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Research article

Leveraging co-production within ecosystem restoration to maximize benefits to coastal birds☆

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ABSTRACT

Coastal Louisiana's ecosystems are threatened by anthropogenic factors exacerbated by climate change induced sea-level rise. The 2010 *Deepwater Horizon* oil spill resulted in injuries and deaths to coastal birds in Louisiana, and the ongoing loss of habitat has limited the potential for successful nesting of resident birds throughout the coast. Habitat loss is being addressed through increased large-scale ecosystem restoration as a result of settlement funds from the *Deepwater Horizon* oil spill. To further inform bird restoration in Louisiana, an avian restoration guidance document (*Guidance for Coastal Ecosystem Restoration and Monitoring to Create or Improve Bird-Nesting Habitat*, 2023) was developed to maximize restoration benefits for coastal breeding birds while also achieving broader habitat restoration objectives. The developed restoration guidance was co-produced by subject-matter experts and professionals, including avian experts, engineers, and coastal restoration project managers. The result of this cross-disciplinary effort was specific and targeted guidance that presents designable habitat features that are in the control of project engineers and are also important high-value bird nesting habitats (e.g., shoreline access, elevation heterogeneity and edge habitat). For the first time in Louisiana, defined nest-site characteristics and monitoring approaches are readily available to inform ecosystem restoration project implementation. The restoration document specifically emphasizes bird species that breed and nest in coastal habitats in Louisiana, and restoration managers can use these guidelines to explicitly incorporate bird nesting habitat features into coastal restoration planning, design, and implementation. In developing this guidance, many knowledge gaps and data needs were identified specific to engineering and project design, enabling the research community to frame research questions around specific coastal restoration questions. The co-production of science model applied here for avian resources is applicable to a wide range of other living marine resources that may benefit from large-scale ecosystem restoration and is an example of the benefits of working relationships, communications, and common goal setting.

1. Introduction

Coastal restoration, specifically large-scale ecosystem restoration for recovery of coastal lands and habitats, is employed globally as a mitigation and adaptation response to climate change (Ismail and Putra, 2022; Lovelock et al., 2022; Rudianto et al., 2022). In response to climate change and a coastal land loss crisis that has claimed nearly 5000 km^2 of land since the 1930s, the State of Louisiana is in the process of implementing a large-scale coastal restoration plan known as the *Louisiana Coastal Master Plan* (Coastal Protection and Restoration Authority [CPRA], 2023a). As part of implementing its Coastal Master Plan, and following a $6.8 billion settlement from the 2010 *Deepwater Horizon* (DWH) oil spill, Louisiana has focused many restoration efforts on natural resources including habitats and associated wildlife that were injured as a result of the spill (Henkel and Dausman, 2020).

Several of the bird species impacted by the DWH oil spill, including

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Seaside Sparrows (*Ammospiza maritima*), Reddish Egrets (*Egretta rufescens*), and Gull-billed Terns (*Gelochelidon nilotica*), have exhibited decreasing population trends due to habitat losses and are identified as birds of conservation concern by both state and federal agencies (Holcomb et al., 2015; U.S. Fish and Wildlife Service, 2021). The types of birds injured because of the spill, including those mentioned, vary greatly in their morphology, biology, and overall use of coastal habitats. To meet the broad suite of specialized needs by birds and benefit the maximum numbers of species, bird habitat restoration efforts must be variable in their design. However, the effects and overall benefits of restoration activities can be difficult to assess, and evaluating restoration success from a biological standpoint is both a challenging and highly variable process often dictated by pre-determined metrics or goals (Block et al., 2001; Ruiz-Jaen and Aide, 2005; Wortley et al., 2013; Zedler, 2007).

Historically, habitat restoration projects in Louisiana have prioritized acreage as the primary metric for success, with the assumption that if land was created, birds will occupy restored sites and thus, ultimately benefit from restored (or created) sites ("Field of Dreams Hypothesis"; see Ahlering and Faaborg, 2006). However, wildlife use, timing of occupancy, and life-history stage benefited (e.g., staging, wintering, breeding) at restored sites differ over the life of the project, and optimal conditions often require specific habitat features that vary by species and through time (Cross et al., 2022; Kneib, 2003; Winchell and Doherty, 2018). Breeding birds, for example, require habitats with specific vegetation, sediment, and elevation characteristics that are suitable for nest establishment and chick rearing (Beaver et al., 1980; Fournier et al., 2021a; Owen and Pierce, 2013; Visser and Peterson, 1994). The complex nature of restoring habitat for a variety of bird species necessitates knowledge sharing and collaboration between restoration engineers, avian habitat biologists, and avian ecologists.

Case studies imply that given the broad reaches of birds across physical, political, and academic boundaries, bird-related conservation issues and research gaps are especially well suited for collaborative, or co-produced science approaches (Saunders et al., 2021). In addition, co-production of science for ecosystem restoration has led to promising outcomes that often include interdisciplinary solutions and tools that help to inform decision making and meet project goals (Durrant et al., 2023; Lavorel et al., 2020; Ladouceur et al., 2022; Manuel et al., 2023).

The DWH Programmatic Damage Assessment and Restoration Plan (PDARP) identifies habitat and bird restoration goals (DWH NRDA Trustees, 2016). To meet the goals of the PDARP, the Louisiana Trustee Implementation Group (LA TIG), which makes restoration decisions and identifies monitoring and adaptive management priorities for Louisiana, identified the need for a comprehensive decision-making tool developed through a collaborative, co-production approach. This resulted in the *Guidance for Coastal Ecosystem Restoration and Monitoring to Create or Improve Bird-Nesting Habitat* (herein referred to as the "restoration guidance"), which was developed as a part of a joint effort across state, federal, academic and non-governmental organizations, with funding support from the LA TIG (DWH LA TIG, 2023a). The primary objective of the developed restoration guidance was to inform restoration project design and monitoring for nesting birds within coastal marsh, barrier island, and ridge habitats.

2. Materials and methods

The developed restoration guidance collates and presents bird nesting habitat considerations for targeted use by restoration project teams. The primary methodological approach in the development of the restoration guidance was co-production (i.e., collaboration between subject-matter experts (SMEs), managers, and restoration project staff), which greatly informed the decision-making process around information synthesis and presentation. This process spanned more than two years, from summer 2020 to spring 2023. In this timeframe, more than 100 facilitated calls and working sessions were conducted with 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 (Table 1).

Members of the project team were selected for their respective knowledge, experience, and willingness to contribute to the collaborative process. The developed restoration guidance additionally required an intensive drafting and review process that included the full project team members, as well as SMEs and graphic design support from Audubon Delta, Barataria-Terrebonne National Estuary Program, and University of Maryland Center for Environmental Science.

There were numerous discussions held by the project team members with regards to how the synthesized information could best be presented, and the document underwent a series of iterations and layout changes. Both bird SMEs and habitat restoration practitioners agreed that the final product should be a navigable document with a primary series of information tables and figures supported by explanatory text.

Common terminology involving bird groupings and habitat classifications that both CPRA and bird biologists recognize were developed and prioritized to promote a common understanding across end-users (see Fig. 1). This was achieved through a series of discussions and meetings that involved all SMEs. First, a select list of coastal nesting birds was selected for representation in the developed restoration guidance using the Strategic Framework for Bird Restoration Activities (DWH LA TIG, 2017). Bird and habitat restoration SMEs were then selected from the project team members to represent each bird group in subsequent discussions and information collection/synthesis. Then, with additional guidance from CPRA, multiple coastal restoration resources (i.e., the Louisiana Barrier Island Comprehensive Monitoring Program; Enwright et al., 2020) were evaluated to determine the most representative habitat classifications to be used in the developed restoration guidance. Habitat types were categorized at a larger scale by landforms (coastal wetland, coastal bay island, barrier island/headland, and overwash fans) to be evaluated across the three bird groups.

Following a deliberate clarification of needs from all stakeholders and a consensus on terminology, nesting birds identified in the *Strategic Framework for Bird Restoration Activities* (DWH LA TIG, 2017) were categorized into three groups based on the habitats in which they nest: 1) shrub-nesting birds, 2) marsh-nesting birds, and 3) ground-nesting birds (Table 2). This decision aligned bird groups with specific and

Table 1
The background expertise and designations of roles for the primary project SMEs.

Agency/Organization	Expertise	Project Roles
Louisiana Department of Wildlife and Fisheries	• Program management • Wildlife habitat restoration • Ornithology	• Project oversight and management • Bird SME • Document review
CPRA	• Coastal restoration	• Coastal restoration SME • Document review
Louisiana State University College of Agriculture	• Marsh bird and habitat relationships	• Bird SME • Document review
United States Geological Survey	• Marsh bird and habitat relationships	• Bird SME • Document review
Department of the Interior	• Louisiana trustees • Program management • Wildlife habitat restoration • Ornithology	• Project oversight • Bird SME • Document review
The Water Institute	• Project coordination • Coastal ecology • Ornithology • Coastal restoration • Technical writing and editing	• Team member coordination • Information synthesis • Bird SME • Coastal restoration SME • Document writing and editing

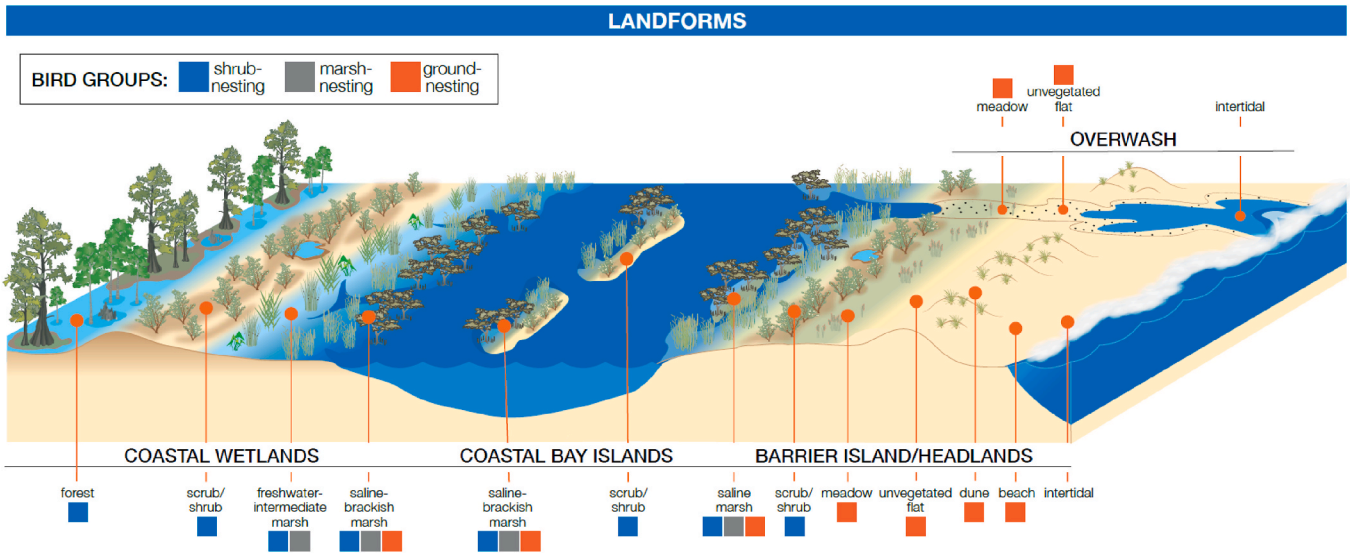

Fig. 1. Common terminology and identified habitat distributions and associated shrub-, marsh-, and ground-nesting birds as presented in the restoration guidance.

Table 2
Bird groupings and descriptions/example species generated as a result of co-production by restoration project teams and avian biologists, subsequently used to convey information in the developed restoration guidance.

Bird Group	Description	Example Species
Shrub-nesting birds	Coastal bird species 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).	Brown Pelican (*Pelecanus occidentalis*) Reddish Egret (*Egretta refescens*) Great Blue Heron (*Ardea herodias*)
Marsh-nesting birds	Coastal bird species 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).	Clapper Rail (*Rallus crepitans*) Purple Gallinule (*Porphyrio martinica*) Seaside Sparrow (*Ammospiza maritima*)
Ground-nesting birds	Coastal bird species that nest primarily 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).	Royal Tern (*Thalasseus maximus*) Black Skimmer (*Rynchops niger*) Wilson's Plover (*Charadrius wilsonia*)

designable locations/habitat features, enabling restoration project teams to consider design elements during the project planning stage for target bird species.

The three bird groups (shrub-nesting, marsh-nesting, and ground-nesting) were then evaluated across the identified habitat landforms (Fig. 1). This diagram helps to illustrate the distribution of bird groups across a typical coastal profile, and the habitats in which those birds may nest.

The resulting guidance for restoration was then presented among four interrelated tables for each bird group: 1) Habitat Considerations, 2) Design Considerations, 3) Lessons Learned, and 4) Data Gaps/Research Needs. Descriptions of these tables is provided in Table 3 and the complete tables are available for reference in the Supplemental file, section 2.

Table 3
Tables presented for each bird group and their purpose, as described in the developed restoration guidance.

Table Title	Purpose
Habitat Considerations	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
Design Considerations	Summarizes aspects of project planning, engineering and design, operation and maintenance, and implementation that are within the control of the project team
Lessons Learned	Summarizes lessons learned from implemented restoration projects in coastal Louisiana
Data Gaps/Research Needs	Summarizes the current state of knowledge and/or assumptions related to bird biology or ecology relevant to ecosystem restoration projects

3. Results and discussion

The outcome of this effort was comprehensive guidance for restoration practitioners detailing how to implement coastal restoration to maximize habitat value for nesting birds (DWH LA TIG, 2023b). The purpose of the developed restoration guidance is to inform ecosystem restoration project planning, engineering and design, construction, and operations and maintenance to support nesting of target coastal bird species. Prior to the development of this restoration guidance, there was no specific document or tool that project teams could reference to create bird nesting habitat and to enhance benefits to birds.

3.1. Co-production outcomes

The development and publication of the restoration guidance required collaborative input from SMEs from multiple state and federal agencies including CPRA, Louisiana Department of Wildlife and Fisheries (LDWF), and Department of the Interior (DOI). Relationship and trust building, critical steps in the co-production process, occurred in the form of team engagement and assurance that each member had an equal voice towards the contribution of the developed restoration guidance (see Fournier et al., 2021b; Fournier et al., 2023; Westwood et al., 2020). This productive working environment fostered the team's ability to clearly identify, refine, and begin to address avian restoration priorities.

This effort can be compared to other case studies in which co-production has been employed for natural resource management. For

example, in an effort to conserve sagebrush ecosystems in North America, the U.S. Department of Agriculture relies heavily on a "co-production approach", which they emphasize needs to 1) have a shared vision, 2) be collaborative and partner driven, 3) be strategic and targeted, 4) be outcome focused, and 5) be product driven (Naugle et al., 2020). Some researchers argue that for effective co-production, processes and outcomes should be prioritized over products (Beier et al., 2017). Although the goal of this effort was the creation of the developed restoration guidance, the collaboration aspect was fundamental to reach that goal, and will continue to be necessary as future iterations of the developed restoration guidance are generated.

3.2. Research applications

Ongoing research is being conducted along the northern Gulf of Mexico to advance the current state of the science and fill-in data gaps about bird nesting habitat needs. As this information is collected, it can be incorporated into the decision-making process for coastal restoration progressing adaptive management of this natural resource (Carruthers et al., 2020). The developed restoration guidance was created to facilitate an adaptive management workflow, providing an explicit framework for knowledge improvement based on a continuous cycle of research, monitoring, and project implementation (Fig. 2).

To successfully implement adaptive management based on assessment of restoration success in supporting nesting birds, effective monitoring is needed. As such, proposed monitoring approaches are included in the restoration guidance document which can be applied as part of programmatic and project-scale planning and reporting. This information, in addition to the identification of data gaps, can lead to enhanced planning and targeted restoration activities in the future.

The tables summarizing the co-developed restoration guidance (see Supplemental, section 2) are intended to serve as the key source of information for project teams who may be looking to understand how specific restoration efforts can be modified to maximize nesting opportunities for targeted bird species. End-users can use the tables as a reference for improving future project decisions, as informed by lessons learned from existing projects (e.g., Queen Bess Island Restoration, CPRA Project ID: BA-0202) and land assessments (e.g., Wetland Value Assessments; Roy, 2006). Elevation considerations to prevent nest inundation, vegetation planting and plant species considerations to promote establishment, and excavation/dredging considerations to create desired marsh elements are some examples of lessons learned in the developed restoration guidance include.

Information from current/ongoing research is formally presented in the developed restoration guidance for the first time. Marsh-nesting bird guidance, for example, was largely influenced by current research conducted by the Louisiana State University AgCenter and the United States Geological Survey (DWH LA TIG, 2022). This research has revealed important relationships between marsh-nesting birds and habitat characteristics, indicating that certain marsh-nesting birds are more commonly observed in emergent marsh habitats with a heterogeneous mix of open water and above water land cover. The restoration guidance identifies maximized potential habitat value for marsh-nesting birds in restoration projects which maximize the duration of project life and maintain an open water to land cover ratio of 30–60% (Fig. 3). As a result, planners and designers may consider novel marsh creation designs or enhancements to existing habitats that incorporate features such as ponds and tidally connected creeks, instead of large contiguous areas of uniform elevation land (see Supplemental, section 3.2).

Another critical aspect identified in the developed restoration guidance for marsh-nesting birds is that a heterogeneous mix of open water and above water land cover results in greater proportion of edge habitat. Available edge habitat is important as it supports loafing and foraging activities that benefit wetland-reliant species including many breeding marsh-nesting birds (O'Connell and Nyman, 2010).

The benefit of co-developed guidelines for restoration implementation is that the information from SMEs can guide specific project designs and maximize the likelihood of application of the guidance. Since publication, the developed restoration guidance has been used to inform several restoration and monitoring decisions in Louisiana. CPRA has referenced the document for upcoming monitoring and restoration activities at Chandeleur Islands (project ID: PO-0199), an important barrier island chain for both breeding and migratory birds (CPRA, 2023b). The document has also informed adaptive management for Terrebonne Houma Navigation Canal Island Restoration (project ID:TE-0165) and Queen Bess Island Restoration (project ID: BA-0202). Queen Bess Island is heavily utilized by birds for nesting, particularly Brown Pelicans (*Pelecanus occidentalis*), which have numbered in excess of 6000 nests in

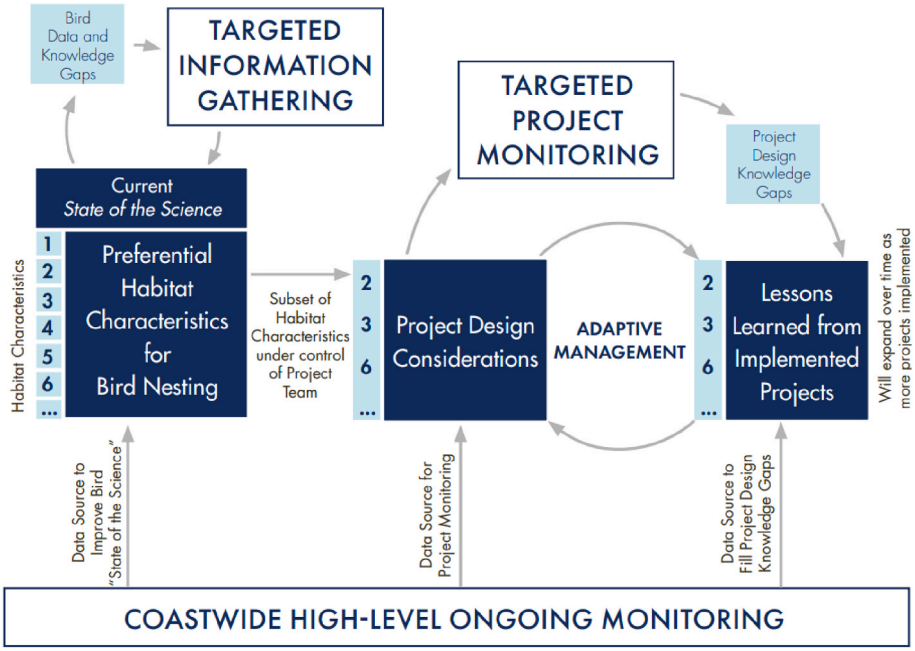

Fig. 2. Linkages between summarized information (from all data and knowledge sources) in support of active adaptive management of coastal ecosystem restoration.

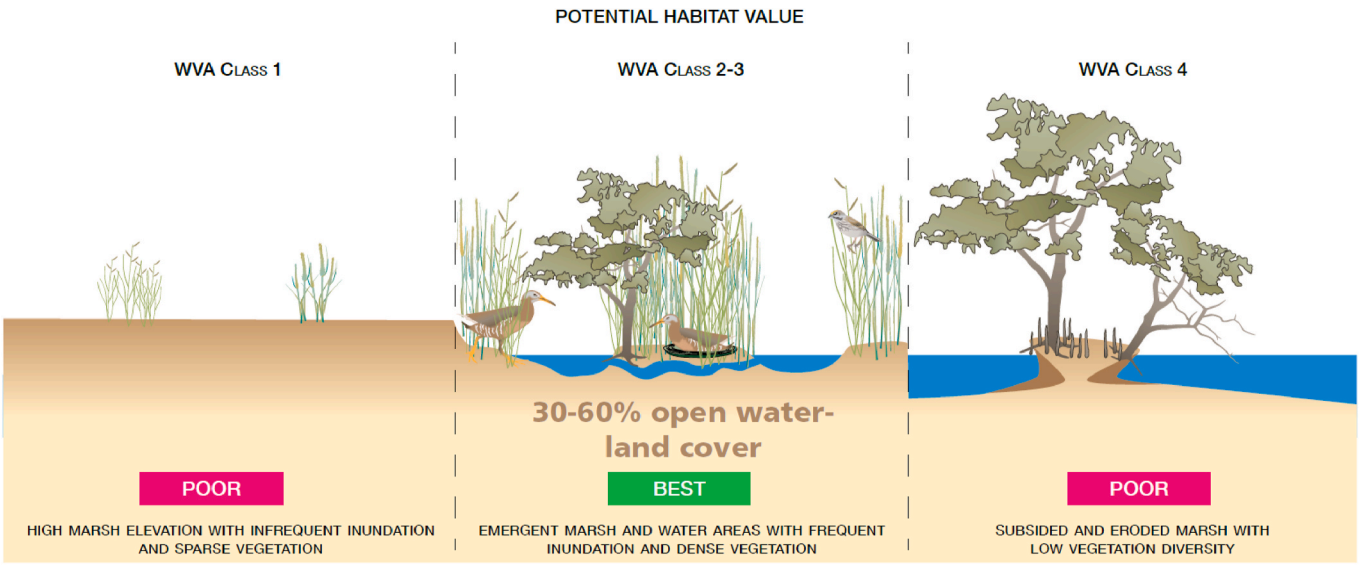

Fig. 3. Marsh-nesting bird habitat suitability relating to land/water interspersion. WVA = Wetland Value Assessment.

recent years (DWH LA TIG, 2023c). In addition, the developed restoration guidance is readily available for the state of Louisiana to determine restoration project needs and to inform future restoration plans.

4. Conclusion

Louisiana's Coastal Master Plan (CPRA, 2023a) and the DWH PDARP (DWH NRDA Trustees, 2016) specifically emphasize the development of restoration guidance to maximize bird nesting habitat as a principal goal. However, due to the inherent variability across coastal bird species and nesting needs, this goal is only attainable when communication barriers are bridged across avian and restoration experts. Through the implementation of a co-production process that brought together experts from across multiple disciples, habitat for nesting birds can be improved at marginal or no additional cost to restoration efforts. The restoration guidance is a novel tool that provides specific and tangible examples of bird nesting habitat, defined in terms of standard engineering specifications. Coastal habitat features identified that are in the control of project engineers and serve as high value bird nesting habitat include access to shorelines, elevation heterogeneity, and maximized edge habitat.

The developed restoration guidance is already being used to inform restoration planning in Louisiana and is inspiring similar efforts in neighboring Gulf states, including Alabama and Mississippi. The restoration guidance also provides an excellent avenue for current and upcoming research to be shared and implemented into restoration project design decisions. Monitoring restoration project resource benefits (i.e., nesting bird use) will provide lessons learned and inform future research needs and data gaps. As coastal habitats continue to change at various spatial and temporal scales due to anthropogenic and climate change effects, lessons learned and data gap resolution will be essential to meet specific habitat needs for nesting birds. To remain successful, the developed restoration guidance will be continually updated using an adaptive management framework that incorporates knowledge from targeted and high-level monitoring.

In summary, the process of developing the restoration guidance serves as an example of how the co-production and synthesis of restoration science, through enhanced coordination and collaboration across interdisciplinary teams of experts, can result in enhanced restoration outcomes. The partners involved in the development of this guidance acknowledge that this effort would not have been successful without the development of consensus goals and terminology, and hope that this process will pave the way for similar collaborations involving other resources in the future. Collaboration, communication, and trust between subject matter experts that historically have not worked together and sometimes had differing objectives, was necessary to maximize restoration project benefits across multiple resources (in this case coastal birds and habitats). This process is an example of how restoration and monitoring planning can be enhanced through efforts that foster common understanding and maintenance of collaborative working partnerships.

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CRediT authorship contribution statement

Eva D. Windhoffer: Writing – original draft. **Tim J.B. Carruthers:** Writing – review & editing. **Jessica Henkel:** Writing – review & editing. **Jeffrey S. Gleason:** Writing – review & editing, Conceptualization. **Jon J. Wiebe:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Appendix A. Supplementary data

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