/biweekly/weekly brood/duckling counts (of marked females with broods) or via transmittered ducklings (one duckling /brood or one male and one female/brood; e.g., Davis et al., 2007; Hoekman et al., 2004; Howerter et al., 2014).

4.6.3.2. Calculated Metrics: Juvenile/Subadult Annual Survival

Definition: The juvenile/subadult period timeframe spans from fledging to the point at which sexual maturity is reached. This interval or period is species-dependent and life-history strategy dependent (see White and Burnham, 1999 and Cooch and White, 2014). Survival (S) is the probability that a marked individual survives some interval of time, e.g., Year 1, Year t+1. S is frequently modeled as a function of some combination of sex (categorical/main effects—IF KNOWN), age at marking (categorical/main effects, e.g., local, HY, or Days Since Hatched [continuous/covariate] IF KNOWN, etc.), site/area/colony (categorical/main effects), morphological measurements (continuous/covariate, e.g., Culmen 1, Total Tarsus, Flat Wing Length, 9th Primary, Head Length, and Body Mass/Body Condition Index or PC1 of some combination; Dzubin and Cooch, 1992), habitat or resource-related (categorical or continuous/covariate, e.g., wetland conditions like number of wet basins or wetland basin fullness, estimates of food abundance, salinity level, etc.), weather and/or environmental conditions (categorical or continuous/covariate, e.g., number of days ≥35°C, number of days <10°C; number of precipitation days, impacts by hurricanes 1= yes, 2 = no), etc. The model should include only those biologically meaningful/relevant variables (and their interactions) that are relevant to the specific objectives /hypotheses and should take into account potential for both over- and under-fitting (Brownie et al., 1985; Burnham & Anderson, 2002; Cooch & White, 2014; Lebreton et al., 1992). For some species of birds, three age-class models (juvenile, subadult, adult) are likely more appropriate/realistic given their avian life-history versus two age-class models (juvenile and subadult pooled, adult; Dooley et al., 2019). This guidance applies to ground- and shrub-nesting birds without refinement.

4.6.3.2.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies only to Mottled Duck. First-Year Survival or Subadult Survival (from fledging to sexual maturity; e.g., M. G. Anderson et al., 2001; Blums et al., 2002, 1996; Dufour and Clark, 2002) can be estimated with telemetry, banding and color marking, or legbands-only (Brownie et al., 1985; Lebreton et al., 1992; Otis et al., 1978). Depending on the study design and objectives, one may use dead recovery models, joint models, multi-state or robust design models in Program MARK (Cooch & White, 2014).

4.6.3.3. Calculated Metrics: Adult Annual Survival

Definition: Survival beginning at the point an individual reaches sexual maturity and may continue into senescence. This interval or period is species-dependent and life-history strategy dependent (see White and Burnham [1999] and Cooch and White [2014]). Survival (S) is the probability that a marked individual survives some interval of time, e.g., Year 1, Year t+1, Year t+2...etc. S is frequently modeled as an Fx of some combination of sex (categorical/main effects—IF KNOWN), age at marking (categorical/main effects- e.g., local, HY, AHY, ASY, etc.), reproductive status of females (categorical/main effects—IF KNOWN), site/area/colony (categorical/main effects), morphological measurements (continuous/covariate, e.g., Culmen 1, Total Tarsus, Flat Wing Length, 9th Primary, Head Length, and Body Mass/Body Condition Index or PC1 of some combination; Dzubin and Cooch, 1992), habitat or resource-related (categorical or continuous/covariate, e.g., wetland conditions like number of wet basins or wetland basin fullness, estimates of food abundance, salinity level, etc.), weather and/or environmental conditions (categorical or continuous/covariate, e.g., number of days ≥ 35°C, number of days <10°C; number of precipitation days, impact by hurricanes 1= yes, 2 = no), etc. The model should include those biologically meaningful/relevant variables (and their interactions) that are relevant to the specific objectives/hypotheses and should take into account over- and under-fitting (Brownie et al., 1985; Burnham & Anderson, 2002; Cooch & White, 2014; Lebreton et al., 1992). For some species of birds, three age-class models (juvenile, subadult, adult) are likely more appropriate/realistic given avian life history than two age-class models (juvenile and subadult pooled, adult; Dooley et al., 2019). This guidance applies to ground- and shrub-nesting birds without refinement.

4.6.3.3.1. Refinements for Marsh-Nesting Waterfowl

Guidance applies only to Mottled Duck. Adult Female Breeding Season Survival (e.g., Devries et al., 2003) and Adult Male & Female Annual Survival (e.g., McDougall and Amundson, 2017; Traylor et al., 2012) can be estimated with telemetry, banding and color marking, or legbands-only (Brownie et al., 1985; Lebreton et al., 1992; Otis et al., 1978; K. H. Pollock et al., 1990). Depending on the study design and objectives, one may use recovery models, joint models, or multi-state or robust design models in Program MARK (Cooch & White, 2014).

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