Appendix C-4

Essential Fish Habitat Assessment

Job No. TGL18185

APPENDIX C-4

DRAFT
ESSENTIAL FISH HABITAT ASSESSMENT
FOR THE
COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Prepared for:

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

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Acronyms and Abbreviations

°F	degrees Fahrenheit
AdH	Adaptive Hydraulics
ADM	Agency Decision Milestone
CFR	*Code of Federal Regulations*
Coastal Texas	Coastal Texas Protection and Restoration Study
CSRM	coastal storm risk management
DIFR-EIS	Draft Integrated Feasibility Report and Environmental Impact Statement
DO	dissolved oxygen
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ER	ecosystem restoration
ERDC	Engineer Research and Development Center
GIWW	Gulf Intracoastal Waterway
GLO	Texas General Land Office
GMFMC	Gulf of Mexico Fisheries Management Council
Gulf	Gulf of Mexico
HAPC	Habitat Areas of Particular Concern
mg/L	milligrams per liter
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NAVD 88	North American Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NWRs	National Wildlife Refuge
ppt	parts per thousand
RSLR	relative sea level rise
SAV	submerged aquatic vegetation
SLR	sea level rise
SMART	Specific, Measurable, Attainable, Risk Informed, Timely
su	standard units
TPWD	Texas Parks and Wildlife Department
TSP	Tentatively Selected Plan
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers

1.0 INTRODUCTION

The Coastal Texas Protection and Restoration Study (Coastal Texas) Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR-EIS) is examining coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities within 18 counties of the entire Texas Gulf coast (Figure 1). The Feasibility Cost Sharing Agreement for this study was signed in November 2015 with the non-Federal sponsor, the Texas General Land Office (GLO). The study has identified and screened alternatives to address CSRM and ER and has presented a Tentatively Selected Plan (TSP) (Preferred Alternative). On March 31, 2016, the U.S. Army Corps of Engineers (USACE), Galveston District published a Notice of Intent (NOI) in the *Federal Register* (Volume 81, Number 62, 18601) declaring its intent to prepare a DIFR-EIS to determine the feasibility of implementing the Coastal Texas Study.

The TSP will consist of a barrier system of levees or floodwalls along Bolivar Peninsula; surge barrier gates across Bolivar Roads, at the Gulf Intracoastal Waterway (GIWW), Clear Lake, Dickinson Bayou, and Offatts Bayou; improvements to the Galveston Seawall; and a barrier system of levees or floodwalls along the west end of Galveston Island. In addition, a ring levee around the city of Galveston and potential nonstructural improvements along the bay rim on the west side of Galveston Bay are proposed along with several pump stations and smaller gates along the bay. Currently, the Coastal Texas Study has completed the TSP milestone phase of the USACE Specific, Measurable, Attainable, Risk Informed, Timely (SMART) Civil Works planning process, where a plan has been tentatively selected for agency, technical, and public review, and vertical chain of command approval. At this stage of the planning, the major components of the plan have been identified and evaluated at a higher level of analysis and will be analyzed in greater detail and refined in the next planning phase, following approval during the Agency Decision Milestone (ADM) meeting. Consistent with USACE policy in Planning Bulletin PB 2017-01, there is a certain level of uncertainty expected in the size and make-up of the TSP, and other plans identified from the suite of alternatives analyzed in this initial phase, including the National Economic Development (NED) Plan, or a variant preferred by the non-Federal sponsor. As such, the final size of the measures (width, length, etc.), and inclusion or exclusion of some of them in the TSP presented in this Draft Essential Fish Habitat (EFH) Assessment may change in the next planning phase. These changes can affect the habitat impacted. Because of the conservative nature of economic and engineering assumptions used during the initial planning of the TSP, it is anticipated that the design of proposed structures will result in equal or lesser environmental impacts.

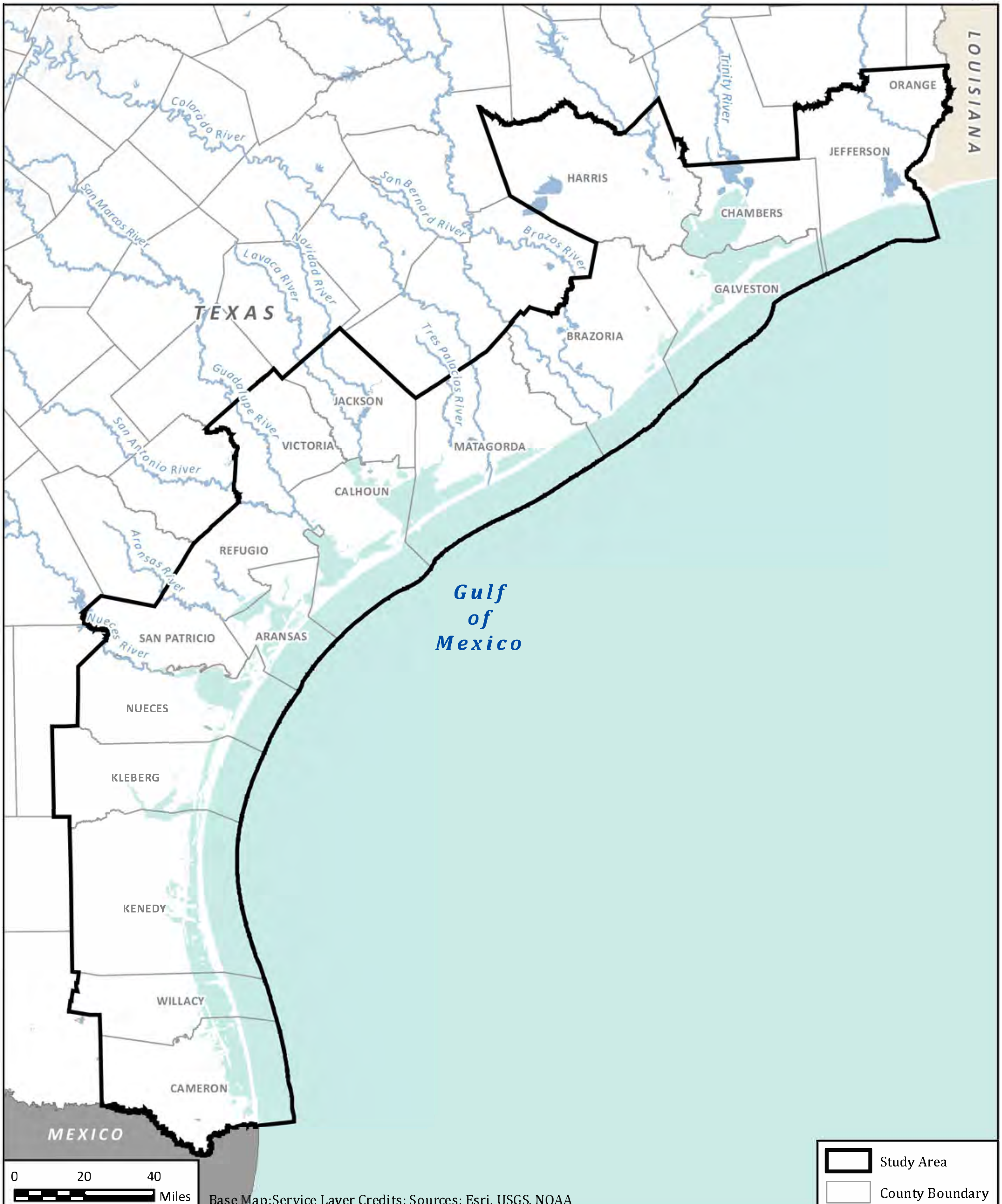
In informal discussions with the National Marine Fisheries Service (NMFS), it was determined that preparation of an EFH Assessment pursuant to 50 *Code of Federal Regulations* (CFR) Section 600.920(i) would be required based on the size of the project and potential impacts to EFH. This report presents an evaluation of potential EFH and fisheries within the project area. The study area encompasses 18 coastal counties along the Gulf coast and bayfronts (Figures 2a through 2e). The project area is defined as those areas that will be directly affected by construction or operation activities as a result of the Preferred Alternative of the Coastal Texas Study. The purpose of the investigation was to identify Federally managed species protected under the 1996 Amendment to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) that might occur in the vicinity of the project. This EFH assessment is included as part of the DIFR-EIS.

1.1 ROLE OF NATIONAL MARINE FISHERIES SERVICE IN ESSENTIAL FISH HABITAT CONSULTATION

Congress enacted amendments to the MSFCMA (PL 94-265) in 1996 that established procedures for identifying EFH and required interagency coordination to further the conservation of federally managed fisheries. Rules published by the NMFS (50 CFR Sections 600.805–600.930) specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake an activity that could adversely affect EFH is subject to the consultation provisions of the above-mentioned act and identifies consultation requirements. EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” EFH is separated into estuarine and marine components. The estuarine component is defined as “all estuarine waters and substrates (mud, sand, shell, rock, and associated biological communities); subtidal vegetation (seagrasses and algae); and adjacent intertidal vegetation (marshes and mangroves).” The marine component is defined as “all marine waters and substrates (mud, sand, shell, rock, and associated biological communities) from the shoreline to the seaward limit of the Exclusive Economic Zone” (Gulf of Mexico Fisheries Management Council [GMFMC], 2004). Adverse effect to EFH is defined as, “any impact, which reduces quality and/or quantity of EFH…” and may include direct, indirect, site specific or habitat impacts, including individual, cumulative, or synergistic consequences of actions.

1.2 PREFERRED ALTERNATIVE AND ALTERNATIVES

The Preferred Alternative involves a combination of CSRM and ER measures along the Texas coast. CSRM features include building and extending levees, T-Wall/L-Walls, a combi-wall system, ring levee/floodwall, seawall modification, surge barrier gates (which include a navigable floating sector gate and environmental lift gates), modernization of existing hurricane flood protection, beach/dune restoration, and limited nonstructural efforts to raise or retrofit existing structures. ER measures include revetment/breakwaters, island restoration, wetland and marsh restoration, oyster reef creation, dune/beach restoration, dredging, and out-year marsh nourishment in 2065. These measures would work together to provide multiple lines of defense to protect coastal ecosystems and human infrastructure from storm damage caused by hurricanes and tropical storms coming ashore from the Gulf.



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	Study Area	SCALE 1:2,377,085 DESIGNED SSJ DRAFTED SSJ	**FIGURE**

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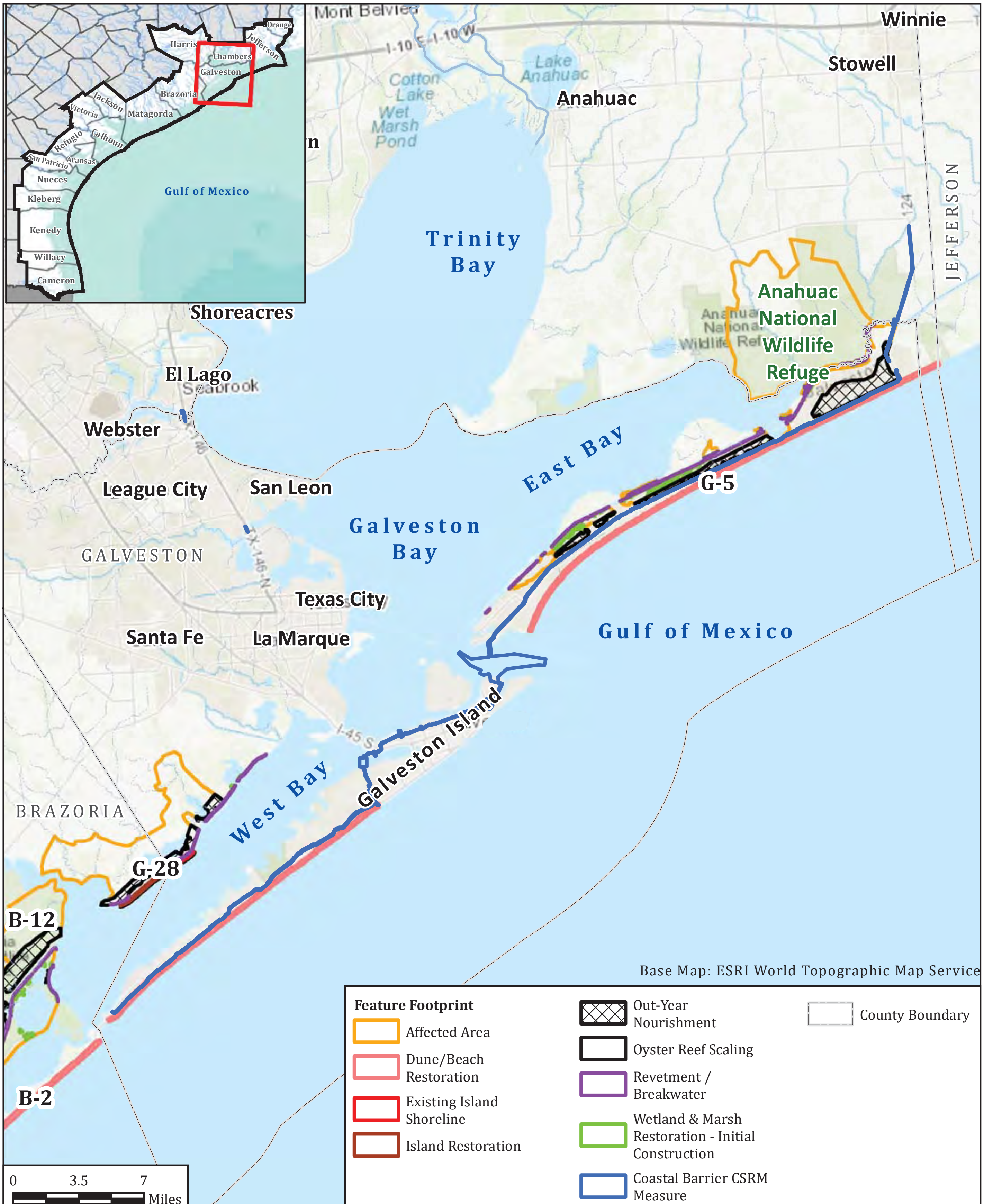

N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Coastal Barrier Alternative
Coastal Barrier CSRM Measure & ER Measures

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2a
FIGURE

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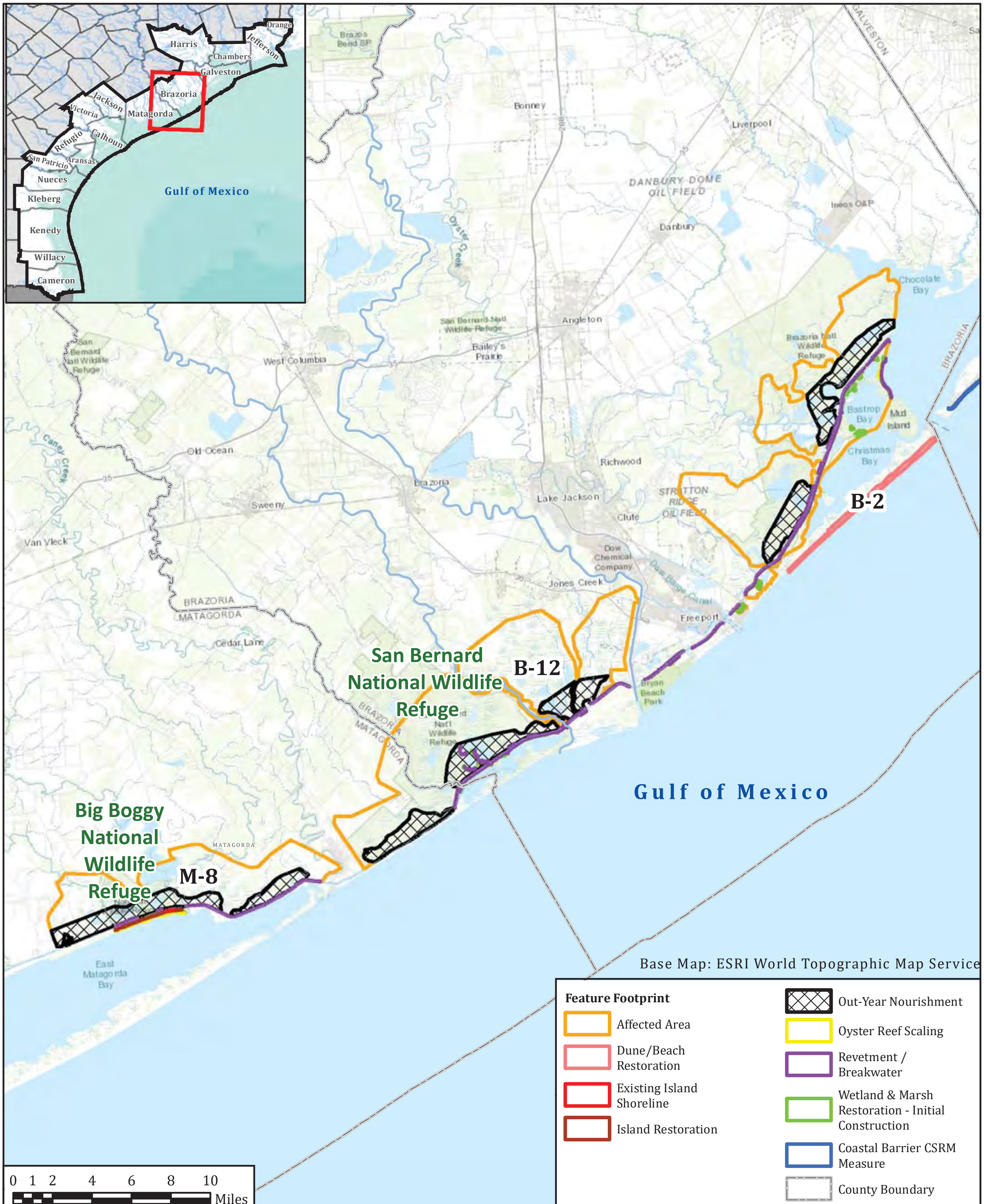

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Coastal Barrier Alternative
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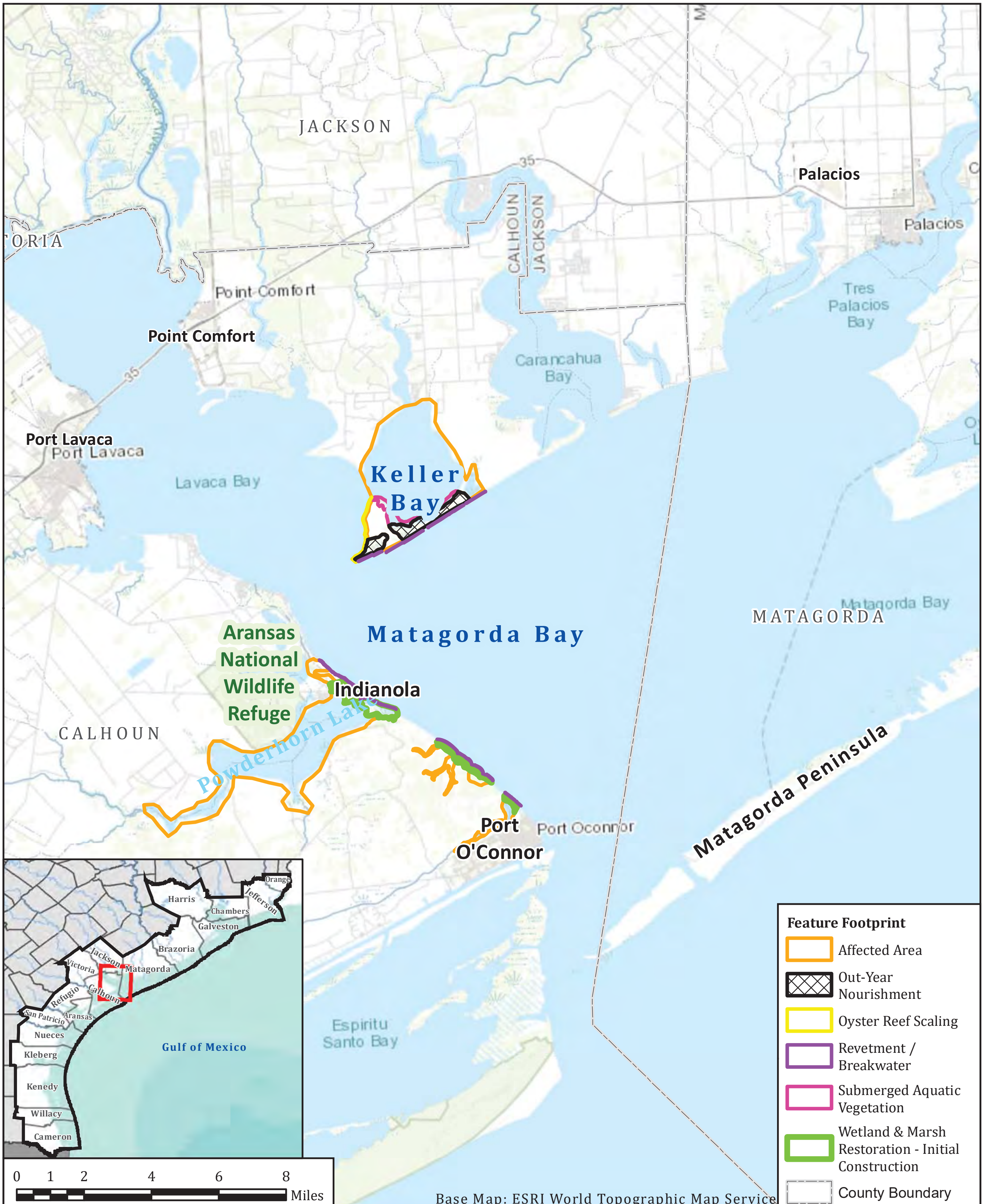

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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Coastal Barrier Alternative
Coastal Barrier CSRM Measure & ER Measures

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FIGURE

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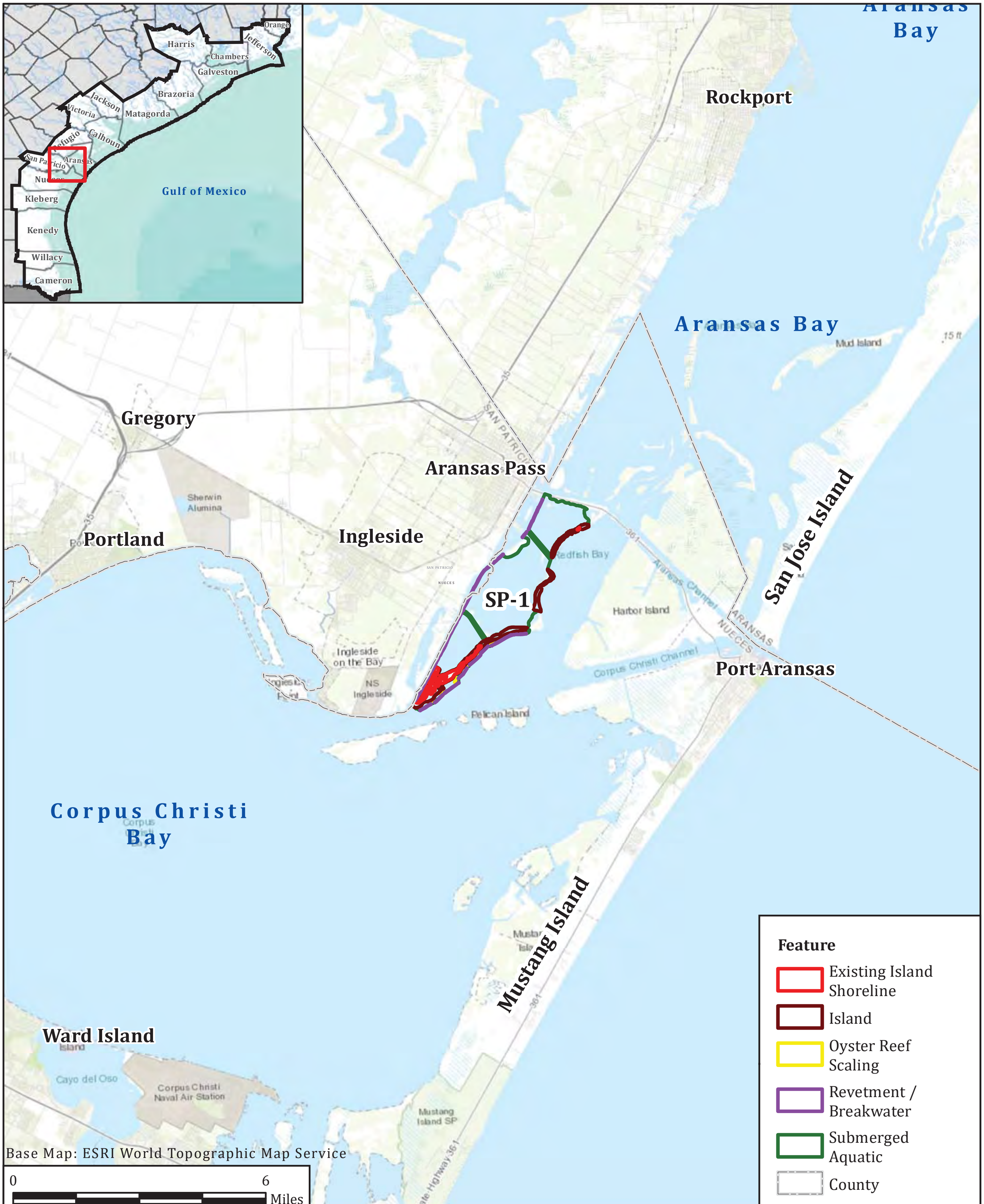

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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Coastal Barrier Alternative
Coastal Barrier CSRM Measure & ER Measures

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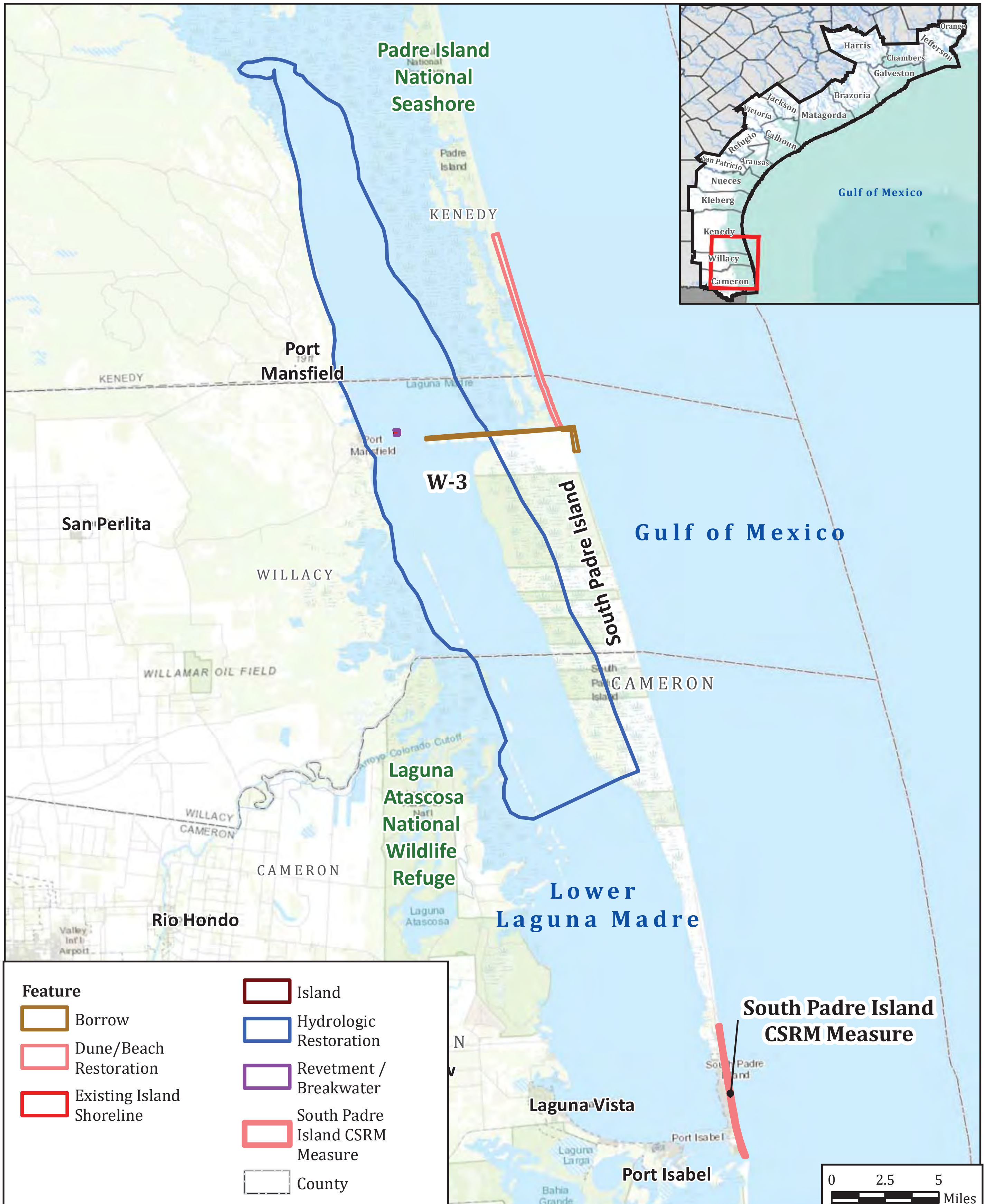
2d
FIGURE

GCS North American 1927



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Coastal Barrier Alternative
South Padre Island CSRM Measure & ER Measure

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2e
FIGURE

1.2.1 No-Action Alternative

The No-Action Alternative provides a means to evaluate the environmental impacts that would occur if the proposed CSRM and ER measures were not constructed. The characterization of the No-Action Alternative provides a baseline for comparison of performance and impacts of the Preferred Alternative.

1.2.2 Coastal Barrier Alternative

The Coastal Barrier Alternative proposes the construction of two CSRM measures, the Coastal Barrier CSRM System (Coastal Barrier) on the upper Texas coast and the South Padre Island CSRM Measure, and the construction of nine ER measures spread out along the entire Texas coast.

The Coastal Barrier includes levees/floodwalls along Bolivar Peninsula and Galveston Island, improvements to the Galveston seawall, a ring levee around the city of Galveston, floodwalls (inverted T-walls), floodgates (both highway and railroad floodgates), drainage structures, pump stations and navigable gate structures on the GIWW near High Island and near the mouths of Offatts Bayou, Dickinson Bayou, and Clear Creek. The biggest feature of the Coastal Barrier is the crossing at the Houston Entrance Channel between Bolivar Peninsula and Galveston Island. This crossing is approximately 11,000 feet across and the feature would span that distance with a floating sector gate with a 1,200-foot-wide opening and approximately 39 environmental vertical lift gates along the length of the barrier. The floating sector gate and environmental vertical lift gates are collectively called surge barrier gates.

The South Padre Island CSRM Measure includes a dune and berm with a 10-year renourishment interval. The ER measures are made up of a combination of the following features: revetment/breakwater, island restoration, wetland and marsh restoration, oyster reef creation, dune/beach restoration, and out-year marsh nourishment based on relative sea level rise (RSLR) in 2065.

1.2.3 Bay Rim Alternative

The Bay Rim Alternative proposes the construction of two CSRM measures, the Bay Rim CSRM System on the upper Texas coast and the South Padre Island CSRM Measure, and the construction of nine ER measures that are spread out along the entire Texas coast. The Bay Rim CSRM system consists of a levee/floodwall along the western rim of Galveston Bay, improvements to the Galveston seawall, a ring levee around the city of Galveston, surge barrier gates, and combi-wall at the Houston Ship Channel, and surge barrier gates near the mouths of Offatts Bayou, Dickinson Bayou, Clear Creek, and Highland Bayou Diversion Channel.

The ER measures and South Padre Island CSRM Measure are the same as described for the Coastal Barrier Alternative.

For the purposes of this EFH Assessment, the TSP (Coastal Barrier Alternative) was used to assess potential project area impacts, as described above. A comparison of potential EFH impact results from the Bay Rim Barrier is provided in the Environmental Supporting Document (Appendix C-1).

2.0 EXISTING ENVIRONMENT

For the discussion of the existing environment, habitat types are described within the study areas (see Figure 1), while the evaluation of potential EFH and fisheries resources focuses on the project area footprints (see Figure 2). It should be noted that the study and project areas are similar in habitat and community types.

2.1 HABITAT/COMMUNITY TYPES

Ecoregions are typically considered large geographic areas that are easily distinguished from adjacent regions by differing biotic and environmental factors or ecological processes. Fundamental differences among ecoregions often include changes in climate, physical geography, soils, and large-scale vegetative structure and composition. The project areas are located entirely within the Western Gulf coastal plain, which is a low-elevation area adjacent to the Gulf of Mexico (Gulf; U.S. Environmental Protection Agency [EPA], 2011). Due to its nutrient-rich soils and abundance of rain, much of the land has been converted to cropland and pastures for livestock. About a third of Texas's population resides within 100 miles of the coast along with a large part of the State's industry. The large expanses of intact wetlands and coastal marshes along the coast are also important rest stops and wintering habitats for waterfowl and migrating birds, and the warm Gulf waters are home to a variety of fish and shellfish (Griffith et al., 2007).

The Western Gulf coastal plain can be categorized further into nine distinct Level IV ecoregions (Griffith et al., 2007). These ecoregions are divided based on similarities of soils, vegetation, climate, geology, wildlife, and human factors. The Texas Gulf coast is highly complex and ecologically diverse, with obvious differences in geomorphology between the upper, mid, and lower coast. Habitats along the coast include wetland systems (tidal and non-tidal), seagrass, estuarine bays, lakes, streams, oyster reefs, and man-made and natural beaches. A brief description of each community type is provided below.

Texas-Louisiana Coastal Marshes: This ecoregion contains vast, flat tracts of freshwater and saltwater coastal marshes with many rivers, lakes, bayous, and tidal channels. This part of Texas receives the most precipitation, 48 to 54 inches per year as an annual average, and remains humid year-round. The land is rich in oil and gas reserves. The coast lacks the barrier islands found farther south along the Texas coast. Cordgrass (*Spartina spartinae*, *S. alternaflora*, and *S. patens*) are the dominant vegetation type. Coastal protected lands such as Anahuac, McFaddin, and Moody National Wildlife Refuges (NWRs) provide habitat for wintering waterfowl, American alligators (*Alligator mississippiensis*), and migrating bird species (Griffith et al., 2007). The coastal marshes are also important for commercial fisheries including brown shrimp, blue crab, eastern oyster, and red drum.

Northern Humid Gulf Coastal Prairies: This gently sloping land was once dominated by coastal grassland prairies of little bluestem (*Schizachyrium scoparium*), yellow Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Today most of the native tallgrass coastal prairies have been converted to croplands, livestock pastures, urban, and industrial land. The relatively flat topography and clay subsoils, provided with an abundance of rain (37 to 58 inches annually), retain moisture and keep the area wet for most of the year. Rice, soybean, cotton, hay, and corn production are the main agricultural commodities within the region and use supplemental upstream water provided by canals and irrigation ditches. The conversion of prairie to pasturelands and industrial trade has brought along a string of invasive species such as red imported fire ants (*Solenopsis invicta*), Chinese tallow (*Triadica sebifera*), Macartney rose (*Rosa bracteata*), and King Ranch bluestem (*Bothriochloa ischaemum*), resulting in detrimental effects to native prairie species like the Attwater's prairie chicken (*Tympanuchus cupido attwateri*). Oak mottes and woodlots still exist in a lesser capacity (Griffith et al., 2007). Throughout the year but peaking in the fall and winter, birds and waterfowl can be found utilizing the remaining coastal plains, croplands, and altered habitat as their wintering grounds on the Gulf coast.

Mid Coast Barrier Islands and Coastal Marshes: Stretching from Galveston Bay to Corpus Christi Bay, this ecoregion generally receives less precipitation than the Texas-Louisiana marshes. This region is characterized by barrier islands, tidal marshes, dunes, and salt/brackish/freshwater marshes. Cordgrass, saltgrass, and sedges (*Cyperaceae* spp.) are typically found in the marsh habitats, while seacoast bluestem (*Schizachyrium scoparium* var. *littoralis*) and sea oats are found on sandy barrier islands. During the fall, endangered whooping cranes (*Grus americana*) migrate to the brackish marshes of Aransas NWR to feed (Griffith et al., 2007). Commercial and sport fishing are popular along the coast.

Floodplains and Low Terraces: This ecoregion consists of Holocene floodplains and alluvial deposits. Bottomland forests are the dominant vegetation type in this region consisting of pecan (*Carya illinnoiensis*), live oak (*Quercus virginiana*), elm (*Ulmus* spp.), hackberry (*Celtis occidentalis*), cottonwood (*Populus* spp.), and bald cypress (*Taxodium distichum*) along streams. Large swaths of these floodplain woodlands have been converted to cropland, pastures, and forests. Freshwater flows through these historic floodplains have also been redirected for municipal, industrial, and agricultural uses. Combined with recent droughts in Texas and the Southwest, the Nueces, Brazos, Colorado, and other rivers have experienced greatly diminished flows, which affect the salinity and productivity of downstream estuaries and bays (Griffith et al., 2007).

Southern Subhumid Gulf Coastal Prairies: Generally drier than the northern humid Gulf Coastal Prairies, this region only receives about 26 to 37 inches of rain annually. The regional soil temperature is hyperthermic meaning it stays above 71.6 degrees Fahrenheit (°F). Decades of fire suppression, overgrazing, and other disturbances have led to an increased abundance of woody and thorny-scrub plants such as honey mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), blackbrush (*Vachellia rigidula*), and granjeno (*Celtis pallida*). Prairie grassland species such as little bluestem, Gulf muhly (*Muhlenbergia capillaris*), and switchgrass can still be found but in less abundance than described in historical records (Griffith et al., 2007).

Coastal Sand Plains: These sandy plains were formed from Holocene-era sand dune deposits blown inshore by Gulf winds. The co-dominant habitat types are mesquite-live oak-prickly pear savannahs and tall coastal grasslands with bluestem and switchgrass. Most of the area is used for cattle grazing, which can lead to land degradation and erosion. The land is semiarid, receiving on average 24 to 27 inches of rain per year. As dry as it may seem, seasonal tropical storms can provide enough moisture to sustain sizable wetland ecosystems in sandy depressions and swales. Saline wetlands are found closer to the coast and contain Gulf cordgrass (*Spartina spartinae*) and seashore saltgrass (*Distichlis spicata*) (Griffith et al., 2007). These are productive habitats that support a variety of nesting birds and waterfowl. Private landholdings, like the King Ranch, are used for hunting, raising livestock, agriculture, bird watching, and wildlife tourism.

Lower Rio Grande Valley: This ecoregion was once an expanse of native grassland and woodland habitat but now much of this region has been converted into cropland, pasture, and urban landscapes. Decades of livestock management have led to mesquite (*Prosopis* spp.), granjeno, and other species of scrub brush invading the landscape and soil erosion. The 320 days of freeze-free temperatures and a network of drainage canals and irrigation ditches make the area ideal for growing grains, vegetables, melons, sugar cane, and a variety of citrus plants. The agricultural fields also provide nesting habitat and forage for game species such as mourning dove (*Zenaida macroura*), white-winged dove (*Zenaida asiatica*), white-tailed deer (*Odocoileus virginianus),* and white-fronted goose (*Anser albifrons*) (Griffith et al., 2007).

Lower Rio Grande Alluvial Floodplain: The lower portions of the Rio Grande were historically dominated by Texas palmetto (*Sabal mexicana*) and floodplain forests. Much of these plains have been converted to cropland and urban areas. Some of the major agricultural crops in the Lower Rio Grande region include cotton, citrus, sorghum, sugar cane, vegetables, and melons. Water diversion, crop irrigation, and human activity has led to water scarcity and an increase in river salinity. The Rio Grande and other bodies of water in Texas have been victims of invasive plant species such as hydrilla (*Hydrilla verticillata*) and water hyacinths (*Eichhornia crassip*es). Unchecked, these plants grow rapidly, often depleting dissolved oxygen (DO) levels and clogging waterbodies. Despite these issues, the Lower Rio Grande Valley remains a biological hot spot for wildlife. The Laguna Atascosa NWR provides a haven for many rare species at the northernmost extent of their range such as ocelots (*Leopardus pardalis*), Gulf coast jaguarundis (*Herpailurus yagouaroundi cacomitli*), and Texas indigo snakes (*Drymarchon corais*). The southern tip of Texas acts as a converging point for both the Central and Mississippi migratory bird flyways, and as many as 500 different bird species have been documented along the Lower Rio Grande Valley (Griffith et al., 2007).

Laguna Madre Barrier Islands and Coastal Marshes: Adjacent to the Gulf, this ecoregion is categorized by tidal mud flats, barrier island, seagrass meadows, and hypersaline lagoons. Seagrass meadows grow in the shallow, clear waters along the Laguna Madre. The seagrass beds serve as a productive nursery habitat for red drum and grazing for sea turtles and redhead ducks (*Aythya americana*). Padre Island is the longest barrier island in the world. Seacoast bluestem, sea oats, and other grassy vegetation can be found along the 113-mile-long island. Ponds and marshes are populated with cordgrass, cattails (*Typha* spp.), and bulrush. Sea turtles including the Kemp's ridley (*Lepidochelys* *kempii*) are dependent on the sandy barrier islands for nesting habitat. Loggerhead (*Caretta caretta*) sea turtles and green (*Chelonia mydas*) sea turtles nest on the barrier island in smaller numbers while leatherback (*Dermochelys coriacea*) sea turtles historically nested there. The Padre Island National Seashore protects most of the barrier island and is under the jurisdiction of the National Park Service. The park has documented 380 species of birds and 81 species of butterflies and moths (Griffith et al., 2007).

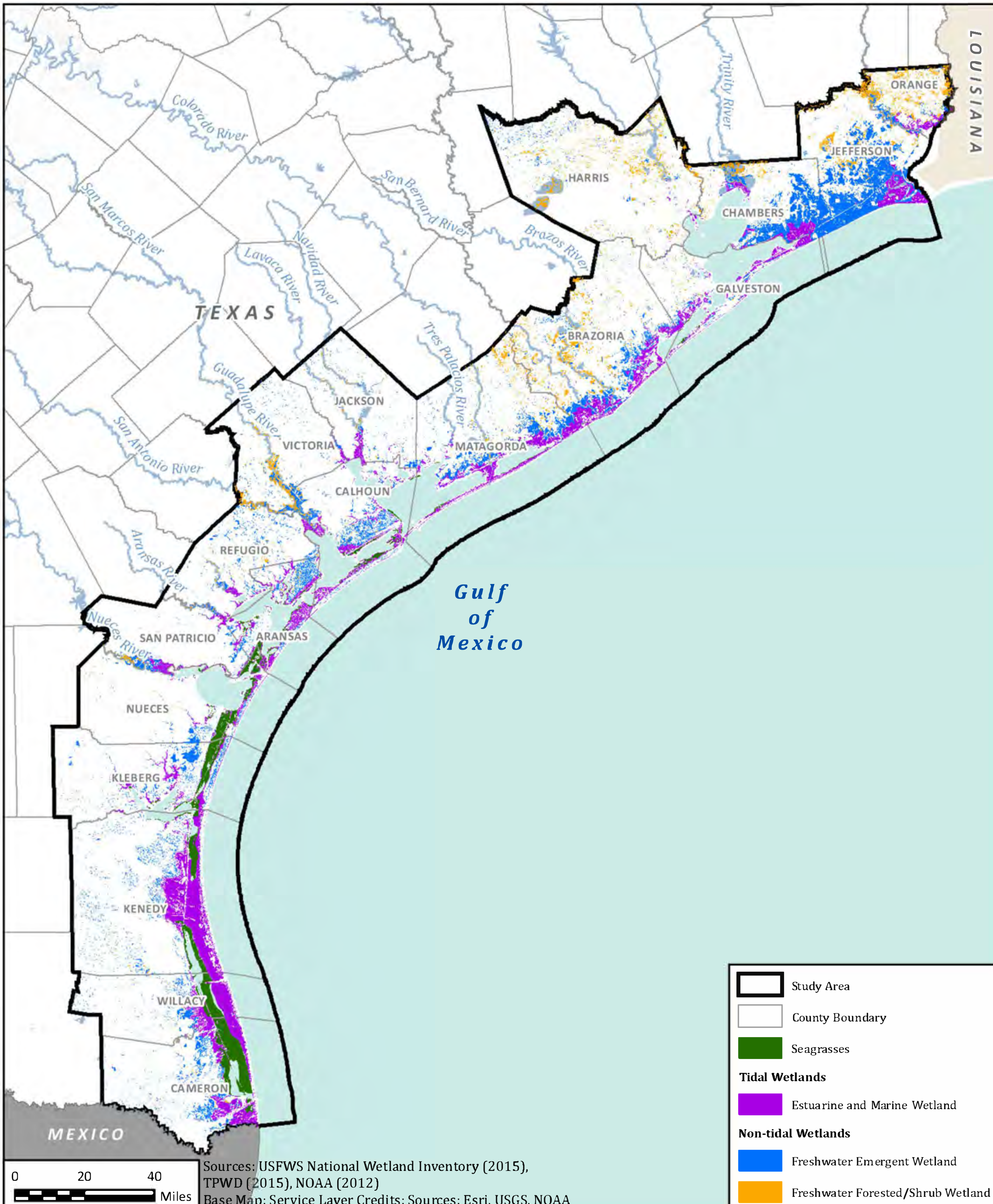
Freshwater Wetlands: Freshwater wetlands consist of riverine forested wetlands, prairie potholes and marshes, and Texas coastal sand sheet wetlands (Figure 3).

Riverine forested wetlands are found on the floodplains of rivers and large streams. The main source of water for this habitat is from overtopped riverbanks and flooding. Within the upper Texas coast from east Houston to Louisiana, swamps are the wettest type of forested wetlands and are typically persistently inundated (Mitsch and Gosselink, 2007). Bottomland hardwood forests are also part of this complex and are flooded less frequently than swamps (Texas A&M AgriLife Extension, 2017a). Coastal flatwood wetlands are unique forested wetlands found between the Louisiana border and the Houston area (Texas A&M AgriLife Extension, 2017b). The lower coast riparian wetlands are unique forested wetlands associated with riverine areas from the San Antonio River to southern Texas. These freshwater, depressional wetlands are maintained by river runoff and regular flooding events (Texas A&M AgriLife Extension, 2017c).

Prairie potholes and marshes occur on the prairie from just west of Beaumont to the Rio Grande. These wetlands once covered vast expanses of prairie before urbanization and agriculture destroyed most of them. Approximately 30 percent of prairies were once wetlands. The difference between a pothole and a marsh is mainly size; marshes occur in larger and generally less-well-defined depressions than potholes. On the upper coast, potholes and marshes occur in complexes with pimple mounds (small hummocks 1 to 2 feet tall) and intermound flats. Rivers and bayous formed this complex pattern thousands of years ago, and it has been modified through time by climatic (especially wind) and biotic forces. Potholes and marshes maintain their hydrology through direct precipitation, runoff from adjacent flats, and occasionally local groundwater (Texas A&M AgriLife Extension, 2017d).

The coastal sand sheet that covers parts of Kleberg, Kenedy, and Willacy counties was formed from sand blown in from the Gulf coast and shaped by the wind. The topography of the area is generally flat but with rolling vegetated dunes, blowouts, and wetlands (Carr, 2007). Because of the dry climate, most of the water supplied to the wetlands is from groundwater percolating through the sandy soils. These wetlands support plant assemblages that reflect the range of salinity found in these depressions (Texas A&M AgriLife Extension, 2017e).

Brackish, Intermediate, and Salt Marshes: Freshwater wetlands consist of estuarine or tidal fringe wetlands and barrier island interior wetlands (Figure 3).



Sources: USFWS National Wetland Inventory (2015), TPWD (2015), NOAA (2012)
Base Map: Service Layer Credits: Sources: Esri, USGS, NOAA

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Texas Coastal Wetlands

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FIGURE

Path: H:\ENVIRONMENTAL\Final_Exhibits\EIS_Overview_Maps\2-12EIS_Tx_Coastal_Wet.mxd

NAD 1983 Texas Centric Mapping System Albers

Estuarine wetlands are tidally influenced wetlands that occur throughout the Texas Gulf coast and can range from being vegetated marshes, to unvegetated mud and barren sand flats found on the bay side of the coastal barrier islands (Texas A&M AgriLife Extension, 2017f). They are concentrated along the upper and mid Texas coast. Estuarine shrub-scrub wetlands were most abundant on the mid Texas coast in Espiritu Santo Bay, south of Port O'Connor, and at the southern end of South Padre Island (Moulton et al., 1997). Estuarine unvegetated flats are more common around the Lower Laguna Madre and along the lower Texas coast. Some of these tidal wetlands are subject to daily tidal ranges (i.e., low salt marsh), where others are only subject to tidal influence during high tides or storm events (i.e., high salt marsh); the upper and lower limits of the tidal range control the extent and location of estuarine wetlands (National Oceanic and Atmospheric Administration [NOAA], 2017a).

Brackish and intermediate marshes grade inland from salt marshes and are subjected to periodic pulses of saltwater. Saline influences are attenuated by high freshwater influences (Mitsch and Gosselink, 2007). The dominant species in brackish and intermediate marshes can include saltmarsh bulrush (*Scirpus robustus*) or bulrush (*Juncus* spp.) while seashore saltgrass and saltmeadow cordgrass are co-dominant species. These species dominate the interior marshes of the Sabine Lake, Galveston Bay, and Matagorda Bay systems (USACE, 2015). Brackish and intermediate marshes are generally more productive and diverse relative to salt marshes (Mitsch and Gosselink, 2007).

Salt marshes are located along the bay shorelines and higher salinity areas of the estuarine systems. Subjected to regular tidal inundation, low saline marsh is dominated by smooth cordgrass (*S. alterniflora*) and often accompanied by seashore saltgrass, blackrush (*Juncus romerianus*), saline marsh aster (*Aster tenuifolius*), and saltmeadow cordgrass (*S. patens*). The dominant species in high salt marsh, which is subject to less-frequent tidal inundation, is often glasswort (*Salicornia* spp.) and shoregrass (USACE, 2015). Black mangrove (*Avicennia germinans*) is also becoming a more common salt marsh species along the Texas coast and can persist in both low and high salt marsh areas (Armitage et al., 2015).

Fringing the Laguna Madre are unique tidal wetland areas consisting of broad, nearly unvegetated wind-tidal flats. These wind-tidal flats are not regularly flooded by tides. They are only occasionally flooded when strong winds push shallow water from the Laguna onto the low flats, or during annual high tides. The cycle of irregular flooding and drying causes salt to build up on the surface of the flats (Tunnell and Judd, 2002). These wind-tidal flats are inhospitable to most vascular plants but are often covered by vast mats of blue-green algae. These habitats may look barren, but they support rich invertebrate populations that, in turn, attract large numbers of shorebirds and wading birds (Texas A&M AgriLife Extension, 2017f).

The Texas barrier islands were created about 4,000 years ago from wave action and sediment deposition from rivers and creeks. Coastal winds and waves created ridges, troughs, and flats between sand dunes where water could collect. Island interior wetlands provide an important source of fresh water for species. Although these wetlands are primarily fresh water, storm events and extreme tides occasionally introduce salt into these barrier island wetlands. Wetland plants are similar to those found in other freshwater marshes but may include some brackish water species due to elevated soil salinity and occasional tidal inundation in some areas (Texas A&M AgriLife Extension, 2017g).

Seagrass: Seagrass can be found along the Texas Gulf coast between the coastal barrier islands and mainland. There are approximately 235,000 acres of seagrass in Texas (Texas Parks and Wildlife Department [TPWD], 1999). Although seagrasses may occur throughout the entire coast, about 75 percent of seagrasses occur within the Laguna Madre in the lower Texas coast (Handley et al., 2007). Shoalgrass (*Halodule wrightii*), turtlegrass (*Thalassia testudinum*), manateegrass (*Syringodium filiforme*), widgeongrass (*Ruppia maritima*), and clovergrass (*Halophilia engelmannii*) can all be found in shallow (generally <5 feet water depth depending on water clarity) Texas coastal water (TPWD, 1999). Although seagrasses are generally declining in most parts of the Texas coast, seagrass beds within the Upper Laguna Madre and Corpus Christi Bay have been generally expanding or are stable (Moulton et al., 1997). Seagrass coverage has also been expanding in West Galveston Bay (Lester and Gonzalez, 2011). Seagrass plays an important part in stabilizing the seafloor substrate and nutrient accumulation. Seagrass communities are an important part of the ecosystem generating high primary productivity and acting as nurseries for recreational and commercial fisheries such as red drum, brown shrimp, and black drum and foraging habitat for manatees, sea turtles, herons, and egrets (Texas Statewide Seagrass Monitoring Program, 2015a, 2015b).

Aquatic Communities: The open bay community is composed of plankton and nekton. Phytoplankton (microscopic algae) are the major primary producers (plant life) in the open bay, taking up carbon through photosynthesis and nutrients for growth. Phytoplankton are fed upon by zooplankton (small crustaceans), fish, and benthic consumers. Nekton (organisms that swim freely in the water column) consist mainly of secondary consumers, which feed on zooplankton and smaller nekton (Armstrong et al., 1987; Britton and Morton, 1989). Diverse and abundant plankton and nekton communities occur throughout the entire project areas. Phytoplankton assemblages in Sabine Lake are comprised primarily of freshwater and marine diatoms and green algae (Armstrong et al., 1987). Galveston Bay has the highest primary productivity of all Texas bays, and the phytoplankton community includes diatoms, green algae, blue-green algae, dinoflagellates, euglenoids, cryptophytes, and golden-brown algae (Armstrong et al., 1987; Lester and Gonzalez, 2011; Sheridan et al., 1989). Diatoms dominate the species composition in Lavaca Bay and the Corpus Christi Bay area (Armstrong et al., 1987). Due to the lack of freshwater inflow and the resulting high salinities, the Upper and Lower Laguna Madre is relatively phytoplankton free (Armstrong et al., 1987; Tunnell and Judd, 2002).

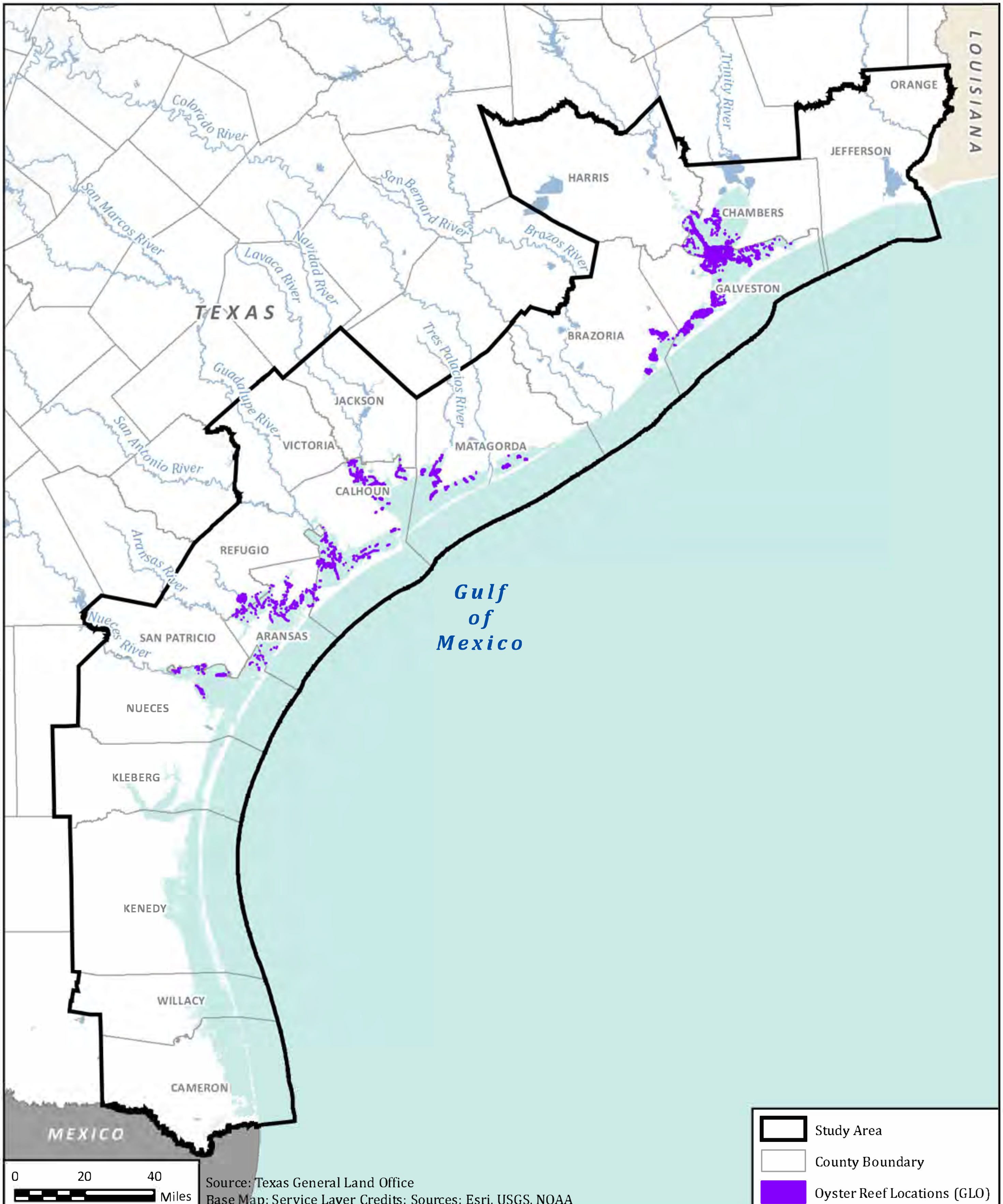
Texas bay systems support a diverse nekton population including fish, shrimp, and crabs. Some of these are resident species, spending their entire life in the bay, whereas others are migrant species spending only a portion of their life cycle in the estuary (Armstrong et al., 1987). Many of these species are estuarine-dependent, migrating through passes of the Gulf to use the different habitats in the bay including submerged aquatic vegetation (SAV), marsh, and oyster reefs as nursery habitat (Tunnell and Judd, 2002). With respect to the Upper and Lower Laguna Madre, the hypersaline waters can affect fish osmotic balance and decrease DO; however, fish occupying these areas are euryhaline (able to tolerate a wide range of salinities) and better able to cope with the harsh conditions (Gunter, 1967).

Dominant nekton species inhabiting Texas estuaries include blue crab, white shrimp, brown shrimp, pink shrimp (*Farfantepenaeus duorarum*), Atlantic croaker, bay anchovy, code goby (*Gobiosoma robustum*), black drum, Gulf menhaden, hardhead catfish, pinfish (*Lagodon rhomboides*), sheepshead (*Archosargus probatocephalus*), silversides, southern flounder (*Paralichthys lethostigma*), spot (*Leiostomus xanthurus*), and spotted seatrout (Nelson et al., 1992; Pattillo et al., 1997). These species are ubiquitous along the Texas coast and are unaffected by salinity changes. Seasonal differences occur in abundance with the fall usually the lowest in biomass and number. Newly spawned fish and shellfish begin migrating into the bays in winter and early spring with the maximum biomass during the summer (Parker, 1965).

Open-bay Bottom: The open-bay bottoms in Texas bay systems include all unvegetated subtidal areas with various sediment types. They are open systems that interact with the overlying waters and adjacent habitats (Armstrong et al., 1987; Tunnell and Judd, 2002). Benthic organisms are divided into two groups: epifauna, such as crabs and smaller crustaceans, which live on the surface of substrate, and infauna, such as mollusks and polychaetes that burrow into the substrate (Green et al., 1992). Mollusks and other infaunal organisms are filter feeders that strain suspended particles from the water column. Other infauna, such as polychaetes, feed by ingesting sediments and extracting nutrients. Many of the epifauna and infauna feed on plankton, which in turn are fed upon by numerous fish and birds (Armstrong et al., 1987; Lester and Gonzales, 2011).

Mud and sandy mud are the dominant sediment types from Sabine Lake to Aransas Bay on the upper to mid coast with sandier sediments occurring along the bay margins and deltas (White et al., 1985, 1987, 1988, 1989a). In Corpus Christi Bay and the Upper Laguna Madre, mud is the dominant sediment type with sandier sediments found along the bay margins (White et al., 1983, 1989b). The lower coast (Lower Laguna Madre and South Bay) is dominated by mud and sand (White et al., 1986). Benthic macroinvertebrates found in the sediments of the bay-estuary-lagoon system along the entire Texas coast consist primarily of polychaetes, bivalves, gastropods, and crustaceans (White et al., 1983, 1985, 1986, 1987, 1988, 1989a).

Oyster Reef: Eastern oysters are present in all bay systems from Sabine Lake to Corpus Christi Bay and South Bay and provide ecologically important functions (Figure 4). Few oysters are present in the Upper Laguna Madre, Baffin Bay, or Lower Laguna Madre. Oyster reefs are formed where a hard substrate and adequate currents are plentiful. Currents carry nutrients to the oysters and take away sediment and waste filtered by the oyster. Most oyster reefs are subtidal or intertidal and found near passes, cuts, and along the edges of marshes. Oysters can filter water 1,500 times their own volume per hour, which, in turn, influences water clarity and phytoplankton abundance (Lester and Gonzalez, 2011; Powell et al., 1992). Due to their lack of mobility and tendency to bioaccumulate pollutants, oysters are an important indicator for detecting contamination (Lester and Gonzalez, 2011).



Source: Texas General Land Office
Base Map: Service Layer Credits: Sources: Esri, USGS, NOAA

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Oyster Reef Locations

FN JOB NO	COH16388
FILE NAME	213EIS_Oyster_Reef.mxd
DATE	8/18/2017
SCALE	1:2,377,085
DESIGNED	SSJ
DRAFTED	SSJ

FIGURE 4

NAD 1983 Texas Centric Mapping System Albers

While oysters can survive in salinities ranging from 5 to over 40 parts per thousand (ppt), they thrive from 10 to 25 ppt, which is the level where pathogens and predators are limited. The lower salinity is critical for osmotic balance. Oysters can survive brief periods of salinities less than 5 ppt by remaining tightly closed. Oysters will remain closed until normal salinities return, or until they deplete their internal reserves and perish. In contrast, oyster drills (*Thais haemastoma*), welks (Buccinidae), and crabs prey on oysters during long periods of high salinities. *Perkinsus marinus* (Dermo) is the most common and deadly oyster pathogen in the bays and is a primary factor affecting habitat suitability (Cake, 1983).

Many organisms, including mollusks, barnacles, crabs, gastropods, amphipods, polychaetes, and isopods, live on oyster reefs, forming a very diverse community (Sheridan et al., 1989). Oyster reef communities are dependent upon food from the open bay and marshes. Many organisms feed on oysters including black drum, crabs, and gastropods, such as the oyster drill (Lester and Gonzales, 2011; Sheridan et al., 1989). A variety of birds will use reefs for resting and feeding when oysters are exposed during low tides (Armstrong et al., 1987).

The eastern oyster populations living in South Bay are genetically distinct from other oysters inhabiting the Texas coast and have adapted to the hypersaline conditions (Tunnell and Judd, 2002). This population is thought to be a remnant of when the Rio Grande flowed into the area (White et al., 1986).

Offshore Sands: There are few seagrasses or attached algae found in the offshore sands due to the strong currents and unstable sediments. Most of the bottom surface is populated with macroinfauna such as an occasional hermit crab (Paguroidea), portunid crab (Portunidae), or ray (Batoidea). Even though there is little life on the sand surface itself, the overlying waters are highly productive. Phytoplankton are abundant, including microscopic diatoms, dinoflagellates, and other algae (Britton and Morton, 1989).

Much of the faunal diversity lies buried in the sand and relies on phytoplankton for food. Bivalves found in offshore sands include the blood ark (*Anadara ovalis*), incongruous ark (*Anadara brasiliana*), southern quahog (*Mercenaria campechiensis*), giant cockle (*Dinocardium robustum*), disk dosinia (*Dosinia discus*), pen shells (*Atrina serrata*), common egg cockle (*Laevicardium laevigatum*), cross-barred venus (*Chione cancellata*), tellins (*Tellina* spp.), and the tusk shell (*Dentalium texasianum*). The most common species occurring in the shallow offshore sands is the sand dollar (*Mellita quinquiesperforata*) and several species of brittle stars (*Hemipholis elongata*, *Ophiolepis elegans*, and *Ophiothrix angulata*). Many gastropods are common, including the moon snail (*Polinices duplicatus*), ear snail (*Sinum perspectivum*), Texas olive (*Oliva sayana*), Atlantic auger (*Terebra dislocata*), Salle's auger (*Terebra salleano*), scotch bonnet (*Phalium granulatum*), distorted triton (*Distorsio clathrata*), wentletraps (*Epitonium* sp.), and whelks (*Busycon* spp.). Crustaceans inhabit these waters including white and brown shrimp (both commercially sought species), rock shrimp (*Sicyonia brevirostris*), blue crabs, mole crabs (*Albunea* spp.), speckled crab (*Arenaeus cribrarius*), box crab (*Calappa sulcata*), calico crab (*Hepatus epheliticus*), and pea crab (*Pinotheres maculatus*). The most abundant infaunal organisms are the polychaetes (Capitellidae, Orbiniidae, Magelonidae, and Paraonidae) (Britton and Morton, 1989).

3.0 ESSENTIAL FISH HABITAT

Essential Fish Habitat is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 United States Code 1802(10)). EFH is found in the tidally influenced or estuarine emergent wetland communities and brackish or marine open-water communities within the proposed project areas (see Figure 1). These communities play an important role in the cycling of nutrients and food energy through coastal ecosystems. Communities, such as wetlands, produce detritus that is transferred to food energy for higher trophic levels via zooplankton, bivalves, crustaceans, and small fish.

Estuaries along the Texas coast often contribute to the shellfish resources of the Gulf. Shellfish species range from those located only in brackish wetlands to those found mainly in saline marsh and inshore coastal waters. Multiple species of penaeid shrimp are expected to occur in the vicinity of the proposed project areas; however, brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) are the most numerous (Nelson et al., 1992). At least eight species of portunid (swimming) crabs are common residents of the coastal and estuarine waters of the northern Gulf. Brown shrimp, white shrimp, blue crabs (*Callinectes sapidus*), and Eastern oyster are the primary shellfish located throughout Texas that comprise a substantial fishery (Turner and Brody, 1983).

Life histories of many Gulf fish can be characterized as estuarine dependent. These species typically spawn in the Gulf, and their larvae are carried inshore by currents. Juvenile fish generally remain in these estuarine nurseries for about a year, taking advantage of the greater availability of food and protection that estuarine habitats afford. Upon reaching maturity, estuarine-dependent fishes migrate to sea to spawn (returning to the estuary on a seasonal basis) or migrate from the shallow estuaries to spend the rest of their lives in deeper offshore waters (Pattillo et al., 1997).

3.1 FISHERIES OF SPECIAL CONCERN

Fish and macroinvertebrate species of special concern that occur in the vicinity of the project areas include those with designated EFH and those of commercial and recreational value. In 1996, the MSFCMA mandated the identification of EFH for all Federally managed species. For a list of commercial and recreational fisheries species within and adjacent to the project areas, refer to Table 1. The categories of EFH that occur within the project area include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, and seagrasses. Additionally, portions of the project area are in marine waters and include the marine water column and unconsolidated marine water bottoms.

3.2 RECREATIONAL AND COMMERCIAL FISHERIES

Table 1 provides a list of representative commercial and recreational fish and shellfish known to occur along the Texas coast. The main commercial species in Texas are black drum (*Pogonias cromis*), southern flounder (*Paralichthys lethostigma*), sheepshead (*Archosargus probatocephalus*), striped mullet (*Mugil cephalus*), blue crab (*Callinectes sapidus*), Eastern oyster (*Crassostrea virginica*), brown shrimp (*Farfantepenaeus aztecus*), white shrimp (*Litopenaeus setiferus*), and pink shrimp (*Farfantepenaeus duorarum*). Commercial fisheries in Texas account for the third greatest sales of all states in the Gulf ($1,017 million) and employment (about 18,000 jobs) compared to other Gulf states (NMFS, 2017).

Table 1
Representative Recreational and Commercial Fish and Shellfish Species Known to Occur in the Project Areas

Common Name	Scientific Name[1]
Eastern oyster	*Crassostrea virginica*
Brown shrimp	*Farfantepenaeus aztecus*
Pink shrimp	*F. duorarum*
White shrimp	*Litopenaeus setiferus*
Blue crab	*Callinectes sapidus*
Bull shark	*Carcharhinus leucas*
Blacktip shark	*C. limbatus*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Gulf menhaden	*Brevoortia patronus*
Striped mullet	*Mugil cephalus*
Cobia	*Rachycentron canadum*
Greater amberjack	*Seriola dumerili*
Lesser amberjack	*S. fasciata*
Red snapper	*Lutjanus campechanus*
Lane snapper	*Lutjanus synagris*
Sheepshead	*Archosargus probatocephalus*
Sand seatrout	*Cynoscion arenarius*
Spotted seatrout	*Cynoscion nebulosus*
Atlantic croaker	*Micropogonias undulatus*
Black drum	*Pogonias cromis*
Red drum	*Sciaenops ocellatus*
Little tunny	*Euthynnus alletteratus*
King mackerel	*Scomberomorus cavalla*
Spanish mackerel	*S. maculatus*
Southern flounder	*Paralichthys lethostigma*

Source: Nelson et al. (1992), NMFS (2017), Pattillo et al. (1997).

[1] Fish species according to Page et al. (2013).

The main recreational species include spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), southern flounder, red snapper (*Lutjanus campechanus*), and king mackerel (*Scomberomorus cavalla*). The recreational fishing industry accounted for $1,938 million in sales impacts in Texas, which is second only to Florida of Gulf coast states (NMFS, 2017).

A description of life history characteristics, habitat preferences, and distribution of commercially and recreationally important species, except for those described in Section 3.4, is provided in the following sections. Table 2 provides the life stage relative abundance of these species. These estuarine-dependent species serve as prey for other fisheries managed under the GMFMC.

Eastern oyster (*Crassostrea virginica*)

Eastern oysters are sessile bivalves that occur throughout the Gulf in shallow bays, mud flats, and offshore sandy bars (Stanley and Sellers, 1986). Oysters grow well on a variety of substrates ranging from rocky bottoms to some types of mud. The presence and growth of oysters are closely correlated with salinity and other abiotic variables. According to Pattillo et al. (1997), salinity, DO, and pH may affect where oysters occur and grow well. Salinity ranging from 10.0 to 30.0 ppt, pH ranging from 8.2 to 8.8 standard units (su), and DO ranging from 7.4 to 8.6 milligrams per liter (mg/L) are preferred optimal habitat conditions for oysters (Pattillo et al., 1997). Oysters also depend on currents to deliver food, remove feces, and prevent smothering by sediments.

Oysters spawn from March through November in the northern Gulf, and the peak of spawning season in Texas is between May and early June (Stanley and Sellers, 1986). Because of high temperatures, spawning occurs during all months except July and August in south Texas. Spawning is triggered mostly by temperatures above 68°F for normal spawn and above 77°F for mass spawning (Pattillo et al., 1997). Salinity also influences spawning. Lower salinity levels can result in late spawning periods (pers. comm., Sammy Ray, Texas A&M University, 2005).

Eggs hatch 6 hours after fertilization, and oyster larvae remain in the water column for 2 to 3 weeks after hatching (Pattillo et al., 1997). Upon setting or attachment, the sessile juveniles are referred to as spat. Spat-fall on the Gulf coast typically occurs from March to mid-November. Juveniles begin to develop once larvae attach. In the Gulf, sexual maturity of oysters may occur as soon as 4 weeks after attachment (Pattillo et al., 1997), but generally maturation occurs at 18 to 24 months of age (Quast et al., 1988).

Growth rates of adult oysters can vary greatly depending on conditions. Some adult oysters have been documented to grow at a rate of 2 inches/year (Pattillo et al., 1997). Pattillo et al. (1997) provide growth rates of 2.4 inches in the first year, 3.5 inches in the second year, and 4.5 inches in the third year. It is possible for an oyster to reach harvestable size (3 inches) within 2 years.

Table 2
Life Stage Relative Abundance of Representative Recreational and Commercial Shellfish in the Project Areas

	Bay System with Project Area Locations				
Species	Galveston Bay	Brazos River	Matagorda Bay	Corpus Christi Bay	Laguna Madre
Eastern oyster	larvae abundant March–November adults abundant year-round	N/D	all life stages common year-round	all life stages common year-round	larvae present Sept–June adults present year-round
Blue crab	all life stages common to abundant year-round	all life stages common year-round	all life stages common to highly abundant year-round	all life stages common to highly abundant year-round	all life stages common to abundant year-round
Gulf menhaden	juveniles common to highly abundant year-round adults seasonal	juveniles abundant November–March	juveniles highly abundant year-round adults highly abundant March–November	juveniles abundant year-round adults common September–November larvae common October–November	juveniles abundant year-round adults common June–December
Striped mullet	juveniles abundant and adults common year-round	juveniles and adults common year-round	juveniles and adults common year-round larvae abundant October–May	juveniles abundant and adults common year-round	juveniles abundant and adults common year-round larvae abundant October–May
Sheepshead	juveniles and adults common year-round	juveniles and adults common year-round	juveniles and adults abundant year-round	all life stages common year-round larvae common February–April	juveniles abundant and adults common year-round
Sand seatrout	juveniles common February–November adults abundant year-round	juveniles common year-round	juveniles common April–December adults common February–November	juveniles and adults abundant year-round larvae common January–March	juveniles and adults rare

Species	Bay System with Project Area Locations				
	Galveston Bay	Brazos River	Matagorda Bay	Corpus Christi Bay	Laguna Madre
Spotted seatrout	juveniles and adults common year-round larvae common March–October	juveniles and adults common year-round larvae common March–October	juveniles and adults common year-round larvae common March–October	juveniles and adults common year-round larvae common March–October	juveniles and adults common year-round larvae common March–October
Atlantic croaker	juveniles highly abundant year-round adults common August–December	juveniles highly abundant year-round	juveniles highly abundant year-round adults abundant February–November	juveniles abundant March–October adults abundant year-round larvae abundant October–April	juveniles and adults abundant year-round larvae abundant September–March
Black drum	juveniles and adults common year-round larvae common February–April	juveniles and adults common year-round	juveniles and adults common year-round larvae common February–April	juveniles and adults common year-round larvae common February–April	juveniles and adults common year-round larvae common February–April
Southern flounder	juveniles common and adults highly abundant year-round	juveniles common January–October adults common April–November	juveniles common year-round adults abundant January–November	juveniles common January–August adults common April–November	juveniles abundant year-round adults common April–December

Source: Nelson et al. (1992), Pattillo et al. (1997)
N/D = No data available

Due to their lack of mobility and their tendency to bioaccumulate pollutants, oysters are an important indicator species for determining contamination in the bay (Lester and Gonzalez, 2011). While oysters can survive in salinities ranging from 5 to 40+ ppt, they thrive within a range of 10 to 25 ppt where pathogens and predators are limited. The low salinity end of the range is critical from an osmotic balance perspective. Oysters can survive brief periods of salinities less than 5 ppt by remaining tightly closed. Oysters will remain closed until normal salinities are reestablished, or until they deplete their internal reserves and perish. In contrast, predators, such as oyster drills, welks, and crabs, reduce oyster populations during long periods of high salinities (Cake, 1983).

Perkinsus marinus (Dermo) is the most common and deadly oyster pathogen in the bays bordering the Gulf. It is a primary factor affecting habitat suitability. On infected reefs, greater than 50 percent of oysters will be killed by Dermo. Obviously, the optimal condition for adult and seed oysters is the absence of the disease (Cake, 1983).

Blue Crab (*Callinectes sapidus*)

Blue crabs are harvested commercially and recreationally throughout the coastal waters of the Gulf. These fisheries have become increasingly important in the Gulf, with reported landings exceeding 4.3 million pounds in 2015 (NOAA, 2017b). Blue crabs occupy a variety of habitats, including the upper, middle, and lower estuaries, as well as associated marine environments, depending on their life history stage. Larvae occupy the lower estuary and marine water with salinities greater than 20 ppt. Blue crabs first enter the estuary during the megalopae life stage where they begin a benthic existence. Spawning occurs during the spring, summer, and fall (Pattillo et al., 1997).

Factors that affect the distribution and survival of blue crabs are substrate, food availability, water temperature, and salinity. Blue crabs are opportunistic omnivores and feed on fish, detritus, crustaceans, mollusks, and other blue crabs. They are also prey for higher trophic levels, including diving ducks, herons, and predatory fish, including commercial and recreational species (Perry and McIlwain, 1986).

All life stages are common to highly abundant year-round in the bay systems where the project areas are located (Table 2) (Nelson et al., 1992; Pattillo et al., 1997).

Gulf Menhaden (*Brevoortia patronus*)

Gulf menhaden occur throughout the northern Gulf from the Caloosahatchee River, Florida, to the Yucatan, Mexico (Hoese and Moore, 1998). Juvenile menhaden prefer low salinity, open-water habitats adjacent to emergent marsh. Adults often occur offshore. This species makes up a majority of the commercial “pogy” purse-seine fishery. As filter feeders, they feed on phytoplankton, zooplankton, and organic detritus. Spawning season usually occurs from October through March but may begin in August and last as late as May. Spawning may occur multiple times during a single spawning season (Lassuy, 1983a; Pattillo et al., 1997). In the bay systems where the project areas are located, juvenile Gulf menhaden are common to highly abundant year-round, while adults are common to highly abundant during the summer and fall; larval are common October through November in Corpus Christi Bay (Table 2) (Nelson et al., 1992; Pattillo et al., 1997).

Striped Mullet (*Mugil cephalus*)

Striped mullet spawn offshore near the surface from October to March. Eggs and sperm are released into the water column for fertilization. Once they reach the pre-juvenile stage, they enter the bays and estuaries to mature. Sexual maturity is reached at 3 years of age, and adults remain near shore throughout their life. Striped mullet feed mainly on microalgae, detritus, and sediment particles (Pattillo et al., 1997). Adult and juvenile striped mullet are common to abundant throughout bays in the project areas, while larval striped mullet are found October through May in Matagorda Bay and the Laguna Madre (Table 2) (Nelson et al., 1992).

Sheepshead (*Archosargus probatocephalus*)

Sheepshead is an estuarine-dependent species that inhabits much of the Atlantic and Gulf coasts of the United States. Spawning occurs offshore from February through April, with the peak in March and April. Eggs typically are laid over the inner continental shelf (Pattillo et al., 1997). Larvae are pelagic, but move into estuaries, seeking refuge in seagrass (Lee et al., 1980; Pattillo et al., 1997). Juveniles begin leaving seagrass in late summer, congregating with adults around nearshore reefs as they mature (Jennings, 1985; Pattillo et al., 1997). Adults also use oyster reefs, shallow muddy bottoms, marshes, piers and rocks, and bare sands of the surf zone. Larval and juvenile sheepshead consume primarily zooplankton, whereas larger juveniles and adults prey on blue crab, oysters, clams, and small fish (Pattillo et al., 1997).

Juvenile and adult life stages of sheepshead are common to abundant year-round in the project areas (Table 2) (Nelson et al., 1992; Pattillo et al., 1997). Since juveniles are typically associated with vegetation (Pattillo et al., 1997), they may occur in the tidally influenced brackish marshes in the project areas. Adults may occur in open-water habitat and probably will not occur in brackish marsh habitats in the project areas. Larval stages are also common February through April in Corpus Christi Bay (Nelson et al., 1992).

Sand Seatrout (*Cynoscion arenarius*)

Sand seatrout is an estuarine species that occurs throughout the Gulf coast in nearshore habitats (Pattillo et al., 1997). Spawning occurs primarily in shallow, higher salinity habitats from February through October (Pattillo et al., 1997; Sutter and McIlwain, 1987). Typical habitats preferred by juvenile sand seatrout are flooded marshes and seagrass meadows with soft organic substrates. Adults are found in open water over most substrates. Sand seatrout migrate to the Gulf in late fall or winter to spawn. Eggs and sperm are released into the water column for fertilization. Larvae are carried into the estuary by the currents and migrate to the upper areas of the estuary, preferring channels, small bayous, and shallow marshes to develop (Pattillo et al., 1997). Adult sand seatrout reach sexual maturity at 12 months (Pattillo et al., 1997). They feed mainly on fish and shrimp (Overstreet and Heard, 1982).

Juveniles and adults are common to abundant almost year-round in the project areas, while larvae are common January through March in Corpus Christi Bay (Table 2) (Nelson et al., 1992). There is a high probability of juvenile and adult sand seatrout occurring in the project areas, especially in tidally influenced emergent wetlands and open-water habitats.

Spotted Seatrout (*Cynoscion nebulosus*)

Spotted seatrout are estuarine residents, spending their entire life cycle in estuarine waters (Lassuy, 1983b). Spawning typically occurs from March to October, with a peak between April and August. Spawning takes place in passes and in shallow, grassy habitats in bays with moderate salinities. Adults and juveniles prefer seagrass meadows and sandy to muddy substrates. Larval spotted seatrout feed on zooplankton while juveniles feed on larger invertebrates and small fish. As adults, their diet consists primarily of fish (Pattillo et al., 1997).

Juvenile spotted seatrout are common year-round occurring in tidally influenced emergent wetlands in the project areas; adults are common and may be found throughout the project areas all year. Larvae are common throughout the project areas during March through October (Table 2) (Nelson et al., 1992).

Atlantic Croaker (*Micropogonias undulatus*)

Atlantic croaker spawn near passes in the Gulf from September through May. Eggs and sperm are randomly released into the water column for fertilization. Early larval stages are usually offshore and are carried by currents inshore to estuarine habitats. Juvenile Atlantic croaker move into tributaries where they spend 6 to 8 months before migrating offshore starting in March and lasting until November (Lassuy, 1983b; Pattillo et al., 1997). Adults have seasonal migrations moving into estuarine waters typically in the summer and then into marine waters typically in the fall (Pattillo et al., 1997).

Adult Atlantic croaker are common to abundant year-round within the project areas (Table 2) (Nelson et al., 1992; Pattillo et al., 1997). Juveniles are highly abundant in estuaries along the Texas Gulf coast through the spring before migrating to the Gulf in April or early summer (Lassuy, 1983b; Nelson et al., 1992). There is a high probability of juvenile and adult Atlantic croaker occurring in the project areas, especially in fresh-intermediate marshes and open-water habitats.

Black Drum (*Pogonias cromis*)

Black drum is an estuarine-dependent species that occurs in open bays and estuaries. Mature black drum spawn in the open bay, in nearshore Gulf waters, or in connecting passes from January to mid-April. During spawning, eggs and sperm are released into the water column for fertilization. Black drum larvae and juveniles move into upper bay areas and tidal creeks, where they remain until they reach about 4 inches in length and then move into the open bay. Black drum remain in the bay until they reach sexual maturity (about 2 years) (Pattillo et al., 1997).

Adult and juvenile black drum are common and occur throughout the project areas all year (Table 2) (Nelson et al., 1992; Pattillo et al., 1997). Larval black drum occur from February through April over the continental shelf. Juveniles inhabit muddy bottoms in marsh habitats year-round and adults are predominantly estuarine, preferring unvegetated sand and mud bottoms and oyster reefs year-round (Nelson et al., 1992; Pattillo et al., 1997; Sutter et al., 1986).

Southern Flounder (*Paralichthys lethostigma*)

Southern flounder are distributed throughout estuarine and coastal waters of the Gulf from Florida to Texas (Hoese and Moore, 1998). Spawning occurs during late fall and early winter in nearshore waters (Gilbert, 1986). Once they reach sexual maturity (2 years), they begin migrating to the Gulf to spawn (Daniels, 2000; Pattillo et al., 1997). Juveniles and adults are demersal and prefer estuarine, riverine, or marine environments, depending on the hydrography (Pattillo et al., 1997). This species is found over unconsolidated clayey silts and organic muds or may be associated with seagrass meadows or flooded marsh (Pattillo et al., 1997). Southern flounder are carnivorous during most life history stages, feeding mostly on crustaceans (Gilbert, 1986).

Juvenile southern flounder are common to abundant throughout most of the project areas year-round (Table 2). Adults are most common in the project areas from the spring through late fall (Table 2). During late fall, they move to deeper offshore waters to spawn (Nelson et al., 1992; Pattillo et al., 1997; Reagan and Wingo, 1985). Within the project areas, southern flounder may occur in the tidally influenced emergent wetlands and within or adjacent to open-water areas.

3.3 FEDERALLY MANAGED SPECIES

Information regarding Federally managed species was obtained through the NOAA EFH Mapper v3.0 (NOAA, 2016) and NOAA Gulf of Mexico Essential Fish Habitat: Offshore Products (NOAA, 2013).

Table 3 lists the species that NMFS and the GMFMC identify in the study and project area as using EFH. The categories of EFH that occur within the project areas include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, seagrasses, and mangroves.

Within areas identified as EFH, Habitat Areas of Particular Concern (HAPC) may be designated in order to focus conservation priorities on areas that are important to the life cycles of Federally managed species and may warrant more targeted protection measures. Designation of specific HAPCs is based on ecological function, habitats sensitive to human-induced environmental degradation, stressors of development activities, and habitat rarity (Dobrzynski and Johnson, 2001). No HAPCs are designated in the project areas (NOAA, 2016).

Table 3
Species Identified as Using EFH in the Project Areas

		Coastal Region		
Common Name*	Species Name*	Upper	Mid	Lower
Brown shrimp	*Farfantepenaeus aztecus*	X	X	X
Pink shrimp	*Farfantepenaeus duorarum*	X	X	X
White shrimp	*Litopenaeus setiferus*	X	X	X
Blacknose shark	*Carcharhinus acronotus*	X	X	X
Atlantic angel shark	*Squatina dumeril*			X
Spinner shark	*Carcharhinus brevipinna*	X	X	X
Silky shark	*Carcharhinus falciformis*		X	X
Finetooth shark	*Carcharhinus isodon*		X	X
Bull shark	*Carcharhinus leucas*	X	X	X
Blacktip shark	*Carcharhinus limbatus*	X	X	X
Dusky shark	*Carcharhinus obscurus*		X	
Tiger shark	*Galeocerdo cuvier*	X	X	X
Lemon shark	*Negaprion brevirostris*	X	X	X
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	X	X	X
Scalloped hammerhead shark	*Sphyrna lewini*	X	X	X
Great hammerhead shark	*Sphyrna mokarran*	X	X	X
Bonnethead shark	*Sphyrna tiburo*	X	X	X
Red grouper	*Epinephelus morio*	X	X	X
Gag grouper	*Mycteroperca microlepis*	X	X	X
Scamp	*Mycteroperca phenax*	X	X	X
Cobia	*Rachycentron canadum*	X	X	X
Dolphin	*Coryphaena hippurus*		X	X
Greater amberjack	*Seriola dumerili*	X	X	X
Lesser amberjack	*Seriola fasciata*	X	X	X
Red snapper	*Lutjanus campechanus*	X	X	X
Gray snapper	*Lutjanus griseus*	X	X	X
Lane snapper	*Lutjanus synagris*	X	X	X
Vermilion snapper	*Rhomboplites aurorubens*	X	X	X
Red drum	*Sciaenops ocellatus*	X	X	X
Little tunny	*Euthynnus alletteratus*	X	X	X
King mackerel	*Scomberomorus cavalla*	X	X	X
Spanish mackerel	*Scomberomorus maculatus*	X	X	X
Sailfish	*Istiophorus platypterus*		X	X
Blue marlin	*Makaira nigricans*			X

Source: NMFS (2009); NOAA (2013, 2016).
* Species according to Page et al. (2013).

3.4 LIFE HISTORY CHARACTERISTICS OF FEDERALLY MANAGED SPECIES

The following describes the preferred habitat, life history stages, and relative abundance of each Federally managed species based on information provided by GMFMC (2004) and GMFMC EFH Excel spreadsheets provided by NMFS (pers. com. R. Swafford [NMFS], 2018). Table 4 describes the relative abundance and adult and juvenile presence of each EFH-managed species occurring in the project areas. Relative abundance is defined as follows (Nelson et al., 1992):

- Highly Abundant: Species numerically dominant relative to others
- Abundant: Species often encountered in substantial numbers relative to others
- Common: Species generally encountered but not in large numbers and not evenly distributed over specific salinity zones
- Rare: Species present but not frequently encountered
- Not Present: Species not found in area

Brown Shrimp (*Farfantepenaeus aztecus*)

Adult brown shrimp are most abundant off the coasts of Texas, Louisiana, and Mississippi from March to December (Pattillo et al., 1997). They inhabit a wide range of water depths up to approximately 360 feet. Nonspawning adults prefer turbid waters and soft sediment. Brown shrimp eggs are demersal and are deposited offshore. The larvae begin to migrate through passes with flood tides into estuaries as postlarvae. Migrating occurs at night mainly from February to April, with some migration in the fall. Brown shrimp postlarvae and juveniles are associated with shallow vegetated habitats in estuaries but are also found over silty sand and nonvegetated mud bottoms. Postlarvae and juveniles occur in salinity ranging from 0 to 70 ppt. The density of postlarvae and juveniles is highest in emergent marsh edge habitat and SAV, followed by tidal creeks, inner marsh, shallow open water, and oyster reefs (Clark et al., 2004). Juveniles and subadults of brown shrimp occur from secondary estuarine channels out to the continental shelf, but prefer shallow estuarine areas, particularly soft, muddy areas, shell substrates, or plant-water interfaces (Baltz et al., 1993; GMFMC, 2004; Peterson and Turner, 1994; Rakocinski et al., 1992). Subadult brown shrimp migrate from estuaries at night on ebb tides during new and full moon phases in the Gulf. Their abundance offshore correlates positively with turbidity and negatively with low DO. Adult brown shrimp inhabit nearshore areas on the continental shelf and are associated with silt, muddy sand, and sandy substrates (GMFMC, 2004). Larval brown shrimp feed on phytoplankton and zooplankton. Postlarvae brown shrimp feed on phytoplankton, epiphytes, and detritus. Juvenile and adult brown shrimp prey on amphipods, polychaetes, and chironomid larvae and graze on algae and detritus (Lassuy, 1983c; Pattillo et al., 1997).

Although adult brown shrimp typically inhabit offshore waters (Pattillo et al., 1997), there is a high probability that they occur within the project areas, as characteristics of the open-water habitat type closely resemble those preferred by adult brown shrimp (e.g., turbid waters and soft sediments) (Lassuy, 1983c; Pattillo et al., 1997). Juvenile brown shrimp are abundant within mid and upper coast bays year-round, while adult brown shrimp are common to highly abundant from April to October (Table 4) (Nelson et al., 1992). In the Gulf, adult brown shrimp are common year-round and spawning year-round at depths greater than 40 feet (Nelson et al., 1992; Pattillo et al., 1997). Brown shrimp are likely to occur in the study and project areas.

Pink Shrimp (*Farfantepenaeus duorarum*)

Pink shrimp inhabit Gulf and estuarine waters and are pelagic or demersal, depending on their life stage. After spawning offshore, postlarval pink shrimp recruitment into the estuaries occurs in the spring and fall through passes. Juveniles can be found in SAV meadows where they burrow into the substrate; however, postlarvae, juvenile, and adults may prefer a mixture of coarse sand/shell/mud. Densities of pink shrimp are lowest or absent in marshes, low in mangroves, and greatest near or in SAV. Adults occur offshore at depths from 30 to 145 feet and prefer substrates of coarse sand and shell (GMFMC, 2004). Pink shrimp feed on phytoplankton and zooplankton. Postlarvae feed on phytoplankton, epiphytes, and detritus. Juveniles and adults prey on amphipods, polychaetes, chironomid larvae, algae, and detritus (Pattillo et al., 1997).

Juvenile pink shrimp are common within mid coast bays, and adults are common on the mid to upper coast bays, while in the Gulf, adults are present year-round (Table 4) (Nelson et al., 1992; Pattillo et al., 1997). Pink shrimp are likely to occur in the study and project areas.

White Shrimp (*Litopenaeus setiferus*)

White shrimp inhabit Gulf and estuarine waters and are pelagic or demersal, depending on their life stage. Their eggs are demersal and larval stages are planktonic and both occur in nearshore Gulf waters. Postlarvae migrate into estuaries through passes from May to November with most migration in June and September. Migration occurs in the upper water column at night and at mid-depths during the day. Postlarval white shrimp become benthic once they reach the estuary where they seek shallow water with mud or sand bottoms high in organic detritus or rich marsh. Postlarvae and juveniles prefer mud or peat bottoms with large quantities of decaying organic matter or SAV. Densities are usually highest along marsh edge and in SAV, followed by marsh ponds and channels, inner marsh, and oyster reefs. Juvenile white shrimp prefer salinities less than 10 ppt and occur in tidal rivers and tributaries (Muncy, 1984). As juveniles mature, they migrate to coastal areas where they spawn. Adult white shrimp are demersal and inhabit soft mud or silt bottoms (GMFMC, 2004). Nonspawning adults are tolerant of temperatures between 7 and 100 ºF, and survival is high between 2 and 35 ppt, while spawning adults prefer salinity above 27 ppt. White shrimp larvae feed on phytoplankton and zooplankton. White shrimp postlarvae feed on phytoplankton, epiphytes, and detritus. Juvenile and adult white shrimp prey on amphipods, polychaetes, and chironomid larvae, but also graze on algae and detritus (Pattillo et al., 1997).

Table 4
Species Adult and Juvenile Life Stages Present in the Project Area for Essential Fish Habitat

Common/Scientific Name*	EcoRegion 4		EcoRegion 5								Marine	
	Galveston Bay		Brazos River		Matagorda Bay		Corpus Christi/ Upper Laguna Madre		Lower Laguna Madre			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Brown shrimp (*Farfantepenaeus aztecus*)	abundant to highly abundant; year-round major nursery area	common Apr-Oct	abundant year-round	not present	common to highly abundant year-round major nursery area	common to highly abundant Apr-July	common to highly abundant year-round	not present	common to abundant Sept-Apr	common Mar-May	spawning area year-round	major adult area spring, summer, fall
Pink shrimp (*Farfantepenaeus duorarum*)	nursery area summer and fall	not present to rare	common Nov - June	not present	nursery area summer and fall	common Feb-May	common	not present	abundant	common	nursery area summer and fall	present year-round spawning area in summer
White shrimp (*Litopenaeus setiferus*)	highly abundant Apr-Dec common Jan-Mar nursery area	rare to common year-round	highly abundant July-Oct abundant Nov-June nursery area	common Apr-June	highly abundant Feb-Nov common to rare Dec-Jan nursery area	abundant March common Apr-June, Aug-Nov	common to abundant Mar-Dec	common Apr-Jul abundant Sept-Nov	common Jun-Jul abundant Aug-Nov	common to rare Nov-Mar	not present	present year-round spawning March-October
Blacknose shark (*Carcharhinus acronotus*)	not present	not present	not present		not present	present	not present		not present		present	
Atlantic angel shark (*Squatina dumeril*)	not present		not present		not present		not present		not present		present	
Spinner shark (*Carcharhinus brevipinna*)	Galveston Bay and all nearshore waters	not present	not present		present	not present	not present		present	not present	present	
Silky shark (*Carcharhinus falciformis*)	not present	not present	not present		not present		not present		present		present	
Finetooth shark (*Carcharhinus isodon*)	not present		not present		not present		not present		present		present	
Bull shark (*Carcharhinus leucas*)	common Mar-Nov	present	present		common	not present	common	not present	rare	not present	present	
Blacktip shark (*Carcharhinus limbatus*)	present	not present	not present		present	not present	not present		not present		present	
Dusky shark (*Carcharhinus obscurus*)	not present		not present		not present		not present		not present		present	
Tiger shark (*Galeocerdo cuvier*)	not present	not present	not present		not present		not present	present	not present	present	present	
Lemon shark (*Negaprion brevirostris*)	present	present	present	not present	present	not present	present	present	present	present	present	
Atlantic sharpnose shark (*Rhizoprionodon terraenovae*)	present		not present		present		present	present	not present	present	present	
Scalloped hammerhead shark (*Sphyrna lewini*)	present	not present	present	not present	present	not present	present	present	present	present	present	
Great hammerhead shark (*Sphyrna mokarran*)	present		present	present	present	present	present	present	not present		present	
Bonnethead shark (*Sphyrna tiburo*)	present	not present	not present		present		present		not present		present	

Common/Scientific Name*	EcoRegion 4		EcoRegion 5								Marine	
	Galveston Bay		Brazos River		Matagorda Bay		Corpus Christi/ Upper Laguna Madre		Lower Laguna Madre			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Red grouper (*Epinephelus morio*)	not present		not present		not present		not present		not present		nursery area year-round	adult occurrence
Gag grouper (*Mycteroperca microlepis*)	not present	adult occurrence	not present		not present		not present		not present		not present	adult occurrence
Scamp (*Mycteroperca phenax*)	not present		not present		not present		not present		not present		not present	adult occurrence
Cobia (*Rachycentron canadum*)	nursery area year-round	adult area summer	nursery area year-round	not present	nursery area year-round	not present	not present		not present		nursery area year-round	present spring - fall
Dolphin (*Coryphaena hippurus*)	not present		not present		not present		not present		not present		present year-round	
Greater amberjack (*Seriola dumerili*)	nursery area	adult and spawning area	not present		not present		not present		not present		present year-round	adult and spawning area year-round
Lesser amberjack (*Seriola fasciata*)	nursery area	adult and spawning area	not present		not present		not present		not present		not present	present
Red snapper (*Lutjanus campechanus*)	nursery area year-round	adult and spawning area	nursery area year-round	not present	nursery area year-round	not present	not present		not present		nursery area year-round	not present
Gray snapper (*Lutjanus griseus*)	nursery area	major adult and spawning area year-round	not present		nursery area	major adult area year-round	rare to not present	rare to not present	common Jul-Oct	rare	not present	major adult area year-round spawn June-August
Lane snapper (*Lutjanus synagris*)	nursery area	adult and spawning area	nursery area	not present	nursery area	not present	not present		not present		nursery area	adult and spawning area year-round
Vermilion snapper (*Rhomboplites aurorubens*)	nursery area	major adult and spawning area	not present		not present		not present		not present		nursery area	not present
Red drum (*Sciaenops ocellatus*)	common year-round nursery area	present year-round major adult and spawning area	common year-round nursery area	common year-round	nursery area year-round	common year-round	common year-round	rare year-round	common year-round	rare to not present	not present	present year-round spawning area fall and winter
Little tunny (*Euthynnus alletteratus*)	not present		not present		not present		not present		not present		present	
King mackerel (*Scomberomorus cavalla*)	nursery area year-round	present year-round major adult and spawning area	nursery area year-round	present year-round	nursey area	adult and spawning area	nursery area	adult and spawning area	nursery area	adult and spawning area	nursery area year-round	present year-round spawning area May-Nov
Spanish mackerel (*Scomberomorus maculatus*)	common May-Oct nursery area	not present	rare to not present	present year-round	nursery area year-round	common July-Oct rare Nov-June	rare to not present	rare to not present	rare to not present	rare to not present	nursery area year-round	present year-round spawning area summer and fall
Sailfish (*Istiophorus platypterus*)	not present		not present		not present		not present	present	not present		present	
Blue marlin (*Makaira nigricans*)	not present		not present		not present		not present		present	not present	present	

Source: Nelson et al. (1992), NMFS (2009), NOAA (2013, 2016), pers. com. R. Swafford (NMFS, 2018).
* Species according to Page et al. (2013).

Adult and juvenile white shrimp are common to abundant in mid to upper coast bays throughout the year. Adult white shrimp also occur year-round throughout the Gulf to depths of about 131 feet (Table 4) (Muncy, 1984; Nelson et al., 1992; Pattillo et al., 1997). White shrimp are likely to occur in the study and project areas.

Blacknose Shark (*Carcharhinus acronotus*)

The blacknose shark is a common tropical and warm temperate species found on the continental shelf mainly over sand, shell, and coral bottoms to depths of 60 to 210 feet (Compagno, 1984; Driggers et al., 2007; Morgan et al., 2008). These sharks undergo seasonal migrations to the northern portion of their range, where they reside from March to November. Although little is known about their migrations in the Gulf, blacknose sharks were captured in March 2003, south of Pascagoula, Mississippi, indicating that these sharks move offshore during the late autumn, winter, and early spring months (Driggers et al., 2007; Sulikowski et al., 2007). Blacknose sharks reproduce once per year in the Gulf, which is in contrast to their biennial reproductive cycle in the south Atlantic (Morgan et al., 2008; Sulikowski et al., 2007). They feed on small fish, including Pinfish (*Lagodon rhomboids*) and porcupine fish (Diodontidae) (Compagno, 1984). Adult and juvenile blacknose sharks occur in Gulf waters of the study and project areas (Table 4) (Bethea et al., 2008; NMFS, 2009). However, Drymon et al. (2010) suspect that the north-central Gulf is not a large nursery area for this species.

Atlantic Angel Shark (*Squatina dumeril*)

The Atlantic angel shark is a temperate and subtropical species of the western Atlantic to the Gulf of Mexico, found at depths up to 4,232 feet, occasionally found in shallower waters. There is little life history information available on this species, and its distribution is not fully understood. These sharks appear to migrate inshore in the spring and summer, moving to deeper waters during the fall and winter. Atlantic angel sharks are known to feed on bottom fishes such as flounders and skates, bivalves, and crustaceans (Heupel and Carlson, 2006). This species is unlikely to occur in the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Spinner Shark (*Carcharhinus brevipinna*)

The spinner shark is a common coastal pelagic species found both inshore and offshore to depths of approximately 240 feet, but most commonly at depths of less than 100 feet. It is a schooling species that commonly leaps spinning out of the water. Spinner sharks are highly migratory, although its patterns are poorly known. They move inshore during the spring and summer to spawn and feed and possibly southward, into deeper water, during the fall and winter (Burgess, 2009; Compagno, 1984). Spinner sharks feed primarily on fish including sardines, herring, anchovies, catfish, mullet, bluefish, tunas, and jacks (Burgess, 2009; Compagno, 1984). Adult and juvenile spinner sharks are present in estuarine and Gulf waters of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Silky Shark (*Carcharhinus falciformis*)

Silky sharks are a tropical, oceanic, coastal pelagic species that have a circumglobal distribution. They can be found along the edge of the continental shelf to depths of greater than 1,640 feet, preferring warmer waters, and often associated with deep-water reefs, islands, and insular slopes (Compagno, 1984; Rigby et al., 2016). Silky sharks are quick moving, aggressive, and active sharks (Compagno, 1984). They give birth to live young with nursery areas typically found in shallower coastal waters while adults occupy deeper waters farther offshore. Silky sharks leave the nursery areas as subadults to move to deeper offshore waters. Atlantic populations of silky sharks were on the decline through the 1990s as a result of longlines and purse seine fisheries, but since 2000 their numbers appear to be increasing (Rigby et al., 2016). They are primarily piscivorous, feeding on tuna, mackerel, sea catfish, and porcupine fish, but also crabs and squid (Compagno, 1984). Silky sharks are likely to occur in the Gulf portions of the study and project areas and south Texas estuaries (Table 4) (NMFS, 2009; NOAA, 2016).

Finetooth Shark (*Carcharhinus isodon*)

Finetooth sharks are a Gulf species occurring in shallow coastal waters including bays, estuaries, along beaches, and near river mouths to about 66 feet. They are common in the Gulf during the summer when the water is warmer, migrating south in the fall and winter when water temperatures drop (Carlson et al., 2009). Documented nursery habitat is located off the Texas and Louisiana coasts (NMFS, 2009). They probably feed on small boney fish and cephalopods including mackerel, croakers, and mullet (Compagno, 1984; Carlson et al., 2009). Adult and juvenile finetooth sharks are found in the estuarine and Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Bull Shark (*Carcharhinus leucas*)

Bull sharks are a common tropical and subtropical species having a wide range along the coast inhabiting shallow waters, especially in bays, rivers, and lakes. They frequently move between fresh and brackish water and can travel great distances inland. They are the only species of shark capable of existing in freshwater for extended periods (Simpfendorfer and Burgess, 2009). Bull sharks are viviparous, have a gestation period of a little less than 1 year, and it is assumed their reproductive cycle occurs every 2 years. Juveniles are found at depths less than 80 feet in shallow coastal waters, inlets, and estuaries (Compagno, 1984; NMFS, 2009). They have a diverse diet, feeding on sea turtles, birds, dolphins, bony fish, sharks, rays, shrimp, crabs, squid, and sea urchins (Simpfendorfer and Burgess, 2009). Adult and juvenile bull sharks are present in the estuarine and Gulf portion of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Blacktip Shark (*Carcharhinus limbatus*)

Blacktip sharks are widespread inhabiting tropical and subtropical shallow waters and offshore surface waters of the continental shelf. This species commonly occurs in loose aggregations in bays, estuaries, off beaches, and near mouths of rivers (Burgess and Branstetter, 2009). They are viviparous (giving birth to live young), and young are born in coastal bays and estuaries in late May and early June after a 1-year gestation period. Their reproductive cycle occurs every 2 years. Juveniles inhabit shallow coastal waters from the shore to the 82-foot isobath (Burgess and Branstetter, 2009; NMFS, 2009). They feed mainly on pelagic and benthic fish, cephalopods and crustaceans, and small rays and sharks (Burgess and Branstetter, 2009; Compagno, 1984). This species is often confused with spinner sharks due to their unusual habit of leaping out of the water and spinning (Burgess and Branstetter, 2009). Juvenile and adult blacktip sharks occur in the Gulf and estuarine portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Dusty Shark (*Carcharhinus obscurus*)

Dusky sharks are a large wide-ranging coastal pelagic species occurring in warm temperate seas. They are found in the surf zone to offshore up to depths of 1,300 feet, not commonly found in estuaries due to their poor ability to osmoregulate at lower salinities (Compagno, 1984; Musick et al., 2009). The dusky shark is a highly migratory species showing seasonal patterns with adults moving to cooler waters during the summer and warmer waters during the winter. They are the latest-maturing sharks, slow growing, viviparous with a long gestation period (as long as 22 months), and produce small litters. As a result, dusky sharks have undergone population declines and are among the most vulnerable of all vertebrates to depletion by fisheries (Musick et al., 2009). Dusky sharks feed on a variety of fish including menhaden, anchovies, mullet, barracuda, groupers, croakers, jacks, sharks, rays, shrimp, squid, and octopi (Compagno, 1984). They are a common apex predator playing an important role in the marine ecosystem (Musick et al., 2009). Juvenile and adult dusky shark occur in the Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Tiger Shark (*Galeocerdo cuvier*)

The tiger shark is a global coastal pelagic species occurring in both very shallow and deep (up to 460 feet) waters (Compagno, 1984; Simpfendorfer, 2009). They prefer turbid areas, often occurring in river estuaries and near wharves and jetties in coastal waters. It is the only shark species in the Carcharhinidae family that is ovoviviparous (Compagno, 1984). Mating occurs in the spring with pupping the following spring to summer. Litters are produced every 2 years or less (Simpfendorfer, 2009). Tiger sharks have the most diverse diet of any shark species, eating both plants and animals, including boney fishes, sharks and rays, sea turtles, sea birds, marine mammals, crustaceans, carrion of terrestrial wildlife, and floating garbage (Compagno, 1984; Simpfendorfer, 2009). They are one of the most aggressive and dangerous of the shark species, being known to consume humans (Compagno, 1984). Juvenile and adult tiger sharks occur in the Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Lemon Shark (*Negaprion brevirostris*)

Lemon sharks are a large coastal species that inhabit inshore waters of the continental and insular shelves occurring to depths of 300 feet, but favoring shallow areas (Compagno, 1984; Sundström, 2015). They can be found around coral reefs, mangroves, docks, enclosed bays, sounds, and river mouths, occasionally venturing into the open ocean during migrations (Compagno, 1984; NMFS, 2009). The lemon shark is viviparous with mating occurring in shallow water during the spring and summer, followed by a 10- to 12-month gestation period, giving birth in shallow nursery areas (Compagno, 1984; Sundström, 2015). The young feed mainly on boney fish, crabs, shrimp, and octopus while adults eat boney and cartilaginous fishes and sea birds (Sundström, 2015). Adult lemon sharks occur in the estuarine portions of the study and project areas, and adults and juveniles are found in the Gulf portions (Table 4) (NMFS, 2009; NOAA, 2016).

Atlantic Sharpnose Shark (*Rhizoprionodon terraenovae*)

The Atlantic sharpnose shark is an abundant warm temperate and tropical waters shark that is one of the most common shark species in the northern Gulf (Cortés, 2009; Hoese and Moore, 1998). Migrations are seasonal, limited to inshore/offshore movements, moving to deeper water in the winter and returning inshore during the spring (Compagno, 1984). They inhabit intertidal to deeper waters, often in the surf zone off sandy beaches, bays, estuaries, and river mouths mostly over mud and sand bottoms (Cortés, 2009). During the summer, juveniles and adults inhabit shallow inshore waters. They are viviparous, and mating occurs in June, with a gestation period of about 1 year using enclosed bays as nursery areas (Cortés, 2009; NMFS, 2009). Juvenile Atlantic sharpnose sharks are found in higher salinity estuaries and the surf zone during the summer (Hoese and Moore, 1998). They feed on fish, shrimp, crab, mollusks, and segmented worms (Cortés, 2009). Juvenile and adult Atlantic sharpnose shark occur in the Gulf and estuarine portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Scalloped Hammerhead Shark (*Sphyrna lewini*)

Scalloped hammerhead sharks are a very common coastal, pelagic species, which occur over the continental shelf and deeper water, often entering bays and estuaries (Compagno, 1984). They are found inshore and offshore from intertidal and surface to depths of approximately 900 feet (Baum et al., 2007). They migrate seasonally forming large schools of small migrating individuals that move to higher latitudes in the summer in certain areas (Compagno, 1984). Adults spend most of the time offshore, with females migrating to coastal areas to have their pups (Baum et al., 2007). Juvenile scalloped hammerhead sharks occur close to shore in bays and nearshore coastal waters, moving to deeper waters as they grow before moving out to adult habitat offshore (Baum et al., 2007; Compagno, 1984). Adults feed on a variety of fish and cephalopods, while juveniles feed mainly on demersal fish, benthic reef fish, and crustaceans (Baum et al., 2007; Compagno, 1984). Juvenile and adult scalloped hammerhead sharks occur in the Gulf and estuarine portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Great Hammerhead Shark (*Sphyrna mokarran*)

Great hammerhead sharks are a large coastal pelagic, semioceanic species occurring in shallow coastal areas over continental shelves and lagoons to far offshore to depths over 260 feet (Compagno, 1984). They are nomadic and migratory, with some populations moving to cooler higher latitude waters during the summer months (Compagno, 1984; Denham et al., 2007). Breeding occurs once every 2 years with birthing in the late spring to summer (Denham et al., 2007). During warmer months, great hammerhead sharks use shallow inshore waters along Florida's Gulf coast as nursery areas (NMFS, 2009). They feed mainly on demersal fish, cephalopods, crustacea, and other elasmobranchs (Denham et al., 2007). Adult and juvenile great hammerhead sharks are present in the estuarine and Gulf portions of the study and project areas (NMFS, 2009). Adult great hammerhead sharks occur in the Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Bonnethead Shark (*Sphyrna tiburo*)

Bonnethead sharks are an abundant coastal species inhabiting shallow estuaries and bays over grass, sand, or mud bottoms and in the Gulf at depths of 30 to 260 feet (Compagno, 1984; Cortés, 2016). They are found in small schools of 3 to 15 individuals, and very rarely alone (Compagno, 1984). Bonnethead sharks exhibit little or no long-distance migratory behavior, preferring to stay in one location (Heupel et al., 2006). They reproduce once a year, having the shortest gestation period of any of the shark species at 4½ to 5 months. Nursery areas are located inshore in shallow seagrass habitat (Cortés, 2016). Bonnethead sharks feed primarily on crustaceans including crabs (especially blue crabs), shrimp, barnacles, and bivalves (Compagno, 1984; Heupel et al., 2006). They are specialist hunters appearing to have higher food consumption rates than other species of shark (Cortés, 2005). Adult and juvenile bonnethead sharks are present in the estuarine and Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Red Grouper (*Epinephelus morio*)

Red groupers are a demersal species occurring throughout the Gulf from depths of 10 to 660 feet (GMFMC, 2004). Adults are found mainly on muddy and rocky bottoms, usually resting on the bottom substrate. Juveniles prefer seagrass beds in shallower water and inshore reefs until they reach larger sizes when they move out to rocky bottom and reef habitats (Froese and Pauly, 2017; Garcia-Moliner and Eklund, 2004). Spawning occurs offshore during the spring in the same areas as they reside. Eggs are pelagic, requiring at least 32 ppt for buoyancy. Juveniles prefer grass beds, shallow reefs, and rock formations that are utilized as nursery areas where they remain until mature before moving to deeper offshore waters. They feed mainly on fish, shrimp, crabs, octopus, and lobsters (GMFMC, 2004). Adult and juvenile red grouper occur in the Gulf portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Gag Grouper (*Mycteroperca microlepis*)

Gag grouper are demersal and are most common in the eastern Gulf. Eggs are pelagic and are spawned from December through April (Bertoncini et al., 2008; GMFMC, 2004). Larvae are pelagic and most abundant in the early spring (GMFMC, 2004). Post-larvae and pelagic juveniles move through inlets into high salinity estuaries from April through May, where they become benthic and settle into grass flats and oyster beds (Bertoncini et al., 2008; GMFMC, 2004). Older juveniles move offshore in the fall to shallow reef habitat in depths of 3 to 170 feet. Adults prefer depths of 30 to 330 feet and utilize hard bottoms, oil platforms, and artificial reefs (GMFMC, 2004). Adult gag grouper school in groups of 5 to 50 individuals or may be found solitary (Bertoncini et al., 2008). They feed on estuarine-dependent organisms such as shrimp, small fish, and crabs during their juvenile stages. As they mature and move farther offshore, they become opportunistic predators, feeding on a variety of fish and crustaceans (Bertoncini et al., 2008; GMFMC, 2004). Adult gag grouper occur in Gulf waters within the study and project areas (Table 4) (NOAA, 2013, 2016).

Scamp (*Mycteroperca phenax*)

Scamp are a deep-water demersal species that is widely distributed throughout the Gulf and found over ledges and high-relief rocky bottoms, congregating at depths of 40 to 240 feet in the Gulf (Bates, 2016; GMFMC, 2004; Rocha et al., 2008). It is estimated that this species lives for at least 30 years. Spawning occurs in aggregations at the shelf edge from February to July in the Gulf (Rocha et al., 2008). Eggs and larvae are pelagic and occur offshore in the spring (GMFMC, 2004). Juveniles can be found in shallow-water mangrove areas and at jetties (Rocha et al., 2008). Adult scamp occur in Gulf waters within the study and project areas (Table 4) (NOAA, 2013, 2016).

Cobia (*Rachycentron canadum*)

Cobia are a widely distributed large, pelagic fish, found over rocky shores, shallow coral reefs, and occasionally in estuaries (Collette et al., 2015; GMFMC, 2004). They are often associated with pilings, platforms, buoys, anchored boats, and flotsam (Florida Museum of Natural History, 2017a). Spawning occurs in large aggregations from April through September in coastal waters (Collette et al., 2015). While cobia rarely use estuarine environments, estuaries are important for most of their prey. They are a voracious eater often swallowing prey whole, feeding mainly on mantis shrimp, eels, crabs, squid, and Spanish mackerel (Florida Museum of Natural History, 2017a; GMFMC, 2004). Adult and juvenile cobia occur in the Gulf and estuarine portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Dolphin (*Coryphaena hippurus*)

Dolphin are a pelagic offshore species often associated with *Sargassum* and other floating objects and found to depths of 280 feet. They travel together in small schools and exhibit north-south seasonal migrations (Collette et al., 2011; GMFMC, 2004a). Multiple spawning events occur throughout the year in open water when temperatures rise above 69.8°F (Collette et al., 2011a; GMFMC, 2004). Eggs and larvae are pelagic and commonly associated with *Sargassum*. Young billfishes often prey upon dolphin larvae and juveniles are eaten by larger pelagic fishes, including other dolphin. Adults feed on small oceanic fish, juveniles of larger pelagic fish, and invertebrates (GMFMC, 2004). Adult and juvenile dolphin occur in the Gulf portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Greater Amberjack (*Seriola dumerili*)

Greater Amberjack occur throughout the Gulf to depths of 1,300 feet (GMFMC, 2004). Adults are pelagic and epibenthic, occurring near reefs, artificial structures, rocky outcrops, and wrecks, usually in small schools but may be solitary (Smith-Vaniz et al., 2015a). Little is known about the spawning habits of greater amberjack; however, it is thought migrations are related to reproduction (Florida Museum of Natural History, 2017b). Spawning occurs offshore from March to July near reefs and wrecks (GMFMC, 2004; Florida Museum of Natural History, 2017b). Juveniles are pelagic and associated with floating *Sargassum* mats and debris in the offshore nursery areas (GMFMC, 2004). Adult greater amberjack feed on benthic and pelagic fish, squid, and crustaceans while juveniles eat plankton and other small invertebrates (Florida Museum of Natural History, 2017b). Adult and juvenile greater amberjack are found in the Gulf within the study and project areas (Table 4) (NOAA, 2013, 2016).

Lesser Amberjack (*Seriola fasciata*)

Adult lesser amberjack occur year-round in the northern Gulf and are near the bottom associated with oil and gas platforms and irregular bottoms at depths from 180 to 430 feet (GMFMC, 2004; Smith-Vaniz et al., 2015b). Spawning occurs in the Gulf from September through December and again in February through March. There is no information on eggs, larvae, and post-larvae. Juveniles are found in the Gulf during late summer and fall, and small juveniles are associated with *Sargassum* mats (GMFMC, 2004). They feed primarily on fish and squid but will take dead bait (Smith-Vaniz et al., 2015b). Adult lesser amberjack are found in the Gulf within the study and project areas (Table 4) (NOAA, 2016).

Red Snapper (*Lutjanus campechanus*)

Red snapper are demersal, found over sand and rock substrates, around reefs, and underwater objects to depths ranging from 10 feet for juveniles to 2,000 feet for adults (GMFMC, 2004; Anderson et al., 2015). However, adult red snapper prefer depths ranging from 130 to 360 feet (GMFMC, 2004). Spawning occurs in the Gulf from May to July and November to December, at depths of 60 to 120 feet over a firm sand substrate (Moran, 1988). Eggs are found offshore in the summer and late fall. Larvae, post-larvae, and early juveniles occur from July through November in shelf waters (GMFMC, 2004). Early and late juveniles are often associated with underwater structures or small burrows of low relief but are also abundant over barren sand and mud bottoms (Gallaway et al., 1999; GMFMC, 2004). Juvenile red snapper feed mainly on shrimp, but after age one, prey primarily on fish and squid (Anderson et al., 2015; GMFMC, 2004; Moran, 1988). Of the vertebrates consumed, most are not obligate reef dwellers, indicating that red snapper feed away from reefs (GMFMC, 2004). Juvenile red snapper are found in the Gulf and estuarine portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Gray Snapper (*Lutjanus griseus*)

Gray snapper can be demersal, structure, or mid-water dwellers inhabiting marine, estuarine, and riverine habitats. They inhabit depths to about 550 feet in the Gulf (GMFMC, 2004). Juvenile gray snapper are common in shallow water around SAV, mangrove roots, docks, pilings, and jetties, while adults tend to congregate in deeper Gulf waters around natural and artificial reefs. Spawning occurs offshore in groups from June to August around structures and shoals. Their eggs are pelagic, and the larvae are planktonic, both occurring in Gulf shelf waters and near coral reefs. Post-larvae migrate into the estuaries and are most abundant over *Halodule* and *Syringodium* grassbeds. Juveniles seem to prefer *Thalassia* grassbeds, seagrass meadows, marl bottoms, and mangrove roots, and are found in estuaries, bayous, channels, grassbeds, marshes, mangrove swamps, ponds, and freshwater creeks (Lindeman et al., 2016a; Pattillo et al., 1997). Juvenile gray snapper feed on estuarine-dependent organisms such as shrimp, small fish, and crabs. Gray snapper are classified as opportunistic carnivores at all life stages (Pattillo et al., 1997). In estuaries, juveniles feed on shrimp, larval fish, amphipods, and copepods. Adults feed primarily on fish, but smaller individuals will prey on crustaceans (GMFMC, 2004; Lindeman et al., 2016a). Juvenile and adult gray snapper are found in the Gulf and estuarine portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Lane Snapper (*Lutjanus synagris*)

Lane snapper are a demersal species occurring over multiple substrate types but are most commonly found near reefs and vegetated sandy bottoms in shallow inshore waters (Florida Museum of Natural History, 2017c). Lane snapper appear to favor grass flats, reefs, and soft bottoms to depths of approximately 70 feet (GMFMC, 2004) but adult lane snapper can occur offshore in depths up to 430 feet near sand bottoms, natural channels, banks, and artificial and natural structures. They tend to remain in the same area their entire lives (GMFMC, 2004; Florida Museum of Natural History, 2017c). Spawning occurs in aggregations in Gulf waters from March through September (Florida Museum of Natural History, 2017c; GMFMC, 2004). Nursery areas include mangrove and grassy estuarine habitats in southern Texas and Florida and shallow waters with sand and mud bottoms along all Gulf states. Juveniles feed on estuarine-dependent organisms such as shrimp, small fish, and crabs. Lane snapper are considered unspecialized, opportunistic predators, feeding on a variety of crustaceans and fish (Florida Museum of Natural History, 2017c; GMFMC, 2004). Juvenile lane snapper are found in the estuarine portions, and adult and juveniles are found in the Gulf and estuarine portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Vermilion Snapper (*Rhomboplites aurorubens*)

Vermilion Snapper are a demersal species occurring in waters 60 to 660 feet deep over rock, gravel, or sand bottoms in the Gulf (GMFMC, 2004; Lindeman et al., 2016b). They often form large schools, especially the young (Lindeman et al., 2016b). Spawning occurs in offshore waters from April to September. Juveniles are found on hard bottoms, reefs, and artificial structures (GMFMC, 2004; Lindeman et al., 2016b). They feed on fish, benthic invertebrates, crabs, shrimp, and cephalopods (Lindeman et al., 2016b). Juvenile vermilion snapper are found in the Gulf portions of the study and project areas (Table 4) (NOAA, 2016).

Red Drum (*Sciaenops ocellatus*)

Red drum occupy a variety of habitats, ranging from offshore depths of 130 feet to very shallow estuarine waters. Spawning occurs in the Gulf near the mouths of bays and inlets from August through November, peaking in September and October (Pattillo et al., 1997). Eggs usually hatch in the Gulf, and larvae are transported with tidal currents into the estuaries where they mature. Adult red drum use estuaries but tend to migrate offshore where they spend most of their adult life. Red drum occur over a variety of substrates including sand, mud, and oyster reefs and tolerate a wide range of salinities (GMFMC, 2004).

Estuaries are especially important to larval, juvenile, and subadult red drum. Juveniles are most abundant around marshes, preferring shallow, protected waters over mud substrate or among SAV (Stunz et al., 2002a). Juveniles show preferences for specific habitat types, occurring at higher densities in seagrass meadows (Stunz et al., 2002a) with higher growth rates in brackish emergent marsh and in seagrass meadows (Stunz et al., 2002b). Subadult and adult red drum prefer shallow bay bottoms and oyster reefs (GMFMC, 2004). Estuaries are also important for the prey of larval, juvenile, and subadult red drum. Their larvae feed primarily on shrimp, mysids, and amphipods, while juveniles prefer fish and crabs (GMFMC, 2004). Adults are an aggressive opportunistic ambush predator feeding primarily on blue crab, penaeid shrimp, and some benthic fishes (Chao, 2015). Adult and juvenile red drum are found in the estuarine portions and adults in the Gulf portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Little Tunny (*Euthynnus alletteratus*)

Little tunny are found throughout the Gulf over the continental shelf in close inshore waters in depths less than 490 feet (Collette et al., 2011d; Florida Museum of Natural History, 2017d). Adults school according to size with other members of the Scombridae family, breaking apart during certain times of the year (Florida Museum of Natural History, 2017d). Spawning occurs March through November in offshore waters. *Sargassum* mats are utilized by early life history stages as habitat (GMFMC, 2004). Little tunny are opportunistic predators feeding mainly on clupeid fishes (herring, sardines, scad), crustaceans, squid, and tunicates (Collette et al., 2011d; Florida Museum of Natural History, 2017d). Sharks, billfishes, dolphin, and other carnivorous fish prey on little tunny (Florida Museum of Natural History, 2017d). Adults and juveniles are found in the Gulf portions of the study and project areas (Table 4) (NOAA, 2016).

King Mackerel (*Scomberomorus cavalla*)

King mackerel are pelagic and found in Gulf coastal waters and outer reef areas at depths of 75 to 110 feet (Collette et al., 2011e; Florida Museum of Natural History, 2017e). Migrations occur along the east coast, dependent upon warm temperatures. Spawning occurs in the Gulf over the outer continental shelf from May to September (Collette et al., 2011e; GMFMC, 2004). Eggs are pelagic, occurring over depths ranging from approximately of 100 to 600 feet in the spring and summer months (GMFMC, 2004). King mackerel feed mainly on schooling fish, crustaceans, penaeid shrimp, squid, and occasionally mollusks.

Juveniles feed on small fish (mainly anchovies) and invertebrates (Collette et al., 2011e). Adults and juveniles are found in the Gulf and estuarine portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Spanish Mackerel (*Scomberomorus maculatus*)

Spanish mackerel are pelagic, inhabiting depths from 30 to 120 feet throughout the coastal zone of the Gulf (Florida Museum of Natural History, 2017f; GMFMC, 2004). They frequent barrier islands and passes and are often found near the surface in very large schools (Florida Museum of Natural History, 2017f). They may also migrate seasonally into estuaries with high salinity, but this migration is infrequent (GMFMC, 2004). Spawning occurs in the northern Gulf from April through October, peaking in August and September. Larvae typically occur in the Gulf at depths up to 300 feet (Pattillo et al., 1997). Juveniles inhabit the Gulf surf and sometimes estuarine habitats. However, juvenile Spanish mackerel prefer marine salinities and are not considered estuarine-dependent. Juveniles also prefer clean sand bottoms, but the substrate preferences of the other life stages are unknown (GMFMC, 2004). While Spanish mackerel rarely use estuarine environments, estuaries are important for most of their prey (Pattillo et al., 1997). They feed on a variety of fishes, extensively herrings, but also on penaeid shrimp and cephalopods (Collette et al., 2011f; Pattillo et al., 1997). Spanish mackerel are often preyed upon by sharks, tunas, and bottlenose dolphins (Florida Museum of Natural History, 2017f). Adults and juveniles are found in the Gulf and estuarine portions of the study and project areas (Table 4) (NOAA, 2013, 2016).

Sailfish (*Istiophorus platypterus*)

Sailfish are an oceanic and epipelagic species generally found above the thermocline to depths of 130 feet (Collette et al., 2011b; NMFS, 2009). They often occur in loose aggregations over a large area, occasionally forming small schools most likely by size (Collette et al., 2011b). It is assumed that sailfish spawn in the Gulf from May to September due to the presence of larvae during these times, moving inshore into shallow waters to spawn (Collette et al., 2011b; NMFS, 2009). Sailfish are opportunistic feeders feeding mainly on fish, crustaceans, and cephalopods, occurring at the surface, mid-water, reef edges, and along the bottom (Collette et al., 2011b; NMFS, 2009). They are preyed upon by killer whales, bottlenose dolphins, and sharks, although not very often (NMFS, 2009). Adult and juvenile sailfish are found in the Gulf portion of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Blue Marlin (*Makaira nigricans*)

Blue marlin are an epipelagic oceanic species found in tropical and subtropical blue waters. They prefer to stay on the surface above the thermocline in warmer waters and are known to undergo north-south seasonal migrations (Collette et al., 2011c; NMFS, 2009). Although they spend most of their time in shallower depths, they can dive to depths of 3,280 feet but remain mostly in the upper 130 feet (Collette et al., 2011c). Spawning is thought to occur during the May to November timeframe; larvae have been found in the northern Gulf in June and July (NMFS, 2009). Blue marlin feed near the surface mainly on tunalike fish, crustaceans, squid, and cephalopods (Collette et al., 2011c; NMFS, 2009). Adult and juvenile blue marlin are found in the Gulf and estuarine portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

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4.0 POTENTIAL IMPACTS TO EFH

The potential impacts from construction and operation of the CSRM and ER measures proposed for the Coastal Texas Study's TSP (Preferred Alternative) are described below. Adverse effects of this project are actions resulting in the reduction of quality or quantity of EFH. Adverse effects analyzed include direct and indirect physical, chemical, or biological alterations of habitat and the cumulative or synergistic consequences. Habitats of concern, such as oyster reefs and SAV, are addressed separately.

4.1 ALTERNATIVES ANALYSIS

4.1.1 No-Action Alternative

Under the No-Action Alternative there would be no direct impacts to EFH resources. Existing EFH (including estuarine water column, estuarine mud and sand bottoms [unvegetated estuarine benthic habitats], estuarine shell substrate [oyster reefs and shell substrate], estuarine emergent wetlands, seagrasses, mangroves, marine water column, unconsolidated marine water bottoms, and natural structural features) would continue as described in Section 3.0 and be available to Federally managed species for which EFH has been designated (managed species).

The main significance of the predicted global climate change is its possible contribution to increasing sea levels, coastal flooding, changing estuarine salinity regimes, and biological communities. Indirect impacts due to climate change stressors (sea level rise, temperature increases, salinity changes, and wind and water circulation changes), storm severity and frequency, and USACE dredging and maintenance dredging operations would impact the aquatic communities. See Appendix C-1, Section 3.2.1 and 3.2.3 for a more detailed discussion on how these changes in physical factors are expected to impact the Texas coast in the future.

Trends of tidal wetland loss are expected to continue. Increased development, hydrologic alterations, drought, flooding, and temperature extremes could affect wetlands. Sea level rise and climate change, including changes to hydrology, nutrient inputs, and flood or tide timing and intensity could have a variety of impacts on wetlands. See Appendix C-1, Section 3.3.1.2 for a more detailed discussion on how these factors are expected to impact Texas coastal wetlands in the future.

Although marshes throughout the Texas coast are declining and would likely continue this trend as sea level rise continues, there is a potential that marshes would develop farther inland where the elevation and topography are conducive for establishment in response to rising sea levels (Borchert et al., 2018; Guannel et al., 2014; Murdock and Brenner, 2016; Scavia et al., 2002). According to the NOAA (2017d) Sea Level Rise Viewer 3-foot scenario model, tidal marsh appears to decrease in Galveston Bay when compared to present day but could increase in other locations along the coast. Feagin and Yeager (2008) found that marsh accretion rates in Galveston Bay were not keeping up with sea level rise but were in other areas of the coast. Murdock and Brenner (2016) reported that Coastal Bend area modeling showed an increase in transitional marsh. If wetlands and marshes are unable to keep up with the rate of sea level rise then those habitats may be submerged and converted to subtidal habitat (Borchert et al., 2018). The main barrier to marsh migration in the Galveston Bay area is urban development of low lying areas preventing marsh establishment from occurring (Borchert et al., 2018). Similar trends are seen for seagrass (see Appendix C-1, Section 3.3.1.3) where it has been generally expanding in the mid and lower Texas coast, but declined from 1950 to 1990 in Galveston Bay (Lester and Gonzalez, 2011). It is unclear how sea level rise would affect seagrass, but like marshes, it is possible that seagrass could migrate in response to sea level rise (Saunders et al., 2014; Texas Water Development Board, 2017).

It is anticipated that future sea level rise will force the landward migration of wetlands and marsh and cause major shifts in the amount and distributions of the natural habitats along the coast (Guannel et al., 2014). Recent modeling efforts have been conducted to look at fisheries habitat response to sea level rise. Guannel et al. (2014) modeled fisheries habitat change in Galveston Bay due to sea level rise (assuming a 3.3-foot sea level rise through 2100) on larval and juvenile stages of blue crab, brown shrimp, southern flounder, and red drum. There are currently over 69,000 acres of suitable wetlands, tidal flats, and nearshore estuarine waters for these species and specifically 346 acres of marsh edge for these species to utilize. As sea level rises, the total surface area of estuarine habitat would increase, wetlands may migrate (if not prevented by increasing elevation), marsh edge would shift landward increasing to nearly 593 acres through 2050 and 1,112 acres by 2100. In the Galveston Bay area, the increase would be mainly due to the topography, which is flatter thus having a greater surface area as sea level rises. Commercial brown shrimp catch may also increase as sea level rises, potentially increasing by 39 percent by 2050 and 100 percent by 2100. As wetlands are lost commercial shrimp catches are also reduced, a 10 percent loss of wetlands equates to a 7 percent loss of shrimp catch and a 20 percent wetland loss to a 17 percent catch reduction. Temperature and salinity variables were not included in this analysis and these variables may have a greater impact on fisheries than habitat area increases caused by sea level rise (Guannel et al., 2014). Wetlands would only migrate landward if there is undeveloped land at the necessary elevations and slopes with appropriate substrate to support establishment of new wetlands. In developed areas or where environmental variables do not meet species needs, this migration would not occur (Murdock and Brenner, 2016).

Fulford et al. (2014) modeled projected sea level rise impacts (between 1996 and 2100) to estuarine nursery areas in the Pascagoula River Estuary of Mississippi. Modeling showed that as sea level rises salt marshes first showed a decline, transitioning from low level marsh to tidal flat to open water followed by a net increase in quality driven by marsh fragmentation. This mirrors the effect on nursery production which was shown to first be negatively affected by sea level rise, but ultimately may produce positive changes in production due to the increase in marsh edge habitat that results from fragmentation. These results are consistent with other salt marsh production studies in the Gulf that showed salt marsh fragmentation correlated with a positive effect on fish nursery production; however, there is a threshold of fragmentation where estuarine fisheries production quickly diminishes (Park et al., 1989; Chesney et al., 2000; Minello et al., 2003). Additionally, Roth et al. (2008) conducted similar modeling on brown shrimp and found access to marsh edge habitat was the main driver of increased growth resulting from inundation and marsh fragmentation. This increased estuarine nekton production has been observed by TPWD coastal fisheries in the Sabine Lake area as fresh and brackish water tidal marsh becomes inundated and destroyed. Organic matter and nutrients are generated and utilized by fish and shrimp at the marsh edge, which benefits nekton productivity while the marsh is disintegrating but is harmful in the long run because after the marsh has finished disintegrating there is reduced organic matter productivity and less (or no) nursery habitat (pers. comm. David Buzan, 2017).

Under the No-Action Alternative, it is likely that as sea level rises most fish species (including commercial and recreational fisheries) could benefit from larger areas of available habitats if marshes can migrate. The upper Texas coast exhibits a higher rate of sea level rise than is seen on the lower Texas coast. Based on this information, areas along the Texas coast that are relatively undeveloped would be most likely to support landward migration of wetlands as sea level rises. The upper coast may see the least benefit due to the high proportion of developed shoreline, in that region, while the lower coast, because of the relatively small proportion of developed shoreline may see the most landward growth of wetlands. According to Jim Tolan of the TPWD, who serves on the Association of Fish and Wildlife Agencies Climate Change Committee, the general consensus is that as long as there is sufficient habitat the seagrass, fisheries, and oyster reefs can and would adapt and likely show no impacts to RSLR (pers. comm. J. Tolan [TPWD], 2017). In addition, Watson et al. (2017) showed that the vulnerability of spotted seatrout, red drum, and blue crab to sea level rise appears low for these species as these species have the ability to move away from these threats and are able to cope with the projected changes.

Increasing salinities are anticipated with global climate change. Most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997). Therefore, no adverse effects on fauna are expected due to changes in salinity that may result from these changes, except loss of habitat due to salinity impacts on marshes. Increases in salinity in wetland habitats may cause small reductions in the health and biological productivity, and may cause additional stress on some marsh vegetation; this could cause some impacts to associated fish and shellfish species.

Increasing water temperature is another effect of global climate change. Tolan and Fisher (2009) describe population increases of gray snapper (*Lutjanus griseus*) in Texas estuaries attributed to increased winter surface water temperatures. Whitney et al. (2016) provide a comprehensive review of possible ways climate change may affect fish communities. These impacts may range from cardiorespiratory responses to changes in reproductive behavior triggered by temperature changes. They also review documented effects of climate change on North American inland fish populations. These effects included changes in community composition, shifts in distribution, and changes in migration timing.

Under the No-Action Alternative, oyster reefs would continue their current decline as described in Appendix C-1, Section 2.4.3. Hurricanes and other storms may catastrophically impact oyster reefs, affecting commercial harvest and ecological services provided by oysters as was seen in 2008 when Hurricane Ike struck Galveston Bay burying 8,000 acres of oyster reef under sediment (Freese and

Nichols, Inc., 2015). Although it is known that oysters can tolerate relatively high salinities, temperatures, and increased water depths, it is also known that some oyster predators (stone crabs [*Menippe mercenaria*] and oyster drills) and diseases (Dermo) may occur more frequently or in higher concentrations with higher temperatures and salinities (Cake, 1983; Murdock and Brenner, 2016; Soniat and Kortright, 1998). Rybovich et al. (2016) found that changes in climate, sea level, and land use would negatively affect oyster reefs, causing decreases in the extent of and/or ecosystem function. Altered weather patterns resulting in salinity changes, increases/decreases in precipitation, and increases in sea surface temperatures also affected oyster growth and survival. Increased mortality of oysters was largely a result of the coupled effects of high temperatures and low salinities (Rybovich et al., 2016). Oyster reefs may be able to shift their distribution in response to these changes assuming conditions are favorable (Watson et al., 2017). Watson et al. (2017) found oysters to be highly vulnerable in Texas; altered hydrology and inability to move away from threats was considered the greatest threat. Oysters' ability to keep up with changing sea level rise is dependent upon recruitment and oyster growth (minus harvesting) exceeding sea level rise rates. If the oyster fishery is managed sustainably, it is assumed that oyster reefs would be able to keep up with moderate sea level rise (Watson et al., 2017; Soniat et al., 2012). Increased acidification would make it more difficult for oysters to thrive; however, the sublethal threshold for oyster larvae is not predicted to be reached until 2099 (Ekstrom et al., 2015; Murdock and Brenner, 2016).

Numerous oyster reef restoration efforts are taking place in Sabine Lake, Galveston Bay, East Bay, Matagorda Bay, and Copano Bay. Some oyster reef restoration is intended to support the commercial oyster fishery, with the expectation that newly created reefs may not persist more than 2 or 3 years. In other cases, hard substrate reefs with vertical relief are being constructed to enhance long-term oyster colonization while providing many of the ecological structures and functions supported by oyster reefs. Reef construction is focused in areas where reefs historically occurred. These activities may not be able to accommodate or survive the current declining trend in oyster reef area.

Currently there are many other restoration efforts being undertaken by the GLO, TPWD, TCEQ (through its National Estuary Program offices), USFWS, local governments, and non-governmental organizations including TNC, Audubon, Ducks Unlimited, and Galveston Bay Foundation along the entire Texas coast that would benefit aquatic communities. However, these activities may not maintain estuarine productivity within the current trends in habitat loss and RSLR.

Maintenance dredging activities and activities associated with authorized deepening and widening projects would continue to increase water column turbidity (i.e., suspended material in the water column) during and for a short time after dredging activities. Benthic organisms would continue to be buried by open-bay disposal of dredged material. Many proposed ER activities would also increase turbidity during construction. Increased turbidity in estuarine and coastal waters is generally cited as having a complex set of impacts on a wide array of organisms (Hirsch et al., 1978; Stern and Stickle, 1978; Wilber et al., 2005; Wright, 1978). Increased turbidity can interfere with light penetration thus reducing photosynthetic activity by phytoplankton, algae, and seagrass. This reduced productivity may be offset by an increase in nutrients released into the water column during dredging activities that can increase productivity (Newell et al., 1998; Wilber and Clarke, 2001). Increased sedimentation can temporarily impact juvenile and adult finfish by disrupting foraging patterns, reducing feeding rates and effectiveness, burying habitat for feeding and reproduction, and coating gills of fish resulting in asphyxiation (Clarke and Wilber, 2000; Newcombe and Jensen, 1996; Wilber and Clarke, 2001). Finfish and shellfish are motile enough to avoid highly turbid areas and under most conditions, finfish and other motile organisms are only exposed to localized suspended-sediment plumes for short durations (minutes to hours) (Clarke and Wilber, 2000; Newcombe and Jensen, 1996; Wilber and Clarke, 2001). Temporary impacts to oysters include reduced filtering rates, and clogging of filtering mechanisms interfering with ingestion, respiration, and abrasion (Newcombe and Jensen, 1996; Stern and Stickle, 1978; Wilber and Clarke, 2001). Shrimp and crabs are less impacted by elevated suspended sediments since these organisms reside on or near the bottom where sedimentation naturally occurs (Wilber and Clark, 2001; Wilber et al., 2005). Turbidities can be expected to return to near ambient conditions within a few months after dredging ceases in an area; thus, no long-term effects are anticipated.

4.1.2 Preferred Alternative

The Preferred Alternative could adversely affect multiple life history stages of several Federally managed species. These include the following: all life stages of brown, pink, and white shrimp, blacknose shark, Atlantic angel shark, spinner shark, silky shark, finetooth shark, bull shark, blacktip shark, dusky shark, tiger shark, lemon shark, Atlantic sharpnose shark, scalloped hammerhead shark, great hammerhead shark, bonnethead shark, red grouper, cobia, dolphin, greater amberjack, red snapper, gray snapper, lane snapper, red snapper, little tunny, king mackerel, Spanish mackerel, sailfish, and blue marlin; adult gag grouper, scamp, and lesser amberjack; and juvenile vermilion snapper. Table 5 provides a summary of project area EFH presence by bay system and Gulf. The sections below detail the potential impacts to EFH for these species, as well as recreationally and commercially important species listed in Section 3.2.

The direct cover types for CSRM and ER measures associated with initial construction of the Preferred Alternative are presented below (tables 5 and 6).

Out-year marsh nourishments in 2065 are proposed in areas that would convert to open water or unconsolidated shoreline over the period of analysis due to RSLR. The locations of the out-year marsh nourishments were identified using the NOAA (2017c) marsh migration RSLR layer of 2.5 feet for year 2065. Table 7 presents the total acres of out-year nourishment proposed for the four ER measures and the direct habitat cover type acres affected, and Table 8 presents the direct cover types affected by the Preferred Alternative.

Table 5
CSRM Measures Direct Habitat Cover Type Acres Affected

CSRM Measure	Developed/ Upland[1]	Palustrine Emergent Wetland[2]	Estuarine Emergent Wetland[3]	Oyster Reef	Open Water	Dune[4]	Supra-tidal[5]	Inter-tidal[6]	Total Acres
Coastal Barrier	1,520.9	512.5	338.0	--	2,154.0	--	--	--	4,525.3
Upper Bay Barrier–Bay Rim	1,371.2	227.1	172.0	0.03	564.0	--	--	--	2,334.3
South Padre Island	4.6	--	--	--	358.5	0.5	2.1	0.1	365.8

Source: NOAA (2017c, 2017e)

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/ herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes freshwater wetland and marsh

[3] Includes saline and brackish wetland and marsh

[4] Subaerial habitat ≥5 feet North American Vertical Datum of 1988 (NAVD 88) and includes foredune, dune, and reardune.

[5] Supratidal habitat occurs from 2.0 to 4.9 feet NAVD 88 and includes swale and may include low-elevation dune and beach habitat.

[6] Intertidal habitat occurs from 0.0 to 1.9 feet NAVD 88 and includes intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulfside and bayside of the barrier island.

Table 6
ER Measures Direct Habitat Cover Type Acres Affected

ER Measure	Developed/ Upland[1]	Islands / Bird Rookeries	Estuarine Emergent Wetland[2]	SAV	Oyster Reef	Open Water	Dune[3]	Supra-tidal[4]	Inter-tidal[5]	Total Acres
G-5	579.3	--	--	--	--	3,362.3	572.0	504.2	39.1	5,056.7
G-28	105.7	23.5	513.7	--	--	735.9	--	--	--	1,378.8
B-2	79.6	--	--	--	--	624.3	220.7	168.3	20.9	1,113.8
B-12	41.1	--	427.0	1.0	0.7	405.6	--	--	--	875.4
M-8	240.4	2.6	29.3	15.2	--	112.3	--	--	--	399.8
CA-5	--	--	--	295.4	2.5	27.8	--	--	--	325.7
CA-6	6.8	--	244.4	4.0	21.2	283.8	--	--	--	560.2
SP-1	90.5	117.8	--	3,088.8	5.2	434.6	--	--	--	3,736.8
W-3	4.6	3.8	--	1.8	--	1,109.4	257.6	53.3	1.0	1,431.5

Source: NOAA (2017c).

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/ herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes saline and brackish wetland and marsh

[3] Subaerial habitat ≥5 feet NAVD 88 and includes foredune, dune, and reardune

[4] Occurs from 2.0 to 4.9 feet NAVD 88 and includes swale and may include low-elevation dune and beach habitat.

[5] Occurs from 0 to 1.9 feet NAVD 88 and includes intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulf side and bayside of the barrier island.

Table 7
Out-Year Marsh Nourishment for 2065 Direct Habitat Cover Type Acres Affected

ER Measure	Developed/ Upland[1]	Estuarine Emergent Wetland[2]	SAV	Open Water	Total Acres
G-28	543.7	5,664.0	3.5	678.4	6,889.7
B-12	751.0	10,056.4	225.6	3,514.3	14,547.3
M-8	632.2	4,513.4	92.6	794.8	6,033.0
CA-5	48.8	530.0	--	43.9	622.7

Source: Pers. com. N. Herold (NOAA) (2017).

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes saline and brackish wetland and marsh

Table 8
Preferred Alternative Measures Direct Habitat Cover Type Acres Affected Summary

Measure	Developed/ Upland[1]	Palustrine Emergent Wetland[2]	Islands/ Bird Rookeries	Estuarine Emergent Wetland[3]	SAV	Oyster Reef	Open Water	Dune[4]	Supra-tidal[5]	Inter-tidal[6]
Coastal Barrier CSRM	1,520.9	512.5	--	338.0	--	--	2,154.0	--	--	--
South Padre Island CSRM	4.6	--	--	--	--	--	358.5	0.5	2.1	0.1
ER	1,148.0	--	147.7	1,214.4	3,406.2	29.6	7,096.0	1,050.3	725.8	61.0
Out-year Marsh Nourishment 2065	1,975.7	--	--	20,763.8	321.8	--	5,031.4	--	--	--

Source: NOAA (2017c, 2017e); pers. com. N. Herold (NOAA, 2017).

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes freshwater wetland and marsh

[3] Includes saline and brackish wetland and marsh

[4] Subaerial habitat ≥5 feet NAVD 88 and includes foredune, dune, and reardune

[5] Occurs from 2.0 to 4.9 feet NAVD 88 and includes swale and may include low-elevation dune and beach habitat.

[6] Occurs from 0 to 1.9 feet NAVD 88 and includes intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulf side and bayside of the barrier island.

Also, an additional 112,666.4 acres of hydrologic restoration occurs at W-3, and SAV protection of 295.8 acres at CA-5 and 3,257.9 acres at SP-1.

The volumes of material that will be dredged to construct the CSRM measures have been estimated. The dredged material from construction of the surge barrier gates for CSRM would be placed beneficially for construction of the proposed ER measures if the quality of material is appropriate. This information will be refined during future planning and design phases of the study including preconstruction, engineering, and design.

Borrow source locations for construction of CSRM and ER measures have been identified by the USACE. Proper coordination to conduct National Environmental Policy Act (NEPA) review of borrow sources has begun and will continue into preconstruction, engineering, and design.

4.2 POTENTIAL IMPACTS TO EFH

4.2.1 CSRM Measures

4.2.1.1 Coastal Barrier CSRM System

4.2.1.1.1 Estuarine Wetlands and Submerged Aquatic Vegetation

The proposed Coastal Barrier system, including the levee, floodwall, seawall, and surge barrier gates, is expected to have direct and indirect impacts to wetland and marsh habitats in the Galveston Bay region.

Direct Impacts. Approximately 512.5 acres of non-tidal and 338.0 acres of tidal wetlands are expected to be altered or damaged due to the construction of this measure. Construction of the measure components on Bolivar Peninsula and Galveston Island would require clearing, grubbing, levelling, and filling of wetland and marsh habitats. The potential for erosion and increased sedimentation during construction could affect the water quality and bury or damage adjacent vegetation in marshes. Hydrological barriers, such as levees, can lead to a loss of sheet flow, degradation of the wetland and marsh vegetation, and fragmentation of the coastal ecosystem (Harvey et al., 2011). Specifically, the wetland and marsh habitats located south of the proposed footprint could potentially be exposed to higher salinity from the Gulf for longer periods of time during storm events. Mitigation will be required for these impacts. Refer to the Mitigation Plan (Appendix C-9) for a more detailed discussion of mitigation for direct wetland impacts.

Diurnal tides account for 50 percent of the water level variance in Galveston Bay; the remainder of the variability is due to wind-driven coastal setup along the Texas-Louisiana shelf (Rayson et al., 2015). The hydrology of wetland and marsh habitats, and more specifically, the duration and seasonality of flooding, has a strong influence on the number, type, and distribution of plants and plant communities within these ecosystems (Carter, 1997). The proposed levee would likely provide some level of protection to wetland habitats located north of the footprint by serving as a barrier from salt water intrusion during storm events.

To reduce impacts during construction, proper best management practices, including implementation of a Storm Water Pollution Prevention Plan and general avoidance and minimization measures, can be utilized to contain and prevent sediments from entering wetlands during construction. Silt fencing, silt curtains, rock berms, and mulch socks may be used to prevent sediment and contaminant transport to wetlands.

Indirect Impacts. Following completion of the surge barrier gates across Bolivar Roads, the cross-sectional entrance into Galveston Bay would be constricted by 27.5 percent causing a reduction in tidal amplitude. This reduction would likely lead to lower high tides and higher low tides and less marsh habitat regularly or seasonally flooded. The constriction is also predicted to minimally affect bay salinities and water and sediment exchange between the Gulf and the bay (McAplin et al., 2018; see Appendix D, Section 2.8). As a result of changes in tidal amplitude and tidal prism, potential changes to the characteristics and abundance of wetland and marsh vegetation could occur. This could potentially result in a conversion of plant communities and an expansion of freshwater wetlands on the bayside of the structure.

Due to the partial closure at Bolivar Roads with the Coastal Barrier, reduced tidal flow and a change in the tidal amplitude may occur (McAlpin et al., 2018). It was assumed that a change in tidal amplitude would affect tidal marsh since the potential would exist for marsh at the upland side of the cover type to experience less inundation while marsh at the open-water side of the area would experience potentially constant inundation. To estimate the potential area of affected wetland and marsh habitats within Galveston Bay as a result of the reduction in tidal amplitude due to the surge barrier gates across Bolivar Roads, an analysis was conducted using the NOAA C-CAP 2010 landcover dataset for estuarine wetlands. Approximately 3,375 acres of wetlands along the interior of the bay are expected to be indirectly impacted as a result of altered hydrology, leading to eventual deterioration of those habitats. A total of 7,295 acres of mitigation will be required for these impacts. Refer to the Mitigation Plan (Appendix C-9) for a more detailed discussion of mitigation for indirect wetland impacts.

4.2.1.1.2 Open Water Column

With the proposed Coastal Barrier CSRM system, navigation and environmental gates at Bolivar Roads, GIWW, Clear Lake, Dickinson Bayou, and Offatts Bayou (Galveston ring levee/floodwall) would impact a total of 2,154 acres of open-water habitat (Table 8). The majority of the impacted acres would be at Bolivar Roads, which would be covered by the support structures and gates for the surge barrier gates. Water depth at the floating sector gate would be 60 feet and 15 to 30 feet through the environmental gates.

4.2.1.1.2.1 Tidal Exchange/Amplitude and Velocities

The USACE Engineer Research and Development Center (ERDC) conducted 3D Adaptive Hydraulics (AdH) modeling for the Coastal Texas Study Preferred Alternative Coastal Barrier CSRM system to understand potential environmental impacts. As no detailed data are available on the storm surge barrier or the environmental gates, modeling was limited only to understanding the general behavior of the bay system while comparing with- and without-project scenarios. All modeling was conducted using a tentative gate configuration across Bolivar Roads that would reduce the flow conveyance roughly by 27.5 percent. All gates were kept in open condition during simulations (McAlpin et al., 2018).

Modeling results suggest that the average tidal prism and average tidal amplitudes at various locations did vary between the with- and without-project scenarios over the simulation year. The tidal prism change with the Preferred Alternative in place is a 13.5 and 16.5 percent reduction for the present and future conditions, respectively. The tidal amplitudes are also reduced at all bayside locations, between 9 and 22 percent. These indicate that the proposed structures have the potential to restrict the flow and limit the volume of water moving in and out of the bay at Bolivar Roads. The velocity magnitudes vary little between with- and without-project conditions. The mean surface and bottom velocity magnitude generally drops when the project is in place, but this change is 0.16 feet per second or less. The change from the without-project condition is greatest in areas at and immediately around the structures. Eddies are also expected on the backside of the gate structures. There are changes to the magnitude of the velocity extending into the bay, but they are much smaller than the effects at the locations of the modifications. The models suggest that in certain situations the velocity differences between the with-project condition and the without-project condition could be as high as 6.6 feet per second. For example, a scenario that presented a combination of a high tide and strong winds could lead to such an increase in velocity. Future project refinements may minimize differences currently seen between with- and without-project velocities (McAlpin et al., 2018).

Eggs and larval stages of aquatic organisms are transported by currents, moving into the bay on the incoming tides. Larval forms of some species drop near the bottom on outgoing tides, particularly in the shallow areas nearshore to reduce transport out of the bay. Environmental gates along the shoreline of Bolivar Roads are expected to help alleviate some of the potential impacts to aquatic organisms that utilize shallow edge habitats. The important commercial/recreational and forage fish target species that are most vulnerable to flow constriction and velocity increases were identified by Rusty Swafford at NMFS (Table 9) (pers. com. R. Swafford [NMFS], 2017). Table 9 describes the life stage relative abundance of these species in Galveston Bay and their migrations and movements.

Fisheries productivity is dependent upon environmental conditions and habitats that are present in marshes. Generally, spawning occurs offshore in coastal waters and larvae move into the estuaries, which serve as nursery habitat, providing protection from predators and food for growth. Subadults migrate back to the Gulf to mature following a certain growth period (Minello et al., 2017). Marshes form a transition between aquatic and terrestrial ecosystems consisting of vegetation interspersed with shallow open water (Minello et al., 2008). The vegetation/edge of the marsh is important in providing access to the marsh surface, which is used by aquatic organisms when it is flooded. The less the marsh surface is flooded, the less surface area is available for these species to utilize as nursery habitat (Minello et al., 2012, 2015).

Table 9
Key Species Most Vulnerable to Flow Constriction

Species	Life Stage*	Galveston Bay Abundance	Migrations and Movements
Commercial/Recreationally Targeted Species:			
Brown shrimp**	E, A	Not present	Adults move offshore to spawn from May through August, eggs offshore
	L, J	Abundant	Larvae move into estuaries from February to April with incoming tides and migrate to shallow, vegetated areas
			Juveniles move into open bays
White shrimp**	E	Not present	Adults spawn offshore from spring through fall
	L, J	Abundant	Larvae move into estuaries from May to November
	A	Common	Juveniles migrate farther up the estuary into less-saline water
			As they grow and mature they leave the marsh for deeper, higher salinity areas of the estuary
			Juveniles and subadults move from estuaries to offshore in late August and September
Blue crab	L, J, A	Abundant	Eggs hatch near the mouths of estuaries and zoeal larvae are carried offshore to grow for up to one month
			Re-entry to estuarine waters occurs during the megalopal stage
Gray snapper**	E, L	Not present	Pre-juveniles move into estuarine habitats, juveniles occupy inshore grassy areas
	J, A	Rare	Adults migrate offshore in summer to spawn
Red drum**	E	Not present	Adults spawn offshore.
	L, J, A	Common	Larvae and early juveniles are carried by tides and currents in the late fall into estuaries and bays and move to quieter back-bay areas to grow
			Young move into primary bays
			Older fish move into the Gulf in the fall and winter
Spotted seatrout	E, L, J, A	Common	Estuarine dependent, completing entire life cycle in inshore waters
			Eggs associated with grass beds at or near barrier islands, larvae in deep channels
			Juveniles and adults found in seagrass, deep basins, tidal river mouths, channels, and canals
			Adults can be found in nearshore Gulf waters (surf zones) during the fall and winter
Sand seatrout	E, L	Not present	Spawning occurs offshore
	J	Abundant	Larvae migrate to estuaries in April to early fall, preferring small bayous, shallow marshes, channels
	A	Common	Migration from bay to offshore occurs late fall or winter, after spawning adults move back into higher salinity areas of the bay
Southern flounder	E, L	Not present	Adults move from estuaries during the fall and winter to spawn offshore
	J	Common	Post-larvae and juveniles immigrate into bays and estuaries from

Species	Life Stage*	Galveston Bay Abundance	Migrations and Movements
			later winter to spring
	A	Abundant	Adults migrate back into the estuary during spring and summer
Atlantic croaker	E, L	Not present	Seasonal inshore and offshore migrations
	J	Abundant	Adults move into bays and estuaries in the spring and offshore in the fall
	A	Common	Larvae are carried by tides into the estuaries October to May
			Juveniles move into headwater areas where they remain 6 to 8 months and begin migrating offshore in March–April
Black drum	E, L, J, A	Common	Larvae and small young move into upper estuary and tidal creeks to low-salinity nursery areas during flood tides
			Juveniles move into bays, passes, and nearshore Gulf
			Spawn near passes, bays, channels, and nearshore Gulf
			Adults occupy bays and nearshore Gulf
Sheepshead	E, L	Not present	Adults move offshore in the spring to spawn, returning to bays after spawning
	J, A	Common	Larvae move from offshore into estuaries
			Adults occur in nearshore waters during warm seasons and move out of the estuaries during periods of low temperatures
Gafftopsail catfish	E L, J, A	Present	Spawn in bays
			Adults migrate offshore in winter and return inshore in the spring
Gulf whiting	E	Not present	Adults spawn offshore
	L, J, A	Present	Eggs are offshore, larvae move to estuarine nursery areas
			Adults generally inhabit offshore waters and near barrier islands
			Juveniles are found mainly offshore, less common in estuaries
Forage Fish of Importance:			
Striped mullet	E, L	Not present	Adults move offshore in the fall and winter to spawn, adults return to estuary after spawning
	J	Abundant	Pre-juveniles migrate to estuary in the spring, migrating to nursery areas (secondary and tertiary bays)
	A	Common	
Gulf menhaden	E, L	Not present	Adults migrate from estuaries to the Gulf late summer to winter to spawn
	J, A	Abundant	Larvae migrate to estuaries October to May
			During flood tides larva can be dense in tidal passes
Bay anchovy	E, L, J, A	Abundant	Bays, estuaries, and shallow waters of the Gulf
			Spawning occurs near barrier islands, bays, estuaries, tidal passes, harbors, and in the Gulf

Source: Pattillo et al. (1997)

*E = eggs; L = larva; J = juvenile; A = adult

** Federally managed species

Tidal inundation is very important in determining marsh value and use. Studies have shown high densities of fish, crabs, and penaeid shrimp utilize about the first 10 feet of vegetation adjacent to open water. In Texas, juvenile red drum, spotted seatrout, penaeid shrimp, and blue crab densities are high in marsh edge habitat; these high densities could be associated with high flooding durations of these marshes (Minello et al., 2012).

Tidal amplitude reduction means less of the marsh would be flooded, resulting in a loss of marsh surface area available for aquatic organisms to use as nursery habitat. Reduced marsh area due to the tidal amplitude change was estimated for impacts due to the Coastal Barrier. A tidal amplitude reduction predicted by the AdH model was used to calculate this area of reduced marsh. This could result in a reduction of fish and shellfish densities thus reducing the overall populations in the bay. This, coupled with reduced immigration of eggs and larvae from the Gulf into the bay because of the flow constriction, could exacerbate the impacts further. It's worth noting that numerous anthropogenic modifications have occurred in the Galveston Bay system (e.g. Causeway Bridge, Texas City Dike, Galveston Jetties, and the establishment of numerous dredge material placement areas), and while those modifications may have had adverse effects on fisheries, the ecosystem in Galveston Bay has proved resilient. For further discussion please see Section 4.4 (Cumulative Impacts).

4.2.1.1.2.2 Turbidity Disturbances

During construction, increased turbidity would cause temporary disturbances and impacts to Federally managed species. In most cases, turbidity is generally localized and short lived, but may impact Federally managed species close to the project areas.

Turbidity in estuarine and coastal waters is generally cited as having a complex set of impacts on a wide array of organisms (Hirsch et al., 1978; Stern and Stickle, 1978; Wilber et al., 2005; Wright, 1978). During construction of the Coastal Barrier, water column turbidity is expected to increase. The release of sediment during dredging increases turbidity in the water column, which creates a sediment plume, the extent of which is determined by the direction and strength of the currents and the sizes of particles (Wilber and Clarke, 2001).

Turbidity from total suspended solids (TSS) tends to reduce light penetration and thus reduce photosynthetic activity by phytoplankton, algae, and seagrass (Wilber and Clarke, 2001). Such reductions in primary productivity would be localized around the immediate area of the dredging and placement operations. This reduced productivity may be offset by an increase in nutrients released into the water column during dredging activities that can increase productivity in the area surrounding the dredging activities (Newell et al., 1998; Wilber and Clarke, 2001). In past studies of impacts of dredged material placement from turbidity and nutrient release, the effects are both localized and temporary (May, 1973). Due to the capacity and natural variation in phytoplankton and algal populations, the impacts to phytoplankton and algae from project construction, dredging within the project area, and dredged material placement of material would be temporary.

Increased concentrations of suspended sediment can temporarily impact benthic macroinvertebrates and juvenile and adult finfish and shellfish by disrupting foraging patterns, reducing feeding rates and effectiveness, burying habitat for feeding and reproduction, and reducing respiration rates by coating gills with sediment (Clarke and Wilber, 2000; Newcombe and Jensen, 1996; Wilber and Clarke, 2001). Finfish and shellfish can avoid highly turbid areas and under most conditions are only exposed to localized suspended-sediment plumes for short durations (minutes to hours) (Clarke and Wilber, 2000; Newcombe and Jensen, 1996; Wilber and Clarke, 2001). Shrimp and crabs are less impacted by elevated suspended sediments since these organisms reside on or near the bottom where sedimentation naturally occurs (Wilber and Clark, 2001; Wilber et al., 2005). Furthermore, turbid waters may actually provide a refuge for these species from predation (Wilber and Clarke, 2001). Research has shown that more-sensitive species and life stages (i.e., eggs, larvae, and fry) are more negatively impacted by longer exposure to suspended sediments than less-sensitive species and older life stages (Germano and Cary, 2005; Newcombe and Jensen, 1996; Wilber and Clark, 2001; Wilber et al., 2005).

Effects of elevated suspended solids on the adult stages of various filter-feeding organisms, such as oysters, copepods, zooplankton and other species, include reduced filtering rates, and clogging of filtering mechanisms interfering with ingestion, respiration, and abrasion (Armstrong et al., 1987; Newcombe and Jensen, 1996; Stern and Stickle, 1978; Wilber and Clarke, 2001). These effects tend to be more pronounced when TSS concentrations are greater than 100 mg/L but are apparently reversible once turbidities return to ambient levels (Newcombe and Jensen, 1996). These impacts would be localized around the immediate area of dredging and placement operations.

Turbidities can be expected to return to near-ambient conditions within a few months after dredging ceases in a given area, thus, no long-term effects are anticipated. Modeling of dredged material discharge in the Laguna Madre, Texas, determined that turbidity caused by dredging was short lived, and therefore, impacts to the estuarine and offshore water column would be minimal (Teeter et al., 2003). No long-term impacts of elevated turbidities to Federally managed finfish or shellfish populations are anticipated from construction, dredging, and placement activities associated with construction of the Preferred Alternative compared with the No-Action Alternative.

4.2.1.1.2.3 Salinity

Construction of the Preferred Alternative could slightly decrease bay salinities on average by about 2 ppt based on the estuarine modeling conducted by the USACE (McAlpin et al., 2018). During normal flow conditions, average salinities range from less than 10 ppt in upper Trinity Bay to 30 ppt at Bolivar Roads (Lester and Gonzalez, 2011). Most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997). Therefore, no adverse effects on Federally managed species are expected due to changes in salinity that may result from the construction of the Coastal Barrier.

4.2.1.1.3 Open-Bay Bottom

A total of 2,154 acres of bay bottom habitat would be permanently lost as a result of construction of the navigation and environmental gates at Bolivar Roads, GIWW, Clear Lake, Dickinson Bayou, and Offatts Bayou (Galveston ring levee/floodwall) (Table 8). Of that loss, the majority would occur at Bolivar Roads, which would be covered by the support structures and gates for the surge barrier gates.

Although the affected bay bottom at Bolivar Roads is considered a permanent loss, the area of the Houston Ship Channel between the floating sector gate would be left as natural bay bottom and dredged regularly by the USACE for channel maintenance. There would be direct impacts during construction of the Coastal Barrier due to the removal of material from the seabed that removes benthic organisms living on and in the sediment. Dredging can result in a reduction of species diversity by 30 to 70 percent, the number of individuals by 40 to 95 percent, and a similar reduction in the biomass of benthic fauna existing within the boundaries of dredged areas (Newell et al., 1998). Recolonization of areas impacted by dredging occurs through immigration of post-larval organisms from the surrounding area, larval recruitment from the water column, and/or sediments slumping from the side of the dredged area (Bolam and Rees, 2003; Newell et al., 1998). The response and recovery of the benthic community from dredged material placement are affected by many factors, including environmental (e.g., water quality, water stratification), sediment type and frequency, and timing of disposal. Communities in these dynamic ecosystems are dominated by opportunistic species tolerant of a wide range of conditions (Bolam and Rees, 2003; Bolam et al., 2010; Newell et al., 1998, 2004). Although changes in community structure, composition, and function may occur, these impacts would be temporary in some dredging areas (Bolam and Rees, 2003).

Repeated dredging during maintenance dredging operations may prevent benthic communities from fully developing (Dankers and Zuidema, 1995; Rehitha et al., 2017). Benthic diversity, biomass, and species diversity is reduced in areas of repeated disturbance (Rehitha et al., 2017). New recruits tend to be small, opportunistic, surface-dwelling organisms with high growth rates. Large, deep-dwelling organisms that grow slower and live longer are lost to the areas of repeated excavation. In this way, excavation associated with maintenance dredging may not cause a decrease in production, but rather a shift in community structure (Montagna et al., 1998; Rehitha et al., 2017). Sheridan (1999) found that benthic communities can take anywhere from 18 months to over 3 years to recover, and Ray and Clarke (1999) found that at least 1 year is required for benthic communities to return to pre-placement conditions. Depending on the maintenance dredging schedule, the reestablishment of a stable benthic community in the area might not be possible (Rehitha et al., 2017).

Dredged material from construction of the Coastal Barrier would be used beneficially for construction of ER measures, mitigation features, and/or other CSRM structures.

4.2.1.1.4 Oyster Reef

Information from the GLO GIS Maps and Database for oyster reefs was used to estimate impacts to oysters. No mapped oyster reefs occur in the direct footprint of the Coastal Barrier system; therefore, no direct impacts are anticipated. The interagency team has noted that oysters do occur in locations that are not illustrated on the GLO dataset, specifically where the proposed Galveston ring levee/floodwall would cross Offatts Bayou. A more-detailed impact assessment, including additional oyster information from the interagency team, will be conducted on the TSP for the Final IFR-EIS. The Final EFH Assessment will be updated accordingly.

Water column turbidity would increase during project construction that could affect survival or growth of oysters nearby. Temporary impacts to oysters include reduced filtering rates and clogging of filtering mechanisms causing abrasion and interfering with ingestion and respiration (Newcombe and Jensen, 1996; Stern and Stickle, 1978; Wilber and Clarke, 2001). Adult oysters are more capable of withstanding such conditions than spat, and during periods of high turbidity can close up tightly for a week or more until normal conditions return (Cake, 1983). Turbidity increases from construction of the Coastal Barrier should be temporary and local.

Indirect effects to oyster reef habitat may result from a lower salinity regime due to the reduced flow of water into and out of the bay and the longer retention times. An overall decrease in salinity of about 2 ppt could be expected based on the estuarine modeling conducted by the USACE (McAlpin et al., 2018). A benefit of a slight decrease in salinity is a potential reduction in exposure to oyster predators and pathogens, which may occur more frequently with higher salinities (Cake, 1983; Soniat and Kortright, 1998). It is not anticipated that this potential salinity decrease would cause any long-term impacts to oyster reefs in the Galveston Bay system.

4.2.1.1.5 Offshore Sands

Under the Preferred Alternative, water column turbidity would increase during construction, specifically dredging and disposal of dredged material. Such effects are temporary and local and can be expected to return to near-ambient conditions within a few hours after dredging ceases or moves out of a given area (Clarke and Wilber, 2000; Newcombe and Jensen, 1996), as described in Section 4.2.1.2. Repeated dredging during maintenance dredging operations of the Houston Ship Channel may prevent benthic communities from fully developing (Dankers and Zuidema, 1995; Rehitha et al., 2017). Recolonization could occur within months after the placement of dredge material; however, depending on the maintenance schedule, reestablishment of a stable benthic community in the area might not be possible (Bolam and Rees, 2003; Bolam et al., 2010; Newell et al., 1998; Rehitha et al., 2017; Sheridan, 1999; VanDerWal et al., 2011; Wilber et al., 2006). Section 4.2.1.1,3, above, provides a more-detailed discussion of impacts to benthic communities.

4.2.1.2 South Padre Island CSRM Measure

Impacts to the estuarine habitats and fauna could occur in the Gulf portions of the South Padre Island CSRM measure due to increased water column turbidity and sediment placement that can be expected during construction activities. A total of 358.5 acres of open water would be impacted. Turbidity impacts would be the same as those described for the Coastal Barrier (Section 4.2.1.1.2.2) and would be expected to return to normal once construction is completed. Renourishment of the measure every 10 years throughout the period of operation would cause short-term water column turbidity and impacts to benthos during placement activities. No long-term impacts to the aquatic community are anticipated as a result of the South Padre Island CSRM measure.

4.2.2 Ecosystem Restoration Measures

Ecosystem restoration measures of the Preferred Alternative would create and protect a variety of habitats along the Texas coast. The following discussion describes the estuarine habitats and fauna impacts associated with the proposed ER features (see Table 5). Acres of each feature and the direct habitat cover types that would be impacted during construction of the ER measures are found in tables 6 and 7. Table 10 lists these ER measures with the number of acres associated with each feature that is described below.

Table 10
ER Measures and Features

ER Measure	ER Measure Features/Acres					
	Revetment/ Breakwater	Island Restoration	Marsh Restoration	Oyster Reef Creation	Dune/ Beach Restoration	Out-year Nourishment 2065
G-5 Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration	–	–	–	–	5,056.7	–
G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	391.2	298.5	671.0	18.0	–	6,889.7
B-2 Follets Island Gulf Beach and Dune Restoration	–	–	–	–	1,113.8	–
B-12 West Bay and Brazoria GIWW Shoreline Protection	257.0	–	616.4	2.1	–	14,547.3
M-8 East Matagorda Bay Shoreline Protection	52.3	96.1	53.9	14.6	–	6,033.0
CA-5 Keller Bay Restoration	22.8	–	–	7.1	–	622.7
CA-6 Powderhorn Shoreline Protection and Wetland Restoration	30.3		529.8	–	–	–
SP-1 Redfish Bay Protection and Enhancement	44.5	432.1	–	2.0	–	–
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	3.9	22.7	–	–	1,404.9	–

4.2.2.1 Revetment/Breakwater

Seven ER measures will incorporate rock revetment/breakwater features (G-28, B-12, M-8, CA-5, CA-6, SP-1, and W-3). As a result of constructing the revetment/breakwater features, a total of 802 acres of bay bottom habitat and open bay habitat would be permanently converted to revetment/breakwater. Impacts associated with bay bottom habitat loss and temporary disturbances to water column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom. Turbidity would be expected to return to normal once construction is completed. No long-term impacts to finfish or shellfish populations are anticipated from construction, dredging, and placement activities associated with construction of revetment/breakwater features of ER measures.

When revetment/breakwaters are placed in areas where the environments are predominantly soft sediments, it creates suitable habitat for marine organisms that can colonize the new hard substrate. The ecological value of the created habitat is low when compared to natural rocky shores, colonized mainly by species with opportunistic traits (Dugan et al., 2011; Fowler and Booth, 2013). Fish and invertebrate communities tend to be less diverse on created habitat when compared to the natural shoreline (Dugan et al., 2011). However, Scyphers et al. (2015) showed that fish populations (including commercial and recreationally important species), smaller fishes, and crustaceans were greater near breakwaters than mudflat areas. It is reasonable to assume that constructed revetment/breakwaters would attract marine organisms and provide a greater ecological service than without the structure in place. If water quality is adequate, revetments/breakwaters provide habitat for oyster colonization and the biological communities associated with oysters. Although there is a permanent loss of bay bottom habitat and open bay habitat, there is a gain of hard substrate habitat that attracts fish and invertebrate communities. These structures would also protect valuable marsh, SAV, and oyster reef habitat from eroding, in turn protecting valuable nursery grounds for the many fish and shellfish species that live within these estuaries.

4.2.2.2 Island Restoration

Island restoration features are components of four ER measures (G-28, M-8, SP-1, and W-3). As a result of island restoration features, a total of 849.4 acres of bay bottom habitat and open bay habitat would be permanently converted to islands. Impacts associated with bay bottom habitat loss and temporary disturbances to water column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom. Turbidity would be expected to return to normal once island restoration is completed. Care would be taken to avoid existing SAV and oyster reef to the greatest extent practicable, and silt curtains would be deployed during construction to prevent movements of sediments into nearby SAV beds and oyster reef habitats. Notwithstanding the potential harm to some individual organisms, no long-term impacts to finfish or shellfish populations are anticipated from construction, dredging, and placement activities associated with construction of island restoration features of ER measures.

4.2.2.3 Marsh Restoration

Marsh restoration features are components of four ER measures occurring behind each of the constructed revetment/breakwater features (G-28, B-12, M-8, and CA-6). A total of 1,871.1 acres of bay bottom habitat and open bay habitat would be permanently converted to marsh. Impacts associated with bay bottom habitat loss and temporary disturbances to water column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom. Turbidity would be expected to return to normal once construction is completed. A total of 10 years would be required for construction, planting, and marsh establishment, and may require construction of temporary containment levees and drainage structures to contain the material. Thin-layer placement may also be considered. Material would be obtained from excavations associated with construction of the revetment/breakwaters and shoaled or virgin sediments from nearby sources. During construction of containment levees and drainage structures, water column turbidity impacts would be the same as those described above for the Coastal Barrier and would be expected to return to normal once construction is completed.

Although bay bottom and open bay habitat would be lost for marsh restoration, once the marsh is functioning, the overall benefits should outweigh the initial impacts. Wetlands and marshes provide numerous ecosystem services including nursery and feeding habitat for juvenile and adult fish and shellfish species, which in turn provide economic value to the community (Schuster and Doerr, 2015). Additionally, they play an important role in estuarine chemical cycles (Minello, 1999; Schuster and Doerr, 2015; Yoskowitz et al., 2012). More fish and invertebrate species utilize vegetated marsh habitat as nursery areas compared to unvegetated habitat, and more adult fish used these areas compared to adjacent estuarine open water habitats (Yoskowitz et al., 2012). Sinuous circulation channels would be created or maintained in the marsh. Minello et al. (1994) showed that creating marshes with these types of sinuous circulation channels was important in determining nekton use. Shrimp showed a strong affinity for marsh edge habitat, which increased their densities on the inner marsh surface. Marsh bottom habitat would be gained supporting benthic organism growth, which would provide food for fish and shellfish species. Nekton densities and species richness in created marshes in Galveston Bay were similar or in some instances greater than natural marshes about 2 years following marsh planting (Minello, 2000; Rozas et al., 2005). It is expected that the marsh restoration features would improve the fish and shellfish habitat in the areas compared to the No-Action Alternative.

4.2.2.4 Oyster Reef Creation

Oyster reef creation features are components of five ER measures (G-28, B-12, M-8, CA-5, and SP-1). Oyster cultch would be placed as part of four ER measures, while CA-5 would be a reef constructed by placing reef balls in shallow water. A total of 43.8 acres of bay bottom habitat would be permanently converted to oyster reef. Creation of oyster reefs is expected to protect restored islands, prevent breaching of islands and shorelines, protect SAV, and increase oyster populations. Impacts during construction of the oyster reefs include water column turbidity and bay bottom habitat loss and would be the same as those described above for the Coastal Barrier. Water column turbidity would be expected to return to normal once construction is completed.

Oyster reef creation is a type of living shoreline that is an improvement over traditional armoring techniques (Schuster and Doerr, 2015). Oyster reefs have a positive benefit to estuaries by providing ecosystem services such as water filtration and nutrient removal, fisheries habitat, benthic invertebrate habitat, and stabilization of adjacent habitats and shorelines (Baggett et al., 2014; LaPeyre et al., 2014; Schuster and Doerr, 2015). Scyphers et al. (2011) found that oyster reef creation using cultch material provided substrate for oyster recruitment and protected a diverse fish and invertebrate community. Oyster reefs also protect adjacent vegetated habitats from wave action, currents, and tides. Reduced wave action can help stabilize the shoreline by allowing sediments to accumulate landward of the reef. Sediment accumulation and shoreline stabilization work hand in hand protecting nearby marsh habitat from erosion, while allowing expansion of marsh through sediment accretion. Water quality improvement and sediment stabilization provided by the oyster habitat may also allow for SAV recruitment or protection (Baggett et al., 2014).

The overall benefits from oyster reef creation as part of an ER measure outweigh any short-term construction impacts. These benefits, coupled with the benefits from the other ER features, work together in the multiple lines of defense strategy to help protect the Texas coast.

4.2.2.5 Dune/Beach Restoration

Three of the ER measures incorporate dune/beach restoration features (G-5, B-2, and W-3). Impacts to the aquatic community could occur in the Gulf portions of the project area due to increased water column turbidity that can be expected during construction of the dune/beach restoration feature. Impacts associated with temporary disturbances to water column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom and would be expected to return to normal once construction is completed. Renourishment of the features would occur through standard renourishing every 5 to 10 years or continuously through a sand motor. Renourishment of the measure throughout the period of operation would cause short-term increase of water column turbidity during placement. If a sand motor is used, large amounts of sand would be deposited at one location along the shoreline near the feature. Placement of the sand would cause benthic organisms to be smothered and water column turbidity impacts as described above for the Coastal Barrier. However, no long-term impacts to the aquatic community are anticipated as a result of dune/beach restoration features.

4.2.2.6 Out-year Marsh Nourishment 2065

A one-time out-year marsh nourishment would occur in 2065 at four of the ER measures in areas that would otherwise convert to open water or unconsolidated shoreline over the period of analysis due to RSLR (G-28, B-12, M-8, and CA-5). A total of 28,092.7 acres are proposed for out-year marsh nourishment. It is assumed that due to RSLR some of those areas would have converted to open water by the year 2065, and therefore some amount of open bay and bay bottom habitat would be lost as a result of this feature. Construction details are currently not available and will be refined during future planning and design phases of the study including into preconstruction, engineering, and design.

Ten years would be required for construction, planting, and marsh establishment, and would require construction of temporary containment levees and drainage structures to contain the material. Material from borrow source locations or maintenance material from nearby sources would be used to construct these features. During construction of containment levees and drainage structures, water column turbidity impacts would be the same as those described above for the Coastal Barrier and would be expected to return to normal once construction is completed. Placement of material could also increase water column turbidity temporarily. Although similar types of water quality impacts to those of the Coastal Barrier may occur, the severity of the impacts may be greater because of proximity of sediment placement to marsh, which is extensively used by juvenile fish and shellfish. Juvenile forms of some species that utilize the marsh are more susceptible to effects of sediment placement activities than adults, which may not occur as frequently or in as high numbers as juveniles in these habitats.

While it has been shown that created marshes are not functionally equivalent to natural marshes for nekton and other estuarine organisms, they do provide a highly productive habitat for these species to thrive (Minello and Webb, 1997; Minello and Caldwell, 2006). The key characteristic for support of fishery populations is access to marsh surface, which can provide food for growth and structure to help increase survival (Minello et al., 2003). The plan is to create sinuous circulations channels and ponds in the created marsh, which would increase the marsh edge/vegetation habitat that is important in providing access to the marsh surface that is used by aquatic organisms when it is flooded (Minello et al., 2012; Minello et al., 2015). Once construction of the out-year marsh nourishment features is complete, the created marsh would increase commercial and recreational fish and shellfish productivity and serve as a nursery area, providing more productive habitat than the open water and bay bottom habitat it replaced.

4.3 POTENTIAL IMPACTS TO FEDERALLY MANAGED SPECIES

The potential for adverse impacts to Federally managed species within the project area is likely to differ from species to species, depending upon life history, habitat use (demersal vs. pelagic), distribution, and abundance.

4.3.1 Direct Impacts

Estuarine wetland and SAV habitat occurs within the proposed project areas of the Preferred Alternative and would be directly impacted by the proposed project. Dredged material from construction of the Coastal Barrier would either be used beneficially for construction of ER measures or put in approved placement areas. If used beneficially for construction of ER features, the created/restored habitat may potentially be more productive than the open-water habitat that would be lost because of the Preferred Alternative. Marsh creation as part of the ER measures may benefit the Texas coastal areas by being more productive than the habitat it would be replacing. The aquatic community may benefit from higher productivity within the bay. The created/restored marsh habitat would provide shelter for increased survival, food for growth, and spawning sites for enhanced reproduction. The created/restored marsh would specifically benefit the Federally managed brown, pink, and white shrimp and red drum providing nursery and foraging habitat. In addition, it may also benefit other commercially and recreationally important species in ER measure project areas with created/restored marsh. While the created marsh may not function at the same level as a natural marsh, populations of finfish and shellfish have the potential to be greater in these areas due to the conversion of open-bay bottom habitat to marsh (Minello, 2000; Minello and Caldwell, 2006). This would create a positive benefit to the bay system throughout the life of the 50-year project when compared to the No-Action Alternative (Rozas et al., 2005).

Dredging and placement activities will directly impact the benthic environment; however, impacts will be short term and localized. Benthic organisms are capable of recolonization within a relatively short period of time. Direct impacts to EFH include temporary displacement of species in the immediate vicinity of the project locations. Fish are expected to rapidly return to these areas once dredging and placement activities are complete. Since benthic habitat is similar throughout the project areas, finfish will be able to find suitable, undisturbed habitat during construction activities. As benthic habitat is recolonized by benthos, finfish will be able to utilize the benthic habitat from which they were temporarily displaced. Refer to Section 4.2 for more detailed information.

The Preferred Alternative could temporarily reduce the quality of EFH in the vicinity of the project area, and some individual species may be displaced. The Coastal Barrier system would result in permanent loss of 2,154.0 acres of open bay and bay bottom habitat for construction of the surge barrier gates, with most of the loss occurring at Bolivar Roads. Dredging and construction activities would cause temporary and localized direct impacts resulting from increased turbidity, suspended sediments, and bay bottom impacts. In-bay construction durations could last for extended periods of time, causing estuarine habitats and fauna in those areas increased time to recover to preconstruction conditions. There could be a reduction of the amount of food available to Federally managed species as a result of the reduction of available bay bottom and open bay habitat with the structures in place. Construction of the ER measures would also result in a loss of open bay and bay bottom habitat and cause temporary disturbances to water column turbidity.

Since most fish can avoid highly turbid areas (Clarke and Wilber, 2000), they may temporarily relocate and feed in undisturbed areas until recovery is complete from dredging and construction-related turbidity. Feeding habits of shrimp would not be impacted since shrimp typically reside on or near the bottom where sedimentation naturally occurs (Wilber and Clark, 2001; Wilber et al., 2005).

Dredging and placement activities are not expected to cause direct mortality to juvenile and adult pelagic finfish since these life history stages are motile and are capable of avoiding turbid areas associated with project construction (Clarke and Wilber, 2000). Penaeid shrimp use deeper water of the bay as a staging area from which they migrate to the Gulf during certain times of the year (GMFMC, 2004). The displacement of juvenile and adult finfish and shrimp during project construction would likely be temporary, and individuals should return to these specific areas once the project is completed. Juvenile and adult finfish and shrimp should experience minimal direct impacts from dredging and placement activities. Juvenile penaeid shrimp may be impacted due to their preference for burrowing in soft muddy areas, although this activity is usually in association with plant/water interfaces.

Demersal eggs and larval finfish may be lost to physical abrasion, burial, or suffocation during dredging and placement activities because of their limited mobility and sensitivity to suspended sediments (Germano and Cary, 2005; Newcombe and Jensen, 1996; Stern and Stickle, 1978; Wilber and Clark, 2001; Wilber et al., 2005). Older life stages are generally more mobile and less sensitive to turbidity. Section 4.2 provides additional descriptions on impacts.

In summary, the Preferred Alternative would result in permanent loss of estuarine water column, estuarine mud and sand bottoms, estuarine shell substrate, estuarine emergent wetlands, seagrasses, marine water column, and unconsolidated marine water bottoms. Some turbidity-related impacts, particularly to early life stages, may occur with dredging, filling, and placement activities; however, those impacts would be temporary and local. It is unlikely that there will be substantial reductions in Federally managed fish/shellfish populations as a result of the direct impacts the structures may cause. In most cases, affected species would return to the areas once construction is completed.

4.3.2 Indirect Impacts

Indirect impacts of the Preferred Alternative from the Coastal Barrier system include long-term effects on prey for Federally managed species and on Federally managed species themselves due to the expected reduced flow, reduced tidal amplitude, and periodic high velocities through the surge barrier gates. Impacts include a reduction in prey for Federally managed species due to the mortality or displacement of benthic species associated with dredging, placement, and construction activities for the Preferred Alternative. Since benthic organisms serve as prey for finfish, their mortality may temporarily reduce finfish feeding. With the exception of the permanent loss of open-bay bottom habitat that would occur at Bolivar Roads, most disturbances to the benthic environment will be temporary and impacts would be minimal.

With the Coastal Barrier system in place, fish and shellfish with larval and juvenile stages that depend largely on passive transport could experience impacts. Losses could result from 1) reduced numbers entering the bay proportional to the reduced volume flowing into the bay, 2) loss of individuals trapped in eddies that could form on the backside of the gate structures; 3) increased exposure to predation while migrating across the open bay to the marshes due to reduced velocities and increased transport times; and 4) reduced area of accessible marsh caused by reduced tidal amplitude. Species that rely on passive transport in early life stages are important forage for other species of fish, birds, and dolphins. This could result in indirect impacts from reduced access to forage. The ER measures are designed to provide an overall positive benefit to the ecosystem in a variety of ways. These benefits work together to contribute to the multiple lines of defense strategy that was developed by the Coastal Texas Study that relates to protection of coastal ecosystems and human infrastructure from storm damage caused by hurricanes and tropical storms coming ashore from the Gulf. The multiple lines of defense provided first by the barrier islands, then by living shorelines, and finally coastal marshes, can reduce the physical impacts of storm surges and winds that enter the bays. This combination of multiple lines of defense and ER is intended to provide redundant and resilient levels of protection and restoration for both humans and Texas coastal ecosystems. When comparing the ER measures to the No-Action Alternative, the benefits as a result of the lines of defense strategy far outweigh the short-term construction impacts that would be expected.

4.4 CUMULATIVE IMPACTS

A cumulative impacts assessment takes into consideration the impact on the environment, which results from the incremental impact of the Preferred Alternative when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. Impacts include both direct effects, which are caused by an action and occur at the same time and place as the Preferred Alternative, and indirect effects, which are also caused by the action and occur later in time and are farther removed in distance, but which are still reasonably foreseeable. Ecological effects refer to effects on natural resources and on the components, structures, and functioning of affected ecosystems, whether direct, indirect, or cumulative. A comprehensive cumulative impact assessment is presented in the Section 5.9 of Appendix C-1 (Environmental Supporting Document).

The TSP would result in several direct and indirect positive and negative impacts to the environment. Some of these positive and negative impacts have the potential to result in positive and negative cumulative effect when considered in conjunction with past, present, and reasonably foreseeable actions. Many of the past, present, and reasonably foreseeable actions pertain to ecological restoration projects (yielding beneficial or positive results), while several include industrial and navigation channel-related projects (with some projects resulting in some level of environmental impacts).

Positive environmental impacts would result from the TSP ER measures, which include beach and dune restoration, marsh restoration, shoreline protection, bird island restoration, and oyster reef creation. Many past, present, and reasonably foreseeable projects address restoration of coastal resources (which have the capacity to alter geomorphology and coastal processes). Some of these projects reduce erosion, provide habitat, function as storm buffers, promote recreational and commercial fisheries, improve water quality, for example; the TSP ER measures would result in the same benefits. Marsh nourishment efforts would complement current and future marsh restoration efforts by State, Federal, non-governmental organizations, and private entities. With regards to ER measures, the cumulative effects of the TSP would be beneficial when combined with other past, present, and reasonably foreseeable restoration actions around Galveston Bay.

Negative environmental impacts may result from the TSP because the Coastal Barrier CSRM system would alter tidal dynamics by creating a constriction through Bolivar Roads. With the Coastal Barrier

CSRM system across Bolivar Roads resulting in a 27.5 percent constriction, analysis shows an overall tidal prism reduction between 10 to 15 percent, and tidal amplitude is expected to decrease by 15 percent. For past, present, and reasonably foreseeable projects that have altered, or have the potential to alter hydrosalinity gradients, there exists the potential for the TSP to contribute to cumulative effects. For example, the Houston Ship Channel Expansion and Channel Improvement Project may alter hydrosalinity gradients slightly and may exacerbate any impacts that result from the Coastal Barrier CSRM system forming the constriction at Bolivar Roads. Past and present projects, like GIWW construction and maintenance, Barbour’s Cut, and other projects with dredging, also contribute to alterations to tidal dynamics, circulation, erosion, and habitat.

To reduce or eliminate the likelihood of the TSP contributing to cumulative effects, Habitat Evaluation Procedure and Wetland Value Assessment were applied to the future without-project and future with-project conditions to identify the potential changes to some species’ habitats and wetland, and appropriate mitigation was identified. Climate variability (e.g., drought and flood events) and RSLR also contribute to the uncertainties regarding the magnitude of TSP impacts, both positive and negative. Interagency coordination, regulatory compliance, mitigation, monitoring, and adaptive management strategies are intended to offset any detrimental impacts of the TSP and further reduce or eliminate contributions to cumulative effects. With these assumptions, modeling, and planning efforts, impacts of the TSP would not contribute considerably to the region’s cumulative impacts, when combined with past, present, and reasonably foreseeable future actions..

5.0 MITIGATION MEASURES

The amount of marsh mitigation required was calculated for the Coastal Texas Study (see Appendix C-9, Mitigation Plan for full details). Using GIS, marsh acres were calculated. Future Without-Project Tidal Marsh Acres were estimated to be 38,696 acres. Future With-Project Tidal Marsh Acres were estimated at 35,321 acres. Subtracting the Future With-Project acre estimate from the Future Without-Project acre estimate resulted in a total of 3,375 acres of tidal marsh indirectly impacted by a CSRM structure or storm surge barrier across Bolivar Roads. Because of the preliminary nature of the planning to identify the TSP at this initial phase and the planning policy requiring detailed analysis post-ADM, the specific mitigation sites have not been fully evaluated. Due to the combination of direct and indirect estuarine emergent marsh impacts, a conceptual plan of potential mitigation sites has been developed. Mitigation involves marsh creation that would have similar impacts as described above in sections 4.2.2.3 and 4.2.2.6.

The following four sites have been identified as potential mitigation areas:

1. Trinity River Delta: 1,106 acres of river delta. Restoration of estuarine emergent marsh in this area would complement potential mitigation sites proposed by the Houston Ship Channel proposed expansion project. Reduction in sediment supply due to impoundment of the Trinity River has altered geomorphic processes that sustain wetlands in this area. The delta, currently reduced in size, would benefit from marsh restoration.

2. Dollar Bay: 487 acres of shallow bay on the west side of Galveston Bay. Restoration of estuarine emergent marsh in this area would complement existing TPWD marsh restoration. A marsh complex historically existed in this area but has since degraded due to erosion and subsidence.

3. West alluvial fan on Bolivar Peninsula: 1,272 acres of back-bay marsh complex. Restoration of estuarine emergent marsh in this area would complement the Houston Ship Channel proposed expansion project as well as the Galveston Bay ER measures of the Coastal Texas Study. Marsh restoration would maintain the depositional environment of the alluvial fan.

4. East alluvial fan on Bolivar Peninsula: 1,682 acres of back-bay marsh complex. Restoration of estuarine emergent marsh in this area would complement the Houston Ship Channel proposed expansion project as well as the Galveston Bay ER measures of the Coastal Texas Study. Marsh restoration would maintain the depositional environment of the alluvial fan.

The mitigation plan (Appendix C-9) will be updated at the end of the post-ADM planning phase to revise the impact and mitigation amounts with changes driven by the project refinement and more-detailed mitigation site planning.

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6.0 CONCLUSIONS

All of the Federally managed species utilize estuarine and Gulf habitat during some portion of their life for spawning, food, development, and/or protection (GMFMC, 2004). The Preferred Alternative will have negative impacts, both directly and indirectly, to EFH in the project area. However, it also has the potential to enhance habitat for EFH with the proposed ER measures that include protection of marshes and seagrass, creation of marsh habitat, and oyster reef creation along the Texas coast.

The Preferred Alternative would result in permanent loss of estuarine water column, estuarine mud and sand bottoms, estuarine shell substrate, estuarine emergent wetlands, seagrasses, marine water column, and unconsolidated marine water bottoms. During construction of the measures/features associated with the Preferred Alternative, there would be turbidity-related impacts, particularly to early life stages of fish and shellfish. Substantial reductions in Federally managed fish/shellfish populations as a result of the direct impacts the structures may cause are not anticipated and, in most cases, affected species would return to the areas once construction is completed.

The Coastal Barrier system could have long-term impacts on prey for Federally managed species and on Federally managed species themselves due to the predicted reduced tidal prism, reduced tidal amplitude, and periodic high velocities through the surge barrier gates. These impacts may include a reduction in prey due to the mortality or displacement of benthic species associated with dredging, placement, and construction activities. Potential long-term direct impacts to fish and shellfish with larval and juvenile life stages that depend largely on passive transport could result from the cumulative impacts of the Coastal Barrier.

The Preferred Alternative's ER measures are designed to provide an overall positive benefit to the ecosystem. Working together to contribute to the multiple lines of defense, barrier islands, living shorelines, and coastal marshes, can reduce the physical impacts of storm surges and winds that enter the bays. These benefits outweigh the construction impacts that would be expected and over the long-term provide an overall benefit to the Texas coastal ecosystems.

The Draft IFR-EIS serves to initiate EFH consultation under the MSFCMA. Prior to Final IFR-EIS release to the public, this EFH Assessment will allow NMFS and GMFMC an opportunity to provide comments on EFH impacts.

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