Appendix B

Agency and Tribal Coordination

U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Appendix B

Agency and Tribal Coordination

Supporting Documentation

for the
Coastal Texas Protection and Restoration Study
Integrated Feasibility Report and
Environmental Impact Statement

October 2018

Appendix B-1

Agency Coordination

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5505
http://sero.nmfs.noaa.gov

F/SER:NS

APR 26 2016

Eric W. Verwers
Director, Regional Planning and Environmental Center
Galveston District, U.S. Army Corps of Engineers
Post Office Box 1229
Galveston, Texas 77553-1229

Attention: Janelle Stokes

Dear Mr. Verwers:

NOAA's National Marine Fisheries Service (NMFS) has received your letter dated April 11, 2016, requesting our participation as a cooperating agency in the preparation of the Integrated Feasibility Report and Environmental Impact statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. Given the scale and scope of the U.S. Army Corps of Engineers' IFR-EIS, there is the potential for impacts and benefits to NOAA-trust resources resulting from projects associated with the IFR-EIS. Therefore, NMFS agrees to serve as a cooperating agency in the preparation of the IFR-EIS. Due to staffing and travel constraints, our participation in the preparation of the IFR-EIS may be limited to our review and comment on draft National Environmental Policy Act documents, teleconferences, and occasional travel to meetings.

We appreciate your invitation to participate in an Interagency Meeting scheduled on May 3, 2016, from 8:30 to 11:30 AM at the Galveston District Headquarters. Mr. Rusty Swafford of our Habitat Conservation Division plans on attending this meeting. Rusty Swafford is the point of contact for any Essential Fish Habitat related issues/questions and can be reached at (409) 766-3699 or rusty.swafford@noaa.gov. Mr. Dennis Klemm of our Protected Resources Division plans to participate remotely via teleconference/webinar. Dennis Klemm is the point of contact for any Endangered Species Act related issues/questions and can be reached at (727) 824-5312, or at dennis.klemm@noaa.gov. Dr. Jim Nance of the Southeast Fisheries Science Center's Galveston Laboratory has also indicated he may attend the Interagency Meeting. Dr. Nance can be reached at (409) 766-3500, or at james.m.nance@noaa.gov.

Sincerely,

Roy E. Crabtree, Ph.D.
for Regional Administrator

cc: GC2: Dillen
F: Leathery, Reid
F/SER: Strelcheck, Silverman, Blough, Giordano
F/SER3: Bernhart, Klemm
F/SER4: Fay, Dale
F/SER46: Swafford
SEFSC: Nance, Hargrove
Files

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

April 29, 2016

Richard P. Pannell
Colonel, U.S. Army
U.S. Army Corps of Engineers
P.O. Box 1229
Galveston, TX 77553-1229

Subject: Detailed Scoping Comments for the Notice oflntent (NOi) to Prepare an Environmental Impact Statement (EIS) for the Coastal Texas Protection and Restoration Feasibility Study.

Dear Colonel Pannell:

Thank you for the opportunity to offer input in response to the request by the U.S. Army Corps of Engineers to provide scoping comments as they develop a Draft Integrated Feasibility Report (IFR) and Draft Environmental Impact Statement (EIS) for the Coastal Texas Protection and Restoration Study. Our comments are provided pursuant to the National Environmental · Policy Act (NEPA), Council on Environmental Quality (CEQ) regulations (40 CFR Parts 1500-1508) and Section 309 of the Clean Air Act.

General Observations

Planning for the entire Texas coastline is a huge undertaking and it is therefore difficult to provide a thorough list of significant issues prior to seeing a more specific statement of the mission and goals. The March 31, 2016, Public Notice sets out a broad conceptual intent of providing "a comprehensive strategy for reducing coastal storm flood risk through structural and nonstructural measures that take advantage of natural features such as barrier islands and storm surge storage in wetlands."

A more detailed review would be facilitated if the goal statement was refined and expanded to provide programmatic results-based goals. Examples could include: providing flood protection at a certain level above the base flood elevation; providing flood protection at a certain level above the standard project flood; or providing an incremental amount of risk reduction for a specified period of time based on a specified rate of future land loss. Similarly, goals for the coastal restoration aspect of the project should be specified and should incorporate results-based elements. This will help provide a solid framework for the planning effort and facilitate public participation.

It would also be helpful to clarify whether this effort amounts to a State-wide coastal master plan or a plan limited only to Corps-funded projects. Although the Final Reconnaissance Report implies that projects funded by other participants could be included, the IFR should clarify that point. Another useful aspect of the goal statement would be an explanation of how this plan might mesh with other significant coastal natural resource restoration and flood risk reduction plans being developed and implemented by the State, metropolitan areas, other agencies at all levels of government, corporate entities, and other organizations. Again, the Final

Reconnaissance Report includes a listing of prior studies and existing water projects but the IFR should provide an integrated evaluation of approved projects or projects underway. Providing as much information as possible from the outset with regard to project goals and the limits of Corps authorities and/or funding will help the public appropriately scale their expectations about the priorities and possibilities for addressing flood and storm surge protection, flood risk reduction, and coastal restoration through this effort. Because there will be a natural desire by those potentially affected by this feasibility analysis to get a community or neighborhood view of the potential benefits and/or adverse impacts from the plan out the outset, it will be essential to define expected results and to explain the overall process. That process would stretch from feasibility to implementation to operations and maintenance. Likewise, a general picture of the funding process and projected time to completion, once funding is secured, should be provided at this early planning stage.

Once a framework is established that defines. the study parameters and delimits the Corps' mission in this overall effort, a more specific evaluation could be provided by EPA. In the meantime, please consider the following planning issues, grouped into three categories according to the Corps' request.

Note, however, that EPA does not, by way of these comments, endorse any specific set of structural features or restoration design options at this initial stage of the feasibility planning. The following information is provided for purposes of scoping under the National Environmental Policy Act and not as endorsements or rejections of specific project alternatives or features.

1) Natural Conditions and Human Environmental Problems and Needs: Policy and Funding Considerations

EPA fully recognizes the need to plan for improved storm damage and flood risk reduction for the coastal communities of Texas. We remain committed to working with the Corps of Engineers, our State and federal partners, and other stakeholders to conduct an effective and efficient environmental review during this program planning effort. We are also committed to ensuring that any resulting storm and flood damage risk reduction projects are consistent with ongoing efforts and plans to protect and restore coastal environmental resources. These coastal resources provide not only vital environmental benefits to the people of the State and our nation but also supply ecosystem services that contribute to our quality life. These natural coastal resources also oftentimes serve to ameliorate the impacts of floods and storms. The comprehensive plan envisioned by the IFR should truly integrate the two goals of flood protection and environmental restoration. However, primacy should be afforded to options that would protect or restore natural coastal habitats and to coastal features that currently contribute to both the environmental and the flood minimization goals.

We recommend that the draft IFR and draft EIS clearly explain the project purposes and identify the limits of Corps involvement in the life of overall proposed project. An explanation should be provided about any limitations of Corps authority for addressing the expansive array of goals listed in the Public Notice, the amount of Corps or other federal funding available to implement the selected alternatives, and the need for additional funding sources and/or project implementers. Similarly, the initial statement of goals should contain a description of the long-term operations and maintenance requirements that might be expected of local sponsors or other non-Corps entities.

The process for securing future funding for the proposed set of projects or actions should be clearly identified at the outset of the study in order to frame public expectations.

Planning Considerations

The Final Reconnaissance Report was organized around four geographic planning areas. We agree that the IFR study area should employ a similar series of inter-related ecosystem-based geographic units for more detailed analyses of human and ecological needs and opportunities for intervention. We would be willing to entertain modifications to these boundaries but we were not able to devote detailed attention to the boundaries at this time. Conceptually, this type of process will provide an opportunity for stakeholders to have input on options and challenges within specific geographic locations and will help shape effective public participation.

Examples of significant existing coastal environmental conditions that deserve special attention, either all along the coast or at certain identifiable hot spots, include: altered freshwater inflows to estuaries; altered estuarine hydrodynamics (deep draft ship channels, GIWW, artificial passes, river diversions, dikes and causeways, cooling water intakes/outfalls); barrier island/barrier headland degradation (sand-starved beaches, dunes, and supratidal habitats); subsidence; development; coastal wetland loss; wetland impoundment; changes to seagrass distribution and productivity, loss of wind tidal flats, and coastal water and sediment quality (low dissolved oxygen, bacteria/pathogen indicators and PCBs that are bioaccumulated into fish tissues), and contaminated sediments.

The discussion of existing problems should provide a clear comparison of the costs of damages from previous storms. Note that Table 4-3 in the Final Reconnaissance Report does not include information that would normalize those costs over time. Without this type of information, it is difficult to compare damage calculations from one storm to another.

The IFR should identify significant gaps in existing coastal monitoring and discuss whether this study could contribute to filling those data needs.

2) Significant Resources:

Policy Considerations

The IFR should acknowledge the need for and establish a firm goal of avoiding, minimizing, and fully mitigating all adverse impacts to estuarine resources from the flood protection aspects of the plan. For those unavoidable adverse impacts, compensatory mitigation should be planned in a manner that would be complementary to he coastal restoration actions proposed as part of the planning effort. The mitigation policy should also consider establishing a goal of implementing mitigation concurrently with project construction features or as close in time as possible. Compensatory mitigation should be based on the EPA/Corps 2008 Mitigation Rule. Accordingly, preservation as a mitigation technique should generally be considered a low priority, unless specifically justified.

Because the IFR goal is a dual one of both flood risk reduction and coastal restoration, the planning should avoid confusing or combining mitigation for unavoidable impacts from construction of flood control features with those features being designed to accomplish the coastal restoration goal. In other words, mitigation for construction impacts should not be ·

considered a substitute for achieving the coastal restoration goals.

.,.The draft IFR should include a policy regarding any borrow material that might be required for construction of individual flood risk reduction projects across the coast. In order to complement the coastal restoration aspect of the planning effort, consideration should be given to establishing a policy that no borrow material, whether from onsite or offsite, will be derived from wetland areas or flood tide deltas. As an example, note that the avoidance of jurisdictional wetlands for borrow material was one of the significant features of a similar large-scale planning project, the Greater New Orleans Hurricane and Storm Damage Risk Reduction System Project managed by the New Orleans District of the Corps of Engineers. We encourage the Corps to repeat this important precedent as part of this coastal planning effort. If significant borrow material will be required, consideration should be given to developing a protocol for the selection of borrow sites that would avoid and minimize impacts to valuable coastal natural resources and that would ensure consistency with coastal restoration strategies. If the use of open water borrow sites are potential alternatives, analysis of any associated water quality impacts should be conducted.

Planning Considerations

.,. The Public Notice listed the following resources to be considered for protection, conservation, and restoration: wetlands, barrier islands, and shorelines. Although this general list is a good starting point, we recommend that public review documents explicitly incorporate, at a minimum: wetlands, including cypress-tupelo swamp forest, bottomland hardwood forest, salt marsh, brackish marsh, intermediate marsh, fresh marsh, seagrass beds, and mangroves; barrier islands, including beach, dunes, supratidal habitats, freshwater marshes, and saltmarshes/mangrove scrub-shrub; seagrass beds; wind tidal flats; oyster reefs; prairie potholes, estuarine and coastal fish and shellfish; and coastal wildlife (specifically including birds, terrapins, and sea turtles, as well as any species of special interest and threatened and endangered species); and protected habitats managed or owned by any entities. To the degree possible, the descriptions of the various resources should be displayed via maps and other graphics in order for the reader to gain an understanding of critical natural resource locations.

.,. Likewise, a thorough presentation about the current understanding of the human and natural resource. conditions and trends that would be impacted by the proposed alternatives would be useful at the earliest possible time in the planning process. The status and ecological significance of freshwater inflows, red and brown tide events, hypoxic conditions, land loss rates and contributing factors, hydrologic alterations, sediment availability and movements, habitat loss and modification, changes in living resources, and land use and socioeconomic trends should be presented and analyzed. Any projected changes to resources as a result of weather and climate projections for the project period should be factored into the planning.

.,. With respect to indirect impacts to coastal natural resources, the analysis should include potential adverse effects of the various alternatives due to changes in: wetland hydrology, salinity regimes, and pollutant loading; estuarine connectivity, including fish and shellfish ingress and egress; sediment processes; and transitions in habitat types as a result of any individual flood reduction feature or as a result of the combined impacts from all proposed features.

.,.The evaluation of the direct environmental consequences of proposed actions should take into consideration not only the magnitude (degree and extent) of the expected changes but the expected duration and speed of the changes. A comprehensive indirect analysis should include effects caused by the proposed action that might occur later in time or are somewhat removed by distance.

Impacts to coastal resources as a result of construction activities should be evaluated along with other environmental impacts. Construction impacts should include the transportation of construction materials to the building site for any alternative that would entail large-scale construction and that would require significant relocation of materials. Potential topics for analysis include road or barge traffic, roadway wear and tear, noise and other community impacts, energy use, and air quality impacts.

The study area is an ecologically important area that is experiencing natural resource declines. Due to the expansive nature of this study and the environmental sensitivity of the coast, a comprehensive and wide-ranging cumulative impacts analysis should be completed. A rigorous cumulative impact evaluation should start by establishing spatial and temporal boundaries for significant resources and including a description of past, present, and reasonably foreseeable future projects or alternatives. The analysis should include the overall impacts to the environment that can be expected from a number of individual projects or alternative features being implemented across the coast.

The IFR will likely show that concurrent implementation of all proposed features across the coast is not a practical alternative. Ifconstruction is to be staged over a significant period of time, plans should be made to develop a series of cumulative impact evaluations which should each incorporate an adaptive evaluation of the preceding construction phases.

Because the IFR has dual goals of flood risk reduction and coastal restoration, it will be essential to plan carefully the flood risk reduction features so as to minimize any associated adverse impacts to coastal natural resources. In particular, flood risk reduction features should be located and designed so as to avoid, to the degree possible, enclosing wetlands or other sensitive habitats within flood control works. For instance, greater wetland loss might be expected in areas enclosed by levees, due to a combination of factors that might make them more susceptible to storm damage or make them otherwise less valuable as wetland ecosystems.

3) Reasonable Alternatives:
Framework Development and Policy Considerations

We recommend that innovative approaches to providing enhanced storm and flood protection be given full consideration during the planning phase, including combinations of structural and non-structural components. Similarly, multiple lines of defense should be considered that might, in combination, reduce vulnerabilities from floods, storms (wind and rain), and storm surge. Alternative sequencing options for the implementation of features should also be analyzed, along with the corresponding levels of project effectiveness and environmental impacts.

We recommend that the IFR clearly explain the relative weight that will be afforded to the flood and storm risk reduction goals as compared to the coastal restoration goals. The restoration goals should not be considered as secondary or simply as mitigation for the flood risk reduction goals. Neither should restoration benefits be calculated as offsetting the costs of storm risk reduction projects. Restoration features should not be put forth to justify storm risk reduction. ,Both major project goals should stand the test of independent review.

In order to maintain a balanced level of effort with regard to both the flood reduction and environmental restoration goals for this project, it would be helpful to integrate the initial environmental and engineering evaluations by considering including environmental staff, in addition to engineering staff, in the formal Corps Alternative Engineering Evaluation Process.

An alternatives analysis should identify ongoing efforts to protect and restore coastal natural resources along the Texas coast. This should include not only projects being considered under Corps authorities but any others that might contribute cumulatively to meeting the goals for this project and/or that might impose constraints on designing reasonable alternatives for this project.

In order to address any uncertainties regarding future coastal dynamics (including relative sea level rise), each of the major alternatives should consider a range of potential changes in water and land elevations projected for each portion of the coast over time and in response to other reasonably foreseeable changes.

Although the feasibility study will apply within specified geographic limits, it is possible that certain parts of the study area will be projected to experience increased or decreased levels of risk reduction due to engineering, hydrologic, economic, or other reasons. This possibility should be discussed early in the planning process.

The presentation of alternatives should clearly present the financial and opportunity costs of acquiring necessary easements, rights-of-way, or property titles.

The role of existing navigation channels in compounding the effects of storm surge should be evaluated, along with the implications of any reasonably foreseeable channel expansions.

The development of alternatives should include some discussion of the types of baseline coastal resource monitoring that would be required and the needs for long-term monitoring for adaptive management purposes.

Non-Structural Alternatives

The IFR should identify the range of potential types of both structural and non-structural alternatives that will be considered for achieving flood risk reduction. The discussion of non-structural alternatives should identify whether buyouts and relocations will be considered at a conceptual level for historically flooded properties or following future storm events. Increasing wetland restoration as a means of flood risk reduction should also be considered as a viable alternative. Non-structural options should include policy changes such as limiting federal infrastructure development on barrier islands/barrier headlands, acquiring undeveloped barrier island/barrier headland properties from willing sellers, requiring onsite restoration or preservation as mitigation for any permitted development on barrier islands/barrier headlands, increasing beneficial use of dredged material for marsh creation, and employing living shorelines in areas where hardened structures are not necessary.

The selection and presentation of IFR alternatives planned for federal funding should not inadvertently discourage individual efforts to elevate properties or install other non-structural adaptive measures.

Structural Alternatives

Structural measures designed for exterior flood control, such as levees, should be evaluated for impacts to interior drainage, subsidence, sediment dynamics, water quality, and salinity regime changes. Goals for the placement of any structural flood control measures should be defined early in the feasibility phase. Goals for upgrading existing structures should include and evaluate alternatives for flood-side vs. protected-side shifts. To the extent possible, structural measures for flood control should be situated in locations other than wetlands or on sensitive barrier island habitats.

If structural measures such as large sector gates or smaller engineered flood control devices are proposed, a full analysis of the altered hydrological and other ecological ramifications should be presented as early as possible, along with the potential social impacts. Operational parameters and adaptive protocols should be considered as priority design elements. There may be a range of environmentally preferable operational schemes for such features that might not compromise the primary purpose of flood risk reduction.

Alternatives for gated or other water control structures should be designed to remain open except during specified conditions of certain storms or high tides. Gates or water control structures should be designed to allow sufficient ingress and egress of aquatic organisms and exchanges of sediment, organic matter, and nutrients. These structures should be sited and designed so as not to cause wetland degradation due to prolonged impoundment or other hydrologic changes.

If structural measures such as levees are proposed, a full analysis of the altered hydrological and other ecological ramifications should be presented as early as possible, along with the potential social impacts. For instance, the construction of levee systems can result in both direct and indirect impacts to wetlands and aquatic resources. While direct impacts are somewhat easier to quantify, indirect impacts can be technically challenging to assess and yet of significant consequence to aquatic resources and other aspects of the environment. The assessment of potential indirect impacts to wetlands and aquatic resources is often the most critical component of the environmental review oflevee projects and such alternatives should incorporate rigorous evaluations.

If structural measures such as pumping stations are proposed, a full analysis of the altered hydrological and sediment exchange and other ecological ramifications should be presented as early as possible, along with the potential social impacts. Alternative operations of pumping stations should also be evaluated with regard to differing types and degree of environmental impacts.

If significant dredging is a reasonably foreseeable component of the major alternatives, beneficial use of the dredged material for purposes of coastal restoration should be considered as a priority. Consequently, appropriate plans should be made for contaminant testing and for evaluating the dredged material in a timely manner. If significant quantities of dredged material are expected, consideration should be given to establishing an interagency team to review and evaluate alternative placement options.

II- If significant dredging is a reasonably foreseeable component of the major alternatives, consideration should be given as to whether compensatory mitigation credit should be waived for any beneficial use activities resulting from construction. Full mitigation of other direct wetland impacts could be provided separately. A reasonable goal might be to ensure that any beneficial use of dredged material combined with other mitigation should result in a net increase in coastal marsh habitat.

II- The presentation of flood risk reduction alternatives should include comparative evaluations of the relative differences among options with regard to the level ofrisk reduction expected and the effect upon National Flood Insurance Program certifications in each area. This might help the public to evaluate the costs and benefits of different alternative arrays.

11- Any proposed infrastructure improvement, such as roadway elevations or widened evacuation routes, should be evaluated for the potential to cause unintended consequences (impounding water, reducing water quality in adjacent wetlands, causing a rebound of storm-induced waves, etc.). Similarly, structural features should evaluated with regard to their potential effects on accidental spills or storm and flood-induced releases of hazardous material.

<u>Restoration Construction Activities</u>

II- In general, alternatives should be considered that would: resto.re hydrology to coastal wetlands (accounting for future projections regarding droughts and flooding); preserve coastal wetlands regardless of their status under the Clean Water Act; and restore coastal depressional wetlands.

II- Consideration should be afforded to using dedicated dredging of sediments of the appropriate grain size from the nearshore Gulf of Mexico, but beyond the depth of closure, for the purpose of barrier island/barrier headland restoration.

II- The potential for tidal flat restoration on the middle and lower Texas coast should be considered cautiously. The tidal flats of these sections of the Texas coast are fundamentally different than any other tidal flats in the U.S. If successful restoration is possible, new techniques would likely need to be developed.

II- Note that "scrape downs" of higher elevation areas in order to create suitable wetland elevations should only be considered after detailed evaluation, and should probably be excluded from consideration in the case of barrier islands.

II- The potential for backfilling coastal oil and gas canals and degrading associated spoil banks should be evaluated for as potential coastal restoration projects.

II-I In conjunction with proposed flood risk reduction features, modifications of existing features that have altered coastal hydrology and ecological dynamics should be recevaluated for long-term ecological efficacy. Possibilities for evaluation might include reconnecting Lake Anahuac with the Trinity Delta, altering the Texas City Dike, ending or deferring federally funded maintenance dredging at the mouth of the San Bernard River, letting certain passes develop without additional intervention by federally-funded dredging, restoring topographic sills at passes where they may have occurred historically, and conveying freshwater across the GIWW to areas such as the Salt Bayou brackish marsh habitat.

We lo.ok forward to continuing to coordinate and collaborate with the Corps on this important endeavor. Ifyou have any questions about the above comments, please contact Barbara Keeler (214-665-6698) or Kenneth Teague (214-665-6687) regarding matters relating to our Coastal Program and our Section 404 Wetland Program respectively.

Other Scoping Issues To Be Considered in the EIS

Under our role as a cooperating agency and Section 309 Review, EPA has identified several other issues for your attention and consideration in the preparation of the EIS and has enclosed detailed scoping comments for your consideration. We believe significant participation in this phase of the planning process plays an extremely important partnership role for both our coastal program and in our role as a cooperating agency and will assist your agency in the EIS development process.

We appreciate the opportunity to review this NOI and are available to discuss all of our comments. Please send one hard copy of the Draft EIS and four CD ROM copies to this office when completed and submitted for public comment. Ifyou have any questions, please contact me at (214) 665-7451 or by e-mail at jansky.michael@epa.gov.

Sincerely,,

Michael Jansky
Regional rdinator
Special Projects Section
Compliance Assurance and
Enforcement Division

Enclosure

DETAILED SCOPING COMMENTS
ON THE
NOTICE OF INTENT (NOi)
FOR THE U.S. ARMY CORPS OF ENGINEERS (USACE)
TO PREPARE AN
ENVIRONMENTAL IMPACT STATEMENT (EIS)
FOR THE PROPOSED
COASTAL TEXAS PROTECTION AND RESTORATION FEASIBILITY STUDY

Based on the Notice oflntent (NO!) filed on March 31, 2016, the following scoping recommendations are provided for consideration by the USACE in preparation of the EIS:

DETAILED COMMENTS

Statement of Purpose and Need

We recommend the EIS clearly identify the underlying purpose and need to which the USACE is responding in proposing the alternatives (40 CFR 1502.13). The purpose of the proposed action is typically the specific objectives of the activity, while the need for the proposed action may be to eliminate a broader underlying problem or take advantage of an opportunity.

Recommendation:

The purpose and need should be a clear, objective statement of the rationale for the proposed project. We recommend the EIS discuss the proposed project in the context of the natural gas supply and the need for an additional export capabilities.

Alternatives Analysis

The National Environmental Policy Act (NEPA) requires evaluation ofreasonable alternatives, including those that may not be within the jurisdiction of the lead agency (40 CFR Section 150.2.14(c)). A robust range of alternatives will include options for avoiding significant environmental impacts. We recommend the EIS provide a clear discussion of the reasons for the elimination of alternatives which are not evaluated in detail.

The environmental impacts of the proposal and alternatives should be presented in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decision maker. and the public (40 CFR 1502.14). The potential environmental impacts of each alternative should be quantified to the greatest extent possible (e.g., acres of bay bottom impacted, tons per year of emissions produced).

Recommendations:

Inthe discussion of Alternatives, we recommend the EIS describe how each alternative was developed, how it addresses each project objective, and how it will be implemented.

We also recommend the EIS clearly describe the rationale used to determine whether Impacts of an alternative are significant or not. Finally, we recommend the EIS describe the methodology and criteria used for determining project siting.

Water Supply and Water Quality

Public drinking water supplies and/or their source areas often exist in many watersheds. Source water is water from streams, rivers, lakes, springs, and aquifers used as a supply of drinking water. Source water areas are delineated and mapped by the state for each federally-regulated public water system. The 1996 amendments to the Safe Drinking Water Act require federal agencies to protect sources of drinking water for communities. We recommend the EIS address the potential effects of project discharges, if any, on surface water quality. Specific discharges should be identified and potential effects of discharges on designated beneficial uses of affected waters should be analyzed.

Recommendations:

EPA recommends the EIS address the potential effects of project discharges, if any, on surface water quality. Specific discharges should be identified and potential effects of discharges on designated beneficial uses of affected waters should be analyzed.

We recommend the EIS describe water reliability for the proposed project and clarify how existing and/or proposed sources may be affected by climate change. At a minimum, the EPA recommends a qualitative discussion of impacts to water supply and the adaptability of the project to these changes.

Groundwater

EPA recommends the EIS address potential adverse impacts to groundwater. For each alternative under consideration, we request that the EIS satisfy the recommendations below to ensure groundwater resources are protected and any unavoidable impacts are fully assessed in the EIS.

Recommendations:

EPA recommends the EIS describe current groundwater conditions in the project area and fully assess any impacts to groundwater quality and quantity associated with the proposed project construction and operational activities.

We also recommend the EIS identify mitigation measures to prevent or reduce adverse impacts to groundwater quality and discuss their effectiveness. EPA asks that the lead agency work closely with state and local agencies which regulate the protection of groundwater resources (i.e., state health departments and water pollution control agencies.)

Stormwater Considerations

EPA recommends the EIS describe the original (natural) drainage patterns in the project locale, as well as the drainage patterns of the area during project operations. Also, we recommend the EIS identify whether any components of the proposed project are within a 50 or 100-year floodplain. We also recommend noting that, under the Federal Clean Water Act, any construction project disturbing a land area of one or more acres requires a construction stormwater discharge permit.

Recommendations:

EPA recommends the EIS document the project's consistency with applicable stormwater permitting requirements. Requirements of a stormwater pollution prevention plan would be reflected as appropriate in the EIS.

We also recommend the EIS discuss specific mitigation measures that may be necessary or beneficial in reducing adverse impacts to water quality and aquatic resources.

Clean Water Act (CWA) Section 303(d)

The CWA requires States to develop a list of impaired waters that do not meet water quality standards, establish priority rankings, and develop action plans, called Total Maximum Daily Loads (TMDL), to improve water quality. We recommend the EIS provide information on CWA Section 303(d) impaired waters in the project area, if any, and efforts to develop and revise TMDLs. EPA further recommends the EIS describe existing restoration and enhancement efforts for those waters, and any mitigation measures that will be implemented to avoid further degradation of impaired waters.

Recommendation:

EPA recommends the EIS provide information on CWA Section 303(d) impaired waters in the project area, if any, and efforts to.develop and revise TMDLs. We recommend the EIS describe existing restoration and enhancement efforts for those waters, how the proposed project will coordinate with on-going protection efforts, and any mitigation measures that will be implemented to avoid further degradation of impaired waters.

Biological Resources, Habitat and Wildlife

EPA asks that the EIS identify all petitioned and listed threatened and endangered species and critical habitat that might occur within the project area, including any areas. We further recommend the EIS identify which species or critical habitat might be directly, indirectly, or cumulatively affected by each alternative and describe possible mitigation for each of the species. EPA asks that FERC consult with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) under Section 7 of the Endangered Species Act. We also recommend that the USACE coordinate across field offices and with USFWS, NMFS, and the Texas Department of Parks and Wildlife (TDPW) to ensure that current and consistent surveying, monitoring, and reporting protocols are applied in protection and mitigation efforts.

Recommendations:

EPA recommends that USACE coordinate across field offices and with the USFWS, NMFS and TDPW protocols are applied in protection and mitigation efforts.

Analysis of impacts and mitigation on covered species would include:

- Baseline conditions of habitats and populations of the covered species.
- A clear description of how avoidance, mitigation and conservation measures will protect and encourage the recovery of the covered species and their habitats in the project area.
- Monitoring, reporting and adaptive management efforts to ensure species and habitat conservation effectiveness.
- A discussion of how the projects potential impacts such as air emissions and/or wastewater discharges may impact species.

If the applicant is to acquire compensation lands, the location(s) and management plans for these lands should be discussed in the EIS.

Recommendations:

EPA recommends incorporating information on the compensatory mitigation proposals (including quantification of acreages, estimates of species protected, costs to acquire compensatory lands, etc.) for unavoidable impacts to WOUS and biological resources in the EIS.

We recommend identifying compensatory mitigation lands or quantify available lands for compensatory habitat mitigation for this project, as well as reasonably foreseeable projects in the area. Specify provisions that will ensure habitat selected for compensatory mitigation will be protected in perpetuity in the EIS.

EPA recommends incorporating mitigation, monitoring, and reporting measures that result from consultation with the USFWS or NMFS that incorporate recently released guidance to avoid and minimize adverse effects to sensitive biological resources in the EIS.

We further request that the EIS describe the potential for habitat fragmentation and obstructions for wildlife movement from the construction of this project and other projects in the area.

The EIS should discuss the need for monitoring, mitigation, and if applicable, translocation management plans for the sensitive biological resources, approved by the USFWS, NMFS and the biological resource management agencies.

EPA is also concerned about the potential impact of construction, installation, and maintenance activities (deep trenching, grading, filling, and fencing) on habitat. We recommend the EIS describe the extent of these activities and the associated impacts on habitat and threatened and endangered species, including all interrelated and interdependent facilities. We encourage habitat conservation alternatives that avoid and protect high value habitat and create or preserve linkages between habitat areas to better conserve the covered species.

Recommendations:

We recommend the EIS describe the extent of potential impacts from construction, installation, and maintenance activities, including all interrelated and interdependent facilities.

We recommend the EIS describe the ROW vegetation management techniques to be used And thei.r potential associated environmental impacts, especially if mechanical methods or herbicides are to be used.

We recommend the EIS indicate the location of important marine and wildlife habitat areas and that the EIS describe what measures will be taken to protect important wildlife habitat areas and to preserve linkages between them.

We recommend the EIS provide detailed information on any proposed fencing design and placement, and its potential effects on drainage systems on the project site. Fencing proposed for this project should meet appropriate hydrologic, wildlife protection and movement, and security performance standards.

Air Quality

EPA recommends the EIS provide a detailed discussion of ambient air conditions (baseline or existing conditions), National Ambient Air Quality Standards (NAAQS) and non-NAAQS pollutants, criteria pollutant nonattainment areas, and potential air quality impacts of the proposed project (including cumulative and indirect impacts). Such an evaluation is necessary to understand the potential impacts from temporary, long-term, or cumulative degradation of air quality.

We further recommends the EIS describe and estimate air emissions from potential construction and maintenance activities, as well as proposed mitigation measures to minimize those emissions. EPA recommends an evaluation of the following measures to reduce emissions of criteria air pollutants and hazardous air pollutants (air toxics).

Recommendations:

- *Existing Conditions* -We recommend the EIS provide a detailed discussion of ambient air conditions, National Ambient Air Quality Standards, and criteria pollutant nonattainment areas in the vicinity of the project.

- *QuantifY Emissions* -We recommend the EIS estimate emissions of criteria and hazardous air pollutants (air toxics) from the proposed project and discuss the timeframe for release of these emissions over the lifespan of the project. We

-

recommend the EIS describe and estimate emissions from potential construction activities, as well as proposed mitigation measures to minimize these emissions.

- *Specify Emission Sources* -We recommend the EIS specify all emission sources by pollutant from mobile sources (on and off-road), stationary sources (including portable and temporary emission units), fugitive emission sources, area sources, and ground disturbance. This source specific information should be used to identify appropriate mitigation measures and areas in need of the greatest attention.

- *Construction Emissions Mitigation Plan* – We recommend the EIS include a draft Construction Emissions Mitigation Plan and ultimately adopt this plan in the Record of Decision. In addition to all applicable local, state, or federal requirements, we recommend the following control measures (Fugitive Dust, Mobile and Stationary Source and Administrative) be included in the Construction Emissions Mitigation Plan in order to reduce impacts associated with emissions of particulate matter and other toxics from construction-related activities. (See Attachment 1)

Hazardous Materials, Hazardous Waste and Solid Waste

EPA recommends the EIS address potential direct, indirect and cumulative impacts of hazardous waste from construction, maintenance, and operation of the proposed facilities. The document should identify projected solid and hazardous waste types, volumes, and expected storage, disposal, and management plans.

Recommendations:

We recommend the EIS address the applicability of state and federal hazardous waste requirements. Appropriate mitigation should be evaluated, including measures to minimize the generation of hazardous waste (i.e., hazardous waste minimization). Alternate industrial processes using less toxic materials should be evaluated as mitigation since such processes could reduce the volume or toxicity of hazardous materials requiring management and disposal as hazardous waste.

Effects of Climate Change on Project Impacts

We recommend describing potential changes to the Affected Environment that may result from climate change. Including future climate scenarios in the EIS would help decision makers and the public consider whether the environmental impacts of the alternatives would be exacerbated by climate change. If impacts may be exacerbated by climate change, additional mitigation measures may be warranted.

Climate Change Adaptation

We recommend considering climate adaptation measures based on how future climate scenarios may impact the project. The National Climate Assessment (NCA), released by the U.S.

Global Change Resource Program [1], contains scenarios for regions and sectors, including energy and transportation. UsingNCA or other peer reviewed climate scenarios to inform alternatives analysis and possible changes to the proposal can improve resilience and preparedness for climate change.

Coordination with Tribal Governments

Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments* (November 6, 2000), was issued in order to establish regular and meaningful consultation and collaboration with tribal officials in the development of federal policies that have tribal implications, and to strengthen the United States government-to-government relationships with Indian tribes. If applicable, we recommend the EIS describe the process and outcome of government-to-government consultation between the USACE and with any and each of the tribal governments within the project area, issues that were raised (if any), and how those issues were addressed in the selection of the proposed alternative.

Recommendation:

We recommend the EIS describe the process and outcome of government-to-government consultation between the USACE and each of the tribal governments within the project area, issues that were raised (if any), and how those issues were addressed in the selection of the proposed alternative.

National Historic Preservation Act and Executive Order 13007(NRHA)

Consultation for tribal cultural resources is required under Section 106 of the National Historic Preservation Act. Historic properties under the NHPA are properties that are included in the National Register of Historic Places or that meet the criteria for the National Register. Section I06 of the NHPA requires a federal agency, upon determining that activities under its control could affect historic properties, consult with the appropriate State Historic Preservation Officer (SHPO)/Tribal Historic Preservation Officer (THPO), Indian tribes, or any other interested party. Under NEPA, any impacts to tribal, cultural, or other treaty resources must be discussed and mitigated. Section 106 of the NHPA requires that Federal agencies consider the effects of their actions on cultural resources, following regulation in 36 CFR 800.

Recommendation:

We recommend the EIS address the existence of cultural and historic resources, including Indian sacred sites, in the project areas, and address compliance with Section 106 of the NHPA. It should also address Executive Order 13007, distinguish it from Section 106 of the NHPA, and discuss how the applicant will avoid adversely affecting the physical integrity, accessibility, or use of sacred sites, if they exist. We recommend the EIS provide a summary of all coordination with Tribes, the SHPO/THPO, or any other party; and identify all NRHP listed or eligible sites, and the development of a Cultural Resource Management Plan.

[1] http://nca2014.globalchange.gov/

Permits and Other Associated Activities

The EIS should include a discussion of relevant permits and other activities associated with the construction, maintenance, and operation of proposed projects.

Environmental Justice and Impacted Communities

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (February 11, 1994) and the Interagency Memorandum of Understanding on Environmental Justice (August 4, 2011) direct federal agencies to identify and address disproportionately high and adverse human health or environmental effects on minority and low-income populations, allowing those populations a meaningful opportunity to participate in the decision-making process. Guidance[2] by CEQ clarifies the terms low-income and minority population (which includes Native Americans) and describes the factors to consider when evaluating disproportionately high and adverse human health effects. We recommend the EIS include an evaluation of environmental justice populations within the geographic scope of the projects. Assessment of the projects impact on minority and low-income populations should reflect coordination with those affected populations. We recommend the EIS also describe outreach conducted to all other communities that could be affected by the project, since rural communities may be among the most vulnerable to health risks associated with the project.

Recommendations:

EPA recommends the EIS include an evaluation of environmental justice populations within the geographic scope of the projects. If such populations exist, EPA recommends the EIS address the potential for disproportionate adverse impacts to minority and low-income populations, and the approaches used to foster public participation by these populations. Assessment of the projects impact on minority and low-income populations should reflect coordination with those affected populations.

EPA's recently released mapping and screening tool EJSCREEN[3] utilizes nationally consistent data to highlight places that may have higher environmental burdens and vulnerable populations. . During the NEPA scoping process EJSCREEN can assist in identifying potential EJ populations and areas likely to have environmental impacts. Used in conjunction with NEPAssist, it can be a very powerful tool to strengthen public outreach and involvement efforts and help facilitate the consideration of environmental justice (EJ) in the decision-making process.

We recommend the EIS describe outreach conducted to all other communities that could be affected by the project, since rural communities may be among the most vulnerable to health risks associated with the project.

Coordination with Land Use Planning Activities

[2] Environmental Justice Guidance under the National Environmental Policy Act, Appendix A (Guidance for Federal Agencies on Key Terms in Executive Order 12898), CEQ, December 10, 1997.

[3] http://ejscreen.epa.gov/mapper/index.html

We recommend the EIS discuss how the proposed action would support or conflict with the objectives of federal, state, tribal or local land use plans, policies and controls in the project areas. The term "land use plans" includes all types of formally adopted documents for land use planning, conservation, zoning and related regulatory requirements. Proposed plans not yet developed should also be addressed if they have been formally proposed by the appropriate government body in a written form (CEQ's Forty Questions, #23b).

ATTACHMENT I

Control Measures
(Fugitive Dust, Mobile and Stationary Source and Administrative)

- o Fugitive Dust Source Controls: We recommend the EIS identify the need for a Fugitive Dust Control Plan to reduce Particulate Matter 10 and Fine Particulate Matter 2.5 emissions during construction and operations. We recommend that the plan include these general commitments:
  - Stabilize heavily used unpaved construction roads with a non-toxic soil stabilizer or soil weighting agent that will not result in loss of vegetation, or increase other environmental impacts.
  - During grading, use water, as necessary, on disturbed areas in construction sites to control visible plumes.
  - Vehicle Speed
    - Limit speeds to 25 miles per hour on stabilized unpaved roads as long as such speeds do not create visible dust emissions.
    - Limit speeds to 10 miles per hour or less on unpaved areas within construction sites on un-stabilized (and unpaved) roads.
    - Post visible speed limit signs at construction site entrances.
  - Inspect and wash construction equipment vehicle tires, as necessary, so they are free of dirt before entering paved roadways, if applicable.
  - Provide gravel ramps of at least 20 feet in length at tire washing/cleaning stations, and ensure construction vehicles exit construction sites through treated entrance roadways, unless an alternative route has been approved by appropriate lead agencies, if applicable.
  - Use sandbags or equivalent effective measures to prevent run-off to roadways in construction areas adjacent to paved roadways. Ensure consistency with the project's Storm Water Pollution Prevention Plan, if such a plan is required for the project
  - Sweep the first 500 feet of paved roads exiting construction sites, other unpaved roads en route from the construction site, or construction staging areas whenever dirt or runoff from construction activity is visible on paved roads, or at least twice daily (less during periods of precipitation).
  - Stabilize disturbed soils (after active construction activities are completed) with a non-toxic soil stabilizer, soil weighting agent, or other approved soil stabilizing method.
  - Cover or treat soil storage piles with appropriate dust suppressant compounds and disturbed areas that remain inactive for longer than I0 days. Provide vehicles (used to transport solid bulk material on public roadways and that have potential to cause visible emissions) with covers. Alternatively, sufficiently wet and load materials onto the trucks in a marmer to provide at least one foot of freeboard.
  - Use wind erosion control techniques (such as windbreaks, water, chemical dust suppressants, and/or vegetation) where soils are disturbed in construction, access and maintenance routes, and materials

stock pile areas. Keep related windbreaks in place until the soil is stabilized or permanently covered with vegetation.

- o Mobile and Stationarv Source Controls:
  - Ifpracticable, lease new, clean equipment meeting the most stringent of applicable Federa1[4] or State Standards[5]. In general, commit to the best available emissions control technology. Tier 4 engines should be used for project construction equipment to the maximum extent feasible[6].
  - Where Tier 4 engines are not available, use construction diesel engines with a rating of 50 hp or higher that meet, at a minimnm, the Tier 3 California Emission Standards for Off-Road Compression-Ignition Engines[7], unless such engines are not available.
  - Where Tier 3 engine is not available for off-road equipment larger than 100 hp, use a Tier 2 engine, or an engine equipped with retrofit controls to reduce exhaust emissions of nitrogen oxides and diesel particulate matter to no more than Tier 2 levels.
  - Consider using electric vehicles, natural gas, biodiesel, or other alternative fuels during construction and operation phases to reduce the project's criteria and greenhouse gas emissions.
  - Plan construction scheduling to minimize vehicle trips.
  - Limit idling of heavy equipment to less than 5 minutes and verify through unscheduled inspections.
  - Maintain and tune engines per manufacturer's specifications to perform at CARE and/or EPA certification levels, prevent tampering, and conduct unscheduled inspections to ensure these measures are followed.

- o Administrative controls:
  - Develop a construction traffic and parking management plan that maintains traffic flow and plan construction to minimize vehicle trips.
  - Identify any sensitive receptors in the project area, such as children, elderly, and the infirm, and specify the means by which impacts to these populations will be minimized (e.g. locate construction equipment and staging zones away from sensitive receptors and building air intakes).
  - Include provisions for monitoring fugitive dust in the fugitive dust control plan and initiate increased mitigation measures to abate any visible dust plnmes.

" EPA's website for nonroad mobile sources is http://www.epa.gov/nonroad/.

[5] For California, see ARB emissions standards, see: http://www.arb.ca.gov/msprog/offroad/offroad.htm.

[6] Diesel engines < 25 hp rated power started phasing in Tier 4 Model Years in 2008. Larger Tier 4 diesel engines , will be phased in depending on the rated power (e.g., 25 hp - <75 hp: 2013; 75 hp - < 175 hp: 2012-2013; 175 hp - < 750 hp: 2011 - 2013; and_::: 750 hp 2011- 2015).

Lisa Vitale

From: Lisa Vitale
Sent: Thursday, August 25, 2016 4:06 PM
To: 'David_Hoth@fws.gov'
Cc: Jan Stokes (janelle.s.stokes@usace.army.mil); Bill Klein (william.p.klein.jr@usace.army.mil)
Subject: Coastal Texas Agency Input
Attachments: Interagency Workgroup Packet - Aug 24 2016 red.pdf; Audubon Society Bird Island Priority List.pdf

Hi David,

I am working on behalf of the GLO/USACE on the Coastal Texas Protection and Restoration Study Integrated Feasibility Report and Environmental Impact Statement. We are looking for feedback from the agencies to help refine the measures that are being considered for the project.

We conducted an interagency workgroup meeting yesterday to help with refining measures, we understand Donna Anderson was unable to attend. We would like to get feedback to include in an upcoming USACE meeting. The USACE suggested I contact you directly to see if the USFWS will provide comments on the measures to us.

I have attached the map book and the Audubon Society bird list that were discussed in the meeting yesterday. Action items include:

1. We request Agency comments, suggestions, and input to help us further develop, refine, and extend the proposed ecosystem restoration strategy and measures to encompass those most critical restoration needs/measures across coastal Texas that are of a national level of significance
2. We request Agency comments, suggestions, and input to help us further develop, refine, and extend the following to encompass the most critical and are of a national level of significance:
   - Identifying and restoring the most critical bird islands, oyster reefs, and seagrass beds from the perspective of a coastwide geomorphic structural line of defense to storms as well as providing essential, important, and critical fish and wildlife habitat.
   - Identifying and restoring the most critical reaches of the entire coastal Texas barrier shorelines/islands that are most susceptible to permanent breaching and accelerating coastal land loss
   - Identifying and restoring the most critical hydrological modifications (e.g., increasing freshwater inflows, rerouting inflows, etc.) in order to reestablish critical hydrologic connectivity

Please notice the multiple uses of the terms: “most critical”, “national level of significance”. We want to emphasize these concepts in developing the overall coastal restoration strategy and restoration measures that will be combined into restoration alternatives.

Please review and send any comments to me by September 2. If you have any questions please let me know.

Thank you!
Lisa

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Marine Biologist / Project Manager

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Texas General Land Office
U.S. Army Corps of Engineers

Coastal Texas Protection and Restoration Study Meeting Minutes
Conference Call with James Lindsay, Padre Island National Seashore

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Date: October 31, 2016

Participants:

Phone:	
Bill Klein	USACE
Jan Stokes	USACE
Dianna Ramirez	GLO
Tom Dixon	FNI
Ray Newby	GLO
Amy Nuñez	GLO
Tony Williams	GLO
James Lindsay	NPS
David Buzan	FNI

Discussion:

- Padre Island National Seashore beach is eroding for approximately 15 miles north of Mansfield Channel. Longshore transport is from the south to the north. The Mansfield Channel jetties block the longshore transport or downstream drift, causing deposition in the protected area behind the southernmost jetty and sand-starving the beach past the northern jetty. Without the longshore transported sediments, erosion on the downstream (northern) side of the jetties is cutting into the first line of dunes.
- The Galveston District has apparently used maintenance dredged material beneficially to nourish the eroding Padre Island shoreline located north of the Mansfield jetties.
- The NPS suggested that the Mansfield Channel be dredged to reestablish circulation patterns with Gulf waters into the back barrier and bays system to help freshen hypersaline waters of the Laguna Madre system.
- Some bird rookery islands in the Laguna Madre are within the park's jurisdiction. Historically the NPS had not strongly supported placement of sediment on the islands. However, it appears the park is becoming more supportive of that approach.
    - Additional brief discussion included further development of additional consideration of developing a coast-wide series of bird rookery islands. Presently we have very few critical rookery islands in our measures and restoration of other existing rookery islands and creation of rookery islands in bays that presently do not have rookery islands should be reconsidered. Open bay placement of materials within the Laguna Madre to create bird islands may raise issues with regulatory agencies because of possible impacts to seagrass.
- The Corps of Engineers policy does not permit restoration actions directly onto other Federal

agency-owned and managed lands. However, in other Corps projects, such as the restoration of the Breton Island National Wildlife Refuge in 1999, the Corps has placed sediments immediately offshore to allow natural current patterns to naturally move the sediments onto the island thereby nourishing and restoring the island. Similar actions for the Mansfield Channel reach of Padre Island National Seashore should be considered.

Action items:

- Find additional information from the Galveston District regarding placement of maintenance dredged material from the Mansfield Channel directly onto or close to the beach north of the jetties. Consider how to use this information in developing additional restoration measures for this area.
- Revise and further define the description of the Sediment Management at Mansfield Channel measure. Sediment management measures could include:
  - Dedicated dredging of sediments from the Mansfield Channel could be placed immediately offshore to allow downstream currents and cross-shore currents to nourish the eroding barrier shoreline north of the channel.
    - Verify that NPS jurisdiction of Padre Island extends to the two-fathom depth into the Gulf of Mexico. We could place sediments outside this limit so as not to violate Corps policy about direct restoration onto other Federal agency lands.
    - Verify if and how Galveston District has placed maintenance dredged material directly onto the beach north of the jetties.
  - There is an opportunity to construct various types of sediment traps (Hugo's example?) in the Mansfield Channel that can serve as a storage site for sediments to be later used in sediment bypassing. Construction of a sediment trap between the jetties would require SWG engineering review to make sure the jetties are not undermined. The authorized channel is already serving to some extent as a sediment trap.
- Discuss this measure again at the November 8 interagency meeting

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

REPLY TO
ATTENTION OF:

December 1, 2016

Regional Planning and Environmental Center

Mr. Michael A. Celata, Regional Director
Bureau of Ocean Energy Management
Gulf of Mexico Region
1201 Elmwood Park Blvd.
New Orleans, LA 70123-2394

Dear Mr. Celata:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Ecosystem Protection and Restoration, Texas, Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of a developing a comprehensive plan for flood damage reduction, hurricane and storm damage risk reduction, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

We are inviting the participation of the Bureau of Ocean Energy Management as a Cooperating Agency pursuant to Council on Environmental Quality Regulations for Implementing the National Environmental Policy Act (40 CFR §1501.6 and §1508.5). Furthermore, we would like to coordinate our review schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007 and Section 1001 of the Water Resources Reform Development Act of 2014. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

Review of Draft IFR-EIS – 45-day review period begins July 2018
State and Agency Review of Final IFR-EIS – 30-day review begins February 2021

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

Kelly A. Burks-Copes
Chief, Coastal Section

From:	Lisa Vitale
To:	Aaron Chastain; Alison Fontenot; Anthony Risko (Anthony.Risko@freese.com); Barbara Keeler; Bill Klein (william.p.klein.jr@usace.army.mil); Bob Heinly; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov); Carla Guthrie (Carla.Guthrie@twdb.texas.gov); Celestine Bryant; Chuck Ardizzone; Colleen Roco (colleen.roco@tpwd.texas.gov); David Buzan (David.Buzan@freese.com); Diana Laird; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV); Donna Anderson (Donna_Anderson@fws.gov); Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil); Elizabeth Vargas; Holly Houghton; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com); Jan Stokes (janelle.s.stokes@usace.army.mil); Jane Watson; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil); Jim Lindsay (james_lindsay@nps.gov); Josh Carter (Joshua.Carter@mottmac.com); Juan Moya (Juan.Moya@freese.com); Kellie Poolaw; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil); Kelsey Calvez; Kevin Cauble; Kristin Shivers (Kristin.D.Shivers@usace.army.mil); Lauren Brown; Leslie Koza; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil); Linda Langley; Lindsey Lippert; Maria Martinez; Matt Mahoney; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com); Michael Lee (mtlee@usgs.gov); Mimi Wallace; Miranda Allen-Myer; Mollie Powell; Nancy Parrish (Nancy.A.Parrish@usace.army.mil); Nelun Fernando; Pat Clements (pat_clements@fws.gov); Paul Kaspar (kaspar.paul@epa.gov); Peter Schaefer (peter.schaefer@tceq.texas.gov); Ray Newby P.G. (Ray.Newby@glo.texas.gov); Rebecca Hensley; Rusty Swafford (rusty.swafford@noaa.gov); Sarah Bernhardt; Scott Alford; Sheri Willey (Sheridan.S.Willey@usace.army.mil); Susan Nahwooksy; Tom Dixon (Tom.Dixon@freese.com); Tony Williams (tony.williams@glo.texas.gov); Travis Creel (Travis.J.Creel@usace.army.mil); Winston Denton
Cc:	Kelsey Calvez; Andrew Labay (Andrew.Labay@freese.com)
Subject:	Coastal Texas Study HEP Species Selection
Date:	Friday, January 13, 2017 12:31:00 PM
Attachments:	Draft Model Species and Habitat Variables-Jan 13 2017.pdf Swannack et al. 2014 - Model for Oyster Restoration Sites.pdf image003.png
Importance:	High

All,

As we discussed during yesterday's meeting we need to get a consensus from you all on the species selected for the HEP analysis and to identify data needs.

Some things to consider when reviewing these materials and providing input:

1. We can only use USACE approved models. You can find the list of approved models here: https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Method&Id=HEP
2. We are only focusing on 1 or 2 species per habitat type because we cannot double or triple count benefits.
3. If we use more than 1 species we have to average the answer so it is a washout when we have multiple species.
4. For oysters we are using the Swannack et al., 2014 model. This is the model that was used for the Houston Ship Channel Study that is ongoing.
5. There will be no field data collection for HEP analysis.

I am attaching the draft information on species models and habitat variables for the HEP discussion. This information includes:

- Recommendations - provides our recommendations for species and cover type.
- Summary Table - provides a quick overview of the more detailed information presented. It outlines what species are associated with what habitat and our reasons for choosing that species. It also contains a questions and uncertainties column.
- HEP Species - provides more detailed information for each species that we chose, including the species HSI habitat variables and descriptions, and HSI life requisites.
- Eliminated Species - follows the same outline as "HEP Species", except for the species that were eliminated.

Review the materials attached and provide us your feedback by **Friday, January 27th**. Information we need for you to provide by that date include:

1. Concurrence with species that we recommended
2. If you do not concur with a species we recommended, your reason why and what species you recommend and your reasons why we should consider using that species.
3. Identification of data needs for species and variables chosen.

If you have any question about the materials provided please contact Andy Labay (Andrew.Labay@freese.com) or Kelsey Calvez (Kelsey.Calvez@freese.com).

Thanks,
Lisa

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FREESE AND NICHOLS

HEP Modeling for Certified Species - Recommendations			
Species	**ER Measures**	**Habitat**	**Reason for Recommendation**
Red Drum	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Wetland & Marsh	Red drum is known as a top predator and if there is an adequate and available food source for the species, then they will be present. The habitat variables for the model can easily have assumptions drawn and they are sensitive to habitat restoration. Particularly, V3 and V4 will reflect FWP and FWOP conditions. Additionally, Brown and White shrimp model habitat variables are not sensitive to fringed marsh edge effect and therefore would not be as sensitive to wetland and marsh restoration projects. Similarly, the Clapper Rail model requires a minimal amount of open water in order to achieve optimal habitat conditions. This would be difficult to achieve with most of the ER measure project areas in the Coastal Texas study.
Spotted Seatrout	SP-1	SAV	Distribution coastwide. Suitability of the model is directly correlated with the percentage of SAV. Additionally, salinity levels and temperature ranges throughout project areas are within optimal ranges. Spotted Seatrout model variables would be good indicators for measures that incorporate oyster reefs. The species is known as a top predator. Further, the habitat variables would be sensitive and responsive to FWP and FWOP conditions.
Brown Pelican	M-7 SP-1 W-1	Islands/ Rookeries	Distribution coastwide. Nesting colonies use woody shrubs/trees on coastal islands. Sufficient data exists for habitat variables. The Brown Pelican model variables would be good indicators for other species that use islands for nesting. The species model utilizes old growth vegetation (the most stable vegetation), which is most ideal for island restoration.
Least Tern	CM-2	Tidal Flats	Distribution coastwide. Least terns prefer to nest in areas with sparse, short vegetation close to extensive areas of open water. With assumptions regarding vegetation, all habitat variables can be measured.
American Oyster	B-2 B-5 CA-4 CA-5 CA-6	Oyster Reefs	The American Oyster will be modeled using the Swannack et al. (2014) model. This model is designed as a spatially explicit, grid-based model that calculates habitat suitability for restoration of Crassostrea virginica.
N/A (Habitat Model)	G-5 East G-5 West B-2 B-4 M-1	Beach/ Dune	Beach/Dune habitat model will be covered by WVA ERDC Spreadsheet and will be used for the Beach and Dune Restoration ER measures.

HEP Modeling for Certified Species - Summary Table			
Species	**ER Measures**	**Habitat**	**Reason for Choice**
Brown & White Shrimp	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Wetland & Marsh	Distribution coastwide. Sufficient data exists for the model habitat variables of both species. Additionally, habitat variables V1 (percentage of estuary covered by vegetation) and V2 (substrate composition) would be sensitive to wetland and marsh restoration, but would require some assumptions.
Red Drum			Distribution coastwide. Sufficient data exists for the model habitat variables of the species. Additionally, habitat variables V3 (percentage of open water fringes with persistent emergent vegetation), V4 (percentage of open water supporting growth of submerged vegetation), and V5 (dominate substrate), would be sensitive to marsh restoration, but would require some assumptions.
Clapper Rail			Coastwide distribution and found in tidal salt and brackish marshes. Strongly dependent on emergent vegetation (V1 and V2). With some assumptions regarding emergent vegetation, sufficient data exists for measuring variables.
Brown & White Shrimp	SP-1	SAV	Distribution coastwide. Sufficient data exists for the habitat variables of both species. Additionally, habitat variables V1 (percentage of estuary covered by vegetation) and V2 (substrate composition) would be sensitive to SAV restoration/protection, but would require sediment quality assumptions.
Spotted Seatrout			Distribution coastwide. Suitability of the model is directly correlated with the percentage of SAV. Additionally, salinity levels and temperature ranges throughout project areas are within optimal ranges. Spotted Seatrout model habitat variables would be good indicators for measures that incorporate oyster reefs.
Redhead			Redhead use bays and estuaries along the Texas coast for overwintering and habitat quality (food) is strongly dependent on SAV (primarily shoal and widgeon grass). With some assumptions about SAV species, all variables can be measured. Redhead is a species with economic and ecological importance. Redhead provide an important component of the SAV model.

HEP Modeling for Certified Species - Summary Table			
Species	**ER Measures**	**Habitat**	**Reason for Choice**
Brown Pelican	M-7 SP-1 W-1	Islands/ Rookeries	Distribution coastwide. Nesting colonies use woody shrubs/trees on coastal islands. Sufficient data exists for habitat variables. The Brown Pelican would be a good indicator for other species that use islands for nesting.
Forster's Tern			Forster's Tern is a species that can be applied to the entire Texas Coast. Additionally, the species exploits resources that are different from the Brown Pelican, such as using the ground and wrack as nesting habitat, and therefore allows for a more robust evaluation of a bird rookery island.
Least Tern	CM-2	Tidal Flats	Distribution coastwide. Least terns prefer to nest in areas with sparse, short vegetation close to extensive areas of open water. With assumptions regarding vegetation, all habitat variables can be measured.
American Oyster	B-2 B-5 CA-4 CA-5 CA-6	Oyster Reefs	The American Oyster will be modeled using the Swannack et al. (2014) model. This model is designed as a spatially explicit, grid-based model that calculates habitat suitability for restoration of Crassostrea virginica.
N/A (Habitat Model)	G-5 East G-5 West B-2 B-4 M-1	Beach/ Dune	Beach/Dune habitat model will be covered by WVA ERDC Spreadsheet and will be used for the Beach and Dune Restoration ER measures.

Habitat Suitability Index for Certified Species - Model Species													
Species Common Name	**Species Latin Name**	**Habitat Type**	**ER Measures Affected**	**HSI Habitat Variable**		**HSI Habitat Variable Description**	**HSI Life Requisites**	**HSI Life Stage**	**HSI Habitat Type**	**HSI Model Limitations & Assumptions**	**HSI Model Type**	**HSI Model Formulas**	**Reasons for Choice**
Brown Shrimp (Northern Gulf of Mexico)[1]	*Farfantepenaeus aztecus*	Wetland and Marsh & SAV	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	**Percentage of Estuary Covered by Vegetation (V_1)		Marsh vegetation and seagrass provide food for growth and protection from predators. If at least 100% of the estuary is covered by marsh and seagrass, the suitability is considered to be optimum for this variable.	Food, Cover	Post larval, Juvenile	Estuarine	**From a long-term perspective, the total yields of adult brown/white shrimp are directly limited by the quantity and quality of marshes/submerged vegetation available to post larvae and juveniles. Bay bottom habitats are critically limiting to shrimp populations.	Multiple	Food, Cover (FC) = $(SI^2_{V1} \times SI_{V2B})^{1/3}$ for brown shrimp. $(SI^2_{V1} \times SI_{V2W})^{1/3}$ for white shrimp. Water Quality (WQ) = $(SI_{V3B} \times SI_{V4})^{1/2}$ for brown shrimp. $(SI_{V3W} \times SI_{V4})^{1/2}$ for white shrimp.	Brown and White Shrimp are found along much of the Atlantic and Gulf of Mexico coasts, with maximum densities occurring along the Texas-Louisiana coast. Sufficient data exists for the model habitat variables. Additionally, habitat variables V1 (percentage of estuary covered by vegetation) and V2 (substrate composition) would be sensitive to impacts from the Coastal Texas Study and would be good indicators for measuring wetland and marsh restoration.
				Substrate Composition (V_2)		Optimal conditions occur when substrate is composed of soft bottoms (peaty silts, organic muds) with decaying vegetation. Muddy sands and/or fine sands are moderately suitable. Coarse or hard bottoms with little to no organic material are least suitable.							
				Salinity (V_3)		Salinities of 10-20 ppt are considered to be optimal. Salinity levels above 45 ppt are unsuitable for brown and white shrimp.							
				Temperature (V_4)		Optimal conditions occur when temperature ranges between 68°F-86°F. Temperature values below or above this range are considered less than optimal, with 41°F and 104°F considered unsuitable.	Water Quality						
White Shrimp (Northern Gulf of Mexico)[1]	*Litopenaeus setiferus*	Wetland and Marsh & SAV	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	**Percentage of Estuary Covered by Vegetation (V_1)		Marsh vegetation and seagrass provide food for growth and protection from predators. If at least 100% of the estuary is covered by marsh and seagrass, the suitability is considered to be optimum for this variable.	Food, Cover	Post larval, Juvenile	Estuarine	**From a long-term perspective, the total yields of adult brown/white shrimp are directly limited by the quantity and quality of marshes/submerged vegetation available to post larvae and juveniles. Bay bottom habitats are critically limiting to shrimp populations.	Multiple	Food, Cover (FC) = $(SI^2_{V1} \times SI_{V2B})^{1/3}$ for brown shrimp. $(SI^2_{V1} \times SI_{V2W})^{1/3}$ for white shrimp. Water Quality (WQ) = $(SI_{V3B} \times SI_{V4})^{1/2}$ for brown shrimp. $(SI_{V3W} \times SI_{V4})^{1/2}$ for white shrimp.	Brown and White Shrimp are found along much of the Atlantic and Gulf of Mexico coasts, with maximum densities occurring along the Texas-Louisiana coast. Sufficient data exists for the model habitat variables. Additionally, habitat variables V1 (percentage of estuary covered by vegetation) and V2 (substrate composition) would be sensitive to impacts from the Coastal Texas Study and would be good indicators for measuring wetland and marsh restoration.
				Substrate Composition (V_2)		Optimal conditions occur when substrate is composed of soft bottoms (peaty silts, organic muds) with decaying vegetation. Muddy sands and/or fine sands are moderately suitable. Coarse or hard bottoms with little to no organic material are least suitable.							
				Salinity (V_3)		Salinities of 10-20 ppt are considered to be optimal. Salinity levels above 45 ppt are unsuitable for brown and white shrimp.							
				Temperature (V_4)		Optimal conditions occur when temperature ranges between 68°F-86°F. Temperature values below or above this range are considered less than optimal, with 41°F and 104°F considered unsuitable.	Water Quality						
Red Drum (Larval and Juvenile)[2]	*Sciaenops ocellatus*	Wetland and Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Veg. Substrate	Mean Temperature (V_1)	Optimal conditions occur when temperature ranges between 77°F-86°F. Mean temperature below 59°F is unsuitable for larval development.	Water Quality	Larval and Juvenile	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	Estuaries with Submerged Vegetation: Water Quality (WQ) = $(SI_{V1}{}^2 \times SI_{V2})^{1/3}$ Food Cover (FC) = $(SI_{V3} \times SI_{V4})^{1/2}$ HSI = WQ or FC, whichever is lower	Red Drum is an estuarine-dependent species found all along the Gulf of Mexico. Red Drum prefer muddier substrates and the modest assumption can be made that if red drum habitat is created, then marsh habitat is created. Sufficient data exists for the habitat variables of the species. Additionally, habitat variables V3 (percentage of open water fringes with persistent emergent vegetation), V4 (percentage of open water supporting growth of submerged vegetation), and V5 (dominant substrate), would be sensitive to impacts from the Coastal Texas Study and would be good indicators for measuring marsh restoration. Each variable would be measured with modest assumptions.
					Mean Salinity (V_2)	Optimal conditions occur when salinity levels range between 25-30 ppt during period of larval development. Salinity levels below 10 ppt are unsuitable.							
					Percentage of Open Water Fringed w/ Persistent Emergent Vegetation (V_3)	Food abundance increases as the percentage of open water edge fringed with intertidal wetlands increases (estuarine area vegetated with persistent emergent species) in a linear fashion. Intertidal wetlands are related to productivity and loss of wetlands results in a reduction in carrying capacity.	Food, Cover						
					Percentage of Open Water Supporting Growth of Submerged Vegetation (V_4)	Optimal conditions occur when the amount of submerged vegetated cover reaches 60%. Habitat suitability decreases as the amount of cover exceeds 75%. Submerged vegetation provides cover, but some unvegetated bottom is necessary for feeding by larval and juvenile red drum.							
				Nat. Non-Veg Substrate	Mean Temperature (V_1)	Optimal conditions occur when temperature ranges between 77°F-86°F. Mean temperature below 59°F is unsuitable for larval development.	Water Quality					Estuaries with little or no Submerged Vegetation: Water Quality (WQ) = $(SI_{V1}{}^2 \times SI_{V2})^{1/3}$ Food (F) = SI_{V3}. Cover (C) = $(SI_{V5} \times SI_{V6})^{1/2}$ HSI = WQ, F, or C, whichever is lower	
					Mean Salinity (V_2)	Optimal conditions occur when salinity levels range between 25-30 ppt during period of larval development. Salinity levels below 10 ppt are unsuitable.							
					Percentage of Open Water Fringed w/ Persistent Emergent Vegetation (V_3)	Food abundance increases as the percentage of open water edge fringed with intertidal wetlands increases (estuarine area vegetated with persistent emergent species) in a linear fashion. Intertidal wetlands are related to productivity and loss of wetlands results in a reduction in carrying capacity.	Food						
					Dominant Substrate (V_5)	Optimal substrate is mud, then fine sand, coarse sand, rock, and finally shell (unsuitable)	Cover						
					Mean Depth (V_6)	Larvae and juveniles prefer water depths of 1.5-2.5 m in naturally unvegetated bottoms.							

Habitat Suitability Index for Certified Species - Model Species												
Species Common Name	**Species Latin Name**	**Habitat Type**	**ER Measures Affected**	**HSI Habitat Variable**	**HSI Habitat Variable Description**	**HSI Life Requisites**	**HSI Life Stage**	**HSI Habitat Type**	**HSI Model Limitations & Assumptions**	**HSI Model Type**	**HSI Model Formulas**	**Reasons for Choice**
Spotted Seatrout[3]	*Cynoscion nebulosus*	SAV	SP-1	Lowest Monthly Average Winter-Spring Salinity (V_1)	December-May: Salinity levels of 19-38 ppt are considered optimal and levels above 45 ppt and below 5 ppt are considered unsuitable.	Water Quality	All Life Stages, eggs and larvae more sensitive	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	Water Quality (WQ) = $(SI_{V1}\ X\ SI_{V2})^{1/2}$ or $(SI_{V3}\ X\ SI_{V4})^{1/2}$, whichever is lower Food/Cover (FC) = (SI_{V5}) HSI = WQ OR FC, whichever is lower	Spotted Seatrout is a species that has a distribution along the entire Gulf of Mexico. Habitat suitability for the species is directly correlated with the percentage of submerged aquatic vegetation in the project area and would provide an important component of the SAV model. Additionally, salinity levels and temperature ranges throughout the Gulf of Mexico are presently within optimal ranges for the species. Spotted Seatrout is a good indicator species for the Coastal Texas ER measures that incorporate oyster reefs.
				Highest Monthly Average Summer Salinity (V_2)	June-September: Salinity levels of 19-38 ppt are considered optimal and levels above 45 ppt and below 5 ppt are considered unsuitable.							
				Lowest Monthly Average Winter Temperature (V_3)	December-March: Temperature range of 68°F-90°F is considered optimal and temperatures below 39°F (extremely cold) and above 104°F (extremely warm) are considered unsuitable.		All Life Stages, eggs and larvae more sensitive					
				Highest Monthly Average Summer Temperature (V_4)	June-September: Temperature range of 68°F-90°F is considered optimal and temperatures below 39°F (extremely cold) and above 104°F (extremely warm) are considered unsuitable.							
				Percentage of Study Area w/ Submerged or Emergent Veg., Submerged Islands, Shell Reefs, and Oyster Reefs (V_5)	Optimal conditions occur when 40% or more of the study area is covered with submerged or emergent vegetation, submerged islands, shell reefs, or oyster reefs. A positive relationship exists between primary and secondary productivity (amount of vegetation) in the aquatic ecosystem.	Food, Cover	All Life Stages					
Clapper Rail[4]	*Rallus longirostris*	Wetland and Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Percentage of Shoreline of Persistent Emergent and Scrub/Shrub Mangrove Wetlands Bordered by Tidal Flats or Exposed Tidal Channels (V_1)	The best habitat is assumed to be that with at least 50% of the persistent emergent and scrub/shrub mangrove wetlands bordered by tidal flats or exposed tidal channels.	Food/Cover	All Life Stages	Estuarine	In areas larger than 5 acres, the following is assumed: each variable is weighted equally. If the area lacks suitable contiguous habitat of at least 5 acres, the HSI is zero.	Single	HSI = $(SI_{V1}\ X\ SI_{V2}\ X\ SI_{V3})^{1/3}$	Clapper rails inhabit estuarine tidal salt and brackish coastal marshes along the Gulf of Mexico. Sufficient data exists for the habitat variables and all variables can be adequately measured. The species habitat variables and life requisites would be sensitive to the Coastal Texas marsh restoration measures, with the assumption that the project areas contain emergent vegetation.
				Percentage of Area Covered by Persistent Emergent and Scrub/Shrub Mangrove Wetlands (V_2)	Clapper rails nest and feed in the persistent emergent and scrub/shrub mangrove wetlands. Survival depends upon the availability of such wetlands (linear graph).							
				Percentage of Persistent Emergent and Scrub/Shrub Mangrove Wetlands Within 15m (49.2 ft.) of Tidally Influences Bodies of Water (V_3)	Important nesting habitat includes Spartina, Salicornria, Grindelia, and possibly mangroves. Optimal conditions occur when 15-m fringe, bordering a tidally influences body of water. Coastal areas with large water to vegetation interface are assumed to provide the best nesting habitat. Areas with a high percentage of the total emergent and scrub/shrub mangrove wetlands within 15m of water will have the highest SI.							
Brown Pelican[5]	*Pelecanus occidentalis*	Islands / Bird Rookeries	M-7 SP-1 W-1	Island Surface Area (V_1)	Islands that are a minimum area of 5 acres are assumed to be of the highest suitability. Islands larger than 20 acres may be able to support resident populations of predators and therefore, suitability decreases in these instances.	Nesting / Loafing Cover	All Life Stages	Estuarine (island)	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Single	Cover (C) = $(SI_{V1}\ X\ SI_{V2}\ X\ SI_{V3}\ X\ SI_{V4})^{1/4}$	The Eastern Brown Pelican is found along the entire Gulf coast. The nesting colonies of the species occur on coastal islands in woody trees and shrubs. Sufficient data exists for the habitat variables of the species. The habitat variables would be sensitive to impacts from the Coastal Texas Study and would be good indicators for restoring bird rookery islands.
				Distance from Mainland (V_2)	Islands that are a distance of 0.25 miles or more away from the mainland are considered optimal.							
				Distance from Human Activity (V_3)	Optimal distance from human activity centers is at least 328 feet and suitability increases to an optimum with a distance of 0.25 miles or more.							
				Nesting Coverage/Island Elevation (V_4)	Nesting vegetation covering 50% or more of an island is considered optimal. Island surface and shrubs that are potential nesting cover must be at least 2 ft. above high tide.							

Habitat Suitability Index for Certified Species - Model Species												
Species Common Name	**Species Latin Name**	**Habitat Type**	**ER Measures Affected**	**HSI Habitat Variable**	**HSI Habitat Variable Description**	**HSI Life Requisites**	**HSI Life Stage**	**HSI Habitat Type**	**HSI Model Limitations & Assumptions**	**HSI Model Type**	**HSI Model Formulas**	**Reasons for Choice**
Forster's Tern[6]	*Sterna forsteri*	Islands / Bird Rookeries	M-7 SP-1 W-1	**Percent of Island Covered with S. alterniflora or S. patens (V_1)	Optimal nesting habitat is found on low, periodically flooded saltmarsh islands vegetated with near-monotypic stands of S. alterniflora with canopy cover of at least 25%. Islands with a max elevation of less than 0.5 meters above mean high tide are normally vegetated with only Spartina spp and do not support woody vegetation (this variable includes an elevation component).	Nesting Cover	All Life Stages	Estuarine	**Variables V1 and V2 are assumed to be very important. Any compensatory interaction would be weak and the equation for cover incorporates a geometric mean of those variables. A low SI score for one of the variables can be compensated by a high score for the other variable. It is assumed that a large island vegetated almost entirely with Spartina would be more suitable than a small marshy island because of the wave-damping effect.	Single	Nesting Cover = $(SI_{V1} \times SI_{V2})^{1/2}$ Island Characteristics = $(SI_{V3} + SI_{V4})^{1/2}$ Disturbance = SI_{V5} HSI =((((2*NestingCover)+(IslandCharacteristics))/3)*DisturbanceLevel)^0.5	Forster's Tern is a species that can be applied to the entire Texas Coast. Additionally, the species exploits resources that are different from the Brown Pelican, such as using the ground and wrack as nesting habitat, and therefore allows for a more robust evaluation of a bird rookery island.
				**Wrack Quality (V_2)	This variable should be measured on a relative scale. Optimum habitat contains extensive wrack deposits that completely cover the underlying marsh vegetation and provide a substrate that elevates the nest above mean high tide							
				Island Size (V_3)	Optimal conditions occur when the island size is 0.1-1.0 ha. As island size increases, potential to support predator population increases. Islands greater than 20 ha are relatively unsuitable for nesting colonies. On the other hand, suitability of very small islands is low due to high probability of colony being damaged by waves.	Island Characteristics						
				Distance of Island from Mainland or Other Island >20 ha in area (V_4)	Optimum nesting islands are separated from the mainland by 1 to 3 km of water (sufficiently deep to create predator barrier, greater than 0.5 m deep at mean low tide). As distance from the mainland increases, the potential for successful predator colonization decreases, but exposes the nesting colony to severe wave and tidal damage.							
				Disturbance Level (V_5)	Optimum nesting habitat is found in areas such as refuges where human disturbance is restricted. Human disturbance and development are often cited as reasons for tern colony abandonment. Commercial/recreational boating near nesting colony does not adversely affect if vessels not closer than 100 m.	Disturbance						
Redhead Duck[7]	*Aythya americana*	SAV	SP-1	Percentage of Study Area Supporting Growth of Shoalgrass and/or Widgeongrass (V_1)	Shoalgrass and widgeongrass are the major food of wintering redheads. As the amount of these species of submergent vegetation increases, the habitat suitability for wintering redheads increases.	Food	Adult	Estuarine Open Water (less than 10% canopy cover of emergent vegetation) less than 5.0 m in depth	A compensatory relationship between V_1 and V_2 determines food quality. This food quality measure is equally as important as the disturbance (V_3) measure in determining the food CI.	Single	Food (CI_F) = $[(SI_{V1} \times SI_{V2})^{1/2} \times SI_{V3}]^{1/2}$ HSI = CI_F, if a freshwater source of dietary water is available within 20.0 km (12.4 mi) or, HSI = $0.9CI_F$, if no freshwater source of dietary water is available within 20.0 km.	Redhead Duck is a species that can be applied to the entire Texas Coast, particularly in coastal lagoons and bays, and is commonly known for it's use of submerged aquatic vegetation. Additionally, Redhead Ducks are a species with economic as well as ecological importance. Redhead Ducks provide an important component of the SAV model.
				Percentage of Shoalgrass and/or Widgeongrass in each of three depth classes (V_2)	Shoalgrass and widgeongrass beds in shallow water are preferred as feeding sites over beds in deeper water.							
				Human Disturbance to Feeding Areas (V_3)	Human disturbance decreases suitability of habitat for wintering redheads. The level of disturbance has a greater effect on habitat suitability when the disturbance is applied to shallow water beds of shoalgrass/wideongrass than to deep beds.							
Least Tern[8]	*Sterna antillarum*	Tidal Flats	CM-2	Percent of the Total Area Within the Average Maximum Flight Distance from the Potential Nesting Habitat that is Aquatic (V_1)	It is assumed that an area composed of ≥ 50% water within the average maximum flight distance (3.2 km) from the potential nesting habitat will provide optimum foraging habitat area.	Food	Adult	Marine, Estuarine, Riverine, Lacustrine, Palustrine	Least terns prefer to nest in areas containing extensive areas of water and diverse aquatic habitat. Most large populations are found along the coast, particularly in the vicinity of inlets.	Multiple	$SI_F = (2{*}SI_{V1}) + SI_{V2})/3$	Least terns prefer to nest in areas containing extensive areas of water and diverse aquatic habitat. Most large populations are found along the coast, particularly in the vicinity of inlets. All habitat variables can be measured and sufficient data exists.
				Number of Disparate Aquatic Wetlands within the Average Maximum Flight Distance from the Potential Nesting Habitat (V_2)	It is assumed that an area composed of a single aquatic system will provide optimum diversity of foraging habitat when it contains two or more disparate aquatic (flooded) wetlands within the average maximum flight distance from the potential nesting habitat.							
				Percent Herbaceous and Shrub Canopy Cover (V_3)	Least tern generally nest in areas of sparse vegetation and usually will not nest in areas with > 20% vegetation cover or with tall vegetation. Habitats with 0-15% coverage provide optimum cover suitability. An area will have 0% suitability when vegetation exceeds 25%.	Reproduction		Shore and Bottom Wetland, Barren Land, Desert Herbland	When percent vegetation cover is < 15 % or > 25%, the suitability index for SI_C is assumed to be determined solely by SI_{V3}.		$SI_C = (SI_{V3} \times SI_{V4})^{1/2}$	
				Average Height of Herbaceous and Shrub Canopy (V_4)	An area has no suitability as potential nesting habitat when the average height of the vegetation is > 40 cm.							
				Substrate Composition (V_5)	Generally nest on unconsolidated substrate with 50-80% sand and 30-70% fragmentary material.							

Habitat Suitability Index for Certified Species - Model Species												
Species Common Name	**Species Latin Name**	**Habitat Type**	**ER Measures Affected**	**HSI Habitat Variable**	**HSI Habitat Variable Description**	**HSI Life Requisites**	**HSI Life Stage**	**HSI Habitat Type**	**HSI Model Limitations & Assumptions**	**HSI Model Type**	**HSI Model Formulas**	**Reasons for Choice**
American Oyster (Gulf of Mexico)[9]	*Crassostrea virginica*	Oyster Reefs	N/A	Percentage of Cultch Cover on Bottom (V1)	100% bottom cover with suitable clutch (hard substrate, including oyster reefs or other hard surfaces) is considered optimal.	N/A	All Life Stages	Estuarine	*See Oyster Model document for detailed model limitations and assumptions.	N/A	**See Oyster Model document for detailed formula descriptions.*	The American Oyster will be modeled using the Swannack et al. (2014) model. This model is designed as a spatially explicit, grid-based model that calculates habitat suitability for restoration of *Crassostrea virginica* .
				Mean Salinity during Spawning Season (V2)	Optimal conditions occur when salinity levels range between 18-22 ppt during the spawning season (May through September).							
				Minimum Annual Salinity (V3)	Minimum annual salinity is the minimum value of the 12 monthly mean salinities. Optimal conditions occur when minimum annual salnity is 8 ppt or more. This variable is essential to describe freshwater impacts.							
				Annual Mean Salinity (V4)	Optimal conditions occur when annual mean water salinity levels are between 10 ppt and 20 ppt. Oysters can survive over a salinity range of 5 or 50+ ppt.							

References:

[1]Turner, R.E., and M.S. Brody. Habitat Suitability Index Models: Northern Gulf of Mexico Brown Shrimp and White Shrimp. U.S. Dept. of Int. Fish Wildl. Serv. FWS/OBS-82/10.54. 24 pp.

[2]Buckley, J. 1984. Habitat Suitability Index Models: Larval and Juvenile Red Drum. U.S. Fish Wildl. Serv. FWS/OBS-82/10.74. 15 pp.

[3]Kostecki, P.T. 1984. Habitat Suitability Index Models: Spotted Seatrout. U.S. Fish Wildl. Serv. FWS/OBS-82/10.75. 22 pp.

[4]Lewis, J.C., and R.L. Garrison. 1983. Habitat suitability index models: clapper rail. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.51. 15 pp.

[5]Hingtgen, T. M., R. Mulholland, and A. V. Zale. 1985. Habitat suitability index models: eastern brown pelican. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.90) 20 pp.

[6]Martin, R.P., and P.J. Zwank. 1987. Habitat suitability index models: Forster's Tern (breeding) -- Gulf and Atlantic Coasts. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.131). 21 pp.

[8]Carreker, R.G. 1985. Habitat suitability index models: Least tern. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.103). 29 pp.

[9]T.M. Swannack, M. Reif, and T.M. Soniat. 2014. A robust, spatially explicit model for identifying oyster restoration sites: case studies on the Atlantic and gulf coasts. Journal of Shellfish Research, Vol. 33, No. 2, 395-408.

Indicates a very important and sensitive (and therefore limiting) habitat variable for the Habitat Suitability Index

Indicates a habitat variable affected by one of more ER measures in the Coastal Texas study

Indicates a very important and sensitive (and therefore limiting) habitat variable affected by one of more ER measures in the Coastal Texas study

Habitat Suitability Index for Listed Species - Eliminated Species

Species Common Name	Species Latin Name	Habitat Type	ER Measures Affected	HSI Habitat Variable	HSI Habitat Variable Description	HSI Life Requisites	Life Stage	Habitat	HSI Limitations & Assumptions	Model Type	Formulas	Reasons for Elimination
Atlantic Croaker[1]	*Micropogonias undulatus*	Wetland & Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Turbidity (V_1)	Optimal conditions occur when turbidity levels range between 15-30 FTU. High turbidity levels are positively related to the abundance of juvenile croackers.	Water Quality	Juvenile	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Atlantic Croaker was eliminated for Wetland & Marsh habitat for the following reason: most ER measure project areas in the Coastal Texas study have salinity levels higher than 20 ppt during the spring, which is not optimal for Atlantic Croakers. Additionally, the habitat variables for Atlantic croaker would not be as responsive as other similar species for wetland & marsh habitat restoration.
				Dissolved Oxygen (V_2)	Optimal conditions occur when levels of dissolved oxygen reach 5 mg/l or more. Low levels of dissolved oxygen are not suitable.							
				Salinity in Spring (V_3)	In the Spring, juvenile croakers are caught at salinities from 0 to 24 ppt. Salinities of 0 to 15 ppt are more suitable.							
				Salinity in Summer (V_4)	In the Summer, fresh water is unsuitable. Salinities from to 26 ppt are most suitable. Salinities greater than 30 ppt are low in suitability.							
				Depth (V_5)	In regions with small tides only, shallow areas closely associated with marsh are most suitable, shallow open water is intermediate in suitability, and deep open water is least suitable.	Cover						
				Substrate Type (V_6)	Soft mud is most suitable. Sandy mud is less suitable. Hard and coarse substrates and seagrass beds are unsuitable.							
Marsh Wren[2]	*Cistothorus palustris*	Wetland & Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Growth Form of Emergent Hydrophytes (V_1)	Optimal conditions occur when cattails, cordgrasses, and bulrushes are the dominant species. Intermediate suitability conditions occur when bluejoin reedgrass, reed canarygrass, and sedges are the dominant species. Least suitability conditions occur when other growth forms not listed are the dominant species.	Cover and Reproduction	Adult	Emergent Wetland and Scrub-Shrub Wetland	A zero value for SI_{V1}, SI_{V2}, or SI_{V3} indicates an unsuitable habitat. SI_{V4} is given more weight because it is assumed that habitat suitability decreases as percent canopy cover of woody vegetation.	Single	**See HSI document for detailed formula descriptions.*	Marsh Wren was eliminated for Wetland & Marsh habitat because the species inhabits mostly freshwater areas, and most of the ER measure project areas for the Coastal Texas study involve saltwater environments.
				Percent Canopy Cover of Emergent Herbaceous Vegetation (V_2)	Optimal conditions occur when the percent canopy cover of emergent herbaceous vegetation is 75-100%.							
				Mean Water Depth (V_3)	Optimal conditions occur when the mean water depth (cm) is 15-40cm.							
				Percent Canopy Cover of Woody Vegetation (V_4)	A negative relationship exists between woody vegetation and habitat suitability - as the percent canopy cover of woody vegetation increases, habitat suitability decreases.							
Northern Pintail[3]	*Anas acuta*	SAV	SP-1	Water Depth (V_1)	Optimal conditions occur when the percentage of open water (<10% canopy coverage of emergent vegetation) is 45% or more. Areas where wintering pintails rest and feed are usually large, open, and <0.5 m deep	Cover	All Life Stages	Estuarine Open Water (less than 10% canopy cover of emergent vegetation) less than 5.0 m in depth	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Northern Pintail was eliminated for SAV habitat because almost every ER measure project area will generally have salinity levels above 5 ppt, which would provide a low HSI value for the species. Additionally, Pintail prefer more freshwater areas with emergent plants that produce seeds, which are not frequently found along the Texas coast.
				Amount of Persistent Emergent Vegetation (V_2)	Optima conditions occur when 0-40% of the area is covered by persistent emergent vegetation. Pintails rest in open portions of wetland where dense strands of tall (>30cm above the water surface) emergent have less than 40% canopy cover.							
				Structure of Emergent Vegetation (V_3)	Optimal conditions occur at 0-5%. Pintails rest in open portions of wetland where dense strands of tall (>30cm above the water surface) emergent have less than 40% canopy cover.							
				Water Depth (V_1)	Optimal conditions occur when the percentage of open water (<10% canopy coverage of emergent vegetation) is 45% or more. Areas where wintering pintails rest and feed are usually large, open, and <0.5 m deep.	Food						
				Percentage of Wetland Dominated by Food Plants (V_4)	Optimal conditions occur when 45% or more o the study area is dominated by submerged or emergent food plants. Feeding areas are large, generally <0.5 m deep, and contain submerged or emergent and drawdown plants that produce an abundance of seeds.							
				Salinity (V_5)	Optimal conditions occur when salinity levels are at 5 ppt or lower. In coastal wetlands lacking extensive beds of Halodule wrightii or Ruppia maritima, pintails prefer freshwater areas. Except in areas southwest of Corpus Christi, Texas (areas that are dominated by shoalgrass or widgeongrass), pintails prefer vegetation that grows in freshwater to intermediate-salinity wetlands over vegetation of higher salinity wetlands.							

Habitat Suitability Index for Listed Species - Eliminated Species

Species Common Name	Species Latin Name	Habitat Type	ER Measures Affected	HSI Habitat Variable	HSI Habitat Variable Description	HSI Life Requisites	Life Stage	Habitat	HSI Limitations & Assumptions	Model Type	Formulas	Reasons for Elimination
Gulf Menhaden[4]	*Brevoortia patronus*	Wetland & Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Lowest Monthly Average Winter Water Temperature (V_8)	Optimal conditions occur when temperature ranges between 5°C and 20°C. It is assumed that larvae and juveniles have lower and broader water temperature requisites than the adult and egg life stages.	Water Quality	Juveniles and Larvae	Estuarine	The food component is considered the most important life requisite for determining the habitat suitability for gulf menhaden.	Multiple	**See HSI document for detailed formula descriptions.*	Gulf menhaden have a wide distribution and use of estuarine and marine waters that is indicative of their tolerance to extremes environmental factors. For this reason, the habitat variables for this species would not be as responsive or sensitive to wetland and marsh restoration. Additionally, the water color variable is indicative of plankton richness, which would be applicable to only the upper Texas coast (Regions 1 and 2). Most ER measure project areas in the Coastal Texas study will have salinity levels higher than 20 ppt.
				Highest Monthly Average Summer Water Temperature (V_{13})	Optimal conditions occur when temperature ranges between 20°C-33°C.		Adult					
				Lowest Monthly Average Winter Salinity (V_9)	Optimal conditions occur when salinity ranges between 5-12 ppt. Estuarine larvae and juveniles have lower and narrower salinity requisites than adult and egg life stages.		Juveniles and Larvae					
				Average Annual Salinity (V_{14})	Optimal conditions occur when average annual salinity ranges between 10-35 ppt. Salinity is the second most important factor governing water quality suitability.		Adult					
				Lowest Weekly Average Dissolved Oxygen (V_{10})	Optimal conditions occur when dissolved oxygen concentrations range between 5-8 ppm. Short-term dissolved oxygen depletions do not diminish overall habitat suitability for gulf menhaden in estuaries.		All Life Stages					
				Average Annual Salinity (V_3)	Optimal conditions occur when salinity ranges between 5-20 ppt. It is assumed that salinity is one factor governing food availability for all gulf menhaden life stages.	Food	All Life Stages					
				Water Color (V_{12})	Optimal conditions occur when long-term Historical water color is brown. This reflects the presence of nutrients that promote growth of suitable food organisms for estuarine gulf menhaden life stages.							
				Substrate Composition (V_5)	Optimal conditions occur when substrate is composed of mud. Sandy mud provides intermediate suitability and sand and shell provides minimal suitability. It is assumed that organic content of bottom sediments potentially available to be suspended in the water column is a third factor governing food requisites.							
				Marsh Acreage (V_{11})	Optimal conditions occur when available acreage of tidal marsh is >1000 acres. Suitability decrease as available acreage decreases.	Cover	Larval					
Spot (Juvenile)[5]	*Leiostomus xanthurus*	N/A	N/A	Dominant Sediment Type (V_1)	Optimal conditions occur when dominant sediment type is mud, versus fine sand, coarse sand, or shell or pebble. Sediment type is an index of food availability.	Food	Juvenile	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	*See HSI document for detailed formula descriptions.	The optimal salinity ranges for Spot are too broad to be sensitive or responsive to the ER measure project areas in the Coastal Texas study. Due to this, and the fact that this species is very much a generalist species, the habitat variables potentially would not be sensitive to habitat restoration.
				Average Summer Water Temperature (V_2)	Optimal conditions occur when average summer water temperature ranges between 17°C-27°C. Extreme temperatures near 5° to 34°C are unlikely to be suitable.	Water Quality						
				Average Summer Salinity (V3)	Optimal conditions occur when average summer salinity ranges between 15-30 ppt.							
				Average Minimum Summer Dissolved Oxygen (V4)	Optimal conditions occur when average minimum summer dissolved oxygen concentrations are 4 mg/l or more.							
				Average Water Depth at Mean High Water (V5)	Optimal conditions occur when average water depth at mean high water is 0 to 3 m. These include the intertidal zone as an optimal habitat.							
Hard Clam[7]	*Mercenaria campechiensis, Mercenaria mercenaria*	N/A	N/A	Dissolved Oxygen (V_1)	Optimal dissolved oxygen concentrations for larval M. mercenaria growth and survival is 4.0 mg/l or higher.	Water Quality	Larval	Estuarine	Percentage of silt-clay is squared because it is considered the most important variable.	Multiple	**See HSI document for detailed formula descriptions.*	Hard clams occurs in very few ER measure study areas.
				Salinity (V_2)	Optimal salinity ranges for growth and survival of adult M. camechiensis is 24-35 ppt. Optimal ranges for adult M. mercenaria is 20-30 ppt. Optimal salinity range of hard clams throughout their range is 22-35 ppt.		Adult					
				Water Temperature (V_3)	Optimal range for growth of both species is assumed to be 20° to 31°C.							
				Percentage Silt-Clay (V_4)	0% silt-clay substrate is optimal. Clams must be capable of burrowing in substrate. As percentage of silt-clay content increases, growth decreases.	Substrate-Suspended Solids	All Life Stages					
				Current (V_5)	Densities of clams are highest where current velocities are 30 to 50 cm/s.							
				Suspended Solids (V_6)	Larval clam growth is optimal at silt concentrations of 0.75 g/l or less from April to September.		Larval					

Habitat Suitability Index for Listed Species - Eliminated Species												
Species Common Name	**Species Latin Name**	**Habitat Type**	**ER Measures Affected**	**HSI Habitat Variable**	**HSI Habitat Variable Description**	**HSI Life Requisites**	**Life Stage**	**Habitat**	**HSI Limitations & Assumptions**	**Model Type**	**Formulas**	**Reasons for Elimination**
Pink Shrimp[8]	*Farfantepenaeus duorarum*	Wetland & Marsh and SAV	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Substrate Class (V1)	Optimal conditions occur when substrate is firm bottom with some organic materials-sandy silt, silty sand. Substrate affects the distribution of pink shrimp. Pink shrimp are more numerous on firm bottoms with some organic material than on soft, muddy bottoms.	Food-Cover	Post larval, Juvenile	Estuarine	The suitability index for vegetation coverage is squared, indicating its importance to pink shrimp. The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Pink Shrimp are not as common as Brown/White Shrimp and comprise of less than 10% of the total commercial harvest across the Texas coast. Additionally the species are low in abundance across the Texas coast when compared to Brown/White shrimp.
				Percentage of Estuarine Area Covered with Vegetation (V2a)	Optimal conditions occur when there is 75% or more open water/seagrass zone covered with seagrass. The availability of vegetative cover is one of the most essential requirements for a satisfactory nursery area. Vegetation provides food and cover.							
				Percentage of Estuarine Area Covered with Vegetation (V2b)	The higher the percentage of emergent wetland zone covered with herbaceous emergent vegetation or mangroves, the higher the suitability for pink shrimp.							
				Salinity (V3)	Optimal conditions occur when mean annual salinity ranges between 15-35 ppt. Salinity levels affect growth and survival of pink shrimp.	Water Quality						
				Temperature (V4)	Optimal conditions occur when mean annual water temperature ranges between 25-35°C. Temperature levels affect growth and survival. Optimal temperatures for pink shrimp are those that support rapid growth.							
American Coot[9]	*Fulica americana*	Wetland & Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Percent of Wetland Basin Dominated by Persistent Herbaceous Vegetation (V1)	Optimal conditions occur when 40-60% of the wetland basin is dominated by persistent emergent herbaceous vegetation (cattails and bulrushes).	Reproduction	All Life Stages	Herbaceous Wetland, Lacustrine, Riverine	Water regime is assumed to have the greatest influence on the determination of a reproductive habitat index value.	Single	**See HSI document for detailed formula descriptions.*	American coots require robust emergent vegetation, such as cattails and bulrush, which may not occur across the entire Texas coast or in all ER measure project areas. Additionally, reproduction is the species limiting variable for the HSI model and, generally, some areas of the Texas coast would not provide optimal nesting habitat.
				Edge Index B/t Emergent Vegetation and Open Water (V2)	Optimal conditions occur when the edge index between emergent vegetation and open water is greater than 4 (four times the amount of edge is present due to emergent vegetation than would be present for the same wetland basin without emergent vegetation).							
				Water Regime (V3)	Optimal conditions occur when the area is semi permanently flooded.							
American Woodcock (Wintering)[10]	*Scolopax minor*	N/A	N/A	Soil Texture and Drainage Class (V1)	Well drained loam soils have optimal soil moisture tension for earthworms. Availability of earthworms to woodcock can be predicted from soil texture and drainage classes. Increasing portions of small soil particles and increasing percent moisture increases soil moisture tension.	Food	All Life Stages	Diurnal Habitat	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	American woodcock require trees and woody vegetation as their habitat covers, which will not exist throughout most of the coastal ER measure project areas. This species mainly inhabits upland and lowland forests.
				Percent Canopy Coverage of Vegetation and Downfall < 30 cm Above Ground (V2)	Dense ground cover limits woodcock mobility and restricts their ability to probe for worms. Optimal conditions exist when canopy coverage of vegetation and downfall ≤30 cm above ground is ≤50%. Suitability declines as percent canopy coverage increases to > 50%, and when canopy coverage is ≥80% earthworms are assumed to be unavailable to woodcock.							
				Percent Herbaceous and Shrub Canopy Cover (V3)	Optimal conditions occur when 45% herbaceous and shrub canopy cover is >0.5m.	Cover						
				Stem Density of Trees (V4)	Optimal conditions occur when stem density of trees is 20+/ha or 8+/acre.							
				Percent Herbaceous and Shrub Canopy Cover (V3)	Optimal conditions occur when 45% herbaceous and shrub canopy cover is >0.5m.	Cover						
				Average Height of Shrub Canopy (V5)	Optimal conditions occur when the average height of shrub canopy is 3.0 m (9.8 ft.).							

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Species Common Name	Species Latin Name	Habitat Type	ER Measures Affected	HSI Habitat Variable	HSI Habitat Variable Description	HSI Life Requisites	Life Stage	Habitat	HSI Limitations & Assumptions	Model Type	Formulas	Reasons for Elimination
Barred Owl[11]	*Strix varia*	N/A	N/A	Number of Trees >51 cm (V1)	Optimal conditions occur when the number of trees ≥51 cm dbh increases, and thus the probability of the existence of suitable cavities increases. More than 2 trees/0.4 ha that are ≥51 cm dbh is sufficient to meet the nesting requirements of the barred owl.	Reproduction	All Life Stages	Forest	Percent canopy cover of overstory trees directly modifies the value calculated for the other two variables.	Single	**See HSI document for detailed formula descriptions.*	Barred Owls require trees and woody vegetation as their habitat covers, which will not exist throughout most of the coastal ER measure project areas. This species mainly inhabits upland and lowland forests.
				Mean dbh of Overstory Trees (V2)	Optimal conditions occur when mean overstory tree dbh is ≥51 cm.							
				Percent Canopy Cover of Overstory Trees (V3)	Optimal conditions occur when there is 55% or more canopy cover of overstory trees.							
Belted Kingfisher[12]	*Ceryle alcyon*	N/A	N/A	Percent Shoreline Subject to Severe Wave Action (V1a)	Optimal conditions occur when 0% of the shoreline is subject to severe wave action. Suitability decreases in a linear fashion as the percent of shoreline affected increases. Only applied to lacustrine habitats that are frequently/constantly subject to wave action severe enough to deter kingfisher foraging.	Water Quality	All Life Stages	Riverine, Lacustrine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Belted Kingfisher are not known to utilize muddy water very frequently, and this factor may exclude Regions 1 and 2 along the upper Texas coast. The species limiting life requisite is their reproductive component and their need for suitable soil banks with overhanging vegetation, which limits their optimal habitat more so. Additionally, the water depth variable would limit feeding because most of the coastal ER measure project areas are in more than 60 cm of water.
				Average Water Transparency (V2)	Optimal conditions occur when average water transparency (secchi depth) is 60 cm or 24 inches.							
				Percent Water Surface Obstruction (V3)	Optimal conditions occur when 0% of the water surface is obstructed (minimal rocks, legs, emergent and floating vegetation, or other obstacles on the water surface)							
				Percent Water Area <60 cm in depth (V4)	Optimal conditions occur when 100% of water area is 60cm in depth.							
				Percent Riffles (V5b)	Optimal conditions occur with 30-70% riffles. Applies to riverine cover type only. The presence of riffles in stream habitats enhances kingfisher habitat quality by providing rich food sources.							
				Average Number of Lentic Shoreline/Stream Subsections Containing 1+ Perches (V6)	Optimal conditions occur when the average number of lentic shoreline/stream subsections that contain 1+ perches exceeds 40.	Cover						
				Sand Composition (V7a)	Suitable soil banks for potential nest sites are vertical or overhanging, devoid of excessive vegetation, root masses, rocks, etc., and are > 1.3m in height. Suitable soils contain 70-96% sand and < 15% clay.	Reproduction						
				Distance to Nearest Suitable Soil Banks (V7b)	Optimal conditions occur when the distance is 0.0 km or 0.0 miles away. Suitability decreases as distance increases to 3.0 km or 1.9 mi away.							
Black-bellied Whistling-Duck (Breeding)[13]	*Dendrocygna autumnalis*	N/A	N/A	Availability of Suitable Cavities per Hectare (V1)	Nesting habitat suitability increases linearly above 0.1 cavities per ha and is optimal at 0.5 per ha and above. Cavities with an entrance width less than 10 cm are unsuitable.	Nesting Cover	All Life Stages	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Black-bellied Whistling-Duck requires trees and woody vegetation as their habitat covers, which will not exist throughout most of the coastal ER measure project areas. This species mainly inhabits upland and lowland forests.
				Percentage of Shrub Understory Beneath a Tree w/ Suitable Cavity (V2)	Quality of nesting habitat is related to the percentage of shrub understory. Optimal conditions occur at 0-20%. An understory greater than 20% is less suitable.							
				Distance of Tree w/ Suitable Cavity to Suitable Brood-Rearing Pond (V3)	The number is ducklings lost en route to water is proportional to the distance transverse. Optimal conditions occur when 0-400 meters is the mean distance. Suitable brood-rearing habitat is defined as shallow water with interspersion of emergent and open water.							
				Size of Brood-Rearing Pond (V4)	Optimal brood-rearing habitat consists of water bodies between 2 and 30 ha.	Brood Cover						
Black-Shouldered Kite[14]	*Elanus caeruleus*	N/A	N/A	Percentage of Study Area that is Tall Grasslands (A1)	**See HSI document for detailed variable descriptions.*	*See HSI document for detailed life requisites and life stages.		Estuarine	*See HSI document for detailed model limitations and assumptions.	Single	**See HSI document for detailed formula descriptions.*	The taxonomy may have changed for this species, and instead this may be the white tailed kite. The HSI data may no longer apply.
				Percentage of Study Area that is Short Grasslands (A2)								
				Percentage of Study Area that is Rush (A3)								
				Percentage of Study Area that is Salt Marsh (A4)								

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Downy Woodpecker[15]	*Picoides pubescens*	N/A	N/A	Basal Area (V1)	Optimal conditions occur when basal area is 10-20 m2/ha. Basal area is defined as the area of exposed stems of woody vegetation if cut horizontally at 1.4 m height.	Food	All Life Stages	Deciduous forest, Evergreen forest, Deciduous forested wetland, and Evergreen forested wetland	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Downy Woodpeckers require trees and woody vegetation as their habitat covers, which will not exist throughout most of the coastal ER measure project areas. This species mainly inhabits upland and lowland forests.
				Number of Snags (V2)	Optimal conditions occur when 5+ snags > 15 cm dbh/0.4 ha occur. Snags is defined as the number of standing dead trees or partly dead trees, greater than 15 cm diameter at breast height; trees in which 50% of branches have fallen, or are present but no longer bear foliage, are to be considered snags as well.	Reproduction						
Eastern Wild Turkey[16]	*Meleagris gallopavo sylvestris*	N/A	N/A	Percent Herbaceous Canopy Cover (V1)	**See HSI document for detailed variable descriptions.*	Summer Food/Brood Habitat	All Life Stages	Deciduous Forested Wetland, Evergreen Forest, Deciduous Forest, Evergreen Tree Saanna, Deciduous Tree Savanna, Evergreen Shrubland, Deciduous Shrubland, Evergreen Shrub Savanna, Graslland, Forbland, Pasture, Hayland	*See HSI document for detailed HSI limitations and assumptions.	Multiple	**See HSI document for detailed formula descriptions.*	The Eastern Wild Turkey occurs in very few ER measure study areas.
				Average Height of Herbaceous Canopy (Summer) (V2)								
				Distance to Forest or Tree Savanna Cover Types (V3)								
				Average dbh of hard mast producing trees that are greater than 25.4 cm dbh (V4a)		Fall, Winter, Spring Food						
				Number of hard mast trees/ha that are greater than 25.4 cm dbh (V4b)								
				Percent Canopy Closure of Soft Mast Producing Trees (V5)								
				Percent Shrub Crown Cover (V6)								
				Percent Shrub Crown Cover Comprised of Soft Mast Producing Shrubs (V7)								
				Type of Crop (V8)								
				Overwinter Crop Management (V9)								
				Distance to a Tree Dominated Cover Type (V10)								
				Percent Tree Canopy Cover (V11)		Cover						
				Average dbh of Overstory Trees (V12)								
				Percent Forest Canopy Comprised of Evergreens (V13)								
Great Blue Heron[17]	*Ardea herodias* L.	Wetland & Marsh	N/A	Distance b/t potential nest sites and foraging areas (V1)	Optimum conditions occur if foraging habitats are within 1.0 km of heronries or potential heronries. Distances 10 km or more between foraging sites and nest sites are unsuitable for herons.	Food Availability (FI)	All Life Stages	Herbaceous Wetland, Shrub Wetland, Forested Wetland, Riverine, Lacustrine, Estuarine	*See HSI document for detailed HSI limitations and assumptions.	Multiple	**See HSI document for detailed formula descriptions.*	The Great Blue Heron optimal nesting cover (presence of treeland cover types within 250 m of wetland, V4) may not exist in close proximity to most ER measure project areas.
				Presence of water body w/ suitable prey population and foraging substrate (V2)	Optimum conditions occur when potential foraging habitats have shallow (up to 0.5 m deep), clear water with a firm substrate and a huntable population of small fish (< 25 cm in length).							
				Disturbance-free zone up to 100 m around potential foraging area (V3)	Optimum conditions occur if there usually is no human disturbance near the potential foraging zone during the 4 hours following sunrise or preceding sunset or the foraging zone is generally about 100m from human activities and habitation or about 50 m from roads with occasional, slow-moving traffic.							
				Presence of treeland cover types within 250 m of wetland (V4)	Optimum conditions occur if potential treeland habitats fulfill the following conditions: a potential nest site as a grove of tress at least 0.4 ha in area located over water or within 250 m of water. Trees used as nest sites are at least 5 m high with many branches at least 2.5 cm in diameters capable of supporting nests. Trees may be dead or alive but must have an "open canopy" that allows easy access to the nest.	Reproduction (RI)		Forested Wetland				
				Presence of 250 m (land) or 150 m (water) disturbance-free zone around potential nest	Optimum conditions occur if the exclusion zone is usually free from human disturbances during the nesting season.							
				Proximity of potential nest site to an active nest (V6)	Optimum conditions occur when suitable treelands are within 1 km of an established heronry because they are potential satellite nest sites for that colony.							
				Distance b/t potential nest sites and foraging areas (V1)	Optimum conditions occur if foraging habitats are within 1.0 km of heronries or potential heronries. Distances 10 km or more between foraging sites and nest sites are unsuitable for herons.							

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Great Egret[18]	*Ardea alba*	Wetland & Marsh, SAV, and Islands	N/A	Percentage of area with water 10-23 cm deep (V1)	Prey is most accessible in water depths of 10-23 cm (4-9 inches). Optimal conditions are achieved when 100% of the study area is water 10-23 cm deep.	Food	All Life Stages	The HSI for feeding (or nesting) habitat is set to 0 if no cover type suitable for nesting (or feeding) can be located within 36 km (22.4 mi) of the project study area.	HSI (Feeding)	Multiple	**See HSI document for detailed formula descriptions.*	The Great Egret habitat variables require a high level of specificity to achieve optimal conditions throughout the coastal Texas ER measure project areas, particularly V1 and V2. Additionally, the species desires deep water surrounding woody vegetation, which is not frequently found throughout the coastal Texas ER measure project areas. Further, this species would not be a good indicator species for wetland and marsh restoration
				Percentage of submerged or emergent vegetation cover in zone 10-23 cm deep (V2)	Substrates with 40-60% coverage of emergent or submerged vegetation provide the optimum balance between cover for prey species and vulnerability of prey to capture by great egrets.							
				Percentage of island covered d by woody vegetation >1m in height (V3)	Suitability of nesting/roosting habitat on islands is positively correlated to the percentage canopy cover of woody vegetation > 1m (3.3 ft.) fall. Optimal conditions are achieved when 55% or more of the island is covered by woody vegetation.	Cover (Island Site)			HSI (Nesting)			
				Mean water depth in wooded wetlands (V4)	Optimal nesting habitat for non-island sites is found when mean water depth beneath the woody vegetation is equal to or deeper than 0.6 m (2 ft.).	Cover (Non-Island Site)						
				Mean height of woody vegetation (V5)	Suitability of nesting/roosting habitat on non-island sites increases with vegetation canopy height; optimum mean height is 7 m or more.							
				Distance to road or dwelling (V6)	Human disturbance is detrimental to great egret nesting/roosting. Optimal habitat occurs where the nearest road or dwelling is 0.5 m or farther from the site.	Disturbance						
				Distance to human disturbance other than road or dwelling (V7)	The optimal distance from potential nesting/roosting sites to disturbance other than roads or dwellings exceeds 50 m.							
Greater White-Fronted Goose (Wintering)[19]	*Asner albifrons*	N/A	N/A	Percentage of study area covered by water <1 m in depth and/or emergent vegetation (V1)	Optimal habitat is found when 100% of the study area is covered by water < 1 m in depth and/or emergent vegetation. Suitability decreases in a linear fashion as the cover percentage decreases.	Cover	All Life Stages	Palustrine Aquatic Bed and/or Emergent Wetland	The overall suitability of a study area is assumed to increase with increasing area of agricultural lands preferred by the geese.	Multiple	**See the Habitat Suitability Index model for Greater White-Fronted Goose (Wintering) to complete the HSI calculation.*	The Greater White-Fronted Goose is not a species that would commonly be found within the ER measure study areas. Additionally, the food variable for the species is highly limiting and it would be difficult to achieve optimal conditions.
				Percentage of vegetative cover that is known food of white-fronted geese (V2)	Optimal habitat is found when 100% of the vegetative cover is known food for the white-fronted geese. The following ranked preferences apply (from most preferred to least preferred): harvested rice, cultivated (plowed), harvested soybean, winter pasture, fallow or rangeland.	Food						
Hairy Woodpecker[20]	*Picoides villosus*	N/A	N/A	Number of snags >25 cm dbh/ha	A snag density of 5/ha represents optimal conditions for reproduction. The optimal number of snags >25.4 cm dbh necessary to support maximum densities of hairy woodpeckers ranges from 180/40 ha to 200/40 ha, or 4.5 to 5 snags/ha.	Reproduction (SIN)	All Life Stages	Deciduous Forest, Evergreen Forest, Deciduous Forested Wetland, Evergreen Forested Wetland	At optimal cover component conditions, the reproduction component will determine the habitat suitability index. If cover conditions are anything less than optimum, then the reproduction value will be reduced based on the quality of the cover conditions.	Multiple	**See the Habitat Suitability Index model for Hairy Woodpecker to complete the HSI calculation.*	Hairy Woodpeckers require trees and woody vegetation as their habitat covers, which will not exist throughout most of the coastal ER measure project areas. This species mainly inhabits upland and lowland forests.
				Mean dbh of overstory trees (V2)	Trees are of an optimum size for nesting if the average dbh of overstory trees is >38 cm.							
				Mean dbh of overstory trees (V2)	Trees are of an optimum size for nesting if the average dbh of overstory trees is >38 cm.	Cover (SIC)						
				Percent canopy cover of trees (V3)	Hairy woodpeckers prefer forests of moderate canopy cover. Optimal conditions for canopy cover occur at 85-90%. However, complete canopy cover represents less than optimal habitat.							
				Percent overstory pine canopy closure (V4)	Optimal habitat is found when there is 0-15% overstory pine canopy closure.							

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Laughing Gull[21]	*Larus atricilla*	Islands, Beach/Dunes, and Tidal Flats	CM-2	Area of Island (V1)	Optimal habitat is found when the area of the island is 2-50 ha. Small islands (<0.5 ha or <1 acre are likely to have a large portion of their surface inundated by storm tides. Large islands (>100 ha or >250 acres) are more likely to be occupied by predators.	Topography (T)	All Life Stages	Salt Marsh, Barrier, and Spoil Islands along the Gulf of Mexico coastline	The cover component is weighted the heaviest, followed by the topography component. The disturbance component is weighted the least. An SI Score of 0 for any variable will result in an HSI score of 0.	Multiple	**See the Habitat Suitability Index model for Laughing Gull to complete the HSI calculation.*	For the identified habitat for Laughing Gull, the woody cover component would highly limit utility for beach/dune restoration and tidal flats. Additionally, the species HSI model is unique in that an SI score of 0 for any variable will result in an HSI score of 0. This would make it difficult to achieve optimal habitat conditions, and therefore a significant amount of habitat units.
				Maximum Ground Elevation (V2)	Optimal habitat is found when the maximum ground elevation is 1-2 m. Islands of this elevation are relatively invulnerable to inundation along the gulf coast during the nesting season, but still promote growth of desirable vegetation.							
				Mean Slope of Island Surface (V3)	Optimal habitat is found when the mean slope of the island surface is 3% or less. Flat or gently sloping terrain is most suitable for nesting laughing gulls.							
				Percentage Herbaceous Cover 0.1-1.0 m tall (V4)	Optimal habitat is found when 50-100% of the herbaceous canopy cover is 0.1-1.0 m tall. Sites dominated by herbaceous vegetation are preferred for nesting.	Cover [C]						
				Percent Woody Cover < 1.0 m tall (V5)	Optimal habitat is found when 5-10% of the woody canopy cover is < 1.0 m tall. Low densities of short bushes increase visual isolation and thereby increase nest densities.							
				Percentage Woody Canopy Cover > 1.0 m tall (V6)	Optimal habitat is found when 5% or less of the woody canopy cover is > 1.0 m tall. Sites dominated by tall bushes or trees are not used by nesting laughing gulls.							
				Distance to Mainland (V7)	Optimal habitat is found when the distance to the mainland is 2.0-2.5 km. Accessibility of an island to terrestrial predators decreases with distance from sources of predators.	Disturbance (D)						
				Distance to Boat Access Point (V8)	Optimal habitat is found when the shortest distance by water to the nearest boat access point is 20-25 km or more. Probability of human disturbance varies as a function of distance from access points.							
Lesser Scaup (Breeding)[22]	*Aythya affinis*	Wetlands & Marsh and Tidal Flats	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Percent herbaceous canopy cover (V1)	Optimal nesting habitat occurs when a 50m zone surrounding permanently flooded, intermittently exposed, and semi permanently flooded wetlands that support 30-75% canopy cover of herbaceous vegetation, ranging rom 25 to 61 cm in height.	Nesting (SIN)	All Life Stages	Within 50m zone around permanently flooded, intermittently exposed, and semi permanently flooded wetlands	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See the Habitat Suitability Index model for Lesser Scaup (Breeding) to complete the HSI calculation.*	Species habitat range not in Coastal Texas study area. Lesser Scaup require a freshwater component within their habitat area, which will not be a common theme throughout the coastal Texas ER measure project areas. Thus, the ER measures would not be conducive with this species and its optimal habitat conditions.
				Average height of herbaceous vegetation (V2)	Optimal nesting habitat occurs when a 50m zone surrounding permanently flooded, intermittently exposed, and semi permanently flooded wetlands that support 30-75% canopy cover of herbaceous vegetation, ranging rom 25 to 61 cm in height.							
				Percent shrub crown cover (V3)	The presence of shrubs enhances nesting habitat suitability when present at densities from 10-25% in the 50 m zone surrounding permanently flooded, intermittently exposed, and semi permanently flooded wetlands.							
				Percent canopy cover of emergent herbaceous vegetation (V4)	Optimal habitats that support maximum densities of lesser scaup broods contain 20-50% canopy cover of emergent herbaceous vegetation.	Brood (SIB)		Permanently flooded, intermittently exposed, and semi-permanently flooded wetlands				
				Water regime (V5)	Permanently flooded areas represent the most optimal habitat, followed by intermittently exposed areas (intermediate suitability), and finally semi permanently flooded areas (least suitable).							

Habitat Suitability Index for Listed Species - Eliminated Species												
Species Common Name	**Species Latin Name**	**Habitat Type**	**ER Measures Affected**	**HSI Habitat Variable**	**HSI Habitat Variable Description**	**HSI Life Requisites**	**Life Stage**	**Habitat**	**HSI Limitations & Assumptions**	**Model Type**	**Formulas**	**Reasons for Elimination**
Lesser Snow Goose (Wintering)[23]	*Chen caerulescens caerulescens*	Wetlands & Marsh and Tidal Flats	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5 CM-2	Food Availability (V1)	Optimal habitat occurs when 80-100% of the study area is covered by food plants, such as roots and rhizomes of native marsh plants.	Food	All Life Stages	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See the Habitat Suitability Index model for Lesser Snow Goose (Wintering) to complete the HSI calculation.*	Lesser Snow Geese require a freshwater component within their habitat area, which will not be a common theme throughout the coastal Texas ER measure project areas. Thus, the ER measures would not be not conducive with this species and its optimal habitat conditions. Additionally, snow geese are not common throughout the entire Texas coast, particularly in Region 4.
				Water Depth (V2)	Deltaic flats covered by water 20 cm (7.9 inches) or less are preferred feeding sites, with optimum roosting depths being similar.							
				Tidal Influence (V3)	Optimal tidal influence comprises of a tide height of 30 cm or greater. Tides affect the suitability of a marsh as a feeding or roosting site.							
				Water Depth (V2)	Deltaic flats covered by water 20 cm (7.9 inches) or less are preferred feeding sites, with optimum roosting depths being similar.	Cover						
				Tidal Influence (V3)	Optimal tidal influence comprises of a tide height of 30 cm or greater. Tides affect the suitability of a marsh as a feeding or roosting site.							
				Open Water (V4)	Areas with over 75% open water are optimal roosting sites. In these areas, geese are able to be protected with open water nearby for escape and have ample waring about predators.							
Mottled Duck[24]	*Anas fulvigula maculosa*	Wetlands & Marsh and Tidal Flats	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5 CM-2	Percentage cover of rushes, bulrushes, and cattails (V1)	Optimal nesting habitat is dominated by grasses and similarly structured vegetation. 0% coverage of submerged substrate by rushes, bulrushes, or cattails provides the most suitable habitat.	Reproductive Cover	All Life Stages	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See the Habitat Suitability Index model for Mottled Duck to complete the HSI calculation.*	Mottled Duck habitat variables are highly specific, with detailed information required to sufficiently measure the habitat variable and achieve optimal conditions. The habitat variables would be difficult to quantify for the coastal Texas ER measure project areas.
				Percentage canopy cover of trees and shrubs (V2)	Quality of nesting habitat decreases with increasing cover of woody vegetation. Habitat with 0% coverage of trees and shrubs on unsubmerged substrate is optimal. Habitat with 30% woody vegetation canopy cover is unsuitable.							
				Structure of herbaceous emergent vegetation (V3)	The optimal structure of herbaceous vegetation on submerged substrate is growth in clumps with overlapping tops at > 0.75 m tall and/or providing > 80% overhead cover. Nesting habitat quality is related to height and density of grasses and similarly structured vegetation excluding bulrushes, rushes, and cattails.							
				Percentage cover of woody or herbaceous emergent vegetation (V4)	Optimal brood-rearing habitat is a submersed substrate supporting growth of emergent vegetation at 50% of its area.							
				Structure of woody herbaceous emergent vegetation (V5)	Optimal habitat is achieved when the structure of woody or herbaceous emergent vegetation growing in continually submerged substrate is > 1.0 m tall and sufficiently dense to be almost impenetrable to a large predator, but with openings and passageways for escape of ducklings. Quality of emergent vegetation as escape cover is related to its height and density.							
				Percentage of study area that is land (substrate not submerged and not supporting growth of rushes, bulrushes, or cattails) (V6a)	50% of the study area being land is most suitable for mottled ducks. Optimal reproductive habitat for mottled ducks consists of equal amounts of nesting and brood-rearing habitats.							
				Percentage of study area that is land (nesting hens) (V6b)	Optimal habitat is achieved when more than 80% of the study area is land for nesting hens.							
				Percentage of study area that is land (hens with broods) (V6c)	Optimal habitat is achieved when 20% or less of the study area if land for hens with broods.							
				Water depth (V7)	Optimal conditions occur when there is 100% of continually submerged substrates with water depth less than 30.0 cm at low mean tide. Depth of water is related to feeding efficiency of mottled duck hens and broods.	Food						
				Disturbance level (V8)	Optimal conditions occur when there is no level of disturbance. Irregular disturbance is terminal to nesting mottled duck hens and hens with broods. *See HSI document for definition of disturbance levels.	Other						

Habitat Suitability Index for Listed Species - Eliminated Species												
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Beaver[25]	*Castor canadensis*	N/A	N/A	Percent stream gradient (V1)	**See HSI document for detailed variable descriptions.*	Water	All Life Stages	Riverine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Species applicable to very few ER measures in Coastal Texas study.
				Avg. water fluctuations on annual basis (V2)								
				Percent tree canopy closure (V3)		Winter Food		Riverine & Wetlands				
				Percent of trees in 1-6 in. dbh size class (V4)								
				Percent shrub crown closure (V5)								
				Avg. height of shrub canopy (V6)								
				Species composition of woody vegetation (V7)								
				Avg. water fluctuation on annual basis (V8)		Water		Wetlands				
				Shoreline development factor (V9)		Water		Lacustrine				
				Percent tree canopy closure (V3)		Winter Food		Lacustrine				
				Percent of trees in 1-6 in. dbh size class (V4)								
				Percent shrub crown closure (V5)								
				Avg. height of shrub canopy (V6)								
				Species composition of woody vegetation (V7)								
				Percent of lacustrine surface dominated by yellow/white water lily (V8)								
Bobcat[26]	*Felis rufus*	N/A	N/A	Percent of the sample area covered by grass/forb-shrub vegetation (V1)	**See HSI document for detailed variable descriptions.*	Food	All Life Stages	Undeveloped, non-flooded lands	The HSI value for a single cover type species is based on the limiting factor concept and equals the lowest life requisite value.	Single	**See HSI document for detailed formula descriptions.*	Species applicable to very few ER measures in Coastal Texas study.
				Percent of the grass/forb-shrub portion of the sample area covered by grass/forb vegetation (V2)								
Fox Squirrel[27]	*Sciurus niger*	N/A	N/A	Percent canopy closure of trees that produce hard mast (V1)	**See HSI document for detailed variable descriptions.*	Winter Food	All Life Stages	Deciduous Forest, Deciduous Tree, Savanna, Deciduous Forested Wetland	The HSI value for a single cover type species is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Species applicable to very few ER measures in Coastal Texas study.
				Distance to available grain (V2)								
				Average dbh of overstory trees (V3)		Cover and Reproduction						
				Percent tree canopy closure (V4)								
				Percent shrub crown cover (V5)								
Gray Squirrel[28]	*Sciurus carolinensis*	N/A	N/A	Proportion of total tree canopy cover that is hard mast producing trees (V1)	**See HSI document for detailed variable descriptions.*	Winer Food	All Life Stages	Forest	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Species applicable to very few ER measures in Coastal Texas study.
				Number of hard mast tree species (V2)								
				Percent canopy cover of trees (V3)		Cover/ Reproduction						
				Mean dbh of overstory trees (V4)								
Mink[29]	*Mustela vison*	N/A	N/A	Percent of year w/ surface water present (V1)	**See HSI document for detailed variable descriptions.*	Water	All Life Stages	Lacustrine, Riverine, Palustrine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Species habitat range not in Coastal Texas study area.
				Percent canopy cover of trees (V2)		Cover						
				Percent canopy cover of shrubs (V3)								
				Percent canopy cover of trees and shrubs within 100m of wetland's edge (V4)								
				Percent canopy cover of emergent								
				Percent shoreline cover w/in 1 m of water's edge (V6)								
				Percent canopy cover of trees and shrubs within 100m of wetland's edge (V4)								

Habitat Suitability Index for Listed Species - Eliminated Species

Species Common Name	Species Latin Name	Habitat Type	ER Measures Affected	HSI Habitat Variable	HSI Habitat Variable Description	HSI Life Requisites	Life Stage	Habitat	HSI Limitations & Assumptions	Model Type	Formulas	Reasons for Elimination
Muskrat[30]	*Ondatra zibethicus*	N/A	N/A	Percent canopy cover of emergent herbaceous vegetation (V1)	**See HSI document for detailed variable descriptions.*	Cover	All Life Stages	Estuarine, Riverine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Species habitat range not in Coastal Texas study area.
				Percent of year with surface water present (V2)								
				Percent canopy cover of emergent herbaceous vegetation (V1)		Food						
				Percent of emergent herbaceous vegetation consisting of bulrush, common three-square bulrush, or cattail (V3)								
				Percent of year with surface water present (V2)		Cover						
				Percent stream gradient (V4)								
				Percent of riverine channel with surface water present during typical minimum flow (V5)		Cover/Food						
				Percent of riverine channel dominated by emergent herbaceous vegetation (V6)		Food						
				Percent herbaceous canopy cover w/in 10m of water's edge (V7)								
Snowshoe Hare[31]	*Lepus americanus*	N/A	N/A	Biomass of available browse (V1)	**See HSI document for detailed variable descriptions.*	Food	All Life Stages	Forest, Savanna, Shrubland	The HSI value is determined by multiplying variables one and two, and multiplying variables two and three.	Multiple	**See HSI document for detailed formula descriptions.*	Species habitat range not in Coastal Texas study area.
				Avg. visual obstruction measurement of live forage class vegetation (V2)								
				Avg. visual obstruction measurement of all living and dead vegetation (V3)		Cover						
Swamp Rabbit[32]	*Sylvilagus aquaticus*	N/A	N/A	Percent tree canopy closure (V1)	**See HSI document for detailed variable descriptions.*	Food/Cover	All Life Stages	Evergreen and deciduous forested wetland	*See HSI document for detailed limitation and assumptions.	Multiple	**See HSI document for detailed formula descriptions.*	Species applicable to very few ER measures in Coastal Texas study.
				Water regime (V2)								
				Percent shrub crown closure (V3)		Food/Cover						
				Percent herbaceous canopy cover (V4)								
				Water regime (V2)								
				Percent herbaceous canopy cover (V4)		Food/Cover						
				Average height of herbaceous canopy (V5)								
				Water regime (V2)								
White-tailed Deer[33]	*Odocoileus virginiaus*	N/A	N/A	Quantity of suitable forage physically available to deer within the habitat block (V1)	**See HSI document for detailed variable descriptions.*	Autumn-Winter Forage (Model I)	All Life Stages	Forests, Savanna, Wetland, Haland, Cropland	*See HSI document for detailed limitation and assumptions.	Multiple	**See HSI document for detailed formula descriptions.*	Species applicable to very few ER measures in Coastal Texas study.
				Apparent dry matter digestibility of forages physically available to deer (V2)								
				Calculation of the metabolizable energy content of each type of forage physically available to deer (V3)								
				Quantity of suitable forage physically available to deer within the habitat block (V1)		Autumn-Winter Forage (Model II)						
				Apparent dry matter digestibility of forages physically available to deer (V2)								
				Average dry matter yield of suitable forage per 1 m2 plots (V4)		Autumn-Winter Forage (Model III)						
				Number of stems/ha of species of woody shrubs and trees that provide mast to deer during autumn-winter (V5)								

Habitat Suitability Index for Listed Species - Eliminated Species												
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American Alligator[34]	*Alligator mississippiensis*	Wetland & Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Percentage of wetland that is open water (V1)	Optimal habitat occurs where 20-40% of the wetland is open water (ponds, bayous, canals). Optimal nesting alligator habitat is composed of 20-40% open water and 60-80% vegetated wetland.	Cover-breeding	All Life Stages	Estuarine	*See HSI document for detailed limitation and assumptions.	Multiple	**See HSI document for detailed formula descriptions.*	American Alligators are not common along the entire Texas coast, and therefore this species would not be able to be modeled equally throughout all four regions for the Coastal Texas study.
				Percentage of open water that is in bayous or canals (V2)	Optimal habitat occurs where 10-20% of open water area is in bayous, canals, or greater than 1.2 m deep in lakes and ponds. Deepwater areas in bayous, canals, ponds, and lakes are essential habitat components for adult alligators during breeding season.							
				Percentage of wetland that is open water (V1)	Optimal habitat occurs where 20-40% of the wetland is open water (ponds, bayous, canals). Optimal nesting alligator habitat is composed of 20-40% open water and 60-80% vegetated wetland.	Cover-Nesting						
				Interspersion (V3)	Optimal habitat occurs when there is high interspersion (10-15 ponds with >0.2 ha per 6 ha). Nesting alligator habitat quality is directly related to the degree of interspersion of water bodies within the vegetated wetlands.							
				Percentage of ponded area with water >15 cm deep (V4)	Optimal habitat occurs where 100% of the ponded area contains waters > 15 cm deep from May to September. Ponds that dry out during the spring and summer tend to restrict the movements of alligators and increase the vulnerability of the young to predation.							
				Percentage of substrate exposed at low mean tide (tidal areas only) (V5)	Optimal habitat occurs where 0% of the substrate is exposed at mean low tide from May to September.							
Slider Turtle[35]	*Pseudemys scripta*	N/A	N/A	Percent cover of emergent and submerged vegetation (V1)	Optimum conditions occur at 90% or more cover of emergent and submerged vegetation, since peak densities of sliders occur at and above this level.	Food/Cover (SIFC)	All Life Stages	Estuarine	The HSI value is based on the limiting factor concept and equals the lowest life requisite value.	Multiple	**See HSI document for detailed formula descriptions.*	Slider Turtles require a freshwater component within their habitat area, which will not be a common theme throughout the coastal Texas ER measure project areas. Thus, the ER measures would not be conducive with this species and its optimal habitat conditions.
				Velocity (V2)	Optimal conditions exist when velocity is 0 cm/sec. Sliders prefer quiet waters, such as those existing in lacustrine environments.	Water (SIW)						
				Water depth (V3)	The slide occurs most often and at the highest densities in bodies of water with a depth of 1-2 m.							
				Water regime (V4)	Wetlands containing permanent water (permanently flooded) will have the highest likelihood of supporting slider turtles throughout the year.							
				Water temperature (V5)	The optimal range for water temperature is 25°C-30°C. Temperatures above 40C at any time during the year are considered to have a suitability index of 0.0. The critical period is during the slider's growing period and when ambient water temperature is at its highest level (April through September).	Temperature (SIT)						
Snapping Turtle[36]	*Chelydra serpentina*	N/A	N/A	Mean water temperature at mid-depth during summer (°C) (V1)	Water temperature must be above 16°C for turtles to eat, and mean preferred temperature is 28.1°C. Critical thermal max is identified as 37°C. Temperatures less than 0°C or warmer than 37°C are lethal to snapping turtles.	Food (SIF)	All Life Stages	Estuarine	*See HSI document for detailed limitation and assumptions.		**See HSI document for detailed formula descriptions.*	Snapping Turtles require a freshwater component within their habitat area, which will not be a common theme throughout the coastal Texas ER measure project areas. Thus, the ER measures would not be conducive with this species and its optimal habitat conditions.
				Mean current velocity at mid-depth during summer (cm/s) (V2)	Optimal conditions occur when mean current velocity at mid-depth during summer is 0 cm/s. Suitability decreases as mean current velocity increases.							
				Percent canopy cover of aquatic vegetation in the littoral zone (V3)	Potential for optimum food conditions for snapping turtles occurs in permanently and semi permanently flooded wetlands with preferred water temperatures, no current, and 100% coverage of aquatic vegetation within the littoral zone.							
				Maximum water depth greater than maximum ice depth (V4)	If winter water depth is greater than maximum ice depth, then optimum suitability is achieved. If winter water depth is less than maximum ice depth, then no suitability is achieved.	Winter Cover (SIWC)						
				Percent silt in substrate (V5)	100% slit in substrate is optimal. Snapping turtles burrow into the mud to hibernate.							
				Distance to small stream (km) (V6)	Optimal distance to a small stream is 0 km.	Reproduction						
				Distance to permanent water (km) (V7)	Optimal distance to permanent water is 0 km.	Interspersion						

Habitat Suitability Index for Listed Species - Eliminated Species												
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Bullfrog[37]	*Rana catesbeiana*	Wetland & Marsh	O-1 O-2 G-11 G-12 G-13 B-5 B-6 M-8 CA-4 CA-6 CA-5 CA-7 SP-1 N-3 N-5	Mean distance from shore to water > 1.5m deep (V1)	Optimal conditions occur when the mean distance from shore at which water depth of >1.5 m occurs is 10-20 m.	Food	All Life Stages	Estuarine	*See HSI document for detailed limitation and assumptions.	Multiple	**See HSI document for detailed formula descriptions.*	Bullfrogs require a freshwater component within their habitat area, which will not be a common theme throughout the coastal Texas ER measure project areas. Thus, the ER measures would not be not condusive with this species and its optimal habitat conditions.
				Percent canopy cover of aquatic vegetation in the littoral zone (V2)	Optimal conditions exist when canopy cover ranges from 55% to 80%.							
				Percent shoreline cover (V3)	A positive linear relationship exists with suitability and percent shoreline coverage. The optimal habitat is 100% covered by shoreline vegetation.							
				Mean water transparency (cm) (V4)	A mean secchi disk depth ranging from 100 to 300 cm corresponds to optimal phytoplankton abundance for larval bullfrogs.							
				Maximum water depth greater than maximum ice depth (V5)	If winter water depth is greater than maximum ice depth, then optimum suitability is achieved. If winter water depth is less than maximum ice depth, then no suitability is achieved.	Winter Cover						
				Percent silt in substrate (V6)	100% slit in substrate is optimal. Bullfrogs burrow into the mud to hibernate.							
				Mean current velocity at mid-depth during summer (cm/s) (V7)	Optimal current velocity at mid depth during summer is 15 cm/s or less.	Reproduction						
				pH (V8)	Optimal pH ranges between 5-8.5.							
				Mean water temperature at mid-depth during summer (°C) (V9)	Optimal mean temperatures at mid-depth during summer is 25-30C.							
				Frequency of water level fluctuations >2m	Optimal frequency of water level fluctuations >2m is <1.							
				Distance to permanent water (m) (V11)	Optimal distance to permanent water is 0.	Interspersion						

References:

[1]Diaz, R.J., and C.P. Onuf. 1985. Habitat suitability index models: juvenile Atlantic Croacker (revised). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.98). 23 pp.

[2]Gutzwiller, K.J., and S.H. Anderson. 1987. Habitat suitability index models: marsh wren. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.139). 13 pp.

[3]Howard, R.J., and H.A. Kantrud. 1983. Habitat suitability index models: redhead (wintering). U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS082/10.53. 14 pp.

[4]Christmas, J.Y., J.T. McBee, R.S. Waller, and F.C. Sutter III. 1982. Habitat suitability index models: Gulf menhaden. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.23. 23 pp.

[5]Stickney, R.R., and N.L. Cuenco. 1982. Habitat suitability index models: Juvenile Spot. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.20. 12 pp.

[6]Cake, E.W., Jr. 1983. Habitat suitability index models: Gulf of Mexico American Oyster. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.57. 37 pp.

[7]Mulholland, R. 1984. Habitat suitability index models: hard clam. U.S. Fish Wildl. Serv. FWS/OBS-82/10.77. 21 pp.

[8]Mulholland, R. 1984. Habitat suitability index models: pink shrimp. U.S. Fish Wildl. Serv. FWS/OBS-82/10.76. 17 pp.

[9]Allen, A.W. 1985. Habitat suitability index models: American coot. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.115). 17 pp.

[10]Cade, B.S. 1985. Habitat suitability index models: American woodcock (wintering). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.105) 23 pp.

[11]Allen, A.W. 1987. Habitat suitability index models: barred owl. U.S. fish Wild. Serv. Biol. 82(10.143). 17 pp.

[12]Prose, B.L. 1985. Habitat suitability index models: Belted Kingfisher. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.87). 22 pp.

[13]McKenzie, P.M., and P.J. Zwank. 1988. Habitat suitability index models: black-bellied whistling-duck (breeding). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.150). 22 pp.

[14]Faanes, C.A., and R.J. Howard. 1987. Habitat suitability index models: black-shouldered kite. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.130). 13 pp.

[15]Schroder, R.L. 1982. Habitat suitability index models: Downy woodpecker. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.38. 10 pp.

[16]Schroeder, R.L. 1985. Habitat suitability index models: Eastern wild turkey. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.106). 33 pp.

[17]Short, H.L., and R.J. Cooper. 1985. Habitat suitability index models: Great blue heron. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.99) 23 pp.

[18]Chapman, B.R., and R.J. Howard. 1984. Habitat suitability index models: great egret. U.S. Fish Wildl. Serv. FWS/OBS-82/10.78. 23 pp.

[19]Kaminski, R. M. 1986. Habitat suitability index models: greater white-fronted goose (wintering). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.116). 14 pp.

[20]Sousa, P.J. 1987. Habitat suitability index models: hairy woodpecker. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.146). 19 pp.

[21]Zale, A.V., and R. Mulholland. 1985. Habitat suitability index models: laughing gull. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.94). 23 pp.

[22]Allen A.W. 1986. Habitat suitability index models: Lesser scaup (breeding). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.117). 16 pp.

[23]Leslie, J.C., and P.J. Zwank. 1985. Habitat suitability index models: lesser snow goose (wintering). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.97). 16 pp.

[24]Rorabaugh, J.C., and P.J. Zwank. 1983. Habitat suitability index models: mottled duck. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.52. 26 pp.

[25]Allen, A.W. 1982. Habitat suitability index models: Beaver. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82-10.30. 20 pp.

[26]Boyle, K.A., and T.T. Fendley. 1987. Habitat suitability index models: bobcat. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.147). 16 pp.

[27]Allen, A.W. 1982. Habitat suitability index models: fox squirrel. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.18. 11 pp.

[28]Allen, A.W. 1987. Habitat suitability index models: gray squirrel, revised. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.135). 16 pp. [First printed as: FWS/OBS-82/10.19, July 1982.]

[29]Allen, A.W. 1986. Habitat suitability index models: mink, revised. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.127). 23 pp. [First printed as: FWS/OBS-82/10.61, October 1983.]

[30]Allen, A.W., and R.D. Hoffman. 1984. Habitat suitability index models: Muskrat. U.S. Fish Wildl. Serv. FWS/OBS-82/10.46. 27 pp.

[31]Carreker, R.G. 1985. Habitat suitability index models: snowshoe hare. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.101). 21 pp.

Habitat Suitability Index for Listed Species - Eliminated Species												
Species Common Name	Species Latin Name	Habitat Type	ER Measures Affected	HSI Habitat Variable	HSI Habitat Variable Description	HSI Life Requisites	Life Stage	Habitat	HSI Limitations & Assumptions	Model Type	Formulas	Reasons for Elimination

[32]Allen, A.W. 1985. Habitat suitability index models: Swamp rabbit. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.107). 20 pp.

[33]Short, H.L. 1986. Habitat suitability index models: White-tailed deer in the Gulf of Mexico and South Atlantic coastal plains. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.123). 36 pp.

[34]Newsom, J.D., T. Joanen, and R.J. Howard. 1987. Habitat suitability index models: American alligator. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.136). 14 pp.

[35]Morreale, S.J., and J.W. Gibbons. 1986. Habitat suitability index models: Slider turtle. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.125). 14 pp.

[36]Graves, B.M., and S.H. Anderson. 1987. Habitat suitability index models: snapping turtle. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.141). 18 pp.

[37]Graves, B.M., and S.H. Anderson. 1987. Habitat suitability index models: bullfrog. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.138). 22 pp.

Indicates a very important and sensitive (and therefore limiting) habitat variable for the Habitat Suitability Index

Indicates a habitat variable affected by one of more ER measures in the Coastal Texas study

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A Robust, Spatially Explicit Model for Identifying Oyster Restoration Sites: Case Studies on the Atlantic and Gulf Coasts

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A ROBUST, SPATIALLY EXPLICIT MODEL FOR IDENTIFYING OYSTER RESTORATION SITES: CASE STUDIES ON THE ATLANTIC AND GULF COASTS

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ABSTRACT The eastern oyster (*Crassostrea virginica*) is a reef-forming organism commonly found in estuaries throughout the Atlantic and Gulf coasts of North America. Eastern oyster reefs provide several ecosystem services, including water filtration, habitat diversity, and storm surge protection, among others. Oyster abundance has declined precipitously during the past century along the Atlantic and Gulf coasts as a result of overfishing, disease and predation, and large-scale human-mediated events. Given the importance of oysters, both ecologically and economically, there have been significant efforts during the past 20 y to reestablish and/or restore oysters to historical levels. Successful reef restoration depends on choosing sites that optimize survival, which requires an understanding of the environmental factors that influence the life stage of an oyster. For most restoration projects, time and budget constraints prevent long-term field studies; therefore, modeling is often used to determine the best locations for restoration. In this study, we developed a spatially explicit, flexible, 4-parameter habitat suitability index model that can be used to determine locations suitable for restoration of eastern oyster reefs throughout the western Atlantic and Gulf coasts. The model captures the minimum environmental parameters required for successful restoration suitability and was applied in 2 studies: (1) Chesapeake Bay, a data rich environment, and (2) northern Gulf of Mexico (western Mississippi Sound), a data poor environment. It illustrates the implications of using data of varying quality when applying the model for identifying restoration potential. In both locations, the model was most sensitive to the presence of appropriate substrate, but not as sensitive to salinity values. This model provides a scientifically based support tool for natural resource managers and project planners, and local conditions may require further consideration.

KEY WORDS: eastern oyster, *Crassostrea virginica*, habitat suitability modeling, spatially explicit, geographic information systems, habitat suitability index

INTRODUCTION

Eastern oyster (*Crassostrea virginica*) reefs are essential components of estuarine ecosystems along the Atlantic and Gulf Coasts of North America, and they provide numerous ecosystem services, including water quality improvements (Newell et al. 2002, Kellogg et al. 2013), landscape diversity (Eggleston 1999), storm surge protection (Meyer et al. 1997, Piazza et al. 2005), and habitat for reef-dwelling and benthic communities (Coen et al. 1999, Posey et al. 1999, Tolley & Volety 2005), among others (Powers et al. 2009, Harding et al. 2010). Reef abundance is currently at its nadir, estimated at 15% of historic levels worldwide (Beck et al. 2011). These declines have been attributed to overfishing, disease and predation, and large-scale human-mediated events (e.g., freshwater diversions). Given the importance of oysters in the estuarine community, significant resources have been dedicated to restoring oyster reefs.

Successful reef restoration depends on choosing sites that sustain reefs over long periods of time (Pollack et al. 2012). Restoration sites should be chosen so they optimize survival (i.e., mitigate mortality factors), which requires an understanding of the complex interactions between oysters and their environment. Often, ecosystem restoration projects are scheduled for locations that have not been well studied and have limited data available, yet time and budget constraints prevent long-term field studies and analysis. Therefore, modeling is often used to determine the best locations for restoration activities. Simplified modeling approaches such as habitat suitability index (HSI) models can provide natural resource managers with a standardized approach for habitat mapping and restoration planning, and have been used extensively by resource agencies for planning and impact assessments for wildlife management, and water resource and ecosystem restoration projects (Brooks 1997, Roloff & Kernohan 1999, Duberstein et al. 2007, U.S. Fish and Wildlife Service 1981). One such example is an HSI developed for the eastern oyster habitat as detailed in Louisiana's Comprehensive Master Plan for a Sustainable Coast (Coastal Protection & Restoration Authority 2012). Although the methods in the plan were designed specifically to assess the impacts of coastal protection and restoration projects on oyster habitat, the overall model approach is considered useful for a broad range of oyster-related restoration efforts, and was adapted for use in this study (Soniat 2012). Briefly, HSI models consist of *a priori* hypotheses that represent the critical relationships between a species and the environmental parameters that affect species mortalities and distributions (Tirpak et al. 2009). These hypotheses are translated into relative assessments of habitat suitability (scaled from 0–1, representing worst to best habitat, respectively) for a particular species based on its species-specific habitat associations. Suitability scores are then combined into a composite score, also scaled from 0–1, that represents the overall quality of a location for particular species and, therefore, for restoration efforts (U.S.

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Fish and Wildlife Service 1981). Habitat suitability index models were developed initially to assess habitat quality based on field measurements of habitat attributes extrapolated across large areas (e.g., a forest stand, a management unit), and advances in geographic information systems (GIS) and remote sensing have allowed the application of HSI models at a variety of spatial scales and extents to meet specific management objectives. HSI models can be incorporated into a GIS in a spatially explicit framework that can reduce uncertainty associated with trial-and-error approaches and can provide standardized, broadly applicable methods (Curnutt et al. 2000, Store & Kangas 2001).

There are several benefits to using an HSI approach. These models can be constructed rapidly and can be developed with a variety of data types, including scientific literature, field studies, modeling results, monitoring data, and/or expert opinion, giving resource managers flexibility when time and budget constraints prevent long-term field data collection. The pliancy of data inputs allows data of different types to be used in HSI models; however, applying a model parameterized with lower fidelity data limits the extent to which the model can be considered reliable. That is, if there is a lot of uncertainty associated with a particular component of the model, then that uncertainty can affect model results and limit its applicability. These models are also designed for portability and can be used among many different sites rather than be restricted to specific locations, as is often the case with complex ecological models (Soniat & Brody 1988). Conversely, HSI approaches have been criticized for their lack of scientific rigor and reliability (Cole & Smith 1983, Roloff & Kernohan 1999). Recent improvements in data quality as well as more rigorous evaluation criteria have improved the reliability of these approaches (Brooks 1997).

The objectives of this study were (1) to develop a spatially explicit, flexible HSI model that can be used to determine locations appropriate for restoration of *Crassostrea virginica* reefs throughout the western Atlantic and Gulf coasts and (2) to apply the model in 2 study areas—1 in the Chesapeake Bay, a data rich environment, and the other in the western Mississippi Sound (northern Gulf of Mexico), a data poor environment—and discuss the implications of using data of varying quality when applying the model for restoration.

MATERIALS AND METHODS

Model Overview

The Oyster Habitat Suitability Index Model (OHSIM) is designed as a spatially explicit, grid-based model that uses a series of linear equations to calculate habitat suitability for restoration of *Crassostrea virginica*. The model presented here is a modification of that of Soniat's (2012) and it follows the methodology established by Cake (1983) and Soniat and Brody (1988). The terminology and model evaluation techniques were adapted from Pollack et al. (2012). The model is composed of 4 variables, with each being assigned a dimensionless oyster suitability index (OSI) value that represents the relationship between an environmental variable and a stage of the oyster's life history. Each OSI is represented quantitatively as a series of linear suitability curves, with a minimum value of 0 for unsuitable to 1.0 for optimal habitats. Suitability curves are formulated as step-functions with linear approximations between each step. A restoration suitability index (RSI) is calculated as the geometric mean of the OSI values and represents the overall suitability of a particular location for restoration (Pollack et al. 2012). Data and equations are imported into a GIS and applied to specific geo-referenced locations.

The overarching assumption of the OHSIM is that substrate and salinity can describe quantitatively suitable oyster habitat for restoration. We adapted the model designed for Louisiana's Comprehensive Master Plan for a Sustainable Coast (Coastal Protection & Restoration Authority 2012) with the following modifications: (1) differences in data type, origin, spatial resolution, and content; (2) update to GIS methods, including the interpolation techniques; and (3) changes to 1 variable, such that we did not consider land building or conversion, and thus analyzed aquatic areas only. Suitable substrate (i.e., cultch) is described as the percentage of the bottom covered with hard substrate (e.g., oyster shell or other suitable bottom). Salinity is resolved into the following 3 variables that address different relationships between salinity and the oyster's life history: (1) mean salinity during the spawning season (MSSS), in which spawning and spat set have a greater optimal salinity than for survival of adults; (2) annual mean salinity (AS), which is the expected range over which adult oysters are viable; and (3) minimum annual salinity (MAS), which defines the impacts of high-mortality events resulting from lower salinities resulting from freshwater influxes (Soniat 2012).

The model is designed to be flexible with regard to data input and spatial scales and can take input from hydrodynamic models, monitoring stations, scientific literature, and expert opinion. Cell size and spatial extent can vary, but the spatial extent must be large enough to include both suitable and unsuitable habitats for the model to be verifiable (Brooks 1997). One limitation for input data is that a value must be available for each cell within the spatial domain. The model has a wide variety of potential application to any engineering or restoration activity that modifies salinity or substrate, including changes in freshwater inflow (e.g., freshwater diversions or any hydrological modifications that alter salinity), reef creation, land building that replaces oyster bottoms with other habitat, and sediment additions that cover suitable cultch.

Suitability Indices

Percent cultch is the percent of bottom covered with hard substrate. Oyster larvae require a hard substrate, such as existing oyster reefs (cultch) or other hard surfaces (e.g., limestone, concrete, granite, and so forth), on which to settle and metamorphose. Cake (1983) considered a high-quality bottom to be one in which 50% or more of the area is hard substrate, although no indication was given of the specific spatial scale over which the variable is to be applied. Although the relationship between percent cultch and its OSI is understood at the extremes (i.e., no substrate is unsuitable and 100% coverage is ideal), there is considerable uncertainty in the intermediate range. Cake (1983) considered the relationship between percent cultch and OSI to be linear, from 0%–50% cultch, and ideal (OSI = 1.0) when percent cultch was greater than 50%. We modified Cake's formulation by using the most parsimonious solution and assumed that oyster habitat suitability increases linearly from 0%–100% cultch cover (Eq (1); Fig. 1A).

$$\mathrm{OSI}_{\%\,\mathrm{Cultch}} = 0.01 \times (\%\ \mathrm{Cultch}) \tag{1}$$

The model was applied to 2 study areas with different types of available benthic habitat data (e.g., Chesapeake Bay and Mississippi Sound, northern Gulf of Mexico). This choice also provides a comparison between Atlantic and Gulf Coast habitats.

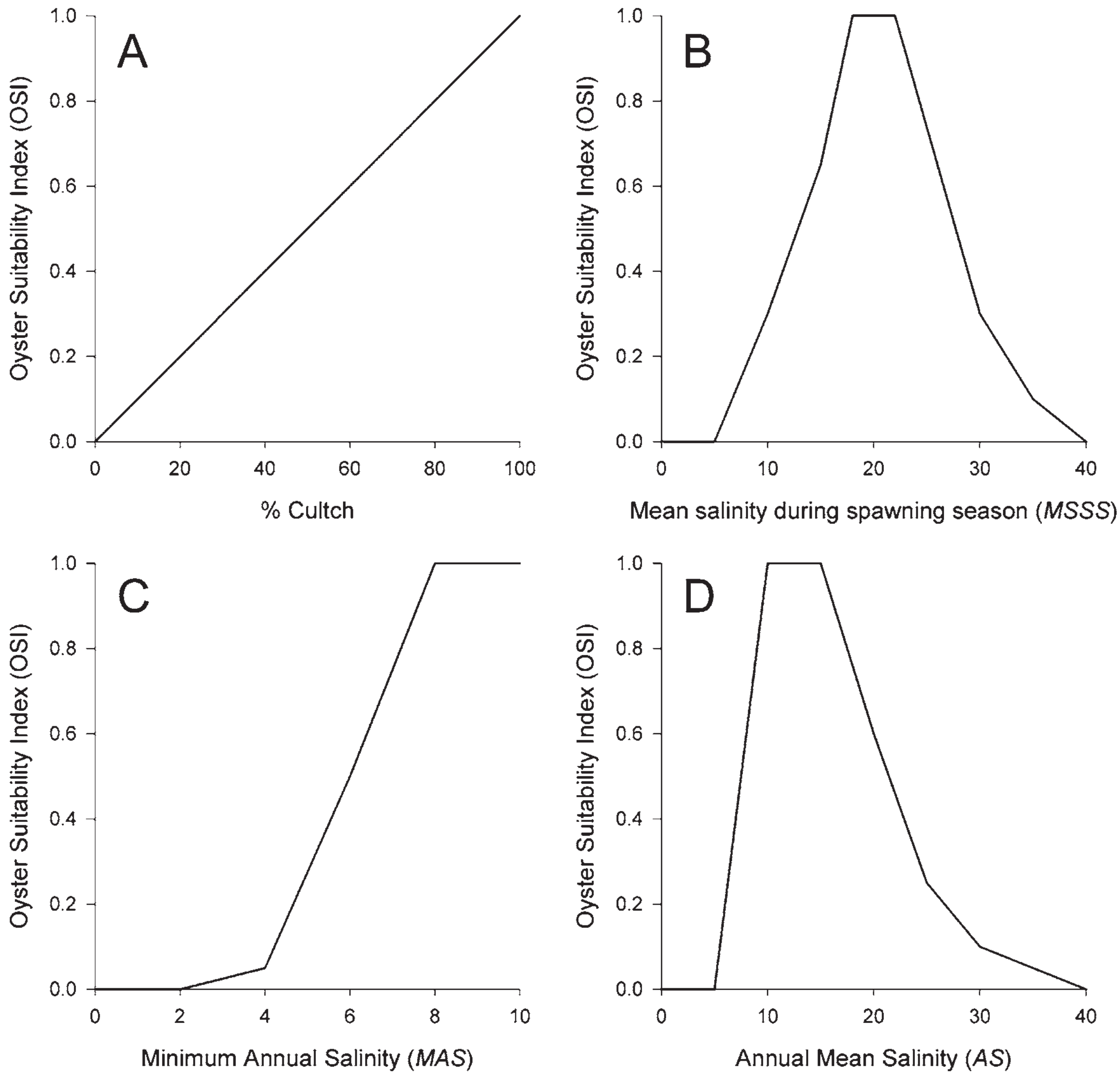

Figure 1. (A–D) Relationships between oyster suitability indices (OSI) and (A) percentage of area covered with hard substrate (% Cultch) (A), mean salinity during spawning season (MSSS) from May through September (B), minimum annual salinity (MAS) (C), and mean annual salinity (AS) (D). Percent cultch was measured as the percentage of each grid cell covered in hard substrate.

Mean salinity during the spawning season represents the mean monthly salinity from May through September, which is the spawning season for *Crassostrea virginica*. Mean salinity during the spawning season was calculated by averaging daily values of salinity from May 1 through September 30. Mean salinity during the spawning season reflects the greater optimal salinities required for spawning and larval stages (Butler 1953, Cake 1983). The relationship between MSSS and its OSI is formulated as a linear step-function (Fig. 1B). Breakpoints in the step-functions were determined by field validation of Cake (1983) by Soniat and Brody (1988). Values between the steps were interpolated linearly, and OSI values for MSSS were calculated as follows:

$$\text{MSSS} \le 5 \text{ or } \text{MSSS} > 40 \qquad \text{OSI}_{\text{MSSS}} = 0 \tag{2}$$

$$5 < \text{MSSS} \le 10 \qquad \text{OSI}_{\text{MSSS}} = -0.3 + (0.06 \times \text{MSSS}) \tag{3}$$

$$10 < \text{MSSS} \le 15 \qquad \text{OSI}_{\text{MSSS}} = -0.4 + (0.07 \times \text{MSSS}) \tag{4}$$

$$15 < \text{MSSS} < 18 \qquad \text{OSI}_{\text{MSSS}} = -1.1 + (0.1167 \times \text{MSSS}) \tag{5}$$

$$18 \le \text{MSSS} < 18 \qquad \text{OSI}_{\text{MSSS}} = 1 \tag{6}$$

$$22 < \text{MSSS} \le 30 \qquad \text{OSI}_{\text{MSSS}} = 2.925 - (0.0875 \times \text{MSSS}) \tag{7}$$

$$30 < \text{MSSS} \le 35 \qquad \text{OSI}_{\text{MSSS}} = 1.5 - (0.04 \times \text{MSSS}) \tag{8}$$

$$35 < \text{MSSS} \le 40 \qquad \text{OSI}_{\text{MSSS}} = 0.8 - (0.02 \times \text{MSSS}) \tag{9}$$

Minimum annual salinity is the minimum value of the 12 monthly mean salinities. This variable is essential to describe freshwater impacts (e.g., freshets, high rainfall years, or freshwater diversions) on oysters and is analogous to the frequency of the killing floods variable used by Cake (1983). Low salinity has a greater negative impact in the summer than in the winter; however, the model does not include a temperature parameter. This could be included easily if month was to serve as a surrogate for salinity, which would require 2 relationships to describe the effect of minimal salinity (1 for the summer months and 1 for the winter months). The relationship between MAS and OSI does not represent any potential positive benefits of increased freshwater, such as reducing predators and disease (Butler 1953, Gunter 1979, LaPeyre et al. 2009). The relationship between MAS and its OSI is formulated as a linear step-function (Fig. 1C). Breakpoints in the step-functions were determined by the field validation of Cake (1983) by Soniat and Brody (1988). Values between the steps were interpolated linearly and OSI values for MAS were calculated as follows

$$MAS \leq 2 \qquad OSI_{MAS} = 0 \tag{10}$$

$$2 < MAS \leq 4 \qquad OSI_{MAS} = -0.05 + (0.025 \times MAS) \tag{11}$$

$$4 < MAS \leq 6 \qquad OSI_{MAS} = -0.85 + (0.225 \times MAS) \tag{12}$$

$$6 < MAS \leq 8 \qquad OSI_{MAS} = -1 + (0.25 \times MAS) \tag{13}$$

$$8 < MAS \qquad OSI_{MAS} = 1 \tag{14}$$

Annual mean salinity represents the range of salinities over which adult oysters are viable (Gunter 1955, Calabrese & Davis 1970, Castagna & Chanley 1973, Cake 1983, Chatry et al. 1983). Annual mean salinity is an annual representation of Cake's (1983) historical mean salinity, and was calculated by averaging mean monthly salinity values. The relationship between AS and its OSI follows that of Soniat and Brody (1988), with the exception that the optimum AS in the current model is a range (10–15) and not a discrete point (12.5). The relationship between AS and its OSI is formulated as a linear step-function (Fig. 1D). Breakpoints in the step-functions were determined by field validation of Cake (1983) by Soniat and Brody (1988). Values between the steps were interpolated linearly. OSI values for AS were calculated as follows:

$$AS \leq 5 \text{ or } AS > 40 \qquad OSI_{AS} = 0 \tag{15}$$

$$5 < AS \leq 10 \qquad OSI_{AS} = -1 + (0.2 \times AS) \tag{16}$$

$$10 < AS \leq 15 \qquad OSI_{AS} = 1 \tag{17}$$

$$15 < AS \leq 20 \qquad OSI_{AS} = -2.2 - (0.08 \times AS) \tag{18}$$

$$20 < AS \leq 25 \qquad OSI_{AS} = 2 - (0.07 \times AS) \tag{19}$$

$$25 < AS \leq 30 \qquad OSI_{AS} = 1 - (0.03 \times AS) \tag{20}$$

$$30 < AS \leq 40 \qquad OSI_{AS} = 0.4 - (0.01 \times AS) \tag{21}$$

Restoration Suitability

The RSI is determined as the geometric mean of the OSI values for the 4 component variables (Pollack et al. 2012). If any component OSI is 0 (unsuitable), RSI is 0 (poor-quality habitat). The RSI is calculated as

$$RSI = \left(\prod_{i=1}^{n} OSI_i\right)^{1/n}, \tag{22}$$

where OSI_i represents the OSI value per cell for each environmental variable i, and n represents the number of variables included in the model. Restoration suitability index results were categorized as 0–0.25 (low), 0.25–0.55 (low/medium), 0.55–0.85 (medium/high), and 0.85–1 (high), similar to the categories described by Soniat and Brody (1988) and Brooks (1997).

Model Sensitivity

To determine how sensitive RSI values were to the inclusion of model parameters, a sensitivity analysis was conducted. The sensitivity analysis shows the percent change in RSI value from a 3-parameter model scenario to the inclusive OHSIM 4-parameter model. More specifically, RSI values were calculated for each possible combination of 3-OSI values (e.g., 1 OSI value removed), and then percent change was calculated from the 3-RSI value to the inclusive OHSIM, 4-RSI value, which reflects the relative importance of each parameter to the model structure. This method is similar to that developed by Pollack et al. (2012), but it considers how the model responds when variables are added to the model rather than removed; the overall interpretation remains the same.

Spatial Data and OHSIM Application

The equations discussed in the previous section were applied in a GIS to a subset of spatial data variables (percent cultch and salinity) to compute an overall RSI. We selected 2 areas for case studies to illustrate the application of the OHSIM: a data-rich area (Chesapeake Bay) and a data-poor area (western Mississippi Sound, northern Gulf of Mexico). By evaluation of both cases, the goal is to illustrate how the OHSIM can be used regardless of origin, condition, or type of input data available. Only the preprocessing of the geospatial data differs in the 2 case scenarios; the application of the equations remains the same. Although the level of granularity differs in the results of the 2 case scenarios (as a direct result of the input data types), the approach is consistent for both areas, yielding examples of the range of results that can be achieved. The following sections describe the application of the OHSIM in 2 case scenarios. All data were processed in ESRI's ArcGIS 10.0/10.1 software (ArcInfo).

Chesapeake Bay

The Chesapeake Bay is a well-studied system that is rich in digital data and oyster resources; therefore, it represents an ideal study area to conduct habitat suitability analysis using high-fidelity, oyster-related geospatial data. For the purposes of this study, we chose an 871-km^2 area along the Lower Rappahannock River (Fig. 2), because this area is among a handful of project sites in the Bay in which detailed seafloor conditions were mapped to produce detailed benthic habitat maps, has had several high-resolution hydrodynamic models applied to it, and has a well-studied oyster fishery. For this case study, we used the National Oceanic and Atmospheric Administration's (NOAA's) integrated benthic characterization database to calculate percent cultch and results from hydrodynamic simulations using the curvilinear-grid hydrodynamics in three-dimensions (CH3D [Kim 2013]) model to derive MSSS, MAS, and AS. We applied OHSIM using 3 y of CH3D data to determine temporal variability in oyster habitat as it relates to changes in salinity.

For the percent cultch variable, we used data from NOAA's integrated benthic characterization database (NOAA 2013), which consists of detailed side-scan sonar, acoustic surveys, sediment grab samples, and historical data sets, including mainstem sediment polygons, Maryland Bay Bottom Survey polygons, and Virginia Oyster Ground Survey polygons (i.e., the Baylor survey grounds) (Fig. 3). All data were clipped to the study area in Figure 2 and reprojected to UTM Zone 18 North NAD 1983.

To prepare the seabed classification data for the OHSIM, only faunal and man-made reef hard bottoms (mollusc class in Fig. 3) were selected from the integrated data set because mud, sand, and other soft bottoms are not suitable for oyster growth. To generate values for the percent cultch variable, the hard bottom layer was combined with the CH3D grid cell layer. First, area was computed for the CH3D grid cell layer (grid cells are not uniform in size and shape, but the total area was 871.4 km^2) in the attribute table, and then the hard bottom and CH3D layers were unioned. A new field of percent coverage was created, illustrating the percent hard bottom coverage in each grid cell. Last, a new attribute field was added in which Eq (1) was applied to each cell within the spatial and temporal domains, resulting in 870 OSI values for percent cultch.

Salinity variables were extracted from hydrodynamic simulations of the Lower Rappahannock River, using the CH3D model, which is a 3-dimensional, finite-difference hydrodynamic model that uses a horizontal curvilinear grid and a vertical z-grid to calculate temporally varying water levels and 3-dimensional velocity, temperature, and salinity (Kim 2013). Annual model runs were archived and calibrated for 8 y, between 1993 and 2000, and bottom salinities were extracted from 870 grid cells for OHSIM application. To evaluate how the OHSIM performed under different environmental conditions, 3 y (1997 to 1999) were selected from the data set—representing average, wet, and dry rainfall conditions, respectively—and providing the opportunity to evaluate a broad range of conditions and their potential influence on oyster suitability.

Bottom salinity values were processed so that they corresponded to the OHSIM salinity variables (AS, MSSS, and MAS). The values were included in the simulation result polygon layer attribute table—3 values per year, resulting in a total of 9 salinity values per grid cell (example of AS bottom values for 1997 are shown in Fig. 4). Therefore, 9 new attribute fields were added to calculate and apply the series of salinity suitability equations (Eqs 2–21). Using the field calculator, the appropriate equation was applied to each grid cell for each year (e.g., Eq (3) was applied to all cells with MSSS values between 5 and 10), resulting in a total of 7,830 salinity-based OSI values

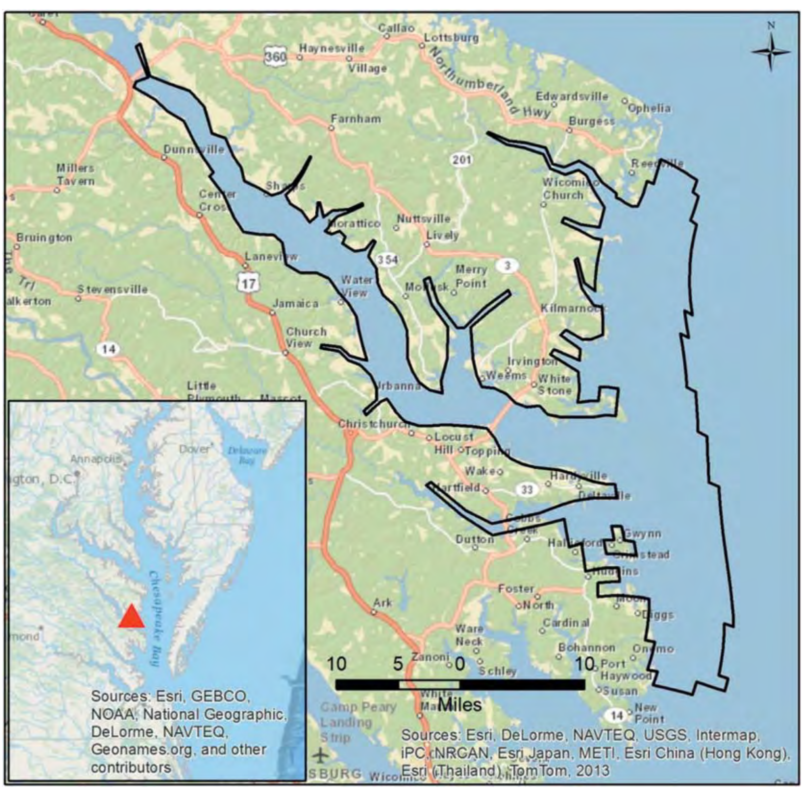

Figure 2. Study area in Lower Rappahannock River in the Chesapeake Bay.

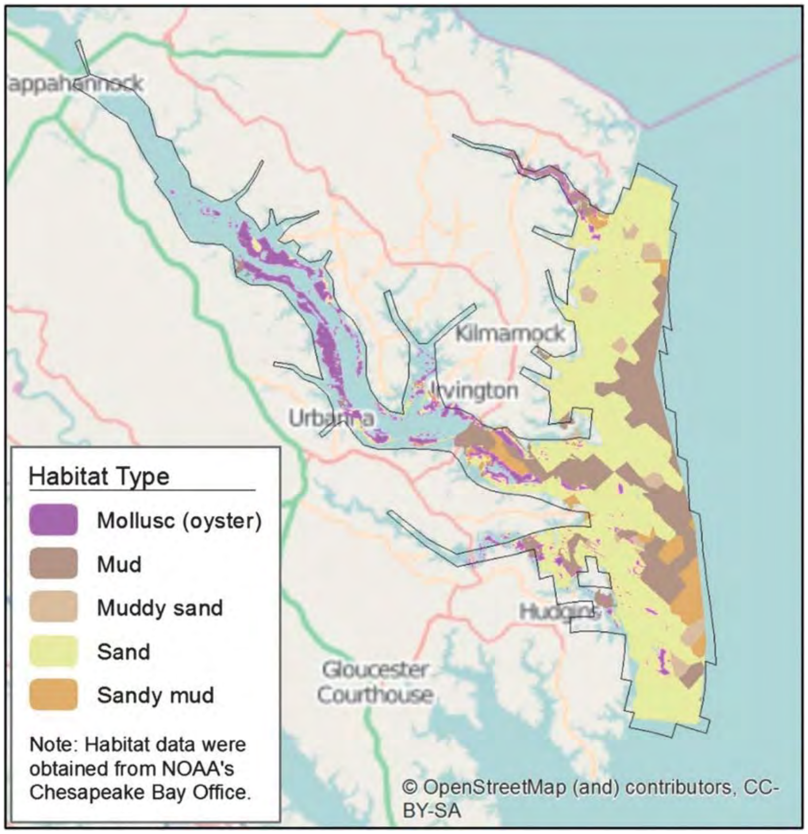

Figure 3. NOAA integrated benthic characterization within the Lower Rappahannock River in the Chesapeake Bay study area.

for the entire spatial and temporal domains of the Chesapeake Bay case study.

When all the OSI values were computed in the 2 polygon layer attribute tables, the 2 layers were combined using a union function for the application of the RSI equation (Eq (22)). The unioned layer file combined all the attributes, and a new RSI field (1 for each year, 1997 to 1999) was added. The field calculator was used to populate RSI values for each grid cell for each year. The RSI equation was also applied to a salinity-only–based model (i.e., percent cultch removed) to determine the sensitivity of the model results and to illustrate more fully the change and influence of the broad range of salinity conditions over the 3 y.

Gulf of Mexico

In contrast to the Chesapeake Bay, many areas do not have ideal geospatial data resources, such as archived, high-resolution hydrodynamic model simulations and detailed seabed classifications, and thus it is important to address how the OHSIM can be applied under such conditions. The Gulf of Mexico, although rich in oyster resources, does not have detailed seabed or salinity data; therefore, it represents a good example of how to make use of different data types that are more coarse in spatial resolution. The OHSIM was applied to a 942-km^2 area in the western Mississippi Sound.

Percent Cultch

Data from the Oyster Reef Mapping Project, collected in 2005, were used to assess the condition of oyster reefs after hurricane Katrina and were generated by the Mississippi Department of Marine Resources and NOAA's National Coastal Data Development Center (NCDDC). Briefly, seafloor samples were collected following predetermined transects and were recorded as a range of different bottom types (e.g., soft mud, shell, and so on). The data were provided directly from NCDDC as a GIS point file. The following designations were considered suitable for the percent cultch variable: live oysters, scattered live oysters, and shell or hash (Fig. 5). The extracted point data were interpolated to a grid surface to illustrate continuous coverage of suitable bottom conditions in a gridded system. The output grid cell size selected was 100 m (the default grid cell resolution was 90 m, which was rounded up). The resultant grid was converted to a polygon layer for integration with the salinity variables for RSI calculations.

Salinity Variables

For the salinity variables, data from NOAA's National Oceanographic Data Center (NODC) were obtained online (http://www.nodc.noaa.gov/OC5/regional_climate/GOMclimatology/). More specifically, the Gulf of Mexico Regional Climatology data includes a set of mean fields at 1°, 0.25°, and 0.10° resolutions for temperature, salinity, oxygen, phosphate, silicate, and nitrate. Statistical mean values for surface salinity were downloaded in GIS point file format for 0.10° and 0.25° for the winter, spring, summer, and autumn seasons (surface values were used in this case study, because numerical values were consistently missing at other depth levels). Statistical mean values are defined as the average of all unflagged interpolated values at each standard

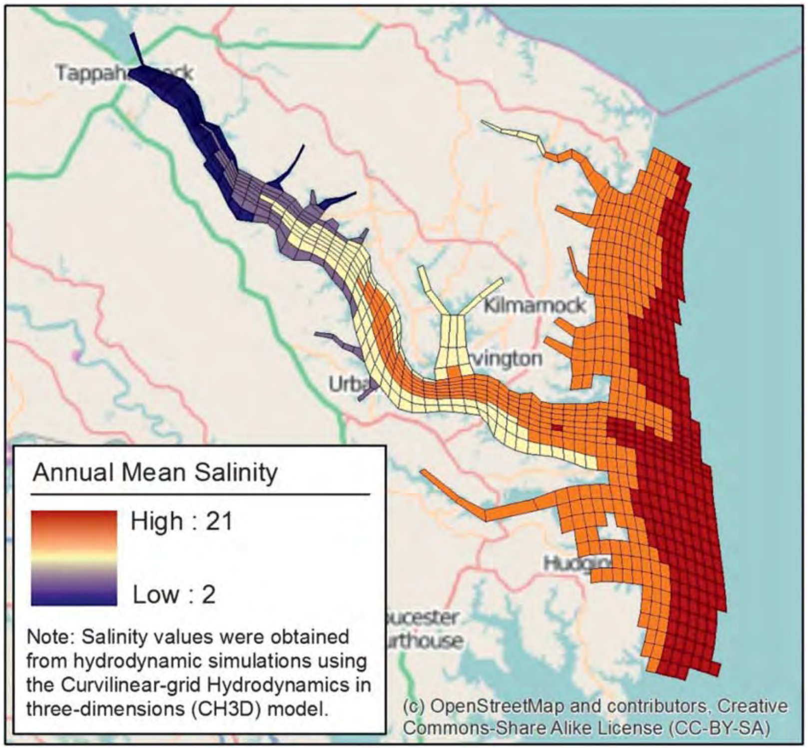

Figure 4. Mean annual salinity values (1997) produced by the CH3D model for the Lower Rappahannock River.

depth level for each variable in a given resolution grid cell (i.e., 0.10°) containing at least 1 measurement for a particular variable (refer to http://www.nodc.noaa.gov/OC5/regional_climate/GOMclimatology/ for more detailed information). In the western Mississippi Sound, 15 points from both the 0.10° and 0.25° data sets were used to interpolate the 3 salinity parameters. These points also helped determine the extent of the study area from which salinity could be interpolated, including the lower part of Bay St. Louis (Fig. 6). The data from the 0.10° data set were used primarily in the analysis because they had the greatest spatial resolution. However, in some cases, missing values were obtained from nearby points in the 0.25° data set. Because neither data set contained monthly values, the lowest value of the seasonal minima was selected for MAS. For MSSS, the mean was calculated from the spring and summer values, whereas for AS, the mean was calculated from all 4 seasonal values. All 3 point data sets were interpolated to a gridded surface using the salinity values and an output cell size of 100 m, matching the grid cell size of the percent cultch layer. Figure 6 shows the spatial extent of the study area and AS interpolation results. The results were

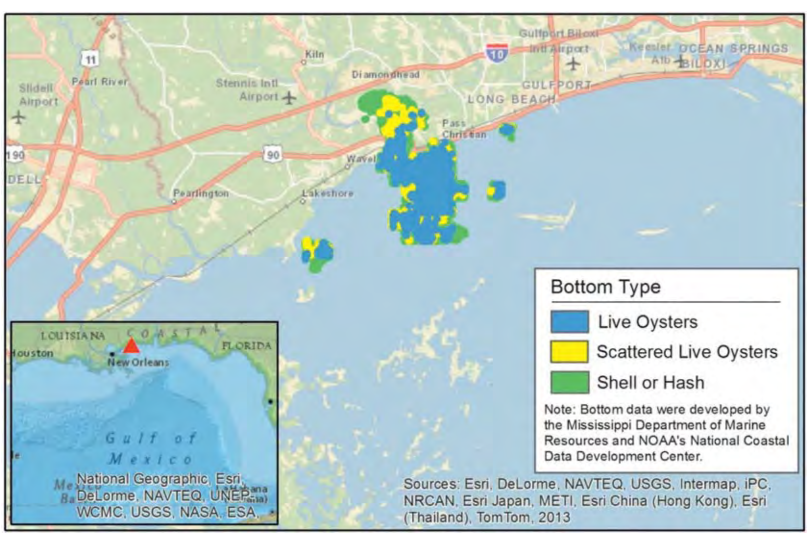

Figure 5. Suitable bottom types in the western Mississippi Sound.

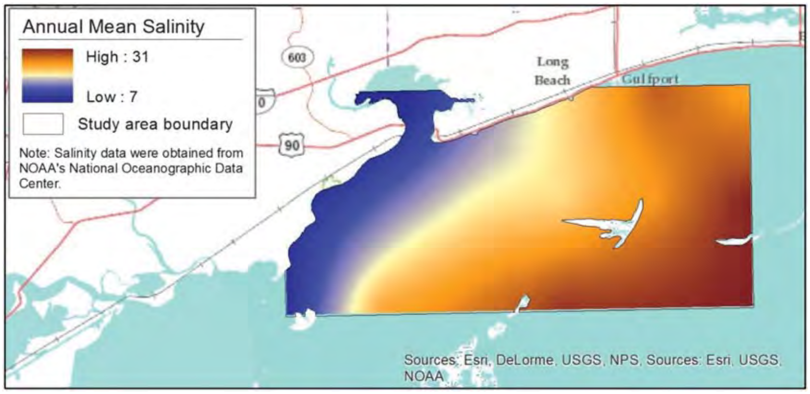

Figure 6. Interpolated annual salinity in the western Mississippi Sound (partial coverage in Bay St. Louis).

converted to polygon layers and unioned into 1 overall salinity variable layer. Eqs 2–21 were applied using the field calculator, resulting in 3 salinity OSI fields.

To compare the cultch and salinity layers, the study area extent file was edited so that only water grid cells were analyzed. This was accomplished by creating a land/water mask that was digitized using current aerial photography. Water areas were delineated and then a 100-m-grid cell fishnet was overlaid to place grid cells in the study area (aligned with the salinity layer grid cells). The gridded study area layer was used to mask the salinity variable layer to ensure the same extent and matching cell size for all data and reprojected to UTM Zone 16 North, NAD 1983. In addition, each grid cell was assigned a percent cultch value—not present in a grid cell (0%) or covering the entire grid cell (100%)—as a result of the interpolation of suitable bottom points to a grid layer. Then, the percent cultch OSI field was created using the field calculator to apply Eq (1) and, last, the RSI equation was applied combining the 4 OSI values in each grid cell.

MODEL RESULTS

Chesapeake Bay

In the Chesapeake Bay, salinity conditions varied during the 3 y period. In 1997, MSSS ranged from 3.6–20.7, MAS ranged from 0.4–16.9, and AS ranged from 2.6–20.1. In 1998, MSSS ranged from 2.5–19.2, MAS ranged from 0–16.2, and AS ranged from 3.2–19.5. In 1999, MSSS ranged from 7.65–22.1, MAS ranged from 0.4–19.8, and AS ranged from 5.6–22.0. Although the salinities varied during the 3-y period, the general trend shows greater salinities in the eastern part of the study area, nearer to the central part of the Bay, whereas lower salinities and/or more variable salinity conditions were observed in the western part of the study area, making up part of the Lower Rappahannock River, and thus were more influenced by freshwater pulses (Fig. 4). Suitable cultch conditions were estimated for 50.9 km^2 of 871 km^2, or approximately 6% of the study area. These conditions were found primarily from the middle to lower reach of the Rappahannock River within the study area boundary (Fig. 3). Restoration suitability index values were calculated for 3 y of data (1997 to 1999), illustrating conditions for average, wet, and dry years, respectively, in the inclusive OHSIM as well as a salinity-only–based model (e.g., percent cultch value removed), as shown in Figure 7. Restoration suitability index values ranged from 0–1, which is necessary to distinguish suitability among sites (Brooks 1997). Tables 1 and 2 summarize RSI statistics for both the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI).

The greatest RSI values generally occurred in the western part of the study area, in the middle to lower reach of the Rappahannock River, corresponding to areas with the most suitable cultch conditions (Fig. 7). The lowest RSI values occurred in the eastern part of the study area, nearer to the central part of the Bay. Although salinity conditions were often suitable in the eastern part of the study area, it ranked lower as a result of unsuitable cultch conditions that were not found in deeper waters. Average salinity conditions in 1997 resulted in 2.5 km^2 of high suitability, 110 km^2 of medium to high suitability, 165 km^2 of low to medium suitability, and 595 km^2 of low suitability in the inclusive OHSIM results, or 4-RSI (Table 1). The year 1998 was considered a wet year in terms of rainfall conditions, and thus salinity conditions were less ideal and RSI values tended toward lower suitability than in 1997. As a result, no area was found to be highly suitable in 1998 (Table 1), and the mean 3-RSI (salinity-only model) value decreased from 0.80 to 0.73 (Table 2), illustrating that rainfall and/or freshwater influences resulted in less area with suitable salinity. Therefore, lower suitability classes increased in area in 1998, with 4-RSI values increasing to 604 km^2 of low suitability and 182 km^2 of low to medium suitability. In contrast, 1999 proved to be a dry year in terms of rainfall, resulting in more area with suitable salinities compared with 1997. For example, the mean 3-RSI value increased from 0.80 in 1997 to 0.84 in 1999 (Table 2), and resulted in an increase in high-suitability area from 2.5 km^2 in 1997 to 9.4 km^2 in 1999 (Table 1).

Sensitivity Analysis

The sensitivity analysis indicated that percent cultch has the most influence on model results (Fig. 8), which was expected given the linear relationship between percent cultch and OSI. Furthermore, not only did most RSI values decrease when the percent cultch OSI value was added, but they decreased by 90% or more, illustrating that salinity conditions were highly suitable in a given grid cell in the salinity-only–based model; without suitable cultch, the value decreased significantly. In contrast,

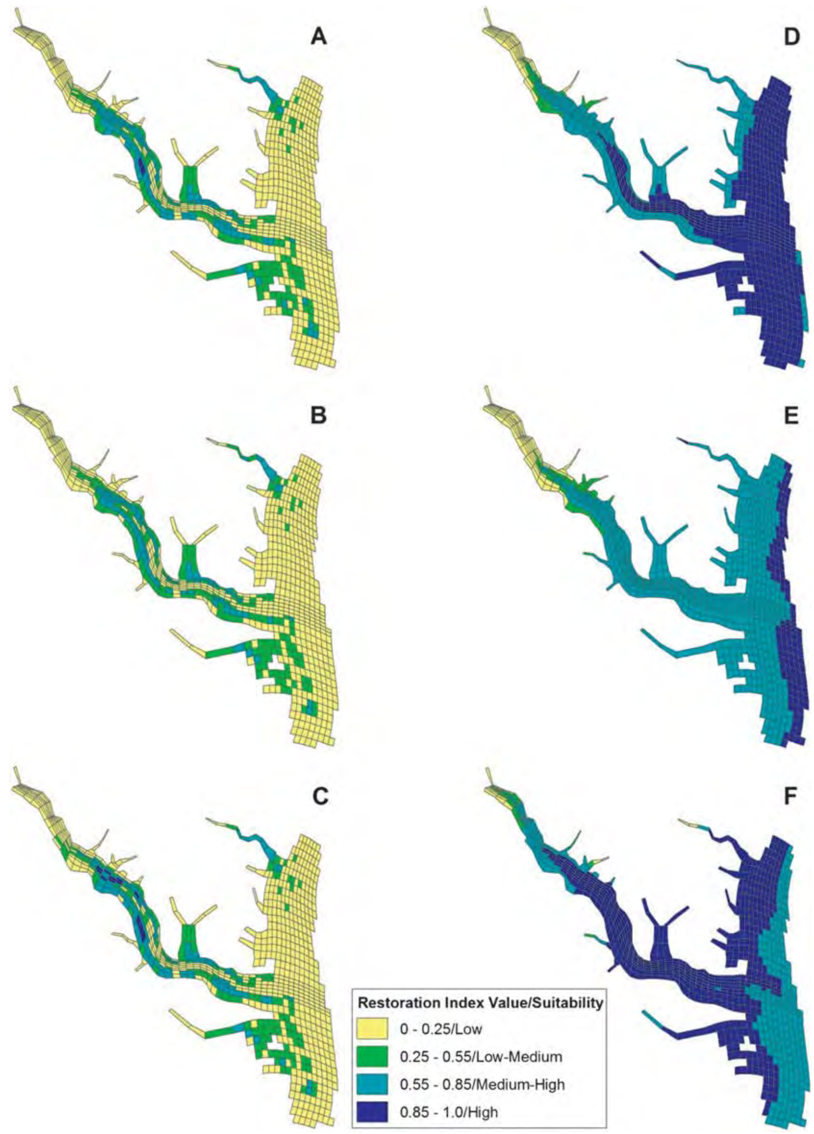

Figure 7. (A–C) RSI results using all OSI values, Lower Rappahannock River, in 1997 (A), 1998 (B), and 1999 (C). (D–F) RSI results for the salinity-only–based model (e.g., percent cultch removed) in 1997 (average) (D), 1998 (wet) (E), and 1999 (dry) (F).

the model was less sensitive to a particular salinity parameter, with much of the habitat in the eastern part of the study area (closer to the central part of the Bay) having a slight decrease or little/no change in RSI value (blue cells) when any salinity OSI value was added to the model (Fig. 8C, D).

Gulf of Mexico

In the western Mississippi Sound, Gulf of Mexico, salinity conditions were as follows: MSSS ranged from 6.0–29.0, MAS ranged from 4.8–26.0, and AS ranged from 6.9–31.2. In general,

TABLE 1.

RSI area statistics for the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI) results (1997 to 1999) for the Lower Rappahannock River in the Chesapeake Bay.

	Area (km^2)					
RSI/suitability	4-RSI 1997	4-RSI 1998	4-RSI 1999	3-RSI 1997	3-RSI 1998	3-RSI 1999
0–0.25/low	594.5	603.9	592.9	34.7	56.8	11.1
0.25–0.55/low–Medium	164.7	181.8	159.2	19.2	27.2	11.5
0.55–0.85/medium–high	109.7	85.6	109.8	221.3	644.1	312.4
0.85–1.0/high	2.5	0	9.4	596.2	143.2	536.4
Total area (km^2)	871.4					

TABLE 2.

RSI summary statistics for the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI) results (1997 to 1999) for the Lower Rappahannock River in the Chesapeake Bay.

Year	4-RSI min	3-RSI min	4-RSI max	3-RSI max	4-RSI mean	3-RSI mean	4-RSI SD	3-RSI SD
1997	0.00	0.00	0.86	0.92	0.17	0.80	0.25	0.20
1998	0.00	0.00	0.79	0.89	0.15	0.73	0.23	0.23
1999	0.00	0.00	0.92	0.93	0.17	0.84	0.27	0.12

lower salinities and/or higher salinity variability were observed along the shoreline and in the lower part of Bay St. Louis, which is closer to inlets and other freshwater sources (Fig. 6). Salinities increased moving away from the shoreline, with the highest salinities occurring in the southeastern and eastern parts of the study area toward the central part of the Gulf of Mexico. Suitable cultch conditions were estimated for 83.7 km^2 of 942 km^2, or approximately 9% of the study area. In general, these conditions extended from the lower part of Bay St. Louis to a concentrated area south of Pass Christian as well as a few small, scattered areas in other parts of the study area (Fig. 5). Restoration suitability index values ranged from 0–1, which is necessary to distinguish suitability among sites (Brooks 1997). Restoration suitability index values were calculated for the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI, percent cultch value removed), as shown in Figure 9A and B, respectively. Tables 3 and 4 summarize RSI statistics for both the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI).

The greatest RSI values generally occurred in an area extending from the lower part of Bay St. Louis to a concentrated area south of Pass Christian, and corresponded to areas with the most suitable cultch conditions (Fig. 9). Low RSI values occurred throughout the study area, especially in the east. Although salinity conditions were often suitable throughout the study area, many areas ranked low as a result of unsuitable cultch conditions that were either not found in deeper waters or not found along some parts of the shoreline. Most of the study area had low suitability (more than 90%; Table 3). In addition, less than 1% had low to medium suitability, 4.1% had medium to high suitability, and almost 5% had high suitability in the inclusive OHSIM (4-RSI) results. Table 3 also reports areas for the salinity-only–based model (3-RSI), in which less than 1% had low suitability, 26.4% had low to medium suitability, 71.2% had medium to high suitability, and 2.1% had high suitability. Minimum and maximum RSI values were similar for the 2 models; however, given the large number of low-suitability RSI values in the OHSIM 4-RSI result, the mean value was only

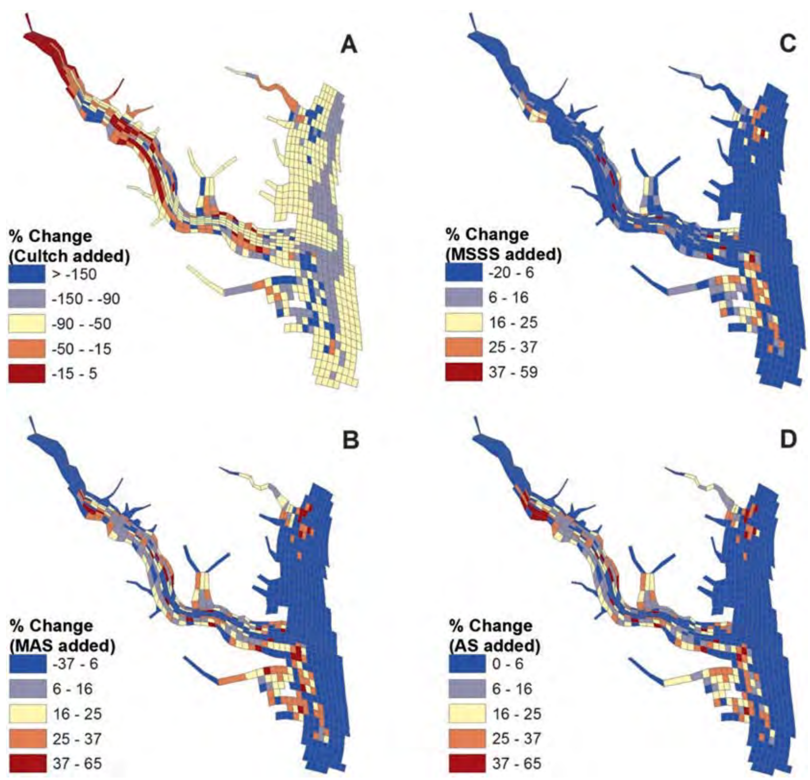

Figure 8. (A–D) Sensitivity analysis for the OHSIM results in 1997, Lower Rappahannock River. The figure shows the percent change in RSI value from a 3-parameter model scenario to the inclusive OHSIM, 4-parameter model when percent cultch (A), MAS (B), MSSS (C), and AS (D) are added to the remaining 3 OSI values. Note the different scales on each legend.

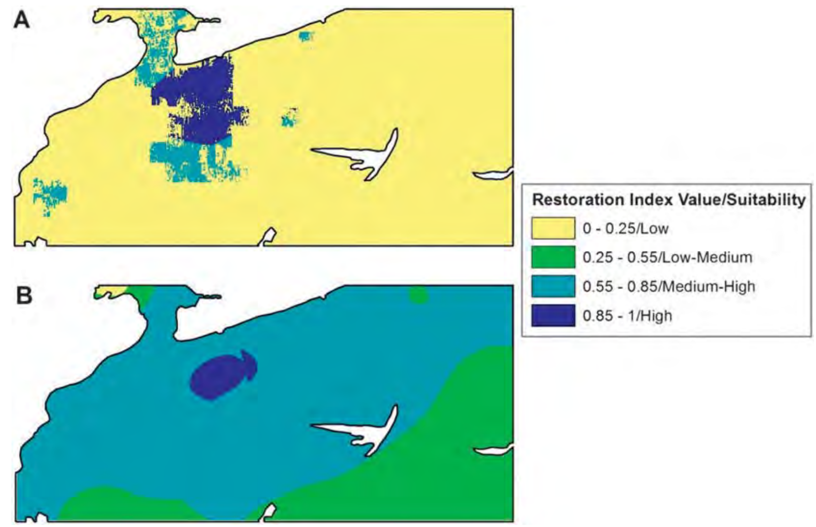

Figure 9. (A, B) RSI results for the inclusive OHSIM (A) and the salinity-only–based model (B) (e.g., percent cultch value removed) for the western Mississippi Sound study area.

0.1, whereas in the salinity-only–based model 3-RSI result, it was 0.63 (Table 4). The majority of highly suitable conditions for both cultch and salinity was concentrated in an area offshore and south of Pass Christian (Figs. 5, 6, and 9) and corresponded to the location of known commercial oyster reefs (Fig. 10).

As with the Chesapeake Bay, a sensitivity analysis was conducted for the western Mississippi Sound case study. The same approach was used, whereby the analysis shows the percent change in RSI value from a 3-parameter model scenario to the inclusive OHSIM, 4-parameter model, illustrating the sensitivity of the model to each parameter (Fig. 11). Similar to the Chesapeake Bay case study, much of the area had favorable salinity conditions; however, with the addition of the percent cultch OSI value, most RSI values decreased (Fig. 11A). This is especially true in the areas close to the shoreline, where salinity-only–based model 3-RSI values ranked high (Fig. 9B); but, because of the lack of suitable cultch, the RSI values decreased by more than 70% (Fig. 11A). The influence of percent cultch is also illustrated in Table 3, in which more than 70% of the study area had medium to high or high suitability in the salinity-only–based model 3-RSI results, decreasing to less than 10% area with medium to high or high suitability in the inclusive OHSIM 4-RSI results. The exception to the decreasing trend was in areas where suitable cultch conditions existed (Fig. 11A), and some values increased by as much as 30%.

Much like the sensitivity analysis for the Chesapeake Bay, RSI values in the Gulf of Mexico were not as sensitive to the addition of the salinity parameters (Fig. 11C, D). For example, when MSSS or AS were added to the model, the majority of the cells showed minimal percent change (–3 to 2%; Fig. 11C, D). When MAS was added to the model, some RSI values increased in areas with suitable cultch (2%–10%). This is also illustrated in a few areas near the mouth of Bay St. Louis when AS was added to the model (Fig. 11D), although areas with suitable cultch farther offshore experienced a decrease in RSI value (by as much as 35%). The reverse trend was shown when MSSS was added to the model, whereby areas with suitable cultch near the mouth of Bay St. Louis decreased in RSI value (by as much as 54%) and areas farther offshore increased (2%–10%).

DISCUSSION

For agencies faced with the task of restoring oyster populations, choosing sites that sustain reefs under dynamic environmental conditions is essential. Often, natural resource managers are not afforded the luxury of long-term field studies that can reduce myriad uncertainties associated with site selection. The application of integrated HSI-GIS approaches provides a standardized, flexible, and rapid approach that managers can use to reduce the uncertainty associated with the trial-and-error of site

TABLE 3.

RSI area statistics for the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI) results for the Gulf of Mexico.

	Area (km^2)			
RSI/suitability	4-RSI	4-RSI area (%)	3-RSI	3-RSI area (%)
0–0.25/low	858.1	91.11	2.38	0.25
0.25–0.55/low–medium	0.12	0.01	249	26.44
0.55–0.85/medium–high	38.6	4.10	670.7	71.21
0.85–1/high	45	4.78	19.75	2.10
Total area (km^2)	941.8	100.00		100.00

TABLE 4.

RSI summary statistics for the inclusive OHSIM (4-RSI) and the salinity-only–based model (3-RSI) results for the Gulf of Mexico.

4-RSI min	3-RSI min	4-RSI max	3-RSI max	4-RSI mean	3-RSI mean	4-RSI SD	3-RSI SD
0	0.17	0.89	0.86	0.1	0.63	0.24	0.14

Figure 10. RSI results for the inclusive OHSIM compared with the location of known commercial oyster reefs, western Mississippi Sound.

selection (Pollack et al. 2012). In this study, we developed a generalized OSI model that determined suitable habitat for oyster restoration based on 3 salinity variables and suitable substrate. The OHSIM is a simplified version of the one developed by Soniat (2012). Our goal was to create a model that could be developed rapidly using available data and then be applied throughout the Atlantic and Gulf coasts. We considered salinity and substrate only, because these parameters capture the critical relationships among environmental factors and the oyster's life history. Model results showed that the OHSIM captured general trends in oyster habitat suitability. During wet years, oysters are impacted negatively by being exposed to lower salinities (Hofmann et al. 1994, Dekshenieks et al. 2000), which is reflected in the 1998 results from the Chesapeake Bay case study (Fig. 7E). In contrast, moderate years (1997 and 1999) were more suitable. One trend not captured is the effect of extreme salinities. The available data never experienced those extremes, but the phenomenon is represented in the equations for MSSS and AS, and would be reflected in RSI values under those conditions.

Salinity is a recognized driver for oyster dynamics (Gunter 1955, Kennedy et al. 1996) and our parameterization captured the critical aspects of that relationship, with the optimal range of salinities for each $OSI_{salinity}$ being in mesohaline conditions, which facilitates oyster growth in disease-prone waters (Carnegie & Burreson 2011, Levinton et al. 2011). Restoration suitability index values were not extremely sensitive to changes in any salinity variable compared with percent cultch. There were, however, differences in how the model responded between Chesapeake Bay and the Gulf of Mexico. Chesapeake Bay was more sensitive to MAS, indicating that available habitat in the Bay was more dependent on freshwater dynamics. The Gulf of Mexico was more sensitive to MSSS, indicating that available habitat was more dependent on summertime salinities.

The presence of hard substrate (represented as percent cultch in this study) has been included in some oyster HSI models (Cake 1983, Soniat & Brody 1988, Soniat 2012, the current study), but not others (Barnes et al. 2007, Pollack et al. 2012). Our results indicated that the OHSIM is highly sensitive to percent cultch. When it was added, the overall amount of suitable habitat was reduced (i.e., RSI values decreased; Figs. 8A and 11A), because of the number of cells that did not have any hard substrate. This is a direct result of the equation that was used to parameterize percent cultch, which stated that no hard substrate resulted in an OSI value of 0. Without suitable substrate, oyster larvae cannot

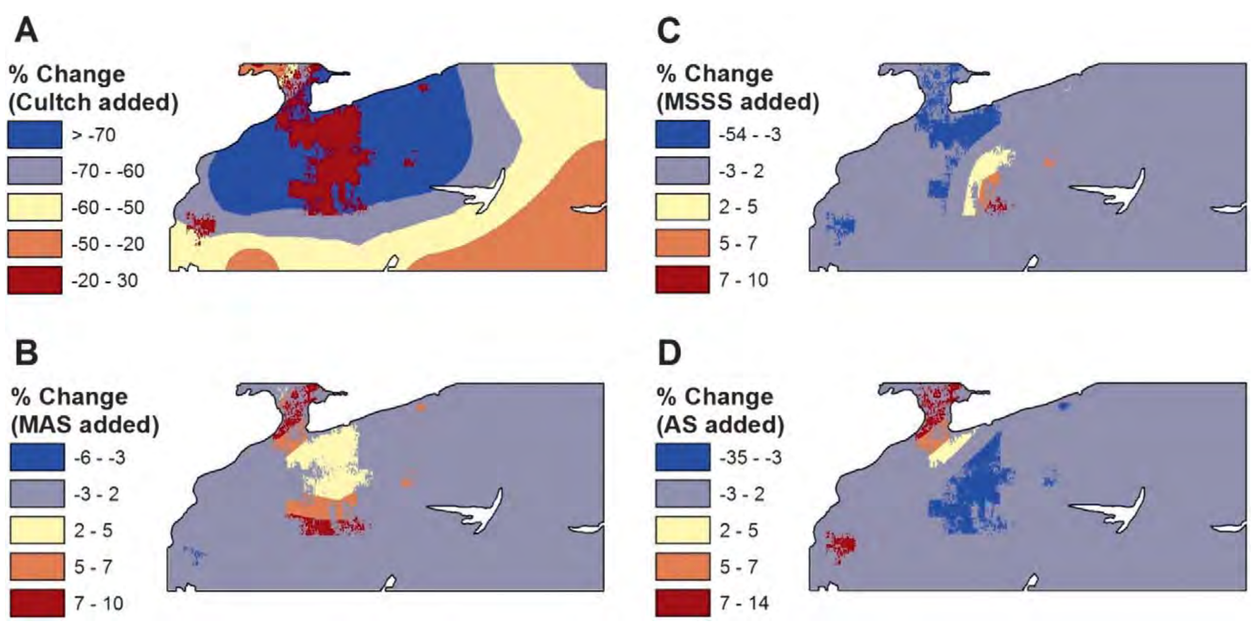

Figure 11. (A–D) Sensitivity analysis for the OHSIM results, western Mississippi Sound. The figure shows the percent change in RSI value from a 3-parameter model scenario to the inclusive OHSIM, 4-parameter model, when percent cultch (A), MAS (B), MSSS (C), and AS (D) are added to the remaining 3 OSI values.

settle and, therefore, our parameterization seems reasonable. By including percent cultch as a variable, areas that did not have hard substrate, but were otherwise suitable, received an RSI score of 0, effectively removing these areas from consideration for restoration. For projects that plan on restoring oyster reefs in areas where they do not currently exist, simulated, geo-referenced reef polygons would need to be added to the model to determine RSI values accurately for those locations. The type of data used to parameterize the percent cultch data layer impacts inferences made from this model. For example, if percent cultch is parameterized with bottom layer data consisting only of existing shell beds/oyster reefs, then oyster suitability is determined by where oysters already exists (with other areas receiving RSI scores of 0). Conversely, if the percent cultch data layer consists of other types of hard substrate where oysters do not currently exist, or if polygons are created to represent where hard substrate could be installed, then the RSI scores for those locations would be more reflective of that location's potential for successful restoration. Given the confounding nature of this variable, it is important to quantify its impact by exploring the parameter space thoroughly through sensitivity analysis as well as by running a version of the model without percent cultch included. In cases when benthic habitat characterization data are available and can be incorporated easily into the HSI framework, it is reasonable to include this variable to examine inclusive RSI values. Future research should explore the functional form of the OSI–percent cultch relationship as well as considering weighing $OSI_{percent\ cultch}$ differently in the RSI calculation.

To determine how robust the OHSIM was to data input, we applied it to 2 regions that had different data resources. Chesapeake Bay is a well-studied system, and salinity values from high-resolution hydrodynamic codes (CH3D) and percent cultch values from detailed seabed classifications were used in the OHSIM. One of the limitations of using hydrodynamic modeling results is that model runs may exist only for historical time periods. For example, in this study, model runs existed from 1993 to 2000, but for demonstration purposes only data from 1997, 1998, and 1999 were used in the OHSIM. Other years were not available and it was cost prohibitive to run the model for current years; however, the 3 selected years illustrated the effects of wet (1998), dry (1999), and average (1997) conditions on the overall RSI.

The Gulf of Mexico did not have high-resolution hydrodynamic model data or detailed seabed classifications available, so surface salinity values were interpolated from mean salinities (points) from NOAA's NODC, whereas percent cultch was interpolated from seafloor sample (points) from the Oyster Reef Mapping Project. Bottom salinity values are generally more appropriate for quantifying oyster suitability, because oysters are found on the seafloor. However, we were trying to determine how robust the OHSIM was when nonideal data were available. For the Gulf of Mexico case study, we were able to obtain a pseudo-independent data set (the commercial reef data) that provided a metric for model validation (Fig. 10) and allowed comparison of model results to existing oyster abundance (as described in Tirpak et al. [2009]). Results from this case study indicated that surface salinity and percent cultch interpolations provided a good indicator of oyster suitability based on our evaluation. Nonetheless, it is important to note that validating an oyster HSI that is parameterized with a percent cultch variable will often result in positive validation because oysters were likely already present in locations with hard substrates and suitable salinities.

The OHSIM represents a generalized model for determining locations suitable for oyster restoration throughout the Atlantic and Gulf coasts, and it provides a scientifically based support tool for natural resource managers and project planners. It was designed intentionally to include only the minimum factors required for oyster suitability—namely, substrate and salinity. Given the complexities of restoring reefs and sustaining them over long periods of time, other local conditions may influence reef sustainability, which should likewise be considered for determining restoration potential. For example, Pollack et al. (2012) determined temperature and turbidity were important in the Mission Aransas estuary in the Texas Gulf, and Barnes et al. (2007) determined that the number of high flow days (>4,000 cfs) per month were important (although our AS variable could serve as a surrogate for that variable). Other potential factors that might impact restoration include substrate firmness and stability, slope of shorelines for intertidal reef restoration, and disease prevalence and intensity. The OHSIM is flexible enough that other variables can be integrated easily into the framework, and local conditions should be considered before using the OHSIM exclusively. The sensitivity analysis also illustrated the importance of evaluating quantitatively the relationship between model inputs, equations, and results for all HSI models. Future work should include additional exploration and refinement of the quantitative relationship between percent cultch and overall RSI values.

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LITERATURE CITED

Barnes, T. K., A. K. Volety, K. Chartier, F. J. Mazzotti & L. Pearlstine. 2007. A habitat suitability index model for the eastern oyster (*Crassostrea virginica*), a tool for restoration of the Caloosahatchee Estuary, Florida. *J. Shellfish Res.* 26:949–959.

Beck, M. W., R. D. Brumbaugh, L. Airoldi, A. Carranza, L. D. Coen, C. Crawford, O. Defeo, G. J. Edgar, B. Hancock, M. C. Kay, H. S. Lenihan, M. W. Luckenbach, C. L. Toropova, G. F. Zhang & X. M. Guo. 2011. Oyster reefs at risk and recommendations for conservation, restoration, and management. *Bioscience* 61:107–116.

Brooks, R. P. 1997. Improving habitat suitability index models. *Wildl. Soc. Bull.* 25:163–167.

Butler, P. A. 1953. The southern oyster drill. *Proc. Natl. Shellfish. Assoc.* 44:67–75.

Cake, E. W. 1983. Habitat suitability index models: Gulf of Mexico American Oyster. Ocean Springs, MS: U.S. Fish and Wildlife Service. 37 pp.

Calabrese, A. & H. S. Davis. 1970. Tolerances and requirements of bivalve molluscs. *Helgoland. Wissen. Meeresunt.* 20:553–564.

Carnegie, R. B. & E. M. Burreson. 2011. Declining impact of an introduced pathogen: *Haplosporidium nelsoni* in the oyster *Crassostrea virginica* in Chesapeake Bay. *Mar. Ecol. Prog. Ser.* 432:1–15.

Castagna, M. & P. Chanley. 1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia on the western mid-Atlantic coast. *Malacologia* 12:47–96.

Chatry, M., R. J. Dugas & K. A. Easley. 1983. Optimum salinity regime for oyster production on Louisiana's state seed grounds. *Contrib. Mar. Sci.* 26:81–94.

Coastal Protection & Restoration Authority. 2012. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Baton Rouge, LA: Coastal Protection and Restoration Authority. Available at: http://coastalmasterplan.la.gov.

Coen, L. D., M. W. Luckenbach & D. L. Breitburg. 1999. The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives. *Proc. Amer. Fish. Soc. Symp.* 22:438–454.

Cole, C. A. & R. L. Smith. 1983. Habitat suitability indices for monitoring wildlife populations: an evaluation. *Trans. N. Amer. Wildl. Nat. Res.* 48:367–375.

Curnutt, J. L., J. Comiskey, M. P. Nott & L. J. Gross. 2000. Landscape-based spatially explicit species index models for Everglades restoration. *Ecol. Appl.* 10:1849–1860.

Dekshenieks, M., E. Hofmann, J. Klinck & E. Powell. 2000. Quantifying the effects of environmental change on an oyster population: a modeling study. *Estuaries Coasts* 23:593–610.

Duberstein, C. A., M. A. Simmons, M. R. Sackschewsky & J. M. Becker. 2007. Development of a habitat suitability index model for the sage sparrow on the Hanford site. Richland, WA: Pacific Northwest National Laboratory. 25 pp.

Eggleston, D. B. 1999. Application of landscape ecological principles to oyster reef habitat restoration. In: M. W. Luckenbach, R. Mann & J. A. Weston, editors. Oyster reef habitat restoration: a synopsis and synthesis of approaches. Gloucester Point, VA: Virginia Institute of Marine Science Press. pp. 213–227.

Gunter, G. 1955. Mortality of oysters and abundance of certain associates as related to salinity. *Ecology* 36:601–605.

Gunter, G. 1979. Studies of the southern oyster borer, *Thais haemostoma*. *Gulf Res. Rep.* 6:249–260.

Harding, J. M., R. Mann, M. J. Southworth & J. A. Wesson. 2010. Management of the Piankatank River, Virginia, in support of oyster (*Crassostrea virginica*, Gmelin 1791) fishery repletion. *J. Shellfish Res.* 29:867–888.

Hofmann, E. E., J. M. Klinck, E. N. Powell, S. Boyles & M. S. Ellis. 1994. Modeling oyster populations II: adult size and reproductive effort. *J. Shellfish Res.* 13:165–182.

Kellogg, M. L., J. C. Cornwell, M. S. Owens & K. T. Paynter. 2013. Denitrification and nutrient assimilation on a restored oyster reef. *Mar. Ecol. Prog. Ser.* 480:1–19.

Kennedy, V. S., R. I. E. Newell & A. F. Eble, editors. 1996. The eastern oyster *Crassostrea virginica*. College Park, MD: Maryland Sea Grant. 734 pp.

Kim, S.- C. 2013. Evaluation of a three-dimensional hydrodynamic model applied to Chesapeake Bay through long-term simulation of transport processes. *J. Am. Water Resour. Assoc.* 49:1078–1090.

La Peyre, M. K., B. Gossman & J. F. La Peyre. 2009. Defining optimal freshwater flow for oyster production: effects of freshet rate and magnitude of change and duration on eastern oysters and *Perkinsus marinus* infection. *Estuaries Coasts* 32:522–534.

Levinton, J., M. Doall, D. Ralston, A. Starke & B. Allam. 2011. Climate change, precipitation and impacts on an estuarine refuge from disease. *PLoS One* 6:e18849.

Meyer, D. L., E. C. Townsend & G. W. Thayer. 1997. Stabilization and erosion control value of oyster cultch for intertidal marsh. *Restor. Ecol.* 5:93–99.

Newell, R. I. E., J. C. Cornwell & M. S. Owens. 2002. Influence of simulated bivalve biodeposition and microphyrobenthos on sediment nitrogen dynamics: a laboratory study. *Limnol. Oceanogr.* 47:1367–1379.

NOAA. 2013. Lower Rappahannock River, VA, benthic habitat characterization. Available at: http://chesapeakebay.noaa.gov/acoustic-seafloor-mapping/lower-rappahannock-river-va-benthic-habitat-characterization.

Piazza, B. P., P. D. Banks & M. K. La Peyre. 2005. The potential for created oyster shell reefs as a sustainable shoreline protection strategy in Louisiana. *Restor. Ecol.* 13:499–506.

Pollack, J. B., A. Cleveland, T. A. Palmer, A. S. Reisinger & P. A. Montagna. 2012. A restoration suitability index model for the eastern oyster (*Crassostrea virginica*) in the Mission-Aransas estuary, TX, USA. *PLoS One* 7:e40839.

Posey, M., T. D. Alphin, C. M. Powell & E. Townsend. 1999. Oyster reefs as habitat for fish and decapods. In: M. W. Luckenbach, R. Mann & J. A. Weston, editors. Oyster reef habitat restoration: a synopsis and synthesis of approaches. Gloucester Point, VA: Virginia Institute of Marine Science Press. pp. 229–238.

Powers, S. P., C. H. Peterson, J. H. Grabowski & H. S. Lenihan. 2009. Evaluating the success of constructed oyster reefs in no-harvest sanctuaries: implications for restoration. *Mar. Ecol. Prog. Ser.* 389:159–170.

Roloff, G. J. & B. J. Kernohan. 1999. Evaluating reliability of habitat suitability index models. *Wildl. Soc. Bull.* 27:973–985.

Soniat, T. M. 2012. Eastern oyster habitat suitability index. In: Louisiana's Comprehensive Master Plan for a Sustainable Coast. Baton Rouge, LA: Coastal Protection and Restoration Authority. Appendix D-13. Available at: http://www.coastalmasterplan.louisiana.gov/2012-master-plan/master-plan-appendices/.

Soniat, T. M. & M. S. Brody. 1988. Field validation of a habitat suitability index model for the American oyster. *Estuaries* 11:87–95.

Store, R. & J. Kangas. 2001. Integrating spatial and multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modeling. *Landsc. Urban Plan.* 55:79–93.

Tirpak, J. M., D. Jones Farrand, F. R. Thompson, III, D. J. Twedt, C. K. Baxter, J. A. Fitzgerald & W. B. Uihlein, III. 2009. Assessing ecoregional scale habitat suitability index models for priority landbirds. *J. Wildl. Manage.* 73:1307–1315.

Tolley, S. G. & A. K. Volety. 2005. The role of oysters in habitat use of oyster reefs by resident fishes and decapod crustaceans. *J. Shellfish Res.* 24:1007–1012.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. Washington, DC: Division of Ecological Services, U.S. Fish and Wildlife Service, Department of the Interior. 103 pp.

Lisa Vitale

From: Colleen Roco <Colleen.Roco@tpwd.texas.gov>
Sent: Thursday, January 26, 2017 5:03 PM
To: Lisa Vitale; Aaron Chastain; Alison Fontenot; Anthony Risko; Barbara Keeler; Bill Klein (william.p.klein.jr@usace.army.mil); Bob Heinly; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov); Carla Guthrie (Carla.Guthrie@twdb.texas.gov); Celestine Bryant; Chuck Ardizzone; David Buzan; Diana Laird; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV); Donna Anderson (Donna_Anderson@fws.gov); Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil); Elizabeth Vargas; Holly Houghton; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com); Jan Stokes (janelle.s.stokes@usace.army.mil); Jane Watson; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil); Jim Lindsay (james_lindsay@nps.gov); Josh Carter (Joshua.Carter@mottmac.com); Juan Moya; Kellie Poolaw; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil); Kelsey Calvez; Kevin Cauble; Kristin Shivers (Kristin.D.Shivers@usace.army.mil); Lauren Brown; Leslie Koza; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil); Linda Langley; Lindsey Lippert; Maria Martinez; Matt Mahoney; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com); Michael Lee (mtlee@usgs.gov); Mimi Wallace; Miranda Allen-Myer; Mollie Powell; Nancy Parrish (Nancy.A.Parrish@usace.army.mil); Nelun Fernando; Pat Clements (pat_clements@fws.gov); Paul Kaspar (kaspar.paul@epa.gov); Peter Schaefer (peter.schaefer@tceq.texas.gov); Ray Newby P.G. (Ray.Newby@glo.texas.gov); Rebecca Hensley; Rusty Swafford (rusty.swafford@noaa.gov); Sarah Bernhardt; Scott Alford; Sheri Willey (Sheridan.S.Willey@usace.army.mil); Susan Nahwooksy; Tom Dixon; Tony Williams (tony.williams@glo.texas.gov); Travis Creel (Travis.J.Creel@usace.army.mil); Winston Denton
Cc: Kelsey Calvez; Andrew Labay
Subject: RE: Coastal Texas Study HEP Species Selection

Hi Lisa,

TPWD has looked at the HIS's for the fisheries species and can agree to the use of Red Drum for marsh habitat, Spotted Seatrout for SAV habitat and Eastern oysters for oyster reef for the ecosystem restoration projects.

At this time, I have not been able to sufficiently review HIS's for bird species, and am not expert enough to comfortably evaluate those choices for rookery islands and tidal flats. However, since not all "Wetland" is emergent marsh suitable for fisheries species, perhaps an avian species (Clapper Rail) should be included for HEP modeling of tidal wetlands comprised of intermediate to higher marsh habitat.

Thanks.
Colleen Roco, Coastal Ecologist
Texas Parks and Wildlife Department
1502 FM 517 East
Dickinson, TX 77539
281-534-0139 office
281-534-0122 fax
Colleen.roco@TPWD.texas.gov

The price of anything is the amount of life you exchange for it. Henry David Thoreau

From: Lisa Vitale [mailto:Lisa.Vitale@freese.com]
Sent: Friday, January 13, 2017 12:32 PM
To: Aaron Chastain <Aaron.Chastain@noaa.gov>; Alison Fontenot <Fontenot.Alison@epa.gov>; Anthony Risko <Anthony.Risko@freese.com>; Barbara Keeler <Keeler.Barbara@epa.gov>; Bill Klein (william.p.klein.jr@usace.army.mil) <william.p.klein.jr@usace.army.mil>; Bob Heinly <Robert.W.Heinly@usace.army.mil>; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov) <Caimee.Schoenbaechler@twdb.texas.gov>; Carla Guthrie (Carla.Guthrie@twdb.texas.gov) <Carla.Guthrie@twdb.texas.gov>; Celestine Bryant <Celestine.Bryant@actribe.org>; Chuck Ardizzone <chuck_ardizzone@fws.gov>; Colleen Roco <Colleen.Roco@tpwd.texas.gov>; David Buzan <David.Buzan@freese.com>; Diana Laird <Diana.J.Laird@usace.army.mil>; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV) <Dianna.Ramirez@GLO.TEXAS.GOV>; Donna Anderson (Donna_Anderson@fws.gov) <Donna_Anderson@fws.gov>; Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil) <Eduardo.Irigoyen@usace.army.mil>; Elizabeth Vargas <Elizabeth.Vargas@GLO.TEXAS.GOV>; Holly Houghton <holly@mathpo.org>; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com) <hugo.bermudez@mottmac.com>; Jan Stokes (janelle.s.stokes@usace.army.mil) <janelle.s.stokes@usace.army.mil>; Jane Watson <Watson.jane@epa.gov>; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil) <Jayson.M.Hudson@usace.army.mil>; Jim Lindsay (james_lindsay@nps.gov) <james_lindsay@nps.gov>; Josh Carter (Joshua.Carter@mottmac.com) <Joshua.Carter@mottmac.com>; Juan Moya <Juan.Moya@freese.com>; Kellie Poolaw <kellie@tribaladminservices.org>; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil) <Kelly.A.Burks-Copes@usace.army.mil>; Kelsey Calvez <Kelsey.Calvez@freese.com>; Kevin Cauble <kevin.cauble@tceq.texas.gov>; Kristin Shivers (Kristin.D.Shivers@usace.army.mil) <Kristin.D.Shivers@usace.army.mil>; Lauren Brown <lbrown@tonkawatribe.com>; Leslie Koza <Leslie.Koza@tpwd.texas.gov>; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil) <Elizabeth.H.Behrens@usace.army.mil>; Linda Langley <llangley@mcneese.edu>; Lindsey Lippert <Lindsey.Lippert@tceq.texas.gov>; Maria Martinez <Martinez.Maria@epa.gov>; Matt Mahoney <matthew.mahoney@txdot.gov>; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com) <Patrick.McLaughlin@mottmac.com>; Michael Lee (mtlee@usgs.gov) <mtlee@usgs.gov>; Mimi Wallace <mimi.wallace@tceq.texas.gov>; Miranda Allen-Myer <mallen@tonkawatribe.com>; Mollie Powell <Mollie.Powell@GLO.Texas.Gov>; Nancy Parrish (Nancy.A.Parrish@usace.army.mil) <Nancy.A.Parrish@usace.army.mil>; Nelun Fernando <Nelun.Fernando@twdb.texas.gov>; Pat Clements (pat_clements@fws.gov) <pat_clements@fws.gov>; Paul Kaspar (kaspar.paul@epa.gov) <kaspar.paul@epa.gov>; Peter Schaefer (peter.schaefer@tceq.texas.gov) <peter.schaefer@tceq.texas.gov>; Ray Newby P.G. (Ray.Newby@glo.texas.gov) <Ray.Newby@glo.texas.gov>; Rebecca Hensley <Rebecca.Hensley@tpwd.texas.gov>; Rusty Swafford (rusty.swafford@noaa.gov) <rusty.swafford@noaa.gov>; Sarah Bernhardt <Sarah.Bernhardt@tceq.texas.gov>; Scott Alford <scott.alford@tx.usda.gov>; Sheri Willey (Sheridan.S.Willey@usace.army.mil) <Sheridan.S.Willey@usace.army.mil>; Susan Nahwooksy <susann@comanchenation.com>; Tom Dixon <Tom.Dixon@freese.com>; Tony Williams (tony.williams@glo.texas.gov) <tony.williams@glo.texas.gov>; Travis Creel (Travis.J.Creel@usace.army.mil) <Travis.J.Creel@usace.army.mil>; Winston Denton <Winston.Denton@tpwd.texas.gov>
Cc: Kelsey Calvez <Kelsey.Calvez@freese.com>; Andrew Labay <Andrew.Labay@freese.com>
Subject: Coastal Texas Study HEP Species Selection
Importance: High

All,

As we discussed during yesterday's meeting we need to get a consensus from you all on the species selected for the HEP analysis and to identify data needs.

Some things to consider when reviewing these materials and providing input:

1. We can only use USACE approved models. You can find the list of approved models here: https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Method&Id=HEP
2. We are only focusing on 1 or 2 species per habitat type because we cannot double or triple count benefits.

3. If we use more than 1 species we have to average the answer so it is a washout when we have multiple species.
4. For oysters we are using the Swannack et al., 2014 model. This is the model that was used for the Houston Ship Channel Study that is ongoing.
5. There will be no field data collection for HEP analysis.

I am attaching the draft information on species models and habitat variables for the HEP discussion. This information includes:

- Recommendations - provides our recommendations for species and cover type.
- Summary Table - provides a quick overview of the more detailed information presented. It outlines what species are associated with what habitat and our reasons for choosing that species. It also contains a questions and uncertainties column.
- HEP Species - provides more detailed information for each species that we chose, including the species HSI habitat variables and descriptions, and HSI life requisites.
- Eliminated Species - follows the same outline as "HEP Species", except for the species that were eliminated.

Review the materials attached and provide us your feedback by **Friday, January 27th**. Information we need for you to provide by that date include:

1. Concurrence with species that we recommended
2. If you do not concur with a species we recommended, your reason why and what species you recommend and your reasons why we should consider using that species.
3. Identification of data needs for species and variables chosen.

If you have any question about the materials provided please contact Andy Labay (Andrew.Labay@freese.com) or Kelsey Calvez (Kelsey.Calvez@freese.com).

Thanks,
Lisa

Lisa Vitale, FP-C
Marine Biologist / Project Manager

Freese and Nichols, Inc.
10431 Morado Circle
Bldg. 5, Suite 300
Austin, TX 78759
Office: (512) 617-3158
lisa.vitale@freese.com

FREESE NICHOLS

Lisa Vitale

From: Rusty Swafford - NOAA Federal <rusty.swafford@noaa.gov>
Sent: Friday, January 27, 2017 7:48 AM
To: Lisa Vitale
Cc: Aaron Chastain; Alison Fontenot; Anthony Risko; Barbara Keeler; Bill Klein (william.p.klein.jr@usace.army.mil); Bob Heinly; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov); Carla Guthrie (Carla.Guthrie@twdb.texas.gov); Celestine Bryant; Chuck Ardizzone; Colleen Roco (colleen.roco@tpwd.texas.gov); David Buzan; Diana Laird; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV); Donna Anderson (Donna_Anderson@fws.gov); Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil); Elizabeth Vargas; Holly Houghton; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com); Jan Stokes (janelle.s.stokes@usace.army.mil); Jane Watson; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil); Jim Lindsay (james_lindsay@nps.gov); Josh Carter (Joshua.Carter@mottmac.com); Juan Moya; Kellie Poolaw; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil); Kelsey Calvez; Kevin Cauble; Kristin Shivers (Kristin.D.Shivers@usace.army.mil); Lauren Brown; Leslie Koza; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil); Linda Langley; Lindsey Lippert; Maria Martinez; Matt Mahoney; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com); Michael Lee (mtlee@usgs.gov); Mimi Wallace; Miranda Allen-Myer; Mollie Powell; Nancy Parrish (Nancy.A.Parrish@usace.army.mil); Nelun Fernando; Pat Clements (pat_clements@fws.gov); Paul Kaspar (kaspar.paul@epa.gov); Peter Schaefer (peter.schaefer@tceq.texas.gov); Ray Newby P.G. (Ray.Newby@glo.texas.gov); Rebecca Hensley; Sarah Bernhardt; Scott Alford; Sheri Willey (Sheridan.S.Willey@usace.army.mil); Tom Dixon; Tony Williams (tony.williams@glo.texas.gov); Travis Creel (Travis.J.Creel@usace.army.mil); Winston Denton; Martina M. Callahan; William Nelson; Carla Kartman; Andrew Labay
Subject: Re: Coastal Texas Study HEP Species Selection

NMFS is good with red drum for marsh, spotted seatrout for SAV and use of the USACE approved oyster model.

On Mon, Jan 23, 2017 at 1:42 PM, Lisa Vitale <Lisa.Vitale@freese.com> wrote:

> All,
>
> Just a reminder to please provide feedback to me by this **Friday, January 27th**, on the HEP species selection (see information needed below and attached). If we do not receive feedback, it will be assumed that you are in agreement with our recommended species selection. We will be finalizing our species selection on Monday.
>
> Please let me know if you have any questions.
>
> Thanks!
>
> Lisa

Lisa Vitale, FP-C

Marine Biologist / Project Manager

Freese and Nichols, Inc.

(512) 617-3158

From: Lisa Vitale
Sent: Friday, January 13, 2017 12:32 PM
Subject: Coastal Texas Study HEP Species Selection
Importance: High

All,

As we discussed during yesterday's meeting we need to get a consensus from you all on the species selected for the HEP analysis and to identify data needs.

Some things to consider when reviewing these materials and providing input:

1. We can only use USACE approved models. You can find the list of approved models here: https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Method&Id=HEP
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4. For oysters we are using the Swannack et al., 2014 model. This is the model that was used for the Houston Ship Channel Study that is ongoing.
5. There will be no field data collection for HEP analysis.

I am attaching the draft information on species models and habitat variables for the HEP discussion. This information includes:

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1. Concurrence with species that we recommended
2. If you do not concur with a species we recommended, your reason why and what species you recommend and your reasons why we should consider using that species.
3. Identification of data needs for species and variables chosen.

If you have any question about the materials provided please contact Andy Labay (Andrew.Labay@freese.com) or Kelsey Calvez (Kelsey.Calvez@freese.com).

Thanks,

Lisa

Lisa Vitale, FP-C

Marine Biologist / Project Manager

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Rusty Swafford
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NOAA FISHERIES

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YouTube	www.youtube.com/usnoaafisheriesgov

Lisa Vitale

From: Lindsay, James <james_lindsay@nps.gov>
Sent: Friday, January 27, 2017 8:06 AM
To: Lisa Vitale
Subject: Re: Feb 1 meeting

Thanks Lisa

I will not be sending input on species for the model runs. I am not knowledgeable enough and do not have the time to read up on species interaction. I am happy to give input on geology and coastal morphological processes. As a geologist I can even tell you what rocks are best for throwing at our detractors!

On Fri, Jan 27, 2017 at 8:02 AM, Lisa Vitale <Lisa.Vitale@freese.com> wrote:

> Hi Jim,
>
> You are correct. I think calling in would be fine....saves you a long drive to Galveston!
>
> Lisa
>
> **Lisa Vitale, FP-C**
>
> Marine Biologist / Project Manager
>
> **Freese and Nichols, Inc.**
>
> (512) 617-3158
>
> **From:** Lindsay, James [mailto:james_lindsay@nps.gov]
> **Sent:** Friday, January 27, 2017 8:01 AM
> **To:** Lisa Vitale <Lisa.Vitale@freese.com>
> **Subject:** Feb 1 meeting
>
> Hi Lisa

Since the meeting Feburary 1 looks more like a informational meeting than a committee work session, do you see a need for me to be there?

--

James Lindsay

Chief of Science and Resource Management

Padre Island National Seashore

Office 361-949-8173 ext. 223

Cell 361-446-1629

Fax 361-949-7091

20301 Park Road 22, Corpus Christi Texas 78418

--

James Lindsay
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Lisa Vitale

From: Keeler, Barbara <Keeler.Barbara@epa.gov>
Sent: Friday, January 27, 2017 10:09 AM
To: Lisa Vitale; Aaron Chastain; Fontenot, Alison; Anthony Risko; Bill Klein (william.p.klein.jr@usace.army.mil); Bob Heinly; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov); Carla Guthrie (Carla.Guthrie@twdb.texas.gov); Celestine Bryant; Chuck Ardizzone; Colleen Roco (colleen.roco@tpwd.texas.gov); David Buzan; Diana Laird; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV); Donna Anderson (Donna_Anderson@fws.gov); Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil); Elizabeth Vargas; Holly Houghton; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com); Jan Stokes (janelle.s.stokes@usace.army.mil); Watson, Jane; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil); Jim Lindsay (james_lindsay@nps.gov); Josh Carter (Joshua.Carter@mottmac.com); Juan Moya; Kellie Poolaw; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil); Kelsey Calvez; Kevin Cauble; Kristin Shivers (Kristin.D.Shivers@usace.army.mil); Lauren Brown; Leslie Koza; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil); Linda Langley; Lindsey Lippert; Martinez, Maria; Matt Mahoney; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com); Michael Lee (mtlee@usgs.gov); Mimi Wallace; Miranda Allen-Myer; Mollie Powell; Nancy Parrish (Nancy.A.Parrish@usace.army.mil); Nelun Fernando; Pat Clements (pat_clements@fws.gov); Kaspar, Paul; Peter Schaefer (peter.schaefer@tceq.texas.gov); Ray.Newby_GLO.TEXAS.GOV; Rebecca Hensley; Rusty Swafford (rusty.swafford@noaa.gov); Sarah Bernhardt; Scott Alford; Sheri Willey (Sheridan.S.Willey@usace.army.mil); Tom Dixon; Tony Williams (tony.williams@glo.texas.gov); Travis Creel (Travis.J.Creel@usace.army.mil); Winston Denton; Martina M. Callahan; William Nelson ; Carla Kartman
Cc: Kelsey Calvez; Andrew Labay
Subject: RE: Coastal Texas Study HEP Species Selection

Lisa et al.:

Thanks for the opportunity to review the HEP species selections. After speaking to Kelsey Calvez about the desktop methodology being proposed for the feasibility stage of the planning process and following a conversation between Alison Fontenot and Jan Stokes, we have no comments to offer about the species selected or the use of HEP as a screening tool for the feasibility study.

However, we recommend that the Corps consider supplementing HEP analyses with additional functional assessments to characterize impacts to wetland/marsh habitats prior to project implementation and to support the determination of appropriate mitigation measures. For instance, the Corps-approved (SWG) interim HGM for tidal fringe wetlands considers parameters relative to the physical, chemical and biological functions of vegetated wetlands and might therefore provide additional information relative to hydrologic conditions. Also note that there is a full regional Tidal Fringe Wetlands HGM available for the northwest Gulf of Mexico.

Please let Alison or me know if you have any questions.

Barbara Keeler
EPA Region 6
Marine, Coastal and Analysis Section
1445 Ross Ave.
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214-665-6698
keeler.barbara@epa.gov

From: Lisa Vitale [mailto:Lisa.Vitale@freese.com]
Sent: Monday, January 23, 2017 1:42 PM
To: Aaron Chastain <Aaron.Chastain@noaa.gov>; Fontenot, Alison <Fontenot.Alison@epa.gov>; Anthony Risko <Anthony.Risko@freese.com>; Keeler, Barbara <Keeler.Barbara@epa.gov>; Bill Klein (william.p.klein.jr@usace.army.mil) <william.p.klein.jr@usace.army.mil>; Bob Heinly <Robert.W.Heinly@usace.army.mil>; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov) <Caimee.Schoenbaechler@twdb.texas.gov>; Carla Guthrie (Carla.Guthrie@twdb.texas.gov) <Carla.Guthrie@twdb.texas.gov>; Celestine Bryant <Celestine.Bryant@actribe.org>; Chuck Ardizzone <chuck_ardizzone@fws.gov>; Colleen Roco (colleen.roco@tpwd.texas.gov) <colleen.roco@tpwd.texas.gov>; David Buzan <David.Buzan@freese.com>; Diana Laird <Diana.J.Laird@usace.army.mil>; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV) <Dianna.Ramirez@GLO.TEXAS.GOV>; Donna Anderson (Donna_Anderson@fws.gov) <Donna_Anderson@fws.gov>; Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil) <Eduardo.Irigoyen@usace.army.mil>; Elizabeth Vargas <Elizabeth.Vargas@GLO.TEXAS.GOV>; Holly Houghton <holly@mathpo.org>; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com) <hugo.bermudez@mottmac.com>; Jan Stokes (janelle.s.stokes@usace.army.mil) <janelle.s.stokes@usace.army.mil>; Watson, Jane <watson.jane@epa.gov>; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil) <Jayson.M.Hudson@usace.army.mil>; Jim Lindsay (james_lindsay@nps.gov) <james_lindsay@nps.gov>; Josh Carter (Joshua.Carter@mottmac.com) <Joshua.Carter@mottmac.com>; Juan Moya <Juan.Moya@freese.com>; Kellie Poolaw <kellie@tribaladminservices.org>; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil) <Kelly.A.Burks-Copes@usace.army.mil>; Kelsey Calvez <Kelsey.Calvez@freese.com>; Kevin Cauble <kevin.cauble@tceq.texas.gov>; Kristin Shivers (Kristin.D.Shivers@usace.army.mil) <Kristin.D.Shivers@usace.army.mil>; Lauren Brown <lbrown@tonkawatribe.com>; Leslie Koza <Leslie.Koza@tpwd.texas.gov>; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil) <Elizabeth.H.Behrens@usace.army.mil>; Linda Langley <llangley@mcneese.edu>; Lindsey Lippert <Lindsey.Lippert@tceq.texas.gov>; Martinez, Maria <Martinez.Maria@epa.gov>; Matt Mahoney <matthew.mahoney@txdot.gov>; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com) <Patrick.McLaughlin@mottmac.com>; Michael Lee (mtlee@usgs.gov) <mtlee@usgs.gov>; Mimi Wallace <mimi.wallace@tceq.texas.gov>; Miranda Allen-Myer <mallen@tonkawatribe.com>; Mollie Powell <Mollie.Powell@GLO.Texas.Gov>; Nancy Parrish (Nancy.A.Parrish@usace.army.mil) <Nancy.A.Parrish@usace.army.mil>; Nelun Fernando <Nelun.Fernando@twdb.texas.gov>; Pat Clements (pat_clements@fws.gov) <pat_clements@fws.gov>; Kaspar, Paul <kaspar.paul@epa.gov>; Peter Schaefer (peter.schaefer@tceq.texas.gov) <peter.schaefer@tceq.texas.gov>; Ray.Newby_GLO.TEXAS.GOV <Ray.Newby@GLO.TEXAS.GOV>; Rebecca Hensley <rebecca.hensley@tpwd.state.tx.us>; Rusty Swafford (rusty.swafford@noaa.gov) <rusty.swafford@noaa.gov>; Sarah Bernhardt <Sarah.Bernhardt@tceq.texas.gov>; Scott Alford <scott.alford@tx.usda.gov>; Sheri Willey (Sheridan.S.Willey@usace.army.mil) <Sheridan.S.Willey@usace.army.mil>; Tom Dixon <Tom.Dixon@freese.com>; Tony Williams (tony.williams@glo.texas.gov) <tony.williams@glo.texas.gov>; Travis Creel (Travis.J.Creel@usace.army.mil) <Travis.J.Creel@usace.army.mil>; Winston Denton <winston.denton@tpwd.state.tx.us>; Martina M. Callahan <martinac@comanchenation.com>; William Nelson <williamn@comanchenation.com>; Carla Kartman <Carla.Kartman@GLO.TEXAS.GOV>
Cc: Kelsey Calvez <Kelsey.Calvez@freese.com>; Andrew Labay <Andrew.Labay@freese.com>
Subject: RE: Coastal Texas Study HEP Species Selection
Importance: High

All,

Just a reminder to please provide feedback to me by this **Friday, January 27th**, on the HEP species selection (see information needed below and attached). If we do not receive feedback, it will be assumed that you are in agreement with our recommended species selection. We will be finalizing our species selection on Monday.

Please let me know if you have any questions.

Thanks!
Lisa

Lisa Vitale, FP-C
Marine Biologist / Project Manager

Freese and Nichols, Inc.
(512) 617-3158

From: Lisa Vitale
Sent: Friday, January 13, 2017 12:32 PM
Subject: Coastal Texas Study HEP Species Selection
Importance: High

All,

As we discussed during yesterday's meeting we need to get a consensus from you all on the species selected for the HEP analysis and to identify data needs.

Some things to consider when reviewing these materials and providing input:

1. We can only use USACE approved models. You can find the list of approved models here: https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Method&Id=HEP
2. We are only focusing on 1 or 2 species per habitat type because we cannot double or triple count benefits.
3. If we use more than 1 species we have to average the answer so it is a washout when we have multiple species.
4. For oysters we are using the Swannack et al., 2014 model. This is the model that was used for the Houston Ship Channel Study that is ongoing.
5. There will be no field data collection for HEP analysis.

I am attaching the draft information on species models and habitat variables for the HEP discussion. This information includes:

- Recommendations - provides our recommendations for species and cover type.
- Summary Table - provides a quick overview of the more detailed information presented. It outlines what species are associated with what habitat and our reasons for choosing that species. It also contains a questions and uncertainties column.
- HEP Species - provides more detailed information for each species that we chose, including the species HSI habitat variables and descriptions, and HSI life requisites.
- Eliminated Species - follows the same outline as "HEP Species", except for the species that were eliminated.

Review the materials attached and provide us your feedback by **Friday, January 27th**. Information we need for you to provide by that date include:

1. Concurrence with species that we recommended
2. If you do not concur with a species we recommended, your reason why and what species you recommend and your reasons why we should consider using that species.
3. Identification of data needs for species and variables chosen.

If you have any question about the materials provided please contact Andy Labay (Andrew.Labay@freese.com) or Kelsey Calvez (Kelsey.Calvez@freese.com).

Thanks,
Lisa

Lisa Vitale, FP-C
Marine Biologist / Project Manager

Freese and Nichols, Inc.
10431 Morado Circle
Bldg. 5, Suite 300
Austin, TX 78759
Office: (512) 617-3158
lisa.vitale@freese.com

FREESE NICHOLS

Lisa Vitale

From: Anderson, Donna <donna_anderson@fws.gov>
Sent: Tuesday, January 31, 2017 2:56 PM
To: Lisa Vitale
Cc: Aaron Chastain; Alison Fontenot; Anthony Risko; Barbara Keeler; Bill Klein (william.p.klein.jr@usace.army.mil); Bob Heinly; Caimee Schoenbaechler (Caimee.Schoenbaechler@twdb.texas.gov); Carla Guthrie (Carla.Guthrie@twdb.texas.gov); Celestine Bryant; Chuck Ardizzone; Colleen Roco (colleen.roco@tpwd.texas.gov); David Buzan; Diana Laird; Dianna Ramirez (Dianna.Ramirez@GLO.TEXAS.GOV); Eddie Irigoyen (Eduardo.Irigoyen@usace.army.mil); Elizabeth Vargas; Holly Houghton; Hugo Bermudez P.E. (hugo.bermudez@mottmac.com); Jan Stokes (janelle.s.stokes@usace.army.mil); Jane Watson; Jayson M SWG Hudson (Jayson.M.Hudson@usace.army.mil); Jim Lindsay (james_lindsay@nps.gov); Josh Carter (Joshua.Carter@mottmac.com); Juan Moya; Kellie Poolaw; Kelly A. Burks-Copes Ph. D. (Kelly.A.Burks-Copes@usace.army.mil); Kelsey Calvez; Kevin Cauble; Kristin Shivers (Kristin.D.Shivers@usace.army.mil); Lauren Brown; Leslie Koza; Libby Behrens (Elizabeth.H.Behrens@usace.army.mil); Linda Langley; Lindsey Lippert; Maria Martinez; Matt Mahoney; McLaughlin, Patrick W (Patrick.McLaughlin@mottmac.com); Michael Lee (mtlee@usgs.gov); Mimi Wallace; Miranda Allen-Myer; Mollie Powell; Nancy Parrish (Nancy.A.Parrish@usace.army.mil); Nelun Fernando; Pat Clements (pat_clements@fws.gov); Paul Kaspar (kaspar.paul@epa.gov); Peter Schaefer (peter.schaefer@tceq.texas.gov); Ray Newby P.G. (Ray.Newby@glo.texas.gov); Rebecca Hensley; Rusty Swafford (rusty.swafford@noaa.gov); Sarah Bernhardt; Scott Alford; Sheri Willey (Sheridan.S.Willey@usace.army.mil); Tom Dixon; Tony Williams (tony.williams@glo.texas.gov); Travis Creel (Travis.J.Creel@usace.army.mil); Winston Denton; Martina M. Callahan; William Nelson; Carla Kartman; Andrew Labay
Subject: Re: Coastal Texas Study HEP Species Selection

All-
There are some questions and concerns regarding the HEP models listed in the attached documents. I appologize if some of these concerns were mentioned during the meeting

We are concerned about not acquiring new data

- Agreed with the majority of species eliminated however there are a few that may provide suitable scores but were deemed to have "highly specific" variables that require detailed information or additional data collection and were subsequently removed.
- Forester tern - how will the wrack quality be measured? It is a relative scale, however how will this be determined?
- Great egret - again, removed due to the "high level of specificity" however this is a good species for islands. Again, not a good reason to eliminate this species.
- We recommend that during these early phases of the project using HEP with these limitations may provide the broad overview that the Corps and the GLO are looking for, however we will continue to recommend that additional HEP or other suitable analysis be conducted prior to construction to verify current conditions.
- Recommend augmenting HEP analysis with other Corp approved wetland/marsh modeling such as HGM. Again, these modeling efforts should be conducted relatively close to the commencement of construction so as to capture the most current habitat conditions.
- Fish species selection look appropriate.
-
-

Donna Anderson
Wildlife Biologist
United States Fish and Wildlife Service
Texas Coastal Ecological Services Office
17629 El Camino Real, Ste. 211
Houston, Texas 77058
Office: (281) 286-8282
Fax: (281) 488-5882
Cell: (713) 542-1861

On Mon, Jan 23, 2017 at 1:42 PM, Lisa Vitale <Lisa.Vitale@freese.com> wrote:

All,

Just a reminder to please provide feedback to me by this **Friday, January 27th**, on the HEP species selection (see information needed below and attached). If we do not receive feedback, it will be assumed that you are in agreement with our recommended species selection. We will be finalizing our species selection on Monday.

Please let me know if you have any questions.

Thanks!

Lisa

Lisa Vitale, FP-C

Marine Biologist / Project Manager

Freese and Nichols, Inc.

(512) 617-3158

From: Lisa Vitale
Sent: Friday, January 13, 2017 12:32 PM

Subject: Coastal Texas Study HEP Species Selection
Importance: High

All,

As we discussed during yesterday's meeting we need to get a consensus from you all on the species selected for the HEP analysis and to identify data needs.

Some things to consider when reviewing these materials and providing input:

1. We can only use USACE approved models. You can find the list of approved models here: https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Method&Id=HEP
2. We are only focusing on 1 or 2 species per habitat type because we cannot double or triple count benefits.
3. If we use more than 1 species we have to average the answer so it is a washout when we have multiple species.
4. For oysters we are using the Swannack et al., 2014 model. This is the model that was used for the Houston Ship Channel Study that is ongoing.
5. There will be no field data collection for HEP analysis.

I am attaching the draft information on species models and habitat variables for the HEP discussion. This information includes:

- Recommendations - provides our recommendations for species and cover type.
- Summary Table - provides a quick overview of the more detailed information presented. It outlines what species are associated with what habitat and our reasons for choosing that species. It also contains a questions and uncertainties column.
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Review the materials attached and provide us your feedback by **Friday, January 27th**. Information we need for you to provide by that date include:

1. Concurrence with species that we recommended
2. If you do not concur with a species we recommended, your reason why and what species you recommend and your reasons why we should consider using that species.
3. Identification of data needs for species and variables chosen.

If you have any question about the materials provided please contact Andy Labay (Andrew.Labay@freese.com) or Kelsey Calvez (Kelsey.Calvez@freese.com).

Thanks,

Lisa

Lisa Vitale, FP-C

Marine Biologist / Project Manager

Freese and Nichols, Inc.

10431 Morado Circle

Bldg. 5, Suite 300

Austin, TX 78759

Office: (512) 617-3158

lisa.vitale@freese.com

Coastal Texas Study
HEP Species Selection – Agency Comments and Responses

USFWS (Donna Anderson)

1. We are concerned about not acquiring new data.

   Response: We plan to get all appropriate data necessary that is required to do a full and complete analysis. An appropriate level of field data collection and verification will be conducted and is currently in the planning phase.

2. Agreed with the majority of species eliminated however there are a few that may provide suitable scores but were deemed to have "highly specific" variables that require detailed information or additional data collection and were subsequently removed.

   Response: There were only two species that were eliminated due to the high specificity of their model habitat variables – Mottled Duck and Great Egret. An appropriate level of field data collection and verification will be conducted for this effort, however the model habitat variables for Mottled Duck would require extensive labor outside of the funding and timeframe permitted for this project. Mottled Duck was the only species solely eliminated based on its highly specific habitat variables (particularly V3 and V7). The species model contains many complexities. For example, we would be required to calculate nesting hen cover in addition to hen with brood cover in order to determine an HSI value. We are not confident that we would have this level of detailed information available.

3. Forester tern - how will the wrack quality be measured? It is a relative scale; however, how will this be determined?

   Response: Forester's Tern was eliminated from model selection. We determined that Brown Pelican would be a more responsive and sensitive species for island restoration, and would ultimately result in a greater lift and a greater quantity of habitat units.

4. Great egret - again, removed due to the "high level of specificity" however this is a good species for islands. Again, not a good reason to eliminate this species.

   Response: One of the reasons Great Egret was eliminated was due to the high specificity of its model habitat variables. However, it was also eliminated since the species desires deep water surrounding woody vegetation. The only Island Rookery Restoration measure carried forward to the alternatives phase is Mansfield Island. This island provides minimal woody habitat (this conclusion was made based on aerial photographs). A limiting habitat variable would be the requirement of trees of 7 meters or more in height - it is unlikely this specific vegetation would occur on nesting islands in the bays. We determined that Brown Pelican would be a more responsive and sensitive species for island restoration, and would ultimately result in a greater lift and a greater quantity of habitat units.

5. We recommend that during these early phases of the project using HEP with these limitations may provide the broad overview that the Corps and the GLO are looking for, however we will continue to recommend that additional HEP or other suitable analysis be conducted prior to construction to verify current conditions.

   Response: The USACE will determine if current conditions have changed significantly immediately prior to construction to warrant additional analyses.

6. Recommend augmenting HEP analysis with other Corp approved wetland/marsh modeling such as HGM. Again, these modeling efforts should be conducted relatively close to the commencement of construction so as to capture the most current habitat conditions.

   Response: HGM, while used by USACE Regulatory Branch for permitting, is not used for USACE Civil Works projects and NEPA compliance. Reasons HGM cannot be used include the fact that HGM is not approved for this type of use, and that HGMs are highly specific to ecotypes and plant communities (i.e., there is not an approved HGM that covers the entire Texas Coast).

7. Fish species selection look appropriate.

   Response: Thank you for your feedback.

TPWD (Colleen Roco)

1. TPWD has looked at the HSI's for the fisheries species and can agree to the use of Red Drum for marsh habitat, Spotted Seatrout for SAV habitat and Eastern oysters for oyster reef for the ecosystem restoration projects.

   Response: Thank you for your feedback.

2. At this time, I have not been able to sufficiently review HSI's for bird species, and am not expert enough to comfortably evaluate those choices for rookery islands and tidal flats. However, since not all "Wetland" is emergent marsh suitable for fisheries species, perhaps an avian species (Clapper Rail) should be included for HEP modeling of tidal wetlands comprised of intermediate to higher marsh habitat.

   Response: We reviewed our decision for why we chose Red Drum versus Clapper Rail or Brown and White Shrimp (these were the other two species in the running before we limited each cover type to one species). One of the main reasons we chose Red Drum was because this species can be applied coastwide to all of the ER project areas. The species model has habitat variables for both vegetated substrate and naturally non-vegetated substrate.

   The Clapper Rail model is unique in that it has an ultimatum: If the project area lacks suitable contiguous habitat of at least 5 acres, the HSI value is zero. This would result in acreages or areas excluded as habitat from the model. The benefits that can be demonstrated from Clapper Rail are area sensitive, and it is possible that no habitat units would be gained because of area sensitivity. Further, looking at HSI habitat variable V1 (in the attached PDF) much of the existing marsh area for the ER project areas has either Spartina or mangroves bordered by open water, not necessarily tidal flats. As of right now, we do not have enough site information to gauge whether there is enough edge effect with tidal flats to achieve optimum habitat for the model.

EPA (Barbara Keeler)

1. Thanks for the opportunity to review the HEP species selections. After speaking to Kelsey Calvez about the desktop methodology being proposed for the feasibility stage of the planning process and following a conversation between Alison Fontenot and Jan Stokes, we have no comments to offer about the species selected or the use of HEP as a screening tool for the feasibility study.

   Response: Thank you for your feedback.

2. However, we recommend that the Corps consider supplementing HEP analyses with additional functional assessments to characterize impacts to wetland/marsh habitats prior to project implementation and to support the determination of appropriate mitigation measures. For instance, the Corps-approved (SWG) interim HGM for tidal fringe wetlands considers parameters relative to the physical, chemical and biological functions of vegetated wetlands and might therefore provide additional information relative to hydrologic conditions. Also, note that there is a full regional Tidal Fringe Wetlands HGM available for the northwest Gulf of Mexico.

   Response: HGM, while used by USACE Regulatory Branch for permitting, is not used for USACE Civil Works projects and NEPA compliance. The USACE believes the various HEP, WVA, and oyster models would provide the appropriate level of analysis for the large scale coast wide project that would enable the team to determine potential project induced impacts.

NMFS (Rusty Swafford)

1. NMFS is good with red drum for marsh, spotted seatrout for SAV and use of the USACE approved oyster model.

   Response: Thank you for your feedback.

NPS (Jim Lindsay)

1. I will not be sending input on species for the model runs. I am not knowledgeable enough and do not have the time to read up on species interaction.

   Response: Thank you for your feedback.

United States Department of the Interior
BUREAU OF OCEAN ENERGY MANAGEMENT
Gulf of Mexico OCS Region
1201 Elmwood Park Boulevard
New Orleans, LA 70123-2394

In Reply Refer To: GM 633D

FEB 16 2017

Dr. Kelly A. Burks-Copes
Chief, Coastal Section
U.S. Army Corps of Engineers
Galveston District
Post Office Box 1229
Galveston, Texas 77553-1229

Dear Dr. Burks-Copes:

Thank you for your letter requesting that the Bureau of Ocean Energy Management (BOEM) become a Cooperating Agency during the National Environmental Policy Act (NEPA) process for the preparation of an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Ecosystem Protection and Restoration Study. It is our understanding that the IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage reduction, hurricane and storm damage risk reduction, and ecosystem restoration for the coastal areas of the State of Texas. As a result, projects may develop requesting the use of sand on the Outer Continental Shelf (OCS), by the U.S. Army Corps of Engineers (USACE), Galveston District, to provide protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands. Since BOEM has jurisdiction over mineral leasing on the OCS, BOEM agrees to serve as a Cooperating Agency in the preparation of the IFR-EIS. In the event that minerals are needed from the OCS, pending completion of environmental review, BOEM will enter into a Memorandum of Agreement with the USACE under the authority of Section 8(k)(2) of the Outer Continental Shelf Lands Act (43 U.S.C. § 1337(k)(2)), which will serve as a noncompetitive negotiated agreement for the use of OCS minerals from designated borrow areas and define each agency's role in the program or project(s).

As a Cooperating Agency, BOEM expects to provide Bureau-appropriate assistance with the preparation of the IFR-EIS. Michael Miner and Bridgette Duplantis will represent BOEM on the IFR-EIS Project Delivery Team and will ensure that the scope accurately reflects BOEM's NEPA and leasing requirements. BOEM also recognizes the importance of participating in the required Endangered Species Act Section 7 consultation, the Magnuson-Stevens Fishery and Conservation Management Act Section 305 essential fish habitat consultation, the National Historic Preservation Act Section 106 process, and the Coastal Zone Management Act Section 307 consistency process.

Beyond the NEPA and interagency consultation coordination discussed above, BOEM also offers the USACE information and expertise related to offshore sediment resources for consideration in the feasibility study. Since the 1980s, BOEM (and its predecessor, the Minerals Management Service) has funded cooperative agreements with various entities in Texas and Louisiana to identify and delineate sediment resources offshore Texas. We have recently entered into a cooperative agreement with the University of Texas titled "Texas Offshore Sediment Resources Inventory: Development and Application of Geophysical Processing Workflows for Sand Resource Evaluation," which will build upon previous investments to characterize offshore sand resources as part of BOEM's larger initiative to develop a Gulfwide Offshore Sand Resources Inventory. BOEM welcomes and encourages input from the USACE on these resource evaluation efforts so that BOEM can better meet the needs of our stakeholders and specifically so that we can direct resources to best support the Coastal Texas Ecosystem Protection and Restoration Study.

BOEM looks forward to working with the USACE during this process. If you would like to discuss any of these items further, please contact Dr. Michael Miner with our Marine Minerals Program at 504-736-2700 or by email at michael.miner@boem.gov.

Sincerely,

Michael A. Celata
Regional Director

Appendix B-2

Tribal Coordination

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

APR 11 2016

Mr. Russell Martin
President
Tonkawa Tribe of Oklahoma
1 Rush Buffalo Road
Tonkawa, Oklahoma 74654

Dear President Martin:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a Cooperating Agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage risk management, hurricane and storm damage risk management, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

In partial fulfillment of responsibilities under Executive Order 13175, the National Environmental Policy Act, and Section 106 of the National Historic Preservation Act, the Corps offers you the opportunity to review and comment on the potential of the proposed study to significantly affect protected tribal resources, tribal rights, or Indian lands. Furthermore, we would like to coordinate our review schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007 and Section 1001 of the Water Resources Reform Development Act of 2014. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

Review of Draft IFR-EIS – 45-day review period begins July 2018
State & Agency Review of Final IFR-EIS – 30-day review begins February 2021

We request that you advise us as to whether the report review periods shown above are acceptable. In addition, please let us know if you plan to attend the Interagency Meeting, either remotely or in person. The meeting will be available by teleconference and web meeting (webinar address http://www.webmeeting.att.com, call-in and web meeting number 866-434-5269, access code 8362189, security code 1234). If you

plan to attend in person, please advise my staff so we can facilitate your entry into the Galveston District facility. Please contact Janelle Stokes of my staff at (409) 766-3039 or at janelle.s.stokes@usace.army.mil.

Sincerely,

E. W. Verwers

Eric W. Verwers
Director, Regional Planning and
Environmental Center

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

APR 1 1 2016

Mr. Danny Breuninger, Jr.
President
Mescalero Apache Tribe
P.O. Box 227
Mescalero, New Mexico 88340

Dear President Breuninger:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a Cooperating Agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage risk management, hurricane and storm damage risk management, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

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Environmental Center

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

APR 1 1 2016

Mr. William Owens
Tribal Administrator
The Comanche Nation
584 NW Bingo Road
Lawton, Oklahoma 73507

Dear Administrator Owens:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a Cooperating Agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage risk management, hurricane and storm damage risk management, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

In partial fulfillment of responsibilities under Executive Order 13175, the National Environmental Policy Act, and Section 106 of the National Historic Preservation Act, the Corps offers you the opportunity to review and comment on the potential of the proposed study to significantly affect protected tribal resources, tribal rights, or Indian lands. Furthermore, we would like to coordinate our review schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007 and Section 1001 of the Water Resources Reform Development Act of 2014. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

Review of Draft IFR-EIS – 45-day review period begins July 2018
State & Agency Review of Final IFR-EIS – 30-day review begins February 2021

We request that you advise us as to whether the report review periods shown above are acceptable. In addition, please let us know if you plan to attend the Interagency Meeting, either remotely or in person. The meeting will be available by teleconference and web meeting (webinar address http://www.webmeeting.att.com, call-in and web meeting number 866-434-5269, access code 8362189, security code 1234). If you

plan to attend in person, please advise my staff so we can facilitate your entry into the Galveston District facility. Please contact Janelle Stokes of my staff at (409) 766-3039 or at janelle.s.stokes@usace.army.mil.

Sincerely,

E. W. Verwers

Eric W. Verwers
Director, Regional Planning and
Environmental Center

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

APR 1 1 2016

Ms. Amber Toppah
Chairperson
Kiowa Indian Tribe of Oklahoma
P.O. Box 370
Carnegie, Oklahoma 73016

Dear Chairperson Toppah:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a Cooperating Agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage risk management, hurricane and storm damage risk management, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

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Director, Regional Planning and
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DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

APR 1 1 2016

Ms. Nina Battise
Chairperson
Alabama-Coushatta Tribe of Texas
571 State Park Road 56
Livingston, Texas 77351

Dear Chairperson Battise:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a Cooperating Agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage risk management, hurricane and storm damage risk management, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

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Sincerely,

Eric W. Verwers
Director, Regional Planning and
Environmental Center

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

APR 1 1 2016

Mr. Kevin Stickney
Chairman
Coushatta Tribe of Louisiana
1940 C.C. Bel Road
Elton, Louisiana 70532

Dear Chairman Stickney:

The U.S. Army Corps of Engineers, Galveston District (Corps) intends to prepare an Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) for the Coastal Texas Protection and Restoration Feasibility Study. The Corps and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a Cooperating Agency in the development of the IFR-EIS. The IFR-EIS will identify and evaluate the feasibility of developing a comprehensive plan for flood damage risk management, hurricane and storm damage risk management, and ecosystem restoration for the coastal areas of the State of Texas. The study will focus on providing for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

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Sincerely,

E. W. Verwers

Eric W. Verwers
Director, Regional Planning and
Environmental Center

Appendix B-3

Fish and Wildlife Coordination

LRZ 28 Nov 17
↳ PPMD

United States Department of the Interior
FISH AND WILDLIFE SERVICE

Texas Coastal Ecological Services Field Office
17629 El Camino Real, Suite 211
Houston, Texas 77058
281/286-8282 / (FAX) 281/488-5882

In Reply Refer To:
FWS/R2/02ETT
XX0-2016-CPA-
0057

November 20, 2017

Colonel Lars Zetterstrom
District Commander
Attention: Janelle Stokes
Galveston District, U.S. Army Corps of Engineers
Post Office Box 1229
Galveston, Texas 77553-1229

Dear Colonel Zetterstrom:

The U.S. Fish and Wildlife Service (Service) is collaborating with the U.S. Army Corps of Engineers (Corps) on the evaluation of the "Coastal Texas Storm Surge Protection and Restoration Study (Coastal Texas Study)". The study was authorized as part of the Water Resources Development Act of 2007 which directs the Corps to develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration (ER) in the coastal areas of Texas. Further, the scope of the study provides for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

The purpose of this Planning Aid Letter (PAL) is to provide the Service's comments and recommendations regarding the Coastal Texas Study and identify planning constraints that have influence on the ability of the Service to fulfill our reporting responsibilities under Section 2(b) of the Fish and Wildlife Coordination Act (FWCA, 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The PAL is prepared under the authority of the FWCA; however, it does not constitute the final report of the Secretary of the Interior as required by Section 2(b) of the Act. Additionally, comments in this letter are provided under, the National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. 4321 et seq.), the Endangered Species Act (Act) of 1973 and the Migratory Bird Treaty Act (MBTA) of 1918. The Service has provided copies of this letter to the National Marine Fisheries Service and the Texas Parks and Wildlife Department (TPWD); if any comments are received on this letter they will be forwarded under a separate cover letter.

As a result of the Corps compartmentalization of the Coastal Texas Study, only the ecological restoration portion of the study is addressed under this PAL and we expect to address storm surge reduction measures and associated impacts in a separate PAL as the information becomes available. Due to geographic span of the study, the Corps delineated the coast into four regions to be applied to both the ER and storm surge protection portions of the Coastal Texas Study (**Figure 1**) and will be utilized throughout both PALs.

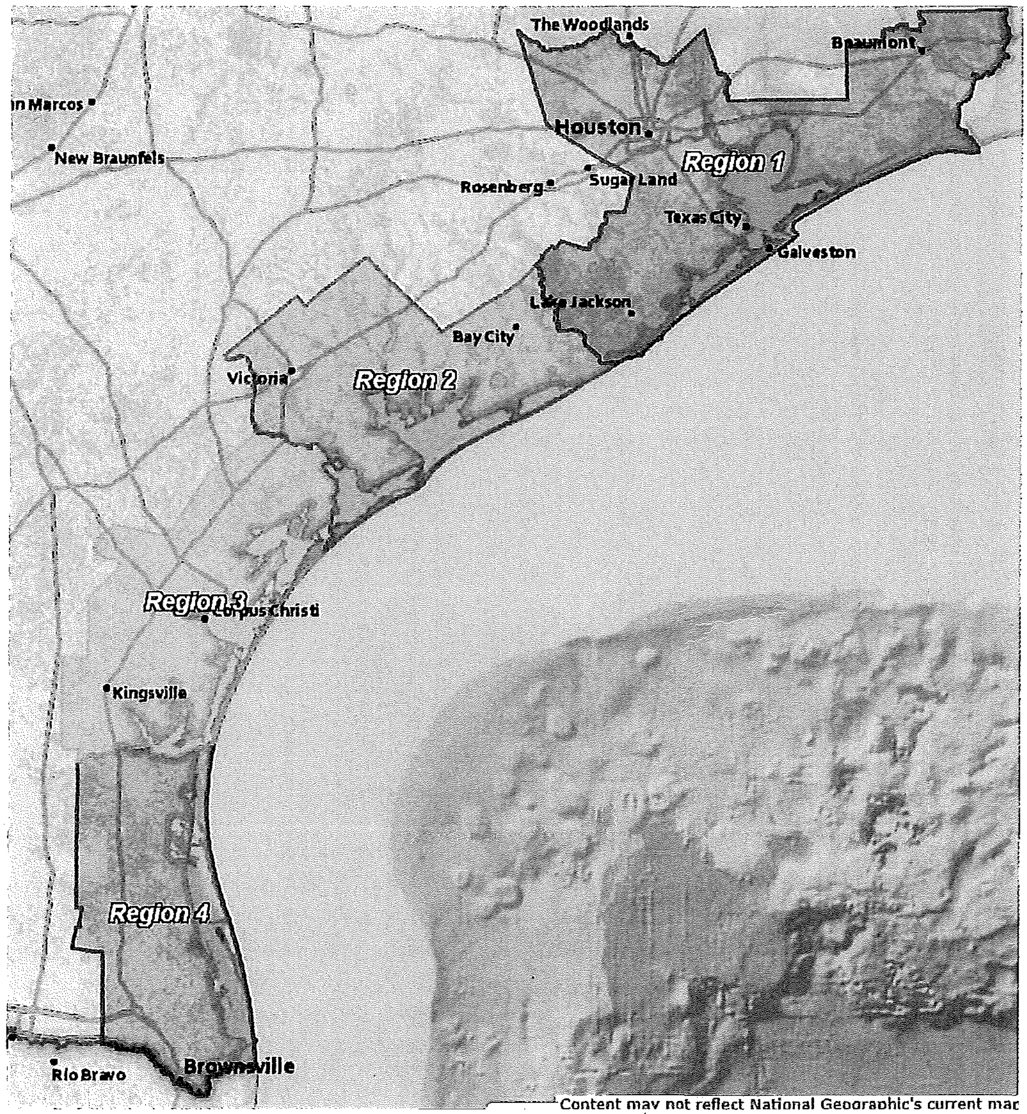

Figure 1 Coastal Texas Regions as delineated by the Corps
Source: Corps (2017)

Due to excessive delays by the Corps in processing a formal scope of work providing the Service the opportunity to formally comment under the FWCA, the Corps moved forward with a list of ecological restoration measures which mimic the Texas General Land Office's (TGLO) list of Coastal Resiliency Master Plan projects; a list compiled from ongoing Restore Council funding; and restoration measures from various other sources. Initial Service review of this project list revealed: previously completed projects; projects formerly vetted by the resource agencies and eliminated from further consideration;

inaccurate project descriptions; and projects not clearly defined as restoration. The Service recognizes that the TGLO is the Texas Coastal Study sponsor and there were time constraints imposed by the Corps Smart Planning Process. This may have resulted in the Corps not fully vetting these projects with the appropriate Service field offices and National Wildlife Refuges during the project scoping process.

The Service believes the Corps' identified restoration opportunities focused largely on protecting barrier islands and coastal and bay shorelines. While these are both important focal areas in light of concerns over sea level rise, the Service contends there is a critical need to restore and protect additional habitats not previously identified by the Corps' "project list" that should be included as part of the comprehensive ER plan. Adjacent areas such as coastal prairies, bottomland hardwood forests, and Tamaulipan thrornscrub are rarities along the Texas coast providing habitat for a vast diversity of fish and wildlife species and were not addressed by the Corps. We have provided a summary of: key focal habitats; environmental concerns; possible study opportunities; the trust species that lie within the Coastal Texas Study's purview; and in some cases, current and future Service coordinated projects. While the coastal storm reduction measures are not addressed here, we believe the Corps should use this PAL to guide and identify measures aimed at avoiding impacts to: fish and wildlife; critical habitat areas; and actions that impede natural flows in the bays, bayous, rivers, and estuaries along the Texas coast.

The Service is dedicated to ensuring the protection and management not only of our federal trust resources (migratory birds, interjurisdictional fisheries, federally threatened and endangered species and public lands), but also for at-risk species and those of concern to our partners. As such, the Service established the Gulf Coast Emphasis Area and adopted a model to effectively establish long-term strategic conservation priorities aimed at creating the greatest return on our conservation investments. The Gulf Coast Emphasis Area (**Figure 2**) includes some of the most productive marsh and estuaries in North America. It encompasses near-coastal bottomland

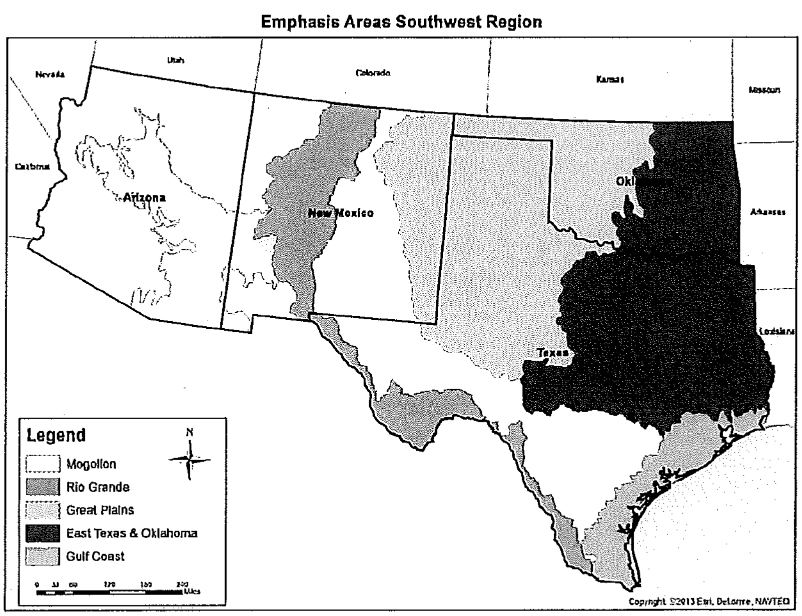

Figure 2 Service Emphasis Areas

hardwood forests and oak mottes, which are important to millions of migrating songbirds, shorebirds, wading birds and other wetland dependent species. The Service has a large conservation presence along the Texas Gulf Coast, roughly 450,000 acres that are either Service owned or managed for trust species and to protect many of the most important wildlife habitats in Texas. We believe the Coastal Texas Study's comprehensive ecological restoration plan provides a unique opportunity to identify, protect, and restore degraded natural resources along the Texas coast to benefit future generations.

Fish and Wildlife Resources

Finfish and shellfish

Close to 97 percent of all finfish and shellfish are dependent in some way on the coastal areas where fresh water from streams and rivers mix with salt water from the Gulf of Mexico creating food rich estuaries. Many species migrate into the estuaries to spawn, or use the estuaries for protection of young against predators with most fish and shellfish migrating back to the Gulf of Mexico as adults. Almost 85percent of recreationally important fish species use coastal wetlands and estuarine habitats during at least one life stage. Marshlands adjacent to the bay systems tend to provide significant quantities of organic material which forms the base of the food chain in the estuaries.

Texas routinely accounts for almost a quarter of the red snapper *Lutjanus campechanus* harvested in the Gulf of Mexico, and one quarter of all domestic shrimp landed in the United States comes from Texas. In fact Texas Parks and Wildlife Department claims shrimp accounts for both 85 percent of landing and overall economic value of the Texas commercial fishing industry. In 2015, 52.6 million pounds of brown shrimp *Farfantepenaeus aztecus* and 16.6 million pounds of white shrimp *Litopenaeus setiferus* were landed with revenues of $96.8 million and $46.6 million respectively in Texas. Brown shrimp landing in Texas accounts for 49 percent of the total harvest in the Gulf of Mexico (Audubon Nature Institute, 2017).

Finfish are usually highly mobile therefore; any impacts to those species will be minimal and temporary. However, increases in suspended sediments and turbidity levels from dredging and disposal operations, could under certain conditions, result in adverse effects on marine animals and plants by reducing light penetration into the water column and by the actual physical disturbance. Likewise, shellfish can suffer from breathing problems associated with clogged and damaged feeding apparatus and young fish can have increased fatalities when sediments become trapped in their gills from heavily turbid waters (Wilbur & Clarke, 2001).

Oyster Reef

Where there is hard bottom in the bays, oysters typically grow as consolidated reefs providing important feeding and refuge habitat for well over 300 aquatic species. Oysters are filter-feeders, filtering up to six gallons of salt water per hour. They consume plankton helping to maintain good water quality in Texas bays and estuaries. Oysters support a valuable commercial fishery in Texas, with 22,760 acres of public reef and 2,321 acres of private reef available for harvesting. Texas A&M reports that Texas provides nearly 15 percent of the nation's total oyster harvest resulting in a $50 million impact on the state's economy (Texas A&M University). Ninety percent of the public reefs utilized by commercial and recreational fisherman are found in Galveston, Matagorda and San Antonio Bays with Galveston Bay landings usually the highest. Galveston Bay's oyster reefs were hit particularly hard during Hurricane Ike in 2008 leaving many of the reefs buried in layers of sediment and debris ultimately smothering live oysters. This devastating event destroyed almost 60 percent of the oyster reef habitat in Galveston Bay, and 80 percent of the East Bay's oyster population. The oyster fishery was slow to bounce back from the devastation of Hurricane Ike. Extreme conditions of drought, algae, red tide, and extreme influxes of fresh water beginning in 2010 led Galveston County to declare a disaster declaration for the ailing oyster industry. Extreme rainfall events during the spring of 2015 and 2016 led to a catastrophic oyster die off in Galveston Bay resulting in 1.67 million pounds of oysters landed (half of the previous year's total landing). Local oyster industry officials suggest restoration of damaged oyster reefs may take $20 to $30 million (Houston Chronicle, 2015). Oyster reef restoration occurs throughout the Texas bay systems and can take several forms. Smaller "oyster gardening" projects are perfect to engage homeowners in active restoration efforts. However, the creation of larger artificially constructed reef pads is necessary to continue oyster reef growth in all of the Texas bay systems.

Recommendations
The Service recognizes the significant contribution of oysters to the aquatic ecosystems, supports the creation of oyster reef habitat throughout Texas bay systems, and is willing to assist with restoration site identification in conjunction with the other federal, state, and local natural resource agencies. Any oyster restoration or creation should be conducted within publicly harvestable or restricted or closed areas and not subject to lease by TPWD or others. Success criteria for created and restored sites should be coordinated with TPWD and harvest limited to sustainable levels.

Migratory Birds

Piping Plover

Listed as threatened and endangered species under the Act in 1986, the piping plover is a small stocky shorebird approximately 7 inches in length with a wingspan of about 15 inches (Palmer, 1967, Service, 2009). Plumage and descriptive characteristics include a pale back, nape, and crown, white under parts, a stubby bill, and orange legs and during the breeding season, the legs and bill are bright orange, the bill has a black tip, and a single black breast band and forehead bar are present. In winter, its legs become pale orange, its bill turns black, and the darker bands and bars are lost (Wilcox, 1959, Service 2009).The historic range of the piping plover has traditionally been divided into breeding and wintering ranges. The breeding range encompasses the northern Great Plains and Prairies, the Great Lakes, and the North Atlantic ecoregions of the United States and Canada while the wintering range extends along coastal areas of the U.S. from North Carolina to Texas and portions of Mexico and the Caribbean (Service, 2009). The species current range remains similar to its historic range except that piping plovers have been extirpated from several Great Lakes breeding areas (Service 2003).

On their migration and wintering range, piping plovers forage and roost among a mosaic of beach and bay habitats and move locally (within a home range) among these habitats in response to a variety of factors including tidal stage, weather conditions, human disturbance, and prey abundance (Drake, 2001, Cohen et al., 2008, Noe and Chandler 2008). Foraging habitats include bayside flats and islands, the intertidal zone of ocean beaches, wrack microhabitats, washover passes (channel cuts created by storm driven water), and shorelines of ephemeral ponds, lagoons, and salt marshes. Roosting habitats include back-beach areas, dunes, wrack microhabitats, inlets, and river mouths as roosting habitats (Arvin, 2009, Service, 2009).

Approximately 35 percent of the known global population of piping plovers winters along the Texas Gulf Coast, where they spend 60 to 70 percent of the year (Haig & Elliott-Smith, 2004). Piping plovers are a common migrant and rare to uncommon winter resident on the upper Texas coast most likely due to habitat conditions (Lockwood, 2004). Plovers on the wintering grounds suggest that they show some site fidelity, returning to the same stretch of beach year after year. On the lower Texas coast, piping plovers are known to use areas about 3,000 acres in size, moving two miles or more between foraging sites as tidal movements shift the availability of productive tidal flats.

Red knot

The red knot *Calidris cantus rufa* is considered a threatened species under the Act and generally flies more than 9,300 miles from south to north every spring and fall without stopping, making this species one of the longest-distance migrants in the animal kingdom (Morrison, Ross, & Niles, 2004). Breeding takes place in the Canadian Arctic with arrival beginning in late May or early June varying with snowmelt conditions. Most adult and juvenile red knots leave the breeding grounds in late July however some remain as late as mid-August. Red knots occupy all wintering areas as early as September and as late as May in Texas. In addition, the birds are found in coastal bays, estuaries, and inlets returning to the same wintering ground yearly. Declines in the red knot population occurred in the 2000s primarily from reduced food availability from increased harvest of horseshoe crabs in Delaware Bay (the main stop over point for red knots). While red knot numbers may have stabilized some in the past few years, their numbers remain at low levels relative to earlier decades and warranted federal protection on January 12, 2015.

Whooping crane

The endangered whooping crane *Grus Americana,* with less than 600 birds in the wild, winters along the marshes of the central Texas coast and feeds on aquatic invertebrates such as insects, blue crabs, small vertebrate fish, amphibians, birds, mammals, and plants commonly found in freshwater to brackish marsh regimes and coastal prairies. A portion of the original wild flock (defined as always living in natural circumstances) winters at the Aransas National Wildlife Refuge September through April each year and then migrates north to breed at Wood Buffalo National Park in Canada. With occasional use of upper Texas coastal marsh habitat, a non-essential experimental population of 59 whooping cranes is yearlong residents of the marsh and rice fields of southwest Louisiana. Across the Texas coast, the primary threat to whooping cranes remains habitat loss; however, adequate food supplies are critical to whooping cranes. Lack of freshwater inflows can create saline conditions not favorable for key forage species and can threaten whooping crane overwinter and migration success. Migration flights to and from the breeding grounds are not direct or non-stop and stop overs are required for rest and refueling. Healthy wetlands (of all types) on the wintering grounds and along the migratory route continue to play an integral part into the whooping crane's survival and should be preserved. Due to the location of potential restoration project within coastal salt marsh, there is the potential for occurrences of the federally listed endangered whooping crane along the upper and mid Texas coast where they are known to utilize similar salt marshes outside of the historic wintering grounds.

Colonial Waterbirds

Colonial waterbirds are birds that gather in large groups called rookeries or colonies during the nesting season and they obtain all or most of their food from the water. While many species of colonial waterbirds appear to have incredibly large populations, they face many threats such as oil pollution associated with increased tanker traffic and spills, direct mortality from entanglement and drowning in commercial fishing gear, depletion of forage fish due to overexploitation by commercial fisheries, habitat limitations, and the presence of predators at nesting sites. Texas islands host nesting colonies for most North America seabirds as well as many of the last populations of endemic landbird species.

Comprehensive restoration of priority islands for breeding birds is needed as many islands are still overrun by invasive species. The Service identified 18 historic colonial waterbird colonies within the project area. These islands or sites are no longer suitable due to: the presence of invasive predator species; overgrown vegetation; lack of open ground nesting habitat; erosion or subsidence; and no longer have appropriate elevations to support nesting birds, or the lack of available forage sites in close proximity to nesting habitat. The Texas Colonial Waterbird Society (TCWBS) recognizes over 500 active and historic colony and sub colony sites within the study area. Since 1978, the TCWBS annually surveys 23 colonial waterbird species to identify population trends and make management recommendations to our partners along the coast. Recent trends (2000 through 2014) indicate a decline for many of the surveyed species which may be attributed to predator presence (including humans) and habitat erosion or conversion. The once endangered brown pelican *Pelecanus occidentalis,* considered a major conservation success story, was delisted in 2009 in large part to intensive rookery management and island creation in Texas promoting optimal breeding and foraging habitats.

The construction of bird islands using new work dredged matieral is well documented, but it was not until the 1970s that the importance of this dredged material to nesting waterbirds was realized (Golder, Allen, Cameron, & Wilder, 2008). Dredge spoil islands created out of local sand and clays provide immediate nesting opportunties for bare ground nesters such as terns and skimmers. Successional vegetation including mangroves, bacharris, and other shrub spieces provide suitable nesting habitat for three species of egrets, five species of herons, white ibis *Eudocimus albus*, and rosette spoonbills *Platalea ajaja*. This and subsequent projects could positively contribute to the colonial waterbird populations across the Gulf of Mexico.

Waterfowl

Most waterfowl depend upon wetlands for some or all stages of their lifecycles. The mottled duck *Angus fulvigula,* a medium sized dabbling and non-migratory duck, is the only duck species adapted to breed in the southern wet coastal prairies and marshes of the Texas gulf coast. Not federally listed under the Act, but a focal species for the Service and many others, mottled ducks spend their entire life on the coastal prairie and adjacent marshes relying on the availability of coastal marsh for its existence (Merendino et. al, 2005). Once abundant along the Texas coast, the mottled duck is primarily found along preserved and development free areas with highest densities often observed in fresh and intermediate coastal marshes of the Texas Chenier Plain and moderate densities found in the coastal marshes of the Texas Mid-Coast. Most common habitats include fresh to brackish coastal marsh ponds, emergent freshwater wetlands, and flooded rice fields of the prairie. In south Texas, mottled ducks are frequently found in resacas of the Rio Grande Valley and freshwater ponds associated with coastal grasslands. Mottled duck populations have declined over the years mostly attributing to the loss of suitable nesting and brood-rearing habitat (Krainyk & Ballard, 2015) which include grasslands and palustrine and estuarine wetlands.

Although the amount of Gulf coastal prairie is small, it provides wintering habitat for large concentrations of waterfowl: 95 percent of gadwall, 90 percent of mottled duck, 80 percent of green-winged teal, 80 percent of redheads, 60 percent of lesser scaup, 25 percent of pintails, and mid-continent lesser snow and white-fronted geese (Ducks Unlimited). Additionally, coastal prairie provides migration habitat for most of the blue-winged teal that winter in Central and South America. With such large waterfowl populations migrating through or wintering in coastal Texas, federal and state partners have set aside land specifically aimed to conserve wetlands and coastal prairies for the benefit of waterfowl.

Other Migrating Birds

The Service published the *Birds of Conservation Concern 2008* (BCC) in December 2008 as a result of the 1988 amendment to the FWCA that mandates the Service to identify species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become candidates for listing under the Act. The BCC is divided into Bird Conservation Regions (BCR). Within the Coastal Texas Study area lies BCRs 36, Tamaulipan Bushlands and 37 Gulf Coastal Prairie U.S. portion only (**Figure 3**) with a full species lists included as an appendix. We expect many of the species identified in BCR 37 will be present within the Texas Coastal Study footprint.

Marsh, bird islands, and placement areas created by large scale Corps projects all are suitable habitat for resident and migratory birds to forage, nest, and may play a critical life cycle role as other coastal habitats erode and become less suitable. The recent State of North America's Birds 2016 (North American Bird Conservation Initiative, 2016) identifies seabirds as declining. This guild continues to be severely threatened by invasive predators on nesting islands, accidental bycatch by commercial fishing vessels, as well as overfishing of forage fish stocks, pollution, and climate change. By adopting broad best management practices such as the continued building of bird islands, managing invasive species and vegetation on existing islands and placement areas, the Corps will help to ensure the growth of colonial waterbird populations and shorebirds along the Texas mid coast and at the broader Gulf of Mexico level for years to come.

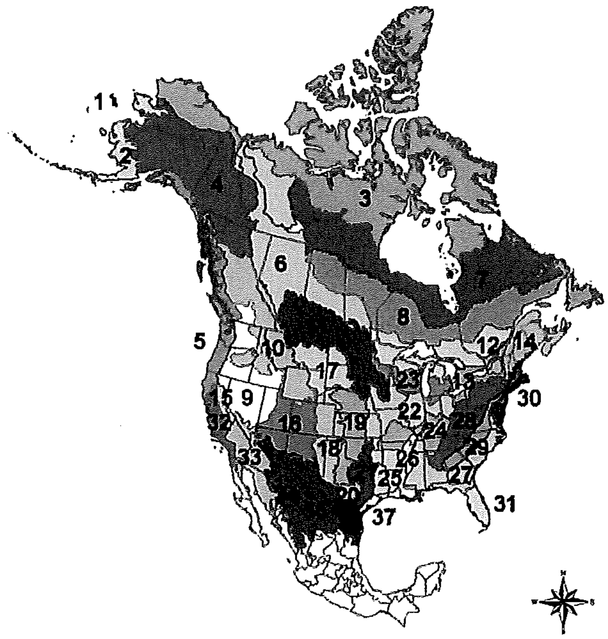

Figure 3 Birds of Conservation Concern Region Map

Most Texas birds are not year-round residents and are considered to be seasonal residents or migrants. The Texas mid coast is critically important habitat for migrating birds due to their use of uplands, wetlands, beaches and marshes as feeding, resting and nesting sites. The Matagorda Bay area is located within the path of the Central flyway. In existence today, there are 338 Neotropic North American species, 333 have been documented in Texas (Haggerty & Meuth, 2015). The coastal and bay shorelines provide stop over and fall-out habitat for many neotropical birds migrating across the Gulf of Mexico to their summer grounds in the northern United States and Canada. These weary and energy-drained birds seek wooded areas to feed and recharge before taking flight again. Various species of hawks and raptors are found in the project area throughout the year, however most are migrants and are found primarily during the winter months. Eagles, owls, and hawks are resident and are common on the landscape.

As of December 2013, the Service documents 1,026 avian species protected under the Migratory Bird Treaty Act of 1918 The Act makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nest, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations. While the purpose of the PAL is to identify key focal habitats within the study area and pinpoint means to minimize impacts to trust resources if alternatives are presented, we recommend the Corps evaluate each ER and coastal storm surge reduction study measures for negative impacts to resident and migratory bird species, specifically those that are listed on the BCC and the North American Bird Conservation Initiative. We recommend the use of the Service's Nationwide Standard Conservation Measures as guidance to reducing impacts to birds and their habitats. The guidelines can be accessed at https://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures/nationwide-standard-conservation-measures.php.

Sea turtles

The Service and NOAA share joint jurisdiction over five species of sea turtles found in U.S. waters and nesting on U.S. beaches: leatherback, hawksbill, loggerhead, green and Kemp's ridley. NOAA retains jurisdiction when sea turtles are in a marine environment and the Service picks up jurisdiction when sea turtle emerge to nest. The leatherback, hawksbill and green sea turtles rarely nest in the southeastern U.S., but offshore waters are important feeding, resting, and migratory corridors. Texas sea turtle nesting season occurs from March 15 to October 1 with the Kemp's ridley, green, and loggerhead sea turtles known to nest along the Texas coast. Kemp's ridley sea turtles nest bi-annually with most nesting occurring along the Tamaulipan coast of Mexico. However, during the 2017 nesting season, Kemp's ridley sea turtles laid a record setting 352 nests along the Texas coast (Shaver, 2017). These turtles return to their natal beaches to nest and can lay more than one clutch in a season. Should the Corps determine that beach nourishment or shoreline protection are viable options under this study, the Service recommends the Corps evaluate these actions for specific impacts to nesting sea turtles under Section 7 of the Act. Similarly, impacts to sea turtles in the marine environment should be evaluated and coordination with NOAA's Protected Resource Division Permitting Office at 877-376-4877.

Threatened and Endangered Species Consultation

The Service recommends the Corps conduct a review for threatened and endangered species two years prior to construction. In order to obtain information regarding fish and wildlife resources concerning a specific project or project area, we recommend that the Corps first utilize the Service developed Information, Planning, and Conservation (IPaC) System. The IPaC system provides information about natural resources the Service has responsibility for and assists project proponents in planning their activities within the context of natural resource conservation. Additionally the system can assist people through the various regulatory consultation, permitting and approval processes administered by the Service, achieving more effective and efficient results for both the project proponents and natural resources. The IPaC system can be found at: http://ecos.fws.gov/ipac/.

Critical Habitat

Critical habitat is the specific areas occupied by the species at the time it was listed that contain the physical or biological features essential to the conservation of endangered and threatened species. Critical habitat may also include areas not occupied by the species at the time of listing but are essential to its conservation. The Act requires Federal agencies to use their authorities to conserve endangered and threatened species and to consult with the USFWS about actions that they carry out, fund, or authorize to ensure that they will not destroy or adversely modify critical habitat. The prohibition against destruction and adverse modification of critical habitat protects such areas in the interest of conservation.

We have reviewed our files and determined that critical habitat for the federally endangered piping plover and whooping crane lie within the study area boundaries and are outlined in yellow in **Figures 4, 5, 6 and 7**. Further analysis for specific habitat units impacted by this study should be conducted and we also recommend coordination pursuant to the "Act" with the Service's Texas Coastal Ecological Services Office prior to the commencement of any restoration activities.

Critical habitat was designated for all wintering piping plovers on July 10, 2001 (66 FR 36038). This designation aimed to provide sufficient wintering habitat to support the piping plover at the population level and geographic distribution necessary for recovery of the species. This designation included

142conservation units along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. A total of approximately 165,211 acres or 1,798 miles were designated. There were 37 critical habitat units (approximately 62,454 acres, 797 miles) designated in Texas (**Figures 4, 5, and 7**). These areas were believed to contain the essential physical and biological elements for the conservation of wintering piping plovers, and the physical features necessary for maintaining the natural processes that provide appropriate foraging, roosting, and sheltering habitat components.

Critical habitat for the endangered whooping crane was finalized in 1978 and occurs on the Aransas National Wildlife Refuge as depicted in **Figure 6** and includes salt marshes and tidal flats on the mainland and barrier islands, dominated by salt grass *Distichils spicata*, saltwort *Kali turgida*, smooth cordgrass *Spartina alterniflora* , glassworts *Salicornia* spp. and sea ox-eye daisy *Borrichia frutescens*. The cranes occasionally fly to upland sites when attracted by fresh water or foods such as acorns, snails, crayfish and insects, and then return to the marsh to roost. Uplands are particularly attractive to the cranes when partially flooded by rainfall, burned to reduce plant cover or when food is less available in the salt flats and marshes.

At this time there is no critical habitat designation for the red knot; however, the Corps should analyze effects of the project for all threatened and endangered species pursuant to Section 7 of the Act prior to the commencement of any construction. The Service's Critical Habitat Mapper provides information regarding threatened and endangered species critical habitat designation that may be of use during project design and evaluation and is found at https://ecos.fws.gov/ecp/report/table/critical-habitat.html?

Essential Fish Habitat

Estuarine wetlands and associated shallow waters within the project area have been identified as Essential Fish Habitat (EFH) for post larval, juvenile and sub-adult stages of brown shrimp *Crangon crangon*, white shrimp *Litopenaeus setiferus*, and red drum *Sciaenops ocellatus*.. EFH requirements vary depending upon the species and life stage with categories within the project area including estuarine emergent wetlands, estuarine water column, submerged aquatic vegetation, and estuarine water bottoms. Detailed information on federally managed fisheries and their EFH is provided in the 2005 generic amendment of the Fishery Management Plans for the Gulf of Mexico, prepared by the Gulf of Mexico.

Fishery Management Council (GMFMC) and can be found at http://gulfcouncil.org/fishery-management/. That generic amendment was prepared in accordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), (P.L. 104-297).

We recommend the Corps initiate consultation with National Marine Fisheries Services, Southeast Regional Office, Habitat Conservation in Galveston, Texas at 409-766-3699 to determine specific impacts to EFH as a result of the proposed ecological restoration measures of the Texas Coastal Study.

Bird Island Creation

Since 1973, the Service along with other federal, state, local non-governmental agencies and private citizens monitored several hundred coastal colonial waterbird sites along the Texas coast. While some islands are natural, most are man-made and are the result of nearby dredging activities. The creation of man-made islands usually occurs in waters adjacent to a shipping channel, cut, or pass and thereby may be subject to increased rates of erosion. In general, spoil islands provide suitable bare ground nesting habitat and subsequent vegetation succession can create shrub and tree habitat for other colonial nesters.

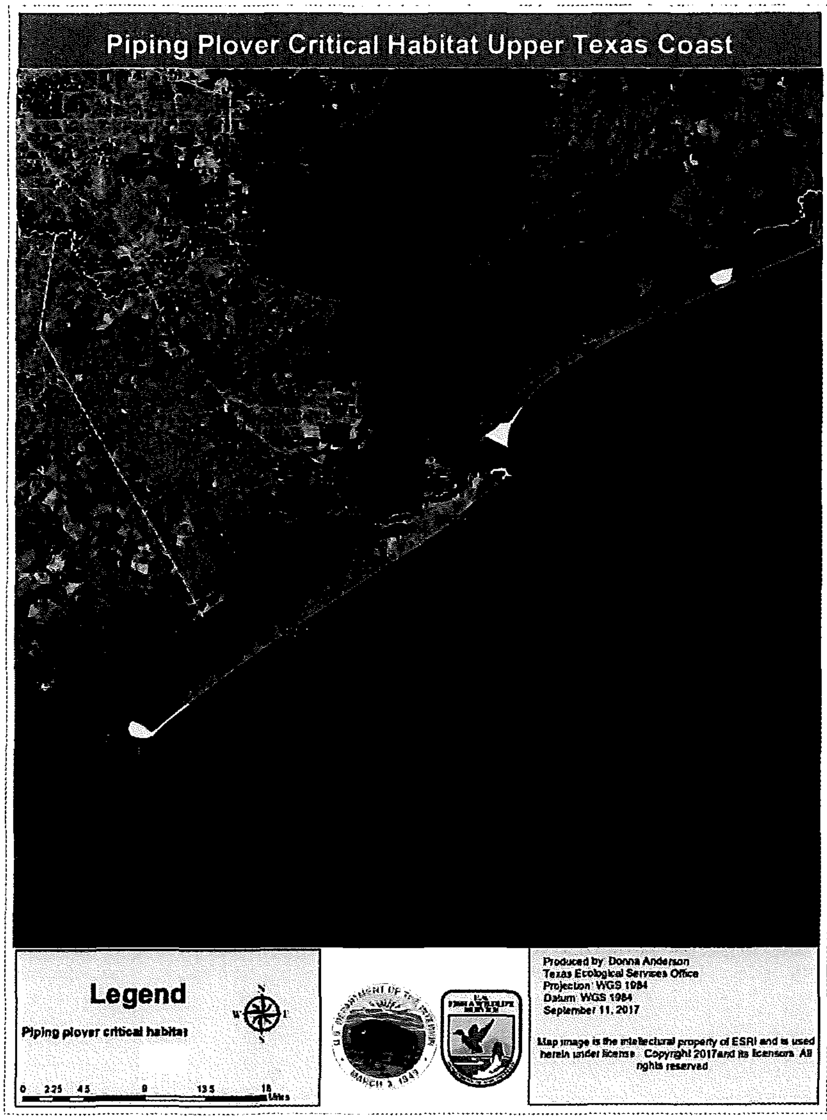

Figure 4 Upper Texas Coast Critical Habitat (piping plover)

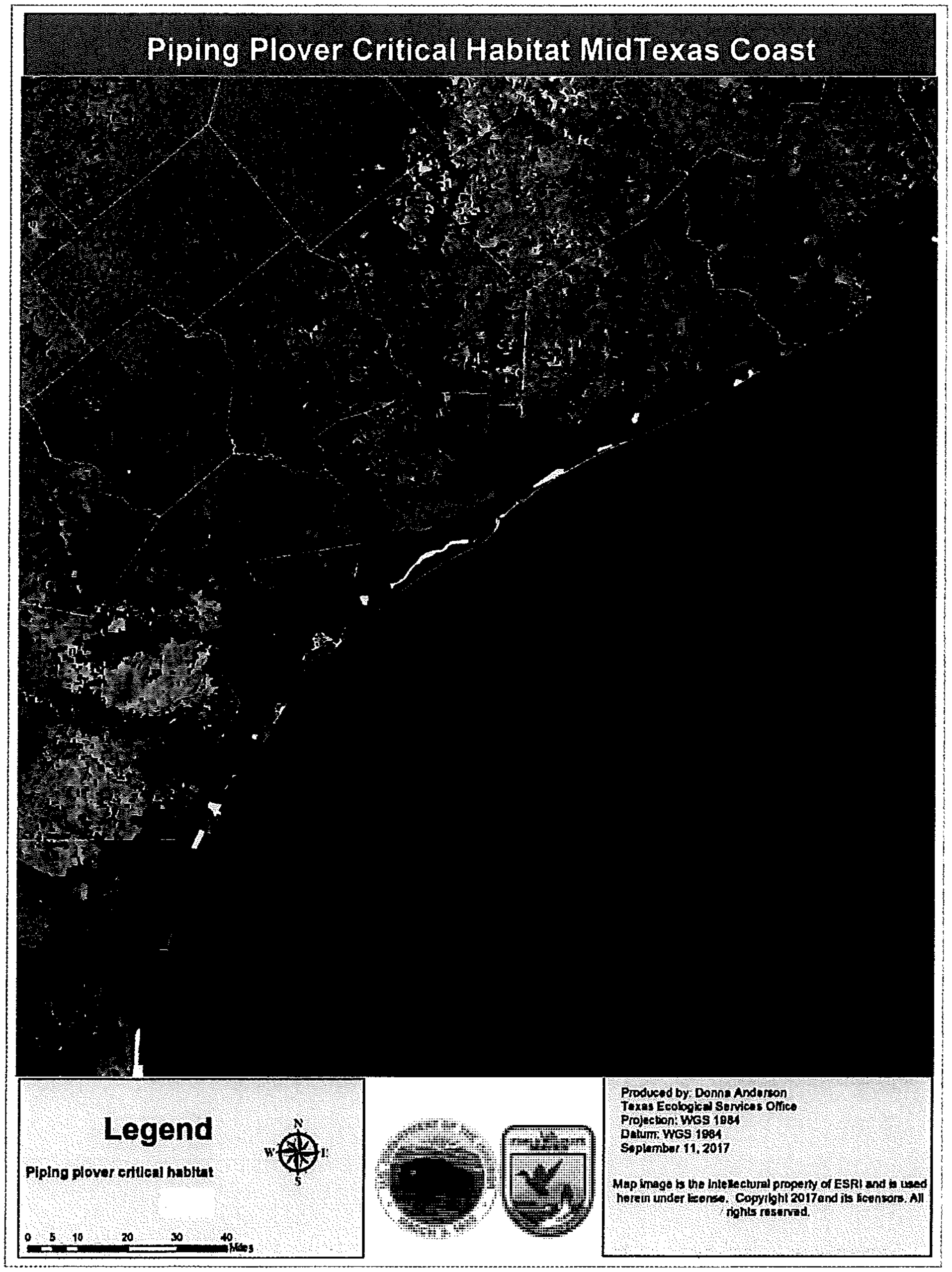

Figure 5 Mid Coast Critical Habitat (piping plover)

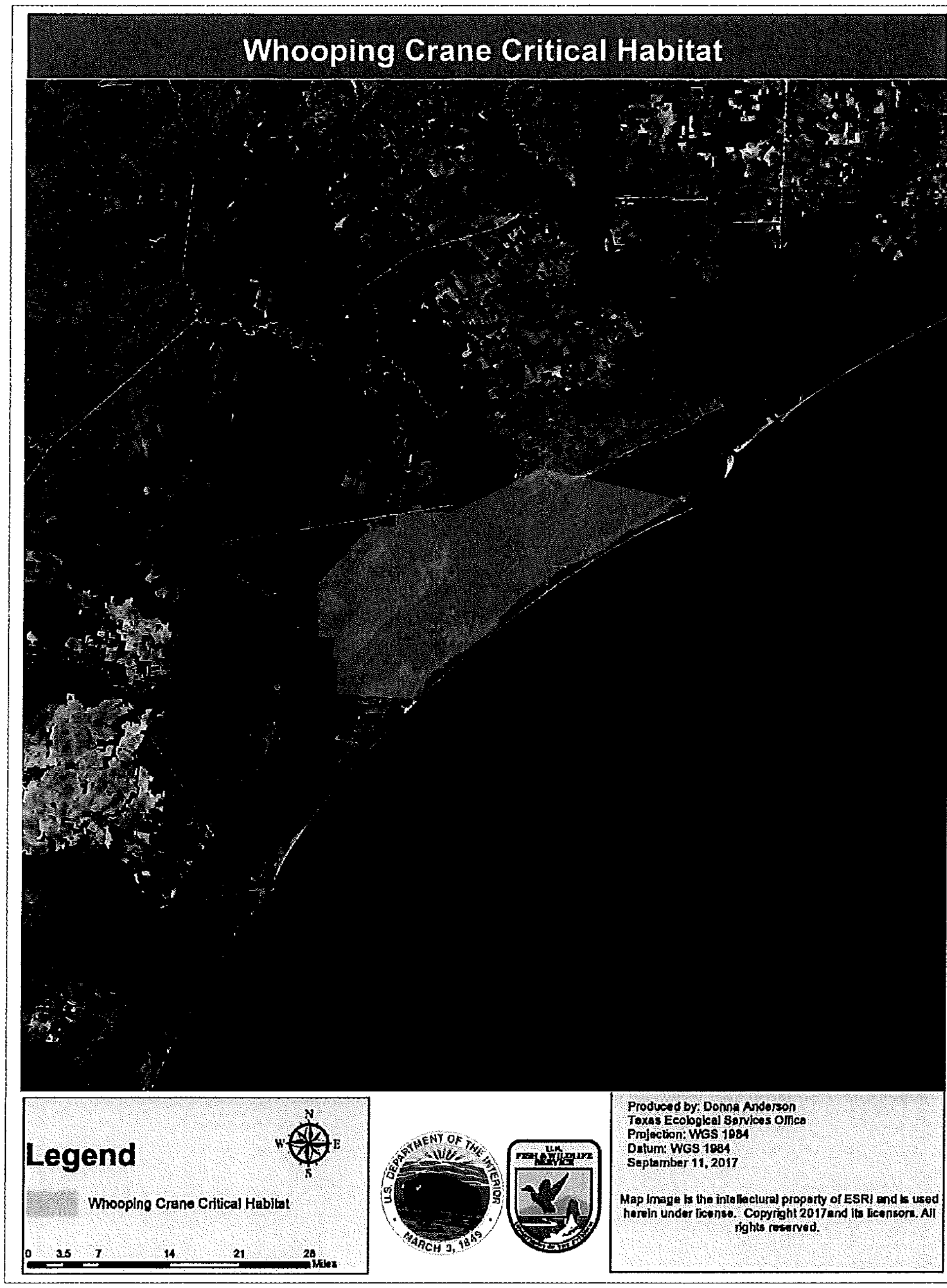

Figure 6 Mid Coast Critical Habitat cont'd (whooping crane)

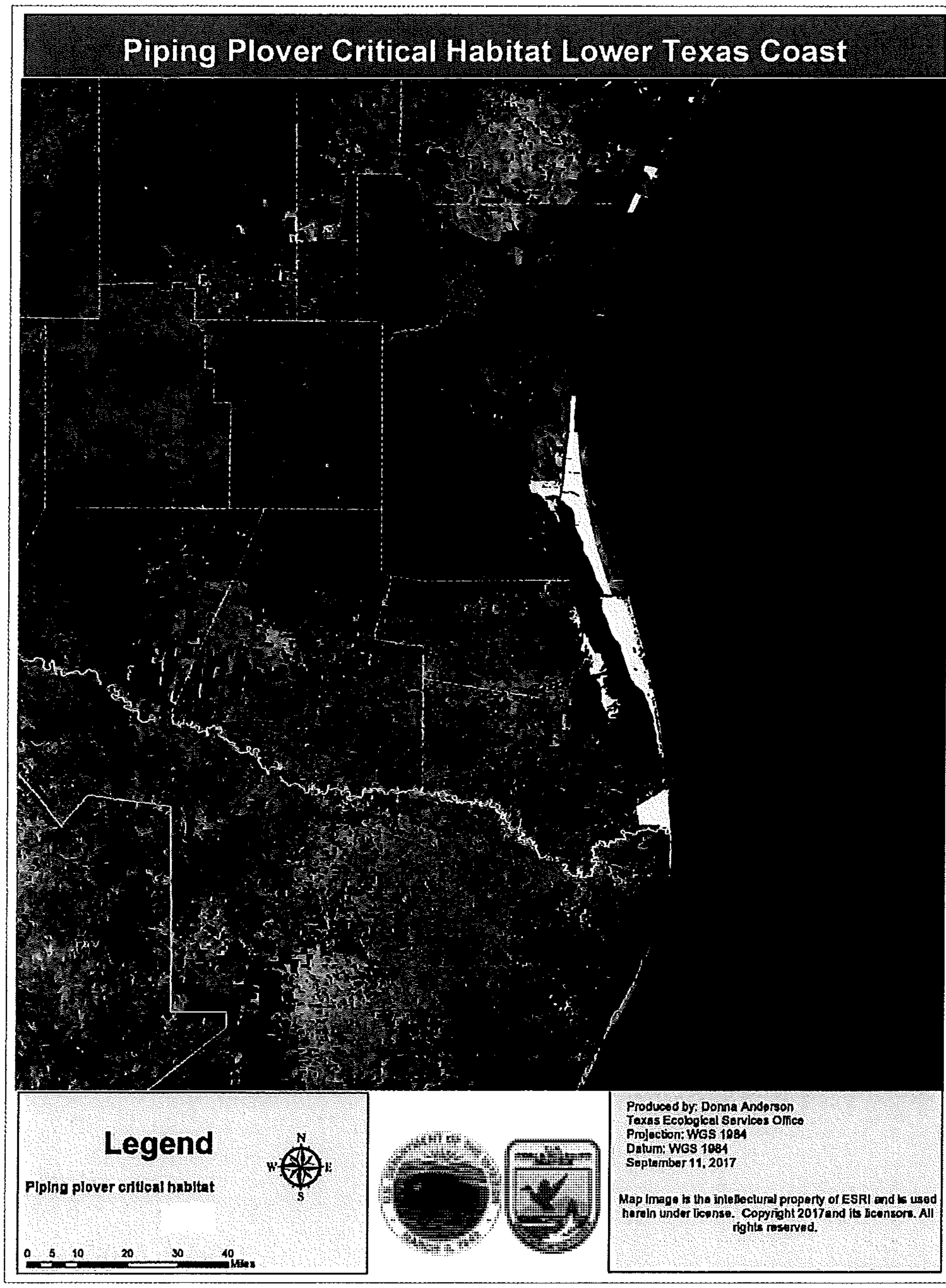

Figure 7 Lower Coast Critical Habitat (piping plover)

The importance of coastal rookeries to bay ecosystems is well documented in terms of fisheries, recreational opportunities, and photography. Audubon Texas (2016) conducted studies to quantify erosion along Texas rookery islands and project future land loss. Fourteen islands were rated as the highest priority in need of protection and eight of those islands are predicted to experience a complete land loss within 50 years. Audubon Texas (2017) authored a comprehensive Texas Coastal Rookery Conservation Plan (Plan) that identified all current and historical colonial waterbird islands as well as birds commonly found breeding at each site. Additionally it identified management needs and challenges for each island. Many coastal rookery islands face erosion issues as a result of increased storm frequency and intensity, sea level rise, and wave fetch caused by increased size and number of commercial and recreational vessel traffic.

Some Texas bay systems appear to be more resilient in terms of bird nesting which may be associated with frequency of dredge events and placement options. Sabine Lake had four active rookery sites however; predator presence, subsidence, and erosion have eliminated all nesting sites as of 2013. Maintenance dredge material from the Sabine Neches Water Way is either placed in upland confinement or pumped offshore and new work material necessary for island creation is seldom available.

The Galveston Bay rookeries experience high rates of erosion and predator presence at most nesting sites. Many sites are Corps dredge spoil islands that are not maintained or managed and are located adjacent to the mainland or near to the Houston Ship Channel. While dredging frequency and material are plentiful, placement of additional dredge material at Galveston Bay rookeries remains a challenging due to limited pumping distances and costs. Jigsaw, Rollover Pass, Struvey Lucy, Marker 52, Vingt-et-un, and Smith Point islands all experience some level of erosion, most likely from increased wind fetch and wave energy, and would benefit from added dredge material and rock protection measures.

Like the Sabine Bay system, Matagorda Bay and the smaller feeder bay systems have few islands suitable for colonial nesters. Chester Island (Matagorda Bay) and Lavaca Bay Spoil (63-77) (Lavaca Bay) line the Matagorda Ship Channel, are both eroding dredge spoil islands, and provide the only nesting habitat for most of the Matagorda Bay systems. The Mouth of Chocolate Bayou, Lavaca Bay Spoils (51-63), Point Comfort-AlCOA, Mouth of Lavaca River, and Matagorda Bay Spoils (39-51), Coon Island sites lack sufficient elevation to support nesting birds and most likely contribute to the declines in nesting bird populations along this portion of the coast during the late 1990s and early 2000s. Increasing nesting opportunities by creating islands strategically placed in Matagorda Bay system may be an alternative to armoring the existing two islands. Designing islands with a suite of habitats to provide nesting and foraging opportunities will attract the greatest diversity of colonial nesters.

The Laguna Madre is a critically important area for natural resources supporting a rich diversity of birds throughout the year. Historically, the Laguna Madre supported 42 colonial waterbird islands; mainly constructed during the original dredging of the Gulf Intercoastal Water Way (GIWW). However, many of these constructed sites (like other Texas bay systems) now lack suitable elevations to support colonial nesters. The Texas Colonial Waterbird Society (2017) reported a declining trend for colonial waterbird populations where habitat availability and predator presence may be limiting factors. While some of these islands receive periodic dredge maintenance material, others have not. Many islands have and continue to erode warranting additional protection measures.

Recommendations
The Service recommends the Corps evaluate bird rookery island design, construction, and restoration opportunities along the entire Texas coast in conjunction with the other federal, state, local resource agencies, and local partners, due to the decline in available nesting habitat in all the major bay systems.

We believe this evaluation will demonstrate the need for both the restoration of the historic islands and the construction of new nesting island or suite of islands. Island design should strongly consider proximity to mainland, sea level rise, erosive forces if placed in high wave energy environments, and should contain habitat suitable for a variety of guilds. In addition, as a study opportunity, the Service recommends research funding be dedicated to identifying colonial waterbird foraging habitats, optimum island capacity, migratory patterns of focal colonial waterbird species, optimal elevation for colony islands, and analysis of preferred island locations and marginal habitat sites. We believe these studies will yield valuable data and would be used to guide site selection, island design, and construction methods. The Study's Comprehensive Plan should also capture migratory bird research needs such as understanding beach recolonization of benthic communities, understanding avian movement in and within adjacent habitats, and optimal foraging distances from nesting areas.
Close coordination with natural resource agencies, academia, and NGOs with expertise in nesting colonial waterbirds and island design is highly recommended to further develop research needs.

Beach Nourishment and Dune Restoration
Beach nourishment is a process that occurs regularly along the Texas Coast and utilizes sand from various sources, either onshore or offshore, to replace sand from beaches suffering erosion. Beach nourishment is often proposed as an alternate to other hard structure alternatives such as seawalls and usually requires an ongoing commitment of public funding. Texas shorelines typically advance or retreat depending on the actions of waves, currents, tides, and availability of sediment in the littoral system. The availability of sediment is hampered largely by natural and anthropogenic means such as increased frequency of hurricane level events, recurring dredging activities, and the presences of jetties, dykes, and groins. Most sediment is either permanently removed from the system or transported far enough offshore that smaller waves are unable to carry the material back to the beach resulting in sand starved beaches. Changes in shoreline location are of enormous importance to Texas residents, industry, local governments, and can result in millions of lost tourist revenue, damages to homes, commercial and industrial businesses, infrastructure (roads, bridges, power lines etc.), and pipelines. These natural and anthropogenic changes generally negatively impact shoreline ecosystems, wildlife, and human recreation activities.

Increased intensity and frequency of natural coastal processes (hurricane and storm events) can reduce the efficiency of dune ecosystems along the Texas coast resulting in severe shoreline and dune degradation. In some coastal areas, overtopping during storm events compromise dune structures, alter ingress and egress flows of historically fresh marsh areas, and can result in the conversion to open water habitat displacing fish and wildlife. The reduction and loss of shoreline habitat can be directly correlated with the status of seven federally threatened and endangered species. With the creation of dunes and forebeach, we expect suitable habitat will be provided for threatened and endangered species such as the piping plover, red knot, nesting Kemp's Ridley, loggerhead, and green sea turtles, hawksbill sea turtles, and the leatherback sea turtle. Historic use of Texas beaches for these species is well documented; however, current habitat conditions may not be favorable (limited sand and dune availability) along some portions of the coast resulting in avoidance or diminished use.

Much of the Texas coast remains severely eroded by hurricane events, sea level rise, regular high tides, and reduced sediment supplies resulting in the loss of dunes and coastal shorelines. Beach nourishment projects provide protection of forebeach, back dune wetlands, and create additional nesting, resting, and foraging opportunities for listed and non-listed migratory shorebirds, sea turtles, and fish species of commercial and recreational importance.

Recommendations
Generally, the Service supports the overall concept of beach renourishment, dune creation, and debris removal along the entire Texas coast. However, the Service recommends the Corps assess and identify the causes for site specific shoreline erosion and provide long term solutions for shoreline stabilization. The Service recommends the Corps work in coordination with local, state and federal resource agencies to identify beach habitat in immediate need of restoration and develop a schedule for recurring renourishment (based on engineering, monitoring, and adaptive management) events in lieu of one-time placement opportunities. We suggest the Corps adopt long term perpetual funding mechanisms for beach nourishment aimed at ensuring future ecosystem benefits to trust resources. The selection of suitable sediment sources is critical and must be dependent upon consistent grain size, color, and mineralogy, is the same quality as the existing beach sediments, and does not contain toxic materials. Beach and dunes should shall be designed and constructed to complement existing conditions or if necessary, constructed to meet historic elevations where the system was once resilient. All beach nourishment projects should include monitoring efforts specific to benthic organisms aimed at assessing impacts or benefits to threatened and endangered species that utilize beach habitat. The Corps should coordinate with state and federal natural resource agencies for site specific beach nourishment recommendations prior to conducting nourishment activities.

Gulf Coastal Prairies
Native grasslands and prairies, with their ecologically complex plant and animal communities, were important components of the landscape of early Texas. The Texas coast was once home to 6.5 million acres of extensive coastal prairies interspersed with a maze of marshes that serve as wildlife nursery and refuge for many wildlife species. Some estimate less than 1 percent of the coastal prairie ecosystem remains in relatively pristine condition and many migratory and grassland bird species utilize coastal prairie habitat for portions of their life cycle. Plants once thought common within coastal prairie habitat have disappeared due to conversion to agriculture, urban sprawl, residential and commercial development, as well as numerous transportation systems. Gulf coastal prairie is a relatively flat and treeless region with rich productive soils suitable for rice production and cattle grazing increases water infiltration and water yield, increases water supply by reducing erosion and reservoir sedimentation, and increases water quality due to the lack of fertilizer, pesticide, and herbicide use. Prairie provide rare native habitat for birds, butterflies, insects, reptile, and other small wildlife and usually are composed of plants seldom found in other habitats. Many tall grass prairie bird populations such as the federally listed Atwater's prairie chicken *Tympanuchus cupido attwateri*, whooping crane, aplomado falcon *Falco femoralis*, and state listed white-tailed hawk *Geranoaetus albicaudatus* were once common on the prairie landscape but are now in decline due to current land practices such as conversion to agriculture, commercial and residential development, and oil and gas exploration. The resulting landscape is fragmented, degraded, and fraught with invasive species.

Historically, once one of the most abundant resident birds of Texas and Louisiana tall grass prairie ecosystems, the critically endangered Atwater's prairie chicken remain on the coastal prairie with only two wild populations (a total of 52 males were counted as part of the annual census). Presently, less than 200,000 fragmented acres of coastal prairie persist, leaving the birds scattered among two Texas counties. The Service's Attwater's Prairie Chicken National Wildlife Refuge is managed specifically for Attwater's prairie chicken; however, recovery activities stretch far beyond the refuge's boundaries. Pressure from coastal development, habitat fragmentation, climate change, predators, and the prolific spread of fire ants negatively affects this imperiled bird. Captive zoo and federal facility rearing programs located across the state show some promise and the Service continues to diligently work with partners to recover this species and acquire coastal prairie habitat.

The endangered aplomado falcon is a medium sized raptor 15 to 18 inches in length, a wingspan of 32 to 36 inches, and is a permanent resident in Texas. Unfortunately, aplomado falcon's numbers were reduced to zero in the United States during the 1930s with small numbers scattered throughout Mexico. Sound recovery efforts along with habitat management strategies allowed the aplomado falcon to become a permanent resident on south Texas coastal prairies, savannahs, marshes and tidal flats, and open grasslands with scattered trees. Release of captive reared birds into the wild and the installation of nest boxes have increased nesting success in South Texas resulting in a stable to increasing population at the present.

Recommendations
The Corps does not readily recognize this habitat type as one to be included within the purview of this study. The Service disagrees and recommends full consideration for the preservation, restoration, and acquisition of remaining coastal prairie habitats benefiting nationally recognized and recreationally important wildlife species. Prairies, in general, provide excellent stopover resting and feeding habitat for migratory birds. Supporting coastal prairie and grasslands through large scale preservation and restoration will sustain threatened grassland birds and wildlife species while improving watershed quality. The Service can work with the Corps to identify parcels for permanent conservation status aimed at reducing landscape fragmentation and enhancing current restoration efforts.

Bottomland Hardwood Forests
Harwood bottomland forests are some of the most widely distributed, biologically diverse, and productive of tree-dominated communities throughout southern regions of North America (Rosiere, Nelson, & Cowley, 2013). Bottomland hardwood forests, spanning over one million acres, are one of the most biologically productive ecosystems along the Texas Gulf Coast from Mexico to Louisiana. These riverine forested habitats play a significant role in the migration of millions of birds across Texas while maintaining river water quality, controlling sediments, and filtering pollutants (Kellison & Young, 1997). Further, these forests increase the quantity and quality of groundwater recharge, retard flood flows, and minimize erosion by providing dense root systems to bind soil material. More than 85 percent of the historical bottomland hardwood forests in Texas were lost (Texas Conservation Alliance) to development.

Bottomland hardwood forests occur within the floodplains of rivers and streams that cross the middle and upper coastal plains in Texas. The Sabine, Neches, Trinity, and Brazos Rivers have broad floodplains that support extensive forested wetlands. Most upper coast bottomland hardwood forests are dominated by willow oak *Quercus phellos*, water oak *Quercus nigra*, overcup oak *Quercus lyrata*, cherry bark oak *Quercus pagoda*, laurel oak *Quercus laurifolia*, green ash *Fraxinus pennsylvanica*, red maple *Acer rubrum*, black willow *Salix nigra*, and water tupelo *Nyssa aquatica*. The mid-coast forests typically exhibit pecan *Carya illinoinensis* , water hickory *Carya aquatica*, American elm *Ulmus americana* , cedar elm *Ulmus crassifolia*, water oak, live oak *Quercus virginiana*, green ash, hackberry *Celtis laevigata* , sycamore *Plantanus occidentalis* and a robust list of understory vegetation are similar along the entire coast. Old-growth examples of this habitat type are very rare. Large tracts of bottomland hardwood forest remain but most are either second or third growth stands.

The Columbia Bottomlands historically covered over 699,300 acres long the Brazos, Colorado, and San Bernard Rivers, but has since been reduced to 25 percent of its former extent (177,900 acres), remains highly fragmented, are threatened by residential and commercial development, agricultural conversion, timber removal, and infestation by invasive plants. The ecological importance, productivity, and diversity of these forests are well documented. Bottomland forests provide temporary or permanent residence as well as critical stopover and staging habitat for Neacrtic-Neoptropical migratory landbirds, and are consistently used year to year though migration patterns can shift. The diversity of the Columbia

Bottomlands is well documented and known to support upwards of 239 million birds representing 237 species. These birds migrate through, overwinter or are found to breed in the Columbia Bottomland forests. Because of the critical significance of bottomland hardwood forests to avian ecology, the Service authored the Columbia Bottomlands Conservation Plan (U.S. Fish and Wildlife Service, 1997) with two objectives: 1) to illustrate strategies that combine federal habitat protection efforts with conservation efforts of local communities and 2) to describe vegetation characteristics of a mature Columbia Bottomlands forest remnant as a formative step in guiding the evaluation, acquisition, and management of other protected tracks. The accelerating loss of habitat, particularly large stands with mature composition and structure, heightened the need to move forward with the plan's outlined protection measures.

Similarly to Columbia bottomland forests, east Texas bottomland hardwoods (from Galveston to Sabine) are much the same in terms of threats, diversity, and structure. They support distinct assemblages of plants and animals associated with particular landforms, hydric soils, and hydrologic regimes and are generally higher, intermittently-flooded strips of land immediately adjacent to the riverine ridge and to meander lakes (oxbows) are often forested by mature bottomland hardwood forest. The largest tracts are at the extreme upper end of the study area, just south of the Neches River saltwater barrier and along the Sabine River north of I-10, within Sabine Wildlife Management Area. Agriculture and silviculture are the major continuing threats on these forested wetlands leading to deforestation and altered hydrology. Restoration efforts are ongoing across Texas and Louisiana in an attempt to reconnect fragmented forest blocks and restore wetland forest functions.

Recommendations
Due to the rarity and ecological significance of the coastal bottomland forests and forested wetlands in general, the Service deemed this habitat a "focus area" for preservation, restoration, and research. We recommends the acquisition of lands adjacent to previously purchased and protected lands that increase the conservation footprint for bottomland hardwoods along the Texas coast. Once the properties have been acquired and placed in perpetual conservation easements, we recommend the Corps develop long-term funding mechanisms to ensure ecosystem benefits for fish and wildlife into the future. Finally, we recommend the Corps develop comprehensive restoration and management plans for the property identifying opportunities for invasive species removal, burning, woody and shrub species propagation, comprehensive species list, and identification of additional tracts of land to compliment acquisition efforts by the Service and other partners for the benefit of resident and migratory birds and wildlife. The Service looks forward to working with the Corps and other partners to identify suitable coastal prairie tracts for restoration and purchase.

Gulf Intracoastal Water Way Shoreline Protection and Sediment Transport
Texas navigable waterways once designed to support only local vessel traffic are now exploited for national and international commerce utilizing increasingly larger vessels. Increases in vessel size and frequency create greater tidal surges resulting in shoreline creep, widening canals, saltwater intrusion into freshwater marsh, and erosion of public and private lands bordering the waterways. The Texas portion of the Gulf Intercoastal Water Way (GIWW) is over 50 years old and 423 miles long, is an essential component of the state's and nation's transportation network, and continues to operate with the goal to provide safe, efficient and effective means for the movement of people and goods throughout the state. The Texas portion of the GIWW supports five of the top 33 leading ports in 2016 with combined domestic and foreign tonnage of 524.5 million. In 2016, Texas ranked second in the nation in total waterborne tonnage transported with 496.67 million tons of the total maritime freight volume on both deep and shallow draft waterways (USACE, 2016). However the total tonnage for the entire GIWW was 111.7 million tons in 2016, down 6.1 percent from 188.9 million tons in 2015. While these shipping volumes are impressive and necessary to sustain a growing national economy, many within the

environmental community have concerns over the degradation of the GIWW shoreline and adjacent lands and that current waterway conditions warrant additional shoreline protection. Authorized at 125 feet wide and 12 feet deep, some stretches of the GIWW are now over 600 feet wide.

Despite the economic gains to many local communities, the GIWW, serves as a conduit for transporting sediments, is a barrier to freshwater inflows from north to south, and continues to degrade the hydrological regimes of adjacent wetlands by eroding existing shorelines. Historic hydrologic sheet flows across the landscape are compromised often resulting in trapping or ponding of freshwater north and increased salinities in wetlands south of the GIWW. The Service continues to advocate for shoreline protection along the entire GIWW protecting state, private, and federal lands.

The Beneficial Use (BU) of dredged material, whether used as thin layer placement on wetlands, marsh creation, seagrass bed enhancement, or bird island creation, is critically important to coastal aquatic ecosystems. Most sediment located within the GIWW is composed of fine silts and does not lend itself well to stacking. However, this material is suitable for thin layer placement on adjacent private, state, and federal lands where wetland conversion, degradation, and subsidence are common. Stiffer clays stack better and are consistent with levee and island building. The Corps typically beneficially uses between 15-20 percent of the dredged material for the entire state and the Service strongly recommends the Corps adopt a stronger BU policy where at least 50 percent of dredged material is beneficially used. The Service can provide technical support for BU marsh and island creation throughout the coastal bay systems.

Recommendations
Shoreline stabilization and protection of lands adjacent to the GIWW continues to be of great concern for the Service. We recommend the Corps work with resource agencies, non-governmental organizations, and private landowners to develop a GIWW wide shoreline stabilization plan with dedicated funding to protect adjacent wetlands. The Service recommends the development of a comprehensive state wide sediment management plan to address sediment transport throughout the state's coastal rivers and bay systems. We expect this plan will address the GIWW as this waterway remains a major conduit for fluvial sediment transport during normal flows and severe flooding events. Preferred options for the placement of dredged material, emergency dredge disposal, beneficial use opportunities, understanding the fate of sediment-bound pollutants in our waterways, analysis of how channels change during flood events, hazard and debris removal, climate change/sea level rise, and the effect on sediment accumulation and transport also should be discussion topics in the plan. We also recommend the Corps analyzes landscape flows for a variety of flood events, identify restrictive barriers, and identify ways to provide safe alternatives for river flooding. The Service recommends the Corps develop a "tool box" with a variety of hard and non-structural technologies aimed at protecting the entire Texas GIWW shoreline. The Service can assist the Corps with identification of suitable protection measures and BU opportunities along the GIWW as some adjacent areas remain environmentally sensitive.

Wetland Preservation
All marsh habitats along the Texas coast serve as breeding, feeding, and nesting, habitat for a diverse range of fish and wildlife species. Many nationally important commercial and recreational fish and wildlife species spend portions of their life cycle within marsh habitats. As a result of agricultural practices, oil and gas exploration, and commercial development, marsh habitat has been drained or filled resulting in low quality and fragmented habitats. Recent efforts to protect, create, and restore marsh along the Texas coast have been successful; however, additional protection and preservation measures are needed. Wetland types found in coastal watersheds include saltwater marshes, bottomland hardwood swamps, freshwater wetlands, mangrove swamps, shrubby depressions, and prairie potholes. Much of the

Texas coast is dominated by intermediate, brackish, or saline wetlands while fresh water wetlands are either impounded and are usually found further inland. Coastal emergent wetlands provide important transitional habitat between the gulf waters and lands protecting against storm surge, act to slow wave velocity, combat sea level rise, and have a tremendous ecological and economic value.

Both freshwater swamp and freshwater marsh, often occurring in intermeshing context within large wetland tracts, occur in abundance within the northern upper Texas coast. Primary swamp type is cypress-tupelo swamp, which is characterized by common baldcypress *Taxodium distichum* and tupelo gum *Nyssa aquatica* overstory, and numerous aquatic understory species such as bulltongue *Sagittaria lancifolia*, swamp lily *Crinum americanum*, pickerel weed *Pontederia cordata*, smartweed *Polygonum sp.*, and blue iris *Iris sp.* Large tracts of cypress-tupelo swamp occur in permanently and semi-permanently flooded areas along the Neches River north of Interstate (I-) 10 and along the Sabine River north of I-10.

Swamp scrub and freshwater marsh are often intermixed within cypress-tupelo tracts, either in natural meander scars or in areas completely logged in the past which have not reforested. Primary plant species here are buttonbush *Cephalanthus occidentalis*, rattlebean *Sesbania drummondii*, box elder *Acer negundo*, swamp privet *Foresteria acuminata*, cattail *Typha latifolia*, and Virginia tea *Itea virginica*. Preserving and restoration of freshwater marsh/scrub shrub habitat, although cypress-tupelo swamp should be the long term goal along the upper Texas coast due to its high productivity and recreational value to wetland users, primarily waterfowl hunters, fishermen, and birdwatchers should be a principal concern for this study.

Intermediate marsh covers much of the study area and is characterized as marsh type is located between brackish and fresh marsh with salinity averages about 3.3 ppt. Intermediate marsh has an irregular tidal regime, is oligohaline, and is dominated by narrow-leaved, persistent species such as marshhay cordgrass (*Spartina patens*). Plant diversity and soil organic matter content is higher than in brackish or saline marshes. This marsh is characterized by a diversity of species, many of which are also found in freshwater and brackish marshes. Characteristic species include roseau cane *Phragmites australis*, bulltongue *Sagittaria lancifolia*, coastal water hyssop *Bacopa monnieri*, spikesedge *Eleocharis* spp., Olney's bulrush *Schoenoplectus americanus*, California bulrush *Schoenoplectus californicus*, American bulrush *Schoenoplectus pungens*, saltmarsh bulrush *Bulboschoenus robustus*, deer pea *Vigna luteola*, seashore paspalum *Paspalum vaginatum*, switch grass *Panicum virgatum*, bearded sprangletop *Leptochloa fascicularis*, camphor-weed *Pluchea camphorata*, Walter's millet *Echinochloa walteri*, fragrant flatsedge *Cyperus odoratus*, alligator weed *Alternanthera philoxeroides*, southern naiad *Najas guadalupe*nsis, big cordgrass *Spartina cynosuroides*, and gulf cordgrass *S. spartina*e. Two other major autotrophic groups in intermediate marsh are epiphytic and benthic algae. Intermediate marsh occupies the least acreage of any of the four marsh types. This marsh type is very productive of many species of wildlife and is important to larval and postlarval marine organisms such as shrimp sp., crabs *Callinectes* sp., Gulf menhaden *Brevoortia patronus*, etc. Hydrological changes to this marsh community may shift to either fresh or brackish marsh if salinities rise or fall due to weather events such as droughts, excessive rainfall, or influxes of sea water.

Brackish marsh occurs in areas located between the high-salinity saline marshes near the Gulf of Mexico and the intermediate areas further removed from the Gulf. Brackish marsh is generally considered "slightly salty"; with salinity levels varying over a wide range from location to location. In coastal Texas, the typical brackish marsh vegetation pattern occurs in areas within approximately the 4 to 15 ppt normal salinity range. Common, usually dominant, vegetation in these areas is saltmarsh bulrush *Bulboschoenus robustus*, seashore saltgrass *Distichlis spicata*, marshhay cordgrass *Spartina patens*, dwarf spikerush

Eleocharis parvula, waterhemp *Amaranthus australis*, and marsh pea *Vigna luteola*. Brackish marsh areas have cyclically high waterfowl populations, especially in years following high-salinity events when freshwater levels return to normal and periodic "blooms" of prime food plants such as widgeongrass *Ruppia maritima* and *Paspalum* sp. occur. Furbearers such as muskrat *Ondatra zibethicus*, formerly an important commercially-harvested animal in portions of the study area, also occur in cyclically high numbers. Brackish marshes have suffered some of the highest rates of marsh loss due to subsidence and loss of organic materials as formerly fresh areas are subjected to salinity intrusion, resulting in plant loss.

Salt marsh is formed when salt-tolerant plants take root on mud flats around edges of bays, usually slowing the flow of water during high tides, allow sediment to settle out, an raises elevation for plant life to continue. Plants in the salt marsh are usually dominated by smooth cordgrass *Spartina alterniflora*, seashore saltgrass, blackrush *Juncus romerianus*, saltmarsh aster *Aster tenuifolius*, and glasswort *Salicornia* sp. Gulf coastal salt marshes are often almost exclusively smooth cordgrass-dominated and comprise important marine nursery habitat, probably due to its ready access to estuaries, though wildlife populations are less diverse than in nearby intermediate and freshwater marshes. However Gulf coast coastal marsh habitat southward from the Coastal Bend area comprises mainly black mangrove *Avicennia germinans* interspersed with smooth cordgrass.

Texas NWRs many established to conserving wetland habitats specifically for the benefit of migratory waterfowl contain coastal marshes that provide wintering habitat for hundreds of thousands of geese and ducks and provide critical landfall sites in the spring for neotropical migratory birds. Wetland hydrologic connectivity remains a challenge across the coastal landscape as much of the region was transformed as a result of agricultural practices, navigation, development, and industry. Reestablishing hydrologic connectivity among wetlands remains a focus for the Service.

Recommendations

The Service supports the creation, preservation, and restoration of wetlands along the Texas coast to include coastal and inland marsh habitats. Much of the coastal landscape is altered in large part due to commercial, industrial, and residential development. Restoring hydrological flows by removing barriers specific to tidal exchange, impoundments, and levees will improve aquatic function, promote fish and wildlife dispersal, and aid in providing improved sediment and water quality on the larger landscape. Large tracts of coastal and inland marsh benefit the endangered whooping crane and other aquatic and terrestrial wildlife species; while providing improved water quality and protection from storm surge events. The Service, in conjunction with the other federal, state, and local natural resource agencies, can assist with priority wetland tract identification that benefits migratory fish and wildlife.

Seagrass Beds

One of the most biologically productive, recreationally and economically valuable habitats, seagrass beds provide feeding and nursery habitat for waterfowl, fish, shrimp, crabs and other economically important estuarine species (U.S. Fish and Wildlife Service) as well as sea turtles, manatees, and countless invertebrates that are produced within, or migrate to seagrasses. Seagrass helps to dampen the effects of strong currents, prevent erosion, enhance water clarity, provide protection to fish and invertebrates, and prevent scouring of bay bottom areas. Sea grasses are usually found in calm, shallow gulf waters where higher salinities, light, and nutrients are plentiful. Excessive freshwater inflows into a bay system can decrease salinities to near brackish conditions, and depending on the duration of the fresh conditions, some seagrass species are not physiologically capable of tolerating these extreme conditions and may die and areas recolonized with less favored species.

The majority of Texas seagrass meadows occur along the middle and lower Texas coast where waters are warm, clear, and have higher salinities. Almost 80 percent of the remaining seagrass habitat in Texas is located in the Laguna Madre System and however abundant, this resource remains threatened. The Laguna Madre is the only hyper-saline coastal lagoon in North America, one of only five in the world. These seagrass beds are the winter home to 80 percent (as many as 700,000 individuals) of the continental population of redhead ducks and are now confined to wintering areas on the Gulf of Mexico due to declining abundance of seagrasses along the Atlantic Coast. Ducks Unlimited, (2017) estimates the decline of shoalgrass, the preferred forage of redheads, is more than 40 percent in the Laguna Madre since 1965 and can be linked to decreasing salinities and navigation projects. 1950's aerial photographs indicate seagrasses once present in the Galveston Bay system, ranged from 2,500 to 5,000 acres, and were completely eliminated by 1989. Restoration efforts by transplanting and seed broadcasting in portions of West Galveston Bay have been successful and seagrasses are slowly spreading on the upper Texas coast. Biotic and abiotic threats to seagrasses such as storms, excessive grazing by herbivores, disease, and anthropogenic threats due to point and non-point sources of pollution, decreasing water clarity, excessive nutrient runoff, sedimentation, sea level rise, and prop scarring negatively affect these diverse communities coast wide.

Conservation and protection of sea grass is the best and first approach for this vital resource, however restoration efforts to benefit seagrasses have had some success along the Texas coast. The Service along with other federal, state, and local partners work cooperatively to restore seagrass meadows along the coast utilizing a combination of hand planting and specially designed boats which rapidly injects nutrients, plant growth hormones and sprigs of seagrass in the bottom substrate, and by hand-planting seagrasses. Although restoration efforts are underway, continued damage from prop scaring, anchors, and ill-timed dredge material deposition threaten coastal seagrass beds all along the coast.

Recommendations
The Service recommends the Corps work in coordination with the federal, state, and local resource agencies to develop an interagency team focused on small and large scale seagrass monitoring and restoration along the entire Texas coast as well as dedicating funding for seagrass research. The Service recognizes the Corps' need to dispose of dredge maintenance material and remains committed to working with the Corps to monitor and address seagrass issues related to on-going maintenance dredging work. We expect any future Corps dredging actions including but not limited to, beneficial use of dredge material and open water placement will fully consider effects to seagrasses and will include coordination with the aforementioned interagency team. Finally, the Service continues to recommend a combined approach of outreach, education, and improved signage within channels and marinas aimed to avoid and reduce impacts to seagrass beds. As part of the outreach effort, the Service recommends the Corps develop and permanently fund a website dedicated to the status, monitoring, and research of seagrasses along the Texas coast.

Tamaulipan Thornscrub Habitat
Tamaulipan thornscrub has a unique richness of flora and fauna not found in other ecosystems and is attributed to improved hunting experiences in South Texas (Erwing & Best, 2004). The presence of rare communities combined with the area's rich diversity of bird and butterfly species make South Texas one of the state's most popular nature tourism destinations. Private wildlife sanctuaries (such as those purchased and managed by The Nature Conservancy and others) provide protection for wildlife and help create much needed migratory corridors aimed at connecting tamaulipan thornscrub habitats. Land clearing for ranching, agriculture and urbanization resulted in the loss of more than 95 percent of the wildlife habitat in the Lower Rio Grande Valley of Texas. While ranching and agriculture traditionally have been the dominant industries in the Lower Rio Grande Valley area, landowners increasingly turn to

alternative land uses; and as a result, landowners are more interested in developing wildlife based habitats and activities. The diverse habitat of the lower Rio Grande Valley combined with the Valley's location within the Central Flyway, more than 500 bird species have been recorded in the area. A diverse avifuana presence on the LRGNWR makes it a key birding destination where over 354 bird species can be seen. The dense scrub habitat

The Service established the Lower Rio Grande Valley National Wildlife Refuge (LRGNWR) to specifically acquire, manage, and restore tamaulipan thornscrub habitat creating a wildlife corridor stretching from Falcon Dam on the Rio Grande to the Gulf of Mexico (approximately 140 miles) (Erwing & Best, 2004). This wildlife corridor aims to benefit wildlife species including the ocelot *Leopardu pardalis,* jaguarundi *Puma yagouaroundi*, Texas tortoise *Gopherus berlandieri*, northern aplomado falcon *Falco femoralis septentrionalis*, Brownsville common yellowthroat *Geothlypis trichas insperata*, Lomita Carolina wren *Thryothorus ludovicianus* , southern yellow bat *Lasiurus ega* , speckled racer *Drymobius margaritiferus* , black-spotted newt *Notophthalmus meridionalis*, Mexican white-lipped frog *Leptodactylus fragilis* , and the Rio Grande lesser siren *Siren intermedia.*

Current population estimates for the ocelots in South Texas is fewer than 60 individuals with a total of 100 remaining in the United States where the gene pool exchange remains limited. Habitat loss, fragmentation, and vehicular collisions are common and contribute to overall population decreases. The Service continues to work with private landowners and other federal, state, and local agencies to acquire, secure easements, and provide technical assistance to restore tamaulipan thornscrub habitat in this area.

While the endangered jaguarundi have historically occurred in southeast Arizona, South Texas, Mexico and Central and South America as far south as northern Argentina, biologists today believe the cat still occurs throughout most of the range except in Arizona; however, the population status is unknown and presumably smaller than the ocelot because confirmed sightings are rare. In South Texas, jaguarundi are known to occur (last verified siting in mid-1990s) in only Cameron and Willacy counties where they prefer dense mixed brush with dry washes, arroyos, resacas, and the floodplains of the Rio Grande. Unfortunately, loss of habitat to agriculture production remains the main threat to the jaguarundi. The Service supports the acquisition of property aimed at preserving thornscrub habitat which furthers the Service's Recovery Plan's (U.S. Fish and Wildlife Service, 2013) effort to create a wildlife corridor for terrestrial species negatively impacted by thornscrub clearing.

Recommendations
Tamaulipan thornscrub is not a recognized habitat within the Texas Coastal Study. The Service considers this a rare habitat unlike any other region of the United States due to the combination of climate, vegetation, and associated wildlife. We remain committed to the preservation of thornscrub habitat and recommend the Corps coordinate with other federal, state, and local natural resource agencies to identify suitable tracts of land for acquisition or placement into conservation status. This action will promote the status of key wildlife species; improve wildlife corridors and the overall health of tamaulipan thornscrub ecosystems in south Texas.

Research and Monitoring Needs
To ensure a bright future for fish and wildlife in the face of widespread threats such as drought, climate change and large-scale habitat fragmentation, we can no longer base our actions solely on past experiences and success. Conserving these large landscapes which are subject to multiple changing pressures and uncertainties will require application of the best available science at every step. Because management of natural systems is not always predictable, having specific and measurable biological

objectives that summarize the existing scientific knowledge and present testable hypotheses is essential for effective restoration planning.

The Service relies on informed decision making where gathering and improving knowledge is a reiterative process and necessary in understanding the stressors on coastal habitats and living marine resources of Texas and the larger ecosystems of the Gulf of Mexico. Stressors such as continued energy exploration, the procession of climate change, coastal developments, alterations in hydrology, industrial activities, fishing pressures, and many others continue to impact the system and can hinder its ability adapt and function at healthy levels.

Losses of these coastal habitats and living marine resources directly translate into diminished future resources available for coastal residents. The Service supports the research priorities identified under the Texas One Gulf draft Strategic Research and Action Plan (2017) which aim to maintain or increase biodiversity, defining "baseline" conditions, idenitfy stressors and pressures impacting the Gulf of Mexico, and understand connections between estuarine and coastal environments and the offshore and deeper Gulf of Mexico environments.

Recomendations
We encourage the Corps to consider recommending the study and analysis of specific coastal issues in the Study's Comprehensive Plan to compliment restoration project identification. The Service in combination with the other state and federal natural resource agencies can work with the Corps to identify gaps in research specific to coastal habitats. This approach will assure the greatest chance for future restoration success. Additionally, monitoring of natural resources after project construction is also recommended where project success will be defined by specific criteria prior to construction. The Service appreciates the opportunity to review and comment on the success criteria developed for each restoration site.

Service Priorities
Through this PAL, the Service outlined key habitats and research opportunities within the four regions of the Coastal Texas Study's boundaries. Specifically, the Service provided concerns and recommendations to conserve and protect these highlighted habitats: wetlands, oysters, bird islands, beach and dune habitat, coastal prairies, seagrasses, and tamaulipan thornscrub. Below is a list of high action coastal Texas priorities based on the Service's visions:

- Restore and conserve agricultural and working ranchlands that complement and support the connectivity of land, invasive species control and water conservation efforts in the Rio Grande area.
- Enhance the existing network of conservation lands linking the Rio Grande River Valley and the South Texas coastal ecosystem to ensure that fish and wildlife resources are sustainable.
- Reconnect hydrology and watershed diversions, such as the Bahia Grande, and restore wetlands and aquatic habitat for fish and other aquatic and wetland dependent species.
- Create a conservation network of lands through conservation easements or acquisition of grassland savanna and prairies, woodlands, and riparian areas in the Texas coastal bend region.
- Manage non-native species, reintroduce native plants, restore natural drainage features and use frequent prescribed fire to restore grassland savannas and prairies on former farmland and working ranchlands to enhance habitat for native plant pollinators.

- Support water-sharing efforts to provide freshwater input to coastal ecosystems that account for the needs of people and natural resources, including commercially significant fisheries and culturally important species like the whooping crane in the Coastal Bend area.
- Conservation, restoration, and continued management of native grassland prairie habitats are necessary to meet the life requisites of federally listed species and species of concern and continue to be a focus for the Service.
- Protect critical bottomland habitat adjacent to the Trinity, San Bernard, and Brazos Rivers that represent significant stopover destinations and staging areas for millions of songbirds and landbirds during their migration across the Gulf.
- Protect and restore coastal prairie in its historic upland and wetland complex on former rice cultivation fields to support pollinators, grasslands and wetland dependent species like the mottled duck and the bobwhite quail, as well as wintering waterfowl, water birds, and shorebirds.
- Restore hydrologic processes including watersheds and diversions (e.g., Salt Bayou project) to restore and enhance wetlands and aquatic habitats to enhance fisheries and habitat for wetland dependent species.
- Restore landscapes and interrupted sedimentary processes by incorporating beneficial use of dredged material, direct, dredging and erosion protection with willing public and private land managers.
- The Chenier Plain is best served by conserving coastal prairie landscapes by recovering historic pothole and mound complexes and re-introducing native prairie species on former agricultural (rice) lands to support pollinators, grassland and wetland dependent species like the mottled duck and bobwhite quail, and wintering waterfowl, waterbirds, and shorebirds.
- Success criteria, monitoring, and adaptive management should be incorporated in to all projects to ensure project success.

We appreciate the opportunity to identify and highlight key coastal habitats and the fish and wildlife that occur there. We look forward to working with the Corps and our partners in the future to identify to develop a list of specific research and restoration opportunities. Please contact staff biologist, Donna Anderson or myself at 281-286-8282 with any questions.

Sincerely,

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Works Cited

Arvin, J. (2009). Hurricane shifts plover populations. *13*(1).

Audubon Nature Institute. (2017). *Texas Shrimp Action Plan.* New Orleans: Gulf United for Lasting Fisheries.

Cohen, J., Wunker, E. H., & Fraser, J. D. (2008). Substrate and vegetation selection by nesting piping plovers. *Wilson Journal of Ornithology, 120*, 404-407.

Drake, K., Thompson, J., Drake, K., & Zonick, C. (2001). Movements, habitat use and survival of non-breeding piping plovers. *Condor*, 259-267.

Ducks Unlimited. (n.d.). *"Redhead Central"*. Retrieved June 5, 2017, from Ducks Unlimited: http://www.ducks.org/conservation/waterfowl-habitat/redhead-central

Ducks Unlimited. (n.d.). *Ducks Limited.* Retrieved July 21, 2016, from Gulf Coastal Prairie: http://www.ducks.org/conservation/where-ducks-unlimited-works/gulf-coastal-prairie

Erwing, K., & Best, C. (2004). South Texas Tamaulipan Thornscrub restoration experiment measures growth of planted woody vegetation. *Eological Restoration, 22*(1), 11-17.

Haggerty, M., & Meuth, M. P. (2015). *Texas Master Naturalist.* College Station: Texas A&M AgriLife Extention Service and Texas Parks and Wildlife Department.

Haig, S., & Elliott-Smith, E. (2004). *Piping Plover Charadrius melodus.* (C. L. Ornithology, Editor) Retrieved August 2017, from The Birds of North America Online.

Houston Chronicle. (2015). *"Galevston County declares oyster disaster"*. Retrieved June 15, 2016, from Houston Chronicle: http://www.houstonchronicle.com/neighborhood/bayarea/business/article/Galveston-County-declares-oyster-disaster-8152865.php

Kellison, R., & Young, M. Y. (1997). The bottomland hardwood forest of the southern United States. *Forest Ecology and Managment, 90*(2-3), 101-115.

Krainyk, A., & Ballard, B. (2015). *Decision Support Tool: Prioritization of Mottled Duck habitat for conservation and management in the Western Gulf Coast.* Kingsville : Texas A&M University-Kingsville.

Lockwood, M. a. (2004). The Ornthilogical Society handbook of Texas birds. College Station: Texas A&M University Press.

Merendino, M. T., Lobpries, D. S., Neaville, J. E., Ortego, J. D., & Johnson, W. P. (2005). Regional differences and long-term trends in lead exposure in mottled ducks. *Wildlife Society Bulletin, 33*(3), 1002-1008.

Morrison, G. R., Ross, R. K., & Niles, L. J. (2004). Declines in wintering populations of Red Knots in Southern South America. *Condor, 106*, 60-70.

Noel, B. a. (2008). Spatial distribution and site fidelity of non-breeding Piping Plover on the Georgia Coast. *Waterbirds, 31*, 241-251.

Palmer, R. (1967). Piping Plover. In *The Shorebirds of North America* (p. 270). New York City: Viking Press.

Rosiere, R., Nelson, A., & Cowley, L. P. (2013). Composition and structure of mixed-hardwood bottomland forest in the West Cross Timbers of North Central Texas. *The Southwestern Naturalist*, 81-90.

Shaver, D. (2017, August 3). Texas Nest Update. *Email.*

Texas A&M University . (n.d.). *Galveston Campus Seafood Safety Lab*. Retrieved July 31, 2017, from Vibrio Studies: http://www.tamug.edu/seafoodsafetylab/Research/Vibrio%20Studies.html

Texas Conservation Alliance. (n.d.). *Importance of Bottomland Harwood Forests*. Retrieved August 3, 2016, from http://www.tcatexas.org/?portfolio=importance-of-bottomland-hardwood-forests

Texas Department of Transportation. (n.d.). *The Texas Maritime Transportation System: Delivering the Goods*. Retrieved June 13, 2016, from https://ftp.dot.state.tx.us/pub/txdot-info/tpp/giww/ports-brochure.pdf

Texas One Gulf Center of Excellence. (2017). *Strategic Research and Action Plan.* Corpus Christi: Texas One Gulf.

U.S. Fish and Wildlife Service. (1997). *Austin Woods Conservation Plan.* U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. (2009). *Piping Plover (Charadrius melodus) 5-Year Review. Summary and Evaluation.* Hadley, Mass.

U.S. Fish and Wildlife Service. (2013). *Gulf Coast Jaguarundi Recovery Plan.* Albuquerque: U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. (n.d.). *Seagrass restoration and protection strategies.* Retrieved July 27, 2016, from https://www.fws.gov/southwest/texascoastal/seagrass.html

USACE. (2016). *Information to be Included in Revising Restoration Strategy Document.* Galveston: USACE.

USACE. (2016). *The U.S. Waterway System 2016 Transportation Facts and Information.* Washington D.C.: U.S. Army Corps of Engineers .

Wilbur, D., & Clarke, D. G. (2001). Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. *North American Journal of Fisheries Management, 21*(4), 855-873.